Universidade do Minho
Escola de Engenharia

Marco Filipe Vieira Gomes

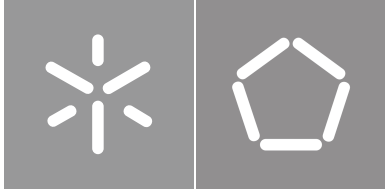
A Conflict Management Environment to Support Decision-Making Process

May, 2021

A Conflict Management Environment to Support Decision-Making Process

Marco Gomes

UMinho | 2021



Universidade do Minho
Escola de Engenharia

Marco Filipe Vieira Gomes

A Conflict Management Environment to Support Decision-Making Process

Doctorate Thesis
Doctoral Program in Informatics

Work supervised by
Paulo Jorge Freitas de Oliveira Novais

May, 2021

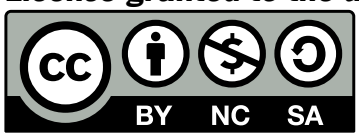
COPYRIGHT AND TERMS OF USE OF THIS WORK BY A THIRD PARTY

This is academic work that can be used by third parties as long as internationally accepted rules and good practices regarding copyright and related rights are respected.

Accordingly, this work may be used under the license provided below.

If the user needs permission to make use of the work under conditions not provided for in the indicated licensing, they should contact the author through the RepositoriUM of Universidade do Minho.

License granted to the users of this work



Creative Commons Atribuição-NãoComercial-CompartilhaIgual 4.0 Internacional
CC BY-NC-SA 4.0

`https://creativecommons.org/licenses/by-nc-sa/4.0/deed.pt`

To Charlène and Vicente

Acknowledgements

I am deeply grateful to my supervisor and friend, Paulo Novais, for the endless support and guidance throughout my whole PhD and every aspect of my life around it. His care and commitment to his research, classes and students have been my inspiration for striving to be better not only as a scientist but as a person. In addition, he has always encouraged us to work with undergraduate and master's students and has created a supportive and friendly environment in our lab. I am also especially grateful to César Analide, who in some way encouraged me to carry on through these years and always had a word of encouragement.

I am also very grateful to all the teaching and research staff that have taken some time to discuss and enrich my work. The University of Minho has provided me with a very stimulating environment in what concerns the quality of its academic staff, and that experience will leave marks beyond this thesis.

I want to express my deep gratitude to the participants of all the case studies, to whom the project is indebted, for their collaboration and openness.

Some special words of gratitude go to my friends and collegues, Davide Carneiro, Fábio Silva, Tiago Oliveira, Ângelo Costa, André Ribeiro Pimenta, Dalila Durães, António Silva, Bruno Fernandes, Francisco Marcondes, Héctor Alaiz-Moretón, and José Carlos Castillo as well as many other friends and collegues, for encouraged me to carry on through these years and has contributed to this thesis.

I would like to thank my family: my parents, my brothers and sister, and my friends for supporting me throughout writing this thesis and my life in general. Thank you Berta, Bernardino, Hugo, Marcelo e Inês.

The last word goes for Vicente, my dear son, and Charlène, my life companion, who has been the pillars of my life for the last years and has given me the extra strength and motivation to get things done. I would not have gotten to this point without their support and companionship. This thesis is dedicated to them.

Health and Fraternity,
Marco Gomes

STATEMENT OF INTEGRITY

I hereby declare having conducted this academic work with integrity. I confirm that I have not used plagiarism or any form of undue use of information or falsification of results along the process leading to its elaboration.

I further declare that I have fully acknowledged the Code of Ethical Conduct of the Universidade do Minho.

"Não sou do ortodoxo nem do heterodoxo; cada um deles só exprime metade da vida, sou do paradoxo que a contém no total." (Agostinho da Silva)

Resumo

A Conflict Management Environment to Support Decision-Making Process

Reconhecer conflitos e lidar com eles é um passo essencial para a estabilidade social. Os conflitos podem ser vistos como um evento natural e uma consequência da complexidade da sociedade, surgindo em quase todos os contextos e fases de desenvolvimento da vida humana. Há um consenso de que a prevalência e a falta de uma gestão adequada dos conflitos acarretam custos substanciais para a sociedade. Apesar da extensa literatura das áreas científicas que habitualmente tratam os conflitos, são escassos os avanços na abordagem de conflitos nas ciências da computação. Portanto, esta tese propõe um conjunto de abordagens conceituais e tecnológicas implementadas através de um sistema computacional que auxilie a tomada de decisão na gestão de conflitos em ambientes virtuais e reais. A principal contribuição desta tese é a exploração de diferentes abordagens para a gestão de conflitos através da criação de modelos computacionais com o objetivo de disponibilizar informações relevantes às partes do conflito e aos sistemas que geram os conflitos em ambiente virtual. Especificamente, esta tese centrou-se no desenvolvimento de modelos para identificar e disponibilizar as informações relevantes decorrentes das interações que ocorrem num ambiente sensorial rico. Os objetivos definidos passaram pelo melhoramento da captura das dimensões de um conflito, da medição da confiança entre as partes, da caracterização e análise das suas redes sociais, da extração de padrões de comportamento e como lidar com informações incompletas. O planeamento e a execução de um conjunto de experiências proporcionou uma compreensão das dificuldades de captura e de computação técnica e algorítmica de informações relacionadas com conflitos num Ambiente Inteligente. A análise mostrou uma aparente diferença entre os grupos em estudo e em relação a alguns aspetos na gestão/resolução de conflitos exibidos durante o jogo. Os resultados concluíram que esta abordagem é um caminho válido no suporte à tomada de decisão na gestão de conflitos, dando às partes intervenientes informações relevantes para a tomada de decisões bem fundamentadas.

Palavras-chave: Inteligência Artificial, Resolução de Conflitos, Analítica legal, Inteligência Ambiente

Abstract

A Conflict Management Environment to Support Decision-Making Process

Recognizing conflicts and handling them is an essential step towards social stability. Conflicts can be seen as a natural event and a consequence of our complex society, arising in almost every context and developmental stage of human life. There is a widespread agreement that the current prevalence and lack of proper management of conflicts incur substantial costs to society. Despite the extensive literature in social and organizational sciences that addresses conflicts, remarkable advances in computer sciences approach conflict are scarce. Consequently, this thesis proposes conceptual and technological frameworks that can be implemented as a computer-based support system to assist decision-making in managing conflict in virtual and real-life environments. The designed Ambient Intelligence (AmI) system comprises several components needed for underpinning an Intelligent Environment (IE) that could be sensitive and responsive to all parts of a conflict management process.

The main contribution of this thesis is the exploration of different approaches for conflict management by creating computational models for delivering relevant information to the disputant parties and systems that manage conflict in a virtual environment. Specifically, this thesis focused on the design and implementation of the models to address the estimation of relevant aspects of interactions that occur in a rich sensory environment to enhance a multimodal approach to emotional, stress, and personality dimensions, to classify the conflict-handling styles, to measure trust, to perform social network analysis characterization, to extract behavioural patterns, and to cope with incomplete information. The deployment of a set of experiments (using a negotiation web-based game) provided an understanding of the difficulties of technically and algorithmically capturing and computing conflict-related information in an IE. The analysis showed an apparent difference between the groups regarding some conflict-handling aspects exhibited during the game. The results concluded that this approach seems a valid path to help decision-making in conflict management by giving the intervenients relevant information (such as parties' conflict styles, trust, etc.) for taking well-grounded decisions.

Keywords: Ambient Intelligence, Conflict Resolution, Legal Analytics, Artificial Intelligence

Contents

List of Figures **xvi**

List of Tables **xix**

Acronyms **xx**

1 Introduction **1**

1.1 Thesis Statement 3
1.2 Approach 5
1.3 Significance of the Study 6
1.4 Structure of the Document 9

2 Background **10**

2.1 Ambient Intelligence and Behavioural Knowledge 10
2.2 Online Dispute Resolution and Artificial Intelligence 12
2.3 Conflict-Handling in a Virtual Environment 15
2.3.1 Current Literature Overlapping Conflict-Handling Projects 16
2.3.2 Technological Platforms Developed by the Research Community 17
2.4 Intersections between AI and Law 19
2.4.1 Projects using AI to Address Justice and Law Needs 21
2.4.2 Status Quo of Judicial Cases in European Union 23
2.5 Summary 24

3 Conceptualization **26**

3.1 Problem Statement, Motivation and Goals 26
3.2 Research Hypothesis, Questions and Objectives 27
3.3 Strategy and Research Plan 31

3.3.1 Research Philosophy . . . 31
3.3.2 Research Approach . . . 32
3.3.3 The Nature and Strategy of Research . . . 34
3.3.4 Methods and Time Horizon . . . 34
3.4 Research Team and Host Institution . . . 35
3.5 Tasks performed during the Doctoral Program . . . 36
3.5.1 Update of literature and related work . . . 36
3.5.2 A Theoretical Framework to Handle Conflict . . . 36
3.5.3 Development of a Conflict Support Framework . . . 37
3.5.4 Analysis of the outcomes . . . 39
3.5.5 Constant diffusion and analysis of results . . . 39
3.6 Summary . . . 39

4 A Computational Approach towards Conflict Management 40
4.1 Keys Aspects and Theoretical Perspectives on Conflict . . . 41
4.1.1 What is a Conflict? . . . 42
4.1.2 Views of Conflict and Its Dimensions . . . 43
4.1.3 Conflict Process . . . 46
4.1.4 Conflict-Handling Styles . . . 46
4.1.5 Methods and Techniques . . . 48
4.1.6 Consolidating perspectives . . . 52
4.2 A Multi-modal Approach to Conflict Management . . . 52
4.2.1 Decision-Making Process . . . 52
4.2.2 Behavioral and Contextual Information Retrieval . . . 54
4.2.3 Modelling Information Extraction . . . 56
4.3 Technological Framework for Supporting Conflict Process . . . 75
4.3.1 An AmI-based Architecture for a Conflict Management System . . . 76
4.3.2 Evaluating (measuring) Conflict in an IE . . . 79
4.4 Summary . . . 83

5 Experiments Performed 84
5.1 Conditions and Methodology . . . 84
5.2 The Negotiation Game Scenario . . . 86
5.3 Multi-modal Approach to Stress and Personality Dimensions . . . 87
5.3.1 Rationale . . . 88
5.3.2 Data collection . . . 89
5.3.3 Preliminary data analysis . . . 90

5.3.4 Data analysis . . . 91
5.3.5 Results and Discussion . . . 91
5.4 Assessing Interpersonal Trust in an Intelligent Environment . . . 92
5.4.1 Rationale . . . 92
5.4.2 Data collection . . . 93
5.4.3 Preliminary data analysis . . . 94
5.4.4 Statistical data analysis . . . 95
5.4.5 Results and Discussion . . . 96
5.5 Incorporation of Social Network Analysis in Conflict Characterization . . . 96
5.5.1 Rationale . . . 97
5.5.2 Data collection . . . 97
5.5.3 Preliminary data analysis . . . 98
5.5.4 Statistical data analysis . . . 98
5.5.5 Results and Discussion . . . 99
5.6 Speculative Computation Approach to Cope with Incomplete Information . . . 100
5.6.1 Rationale . . . 101
5.6.2 Data collection . . . 101
5.6.3 Preliminary data analysis . . . 101
5.6.4 Data analysis . . . 102
5.6.5 Results and Discussion . . . 103
5.7 Extracting Behavioural Patterns . . . 105
5.7.1 Rationale . . . 105
5.7.2 Data collection . . . 105
5.7.3 Preliminary data analysis . . . 106
5.7.4 Statistical data analysis . . . 106
5.7.5 Results and Discussion . . . 108
5.8 Human Activity Recognition . . . 108
5.9 Consolidating Experiments and Results . . . 110
5.10 Summary . . . 112

6 Conclusion and Future Work **113**
6.1 Summary of Contributions . . . 113
6.2 Validation of the Research Hypothesis . . . 114
6.3 Discussion and Future Directions . . . 117
6.4 Dissemination of Results . . . 119
6.4.1 Scientific Publications . . . 119

6.4.2 Lectures 122
6.4.3 Invited Presentations 122
6.5 Research Activities During the Doctoral Programme 122
6.5.1 Participation in Scientific Events 122
6.5.2 Research Stay 124
6.5.3 Other Research Projects 125
6.5.4 Tutoring of Students 127

Bibliography **130**

Appendices

A System Overview **153**

B Conflict Management Platform **154**

C Conflict Management System **156**
C.1 Conflict Engine 156
C.1.1 Sensor Selection 156
C.1.2 Features Extraction 157
C.1.3 Inference/Classification Processes 159
C.2 Conflict Intelligent Environment 159
C.2.1 Manager's Application 160
C.2.2 Parties' Application 160

D SNA: Centrality Measures **164**

Annexes

I Newcastle Personality Assessor questionnaire **166**

List of Figures

1 Ramon Llull, the medieval *prophet* of computer science, argued that truth could be automated and used logic over force to prove the existence of the Christian God. Llull connected his "basic concepts" with lines, and prescribed that the lines had to be followed to combine the concepts and derive the consequences, and compiled this information in the form of a two-entry table (the adjacency matrix of the graph). Images from "From the Ars Magna to Artificial Intelligence" [1]. 1

2 Ambient Intelligence as a multidisciplinary field by Cook et al [11]. 11

3 A possible structure of a Corporate ODR system. Diagram from Barnett et al [31]. . . . 15

4 Steps for obtaining scientific knowledge. 33

5 The graphical representation of the five conflict-handling styles; one axis as 'assertiveness' and the other as 'cooperation.' 47

6 Simplified decision-making process. 1) Problem Identification; 2) Development of Solutions; 3) Selection of the final decision. 54

7 Overview of a Conflict Management System to support decision-making. 55

8 Schematic representation of the workflow. 56

9 The two rectangles represent the utility range of values proposed by two hypothetical parties. 60

10 An overview of the dynamic stress recognition system embedded in an intelligent environment. Diagram from Gomes et al [145]. 67

11 High-level view of the architecture. 76

12 Conflict Management Platform. The number (1) denotes the raw data process component; number (2) denotes the features extraction component; the number (3) denotes de inference/classification component. 79

13 An overview of computer-based processes to argument/proposal generation, conflict characterization, and strategy production. 80

14 A sensor-based application for the Android Operating System. 87
15 A web application developed in the context of this PhD project and used on the experiments. 87
16 An overview of a generic diagram outlining the stress and personality dimensions. . . . 88
17 The stress recognition module and the mood recognition module incorporated in the conflict management intelligent environment. 90
18 The pivotal phase of conflict consists of dealing with the actual conflict. Simply speaking, it is the phase in which disputants attempt to cope and manage conflict. 93
19 These graphs were obtained after computing the degree centrality of the resulting friendship network (at left) and hindrance network (at right). This centrality measure counts how many neighbors a node has. 99
20 The difference in the distribution (X-axis) of the Conflict-Handling Style (Y-axis) was used by the participants when they were negotiating with a friend or not. 99
21 Distance of value of the final proposal to the optimum result when the participant is a friend or not. 99
22 The difference between the size of the messages exchanged when the participants are friends or not. 100
23 Difference in the necessary number of rounds to reach an agreement when the participants are friends or not. 100
24 From the Seller network, it is possible to verify that the most likely negotiation style for a Seller is Competing throughout the three rounds. As such, the default set consists of the Competing values for Round1, Round2, and Round3. 104
25 Supposing the recommendation of the Conflict Manager produced an effect. The observed conflict-handling style of the Seller in Round1 was Collaborating. This real value would be used to condition parameter Round1 in the Seller network. 104
26 Representation of the learned network visualized in the SamIam software tool [189]. . . 107
27 These images are representing audio scenarios of a spectrogram analysis. All these samples are from a public dataset containing non-violence and violence audio scenarios. 110

A.1 The graphical representation of the developed system. 153

B.1 This Conclifct Management Platform comprises three main components. 155

C.1 A generic diagram for representing the levels of information gathering. 157
C.2 Conflict Engine module. The number (1) denotes the raw data process component; number (2) denotes the features extraction component; the number (3) denotes de inference/classification component. 158

C.3 The graphical representation of the communication flow between the parties and manager applications. 161
C.4 The database diagram representing the data model suitable to store the information related to the negotiation process in the context of a conflict management session in a digital environment. 162
C.5 The database diagram representing the data model suitable to store the information related to the recommendation process in the context of a conflict management session in a digital environment. 163

List of Tables

1 Categorization of ODR Systems. 14

2 Brief description of a range tools of conflict management. 49

3 Classification categories and correspondent equations, where φ represents a party's proposal utlity value 59

4 Results of the structure learning and structure assessment processes. 102

5 Objectives of the doctoral programme and respective document chapters where they were achieved. 115

6 NPA summarized and applied (adapted to Portuguese) in the experiment reported and published in book chapter 167

Acronyms

ADR	Alternative Dispute Resolution
AI	Artificial Intelligence
AIC	Akaike Information Criterion
AmI	Ambient Intelligence
ANN	Artificial Neural Network
BATNA	Best Alternative to a Negotiated Agreement
BN	Bayesian Networks
CAR	Computer-Aided Reasoning
CATS	Cognitive Activation Theory of Stress
CBR	Case-Based Reasoning
CNN	Convolutional Neural Network
DI	Department of Computer Science and Informatics
HAR	Human Activity Recognition
HCI	Human-Computer Interaction
ICT	Information and Communication Technology
IE	Intelligent Environment
IR	Information Retrieval
ISLab	Synthetic Intelligence Laboratory

KBS Knowledge-Based Systems
KR Knowledge Representation

LIIS Legal Intelligent System Stack
LLP Legal Language Processing

MAP *Maximum a Posteriori*
MAS Multi-Agent Systems
ML Machine Learning
MLATNA Most Likely Outcome for a Negotiated

NPA Newcastle Personality Assessor
NSS Negotiation Support System

ODR Online Dispute Resolution

PAD Pleasure, Arousal and Dominance

RBR Rules-Based Reasoning
REST Representational State Transfer

SC Speculative Computation
SCA Service-Component Architecture
SNA Social Network Analysis
SOA Service-Oriented Architectures

WATNA Worst Alternative to a Negotiated Agreement

ZOPA Zone of Possible Agreement

Chapter 1

Introduction

"A man is composed of a soul and a body. For this reason he can be studied using the principles and rules in two ways: namely in a spiritual way and in a physical way. And he is defined thus: man is a man-making animal".

Ramon Llull

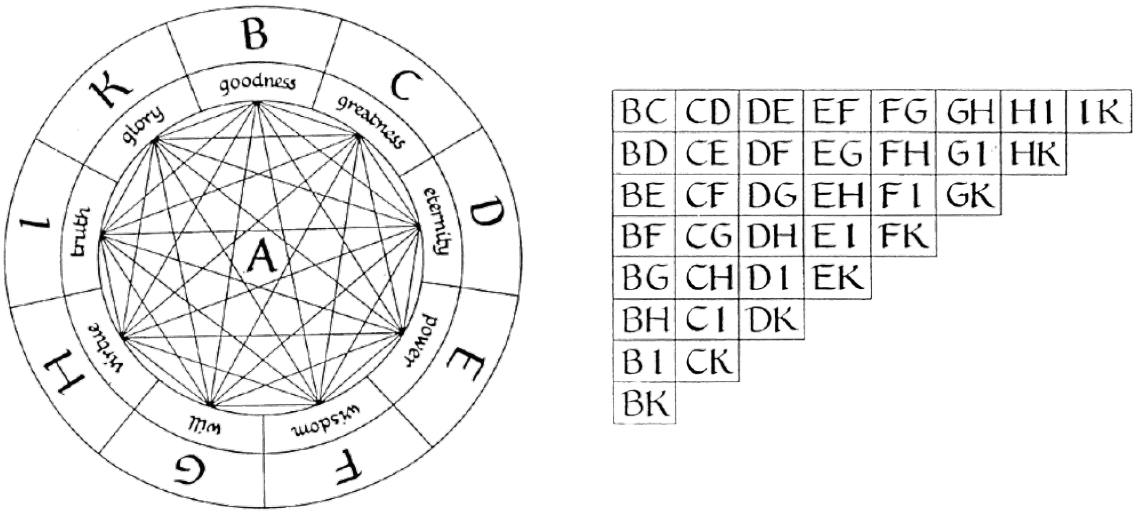


Figure 1: Ramon Llull, the medieval *prophet* of computer science, argued that truth could be automated and used logic over force to prove the existence of the Christian God. Llull connected his "basic concepts" with lines, and prescribed that the lines had to be followed to combine the concepts and derive the consequences, and compiled this information in the form of a two-entry table (the adjacency matrix of the graph). Images from "From the Ars Magna to Artificial Intelligence" [1].

Conflicts arise from the complexity of society and the human mind. They may have positive or negative consequences depending on how conflicts are handled or managed. Learning to drive them correctly is a complex, challenging, but crucial task. Especially when, these days, the conflict is brought to the digital environment[1] where new business processes (buying and selling products on the internet) are already sufficiently widespread. Therefore, the conflict that arises in digital environments or those brought to must be managed appropriately.

Facing this issue, we must raise a critical question: how to balance the subjective nature of the conflict with the objectivity-dependent nature of a *computer system*? On the other hand, how can a *computer system* deal "intelligently" with this kind of subjectivity? Thoroughly, some glimpses into the ways that computer systems *handle* subjectivity can be found in the "expert" literature and can be summarized in work undertaken by Rosalind Picard, in which she stressed that this endeavour is challenging, but achievable [2]. She outlined a strategy for computer systems to cope with subjectivity issues. Specifically, it is proposed a three-fold approach: that they [computer systems] will need to (1) share some of the common sense of the user; (2) observe and model the user's actions; and (3) learn from these interactions. This approach, to simplify, suggests that subjectivity is displayed as the user interacts with the system during a succession of actions, in which the user inputs can be tracked, modelled, and used to retrieve data consistent with changing requests. This strategy seems to be suitable to implement, so it was planned to follow it in this PhD work in order to overcome the challenges of handling conflict in a digital environment. Hence, with such an approach, the motivation of this research was in part to examine conflict, focusing on some particular aspects of conflict handling, simplified to manage these properties algorithmically. The other part of the motivation was to produce a theoretical and computational framework to assist parties in a conflict situation. The construction and use of this framework were designed to provide all the intervenients parties of conflict the appropriate knowledge at the right time. The underlying idea is that by having access to valuable knowledge, the parties could make more informed and, thus, *proper* decisions.

For this reason, with conflicts now also emerging in digital environments and aiming to implement a strategy to cope with the subjectivity of conflict, this study focused on a new approach of handling conflict using an Artificial Intelligence (AI) and mainly AmI techniques to improve (shifting towards more cooperative solutions) the management of conflicts. Evidence suggests that an AmI system that could deliver valuable knowledge to make more informed decisions can effect a significant shift in the current way of managing conflict because it can enhance the possibilities of reaching a favourable outcome in a conflict process. However, as previous research has been established and explained in the following chapters, the development of such systems to handle conflict in a digital environment is still insufficient.

[1] The term *digital environment* is an umbrella term that can cover face-to-face conflict management/resolution using a digital platform, with virtual management/resolution and asynchronous facilitation such as the exchange of emails and messages. In other words, the digital environment combines asynchronous and synchronous collaboration with remote and physical interaction, and by doing so, provides unlimited possibilities to engage with the participants.

Thus, this research proposed to study the problem and the challenges to develop an *efficient* AmI platform covering critical aspects present in traditional resolution and conflict management processes, including context-dependent elements that significantly affect human behaviour as a means to meet this knowledge gap.

Most conflict scholars, practitioners, and parties dedicated to the thematic of conflict agree that alternative means of solving and managing conflicts other than the traditional court system offer an efficient and cost-effective way to manage and resolve conflicts. Consequently, this PhD proposes conceptual and technological frameworks that can be implemented as a computer-based support system to assist decision-making in managing conflict in virtual and real-life environments. The designed AmI system comprises several components needed for underpinning an IE that could be sensitive and responsive to all parts of a conflict management process. This PhD research contributes in this way to studying and exploring different approaches to handle conflict in a rich and digital sensory environment. The objective was to enhance the strategies that can increase the success rate of conflict resolution and management procedures and bring them closer to the rich communicative environment that parties have when they communicate face-to-face. Specifically, this work focused on the design and implementation of the models to address the estimation of emotional, stress, and personality dimensions, to classify the conflict-handling styles, to measure trust, to perform social network analysis characterization, to extract behavioural patterns, and to cope with incomplete information in the context of conflict management "intelligent" environment.

1.1 Thesis Statement

Despite the personal and collective gains of using Information and Communication Technology (ICT) as mechanisms to improve the management of conflicts [3], one must agree that exists some risks and constraints in using technology to enhance conflict resolution processes. Quoting Leah Wing, "*those with greater access to decision-making power and resources can find ways to use technology to enhance their personal and institutional goals about conflict and its resolution or continuance*"'. Accordingly, "*it is all the more critical that whoever is harnessing technology as part of dispute prevention and resolution activities consider the ethical implications of their system's design and implementation in practice*´´. Indeed, as highlighted by Carneiro [4], given the understandable technological and ethical constraints [5] it is more pragmatic to focus on decision-support rather than on autonomous decision-making. In other words, it is more feasible and more promising to have a computer-based system to support parties in making a better decision than to devise solutions for automatic conflict resolution. Thus, this PhD work stands on the idea that parties engaged in a conflict situation must access valuable knowledge to make proper decisions; this assumption is of crucial importance if we want to produce an innovative decision-support system able to assist parties in a conflict situation and centred it on providing to all sides of a conflict the appropriate knowledge at the right time. These premises supported the studies carried out during this research to

explore the relationship between more informed decisions and favourable outcomes. In other words, this study aimed to test the following research hypothesis:

Research Hypothesis

An AmI system can create scenarios that enhance the possibilities of reaching a favourable outcome in a conflict management process using contextual and behavioural knowledge.

The central claim of this work was that some conflict aspects could be estimated using non-invasive and non-intrusive methods and that an AmI system could deliver valuable knowledge to make more informed decisions. Supported by the feedback from preliminary work (outlined in Chapter 2) in which this proposal is framed, two main lines of research are put forward:

- The research will focus on the possibility to estimate, using non-invasive and non-intrusive methods, relevant conflict aspects (dimensions) by analyzing critical features of a conflict situation and conflicting parties' interactions with the framework and between themselves;
- The conflict process is seen as an iterative process that should converge to an outcome acceptable by the parties involved. The process's activities will be incorporated in the framework, facilitating the resolution/management process and considering some functional needs of the conflict process, namely: communication support; problem formulation; data gathering and solution generation; coordination of information sharing; and evaluation of results.

The research hypothesis was developed from the research questions presented and detailed in Chapter 3. The primary objectives of this work were coupled with the hypothesis of the study. The study objectives defining the study's specific aims are clearly stated in the following Chapter 3. By generalizing the research hypothesis to an assertion that summarizes the main point or claim of this work, we have the following thesis statement:

Thesis statement

This research demonstrated that critical conflict aspects could be estimated using non-invasive and non-intrusive methods and that an AmI system could deliver valuable knowledge to make more informed decisions.

By *critical conflict aspects* this work considers as the main communicational and behavioural aspects present in traditional resolution and conflict management[2] processes, including context-dependent elements that have a significant role in human behavior (such trust, stress level, mood, etc.). The specification if these *aspects* can be found in Chapter 4. Further, the decision-support system should be more than a conventional mechanism that responds to user's requests. Much in line with the AmI view should be "listening" to the user, intervening if and when necessary, without an explicit request of the user. By concept underpinning the *"using non-invasive and non-intrusive methods and that an AmI system could deliver valuable knowledge to make effective decisions"* this work understands that is an environment in line with the ones for supporting conflict resolution. Here, the AmI should be seen as a set of devices, software solutions, and methodologies that result in a seamless group of services that assist the user in tasks related to conflict resolution/management processes. Indeed, clarified the concepts that underpin this statement, one can clearly state this thesis proposes a new approach to the conflict management topic, which is based on the intersection of different technologies and approaches aimed to be sensitive and responsive with both parties of a conflict management platform.

1.2 Approach

The multi-dimensionality of conflict (means that conflict is not determined by one component but by multiple components) makes conflict interventions more complicated since they have to meet different conditions. But it also allows more entry points for the interventions. From a computer science perspective, it becomes attractive to adopt an approach that reduces this multi-dimensionality to something that computer systems can handle more *easily*. The reduction of conflict to a manageable number, quantity, or probability can be highly satisfactory. After realizing the difficulty of interpreting the human perception of conflict, measuring it can establish objective evaluation criteria. As stated before, a phenomenon like *conflict* can be displayed through the user interaction with the system during a succession of actions. *Measure* conflict will consist, in this context, in addressing the user inputs that can be tracked, modelled, and used to retrieve data consistent with changing requests. Therefore, to develop a conflict management platform covering critical aspects present in traditional resolution and conflict management processes, including context-dependent elements that significantly affect human behavior, these user interactions must be modeled and processed. This line of work is the basis of the thesis statement, and it is supported in this document with different models, theoretical justifications, and experimental results.

The idea of a comprehensive analysis of conflict hinges on the assumption that its dimensions must also be understood and addressed. Having a conceptual framework that highlights these critical dimensions of this process, such as changes in the personal, structural, relational, and cultural aspects of

[2]Conflict management refers to a variety of collaborative approaches that seek to reach a mutually acceptable resolution of issues in a conflict through a voluntary process.

conflict, brought about over different periods (short-, mid- and long-term) and affected different system levels at other times, is an important step. Indeed, it will also be needed to depict the factors that drive change in conflict management, the processes that determine its nature, and the implications of the decisions. The underlying idea was thus to have an adequate theoretical basis for analyzing conflicts and devising appropriate responses to them, and evaluating the effects of these responses [6].

Throughout this document is introduced and discussed that contextual and behavioural information can influence the course of the process and, therefore, the conflict setting. Making assumptions about the information that can characterize a person's situation is hugely relevant to assist conflict resolution/management platforms in finding the path to achieving successful outcomes. From the parties' and the human mediator's point of view, access to this information is vital to plan the right strategy and perceive how each issue affects each party, much like it is done in traditional conflict resolution processes when parties meet face-to-face. With this purpose, developing such a framework (to collect context information and perceive activities being performed) will result in a set of services or functionalities that will support the work of the conflict manager. The aim is to release the parties and the conflict manager to have a more informed and practical approach to dealing with complex issues such as improving interpersonal communication and relationships in the environment of a conflict resolution/management process. To do so, this project proposal bases on the idea that an AmI system can create scenarios that enhance the possibilities of reaching a favorable outcome using contextual and behavioural knowledge.

In this context, is established a description of how valuable knowledge may be used to understand the conflict further, exploring it at a higher level of abstraction, and considered an execution model for a conflict management environment. Using these insights was revised the main challenge: to support a conflict management process and accurately providing valuable information, capture in a non-intrusive and non-invasive way, to decision-makers. Objectively, as a way for overcoming it, this work presented a proposal to tackle this with an approach that can be subdivided into two parts: a technological part (an instrument used to measure the phenomenon under study) and a conceptual part (developing models representing the universe of conflict). For each one, was planned a research strategy. Besides, one must emphasize that no research strategy is inherently more important or less important than any other. Because, the most significant was not the label attached to a particular strategy but whether it enable to answer a specific research question(s) and meet the objectives (detailed in Section 3.2).

1.3 Significance of the Study

The work carried out and described in this PhD thesis lead to the following key theoretical and practical contributions:

Contribution 1. The development of a theoretical framework considering the methods and techniques used to handle conflict. The aim is to provide to scholars, in a systematic and organized way,

existing critical literature, a baseline understanding in place of an agreed definition of conflict, depict relevant conflict aspects (dimensions) by analysing features of a conflict situation, and made an overall evaluation of a range of methods and techniques of conflict management (Chapter 4);

Contribution 2. The development of a computer-based approach to conflict management that comprises models for performing decision-support-related tasks. A central claim in this work is that a decision-support system in the scope of a conflict management environment should be centred on providing all the intervenient parties of conflict the proper knowledge at the right time. Therefore, computational models were designed and experimentally tested for delivering relevant information to the disputant parties and systems that manage conflict in a virtual environment (Chapter 4). Specifically, the models were designed to address the estimation of relevant aspects of interactions that occur in a rich sensory environment to enhance a multi-modal approach to emotional, stress, and personality dimensions, to classify the conflict-handling styles, to measure trust, to perform social network analysis characterization, to extract behavioural patterns, and to cope with incomplete information (Chapter 5);

Contribution 3. A technological framework to acquire and provide context and behavioural information about the participants of a conflict situation. The framework's general work is to sense conflict context, gather it, and then make reasoning on the acquired context and act on the parties' behalf. The system to achieve it must build up each individual's profile and subsequently link that profile with the correct individual performance within the conflict process that the system has monitored. In other words, while the user conscientiously interacts with the system and takes his/her decisions and actions, a parallel and transparent process occurs in which contextual and behavioural information is sent in a synchronized way to the conflict support platform (Section 4.3);

Contribution 4. The development of an experimental setup to test the applicability of the concepts of conflict management in an IE. To do so was used on the experimental settings quantitative techniques (monitoring users' reactions and interactions), qualitative data collection (questionnaires), and analysis procedures to determine associations through analysis of plausible relationships (Chapter 5);

Contribution 5. The deployment of an experiment (using a negotiation web-based game) designed to validate and to provide an understanding of the difficulties of technically and algorithmically capturing and computing conflict-related information in an IE. The analysis showed an apparent difference between the groups regarding some conflict-handling aspects exhibited during the game. The results concluded that this approach seems a valid path to help decision-making in conflict management by giving the intervenients relevant information (such as parties' conflict-handling styles, trust, etc.) for taking well-grounded decisions.

The key contributions described in this thesis are related to work that has already been published. The following list provides a reference to such contributions, the chapters, and the selected[3] publication to which it is related.

- Gomes, M. V., & Novais, P. (2016). Conflict and its different dimensions. In Interdisciplinary perspectives on contemporary conflict resolution (pp. 1-20). IGI Global, https://doi.org/10.4018/978-1-5225-0245-6.ch001. **Contribution 1**. (Chapter 4)

- Gomes, M., Zeleznikow, J., & Novais, P. (2015). A Non-intrusive Approach to Measuring Trust in Opponents in a Negotiation Scenario. In AI Approaches to the Complexity of Legal Systems (pp. 528-542). Springer, Cham, https://doi.org/10.1007/978-3-030-00178-0_36. **Contributions 2,3**. (Chapter 4, 5)

- Gomes, M., Alfonso-Cendón, J., Marqués-Sánchez, P., Carneiro, D., & Novais, P. (2014). Improving Conflict Support Environments with Information Regarding Social Relationships. In Ibero-American Conference on Artificial Intelligence (pp. 779-790). Springer, Cham, https://doi.org/10.1007/978-3-319-12027-063. **Contributions 2,3,4**. (Chapter 4, 4.3, 5)

- Gomes, M., Oliveira, T., Carneiro, D., Novais, P., & Neves, J. (2014). Studying the effects of stress on negotiation behavior. Cybernetics and Systems, 45(3), 279-291, https://doi.org/10.1080/01969722.2014.894858. **Contribution 4,5**. (Chapter 4, 5)

- Gomes, M., Carneiro, D., Pimenta, A., Nunes, M., Novais, P., & Neves, J. (2014). Improving modularity, interoperability and extensibility in ambient intelligence. In Ambient Intelligence-Software and Applications (pp. 63-70). Springer, Cham, https://doi.org/10.1007/978-3-319-07596-9_7. **Contributions 4,5**. (Chapter 4)

- Gomes, M., Oliveira, T., Silva, F., Carneiro, D., & Novais, P. (2014). Establishing the relationship between personality traits and stress in an intelligent environment. In International Conference on Industrial, Engineering and Other Applications of Applied Intelligent Systems (pp. 378-387). Springer, Cham, https://doi.org/10.1007/978-3-319-07467-2_40. **Contributions 2,3,4**. (Chapter 4, 5)

- Gomes, M., Oliveira, T., Carneiro, D., Novais, P., & Neves, J. (2013). Extracting behavioural patterns from a negotiation game. In International Conference on Practical Applications of Agents and Multi-Agent Systems (pp. 304-315). Springer, Berlin, Heidelberg, https://doi.org/10.1007/10.1007/978-3-642-38061-7_29; **Contributions 2,3**. (Chapter 4, 4.3, 5)

[3] A more extensive list of publications related to this thesis can be found in Sect. 6.4.

- Gomes, M., Carneiro, D., Novais, P., & Neves, J. (2012). Modelling stress recognition in conflict resolution scenarios. In International Conference on Hybrid Artificial Intelligence Systems (pp. 533-544). Springer, Berlin, Heidelberg, https://doi.org/10.1007/978-3-642-28942-2_48. **Contributions 2,3,4**. (Chapter 4, 5)

1.4 Structure of the Document

This document contains seven chapters and is organised as follows. In this chapter the main problem is contextualized and defined, and the principal motivation for this work and its contributions are described. Chapter 2 presents an overview of the related background and prior research, establishing the current state-of-the-art and identifying its main drawbacks. A summary of the most appropriate technologies and research approaches for developing the research work is described. The research design of this work and the methodological choices are revealed in Chapter 3. The plan for transforming research questions in a research project is also presented. The model on which the research answered the questions posed above to gather reliable and valid results is disclosed. The primary subject of this thesis appears in Chapter 4, where is introduced a conceptual framework for conflict management to retrieve contextual and environmental information, along with a basic structure utilized to frame conflict in a virtual environment. The Chapter begins exploring the nature of conflict from a computer science perspective, throwing to light an up-to-date review of the evolution and state-of-the-art intersection of conflict with technology-assisted systems and instruments. Next, the investigation and development of conceptual mechanisms to support the exploration of conflict are described. This chapter then presents a computer-based approach to conflict management that comprises models for performing decision-support-related tasks. Moreover, this chapter also gives an overview of the technologies implementing a technological platform for handling conflict in a virtual environment. Next is proposed an architecture that covers the central conflict management system's technical needs. A modular development approach that is backgrounded with conceptual models and frameworks is described. This description is followed by a detailed explanation of extending previous approaches. The validity of research hypotheses and the applicability of the concepts of conflict management in an IE are demonstrated through a proof of concept method and the results presented in Chapter 5. The chapter provides the experimentation methodology and gives the results obtained. Therefore, the studies designed to acquire and provide context and behavioural information about the participants of a conflict situation are presented. The findings are outlined and linked with this work objective. The document finishes with Chapter 6 providing a summary of contributions, the conclusions of this work, and raises some points of discussion and future lines of research.

Chapter 2

Background

"Eventually ODR may be the way we resolve most of the problems in our lives, with algorithmic approaches even more trusted than human powered resolutions".

Ethan Katsh & Colin Rule

This chapter consists of reviewing the most appropriate technologies and research approaches for developing the conceptual and technological frameworks that can acquire and provide context and behavioural information about the participants of a conflict/dispute [1] situation. In the following sections, the literature review is presented, establishing the current state of the art and identifying its main drawbacks, namely on conflict-handling projects as foreseen in the works of Carneiro [4] and Campos [7], and a brief overview of the current state of the legal systems and the intersections of AI and Law is performed. Thus, based on these works, this thesis aims to move forward from a paradigm in which reactive ICT tools are used by parties to share information to an immersive intelligent environment [8] which proactively supports the lifecycle of the conflict resolution mechanism with relevant knowledge.

2.1 Ambient Intelligence and Behavioural Knowledge

Ambient Intelligence (AmI) is a technological field that provides methods to make smooth decisions instead of a user, i.e., "a digital environment that proactively, but sensibly, supports people in their daily lives" [9]. Sensors must surround the ambient to provide information from the user and the ambient itself to do this decision-making. Furthermore, it has to make *intelligent* choices supported by Artificial Intelligence

[1] Throughout the manuscript, the concepts "dispute" and "conflict" are used interchangeably. Indeed, and even though the terminological clarification of these terms is simultaneously necessary but lateral in this thesis, is advised to read the essay written by Brad Spangler and Heidi Burgess on this subject: `http://www.beyondintractability.org/essay/conflicts-disputes`.

(AI) algorithms. Thus, Ambient Intelligence systems implicate complex cooperation between hardware, software, and networks, and this has to be done efficiently and effectively to provide an accurate result to users [10].

In AmI sensors have an essential role; to perceive the environment is necessary to request data from it; this is made using sensors such as temperature, presence, humidity, temperature, stress, and others. Actuators also have a role in this ecosystem, with that is possible to make autonomous changes on ambient like controlling light and temperature, open windows, heating water. Therefore, mixing sensors, actuators,AI techniques to give to certain ambient levels of intelligence without interfering in a person's life must be the objective of a platform. AmI is a multidisciplinary field besides sensing and acting layers, a system of this type must have a reasoning component that makes decisions upon the entire system; to do that, it just has a knowledge base about the environment, the data collected from sensors, and information about the users and their actions [11]. For example, to know the user's actions and make decisions upon these actions, the system has to reason about spatial and temporal conditions of the events. This propriety gives clues about the daily activities of users [12]. Another aspect of an AmI system is that it must be secure and ensure users' privacy. A house equipped with pervasive devices that might change the ambient surrounding and realize what is being carried out also can become a surveillance network used by external entities. To ensure users' acceptance, must counteract this capability (no privacy), and these systems must be reliable for consumers[13].

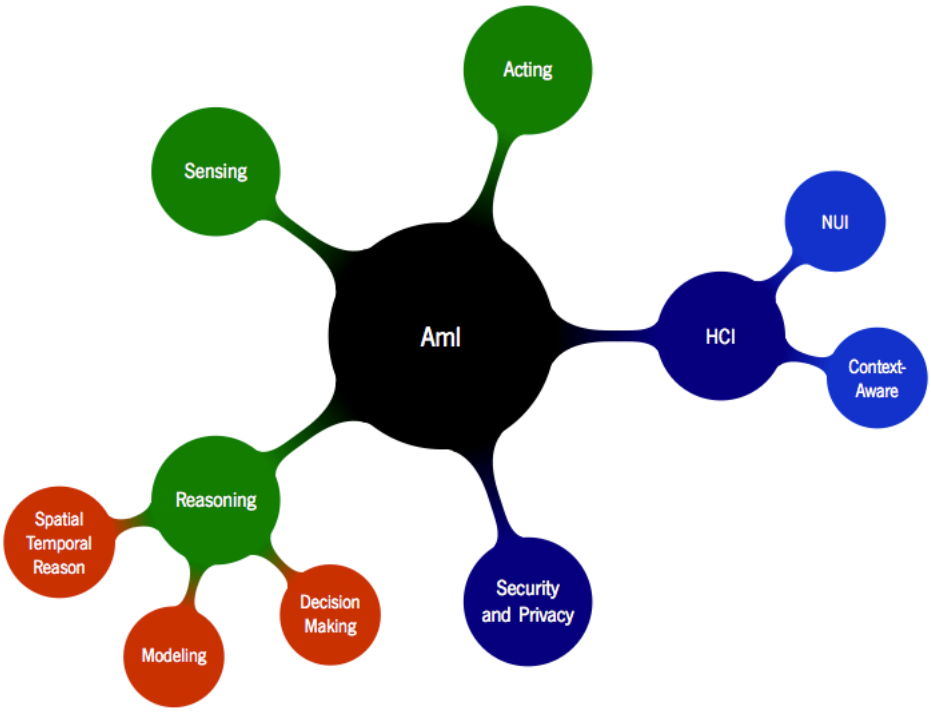


Figure 2: Ambient Intelligence as a multidisciplinary field by Cook et al [11].

To ensure the acceptance of society, it is also necessary that AmI "should be made easy to live with" [11], to tackle this matter, this area has been aware the concepts of Human-Computer Interaction (HCI). Sensors tend to have a pervasive effect, or ubiquitous (almost invisible to the naked eye and everywhere), and the raw data from sensors has to be taken to a context (Context Awareness) for introduces significant information from the action on the environment and to act upon it [11]. The user's interaction with the system needs to be natural (Natural user Interface -NUI) without cause friction in users; this need is justified turning to the notion that human beings change dynamically through emotion and mood. They are unique, so the platform needs to change and decide when users need them and not when users cannot approve changes. In other words, the system has to be aware of users' emotions and intention to perform certain behaviors (Emotion-Aware that is closely related to AC) [14]. Sustainable behavior management must be quiet, unobtrusive, but capable of changing a person's habits to be more efficient and reduce the environmental impact. This aspect is the step that approximates psychology and Ambient Intelligence and may result in a better understanding of how people can reduce their negative impact on the environment.

AmI has, as already seen in this section, many uses in a vast domain. Under this paradigm, computational power is seamlessly embedded into the environment, ultimately creating computational environments that implement their lifecycle in an ideally transparent way for the user. Our main aim is to develop conflict resolution environments that will support the already traditional conflict resolution tools by providing important context information derived from the environment. In that sense, from the user's point of view, he still interacts with a common conflict resolution platform. However, he does it from within an intelligent environment that is transparently supporting the conflict resolution tool with additional information that may be important for the evolution of conflict resolution. This information that is seamlessly provided to the conflict resolution platform, potentially without the user's interference, will allow the development of more complete conflict resolution models that, by being more abundant in information, will shape the ones undertaken by human experts more realistically.

2.2 Online Dispute Resolution and Artificial Intelligence

With moving on to a global society based on computers, new needs emerged in Alternative Dispute Resolution (ADR) [15]. As disputes can now occur between virtually any two entities in the world regardless of their location, it would be impracticable for these two entities, although all the goodwill, to use an ADR mechanism. Although there is no court in ADR designated for solving the case and the area for the dispute resolution can be chosen by the parties, there is still a need for a physical location to meet and carry on the process. Consequently, different modes or methods of alternative dispute resolution for electronic environments have been pointed out by the legal doctrine. As a result, we can now speak of Online Dispute Resolution (Online Dispute Resolution (ODR)) as any method of dispute resolution where an open

or closed network is used as a virtual place to resolve a dispute in whole or in part [16]. From a technical perspective, the relevant question is to determine how and to what extent traditional mechanisms can be transplanted or adapted to new telematic environments. These environments take advantage of the resources made available by the latest information and communication technologies. Namely, Artificial Intelligence models and techniques that include but are not limited to Argumentation, Game Theory, Heuristics, Intelligent Agents, and Group Decision Systems, as described by Peruginelli and Chiti [17], and Lodder and Thiessen [18]. Moreover, contrary to previous approaches, in ODR, it must be considered the disputant parties and the eventual third party and what Ethan Katsh and Janet Rifkin call the fourth party, i.e., the technological elements involved. The ultimate goal of AI research in this area is to accomplish a technical threshold, resulting in computational systems that are assuredly the 3rd party. There is no significant human intervention on this comprehensive approach or guiding the parties to a particular situation. There is, on the other hand, a computational system that performs that significant role. This role is usually known as an electronic mediator or arbitrator. This aspect is the most challenging approach to follow as computational systems that implement the cognitive capabilities of a Human expert are not easy to accomplish, mainly if we include the ability to understand the emotions and desires of the parties involved.

Depending on the importance of the function that computer systems play on ODR systems, they can be categorized as first or second generation [17]. While in first-generation ODR systems, technology is a mere tool and has no autonomy, second-generation ODR systems are defined mainly by a more autonomous and efficient use of technical tools. One can look at areas as diverse as Artificial Intelligence, Mathematics, or Philosophy to implement such services. Moreover, the leading technologies used in ODR ranged are:

- Multi-agent Systems (Multi-Agent Systems (MAS)) that emerged from AI with distributed computational models [19]. In this paradigm, simple agents or modules are responsible for some part of the environment, and the global objective is achieved through the cooperation of the agents [20]. MAS technology is suited for many different fields and especially suited for implementing distributed ODR systems mainly because agents may mimic social interactions between humans. Much research has also been done in argumentation with agent technologies to foster agents' debate, defend their beliefs, and convince the other agents to believe the same [21]. Agents may also implement negotiation techniques [22]. In MAS, negotiation refers to the modeling of Human negotiation techniques for conflict resolution between agents. In ODR, these are especially useful as argumentation and debate are the central parts of any dispute resolution process;

- Decision Support Systems may be used in virtually any knowledge-based environment, and ODR is not an exception [23, 24]. More complex processes may involve much information that can become hard to deal with by the parties, and above all, by the mediator. They can also be helpful when the

Table 1: Categorization of ODR Systems.

Category	**Methods**	**Main players**
Information systems	Provision of information that parties can use to resolve their dispute	Scenario Builder Notgoode-nough.org
Univariate blind bid-Automation	Automation for single monetary issues	CyberSettle
Document management for negotiation	Facilitators working online and/or offline with parties making use of formally structured document management tools to help them create their contract	Negoisst
eNegotiation (or automated mediation) systems	Sophisticated optimization algorithms to generate optimal solutions for complex problems	Family_winner Inspire SmartSettle
Customized for negotiation or mediation of a particular type of dispute	Automated negotiation with structured forms	eBay UPI SquareTrade
General virtual mediation rooms	Human mediators working online with parties making use of mediums such as email, instant messengers, telephone, and discussion forums	ECODIR Mediation Room SquareTrade
Arbitration systems	Human arbitrators working online with parties making use of mediums such as email, instant messengers, telephone, and discussion forums	Work & Bond

parties are not at ease with a certain kind of information or summarize too much information to understand better;

- Expert systems try to replicate the skills of a human expert in a determinate field of expertise [25], and before these expert systems are ready to be used, they must be trained [26]. Therefore, it is expected that an expert system can deal with information relating to the specific problem domain, analyze it and produce knowledge and then take actions and decisions based on that knowledge. It is also expected that these actions and decisions resemble the ones that the human would take.

Specific implementation scenarios of expert systems can be found in ODR replacing human experts with software ones [27–30].

Hence, by intersecting these fields, one can find a range of technologies that will significantly empower the previous generation of ODR tools. Thiessen and Zeleznikow [2] observed that ODR could be classified into the following seven categories as indicated in Table 1. The systems represent a wide range of approaches to dispute resolution (e.g., Artificial Intelligence, Social Psychology, and Game Theory). Given the wide variety of possibilities, it should be clear that there is no universally best approach or technique. Recently, some researchers have been to go a little further by crossing automated ODR system with smart contract technology designed to resolve disputes (see Fig. 3).

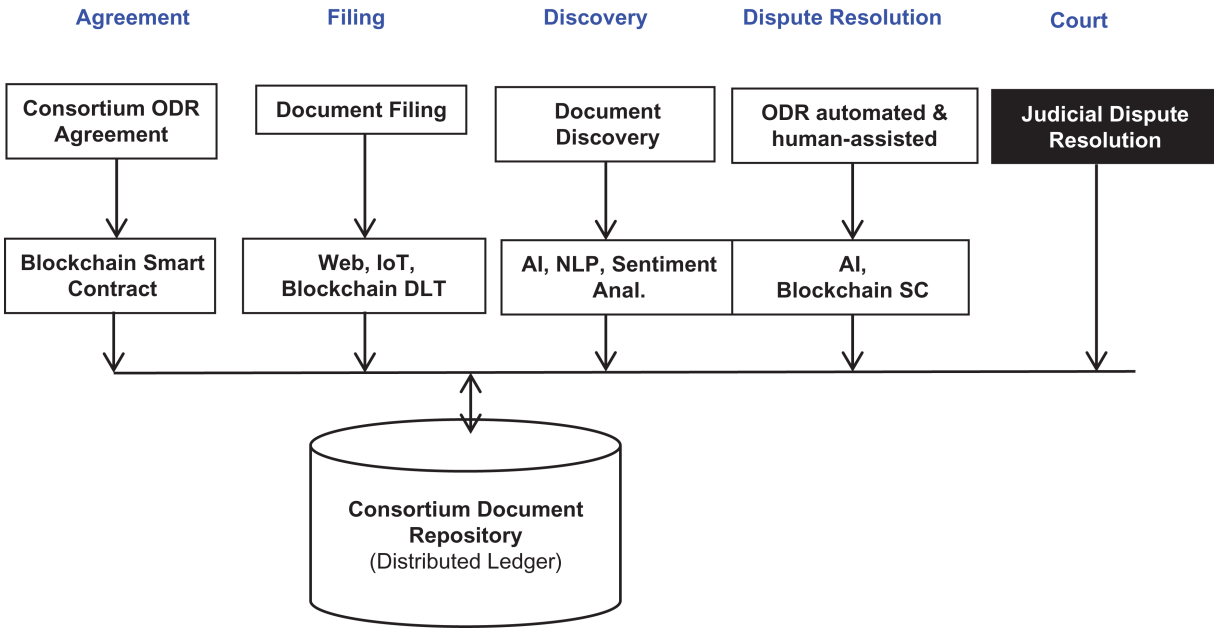


Figure 3: A possible structure of a Corporate ODR system. Diagram from Barnett et al [31].

2.3 Conflict-Handling in a Virtual Environment

Many works have focused on the support of negotiation activities to resolve/manage conflicts between human and or software agents [32]. Two general ways have been employed to express and manage conflict issues:

1. Mathematical model-based systems - which are generally based on game theory and economic behavior, where a vast majority of developed systems have utilized quantitative models, such as

[2]Visit: `http://www.mediate.com/pdf/lodder_zeleznikow.pdf`

multi-criteria decision making, conflict analysis, group decision theory, multi-objective linear programming, and fuzzy arithmetic to search for an efficient solution based upon the negotiation criteria and preferences provided from the users;

2. Heuristics model-based systems - which are developed using AI techniques to model the strategic behavior of the negotiating parties. For instance, systems using knowledge-based systems to model the impact of decisions within competitive negotiations and model and simulate possible negotiating positions. Moreover, some researchers use case-based reasoning techniques in conjunction with multi-attribute utility theory to assess the negotiation problem and compare it to stored similar past cases. As a result, a solution to the considered conflict can be adapted. Cooper's work [32] presented some works attempting to abstract out strategic negotiation knowledge from domain knowledge and has identified generic negotiation strategies, which are considered a fundamental concept for developing a multi-agent negotiation framework. Lander and Lesser, cited by [32], have been among the few who recognize and address the need for a computational distributed control model, which is the essence of multi-agent negotiation. Their developed 'negotiated search' algorithm provides a generic search method that explicitly recognizes and exploits search activity between agents. Conflicts are used as sources of control information for the search.

A literature review is presented to identify the models, technologies, and failures that support system conflicts can accommodate in a virtual environment. Several challenges have been tackled in the past in the research context in which this proposal is framed. It was defined an architecture for supporting context-aware systems that are extensible and highly dynamic and configurable, based on the intersection of MAS and Service-Oriented Architectures (SOA) [33]. It was also focused on acquiring context information in different domains, including Conflict Resolution [34–37] or domestic assistive environments. These works gave to the candidate the necessary background for understanding the challenges of developing conflict-handling systems in the context of IEs.

2.3.1 Current Literature Overlapping Conflict-Handling Projects

When analysing the current literature searching for potentially overlapping projects already taking place, it is concluded that projects targeting these specific issues are nearly non-existent. In fact, despite the extensive research in social and organizational sciences that address these issues, remarkable advances in computer sciences are still scarce. However, one can find some approaches to address parts of these topics. For example, in Nandalal works [38], a conflict support system for water resources planning is detailed. However, this work presents a relatively static perception of the conflict. No conflict style inventory is used even though the method proposed to resolve the conflict is based on two handling styles. On the other hand, in Ludwig's work [39], the author developed an agent-based assistant for electronic negotiations, using the Thomas-Kilmann Conflict Model [40] and negotiation data from an

experiment conducted by human negotiators. In this approach, capturing the participant's behaviour uses assumptions based on preferences obtained through questionnaires. On the one hand, in Yiu's work [41] the author applied the Rahim Organizational Conflict Inventory [42] to classify five negotiation/conflict styles. Still, the approach has a similar problem to Ludwig's work [39]: both rely on self-report instruments to measure the personal conflict-handling styles. On the other hand, Jain's work [43] highlighted the unaddressed issue of the participants' predisposition to conflict on negotiation outcomes and concludes that future research may focus on the effects of realistic elements of negotiations, such as task complexity and participants' susceptibility to conflict.

The work of Holt [44] points out the need for a rigorous conflict resolution instrument that measures conflict behaviour rather than the self-report instruments used in the past decades. In addition, Holt underlines that the participants' interpretations of the conflict style versus the perception by others of their conflict style is critical but still a new topic. This proposal's fundamental idea addresses these issues with dynamic and automated conflict style classification methods incorporated in a conflict support framework that also provides perception/cognition tests. The project will follow after the conclusions presented in Wood's work [45] to enrich contextual factors that influence conflict behaviour. This work has shown that new personality measures are significant predictors of conflict styles. We will also consider the work of Khan [46] that suggests the possibility of estimating personality traits from the analysis of the interaction patterns with the keyboard and mouse. Also, Chittaranjan's work [47] in which describes a machine learning method to detect the personality trait based on mobile device usage. This thesis will thus be based partially on the intersection of insights from these research works with the continuation of this research on the extraction of behavioural information from the use of mobile devices [34].

2.3.2 Technological Platforms Developed by the Research Community

This Section will be looking at a few projects that are being developed by the research community. Most of the projects analysed are maintained by universities and other institutions and focus on particular questions rather than the whole conflict management problem.

- **Conflict Resolution Software** - It is an online solution to case tracking and reporting and work-flow automation for any mediator, arbitrator, neutral, alternative dispute resolution (ADR) specialist, or organization that practices conflict resolution mediation and informal or formal mediation and/or arbitration. `http://www.conflictresolutionsoftware.com/`
- **Cascon** - Is a computerized history-based conflict analysis and decision-support system, designed to serve as both an aid to the memory and as an aid to the imagination. CASCON derives from earlier research at MIT under the direction of Professor Lincoln P. Bloomfield on the subject of local conflict and its prevention. `http://web.mit.edu/cascon/`

- **Dispute Systems Design** - Dispute systems design involves the design of systems or mechanisms used routinely to handle similar, repeated disputes. It is beneficial for organizations with the same kinds of problems repeatedly occurring–such as disputes between co-workers over work assignments or between workers and management overcompensation, working conditions, or work performance. `www.colorado.edu/conflict/peace/treatment/dsd.htm/`

- **3E** - An essential aspect of managing risk is controlling and identifying potential conflicts before they happen. 3E provides conflict management capabilities that allow you to manage your new business intake and conflict search efforts confidently. An intuitive Web-based solution, 3E has built-in, configurable workflow processes, collaboration tools, automated tracking in a secure environment, and offers a single entry point. `http://www.elite.com/3e/rm/conflicts-management`

- **LegalKEY Conflicts Management** - It is a comprehensive, interactive conflict resolution system that aims to help lawyers get the information they need to quickly identify, prioritize, and resolve potential exposure begin billable work while protecting the firm from taking on the problematic business. `http://www.opentext.com/what-we-do/industries/legal/legal-content-management/law-firms/OpenText-Conflicts-Management-LegalKEY-Edition`

- **Profile** - Negotiation approach reflects people's predispositions toward conflict resolution. It is believed to have a significant impact on effectiveness. Therefore, this project conducted this experiment to examine negotiator's negotiation approaches and their influences on the negotiation process and outcomes. Traditionally, studies in negotiation literature consider people's negotiation approaches in an isolated manner. They assume that people use negotiation approaches exclusively throughout the negotiation session. However, people tend to use more than one approach sequentially or simultaneously. The approaches in the negotiator's profile will jointly determine the negotiation process and outcomes. Profile project examines negotiator's approach profiles and their relationship with effectiveness in both the individual and dyadic levels. `http://interneg.concordia.ca/index.php?id=newproject&project=Profile.html`

- **Genius** - Genius is a negotiation environment that implements an open architecture for heterogeneous negotiating agents. It provides a testbed for negotiating agents that includes negotiation problems for benchmarking agents, a library of negotiation strategies, and analytical tools to evaluate an agent's performance. `http://ii.tudelft.nl/genius/`

- **Pocket Negotiator** - The Pocket Negotiator project is divided into four sub-projects dealing with different aspects of a negotiation support system: Qualitative Negotiation Models, Emotion and Interaction in Negotiation, Man-machine interaction and negotiation, and Negotiation Strategies. `http://ii.tudelft.nl/negotiation/index.php/Pocket_Negotiator/`

- **Tiarac** - The Telematics and Artificial Intelligence in Alternative Conflict Resolution project aimed

at developing technological solutions towards proper resolution methods, mainly in dispute resolution and assets division. Argumentation, artificial intelligence, game theory, Heuristics, Intelligent Agents, and Group Decision Systems were integrated into the resulting intelligent negotiation support system. `http://islab.di.uminho.pt/tiarac/`

2.4 Intersections between AI and Law

Almost since 1970, it has been noticed the "information crisis in law" (an ever-increasing amount of legal data that is being generated and not plenty or properly used) encouraging the development of legal Information Retrieval (IR) systems [48]. Also, almost since 2007, the "natural language barrier" [49] has been discussed as a barrier that hinders artificial intelligence in the legal domain. However, even using artificial intelligence and other computing approaches almost since the 1970s, there was no breakthrough in such matter [50]. Most of the research performed on the use of AI in the legal domain appears to relapses in three main categories: Computer-Aided Reasoning (CAR), Knowledge-Based Systems (KBS), and Legal Language Processing (LLP). Those categories are highly coupled since CAR needs KBS, which relies on LLP, so that those groups are a matter of research focus. This is suggested to be called a Legal Intelligent System Stack (LIIS). Considering a legal system stack, CAR appears to be performed most by Case-based Reasoning. KBS seems to be built in most cases using one or another ontology strategy; on the other hand, on LLP, a commonly used approach appears not yet to exist. Regarding application, most of the research seems to aim one way or another of Legal Information Retrieval. Datastore and querying are ancient human needs performed by cataloguing and retrieving systems [50, 51]. Cataloguing systems are used to handle structured data and retrieving the system's unstructured data. The first is related to SQL (or relational) within a computer science scope, yet the second to NoSQL (or non-relational) technology. Shall highlight that it is not a matter of choice but the impossibility to structure some types of information [52]. Moreover, Computer-aided Reasoning cannot only rely on formal logic [53]. It must also rely on a knowledge-based system that needs a legal language processor to be composed [51]. The stack sits on legal language processing. While it is not properly settled, it will not be possible to reach the expected breakthrough, called the "natural language barrier" [51]. The stack sits on legal language processing. While it is not properly settled, it will not be possible to reach the expected breakthrough, called the "natural language barrier"[49]. In this sense, it was realized that most natural language processing approaches do not adequately suit legal texts due to their idiosyncrasies, and legal language processing comes into use [53].

Specific issues of legal texts include sentences twice longer, and prepositional chaining is a third deeper than those used in newspapers [53]. Also, legal terms may present proper semantics being different from the regular use of it. Moreover, the law of each country is written in its official language and considers a particular legal structure [54]. Because of that, those concerns must be dealt with locally

and hinders international cooperation. In other words, the "natural language barrier"in the legal field includes lexical, syntactic, semantic, pragmatic, and idiom obstacles. But once surpassed, it is believed that conventional approaches of Computer-aided Reasoning and knowledge-based systems are feasible to be used [49].

The difficulties are not restricted to legal language processing, although it typifies a barrier. Information retrieval itself presents several issues to be handled. The index formation (that can be static or dynamic), according to the complexity of data and the index itself, may lead to computational complexity (time and space) issues requiring some cluster processing and other big-data approaches [52]. A significant data source may return more information than the user can handle, requiring a scoring system to rank the fetched documents. Due to the diversity of possible approaches, shall build an information retriever as specific as possible given a domain and user [50] within a user-centered design. Also, another peculiarity of legal retrieving is the need to encompass juridical dynamics and context. Case-Based Reasoning (CBR) is a problem-solving method that addresses new problems by remembering and adapting solutions previously used to solve similar issues [55]. CBR is based on two tenets to understand intelligence: problems tend to occur repeatedly, and similar problems have similar solutions [56]. Also, the answer to each new problem in CBR becomes the basis for a new case, being learned and stored for potential reuse in the future [57].

The typical CBR cycle is composed of [55, 58]: Retrieve, Reuse, Revise and Retain. The retrieving step is responsible for determining which case is most similar to the new problem. Two different approaches can calculate cases' similarities: the K-Nearest neighbours approach - which uses a weighted sum of features to identify the similarities - and the template retrieval approach - which returns all cases that fit within specific parameters. During the CBR cycle, some stages usually have human interaction. For example, while it may automate case retrieval and reuse, case revision and retention are performed by human experts. Reuse is the process that receives the retrieved cases and makes the necessary adapts to solve the new problem. There are two methods used to perform this action: transformational and derivational. While derivational methods modify the previous solution using domain-specific transformation operators, the transformational methods reuse the algorithms, techniques, or rules that generated the original solution to produce a new solution to the current problem.

Traditionally, intelligent systems procedures were described through rules, called Rules-Based Reasoning (RBR). For Hayes [59], expressing knowledge using this model is difficult and time-consuming in real situations. In contrast, in CBR systems, the cases are knowledge, leading to automatic maintenance and updating of knowledge, while in RBR systems, new rules are created. This type of system proposes a solution to a given problem, from knowledge not wholly defined, low structured, or unknown as well as allows it to pay attention during the process of constructing a solution to the aspects/characteristics of the problem considered a determinant for the construction the same solution.

In the legal context, CBR-based systems have found vast opportunities to develop their application

methodologies and with satisfactory results [60]. The SCALIR is an example of a hybrid symbolic/sub-symbolic system that uses legal network knowledge to perform retrieval through spreading activation to perform the task [61], considering legal decisions as complex networks [62]. Indeed, the law may thus be thought of like a giant network containing information embedded in cases (nodes) and relationship information called citations (arcs) going from node to node. Measures such as betweenness, closeness, and Markov Centrality can help find the cases that lie at the core of a judicial system. Likewise, measures such as clustering enable understanding the degree of interdependence of cases that comprise a jurisprudence database.

Meanwhile, as pointed out by Carneiro [4], both RBR and CBR approaches to negotiation face criticism. Thus the main drawbacks can be succinctly enumerated as follows:

- Laws constantly change, thus implying updates to the rules that establish how solutions are generated in RBR. This may result in inconsistencies and/or redundancy. Moreover, this might be quite a complex task (depending on the complexity of the legal domain) that must be performed manually, despite the use of some supporting tool;
- The quality of an RBR tool is directly dependent on the quality of the work of the humans, translating the legal norms into rules. The quality of information of the rules may be hard to determine;
- RBR are static and will not shape changes in the legal domain unless these are coded manually by a human expert;
- The quality of a CBR tool is directly dependent on the quality and amount of past cases known;
- The fact that legal norms change frequently also has a negative impact on CBR approaches, rendering past cases potentially useless under the light of the new norms;
- Both CBR and RBR approaches are domain-dependent. This implies that rules are defined independently for each legal domain and that cases from a specific field can hardly be reused.

2.4.1 Projects using AI to Address Justice and Law Needs

Aided by growing access to large bodies of semi-structured legal information, some data-driven emergent studies have paid particular attention to processing and deriving insights from large-scale data or document sets (in which humans have important cognitive limitations) specially designed to support the work of judges. And they must be pointed out. As an example, some studies have guessed at justices' behaviour with algorithms. Blakeley McShane articulates the first predictive model of securities fraud class action lawsuits. It predicts both the likelihood of settlement and the expected settlement amount. The model is fully predictive from the initial stages of litigation, as it uses only variables that are known at the day of filing [63]. A 2011 project, for example, used the votes of any eight justices from 1953 to 2004 to predict the vote of the ninth in those same cases, with 83% accuracy [64]. A 2004 paper tried seeing into

the future by using decisions from the nine justices who'd been on the Court since 1994 to predict the outcomes of cases in the 2002 term. That method had an accuracy of 75% [65]. One particular study sought to employed Natural Language Processing and Machine Learning to analyse the European Court of Human Rights decisions. The predictions from this modelling were 79% accurate [66]. More recently, a study applying machine learning and prior work in the science of judicial prediction construct a model designed to predict the behaviour of the Supreme Court of the United States. The study presented a 70.2% accuracy at the case outcome level and 71.9% at the justice vote level. Indeed, the core algorithms of these works were all published in academic journals long ago and are readily available [67]. The hard (very hard) work is effective implementation against good data at scale. Furthermore, these works highlighted the problem of implicit bias (and its potential influence on behaviour). As Daniel Katz states, Human reasoners have well-documented cognitive biases, such as the availability heuristic, optimism bias, anchoring, confirmation bias, illusion of validity, and the frequency illusion [68]. Indeed, there are challenging normative and practical concerns regarding the ability of "machine-made justice" to meet appropriate procedural and substantive standards[69]. Therefore, Katsh points out the need for new dispute resolution processes and new ways to avoid disputes to improve access to justice [70]. At the same time, Daniel Katz reinforces this idea by stating that the transparency associated with developing predictive models can ultimately help to tackle down some of these important and well-known human deficit [68].

Moreover, Susskind [71] argues that technologies like AI are going to bring about a decade of change in the legal sector and transform the legal systems as we know it. Likewise, Kauffman [72] prognosticates *that future legal system could use AI technology to help solve disputes without requiring lawyers or the traditional court system.* Meanwhile, however, and attaching to the present, and still quoting Kauffman, AI solutions in legal services can be nowadays grouped into one of the three areas: document analysis, legal research, and practice automation [73]. So, for Kauffman, the present AI-based legal research tools offer a diversity of analytical and predictive capabilities, such as litigation analytical tools that analyse precedent case data and other data to aid lawyers in predicting case outcomes [74]; and practice automation (refers to the use of AI solutions to perform tasks ranging from document automation to e-billing management)[75]. Furthermore, Kauffman highlight that *future research in this area must be multidisciplinary and representative of the key challenges which will be faced in the deployment of AI solutions as services to improve the legal practice.* Specifically, the development and use of AI for the provision of legal services is limited concerning three main aspects, namely (1) data, (2) algorithms, and (3) implementation [76].

Meanwhile, regarding the legal framework of legal services, as stated by Viana, it seems to be based on the traditional paradigm of legal services: provided mainly through lawyers, who make themselves known only through "word of mouth" and who practice their profession without partnering with colleagues from other areas [77].

2.4.2 Status Quo of Judicial Cases in European Union

Every year, in Europe, about 20 million judicial cases see their final decision rendered in first instance courts [3]. In contrast, the number of pending cases per 100 inhabitants decreased from 2010 to 2018, which manifests an encouraging trend in Europe [78]. However, these numbers still relatively high, and although they vary considerably between the different State Members of Europe, they focus a great deal of attention from the competent authorities to ensure the effectiveness of the different European judicial systems. To evaluate the effectiveness of legal systems, the European Commission has established several metrics. Namely the resolution time, which corresponds to the estimated time, in days, necessary for the resolution of a court case; the rate of resolution of the cases, which concerns the ratio between the number of cases resolved and the number of cases initiated and also the number of cases pending at the end of each year. According to these indicators, Portugal is at an intermediate level compared to other European State Members. In 2019, the Directorate-General of Justice Policy released statistical information on Portuguese judicial courts, presenting a procedural resolution rate in the order of 124.6% and an estimated time to complete a process of approximately 30 months. Regarding pending cases, Portugal follows the trend in Europe since the number of judicial pending cases has been relatively high over the years. However, in 2018 it was the lowest pending since 2016, with a decrease of 35% between 2015 and 2018 (less than 463 273 cases).

Because of the current status, several entities are calling for methods for resolving conflicts alternatives to litigation[4]. Specifically, these suggested the availability of ADR and ODR processes to complement court structures that promotes access to justice for citizens alike (Mania's work emphasises the importance of new European regulations on ODR and ADR [79, 80]). Moreover, they also accentuate prominent cultural and economic resistance to the promotion and use of ADR and ODR processes in the many Member States, and these processes only grow where ADR and ODR providers are trusted to provide fair and just outcomes [81, 82]. As example, Schmidt-Kessen's work points out how the potential of extrajudicial mechanisms can be exploited in order to close the gap in consumer enforcement [83]. Moreover, the study developed by Hörnle [84] illustrate the current global panorama of ODR mechanisms in some countries (among which Germany, France, Poland, Switzerland, etc.) encourage the use of ADR procedures in a pre-trial stage. However, it is not a mandatory requirement in the processing of civil cases. What is certain is that the vast majority of Member States studied do not report the use of ODR techniques before the traditional judicial context. In countries that previously resorted to ODR, they do so through remote communication tools (as in France, with family mediation).

[3] European Commission. The 2019 EU justice scoreboard.

[4] Report of the European Law Institute and of the European Network of Councils for the Judiciary - 2018.

2.5 Summary

In this chapter, it was analysed the relationship between conflict and ICTs. It also explored the challenges individuals face in using online technology for collaboration and conflict mediation purposes. Can conclude that developments in ICTs have played a critical role in exacerbating and/or resolving conflicts. It was also shown how recent AI innovations could facilitate knowledge acquisition, network building, and the analysis and presentation of conflict-related data. Indeed, several online-specific techniques have been developed to take advantage of the new technology; these include automated negotiation (without human intervention) and negotiation support systems. Meanwhile, regarding the review of literature in previous sections, the main drawbacks of current approaches can thus be summarized:

- the need for a rigorous conflict resolution instrument that measures conflict behaviour rather than the self-report instruments;
- acquisition of information is performed in rudimentary ways, without support;
- there are no advanced tools for the structuring and retrieval of complex legal information;
- current trend continues to focus mainly on the development of technological tools, leaving aside essential issues that are present in traditional dispute resolution processes;
- current conflict-handling systems have no autonomy and still rely primarily on humans.

Several sub-fields of AI should be regarded as particularly interesting to achieve the goals exposed in Section 3.2. The use of AI and, more particularly, AmI techniques can help to suppress these gaps. This project considers that a Conflict Management intelligent environment should be envisioned as a virtual space in which disputants have various conflict resolution tools at their disposal. Participants or managers can select any tool they consider relevant for solving their conflict and using the instruments in any order or manner they desire or guide them through the process. It was also planned that should enrich decision-making with relevant knowledge (contextual and behavioural information). An intelligent system design to assist parties to overcome the challenges of current negotiation through a range of analytical tools (based on Chapter 4) is presented in the following Section 4.3. The idea is to clarify interests, identify trade-offs, recognize party satisfaction and generate optimal solutions. In this context, one must point out that the use of ICT and AmI applications and new technologies are not entirely risk-free. In any online medium, communications and data may be intercepted, monitored, altered, accessed, downloaded, or even destroyed. These risks, however, can be mitigated and minimized through encryption technologies, firewalls, and passwords, as well as privacy-enhancing technologies to ensure that information about parties remains confidential and secure.

Furthermore, these frameworks will encompass the determination of the existence or not of a conflict, its characterization and nature, the generation of possible arguments/proposals, and the closure of the process. The development of a conceptual and technological approach capable of covering this kind

of information will follow the concept of IEs, in which an intelligent environment supports the conflict management platform with context information.

Chapter 3

Conceptualization

"The poet was a fool who wanted no conflict among us, gods or people. Harmony needs low and high, as progeny needs man and woman".

Heraclitus of Ephesus

This Chapter aims to reveal the research design of this work and the methodological choices made herein. Thus, it has its primary function to highlight the plan carried out for transforming research questions in a research project. Nevertheless, this was a process influenced by philosophical assumptions and research approaches. Indeed, the choice of research questions affected the research strategy, the techniques for collecting and analysing data, and the time horizon for completing the project. Briefly, this Chapter aims to disclose the model on which the research answered the questions posed above to gather reliable and valid results.

3.1 Problem Statement, Motivation and Goals

Conflicts arise from the complexity of society and the human mind. They may have positive or negative consequences depending on how conflicts are handled or managed. Learning to handle with them correctly is a complex, challenging, but essential task. Especially when, these days, the conflict is brought to the digital environment where new business processes (buying and selling products on the internet) are already sufficiently widespread. Therefore, the conflict that arises in digital environments or those brought to must be managed appropriately. With conflicts now also emerging in virtual environments, a new field of research has been developed in which AI and mainly AmI are interesting. However, the development of tools for this purpose is insufficient (See Sec. 2.5). Therefore, it is essential to develop conflict management platforms covering critical aspects present in traditional resolution and conflict management processes, including context-dependent elements that significantly affect human behaviour. For

a comprehensive analysis of conflict, its dimensions must also be understood and addressed. Having a conceptual framework that visually highlights the critical dimensions of this process, such as changes in the personal, structural, relational and cultural aspects of conflict, brought about over different periods (short-, mid-, and long-term) and affected different system levels at other times, is an important step. Indeed, it will also be needed to depict the factors that drive change in conflict management, the processes that determine its nature, and the implications of the decisions. Simply speaking, the underlying idea is to have an adequate theoretical basis for analysing conflicts and devise appropriate responses to them and evaluate the effects of these responses [6].

Contextual information can influence the course of the process and, therefore, the conflict setting. Making assumptions about the information that can characterize a person's situation is hugely relevant to assist conflict resolution/management platforms to find the path to achieving successful outcomes. From the point of view of the human mediator, access to this information is also vital to plan the right strategy and perceive how each issue affects each party, much like it is done in traditional conflict resolution processes when parties meet face-to-face. With this purpose, developing such a framework (to collect context information and perceive activities being performed) will result in a set of services or functionalities that will support the work of the conflict manager. The aim is to release the conflict manager to have a more informed and practical approach to dealing with complex issues such as improving interpersonal communication and relationships. To do so, this project approach bases on the idea that an AmI system can create scenarios that enhance the possibilities of reaching a favourable outcome using contextual knowledge. In addition, it may shed light on the conflict and establish a description of how may use valuable knowledge to understand the conflict further. Therefore, a particular set of new challenges will be presented: supporting a conflict process and adequately providing helpful information, captured in a non-intrusive and non-invasive way, to decision-makers.

3.2 Research Hypothesis, Questions and Objectives

As stated before (in Sect. 1.1), this PhD work stands on the idea that parties must engage in a conflict situation access valuable knowledge to make proper decisions; in that sense, having a decision-support system to assist parties in a conflict situation should be centred on providing to all the intervener of conflict the appropriate knowledge at the right time. Therefore, the main research hypothesis that guided the work performed during the doctoral program was the following:

Research Hypothesis

An AmI system can create scenarios that enhance the possibilities of reaching a favourable outcome in a conflict management process using contextual and behavioural knowledge.

The central claim of this work was that some conflict aspects could be estimated using non-invasive and non-intrusive methods and that an AmI system could deliver valuable knowledge to make more informed decisions, supported by the feedback from preliminary work (outlined in Chapter 2) in which this proposal is framed.

As a result, there are objectives related to the research hypothesis and the work plan detailed aimed to validate and justify this research program. These are presented here in the form of research questions. In that sense, these are presented here in more specific and better-defined research questions to be addressed during the PhD work. Managing and validating each of the different research questions will determine the research hypothesis's eventual validity. Therefore, each of the research questions and its objectives and validation methodologies is put forward.

Research question no. 1: *An AmI system is suitable for implementing a Conflict Management Platform?*

AmI systems are seamlessly embedded into the environment, ultimately creating computational environments that implement their lifecycle in an ideally transparent way for the user, i.e., aim to provide information from the user and the ambient itself to enhance decision-making. In this work, the candidate argues that an AmI architecture, in which an environment where a group of devices could cohabit and share information towards a common goal, is a suitable approach.

Objectives: The main objective of this research question is to determine an appropriate or the most appropriate technologies to implement a technological platform for handling conflict in a virtual environment, given the requirements provided above. A working prototype will be developed.

Validation: With the assessment of this research question, an existing AmI architecture will be developed with a basic set of services that implement functionalities identified as central for a successful conflict management process. The focus will be placed on exploiting special features such as modularity, interoperability, and extensibility.

Research question no. 2: *AI can be used to depict relevant conflict aspects (dimensions) by analysing features of a conflict situation?*

In work developed in the scope of this research topic, AI techniques will be used to explore the nature of conflict from a computer science perspective, throwing to light an up-to-date review of the evolution and state-of-the-art intersection of conflict with technology-assisted systems and tools

and, in particular, extending traditional technology-based conflict resolution/management methods with an IE. Indeed, managing a conflict in a virtual environment will thus entail designing a computer-based approach that comprises models for performing decision-support-related tasks by delivering relevant information to the disputant parties.

Objectives: The main objective of this research question is to determine a conceptual framework for conflict management to retrieve contextual and environmental information, along with a basic structure utilized to frame conflict in a virtual environment. A working prototype will be developed.

Validation: This research question will be presented to the the scientific community in the legal and computer sciences fields, properly grounded by justifying the utility of each modality and by giving plausible paths to the implementation of models for acquiring and providing relevant information.

item[Research question no. 3:]*Is it possible to acquire and provide contextual and behavioural information about the participants of a conflict situation "mediated" by an AmI system?*

By monitoring the conflict process and perceiving how each issue or event affects each party can be beneficial in conflict management supported by an AmI system, namely, by having access to the level of stress, trust, relationships, and the conflict-handling style used in each round. This knowledge gives relevant insights that can increase the success rate of conflict resolution and management procedures and bring them closer to the rich communicative environment that parties have when they communicate face-to-face.

Objectives: The main objective of this research question is to design and implement a AmI system that is backgrounded with conceptual models and frameworks, to build up each individual's profile and subsequently link that profile with the correct individual performance within the conflict process that the system has monitored.

Validation: This research question will be considered validated if such a platform is produced, deployed, and legitimized by the scientific community.

Research question no. 4: *It is possible to estimate relevant aspects of interactions that occur in a rich sensory environment in a non-invasive and non-intrusive way, in real-time?*

While the user conscientiously interacts with the AmI system and takes his/her decisions and actions, a parallel and transparent process should occur in which contextual and behavioural information is sent in a synchronized way to the conflict support platform. As a result, this environment allows that all the components able to measure and estimate can be combined to implement complex functions. Here, it is considered the hypothesis of measuring relevant aspects in a non-invasive and non-intrusive way by analysing features of the interaction patterns of individuals with technological devices.

Objectives: The main objective will be the conception of models to address the estimation of relevant aspects of interactions that occur in such virtual environments. This approach must be non-invasive, non-intrusive, and run in real-time.

Validation: This research question will be validated through the implementation of a prototype for information assessment using models validated by the scientific community.

Research question no. 5: *Is it possible to improve the understanding of how a given party responds to particular scenarios?*

When parties had to perform some activities that implied the interaction with the devices and/or with the conflict environment, data about the user's context and behaviour can be provided through a monitoring framework to be analysed. Thus, to help decision-making in conflict management, it is important to elicit how does a party behave during a conflict situation, among others.

Objectives: Intending to conceive a monitoring framework that works under the sensing and acting in a non-intrusive way, the main objective of this research question is to find out if an AmI system is a way of improving understanding of how does a party behave during a conflict situation, among others.

Validation: To validate this approach, a set of experiments will be set in which the effect of different conflict dimensions on interaction patterns will be studied by statistically comparing the behaviour of individuals in two distinct phases. Statistical hypothesis tests will be performed that will account for the validity of the research question.

The main objective of this PhD project is to provide conflict managers with models and tools to lead with conflict. This primary goal may be approached in terms of the objectives structured as follows: (1) (2) main ideas that this work aims to implement; and (3) how this project will advance state of the art.

1. This research aims to outline an alternative approach to the conceptualization and management of conflict, developing conceptual tools to aid the exploration of conflict. The identification (measured conflict dimensions/characteristics applying appropriated metrics), application and further development of methodologies, and a generalized conflict model will yield several conceptual tools for conflict management.

2. This research plan aims at a technological framework that can acquire and provide context and behavioural information about the participants of a conflict situation. The framework will encompass the determination of the existence or not of a conflict, its characterization and nature, the generation of possible arguments/proposals, and the closure of the process. This work will follow an approach in line with the concept of IEs, in which an intelligent environment supports the conflict resolution platform with context information, as envisioned by [8].

3. This project will result in a conflict support environment that, when compared with the current approaches, will be innovative in several aspects:

    - i) Dynamicity – Relations between participants in a negotiation are dynamic. They may change suddenly due to exogenous or endogenous factors, being difficult for a manager to detect and monitor these changes in time. We will focus on the use of Context-aware Systems and Ambient Intelligence techniques to compile important information about the state and context of the participants (e.g., levels of stress, conflict resolution style, background information);
    - ii) Adaptability – After perceiving a significant adverse change in the context of interaction, the manager is required to intervene. He will do so by adapting strategies (e.g., making a pause, suggesting solutions, using arguments to influence the participants). We propose the development of algorithms for the generation of solutions and strategies that can alleviate this effort and allow the manager to focus on other issues;
    - iii) Learning – We propose using machine learning techniques to allow a more efficient and thorough correlation of these factors to point out potential improvements in the conflict resolution workflow and decision-making models.

To follow the general and specific objectives mentioned in these sections, the work plan for this PhD project was divided into five main tasks to be executed during the following years of the doctoral program. The phases and their description are described in the following Section 3.5.

3.3 Strategy and Research Plan

This section aims to reveal the research design of this work and the methodological choices made herein. Thus, it has its primary function to highlight the plan for transforming research questions in a research project. Nevertheless, this is a process influenced by philosophical assumptions and research approaches. Indeed, the choice of research questions affects the research strategy, the techniques for collecting and analysing data, and the time horizon for completing the project. Briefly, this Chapter aims to find the model on which the research will be based to answer the questions posed above with the intent of gathering reliable and valid results.

3.3.1 Research Philosophy

Developing knowledge in a particular field is a fundamental achievement when embarking on research. Knowledge development is strongly related to the philosophical commitments that a researcher makes

thorough research strategy. Since this has a significant impact not only on what he does but if he understands what it is, he is investigating. Indeed the adopted research philosophy contains essential assumptions about how the researcher views the world. These assumptions will underpin his research strategy and the methods he chooses as part of that strategy.

A range of philosophical assumptions upon which this research will be based, and the implications for the method or methods adopted will be discussed within this section. Conflict is often seen as socially constructed, subjective, may change, and multiple - a multidimensional part of human existence. Studying conflict is a social phenomenon that leads to subjective meanings and encourages a researcher to face conflict as an essential characteristic of life and reality. Understanding the differences between humans and social actors is necessary to focus on a conflict situation's details. This understanding helps highlight different contexts, backgrounds, and cultures and therefore assists in making appropriate choices. In that sense, the interpretive philosophy[1] seems to me, under the epistemological perspective, the most appropriate to guide the development of this research. It would be easy to fall into the trap of thinking that one research philosophy is "better" than another. This case, which is "better" depends on the questions that this project seeks to answer. According to Saunders [85], the deconstruction of the interpretive paradigm view shows that this stance is justified as providing the best way of collecting social phenomena in natural settings. Symbolic interactionism (an intellectual tradition that can see to have a propensity with interpretivism[2]) demonstrates a relation for research in artificial intelligence [86].

3.3.2 Research Approach

Choosing a specific research approach should be based on its suitability to answer the research questions. This decision is whether this research should use the deductive method, in which develops a theory and hypothesis (or hypotheses) and design a research strategy to test the hypothesis, or the inductive approach, in which the researcher would collect data and develop a theory as a result of your data analysis. However, this stance may convey the impression that there are rigid divisions between deduction (testing theory) and induction (building theory) and misleading. It is entirely possible to combine deduction and induction within the same piece of research, but it is often advantageous to do so.

From the candidate perspective, it will be more appropriate for this project to use a combination of different ways of reasoning, especially induction (inferring a general law or principle from the observation of particular instances) and deduction (inferring from generals to particulars). Thus the chosen approach will be the combination of the two above mentioned, i.e., the hypothetical-deductive method, a research

[1] Interpretive research is based on the assumption that social reality is not singular or objective, but is instead shaped by human experiences and social contexts, and is, therefore, best studied within its socio-historic context by reconciling the subjective interpretations of its various participants

[2] The term interpretivism refers to epistemologies or theories about how we can gain knowledge of the world, which loosely rely on interpreting or understanding the meanings that humans attach to their actions.

plan that begins with a theory about how things work and derives testable hypotheses from it, which is that by which it. In Figure 4, it can be seen the steps for obtaining scientific knowledge schematically. According to this approach, the algorithmic search for knowledge is as follows:

- Make observations of the experiment/phenomena;
- Arrange the observations;
- Test the hypotheses in later observations;
- If necessary, modify the original hypotheses;
- Making predictions based on hypotheses;
- Test conclusions.

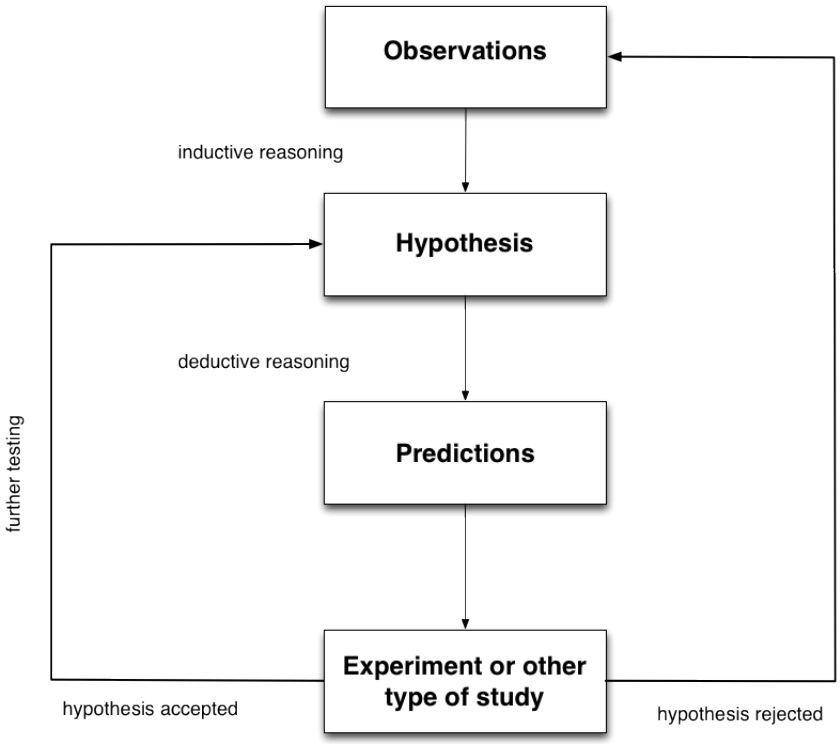


Figure 4: Steps for obtaining scientific knowledge.

This approach is a form of deductive reasoning. The hypotheses are then tested by gathering and analysing data, and the theory is then either supported or refuted by the results. This method is following the philosophical assumptions of this project.

3.3.3 The Nature and Strategy of Research

When the research aims to gain familiarity with a phenomenon, exploratory studies come in handy. Indeed, it is an advantageous approach if you wish to clarify your understanding of a problem. Due to the characteristics of conflict, an exploratory study will be adopted in this work and will be the leading way to explore various topics related to this research.

Objectively, this project can be subdivided into two parts: a technological part (an instrument used to measure the phenomenon under study) and a conceptual part (developing models representing the universe of conflict). For each one, we can plan a research strategy. Besides, one must emphasize that no research strategy is inherently higher or lower than any other. Consequently, the most important is not the label attached to a particular strategy but whether it will enable you to answer your particular research question(s) and meet your objectives. The chosen research strategies are as follows:

- Given the technological objective of this project (the development of a platform in an intelligent environment), an experiment seems to be the most suitable procedure to be carried out to establish the validity of the hypothesis proposed. The starting point of this investigation is developing a technology platform in an intelligent environment that can capture and treat relevant information to handling the conflict in a framed way. Then, base on the obtained experimental data using this platform will make a comparative analysis.
- Regarding the conceptual aspect of the work, a research strategy based on grounded theory will be planned. It can be understood as a methodology for exploratory nature that highlights the generation and development of theories that specify the phenomenon you want to study (conflict) and the conditions for its manifestation. Subsequently, the development of the technological platform is intended to carry out empirical research (an experiment) to generate data from observations. The aim is to provide empirical research to encompass the conflict dimensions through monitoring, sensing, and actuating an intelligent environment. For instance, developing a trading game based on the technology platform on which the parties in conflict try to sell or buy an object. In this case, the observations generate data that applying the appropriate models will create predictions. These predictions are subsequently tested whether or not confirming their validity. The underlying idea is to construct theories (minimum) that might expedite the process of conflict handling.

3.3.4 Methods and Time Horizon

During the execution of the plan will be advantageous to use more than one method of investigation, given the multi-disciplinary nature of the research topic. Meanwhile, there is inevitably a relationship between the data collection technique you choose and the results. In short, your results will be affected by the methods and procedures used. The problem here is that it is impossible to ascertain the nature of that effect.

Due to the novelty of the research area, the proof of concept research method was to choose to demonstrate the applicability of the concepts of conflict management in intelligent environments. Furthermore, this method aims to prove the viability and feasibility of innovative concepts through prototypes and demonstrations of features. In this case, one will use quantitative techniques (monitoring users' reactions and interactions), qualitative (questionnaires) data collection, and analysis procedures, either simultaneously (in parallel) or one after the other (sequential), but without combine.

Structured qualitative methods (experiences) will cover situations that highlight the importance of a qualitative approach to understanding psychological aspects -whose data can not be entirely gathered by other methods. In particular, the classification of conflict handling styles and other subjective variables under study.

One crucial factor is the time horizon over which the researcher undertakes the research. Should emphasize that these time horizons to research design are independent of which research strategy is pursuing or choosing. Following the analogy presented by Saunders [85], the "snapshot' time horizon is called cross-sectional while the "diary' perspective is called longitudinal. In this work, the research (is time-constrained.) will be cross-sectional, focusing on studying a particular phenomenon (conflict) at a specific time.

3.4 Research Team and Host Institution

The research team is made of two people. Marco Gomes holds a Master's degree in Informatics from the University of Minho in Braga, Portugal. He is a scientific researcher at the ALGORITMI Centre, a research unit of the School of Engineering of the University of Minho.Paulo Novais, the supervisor, is a scientific researcher in the AI field. He is also a Full Professor at the Department of Informatics of the University of Minho, a founder member of the Synthetic Intelligence Laboratory (ISLab). His main research interests are in the domains of AmI, Knowledge Representation (KR), MAS, and Machine Learning (ML). His interest, in the last years, was absorbed by different, yet closely related concepts of ambient intelligence, ambient assisted living, intelligent environments, behavioural analysis, conflict resolution, and the incorporation of AI methods and techniques in these fields. The research team conducts scientific research at the ALGORITMI Centre, a research unit of the School of Engineering at the University of Minho, focusing its activity on projects that explore a strong link with the community. It is a center of excellence, receiving a Very Good in FCT's last R&D Units evaluation. Marco Gomes and Paulo Novais belong to the ISLab, which has, over the years, made significant contributions to the domains of AI and Intelligent Systems. The group also has solid partnerships with the School of Medicine, the School of Law, and the Institute of Social Sciences of the University of Minho, and other national and international institutions, having extensive experience in joint projects.

3.5 Tasks performed during the Doctoral Program

This work was carried out to cover all the phases, as proposed by Robbins [87] vision on a conflict process, of an iterative process comprising five functional activities. Thus this research plan was divided into five phases. Below is given a synopsis of the phases, their description, and outcomes. Meanwhile, changes occurred from the initial plan, and the execution of some tasks took longer than initially anticipated. Therefore, this plan was not regarded as strictly bounded to the dates and time slices initially presented. Thus, the work plan for this PhD project was divided into five main tasks and executed during the doctoral program duration. The phases, their description, and outcomes are described being as follows:

3.5.1 Update of literature and related work

This task aimed to gather information on conflict resolution and management advancements until the end of the doctoral program. Was conducted a scientific review of the main areas touched by this work, such as conflict literature, knowledge representation, information retrieval, and machine learning to determine the leading technologies and paradigms currently used. The main objective of this task was to update the knowledge about state of the art and was divided into three subtasks:

- Analysis of state of the art – A generic analysis of the current literature on the main topics of interest of this project was performed, from the point of view of computer sciences;
- Adoption/definition of a generic conflict conceptual model – Analysis of existing conflict models, theories, vision, and processes;
- Analysis of the legal framework – The objective was to gain insights into the main legal implications of developing such a potentially sensitive system, namely, in what concerns fundamental human rights, privacy, and data protection.

This phase resulted in a thorough knowledge about the main domains addressed, which gave the needed background to undertake realistic and well-funded research.

3.5.2 A Theoretical Framework to Handle Conflict

The first logical step was to define the stakeholders. These may include human specialists (e.g., mediators, arbitrators, law experts), the parties, and system agents with specific tasks. Therefore, this first step depended on the particular details of each implementation scenario, i.e., the nature of human experts or the type of system agents depend on factors like the part of the law addressed or the conflict methodology (e.g., mediation, negotiation, arbitration). Furthermore, the conflict parameters were defined not only from a theoretical viewpoint but from a practical one. Therefore, it was essential to consider the conceptual

consequences and find a working definition to aid the resolution. The output of this task can be found in several publications is summarized in chapter 4.

3.5.2.1 Modelling oppositions and incompatibilities

When conflict is still latent, certain factors like communication, structure, and personal variables, can trigger it. It is essential to point out that it is not necessary to have the simultaneous occurrence of all three factors. The output of this task was the production of a generic model to deal with objective incompatibilities in a conflict situation. It follows an economic point of view, using approaches from game theory and Artificial Intelligence. Can find the depiction of this model in Section 4.2.3.

3.5.2.2 Identification and Characterization of the conflict

Several issues were dealt with in this task and resulted in findings presented in Section 4.1, namely the ones concerning to:

1. Model definition for pointing out an analysis of the background and contextual information provided by the participant of a conflict;
2. Model definition of the influence of emotions on the escalation of the conflict. Emotions have a significant role in human relationships. In conflict resolution, emotions can be used as a measure of the convictions of the individual and as a measure of the level of escalation;
3. Model definition for characterizing a conflict (e.g., sources, objects of conflict, background information on parties involved). The model addresses all the main topics involved in the conflict and its management and supports developing the technological framework created, giving it a solid theoretical background.

3.5.3 Development of a Conflict Support Framework

In this task, it was developed a technological framework (detailed in Section 4.3) aimed to support the decision-making of the conflict manager and parties by facilitating access to information such as the coping style of the parties or their levels of stress, among others. Several main functionalities were considered and developed:

1. Development of a service-oriented architecture - This phase consisted in the development of a supporting framework for the conflict management process, focusing on workflows, the communication between the parties, and the collection and providing of information for the manager. This architecture will be developed under a service-oriented approach;

2. Non-invasive estimation of stress – The main objective will be to adapt/incorporate non-invasive methods to estimate the participants' stress levels. The level of stress is of the utmost importance in conflict resolution and is correlated with the conflict resolution style and escalation of the conflict. To accomplish this, we will build on previous work in which was successfully measured the effects of stress by analysing the interaction patterns of users with handheld devices, considering features such as touch intensity, acceleration of gestures, amount of movement, or touch duration;
3. Automatic estimation of personal conflict-handling styles – based on previous works, achieved this task by estimating the conflict resolution style without questionnaires. This work extends the previous results by using a more generic model, with a theoretical background, that can be used in the context of interpersonal conflicts;
4. Generation of arguments/solutions – the focus was on developing algorithms for the automatic generation of arguments or solutions. The main objective was to provide the conflict manager with arguments that he can use to influence the participants' behaviour - it was built on previous work on the generation of solutions for pointing out potential solutions and their utility, supporting the manager in one of the most challenging tasks in negotiation;
5. Incorporation of Artificial Intelligence- the main objective was to research and applied AI algorithms that can contribute to an automated or semi-automated improvement of some aspects of the framework. Moreover, the framework collected statistical information on the success or failure of the strategies followed to reuse successful strategies for similar cases. In this task was reuse some part of the candidate's previous work on the legal and conflict resolution fields;
6. Analysing and Classifying Human Behaviour - Following Galitsky's work [88], the following sequence of problems needs was managed for analyzing and classifying human behaviour using a conflict management system:

    a) Discover how to reconstruct behaviour patterns from the intelligent environment sensory/interaction data. Galitsky [88] stands that it turns out that communicative actions and their subjects are essential elements of behaviour discourse;

    b) Built a way to extract information from natural language for communicative actions and their subjects and parameters (which is significantly more complex due to implicit references to these subjects in natural language);

    c) Observe that the sequence of behaviour patterns can be packaged as a scenario. Defining a scenario as a graph including communicative actions and interaction between their subjects, based on causal links and relations for argumentation, seems plausible in dealing with this.

    d) Define relationships between scenarios via subgraphs, with respective operations on vertices and arcs. Define similarities between scenarios based on graphs and similarities between individual communicative actions.

Such a framework resulted in a set of services or functionalities that support the manager's work and release him to dedicate more time to more complex issues such as improving interpersonal communication and relationships.

3.5.4 Analysis of the outcomes

The final phase of a conflict deals with the outcomes, regardless of whether they are good or bad. In this phase, generic indicators of a positive or negative result were defined. This is useful for the conflict manager and the participants to perceive the final state of the conflict. This encompasses both objective and subjective parameters (e.g., the value of items under negotiation).

3.5.5 Constant diffusion and analysis of results

During the project, the aim was to disseminate the conclusions achieved publicly, the challenges faced and how we dealt with them, and the lessons learned. To accomplish this, the public dissemination and communication of knowledge happened at two primary levels: local and global. Locally, the objective was to the project and its developments being known in academia, the business sector, and the general public. Thus, the focus was on disseminating the results/lessons learned through the organization of scientific meetings. At a global level was by attending conferences and publishing papers in conferences and journals. This diffusion and communication were carried out are reported in Section 6.4.

3.6 Summary

This Chapter depicted a research design to present a systematic plan to study the scientific problem behind this PhD project. The main objective of the proposed plan was to transform the research mentioned above questions into a research project. Therefore, the choice of research questions influenced the research strategy, the techniques for collecting and analysing data, and the time horizon for completing the project. Moreover, it was focused on defining a research plan regarding the main tasks, their interdependence, and their approximate duration. This project was envisaged to answer the proposed research questions and achieve the associated contributions. Some parts of the plan were very concrete, and it is possible to schedule them in a timetable. For others, it was more complex to predict an exact delivery time or may require external confirmation to be executed.

Chapter 4

A Computational Approach towards Conflict Management

"The age of quantitative legal prediction is about a mixture of humans and machines working together to outperform either working in isolation. The equation is simple: Humans + Machines > Humans or Machines".

Daniel Katz

In the context of a conflict situation, the attitudes and behaviours of the disputants are particularly important for the conflict manager, who can better prepare the right strategy for conflict resolution. Traditionally, all the participants in a conflict apprehend the actions and reactions of disputants through their interactions but also from the unconscious exhibition of a sequence of non-verbal cues such as the tone of voice or elements of body language. Indeed, it is how humans naturally interact with the world through a parallel and sequential multi-modal way. However, a problem arises when we move from traditional face-to-face conflict resolution to an interactive system mediated by computers, in which interactions are far more impersonal and deprived of the rich contextual framework that stems from our natural, multi-modal communication environment. The problem of the lack of such contextual information can be critical since personality traits, conflict-handling styles, emotional cues, and stress response are some of the key determinants of how conflicts are resolved and managed. One way to overcome this drawback is to take into account new approaches that came from AI. These strategies focus on sensing the life-cycle of the conflict and acting upon the conflict participants expressly by transparent and non-invasive manners. Moreover, these are distinguished from others by focusing on creating intelligent environments for conflict resolution that can complement the existing tools with relevant knowledge about the context of interaction. Therefore, this chapter presents a computational approach towards conflict management that pretends to

monitor and assist users and seamlessly acquire information from the environment to analyze users' data. Ultimately, the user forgets about monitoring and notices only the environment's contextualized actions.

The first section of this chapter introduces a conceptual framework for conflict management to retrieve contextual and environmental information by highlighting some key aspects and theoretical perspectives on conflict:

- This framework is a basic structure to identify, frame, and understand the conflict in a virtual environment;
- It pretends to be a means to explore the nature of conflict from a computer science perspective, throwing to light an up-to-date review of the evolution of conflict;
- The aim was to organize existing literature, provide a baseline understanding of an agreed definition of conflict, and depict relevant conflict aspects (dimensions) by analyzing critical features of a conflict situation.

A detailed state-of-the-art intersection of conflict resolution with technology-assisted systems and tools is presented in the second section of this chapter. Specifically, this works intended to extend the established technology-based conflict resolution/management methods with an IE. Therefore, a computer-based approach to conflict management that comprises models for performing decision-support-related tasks is described and explained. In addition, the idea was to present a more precise specification and implementation of such notions. Specifically, this section describes how meaningful knowledge is retrieved and compiled to be made available for the parties.

Finally, the third section of this chapter has covered the selection of the most appropriate technologies to implement a technological platform for handling conflict in a virtual environment, as defined in Section 3.2. The presented platform is thus based on a combination of open standards and technologies to increase compatibility with similar or complementary platforms to share services and functionalities (see Appendice A). In addition, this section is the result of extending previous approaches [35] by improving the modularity, interoperability, and extensibility of this particular AmI system. The results were presented in a book chapter[37].

The central parts of this chapter are based on papers presented in conference proceedings [36, 89–93] and a book chapter about interdisciplinary perspectives on contemporary conflict resolution [94].

4.1 Keys Aspects and Theoretical Perspectives on Conflict

The purpose of this section is to develop a holistic understanding of the constituents of conflict. The need for a framework for conflict identification and the diagnosis was identified and incorporated into the

review. A literature review is presented in all subsections of this section, focusing on a different aspect of the conflict. The section opens up discussions around the concept of conflict, prompting a deeper consideration of what is included under the term, and is intended to stimulate further thinking on the impact and potential future role of conflict. The objective is to organize existing literature, provide a baseline understanding in place of an agreed definition of conflict, depict relevant conflict aspects (dimensions), and made an overall evaluation of a range of methods and techniques of conflict resolution.

4.1.1 What is a Conflict?

Some authors notice that there is no single, universally accepted definition of conflict. Researchers have been seeking decades to generate a suitable description. Yet, it remains unclear, creating conceptual and terminological confusion. Consequently, the concept has acquired divergent and multiple meanings (it has different semantic associations) and is used to label various human experiences, ranging from indecision to disagreement [95]. Yet, a chronological approach to defining conflict can be found in Watkin's work [96]. It is stated that the concept of conflict has evolved: March and Simon refer to the conflict as a breakdown in the mechanisms of decision-making [97]. This new view shifted to consider conflict as an incompatibility of goals. In Jehn's work [98] is believed contradictory opinions on the means to achieve those goals as necessary. In contrast, others have proposed that conflict exists when views are perceived to be incompatible [99]. Assuming that conceptual clarity is a challenge, Nair highlighted that the definition and meaning of what constitutes conflict have not only changed over time but remain vague and contextual [100]. The literature on conflict spans multiple disciplines, such as sociology, game theory, and international relations, each with its perspective on the conflict. Consideration of its components varies across disciplines and by the author, requiring a vast amount of research to generate an elementary understanding of the conflict. Also, a wider range of definitions of conflict exists in the literature. Following the attempts of various authors when trying to define conflict, and its nature, 78 definitions from various sources between 1933 and 1996 were analyzed by Infante [101]. Key features of these definitions include conflict as a "process" rather than an event [102, 103], as the experience or perception of "incompatibilities" [104–106], as a "struggle" over tangible resources as well as intangible values, status and power [107], and as disagreements involving "task and relationship" issues [108]. Tjosvold noted that many current definitions of conflict are confounded as they assume conflicts involve opposing interests and conflicting goals [109].

Defining a conflict in this way results in an implicit view of conflict as negative and fails to account that individuals can have similar interests and goals yet still have conflict. In this study, conflict is presumed to be associated with both potential destructive and constructive outcomes. Therefore, a definition with less confounding is required. In Tjosvold's work [109] is suggested that Deutsch's definition [106] is among those falling into such a category and which is defined as ". . . incompatible activities; one

person's actions interfere, obstruct or in some way get in the way of another's action" (p. 90). Deutsch further states that "...conflict can occur in a cooperative or competitive context, and the processes of conflict resolution that are likely to be displayed will be strongly influenced by the context within which the conflict occurs" [110]. One limitation of Deutsch's definition is that it fails to mention conflict as a process occurring over time explicitly. This aspect is an important feature of current definitions, such as those by Barki [102] and Dreu [103]. Hence, conflict is understood using the following definition by Deutsch [106] which maintained that:

> *Conflict exists whenever incompatible activities occur an action which prevents, obstructs, interferes with, injures, or in some way makes it less likely or less effective.*

Similarly, a conflict can be seen as a conflict of interests that somehow disrupts or blocks an action or process of decision-making [87]; as a process that begins when one party feels that the other has or is about to negatively affected their interest. This definition is, in our opinion, the closest to the objectivity required to be dealt with in a digital environment.

4.1.2 Views of Conflict and Its Dimensions

There has been a transition in the way conflict has been viewed over time. Indeed, over the years, three distinct views have evolved about conflict [111]. These perspectives are synthesized by Verma as:

- The traditional view (dominant from the late nineteenth century until the mid-1940s) assumes that conflict is destructive, always has a negative impact and leads to declines in performance as the level of conflict increases. Conflict must, therefore, always be avoided. In this view, conflict is closely associated with such terms as violence, destruction, and irrationality. The response to the conflict in the traditional view is to reduce, suppress, or eliminate it. The manager was responsible for freeing the project of any conflict, often using an authoritarian approach. This traditional view of conflict is still widely held because industrial and business institutions strongly influence our society to concur with it. This negative view of conflict played a role in the development of labor unions. Violent or disruptive confrontations between workers and management led people to conclude that conflict was always detrimental and should, therefore, be avoided.
- The behavioral or contemporary view, also known as the human relations view, emerged in the late 1940s and held sway through the 1970s. It argues that conflict is natural and inevitable in all organizations and that it may have either a positive or negative effect, depending on how the

conflict is handled. Performance may increase with conflict, but only up to a certain level, and then decline if the conflict is allowed to grow further or is left unresolved. This approach advocates acceptance of conflict and rationalizes its existence.

- The newest perspective, the interactionist view, assumes that conflict is necessary to increase performance. While the behavioral approach accepts conflict, the interactionist view encourages conflict based on the belief that a harmonious, peaceful, tranquil, too-cooperative project organization is likely to become static, apathetic, stagnant, and unable to respond to change and innovation. This approach helps managers maintain an appropriate level of conflict -enough to keep projects self-critical, viable, creative, and innovative.

Regardless of our perspective and view of the conflict, this phenomenon is structurally categorized and defined. And knowing how to deal with it is knowing how it is structured in terms of categories and dimensions. Indeed, a typology of conflict is useful when the issues in a conflict are centralized in categories. Therefore, let start by making a distinction between typologies of conflict and dimensions of the conflict. A typology classifies conflicts into types. A dimension is a variable that applies to all conflicts, regardless of type. Moreover, they can be conceived dynamically: a conflict can move along these dimensions, making them different from a taxonomic, static scheme. Afterward, different approaches to identify conflict dimensions based on Watkin [96] work are presented, namely the conflict circle and conflict assessment helix:

The Conflict Circle The circle categorizes the underlying causes of conflict that a practitioner may face, offers a framework for diagnosis, and (in some versions) strategic direction on ways to move forwards [112]. The utilization of the model allows more objective analysis, and as a tool, is aimed at and used by conflict resolution practitioners. Furthermore, the circle of conflict is not limited to any substantive type of dispute, allowing it to be potentially applied to various environmental scenarios. These characteristics represent a functional starting point for a “Mode 2” exploration of conflict, further developed into a conceptual framework. Numerous other models of conflict exist; due to its conceptual clarity and functionality, the circle of conflict was selected. Associated drivers and their descriptions as depicted by a) Moore [112] [113], b) Mayer [114], c) and Furlong [115] works. The circle provides a framework for conflict diagnosis by providing drivers for consideration, and each model is slightly different in design. The model highlights five drivers and divides them into genuine and unnecessary conflict components (indicated by a dotted line and arrows). Model b introduces a sixth driver of history and places needs at the fundamental center of all conflict; it does not classify components. Model c introduces a further driver of external factors, and the author suggests reducing drivers below the central line (indicated by arrows) and managing those above.

Conflict Assessment Helix Watkin using the same design principles as the circles of conflict, functionality, and simplicity, a conceptual structural framework of conflict was created [96]. Alongside the seven amalgamated categories present in the circles of conflict (depicted in the previous section), additional themes of power and timing are included following the exploration of conflict. The framework is described as a double helix to convey structure, based on the analogy of DNA. Just as DNA is made up of different combinations of chemical bases (adenine, guanine, cytosine, and thymine) around a sugar backbone, conflict is made up of other categorical drivers (e.g., needs/interests, structures, communication, etc.) within the problem situation boundary. The exact combination presented is therefore unique to each case, as with DNA. While all categories interact to create a conflict structure, there are several special links between some elements. These elements are therefore presented as "base pairs" within the conceptual conflict helix. Still, all categories are interlinked, and interactions are not limited to these couples, as with existing DNA bases. Categories have equal weighting; the sequence presented is not representative of importance. As with the circle of conflict, this approach provides a strategic direction for conflict resolution/management. The framework highlights nine categories (needs/interests, structures, power, information, communication, emotions, values, timing, and history) which can then use to frame an interdisciplinary review of conflict literature to outline the potential dimensions to be considered in each category. It is intended that this framework, along with the associated preliminary literature review, can be used as a working definition of conflict, ensuring objective consideration by practitioners. A key conclusion from this approach is that conflict at the proposal stages is more functional and less inclined to escalate (assuming resolution). As conflict is recognized as being dynamic over time, history and timing are incorporated into the process via feedback loops and progression through the various models. Moreover, it is understood that the framework presented represents an oversimplification of a very complex process and could be argued by some to be deficient, with some parameters of conflict (e.g., conflict-handling styles) absent.

Incapacity to fully define conflict dimensions represents a significant problem for resolution and management processes, as accepting a limiting definition can have severe consequences on conceptualisation and analysis [109], as pointed out by Watkin [96]. In pursuit of definition, this work does not follow an intense search on determining the full parameters of conflict, a process that has continued iteratively over the last decades. Further, it tries to expand understanding but arguably limits functionality and application to a more "functional" concept of conflict parameters, especially those suitable for being detected and handled in computational environments. Therefore, the conflict dimensions considered in this work are the ones most straightforward. The ones that were possible to identify, capture, and handle by computerized processes. These dimensions are described and explained further in the document (see Sect. 4.2.3).

4.1.3 Conflict Process

There are many approaches in the literature to describe the conflict process. Though definitions vary, conflict is consistently viewed as a sequential, dynamic process. In other words, it is accepted that conflicts do not just erupt; instead, they develop through various stages and tend to follow a pattern, even though, in the beginning, conflict may be perceived as a state or situation. Recognizing and delineating the different dynamics occurring at each stage of a conflict can be helpful to understand better and address the dynamics of conflict. Consequently, determining how conflict develops and changes over time might allow us to understand better which strategies and tactics for participants and intervenients should apply to particular stages in the process to enable parties maximum choice to tailor their dispute resolution process to their needs [116]. Nevertheless, for many years, researchers have tried to determine how conflict develops and changes. Lois Pondy proposes one popular approach. He has suggested that conflict goes through a five-stage process called "conflict episodes" [117]. These stages help diagnose task conflicts (one of two types of conflicts within a group or team). If one can locate where the group is in the process, he/she can predict where it will go next and thus may try to find ways to manage conflict. Another five-stage conflict resolution process is proposed by Donelson Forsyth [118], which may be used to understand the task and process conflict. One of the most widely-used versions is that of Robbins [87] and represents a synthesis of prior definitions. This approach emphasizes intra-individual and interpersonal processes that are linked to manifestations of conflict. The Robbins model also comprises five stages: potential opposition or incompatibility, cognition, personalization, intentions, behaviour, and outcomes. Therefore, in this work, the conflict will be seen as a dynamic process divided into five phases, as proposed by Robbins. The rationale for this choice can be found in previous work [94].

4.1.4 Conflict-Handling Styles

People are involved in developing various strategies, solutions or behaviors, to handle a conflict. Therefore, the style of dealing with a conflict that each part has must be seen as having a dominant role in the outcome of a conflict resolution process, especially in those where parties interact directly (e.g., negotiation, mediation). First introduced by Blake and Mouton [119], and reinterpreted by Thomas [40], the scheme includes the modes of competing, compromising, avoiding, and accommodating. In addition, the scheme is based upon the two separate dimensions of cooperation (attempting to satisfy other's concerns) and assertiveness (trying to satisfy one's concerns). Kenneth Thomas presented a well-known definition and Ralph Kilmann (Figure 5), which encoded the way that we react under a conflict into five different modes [40].

To define these modes, they consider the individual's assertiveness, which denotes how much a party tries to satisfy his interests and cooperativeness. It means, in other words, to which extent the party is willing to satisfy the other's interests. The five different conflict-handling styles defined are as follows

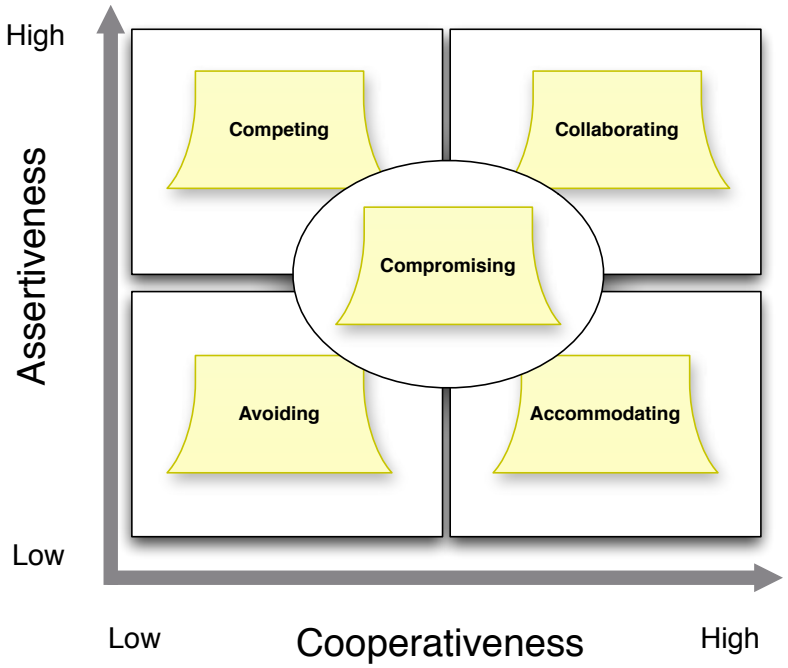


Figure 5: The graphical representation of the five conflict-handling styles; one axis as 'assertiveness' and the other as 'cooperation.'

[120]:

- **Competing** - A party that shows this uncooperative style aims at maximizing his gain, with a consequent depreciation of the others. Usually, a competing individual will use his ability to argue, rank, social status, or whatever advantageous position that he can have to show dominance over the other party. This is thus a power-oriented style;
- **Accommodating** - An accommodating party will show behavior that can be classified as the opposite of a competing one in the sense that he will be cooperative. It may happen that an accommodating party will even neglect his gain, thus maximizing one of the others, to achieve a solution. Thus, it may be said that there is an element of self-sacrifice. Generally, such a party will tend to show generosity or charity, will be understanding, and will easily obey other's orders or desires even if they represent a drawback;
- **Avoiding** - An individual that shows avoiding behavior is most likely not dealing with the conflict as he usually satisfies neither his interests nor those of the other party. Common behaviors in this conflict style include diplomatically sidestepping or postponing some issue or even withdrawing from threatening or unpleasant situations;
- **Collaborating** - On the opposite side of avoiding is collaborative behavior. This is a cooperative style in which the party shows the willingness to work with the other party to find solutions that

can be interesting for both. This implies that the party is interested in finding what the fears and desires of the other are and might even try to explore a disagreement to learn from other's insights;

- **Compromising** - A compromising party will generally try to find a fast and satisfactory solution that can be interesting for both parties. This conflict style can be seen as an intermediary one between competing and accommodating. A compromising party is generally willing to split the differences between two positions, exchange some concessions, or seek middle-ground solutions.

None of us can be characterized as having one single style of dealing with conflict. Each person tends to use more conflict styles than others because of their personality or past experiences. Moreover, it is common for parties to change the conflict style during the conflict resolution process, according to how it is developing. For example, it is common for a party to exhibit an avoiding behavior at the outset of the process and start being more cooperative as confidence grows. Moreover, it is also common for parties to begin by being competitive and with high expectations. Then, as the process develops and they gain a more realistic view that includes the desires and rights of the others, they tend to be more compromising. The opposite may also happen, i.e., parties that start fully cooperative but do not like how the process starts moving towards a more uncooperative style. Once the conflict styles are identified, one can implement strategies to improve the success rate of the conflict resolution process. Namely, we are interested in developing dynamic processes that adapt strategies based on changes in the conflict styles of the parties. For instance, it is usual for parties to show a competitive conflict style at the beginning of the process. However, they tend to advance into a more cooperative style gradually.

4.1.5 Methods and Techniques

Conflict management is a continuous process in which participants are constantly working to create the conditions that discourage dysfunctional conflict and encourage conflict resolution results that facilitate "win-win" solutions. In a more restricted sense, conflict management refers to a wide range of tools used to predict, prevent, and respond to conflict. A conflict management strategy involves a combination of these types of instruments. These tools convince the parties to open up, identify the real issues behind the positions uttered publicly and find solutions "win-win" that leave both parties better off with the result. However, it is not possible to achieve results "win-win" all the time. In some cases, if a party believes that collaborative efforts will not produce anything better than what he can earn through unilateral action, it will not go to any collaborative activity. In this work, a theoretical framework will consider the methods and techniques used to deal with a conflict. This approach also uses methods involving negotiation, mediation, arbitration, conciliation, consensus-building (Alternative Dispute Resolution ADR techniques), and litigation (legal process). A range of tools of conflict management and their main characteristics are resumed in 2.

A more descriptive definition is depicted as follows:

Table 2: Brief description of a range tools of conflict management.

Technique	**Litigation**	**Negotiation**	**Mediation**	**Arbitration**
Result sought	Court judgement	Mutually acceptable agreement	Mutually acceptable agreement	Arbitration award
Voluntary or involuntary	Involuntary	Voluntary	Voluntary	Voluntary
Binding or non-binding	Binding	Agreement enforceable as contract	Agreement enforceable as contract	Binding
Private or public	Public	Private	Private	Private
Participants	Judge and parties	Parties only	Mediator and parties	Arbitrator and parties
Third-party involvement	None	Parties communicate directly	Mediator, selected by parties, facilitates the negotiation process	Arbitrator
First steps	One party initiates court proceedings	Flexible	Parties agree on mediation and appoint mediator	Parties agreed on an arbitrator and appoints him

- **Litigation**- is the process of taking a case through court. The litigation or legal process is most common in civil lawsuits. In litigation, there is a plaintiff (one who brings the charge) and a defendant (one against whom the charge is delivered). Its approach is formal, structured by predetermined rules, and adversarial. As an advantage, the application of legal rules may help to address power imbalances. As for disadvantages, the litigation process is slow and expensive, resulting in further litigation. Moreover, the court's decision is restricted within narrow legal parameters, and the parties relinquish control over the process. This feature can be inappropriate for disputes involving policy issues. The dominant trend in addressing the challenges faced by courts has been the ever-increasing utilization of new information and communications technology. The movement began

in the 1990s and accelerated during the first decade of the 21st century. Courts in many countries now rely on *videoconferencing* to reduce the costs of inmate transport, judicial travel, and attorney travel; Web-based distance education to ensure that court personnel receives standard, consistent training in core subject areas; electronic court case processing system in a digital environment, eliminating paper processes and decreasing case processing time; self-help centers through Web sites; and on Web-based resources provide general information about the court system. As an example, the Cyber Justice Laboratory [1] pretend to create an e-filing system for procedures, which would alleviate bailiff costs, traveling costs, legal fees and reduce photocopying; video teleconferencing for procedures; virtual reality and holographic technology to recreate crime scenes; facial analysis software to study witness credibility, and assistive technology for those who choose to defend themselves. However, progress on e-justice and electronic court management systems is a long way off, conveniently implemented, and disseminated in the judicial system. It will be essential to understand the psychological and social factors that resist the utilization of ICT in the judicial system, analyze the cultural context in which current traditions were born, and question our attachment to these traditions.

- **Negotiation**- according to Raifa [121] is a collaborative and informal process through which the parties communicate and, without any external influence, try to achieve an outcome that can satisfy both as an approach-methodology is usually informal and unstructured and non-adversarial. As advantages this process is quicker and cheaper than others, parties retain control over policy and outcome, parties work together to find win-win solutions, decisions can be tailored to parties' needs, agreements more likely to be implemented, and future problems solved non-adversarial way. As for disadvantages, this method may not be helpful in significant and complex cases; failure to perform agreement may necessitate enforcement through courts. It is, however, a non-binding process, which means that the parties do not have to accept the outcome. There are many ways of organizing several negotiation techniques. From the perspective of [122], negotiation can be classified as distributive or integrative. In the distributive approach, one looks at the items in dispute as something divided and distributed by the parties to maximize their satisfaction. In integrative negotiation, the problem is expected to have more solutions than those visible at first sight. In these issues, the parties try to bring as many interests as possible to negotiate more valuable items. Regarding the use of ICT in negotiation, according to Kersten's [123], electronic negotiations (e-negotiations) encompasses all online transactions in which two or more parties seek an agreement through negotiation. These processes use a Negotiation Support System (NSS). This system is designed to facilitate the various phases of the negotiation process, such as understanding the negotiation case, assigning preference ratings for negotiable issues and options, and setting the reservation

[1] See `http://www.cyberjusticelaboratory.org/`

level before the negotiation begins. The support tools are varied, including decision science methods (e.g., decision tables, decision trees, multi-attribute utility theory), statistical methods (e.g., forecasting, regression analysis), and game theory. NSS support ranges from systems that help negotiators prepare for a negotiation to mediation and interactive systems that restructure the way negotiations usually take place.

- **Mediation**- is a way of resolving disputes between two or more parties with substantial effects. Typically, a third party, the mediator, assists the parties in negotiating a settlement. Parties may mediate conflicts in various domains, such as commercial, legal, diplomatic, workplace, community, and family matters. The third neutral and independent entity tries to guide the process to an outcome that may satisfy both parties. In this approach, the parties decide about the result instead of being imposed by another entity, but with the added assistance of the neutral part. This technique is flexible, usually informal and unstructured, and non-adversarial. As an advantage, this technique is quicker and cheaper, enables a creative solution to be found, can resolve conflicts over policy issues and/or where clear legal rights/obligations are lacking. The parties retain control over the process and outcome and work together to find win-win solutions. In addition, parties can directly contribute expert understanding and expertise. In this case, the agreement is more likely to be implemented and future problems solved in a non-adversarial way. As for disadvantages, power imbalances may be enhanced, the agreement may not be reached, and failure to implement the agreement may necessitate enforcement through courts. Unlike courts, mediation does not ensure binding agreements, and the mediator does not decide the outcome. It is also important to say that mediation and negotiation are non-binding processes, i.e., the parties are not legally obliged to accept the result.
- **Arbitration**- is a legal alternative to court used to settle disputes between parties to a contract by a neutral third party (the Arbitrator) without resorting to court action. The approach is less formal in this technique, and parties may set procedural rules and substantive laws. As an advantage, arbitration is quicker and cheaper than litigation. Moreover, parties can tailor the procedure to suit their needs and choose subject matter experts as arbitrators. As the main disadvantages, parties relinquish control over the final decision, and success depends on the competence of arbitrators and no appeal against the decision. From the computer science view, many practitioners are (still) reluctant to use ICT in arbitration. Because arbitration is a quasi-judicial process, it must comply with procedural guarantees, which impose certain constraints on the process [124]. Nevertheless, it has been seen that traditional conceptions remain in a constant state of flux and are increasingly challenged due to the progressive advancement in ICTs and their integration in arbitration. For instance, e-arbitration nowadays entails sufficient utilization of ICT applications. Meanwhile, it is far from complete. Much work lies ahead before the existence of a distinct, well-established, and efficient e-arbitration system at national, regional, and global levels [125].

4.1.6 Consolidating perspectives

Focusing on identifying some key aspects of the conflict and the theoretical perspectives for dealing with it in different contexts and environments, this section aimed to organize existing literature, provide a baseline understanding in place of an agreed definition of conflict, depict relevant conflict aspects (dimensions) by analyzing critical features of a conflict situation and made an overall evaluation of a range of methods and techniques of conflict management. The literature review presented was designed to communicate the findings of a wide range of studies but is by no means definitive. It can be concluded that this literature review addresses the first gap identified during the preliminary assessment and opens the discussion to design a set of conceptual tools developed to aid the exploration of conflict. It also aims to challenge individual assumptions about the nature of the conflict, providing a comprehensive guide on the dimensions of a given conflict.

As exposed in section 3.2, this work has the objective to create scenarios that can enhance the possibilities of reaching a favourable outcome in a conflict management process using contextual and behavioural knowledge and, to do it, relevant conflict aspects (dimensions) must be identified and understood. In this section, the first step to elaborate on such a theoretical framework was performed. Indeed, the literature review depicted various critical features of conflict situations and conflict analysis models. Defining conflict parameters is significant from a theoretical viewpoint and a practical one; it is essential to consider the conceptual consequences and find a working definition to aid the resolution.

4.2 A Multi-modal Approach to Conflict Management

This section outlines a generic model for characterizing a conflict (e.g., behavioural and contextual information retrieval and describing the decision-making process). The intention is to describe a model capable of address all the main topics involved in a conflict and its management that will support developing a technological framework, giving it a solid theoretical background. Thus, we can state that the underlying intent expressed in this section is to extend the traditional technology-based conflict resolution/management methods, in which a user interacts with the AmI system, with a new component, an Intelligent Environment (IE).

4.2.1 Decision-Making Process

Having access to the context and behavioural information of the parties, the conflict manager will have to decide what to do. Indeed, if one consider ODR as a communicative process involving a group of individuals engaged in an interactive decision-making task [126]. For this, the platform should provide a systematic way of supporting this process of decision-making. This process has been represented in seven steps by Carrel [127]: Goal statement, problem identification, search for alternatives, evaluation of

the alternatives, rational choice of the best alternative, implementation, and control and evaluation. Another approach, presented by Mintzberg [128], divided the strategic decision process into three phases: Problem identification, development of the solution, and selection of the best alternative. These phases consist of different routines. In the identification phase, the problem is identified (decision recognition routine), and resources are given to the decision-making (diagnosis routine). In the development phase, the solutions for the problem are searched (search routine) or created (design routine). In the selection phase, the alternatives are chosen (screen routine), evaluated (evaluation-choice routine), and the decision is authorized (authorization routine). Based on these descriptions, simplified decision-process is represented in Figure 6 (adapted from [129]). Applying the aforementioned strategic decision process to the proposed system:

- **Identification Phase**: After gathering information, should be applied a theoretical framework (see Sec. 4.1) to identify, organize, and depict relevant conflict aspects (dimensions). By analyzing the key features of a conflict situation, evaluating the more appropriate methods and techniques to deal with the current conflict must be performed.

- **Development Phase**: After perceiving a significant adverse change in the context of interaction, the manager is required to intervene. The system will do so by adapting strategies (e.g., making a pause, suggesting solutions, using arguments to influence the participants). We propose developing algorithms for the generation of solutions and strategies that can alleviate this effort and allow the manager to focus on other issues. To do it, generating solutions can be implemented abstractly. The specific rules for the domain allow for reasonable and meaningful solutions to develop this conceptual model for generating keys for conflict resolution review of the domains.

- **Authorization Phase**: Authorization will be a typically binary process, acceptance or rejection of the solution. In particular cases, conditional approval can occur, leading to a recycling of the solution presented through the development phase with every attempt to overcome the parties' objections. Depending on the chosen method of conflict resolution, the parties or the conflict manager will decide whether the current solution/method is the most appropriate. For instance, according to Zeleznikow [2], to be effective, a comprehensive system to support conflict management should encourage parties to start with negotiation. Suppose the dispute is not settled with bargaining. In that case, the process can progress to mediation and finally recommendation or arbitration until the dispute is resolved or failure to resolve the dispute is reported.

In short, this work considered this simplified version of a decision-making process that reflects the facilitation of information taken from the environment and made available to the conflict actors.

[2]Visit: `http://www.mediate.com/pdf/lodder_zeleznikow.pdf`

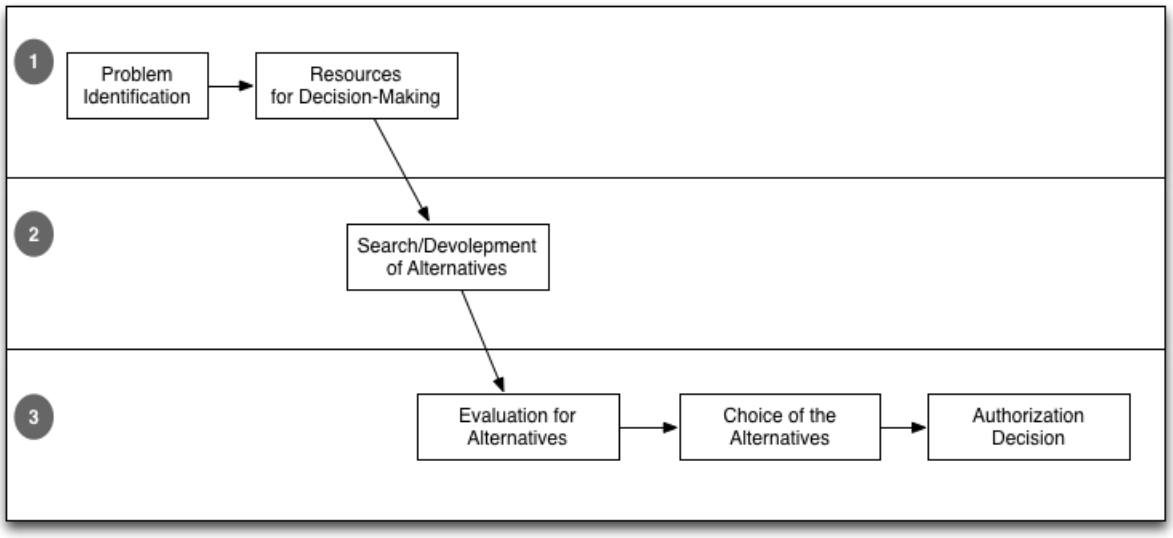


Figure 6: Simplified decision-making process. 1) Problem Identification; 2) Development of Solutions; 3) Selection of the final decision.

4.2.2 Behavioral and Contextual Information Retrieval

Previous sections have discussed relevant abstract concepts and processes in the context of a Conflict Management platform. In addition, the methods and technologies that are made up have also been briefly described. Hence, in this section, one step forward is taken toward a more precise specification and implementation of such concepts. Specifically, here it is described how meaningful information is retrieved and compiled to be made available for the parties. The proposed AmI system is a conceptual framework that can be implemented as a computer-based support system to assist decision-making when handling conflict (Fig. 7).

The system consists of parts underpinning an IE that could be sensitive and responsive to both parties of a conflict management process. Pragmatically speaking, the system was designed to sense conflict context, acquire it and then make reasoning on the received context and thus acting on the parties' behalf. On the one hand, the system builds up a consented information database of each, and it can link that subsequently with the proper individual performance within the system's conflict process. On the other hand, while the user conscientiously interacts with the system and takes his/her decisions and actions, a

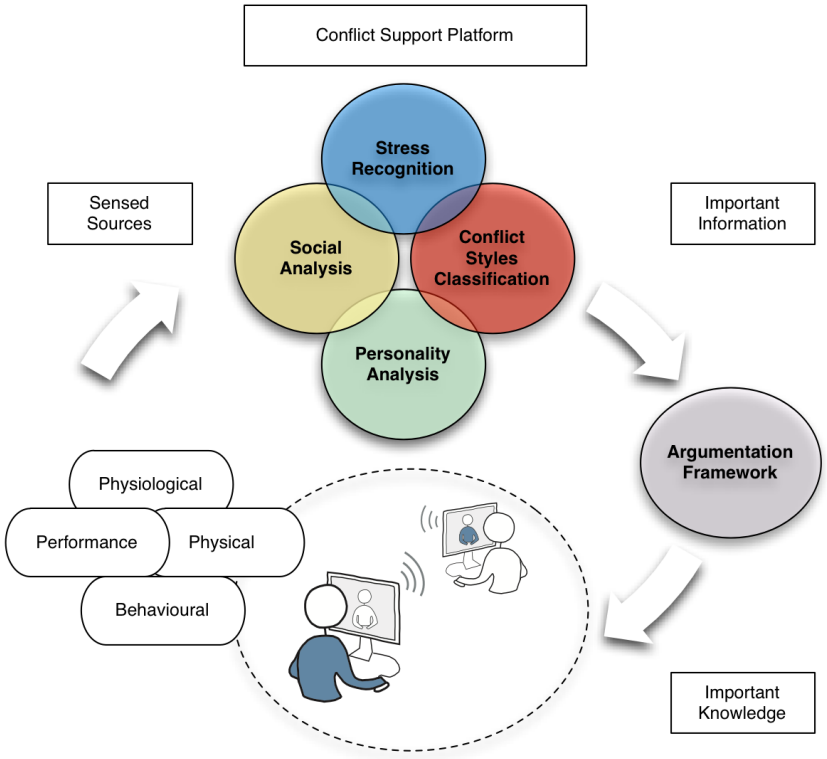


Figure 7: Overview of a Conflict Management System to support decision-making.

parallel and transparent process occurs. Contextual and behavioural information is sent in a synchronized way to the conflict support platform. The platform allows conflicting managers to contextualize the user's data upon converting the sensory input into valuable data.

Specifically, the system's general work is to sense conflict context, acquire it, and then make reasoning on the acquired context and act on the parties' behalf. The system to achieve it must build up each individual's profile and subsequently link that profile with the correct individual performance within the conflict process that the system has monitored. In other words, while the user conscientiously interacts with the system and takes his/her decisions and actions, a parallel and transparent process occurs in which contextual and behavioural information is sent in a synchronized way to the conflict support platform. Upon converting the sensory input into valuable data, the platform allows the conflict manager to contextualize the user's data. The contextualized analysis of user data is more critical when the data is from heterogeneous sources of diverse nature like sensors, user profiles, and social media and also at different timestamps[3]. Therefore, and to overcome some of these problems, features are extracted from multiple sensor observations and combined into a single concatenated feature vector introduced into other

[3]Vinciarelli et al. highlight the importance of tracing social signals over time [130].

classification modules (conflict styles, stress recognition, etc.). To integrate all the multi-modal pieces of evidence is planned to use a decision-level integration strategy. Examples of decision level fusion methods used in this work include weighted decision methods and machine-learning techniques and are detailed in previous work [92].

4.2.3 Modelling Information Extraction

To implement a technological framework (detailed in Section 4.3) that will support the decision-making in conflict management by facilitating access to information (specially the one related do the conflict dimensions), a computational approach to develop main functionalities will be considered and developed. The primary aim was to create the models to provide the relevant context information derived from the environment.

As previously stated, it is possible to extract knowledge from behavioural and context features of a conflict management environment, providing valuable understanding about what is being done at each step. First, however, it needs a model that relates every feature to each other and, considering past actions, provides valuable information about the current state and future actions. Secondly, the effect of these features on decision-making is considered. Finally, given the value of the previous step, the aim is to define a better way to handle the information and what methods the system should apply to deliver an informed decision.

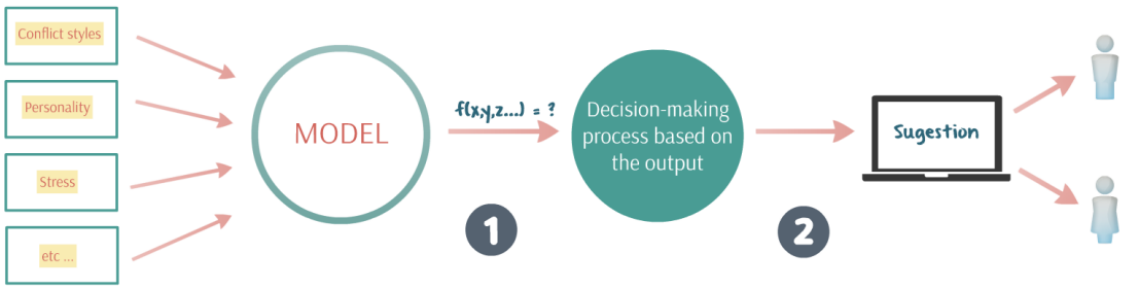


Figure 8: Schematic representation of the workflow.

4.2.3.1 Classification of the Personal Conflict Handling Style

It is reasonable to state that in a negotiated process, the most significant factor is the parties' behavior. In that sense, by knowing how each party behaves, it is possible to draw the best strategy to achieve a successful outcome. The parties' behavior can essentially be determined in two different ways: by questioning the parties and by analyzing their behavior. The first provides information before starting the

process, although it is easy to lie and fake behavior. Moreover, when we are under stressful situations (as a negotiated process potentially is), we tend to behave differently than we usually do. The second one takes some time to gather enough information to be accurate, although it reflects the parties' behavior more reliable.

In this work, we focus on the interpretation of conflict styles during the negotiated process by analyzing the behavior of the parties in real-time. In that sense, we analyze the parties' actions in each negotiation stage, where a party may ignore, accept, refuse, exit, reply with a new proposal or reply with a counterproposal. Moreover, we also consider the nature of the solutions proposed (e.g., is a party being too greedy? is a party being realistic?). The approach proposed consists of analyzing these factors together with the Best Alternative to a Negotiated Agreement (BATNA) and the Worst Alternative to a Negotiated Agreement (WATNA) of each party as well as the Zone of Possible Agreement (ZOPA), to classify the behavior of each party.

During the negotiation process, parties make successive proposals and counterproposals to achieve a mutually agreeable solution. We can thus analyze the proposals of each party in each round according to the actions of the parties and a space defined by the BATNA and WATNA of each party. In each round, each party's action will contribute to the overall characterization of this conflict style. Thus, the personal conflict style computed for each party in each round results from all the previous interactions. Two main scenarios are possible: the party ignores the proposal or answers the proposal. Upon receiving a proposal for a solution, a party ignores it; it does not satisfy his interests or the other party's ones. In such a scenario, the conflict style evidenced in the Avoiding one.

If the party makes a proposal or a counterproposal, he is cooperating on the process. However, the nature of the proposal must be analyzed, namely in terms of its utility for each party. Suppose the utility of the proposal is higher than the BATNA of the other party. In that case, he is clearly showing a Competing style as he is trying to maximize his gain, probably in an unrealistic way, completely disregarding the other party. On the other hand, if the utility of the proposal is lower than the WATNA of the other party, he is neglecting his gain or even maximizing the gain of the other party. In such a scenario, it is reasonable to state that the party is evidencing an Accommodating behavior. When the utility of the proposal falls within the range of the ZOPA, it indicates that the party is being reasonable and trying to propose a settlement in which both parties will not win everything but will not lose everything either. In such a scenario, the conflict style is determined according to the distance to the meant point of the ZOPA, defined in equation (4.1).

$$\beta = \left(\frac{ZOPA_{MIN} + ZOPA_{MAX}}{2} \right) \tag{4.1}$$

Two additional points can be defined that will allow the classification of the remaining conflict styles. These points, depicted in (4.2) and (4.3), allow the definition of additional intervals to classify the personal conflict styles.

$$\begin{aligned}\alpha &= \left(ZOPA_{MIN} + \frac{\beta - ZOPA_{MIN}}{2}\right) \\ &= \left(\frac{ZOPA_{MIN} + \beta}{2}\right)\end{aligned} \tag{4.2}$$

$$\begin{aligned}\gamma &= \left(ZOPA_{MAX} + \frac{ZOPA_{MAX} - \beta}{2}\right) \\ &= \left(\frac{ZOPA_{MAX} + \beta}{2}\right)\end{aligned} \tag{4.3}$$

Namely, when the utility of a proposal falls within the range $[\alpha, \gamma]$, it means that the proposing party is negotiating in intermediary points of the ZOPA. The party is trying to work out a compromise that implies a loss from both parties. In such a scenario, it may be said that the party was evidencing Compromising behavior. On the other hand, if the value of the utility belongs to the range defined by $[ZOPA_{MIN}, \alpha[$, the party is proposing a solution that is closer to the limits of the ZOPA. This is interpreted as the party is trying to work out a mutually agreeable solution. However, he may be trying to explore the opposing party's weaknesses in forcing him to accept a given solution. This approach classifies scenarios such as this one as Collaborating. Nevertheless, as depicted in the literature and our daily interactions, we do not use a single conflict style throughout a conflict resolution process. More likely, we evidence a combination of conflict styles. In that sense, to more accurately define the boundaries, we propose an approach in which the central conflict style is inferred, potentially accompanied by a trending style. This means that a party shows a given style with a possible tendency towards another one. The notation used to denote the main conflict style with a trend to a secondary one is as follows: $Main \longrightarrow secundary$. The following personal conflict styles are defined in Table 3.

Whether it is because of past experiences or because of our temperament, each of us is capable of using all of these conflict-handling styles. Moreover, none of us can be characterized as having one single style of dealing with a conflict. Nevertheless, specific individuals rely on some modes more than others and tend to use them more often. From the point of view of a mediator and even from the point of view of a conflict resolution platform, it is essential to determine the parties' conflict style to define how each party will be affected by a given issue. Once the conflict styles are identified (using the models above, see Figure 9), we can implement strategies that aim at improving the success rate of the conflict resolution process. Namely, we are interested in developing dynamic processes that adapt strategies based on changes in the conflict styles of the parties. For instance, it is usual for parties to show a competitive conflict style at the beginning of the process. However, they tend to advance into a more cooperative style gradually. When the conflict resolution platform detects these changes, it may start proposing more 'audacious' outcomes since parties will more likely accept them.

Table 3: Classification categories and correspondent equations, where φ represents a party's proposal utlity value

Conflict Styles	Condition
Compromising$_{\rightarrow Accommodating}$	if $\varphi \in \left[ZOPA_{MIN}, \frac{ZOPA_{MIN}+\alpha}{2}\right[$
Collaborating$_{\rightarrow Compromising}$	if $\varphi \in \left[\frac{ZOPA_{MIN}+\alpha}{2}, \alpha\right[$
Compromising$_{\rightarrow Collaborating-Accommodating}$	if $\varphi \in \left[\frac{ZOPA_{MIN}+\alpha}{2}, \alpha\right[$
Compromising$_{\rightarrow Collaborating-Competing}$	if $\varphi \in [\alpha, \beta[$
Collaborating$_{\rightarrow Compromising}$	if $\varphi \in \left[\gamma, \frac{ZOPA_{MAX}+\gamma}{2}\right[$
Collaborating$_{\rightarrow Collaborating-Competing}$	if $\varphi \in \left[\frac{ZOPA_{MAX}+\gamma}{2}, ZOPA_{MAX}\right]$

By determining the personal conflict style of each party in each round, it is possible to analyze its evolution throughout the conflict resolution process. Furthermore, when the conflict resolution system has a temporal representation of the development of the conflict styles, it may implement dynamic conflict resolution methods that adapt strategies in real-time.

4.2.3.2 Assessing Interpersonal Trust

A trust data model to collect and evaluate relevant information found on the assumption that observable trust between two entities (parties) results in certain typical behaviors is presented in this section. The approach to define and design the trust data model that was validated and introduced in previous work [90].

Considering Sherchan's strategy [131], we will highlight the trust definitions, trust types, properties, and measurement models from the perspective of the Computer Science and Economics disciplines. Such an approach seeks to focus on some aspects of trust measurement, which are simplified to capture these properties algorithmically. The simplifying process is attached to obtaining and/or quantifying trust using detecting statistically significant trust-like behaviors. Therefore, the basis for our study is a proposition that trust results in characteristic interaction behavior patterns that are statistically different from random interaction in a computerized conflict and negotiation management system [132]. However, regarding the relationship between trust and negotiation, one must stress that different research streams view trust differently depending upon the relationship under consideration [133]. So another critical decision was to reduce the study of *trust domain* to the survey of *interpersonal trust*, transforming the challenge of

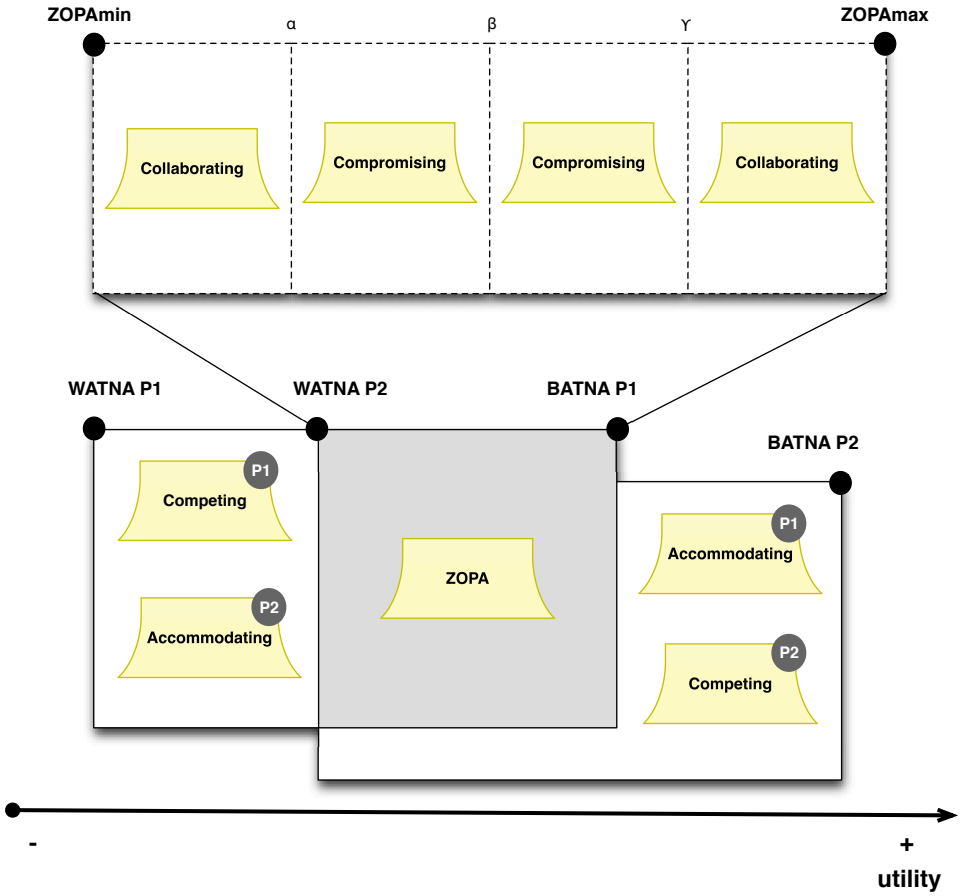


Figure 9: The two rectangles represent the utility range of values proposed by two hypothetical parties.

measuring trust slightly more accessible.

Facing these challenges, how can trust measurements be classified? Accordingly, following Sherchan [131], in general, it can be classified into two broad categories: "user" and "system". For the scope of this present work, we will consider only the notion of "user" trust is derived from Psychology and Sociology, with a standard definition as "a subjective expectation an entity has about another's future behavior" [131]. This definition implies that trust is inherently personalized. In this sense, trust is *relational*. As two individuals interact frequently, their relationship strengthens, and trust evolves based on their experience. Following Adali proposition [134] related to interpersonal trust, the main type or facet of trust understudy will be the basis for our proposal. Hence, the focus will be on the following proposition: it is possible to observe that trust between two entities A and B will result in certain typical behaviors that can statistically capture. In other words, we aim to quantitatively measure dyadic trust (trust between two entities) based on observed behavior in a negotiation process. These behaviors are not only an expression of trust but can also facilitate the development of further trust. The simplest such behavior is just interaction, in which an action occurs as two or more entities have some two-way effect upon one another. Regarding

trust evaluation models, our approach to trust computation will be based on an interaction-based trust model. In this case, our interaction-based model evaluates trust based on the interactions performed in a computer-based conflict management system. Then trust-related information will be captured and assessed following the strategy above [90]. Can resume the sources and the means to assess trust to:

- **Source of trust information gathering**: Behaviours. Why? Because user behaviors are an important aspect of trust. Another reason is as patterns of interactions identify them, they can be easily captured by an algorithm running on a computer system. Therefore, this will be our main source of information gathering. For example, if a party is an extremely active participant in a negotiation scenario and suddenly stops participating, this behavior change (the interaction is interrupted) is noticeable. It might imply that this party's trust in the other party or with the party with whom he/she had frequently been interacting has decreased.
- **Trust value assessment**: Regarding the techniques used to measure (compute) trust, they can be broadly classified into statistical and machine learning techniques, heuristics-based techniques, and behavior-based techniques. In the present work, we will use behavior-based techniques to assess trust. The reason for this choice lies in the fact that our measure of trust is based on quantifiable behavior. So it seems obvious to choose assessment techniques based on this proposition.

After defining which directions and techniques we will embrace to measure trust, let us formally define our proposal based on Adali's approach [134]. This formalization is applied to the context of a negotiation, a process for two (or more) parties to find an acceptable solution to a conflict. Within a negotiation process, each party can make several proposals and exchange an unlimited number of messages. For the context of the interaction in a negotiation, the input is the proposal stream in a negotiation process, specified by a set of *4-tuples*,

$$\langle sender, receiver, message, time \rangle \tag{4.4}$$

note that we pretend to study the problem of trust purely from the observed interaction statistics, using no semantic information. Meanwhile, in our formalization, some semantic aspects (e.g., message) are considered to provide posterior semantic analysis in an interaction between parties. The output considered here is a set T induce from these inputs. The elements of this set represent the participants of the negotiation.

Despite what common sense stands in a *regular* situation (which more often interactions occur, the more likely that a trust relationship is likely to exist or to develop), the presence of distrust can imply a lack of interaction in the conflict mitigation process. Assuming that, we postulate in this present work that the shorter and less balanced (means the average number of times that two entities interact within the process) an interaction is between two parties, the more likely it is that they have a trust relationship; in addition, the more interaction there are between such a pair of elements, the less tightly connected they are. The fundamental task is first to identify when two elements of the T set are interacting. Let A and B

be a pair of users, and let $P = \{t_1, t_2, ..., t_k\}$ be a sorted list of the times when a message was exchanged between A and B. Therefore the average time between messages is defined as $\tau = (t_k - t_1)/k$.

The measure of trust will be based on the interactions in I, obeying the following postulates:(1)Longer interactions imply less trust;(2)More interactions imply less trust; and (3)Balanced participation by A and B implies less trust. We define the relational trust $R_I(A, B)$ as follows:

$$R_I(A, B) = \sum_{i=1}^{l} \|I_i\| \cdot H(I_i) \tag{4.5}$$

Where $H(I_i)$ is a measure of the balance in the i interaction contained in I. We use the entropy (measure of the amount of information that is missing in the flow of interaction) function to measure balance:

$$H(I_i) = -p \log p - (1 - p) \log(1 - p), \tag{4.6}$$

where $p(Ii)$ is the fraction of messages in the interaction Ii that were performed by A. The complexity of the algorithms for computing relational trust is $\Theta(|D| \log |D|)$, where $|D|$ is the size of the interaction stream.

4.2.3.3 Social Network Analysis

Social interaction is and has always been an important function of the human experience, organized and directed in terms of social acts. If, on the one hand, intense and fruitful interaction between two individuals can solidify a social relation, on the other hand, it also can quickly shift into a tense and conflicting behaviour. This volatile nature is quite evident when a conflict erupts between social-related individuals. Exploring the structure and degree of the relation linking individuals handling a conflict can reveal new paths that reduce the severity of a conflict. Being dynamical by nature, a social connection to be modelled requires a set of methods and techniques to manage changes over time, conditions, and associated mechanisms to provide useful insight. In this context, some attempts have been made to address the importance of the knowledge about social interactions as a basis for informed decision support in situations of conflict. The model detailed in this section is a continuation of previous work [91], which regards analysing social connections in conflict situations. Specifically, social network analysis to map and measure the participants' relationships in a conflict scenario. The network analysis is based on the intuitive notion that these patterns are essential features of the individuals who display them through their interaction, namely in a conflict situation. As highlighted in previous work [91], the Advice, Hindrance, and Friendship measurements were selected to analyse the participants' networks. The primary objective was to identify and study how social connections shape how conflict is processed within dispute resolution mechanisms. This research tried to draw a real-life picture of how the dispute process occurs in society, which is, in turn, important in understanding the functioning of different social relationships. The network analysis is based on the intuitive notion that these patterns are essential features of the individuals who

display them through their interaction, namely in a conflict situation. Hence, we will analyse the parties' network with a particular focus on friendship relations because they can be especially valuable [135, 136]. The underlying intent is to have information on how friendship ties within a group of individuals are correlated with their conflict performance.

The data to extract each of the measurements mentioned earlier is obtained through a questionnaire (carefully adapted) to social networks. For example, according to studies [137], the Advice Network can be measured by asking respondents to answer two questions. Since the interest is to analyse the strength of relationships, we will use responses to a 5-point Likert Scale[4] from "not at all" (1) to "very much" (5). With the data obtained, in-degree centrality scores for each respondent can be measured. The in-degree is a measure of centrality, which measures the number of nominations received by a person. This variable will be calculated for all individuals in the Advice, Hindrance, and Friendship Network (see Appendice D). At the individual level, we can also calculate the position of individuals who may be intermediaries (Betweenness Centrality), influential (Eigenvector Centrality), or conflicting (In-degree Centrality in Hindrance Network).

4.2.3.4 Mood Recognition Model

Identifying the degree of relationship between one's personality characteristics, emotional response, and stress level can facilitate the communication process in conflict resolution, by focusing on the human and psychological side of disputes [139]. It was with this intention that in 2014 we presented a proposal for the formalization of a mood recognition model to study the emotional response of each person in a rich sensory environment, such as a virtual environment in conflict resolution [36], presented below.

Personality traits, beliefs, mood, or the state of the physical environment influence people's emotional arousal. A computational system is still a challenging process to acquire accurate and rich information in this domain. Still, there are some approaches proposed in the research community that has had broad acceptance. Regarding the representation of a personality, this work uses an OCEAN[5] structure similar to the approach adopted by the ALMA framework to represent the personality of people and initiate mood states [140]. In this theory, personality is defined by a set of variables:

$$\begin{aligned} &personality(o, c, e, a, n) \\ &let\ o, c, e, a, n \in [-1, 1] \end{aligned} \tag{4.7}$$

These o, c, e, a, n variables represent five personality traits: Openness, Conscientiousness, Extraversion, agreeableness, and Neuroticism, respectively. The process of acquiring personality traits from real people

[4] Likert scale is applied as one of the most fundamental and frequently used psychometric tools in educational and social sciences research [138].

[5] The five factors (extraversion, agreeableness, openness to experience, conscientiousness, and neuroticism) ordered using the acronym 'OCEAN'

is carried out through their answers to questionnaires used by psychologists in psychological studies. In this particular case, is used the summarized version of the Newcastle Personality Assessor (NPA) as a reference questionnaire [141].

Contrary to personality, which is regarded as almost static during people's lifetimes, the mood is a temporary state of the human mind, can last for minutes, hours, or even days. Therefore, it is seen as medium-term emotion. Given that personality also influences mood, the preliminary definition of personality traits, initial mood assessments can be implemented considering the predominant mood state for each personality. In addition, individual personality parameters can also be considered for mood updates over time for each person.

The mood recognition model described here is responsible for assessing the current mood of each person using their personality structure and the perception of environmental variables such as sound, temperature, and luminosity. Mood representation is based on the Pleasure, Arousal and Dominance (PAD) space computationally designed by Gebhard in his work ALMA [140]. A person's mood is represented using the three variables that define PAD space, P, A, and D for actual pleasure, arousal, and dominance, respectively. These variables are in the domain $[-1, 1]$ to create the representation of the eight moods that are possible: hostile, exuberant, disdainful, docile, bored, anxious, dependent, and relaxed. Other variables included in mood are the $emotionalWeight$ to represent the weight of the emotions related to each personality and $const$ which means the velocity of the Mood update.

Everyone is different and, just as the literature suggests, people with the high trend of neuroticism (n) have more probability of being emotionally negative, i.e., they have a predisposition to feel emotions like hate, anger, or distress more often than people with a low score of this trend. On the other hand, extraversion (e) awakens positive feelings more often, such as joy, love, or gratitude.

As a consequence, the calculation of the weight is carried out through the signal of emotion: if it is higher than $emotionalWeight = (e + 1.0) * const$ else $emotionalWeight = (n + 1.0) * const$. This variable is in the range $[0, 2]$ turning $emotionalWeight$ positive to facilitate future calculations. The constant $const$ is used to reduce or increase the velocity when mood is crossing from state to state. In this work the value used was 0.1. One of Mood's parametrized constructors receives as parameters personalities' values o, c, e, a, n. To initiate mood in relation to personality in the PAD space an weighted reference was used as in:

$$\begin{aligned} P &= 0.59a + 0.19n + 0,21e; \\ A &= -0.59n + 0.30a + 0,15o; \\ D &= 0.60e - 0.32a + 0.25o + 0.17c; \\ leto, c, e, a, &\in [-1, 1] \end{aligned} \tag{4.8}$$

These values create an initial mood state different from user to user, giving them a mood foundation that allows software agents to deal with different emotion types during their lifetime. These variables represent the mood state relating it with emotions triggered by events. The events are triggered by the environment's sound, luminosity and temperature conditions according to which the final mood is calculated. This final mood state is the predicted value for people's exposure to those environmental conditions after an infinite amount of time. The transition between mood states is assessed by applying an increment in the mood variables in the order and direction of the predicted final mood state after an event is triggered. An expression that makes the update of the current value with the displacement times the weight of emotion is used to calculate the displacement vector for each portion of time, as in :

$$\begin{aligned} \overrightarrow{M_{actual}M_{final}} &= M_{final} - M_{actual} \\ M_{actual} &= M_{actual} + \overrightarrow{M_{actual}M_{final}} * emotionalWeight \end{aligned} \tag{4.9}$$

The vector $\overrightarrow{M_{actual}M_{final}}$ is divided into small pieces that are relative to $emotionalWeight$, and this causes the mood state to move more or less slowly, depending on each person's personality, over the time, thus preventing the instant passage from one state to another which does not happen in real life frequently.

Emotions are mapped in the PAD space [142] using the OCC[6] model [143] for emotion representation and ergonomic studies on the effect of the state temperature, luminosity, and sound in emotion states [144]. From these studies and the current assessment of the environment state, a final mood state can be calculated, mapping the emotion derived and the current mood state using the PAD space and equation 4.9. The equation assumes that the mood state does not react instantly to new emotions, but it is gradually affected.

4.2.3.5 Non-invasive Estimation of Stress

Having access to the stress level of the parties is essential to plan the appropriate strategy and perceive how each issue affects each party, much like it is done in traditional conflict resolution processes when parties meet face-to-face [145]. Therefore, this work aims to develop mechanisms that operate in the virtual environment of ODR or conflict management. The purpose is to collect context information to analyze the stress level of a party and present this information to the mediator or conflict management platform. This approach to determining how an individual is affected in real-time is built and developed on previous work [146, 147], especially on modeling stress recognition [145] and how to extract behavioral and contextual data from an IE [35].

[6] A model of emotion that states that the strength of a given emotion primarily depends on the events, agents, or objects in the environment of the agent exhibiting the emotion

How to recognize stress in a virtual environment Many experts defend the original definition of stress proposed by Hans Selye [148], who coined the term as it is used today. He defined stress as a non-specific response of the body to any demand placed on it. However, this is an open discussion. Some argue that the concept of stress is elusive because it is ill-defined [149] and others prefer not to limit the concept until stress research reaches a consensual meaning. Meanwhile, scientists have circumvented the problem of a clear, consensual definition of *stress* by defining it empirically. Consequently, instead of evaluating an individual's absolute level of stress, this work will assess changes in the level of stress throughout the communication process, analyzing, in a non-invasive way, the effects of acute stress on the individual. Various approaches have been developed to recognize and detect user stress [150–153]. The approaches or systems differ from each other in the evidence modalities or detection techniques. Some experimental results [153] demonstrate that single-modality features are not sufficiently precise for stress recognition, while the integration of multiple-modality features is beneficial for accurate stress recognition [154]. So, among the features that can reveal stress, user's conflict style [34, 155]). A conflict-handling style can be one of these features because it is, *de facto*, a manifestation of a coping strategy to a stressful conflict. Indeed, having information about the level of stress of the disputant parties is quite important for a mediator to correctly understand how each issue or event is affecting each party. Acknowledging this kind of information, the (electronic or human) mediator can perceive how the state of each party is evolving.

The Figure 10 streamlines the main procedures of applying the dynamic stress recognition to conflict resolution environment. Each time t, the platform performs three procedures - sensor optimal set [156], stress recognition, and returns information (more details can be found at Gomes et al.[145]). Particularly, the system decides an optimal sensory action set to collect data with a sensor selection strategy. Then, the collected data are propagated through the stress recognition model. Through this model, the stress detection module computes the stress value at time t, and the stress prediction model (based in Cognitive Activation Theory of Stress (CATS)) determines the tendency of stress evolution for time $t + 1$. After providing information to the users, their stress levels may change, and new evidence needs to be collected. Thus, the system goes to the next step and repeats the three procedures.

The strategy, as stated in several works [36, 145, 157], allows asynchronous processing of the available modalities, provides greater flexibility in modelling, and allows adaptive channel weighting between different modalities based on environmental conditions [158]. This proposition uses a weighted sum to estimate the stress value with a temporal approach.

$$stress_t = \sum_{i=1}^{t-1} \left[c(i)_{wc} + b(i)_{wb} + p(i)_{wp} + ph(i)_{wph} + phy(i)_{wphy} \right] \tag{4.10}$$

In Equation 4.10 is used the first characters of the modality (variable) name to refer to the component that represents the sum of the normalized values from all the extracted features, i.e., c referring to the

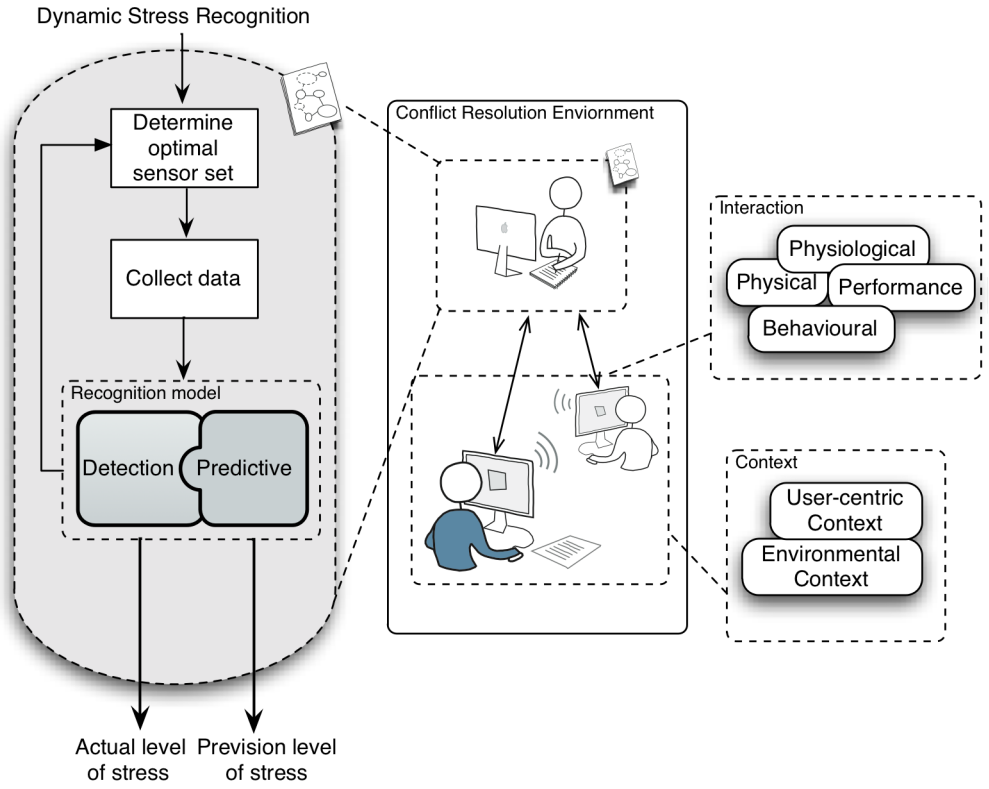


Figure 10: An overview of the dynamic stress recognition system embedded in an intelligent environment. Diagram from Gomes et al [145].

context, p referring to performance, and so on. When a variable is associated with the letter t, it relates to the value of that variable at time t. The $w's$, followed by the letters representing the variables, denote the weight of each component. In the beginning, the weights are equally distributed: every variable's weight is 0.2. Meanwhile, in the scientific literature, the influence of each modality in the estimation of stress is not specified and has not been adequately explored yet. But this is not an irrelevant factor in terms of the accuracy of stress recognition systems. The relevance comes from the strong relationship between interpreting an individual's stress and situation dependency issues [7].

Specifically, the quantification of human stress (based on previous work [36, 146]) relies on an approach of Behavioural Biometrics[8][159]. It can be used, for example, to accurately determine the identity of people for access control through their behavior (e.g., how they talk, how they walk, how they use the computer). This field is very close to the more traditional area of Biometrics, which relies on unique physical characteristics (e.g., hand size, fingerprint), independent of human behavior but unique for each

[7] To fill this gap was proposed a novel approach to calculate the degree of influence by using Artificial Neural Network (ANN). For each modality, an ANN (trained with synthetic datasets) is used to calculate the values of the weights.

[8] A field of science that seeks to study the particularities of the behavior of each individual in a given situation.

individual. However, Behavioural Biometrics looks at behavioral traits (e.g., the typing rhythm on a keyboard, the way the user looks at the computer screen). These characteristics change with factors such as mood, fatigue, stress, or others [160]. When one knows how each individual behaves in each scenario or condition, one can then identify the individual from their behaviors or changes in these behaviors. This is a central idea behind Behavioural Biometrics. Therefore, for this work, and documented in the previously cited works, Keystroke Dynamics and Mouse Dynamics were selected to this end. From between more than two dozen features that can be extracted in a non-invasive and transparent way, the following were selected from these two types of behavioral biometrics:

- *Time between Keys (TBK):* time spent between the use of two keys, that is, the time between events KEY_UP and KEY_DOWN row. Unit: millisecond
- *Key Down Time (KDT)* - time spent since the key is pressed down and is released later, in other words, time since the event KEY_DOWN and KEY_UP consecutively. Unit: milliseconds
- *Absolute Sum of Angles (ASA)* - the absolute sum of the angles when turning left or right pointer during its travel. This measure tries to find just how much the mouse "turned,"regardless of the direction to which it turned. Unit: degree
- *Mouse Velocity (MV)* - Mouse Velocity - velocity at which the cursor travels. The distance travelled by the mouse (in pixels) between a $C1$ coordinate $(x1, y1)$ and $C2(x2, y2)$ corresponding to $time1$ and $time2$ over travel time (in milliseconds). Unit: Pixel/Milliseconds
- *Mouse Acceleration (MA)*: acceleration of the mouse at a given time. The acceleration value is calculated using the mouse velocity on movement time. Unit: Pixel/Milliseconds
- *Distance Pointer To Line Between Clicks (DPTLBC)* - between every two consecutive clicks, measures the distance between all the points of the path traveled by the mouse and the closest point in a straight line (that represents the shortest path) between the coordinates of the two clicks.

These features were used in successful attempts in previous studies to detect the stress of an individual or, to be more precise, to identify the transition of an individual to a higher state of arousal [36, 161].

Predicting stress levels with CATS The CATS [162] presents a formal set of definitions that tries to reduce the group of terms, which may cover the same stress phenomenon. Therefore, CATS offers meanings formulated in symbolic logic, which is a natural advantage (from a computational point of view) in an area so subjective as the stress phenomenon. This is *cognitive* stress theory because CATS assumes that the stress response depends on acquired expectancies of the outcomes of stimuli and available responses, which can be regarded as acquired (learned) relations between stimuli and between responses and stimuli. It is an activation theory since it is based on neurophysiological activation and arousal concepts.

According to CATS, the stress response (alarm) depends on the individual's appraisal (evaluation) of the stress situation. Formally, CATS stipulates that the alarm occurs when there is a discrepancy (D in Eq. 4.11) between what is expected or the *normal* situation (set value) and what is happening in reality (actual value). The *normal* situation is understood as the classification obtained by collecting reference values from the tests performed by normal persons in a normal (non-pathological) state. Symbolically, the discrepancy is represented by the difference (Eq. 4.11) between the value a variable should have (set value SV) and the real value (actual value AV) of the same variable.

$$D = (SV - AV); \tag{4.11}$$

In our approach, the predicted value at time $t + 1$ is the discrepancy (D) value between the stress actual value (AV) obtained at time t and the CATS set value (SV) at $t + 1$, during the events (e.g., send a proposal, receive a proposal, reject, accept, etc.) sequence on the resolution conflict lifecycle. The actual value of stress (AV) is calculated by the stress detection module (see Section 4.2.3.5) and the set value (SV) by Eq. 4.14. The level of alarm depends on expectancy (Eq. 4.12) of the outcome of stimuli and the specific responses available for coping. When the subject has learned (stored) that one stimulus ($S1$) predicts the occurrence of another stimulus ($S2$), this is referred to as stimulus expectancy. The stimulus expectancy (Eq. 4.12) is expressed as ${}_{S1}E_{S2}$ and is equivalent to the stimulus expectancy $S1 - S2$, which means that $S1$ implies $S2$.

$${}_{S1}E_{S2} = (S1 \rightarrow S2); \tag{4.12}$$

$$H({}_{S1}E_{S2}) = SL_{S1} +_{S1} CT_{S2} +_{S1} PP_{S2}. \tag{4.13}$$

Expectancies are quantified by several dimensions: acquisition strength, the saliency of the event, and perceived probability. According to the general principles of learning theory, the acquisition strength of an expectancy (H) expresses that expectancies are acquired. This is calculated through the saliency of the event (SL), the continuity of the event presentations (CT), and how often the events are occurring together (perceived probability PP). Primarily, an event's salience (SL) can be achieved through an attention analysis, i.e., gathering the level of attention/interest when a party is experiencing the event. We can get this by using some elicited visual features like the gaze direction, the degree of eye openness, and the size of the pupil relative to luminance to classify the attention/interest level that arises from the event. The contiguity of the events represents the distance (temporal or spatially) between two events. Through a machine learning technique and using a dataset extracted of the ODR prototype, we can distinguish between a contiguous and non-contiguous event. The perceived probability expresses the probability of the expected event as the individual perceives it. This is a subjective evaluation of the probability that we interpret as the probability of how often the events are occurring together. This is obtained by the conditional probability of two events occurring successively in the same probability space. Finally, the H

value is normalized by a max-min normalization technique (Eq. 4.14).

$$SV = H_{norm}({}_{S1}E_{S2}) = \frac{(SL_{S1}+{}_{S1}CT_{S2}+{}_{S1}PP_{S2})-H_{\min}}{H_{\max}-H_{\min}}; \tag{4.14}$$

The discrepancy (D) can take three distinct values, a positive ($(SV-AV) > 0$), neutral ($(SV-AV) = 0$), and negative ($(SV-AV) < 0$), that are mapped into the following classification: increase, maintain, and decrease, respectively. So, the predictive module of the stress recognition process returns a stress outlook (decrease, maintain, or increase) for the next step of the conflict resolution process. However, we should further develop and improve this approach in order to explore all the formalisms available in CATS.

4.2.3.6 Generating Recommendations for the Conflict Manager

It is in this context that, in work carried out in 2016, we presented an approach to the generation of recommendations in a conflict resolution scenario using a model combining Bayesian Networks with Speculative Computation [89]. An individual perception based on inaccurate or incomplete information could undermine a conflict resolution process.

In light of this assumption, this prospective work was designed to provide a set of techniques suitable for handling incomplete information, specifically concerning conflict-handling styles, in a computer-based conflict support system environment. The findings of this work produced an interesting contribution to the process of a conflict manager to come up with a decision, that is, to find an optimal or satisfying solution that leads to a convergence of parties' positions. Therefore, the cornerstone of this approach is the idea that if a conflict manager, in an intelligent conflict support system, knows to be able to identify parties' conflict styles, he will promote better strategies and, consequently, lead to better solutions [163].

A Probabilistic Model for Conflict Style Assessment The critical issue to using a Speculative Computation (SC) approach to cope with incomplete information in a negotiation, namely information regarding the negotiation style used by participants, is to generate a likely set of default parameters. The same is to say, to predict the negotiation styles of participants in each round. The intuition here is that the conflict style in a round will affect the conflict style used by the very same participant in the following round. Therefore, a predictive model capable of this has to produce the most likely values for a set of parameters, in this case for the negotiation style, and establish dependence relationships between the negotiation styles in different rounds. Bayesian Networks (BN), for their set of characteristics [164], fulfill these requirements.

Bayesian Networks BNs are graphical representations of statistical dependences and independences between variables [164]. They provide a network structure and a probability distribution that is humans and machines easily interpret. The problem at hand goes beyond the typical classification and regression problems. It is, instead, a density estimation problem where the objective is to

find the most likely collective state of information for the negotiation styles in successive rounds of negotiation. As such, BNs fit the problem description better than other machine learning models [164]. Formally, a BN is an acyclic directed graph $G = (V(G), A(G)$ with a set of vertices $V(G) = \{V_1, ..., V_n\}$ where each vertex $Vi \in V(G)$ represents a discrete stochastic variable, and a set of arcs $A(G) \subset V(G)XV(G)$ where each arc $(V_i, V_j) \in A(G)$ represents a statistical dependence. A BN defines a joint probability distribution Pr that may be factorized according to Equation 4.15, where π is associated with the set of variables that denote the vertex parents of V_i.

$$Pr(V_i, ..., V_n) = \prod_{i=1}^{n} Pr(V_i|\pi(V_i)) \tag{4.15}$$

Building Predictive Model Since previous analyses revealed that the role of a participant significantly influences his conflict-handling style [157], parties should be modeled in different networks. Understanding the dependence relationships between conflict-handling styles in different rounds of negotation is possible by performing BN structure learning on the data gathered from the experiments. Some of the most well known BN structure learning algorithms include: the *hill-climbing* (*hc*) search [165], the *grow-shrink* (*gs*) [165], the *max-min hill-climbing* (*mmhc*) and *restriction maximization* (*rsmax2*) [166], and the *chow-liu* algorithm. Using the above-mentioned algorithms, the goal is to obtain the network structure that best describes the dependences between negotiation styles in different rounds, based on the available data. Different scores can be used to assess the fitness of the network. In the present work, the Akaike Information Criterion (AIC) [167] was the selected metric. It is defined as in Equation 4.16.

$$AIC = logL(X_1, ..., X_n) - d \tag{4.16}$$

The $logL$ component corresponds to an assessment of goodness of fit, of how well a model fits the data. The d component is a penalty that is an increasing function of the number of estimated parameters and is used to avoid overfitting. Given Equation 4.16, the goal is to maximize the AIC. With a BN structure and the corresponding probability distribution, it is possible to retrieve the values for the variables that maximize the distribution, given the available evidence. This is modelled as a *Maximum a Posteriori* (MAP) estimation, defined as in Equation 4.17 [168].

$$MAP_\theta = \underset{\theta}{argmax}\ Pr(\theta|e) \tag{4.17}$$

The θ component represents the goal variables for which the estimation is calculated, and e represents the available evidence. This will be the mechanism by which will produce the default values for negotiation styles in successive rounds of negotiation. These values will be used in a Speculative

Computation framework that models interventions in the negotiation to influence the participants to adopt *collaborating* negotiation styles.

Speculative Computation Approach to Cope with Incomplete Information Considering that the main procedures occurring in a conflict management situation can assume Speculative Computation phases. The set of rules that allow the inference of the recommendations the conflict manager may provide to parties based on their conflict-handling styles is represented in the $\mathcal{P}$ component of the framework. At the beginning of the negotiation, when there is no information about the negotiation styles, a MAP query provides the initial default set Δ. Through a process reduction phase, this would result in tentative scenarios representing possible recommendations of the conflict manager. For instance, in the example given above, it was determined that the most likely negotiation style of a Seller in the first three rounds would be *competing*. *Competing* would then be used in Δ for the three rounds, and process reduction would produce a scenario in which the conflict manager should advise the Seller to lower the value of his proposal to become more collaborative in the first round. After the first round takes place, the true negotiation style is observed, and it triggers a fact arrival phase. The previous scenarios are revised and incorporate the newly arrived information. At the same time, the observed negotiation style is used to condition the Bayesian probabilistic model with a new MAP query, which results in a new default set Δ for the negotiation styles in the remaining rounds. This new default setting is used in the default revision phase to generate a new set of scenarios and, thus, new recommendations for the conflict manager to give. Supposing the observed negotiation style of the Seller in round one was *collaborating*, as an effect of the recommendation provided by the conflict manager, this would be used to condition parameter $Round1$ in the Seller BN, through the second MAP query. This would generate a new default set with the style *collaborating* for round two and *collaborating* or *accommodating* for round three. With default revision, this new default can produce scenarios that let the conflict manager know that it should not intervene since the predicted negotiation style is according to the goal it set out for the Seller. This whole process repeats itself throughout the subsequent rounds until the negotiation is brought to a conclusion.

The goal here is to model a dynamic and flexible conflict manager. For this purpose, BNs are combined with Speculative Computation. While BNs have the task of producing default values, Speculative Computation structures the reasoning process. This allows a quick adaptation to changes in the negotiation style throughout the rounds. This setting also provides a mechanism for the management of conflicts through the anticipation of competing postures.

Speculative Computation The part taken by the conflict manager in the negotiation is trying to bring it to a satisfactory conclusion to both parties, to make them collaborate. Therefore, it has to anticipate the conflict handling style used by the participants in each round, fill in this incomplete information, and recommend changes to the participants' behaviours. This is modelled using

Speculative Computation, a logic programming framework that provides a way to compensate for the lack of information in decision processes.

Speculative Computation is a logic programming framework that structures reasoning with incomplete information based on default values. Its complete semantics and procedures are presented in Satoh and Oliveira's works [169, 170]. The framework has two principal components:

- **Default set (Δ):** This is a set containing default values for the parameters that serve as premises in the inference process. In the context of this work, this set includes default values for the conflict styles exhibited by the participants in the negotiation, obtained from the predictive models;
- **Logic Program ($\mathcal{P}$):** This is a set of rules that allow the drawing of conclusions based on specific parameters. In the problem at hand, these are the rules that model the interventions of the conflict manager.

The normal execution of the framework includes providing values for the parameters and traversing the rules in $\mathcal{P}$ until a conclusion is reached. The execution is structured in three phases:

- **Process Reduction Phase:** This corresponds to the derivation of tentative conclusions based on the existing values for the inference parameters (defaults or not). At the start of the Computation, all the values are default values. This results in likely scenarios. The computations that are not consistent with the defaults are suspended but can be activated in a later phase;
- **Fact Arrival Phase:** This corresponds to the replacement of a default value for a parameter with the actual observed value. As a result, the scenarios produced in the previous phase are revised. Those that are still consistent are maintained, and those that become inconsistent are removed. At the same time, suspended computations can be resumed and become new scenarios;
- **Default Revision Phase:** This corresponds to the replacement of a default value for a parameter with a new default value. This new default value may be produced by the arrival of a true observed value that conditions another parameter. As a result, the scenarios produced in the previous phase are revised.

Speculative Computation fits systems that have a well-defined logic. Thus, it can serve as an interface between a predictive model and the rules that guide the enactment of system functions. Its advantage is in the precise definition of the procedures to manage the derived conclusions in a logical framework, according to the ever-changing state of the information. For example, using it to structure the decision processes in the conflict manager will enable it to predict conflict styles and act upon those predictions. The procedures are disclosed in the following Section 5.4.

Argumentation The argumentation model is based on the case-based argumentation framework for agent societies presented by Heras [171]. When the mediator has to select a specific proposal among the set of feasible offers (activities to recommend), the system tries to create one argument (or more) to support each one. This approach launches an internal argumentation process to decide which offer is better supported by arguments.

We have adapted one of the knowledge resources proposed in our framework, the *argument-cases case base*, to use it as an argumentation resource for our system. An *argument-case* stores information about previous argumentation experiences and their outcome. In our application domain, they can be used by the system: 1) to generate new arguments to support a decision; 2) to strategically select the best proposal given the degree of acceptance that a similar proposal in a similar situation had in the past; and 3) to store new argumentation knowledge gained in the recommendation process, improving the system's recommendation and argumentation skills.

Furthermore, in our system, parties can play the different roles. Thus, we consider the following dependency relations among them: i) *power*: when an individual has to accept a request from another individual because of some pre-defined domination relationship between them. For instance, in our application domain, some parties have a power relation over other parties; i) *authorization*: when an individual has been committed to another individual for a particular service; and iii) *charity*: when an individual is willing to accept a request from another individual without being obliged to do so. For instance, by default, each party has a charity dependency relation to any person who plays the same role. The argument cases are the main structure that we use to implement our argumentation framework and computationally represent arguments generated in negotiation processes. The argument-cases have the following components:

- **Problem:** the description of the problem that the case represents. In addition, if we want to store an argument and use it to generate a persuasive argument in the future, the features that characterize the audience of the previous argument (the social context) must also be stored.
  - **Domain context:** these are the features that characterize the negotiation encounter where an activity has to be recommended (e.g. time, number of round, round's duration, minamax outcome, optimum value, etc.).
  - **Social context:** there are the features that characterize the social information about the negotiation encounter:
    * The **proponent** of the proposal: ID, role, psychological trait, stress value, conflict style, expected proposal's utility value, emotion, BATNA, WATNA, ZOPA.
    * The **opponent** to which the proposal is addressed: ID, role, psychological trait, stress value, conflict style, expected proposal's utility value, emotion, BATNA, WATNA,

ZOPA.

* The **dependency relation** established between the roles that these parties play.

- **Solution:** the solution applied to this negotiation situation (i.e. the activity recommended) and other elements that describe it:
  - **Proposal:** the activity proposed.
  - Final **utility value** gained by the parties.
  - **Acceptability status:** whether it was accepted in this particular negotiation encounter or not.
  - **Received attacks:** whether the proposal received objections or attacks, no matter if it was finally accepted or not. These attacks can be of different types:
    * **Undercuts:** distinguishing premises, which are features that distinguish this case from another that was used to support this proposal in view of past experiences. **Rebuts:** counter-examples, which are other argument-cases that match this negotiation situation but support a different proposal.
- **Justification:** the reason why this particular activity was proposed (i.e. any piece of information that support this specific proposal). This can also include:
  - **Outcomes** inside ZOPA.
  - **Negotiation steps** until this proposal: sequence of possible moves represented by a solution tree describing the path followed until this negotiation step.

With this structure of argument-cases, the system would be able to generate attack or support arguments with this structure: $Argument = \{Proposal, Utility\ value, Support\ Set\}$ Where the support set is the set of all these elements that support the argument. Semantically, an argument explains the acceptance or rejection of a proposal. On the other hand, the support set can also include any of the allowed attack elements of our framework (distinguishing premises or counter-examples). There are two typical attacks studied in argumentation: *rebuts* and *undercuts*.

4.3 Technological Framework for Supporting Conflict Process

This section presents the work regarding the most appropriate technologies to implement a technological platform for handling conflict in a virtual environment, as defined in Section 3.2. Furthermore, the platform is based on open standards and technologies to increase compatibility with similar or complementary platforms to share services and functionalities (see Appendice A). Therefore, this work focuses

on a modular development paradigm that was backgrounded with conceptual models and frameworks. Moreover, this chapter is the result of extending previous approaches [35] by improving its modularity, interoperability, and extensibility in this particular AmI system. These results were presented in a book chapter[37].

4.3.1 An AmI-based Architecture for a Conflict Management System

In our pursuit to develop an architecture that covers the central conflict management system's technological needs, we first definite it at a conceptual level. Then, the proposed architecture is logically divided into several packages that encapsulate a set of features and tasks. Figure 11 presents its high-level view, detailing the five packages that compose the system.

The Runtime Environment is the main component of the architecture, where system operations are executed. It is also through this environment that the remaining components are accessed. The Service component, conducted by the Runtime Environment, contains all monitoring and data collection services through sensors and is responsible for encapsulating all external resources collected by the system, represented by the External Resources. The tasks carried out by the Runtime Environment are also supported by queries to components Knowledge Management and Intelligent Component. Knowledge Management supports the management of information and knowledge collected by the system. The Intelligent Component contains components of Intelligent Systems/Artificial Intelligence used in this architecture for data processing. The Runtime Environment corresponds to the core component of the architecture, where the

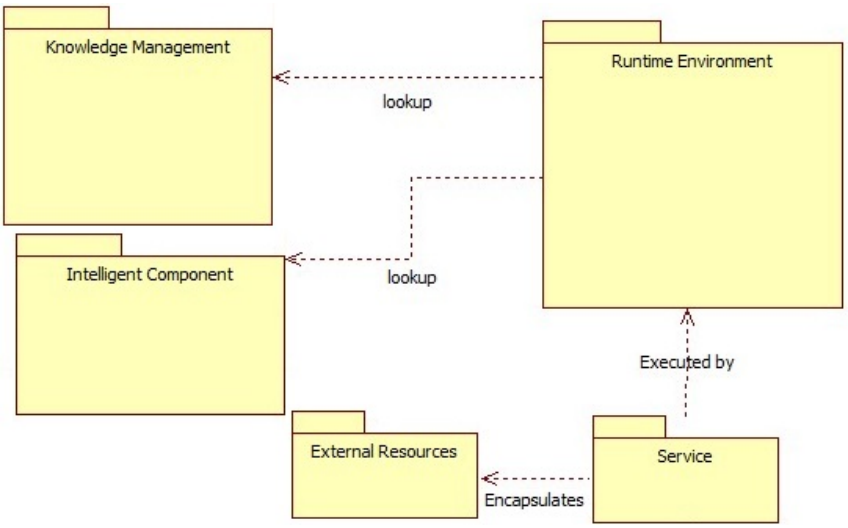


Figure 11: High-level view of the architecture.

main features are executed. It is also divided into two subcomponents, which are interconnected: the Runtime Management and Runtime Platform. The first is a platform for managing processes running on

the system. It is composed of a Data Manager that contains an interface to link the Knowledge Manager, an Execution Manager responsible exclusively for managing the execution of system processes. In addition, the Service Directory includes all information from the execution of services in the architecture. It should also note that Runtime Management has an interface to connect the Service component. Finally, the Runtime Platform is a platform for the execution of the Runtime Environment. This component is composed of a Service Bus that, through the interface provided by the Runtime Management, establishes communication between the two subcomponents and a Service Execution Engine that represents the execution engine services in the architecture.

AmI systems are commonly described as electronic environments that seamlessly interact and adapt to human needs. People are surrounded by intelligent and intuitive interfaces embedded in all kinds of objects. Hence, the need for a software infrastructure that allows easy integration promotes interoperability and focuses on extensibility. The reason is straightforward: to take full advantage of the information gathered ubiquitously from various sources in the environment. By considering these aspects, in this work, we present an infrastructure to support an efficient approach for the development of AmI applications, following an approach based on SOA.

The more appropriate way of doing so is to adopt a Service-Component Architecture (SCA): a group of OASIS specifications that has become an industry standard. It is intended to develop applications based on SOA, which defines how computing entities interact to perform work for each other. Originally published in November 2005, SCA is based on the notion that all the functions in a system should exist in the form of combined services into composites to address specific business requirements. In other words, it allows building service-oriented applications as networks of service components. SCA is used for building service components, assemble components into applications, deploy to (distributed) runtime environments, and reuse service components built from new or existing code using SOA principles. This approach is advantageous in AmI for the following reasons:

- Interoperable. Provides loose coupling allowing to integrate without the need to know how components are implemented. Components can be written using any language and can handle any communication protocols and infrastructure to link them, making it easier to integrate components to form composite applications.

- Maintainable. The composition of solutions is clearly described as a declarative application of infrastructure services simplification for all developers, integrators, and application deployers.

- Flexibility of Development. Service Components are more natural to develop because the semantics of each independent Service Component is significantly less complex than the overall of a single (relatively large) monolithic application; each Service Component can be developed by a different team of developers, each of whom focuses only on their component without having to know the

details of work done by others. In addition, components can easily be replaced by other components and easily invoke services either synchronously or asynchronously.

- Reuse. Since each Service Component has well-defined interfaces, each component can be developed, tested, and debugged independently of the other components. This feature speeds up project implementations and leads to significantly enhanced reuse in the case of well-designed Service Components.
- Dynamic Deployment and Runtime Modification/Replacement. Service Components can dynamically deploy to remote nodes at runtime. In addition, components within a process can be easily replaced by new or updated components, further reducing the time taken to modify or change an existing process in response to business requirements.
- Configuration Management and Version Control. Service Components facilitate version control and dynamic configuration management, allowing fine-grained control over deployments across the enterprise.

SCA provides a reasonable basis for AmI applications [172], it is in line with our architectural model, and it fulfills major AmI deployment requirements by promoting late bindings at deploy time and runtime with the support of several relevant technologies, including POJO, SOAP, REST, BPMN, BPEL, JMS, Camel or Rules services. But most of all, it is currently supported by several major commercial and open sources products such as JBoss Switchyard, IBM WebSphere, or TRENTINO (C++). From the several available implementations of SCA, we have chosen JBoss SwitchYard since it is an open-source solution in a relatively mature state and enhances some of the SCA advantages. Specifically, Switchyard advocates transparency when running a service during its whole lifecycle. Essential aspects such as connectivity, orchestration, and routing exist on SwitchYard in a modular format, enabling one to deploy them independently. Using a SwitchYard graphical user interface turns easy to build visual models of the applications that are meant to improve the software engineer's ability to comprehend and communicate the total composition of their applications and also to speed up development and integration projects.

Moreover, this conflict management platform was developed with web-based technology. The reasons for that are two-fold. The first is that the Internet is an excellent resource for capturing valuable data from real interaction environments and gaining knowledge from it. The second reason is that its main features, such as interoperability, flexible core technologies, accessibility, and customizability, provided us a rapid and efficient means to prototype our system. Fig. 12 presents, schematically, the main workflow intended to gather, convey and deliver sensed data to the main modules that comprise the current intelligent system. It is presented how the platform operates through web-based means to collect, convey and deliver sensed data to the components that comprise the current intelligent system. The main workflow runs as follows: raw data is acquired through the commonly available input devices used to interact with a computer (e.g., mouse, keyboard, digital camera) in a non-intrusive way. Simultaneously,

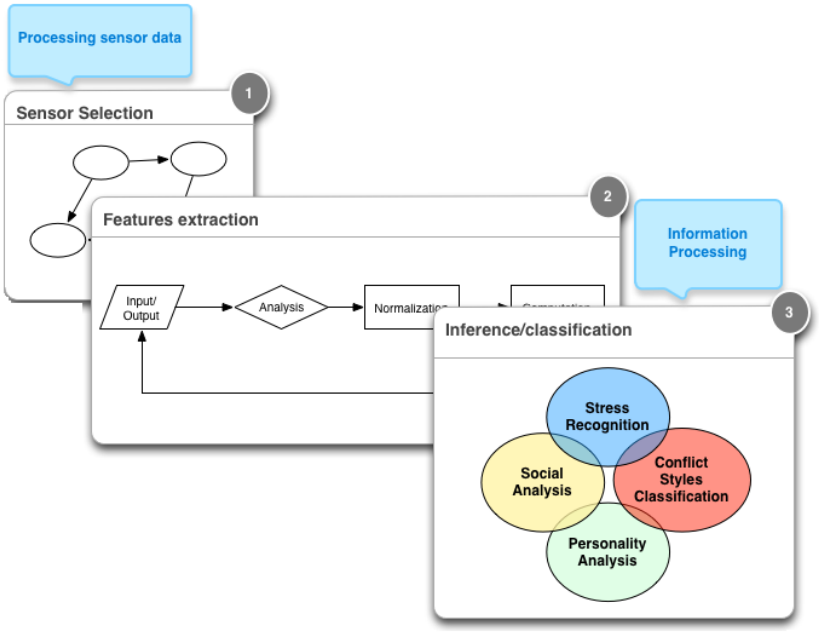


Figure 12: Conflict Management Platform. The number (1) denotes the raw data process component; number (2) denotes the features extraction component; the number (3) denotes de inference/classification component.

information related to the process (the issues being negotiated and the utility values of the proposal being presented) is also collected. Next, features are extracted from the sensed data and combined into a single concatenated feature vector to be processed by the data analysis modules (stage number three in Fig. 12). This component combines all the processes that manage the data gathered from the available sensors, comprising four operational modules. Its implementation details (see Appendice A) are presented in previous work [35, 37] and the experimental results in the following sections (especially Chapter 5).

4.3.2 Evaluating (measuring) Conflict in an IE

In work undertaken by Rosalind Picard, she stressed that this endeavour is challenging but achievable [2]. Then she outlined a strategy for computer systems to cope with subjectivity issues. Specifically, it is proposed a three-fold approach: that they [computer systems] will need to (1) share some of the common sense of the user, (2) observe and model the user's actions, and (3) learn from these interactions. This approach suggests that subjectivity is expressed as the user interacts with the system during a succession of queries. These involving user inputs can be tracked, modelled, and used to retrieve data consistent with changing requests. In sum, this strategy seems suitable to be applied, so we planned to follow it in our work to overcome the further issue.So this is the context in which a Conflict Resolution Environment that could be sensitive and responsive with both parties of a conflict management platform was developed. The main

concern was designing an environment where a group of devices could cohabit and share information towards a common goal: sensing and acting in a non-intrusive way to influence the conflict resolution process. Therefore, this work focuses on a modular development paradigm that was backgrounded with conceptual models and frameworks. As a result, this environment allows that all the components can be combined to implement complex functions. Namely, monitoring the conflict process and perceiving how each issue or event affects each party, knowing the level of stress, trust, relationships, and the conflict handling style used in each round. This knowledge gives relevant insights that can increase the success rate of conflict resolution and management procedures and bring them closer to the rich communicative environment that parties have when they communicate face-to-face.

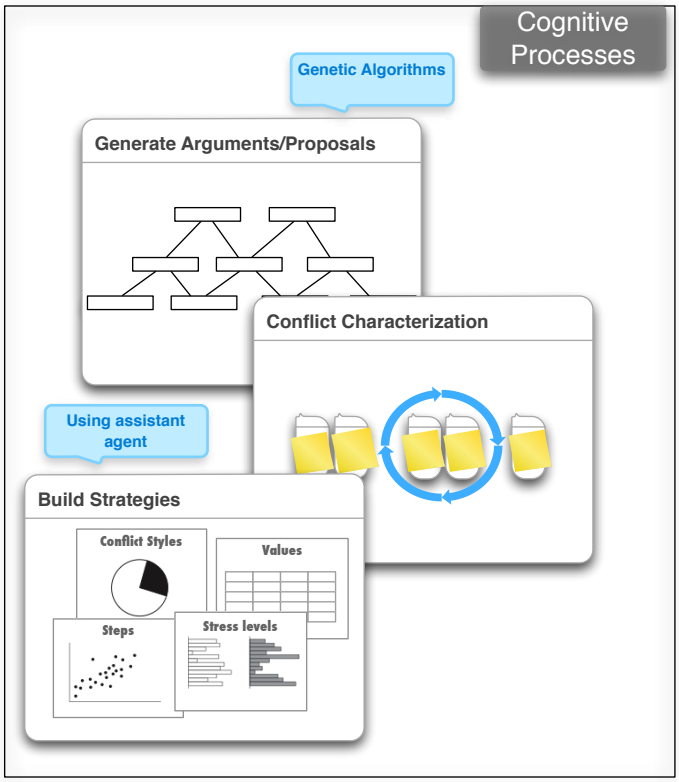


Figure 13: An overview of computer-based processes to argument/proposal generation, conflict characterization, and strategy production.

Regarding the generation of proposals (Fig. 13, this framework performs tasks using algorithms (deployed in the platform) to find potential associations between case features and decision outcomes and intent to predict future trends and behaviour patterns. Moreover, this framework applies a specific mathematical model (see Section 4.2.3.1) to identify the best and worst-case scenarios. This model is fed by data from the conflict under analysis (meta-data, contextual information, etc.), descriptive information generated by the platform, and the prediction outputs (previously performed) and will create different scenarios for a case outcome. In addition, the concepts such as Most Likely Outcome for a Negotiated

(MLATNA), BATNA, and WATNA will serve as the boundaries to the possible range of outcomes. Finally, this framework will systematically support decision-making by implementing a three-step strategy. The identification phase (the problem is identified, and resources are given to the decision-making), the development phase (the solutions for the problem are searched or created), and; the selection phase (the alternatives are chosen, evaluated, and the decision is authorized). Following, in the next sections, is presented the components of the framework respecting the conflict characterization and build strategies (Sect. 4.3.2.1, 4.3.2.2, 4.3.2.3, 4.3.2.5, 4.3.2.6).

4.3.2.1 Conflict-Handling Styles Classification

Through the implementation of the model described in Section 4.2.3.1, it is possible to estimate the conflict-handling style without the use of questionnaires. After the determination of the boundaries utility values (e.g., BATNA, WATNA) using pre-determined information (specific for each case), the person handling conflict style is classified using data extracted from the proposals' workflow as input to a computation process implemented (using Java technology) in the conflict engine. Therefore, by determining the conflict-handling style of each party in each round, it is possible to analyze its evolution throughout the conflict resolution process [34]. When the conflict resolution system has a temporal representation of the evolution of the conflict styles, it may implement dynamic conflict resolution methods that adapt strategies in real-time.

4.3.2.2 Stress Recognition

The main objective of the Stress Recognition process is achieved by applying machine-learning algorithms that can contribute to an automated or semi-automated improvement of some aspects of the framework. So, in this work, machine learning techniques will allow a more efficient and thorough correlation of the stress factors to point out potential improvements in the conflict resolution workflow and decision-making models. Two standards and popular machine learning tools were used: a decision tree constructor and a support vector machine. As the decision tree constructor was used, the J48 algorithm - the java implementation of the C4.5. As a support vector machine, we use the SMO function, which implements John Platt's sequential minimal optimization algorithm for training a support vector classifier [173]. Some experiments were performed using the Weka workbench [174]. Given the results [147, 157], it was concluded that both classifiers are similar; we decided on using the J48 tree since our system can easily use it to classify stress in real-time.

4.3.2.3 Social Network Analysis

Knowing to map and measure the relationships between the parties will allow the conflict manager to measure the relationship, communication, and information flow between the parties through relations

and focus on uncovering the patterns of parties' interactions in the network. This kind of information can be obtained using the well-known Social Network Analysis (SNA) theory[137] and be useful to the understanding of conflict [175]. This approach has been used to connote complex sets of relationships between members of social systems [176]. The Advice, Hindrance, and Friendship measurements were considered to analyse the participants' networks. Special attention is given to friendship relations because they can be significant [135, 136].

4.3.2.4 Trust Assessment

The multi-dimensionality of trust (meaning that trust is not determined by one single component of the relationship, but by multiple components) makes conflict interventions more complex since they have to meet different conditions [90]. Our model focus on one type of trust, the *interpersonal trust*. Supporting this choice is simple: it is the type of trust that is common in most conflict situations, and it plays a key role in conflict dynamics [177]. The trust-related information that needs to be assessed following Adali's strategy [134] is resumed in previous work [90].

4.3.2.5 Probabilistic Approach

Probabilistic models have been indicated as effective ways to deal with uncertainty [178]. Resorting to probabilities enables the ranking of predictions and minimizes their expected cost [179]. Graphical representations as a support for displaying probability distributions provide an effective way to interface models and data. They are appealing and intuitive and lend themselves naturally to the design of efficient algorithms [180]. One of such support mediums is BN: graphical structures used to display a probability distribution and an inference mechanism, and they are a powerful tool to manipulate dependence relationships [181]. For these reasons, this model was developed based on these previous approaches to handle high-level information derived from the data collected in the experiments.

4.3.2.6 Personality and Mood Analysis

To identify which and how human psychological traits [182] are correlated to behavioural features and how they can be pointed out, first, we try to estimate all the relevant aspects of the interaction between the individual and their environment in a rich sensory environment (where the contextual modalities were monitored). This environment is equipped with sensors and devices that acquire different kinds of information from the user in a non-intrusive way using the multi-modal approach. Second, to have a psychological profile of the individual understudy, we apply a small questionnaire, the NPA)[141], referenced in scientific literature [36].

4.3.2.7 Human Activity Recognition

Disputants' actions and reactions can be conveyed through their interactions in a digital environment and from the unconscious exhibition of a sequence of non-verbal cues such as the tone of voice or elements of body language. Indeed, it is how humans naturally interact with the world through a parallel and sequential multi-modal way. Accordingly, in the context of this research, some experimental studies were performed to recognize some aspects of human activity relevant to characterize a conflict situation, namely the amount of movement of a user to be analysed through image processing, allowing to estimate the level of agitation, thus *stress*, and using audio classification. Previous work was done by using visual features to classify stress [145, 147, 183]. Some experimental work was performed to classify audio samples (See Sect. 5.8) using Human Activity Recognition (HAR) approaches applied on previous work [184, 185].

4.4 Summary

This chapter aimed to organize existing literature, provide a baseline understanding in place of an agreed definition of conflict, depict relevant conflict aspects (dimensions) by analysing critical features of a conflict situation and made an overall evaluation of a range of methods and techniques of conflict management. To do it, many methods to address conflict in a virtual environment were considered, ranging from negotiation and mediation to modified arbitration or modified jury proceedings [186]. A brief review of instruments or approaches [187] that provide relevant information to the disputant parties and systems that manage conflict in a virtual environment was also regarded.

Furthermore, it also aimed to analyse the relationship between conflict and ICTs, explored the challenges individuals face using online technology for collaboration and conflict mediation purposes. Thus, one can conclude that developments in ICTs have played a critical role in exacerbating and/or resolving conflicts. It was also shown how recent AI innovations could facilitate knowledge acquisition, network building, and the analysis and presentation of conflict-related data. Indeed, several online-specific techniques and models have been developed to take advantage of the new technology.

At the end of the chapter, it was decided to present the prototype of the technical platform underpinning a Conflict Resolution Environment that could be sensitive and responsive with both parties of a conflict management platform. The main concern was to design an environment where a group of devices could cohabit and share information towards a common goal: sensing and acting in a non-intrusive way to influence the conflict process. To accomplish this, this work focused on a modular development paradigm that was backgrounded with conceptual models and frameworks. As a result, this environment allows that all the components can be combined to implement complex functions.

Chapter 5

Experiments Performed

"The true knowledge is NOT in the things, which are few, but in finding the connections between the things". Archos speaking to Wasserman.

Robopocalypse, Daniel H. Wilson

As stated before (see Sec. 3.3.4), the *proof of concept*[1] research method is chosen to demonstrate the validity of our research hypotheses and to verify the applicability of the concepts of conflict management in an IE. Furthermore, this method aims to prove the viability and feasibility of innovative ideas through prototypes and demonstrations of features. To do so was used on the experimental settings quantitative techniques (monitoring users' reactions and interactions), qualitative data collection (questionnaires), and analysis procedures to determine associations through analysis of plausible relationships. The following sections detail the case scenario, the conditions and methodology followed, and specific studies (in which the results have been published as an academic journal article and as conference proceedings of which the candidate is the first author, and main contributor [36, 89–93, 157, 189]). Therefore, a test environment was set up and carried out in the ISLab [2] at the Department of Informatics of the University of Minho. In this environment, the users had to perform some activities that implied the interaction with the devices and/or with the conflict environment described in Section 4.3 and functionally detailed in Appendice C.

5.1 Conditions and Methodology

During this PhD work, several studies and experiments were performed to understand how a given party responds to particular scenarios: how does a party behave during a conflict situation, among others.

[1] The notion of proof of concept research is framed in terms of a particular kind of research that aims to answer a question whose answer has wide applicability in areas beyond that tested [188]

[2] The website of the Intelligent System Lab is available at `http://islab.di.uminho.pt` *(accessed in May 2021)*

The experimental period was from 2013 to 2017, divided into several studies, and the setting was at ISLab. Social science procedures were thus applied to allow studying and to influence behaviour in a systematic and scientifically valid way. In particular, an algorithm defined by Cooper [190] was followed. It provides a complete description of the methods and principles required to identify the behaviour sources and perceive the relationship between sources and behaviours and how to adjust them to influence the doings as preferred. According to Cooper [190], all behavioural research should include the following:

1. At least one participant;
2. At least one behaviour (which stands for the dependent variable);
3. At least one setting or environment;
4. A system for measuring the behaviour and ongoing visual analysis of data;
5. At least one treatment or intervention condition;
6. Manipulations of the independent variable so that its effects on the dependent one may be quantitatively or qualitatively analyzed;
7. An intervention that will benefit the participant somehow.

Thus, these points served as the guiding lines that directed the work here described, as the following subsections detail. In that sense, several conditions for experimenting were established and included the following:

- Number of subjects enrolled in the study is more than 10;
- The environment of the experiment was the ISLab, at the University of Minho;
- Each experiment included two sessions: an initial baseline session and a test session similar to the baseline;
- The implicit learning session was replaced by a simple perceptual task in the control condition and no reward was delivered.

Moreover, the experiments were performed with regular devices with custom software and hardware. A monitoring framework that worked under the sensing and acting in a non-intrusive way -since less intrusive techniques facilitate more accurate and frequent monitoring- was deployed at ISLab servers. The framework allowed the user to interact with the conflict management environment completely. The data about the user's context and behaviour was provided through this monitoring framework during the experiments.

5.2 The Negotiation Game Scenario

To simulate a conflict situation in real-life environments, an android[3] and web-based[4] game was developed (See Figure 14 and Fig. 15). It was designed to enable test participants to have a conflict experience induced by the presence of an AmI system and by implementing this system with the help of web technologies, it was possible to develop a more responsive and user-friendly system. In that sense, the web-based game simulates a business situation (a conflict) where each party wishes to achieve a desired result in the negotiation or go bankrupt. The desired outcome was a win/win situation for both parties. The game starts with the application randomly giving one of the predetermined roles to each party. The instructions to win the game were to negotiate an acceptable deal and ensure that the party in question didn't go bankrupt. Each party's instructions were presented, visible to them through the application interfaces. The objectives and the *persona*[5] for each party are depicted as:

- Role A - party A was a light bulb manufacturer who specialized in specific light bulbs. He was not the only supplier of this light bulb. He needed to sell 6,000 light bulbs at 1 euro or more per light bulb to stay in business. If he did not achieve this, he would go bankrupt. He was also given the information that Party B needed to make this deal.
- Role B - party B was designed retailer of light bulbs. He had recently received a contract to supply a hotel chain with 6,000 of these specific light bulbs. The hotel was prepared to pay 2 euros per light bulb. If Party B did not manage to negotiate with Party A to buy the light bulbs at 1,20 or less, he would go bankrupt. Party B was told that party A was in a little financial trouble and needed to make the deal to survive.

The game lasts at most ten rounds (in the training phase) or five minutes (in the stressful phase). If a negotiation could not be done at this time, both parties would go bankrupt. The ZOPA was bounded by the BATNA (1 euro) and WATNA (1,20 euro) values. The range of possible agreement is 0.20, but the parties were not aware of this detail.

In all the experiments, a negotiation *scenario* was commonly used to describe the setting of a negotiation. It consists of a *domain*, an *outcome space*, *preference profiles*, and *negotiation/conflict-handling styles* (adapted from [191]). A negotiation *scenario* should specify everything we know about the problem being addressed to frame the interactions that occur within. Taking into account the *domain* of the negotiation (which specifies the *issues* that the negotiators need to agree upon), in the studies performed,

[3]This sensor-based application for the Android Operating System was developed in previous work [35] and used on this PhD research activities until 2014.

[4]This is the front end of the web application developed in the context of this PhD project and was used on the experiments from 2013 until 2017.

[5]In the different studies carried out, the test case is similar, with only a few differences in the game description (e.g., a municipality and a service provider instead of a hotel; a piano seller instead of a lamp manufacturer) without any loss of meaning.

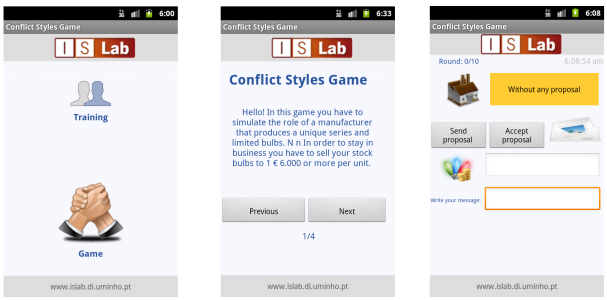


Figure 14: A sensor-based application for the Android Operating System.

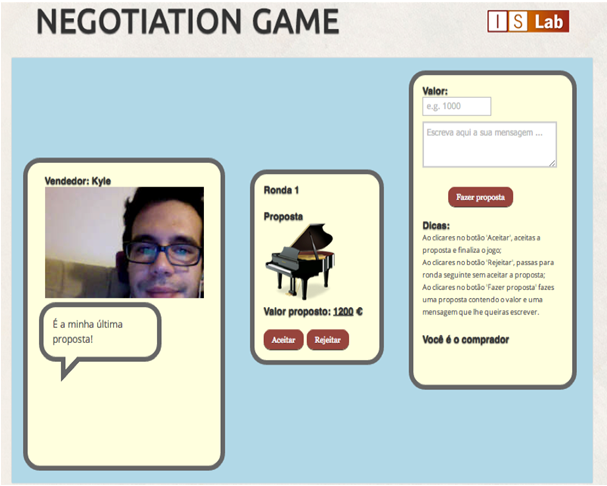


Figure 15: A web application developed in the context of this PhD project and used on the experiments.

the single issue negotiators need to agree on is the price of the item being sold. The *negotiation space* represents all the outcomes achievable, i.e., all possible issue value combinations with the domain. Once again, the negotiation space is restricted following the mathematical model described in Section 4.2.3.1.

5.3 Multi-modal Approach to Stress and Personality Dimensions

Identifying the degree of relationship between one's personality traits and one's current stress state can facilitate the communication process and help address a conflict situation. In particular, the lack of gestural information limits successful communication in virtual environments [192]. The authors experimentally prove not only that body language is very important for transmitting information but it is also important to perceive feedback from that transmission, i.e., to perceive if the communication is being successful

or a different approach should be followed. With this aim, an experiment conducted by the candidate in 2014 at ISLab studied the correlation between some personality traits and the stress levels exhibited by users' interactions and behaviours [36]. The experiment has been designed to address the estimation of relevant aspects of interactions that occur in a rich sensory environment. This experiment, therefore, produced valuable outputs for this research, such as the relation between personality characteristics and stress that can be used to maximize the benefits of virtual environments and their application in a conflict management situation. Finally, in this research, an IE was used to support the stress recognition process providing important personality-related information.

5.3.1 Rationale

Different emotional reactions can be deduced in part by the personality structure of each person, represented in this study by the BFP theory[6] and a mood simulator reacting to environment configurations. Considering the stress and personality dimensions was followed a multimodal approach to analyse how they are related to each other. The generic diagram (See Fig. 16) outlines our approach to stress and emotion recognition problems in the context of conflict management. It consists of two parts. The rightmost depicts the elements that can alter human stress and emotional state. These elements are included in the 'context' category and represent the generalization of two sub-categories (sources of contextual information): the 'user-centric context and 'environmental' context. The leftmost part of the diagram depicts the observable features that reveal stress and emotion. These features include quantifiable measurements of the user's physical state, physiology, behaviours, and performance.

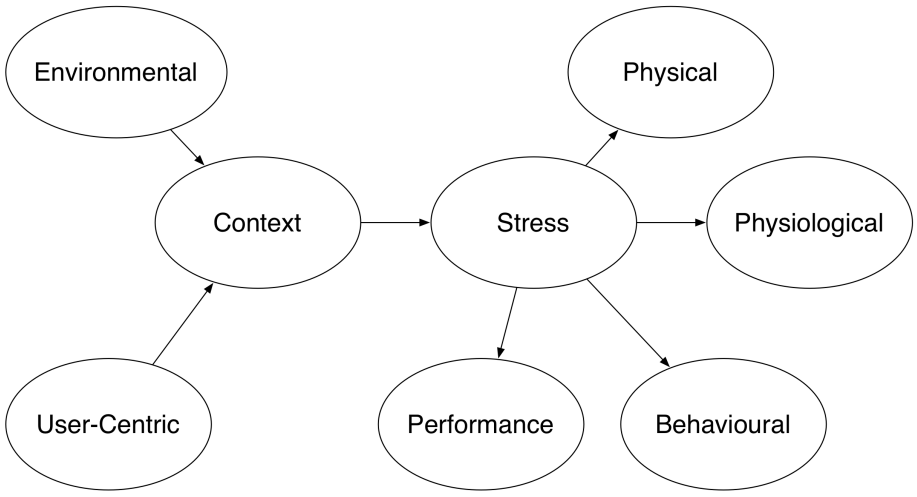


Figure 16: An overview of a generic diagram outlining the stress and personality dimensions.

[6] Big-Five Personality theory.

The environment in which the experiments occurred was composed of hard sensors (i.e., hardware sensors, in the traditional sense) and soft sensors (i.e., software sensors such as sensors for the interaction with the mouse and the keyboard), independent systems (with logic and intelligent services), and an integration framework. Furthermore, from the point of view of this study and described with more detail in the scientific report about this research [36], the two most interesting components are the Stress Recognition and the Mood Recognition modules (described in the Section 4.2.3.5 and Section 4.2.3.4, respectively). The first classifies, in real-time, the level of stress of a user; the second provides an outlook of the user's mood using information about the personality traits previously offered.

5.3.2 Data collection

The participants of the proposed experiment were volunteers from ISLab. Eight individuals participated, both female and male, aged between 20 and 32. All these individuals were familiar with the devices used. Therefore, the interaction with them was not an obstacle. The first step of the experiment was to ask the volunteers to fill in the NPA individual questionnaire (detailed in Annex I). The following step was to monitored the individuals' interaction with their devices (where the stress recognition module and mood module were installed, see Fig. 17) within the set environment. The data collection related to the Keystroke Dynamics and Mouse Dynamics approach to recognize users' stress levels was based on the stress recognition model (explained in Section 4.2.3.5 and the used methods to implement it was depicted in Section 4.3.2.2) and was selected the following features from these two types of biometrics[7]:

- Time between Keys (TBK);
- Key Down Time (KDT);
- Absolute Sum of Angles (ASA);
- Mouse Velocity (MV);
- Mouse Acceleration (MA);
- Distance Pointer To Line Between Clicks (DPTLBC).

A parallel and transparent process was responsible for capturing and processing the users' interaction data. First, the contextual and behavioural data were obtained and sent synchronously to the platform (a framework deliberately designed to handle stress and mood recognition, see Section 4.3 and Section 4.2.3 for details). Then, upon converting the sensory data into useful information, the platform allows for a contextualized analysis of the users' data to produce stress and personality-related information meaningful for a conflict management situation.

[7] Behavioural Biometrics looks at behavioural characteristics (e.g. the typing rhythm on a keyboard, the way the user looks at the screen of the computer). These characteristics change with factors such as mood, fatigue, stress or others [160].

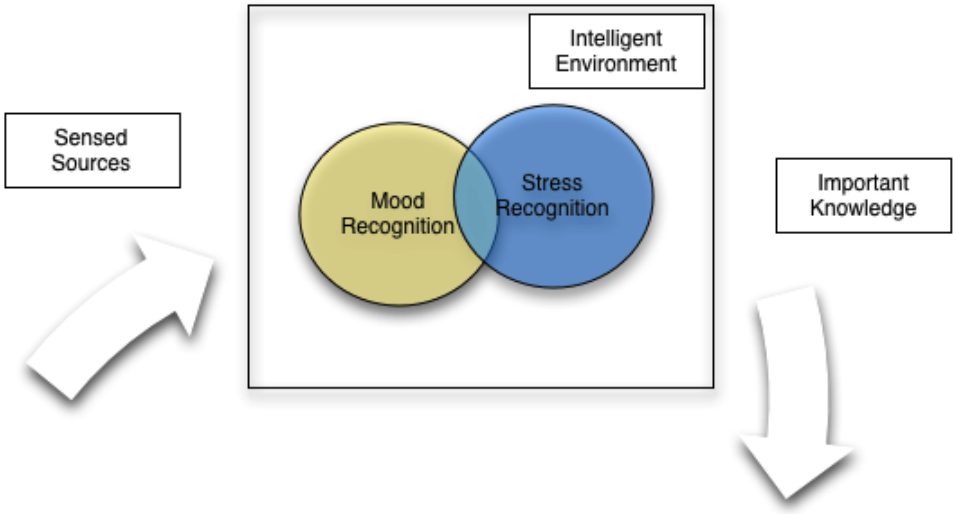


Figure 17: The stress recognition module and the mood recognition module incorporated in the conflict management intelligent environment.

5.3.3 Preliminary data analysis

In this experiment, the creation of a dataset, the pre-processing, and attribute selection were performed to construct Naïve Bayes classifiers designed for the personality traits. The datasets used to train held data from all six interaction features (mentioned earlier), meaning that there would have to be a correspondence between all the records. However, keyboard and mouse activities were not simultaneous or happen with the same frequency, resulting in log datasets with different sizes. The solution for this problem was to calculate the mean values of the features for each every half hour during the length of the experiment. Using this method, and after a selection of the valid records, it was possible to obtain a dataset with 138 instances with values of the individuals' key downtime, the time between keys, mouse velocity, mouse acceleration, the distance pointer to the line between clicks and the absolute sum of degrees between clicks. Then, the results of each individual's NPA questionnaire (detailed in Annex I) were added to this dataset. These results consist of the categories the subjects got for Openness, Conscientiousness, Extraversion, Agreeableness, Neuroticism, and the final emotion in their personalities (as determined as described in Sec. 4.2.3.4). The full set variables consisted of the following: *TBK*, *KDT*, *MV*, *MA*, *ASA*, *DPTLBC*, *Openness*, *Conscientiousness*, *Extraversion*, *Agreableness*, *Neuroticism* and *Emotion*.

Bayesian models do not perform well in continuous data. Therefore, it was necessary to *discretize* the values of the interactive features. Using *Weka*, and more specifically the *PreProcess* tab of the Explorer interface, a supervised filter called *Discretize* was applied to the dataset to convert these values into intervals

[193]. Therefore, the dataset underwent an attribute selection phase[8], supported by the resources in the *Select Attributes* tab of the *Explorer* interface. As exposed in previous work [36], the *ClassifierAttributeEval* was selected as the attribute evaluator. Accordingly, the Naïve Bayes was set as the target classifier, and the parameter folds were set to 12 for 12-fold cross-validation. Only the three best features were selected for each personality trait. The results showed that the *DPTLBC* is always selected as one of the top three features, which reveals that the behaviour of this variable is more permeable to the characteristics of an individual's personality. On the other hand, the *KDT* is never selected, which eventually means that it is the feature that reflects less the personality traits.

5.3.4 Data analysis

The Naïve Bayes classifiers were learned using subsets of the dataset containing all the attributes. The learning phase was executed using *R* software, more specifically, the functionalities provided by the *bnlearn* library. A 12-fold cross-validation was performed to assess the model with the classification error as the loss function [193]. In the attribute selection phase, the top three features for Neuroticism and Emotion were *DPTLBC*, *MV*, *ASA* and *DPTLBC*, *MV*, *MA* , respectively. The mean classification errors for the classifiers using these features were 0.08018 (for Neuroticism) and 0.09596 (for Emotion). In other words, the individuals that score high on Neuroticism respond poorly to stressors and manifest a behaviour change when submitted to them. As a result, when looking at it and performing the same type of conditioning for the features mouse velocity, mouse acceleration, and the distance of the pointer to the line between every two consecutive clicks, it is revealed that the anxious class has higher probabilities for the central intervals of these features. For low intervals of *DPTLBC*, *MV* and *ASA* was possible to see that the classifier assigns higher probabilities to the *high* class of Neuroticism. This result indicates that more precision may be associated with a high score in Neuroticism. This result is also in line with what is expected as a tendency for the evolution of an individual in a stressed state [161]. The emotions expressed in the upper and lower boundaries of the features are usually *bored* and *relaxed*.

5.3.5 Results and Discussion

This experiment pointed out dependence relationships between the features being monitored and the main personality traits. These relationships, especially those regarding Neuroticism, can enable the characterization of individuals through their device interaction patterns. The results indicate that stress state influences the interaction patterns in a significant manner. This conclusion was also supported by the work of other researchers who proved that stress does affect people's behaviours and physical responses [151, 183, 194, 195]. Thus, the findings presented herein may help identify the degree of association

[8]The reason was to select the variables with the strongest dependence relationship.

between one's personality characteristics and his current stress state, maximizing communication benefits within virtual environment applications in fields such as learning, medicine, or conflict resolution. The main contribution of this work was in the development of a set of functionalities in the context of an IE that have the potential to enable the characterization of individuals through their device interaction patterns. However, the small size of the dataset and the lack of statistical significance of the results are the major drawbacks of this study.

5.4 Assessing Interpersonal Trust in an Intelligent Environment

While trust in the system and your adversaries is vital in negotiating a dispute, it is unclear what trust means in a conflict or how can be enhance. The most effective concern about trust seems to be when it is absent [196]. Although a variety of definitions of the term *trust* have been suggested, this paper will use the definition proposed by Castelfranchi, who saw trust as a rich and complex mental attitude of *x* towards *y* as for a given action and goal [197]. This attitude consists of evaluations of *y* and the situation and expectations about *y*'s mind, behaviour, and possible results. Having this in mind, the candidate conducted a study in 2015 [90] to investigate the link between relational trust (interpersonal) and personal conflict-handling styles. The assumption that guided the research was that trust plays a significant role in promoting parties to engage in the conflict management process. Therefore, the main objective of this research work [90] was to identify and measure the users' interpersonal trust, to correlate to their negotiation performance, and how it can be used in a simple conflict (zero-sum) situation. In other words, this study aimed to quantitatively measure dyadic trust (trust between two entities) based on observable behaviour present within a negotiation process (Fig. 18).

5.4.1 Rationale

Scholars and practitioners agree that trust and trust scarcities play a central role in conflict and conflict resolution [198]. Further, the presence of trust is stated as a necessary condition for parties engaging in a conflict mitigation process. These considerations can be distinctly observed in a typical conflict scenario (buyer versus seller). Trust emerges where the eventual outcome depends on both parties' actions and strategies within the conflict management process itself.

Therefore, it was assumed that, by investigating this link, one could better understand the potential effects of trust in conflict and be better prepared to prevent conflict from escalating. In this sense, a study was carried out by the candidate in which was pretended to approach trust measurement[9] in the

[9] One can see *trust* as a measure of confidence in which an entity will behave expectedly.

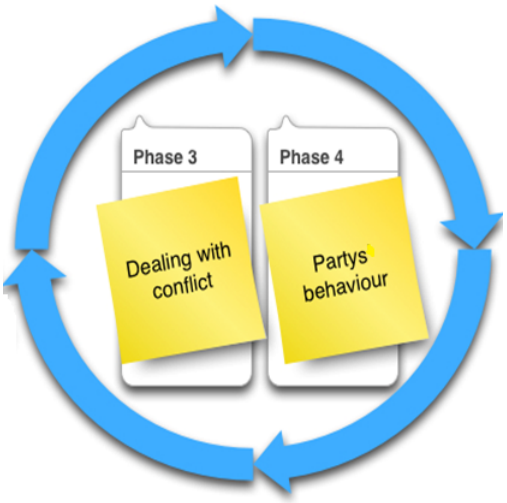


Figure 18: The pivotal phase of conflict consists of dealing with the actual conflict. Simply speaking, it is the phase in which disputants attempt to cope and manage conflict.

context of a AmI system to support conflict management activities[10]. Thus, assuming the intuitive notion that these patterns are essential features of the individuals' actions through their interaction in a conflict situation, a trust analysis component was developed. The procedures, the means, the data analysis of this experience will be outlined in the following sections. The findings of this study were published in a scientific article related with AI approaches to the complexity of Legal Systems [90].

5.4.2 Data collection

This study hypothesized that the degree of a relationship between two individuals could be a proper measure of their trust relationship. Therefore, was applied social network analysis methods to map and measure the experiment's participants' relationships. This approach was based on the intuitive notion that these patterns are essential aspects of trustworthy relations of the individuals who display them through their interaction, namely in a conflict situation. Therefore, by limiting the trust domain understudy to interpersonal trust, it was possible to observe trust between A and B resulted in typical behaviours and thus able to be statistically captured. The behaviours exhibited by the parties in a conflict situation (interaction patterns) were the primary source of data to infer trust measurements. Indeed, one can stand that the trust value assessment in the study was possible through the application of behaviour-based techniques. Meanwhile, in this process, it was assumed that *distrust* could imply a need for interaction in a conflict

[10] Dynamics of trust, the role of context, and the influence of display characteristics were not taken into account in this work because it seemed out of scope, even knowing that exist emerging theories around people's experiences with algorithmic technologies and trust (such as presented in Lee's works [199, 200]) could have enhanced the research results.

mitigation process. Therefore, was postulate that:

- More extended interactions imply less trust;
- More interactions imply less trust;
- Balanced interactions by A and B implies less trust;
- Trust is measure by a function: based on the interactions that occur in the process plus the degree of balance. An entropy function measures balance: aims to measure the amount of information missing in interaction flow.

The participants of the experiment were volunteers socially connected with ISLab members. Twenty individuals participated, both female and male, aged between 22 and 36. The first step of the experiment was to ask the volunteers to fill in a individual questionnaire (see Annex I). The next step was the monitoring of the individuals' interaction with the aformentioned web-based negotiation game.

5.4.3 Preliminary data analysis

As stated in the published work, the data containing the required information was acquired in digital form through the players' monitoring framework (see Appendice C), which was customized to collect and handle the interaction data. This data was thus combined and synchronized to describe several important aspects of the behaviour of the user. The participants played the web-based game through computers that allowed the analysis of the related features. In the preliminary data analysis, the experimental data was organized into two groups based on the social network analysis (fed with the data extracted from the application of the questionnaire mentioned before). One group contained the collection of data obtained through the application of the questionnaire (measuring the participant's relationships). This aspect enabled establishing a baseline for comparison with the second group, gathered through the web-based negotiation game (applying the trust measuring algorithm presented), which comprises the data collected from the parties negotiating.

To statistically deal with data concerning the parties' proposals' utility values, it was necessary to convert data to an arbitrary numeric scale (zero is the least favourable style for the resolution and four the most favourable style). This type of scale ensures that the exact numeric quantity of a particular value has no significance beyond its ability to establish a ranking over a set of data points. Therefore, rank-ordering was built, which describes an order but not the relative size or degree of difference between the items measured. This step was necessary to make the data suitable for statistical and machine-learning techniques.

Further, according to our postulates, the basis for this analysis was the assumption that if A and B have a strong relationship, then $R_I(A, B)$ value (the *relational trust*) is below the median of the calculated trust for all the pairs within the interactions data set. In other words, this implied that if one pair of

participants had a high degree of relationship then the same pair of participants, during the game, will perform fewer interactions than the median of total interactions per game.

5.4.4 Statistical data analysis

The experimental data is organized into two groups based on the analysis of the trust measurements in the preliminary data analysis. One group contains the collection of experimental data about how a user (A) behaves when he/she negotiates with someone (B) in which $R_I(A, B)$ has a low value ($R_I(A, B) <$ median). This approach enables the establishment of a baseline for comparison with the second group, which comprises the data gathered from parties that negotiate with someone that has high R_I values ($R_I \geq$ median). To statistically deal with data concerning the parties' proposals' utility values, it was necessary to convert the data to an arbitrary numeric scale (0 is the least favourable style for the resolution and four the most favourable style). This type of scale means that the exact numeric quantity of a particular value has no significance beyond its ability to establish a ranking over a set of data points. It was constructed using rank-ordering (which describes order) but not the relative size or degree of difference between the items measured. This step was necessary to make the data suitable for statistical and machine-learning techniques.

From the data analysis regarding the evolution of the conflict-handling styles evidenced by the parties, we concluded that the conflict style is on average more favourable (mutually beneficial) when the parties have a lower value of R_I than average. The final value of the negotiation process occurs when R_I is lower, the parties reach mutually satisfactory solutions, i.e., solutions that are closer to the optimum result. Also interesting is the conclusion that participants who have a high R_I value need more rounds and exchange longer messages to achieve a successful outcome. This outcome is aligned with our postulates, in which we have hypothesized that more interaction implies less trust in a conflict situation. However, it can be assumed that when the trust relationship is weak, the development of trust between the opponents needs more steps than otherwise. Indeed, events at the beginning and end of a negotiation sequence play a significant role in building and maintaining trust in negotiation performance [201].

At this point, to apply non-parametric statistical analysis, first pre-processed the raw data, and secondly, it was subjected to tests. The outcomes were compared using the Mann-Whitney U test (compares the central tendencies of two independent samples), given that most of the distributions are not normal. The null hypothesis is thus: H_0 = The medians of the two distributions are different. For each pair of distributions compared, the test returns a p-value, with a small p-value suggesting that it is unlikely that H_0 is true. For each parameter (a pair of participants), data from both samples are compared. In all the tests, a value of $\alpha = 0.05$ is used. Thus, for every Mann-Whitney test whose $p-$value $< \alpha$, the difference is considered to be statistically insignificant, i.e., H_0 is rejected. Consequently, the results have shown that no (statistically) significant difference between data from the two samples was found. In other words,

it means that our assumptions were valid. So it is possible to infer that trust measurements using our algorithmic approach are valid to a certain extent.

5.4.5 Results and Discussion

The analysis shows an apparent difference between the two groups regarding the conflict styles exhibited during the game. One conclusion is that when participants share a significant trust relationship (low R_I value), the frequency of collaborative behaviours is far superior (49%) than otherwise (24%). This conclusion corroborates the results presented in Malhotra and Murnighan study [202]. They found in their research that an individual's trust will increase as the number of positive interactions between parties increases. In a similar analysis, but now concerning the roles played by participants, it is possible to conclude that the sellers are much more competitive than buyers (57% vs. 29%) while buyers are primarily collaborative. To interpret the significance of these results, it is essential to recall that participants were asked to negotiate a favourable deal in a competitive and win-lose scenario. Nevertheless, it is shown that when participants have a significant trust relationship, they are more likely to transform it into a win/win situation. This is especially visible in the final results of the negotiations. On the one hand, we find that 100% of the agreements made by parties with a vital trust relationship accomplished a successful deal, i.e., between the range of solutions that would benefit both. On the other hand, only 50% of negotiations that occurred between untrusted opponents (low R_I value) reached a mutual benefits agreement. It may be that they assumed they had to negotiate and get the best price (win/lose). But that was not the objective. Their objective was to negotiate a deal so they would not go bankrupt (win/win).

5.5 Incorporation of Social Network Analysis in Conflict Characterization

Contextual information can influence the course of the conflict process and, therefore, the result of a conflict setting. Additionally, it is generally accepted that the type of relationship that exists between conflicting parties will often determine the intensity of the conflict and its outcome. Indeed, a key aspect of the dynamics of conflict is how people relate with each other and how their relationships change over time as a consequence of conflict episodes. Thus, knowing to map and measure the relationships between the parties will allow the conflict manager to measure the connection, communication, and information flow between the parties through relations and focus on uncovering the patterns of parties' interactions in the network. This kind of information can be obtained using the well-known SNA theory. Therefore, in 2014, a research was conducted with the objective of implementing the model detailed in Section 4.2.3.3 which regards analyzing social connections in conflict situations. This work aimed to apply social network analysis to map and measure the participants' relationships in a conflict scenario. The application of

network analysis was based on the instinctive assumption that these patterns are essential features of the individuals and they display it through interaction, namely in a conflict situation [203]. As highlighted in the study [91], the Advice, Hindrance, and Friendship measurements were selected to analyze the participants' networks. The primary objective was to identify and study how social connections shape how conflict is processed within dispute resolution mechanisms. The results of this research have been published in a conference proceeding [91].

5.5.1 Rationale

Introducing a new module that considers the social context using social network analysis can potentially enable individuals' characterization and enhance negotiation performance. The study was based on the following assumptions: 1) a AmI system can create scenarios that augment the possibilities of reaching a favourable outcome, taking into account the role of contextualized social relationships in various conflict management strategies [176]; 2) having a general overview of how one can apply social network analysis to establish a reliable description of how one may use meaningful information to understand further conflict [175]. So, the main contribution of this approach was thus the identification of situations in which peoples' social networks influence the negotiation performance. And this can be especially important when facing conflict mediators, or conflict managers have access to this knowledge, facilitating processes and not letting people lose efficiency when they get tangled by their own social and contextual circumstances.

5.5.2 Data collection

The data to extract each of the measurements mentioned earlier was obtained through a questionnaire (carefully adapted) of social networks:

The Advice Network, in this experiment, was measured by asking respondents two questions (following Sparrowe's work [137]):

- Do you go to these people to ask for help or advice on the work-related matter? [137]
- Do you talk with these people about confidential work-related matters? [137]

To test the Hindrance Network, the question used was:

- Does he/she makes it difficult for you to carry out your job responsibilities? [137]

Friendship Network was measured by asking respondents:

- Do you consider this people like "personal friend'? [135]

Since the research interest was to analyze the strength of relationships, we use responses in a 5-point Likert Scale from "not at all" (1) to "very much"(5). The centrality scores for each individual were obtained by applying centrality measures (presented in Sec. 4.2.3.3 and explained on Appendice D) on the received

data. The questionnaire was sent to a network of 20 individuals[11], and the data was collected in binary format and were stored in square matrices of 20 x 20. Calculate relational variables was performed with the software program UCINET VI. The meta-analytic techniques used to analyze the data obtained were as follows:

- Descriptive statistics, both standard deviations, etc.;
- Correlations between the independent variables (centrality and density) and dependent variables (hindrance);
- Regressions to test the model. Gender was used as a control variable.

5.5.3 Preliminary data analysis

The study [91] points out, from preliminary analysis, that individuals who do not have an exemplary reputation or central position in the first networks are hypothetically those most drawn to other individuals as conflicting. This statement can be acknowledged because, through the data extracted from the questionnaires, some individuals identified as conflicting were individuals with prestige as in the Advice and Friendship networks. Some of them were even appointed as a bridge between subnets. Yet, on the other hand, there are a large number of nodes that have not denoted to any partner as conflictive by what might not have a high degree of conflict in this group, and this may be because they do not have a high degree of conflict in this group or because when they have answered the questionnaires they not have felt comfortable answering this item.

The preliminary evidence (See Fig. 19) suggests that exists a theoretical basis for expecting a connection between social networks and the use of conflict styles. However, despite these results, one still not knowing much about how internal configurations of social networks might facilitate (or inhibit) positive conflict outcomes.

5.5.4 Statistical data analysis

Regarding the evolution of the conflict-handling styles evidenced by the parties (Fig. 20), the study concludes that the conflict-handling style is on average more favourable (mutually beneficial) when the parties are friends. We also conclude that the style tends to improve (shifting towards more cooperative solutions) as the rounds advance. In what concerns the final value of the negotiation process, we conclude that friends reach more mutually satisfactory solutions, i.e., solutions that are closer to the optimum result (Fig. 21). Also interesting is the conclusion that participants who are friends need fewer rounds (Fig.

[11] The participants of the proposed experiment were volunteers socially connected with our lab members. Twenty individuals participated, both female and male, aged between 22 and 36.

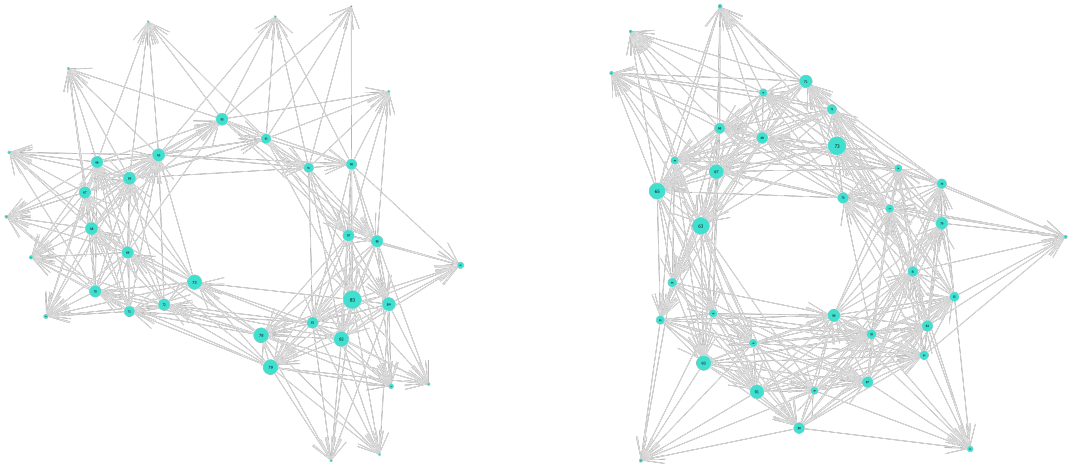


Figure 19: These graphs were obtained after computing the degree centrality of the resulting friendship network (at left) and hindrance network (at right). This centrality measure counts how many neighbors a node has.

23) and exchange smaller messages (Fig. 22) to achieve a successful outcome (which is also more satisfactory, as described previously).

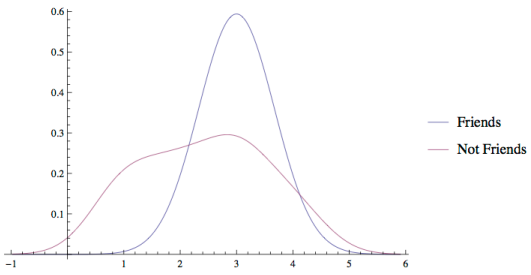


Figure 20: The difference in the distribution (X-axis) of the Conflict-Handling Style (Y-axis) was used by the participants when they were negotiating with a friend or not.

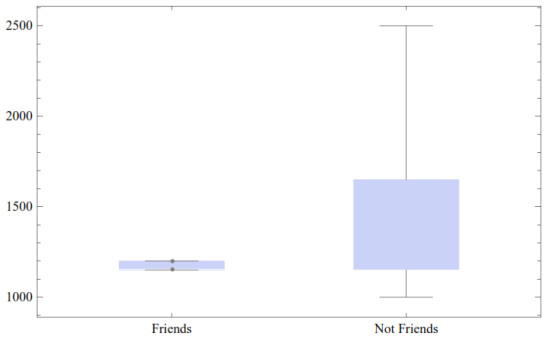


Figure 21: Distance of value of the final proposal to the optimum result when the participant is a friend or not.

5.5.5 Results and Discussion

The results shows a clear difference between the two groups regarding the conflict styles exhibited during the game. The main conclusion is that when participants are friends, the frequency of collaborative behaviours is far superior (42%) than when they are not friends (17%). This result may mean that *friendship* between the parties will make them more sensitive to each other's concerns, despite being in a competitive game. In a similar analysis, but now concerning the roles played by participants, we conclude that

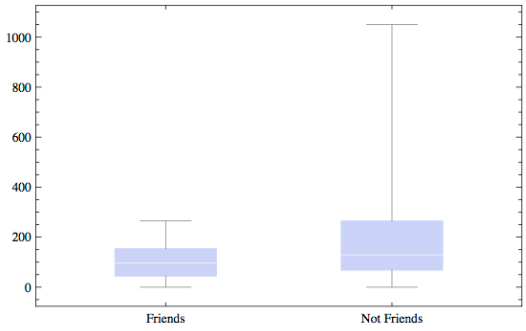


Figure 22: The difference between the size of the messages exchanged when the participants are friends or not.

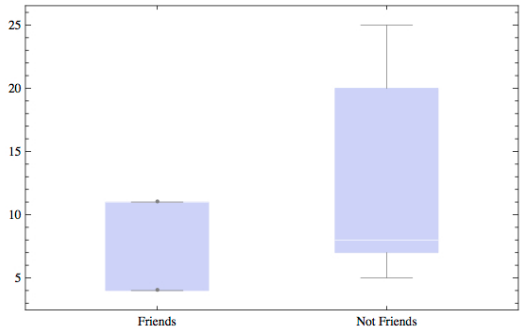


Figure 23: Difference in the necessary number of rounds to reach an agreement when the participants are friends or not.

the sellers are much more competitive than buyers (63% vs. 25%). In contrast, buyers are essentially collaborative. To interpret these results' significance, it is important to recall that participants were asked to negotiate a successful deal in a competitive and win-lose scenario. Nonetheless, it is shown that when participants are friends, they are more likely to transform it into a win/win situation. This is especially visible in the final results of the negotiations. On the one hand, we find that 100% of the agreements made by friends accomplished a successful deal, i.e., between the range of solutions that would benefit both. On the other hand, only 50% of negotiations between non-friends opponents reached a mutual benefit agreement. It may be that they assumed they had to negotiate and get the best price (win/lose). But that was not the objective. Their objective was to negotiate a deal so they would not go bankrupt (win/win).

5.6 Speculative Computation Approach to Cope with Incomplete Information

Properly dealing with incomplete information during a conflict management process is crucial to its final result. Conflict itself can convey information and potentially become a bargaining instrument [204]. However, it also can be viewed as the outcome of misperceptions, incomplete information, or even irrationality [205]. Hence, it becomes relevant to deal with the provision of incomplete information. Bearing this in mind, in 2016, the candidate involved in research to design and test a set of techniques suitable for handling incomplete information in a computer-based conflict managgement environment (see Sec. 4.2.3.6 for more details). More precisely, the work described the design of a speculative computation framework to cope with incomplete information concerning the parties' conflict-handling style assessment. This approach was seen as an experimental method to apply when a complete description of the parties' conflict-handling style is not obtained or can not be obtained. The approach, the experiment, and the findings raised here were reported and published in a conference proceeding [89].

5.6.1 Rationale

This work investigated how to cope with incomplete information when analyzing the parties' conflict styles. It sought to contribute by supporting the process of a conflict manager or a party to come up with a decision, that is, to find an optimal or satisfying solution that leads to a convergence of parties' positions. Underpinning this approach was the idea that if a conflict manager, or a party, in an intelligent conflict support system, knows to be able to identify parties' conflict-handling styles adequately, he will promote better strategies and, consequently, lead to better solutions [163]. Once identified, tasks can be mapped onto the most appropriate artificial reasoning model (if any) for computer-based implementation to handle conflict resolution.

5.6.2 Data collection

Forty individuals participated, both female and male, aged between 22 and 53. The experiments provided the user's context through a monitoring framework customized to collect and treat the interaction data. The participants played the web-based game through computers that allowed the analysis of the described features. The obtained results comprised data about the negotiation experiments carried out in a controlled environment at ISLab.

Since previous analyses [157] revealed that the role of a participant significantly influences his conflict-handling style, Sellers and Buyers should be modelled in different networks. Understanding the dependence relationships between negotiation styles in different rounds is possible by performing BN structure learning on the data gathered from the experiments. Some of the most well known BN structure learning algorithms include: the *hill-climbing* (*hc*) search [165], the *grow-shrink* (*gs*) [165], the *max-min hill-climbing* (*mmhc*) and *restriction maximization* (*rsmax2*) [166], and the *chow-liu* algorithm. By applying these algorithms, the goal was to obtain the network structure that best describes the dependencies between negotiation styles in different rounds, based on the available data. Different scores can be used to assess the fitness of the network. In the present work, the AIC [167] was the selected metric.

5.6.3 Preliminary data analysis

As reported [89], the experiments mentioned above produced data regarding 20 negotiation games, which means data for 20 Sellers and 20 Buyers. Out of all the games, the minimum number of rounds was two, the maximum was 12, and the most frequent number of rounds was three (observed in nine games). It was also possible to observe that 95% of the games had three or more rounds. Given this analysis, it was decided that the model would feature predictions for up to three rounds of negotiation. As such, it was produced two datasets, one for Sellers and another for Buyers. Each data set had three columns representing the first three rounds, filled in with the conflict-handling styles exhibited by 19 participants

Table 4: Results of the structure learning and structure assessment processes.

Network Model	Seller	Buyer
	AIC score	AIC score
hc	-38.749	-78.361
gs	-40.233	-78.361
mmhc	-40.233	-78.361
rsmax2	-40.233	-78.361
chow-liu	-40.795	-79.990
expert	-40.795	-79.990

for each data set. It was removed only the records of the game with two negotiations. The structure learning algorithms mentioned in the previous section (see Sec. 4.2.3.6) were applied to the two data sets, producing the AIC scores presented in Table 4.

At the same time, it was modelled a network structure based on the underlying intuition that the conflict-handling style exhibited in a round by both Sellers and Buyers would be probabilistically dependent on the negotiation style exhibited in the previous round. Let $Round1$,$Round2$, and $Round3$ be variables that represent the conflcit-handling styles in rounds 1, 2, and 3. This supposition can be translated into the network structure. The network was called *expert*. In Table 5, it is possible to observe that the AIC scores of the network structures were, overall, very low. This result was most likely due to the reduced size of the sample used to learn them. However, given the complex data collecting process described above, the experiments would have had to be carried out on a much larger scale to produce better results. That being said, based on the available scores, the best network structure for the Seller role was the one resulting from the *hc* algorithm.

5.6.4 Data analysis

Based on the available scores, from the results published, one can stand that the best network structure for the Seller role was the one resulting from the *hc* algorithm. The network of the Seller and its score was even higher than the *expert* network structure, thus contradicting the initial intuition. It has a diverging arc disposition, and the negotiation styles of $Round2$ and $Round3$ are shown to be conditionally independent given $Round1$. Throughout the rounds, it is possible to observe that Sellers remain competitive, but the probability of their assuming a *collaborating* negotiation style does increase. Regarding the networks for the Buyer role, the *hc*, *gs*, *mmhc* and *rsmax2* algorithms produced the same type of structure, which was also, coincidentally, the highest-scoring network. Again, the score was higher, although slightly, than that of the *expert* network. It was only possible to establish a probabilistic dependence relationship between the negotiation styles of $Round1$ and $Round2$. $Round3$ was considered to be independent of the other two. Be that as it may, the network reveals that Buyers usually start with a *competing* negotiation style.

Still, they are the ones to respond to the lack of dynamism in the negotiation by changing the negotiation style towards *accommodating* in the third round, thus unlocking a possible impasse. With the networks and using MAP queries, it is possible to obtain the most likely negotiation styles for the three rounds before the negotiation starts, or midway, for the remaining rounds, after a round is over. Supposing one is at the beginning of the negotiation, no round has taken place yet, and there is no information about previous negotiation styles. It would be possible to determine the most likely set of negotiation styles of a Seller for each round. Performing the MAP query with no evidence on the network of the Seller would result in assuming, by default, that $Round1$, $Round2$, and $Round3$ would have the value *competing*, with a probability of 0.563. Now, supposing the first round is over and the Seller adopted a *collaborating* style instead, the MAP query to determine the most likely styles in the next two rounds would have $Round1 = collaborating$ as evidence. This query would produce two sets of predictions. The first would be $Round2 = collaborating$ and $Round3 = collaborating$, and the second would be $Round2 = collaborating$ and $Round3 = acommodating$. Both sets would have a probability of 0.500. These predictions are used in the Speculative Computation framework modelling the interventions of the conflict manager in the negotiation (see Fig. 24)[12]. The new default setting would lead to a new set of recommendations produced by the logic program, allowing the Conflict Manager to advise the Buyer accordingly (see Fig. 25)[13].

5.6.5 Results and Discussion

This study set out to determine a way to deal with incomplete information, namely information regarding the conflict-handling style used by parties [89]. It followed an approach consisting of Bayesian networks for default prediction and Speculative Computation to structure the reasoning process. Thus, it was aimed to identify and apply a set of methods for classifying conflict-handling styles with incomplete information; secondly, we aim to validate this approach by opposing data collected from a web-based negotiation game. The findings suggest that, in general, it is now possible to state that our approach copes with incomplete information by producing valid conflict-handling styles default values; and anticipating competing postures through the dynamic generation of recommendations for a conflict manager. So, facing these results, we can claim that this work advances the state of the art in that such an analysis has not previously been undertaken. Additionally, must point out the limitations of the current research must. First, the participants were recruited from a particular population- a population that may limit the generalizability of the results.

[12]This would generate a new default set with style Collaborating for Round2 and Collaborating or Accommodating for Round3, thus resulting in scenarios recommending the Conflict Manager to reinforce this behaviour from the Seller.

[13]Through process reduction, a scenario is generated based on these default values with the proper recommendation that the Conflict Manager should give. The conflict Manager advises the Seller to lower the value of his proposal in order to become more collaborating in the first round and help the negotiation come to a swift conclusion.

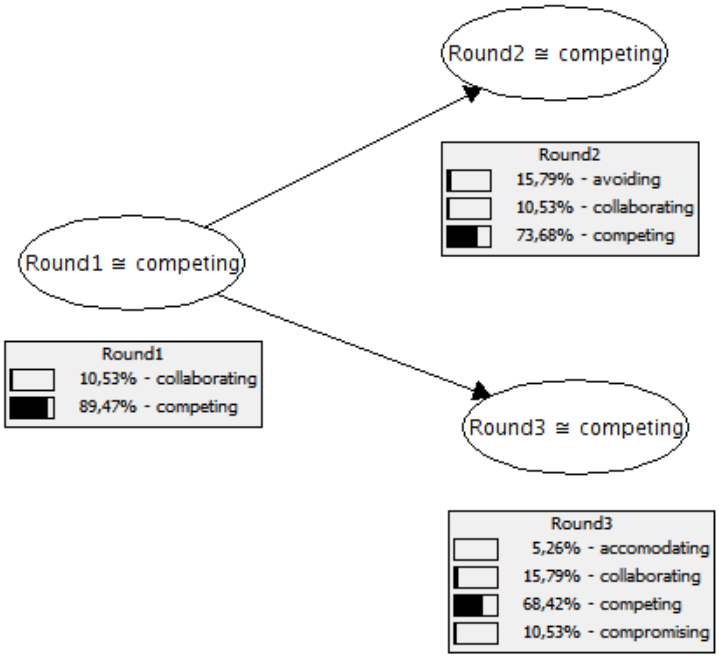


Figure 24: From the Seller network, it is possible to verify that the most likely negotiation style for a Seller is Competing throughout the three rounds. As such, the default set consists of the Competing values for Round1, Round2, and Round3.

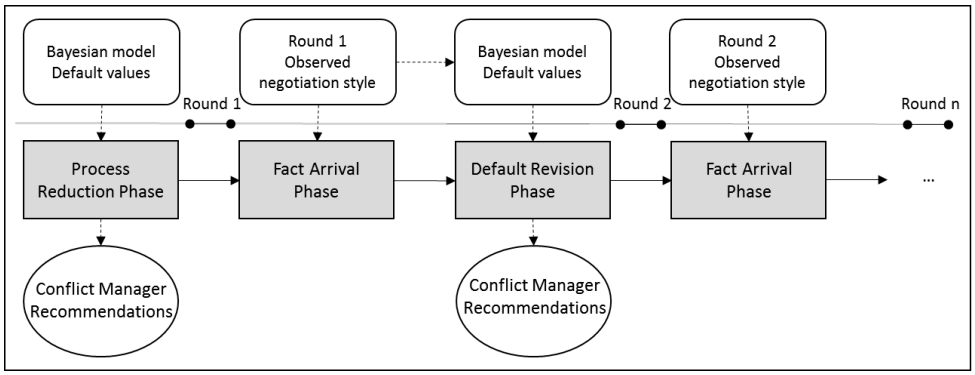


Figure 25: Supposing the recommendation of the Conflict Manager produced an effect. The observed conflict-handling style of the Seller in Round1 was Collaborating. This real value would be used to condition parameter Round1 in the Seller network.

Admittedly, the participants of the experiment may not be representative of conflict parties in general. Consequently, we are unable to demonstrate the causality of the variables conclusively. Finally, returning to the question posed at the beginning of this study, it is now possible to state that it is possible to cope with incomplete information to enable more accurate characterization of conflict styles in a resolution

process. However, more research is needed to provide more definitive evidence.

5.7 Extracting Behavioural Patterns

In this work is assumed that if a conflict manager, in an intelligent conflict support system, can identify parties' behavioural patterns, then he will promote better strategies and, consequently, lead to better solutions. Furthermore, the patterns expressed by users, namely in negotiation processes, may provide this relevant information for mediation/management purposes and thus may help to achieve better outcomes. Hence, the ability to learn patterns of behaviour became an essential aspect for the successful implementation of IEs. Therefore, in 2013, an experiment was carried out and focused not only on the behavioural patterns that influence the outcome of negotiation but also on discovering ways to predict the type of conflict-handling style used in the process and the stress levels of the party. The findings of this experiment and the methods to obtain were published in a conference proceeding [189].

5.7.1 Rationale

In order to provide personalized and adapted services to help the conflict resolution field, the need for knowing the most frequent behaviour patterns is very clear. The patterns expressed by users, namely in conflict management processes, may provide vital information for mediation purposes and thus may help to achieve better outcomes. The ability to learn patterns of behaviour became an essential aspect for the successful implementation of IEs.

5.7.2 Data collection

A set of models were developed and tested to acquire this contextual and behavioural information. Indeed, the data from physical sensors, named low-level context, maybe meaningless, trivial, vulnerable to minor changes, or uncertain [206]. A way to mitigate this problem is the extraction of high-level context information from raw sensor values [207] to attain descriptions of human behaviour that may be relevant to a conflict resolution process. Such specifications include the conflict-handling style or strategy and the stress state of the parties (when facing a resolution process). To assess this kind of information, the models introduced in [34] were used to classify the negotiation/conflict resolution styles along with a multi-modal approach to identify and classify a party's stress progress during a negotiation in a contextually rich and dynamic environment [145].

5.7.3 Preliminary data analysis

The experimental data was organized into two groups based on the results of applying social network analysis techniques. One group contains some empirical data about how a user behaves when they negotiate with someone without any degree of relationship. This step enables establishing a baseline for comparison with the second group that comprises the data gathered from parties that negotiate with someone socially related. To statistically deal with data concerning the parties' proposals' utility values, it was necessary to convert to an arbitrary numeric scale (zero is the least favourable style for the resolution and four the most favourable style). This type of scale means that the exact numeric quantity of a particular value has no significance beyond its ability to establish a ranking over a set of data points. Therefore, rank-ordering (which describes order) was built, but not the relative size or degree of difference between the items measured. This ordering was a mandatory step to make the data suitable for statistical and machine-learning techniques.

By analyzing the data, and as reported in the study, the parties used a competitive style most of the time, either in stress or calm phases. The evaluation of the progress of the conflict styles was on the average slope of its numeric values. It concluded that the parties tend to vary slowly in handling the conflict in a stressful state than when they are calmer. Regarding proposal values made by the parties during the negotiation, one may make similar conclusions. At the training phase, both parties change more quickly their conflict styles than during the stressful phase. Considering the duration of the rounds, one may state that a high percentage of the negotiation rounds performed were shorter under a stressful environment than a stress-free one. However, only a small amount of these cases were statistically significant.

Looking at the statistical data, one notices that 80% of the participants used a competitive conflict style in the early moves, 55% improve their styles (shifting towards more cooperative solutions), 35% do not change their competitive style until the end, and 10% become even more competitive. It is stated that *competitors* often use power as the primary tool for handling conflict and work to prove the importance of one side of the argument to win. This may be one of the explanations. Otherwise, they are usually more concerned with winning the game than finding the best solution. The second hypothesis seems more appropriate considering the game pre-conditions, but one may not extrapolate the given results.

5.7.4 Statistical data analysis

Before feeding the data to the learning algorithms, some pre-processing was needed, namely converting the variables round number, proposal value, and round duration to nominal variables. The dataset included 103 instances, and the set of variables used to acquire knowledge about the model were:

- *ExperienceType:* if the experience occurred under stress conditions or training conditions;
- *Round:* the round interval to which the instance belongs;

- *Part:* if the role played in the instance was a manufacturer or a reseller;
- *ProposalValue:* the value in euros of the proposal;
- *ConflictStyle:* : the conflict style detected in the negotiation; and
- *RoundDuration:* the estimated duration of the round in terms of time intervals.

There are essentially two ways of learning the structure of BNs: *score-based* search and *constraint-based* search [181]. *Score-based* algorithms search for a BN structure that better fits the data by starting with an initial network and then traversing the search space of structures, removing, adding, or reversing arcs in each step. On the other hand, *constraint-based* algorithms carry out a conditional (in)dependence analysis on the data. Based on this analysis, an undirected graph is generated to be interpreted as a Markov network. Given the reduced number of available instances, the method used was *score-based* search since it appears to work better in these cases. The algorithms used to learn the topology of the network were the *hill-climbing* and the *tabu* algorithms which are available in the *bnlearn* package for R. When retrieving the score (a measure of the fitness of the network to the data) for each network, the one learned by *hill-climbing* was the one with the highest. So it was the one used to learn the probability distribution of the parameters. The retrieved network is represented in Figure 26. When one observes

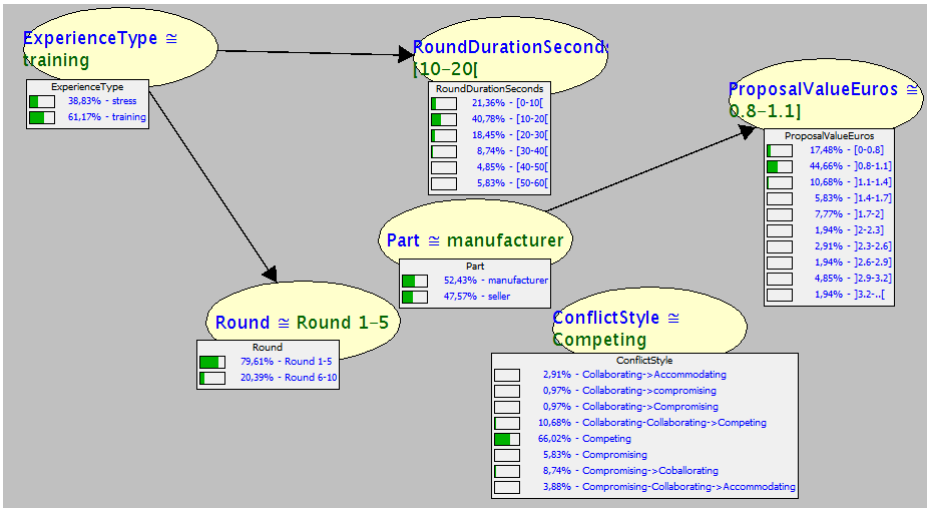


Figure 26: Representation of the learned network visualized in the SamIam software tool [189].

the BN of Figure 26, it is visible that it is rather sparse, probably due to the small amount of data used to construct it. None of the algorithms used managed to establish a dependence relationship between the *ConflictStyle* and the other variables under study, which does not fit the desired outcome of the process. However, it is noticeable that the *competing style* is the most frequent. Some other relationships were detected, namely between *Part* and *ProposalValue*. When the *manufacturer* part is taken, the value of the proposals tends to be at lower intervals than when the *reseller* part is the one chosen. Again,

the algorithms did not establish a connection between these two vertices and the other variables. By observing the remaining network, one detects some diverging arcs between *Round*, *ExperienceType* and *RoundDuration* which means that instantiating *ExperienceType* blocks the flow of probabilistic information, i.e., the influence from the *Round* interval to the *RoundDuration* (and vice versa). This means that if the *ExperienceType* is not instantiated, instantiating the *Round* may change the marginal probability distribution of the *RoundDuration*, but if *ExperienceType* is instantiated, instantiating *Round* will not change the probability distribution of *RoundDuration*. This statement was within the expected outcome. These results point to the necessity of developing the experiment to gather more data that may uncover the interactions between the variables under analysis.

5.7.5 Results and Discussion

To provide personalized and adapted services to help the conflict resolution field, the need for knowing the most frequent behaviour patterns is very clear. Furthermore, the patterns expressed by users, namely in negotiation processes, may provide vital information for mediation purposes and thus may help to achieve better outcomes. Therefore, the ability to learn patterns of behaviour is an essential aspect for the successful implementation of IEs in this context. Hence, after setting up an experimental intelligent environment provided with sensors to capture behavioural and contextual information, a set of relevant data was collected and analysed, with the underlying objective of using the behavioural patterns (obtained by statistical/probabilistic methods) as a basis to design and present plans and suggestions to the associated participants. Furthermore, the idea was to study if these proposals influence in a positive way the course and outcome of a negotiation/conflict resolution task in many aspects. This published work highlighted the importance of knowledge in negotiation and other social forms of interaction, providing some new insights for informed decision support in situations in which uncertainty and conflict may be present.

5.8 Human Activity Recognition

Some experimental studies were performed to recognize some aspects of human activity relevant to characterize a conflict situation. It is assumed that human activity recognition aims to recognize activities from observations on subjects' actions and the environmental conditions. The vision-based HAR research is the basis of many applications, including video surveillance, health care, and HCI [208]. Therefore, in the context of these studies, the goal of human activity recognition approach was to examine activities from video sequences or still images and audio information to identify certain patterns.

Regarding the visual data, the experiments described previously were customized to obtain movement detection from a camera located in front of the user and collect and handle the interaction data from the devices. Portable devices were equipped with touch screens and sensors to access this information and

act as interfaces for the conflict resolution platform. Moreover, video cameras placed in front of and around the user allowed the gathering of additional information. After data acquisition, a timestamp is associated with the images to be matched with the touch information. The amount of movement is calculated as the amount of pixels that have changed their RGB color value over a given threshold between two consecutive images. This approach, based on applying a statistical classifier for assessing the level of stress from the analysis of interaction patterns, has proved that user movement is a good stress indicator combined with other sensors, such as the touch. The results revealed that when people are nervous or stressed, accuracy tends to decrease [145, 147, 183]. Furthermore, it was also concluded that the relation movement-touch is more emphasized when more stress occurs, e.g., after-parties receive disadvantageous proposals.

When visual information can not recognize the activities (events) and environments (contexts), audio signals are supplementary to visual cues (sometimes the audio contains information that visual data cannot represent) [209, 210]. As the data gathered by audio sensors is considered a measure complementary to other modalities for the analysis purposes to study separately [211], some experiments were carried out to obtain some knowledge in how to gather, process, and interpret audio data in the context of an AmI system designed to handle a conflict management process. Hence, regarding the audio-visual data generated in an intelligent environment, some preliminary work was performed, and the results published [184, 185]. Some of these obtained results can be stressed out. Firstly, the idea behind these experiments was to find a public data set that would represent the most "extreme" environmental situations and conditions that can exist in a conflict situation. Thus, the dataset used in the experiments was a composition of Real Life Violence Situations Dataset (RLVS) [212] and the Kinetics-700-2020 Human Action Dataset [213]. The audio samples were extracted from the videos in RLVS and were removed from there the videos without audio. This resulted in 745 (video + audio) elements for the violent behaviour class and 193 elements for the non-violent behaviour class. To balance the dataset was selected from Kinetics data from different classes for balancing the dataset, resulting in a final dataset with 770 elements in both classes. Further, all the audio files were converted into spectrograms[14] (see Figure 27). Two reasons sustain this approach. The first one is because a spectrogram is a detailed view of audio, representing time, frequency, and amplitude all on one graph; a spectrogram can visually reveal broadband, electrical, or intermittent noise in the audio. The second one is that it can handle the audio recognition problem as an image classification problem and follow standard procedure. The application of machine vision algorithms to spectrograms is an idea that opens the door to the application of well-known machine vision algorithms, including Convolutional Neural Network (CNN) [214].

Therefore, the resulting dataset of spectrograms was used to train deep learning[15] models. Indeed, in these studies, a set of machine learning models was developed to classify, describe, or generate audio

[14]A spectrogram is a visual representation of the spectrum of a signal's frequencies as it varies with time.

[15]Deep Learning is a subfield of Machine Learning. It is composed of computational models with multiple layers of processing. Each layer of this model is responsible for learning high-level representations from the data. The most common types of layers are Convolutional layers, fully-connected layers, and recurrent layers.

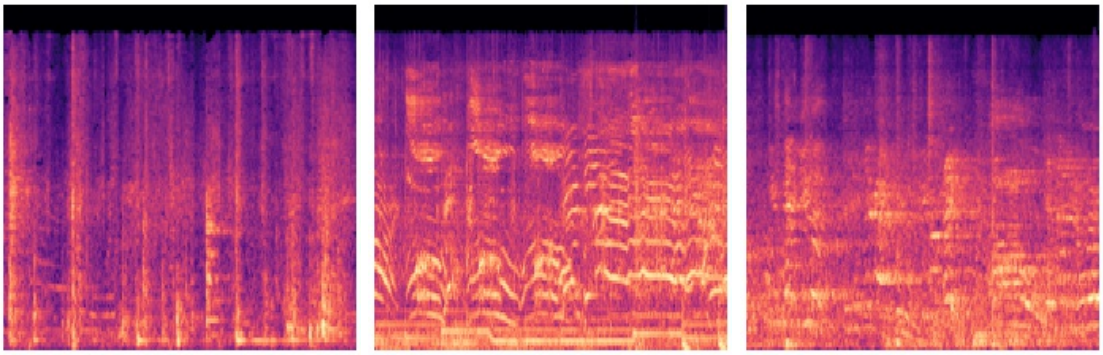


Figure 27: These images are representing audio scenarios of a spectrogram analysis. All these samples are from a public dataset containing non-violence and violence audio scenarios.

having as input data some audio samples. Our main objective was to classify audio data as violent or non-violence, considering these classes as "non-extreme" and "extreme" environmental situations and conditions in a conflict situation. As stated before, by converting the audio data into a spectrogram and transforming the problem of audio recognition into an image recognition problem, the best approach was thus to apply well-known ML algorithms. Thus, to perform the audio analysis, a CNN was adopted. In recent years, significant results have been achieved in generating and processing images with this kind of ANN. This can partly be attributed to the outstanding performance of deep CNN s to capture and transform high-level information in images. Therefore, the audio was trained by applying a CNN, ResNet, VGG, and EfficientNet, achieving the accuracy of 61%, 67%, 80%, and 66%, respectively.

5.9 Consolidating Experiments and Results

This section aimed to organize existing experimental findings, provide a baseline understanding, depict relevant conflict aspects (dimensions) by analysing critical results of the studies, and evaluate a range of methods and techniques applied in the context of the conflict management simulations.

The systematic application of statistical and logical techniques to describe the data scope, representation, and evaluate statistical inclinations, probability data, and derive meaningful conclusions was done in the previous sections for each study presented. The analytical procedures are organized and presented as follow:

- The data is analysed, taking into consideration the context in which it was acquired. In that sense, data generated from the game interactions are used to calibrate the system and establish a baseline for stress, namely, on the training phase. The newer values have a weight more significant to capture de dynamic stress evolution than the older ones. The up-to-date values have a weight higher than the older ones because it is important to *accommodate* the temporal development of stress. This may be configured by changing the value of parameter b, i.e., the higher the value,

the faster the weight of the older ones decays. The formula returns a normalized value of stress between 0 and 1, with 0 corresponding to the more relaxed state and 1 to the more stressed one;

- The estimation of the conflict-handling style has a different configuration. It is focused only on the static data (the calculation of utility values do not use weighted sums) that came from every step of the negotiation performed in the game. In other words, the conflict-handling styles are associated with the utility of the proposals through the classification (formulae detailed in Sect. 4.2.3.1) using data extracted from the proposals' workflow;

- The computation of trust is made from the observed interaction statistics, using no semantic information. It was postulated that the shorter and less balanced (means the average number of times that two entities interact within the process) an interaction is between two parties, the more likely it is that they have a trust relationship;

- To perform social network analysis, the experimental data was extracted through a questionnaire. With the data obtained, several centrality scores for each respondent were measured. The in-degree is a measure of centrality, which measures the number of nominations received by a person. This variable was calculated for all the nodes in the Advice, Hindrance, and Friendship networks;

- The personality and mood analysis of each subject understudy was obtained from applying a questionnaire (NPA, detailed in Annex I) and applying the formulae described in Sect. 4.2.3.4 to the data derived from the interaction of the subject with the intelligent environment;

- To deal with incomplete information regarding the conflict style used by parties, an approach consisting of Bayesian networks for default prediction and Speculative Computation was followed to structure the reasoning process;

- BN algorithms used managed to establish a dependence relationship between the conflict-handling style and the other variables understudy, which does not fit the desired outcome of the process;

- To determine to what extent each feature considered is or is not influenced by variable understudy, the training data is compared with the real data. The Mann-Whitney test is thus used to perform the analysis because most of the distributions are not normal. This test is a non-parametric statistical hypothesis test for assessing whether one of two samples of independent observations tends to have larger values than the other. The null hypothesis is thus: $H0$ = *Medians of the two distributions are equal*. For every two distributions compared, the test returns a p-value, with a small p-value suggesting that it is unlikely that $H0$ is true. For each parameter, the training data is compared with the remaining four groups. In all the tests, a value of $\alpha = 0.05$ is used. Thus, for every Mann-Whitney test whose $p - value < \alpha$, the difference is considered to be statistically significant, i.e., $H0$ is rejected.

5.10 Summary

After the conceptualization and development of a framework within an IE, explained in the previous sections, a test environment was set up. Thus the experiments (using a negotiation web-based game), designed to validate and to provide an understanding of the difficulties of technically and algorithmically capturing and computing conflict-related information in an intelligent environment, were performed. Therefore, in a transparent and non-invasive way, the data gathered on most of the experiments was analyzed to determine statistically significant differences between two different phases. Measures of central tendency and variability were calculated for all variables of interest, using statistical tests to find actual differences in the data distributions. The analysis of the results shows an apparent discrepancy between the groups exhibited during the game. These results give important insights into the contextual and behavioural clues that can lead the management and resolution processes. Having the development of methods that can adapt, in real-time, to significant changes in the context of interaction can be truly enhanced by giving all actors of a conflict process relevant information (such as parties' conflict styles, trust, etc.) for taking a well-grounded decision.

Chapter 6

Conclusion and Future Work

"The true knowledge is NOT in the things, which are few, but in finding the connections between the things". Archos speaking to Wasserman.

Robopocalypse, Daniel H. Wilson

Unresolved conflicts or unmanaged often represent the largest share of costs that can reduce an organization. This happens partly because traditional approaches to conflict management are inefficient and do not conveniently exploit communication and information technologies. In this work, it was identified that one of the primary faults is the failure to consider the context information and the parties' conduct, inaccessible in the current conflict management information systems in digital environments. Thus, it was presented to implement intelligent environments to enhance conflict management in digital environments. Having an adequate theoretical basis for the analysis of conflicts and devising appropriate responses to them, and evaluating the effects of these responses is also a mandatory requirement. This chapter describes the conclusions of the work developed. It is also highlighted the objectives achieved and the contributions of this doctoral thesis in light of the objectives outlined. Then, it is explained how the research hypothesis was validated by the results achieved. Also, it is pointed out the activities performed to disseminate results, the work developed so far, the limitations, and future work considerations.

6.1 Summary of Contributions

The work carried out and described in this PhD thesis lead to the following key theoretical and practical contributions (presented with more detail in Section 1.3):

- The update of the acquired knowledge by reviewing recent and state-of-the-art publications.

- The first scratch of a theoretical basis for the analysis of conflicts, defining the parameters of conflict is significant not only from an academic viewpoint but from a practical one; it. Therefore, it is essential to consider the conceptual consequences and find a working definition to aid the resolution.
- A proposal of a Conflict Management System, combined with an Intelligent Conflict Environment that can support many different devices and technologies, provides a way of communication and interconnection. This framework is also very modular, extensible, and dynamic, enabling the continuing of its development and the inclusion of new technologies.

Also, we present Table 5 showing the objectives and the corresponding chapters where they were achieved.

6.2 Validation of the Research Hypothesis

This PhD work persisted on the idea that parties engaged in a conflict situation must access valuable knowledge to make proper decisions; thus, having a decision-support system to assist parties in a conflict situation should be centered on providing all the intervenient of conflict the appropriate knowledge at the right time. Hence, the central research hypothesis that guided the work performed during the doctoral program was the following:

Research Hypothesis

An AmI system can create scenarios that enhance the possibilities of reaching a favourable outcome in a conflict management process using contextual and behavioural knowledge.

The central claim of this work was thus, in other words, that some conflict aspects could be estimated using non-invasive and non-intrusive methods and that an AmI system could deliver valuable knowledge to make good decisions. This research hypothesis was therefore developed from the research questions presented and detailed in Chapter 3. To analyze the accomplishment and validation of the research hypothesis of this thesis (formulated in Section 3.2), the several research questions defined are first recalled:

1. An AmI system is suitable for implementing a Conflict Management Platform?
2. AI can be used to depict relevant conflict aspects (dimensions) by analyzing features of a conflict situation?

Table 5: Objectives of the doctoral programme and respective document chapters where they were achieved.

Objective	Chapter
Objective 1: Development of conceptual tools to aid exploration of conflict. The identification (measured conflict dimensions/characteristics applying appropriated metrics), application and further development of methodologies, and a generalized conflict model will yield several conceptual tools for conflict management.	Chapter 2: Background; Chapter 4: A Conceptual Framework to Manage Conflict;
Objective 2: A technological framework that can acquire and provide context and behavioral information about the participants of a conflict situation;	Section 4.3: A Technological Framework for Supporting Conflict Process; Appendices C, B, C .
Objective 3: A computer-based approach to conflict management that comprises models for performing decision-support-related tasks;	Chapter 4: A Conceptual Framework to Manage Conflict;
Objective 3.1: A conflict support environment innovative: Dynamicity;	Chapter 5: Experiments Performed; Chapter 4: A Conceptual Framework to Manage Conflict;
Objective 3.2: A conflict support environment innovative: Adaptability;	Chapter 5: Experiments Performed; Chapter 4: A Conceptual Framework to Manage Conflict;
Objective 3.3: A conflict support environment innovative: learning.	Section4.3: A Technological Framework for Supporting Conflict Process; Chapter 4: A Conceptual Framework to Manage Conflict;

3. Is it possible to acquire and provide contextual and behavioural information about the participants of a conflict situation "mediated" by an AmI system?

4. It is possible to estimate relevant aspects of interactions that occur in a rich sensory environment

in a non-invasive and non-intrusive way, in real-time?

5. Is it possible to improve the understanding of how a given party responds to particular scenarios?

Given this, a systematic question-by-question analysis is performed in which each of the research question's objectives is put forward, and its validation is assessed by considering the validation conditions established in Section 3.2.

Research question no. 1: An AmI system aimed to provide information from the user and the ambient itself to enhance decision-making was implemented in the form of a prototype and validated by scientific peers. The validation of this research question resulted in extending previous approaches [35] by improving its modularity, interoperability, and extensibility in this particular AmI system. These results were presented in a book chapter[37].

Research question no. 2: The main objective of this research question was to determine a conceptual framework for conflict management to retrieve contextual and environmental information, along with a basic structure utilized to frame conflict in a virtual environment. Therefore, a working prototype was developed, comprising computer-based models for obtaining emotional cues, classifying the actual conflict-handling style, measuring the stress level or trust, performing social network analysis, and generating recommendations. This research question was presented to the scientific community in the legal and computer sciences fields. It was validated by results presented in conference proceedings [36, 89–93] and in a book chapter about interdisciplinary perspectives on contemporary conflict resolution [94].

Research question no. 3: To address this research question, an AmI system that is backgrounded with conceptual models and frameworks was developed. The existence of prototypes and several scientific publications backgrounded validate the accomplishment of this objective and, thus, a positive answer to this question (see Sections 4.3, 5).

Research question no. 4: the main objective of this research question was to conceive models to address the estimation of relevant aspects of interactions that occur in such virtual environments. This approach must be non-invasive, non-intrusive, and run in real-time. This research question was validated through the implementation of a prototype for information assessment using models validated by the scientific community (the results were published in several conference proceedings [36, 91–93, 157, 189]).

Research question no. 5: To address this research question, some laboratory experiments were carried out to elicit how a party behaves during a conflict situation. To validate it, a test environment

was set up and carried out in the ISLab. In this environment, the users had to perform some activities that implied the interaction with the devices and/or with the conflict environment described in Section 4.3 and functionally detailed in Appendice C. Moreover, was performed some specific studies (in which the results have been published as an academic journal article and as conference proceedings of which the candidate is the first author and primary contributor [36, 89–93, 157, 189]) and some statistical hypothesis tested.

From the research questions presented and detailed in Chapter 3 a research hypothesis was developed. At the same time, the main objectives of this work were coupled with the hypothesis of the study. The study's objectives defining the study's specific aims were clearly stated in the Chapter 3. Given the analysis of the research questions performed, it can be concluded that, in a general sense, all of them have been validated, some through statistical methods, others through the development of working prototypes, and all by scientific peers. Moreover, the proof is a set of experiments that were intended to represent a test case for the hypothesized statement. Therefore, the research hypothesis of this thesis is considered validated.Hence, these evidence are directly and clearly related to proving the conclusion, i.e., the following thesis statement:

Thesis statement

This research demonstrated that critical conflict aspects could be estimated using non-invasive and non-intrusive methods and that an AmI system could deliver valuable knowledge to make more informed decisions.

6.3 Discussion and Future Directions

A conflict may be viewed as a process that begins when a party feels that the other has or is about to affect any interest negatively. The ideal conflict management process is one in which the parties are better at the end than initially. Unfortunately, not all conflicts have such a conclusion. To improve this, it was assumed on this thesis that the contextual and behavioral information is important to conflict management and is of utmost importance to (1) provide the parties and manager with relevant knowledge about the conflict and (2) potentiate the role of the parties throughout all the process. Furthermore, having this kind of information can reduce the severity of the conflict, in which parties continue the conflict but adopt less extreme/harmful tactics.

The work elaborated in the context of this thesis resulted in several contributions to the State of the Art in both technology and the law. Several AI methods were used to identify and solve the most significant problems in conflict management using an AmI system, including the compilation of important information and the generation of information and knowledge relevant to the process. This, when incorporated into conflict management instruments, will result in better conflict resolution processes, with better-informed parties making better decisions. Once the relevant information and valuable knowledge are identified and transmitted, strategies can be implemented to improve resolution and conflict management procedures. As established in the previous section (see Sec. 6.2), this work produced experimental research that generates highly transferable knowledge and know-how that has been used in the conception and development of a wide range of techniques in a variety of conflict management and conflict resolution domains.

Meanwhile, one must point out some limitations of the work presented in this thesis. First, most of the participants were recruited from an undergraduate population - a population that may limit the generalizability of the results. Indeed, the undergraduate participants may not be representative of disputant parties in general. Second, individual differences (i.e., personalities) during the experiments might have influenced the cognition of conflict [215] and the outcomes of the resolution process under study. This entails that it makes sense to initially start with a group-level exploration of a phenomenon and move to the more detailed individual-level analysis afterward [216]. Third, the preliminary evidence suggests a theoretical basis for expecting a connection between social networks and the use of conflict-handling styles. However, despite the results, we still do not know much about how internal configurations of social networks might facilitate (or inhibit) positive conflict outcomes. Therefore, a perform more profound experiments to understand how to collect and analyse relational ties that can influence negotiation performance. Fourth, due to the small sample size used in the studies, some caution must be taken when interpreting the research results. However, some degree of confidence in the results is restored due to the moderate effect size. Fifth, the conflict resolution/management model used in the experiments assumes that all actors behave rationally. The model is predicated on economic bases; that is, the protagonists act in their own economic best interests while much human interaction is not necessarily based upon rational economic behaviour. The conflict environment developed, and the experiments carried out during this thesis assumed rational actors. As a conclusion regarding the study's limitations, it is clear that to achieve more conclusive results, is need to perform more experiments to obtain readings from more and different users and better calibrate our models. Finally, regarding the platform, its modular design enables its future development while keeping knowledge already acquired.

Nevertheless, as disclosed, this thesis also reveals some research limitations, and therefore, suggestions for future work. As future work, some techniques can be explored to enhance the capability to support decision-making. Some examples as following:

- One line of research could be implementing an automated mechanism to extract argumentation

elements using Natural Language Understanding methods [217] and develop mechanisms that allow for an easier interpretation of norms and arguments written in natural language, its translation into rules, and the verification of their correction. Indeed, some work is now being done on identification, representation, and extraction of legal information, legal data storage and processing, and forming a legal database on jurisprudence and cases. The key idea is thus to get valuable knowledge and provide it to the conflict management actors by running specific algorithms trained to detect rankings, clusters, and dimensionality reduction applied to the aggregated data from past judicial decisions and current legal corpus. This line of research will involve the pursuit of computational models for legal reasoning, with an ethical background, can make decisions and argue about them. This would be a step forward in accurately informing all the actors in a conflict resolution/management process. Some steps toward implementing a conversational dialogue [218] as been taken [219].

- Another line of research is to continue researching in the social network analysis approach by developing a social sensing pipeline focusing on obtaining a representative data set to build a more robust model. The first challenge to overcome is to build a social sensing data collection platform that can obtain the relevant social signals about the parties from online social media users. The second challenge lies in developing reliable data analysis models based on adaptive AI architectures that can obtain credible information from noisy, sparse and unstructured social data.
- Continue to develop the technological architecture by adding some extra features such as a trusted, secure, and transparent data backbone (ensuring that information is immutable and auditable using blockchain), deriving reliable insights from the analysis of data; the support for decision-making process by flagging any irregularities including the recognition and prediction of conflict-handling behaviours that can decrease the success rate; a set of dashboards providing different analytical angles through which end-users can view data insights.

6.4 Dissemination of Results

The PhD research plan encompassed disseminating the developed work in scientific conferences, journals, and the participation and organization of scientific events.

6.4.1 Scientific Publications

The work described in this manuscript was disseminated through the participation in diverse scientific meetings in the fields of Computer Science and The Law, as well as through the publication in international journals and conference proceedings.

6.4.1.1 International Journals

The work detailed in this thesis has been documented in international scientific journals. The following list presents the journal articles published:

- Casteleiro-Roca, J. L., Gomes, M., Méndez-Pérez, J. A., Alaiz-Moretón, H., del Carmen Meizoso-López, M., Rodríguez-Gómez, B. A., & Calvo-Rolle, J. L. (2020). Electromyogram prediction during anesthesia by using a hybrid intelligent model. Journal of Ambient Intelligence and Humanized Computing, 11(11), 4467-4476, https://doi.org/10.1007/s12652-019-01426-8;
- Gomes, M., Oliveira, T., Carneiro, D., Novais, P., & Neves, J. (2014). Studying the effects of stress on negotiation behavior. Cybernetics and Systems, 45(3), 279-291, https://doi.org/10.1080/01969722.2014.894858;
- Carneiro, D., Gomes, M., Costa, Â., Novais, P., & Neves, J. (2013). Enriching conflict resolution environments with the provision of context information. Expert Systems, 34(5), https://doi.org/10.1111/exsy.12049.

6.4.1.2 Book Chapters

Along with the dissemination through international journals, it was possible to spread work through the publication of scientific proposals and results in book chapters:

- Gomes, M. V., & Novais, P. (2016). Conflict and its different dimensions. In Interdisciplinary perspectives on contemporary conflict resolution (pp. 1-20). IGI Global, https://doi.org/10.4018/978-1-5225-0245-6.ch001;
- Gomes, M., Analide, C., & Novais, P. (2016). Assessing Interpersonal Trust in an Ambient Intelligence Negotiation System. In International Symposium on Ambient Intelligence (pp. 141-149). Springer, Cham, https://doi.org/10.1007/978-3-319-40114-0_16;
- Gomes, M., Alfonso-Cendón, J., Marqués-Sánchez, P., Carneiro, D., & Novais, P. (2014). Improving Conflict Support Environments with Information Regarding Social Relationships. In Ibero-American Conference on Artificial Intelligence (pp. 779-790). Springer, Cham, https://doi.org/10.1007/978-3-319-12027-063;
- Gomes, M., Carneiro, D., Pimenta, A., Nunes, M., Novais, P., & Neves, J. (2014). Improving modularity, interoperability and extensibility in ambient intelligence. In Ambient Intelligence-Software and Applications (pp. 63-70). Springer, Cham, https://doi.org/10.1007/978-3-319-07596-9_7;
- Gomes, M., Oliveira, T., Silva, F., Carneiro, D., & Novais, P. (2014). Establishing the relationship between personality traits and stress in an intelligent environment. In International Conference

on Industrial, Engineering and Other Applications of Applied Intelligent Systems (pp. 378-387). Springer, Cham, https://doi.org/10.1007/978-3-319-07467-2_40;

- Gomes, M., Oliveira, T., Carneiro, D., Novais, P., & Neves, J. (2013). Extracting behavioural patterns from a negotiation game. In International Conference on Practical Applications of Agents and Multi-Agent Systems (pp. 304-315). Springer, Berlin, Heidelberg, https://doi.org/10.1007/10.1007/978-3-642-38061-7_29;

- Carneiro, D., Novais, P., Gomes, M., Oliveira, P. M., & Neves, J. (2013). A statistical classifier for assessing the level of stress from the analysis of interaction patterns in a touch screen. In Soft Computing Models in Industrial and Environmental Applications (pp. 257-266). Springer, Berlin, Heidelberg, https://doi.org/10.1007/978-3-642-32922-7_27;

- Novais, P., Carneiro, D., Gomes, M., & Neves, J. (2012). The relationship between stress and conflict handling style in an ODR environment. In JSAI International Symposium on AI (pp. 125-140). Springer, Berlin, Heidelberg, https://doi.org/10.1007/978-3-642-39931-2_10;

- Novais, P., Carneiro, D., Gomes, M., & Neves, J. (2012). Non-invasive estimation of stress in conflict resolution environments. In Advances on Practical Applications of Agents and Multi-Agent Systems (pp. 153-159). Springer, Berlin, Heidelberg, https://doi.org/10.1007/10.1007/978-3-642-28786-2_17;

- Gomes, M., Carneiro, D., Novais, P., & Neves, J. (2012). Modelling stress recognition in conflict resolution scenarios. In International Conference on Hybrid Artificial Intelligence Systems (pp. 533-544). Springer, Berlin, Heidelberg, https://doi.org/10.1007/978-3-642-28942-2_48.

6.4.1.3 Conference Proceedings

In the context of the PhD, the candidate participated in several scientific events in which preliminary results and findings of the work performed were presented. These meetings were essential to collect insights and opinions from experts in the fields.

- Gomes, M., Oliveira, T., Silva, F., Carneiro, D., & Novais, P. (2014). Establishing the relationship between personality traits and stress in an intelligent environment. In International Conference on Industrial, Engineering and Other Applications of Applied Intelligent Systems (pp. 378-387). Springer, Cham, https://doi.org/10.1007/10.1007/978-3-319-07467-2-40.

6.4.2 Lectures

The candidate delivered, in the context of this thesis, invited lectures on "Handling Conflict From Theory to Practice" in the academic years of 2015/2016 and 2016/2017 and on "Conflict and its Different Dimensions" in the academic years of 2018/2019, 2019/2020 and 2020/2021 within the scope of the Curricular Unit "Conflict Resolution"in the Master Courses of Law and Informatics at Law School of University of Minho. Moreover, he also delivered an invited lecture on "Introduction to Julia Programming Language" in the academic years of 2018/2019 and 2019/2020 within the scope of the Curricular Unit "Natural Computing" in the Master Courses of Informatics Engineering at the Department of Informatics at University of Minho.

6.4.3 Invited Presentations

The research conducted in this PhD thesis was also disseminated via invited talks, as described in the following list:

- *Criteria and methods for the identification and analysis of methods for integration and empowerment*. Invited talk performed in September 2019 at Interdisciplinary seminar on "Empowering Women with Disabilities" at the University of Minho;
- *Conflict management environment to support Decision-Making Processes*. Invited talk performed in March 2019 at "TalkAbout: Artificial Intelligence" organized by IEEE UMinho Student Branch;
- *Conflict management environment to support Decision-Making Processes*. Invited talk performed in July 2017 at Università degli Studi di Genova;
- *A new direction to assess conflict styles within an Ambient Intelligence Negotiation System*. Invited talk performed in April 2017 at "Online Behavior" session within the scope of International Perspectives On Emerging Challenges in Law;
- *Inteligência Artificial é a nova electricidade?*. Invited talk performed in March 2017 within the scope of "Workshop Direitos Fundamentais e Smart Cities" at School of Law of University of Minho.

6.5 Research Activities During the Doctoral Programme

6.5.1 Participation in Scientific Events

During the execution of his PhD plan, the candidate participated in the following scientific events, in which some of them preliminary results and findings of the work performed were presented. These meetings were important to collect insights and opinions from experts in the fields:

6.5.1.1 Summer School and Mentoring Program

During this Ph.D., the candidate engaged on a summer school, which took place in Utrecht, Netherlands, in 2014, and also in a mentoring and coaching program, which took place in Braga, Portugal, in 2015:

- *Mentoring and Coaching Program University of Minho, School of Psychology - 2015*

  The goals of this program was to promote a team of students to provide students (tutees) with personalized support carried out by other students (tutors) from the University of Minho (structural and functional aspects, cooperation relationships development, academic, social and personal skills improvement) aiming for quality education;

- *Survey Research: Statistical Analysis and Estimation Utrecht University, Faculty of Social and Behavioural Sciences (UU) - 2014*

  The course was based on a total survey error perspective and discusses the significant sources of survey error. Participants will be presented with tools for the detection and adjustment of such errors. Analysis methods are introduced using both SPSS and R. Topics included complex sampling, non-response adjustment, measurement error, analysis of incomplete data, and advanced use of administrative data. Special attention was given to the analysis of complex surveys that include weighting, stratification, and design effects. This course was organized by the Department of Methodology and Statistics (UU) in collaboration with Statistics Netherlands (CBS).

6.5.1.2 Organization of Scientific Events

The organization of scientific events was carried out as part of the *Program Committee* and the *Local Organizing Committee* for the following events:

- Workshop on Deep Learning Applications (DeLA), part of the 19th International Conference on Practical Applications of Agents and Multi-Agent Systems (PAAMS), 2021;
- 11th International Conference in Methodologies and Intelligent Systems for Technology Enhanced Learning (MIS4TEL), 2021;
- 12th International Symposium on Ambient Intelligence (ISAmI), 2021;
- 1st Workshop on Intelligent Decision Support Systems in Fintech, part of the 16th Iberian Conference on Information Systems and Technologies (CISTI), 2021;
- Citizen-Centric Smart Cities Services (CCSCS'2020) is a workshop organized as part of the 16th International Conference on Intelligent Environments, 2020;
- Workshop on Non-intrusive acquisition and fusion of context information in Ambient Intelligence (Ni-AFCiA) part of the 11th International Symposium on Ambient Intelligence (ISAmI), 2020;

- Citizen-Centric Smart Cities Services (CCSCS'2019) is a workshop organized as part of the 15th International Conference on Intelligent Environments, 2019;
- Citizen-Centric Smart Cities Services (CCSCS'2018) is a workshop organized as part of the 14th International Conference on Intelligent Environments, 2018;
- Citizen-Centric Smart Cities Services (CCSCS'2017) is a workshop organized as part of the 13th International Conference on Intelligent Environments, 2017;
- Workshop on Decision Making in Dynamic Information Environments (DeMaDIE) part of the Conference on Practical Applications of Agents and Multi-Agent Systems PAAMs, 2017;
- Personal Assistants: Emerging Computational Technologies, Intelligent Systems Reference Library, 2017;
- Inteligencia Artificial. An international open access journal. Edited by Iberamia. e-ISSN: 1988-3064 Vol. 20 No. 59 (2017): Inteligencia Artificial, 2017;
- International Workshop on Computational Sustainability, Technologies and Applications (CoSTA'2016) organized in conjunction with the 12th International Conference on Intelligent Environments - IE, 2016;
- 9th International Symposium on Intelligent Distributed Computing - IDC, 2015.

6.5.2 Research Stay

The PhD candidate advanced research work, under the context of his PhD, at the Università Degli Studi di Genova, from 15th July 2017 to 15th August 2017. During that time, he gave a talk on the topic "A Conflict Management Environment to Support a Decision-Making Process" on 26th July 2017. Furthermore, he participated in several meetings discussing current and future potential projects and collaborations during his stay. Specifically, the identification of collaboration opportunities was conducted by interacting with members 3DLabFactory of the University of Genoa, Gianni Vercelli (University of Genoa), and Saverio Iacono (University of Genoa). The 3D Lab Factory is run by staff and fellows of the University of Genoa. They focus and promote research on video making, stereo 3D, augmented reality, virtual reality, gamification, photography, drones, and photogrammetry.

Moreover, in 2018, and the context of the research work developed during the doctoral program, a research period of one month of 2018 was spent in Ankara, Turkey, at the Middle East Technical University. This stay was performed in coordination with the RiseWise project, had the primary goal of discussing the problem of women with disabilities and the drawbacks that such people face today in our society. During the stay, the candidate had meetings with the collaborators of the organization ENGKAD (Ankara) and with researchers of Middle East Technical University - METU (Ankara). In addition, he has also worked

collaboratively with Idil Seda Ak (ENGKAD/METU) and Zeynep Hatipoğlu-Sümer (METU - Department of Educational Sciences).

Finally, in 2019, a research period of one month was spent in Madrid, Spain, at the Complutense University of Madrid. This stay was also conducted in coordination with the RiseWise project. Several meetings were held with AFADIS-UCM. This Spanish non-profit association aims to promote and carry out activities to improve the quality of life of people with disabilities. AFADIS-UCM has provided support to many disabled people, with the majority being women between 30 and 40.

6.5.3 Other Research Projects

During the doctoral program, the candidate developed research in other projects that do not involve this doctoral thesis's same research field. However, despite these projects not being related to the research areas of this thesis, the candidate applied some of the techniques of extraction, manipulation, and analysis of data presented, therefore relevant to mention them. Thus, the list of other projects will be present, and a summary of each work plan:

- 2020-2021: Easy Ride research project (supported by COMPETE: POCI-01-0247-FEDER-039334) aims to develop technologies to respond to future mobility paradigm, and it is the third iteration of the partnership between the University of Minho and BOSCH CAR Mutimedia research project. The work carried out by the candidate in the context of this project consisted of the development of intelligent solutions for synthetic data generation and algorithm classification for Activity Recognition using audio-visual information;
- 2017-2021: Risewise research project (RISE Women with disabilities In Social Engagement under the Agreement N 690874 and by FCT - Portuguese Foundation for Science and Technology within the Project Scope: UID/CEC/00319/2019, is project that focuses on the collective of women with disabilities from different perspectives, trying to identify needs and best practices in several EU countries, representing different cultural and socio-economic environments, for the integration and improvement of their quality of life in several respects;
- 2016-2018: IFactory research project (Adaptable Standardised Work and Electronic Work Instructions supported by COMPETE: POCI-01-0145-FEDER-007043 and FCT -Portuguese Foundation for Science and Technology) Project Scope UID/CEC/00319/2013, resulted from a collaboration between the University of Minho and Bosch Braga. The research carried out by the candidate in the context of this project consisted of the development of a Decision Support System for production planning;
- 2013-2015: CAMCoF research project (CAMCoF: Context-aware Multimodal Communication with reference FCOMP-01-0124-FEDER-028980PTDC/EEI-SII/1386/2012), funded by the Portuguese

Foundation for Science and Technology (FCT), had as main goal the development of an approach to model a computer user's context, with an emphasis on stress and fatigue, and the providing of this type of information to the intelligent environment so can develop richer interaction and communication processes that allow more efficient communication mechanisms between machines and their users.

6.5.3.1 Other Publications

In addition to the publications related directly to this doctoral thesis, during the doctoral program the candidate produced other publications in conference proceedings and international journals. These publications were developed in the fields of Computer Science and Artificial Intelligence.

- Santos, F. A. O., Durães, D., Marcondes, F. S., Gomes, M., Gonçalves, F., Fonseca, J.,& Novais, P. (2021). Modelling a Deep Learning Framework for Recognition of Human Actions on Video. In WorldCIST (1) (pp. 104-112), https://doi.org/10.1007/978-3-030-72657-7_10;
- Jesus, T., Duarte, J., Ferreira, D., Durães, D., Marcondes, F., Santos, F., Gomes, M & Machado, J. (2020). Review of Trends in Automatic Human Activity Recognition Using Synthetic Audio-Visual Data. In International Conference on Intelligent Data Engineering and Automated Learning (pp. 549-560). Springer, Cham, https://doi.org/10.1007/978-3-030-62365-4_53;
- Gomes, M., Costa, A. M., Analide, C., Novais, P., & Silva, F. (2020). Optimising User Experience with Conversational Interface. In Intelligent Environments 2020: Workshop Proceedings of the 16th International Conference on Intelligent Environments (Vol. 28, p. 197). IOS Press;
- Gomes, M., & Novais, P. (2019). A Data-Driven Tool to Promote Tourism for People with Disabilities in a Smart City Environment. In Intelligent Environments 2019: Workshop Proceedings of the 15th International Conference on Intelligent Environments (Vol. 26). IOS Press, https://doi.org/10.3233/AISE190021;
- Martins, R., Gomes, M., Almeida, J. J., Novais, P., & Henriques, P. (2018). Hate speech classification in social media using emotional analysis. In 2018 7th Brazilian Conference on Intelligent Systems (BRACIS) (pp. 61-66). IEEE, https://doi.org/10.1109/BRACIS.2018.00019;
- Silva, F., Martins, R., Gomes, M. F. V., Ferreira da Silva, A., Machado, J. M., Novais, P., & Analide, C. (2018). Cloud computing environments for simulation of adaptable standardized work and electronic work instructions in industry 4.0, http://repositorium.sdum.uminho.pt/handle/1822/58293;
- Abreu, M. F., Pereira, A. C., Silva, A., Silva, F., Ferraz, F., Alves, A. C., Gomes, M., ... & Vicente, S. (2017). Collaborative process mapping to improve work instructions and standardized work.

In World Conference on Information Systems and Technologies (pp. 603-615). Springer, Cham, https://doi.org/10.1007/978-3-319-56535-4_60;

- Gomes, M., Silva, F., Ferraz, F., Silva, A., Analide, C., & Novais, P. (2016). Developing an ambient intelligent-based decision support system for production and control planning. In International Conference on Intelligent Systems Design and Applications (pp. 984-994). Springer, Cham, https://doi.org/10.1007/978-3-319-53480-0_97;

6.5.4 Tutoring of Students

The candidate has successfully tutoring students enrolled in masters classes in Informatics Engineering and Law and Informatics that developed their work in the context of this PhD thesis. The list of students will be presented along with a summary of each work plan in this section.

6.5.4.1 Master's Dissertations

1. **Victor Moreira Mulin Leal**

   The General Data Protection Regulation as an Instrument for Regulatin Trustworthy Artificial Intelligence in the light of the European Comission'S Ethical Guidelines.
   In co-supervision with professors Paulo Novais and Joana Abreu.
   Law and Informatics Master degree from University of Minho.
   Year of conclusion: 2021.

   This dissertation studies the ethical and rights principles are presented to build a trustworthy and ethical AI. It points out that in the absence of specific legislation, it becomes essential to understand whether the General Data Protection Regulation (GDPR) is an appropriate instrument to turn the European design of an ethical and trustworthy AI into reality. To verify this possibility, the provisions of the GDPR, and mainly the Data Protection Impact Assessment (DPIA), were analysed in the light of an ethical and trustworthy European AI.

2. **Ana Sofia Lopes Soares**

   The General Data Protection Regulation as an Instrument for Regulating Trustworthy Artificial Intelligence in the light of the European Comission's Ethical Guidelines.
   In co-supervision with professors Paulo Novais and Marco Gonçalves.
   Law and Informatics Master degree from University of Minho.
   Year of conclusion: 2021.

   The dissertation focused on problematization as to introducing a civil mandatory mediation system in the Portuguese juridical order. We know that mediation consists of an alternative means of voluntary dispute resolution, conducted by public or private entities, in which the parties in a dispute

seek to reach an agreement and, for this, they have the assistance of an impartial mediator who has the purpose of facilitating the dialogue between the parties. Moreover, it also focused on computer-based assisting technologies and the role of Artificial Intelligence in supporting mediation, pointing out its benefits and problems.

3. **Bianca Alexandra Agostinho Moreira**

   Identification of strategies and techniques applied to alternative dispute resolution, studying previous resolutions.

   In co-supervision with professors Paulo Novais and Marco Gonçalves.

   Law and Informatics Master degree from University of Minho.

   Year of conclusion: 2019.

   This work tries to identify patterns in different conflicts expressed on the cases handle by arbitrations centres. The investigation and collection of data were done at the CIAB, an arbitration center that promotes the resolution of the consumption conflicts. After converting all the paper information to a digital format, the author applied statistical analysis to identify the regularities of data. Indeed, the main goal of this work was to understand the adequate ADR for each conflict, which areas had more claims, and which conflict-handling style was adapted during each phase of the process.

4. **Hugo Filipe da Silva Ribeiro**

   Applying Data Science and Machine Learning for Psycho-Demographic Profiling of Internet Users.

   In co-supervision with professor Paulo Novais.

   Informatics Engineering Master degree from University of Minho.

   Year of conclusion: 2018.

   This dissertation aimed to address prediction and classification tasks on online social network data. The goal was to predict psycho-demographic - personality and demographic - traits by doing text emotion analysis on social networks like Twitter and Facebook. The motivation was to raise awareness of what can be done with users' social media or network information or usual behaviours on the web. From text analysis, it was possible to trace personality, know their tastes, behave, etc.

5. **Nuno Miguel Vilela Carvalho**

   A Data Analysis approach to study events' influence in Social Networks.

   In co-supervision with professor Paulo Novais.

   Informatics Engineering Master degree from University of Minho.

   Year of conclusion: 2018.

   This dissertation intended to study the impact and role that an event's social influence has and how it propagates, particularly on its surrounding territory. This influence is inferred by analysing the online platform's data by applying intelligent techniques right after its extraction. The results were validated with data from different sources.

6.5.4.2 Informatics Engineering Laboratory

1. **Bruna Cruz, Bruno Sousa and Sérgio Jorge**

   Automatic identification of building shapes based on geospatial images.
   In co-supervision with professor Paulo Novais.
   Informatics Engineering Master degree from University of Minho.
   Year of conclusion: 2020.

2. **Adriana Meireles, Nuno Silva and Pedro Pinto**

   Microblog rumour detection via users' interaction.
   In co-supervision with professor Paulo Novais.
   Informatics Engineering Master degree from University of Minho.
   Year of conclusion: 2020.

3. **Diogo Braga, Ricardo Caçador and Rui Ribeiro**

   Scrap My Prop.
   In co-supervision with professor Paulo Novais.
   Informatics Engineering Master degree from University of Minho.
   Year of conclusion: 2020.

4. **Ludgero Diogo, Luís Mendes and Vítor Figueiredo**

   Scrap My Prop.
   In co-supervision with professor Paulo Novais.
   Informatics Engineering Master degree from University of Minho.
   Year of conclusion: 2019.

5. **Miguel Calafate and José Bastos**

   Automatic identification of irregularities through the analysis of data present on the Public Procurement Portal.
   In co-supervision with professor Paulo Novais.
   Informatics Engineering Master degree from University of Minho.
   Year of conclusion: 2018.

6. **Carlos Castro, Hugo Ribeiro and José Silva**

   Identification of Tourism Flows.
   In co-supervision with professor Paulo Novais.
   Informatics Engineering Master degree from University of Minho.
   Year of conclusion: 2017.

Bibliography

[1] A. M. A. Fidora et al. “Ramon Llull: From the Ars Magna to Artificial Intelligence”. In: 2011 (cit. on p. 1).

[2] R. W. Picard. “Computer Learning of Subjectivity”. In: *ACM Comput. Surv.* 27.4 (Dec. 1995), pp. 621–623. issn: 0360-0300. doi: 10.1145/234782.234805. url: http://doi.acm.org/10.1145/234782.234805 (cit. on pp. 2, 79).

[3] K. Karpouzis et al. “User Modelling and Adaptive, Natural Interaction for Conflict Resolution”. In: *2012 IEEE 12th International Conference on Advanced Learning Technologies*. 2012, pp. 692–693. doi: 10.1109/ICALT.2012.234 (cit. on p. 3).

[4] D. Carneiro. “An agent-based architecture for online dispute resolution services”. PhD thesis. University of Minho, 2013. url: http://hdl.handle.net/1822/28773 (cit. on pp. 3, 10, 21).

[5] J. DeMars et al. “Virtual Virtues: Ethical Considerations for an Online Dispute Resolution Practice”. In: *Disp. Resol. Mag.* 17 (2010), p. 6 (cit. on p. 3).

[6] H. Miall. “Conflict transformation: A multi-dimensional task”. In: *Transforming ethnopolitical conflict*. Springer, 2004, pp. 67–89. doi: 10.1007/978-3-663-05642-3_4 (cit. on pp. 6, 27).

[7] J. Campos. “Modelling Interpersonal Conflict in Multi-Agent Societies”. PhD thesis. Instituto Superior Técnico - University of Lisbon, 2017 (cit. on p. 10).

[8] E. Aarts and F. Grotenhuis. “Ambient Intelligence 2.0: Towards Synergetic Prosperity”. In: *J. Ambient Intell. Smart Environ.* 3.1 (Jan. 2011), pp. 3–11. issn: 1876-1364 (cit. on pp. 10, 30).

[9] A. Aztiria, J. C. Augusto, and A. Izaguirre. “Spatial and temporal aspects for pattern representation and discovery in intelligent environments”. In: *In Workshop on Spatial and Temporal Reasoning at 18th European Conference on Artificial Intelligence (ECAI 2008*. 2008 (cit. on p. 10).

[10] A. Aztiria, A. Izaguirre, and J. Augusto. “Learning patterns in ambient intelligence environments: a survey”. English. In: *Artificial Intelligence Review* 34.1 (2010), pp. 35–51. issn: 0269-2821. doi: 10.1007/s10462-010-9160-3 (cit. on p. 11).

[11] D. J. Cook, J. C. Augusto, and V. R. Jakkula. “Review: Ambient Intelligence: Technologies, Applications, and Opportunities”. In: *Pervasive Mob. Comput.* 5.4 (Aug. 2009), pp. 277–298. issn: 1574-1192. doi: 10.1016/j.pmcj.2009.04.001 (cit. on pp. 11, 12).

[12] B. Gottfried, H. Guesgen, and S. HÃ¼bner. “Spatiotemporal Reasoning for Smart Homes”. English. In: *Designing Smart Homes*. Ed. by J. Augusto and C. Nugent. Vol. 4008. Lecture Notes in Computer Science. Springer Berlin Heidelberg, 2006, pp. 16–34. isbn: 978-3-540-35994-4. doi: 10.1007/11788485_2. url: http://dx.doi.org/10.1007/11788485_2 (cit. on p. 11).

[13] J. Bohn et al. “Social, Economic, and Ethical Implications of Ambient Intelligence and Ubiquitous Computing”. English. In: *Ambient Intelligence*. Ed. by W. Weber, J. Rabaey, and E. Aarts. Springer Berlin Heidelberg, 2005, pp. 5–29. isbn: 978-3-540-23867-6. doi: 10.1007/3-540-27139-2_2 (cit. on p. 11).

[14] G. Marreiros et al. *Ambient Intelligence in Emotion Based Ubiquitous Decision Making*. 2010 (cit. on p. 12).

[15] E. Katsh and C. Rule. “What we know and need to know about online dispute resolution”. In: *SCL Rev.* 67 (2015), p. 329 (cit. on p. 12).

[16] S. H. Bol. “Ethan Katsh and Janet Rifkin, Online Dispute Resolution, Resolving Conflicts in Cyberspace”. In: *Artif. Intell. Law* 11.1 (2003), pp. 69–75 (cit. on p. 13).

[17] P. G and C. G. “Artificial intelligence in alternative dispute resolution”. In: *Proceedings of the workshop on the law of electronic agentsâ€“LEA*. 2002 (cit. on p. 13).

[18] A. Lodder and E. Thiessen. “The role of artificial intelligence in online dispute resolution”. In: *Workshop on Online Dispute Resolution at the International Conference on Artificial Intelligence and Law*. Edinburgh, UK, 2003 (cit. on p. 13).

[19] M. Wooldridge. *An introduction to multiagent systems*. John wiley & sons, 2009 (cit. on p. 13).

[20] G. M. Olson, T. W. Malone, and J. B. Smith. *Coordination theory and collaboration technology*. Psychology Press, 2001. doi: 10.4324/9781410605863 (cit. on p. 13).

[21] G. Marreiros et al. "An agent-based approach to group decision simulation using argumentation". In: *International MultiConference on Computer Science and Information Tecnology, Workshop Agent-Based Computing III (ABC 2006), Wisla, Poland*. Citeseer. 2006, pp. 225–232 (cit. on p. 13).

[22] L. Brito, P. Novais, and J. Neves. "The logic behind negotiation: from pre-argument reasoning to argument-based negotiation". In: *Intelligent agent software engineering*. IGI Global, 2003, pp. 137–159. doi: 10.4018/978-1-59140-046-2.ch007 (cit. on p. 13).

[23] R. H. Bonczek, C. W. Holsapple, and A. B. Whinston. *Foundations of decision support systems*. Academic Press, 2014. doi: 10.1016/C2013-0-10396-0 (cit. on p. 13).

[24] E. Turban. *Decision support and expert systems Management support systems*. Prentice-Hall, Inc., 1995 (cit. on p. 13).

[25] P. Jackson. "Introduction to expert systems". In: (1986) (cit. on p. 14).

[26] F. Hayes-Roth, D. A. Waterman, and D. B. Lenat. "Building expert system". In: (1983) (cit. on p. 14).

[27] G. Greenleaf, A. Mowbray, and A. L. Tyree. "Expert Systems in Law: The Datalex Project". In: *Proceedings of the 1st International Conference on Artificial Intelligence and Law*. ICAIL '87. Boston, Massachusetts, USA: Association for Computing Machinery, 1987, pp. 9–17. isbn: 0897912306. doi: 10.1145/41735.41737. url: https://doi.org/10.1145/41735.41737 (cit. on p. 15).

[28] A. Elziny et al. "An expert system to manage dispute resolutions in construction projects in Egypt". In: *Ain Shams Engineering Journal* 7.1 (2016), pp. 57–71. issn: 2090-4479. doi: 10.1016/j.asej.2015.05.002. url: https://www.sciencedirect.com/science/article/pii/S2090447915000684 (cit. on p. 15).

[29] D. Thompson. "Creating new pathways to justice using simple artificial intelligence and online dispute resolution". In: *IJODR* 2 (2015), p. 4 (cit. on p. 15).

[30] D. A. Larson. "Designing and Implementing a State Court ODR System: From Disappointment to Celebration". In: *J. Disp. Resol.* (2019), p. 77 (cit. on p. 15).

[31] J. Barnett and P. Treleaven. "Algorithmic Dispute Resolution—The Automation of Professional Dispute Resolution Using AI and Blockchain Technologies". In: *The Computer Journal* 61.3 (2017), pp. 399–408. issn: 0010-4620. doi: 10.1093/comjnl/bxx103 (cit. on p. 15).

[32] S. Cooper and A. Taleb-Bendiab. "CONCENSUS: multi-party negotiation support for conflict resolution in concurrent engineering design". English. In: *Journal of Intelligent Manufacturing* 9.2 (1998), pp. 155–159. issn: 0956-5515. doi: 10.1023/A:1008820029707 (cit. on pp. 15, 16).

[33] D. Carneiro et al. "Developing Intelligent Environments with OSGi and JADE". English. In: *Artificial Intelligence in Theory and Practice III*. Ed. by M. Bramer. Vol. 331. IFIP Advances in Information and Communication Technology. Springer Berlin Heidelberg, 2010, pp. 174–183. isbn: 978-3-642-15285-6. doi: 10.1007/978-3-642-15286-3_17 (cit. on p. 16).

[34] D. Carneiro et al. "Developing Dynamic Conflict Resolution Models Based on the Interpretation of Personal Conflict Styles". In: *EPIA*. Ed. by L. Antunes and H. S. Pinto. Vol. 7026. Lecture Notes in Computer Science. Springer, 2011, pp. 44–58. isbn: 978-3-642-24768-2 (cit. on pp. 16, 17, 66, 81, 105).

[35] M. Gomes. "Behavioural and Context Analysis in an Online Dispute Resolution Environment". MA thesis. University of Minho, 2012 (cit. on pp. 16, 41, 65, 76, 79, 86, 116).

[36] M. Gomes et al. "Establishing the relationship between personality traits and stress in an intelligent environment". In: *International Conference on Industrial, Engineering and Other Applications of Applied Intelligent Systems*. Springer. 2014, pp. 378–387. doi: 10.1007/978-3-319-07467-2_40 (cit. on pp. 16, 41, 63, 66–68, 82, 84, 88, 89, 91, 116, 117, 164).

[37] M. Gomes et al. "Improving modularity, interoperability and extensibility in ambient intelligence". In: *Ambient Intelligence-Software and Applications*. Springer, 2014, pp. 63–70. doi: 10.1007/978-3-319-07596-9_7 (cit. on pp. 16, 41, 76, 79, 116).

[38] K. Nandalal et al. *Conflict Resolution Support System: A Software for the Resolution of Conflicts in Water Resource Management*. Water resources research report. University of Western Ontario, 2003. isbn: 9780771426186 (cit. on p. 16).

[39] S. A. Ludwig. "Agent-Based Assistant for e-Negotiations". In: *Foundations of Intelligent Systems*. Ed. by A. An et al. Berlin, Heidelberg: Springer Berlin Heidelberg, 2008, pp. 514–524. isbn: 978-3-540-68123-6. doi: 10.1007/978-3-540-68123-6_56 (cit. on pp. 16, 17).

[40] R. Kilmann and K. Thomas. *Developing a Forced-Choice Measure of Conflict-Handling Behavior: The MODE Instrument*. Educational and Psychological Measurement, 1977 (cit. on pp. 16, 46).

[41] T. Yiu, C. U. of Hong Kong. Dept. of Building, and Construction. *A Behavioral Analysis of Construction Dispute Negotiation*. City University of Hong Kong, 2005 (cit. on p. 17).

[42] M. A. Rahim. "A Measure of Styles of Handling Interpersonal Conflict". In: *The Academy of Management Journal* 26.2 (1983), pp. 368–376. issn: 00014273 (cit. on p. 17).

[43] B. A. Jain and J. S. Solomon. "The effect of task complexity and conflict handling styles on computer-supported negotiations". In: *Information and Management* 37.4 (2000), pp. 161–168. issn: 0378-7206. doi: 10.1016/S0378-7206(99)00049-X (cit. on p. 17).

[44] J. L. Holt and C. J. DeVore. "Culture, gender, organizational role, and styles of conflict resolution: A meta-analysis". In: *International Journal of Intercultural Relations* 29.2 (2005), pp. 165–196. issn: 0147-1767. doi: 10.1016/j.ijintrel.2005.06.002 (cit. on p. 17).

[45] V. F. Wood and P. A. Bell. "Predicting interpersonal conflict resolution styles from personality characteristics". In: *Personality and Individual Differences* 45.2 (2008), pp. 126–131 (cit. on p. 17).

[46] I. A. Khan et al. "Measuring Personality from Keyboard and Mouse Use". In: *Proceedings of the 15th European Conference on Cognitive Ergonomics: The Ergonomics of Cool Interaction*. ECCE '08. Funchal, Portugal: ACM, 2008, 38:1–38:8. isbn: 978-1-60558-399-0. doi: 10.1145/1473018.1473066. url: http://doi.acm.org/10.1145/1473018.1473066 (cit. on p. 17).

[47] G. Chittaranjan, J. Blom, and D. Gatica-Perez. “Mining Large-scale Smartphone Data for Personality Studies”. In: *Personal Ubiquitous Comput.* 17.3 (Mar. 2013), pp. 433–450. issn: 1617-4909. doi: 10.1007/s00779-011-0490-1. url: http://dx.doi.org/10.1007/s00779-011-0490-1 (cit. on p. 17).

[48] D. Merkl, E. Schweighoffer, and W. Winiwarter. “Exploratory analysis of concept and document spaces with connectionist networks”. In: *Artificial Intelligence and Law* 7.2 (1999), pp. 185–209. doi: 10.1023/A:1008365524782 (cit. on p. 19).

[49] L. T. McCarty. “Deep semantic interpretations of legal texts”. In: *Proceedings of the 11th international conference on Artificial intelligence and law*. 2007, pp. 217–224 (cit. on pp. 19, 20).

[50] E. Nissan. “Digital technologies and artificial intelligence’s present and foreseeable impact on lawyering, judging, policing and law enforcement”. In: *Ai & Society* 32.3 (2017), pp. 441–464. doi: 10.1007/s00146-015-0596-5 (cit. on pp. 19, 20).

[51] M. Sanderson and W. B. Croft. “The history of information retrieval research”. In: *Proceedings of the IEEE* 100.Special Centennial Issue (2012), pp. 1444–1451. doi: 10.1109/JPROC.2012.2189916 (cit. on p. 19).

[52] C. D. Manning, P. Raghavan, and H. Schütze. *Introduction to Information Retrieval*. Cambridge, UK: Cambridge University Press, 2008. isbn: 978-0-521-86571-5. doi: 10.1017/CBO9780511809071 (cit. on pp. 19, 20).

[53] E. Francesconi et al. *Semantic processing of legal texts: Where the language of law meets the law of language*. Vol. 6036. Springer, 2010. doi: 10.1007/978-3-642-12837-0 (cit. on p. 19).

[54] G. Lame. “Using NLP techniques to identify legal ontology components: Concepts and relations”. In: *Artificial Intelligence and Law* 12.4 (2004), pp. 379–396. doi: 10.1007/s10506-005-4160-3 (cit. on p. 19).

[55] J. Kolodner. *Case-based reasoning*. Morgan Kaufmann, 2014 (cit. on p. 20).

[56] D. B. Leake. “Case-based reasoning: experiences, lessons, and future directions”. In: (1996) (cit. on p. 20).

[57] B. Smyth and M. T. Keane. “Remembering to forget”. In: *Proc. 14th IJCAI*. Citeseer. 1995, pp. 377–382 (cit. on p. 20).

[58] S. Slade. “Case-based reasoning: A research paradigm”. In: *AI magazine* 12.1 (1991), pp. 42–42. doi: 10.1609/aimag.v12i1.883 (cit. on p. 20).

[59] F. Hayes-Roth. “Rule-based systems”. In: *Communications of the ACM* 28.9 (1985), pp. 921–932. doi: 10.1145/4284.4286 (cit. on p. 20).

[60] E. L. Rissland and J. J. Daniels. “A hybrid cbr-ir approach to legal information retrieval”. In: *Proceedings of the 5th international conference on Artificial intelligence and law*. 1995, pp. 52–61. doi: 10.1145/222092.2221250 (cit. on p. 21).

[61] D. E. Rose. *A symbolic and connectionist approach to legal information retrieval*. Psychology Press, 2013 (cit. on p. 21).

[62] Y. Lupu and E. Voeten. “Precedent in international courts: A network analysis of case citations by the European court of human rights”. In: *British Journal of Political Science* (2012), pp. 413–439. doi: 10.1017/S0007123411000433 (cit. on p. 21).

[63] B. B. McShane et al. “Predicting securities fraud settlements and amounts: a hierarchical Bayesian model of federal securities class action lawsuits”. In: *Journal of Empirical Legal Studies* 9.3 (2012), pp. 482–510. doi: j.1740-1461.2012.01260.x (cit. on p. 21).

[64] R. Guimerà and M. Sales-Pardo. “Justice blocks and predictability of us supreme court votes”. In: *PloS one* 6.11 (2011), e27188. doi: 10.1371/journal.pone.0027188 (cit. on p. 21).

[65] T. W. Ruger et al. “The supreme court forecasting project: Legal and political science approaches to predicting supreme court decisionmaking”. In: *Columbia Law Review* (2004), pp. 1150–1210. doi: 10.2307/4099370 (cit. on p. 22).

[66] N. Aletras et al. “Predicting judicial decisions of the European Court of Human Rights: A natural language processing perspective”. In: *PeerJ Computer Science* 2 (2016), e93. doi: 10.7717/peerj-cs.93 (cit. on p. 22).

[67] D. M. Katz, M. J. Bommarito, and J. Blackman. “A general approach for predicting the behavior of the Supreme Court of the United States”. In: *PloS one* 12.4 (2017), e0174698. doi: 10.1371/journal.pone.0174698 (cit. on p. 22).

[68] D. M. Katz. “Quantitative legal prediction-or-how i learned to stop worrying and start preparing for the data-driven future of the legal services industry”. In: *Emory LJ* 62 (2012), p. 909 (cit. on p. 22).

[69] A. Sela. "Can Computers Be Fair: How Automated and Human-Powered Online Dispute Resolution Affect Procedural Justice in Mediation and Arbitration". In: *Ohio St. J. on Disp. Resol.* 33 (2018), p. 91 (cit. on p. 22).

[70] M. E. Katsh and O. Rabinovich-Einy. *Digital justice: technology and the internet of disputes*. Oxford University Press, 2017. doi: 10.1093/acprof:oso/9780190464585.001.0001P (cit. on p. 22).

[71] R. E. Susskind. *Online courts and the future of justice*. Oxford University Press, 2019 (cit. on p. 22).

[72] M. E. Kauffman and M. N. Soares. *AI in legal services: new trends in AI-enabled legal services*. 2020. doi: 10.1007/s11761-020-00305-x (cit. on p. 22).

[73] R. Yu and G. S. Alì. "What's Inside the Black Box? AI Challenges for Lawyers and Researchers". In: *Legal Information Management* 19.1 (2019), pp. 2–13. doi: 10.1017/S1472669619000021 (cit. on p. 22).

[74] R. Catterwell. "Automation in contract interpretation". In: *Law, Innovation and Technology* 12.1 (2020), pp. 81–112. doi: 10.1080/17579961.2020.1727068 (cit. on p. 22).

[75] S. D. Becerra. "The rise of artificial intelligence in the legal field: where we are and where we are going". In: *J. Bus. Entrepreneurship & L.* 11 (2018), p. 27 (cit. on p. 22).

[76] H. Surden. "Artificial intelligence and law: An overview". In: *Ga. St. UL Rev.* 35 (2018), p. 1305 (cit. on p. 22).

[77] P. P. Viana. "Online legal platforms–the beginning of the 4.0 law practice?" In: *UNIO–EU Law Journal* 5.2 (2019), pp. 43–62. doi: 10.21814/unio.5.2.2291 (cit. on p. 22).

[78] M. Medvedeva, M. Vols, and M. Wieling. "Using machine learning to predict decisions of the European Court of Human Rights". In: *Artificial Intelligence and Law* 28.2 (2020), pp. 237–266. doi: 10.1007/s10506-019-09255-y (cit. on p. 23).

[79] K. Mania. "Online dispute resolution: The future of justice". In: *International Comparative Jurisprudence* 1.1 (2015), pp. 76–86. issn: 2351-6674. doi: 10.1016/j.icj.2015.10.006 (cit. on p. 23).

[80] P. Cortés. *The law of consumer redress in an evolving digital market: upgrading from alternative to online dispute resolution*. Cambridge University Press, 2017. doi: 10.1017/9781139940900 (cit. on p. 23).

[81] M. C. Gonçalves. “Alternative Dispute Resolution in Civil and Commercial Matters in the EU”. In: *Interdisciplinary Perspectives on Contemporary Conflict Resolution*. IGI Global, 2016, pp. 111–127. doi: 978-1-5225-0245-6.ch00 (cit. on p. 23).

[82] R. Jokubauskas and M. Swierczynski. “Is revision of the council of Europe guidelines on electronic evidence already needed?” In: *Utrecht L. Rev.* 16 (2020), p. 13. doi: 10.36633/ulr.525 (cit. on p. 23).

[83] M. J. Schmidt-Kessen, R. Nogueira, and M. C. Gamito. “Success or Failure?—Effectiveness of Consumer ODR Platforms in Brazil and in the EU”. In: *Journal of Consumer Policy* (2020), pp. 1–28. doi: 10.2139/ssrn.3374964 (cit. on p. 23).

[84] M. H. Julia Hörnle and I. Chernohorenko. *Online Dispute Resolution and Compliance with the Right to a Fair Trial and the Right to an Effective Remedy (Article 6 and 13 of the European Convention of Human Rights)*. Tech. rep. Council of Europe, 2018 (cit. on p. 23).

[85] M. Saunders, P. Lewis, and A. Thornhill. *Research Methods for Business Students*. Always learning. Financial Times Prentice Hall, 2009. isbn: 9780273716860 (cit. on pp. 32, 35).

[86] J. Strübing. “Bridging the Gap: On the Collaboration between Symbolic Interactionism and Distributed Artificial Intelligence in the Field of Multi-Agent Systems Research”. In: *Symbolic Interaction* 21.4 (1998), pp. 441–463. issn: 1533-8665 (cit. on p. 32).

[87] S. Robbins and T. Judge. *Organizational Behavior*. Pearson/Prentice Hall, 2007. isbn: 9780132431569 (cit. on pp. 36, 43, 46).

[88] B. Galitsky and J. L. de la Rosa. “Concept-based learning of human behavior for customer relationship management”. In: *Information Sciences* 181.10 (2011). Special Issue on Information Engineering Applications Based on Lattices, pp. 2016–2035. issn: 0020-0255. doi: 10.1016/j.ins.2010.08.027 (cit. on p. 38).

[89] M. Gomes, T. Oliveira, and P. Novais. “A Speculative Computation Approach for Conflict Styles Assessment with Incomplete Information”. In: *International Symposium on Intelligent and Distributed Computing*. Springer. 2016, pp. 163–172. doi: 10.1007/978-3-319-48829-5_16 (cit. on pp. 41, 70, 84, 100, 101, 103, 116, 117).

[90] M. Gomes, J. Zeleznikow, and P. Novais. “A Non-intrusive Approach to Measuring Trust in Opponents in a Negotiation Scenario”. In: *AI Approaches to the Complexity of Legal Systems*. Springer, 2015, pp. 528–542. doi: 10.1007/978-3-030-00178-0_36 (cit. on pp. 41, 59, 61, 82, 84, 92, 93, 116, 117).

[91] M. Gomes et al. “Improving Conflict Support Environments with Information Regarding Social Relationships”. In: *Advances in Artificial Intelligence – IBERAMIA 2014*. Ed. by A. L. Bazzan and K. Pichara. Vol. 8864. Lecture Notes in Computer Science. Springer International Publishing, 2014, pp. 779–790. isbn: 978-3-319-12026-3. doi: 10.1007/978-3-319-12027-0_63 (cit. on pp. 41, 62, 84, 97, 98, 116, 117).

[92] M. Gomes et al. “Studying the Effects of Stress on Negotiation Behavior”. In: *Cybernetics and Systems* 45.3 (2014), pp. 279–291. doi: 10.1080/01969722.2014.894858 (cit. on pp. 41, 56, 84, 116, 117).

[93] M. Gomes, F. Andrade, and P. Novais. “Enhancing Municipal Decision-Making Through an Intelligent Conflict Support System”. In: *International Conference on Digital Transformation and Global Society*. Springer. 2016, pp. 189–204. doi: 10.1007/978-3-319-49700-6_19 (cit. on pp. 41, 84, 116, 117).

[94] M. V. Gomes and P. Novais. “Conflict and its different dimensions”. In: *Interdisciplinary perspectives on contemporary conflict resolution*. IGI Global, 2016, pp. 1–20. doi: http://doi:10.4018/978-1-5225-0245-6.ch001 (cit. on pp. 41, 46, 116).

[95] H. Buss. *Measuring and Reducing the Cost of Conflict at Work in UNHCR: The Business Case of Conflict Management*. Institut universitaire Kurt Bösch, 2009 (cit. on p. 42).

[96] L. Watkin. “Environmental conflict and decision-making: the case of hydroelectric power”. 2012 (cit. on pp. 42, 44, 45).

[97] J. March and H. Simon. *Organizations*. J.Wiley, New York, 1958 (cit. on p. 42).

[98] K. A. Jehn. “A qualitative analysis of conflict types and dimensions in organizational groups”. In: *Administrative science quarterly* (1997), pp. 530–557 (cit. on p. 42).

[99] D. M. Kolb and L. L. Putnam. “The multiple faces of conflict in organizations”. In: *Journal of Organizational Behavior* 13.3 (1992), pp. 311–324. issn: 1099-1379. doi: 10.1002/job.4030130313 (cit. on p. 42).

[100] N. Nair. “Towards understanding the role of emotions in conflict: a review and future directions”. In: *International Journal of Conflict Management* 19.4 (2008), pp. 359–381. doi: 10.1108/10444060810909301 (cit. on p. 42).

[101] E. Infante. “On the interpersonal conflict definition: Cluster analysis application to the semantic study”. In: *Revista de PsicologÃa Social* 13.3 (1998), pp. 485–493. doi: 10.1174/021347498760349733 (cit. on p. 42).

[102] H. Barki and J. Hartwick. “CONCEPTUALIZING THE CONSTRUCT OF INTERPERSONAL CONFLICT”. In: *International Journal of Conflict Management* 15.3 (2004), pp. 216–244. doi: 10.1108/eb022913 (cit. on pp. 42, 43).

[103] C. K. W. d. Dreu. “The virtue and vice of workplace conflict : food for (pessimistic) thought”. In: *Journal of organizational behavior* (2008) (cit. on pp. 42, 43).

[104] K. Boulding. *Conflict and defense. a general theory*. The university library. New York, NY: Harper & Row, 1963. IX, 349 (cit. on p. 42).

[105] P. T. Coleman. “Characteristics of Protracted, Intractable Conflict: Toward the Development of a Metaframework-I”. In: *Peace and Conflict: Journal of Peace Psychology* 9.1 (2003), pp. 1–37. doi: 10.1207/S15327949PAC0901_01 (cit. on p. 42).

[106] M. Deutsch. “The resolution of conflict: Constructive and destructive processes.” In: *New Haven: Yale University Press.* (1973) (cit. on pp. 42, 43).

[107] L. A. Coser. “The Functions of Social Conflict”. In: (1956) (cit. on p. 42).

[108] K. A. Jehn. “A Multimethod Examination of the Benefits and Detriments of Intragroup Conflict”. In: *Administrative Science Quarterly* 40 (1995), pp. 256–282 (cit. on p. 42).

[109] D. Tjosvold. “Defining conflict and making choices about its management”. In: *International Journal of Conflict Management* 17.2 (2006), pp. 87–95. doi: 10.1108/10444060610736585 (cit. on pp. 42, 45).

[110] M. Deutsch. “Cooperation and Conflict: A Personal Perspective on the History of the Social Psychological Study of Conflict Resolution”. In: *International Handbook of Organizational Teamwork and Cooperative Working*. John Wiley & Sons Ltd, 2008, pp. 9–43. isbn: 9780470696712. doi: 10.1002/9780470696712.ch2 (cit. on p. 43).

[111] V. K. Verma. “Conflict Management”. In: *The Project Management Institute Project Management Handbook*. Jeffery Pinto, 1998. isbn: 0-7879-4013-5 (cit. on p. 43).

[112] C. Moore. *The Mediation Process: Practical Strategies for Resolving Conflict*. Jossey-Bass conflict resolution series. Wiley, 1986 (cit. on p. 44).

[113] C. Moore. *The Mediation Process: Practical Strategies for Resolving Conflict, 2nd edition*. Jossey-Bass conflict resolution series. Wiley, 1996 (cit. on p. 44).

[114] B. Mayer. *The dynamics of conflict resolution: A practitioners guide*. Administrative Science Quarterly. Wiley, 2000 (cit. on p. 44).

[115] G. T. Furlong. *The conflict resolution toolbox: models and maps for analyzing diagnosing and resolving conflict*. New Delhi: Wiley India (P) Ltd., 2006 (cit. on p. 44).

[116] C. Menkel-Meadow. "Hybrid and mixed dispute resolution processes: integrities of process pluralism". In: *Comparative Dispute Resolution*. Edward Elgar Publishing, 2020. doi: 10.4337/9781786433039 (cit. on p. 46).

[117] L. R. Pondy. *Organizational Conflict: Concepts and Models*. Vol. 2. Sage Publications, Inc., 1967 (cit. on p. 46).

[118] D. R. Forsyth. *Group dynamics*. Cengage Learning, 2018 (cit. on p. 46).

[119] R. Blake and J. Mouton. "The Managerial Grid." In: *Houston, TX: Gulf Publishing*. (1964) (cit. on p. 46).

[120] D. Carneiro et al. "Automatic Classification of Personal Conflict Styles in Conflict Resolution". In: *Legal Knowledge and Information Systems - JURIX 2011: The Twenty-Fourth Annual Conference, University of Vienna, Austria, 14th-16th December 2011*. Ed. by K. Atkinson. Vol. 235. Frontiers in Artificial Intelligence and Applications. IOS Press, 2011, pp. 43–52. doi: 10.3233/978-1-60750-981-3-43. url: 10.3233/978-1-60750-981-3-43 (cit. on p. 47).

[121] H. Raiffa. *The art and science of negotiation: how to resolve conflicts and get the best out of bargaining*. Cambridge: The Belknap Press of Harvard University Press, 1982 (cit. on p. 50).

[122] R. Walton and R. McKersie. *A Behavioral Theory of Labor Negotiations: An Analysis of a Social Interaction System*. G - Reference,Information and Interdisciplinary Subjects Series. ILR Press, 1991. isbn: 9780875461793 (cit. on p. 50).

[123] G. kersten and G. Lo. “Negotiation Support Systems and Software Agents in E-Business Negotiations.” In: *The First International Conference on Electronic Business, Hong Kong*. 2001 (cit. on p. 50).

[124] G. Kaufmann-Kohler and T. Schultz. “The use of Information Technology in arbitration”. In: *Jusletter* 5. Dezember (2005) (cit. on p. 51).

[125] M. Wahab, E. Katsh, and D. Rainey. *Online Dispute Resolution: Theory and Practice*. Eleven International Publishing, 2012 (cit. on p. 51).

[126] M. Poblet and P. Casanovas. “Emotions in ODR”. In: *International Review of Law Computers & Technology* 21.2 (2007), pp. 145–156. doi: 10.1080/13600860701492146 (cit. on p. 52).

[127] M. R. Carrel, D. F. Jennings, and C. Heavrin. “Fundamentals of Organizational Behavior”. In: *Prentice-Hall* (1997) (cit. on p. 52).

[128] H. Mintzberg, D. Raisinghani, and A. Theoret. “The structure of unstructured decision processes”. In: *Administrative Science Quarterly* 21 (1976), pp. 246–275 (cit. on p. 53).

[129] M.-M. Saarelainen et al. “Group Decision-Making Processes in Industrial Software Evolution”. In: *Software Engineering Advances, 2007. ICSEA 2007. International Conference on*. 2007, pp. 78–78 (cit. on p. 53).

[130] A. Vinciarelli, H. Salamin, and M. Pantic. “Social signal processing: Understanding social interactions through nonverbal behavior analysis”. In: *2009 IEEE computer society conference on computer vision and pattern recognition workshops*. IEEE. 2009, pp. 42–49. doi: 10.1109/CVPRW.2009.5204290 (cit. on p. 55).

[131] W. Sherchan, S. Nepal, and C. Paris. “A Survey of Trust in Social Networks”. In: *ACM Comput. Surv.* 45.4 (Aug. 2013), 47:1–47:33. issn: 0360-0300. doi: 10.1145/2501654.2501661. url: http://doi.acm.org/10.1145/2501654.2501661 (cit. on pp. 59, 60).

[132] D. Carneiro et al. “Online dispute resolution: an artificial intelligence perspective”. In: *Artificial Intelligence Review* 41.2 (2012), pp. 211–240. issn: 1573-7462. doi: 10.1007/s10462-011-9305-z. url: http://dx.doi.org/10.1007/s10462-011-9305-z (cit. on p. 59).

[133] W. Ross and J. LaCroix. "Multiple meanings of trust in negotiation theory and research: A literature review and integrative model". In: *International Journal of Conflict Management* 7.4 (1996), pp. 314–360. doi: 10.1108/eb022786. url: http://dx.doi.org/10.1108/eb022786 (cit. on p. 59).

[134] S. Adali et al. "Measuring behavioral trust in social networks". In: *Intelligence and Security Informatics (ISI), 2010 IEEE International Conference on*. 2010, pp. 150–152. doi: 10.1109/ISI.2010.5484757 (cit. on pp. 60, 61, 82).

[135] A. Mehra et al. "The Social Network Ties of Group Leaders: Implications for Group Performance and Leader Reputation". In: *Organization Science* 17.1 (Jan. 2006), pp. 64–79. issn: 1526-5455 (cit. on pp. 63, 82, 97).

[136] P. Balkundi and D. A. Harrison. "Ties, Leaders, and Time in Teams: Strong Inference about Network Structure's Effects on Team Viability and Performance." In: *Academy of Management Journal* 49.1 (2006), pp. 49–68. doi: 10.5465/AMJ.2006.20785500 (cit. on pp. 63, 82).

[137] R. T. Sparrowe et al. "Social Networks and the Performance of Individuals and Groups". In: *Academy of Management Journal* 44.2 (Apr. 2001), pp. 316–325. issn: 1948-0989. doi: 10.2307/3069458 (cit. on pp. 63, 82, 97).

[138] A. Joshi et al. "Likert scale: Explored and explained". In: *Current Journal of Applied Science and Technology* (2015), pp. 396–403. doi: 10.9734/BJAST/2015/149750 (cit. on p. 63).

[139] J. R. Sternlight. "Pouring a little psychological cold water on online dispute resolution". In: *J. Disp. Resol.* (2020), p. 1 (cit. on p. 63).

[140] P. Gebhard. "ALMA: a layered model of affect". In: *Proceedings of the fourth international joint conference on Autonomous agents and multiagent systems*. AAMAS '05 (2005), pp. 29–36 (cit. on pp. 63, 64).

[141] D. Nettle. *Personality: What Makes You the Way You are*. OUP Oxford, 2007. isbn: 9780199211425. url: http://books.google.pt/books?id=vk1kXARv1-IC (cit. on pp. 64, 82, 166).

[142] A. Mehrabian. *Basic dimensions for a general psychological theory: Implications for personality, social, environmental, and developmental studies*. Vol. 2. Oelgeschlager, Gunn & Hain Cambridge, MA, 1980 (cit. on p. 65).

[143] A. Ortony, G. Clore, and A. Collins. *Cognitive Structure of Emotions*. Cambridge University Press, 1988 (cit. on p. 65).

[144] K. Parsons. "Environmental ergonomics: a review of principles, methods and models". In: *Applied Ergonomics* 31.6 (2000), pp. 581–594. issn: 00036870. doi: 10.1016/s0003-6870(00)00044-2. url: http://dx.doi.org/10.1016/s0003-6870(00)00044-2 (cit. on p. 65).

[145] M. Gomes et al. "Modelling stress recognition in conflict resolution scenarios". In: *Proceedings of the 7th international conference on Hybrid Artificial Intelligent Systems - Volume Part I*. HAIS'12. Salamanca, Spain: Springer-Verlag, 2012, pp. 533–544. isbn: 978-3-642-28941-5. doi: 10.1007/978-3-642-28942-2_48. url: http://dx.doi.org/10.1007/978-3-642-28942-2_48 (cit. on pp. 65–67, 83, 105, 109).

[146] D. Carneiro et al. "Multimodal Behavioral Analysis for Non-invasive Stress Detection". In: *Expert Syst. Appl.* 39.18 (Dec. 2012), pp. 13376–13389. issn: 0957-4174. doi: 10.1016/j.eswa.2012.05.065. url: http://dx.doi.org/10.1016/j.eswa.2012.05.065 (cit. on pp. 65, 67).

[147] D. Carneiro et al. "A Statistical Classifier for Assessing the Level of Stress from the Analysis of Interaction Patterns in a Touch Screen". In: *Soft Computing Models in Industrial and Environmental Applications*. Vol. 188. Advances in Intelligent Systems and Computing. Springer Berlin Heidelberg, 2013, pp. 257–266. isbn: 978-3-642-32922-7 (cit. on pp. 65, 81, 83, 109).

[148] H. Selye. *The stress of life*. McGraw-Hill paperbacks vol. 5. McGraw-Hill, 1956 (cit. on p. 66).

[149] R. Cox. *Sport psychology: concepts and applications*. W.C. Brown, 1985. isbn: 9780697001412 (cit. on p. 66).

[150] Y. Shi et al. "Personalized Stress Detection from Physiological Measurements". In: *International Symposium on Quality of Life Technology* (2010) (cit. on p. 66).

[151] J. Healey and R. W. Picard. "Detecting stress during real-world driving tasks using physiological sensors". In: *IEEE Transactions on Intelligent Transportation Systems* 6.2 (2005), pp. 156–166. doi: 10.1109/TITS.2005.848368 (cit. on pp. 66, 91).

[152] B. Gyselinckx et al. “Human++: Emerging technology for body area networks”. In: *2006 IFIP international conference on very large scale integration*. IEEE. 2006, pp. 175–180. doi: 10.1007/978-0-387-74909-9_210 (cit. on p. 66).

[153] W. Liao et al. “Toward a decision-theoretic framework for affect recognition and user assistance”. In: *International Journal of Human-Computer Studies* 64.9 (2006), pp. 847–873 (cit. on p. 66).

[154] R. W. Picard. *Affective computing*. Cambridge, MA, USA: MIT Press, 1997. isbn: 0-262-16170-2 (cit. on p. 66).

[155] T. S. Tidd and R. Friedman. “Conflict Style and Coping With Role Conflict: An Extension of the Uncertainty Model of Work Stress”. In: *International Journal of Conflict Management* 13.3 (2002), pp. 236–257 (cit. on p. 66).

[156] Y. Zhang and Q. Ji. “Efficient sensor selection for active information fusion”. In: *IEEE Transactions on Systems, Man, and Cybernetics, Part B (Cybernetics)* 40.3 (2009), pp. 719–728. doi: 10.1109/TSMCB.2009.2021272 (cit. on p. 66).

[157] M. Gomes et al. “Studying the Effects of Stress on Negotiation Behavior”. In: *Cybernetics and Systems* 45.3 (2014), pp. 279–291. doi: 10.1080/01969722.2014.894858 (cit. on pp. 66, 71, 81, 84, 101, 116, 117).

[158] L. Wu, S. L. Oviatt, and P. R. Cohen. “Multimodal Integration - A Statistical View”. In: *IEEE Transactions on Multimedia* 1 (1999), pp. 334–341 (cit. on p. 66).

[159] R. V. Yampolskiy and V. Govindaraju. “Behavioural biometrics: a survey and classification”. In: *International Journal of Biometrics* 1.1 (2008), p. 81. issn: 1755-8301. doi: 10.1504/IJBM.2008.018665. url: http://www.inderscience.com/link.php?id=18665 (cit. on p. 67).

[160] A. Jain, R. Bolle, and S. Pankanti. “Introduction to Biometrics”. English. In: *Biometrics*. Ed. by A. Jain, R. Bolle, and S. Pankanti. Springer US, 1996, pp. 1–41. isbn: 978-0-387-28539-9. doi: 10.1007/0-306-47044-6_1. url: http://dx.doi.org/10.1007/0-306-47044-6%5C_1 (cit. on pp. 68, 89).

[161] M. Rodrigues et al. “Keystrokes and clicks: Measuring stress on e-learning students”. In: *Management Intelligent Systems*. Springer, 2013, pp. 119–126. doi: 10.1007/978-3-319-00569-0_15 (cit. on pp. 68, 91).

[162] H. Ursin and H. R. Eriksen. “The cognitive activation theory of stress.” In: *Psychoneuroendocrinology* 29.5 (2004), pp. 567–592 (cit. on p. 68).

[163] A. Stranieri and J. Zeleznikow. “Tools for intelligent decision support system development in the legal domain”. In: *12th IEEE International Conference on Tools with Artificial Intelligence (ICTAI 2000), 13-15 November 2000, Vancouver, BC, Canada*. 2000, pp. 186–189. doi: 10.1109/TAI.2000.889867 (cit. on pp. 70, 101).

[164] F. V. Jensen. “Bayesian networks”. In: *Wiley Interdisciplinary Reviews: Computational Statistics* 1.3 (2009), pp. 307–315. issn: 1939-0068. doi: 10.1002/wics.48. url: http://dx.doi.org/10.1002/wics.48 (cit. on pp. 70, 71).

[165] D. Margaritis. “Learning Bayesian network model structure from data”. PhD thesis. Carnegie-Mellon University, Pittsburgh, 2003 (cit. on pp. 71, 101).

[166] L. E. Tsamardinos Ioannisand Brown and C. F. Aliferis. “The max-min hill-climbing Bayesian network structure learning algorithm”. In: *Machine Learning* 65.1 (2006), pp. 31–78. doi: 10.1007/s10994-006-6889-7 (cit. on pp. 71, 101).

[167] M. Scutari. “Learning Bayesian networks with the bnlearn R package”. In: *Journal of Statistical Software* 35.3 (2010), pp. 1–22 (cit. on pp. 71, 101).

[168] K. Korb and A. Nicholson. *Bayesian Artificial Intelligence*. 2nd ed. London: CRC Press, 2011. isbn: 978-1-4398-1591-5 (cit. on p. 71).

[169] K. Satoh, P. Codognet, and H. Hosobe. “Speculative Constraint Processing in Multi-agent Systems”. In: *Intelligent Agents and Multi-Agent Systems*. Ed. by J. Lee and M. Barley. Vol. 2891. Lecture Notes in Computer Science. Springer Berlin Heidelberg, 2003, pp. 133–144. isbn: 978-3-540-20460-2 (cit. on p. 73).

[170] T. Oliveira et al. “Applying Speculative Computation to Guideline-Based Decision Support Systems”. In: *IEEE 27th International Symposium on Computer-Based Medical Systems 2014 (CBMS)*. 2014, pp. 42–47. doi: 10.1109/CBMS.2014.32 (cit. on p. 73).

[171] S. Heras et al. “Case-based strategies for argumentation dialogues in agent societies”. In: *Information Sciences* 223 (2013), pp. 1–30 (cit. on p. 74).

[172] P. Giner and V. Pelechano. “An Architecture to Automate Ambient Business System Development.” In: *AmI*. Ed. by E. H. L. Aarts et al. Vol. 5355. Lecture Notes in Computer Science. Springer, 2008, pp. 240–257. isbn: 978-3-540-89616-6. doi: 10.1007/978-3-540-89617-3_16 (cit. on p. 78).

[173] J. C. Platt. “Advances in kernel methods”. In: ed. by B. Schölkopf, C. J. C. Burges, and A. J. Smola. Cambridge, MA, USA: MIT Press, 1999. Chap. Fast training of support vector machines using sequential minimal optimization, pp. 185–208. isbn: 0-262-19416-3. url: http://dl.acm.org/citation.cfm?id=299094.299105 (cit. on p. 81).

[174] G. Holmes, A. Donkin, and I. H. Witten. “WEKA: a machine learning workbench”. In: 1994, pp. 357–361 (cit. on p. 81).

[175] R. E. Nelson. “The strength of strong ties: Social networks and intergroup conflict in organizations”. In: *Academy of management Journal* 32.2 (1989), pp. 377–401. doi: 10.5465/256367 (cit. on pp. 82, 97).

[176] S. Judd, M. Kearns, and Y. Vorobeychik. “Behavioral conflict and fairness in social networks”. In: *International workshop on internet and network economics*. Springer. 2011, pp. 242–253. doi: 10.1007/978-3-642-25510-6_21 (cit. on pp. 82, 97).

[177] N. Ebner. “Online Dispute Resolution and Interpersonal Trust”. In: *ODR: Theory and Practice* (2012). Ed. by E. K.
bibinitperiod D. R. M.S. Abdel Wahab (cit. on p. 82).

[178] F. Sheridan. “A survey of techniques for inference under uncertainty”. In: *Artificial Intelligence Review* 5.1 (1991), pp. 89–119. doi: 10.1007/BF00129537 (cit. on p. 82).

[179] I. H. Witten and E. Frank. “Data mining: practical machine learning tools and techniques with Java implementations”. In: *Acm Sigmod Record* 31.1 (2002), pp. 76–77. doi: https://doi.org/10.1016/C2009-0-19715-5 (cit. on p. 82).

[180] M. I. Jordan. *Learning in graphical models*. Vol. 89. Springer Science & Business Media, 1998. doi: 10.1007/978-94-011-5014-9 (cit. on p. 82).

[181] F. V. Jensen. “Bayesian networks”. In: *Wiley Interdisciplinary Reviews: Computational Statistics* 1.3 (2009), pp. 307–315. doi: 10.1002/wics.48 (cit. on pp. 82, 107).

[182] P. T. Costa and R. R. McCrae. “Normal personality assessment in clinical practice: The NEO Personality Inventory.” In: *Psychological assessment* 4.1 (1992), p. 5. doi: 10.1037/1040-3590.4.1.5 (cit. on pp. 82, 166).

[183] P. Novais et al. “Non-invasive Estimation of Stress in Conflict Resolution Environments”. In: *PAAMS*. Ed. by Y. Demazeau et al. Vol. 155. Advances in Soft Computing. Springer Springer, 2012, pp. 153–159. isbn: 978-3-642-28785-5. doi: 10.1007/978-3-642-28786-2_17 (cit. on pp. 83, 91, 109).

[184] T. Jesus et al. “Review of Trends in Automatic Human Activity Recognition Using Synthetic Audio-Visual Data”. In: *International Conference on Intelligent Data Engineering and Automated Learning*. Springer. 2020, pp. 549–560. doi: 10.1007/978-3-030-62365-4_53 (cit. on pp. 83, 109).

[185] F. A. O. Santos et al. “Modelling a Deep Learning Framework for Recognition of Human Actions on Video.” In: *WorldCIST (1)*. Springer. 2021, pp. 104–112. doi: 10.1007/978-3-030-72657-7_10 (cit. on pp. 83, 109).

[186] J. Goodman. “The Pros and Cons of Online Dispute Resolution: an Assessment of Cyber-Mediation Websites”. In: *ReviewDuke Law and Technology* 4 (2003) (cit. on p. 83).

[187] B. de Vries, R. Leenes, and J. Zeleznikow. “Fundamentals of Providing Negotiation Advice Online: the Need for Developing BATNAs”. English. In: *Second International ODR Workshop (odrworkshop.info)*. Ed. by J. Zeleznikow and A. Lodder. Pagination: 9. Wolf Legal Publishers (WLP), 2005, pp. 59–67. isbn: 9058505014 (cit. on p. 83).

[188] C. E. Kendig. “What is proof of concept research and how does it generate epistemic and ethical categories for future scientific practice?” In: *Science and engineering ethics* 22.3 (2016), pp. 735–753. doi: 10.1007/s11948-015-9654-0 (cit. on p. 84).

[189] M. Gomes et al. “Extracting behavioural patterns from a negotiation game”. In: *International Conference on Practical Applications of Agents and Multi-Agent Systems*. Springer. 2013, pp. 304–315. doi: 10.1007/978-3-642-38061-7_29 (cit. on pp. 84, 105, 107, 116, 117).

[190] J. O. Cooper, T. E. Heron, W. L. Heward, et al. “Applied behavior analysis”. In: (2007) (cit. on p. 85).

[191] I. Marsa-Maestre et al. “From problems to protocols: Towards a negotiation handbook”. In: *Decision Support Systems* 60 (2014), pp. 39–54. issn: 0167-9236. doi: http://dx.doi.org/10.1016/j.dss.2013.05.019 (cit. on p. 86).

[192] T. J. Dodds, B. J. Mohler, and H. H. Bülthoff. “Talk to the virtual hands: Self-animated avatars improve communication in head-mounted display virtual environments”. In: *PloS one* 6.10 (2011), e25759. doi: 10.1371/journal.pone.0025759 (cit. on p. 87).

[193] I. Witten, E. Frank, and M. Hall. *Data Mining: Practical machine learning tools and techniques*. Third. Morgan Kaufmann, 2011. doi: 10.1016/C2009-0-19715-5 (cit. on p. 91).

[194] L. M. Vizer, L. Zhou, and A. Sears. “Automated stress detection using keystroke and linguistic features: An exploratory study”. In: *Int. J. Hum.-Comput. Stud.* 67.10 (Oct. 2009), pp. 870–886. issn: 1071-5819. doi: 10.1016/j.ijhcs.2009.07.005. url: http://dx.doi.org/10.1016/j.ijhcs.2009.07.005 (cit. on p. 91).

[195] M. Rehm, N. Bee, and E. André. “Wave like an Egyptian: accelerometer based gesture recognition for culture specific interactions”. In: *Proceedings of the 22nd British HCI Group Annual Conference on People and Computers: Culture, Creativity, Interaction - Volume 1*. BCS-HCI ’08. Liverpool, United Kingdom: British Computer Society, 2008, pp. 13–22. isbn: 978-1-906124-04-5. url: http://dl.acm.org/citation.cfm?id=1531514.1531517 (cit. on p. 91).

[196] R. Fells. “Developing Trust in Negotiation”. In: *Employee Relations* 15.1 (1993), pp. 33–45. doi: 10.1108/01425459310024910. eprint: http://dx.doi.org/10.1108/01425459310024910. url: http://dx.doi.org/10.1108/01425459310024910 (cit. on p. 92).

[197] C. Castelfranchi and R. Falcone. “Trust Is Much More Than Subjective Probability: Mental Components and Sources of Trust”. In: *Proceedings of the 33rd Hawaii International Conference on System Sciences-Volume 6 - Volume 6*. HICSS ’00. Washington, DC, USA: IEEE Computer Society, 2000, pp. 6008–. isbn: 0-7695-0493-0. url: http://dl.acm.org/citation.cfm?id=820262.820320 (cit. on p. 92).

[198] M. Kappmeier. “It’s All About Trust – How to Assess the Trust Relationship between Conflict Parties”. In: *Proceedings of the IACM 24th Annual Conference Paper*. 2011. url: http://dx.doi.org/10.2139/ssrn.1872885 (cit. on p. 92).

[199] J. D. Lee and K. A. See. “Trust in automation: Designing for appropriate reliance”. In: *Human factors* 46.1 (2004), pp. 50–80. doi: 10.1518/hfes.46.1.50_30392 (cit. on p. 93).

[200] M. K. Lee. “Understanding perception of algorithmic decisions: Fairness, trust, and emotion in response to algorithmic management”. In: *Big Data & Society* 5.1 (2018), p. 2053951718756684. doi: 10.1177/2053951718756684 (cit. on p. 93).

[201] R. J. Lewicki and B. Polin. “Trust and negotiation”. In: *Handbook of research on negotiation* (2013), p. 161 (cit. on p. 95).

[202] D. Malhotra and J. Murnighan. “The effects of contracts on interpersonal trust”. In: *Administrative Science Quarterly* 47.3 (Sept. 2002), pp. 534–559. issn: 0001-8392 (cit. on p. 96).

[203] L. C. Freeman. “Finding social groups: A meta-analysis of the southern women data”. In: *Dynamic Social Network Modeling and Analysis. The National Academies*. Press, 2003, pp. 39–97. doi: 10.1.1.93.381 (cit. on p. 97).

[204] S. Sanchez-Pages. “Bargaining and conflict with incomplete information”. In: *The Oxford Handbook of the Economics of Peace and Conflict*. Citeseer, 2012. doi: 10.1093/oxfordhb/9780195392777.013.0004 (cit. on p. 100).

[205] M. R. Garfinkel and S. Skaperdas. “Conflict without misperceptions or incomplete information: how the future matters”. In: *Journal of conflict resolution* 44.6 (2000), pp. 793–807. doi: 10.1177/0022002700044006005 (cit. on p. 100).

[206] J. Ye et al. “Using situation lattices to model and reason about context”. In: *Proceedings of MRC* 2007 (2007), pp. 1–12 (cit. on p. 105).

[207] C. Bettini et al. “A survey of context modelling and reasoning techniques”. In: *Pervasive and mobile computing* 6.2 (2010), pp. 161–180. doi: 10.1016/j.pmcj.2009.06.002 (cit. on p. 105).

[208] M. Vrigkas, C. Nikou, and I. A. Kakadiaris. “A review of human activity recognition methods”. In: *Frontiers in Robotics and AI* 2 (2015), p. 28. doi: 10.3389/frobt.2015.00028 (cit. on p. 108).

[209] H. Souto, R. Mello, and A. Furtado. “An acoustic scene classification approach involving domestic violence using machine learning”. In: *Anais do XVI Encontro Nacional de Inteligência Artificial e Computacional*. SBC. 2019, pp. 705–716. doi: 10.5753/eniac.2019.9327 (cit. on p. 109).

[210] S. Chandrakala and S. Jayalakshmi. “Environmental audio scene and sound event recognition for autonomous surveillance: A survey and comparative studies”. In: *ACM Computing Surveys (CSUR)* 52.3 (2019), pp. 1–34. doi: 10.1145/3322240 (cit. on p. 109).

[211] M. Crocco et al. “Audio surveillance: A systematic review”. In: *ACM Computing Surveys (CSUR)* 48.4 (2016), pp. 1–46. doi: 10.1145/28711830 (cit. on p. 109).

[212] M. M. Soliman et al. “Violence Recognition from Videos using Deep Learning Techniques”. In: *2019 Ninth International Conference on Intelligent Computing and Information Systems (ICICIS)*. 2019, pp. 80–85. doi: 10.1109/ICICIS46948.2019.9014714 (cit. on p. 109).

[213] L. Smaira et al. “A Short Note on the Kinetics-700-2020 Human Action Dataset”. In: *CoRR* abs/2010.10864 (2020). arXiv: 2010.10864. url: https://arxiv.org/abs/2010.10864 (cit. on p. 109).

[214] G. Harp et al. “Machine Vision and Deep Learning for Classification of Radio SETI Signals”. In: *arXiv preprint arXiv:1902.02426* (2019) (cit. on p. 109).

[215] D. Keye et al. “Individual differences in response conflict adaptations”. In: *Frontiers in psychology* 4 (2013), p. 947. doi: 10.3389/fpsyg.2013.00947 (cit. on p. 118).

[216] D. Frey, E. D. Johnson, and W. De Neys. “Individual differences in conflict detection during reasoning”. In: *Quarterly Journal of Experimental Psychology* 71.5 (2018), pp. 1188–1208. doi: 10.1080/17470218.2017.1313283 (cit. on p. 118).

[217] Y. Pruksachatkun et al. “Intermediate-task transfer learning with pretrained models for natural language understanding: When and why does it work?” In: *arXiv preprint arXiv:2005.00628* (2020) (cit. on p. 119).

[218] D. Braun et al. “Evaluating natural language understanding services for conversational question answering systems”. In: *Proceedings of the 18th Annual SIGdial Meeting on Discourse and Dialogue*. 2017, pp. 174–185. doi: 10.18653/v1/W17-5522 (cit. on p. 119).

[219] C. Iglesias et al. “Optimising User Experience with Conversational Interface”. In: *Intelligent Environments 2020: Workshop Proceedings of the 16th International Conference on Intelligent Environments*. Vol. 28. IOS Press. 2020, p. 197 (cit. on p. 119).

[220] J. C. Castillo et al. “A multisensory monitoring and interpretation framework based on the model-view-controller paradigm”. In: *Proceedings of the 4th international conference on Interplay between natural and artificial computation - Volume Part I*. IWINAC’11. Canary Islands, Spain: Springer-Verlag, 2011, pp. 441–450. isbn: 978-3-642-21343-4 (cit. on p. 158).

[221] A. Fernández-Caballero et al. “Optical flow or image subtraction in human detection from infrared camera on mobile robot”. In: *Robotics and Autonomous Systems* 58.12 (2010). Intelligent Robotics and Neuroscience, pp. 1273–1281. issn: 0921-8890. doi: 10.1016/j.robot.2010.06.002. url: http://www.sciencedirect.com/science/article/pii/S0921889010001168 (cit. on p. 158).

[222] M. Franceschet. *Network Science*. url: https://www.sci.unich.it/~francesc/teaching/network/ (visited on 04/30/2021) (cit. on p. 164).

Appendix A

System Overview

This appendix depicts the systems architecture .

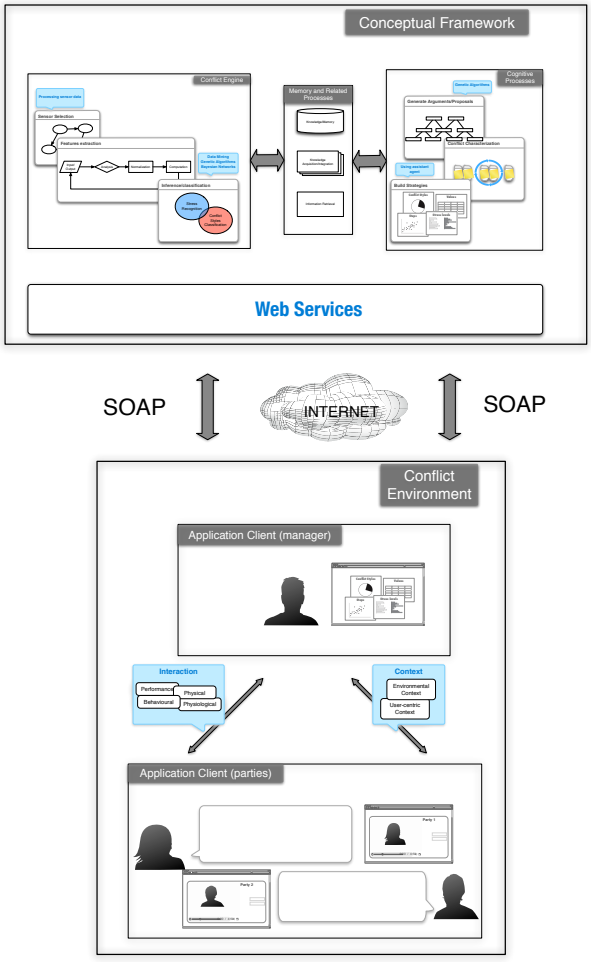


Figure A.1: The graphical representation of the developed system.

Appendix *B*

Conflict Management Platform

The system described in builds on telecommunication technologies and on a conflict management platform that provides a range of services previously developed (e.g., negotiation environment, information retrieval). The plataform was built, taking into consideration the possible integration with other applications. The main intention of this system was to provide a set of public services that external applications may use. These public services implemented the functionalities of the platform and allowed external applications to use them. Moreover, to support interoperable machine-to-machine interaction over a network, a set of Web services, using Simple Object Access Protocol protocol to the structured information exchange, was developed. Other components (like the Conflict Environment) interact with the Web service using SOAP messages, conveyed using HTTP with an XML serialization in conjunction with other Web-related standards. Thus, one major concern was implementing the Conceptual Framework and the Conflict Environment as platform-independent so that the developed applications perform minimum changes to integrate this layer.

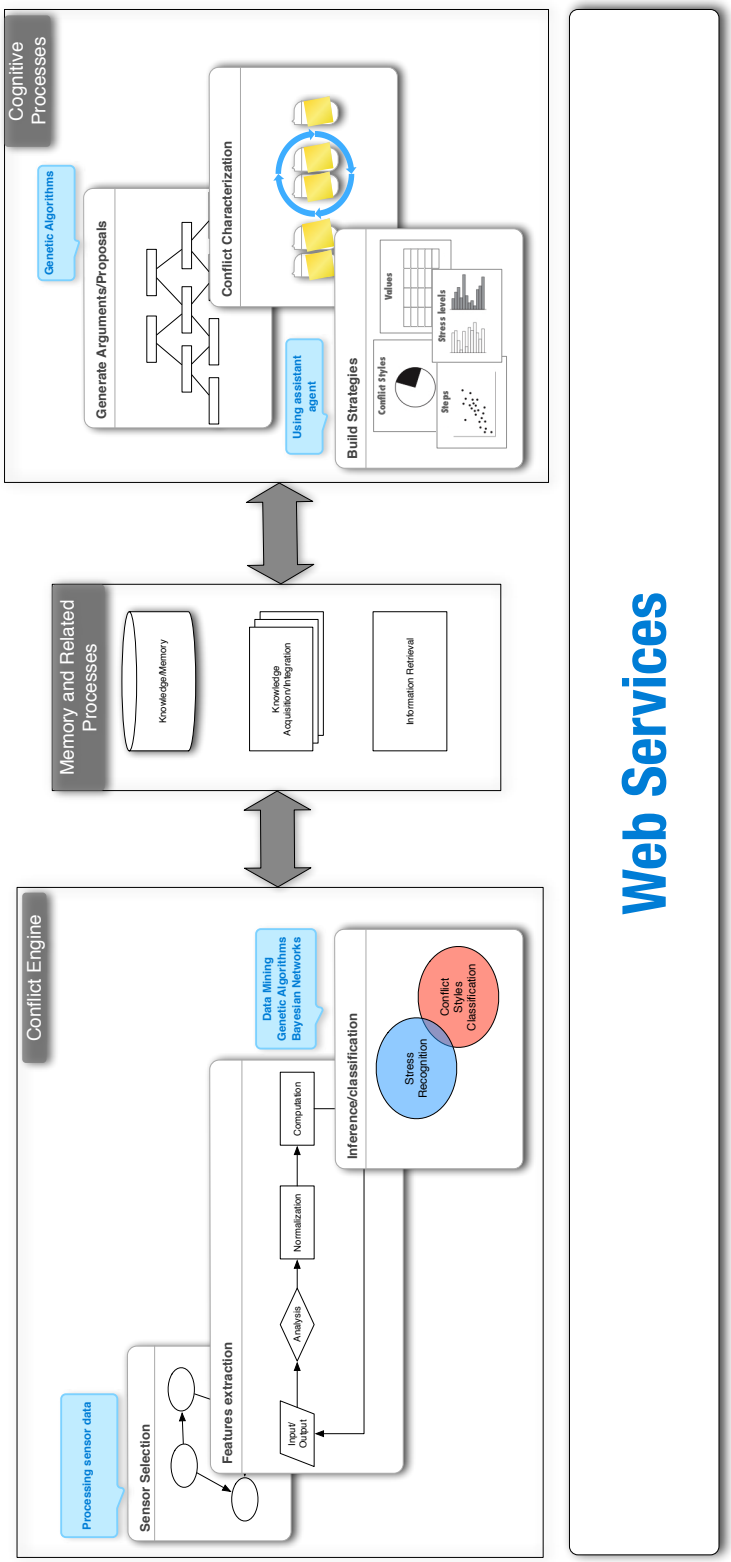


Figure B.1: This Conclifct Management Platform comprises three main components.

Appendix C

Conflict Management System

The Conflict Management system can be depicted in several components. Namely, the Conflict Engine, the Memory and Related processes, and the Cognitive Process component. The Memory and Related processes and the Cognitive Process components are directly related to the low-level technological characteristics. Therefore its detailed description is out of scope. Moreover, the main functionalities of the Conflict Engine component are presented, and a conflict environment (the intelligent environment component of the conflict management system) is briefly depicted.

C.1 Conflict Engine

Information from physical sensors, called low-level context and acquired without any further interpretation, can be meaningless. So, to alleviate this problem, a piece of high-level context information must be derived from raw sensor values. The idea is to abstract from low-level context by creating a new model layer that gets sensor perceptions as input and generates or triggers system actions (represented in Figure C.1).

This can be done through a specification process when high-level information is recognized, i.e., sensor perceptions are aggregated and associated to a human-defined information label using classification techniques. This approach can be widely used in this conflict experiments mainly because conflict scenarios are richer in contextual knowledge. The Conflict Engine (Figure C.2) hosts three functional components that will be described in the following sections.

C.1.1 Sensor Selection

Although many sensors are available in the system, more sensors incur more costs for acquiring information. For making a timely and efficient recognition of user contextual information, it is essential to avoid unnecessary or unproductive sensory actions. This is accomplished by deliberately choosing sensors, i.e.,

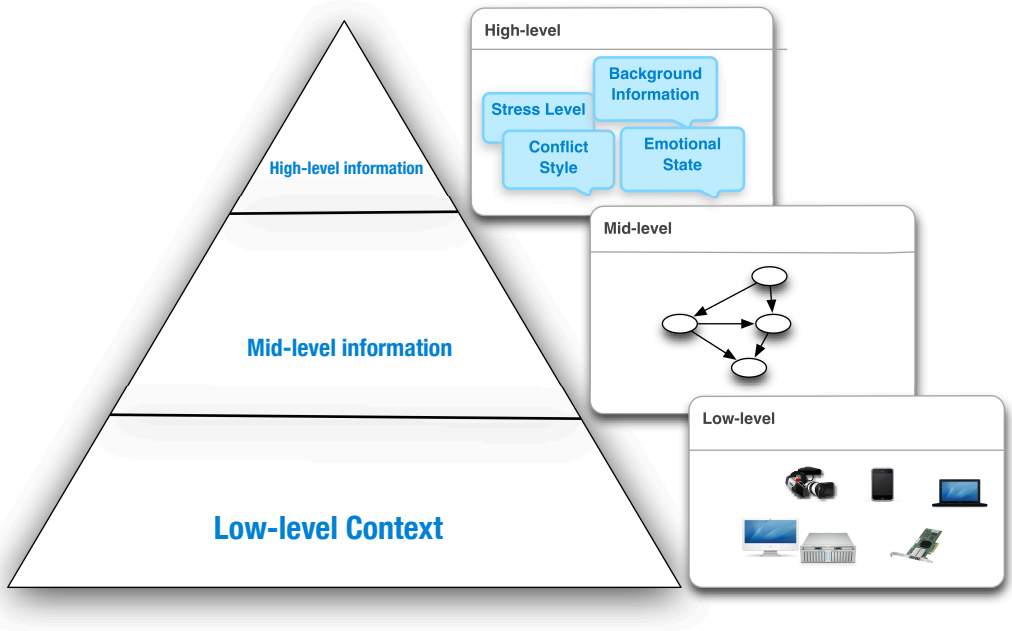


Figure C.1: A generic diagram for representing the levels of information gathering.

performing attempts to identify a set of sensors that achieve the optimal tradeoff between the benefit and cost of the sensors. The cost includes both physical and computational costs. Attending to the number of sensors that are planned to be used in this project, a methodology addressing these issues will be used.

C.1.2 Features Extraction

Extraction of representative features from sensor data is the core of the high-level information model construction. In this stage, the features are extracted from multiple sensor observations and combined into a single concatenated feature vector introduced into the above-mentioned approaches and generate or trigger system actions based on template methods. Due to the limited number of available sensors in the laboratory experiments, only the following features were considered:

- Context features: The dynamic behavior reflects the contextual attributes related to the user's activity within the conflict resolution platform. As stated before, these can be depicted by the user's intention (if he/she wants to achieve an outcome) and by the activity (if the user is an active or passive party in the process). This information can be gathered from the analysis of the actions and the number of actions performed (e.g., the number of parties' proposals). The user-centric background information is composed of several attributes that can be extracted from the user's profile. Using forms is the easiest way to obtain this kind of information.
- Physical Features: Amount of body movement - the amount of movement represents how and how

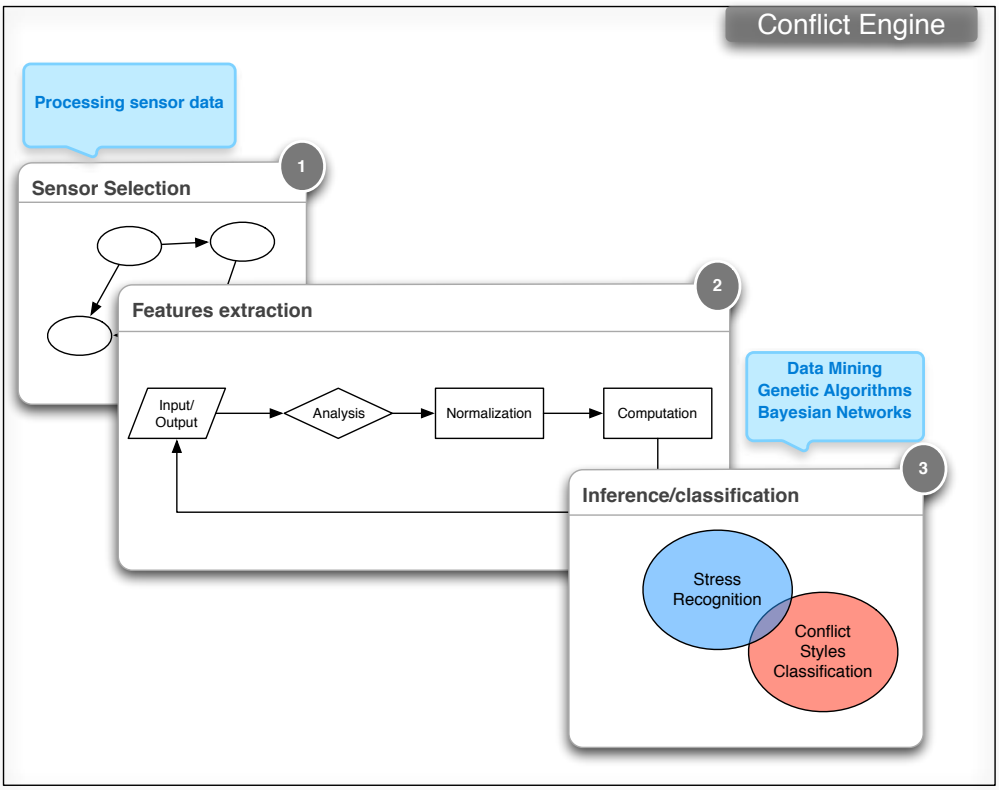


Figure C.2: Conflict Engine module. The number (1) denotes the raw data process component; number (2) denotes the features extraction component; the number (3) denotes de inference/classification component.

much the user is moving inside the environment. An estimation of the amount of movement from the video camera will be considered. The image processing stack uses the principles established by Castillo [220] and uses image differentiation techniques to calculate the amount of movement between two consecutive frames [221].

- Behavioural Features:
  - Touch patterns - the touch pattern represents how a user touches the device and represents a variation of intensity over some time. This information is acquired from touchscreens with support for touch intensity.
  - Touch intensity - the intensity of the touch represents the amount of force that the user is putting into the touch. It is analyzed in terms of the maximum, minimum, and mean intensity of each touch. This information is acquired from touchscreens.
  - Agitation level - the acceleration is measured from accelerometers in mobile devices. It is useful for estimating how much the user is moving and how he is doing it (e.g., is the user

having sudden movements?).

- Performance Features:
  - Accuracy - a comparison between touches in active controls versus touches in passive areas (e.g., without controls, empty areas) in which there is no sense in touching. This information is acquired from touchscreens.
  - Response - this represents the period between the beginning and the end of the user's responses to the conflict resolution demands. This data is acquired from devices with touchscreens.

C.1.3 Inference/Classification Processes

To integrate all the multimodal pieces of evidence referenced in this work was chosen as a decision-level integration strategy. Examples of decision level fusion methods used in this work include weighted decision methods and machine-learning techniques. This component unites all the processes that deal with the data level integration of the contextual and behavioral data gathered from the available sensors.

C.2 Conflict Intelligent Environment

One of the main characteristics of IEs is the key role that the user plays as the focus of the entire process, from the beginning to the end. In other words, the process starts by collecting data about the user and the environment in which the user is situated, and it finishes by acting intelligently for the user. The variety of user types that can be involved in each IE, and the multitude of potential objectives of each particular environment demands an exhaustive analysis of all components to be included. Therefore, an intelligent environment with various devices and functionalities was designed to provide the user's context and state information to the applications being used. In this case, the developed prototype is in the field of conflict management systems. Figure C.3 gives a general overview of the proposed approach. Each user participates in the conflict resolution from his/her real environment. This environment is equipped with sensors and devices that acquire a different kind of information from the user in a non-intrusive way. The aim is, while the user conscientiously interacts with the system and takes his/her decisions and actions, a parallel and transparent process takes place in which contextual and behavioral information is sent in a synchronized way to the conflict management platform. Upon converting the sensory information into useful data, the platform allows for a contextualized analysis of the user's data. The platform itself performs this contextualized analysis (e.g., for performing decision-support-related tasks, like classifying the actual conflict-handling style) and by the mediator. Then, the parties receive feedback from the platform (e.g., a new proposal), which may also include feedback from the state of the parties (e.g., an information field

showing the parties' proposals). All this process is completely transparent to its users. The data about the users' context is collected, processed, and transparently added to the data that will feed Classification processes. The platform operates through a multi-thread client/server model, using network sockets as the interfaces between the application layer and transport. The languages and platforms used for developing this environment were chosen by considering the independence of the operating system and the type of computer system. A more detailed description is made in the following sections.

C.2.1 Manager's Application

The work includes developing and implementing application software for testing and implementing the models mentioned above and techniques. The manager's application developed consists of two independently running Java-based programs: the client and server programs. When 'alive', this Java-based application continuously runs on the server without a graphical interface, managing the workflow information that occurs on the conflict management platform, using network sockets to communicate with other applications.

However,the manager's application can act as a client too. It acts as a client when requests the conflict resolution platform to compute some values and acts as a server when receiving the behavioral and raw contextual data from the parties' applications. Indeed, the manager's application is responsible for coordinating the proposal and contextual data flow within the Conflict Environment by collecting raw data (organized and transferred from the parties' application) and proposal content and sending them to the conflict resolution platform requesting processed data. After receiving the server response (from the platform side), the information is presented to the user (in this case, the conflict manager). The user can now choose what information volume (excluding the received proposal) he/she wants to share with the other party and decide what action must be performed (e.g., finishing the conflict resolution process).

C.2.2 Parties' Application

The fulfillment of the objectives of this work required the idealization of an application that facilitated contextual and behavioral data gathering in web-based means. Thus, it was designed a sensor-based application for the Android Operating System and based on a service-oriented, client-server architecture that combines the Representational State Transfer (REST) protocol and web services for data interchange. The choice of a mobile platform relies on the technological needs that this work has pointed out in previous chapters. Namely, computer-based systems that had the capability of sense interact, store, and manage sensor-based data with the portability and platform-independence requirements, such as smartphones and tablet computers.

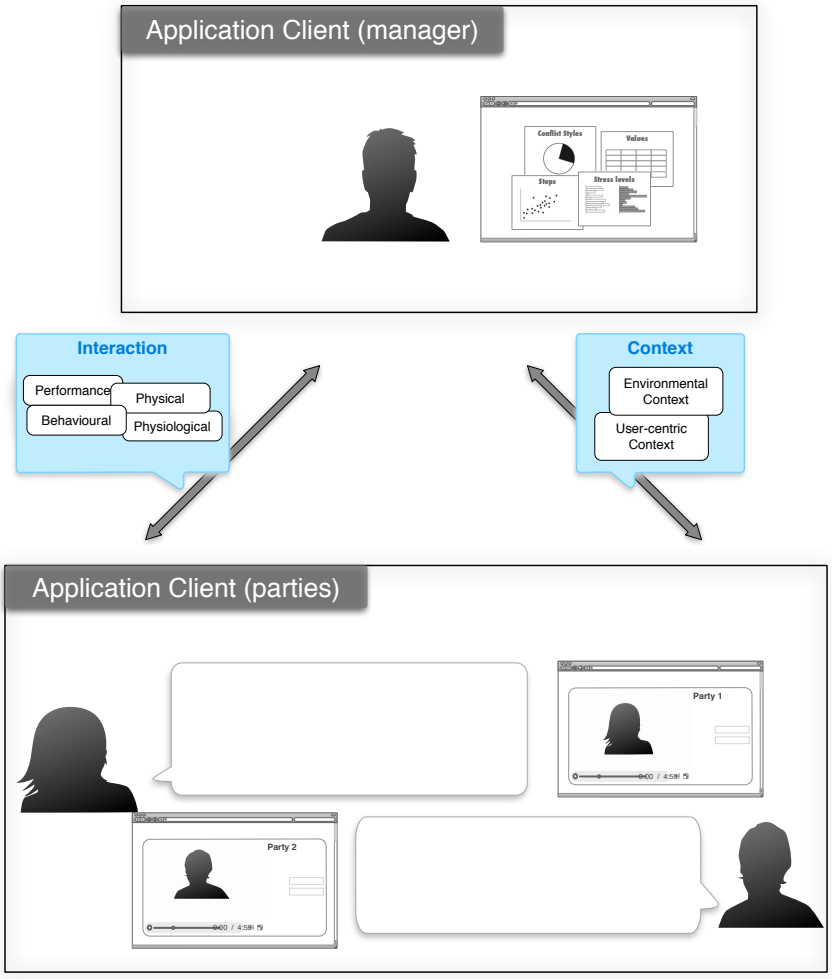


Figure C.3: The graphical representation of the communication flow between the parties and manager applications.

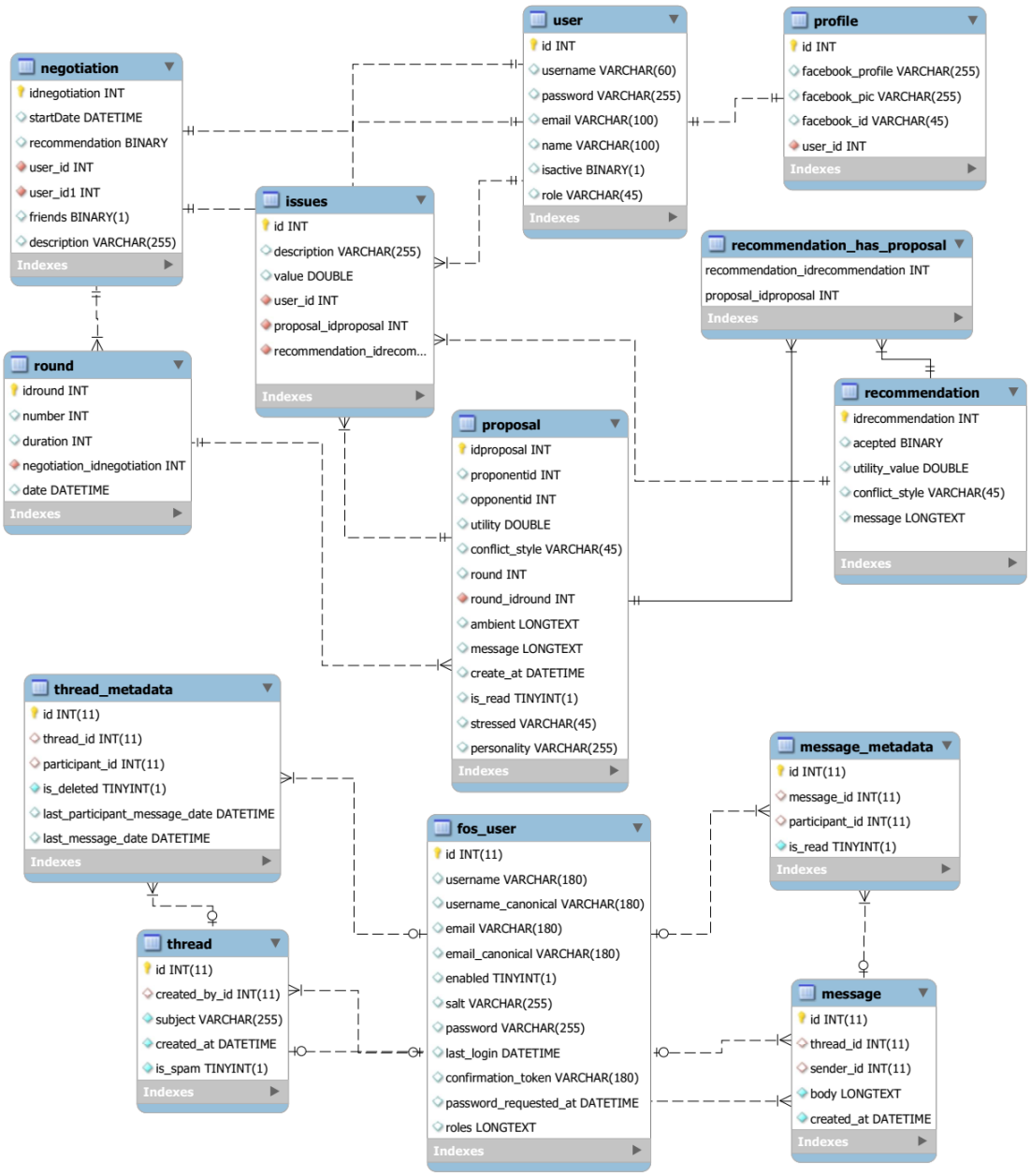


Figure C.4: The database diagram representing the data model suitable to store the information related to the negotiation process in the context of a conflict management session in a digital environment.

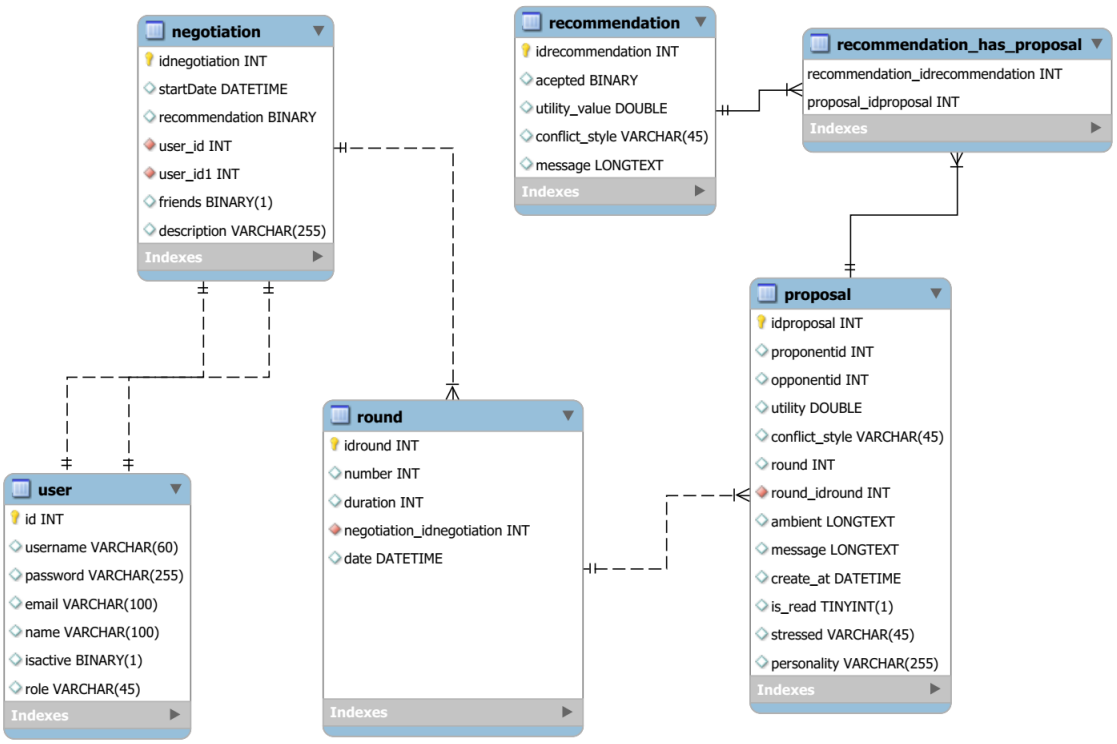


Figure C.5: The database diagram representing the data model suitable to store the information related to the recommendation process in the context of a conflict management session in a digital environment.

Appendix *D*

SNA: Centrality Measures

The SNA measures used in this work (which results applying these *formulae* are published in a conference proceeding [36]) are depicted as follows[1]:

Betweeness Centrality

Betweenness centrality measures the extent to which a vertex lies on paths between other vertices.
Let $n^i_{s,t}$ be the number of geodesic paths from s to t that pass through i and let $n_{s,t}$ be the total number of geodesic paths from s to t. Then betweenness centrality of vertex i is:

$$b_i = \sum_{s,t} w^i_{s,t} = \sum_{s,t} \frac{n^i_{s,t}}{n_{s,t}} \tag{D.1}$$

In-degree Centrality

Degree centrality thesis reads as follows: *A node is important if it has many neighbors, or, in the directed case, if there are many other nodes that link to it, or if it links to many other node*.
Let $A = (a_{i,j})$ be the adjacency matrix of a directed graph. The in-degree centrality x_i of node i is given by:

$$x_i = \sum_k a_{k,i} \tag{D.2}$$

or in matrix form (1 is a vector with all components equal to unity):

$$x = 1A \tag{D.3}$$

[1] Text and definitions extracted from Massimo Franceschet's Network Science web page [222].

The out-degree centrality y_i of node i is given by:

$$y_i = \sum_k a_{i,k} \tag{D.4}$$

or in matrix form:

$$y = A1 \tag{D.5}$$

Eigenvector Centrality

The eigenvector centrality thesis reads: *A node is important if it is linked to by other important nodes*. Let $A = (a_{i,j})$ be the adjacency matrix of a graph. The eigenvector centrality x_i of node i is given by:

$$x_i = \frac{1}{\lambda} \sum_k a_{k,i} x_k \tag{D.6}$$

where $\lambda \neq 0$ is a constant.
In matrix form we have:

$$\lambda x = xA \tag{D.7}$$

Hence the centrality vector x is the left-hand eigenvector of the adjacency matrix A associated with the eigenvalue λ. Therefore, it is wise to choose λ as the largest eigenvalue in the absolute value of matrix A. By Perron-Frobenius theorem, this choice guarantees the following desirable property: if matrix A is irreducible, or equivalently if the graph is (firmly) connected, then the eigenvector solution x is both unique and positive.

Annex I

Newcastle Personality Assessor questionnaire

This appendix shows the NPA questionnaire used on tests. The test case scenario in which the questionnaire was applied, aimed to identify which and how human psychological traits [182] are correlated to features and how they can be pointed out. Therefore, to have a psychological profile of the individual understudy, it was applied this questionnaire, the NPA), supported on scientific literature [141].

Table 6: NPA summarized and applied (adapted to Portuguese) in the experiment reported and published in book chapter .

	Very unlikely	**Moderately unlikely**	**Neither likely or unlikely**	**Moderately likely**	**Very likely**
Starting a Conversation with a stranger					
Making sure others are comfortable and happy					
Creating an artwork or a music piece					
Preparing for things well in advance					
Felling blue or depressed					
Planning parties or social events					
Insulting people					
Think about philosophical questions					
Letting things get into a mess					
Feeling stressed or worried					
Use complex words					
Sympathizing with others' feelings					