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Abstract

The industrial production of garments and similar textile end products is an activity that has roots back to the 19th century, and that has profited immensely from continuous technological developments since its first emergence. However, several characteristics of the materials that are processed give rise to technical issues that are difficult to objectively manage and control.

The limpness and elasticity of textiles make automated material handling and transportation within the shopfloor, and at the individual assembly operations, very difficult to automate. Another important aspect is the unpredictable behaviour of the materials when they undergo the manufacturing operations. Particularly in sewing operations, most of the process design is still based on subjective and empirical judgement. The machines, although often equipped with complex devices to aid in material handling, are blind regarding the process itself; they run with an initial set-up and are neither capable of adapting to varying sewing conditions nor can they detect anomalous operation.

The current market trends, with an increasing variety of materials and styles, combined with small production runs, stress the significance of machine and production system set-up times. The importance of better control over quality at both the design and manufacturing stages is also much greater now than in the past. Another motivation for objective process control is the growing need to quantitatively monitor and even document sewing conditions concerning *high-tech* seams (air bags, safety belts, technical textiles), in the framework of quality certification.

This work is integrated in a project that intends to measure and analyse several sewing variables in-process, in order to develop objective tools to plan, monitor and control the process. A sewing test rig has been set up in previous work, based on an industrial overlock machine. Several variables related to stitch formation, material feeding and needle penetration, are being measured dynamically.

This thesis has been developed according to two fundamental objectives, namely:

- Development of specific tools for sewing parameter measurement and analysis;
- Study the effect of needle penetration and the possibility of its automatic monitoring.

To accomplish these two objectives, it was necessary to fulfil a series of tasks of different nature.

The development of the sewing test rig involved in the first place the cooperation with the other researchers in the project. Support to the design of new measurement devices was provided, and these devices were added to the sewing test rig and integrated into its software. Processing tools were developed.

In the course of this work, the sewing test rig was extensively enhanced with new functions related to acquisition, analysis, graphical display, sensor calibration, file I/O and data management. The ease of use was greatly increased by these functionalities and by redesigns of the user interface. In the background, a constant evaluation and revision of the software code's structure allowed an ordered expansion of the system.

Ultimately, all the relevant processing tools were gathered and integrated into a set of test modules, allowing an automatic computation and quick display of a collection of parameters describing sewing efficiency in all aspects. During this development process, new functions beyond those already existing in the initial software versions were conceived.

The study of needle penetration, by its turn, involved in first place the study of the measurement set-up, with all effects involved. A careful examination of needle-bar force signals led to a new software application with which the measurement process could be simulated. This application would serve to study the accuracy of the processing methods and to optimise them. Other approaches to signal processing were evaluated, but it was not possible to find any advantage over the adopted spectral filtering method. A trial to increase measurement accuracy was made training a neural network to correct the results provided by the existing processing methods. The network was trained and tested with data generated by the simulation program.

Finally, an experimental plan was designed to study needle penetration forces related to various factors, and to evaluate the effectiveness of the measurement method. Although this experiment was specifically designed to analyse needle penetration variables, the feeding system and stitch formation performance were also evaluated. The results found point to the possibility of designing monitoring and control algorithms for several sewing parameters, concurrently with process planning and material testing tools. A brief insight into possible industrial applications and suggested future work is also presented.

Resumo

A produção industrial de vestuário e outros produtos têxteis confeccionados tem raízes no século 19, tendo desde então beneficiado extraordinariamente de um constante desenvolvimento tecnológico nos sistemas e equipamentos de produção. No entanto, as características dos materiais processados nesta indústria originam diversas questões técnicas cuja resolução objectiva é difícil.

Devido à flexibilidade e elasticidade dos materiais têxteis, a sua manipulação nas operações de montagem, bem como o seu transporte na linha de produção, são extremamente difíceis de automatizar. Outro aspecto a realçar é a imprevisibilidade dos materiais quando sujeitos às operações de fabrico. O planeamento do processo e a configuração e ajuste dos equipamentos baseiam-se sobretudo em processos empíricos e de avaliação subjectiva, especialmente nas operações de costura. As máquinas de costura, embora em alguns casos equipadas com complexos dispositivos de manipulação, não têm qualquer controlo sobre o processo de fabrico em si. São utilizadas com um ajuste e configuração definidas antes do início de produção, não tendo a capacidade de se adaptarem a condições de costura variáveis ou de detectarem anomalias de funcionamento.

No contexto actual do mercado, em que se assiste a uma crescente variedade de materiais e modelos, combinada com séries pequenas, o significado dos tempos de reconfiguração e ajuste dos sistemas e equipamentos de produção torna-se cada vez mais relevante. Assiste-se assim a um crescimento da importância do controlo sobre a qualidade, tanto nas fases de desenvolvimento como nas do fabrico do produto. Outro factor de relevância é a crescente necessidade de monitorizar quantitativamente e documentar as condições de costura em aplicações técnicas (*airbags*, cintos de segurança, outros têxteis técnicos), no contexto da certificação de qualidade.

Este trabalho insere-se num projecto em que se pretende medir e analisar diversas variáveis do processo de costura em tempo real, de modo a desenvolverem-se ferramentas para planeamento objectivo do processo, bem como métodos para monitorização e controlo do mesmo. Em trabalho anterior, foi criado um banco de ensaios baseado numa máquina industrial tipo corta-e-cose. Este banco de ensaios efectua a medida dinâmica de variáveis relacionadas com a formação de ponto, alimentação de tecido e penetração da agulha.

O trabalho de investigação documentado nesta tese foi desenvolvido tendo em conta dois objectivos principais:

- O desenvolvimento de ferramentas específicas para a medição e análise de parâmetros de costura;
- O estudo do efeito da penetração da agulha e da possibilidade de implementar a sua monitorização automática.

Para cumprir estes objectivos, foram realizadas tarefas de âmbitos diversos.

O desenvolvimento do banco de ensaios envolveu em primeiro lugar uma cooperação estreita com os restantes investigadores no projecto. Foi desse modo possível desenhar novos dispositivos de medida e ferramentas de análise, que foram integrados no sistema existente.

No decurso dessa tarefa, o banco de ensaios foi extensivamente complementado com funções relacionadas com aquisição, análise, visualização gráfica, calibração de sensores, e armazenamento e gestão de dados. A facilidade de utilização do sistema

foi significativamente melhorada com estas funções, como também com constantes revisões da interface com o utilizador. Em paralelo, uma avaliação e reformulação constante da estrutura do código-fonte do software permitiu uma expansão ordenada do sistema.

As funções de processamento relevantes foram finalmente integradas num conjunto de módulos de cálculo específicos. Estes possibilitam um rápido cálculo e visualização de parâmetros que descrevem a eficiência do processo em diversos aspectos.

Por sua vez, o estudo da força de penetração da agulha visou em primeiro lugar a implementação física da medição, com todos os efeitos envolvidos. O estudo detalhado dos sinais de força sobre a barra de agulha permitiu o desenvolvimento de uma aplicação para simular todo o processo de medida, que viria a ser utilizada para a avaliação e optimização do mesmo. Foram analisados vários processos de filtragem alternativos ao da filtragem espectral, criado no início deste trabalho, mas não se conseguiram demonstrar vantagens evidentes sobre este. Uma tentativa final para melhorar a exactidão da medida foi empreendida utilizando redes neuronais. Para o efeito, foram criadas redes com o propósito de corrigir os resultados fornecidos pelos métodos de processamento existentes. O seu treino foi efectuado com dados gerados pelo programa de simulação.

Finalmente, foi feito o planeamento de uma experiência para avaliar a relação da força de penetração da agulha com diversos factores, bem como a eficiência do processo de medida. Apesar de esta experiência ter sido projectada com o intuito de analisar a força da penetração da agulha, foi também possível estudar o comportamento dos parâmetros relacionados com a alimentação dos tecidos e com a formação de ponto. Os resultados encontrados indicam que é possível o projecto de dispositivos de monitorização e controlo automático, concorrentemente com ferramentas de teste de materiais e planeamento do processo. O trabalho apresenta por fim uma breve resenha de aplicações futuras que poderão daí resultar.