User-centered support to localized activities in ubiquitous computing environments

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Abstract. The design of pervasive and ubiquitous computing systems must be centered on users' activity in order to bring computing systems closer to people. The adoption of an activity-centered approach to the design of pervasive and ubiquitous computing systems should consider: a) how humans naturally accomplish an activity; and b) how computing artifacts from both the local and personal domains should contribute to the accomplishment of an activity. This work particularly focuses on localized activities performed by occasional visitors, i.e., activities having a strong association with a specific physical environment, which may be visited by people who are not accustomed to it. We are investigating how ubiquitous computing environments can provide user-centered support to localized activities, by exploring activity specification models and mechanisms allowing for the integration between local and personal environments.

1 Introduction

Ubiquitous computing environments promise to transparently support people in their daily activities by leveraging computing resources existent in the physical environment. However, two major challenges have not yet been solved: firstly, mobile users still do not have much support in the accomplishment of activities that go beyond the virtual workspace, particularly activities that are strongly related with the physical environment in which they are performed; and, secondly, the application- and document-centered paradigms remain the central interaction models, despite their strong limitations for mobility scenarios. In order to bring computing closer to people, the design of ubiquitous and pervasive computing systems must be centered on the user, particularly on the user activity [1, 2]. Designing ubiquitous and pervasive computing systems so that user activity is handled as a first class object enables those systems to transparent and effortlessly meet user expectations, relieving users from the current burden of dealing with computer applications. The adoption of an activity-centered approach to the design of pervasive and ubiquitous computing systems should consider: a) how humans naturally accomplish an activity; and b) how computing resources from both the environmental and personal domains should contribute to the accomplishment of an activity.

Activity Theory [3] sets the ground for the psychological aspect of activity-centered computing by defining a theoretical framework for analyzing activities. We, as designers and developers of ubiquitous and pervasive computing systems, must understand how people perform their activities: which actions may compose an activity and what is their usual sequence; which operations and tools are required for the conditions in which an activity may unfold; how to design tools so that users are not distracted; how does context influence actions, operations, and required tools; and how to support the evolution of an activity and the different ways it may be performed by different people.

The following section details the association between computer-supported human activity and its physical environment, describing the concept of localized activity and the role of the integration between resources from both local and personal domains. Section 3 presents some of the previous research that relates with our current work. Section 4 is a simple scenario illustrating our vision and finally Sect. 5 describes the approach we are taking for accomplishing the support to localized activities performed by occasional users.

2 Computer-supported activity and its environment

Computer-supported activities and the physical environments in which they take place have different levels of association. Some activities can be performed everywhere, as long as there appropriate resources, and their relevance is not associated to the physical environment (e.g., managing e-mail or editing a report). The user may possibly need to explore some local resources (e.g., a display, a keyboard, connectivity, etc.), but these are not specific to the activity and can also be found elsewhere. On the contrary, other activities are closely related with specific physical environments. In this work, we are addressing *localized activities*, which we see as those activities that have a strong association with the physical environment, i.e., activities that can only be accomplished in specific places (e.g., visiting a relative at the hospital or visiting an exhibition at the museum). We are particularly interested in physical environments that may be occupied by people that are not used to live or work in that place – *occasional visitors*. These people may not have *a priori* knowledge about the environment, and they possibly want to know which activities can be accomplished in place, or how they can achieve them, or even how they can be supported by the ubiquitous computing environment. This does not happen with day-to-day home or work place activities, which, although possibly having a strong association with physical space, do not pose the same challenges referred above, i.e., people is accustomed with the physical environment, possible localized activities, and how the ubiquitous computing environment can support them.

In this work, two aspects of Activity Theory are particularly investigated with respect to ubiquitous computing support to localized activities: a) the flexible structure of an activity; and b) evolution of activity influenced by historical and social forces. A localized activity may be carried out in a variety of ways by employing different actions under different conditions. Individual characteristics and changing local and personal context are the factors driving the structure of a localized activity. For example, the activity of visiting a museum may employ different actions and operations, depending on the visitor age (e.g., adults are mainly interested in observing artworks and learning about their details, while children would prefer to play an artwork-related game), preferences (e.g., devoting more visit time to roman artwork than to Visigothic pieces), available resources (e.g., viewing additional information about an artwork in a personal or local display vs. being directed to the museum's library when no display is available), or context (e.g., planning the visit route in function of available time or crowdedness). The specification of the support to a localized activity should thus provide that required flexibility, comprising the identification of the different combinations of goals (and respective actions) that may compose an activity, along with the possible conditions (and respective operations) under which each action may be executed. Decomposing an activity into different levels of granularity and identifying individual characteristics and context elements applying to each sub-component of activity should provide the means for specifying the support to a localized activity with the required flexibility.

Social interaction and historical background should also be considered in the support to a localized activity, especially in occasionally visited environments, where sharing experiences between users and recording experiences for future remembering are of special relevance. The way a localized activity is performed may develop along time. New types of resources may become available, better processes may be unravelled, etc. As stated by Bardram [4], an activity plan should be flexible enough to allow adaptation to variable circumstances and to integrate feedback from users. A localized activity evolves based on accumulated experience, and thus this experience should be kept for future accomplishments. Moreover, social interaction plays an important role in the dissemination of experience. Experience is generally shared between people (e.g., adults to children, teachers to students, etc.). Thus, besides mechanisms for experience memory, learning, and configurability, the support to a localized activity should also include mechanisms for experience to be shared among people.

In our view, providing support to localized activities in a user-centered manner (personalized, context-aware, and without obliging users to considerable efforts) requires a thorough knowledge about both the local and personal environments, and can only be accomplished with a strong integration between both these environments. Personal environments – devices, applications, preferences, context information, etc. – are the driver for the user-centered aspect of the support to localized activities, whereas local environments provide the association with the elements in the physical environment of the activity. Personal environments cannot be prepared beforehand to support all possible activities users may perform in the many different physical environments to which they can move. Activities associated to a specific place have particular characteristics that cannot be foreseen by someone developing pervasive computing systems to be used in any location. Additionally, details about activity unrolling that may differ between individuals (e.g., supporting an activity performed by a blind person) are better determined locally than by some external personal entity. It is thus reasonable to expect that support to a localized activity is better managed by the local environment (or by some local entity, e.g., a city council centrally supporting activities that may be unrolled in the city area), which owns most of these knowledge and resources, than by the personal environment, which knows the user domain but is hardly aware of details regarding activities that may be locally unrolled.

3 Related work

Existing location-based services, e.g., mobile network operator (MNO) portals, can be seen as a form of support to localized activities in that they can provide information that is related with the user's current location. However, they are too generic to provide real value to satisfy specific user needs and are generally not able to explore the resources that may be available in the physical environment. Location-aware systems that are targeted at specific environments (e.g., museum assistants) can be made to fully explore the capabilities of the local infrastructure to support a localized activity. However, they lack the integration with personal resources, either treating users anonymously, thus hindering personalization, or offering their own user identification mechanism, obliging users to deal with possibly different interaction mechanisms and to manage several duplicates of their personal data across different environments.

Project Aura [2] implements the concept of task-driven computing by capturing user intent and mapping it into a task corresponding to a set of abstract services, which are further concretized by the environment infrastructure providing continuous support to user tasks regardless of the environment in which the user is. What mainly distinguishes the work presented in this paper from Aura is the location scope of an activity and how much the user is accustomed with the activity in that location. While Aura addresses daily routine activities that may span more than one location, our work is targeted at activities with a strong association to a specific, occasionally visited location.

Christensen and Bardram [1] also grounded on Activity Theory to develop a pervasive computing system supporting collaborative activities within specific environments. However, unlike our work, their effort is centered on environments where users are well-known and not for situations where the user population is dynamic and unknown, which requires a special attention to issues regarding integration with personal environments.

Our previous work in the VADE project [5] introduced the concept of Value ADded Environment as an administrative and physical domain where the locally available computing facilities can be combined with the personal environment of visiting users. The overall scenario is that when entering a VADE, mobile users are provided with functionality that corresponds to the dynamic combination of predefined preferences, currently active applications, current user context and locally available services and applications. This approach successfully attains some level of integration between personal and local environments. However, the system does not consider the concept of activity in the functionality provided to users. It would be valuable to enrich the integration possibilities to other types of personal environments (not only web portals) and to broaden the user interaction means beyond the personal device (e.g., using local displays).

4 Scenario

A scientist - João - was invited for a talk in a seminar on computer science taking place at the University of Minho. The seminar organization deployed a localized activity support through which seminar participants are provided with assistance during the seminar activity. Each speaker was previously sent an invitation code through SMS, which is further used for identification purposes when arriving at the University of Minho. The support to the seminar activity is composed of a variable sequence of actions: going to the seminar room, attending to seminar talks, making a talk, meeting seminar participants, etc. Each action is decomposed in a set of operations (e.g., setting up the personal laptop, controlling the overhead projector, etc., for making a talk) requiring different resources from both the local and personal environments. Depending on user context, some of the actions/operations may not be performed or their order may vary, and required resources may be allocated between local and personal environments, depending on their availability and adequateness to context.

When arriving at the university main hall, João sees a public LCD display which he guesses may provide him with help. Just below the display, he sees an infra-red receiver to which he beams the seminar invitation code. The University of Minho ubiquitous computing infrastructure associates that code to the seminar activity and shows through the display some initial support to João, e.g., instructions explaining him how to go to the room where the seminar takes place. João is told to browse in his PDA through his MNO portal for more advanced help. He logs in the portal and is now presented with an additional portal functionality called "Seminar at University of Minho" corresponding to the support to that localized activity. The support begins with detailed guidance to the seminar room; when in the seminar room, João browses through the scheduled talks and reads detailed information about talks and respective speakers; when the time comes to his talk, the activity support allows him to control the overhead projector; after the end of the talk and discussion, João can save in his PDA a sound record of the discussion which he may analyze later; at the conclusion of the seminar, João is asked to fill in a survey about the quality of the seminar. The activity support always include directions to the bar, toilets, and, at lunch time, to the restaurant (including the menu).

5 Proposed approach

The vision supporting this work poses essentially two categories of challenges: activity management (specifying an activity and managing its accomplishment) and resource management (composing and coordinating the resources needed for the activity unfolding). These research tasks are further described, along with our proposal of an architecture for supporting localized activities, which we intend to instantiate in our initial demonstrative scenario.

5.1 Activity modelling

Although not intending to contribute especially to the field of activity specification or task-description languages, this work has to explore previous results in the field [2, 6, 7] in order to define a comprehensive model for the representation of a localized activity, considering different purposes:

- identifying which localized activity the user may be interested in accomplishing - this involves matching activity descriptions with personal profile, preferences, context, and resources.
- describing the activity plan - which actions and operations compose the activity, how context influences activity, which resources are required in each stage of activity, etc.
- interrupting and further resuming activity - here, activity description must be more concrete, defining who was unrolling the activity, what had been done before interruption, or what is needed (resources, context, etc.) for resuming activity.
- remembering or sharing an activity experience - this activity description must be preferably in a human-understandable language, although it may also include a machine-understandable version so that the experience may be re-instantiated in the local infrastructure by the same person or by whom it was shared with.
- customizing activity experience - this involves defining which parts of the activity structure may be customizable and how the customization can be done. The end result of an activity customization could be the machine-understandable version of the description for remembering or sharing purposes.

5.2 Integration with personal environment

The integration between local and personal environments begins at the moment when a new user enters in the physical environment and ends when the user leaves. The first integration stage is the detection of the personal environment and interaction with it in order to determine the user's profile, preferences, context, and available resources. This work considers that a ubiquitous computing environment should not impose any special technology to its users, but rather cover a wide range of heterogeneous personal environment types. Therefore, different mechanisms should be devised for detecting users, as long as interacting with different types of context providers, profile types, resources, etc., which may last for the whole activity experience (e.g., keeping information about user context or available resources up to date throughout the activity). Secondly, advertising possible activities and supporting the activities themselves, possibly requires from the local infrastructure to integrate the user interaction mechanisms into different types of personal environments, unless the interaction is performed uniquely through local means. To deal with this issue, this work builds on existing solutions for multi-modal and multi-channel interfaces [8]. Both these issues require a technical survey of existing types of personal environments, studying their communication protocols, APIs, information representation formats for context, profile, and preferences, presentation languages, etc.

5.3 Architecture

Aiming at dealing with both issues of activity management and integration of local and personal environments, we propose an architecture for supporting localized activities (see Fig. 1), which imports some ideas from the Aura architecture [2], and is also designed to separate user interaction from data and logic.

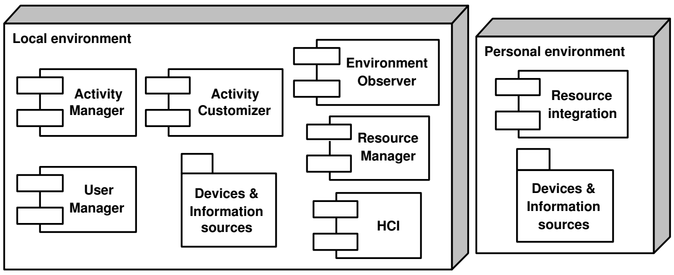

Fig. 1. Architecture

Activity Manager – keeps specifications of one or more localized activities and, each time a user enters the environment, is responsible for checking which activities can be unrolled; manages the sequence of actions/operations, depending on the user and local context; manages activity interruption and later resumption; is responsible for providing feedback to users.

Activity Customizer – provides mechanisms for managing customization, remembering, and sharing of localized activities by users.

Resource Manager – allocates local resources to activities, managing possible situations of concurrency between multiple users; evaluates resource characteristics in order to select the optimal configuration; discovers available personal resources and manages the access to them.

Environment Observer – detects users entrance, changes in users' context, or user interaction signals, either by means of local sensors or through operations executed by users.

User Manager – keeps users' information specific to localized activities they have been carrying out (e.g., activity state for later resumption, activity description for further remembering, etc.).

Human-Computer Interaction component – presents information to and accepts input from users, either through local devices or through the personal environment.

Local devices and information sources – local resources managed by the Resource Manager.

Resource integration – mechanisms allowing for the discovery (by the local Resource Manager), access, and integration of personal resources into the flow of localized activities.

Personal devices and information sources – personal resources to be managed by the local Resource Manager.

5.4 Validation scenarios

We are developing a group of representative scenarios, in which people are more or less equipped and their personal environments embody different types (e.g., a personal profile in a web portal, a personal ICQ number, etc.). In our initial prototype, we are building on the VADE infrastructure [5], which sets a basis for the integration between local and personal environments, seeking to augment it with an activity-centered approach, by adapting it to the architecture here defined. In our initial scenario (see Sect. 4), the local environment corresponds to the University of Minho ubiquitous computing infrastructure and is characterized as follows. The Activity Manager is responsible for following the sequence of actions/operations during the seminar, depending on the user and local context; it is also responsible for providing feedback to users about how the activity is being unrolled. The Resource Manager only knows about João's PDA and personal service environment and manages local resources, either for local use, e.g., controlling the overhead projector, or for integration with the MNO portal, e.g., providing the access to the local functionality supporting the activity. The Environment Observer processes information coming from the infra-red receiver and both from user interaction and context information. The HCI component is constituted by markup code locally generated and integrated into the portal page. Local devices and information sources include the public LCD display, the overhead projector, the sound recorder, maps, instructions, the restaurant menu, and seminar details. João's personal environment is composed of the invitation code, a PDA with connectivity, his MNO portal and personal service environment [9]. The integration of the support to the seminar activity into João's MNO portal is made possible by providing the seminar invitation code to the portal service, which is thus able to integrate local functionality when João enters the University of Minho area.

Further versions of the prototype will concretize more advanced scenarios, in which we will improve the support to heterogeneity, by developing the integration with other types of personal environments other than portal services. We will also develop our activity model by including the support to activity interruption/resumption, remembering, sharing, and customization.

6 Conclusion

This work investigates how ubiquitous computing environments can offer user-centered support to localized activities performed by occasional visitors, i.e., activities having a strong association with a specific physical environment, which may be visited by people who are not accustomed to it. In our view, this can only be accomplished by: a) understanding the way humans achieve their activities; b) by applying this knowledge to the modelling of the ubiquitous computing support to activities; and c) by integrating the local infrastructure with the personal environment, so that the support is user-centered. Our work thus explores activity specification models which are adequate to the support to localized activities and mechanisms allowing for the integration between local and personal environments. An initial prototype is being developed, putting into practice our previous experience in the integration between local and personal environments and extending it with the concept of activity.

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