SUPPORTING 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. Adopting an activity-centered approach to the design of pervasive and ubiquitous computing systems leads us to seek to understand: a) how humans naturally accomplish an activity; and b) how computing artifacts from both the environmental and personal domains may contribute to the accomplishment of an activity. This work particularly focuses on localized activities, i.e., activities having a strong association with a specific physical environment. This work investigates how ubiquitous computing environments can publish and offer user-centered activity support to users with heterogeneous personal environments, by exploring mechanisms allowing for the integration between local and personal environments.

1. Introduction

Mobile computing has been allowing people to perform activities that before were confined to fixed devices. Furthermore, ubiquitous computing environments promise to transparently support people in their activities, by leveraging computing resources existent in the physical environment [17]. However, these evolutions did not solve yet two major challenges: firstly, mobile users still do not have much support in the accomplishment of activities that go beyond the virtual workspace, such as activities that are related to, and rely on resources from, the physical environment; and, secondly, people have still to deal with the application- and document-centered paradigms, which are both inadequate for mobility scenarios, and never were truly successful in office-like ones [9].

This work argues that the design of computing systems, specially ubiquitous and pervasive computing systems, must be centered on the user, particularly on the user activity, in order to bring computing systems closer to people. Other authors have been proposing the same argument [2, 4, 14]. 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 users' expectations, relieving users from the current burden of dealing with computers [12]. A user-centered system is oriented to provide users with rich, personalized, context-aware information, in a graceful and non-obtrusive manner. It has to have some knowledge about users and a full awareness of the resources available in users' environment, providing users with physical and logical artifacts that support their current activity. Adopting an activity-centered approach to the design of pervasive and ubiquitous computing systems thus leads us to seek to understand: a) how humans naturally accomplish an activity; and b) how computing

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artifacts from both the environmental and personal domains may contribute to the accomplishment of an activity. The former issue is studied from the perspective of Activity Theory, while the latter corresponds to analyzing the integration between local and personal computing artifacts in the support to an activity. This work particularly focuses on *localized activities* – activities having a strong association with a specific physical environment and, consequently, to local computing artifacts.

1.1. Activity Theory

Activity Theory [7] 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 tools (particularly computers) must support each operation; how to design tools so that users do not lose attention in their actions/activity; which context variables may influence the activity unfolding, i.e., how does context influence actions, operations, and required tools; how to support the evolution of an activity and the different ways it may be performed by different people; and how to naturally combine social interaction and computer-supported activities.

1.2. Localized activities

Activities and the physical environments in which they take place have different levels of association. There are activities that can be performed everywhere and their relevance or interest is not associated to the physical environment (e.g., managing e-mail). 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. Other activities can only be accomplished in specific places (e.g., visiting a relative at the hospital) or can be achieved in different places, but only in specific ones they acquire a special relevance or interest (e.g., on-line shopping vs. traditional shopping). This work concentrates on localized activities, i.e., activities that have an important association with the physical environment (depending on or being relevant in a specific place).

Localized activities depend on resources that are specific to the physical environment in which they are accomplished. For example, while a document can be edited in several locations, provided that the document is globally available and that the local environment has input/output devices and a text editor, people visiting an exhibition at the museum mainly need information that is related to that specific physical environment (e.g., guidance, visit suggestions, artwork details, etc.). Providing this location-based information 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 about how to integrate them. Moreover, the support to a localized activity involves the consideration of aspects like the possible flows of actions and operations, required local, personal, and global resources, and dynamic composition of all these elements. It is thus reasonable to expect that the support to a localized activity is better managed by the local environment, which owns most of these resources (or knowledge about them), than by the personal environment, which knows the user domain but is hardly aware of details regarding activities that may be locally unrolled. Furthermore, personal environments cannot be prepared beforehand to support all possible activities users may perform in the different environments they move between.

1.3. Integrating local and personal environments

Local environments provide physical and logical resources (e.g., display, interaction surfaces, sensors, information services, applications, etc.) consumed by the user or by personal applications. The local environment may adopt either a passive behavior, in which users (or some surrogate) have to discover available resources and interact with them, or an active role, by detecting users and pro-actively providing them with relevant information, either by pushing it to a personal device or through a local device. A common limitation in local environments is the lack of integration with personal resources, either treating users anonymously, thus hindering personalization, or offering its 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.

A personal environment is an individual's familiar computing space, with personalized features, concretizing the individual's presence in a computing system. Possible elements of a personal environment may be, for example, preferences, context information, documents, applications, etc. The personal environment may be inside a specific personal device (e.g. a PDA, a personal server [16], etc.) or managed by a global entity, like, for instance, a Personal Service Environment [1] in a mobile network operator. The integration of personal environments with local infrastructure can be accomplished by personal applications with some sort of location-awareness. However, they are either targeted at very specific activities (e.g., tourist guides or museum assistants) or too generic to provide real value to satisfy specific user needs (e.g., mobile portals). These systems are generally not able to fully explore the resources that may be available in the physical environment. Furthermore, most of this kind of prototypes were developed for a specific ubiquitous computing infrastructure, thus not addressing the potential heterogeneity of ubiquitous computing environments.

Localized activities require resources both from the personal and local scopes. The personal environment is the major driver for a user-centered perspective of activity, while the local environment provides most of the resources required by the activity in order to be successfully carried out in that place. Therefore, this work argues that integrating local and personal environments is a fundamental requirement for the user-centered support to a localized activity.

1.4. Hypothesis

The research hypothesis of this work is that *ubiquitous computing support to localized activities is better accomplished by integrating both local and personal environments*.

2. Related work

The concept of activity (or task) has been applied in several works in computer science. As an abstraction, the concept of activity has to be concretized in a machine-understandable manner. For example, robotics [13] and agent-based systems [10] use task descriptions to define the behavior of autonomous entities. Workflow [5] and computer-supported cooperative work [3] systems also use formal descriptions to model human activities. Unlike workflow systems, in which computational activity dictates human activity (users follow a pre-defined flow of actions to accomplish organization's goals), this work considers rather that human activity influences computational activity (the user context may determine changes in the activity plan) [4].

Another area exploring the specification of activity is task-driven computing [15]. Project Aura [14]

implements this concept 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 this work from Aura is the location scope of an activity. While Aura addresses activities that may span more than one location, this work is targeted at activities with a strong association to a specific location.

Christensen and Bardram [4] also grounded on Activity Theory to develop a pervasive computing system supporting collaborative activities within specific environments. However, unlike this 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.

The VADE project [6] 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 mobile portals) and to broaden the user interaction means beyond the personal device (e.g., using local displays).

3. Research challenges

The challenges posed by the vision supporting this work are essentially of two categories: activity management (specifying an activity and managing its accomplishment) and resource management (composing and coordinating the resources needed for the activity unfolding):

- specification of activities – how to formally represent which actions, and operations compose the activity, and which artifacts are required for each operation.
- context-awareness [11] and personalization – an activity may depend on contextual and personal factors (e.g., elderly or impaired people have to perform an activity possibly in a very different manner). Context is also fundamental when deciding which localized activities is the user interested to accomplish (e.g., a person that arrives at the hospital reception may go there for different reasons: for visiting a relative, for a consultation, for equipment maintenance, etc.).
- offering localized activities to users – advertising users about available support for localized activities and about how to perform them. Advertisement should adapt to personal environment (e.g., advertising to users carrying a PDA is different from advertising to users carrying only a smart tag).
- describing and storing activity state – allowing for activities to be interrupted and later resumed in the same place, or enabling activity memory, i.e., allowing users to browse and remember their past activities in a specific place.

- customizing localized activities – people may want to customize their recurrent activities in a specific place, so that next time they perform a localized activity they are better supported.
- concurrency and collaboration – several users in the same physical environment pose concurrency problems when accessing local resources. Collaborative activities increase the complexity of specifying an activity (e.g., role management, coordination of users' actions, allocation of resources, etc).
- integrating with personal resources – how to describe personal resources, how local environments discover them, and how they decide between personal or local resources (e.g., between a personal or a public display) and dynamically compose the whole.
- privacy – how to access personal/private information on large displays that tend to be rather public by nature (in contrast to, e.g., PDAs), and how to specify privacy preferences for interacting with local environments.

4. Proposed work and methodology

The focus of this work is on providing people with the perception of how the local environment can assist them in performing localized activities. A particular interest will be devoted to investigate models of publishing and offering activity support in different modalities (Web, public displays, etc.). This work is not only centered on human-computer interaction issues [8], but also in the integration with the personal environment, i.e., analyzing how different types of personal environments can be used as a basis for providing the user-centered aspect of the support to a localized activity. We will consider 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 mobile portal, a personal ICQ number, etc.).

This work started in July 2003 and is to be finished by July 2006. After this initial phase, in which the conceptual ground for the vision supporting the work is being established, the next step will be to define a base architecture for ubiquitous computing environments supporting localized activities. Afterwards, the work will be directed to different types of personal environments and their critical points of integration with local environments, i.e., components directly involved in the integration with local infrastructure and defining the required integration mechanisms for each type of personal environment. Further, existing solutions for the description and discovery of personal resources will be explored, as long as models for publishing offered activities and integrating their human-computer interface with the personal environment. The validation phase will include the development of two representative prototypes of different levels of complexity. The former will be a proof-of-concept of the vision supporting this work, while the latter will validate the ubiquitous computing framework that will be proposed for combining local and personal environments in the support to localized activities.

5. Conclusion

This work investigates how ubiquitous computing environments can publish and offer user-centered activity support to users with heterogeneous personal environments. This requires ubiquitous computing environments to cast with personal environments in order to provide users with personalized, context-aware, and rich information. This work expects to contribute to achieve these goals by identifying the integration issues between ubiquitous computing infrastructure and different types of per-

sonal environments, and proposing a framework comprising technological and architectural solutions to those issues.

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