Evaluating an Activity-centered Ubiquitous Computing Framework for User Assistance in Public Spaces

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Abstract

This paper describes a ubiquitous computing framework for supporting activities that are strongly associated to a specific physical environment and that are performed by occasional visitors. Our framework implements an activity-centered approach to ubiquitous computing, by defining a conceptual model inspired by Activity Theory and implementing a software infrastructure derived from this conceptual model. The framework has been evaluated from the user view-point by experiments run at different public spaces. We are proposing to perform an additional experiment with the framework, providing user assistance to Interacção 2006 participants and organizers.

Keywords

Ubiquitous computing frameworks, activity-centered computing.

1. INTRODUCTION

Public spaces accommodate many kinds of users and activities. Some people are recurrent users of such spaces (e.g., local workers) while others go there occasionally for short-term activities (e.g., conference participants). The activities that can be performed in public spaces vary between activities which relevance or interest is not associated to the physical environment (e.g., managing e-mail or editing a report) and activities that can only be physically achieved in a specific place (e.g., visiting an exhibition at a museum or visiting a relative at the hospital). The latter are called *localized activities* given that they are strongly related to a specific physical location. Particularly interesting are localized activities performed by *occasional visitors*, i.e., people that are not used to live or work in that place and that occasionally pass by. Before these visitors come to some public space, they have little or no idea about the physical setting nor about the resource infrastructure that such an environment may provide to support localized activities. These users need anchors that help them to easily orient in the physical environment and to identify and use the resources (humans or artifacts) available for achieving the activity. Public spaces in general are designed to provide such assistance to occasional visitors, for example, by the means of wall signs, panes, brochures, etc. However, these means lack some important characteristics such as personalization, full availability, completeness, or interactivity. Moreover, these means are seldom integrated with each other and are often designed with a functional perspective rather than oriented towards the possible activities each particular visitor may achieve.

We believe that ubiquitous computing can greatly enhance the experience of public space visitors, by offering effective and transparent means for achieving their localized activities, while providing a personalized assistance, treating users as individuals with different motivations, context, and preferences. This work is also based on the conviction that an activity-centered approach to ubiquitous computing is a promising path for bringing computing closer to people and to transparently support activities that take place in the physical world [Banavar 00, Christensen 02, Sousa 02, Norman 05]. Taking an activity-centered approach for system design becomes especially important in situations in which people have little or no prior knowledge about the physical environment or about the local means available for the activity they are going to perform. This approach faces several challenges:

- how to model human activity and user interaction independently of the different mental models of activity that people may have;
- how to represent this model in a machine-understandable manner, simple enough to require minimum specific know-how and effort from public space administrators managing the local ubiquitous computing infrastructure;
- how to deal with the heterogeneity of interaction devices a ubiquitous computing environment may supply while not compromising simplicity of user interaction;

- how to deal with the possibly varied interaction devices the same person may use within the course of an activity and to make that person feel that all interactions, whatever device is used, are integrated and all part of the same activity;

- and personalization issues like availability of and access to personal data or privacy issues.

In the following section, we present Activity Theory, the theoretical framework upon which we ground our conceptual model for representing activities and user interaction. Section 3 describes this conceptual model and presents ActivitySpot, the activity-centered software framework we propose for supporting localized activities. Section 4 describes the evaluation objectives of our demonstration in the conference. Finally, section 5 concludes the paper.

2. MODELLING ACTIVITY AND USER INTERACTION

We believe that the best approach to overcome the activity and user interaction modelling challenges is to ground our research on previous work on human activity analysis. The importance of a theoretical framework of human activity is that it provides ubiquitous computing researchers with an agreed set of terms to describe activity and with concepts that drive them in the construction of systems that intend to support activity. Among several frameworks produced mainly by the fields of psychology and philosophy, we chose Activity Theory [Leontiev 81] as the background for this work, based on its maturity acquired by several decades of research and its set of simple and solid concepts. Among these concepts, we are particularly interested in the different levels of analysis of an activity: *activities*, at the uppermost level, are distinguished on the basis of their motive and the object toward which they are oriented; *actions* are distinguished on the basis of their goals; and, finally, *operations*, on the basis of the conditions under which they are carried out. For example, an activity motivated by food is composed of several goal-oriented actions (e.g., collecting ingredients, preparing a recipe, etc.) and operations which vary in function of conditions (e.g., going to the kitchen-garden, picking vegetables, taking ingredients from the fridge, etc.).

An activity may be carried out in a variety of ways by employing different actions and operations, which may respectively be part of different activities and actions. Individual characteristics and changing local and personal context are the factors driving the structure of a localized activity. For example, a public space like a museum may support different activities, which in turn may employ different actions and operations, all depending on several factors, like the visitor role (e.g., regular museum visitors, authors, external security inspectors, etc.), age, preferences, available resources, or context. In a ubiquitous computing environment supporting these hypothetical localized activities, each ubiquitous computing device can be seen as a tool that may be used for the execution of one or more operations. Figure 1 depicts our Activity-Theory-inspired abstract model of activity applied to the museum example.

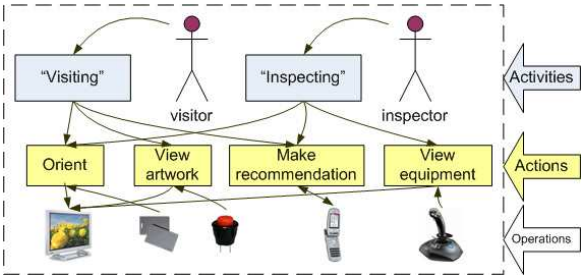

Figure 1. Example of an activity-based model for a ubiquitous computing environment

For the sake of clarity, the model omits the details of operations. In a ubiquitous computing system, an operation can be a user interaction, a sensor read, a web-service request, a database query, etc. We just represent the user-facing devices, which are the most visible part of operations. The model exemplifies how flexible an activity structure can be: a plasma screen can be used both by visitors and inspectors to achieve different actions; an "orient" or a "make recommendation" action can be executed in different activities, with different goals in mind (a recommendation made by a visitor has a different goal from a recommendation made by an inspector).

Given that user interaction with a ubiquitous computing system is done through multiple, heterogeneous means, we reduced user interaction analysis to basic human-computer interaction concepts: stimulus and response. We assume that, for a given stimulus through a given device, a response is produced, synchronously or not, through the same device or through other device or set of devices. We also assume that people interact with ubiquitous computing systems mainly through simple devices. We consider a simple interaction device in a ubiquitous computing environment as being the equivalent of a mouse, a keyboard, or a screen in a desktop computer. We are talking about elementary, easy-to-use interaction means that cannot be used only by themselves to carry out an activity. The execution of an activity is thus distributed by the interactions made with each of those devices. Every user interaction, whatever the underlying medium, is framed within the user activity and is integrated with other previous and further interactions, becoming more meaningful and contributing to compose the whole activity.

3. THE ACTIVITYSPOT FRAMEWORK

The ActivitySpot framework provides a set of conceptual and software tools for designers and developers applying an activity-based approach for supporting occasional visitors to ubiquitous computing environments. The concepts basing the framework are derived from Activity Theory, namely those associated to the activity structure analysis. Therefore, the principles of the ActivitySpot framework originated from the concepts of activity, action, and op-

eration, as well as the activity structure hierarchy and flexibility. We also consider that activities or actions depend on local and personal context, either as an execution condition or as a variable influencing the response of an operation. Finally, the framework includes the basic concepts of stimulus and response to model user interaction. The conceptual model is implemented in the architecture described in Sect. 3.2.

The main strength of this conceptual model, besides its activity-centered character, is its simplicity. Such a simple model leads to simple architectural abstractions and, therefore, to an easier task for public space administrators using ActivitySpot for supporting localized activities.

3.1. Environment Specification

In order to be independent of physical space and activities and thus support any localized activity scenario, the ActivitySpot framework is based on a generic specification format for activities, actions, and interaction devices available in an environment. Each environment supported by ActivitySpot has a specification of: a) which actions can be executed – name, supported stimulus and response types, a reference to the component implementing the action controller, and execution conditions; b) which activities are available – name, execution conditions, and references to the actions composing it; and c) which local devices can be used – stimulus or response type, physical location, and references to other devices which have some physical or logical association.

Activity specification is currently done by means of an XML document. Future developments of ActivitySpot will include a graphical user interface providing high-level abstractions easing the generation of the activity specification.

3.2. The ActivitySpot architecture

The ActivitySpot architecture (see Fig. 2) implements the activity-centered conceptual model described earlier. Following the generic character of the environment specification, the ActivitySpot architecture provides abstractions powerful enough to be instantiated in several concrete scenarios and simple enough to facilitate the adoption and usage by public space managers without requiring deep computer science know-how. The main architecture component is the Activity Manager. It manages activity execution by coordinating stimuli, execution conditions verification, and response generation. Another crucial component is the EQUIP [Greenhalgh 02] data-space, which is used as a communication middleware between interaction devices and Activity Manager.

The Activity Manager, following the environment specification, knows the characteristics of each supported activity and respective actions. The Activity Manager is also responsible for launching action controllers – the components implementing action logic[1] – and listening for interaction events in the data-space. Data collected from visitors is kept in a relational database. We assume that visitors, previous to the system usage or during the activity unrolling, provide the association to their personal domain. We currently support *ad-hoc* associations mechanisms, e.g., providing the mobile phone number through an initialization message or associating RFID tags or a Bluetooth address to a visitor at a registration desk. The aimed generalizable association mechanisms, which would be used by visitors wherever they go, are going to be investigated in future work.

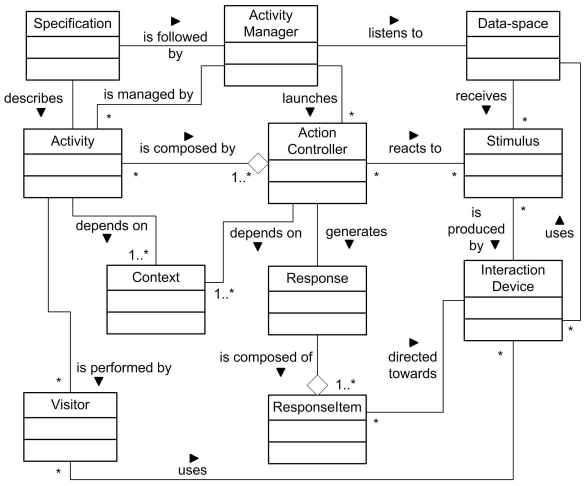

Figure 2. The ActivitySpot architecture

Whenever a visitor generates a stimulus through an interaction device, a corresponding stimulus description is sent to the data-space. The Activity Manager senses this stimulus, identifies its author (e.g., a mobile phone number, a MAC address, an RFID code, etc.), and triggers all the action controllers that fill the execution conditions and that support the respective stimulus type. Each of these action controllers processes the stimulus sent by the Activity Manager and, in the case the stimulus was effectively targeted to the respective action[2], a corresponding response is produced – a response may be composed of one or several response items directed towards specific interaction devices. The Activity Manager sends the response items to the data-space, which propagates them to the interaction device presenting that response type. When several devices may consume the same response type, the Activity Manager is able to address the response item to the device that is physically closer to the user. This is achieved when the Activity Manager is able to derive the user location from the stimulus. For example, if an RFID tag carried by the user is intentionally brought near a reader, the user is expecting to see the response in a nearby display, not in a display elsewhere.

The stimulus reaction behavior is similar to what happens for an event generated by a context sensor. Actions that are

[1] The logic implemented in the action controllers corresponds to the set of operations that constitute the respective actions. The operational logic may be shared between action controllers.

[2] In order to avoid ambiguity, we assume that a given stimulus (e.g., a specific RFID tag, an SMS message with a specific format, etc.) is always targeted to a single action

sensible to context changes may thus generate a response to an interaction device or, if a response is not suitable, execute some logic without producing any response.

4. EVALUATION

Although ActivitySpot has been demonstrated in different public space scenarios [Pinto 06], we are seeking to evaluate it in a scenario that better meets our objectives. A conference scenario such as Interacção 2006 has characteristics that make it a particularly interesting place for demonstrating ActivitySpot: it provides at least two different activities – participating in the conference and collaborating in the conference organization; both activities are performed by people that generally are not used to the physical environment nor to the activity performed in that particular place; both activities may share common actions and operations (e.g., viewing the list of participants), demonstrating a central concept of our work; both activities may be performed by a control group without ubiquitous computing assistance and compared to ActivitySpot users. Furthermore, conference participants and organizers would certainly be interested and active evaluators of our framework. The demonstration will be held during the whole conference and intends to provide assistance both to conference attendees and organizers in their respective activities.

5. CONCLUSION

This paper presents ActivitySpot, a ubiquitous computing framework for supporting localized activities performed by occasional visitors to public spaces. This work is based on an activity-centered approach for system design, which becomes especially important in situations in which people have little or no prior knowledge about the physical environment or about the activity they are going to perform. The main contributions of this work are the Activity Theory-inspired conceptual model and a software infrastructure, derived from this model, providing a generic tool set for ubiquitous computing environments supporting localized activities. We are proposing to evaluate ActivitySpot in the Interacção 2006 conference, by providing user assistance to Interacção 2006 participants and organizers, which is a particularly interesting and rich scenario meeting our evaluation requirements.

6. ACKNOWLEDGEMENTS

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