Modelling Space for Location-Dependent Tasks:
Why Location-Independent Computing Isn't

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The growth in mobile and distributed computing have highlighted a category of task in which the location of the user and/or resources or other task agents affects the way the task is performed. We identify important features of such tasks and propose requirements for a spatial framework to model location information for task support.

Keywords: mobile computing, distributed computing, task analysis, spatial models

1. Introduction

The development of mobile computing systems and the explosion in use of large distributed information systems, such as the World Wide Web, are generating a new set of challenges for interactive system design. These problems range from the design of small displays and input devices for mobile computers [1] to the less well-understood issue of how physical location impacts on interaction. Much of the work to date on the interaction with mobile and distributed systems assumes that we understand how location effects human activity and that the main research questions are how to represent location and how to handle the computer-mediated management of location-dependent resources [4,5].

In contrast, we believe it is important to start with an examination of computer-mediated, location-dependent activity. A somewhat similar approach has been taken in connection with personal information management [3]. However, our focus is not on the nature of the information and its use but on the class of activity in which agents and resources are essentially distributed through space and potentially mobile. In this paper we characterise location dependent tasks, identify the need for a model of space for location dependent computing, and we propose some properties that such a model should possess.

2 Location-dependent Tasks

Consider the following scenario: Phil and Dan are writing a paper together. The day before the deadline for sending the paper, Dan sends to Phil his final version by email. Since Phil is away from the office, Dan decides to send him a plain text version (instead of the Word version) so Phil can read it on any machine he has access to while away. Dan then leaves for a meeting in Paris. At night at the hotel, he uses his portable computer and modem to read the comments Phil has sent by email. Dan has to change his communication configuration (the dialling prefix) to be able to connect to the email server. In his comments, Phil refers to a World-Wide Web page. But the WWW page is located on a US server and, at that time in the evening, transatlantic connections are overloaded and Dan is unable to connect. The following day, while in the subway on his way to the meeting (it's two hours before the deadline), Dan gets an idea he wishes to discuss with Phil. Since Phil is now back in his office, Dan can contact him at the office using his cellular phone/PDA combination. But the phone isn't usable in the subway underground. Dan gets off at the next station to make his phone call.

This example highlights a number of computer-related tasks in which certain features of the user's location affects the possibility or the method of task execution. We call such tasks *location-dependent tasks*. Sometimes it is the physical position or related properties which matters. Sometimes what is important is the position of resources in a non- or semi-physical space, such as a computer network. Our use of the term 'location' is intended to refer to position in any space or network, either geographic or non-geographic.

The effects of location on tasks can be divided into three basic categories:

- ***VIABILITY***

The executability of the task can be conditional on the current location of the user and/or resources/agents. Some tasks may be hindered because of environmental constraints (e.g., pen-based input on a moving vehicle or cellular phone outside of the coverage zone), because of distance (e.g., file transfer time or time zone lag) or because a location may be unknown (e.g., the user wants to contact a colleague who is travelling but s/he doesn’t know the exact location).

- ***METHOD***

If a task is viable, location may nevertheless constrain the methods available to perform the task. For example, pen-based text input on a moving train is impractical but keyboard text input may be feasible. Cellular phone communication from within a building may prove impossible and may lead the user to prefer a standard phone line. Sending a message to someone may well depend on whether they are at home or in their office.

- ***CONSEQUENTIAL SUBTASKS***

Finally, a particular method for performing the task may require the execution of extra tasks as a consequence of location. For example, a user travelling between two countries has to reconfigure the dialling prefix of his/her communication software to access the company file server. Often, but not always, these consequential subtasks are required to enable the successful execution of the main task.

It might be argued that it is not the location, but the availability or accessibility, of resources and/or task agents (e.g., the potential recipient of a message) which is the central feature of this class of tasks. However, the accessibility of a resource or agent can be expressed as a relationship between the location of the resource/agent and that of the user/user's system. It is our claim that such locational information offers a powerful means by which users (and systems) can make the decisions regarding viability, method and consequential enabling tasks which are required for successful performance of location-dependent tasks. Location (in some space or other) can be viewed as a repository of important task planning information .

The notion of location dependency is neutral with respect to the means of its resolution. That is, some location dependent tasks can be dealt with automatically without user awareness or intervention. In other cases, users must consciously intervene, making decisions and executing needed subtasks. However, whether the location dependency is handled by the user or by the system or by both collaboratively, it is necessary to provide the location information in an appropriate form.

Location-dependent tasks are not well handled by most existing systems. Most of the examples described above require the user to be aware of his/her location and as well as others, and to develop heuristics to perform tasks that depend on location. Often, the necessary location information is unavailable from the system, misleading or inappropriately represented. Part of the problem lies in the inadequacy of the representation of user/resource position. The primacy of physical location makes physical space a natural candidate for modelling resource position. In the next section we consider its suitability and examine the role of alternatives.

3 Representations of Location

Geographical data representations such as physical maps and Cartesian coordinates are an obvious option when looking for a model of space. Global Positioning System (GPS) devices allow mobile devices to get information about the current location with fairly good accuracy. However, GPS-type geographical data is of little help with most of the examples we've presented in the previous section. Geographical doesn't give much information about environmental constraints due to the location nor the network links among resources.

Networks models may be helpful here. These models provide a topological model along with an addressing scheme. Such connectivity models are appropriate for capturing resource availability and the "logical distance" between locations (e.g., the number of routers from source to destination). However, connectivity is only part of the location-related information which is related to realistic tasks. We have already mentioned environmental constraints. Physical distance is also often an issue ("How far do I have to walk to be able to connect successfully to the network?").

In general, relying on a single model of space is not enough. We should also be aware that each user relates to space in a different way and defines personal models of space. For example, “at home” or “at the office” means a different geographical location for each of us. We switch quite easily between different models of space or addressing schemes and often require more than one for a given task. We know how phone prefixes or postcodes relate to geographical locations and Internet users quickly learn how to identify in which country a particular site is located. In addition, some locations relate to social or institutional spaces (e.g., one's association with an organised collection of workgroups); such locations can place constraints on appropriate behaviour [2] and, when linked to other spatial information, provide important support for task planning.

It should be noted that most, if not all, of these spaces require time as a dimension. Task resources are dynamic and change their location (or even appear in / disappear from spaces). Sometimes a snapshot of a space is sufficient for deciding how to proceed, in which case time can be abstracted away. However, scheduling and synchronisation problems demand that time be explicity included.

Current locational representations in use are often poor at providing appropriate task-relevant information. On the Internet, .com suffixes denote commercial sites in the US while .uk and .fr are used by English and French sites. However, there are exceptions to these addressing schemes and a given address may actually be unrelated to the physical location. For example, the location of a company cannot be determined from its toll-free phone number. On the Internet, the .com suffix is even misleading: if www.apple.com is located in the US as one expects, its European mirror www.euro.apple.com is located in the Netherlands!

These different models of space can be linked but, because of exceptions in the addressing schemes and dynamic changes in task requirements, none can serve as a reference to which all others can be systematically related. We feel the need for a common framework that would unify and link different spatial information expressed in different models. We now present some desirable properties of such a common framework.

4 Requirements for a Locational Framework

The reference model of spatial information we wish to build is intended as a framework for the description and analysis of location-dependent tasks and as the foundation for the construction of computer-assistance with such tasks. To be acceptable, it must preserve essential properties of existing space models. In this section, we identify these essential properties and additional properties that are required.

- *MULTIPLE LINKED SPACES*

The first requirement of a framework of space models stems from its very definition. The framework should provide the ability to handle multiple linked space models. These space models express locations, regions, distances between locations, and use a variety of naming schemes. Thus, the framework should let one link and relate locations, distances and names expressed in different space models.

- *PHYSICAL AND LOGICAL DISTANCES*

A space model is useful for expressing distances between locations. Distances may be physical distances in the case of geographical maps but may also be logical distances as in the case of network topology maps. An important requirement of the framework is its ability to handle distances, either physical or logical, and to provide a way to express relationships between them.

- *REGIONS AND CONTAINMENT*

In addition to precise positions in a space, regions must be also be expressible. Relationships of containment and intersection between regions and locations (or other regions) are important for modelling collections of task resources and for building spatial models (a resource might only be known to reside within a region).

- *PERSONAL VIEWPOINTS*

Space models are commonly used to find out one's location and its relationship to other locations and resources. One should be able to relate to the model from a given viewpoint and derive relationships related to the current viewpoint. This property guarantees that the model fits the needs of mobile users.

- *DYNAMIC BEHAVIOUR OF AGENTS AND RESOURCES*

Space models can also account for the movement of resources or people within the space they describe. Thus, a spatial framework should handle dynamic behaviour of resources or people.

- *DIFFERENT LEVELS OF PRECISION*

Most common models of space provide different levels of precision. Hierarchical representations or naming schemes (e.g., country/city/street for addresses or Internet hierarchical domains) are a way of accommodating various degrees of precision. Scaling offers another approach to the modification of precision. The model should allow different levels of precision to be specified. It should be possible to associate properties with a level of precision. Thus, details of the internal layout of a building may be associated with a high level of precision and unavailable or differently represented from lower levels of precision.

- *EFFECTIVE TASK SUPPORT*

Space models often fail to capture the information which is needed for a user's location dependent tasks. For example, the Internet domains are organised on the basis of a naming scheme which is ambiguous or misleading in its relationship to physical location. An ideal spatial framework should correct these exceptions and be both non-ambiguous and non-deceptive to users.

5. Conclusion

We have identified a class of computer-related tasks, called location-dependent tasks, and highlighted the main categories of effect of location on task performance. The notion of location requires some framework of reference - a space - in terms of which location is defined. We consider several requirements for a spatial framework for location dependent tasks. The next step is to develop a model which meets these requirements and to investigate it in use.

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