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USING SPATIAL CONDITIONS FOR PROACTIVE COMPUTING AND INTERACTION METAPHORS

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ABSTRACT
The position of a user with respect to devices or the relative position of multiple devices provides an indication of interaction that is intended by the user. Based on this assumption many applications proactively trigger an action when certain spatial conditions are fulfilled. A typical example is executing a local service when the proximity of a user is detected.

This paper presents a concept of spatial conditions which aims to unitize the handling of such mechanisms. The concept is integrated in a toolkit that supports applications in making use of it. Furthermore we propose a new interaction technique for mobile devices, which is based on spatial conditions but at the same time avoids the disturbance of users by triggering unwanted services.

KEY WORDS
Location-aware applications, spatial conditions, mobile interaction, proactive computing, mobile HCI.

1 Introduction

Spatial information can be used to predict which interaction is possible or even likely. By knowing the location and orientation of a user with respect to his environment, one can make assumptions on his intentions and actions. As Schilit et al. put it, "There are certain things we do when in the library, kitchen, or office." [7]. If the user is e.g. close to a device, this is an indication that he might want to interact with it.

A common mechanism, which makes use of this assumption, is automatically triggering an action when certain spatial conditions are fulfilled. Location-aware applications can react to the users proximity in order to make the interaction easier or more intuitive. If e.g. the user is standing in front of a public device, a user manual can be shown on a nearby screen or on the users personal device. Another example is ambient displays, which show user-specific information or allow users to interact with the display when he is nearby.

Next to monitoring the presense of users, the proximity of co-located devices can be used to initiate a synchronization or backup process, borrow computer equipment to other machines, or trigger a variety of other local services.

However, proximity is not the only spatial condition that is suitable to trigger actions. In a guided museum tour e.g. information is presented to visitors depending on how fast they walk by. If someone is standing directly in front of an object, all available information is shown. The faster the person walks, the less details are included. As soon as the visitor passes the object, information for the next piece is shown. In this situation it makes sense to consider the visitors movement or orientation in addition to his location.

After demonstrating the relevance of triggering actions under spatial conditions by describing applications that were developed in related work, we will present the Spatial Condition Toolkit (SCT), which supports the use of such mechanisms. Using this toolkit applications can easily compose spatial conditions and specify actions that are to be executed when the according condition is fulfilled.

Based on the SCT a new interaction technique was developed. It involves small windows called *Gateways* that allow the user to interact with services in the environment. The advantage is that a service is not automatically executed when the spatial conditions are fulfilled. This may disturb the user if the service is not needed at that time. Instead a gateway window appears on the edge of the user's screen to indicate that a local service can be used. The gateways position on the screen points to the direction in which the according device is located. In order to execute a service the user either has to click on the corresponding gateway or drag-and-drop a file onto the gateway window.

2 Related Work

There are several research projects that deal with the triggering of actions in specific situations and many applications make use of such mechanisms. Some are limited to spatial relations while others consider more aspects, which describe the situation or context (e.g. identity, time or activity).

Rukzio et al. [6] thoroughly analyzed three physical mobile interaction techniques: touching, pointing and scanning. Touching (which means physically attaching mobile devices) and pointing with one device to another, both involve spatial conditions. Many applications use touching and pointing to trigger actions such as Proximal Interactions [5].

Other context-aware applications consider more than just spatial information. Stick-e Notes [4] e.g. are electronic versions of the yellow Post-It notes, that are bound to the context in which they were taken. Later when the same context occurs again, the note is automatically shown to the user. Based on this application Brown [1] developed a framework for applications that present information to the user depending on the context.

Schilit et al. [7] presents a classification of context-aware applications. The four categories are *Proximate Selection*, *Automatic Contextual Reconfiguration*, *Contextual Information and Commands* and *Context-triggered Actions*. As all examples involve position information, the classification is highly relevant and helps to understand how the triggering of actions under spatial conditions is related to the wider field of context-aware applications.

Although the amount of related applications demonstrates the importance of spatial conditions, a general approach has not been developed, yet. In this work spatial conditions are analyzed in an abstract way and intergrated into an overall concept.

3 Spatial Condition Toolkit

The automatic triggering of local services under certain spatial conditions is a mechanism, which is used by many applications. Depending on the service and situation different criteria are suitable. Some applications, for example, use pointing to trigger a service, others are proximity-based, yet others consider the users orientation towards a device. For each of these examples different technologies stand to reason: infrared is suitable for pointing, bluetooth or sensor-based positioning systems for proximity, and so forth. Thereby the technology comes to the forth, which makes it hard to use conditions in a consistent way. In order to solve this problem we have developed a concept for spatial conditions and based on this the Spatial Condition Toolkit (SCT), which provides a uniform handling of conditions as well as the desired abstraction of the underlying technology. The SCT is implemented in Java and is available as open source project.

In contrast to other toolkits, such as the Context Toolkit [8], which is useful for a significantly wider range of applications, the SCT focuses on location-triggered actions. For this subset of context-aware applications the SCT provides additional functionality, which is not supported by other previous work.

3.1 The Concept of Spatial Conditions

A spatial condition is defined as boolean expression. The complexity of conditions varies: The simplest form is a basic condition, which refers to one aspect of location, orientation or motion with respect to a specific (set of) involved objects or people. For example ”the user is facing the display” addresses the orientation of a user with respect to the display. In addition there are complex conditions, which are composed of basic conditions.

3.1.1 Basic Conditions

Figure 1 shows the most common basic conditions. They are grouped by the three main components of position information: *location* (where is something located?), *orientation* (which direction is something facing?) and *motion* (where is something going and how fast?).

For each component there are quantitative and qualitative aspects. Quantitative aspects are determined by (a set of) numbers whereas qualitative aspects describe the relation between multiple people, objects, or places. The quantitative aspect can be used to define a location (by its x-, y- and z-coordinates), orientation (by its degree), or motion (by its direction, velocity, and acceleration).

One way of defining spatial conditions is using these quantitative definitions, e.g. ”if the distance is less than 3 meters”. Besides calculating the distance you can also define zones and check whether something is within this zone. A zone is defined as an area of any shape with a reference point that is set to a specific location.

In addition there are qualitative aspects, which cannot be expressed in numbers, but often are just as useful. Qualitative statements that specify the relative location of two or more entities are ”in the same room”, ”on top of”, or ”in line of sight”. ”Left of” / ”right of”, ”facing” and ”turning back to” on the other hand are associated with orientation. The reason is that after turning around (that is: changing your orientation by 180 degree) an object that was previously to your left is now to your right. Thereby the location did not change. A qualitative aspect concerning motion is whether one is moving towards or away from an object.

3.1.2 Complex Conditions

In most situations basic conditions are insufficient. To control an ambient display, for example, it is not only interesting to know if the user is facing the display. At the same time the user should be within a certain range if personalized information is to be shown. Here a suitable spatial condition could be ”the user is facing the display AND the distance between user and display is less than 5m.” Complex conditions like this are combined of basic conditions using the boolean operators ”AND” ”OR” and ”NOT”.

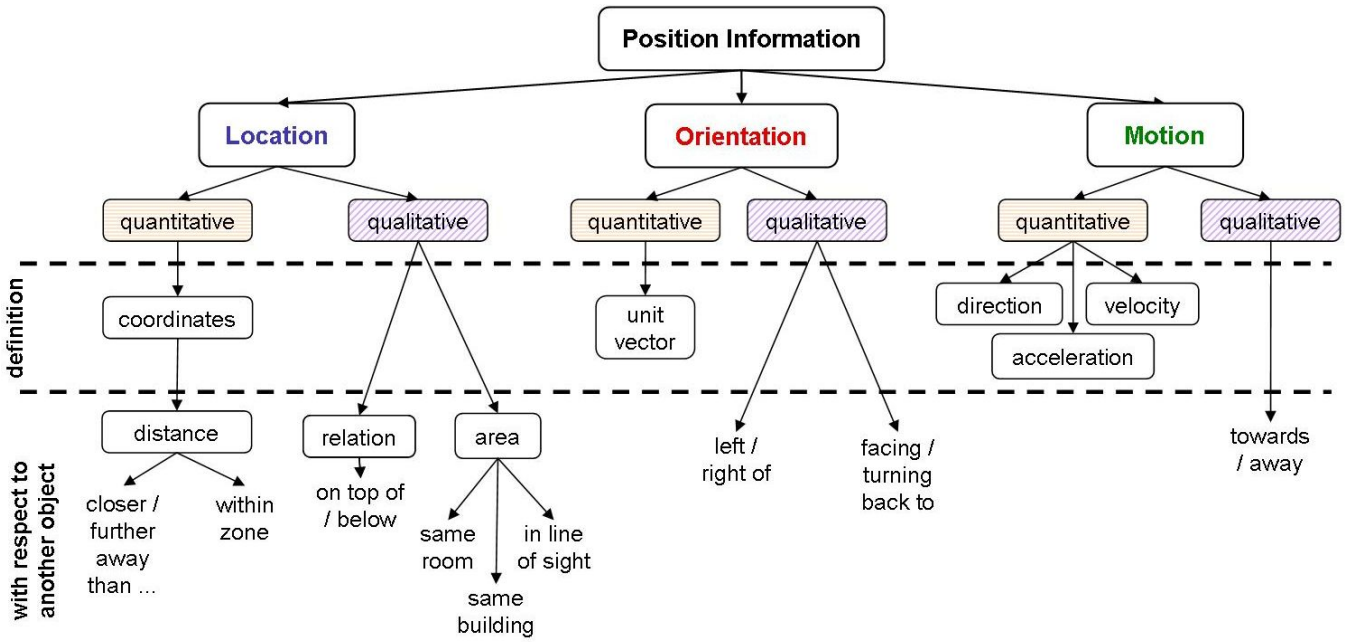


Figure 1. The Concept of Spatial Conditions

3.2 Toolkit Architecture

The Spatial Condition Toolkit allows applications to specify any spatial condition as well as an action which is to be triggered when the condition is fulfilled. It consists of four layers (see figure 2). The positioning system at the bottom delivers the position of so-called *Trackables*, which are people, electronic devices or physical objects with a known position. On top of the positioning system is a monitor, which reports position changes of registered *Trackables*. The trigger agent, which sits on top of the monitor, detects when a spatial condition is fulfilled and where appropriate triggers the corresponding action. The layer on the top is the application, which actually uses the toolkit's functionality.

At the beginning the application registers a pair of spatial condition and action. The condition is then analyzed by the trigger agent. In particular the *Trackables* that are involved in the condition need to be determined. If e.g. the condition is "the user is within 5 meters of the display", the involved *Trackables* are (1) the user and (2) the display. Both are registered at the monitor in order to assure that the trigger agent is informed whenever one of them changes the position. Each time an update is received all affected spatial conditions are checked and if the state of a condition has changed, the according actions are taken.

4 The Gateway Interaction Technique

The automatic triggering of local services is a common concept. It is based on the assumption that by knowing a user's position with respect to his environment it can be presumed which actions are possible or even likely. In other words, the computer guesses what the users intention is and proactively triggers the desired action. However, there is always the risk that the guess is wrong and the action is not needed at that time. For some services this would be unproblematic. For other services, however, an unwanted execution can be disturbing. E.g. automatically synchronizing devices, which are physically next to each other, can waste system resources that could be needed for other purposes.

A possible tradeoff is to inform the user of available local services in a way that is not disturbing. If the user decides to use one of the proposed services, it can be executed with a few mouse clicks. Our solution it to use so-called *Gateways*. Instead of triggering a service directly, a gateway widgets appears for every co-located device. The gateways are located on the edge of the screen and point to the direction in which the device is located. Figure 3 shows an OQO handheld device with three gateway widgets.

This interaction technique has two major benefits: First, it allows for drag-and-drop, and second, the occupied display space is very small.

4.1 Interrelation between SCT and Gateways

The gateway interaction technique is build on top of the SCT. Figure 4 illustrates the interrelation. As already discussed, the SCT automatically triggers actions when certain spatial conditions are fulfilled. In the case of the gateways this action is showing the gateway widget on the display. The user can then interact with the gateway in order to trigger a service. Depending on the service it is possible

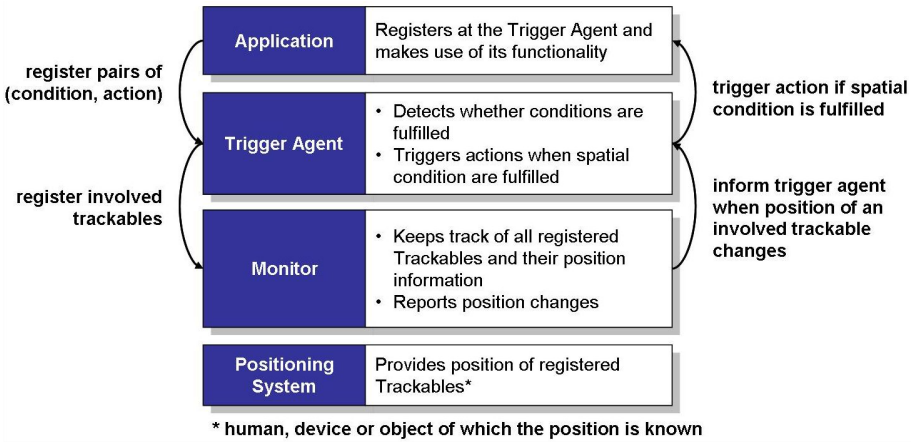


Figure 2. Architecture of the SCT

Figure 3. OQO handheld computer displaying three gateways

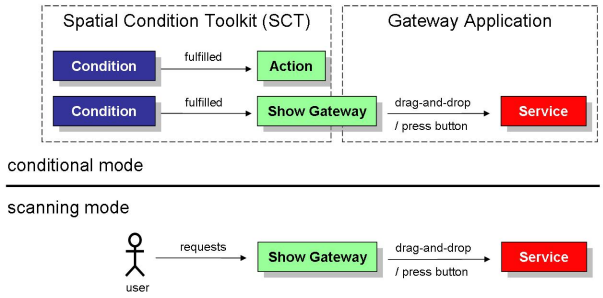


Figure 4. Interrelation between SCT and Gateways

to either click on the gateway widget, use drag-and-drop, or both.

This is called *conditional mode* as the appearance of gateways is bound to conditions. In addition there is a second mode, the *scanning mode*, which allows users to request that gateways for all local services in the room are shown. This is helpful particularly in unknown environments.

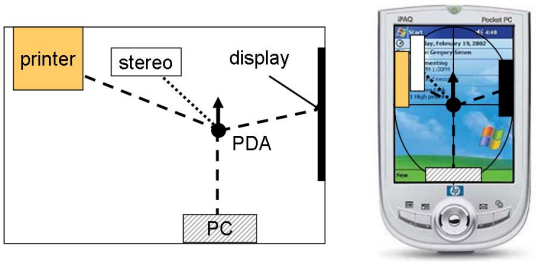
4.2 Design

For a new interaction technique like the gateways, the design is essential. In the end the design determines whether the application is helpful and intuitive to use or frustrating. One key factor is finding the right level of alertness, especially in the conditional mode. On the one hand the gateways have to draw attention in order to be useful. On the other hand they should claim as little display space as possible, so that the user is not disturbed if he does not want to use the service at that moment. Additionaly, important user interface elements should not be superimposed, in particular the taskbar. To avoid hiding other important information the gateway widgets could also be half transparent.

Another issue is designing the gateways in a way that suggests how they can be used. Both the button and drag-and-drop functions should be obvious to the user. As for the button the gateway is highlighted when the mouse is placed over it. The same concept is used for buttons in most applications as well as for HTML-links.

In addition a message appears when the mouse hovers above the gateway for more than two seconds. The message is individual for each service. For the printer it would e.g. be ”drag a file here to print it or click for more options”.

Furthermore multiple devices, which are located in the same direction, need to be distinguished. If, from the users point of view, there is one device behind another one, the according gateways will not overlap but appear next to each other. A possible scenario is shown in Figure 5. From the user’s point of view, printer and stereo are roughly in the same direction. To prevent the according gateways from overlapping, the nearest device (that is the stereo) moves away from the edge towards the center of the screen. That way, and by looking at the device icon, multiple devices in the same direction can be distinguished.



Map of a room with four local services. The black spot shows the user's position. The arrow indicates in which direction the PDA is being held.

As printer and stereo are in the same direction, their gateways would normally overlap. To avoid this, the stereo gateway is placed next to the printer gateway. The order of the gateways represents the distance to the user.

Figure 5. Avoiding Overlapping Gateways

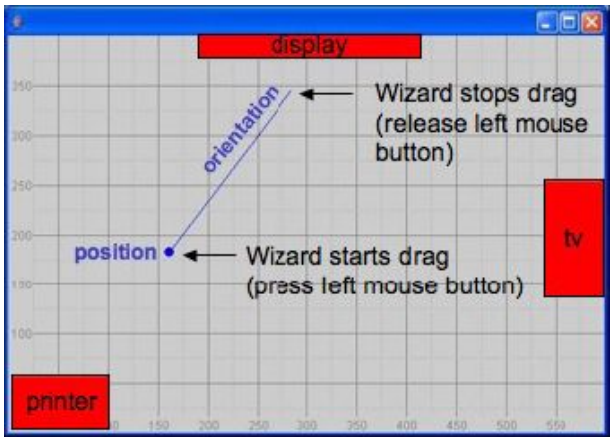


Figure 6. Wizard of Oz Map

5 Formative User Study

In order to get feedback on the gateway interaction technique a qualitative user study was conducted. The key questions were whether the gateways are intuitive to use and which mode (conditional or scanning mode) is more attractive.

The study took place in a meeting room. Distributed across this space were three devices: a keyboard, a large meeting display and a printer. Each device provided a local service implemented using the RelateGateways framework described in [2]. Participants tested these services one after another. Therefor they were provided with a handheld device, on which the gateway application was running. For each service the user was asked to perform at least one task.

For this part of the study the conditional mode was chosen. As the gateways only appeared on the handheld when the user was close enough to the corresponding device, participants were forced to move across the room and get a feeling for the application's behavior.

The study was conducted with 15 users in consecutive sessions. All of them were students, 13 male and two female. 12 participants were between 21 and 25 years old, two between 26 and 30, one between 31 and 40. The study took about 30 minutes for each person. After a short introduction, the participants performed the tasks in the conditional mode. Afterwards they were shown the scanning mode and moved around to see how the multiple gateways simultaneously adapted to their position. The remaining time was spent on a questionnaire.

To be independent of any particular positioning system the Wizard of Oz approach was used in the study. Thereby the positioning information is simulated by the wizard who is using a map of the room where the study takes place, similar to the one in Figure 6. On this map the wizard can specify the user's relative position and orientation with a single mouse gesture.

Concerning the usability of the gateway interaction technique, the feedback gained in the study was quite positive. All participants figured out at least one way of using the gateways quickly and without assistance. In the end everyone could name at least one benefit compared to traditional interaction techniques. The most frequent answers were "I can use devices on site, so I do not have to carry my own devices with me" and "it is convenient since there is no installation and configuration process". 67% participants said they would mainly use it in unfamiliar places, e.g. in public buildings, at work or university. 33% would use it everywhere, even at home.

When asked how often they would use which mode, people would on average use the scanning mode 57% of the time (accordingly 43% for the conditional mode). The distribution of these results on a per user basis is shown on 7. More revealing than these numbers, however, were the users' explanations. Most participants said they would use the scanning mode mainly when they enter a new room. When they are in a familiar environment - that is most of the time - about half of the users would use the conditional mode while the others would rather manually activate the gateways when they need it.

6 Discussion

In the current implementation, the gateway interaction technique focuses on spatial conditions that decide when to show the gateways. The premise is that spatial information indicates whether an interaction is possible or likely. For example, when the user is sitting in front of a keyboard working with a handheld, a gateway appears which tells him that the keyboard can be used to enter text on the handheld. Using the distance between the user's handheld and the keyboard as trigger makes sense, because in order to use the service, both devices need to be next to the user. However, considering more than just position information would be even better. In particular, it would be interesting to know whether the user is entering text. A better rule would be "if the user is typing a long text passage and the user is within reach of the keyboard device, the gateway should appear". Thus, spatial criteria are only part of

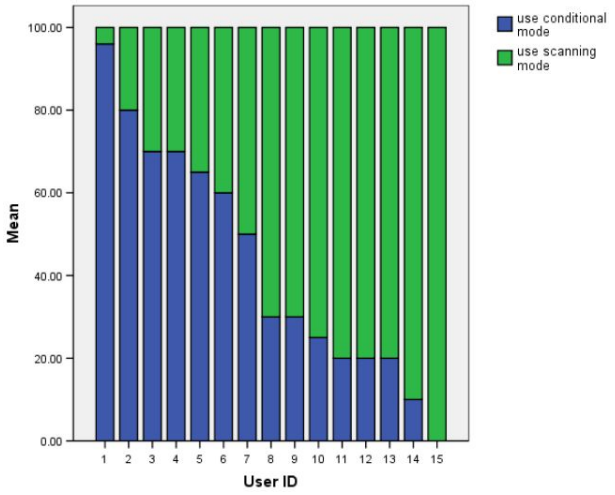


Figure 7. Conditional vs. Scanning Mode

the information that should be considered for the gateway interaction technique. For a start the current engagement of the user should be observed and factored into the conditions, which lead to the triggering. Ideally the decision when to show the gateways could be made by an artificial intelligence (AI) system.

7 Conclusion

In this paper, we presented the Spatial Condition Toolkit (SCT), which allows applications to register pairs of spatial conditions and actions, that are triggered when the according condition is fulfilled. It is based on a profound model of spatial conditions and provides an abstraction of the underlying technology.

Furthermore a new interaction technique was introduced, which allows convenient interaction with co-located devices. It involves small widgets called *Gateways*, which appear on the edge of the screen, when certain spatial conditions are fulfilled. Using the gateway widget the user can then interact with the according device. Combined with a suitable service framework the gateways allow the use of local services without any installation or configuration process. Thereby the target devices are identified by spatial criteria rather than IP addresses.

A formative user study showed that people like the idea of spatially discovering services very much. Also, the participants were able to interact with the gateways immediately and without assistance. Furthermore it was examined whether people would like the gateways to automatically appear when needed or if they want to actively request the emergence in order to scan the environment. The answers suggest that both modes are attractive even though they are suitable for different situations.

However, a long-term follow-up study would achieve more profound answers to the question of how disturbing the automatic appearance of gateways in real life. On this account a positioning system is currently being integrated, which in essence will replace the data, that was provided by the Wizard-of-Oz interface before. This would allow us to compare different spatial conditions in order to find out which ones are suitable for which services. Also, it would be interesting to know whether well though-out conditions provide a benefit and to what level users are aware of the specific conditions.

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