Directional Interaction with Large Displays Using Mobile Phones

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Abstract

In this paper we present a technological approach to support individual and cooperative interactions in collaborative learning environments. We designed and implemented prototype applications that allow to interact with a shared display by means of infrared-enabled mobile phones. The aim is to develop a technique to decouple personal and presentation devices. An experimental evaluation, based on a survey carried out with students from our university, is presented.

1 Introduction

In the last decade our laboratory has been devoting attention to the design of systems integrating different types of interaction mechanisms while supporting the practices of people cooperating in a large variety of situations: from individual work to remote cooperation, from formal meetings to social gatherings at cafeterias, from sitting at a workplace to moving within a building or in the territory. We started with systems offering people the possibility to interact through PCs, large interactive screens and paper-based artifacts [2]; we later developed another system supporting the interaction of people through PCs, screens and cellular phones [1]; and worked at a system supporting a large and rich set of interaction modes of users in an augmented ubiquitous computing environment [3].

Our last project, in particular, has been dealing with environments for cooperative and creative learning[1]. Considering interactions among students (working in groups) and teachers, we have started to develop a prototype system for a classroom provided with integrated support for mobile technologies.

The solution we have envisioned is particularly interesting for us, since it leads us to enrich the integration of different interaction modes, designing new types of interaction involving more interlaced interaction devices. In fact, if we want to have a localized interaction with both adjacent devices (e.g., a large display) and remote information (i.e., a file in a remote work-station), or if we want to interact with a large screen and have at the same time the possibility to choose the object to display and to browse it, then we must create complex interaction modes involving more than one device.

The system we present in this paper is the first step we have made to put together mobile phones and large interactive displays by directly connecting them. In particular, we have tested the capabilities of infrared-enabled mobile phones to support interactions (with screens) where gestures and directionality have to be taken into account. Directionality is the reason why we still do not adopt technologies like Bluetooth or WiFi networks, even if we probably will in the near future.

The rest of the paper is structured as follows: first, the motivation for this work is expressed by stating the topics of interest for the research; the application field is described through two cases, one relating to individuals and one concerning cooperation and resource sharing; next, some implementation details are given and the application architecture is sketched; a synthesis of the outcomes of the tests we have lead with students is given in Section 5; in Section 6, the results are briefly discussed, and also future works are envisionend, to give an idea about our plans to integrate the prototype in a real setting and to present the improvements we have already identified as necessary; some related works are then presented to give a context with respect to the literature; finally some conclusions are drawn.

2 Topics of interest

An interesting problem to be analyzed is the necessity for nomadic users to transfer data to a local/fixed resource before being able to access it. Nomadic users are those who

[1]ATELIER: "Architecture and Technologies for Inspirational Learning Environments", IST-2001-33064, `http://atelier.k3.mah.se`

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do not stay for a long time in the same place. Consider the case of any user needing to show some presentation, or to read a personal document on a shared display (e.g., a large screen or a whiteboard) and who is not equipped with the necessary hardware to plug his/her laptop to the display. It is annoying for the user to seek the suitable wires or to configure complex wireless protocols that usually require authentication and some local account for the system or the network. An even simpler (yet common) case is when users carry no laptop at all. If the information to be presented is safely stored on a remote personal machine, maybe at the user's home or workplace, then it should be possible for the information owner to access his/her own computer and to show the presentation just as if the shared display was a remote monitor for his/her personal computer. We are looking for a way to achieve this goal.

The reason for such a consideration is the same that made computer printers shift from the status of personal devices to that of shared resources. Likewise, PC screens could soon be considered nothing more than (standalone) entities that are at each time providing a service to a user, and are not just peripherals for a specific central processing unit. Moreover, just as network printers have no memory of what they print, meaning that information is not persistent in the printer after the paper sheets are produced, also information presented on a shared, standalone display should not persist somewhere locally. Such a decoupling would grant a better preservation of private, personal information for nomadic users.

In settings where screens are independent processing units, several displays could populate a shared environment and there would thus be the need for directly identifying a specific resource. This leads to the choice of a technology that (1) enables directional interaction, meaning that gestures are important for referring to a specific screen and not to another [4] (2) enables identification also by proximity, increasing both the degree of precision when approaching a device and the awareness of users about the fact that they are choosing a device instead of another just because they are getting closer to it. The required enabling technology needs then to be directional and short-range distance dependent [8]. The natural candidate is infrared technology, as everyone can experience it at home with common remote controls. Moreover, other additional requirements come from the fact that ubiquitous support should be given to users. The only personal devices that are truly ubiquitous nowadays and that enable complex interaction are mobile phones. These are also a cheap technology, in that no additional cost or device adoption is required to potential users of the application.

3 The applications

The experiment conceived to test our ideas actually encompasses two different settings, and thus two different applications that are running on shared displays (i.e., on computers to which large screens are connected, at the moment) and that are controlled by the same "remote control", that is a mobile phone running Symbian OS and the application we have built.

3.1 Individual interaction

The first application is meant to support a single user. The typical case is a slide-show presentation. For example, we want to support a teacher who is discussing some documents (or pictures, for simplicity) on a large screen during a lesson. The teacher needs a device allowing him/her to browse the displayed information. It could also be the case of a student presenting his/her work to the rest of the class, e.g. during a master class, like the ones studied in our last project, or an exam. In our first hypothesis, that is the application we currently developed, the information is already available on the screen and the mobile phone just works on four main actions: *go to first slide, go to previous slide, go to next slide, go to last slide*. What we are working on at the moment is the transfer of the actual content to be displayed, but it is only a technical issue.

The current mechanism relies on the transmission of XML messages between the mobile phone and the receiver on the PC the screen is plugged to and we are now transmitting very simple messages that encode the action to be performed.

```
<cmd name="selection">
  <parameters>
    <parameter name="IMEI">654321--52-123456-1</parameter>
    <parameter name="button">2</parameter>
  </parameters>
</cmd>
```

Figure 1. Simple command message

Figure 1 above shows the part of the XML message through which a simple command is sent from the mobile phone to the infrared receiver of the screen. The only field of interest, in this case, is the `button`, that simply conveys the information regarding which button of the phone was pressed. This information is included in a `cmd` tag whose `name` value is set to "`selection`". This value is used by the receiving command interpreter to parse the message content. If the application is also able to process files (e.g., to display images), then the XML message adopted for the transmission will look like the one in Figure 2.

In this case the name of the command is "`fileTrans`": it is interpreted by the receiving application as a file transfer request. This is a direct request because the file to be

```
<cmd name="fileTrans">
 <parameters>
   <parameter name="IMEI">654321--52-123456-1</parameter>
   <parameter name="fileType">image/jpeg</parameter>
   <parameter name="fileName">img.jpg</parameter>
   <parameter name="content">
          .
          .
    </parameter>
  </parameters>
</cmd>
```

Figure 2. File transfer XML message

transferred is already encapsulated in the message itself. It is then a one-way protocol, but the message is ignored if the application is not configured to receive such a command. Moreover, the `fileType` field specifies, according to MIME taxonomy, the kind (extension) of the file to be transfered, whereas the `fileName` field specifies the file name and in the `content` tag is encoded and enclosed the file itself.

The file transfer message above (Figure 2) has already been used in our current implementation but we registered some technical difficulties with keeping a stable alignment, and thus a stable connection and data transfer, between the phone and the receiver. The consequences of this problem are addressed in Section 6.

3.2 Multi-user interaction

Another issue to deal with is the possibility of supporting the interaction of multiple users (from two up) in front of a large screen. The first problem, that is giving simple commands to an application and transferring data from the phone (or a remote source) to the display, is not significantly changing if compared to individual interaction. We had other concerns regarding cooperation: in our laboratory we have at our disposal two Smart whiteboards that have a touch sensitive surface. For this experiment, we however wanted to investigate a kind of interaction that is rather unusual for these objects (using a complementary "no-touch" approach). We want to use mobile phones as lightweight, general-purpose remote controllers and the infrared protocol gives us suitable possibilities to establish such a unidirectional, non-session-based communication.

In the particular application implemented as a test, two users operate a simple interaction by following some simple rules, acting with simple commands in well defined turns, just like in a *tic-tac-toe* game. In this case, also the `IMEI` value in the XML messages (see Figure 1) is required[2], and is necessary to assign turns and forbidding a player to make two moves in a row. What is extremely useful is that commands may be sent using the infrared protocol without any supplementary negotiation for the user, who has simply to

Figure 3. A student testing the protoype

point his/her mobile phone towards the receiver and press the button (from '`1`' to '`9`') associated with his/her move. The '`0`' button is used to reset the application and thus start a new game. What we achieved is a straightforward identification of users and capture of their commands, allowing them to quickly and safely interact and eventually exchange some information.

4 Implementation

From an architectural point of view, the system has been implemented in two separate components, one running on the mobile phone and one on the PC controlling the screen.

To develop the mobile phone component of the application, we took the Nokia Series 60 phones as references. We needed phones running Symbian OS to develop a reliable control mechanism over the infrared port. Java Micro Edition (J2ME), for example, does not allow direct control over the infrared port, mainly because of issues regarding the transfer of commercial and copyright-protected data (i.e., games and ringtones). The *Remote Control* application may easily be installed and executed on the phone. While it is running, any time a button is pressed on the phone keypad, an XML message is built and sent out (see Figure 1). From an option menu, a file transfer can also be started (see Figure 2).

The PC side of the application is developed in Java. The PC-based component, acting as a server, basically has to listen to incoming messages from the infrared port. We actually had to plug an external infrared port (IrDa) with no additional coding efforts but with the advantage of having the possibility of moving the port from the PC closer to the screen, hiding the PC in the background, behind the board. The XML commands are read and parsed, and data transfer

[2] IMEI: International Mobile Equipment Identity, a 15 digit number that is unique for each cellular phone.

is eventually processed, and then the PC component has just to interpret the command according to the current application semantics. If the *Slide Show* application is running then the `button` command will, for example be mapped to one of the four possible actions (first, previous, next, last slide). If the *Tic-Tac-Toe* application is running then the command will be interpreted as a move to be checked by game logics or as a *restart* command. The server side of the architecture is then composed by three elements: a listener for the IrDa port (that is receiving messages from outside, i.e. from the mobile phone), a command parser (that interprets the messages) and one or more specific application clients to which the unpacked commands are dispatched to be executed.

5 Evaluation

In September 2005, the system was presented to a test group of university students along with a questionnaire to be filled out after a short demonstration of the implemented features. Students were first demonstrated the possibilities of the system, with a live demonstration, and they could afterwards test the system themselves and express their opinions. No time limit was imposed on them and only after the practical test they were given the questionnaire. Questions regarded students' skills with mobile phones, attitude towards the system, and they were also asked to envision other possible scenarios of use.

19 university students, mostly master's students, were polled (78% males, 22% females), they were aged 22 to 31 (average age: 25). All of them owned a cellular phone (50% a Nokia phone) and 56% of them owned a phone with infrared capabilities. 33% declared that they already use the phone also as a camera, so they could be interested in sharing their pictures on a large screen: 50% of the total declared that they were interested in the feature (only one student who had a camera-phone was not interested in sharing pictures on the whiteboard), and 78% said they would be interested in using the whiteboard as a bulletin board and in leaving messages on it (possibly along with pictures). Moreover 61% suggested extending projection features to video clips, even if our application does not provide audio functionalities at the moment. 78% said they feel comfortable with the interface, which also means 22% of the test users were uneasy with it (even if we did not notice particular problems with any user). According to students, among places where infrared-enabled shared whiteboards should be included coffee rooms (67%, meaning rooms with automatic vending machines), laboratories (61%), and classrooms (44%). Students do not believe that crowded places like cafeterias (94% negative feedback), and halls (83% negative) would be suitable positions for the whiteboards. Regarding other possible applications that should be developed relying on the mechanism, (collaborative) gaming is not interesting (83% negative), as well as medical applications (83% negative). Among the free notes left by students at the end of the questionnaire two were of particular interest. One student was concerned that the installation of the application on regular phones could be used as a trick to raise the price of the phones. Another student, probably with higher technical skills, wrote that other phones, and she mentioned her own Ericsson device, already provide functionalities to interact with desktop PCs.

6 Discussion and future works

Even if the small demonstrations and tests can not be considered to be conclusive, or representative for research trends, a general attention to the problem of developing innovative applications, and interactions can be seen in the higher-education students we polled. Users are well aware of the technical possibilities their devices might provide them, and at they same time are aware that such capabilities are not yet fully exploited and integrated with the rooms in which they live and work.

We collected critics concerning infrared technology to transfer data, due to the fact that the phone and the IrDa receiver have to be close and aligned for a certain time, and it is not always easy to do. Students however did not mention it explicitly in the questionnaires (even if they complained verbally), probably understanding that the work we have been presenting is just the initial step of a bigger project.

In fact, as a substantial improvement to the applications we have already implemented, we are building a robust mechanism to access remote data (i.e., data on remote repositories, such as a personal computer connected to the internet) and presenting them on the screen using the phone only like a bridge to the display (exploiting other technologies like Bluetooth and Wi-Fi).

Moreover, how to support learning is being investigated from other perspectives than higher education. An integrated setup, encompassing other mobile devices, such as PDAs and digital pens, and identification technologies, such as RFID, is being developed with the purpose of supporting learning processes in primary education. Teachers, children, and also their parents will be able to use mobile devices (owned by grown-ups, or provided to children in an adequate form) to access knowledge retained in the system in a multichannel fashion. Applications and interfaces for personal mobile devices will then be designed to explicitly support specific tasks, for example to study some specific subject, and not only scientific subjects. The experience gained with the system presented in this paper will be useful both to support children, who need very simple access functionalities (based on a few keys), and to develop an environment which is appealing for adults and allow them to exploit the devices they already own.

7 Related works

With the continuous evolution of new technologies and protocols for short-range wireless communication (e.g., IEEE 802.11, Bluetooth, NFC), there are always new possibilities for ubiquitous computing and new applications being developed. The topic of supporting collaboration by means of handheld devices has been thoroughly treated but the problem with this kind of approach, as for example in Quickstep [6] or FReCon [7], is the requirement of having devices (PDAs) that (1) are not as popular and widespread as mobile phones (2) carry issues regarding data storage, replication and manipulation apart from the real interaction time. Moreover, the concept of using some kind of remote control that is suitable for many devices in the environment has also been taken into account. The Bluetooth Remote Control System (BTRC) [5] is another example of how that protocol, which is very common in mobile phones, was used with PDAs to build an application to integrate all the devices in an environment. The biggest problem with Bluetooth is that it is not directional and so further steps, other than just pointing, are required to identify a device (i.e., the device and the remote control need to be *paired*). This leads to additional efforts for the user to control the device, and it takes a longer time to perform the desired action. The most desirable scenario for interacting with a specific device is when the actions required are as natural and as few as possible. For this reason, the approach we like most is when it is sufficient that the devices are in the line-of-sight and close enough to each other to avoid ambiguities. The gesturePen [9] is a line-of-sight, tag-based identification system that allows users to create networks of devices (e.g., for data transferring) by simply pointing with a stylus to the selected devices. These actions actually replace the need for explicitly configuring the network, that is necessary for example with Bluetooth networks. The gesturePen approach is very interesting but (1) it requires the development of a specific (additional) device to perform commands in the environment (2) the pen is only capable of one single action, and it is not capable of directly sending commands to other devices or to actually transfer any data or provide connectivity by itself. Even if the experiment we are describing may look naive and lacking the robustness of more recent technologies like Bluetooth [5] or WiFi [9] for data transfer, it proves the feasibility of the integration between devices that are part of everyday life with a foreign environment with very little effort.

8 Conclusion

The experiment we did with cellular phones and large displays is quite simple but it is, from our point of view, quite promising: the creation of bundles of devices supporting sophisticated interactions with present and remote, physical, digital, and mixed objects can enrich the services offered to users by systems supporting cooperation, social interaction and/or knowledge management. Moreover, as in the case of large screens discussed in the paper, we would like to suggest a direction for the evolution of these devices, transforming them from mere interfaces for existing systems into open network resources. The scenario that we envision from our work is one where system designers can build any interactive system composed of physical and digital modules, that have been conceived to be part of a larger whole. From this perspective, we are also willing to experiment, for future applications of this type, the open source Chandler platform that the Foundation for Open Source Applications[3] is developing in these years, adopting a strict and elegant modular architecture. This will lead to opening the above platform to multimodal interfaces and to enriching its services and its mission.

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