GENERIC INTERACTION TECHNIQUES FOR MOBILE COLLABORATIVE MIXED REALITY SYSTEMS

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ABSTRACT

The main characteristic of a mobile collaborative Mixed Reality (MR) system is that augmentation of the physical environment of one user occurs through available knowledge of where the user is and what the other users are doing. Links between the physical and digital worlds are no longer static but dynamically defined by users to create a collaborative augmented environment. In this article we present generic interaction techniques for smoothly combining the physical and digital worlds of a mobile user in the context of a collaborative situation. We illustrate the generic nature of the techniques with two systems that we developed: MAGIC for archaeological fieldwork and TROC a mobile collaborative game.

Keywords

Mixed Reality, Mobile Computing, CSCW, Interaction Techniques

INTRODUCTION

Mixed Reality (MR) systems seek to smoothly link the physical and data processing environments. This is also the objective of other innovative interaction paradigms such as Ubiquitous Computing, Tangible Bits, Pervasive Computing and Traversable Interfaces. These examples of interaction paradigms are all based on the manipulation of objects of the physical environment [2]. Typically, objects are functionally limited but contextually relevant [7]. The challenge thus lies in the design and realization of the fusion of the physical and data processing environments (hereafter called physical and digital worlds). The object of our study is to address this issue in the context of a collaborative mobility situation. Context detection and mixed reality are then combined in order to create a personalized augmented environment.

The structure of the paper is as follows: first, we clarify the notion of mobile collaborative MR systems. Having defined the goal and challenge of mobile collaborative MR systems, we then present generic interaction techniques for smoothly combining the physical and digital worlds of a mobile user in the context of a collaborative situation. We illustrate the generic nature of the techniques with two systems that we developed: MAGIC for archaeological fieldwork and TROC a mobile collaborative game.

MOBILE COLLABORATIVE MR SYSTEMS

A mobile collaborative MR system combines the characteristics of a mobile MR system and of a collaborative MR system. First a mobile MR system is one in which augmentation occurs through available knowledge of where the user is (the user's location and therefore the surrounding environment). Second a collaborative MR system is one in which augmentation of the physical environment of one user occurs through the actions of other users and no longer relies on information pre-stored by the computer. Links between the physical and digital worlds are therefore dynamic, based on the users' actions. Combining the characteristics of a mobile MR system and of a collaborative MR system, a mobile and collaborative MR system is one in which augmentation occurs through available knowledge of where the user is and what the other users are doing.

Few MR systems combine the mobile and collaborative aspects. The main application domain of such systems is game and one of our developed system, TROC, is a game. Indeed, instead of recreating a virtual world, the existing games are based in the real world, the system only adding the magical possibilities related to the game rules. WARPING [9] is one example, but one of the users is not mobile, since s/he is in front of an augmented desktop. ARQuake [10] and Human-Pacman [1] are two additional examples of games. The users are mobile and they must kill digital enemies (ARQuake) or collect digital cookies (Human-Pacman). In these two examples, we can nevertheless notice that the links between the physical and digital worlds are predefined (positions of enemies or cookies) and the users can only destroy them, they cannot create new “links” such as putting a new cookie in the game field.

Beyond the HCI classical design approach, mobile collaborative MR systems make it compulsory to use a multidisciplinary design approach that embeds complementary methods and techniques for the design and evaluation phases. In [5] we present a scenario-based design approach for mobile collaborative MR systems. In particular scenarios enable the description of how the system would affect the way mobile users carry out their individual and collective activities. Based on the functions integrated in the so-called "projected scenarios", different interaction techniques can be designed. The interaction techniques, described in the following section, are generic and are those supported by our two mobile collaborative MR systems: MAGIC dedicated to archaeological fieldwork and TROC a mobile collaborative game.

GENERIC INTERACTION TECHNIQUES

In order to explain the generic interaction techniques, we first describe the underlying hardware platform. This is an assembly of commercial pieces of hardware. The platform includes a Fujitsu Stylistic pen computer. This pen computer runs under the Windows operating system, with a Pentium III (450 MHz) and 196 Mb of RAM. The resolution of the tactile screen is 1024x768 pixels. In order to establish remote mobile connections, a WaveLan network by Lucent (11 Mb/s) was added. Connections from the pen computer are possible at about 200 feet around the network base. The hardware platform also contains a Head-Mounted Display (HMD), a SONY LDI D100 BE: its semi-transparency enables the fusion of computer data (opaque pixels) with the real environment (visible via transparent pixels). Secondly, a (D-)GPS is used to locate the users. Finally, capture of the real environment by the computer is achieved by the coupling of a camera and an orientation sensor. We first used an absolute orientation sensor, the magnetometer HMR3000 by Honeywell. We now use an intertrax 2 that is more accurate. The camera orientation is therefore known by the system. Indeed the orientation sensor and the camera are fixed on the HMD, in between the eyes of the user. The system is then able to know the position (GPS) and orientation (magnetometer or intertrax) of both the user and the camera. Figure 1 shows a user, fully equipped: the equipment is quite invasive and suffers from a lack of power autonomy. Our goal is to demonstrate the feasibility of our interaction techniques by assembling existing commercial pieces of hardware and not by designing specific hardware out of the context of our expertise. For a real and long use of the platform in a “real” site, a dedicated hardware platform must clearly be designed.

Fig. 1. A user wearing and holding the hardware platform

The mobile users manipulate objects that are either digital or physical. Interaction techniques must be designed in order to let them manipulate the two types of objects: physical and digital. For flexibility and fluidity of interaction, such manipulation is either in the physical world or in the digital world. We therefore obtain four cases, by combining the two types of objects and the two worlds: the physical world (i.e., the archaeological field or the game ground) and the digital world (i.e., the screen of the pen computer):

1. Interaction with a physical object in the digital world: Mixed interaction.

2. Interaction with a digital object in the physical world: Mixed interaction.

3. Interaction with a physical object in the physical world: Interaction purely in the real world.

4. Interaction with a digital object in the digital world: Interaction in the digital world (graphical user interface).

In [5] we fully describe the four types of interaction. We focus here on the interaction techniques corresponding to the types (1) and (2). For both cases, passive and active interaction techniques are designed. Passive interaction techniques are based on tracking mechanisms (such as localization and orientation of the mobile user). With passive techniques, the user does not explicitly issue a command to the system as opposed to active interaction techniques that correspond to the case where the user issues a command to the system, for example a drag&drop of an object.

The two types of mixed interaction ((1) and (2)) respectively imply (i) that physical objects must be manageable in the digital world (ii) that digital objects must be manageable in the physical world. To do so we designed a generic interaction technique, a gateway that plays the role of a door between the physical and digital worlds. As a door belongs to two rooms, the gateway exists in both worlds:

– the gateway is an area of the physical world, delimited by a rectangle displayed in a semi-transparency Head-Mounted Display (HMD),

– the gateway is a rectangular area in the digital world, on the pen computer screen as shown in Figure 2a (window entitled “Head Mounted Display”).

Concretely the gateway is simply a window both displayed on the HMD (Java JFrame) on top of the physical world and on the pen computer screen (Java JInternalFrame). Objects in the gateway are visible on the HMD (i.e., in the physical world) as well as on the pen computer screen (i.e., in the digital world). Based on the gateway, we designed two interaction techniques, namely the “clickable reality” and the “augmented field”.

– The “Clickable reality” technique: from the physical world to the digital world. If the object is physical (1), the object is transferred to the digital world thanks to the camera (fixed on the HMD, between the two eyes of the user). The real environment captured by the camera is displayed in the gateway window on the pen computer screen as a background. We allow the user to select or click on physical objects: we therefore call this technique "the clickable reality". Before taking a picture, the camera must be calibrated according to the user's visual field. Using the stylus on screen, the user then specifies a rectangular zone thanks to a magic lens (kind of camera lens). The cursor displayed on the pen computer screen is also displayed on top of the physical world. The corresponding specified zone (magic lens), displayed in the gateway window on screen and on the HMD, corresponds to the physical object to be captured. The picture can then be stored in the shared database along with the location of the object. Note that although the user is manipulating a magic lens using the stylus on screen, s/he perceives the results of her/his actions in the physical world.

– The “Augmented field” technique: from the digital world to the physical world. If the object is digital (2) dragging it inside the gateway makes it visible in the real world. For example the user can drag a drawing or a picture stored in a database to the gateway window. The picture will automatically be displayed on the HMD on top of the physical world. Moving the picture using the stylus on the screen will move the picture on top of the physical world. This action is for example used if a user wants to compare an object from a database with a physical object in the field. Putting them next to each other in the real world will help their comparison. The motion of a digital object (ex: drag and drop on the pen computer) can be viewed by the user without looking at the pen computer screen. This is because in using the HMD the user can simultaneously view digital objects and the real world. As for the previous case (1), although the user is manipulating a digital object, s/he perceives the results of her/his actions in the physical world. Transfer of digital objects to the physical world can be explicitly managed by the user by drag and drop (active interaction technique) as explained above or can be automatic (passive interaction technique). Automatic transfer is performed by the system based on the current location of the user. When a user walks in the site, s/he can see discovered objects specified by colleagues. The "augmented field" is an example of asynchronous collaboration.

These generic interaction techniques are supported by two mobile collaborative MR systems that we developed: MAGIC dedicated to archaeological fieldwork and TROC a mobile collaborative game.

SYSTEMS: MAGIC AND TROC

MAGIC for archaeological fieldwork

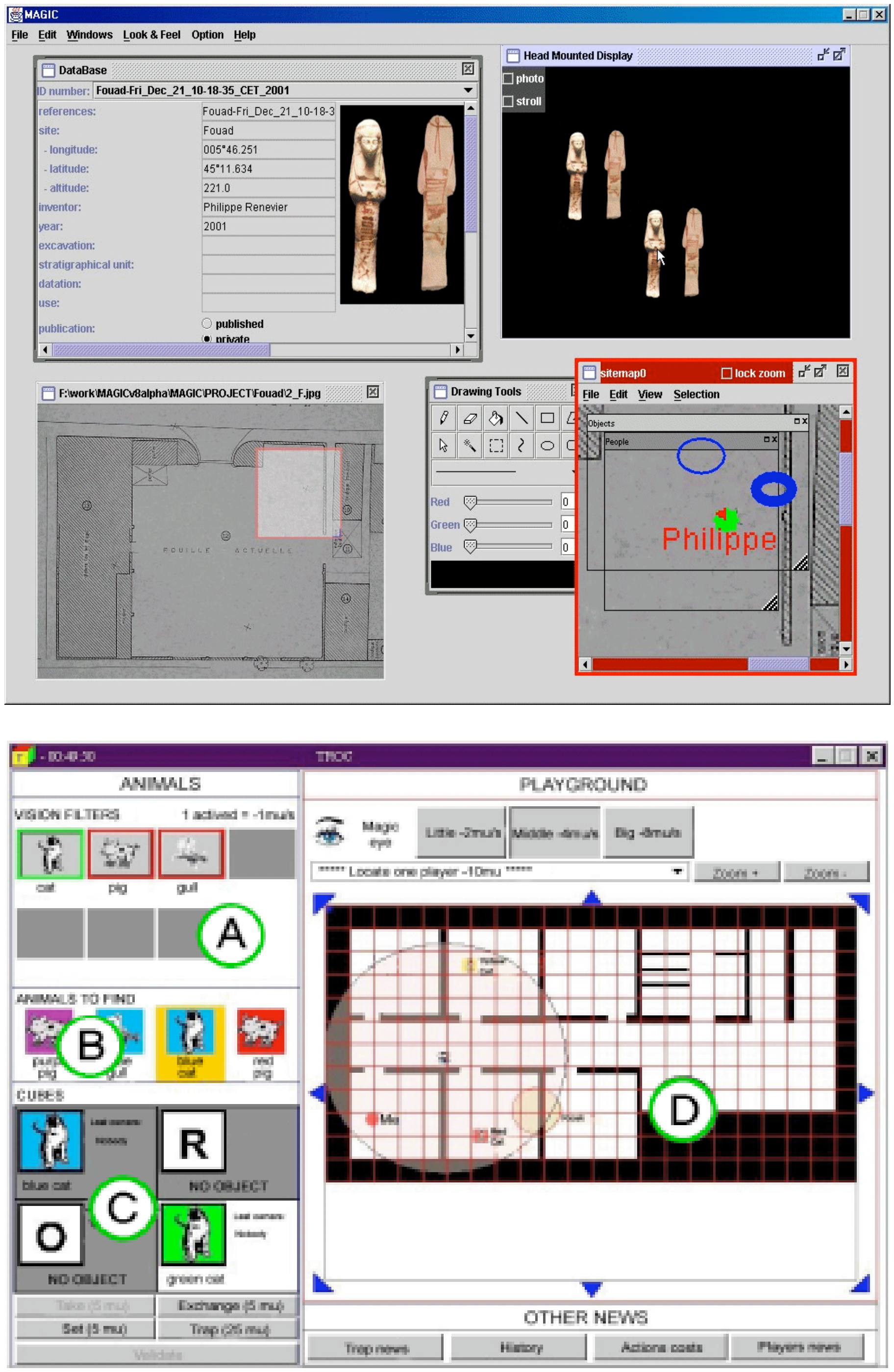
The design of the MAGIC system is based on a study of the tasks of archaeological fieldwork, interviews and observations in Alexandria (Egypt) [5]. The archaeological fieldwork in Alexandria is time-constrained because the archaeological site must be explored in less than three months (rescue archaeology). Tools that can make such fieldwork more efficient are therefore important. This is a suitable application domain for mobile collaborative MR systems because archaeologists work in groups, moving in a delimited site and requiring collections of data. Figure 2a presents the graphical user interface of MAGIC on the pen computer. Coordination between users relies on the map of the archaeological site, displayed within a dedicated window (at the bottom left corner of Figure 2a). For each found object, archaeologists fill a form describing the object, draw some sketches or very precise drawings and take pictures using the "clickable reality" technique. Analysis of objects relies on comparisons with known objects ("Augmented field" technique) from other archaeologists or reference manuals (database) and on discussions with other archaeologists in the site or with a distant expert. After validation, the object is then added to the shared database and is visible on the map of each user. Because a picture is stored along with the location of the object, we can restore the picture in its original real context (2D representation). When an archaeologist walks in the site, s/he can see discovered objects removed from the site and specified in the database by colleagues ("Augmented field" technique). S/he can then see the object as it was before being removed from the site. The "augmented field" technique is particularly useful to see objects belonging to a stratum lower than the current one, because by definition the objects have all been removed. The MAGIC system along with its software architecture is fully described in [8].

Although the design is based on task and activity analysis performed in Alexandria (Egypt), we were not able to experimentally test MAGIC on a site there. In order to show the generic aspect of our techniques and also to be able to perform experimental tests we developed a second application, TROC, a collaborative game.

TROC: a mobile collaborative game

TROC (barter in French) is a mobile collaborative game. Each player has to collect a list of digital objects that are positioned in the game field at the beginning of the game. As shown in part B of Figure 2b, the digital objects to be collected are animals (cat, gull, etc.). Thanks to the "augmented field" technique, the player while moving discovers the objects. TROC also includes 3D sounds that help the player to find the objects. In addition the player can use "magical tools" to locate the objects as well as the other players on the map displayed on the pen computer (part D of Figure 2b, the round circle specifying the zone of observation). The player can also specify filters (part A of Figure 2b) so that s/he will only see one kind of digital object, in the physical world (the game field) as well as on the map.

Digital objects collected by a user are stored in four physical cubes carried by the player. The content of the four cubes is displayed on the pen computer (part C of Figure 2b) as well as on top of the physical cube (Figure 3) recognized by a vision algorithm thanks to the camera fixed on the HMD. To collect a digital object, the player has two possibilities: first s/he can use the "clickable reality" technique or s/he can present a physical cube to the camera fixed on the HMD while issuing the voice command "take" (Figure 3). The player can also empty a cube and put back on the game field a previously collected digital object ("augmented field" technique). This is an example of asynchronous collaboration between players.



(a) (b)

Fig. 2. (a) User interface of MAGIC (b) User interface of TROC

In order to win and collect her/his assigned list of objects, the players must collaborate and exchange collected objects. The game is based on the barter technique. During exchanges, a player can lie saying that s/he has a given object and can also give a trapped object to another player.

We performed a first set of experimental tests of TROC. The primary analysis of the collected data shows that 3D sounds facilitate the location of digital objects, sound being available before the object is visible. In addition, the players underlined the fact that the sound reinforces the link between the physical and digital worlds, by making digital objects more real. Moreover, it has been observed that digital objects, the focus of the players, had a strong presence to the point that players forgot the physical obstacles. Players underlined the inconsistency of seeing an object through a wall and having to go inside the room to be able to pick it up. Although such a possibility was presented as a magical tool which allows one to see through the walls, it confirms the fact that consistency must be maintained while combining the physical and digital worlds. The participants also wanted to pick up objects by hand. In particular such behavior has been observed when the objects were very close to the players and therefore very big. Moreover players had more difficulties to locate objects in a game field without physical landmarks. Indeed, they adopted an approach of blind searching, while with physical landmarks they first located the objects on the map and then went to pick them up.

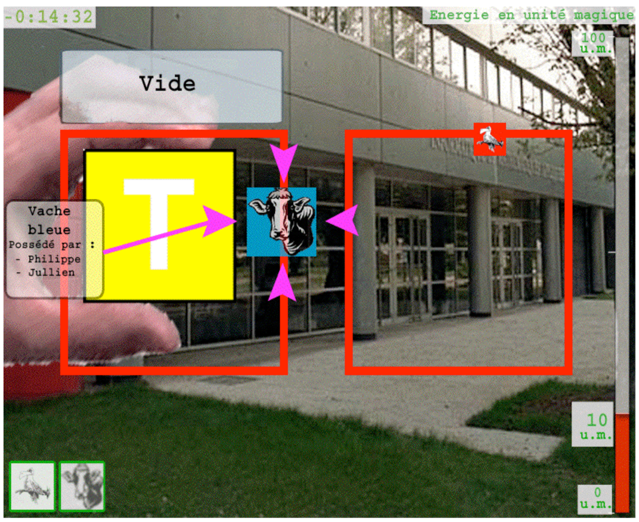


Fig.3. TROC: the content of a cube is displayed on top of the physical cube recognized by a vision algorithm thanks to the camera fixed on the HMD.

CONCLUSION

The generic techniques, "clickable reality" and "augmented field", define a reusable hardware and software platform. We are currently reusing and extending the platform for new applications: we are developing a system that allows users to annotate physical locations with digital notes, which are then read/remove by other mobile users.

The presented interaction techniques therefore constitute the first bricks of a toolkit for developing mobile collaborative MR systems. Reusability of the code and independence of part of it from the hardware are guaranteed by the software architecture model that we applied for developing the platform [8]. During the workshop, we would like to address the issue of toolkit for developing MR systems by making an inventory of existing interaction techniques.

In addition the collaborative situation of the MR systems studied in the paper emphasizes one interesting issue about the links between the real and digital worlds, namely: who is the owner of the link, who is the one who defined it. We suggest that during the workshop we further study the characteristics of the links between the two worlds. As a starting point to this discussion, in [6] we identified two axes for characterizing the links between the two worlds: the owner of the link (i.e., he/she who is defining the link: the designer, one user, all the users) and their static/dynamic character. The link is static if it has been fixed during the design. For example in a computer assisted surgery system that displays anatomical information on top of the patient's body, the link between the digital image (anatomical information) and the physical object (the patient's body) is static and fixed by the designer. On the other hand, using MAGIC, the users dynamically define new digital objects that are combined with physical objects. As pointed out in [3], instead of fixing the relationship between the two worlds during the design, "another strategy is to explicitly give the control to the users, allowing them to define and more importantly, continue to evolve, the relationship between the physical and virtual documents". A promising way to let the users specify such links is through multimodal commands [4]. For example in our TROC system, the player could issue the voice command "this door is now a trap for others" while designating a door.

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