Distributed Display Environments in Computer-Assisted Surgery systems

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ABSTRACT
This paper describes a specific Distributed Display Environment (DDE) developed for a Computer-Assisted Surgery (CAS) system. A mini LCD screen is used to display surgical guidance information. The resulting DDE is described according to a multimodal viewpoint.

Author Keywords
Multimodal interaction, software components, augmented reality.

ACM Classification Keywords
H.5.2 Information Interfaces and Presentation: User Interfaces.

INTRODUCTION

Many Distributed Display Environments (DDE) prototypes were developed according to an efficient “focus + context” distribution such as the “perspective wall” [4]. More recent works have broader contributions from window and task management [8] to interaction techniques [2] [7] via software design support [3].

In Computer-Assisted Surgery (CAS) systems, Augmented Reality (AR) devices (e.g. a see-through head-mounted display) tend to overcome standard CRT monitors for displaying surgical guidance information. We present an intermediate approach [5] in which we use a mini-screen as “focus” and the standard screen as “context”, hence building a DDE. With this approach, we can consider several visual output interaction modalities along both devices. In the next section, we present a conceptual model for multimodality that can be used in DDE design. Then, we briefly describe our CAS system. In the final section, we present the developed interaction techniques based on the mini-screen.

MULTIMODALITY OUTPUT

An interaction modality is seen as a couple <d, L> between a physical device d and an interaction language L [6]. The development of multimodal systems can be achieved by the ICARE platform [1], a component-based approach. ICARE focuses on input modalities but its conceptual model is also valid for output ones. Briefly, this model defines two kinds of component, elementary components and composition components. Both Device and Language are the elementary components that build a “pure” interaction modality. Those elementary components can be composed to make multimodal systems. The Composition components define the CARE (Complementarity, Assignment, Redundancy, Equivalency) properties [6] but there are not specific components for Assignment and Equivalency.

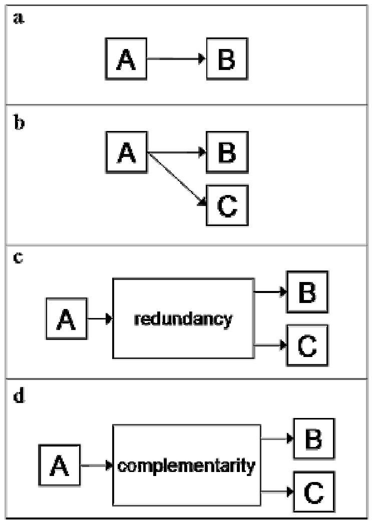

Figure 1. The CARE properties for output interaction

Figure 1 shows each property. When a component B is assigned to a component A (Fig 1.a), only B can process the information flow from A. When several components are linked to the same component (Fig. 1.b), they are equivalent (e.g. a CRT screen and a LCD screen are equivalent to display textual information). On a cell phone, an incoming call can be announced to the user with three simultaneous (i.e. redundant) modalities such as ringing, blinking and vibrating (Fig 1.c). Finally, Complementarity (Fig 1.d) is illustrated when one part of the information from A is passed to B, the other “complementary” part to C.

DESCRIPTION OF THE SYSTEM (CASPER)

CASPER assists the surgeon by providing in real time the position of a puncture needle according to the planned strategy. On screen, the current position and orientation of the physical needle are represented by two mobile crosses, while a stationary cross represents the planned trajectory. When the three crosses are superimposed the executed trajectory corresponds to the planned one. Ergonomic evaluations of CASPER highlighted that the required shift between looking at the crosses on screen and looking at the operating field (i.e. the patient and the needle) was disturbing to the surgeon. The interactive system does not respect the ergonomic property of perceptual continuity. The perceptual continuity means having no perceptual gap between the real and the digital worlds: the user can perceive all the relevant information for her/his task within the same perceptual environment (e.g. the same visual environment).

To improve the perceptual continuity of CASPER, we have decided to use a mini-screen to display guidance information very close to the operating field.

DISTRIBUTED DISPLAYING

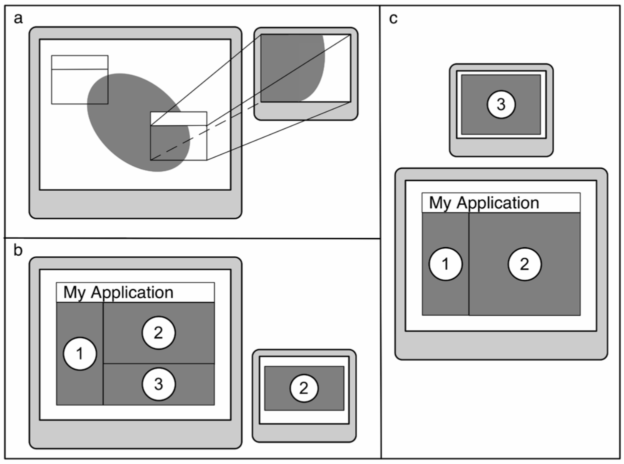

Figure 2. Different display strategies using two screens.

While designing the interaction techniques on mini-screen, we faced the problem of extending existing applications relying on a standard screen. We therefore studied the relationships that can be maintained between the information displayed on the standard screen and the one displayed on the mini-screen. We have identified three main display strategies.

The three strategies are presented in Figure 2. On the left part of Figure 2, the strategies (a) and (b) are based on the replication of information. On the right part of Figure 2, the strategy (c) is based on the distribution of information. The strategy (a) consists of a raw copy of a part of the big screen, pixel per pixel. That strategy works without knowing what is displayed and is therefore independent of the surgical application. For defining what is displayed on the mini-screen, the user places one or several transparent windows on screen. What is visible through a transparent window is also visible on the mini-screen. The user can freely move and resize the transparent windows. Only one transparent window has the focus at a time, so only the content of that window is copied to the mini-screen. The switch between transparent windows is achieved by a pedal or voice commands. The drawback of that strategy is that it needs many articulatory user tasks to place and size all the transparent windows. The strategy (b) also relies on replication but is application-dependent. It is a replication of a specific workspace of the application. The workspaces that can be replicated must be defined by the designer.

According to our conceptual multimodal point of view, the strategies (a) and (b) are partial redundant modalities since parts of the big screen interface are duplicated in the mini-screen. At last, in the strategy (c), a specific workspace is displayed on the mini-screen and only on it. There is no more redundancy but complementarity between the standard screen and the mini-screen.

CONCLUSION

We have presented a specific Distributed Display Environment for a Computer-Assisted Surgery system. The display environment of that system can be described by a multimodal approach.

The display strategies are currently in development. Then, the prototype will be evaluated by comparing the use of two screens versus the first version of the system. Furthermore, we want to find good graphical representations (i.e. screen design) for the concepts on the small display.

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