Ariel: Augmenting Paper Engineering Drawings

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ABSTRACT
Ariel is an example of a new approach to user interfaces called Augmented Reality (see Wellner et al., 1993, Mackay et al., 1993). The goal is to allow users to continue to use the ordinary, everyday objects they encounter in their daily work, and then to enhance or augment them with functionality from the computer. Ariel is designed to augment the use of a particular type of paper document: engineering drawings. Computer information (menus, multimedia annotations, access to a media space) is projected onto a drawing and users can interact with both the projected information and the paper drawing.

The design of Ariel is based on studies of users in a distributed cooperative work setting (the construction of a bridge) combined with a scenario-based design approach in which users contribute to the development of design scenarios. This video shows the third Ariel prototype. Future versions will continue to evolve, based on input from users when the system is installed at the work site.

EUROCODE PROJECT
Ariel is part of a three-year European ESPRIT project called EuroCODE, which provides an object-oriented, open development environment for the development of distributed, multimedia cooperative work applications. The consortium includes partners from Denmark (Aarhus University, Jdysk Telphon, Storbælt), Norway (Norsk Regnecentral), Germany (GMD, Empirica, CAP Debis), and the United Kingdom (ICL, Nexor and Rank Xerox).

A key goal of the project is to create innovative technologies for real users. We are working with the engineers responsible for the construction of the world's longest suspension bridge, which spans the Great Belt (Storbælt) waterway that divides Denmark. By studying their work practices, we have been able to ground the development of the Ariel technology in real-world problems. We are experimenting with 'scenario-based design', in which we work directly with users to create scenarios of work activities and then co-develop technologies with them to support those activities (Mackay and Bødker (1994).

One of Rank Xerox's contributions to the project is the 'High Road Demonstrator' (Mackay et al., 1993), or Ariel, which provides high bandwidth communication facilities for the engineering supervisors. Ariel's design is influenced both by technologies developed at Rank Xerox, particularly the media space (Gaver et al., 1992) and the Digital Desk (Wellner, 1992) and by our studies of users at the site.

USER STUDIES
We interviewed people in a variety of positions at the Great Belt and selected a group of supervisors as our target user group. We accompanied them on trips to the bridge sites and observed them in the course of their daily activities. We discovered that most of their work centers around the use of engineering drawings: updating them, checking them, and comparing them with the real construction. They spend much of their time travelling from site to site. Although they all have computers on their desks, they rarely refer to the on-line versions of the drawings. Instead, they keep personalized paper copies, which they annotate. They also record information during their site visits, either with a Dictaphone for verbal comments or a video camcorder, to record problems or inconsistencies between the construction and the drawing.

Although they find paper very convenient, it can also cause problems. A major issue is the mismatch between the paper and the on-line, officially approved CAD version. Given tight schedules, small changes are often only recorded on their personal drawings. Approval and update of the on-line version (which can take three months) occurs later. If the engineers actually waited for formal approval for every minor change, the bridge would never get built.

The result is that these small changes are often omitted from the final, approved CAD drawings. This was clearly the case when, in the review of the CAD drawings for the recently-completed west section of the bridge, they discovered many discrepancies between the 'final' drawings and what was actually built.

For the most part, the relevant people are all aware of the minor changes. They copy their sketches and notes and fax them to each other. However, the information is sometimes lost, particularly when someone is out of town, or misses an important meeting.

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SCENARIO-BASED DESIGN OF ARIEL

The observation that engineering documents are central to the engineer's work caused us to revise our initial vision of Ariel as an office-based media space. Instead, we used a Digital Desk style of interface, centered around the engineering drawings, and added a media space. This avoids forcing supervisors to change their work patterns while still providing them with significantly new functionality and better access to each other. Their personalized engineering drawings become the interface to the computer system.

We invited users and other members of the EuroCODE project to participate in a series of workshops, in which we developed scenarios of daily work practices and brainstormed ideas about how to better support those practices with new technologies. We created a video prototype that illustrated several user scenarios and showed it to the users. Based on their reactions (and innovative ideas!), we developed several prototypes on different hardware and software platforms. This allowed us to explore both software user interface issues and different hardware options.

We brought potential users to our laboratory in England and got their feedback on some of the possible interfaces. We also created a portable version of Ariel which we brought to the Great Belt and ran a workshop for users. The current version of Ariel, shown in the videotape, is undergoing revision and is scheduled to be installed and tested with real users at the bridge site in the fall and winter of 1994-1995.

ARIEL TECHNOLOGY

Ariel is not a single system, but rather an exploration of a design space. However, all versions of Ariel must address how to identify individual engineering drawings and relate them to on-line versions, capture and respond to user commands, record information supplied by the user (including sketches, hand-written notes, audio and video clips), project information (menus, user information) onto the paper drawings, and provide live, audio/video communication between various bridge and on-shore sites. The Macintosh version of Ariel shown in the video includes the following:

Screen projection:

- an active-matrix, thin-film transistor (TFT) color LCD projection panel mounted on an overhead projector (Proxima Ovation 820, 640x480 pixels with 2 million colors)

Input from the engineering drawing:

- video camera for capturing the x-y position of a pointer (Proxima Cyclops, added to the LCD projection panel). The pointer can be any source of red light: a red LED; a laser beam; the red light on the bar code reader wand
- switchable LED on a paper clip and on a magnet
- bar-code reader (Worthington)
- hand-held scanner (Logitech ScanMan 32)
- A2 digitizing tablet (Wacom)
- video camera and video grabber (using a NuBus expansion slot)

Computer Hardware

- Apple Macintosh PowerBook 180 (portable version)
- Apple Macintosh Quadra series

Communications

- ATM (high bandwidth) or ISDN (lower bandwidth) lines

Software

- HyperCard 2.2
- Custom software to handle input devices

Special Features

- hypermedia linking of multimedia annotations
- detection of the user's current position on the drawing
- bar codes for commands and drawing identification
- access to live video connections via a media space
- virtual paper window: a computer window is projected on to a white piece of paper with a switchable LED attached. The computer tracks the position of the virtual window and projects the computer window on top of it.

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