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Design of Computer Support for Field Operations

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Field personnel, such as bridge inspectors, crane operators and structural welders, often operate in harsh environments where their hands must be free for personal safety or equipment operation. In these situations, the efficiency and quality of field operations are limited by the operator's difficulties in accessing information and understanding the environment. Appropriate computing support can improve field operations by addressing these problems. In these projects, computers were used to provide relevant information, sense and visualise the operating environment, and communicate with remote locations.

It is important that the application of computing support be a step forward for the task and the operator. It is not sufficient to put a desktop application on a portable computer for field use. This implementation may improve the operator's ability to store data but also compromise safety and increase the time required for the task. There are many additional concerns in the design of field computing that are not applicable to desktop systems. Field computing designs often need to address issues such as control through limited user interaction, sensing of the environment, data communication, power, and ruggedness. The user-centred design approach can ensure appropriate use of computing in the field by using the experience of the field personnel to focus on the critical aspects of operations.

The key to the successful development of field computing solutions is to focus on the information processing needs and field location of operations. User-centred design begins with extensive interviews with field personnel and visits to field operations. These observations are compiled into a baseline scenario that identifies the current state of operations including the process and products of the operation and the difficulties posed by the field setting. This information is then combined with field personnel "wish lists" to develop a visionary scenario of idealised field operations. A technology survey produces a list of potential system components. The developers use these components to design alternatives that meet at least the requirements of the baseline scenario and as much of the visionary scenario as possible. A successful field support solution requires: (1) a hardware system that is unobtrusive and designed based on the field inspector's tasks and mode of operation; and (2) a software system designed to support specific tasks by providing knowledgeable advice and context-sensitive forms of human-computer interaction. Communication with the field personnel is critical throughout the process, culminating in the testing, feedback, and design iterations of the selected alternative. Three examples demonstrate the application of this process.

During the spring of 1998, students at Carnegie Mellon University worked with inspectors from the Pennsylvania Department of Transportation (PennDOT), District 11 Office to design and implement an aid for bridge inspectors to use when inspecting bridges. The purpose of the Mobile Inspeciton Assistant (MIA) is to reduce the amount of time inspectors spend on paperwork so that they can spend more time inspecting bridges. When bridge inspectors are in the field, they take a clipboard with inspection forms, previous reports, a photo album, and a collection of generic sketches. To locate information, inspectors have to flip through a number of pages of information on the clipboard. Based on observations such as this and conversations with bridge inspectors, a wearable, speech enabled computer system with a flat panel display was selected as the best solution. MIA provides several data input modalities for bridge inspectors: handwriting, speech, and virtual keyboard. When one modality fails or is not working well, bridge inspectors can always change to another modality that works better for them. MIA integrates commercially available off the shelf software with an application specific user interface. The advantage of using commercially available software is that the prototype development time was shortened. However, inconsistency between the tool interfaces may lead to a steeper learning curve and effect the productivity of the inspectors.

The first prototype of MIA was demonstrated to PennDOT District 11 inspectors and engineers in April 1998, four months after the project was started. MIA has seen frequent upgrades since then to provide additional functionality. Several rigorous full-scale field tests are planned for the spring of 1999. These tests will determine how well the MIA system performs under field conditions and usage.

During the summer of 1998, students at Carnegie Mellon University worked with the Chevron Corporation and Applied Hydraulic Systems (Houma, LA) to design and implement the Offshore Supply Crane Assisting Resource (OSCAR) aid for oil platform crane operators to use for sensing and visualising the operating environment during critical lifts. Potential aids for the crane operators must also withstand a number of environmental and occupational hazards. System components on the boat, cargo, and platform will be exposed to the worst of a marine environment including sun, salt, water, and temperature variation. Two basic project areas emerged: identifying and extracting the data from the scene and processing the data and displaying it as information. Additionally, each component had to be designed to permit self-contained power and flexible mounting options while protecting against the elements, explosion, and physical abuse.

The chosen system design used a sonar transducer to vertically locate the cargo relative to the boat deck. Once the computer in the crane cab receives the data, it must be processed into information that can be readily acted on by the operator. The current display offers a single view with the deck of the boat shown to rise up to meet the cargo. This was chosen over a moving cargo and stationary boat that might lull the operator into thinking the boat was fixed. Visibility concerns ranged from the size and colour of text and objects to the type of display hardware. The user interface for the OSCAR system was kept deliberately simple; computer start-up is the only necessary interaction. Problems should be resolvable with the replacement of a component with a spare.

The OSCAR system has twice been tested on cranes using simulated cargo. Though neither of these tests incorporated the crucial element of the boat motion on real seas, they did allow the operators to offer valuable feedback.

January 1998 saw the start of a new project with General Dynamics Electric Boat (GDEB) Division. The project has developed several prototypes to address remote data access and communication needs at the boat assembly site. A large number of structural welds are performed while constructing a nuclear submarine. At GDEB, these welds are tracked using a mainframe-based system referred to as the Structural Weld Status System (SWSS). Tracking should be updated each time a weld progresses from one step to the next. In reality, SWSS updating is batched, thus causing several problems. If the records are updated as required, the supervisors spend a great deal of time away from the work site and in front of an SWSS terminal.

The SHIP project team at GDEB is currently building a "SHIP Desktop" from which supervisors will access and enter information about the jobs they are supervising. From this desktop, supervisors will be able to track their personnel, assign work tasks, authorise work, etc. The mobile computer being developed downloads pages from this desktop and displays them appropriately on the smaller screen of the mobile device. Wireless communication, a barcode reader, a Java ibutton, and a magnetic card reader have all been integrated into a prototype mobile device for this application.