User-interface Technologies for the Industrial Environment: Towards the Cyber-factory

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Abstract

In the past few years the so-called gadgets like cellular phones, personal data assistants and digital cameras are more widespread even with less technological aware users. However, for several reasons, the factory-floor itself seems to be hermetic to this changes ... After the fieldbus revolution, the factory-floor has seen an increased use of more and more powerful programmable logic controllers and user interfaces but the way they are used remains almost the same. We believe that new user-computer interaction techniques including multimedia and augmented reality combined with now affordable technologies like wearable computers and wireless networks can change the way the factory personal works together with the machines and the information system on the factory-floor. This new age is already starting with innovative uses of communication networks on the factory-floor either using "standard" networks [1] or enhancing industrial networks with multimedia and wireless capabilities [2].

1. Some Background

1.1. Wearable Computers

One of the projects of the Wearable Computer Systems at the Carnegie Mellon University is the Navigator 2 [3]: a multimedia wearable computer for a Boeing aircraft inspection application. An inspector uses the system to examine the skin of a KC 135 aircraft for cracks and corrosion during introduction to depot-level maintenance. The location and type of each defect found is recorded on the device (using a graphical representation of the aircraft as a location indicator). This type of inspection requires crawling over all of the aircraft's skin, typically standing on a "cherry picker" but also attached via safety harness and standing on top of the aircraft. The primary input is a joystick providing general 2-dimensional input that is useful for positioning on the geographic-based input where location is important. The joystick is used in conjunction with speech to mark discrepancies. Field evaluations for aircraft inspection at McClellan Air Force Base indicate not only approximately a 20 percent savings in inspection time but also a dramatically reduced inspection data entry time from hours to minutes.

The Factory Automation Support Technology (FAST) [4], a project of Georgia Tech is intended to: 1) train employees as they perform their jobs, rather than before they perform their jobs, and 2) meet the needs of today's mobile work force. To meet these needs, FAST combines performance support software with wearable hardware. The main idea is that this will decrease the amount of non-productive training time while improving worker performance. To support mobile workers in factory environments, Georgia Tech designed and developed special wearable hardware. This hardware includes: a small computer that can be worn on a belt which allows for portability and transmission of data in real-time to other computer systems, a visor which is worn like safety glasses to display computer information to the user via a miniaturised CRT, earphones for listening to auditory information provided by the computer, and a microphone to allow for voice-activated, hands-free operation of the computer. This hardware enables workers to get information at the task site and, since their hands are not tied up operating the computer, to continue to perform the task as they are receiving the information. This equipment enhances the software-based performance support system by making it accessible to employees at all times.

1.2. Augmented Reality and Location Awareness

The Medical Vision Group [5] at MIT has an AR surgical medical navigation system (depicted left the view of a patient with a synthetic image of the brain) that has been used in the Brigham and Women's Hospital for over 200 neurosurgical cases, and is currently being used routinely for 1-2 cases per week. The system achieves high positional accuracy with a simple, efficient interface that interferes little with normal operating room procedures, while supporting a wide range of cases. An investigation is underway to calculate the monetary savings of using the system for neurosurgery. Initial estimates indicate that the use the system reduces the cost of a neurosurgical procedure by USD 1000 to USD 5000, on average, per case. These savings are mainly due to the fact that the system enables the surgeon to confidently perform the surgery more quickly. In one case, the neurosurgeon reported that the use of the system reduced the length of the surgery from eight hours to five.

The Columbia University Computer Graphics and User Interfaces Lab developed a prototype system [6] that that uses a see-through head-mounted display to explain simple end-user maintenance for a laser printer. It has several 3D trackers to key components of the printer, allowing the system to monitor their position and orientation. A rule-based illustration generation system interactively designs graphics and simple textual callouts that fulfil a set of goals that are input to This virtual world is intended to complement the real world on which it is overlaid. For example, one rule states that if a goal is to show the user where an object is located, the system must determine if the object is blocked by other objects. If it is blocked, it will be displayed so that it appears to be seen through the blocking objects; if it is already visible in the real world, it need not be drawn at all.

The Office of Naval Research (USA Navy) has research on the Battlefield Augmented Reality System (BARS) project [7]. This project examines how three-dimensional strategic and tactical information can be transferred between a command center and individual warfighers who are operating in an urban environment. It is a multi-disciplinary research project that encompasses a number of research and technical issues. These include: (i) the design of novel user interfaces; (ii) the design of new interaction methods; (iii) the development of an interactive, scalable three-dimensional environment; (iv) tracking and registration systems of sufficient accuracy; (v) develop a prototype demonstration system.

The project Hear&There [8] of Sociable Media Group at the MIT Media Lab allows people to virtually drop sounds at any location in the real world. Once one of these "SoundSpots" has been created, an individual using the Hear&There system will be able to hear it. These sounds can be recordings of personal thoughts or anecdotes, and music or other sounds that are associated with a given area. The authors hope that this system can be used to build a sense of community in a location and to make places feel more alive. In addition to being able to drop sounds in a space, Hear&There includes a graphical user interface to allow precise control over where a sound exists in space, how large it is, and various properites of the audio. This is the first stage of a project that will branch into new areas in the future. Some questions that may be addressed in the future are the notion of temporal information (so that a SoundSpot changes over time), augmented communication channels within a space, and moving sounds.

2. Prospective Applications

This section presents several relevant examples of potential factory-floor applications. Some of these applications may seem a little awkward in the industrial environment but can give significant productivity gains and enable new working solutions.

Monitoring and Control - A data network can be used to send real-time data not only from traditional sensors like position detectors or level meters but also from more demanding ones like microphones or video cameras. This can be particularly interesting for gathering information when workers are part of the process, thus enabling more simplified data input and new user interfaces.

Tutorials and Documentation - A device can be used to access tutorial databases, presentations and interactive applications. The installed industrial network with wireless extensions can be a cost-effective solution to make this kind of information available where it is needed.

Multimedia Location Aware Applications - These applications rely on information from the system on the current user location and are also related to mobility issues. This capability could enable innovative ways to deal with faults and maintenance in the factory-floor.

Interpersonal Multimedia Communications and Conferencing - The possibility of using audio or video streams to connect several persons is even more interesting if wireless communications are available for the industrial environments. By definition it is an interactive application so we must have rather small round-trip delays, most of the data is time-sensitive and should be discarded if out of date.

Hidden Box Paradigm and Ubiquitous Computing - Given the appropriate bandwidth, a small, lightweight, low-power device can gather or present information, exchanging it (using a wireless link) with a more powerful processing unit located nearby. Two examples of these applications are wearable computers for data collection, and ubiquitous surveillance cameras and sensors.

2.1. *Monitoring and Control*

A data network can convey real-time data not only originated in traditional sensors or video cameras but also data resulting from direct input by users.

Examples:

Multimedia schematics: a standard monitoring schematic can be enhanced with video streams on demand or in a emergency situation. It can also contain hyperlinks [9] that enable fast access to more documentation or other resources on the network.

Hazardous or inaccessible location monitoring: a camera is placed in a hazardous (radiation, temperature, atmosphere) or inaccessible (pipe, tower, machine) location and a human user can monitor the process.

Remote control: a camera and sensors are placed in a remote location and a human user can interact on the process using the data received.

2.2. *Tutorials and Documentation*

A device can be used to access tutorial databases, presentations and interactive applications.

Examples:

Electronic book: a handheld device with video display and simple controls presents the multimedia (video, text, audio and schematics) data to the user. Data can be streamed from a server or downloaded (with a variable delay) on demand.

On-line help: a machine has a video display and a connection to the central database with documentation. If the user needs some information on the machine data is downloaded and presented in the machine.

Process documentation: the worker can check out the process using data directly from the planing department. This data can be a textual description, a spreadsheet, schematics, or even video sequences or 3D models. The data can be presented using a Personal Computer, the GUI (Graphical User Interface) of a machine, a personal device (including augmented reality devices) or an audio interface.

2.3. *Location Awareness*

Applications that react to the position of the users in the factory-floor.

Examples:

Location-aware Messages: a worker (or an application in the system) can "place" an electronic memorandum, i.e. text, voice or any other document, in a certain location either where he is at the current moment or at any possible spot in the system area. When a worker visits the designated location he is informed that there is a memo available and can access it. The message is really stored in a central system, but since the system knows the location of users this behaviour can be easily implemented. In this way messages like warnings or maintenance notes can be transmitted based on the location of the recipient.

Location-aware Security: the access to certain documents or applications via the wireless or wired network can be limited depending on the users current position.

2.4. *Inter-Personal Multimedia Communications and Conferencing*

The possibility of using audio or video streams to connect several persons is even more interesting if industrial wireless communications are available.

Examples:

Standard video-conference: several units with video cameras and displays are interconnected enabling one-to-many communication. Commonly used for management meetings, tutorials, brainstorming, etc. Its more cost-effective when the groups are geographically distant (travel costs and times balance telecommunication costs). In a factory floor it can be used to help workers in certain tasks remotely including problem solving or collaborative tasks.

Distance lecturer: similar to video-conference but most of the video and sound comes from only one location. Optionally the stream can be switched on demand to other locations (Questions and Answers) but a switching delay is acceptable. Commonly used for lectures and for very long distance meetings. In the factory floor this application could be used when one worker is doing a critical task and several workers can monitor remotely the operation.

Mobile Telephony: using mobile devices to inter-personal voice communication. Used as a cost-effective alternative to standard cellular phones, when no coverage is available, or when security can be a concern. Optionally a PSTN (Plain Standard Telephone Network) interface may be available. This application can be particularly interesting when integrated in computing devices with access to additional information like directories e.g. making a voice call to workers in the factory floor based on their profiles.

Mobile Videophony: using mobile devices to inter-personal video communication. Visual (eye to eye contact) communication gives the clues to the emotional status of the other party. This can be particular interesting if stress prone situations like an emergency.

2.5. Hidden Box Paradigm

Given the appropriate bandwidth a small, mobile, low-power device can gather or present information sending it to a more powerful processing facility located nearby.

Examples:

Use cellular phone to read email: the email is stored in the laptop computer in the briefcase or in your car, using a wireless interface [10] the phone communicates with the laptop and interfaces with the email software.

Surveillance cameras and sensors: the sensors are placed in appropriate locations and only need a power connection (solar power or battery power can be an option), the data is sent to the central unit via wireless. It's very easy to change configuration and the devices can be placed virtually anywhere. The central station can provide advanced processing capabilities like motion or pattern recognition. In an industrial environment it can be use for counting, measuring, quality check, etc.

Ubiquitous computing: the user has a 4small display and sensor devices and the data streams from these is processed in and PC via wireless link. Applications: high quality voice recognition, possible video processing for face recognition, emersive tutorials (using video overlay).

3. References

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