Industrial IT meets The Matrix

Information and communication technologies continue to develop at a ferocious pace, with each new breakthrough radically changing the way we live and work. For most of us, though, it is the way the human-computer interface has changed, and is still changing, that stands out. Progress here is liberating users from traditional screen and keyboard control to provide a more intuitive approach that, among other things, offers relief from information overload.

A major area of interest is augmented reality – the technique of superimposing computer-generated information onto the real world in real time. This technology has now matured to the point where it is beginning to migrate from research labs to real industrial applications.

Imagine you are an engineer in the central control room of a complex process plant. Suddenly, a vibration alarm goes off, indicating that a pump supplying the facility with fresh water is about to fail. You have experienced similar alarms in the past, but they were all false and you are not sure if this one is real. To check it, you call on a plant operator using the intra-plant wireless communication network. The operator, who is wearing a headset, a microphone and a head-mounted display connected to a wearable computer, receives your request to physically inspect the pump. Not knowing exactly where the pump is, he refers to his virtual 'Follow Me' guide, which gives him the directions he needs to find it.

Soon, an alarm sounds in his headset to tell him the pump is just around the corner. Standing next to the motor, he looks at his display, on which the pump is now flashing red. This close to it, he can now actually feel the pump vibrating – quick action is needed: First he acknowledges the alarm; then he pulls up the pump's maintenance record onto his head-mounted display, only to see that the pump should have been serviced several weeks ago, but wasn't. A quick look at the process flow diagram displayed on the screen shows him that there is a bypass pump with enough capacity to take over the defective pump's work. A few minutes later, after consulting with you, he starts up the bypass pump, shuts down the faulty pump, and requests permission to carry out maintenance.

What makes this 'futuristic' scenario possible is something called augmented reality (AR). But what is AR exactly, and what still has to be done before we see it take over on the shop floor?

Seeing more than meets the eye

An augmented reality (AR) system superimposes computer-generated, virtual objects onto the real world so that they appear to seamlessly co-exist in it. The purpose of using such systems is to enhance the perception of, and interaction with, the real world [1].

Although not strictly AR, we are exposed to its concept almost daily on television. News programs and, increasingly, sport events, all overlay real-world broadcasts with virtual (computer-generated) objects. In American football, for example, AR is used to highlight the location of the player with the ball, while in motor sports the racing cars have virtual dashboards 'attached' to them.

Such concepts have also given a boost to the film industry in the last decade or so: The huge success of films like 'Jurassic Park', 'Terminator', 'Titanic', 'The Matrix' and 'Lord of the Rings' can be attributed at least in part to the use of virtual objects.

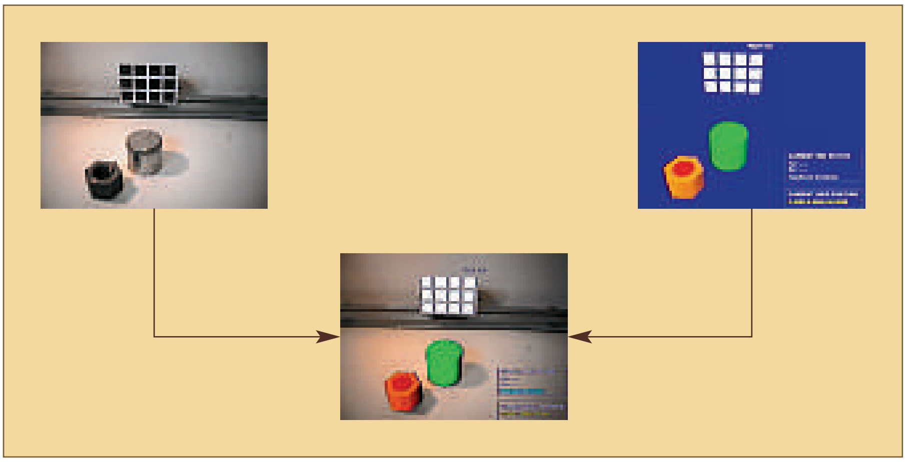
The AR system has to be run interactively in real-time and the real and virtual objects have to be superimposed and aligned in 3D. If this is done well, the real and the virtual should co-exist, making it difficult for the user (or viewer) to easily distinguish between the two.

Although work on AR is focused mainly on information visualization, the concept may also be applied to other human senses, such as smelling, hearing and feeling.

AR technologies have been around ever since the 1960s [2], but it is only in the last decade or so that AR has become widely recognized as a technological field in its own right. This is mainly due to advances in the underlying technology, but also to the widespread adoption of new technologies in other areas. For example, it has benefited greatly from progress made in virtual reality and the growing acceptance and use of support technology used in PDAs, mobile phones, computer games, web cameras and wireless networks.

While still very much in the research domain, there are a number of important application areas where AR is already showing its potential. One is medical visualization. Here, AR is being used to merge and render MRI, ultrasound and CT imagery in real-time to provide surgical teams with images of patients that allow them to plan and discuss operations without having to first perform exploratory surgery. Such techniques are also useful for training.

In another conceivable application an architect with a see-through, head-mounted display could walk around a site and see how a proposed building would look in-situ.



Real-world image (left) combined with virtual objects (right) to provide an augmented view (center)

For several years now, the pilots of military aircraft and helicopters have been using 'head-up' displays to view crucial flight information, overlaid on their view of the real world. Some of this information is synchronized with features and objects in the real world and provides a means of steering the weapon systems.

Researchers are also exploring the benefits of using AR in the assembly, maintenance and repair of complex machinery. Here, instead of using text, instructions could be displayed as 3D animations, superimposed upon the 'real' equipment.

AR technology

The technical equipment required for an AR visualization system varies according to the application, but all systems consist of a display device for presenting the computer-generated images, a tracking system for determining the user's viewing point, a graphics engine for generating the virtual objects, and a software system for calibrating and registering the virtual and real worlds.

Of these subsystems the most interesting and controversial is the display device. Head-mounted displays (HMDs), which position the images in full view of the user's eyes, are the most common. Two configurations are available: optical see-through and video see-through.

With the *optical see-through HMD*, the user sees a view of the real world through partially transmissive image combiners. These combiners are also used to display the virtual objects, which appear to the user to be combined with the real world. With this type of HMD, the view seen by the user is less bright than in the real world.

Video see-through systems use head-mounted video cameras to provide the user with a view of the real world. Views seen by these cameras are combined with the virtual objects created by the graphics engine. The output from the video compositor is sent to the HMD. LCD or OLED based HMDs are now available on the open market. While these devices have a relatively low resolution and narrow field of view, they are comparatively light and cheap, and a great deal can be achieved with them.

The progress being made in display technology is evidenced by the fact that performance, resolution and brightness are all increasing as costs continue to fall. Ideally, any future display would be no larger than a pair of sunglasses and inconspicuous enough for users to forget that they are wearing them.

There are applications, of course, for which HMDs are not ideal. However, alternatives do exist. One is a tablet display that acts as a window through which the user looks and sees the AR view of the world, while another is a projection system that allows the virtual information to be projected directly onto the real objects.

Potential benefits

As indicated, the purpose of an AR system is to extend information visualization and interaction, adapting it to the user, the situation and the physical location. The user's awareness of the situation is unaffected and may even be improved by this, as the AR system provides virtual, context-sensitive information synchronized with the real world that the user is already familiar with. The user of a successful AR system will not be able to distinguish between real-world and virtual information.

Industry already profits today from the ability of computer systems and technology to simplify complex and often stressful work situations, eg through advanced visualization, wireless communication and positioning technology. Further development of AR technology has some significant potential benefits for industry, but it presupposes that, in addition to the technological factors that have to be considered, users are included in the design phase.

The challenges

AR has been slow in coming to market for several reasons: the enabling technology has not been sufficiently mature; the business impact has been unclear; the concept requires users to rethink their working methods; and firms' organizational cultures were not yet ready for the changes that this technology brings.

This situation is, however, changing as industrial IT systems become increasingly complex and require better and more effective user interfaces. Because of this greater complexity, users need information 'at a glance', optimized for

Benefits of AR foreseen for industry

- Users can see information that is not otherwise available.
- Information is presented in the context of physical location, situation, proximity to colleagues, etc.
- Users' awareness of situations is enhanced.
- Information is presented in relation to actual situations.
- Both hands are free for other activities.
- Assets and manpower can be deployed more effectively.
- Quality and safety are improved.

AR applications in broadcast TV, Nascar racing and American football

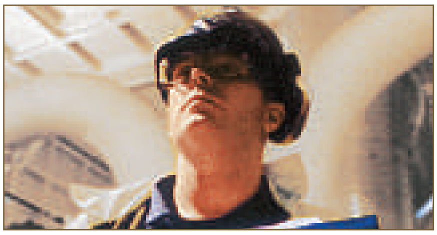
Source: Sportvision, Inc.

Types of display: optical see-through (left) and video see-through (right)

the presentation of concepts and information and also sensitive to context.

For AR technology to take off, two things must happen: First, the price-performance ratio must continue to fall; second, the enabling technologies, which are only now beginning to satisfy requirements, must attain a higher level of maturity. This is particularly true of the displays and to some extent the tracking technology – still the 'Achilles' heel' for many applications.

A large amount of previous research has focused on tracking. To superimpose computer-generated visual information correctly onto a real-world representation, it is necessary to know the exact position of the display or camera in relation to a fixed world reference frame. Technologies commonly used for this include magnetic tracking, ultrasonic tracking, vision-based tracking and tracking based upon intertial navigation.



However, all of these have disadvantages for industrial applications.

Safety is always an important issue when introducing new technology in industry, especially where plant-wide communication and user authentication are involved, and where operators interact with plant control. At the same time, there are many applications, as in maintenance, service and training, where it is less important. AR also has the potential to increase plant or process security by offering a platform for more realistic operator training.

For industry to see AR as being a valuable tool it must offer ease of use; display devices must be comfortable to wear for long periods of time and on no account hinder the user's movements or field of vision.

One of the challenges in introducing a new technology like AR to industry lies in the perceived threat to established work processes. There is also the psychological aspect to consider: Operators are used to controlling and monitoring industrial processes from a centralized control room, and typically communicate via conventional handheld radios. To overcome such problems, senior managers need to understand the positive business impact of using AR technology and operators must see how their everyday tasks are made easier by it.

No longer so futuristic

AR's potential for improving asset utilization, service quality and safety is being realized across a broad industrial spectrum. ABB is therefore moving to integrate AR in its industrial automation solutions through collaborations with leaders in this field, such as MIT's media labs in Boston and Dublin.

While significant challenges remain, a great deal has already been achieved, particularly in base technologies like image capture, display and graphics engines. As these technologies mature we can expect to see lighter, faster and more powerful devices at decreasing cost. When this happens, we will have achieved what has been called 'intelligence amplification' [3] – with machines, computers and humans used in harmony to do what none of them could do alone.

But, as filmgoers the world over already know: 'No-one can be told what the Matrix is. You have to see it for yourself.'

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