Augmented Reality and the Future of Virtual Workspaces

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ABSTRACT

Until recently, Augmented Reality (AR) technology has rarely been discussed outside of the computer science world. It has taken years for this technology to become closer to a stable existence, and will most likely take several more years before it will be used by average citizens. However, the technology does exist, it has been applied in several areas, and research is being done to create even more stable systems that are adaptable to various environments. For this reason, it is necessary for decision-makers in establishments where education and training, knowledge distribution, and individual and collaborative task completion are essential, to be aware of this technology, its abilities, and the possible impacts to common workspaces and workers. The purpose of this chapter is to inform decision-makers of AR's history, the completed research and current applications of AR, possible impacts to managers and workers, and the future trends of the technology.

INTRODUCTION

As humans we have an amazing ability to use whatever items available to complete a task, and if an appropriate item does not exist, we attempt to invent a technology to assist us. For example, we understand that, although possible, it is not practical to memorize the name and location of every body of water on Earth, or every mountain range. Instead, we create a drawing that represents the location and name of every body of water or mountain range. We place this information on a large piece of paper that may be displayed on a wall, or smaller versions that may be rolled or folded for travel purposes. Then, during a task-solving situation where it is necessary for us to recall a specific locale, we check the inscription on the map for an appropriate answer. Here, the map works as a mnemonic device for solving a simple task. In the case of using a map for travel, we open our map, check our location, envision our place on the map in contrast to the destination, possibly take a few notes to assist our memory, and plan our voyage with a higher level of understanding of our location in comparison to our destinations. A document with inscribed symbols has allowed us the ability to simply recall information, or more importantly as a task-solving traveler, it has shown us multiple ways to envision our path to our destination. The information needed to solve our task, the location and possible routes, has been enhanced, and thus, so has our mind. The microscope, telescope and x-ray machine are other examples of technologies that enhance information and allow us to better understand and conceptualize our world. Without them, we would struggle to envision solutions or possible pathways to solutions in scientific and medical applications. With Augmented Reality technology, enhancement of information in a variety of workspaces is possible.

Great technological inventions allow us to not only complete tasks in more efficient and less error-filled ways, they also allow us to "see," categorize and understand the task at hand in multiple new ways that we were once unable to envision. Douglas Engelbart (1963) explains his plan for a "program aimed at developing means to augment the human intellect. These methods or devices can include many things, all of which appear to be but extensions of those developed and used in the past to help man apply his native sensory, mental, and motor capabilities" (p.1). Engelbart's view was to develop technologies, namely computer technologies, that assisted in augmenting the human mind. Personal computers and the internet have followed. Technologies that augment of this sort are needed in the workplace, and this chapter discusses Augmented Reality as such a device that as Engelbart (1963) believed, can be used for "increasing the capability of a man to approach a complex problem situation, gain comprehension to suit his particular needs, and to derive solutions to problems" (p. 1).

It is imperative for those of us that research the interactions of humans, technology and communication, or manage in industry those complex interactions, to be at the forefront of advanced technological equipment information. Augmented Reality Systems hold promise of impacting workplace environments as drastically as the internet did in the 90's and continues to do so today. Similarly to early publications that explained and defined the possibilities of the internet, its impacts on education, workplace settings, and information distribution for humans worldwide, this chapter takes similar aim.

It is true that information on Augmented Reality has been contained mainly in computer science journals and in editorials forecasting new technologies in popular tech-related magazines. Because of the limited number of stable systems, the lack of widespread use in industry, and the lack of collaboration across academic departments on most campuses, information on this technology has yet to find its exit from computer science literature. However, Augmented Reality systems are being used in several areas. The military has used Heads Up Displays in fighter jets for years assisting pilots in finding targets and providing additional information. BMW is likely the most popular car manufacturer that has conducted research into how the systems may be used to assist while driving and in engine repairs. There are several examples of systems designed for use in the field of medicine. These systems provide doctors additional information overlayed on a patient's body to assist in surgery, or provide a type of x-ray vision into the patient's body. This chapter discusses similar examples in a variety of fields and how it can be used in the average office setting.

It is because knowledge of Augmented Reality has stayed within such a narrow audience and because it is an immerging technology, we find it necessary to provide information so that researchers in social sciences, human computer interaction, writing studies / technical communication and similar fields will begin to apply methods of research to this technology. We also wish to inform managers and workers in industry of the technology and the possible impacts on workplace environments to better prepare decision makers when the technology becomes readily available.

This chapter will:

1. Define Augmented Reality (AR), situate it amongst similar technologies, and provide a brief history of research conducted.
2. Explain how workers can use AR as an Online Communication Tool (OCT) for:

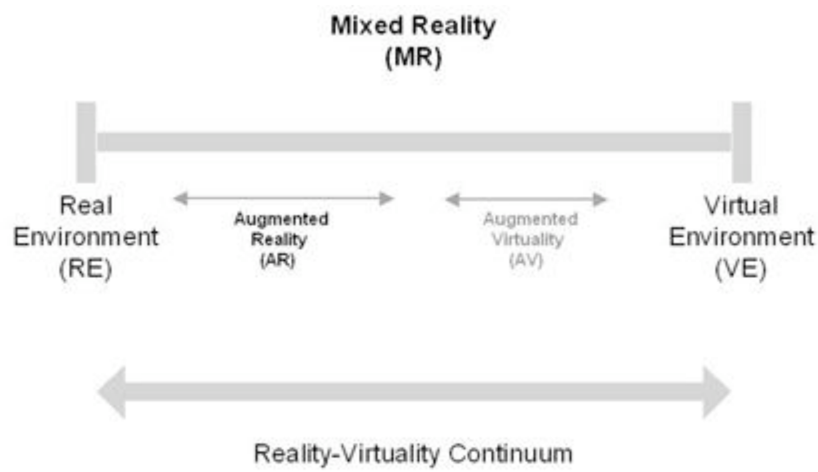
-Organizational Knowledge Management
-Workplace Training / Education
-Conceptual Design and Display
-Advanced Concept Understanding

3. Provide an outlook for the future of AR systems, including an explanation of Mobile Augmented Reality (MARS), the inclusion of voice, sound, and an authoring system.
4. Discuss appropriate workplaces for AR and the potential impact on workers.

AUGMENTED REALITY DEFINED AND SITUATED

In 1965 Ivan Sutherland, a pioneer computer scientist, coined the term, "The ultimate display," and in 1968 he published a paper on his invention of the first Head Mounted Display (HMD). His invention provided a user of the HMD with additional three-dimensional information only the user could see while wearing the HMD. This invention is accepted amongst augmented reality (AR) researchers as the first attempt at creating what is now the modern day AR system. An AR system "supplements the real world with virtual (computer-generated) objects that appear to coexist in the same space as the real world" (Azuma et al., 1997, p 34). Thus, the world around the user becomes augmented in real time, and the real world with the virtual information becomes the user's interface.

To better understand AR, we can define it within what Paul Milgram and Herman Colquhoun Jr. (1999) call the Reality-Virtuality (RV) Continuum. Within the continuum there are five terms: Real Environment (RE), Augmented Reality (AR), Mixed Reality (MR), Augmented Virtuality (AV), and a Virtual Environment (VE). The two polar opposites are the RE and VE. The RE contains no computer assistance or modeling, and the VE is completely computer assisted and modeled. MR encompasses both AR and AV because in both of those worlds the computer assisted and modeled portions of what the user encounters, thus creating a mixture of virtual and real information in an environment. In the case of AV, the base environment in which the presentation takes place is predominantly virtual. A few real objects, plus 2D and 3D photographs add more realism to such an AV. AR, the topic of this chapter, is closer to the RE side of the spectrum, because it is concerned with augmenting a user's RE with virtual information. The base environment is the physical world itself. Below is a graphical representation of the Reality-Virtuality Continuum.



Definition of Mixed Reality and Augmented Reality within the Context of the Reality-Virtuality Continuum (as introduced by Milgram and Colquhoun Jr. (1999))

This definition is based on the affordances of the technology, and not based on the user's perception, or feeling of presence or telepresence as described in Jonathon Steuer's (1992) work. However, in regard to Steuer's explanation, where he rightly argues that the virtualness of the environment is based on the user's perception, it is the goal of AR systems to keep the user within the realm of reality and to simply augment that reality with unobtrusive and purely assistive virtual information.

Another commonly held definition for AR presented by Ronald Azuma (1997), which does not limit AR by the technological hardware, is that an AR system contains the following characteristics:
1. Combines real and virtual
2. Interactive in real time
3. Registered in 3-D

This definition works well because it separates those technologies that do provide much needed enhanced information like a map, the dashboard of a car, a digital wristwatch, television (even with the enhanced information provided for sporting events) from a pure AR technology.

AUGMENTED REALITY HISTORY AS A RESEARCH FIELD

Although a version of AR can be traced back to the time of Sutherland, AR was not a field of study itself until the early 90's. Realizing that although VR was a powerful technology with many applications, VR technologies provided only virtualized representations, or engulfed a user fully in virtuality, and there are many applications where a user needs to remain in synch with reality while receiving augmented information via a virtual image, text or sound. Thus, AR branched off from VR and researchers began to create what was once only theorized into actual working AR environments.

AR visionaries began to see the potential use of the technology in many areas of life. Azuma's (1997) *A Survey of Augmented Reality* outlines ways that AR can be a powerful tool in medicine, architecture, assembly and maintenance, teleoperation of robots, entertainment, and the military. It is safe to add to this list the areas of education, industry training and communication, and tourism. Through the 90's computer scientists concentrated on simply creating AR systems that worked. Although still difficult, creating an AR system in a controlled, indoor environment can today be done routinely. Computer scientists are currently tackling the issue of creating stable AR systems in uncontrolled, outdoor environments where tracking is difficult, displays are not as clear, and computer failures are common. The Mobile Augmented Reality System (MARS) (Feiner, S., MacIntyre B., Höllerer, Webster, A., 1997) created at Columbia University is the first functional example of a mobile outdoor system. (The difficulties of mobile AR system applications and implications are discussed in the *Future Trends* section.)

Of the major projects in AR, most have been Industrial Augmented Reality (IAR) projects. One of the first attempts of using AR in industry as a workplace assistive tool, was conducted at Boeing in 1992. This project attempted to provide a, "'see-thru' virtual reality goggle to the factory worker, and to use this device to augment the worker's visual field of view with useful and dynamically changing information" (Caudell & Mizell, 1992, p.660). The idea was to provide information that would assist the worker who was responsible for complex wiring tasks in the 747 aircraft. Another, ARVIKA, was "designed to implement Augmented Reality system(s) for mobile use in industrial applications" (Friedrich, 2002, p.3). ARVIKA, sponsored by BMBF (German Federal Ministry of Education and Research) and carrying a consortium holding such companies as Daimler Chrysler, Volkswagen, Audi, Ford, and Siemens (amongst many others), began in 1999 and ended in 2003. The project created "about 30 application-specific prototypes …and have been evaluated in usability tests" (Friedrich, 2002, p.3). Another very large, but non industrial AR project was the Key Technology Research Project on Mixed Reality Systems (MR Project) (Tamura, H., Yamamoto, H., Katayama, A., 2001) which was launched in 1997 and backed with funding from Canon and the Japanese government. The project lasted until March of 2001 and yielded several major advances in the areas of image-based rendering, registration, HMD's, mobile AR and collaborative MR.

While computer scientists are working hard at creating new stable systems and publishing their results in the computer science world, very few researchers are looking at potential information distribution and communication impacts in the workplace and on workers.

AUGMENTED REALITY IN WORKSPACES

The affordances of an AR system are numerous. As a training / education tool it can be used to direct a user through a series of steps to complete a task, in place of a technical manual. As a persuasive / rhetorical tool it can be used to assist in the design or display of a 3D object that has yet to be modeled with real materials. As a collaborative tool, an AR system allows multiple users to view the same 3D material, and it allows real time communication among collaborators distributed across geographical locations. As a knowledge management tool, AR may record and document the viewpoint of the user at all times, and then replay the interactions for educational / training / safety / legal purposes. As a conceptual display tool, AR works as an advanced schematic of a concept in that it can display all of the inner workings and connections of a system to a user.

Augmented Reality as a Knowledge Management Tool

In Wensley and Verwijk-O'Sullivan's, *Tools for Knowledge Management* (2000), AR was not included in the list of possible Knowledge Management (KM) tools. This is because AR is usually seen as a technology that is used to display or augment information. However, AR technology does have the ability to assist in what Schwartz, Divitini and Brasethvik (2000) call the "three tenets of internet-based knowledge management" (p. 10). Acquire, Organize and Distribute, the AOD model, are the overarching actions required in a KM system dealing with digital information. In fact, AR technology is based as a system for documenting (with an authoring system), saving/recording, retrieving and creating information in both a 2D and 3D text, visual, and sound based environment.

"Acquisition relates to how we collect knowledge from members of the organization or other resources, and store them in an organizational memory" (Schwartz, Divitini and Brasethvik, 2000, p.10). An AR system can record the actions of a user interacting with virtual and real information, the communication amongst users surrounding the activities, and with an authoring system that allows users to document, via digital text, voice or image, information for other users. Thus, an AR system is acquiring new organizational information each time a user works with the system, and this information can be stored in a database. Also, each time an AR system environment is authored, knowledge of the environment, the virtual information involved, the virtual objects that have been created, etc., are being timestamped in the system and can be retrieved, analyzed, or relived, by future users. Acquisition of information refers to not only the way in which we acquire needed information for a database system, but also the time and space in which that information or knowledge is understood. When information is acquired by a worker, that information must be logged in some form and then acquired in another form by the recording system. An AR system allows, for instances when the information is 3D or not, the worker to immediately document organizational knowledge and physically place that information in a 3D environment.

"Distribution is the ability to get the relevant knowledge to the person who needs it at the right time" (Schwartz, Divitini and Brasethvik, 2000, p. 11). As a distribution technology, an AR system could be programmed to provide a user with the relevant virtual information, overlayed on the real world, in 3D, and that is interactive, in the time period when the user requires it most. Thus, a worker could be solving a task using the AR system, pertinent virtual information that is applicable to the situation could appear, the user can choose to use the information or disregard it, or, the worker can add to the current database of knowledge for future workers involved in a similar task at a later date. As with the system described by Ayatsuka, Hayashi and Rekimoto (1998), users of an AR system are able to leave virtual notes, instructions or directions for coworkers throughout a workspace and throughout time. Those special pieces of organizational information can be saved in a database system as well, and then redistributed at later dates for other employees during the completion of a similar task. This would be similar to leaving a sticky note on a copy machine that is not working properly, only it is possible for the information to be only retrieved by a certain employee using the AR system with an appropriate password (if needed). The system can even decide if the information is relevant to the specific task of the user at that time.

These examples are not meant to glorify AR as a technology that somehow can read a user's mind, or create new organizational "knowledge" for a worker. Donald Hislop's (2005) distinction between data, information and knowledge is valuable here. He explains the three by defining data as "raw numbers, images, words, sounds…", information as, "data arranged in a meaningful pattern…where some intellectual input has been added", and knowledge, "can be understood to emerge from the application analysis, and productive use of data and/or information" (p. 15). We also understand that AR is similar to internet information in that, "to assume that the Web can "deliver" knowledge is as naive a belief as the idea that knowledge can be "extracted" from individual experts and embedded in computer programs" (Wensley & Verwijk-O'Sullivan, 2000, p.120).

Managers and workers must somehow interact and use all of this data, and AR is a system similar to other KM tools in that it can save data, with the interaction of workers acquire information, organize it in a database, and provide retrieval of that information in new ways possibly allowing for the making of knowledge for workers. The obvious benefit to this is that the information being stored and retrieved is not based on a top-down system, but closer to Fischer and Ostwald's view of KM as a cyclic process where workers are reflective practitioners and, "workers, not managers, create knowledge at use time [and]…knowledge is a side effect of work" (2001, p.60). In this AR KM system, the information is dynamic, interactive, virtual, 3D, overlayed on the real environment, and is not attached to a particular time and space.

Augmented Reality as a Workplace OCT for Training, Education, Design and Display

In light of the above examples explaining AR as a KM technology, it is easy to imagine how an AR system could assist workers as an OCT for workplace training, education, design and display.

AR Workplace Training and IAR's

One of the first attempts at creating an Industrial Augmented Reality (IAR) system would be the KARMA (Knowledge Based Augmented Reality for Maintenance Assistance) printer created by AR researchers at Columbia University in 1993, which was a "testbed system for exploring the automated design of augmented realities that explain maintenance and repair tasks" (Fiener, Macintyre, Seligmann, p.54). Basically the KARMA printer, with the use of a HMD, provided the user with additional 3D information about the printer itself. It could show the user simple information like how to remove a tray or which handle to lift by showing virtual 3D arrows or virtual trays located inside the printer. These virtual cues were intended to be used to assist a user in completing a simple task of opening a tray or lifting a handle.

The technology has advanced since 1993 with projects such as the ARVIKA initiative that, along with other AR tools, created systems allowing users to work with 3D information that provided step-by-step instructions for task completion. Unlike a paper or online training manual, an AR system places the information on top of the object so the user does not have to move away from the task, interact with the help system, and then return to task. Prototype systems have been created that take a trainee through simulations where the user may interact with 3D models containing the augmented information. The technology also allows communication and collaboration with expert trainers who may work with their trainees across any distance. Distributed AR, "enables users on remote sites to collaborate on the training tasks by sharing the view of the local user equipped with a wearable computer. The user can interactively manipulate virtual objects that substitute for real objects, try out and discuss the training tasks" (Zhong, Liu, Georganas, 2003, p.7).

The major advancement in AR here is that the system is now being used as a Computer Supported Collaborative Work (CSCW) technology. "The combination of Augmented Reality, mobile computing and CSCW produces a new technology, called Mobile Collaborative Augmented Reality (MCAR)" (Boulanger, 2004, p.321). Because, "Training costs are a considerable part of expenses for many industries…" and, "The problem is compounded when the trainers are far from the would-be trainees," (Boulanger, Geoganas, Zhong Liu, 2003, p.2). "The trend is to provide on-the-job training, giving learners performance support by integrating computer-based guidance and information into the normal working environment through augmented reality technology" (Boulanger et al, 2004, p.2).

Spatial Augmented Realty (SAR) and the Office of the Future

In 1999, Raskar et. al. described their version of the "office of the future" and the technology required to create such a space. Their office consisted of using "real-time computer vision techniques to dynamically extract per-pixel depth and reflectance information for the visible surfaces in the office including walls, furniture, objects, and people, and then to either project images *on* the surfaces, render images *of* the surfaces, or interpret changes *on* the surfaces (p.179). This is what Bimber and Roslear (2005) define as Spatial Augmented Reality (SAR). SAR refers to the application of AR in non-mobile environments, like a traditional office workplace, by displaying interactive 3D objects for the user without the need of a HMD.

A similar type of "smart" display technology has been put into practice in the "Augmented Reality Kitchen" (Bonanni, Lee, Selker, 2005). The MIT Media Laboratory undertook the complex workspace of a kitchen and "built a series of discrete context-aware systems to monitor and inform the most commonly performed tasks in a residential kitchen. These five systems collect information from the environment and project task-specific interfaces onto the refrigerator, cabinets, countertop, and food"(Bonanni, Lee, Selker, 2005, p.2). In this kitchen a virtual recipe is displayed on a wall, food temperature is calculated by an infrared thermometer, food inside the refrigerator is displayed, cabinets contain a inventory system that lights up the item needed in chorus with the current step of the virtual recipe, and a sink that colors its water depending on its temperature. A system like this built for a kitchen could easily be adapted for use in task completion in a traditional office setting.

These types of displays may be used to enhance office communication during the planning stages of a project, presentation, or during deliberations. Maintaining the idea of projected AR displays, Claudio Pinhanez (2001) described how Everywhere Displays Projectors (ED-projector) can be used to "provide computer access in public spaces, facilitate navigation in buildings, localize resources in physical space, bring computational resources to different areas of an environment, and facilitate reconfiguration of the workplace" (p.93). This type of system is particularly advantageous because it provides an AR environment, but it does not require a HMD. In a traditional office setting this type of display would assist presenters by providing 3D object display for all attendees to view and discuss. MagicMeeting (Regenbrecht, Wagner, Baratoff, 2002), is a collaborative AR system "designed to support a scenario where a group of experts meet to discuss the design of a product" (p.151). Such a system would be of particular value to those in architecture, or other design fields where 3D interactive models are necessary to fully explain concepts. Workers can collaborate on a design by displaying the information anywhere that is suitable, and that design is now an interactive and dynamic display ready for manipulation by local or telepresent observers.

<u>AR Videoconferencing</u>
Not all workplace meetings revolve around a 3D designed artifact. However, these meetings do revolve around workplace information. AR based videoconferencing systems exist to assist in the communication practices usually found in a traditional office meeting. "cAR/PE!" is a system that allows "three participants at different locations to communicate over a network simulating a traditional face-to-face meeting. Integrated into the AV environment are live video streams of the participants spatially arranged around a virtual table, a large virtual presentation screen for 2D display and application sharing, and 3D geometry (models) within the room and on top of the table" (Regenbrecht et al, 2004, p.338). Barakonyi, Fahmy, and Schmalstieg (2004) describe a similar AR videoconferencing system that is a "remote collaboration tool combining a desktop-based AR system and a videoconferencing module" (p.89). This system merges the advantages of face-to-face communication in a videoconferencing environment and AR's technological affordances with virtual objects. Kato, Billinghurst, Weghorst and Furness (1999), describe a system where "users can easily change the arrangement of Virtual Monitors, placing the virtual images of remote participants about them in the real world and they can collaboratively interact with 2D and 3D information using a Virtual Shard Whiteboard" (p.1).

Although similar to a webcam display in that participants can discuss information in real time while viewing each other, an AR videoconferencing system allows for the display of 2D and 3D information in the space of each worker taking part in the meeting, and thus workers have access to shared virtual information that each participant may manipulate.

A collaborative AR conferencing example: This picture shows one meeting participant's view of an architectural scene, a reminder of a meeting agenda, and some information on a particular building, all overlaid on top of a meeting table to create a common shared scene with other meeting participants, such as the colleague in view, or remote collaborators.

<u>AR in Workplace Design and Display</u>

In workplaces that require workers to create 3D models, as in engineering and architecture, and for jobs that require workers to explain, discuss, and sell ideas based on 3D models, an AR system can work well as an assistive design / rhetorical tool because of its ability to show 3D models of advanced designs, interactive in real time, and available for numerous observers to view. Often, it is necessary for designers to create models to sell their project ideas. In certain situations a paper or digital diagram, built-to-scale model, or a computerized 3D virtual tour may be the appropriate design / selling medium. However, there are instances where a diagram may not be augmented enough, a model does not provide enough detail, and a virtual tour is too separate from the real environment. An AR system like ARTHUR may be an alternative as it “aims to put virtual 3D models on the designer’s meeting table alongside conventional media” (Penn, A., et al., 2004, p.220). Wearing HMD’s, users can collaboratively create 3D architectural designs complete with pedestrian simulations. The benefit of this technology is that users are present in their current work desk locations, and maintain access to other design tools, like pencil and paper, a computer, tangible models, etc. Users are able to see and interact with the virtual design creations and changes of other users.

Whether a designer is selling the idea to a superior in the workplace or potential outside buyers, an AR system can be used as a powerful rhetorical tool, or it may be used earlier in the design process as a participatory design tool.

An image sequence documenting an interactive Augmented Reality presentation of a planned building (UCSB California Nanosystems Institute) in its future location before construction has started.

The technological affordances of AR as an OCT for training explained in the above examples allow workers to be trained with virtual 3D objects, images, text, or sound in conjunction with completing their task, with the option to collaborate with a trainer who is physically or virtually present. As an OCT for education in the workplace, AR allows for enhanced design and discussion strategies, enhanced displays for presenting 2D or 3D content, and as a CSCW system, AR is excellent because enhanced collaboration across vast distances, with the ability to interact with tangible tools in the same virtual space is possible.

As valuable as these tools are, the future of AR research is looking to expand on these affordances by using ubiquitous computing technology and Mobile Augmented Reality Systems (MARS).

FUTURE TRENDS OF AUGMENTED REALITY

The true potential of AR as an enabling technology for virtual workplaces will likely be reached only when it can be applied in truly arbitrary, dynamic and mobile settings; that is, away from the carefully conditioned environments of research laboratories and special-purpose work areas. Several technologies must be combined to make this possible: global tracking technologies, global wireless communication, location-based computing and services, and wearable computing. From the pace of development and improvement of these communication and information technologies over the past decade, we can safely predict that the basic technological needs for what we may want to term “anywhere augmentation” will be met in the not-too-distant future, but research will have to focus on a few key concepts. Possible scenarios include:

An architect stands in front of a future construction site, discussing his ideas with the owner. Both carry tablet-shaped Anywhere Augmentation devices, which allow them to visualize, modify, and jointly review the design for a new nine story building that they want to blend in with the neighborhood as much as possible. Since it will be the tallest structure around, they carefully simulate the shadowing and light reflection effects at different weather conditions and times of day. They often use the tablet display, which has a camera on its back, as a magic lens that they hold up and “see through” to observe the construction site with the simulated building appearing directly on top of the filmed physical world.

A field scientist assesses a natural reserve to determine where to place a sensor that will report data critical to an evolving model of erosion and runoff phenomena. She dons her augmentation glasses, overlaying several measured and simulated data distributions of relevant variables on the landscape: humidity, percentage of daily sunlight, slope angle, vegetation index, and the anticipated degree of erosion. Despite imperfect localization, she is quickly able to align the contours of the virtual 3D elevation model with the outline of the hill in front of her, establishing registration for overlaying the landscape and data values behind the hill directly in her field of view, in the fashion of Superman's X-ray vision. The system helps her to get an overview, spot anomalies and lets her pinpoint exactly where to place the new sensor.

A schoolchild is on a field trip to learn about botany. Distinguishing different orders and families of trees has never been his strength, but help is at his fingertips. His small electronic companion allows him to see labels of already classified trees directly overlaid on his view and allows him to add tentative new classifications and take pictures for later verification by the teacher or field guide.

What all these scenarios have in common is the idea of having computational resources available anytime and anywhere, and moreover, being able to form a link between the location-specific information and the physical world by direct vision overlays. The term Anywhere Augmentation emphasizes the necessity for such a system to work in arbitrary workspaces in order to become adopted by users and make life easier for them.

One approach that pursues the goal of Anywhere Augmentation is Ubiquitous Computing (Want et al., (1995), but despite fifteen years of strong research contributions in this field, the overall vision of a pervasive infrastructure of interconnected and inter-functioning computing engines, sensors, and displays remains elusive. Even though computing, sensing, and display equipment has become orders of magnitude more powerful and cost-effective while shrinking in size, the cost and effort to integrate vast interconnected networks of this equipment with architectural and urban developments is very high, and maintenance and upgrades for such deployed infrastructure is difficult and expensive. Apart from these problems there will always be scenarios where deployment of an infrastructure will be prohibitive or where the user could be prevented from using an infrastructure deployed by non-cooperating parties. Privacy issues would also be harder to handle because personal data would have to flow through a common central infrastructure in order to be useful to an individual.

Different examples of Anywhere Augmentation hardware platforms: a) a research prototype mobile AR system, b) ruggedized tablet computer (camera and GPS and orientation sensor not in view), c) a handheld AR prototype from an Austrian-German 2003 research collaboration, based on two PDAs and sensors, d) hypothetical smart-phone platform and user situation for dominant hand pointing and non-dominant hand framing.

For all these reasons, the more user-centric combination of wearable computing and augmented reality (Barfield & Caudell, 2001) appears to be a more promising approach to Anywhere Augmentation. Mobile and wearable computing technologies have found their way into mainstream industrial and governmental service applications over the past decade. They are now commonplace in the shipping and hospitality industries, as well as in mobile law enforcement, to highlight a few successful examples. However, current mobile computing solutions outside of research laboratories do not sense and adapt to the user's environment and they do not link the services they provide with the physical world.

If the computer cannot make sense of arbitrary new environments all by itself, the idea must be to enable the human to achieve this task together with the computer. The overall task is easy to describe: The computer has access to a wealth of information about a specific physical environment, and has approximate knowledge of the user's current location, orientation, and interests with regard to that environment, but it lacks the capabilities to link the information accurately to the physical world. Consequently, the human should be empowered with efficient computer-assisted interaction techniques to manage the different data sources that the computer has access to, and to help establish the link and registration with the physical world. After this necessary semi-automatic initialization step for the new environment, the user will be able to reap all the benefits of a directly coupled AR interface.

Humans will have to drive the task of pairing the available digital information with locations in the physical environment, and in order to be able to benefit from grassroots activities, the user interfaces for doing this should be simplified and smartly assisted by computers. A standard access method needs to be in place for retrieving location data from databases responsible for the area the augmented worker is currently passing through. This requires mechanisms such as automatic service detection and the definition of standard exchange formats that both the database servers and the mobile AR software support. It is clear from the history of protocol standards that without big demand and money-making opportunities on the horizon, progress on these fronts can be expected to be slow. On the other hand, the World Wide Web, HTML, and HTTP evolved from similar starting conditions. Some researchers see location-aware computing on a global scale as a legitimate successor of the World Wide Web as we know it today (Spohrer, 1999).

In general, *AR authoring*, the process of generating content for augmented environments, is a key software technology that will have a big impact on the possible success of AR in workplaces. The process can be compared with data entry for today's standard computer-assisted workspaces, in which a set of databases and a business-wide network, a so-called intranet store, distribute information for a large set of decision makers in a company. Because of improved user interface technologies, data entry was shifted from a task that required a computer specialist to a more distributed task that could be performed by the very employees who encountered new data in their daily work processes. Workers on many different levels of the employment hierarchy were enabled to enter, view, analyze, and update business data directly. The same goal holds for AR systems, only that the task is far more complicated, since all information has a very specific positional and contextual component and the data presentation will potentially involve a much more flexible interface than the fairly standardized 2D desktop environments of current office computers. This is why it is of utmost importance to keep the authoring system simple and detached from implementation details. Non-programmers need to be enabled to add computer annotations to arbitrary environments to bring about all the benefits we have discussed so far.

In AR, information presentation is not limited to the visual sense. Interaction with a portable or wearable computer can benefit significantly from multimodal interfaces (Cohen et al., 1998) which allow for direct and robust user input, employing the input and output resources most practical in a specific user context. Valuable input and output modalites for AR interfaces include audio, and in particular speech input and output, and also gesture-based input, either using a pen on a display surface, or through free-form hand motion. The goal is for the worker to operate as unencumbered by technology as possible. This, however, means that computers need to be enabled to infer information by simple observation rather than by interpreting specific learned input sequences using particular input devices. The multi-modal requirements for convenient computer access also differ substantially depending on the current user activity. A user who is surveying a terrain from an elevated observation point with the goal of getting an overview of a larger area's geographic properties has very different computer access needs than, for example, a field scientist who is using both hands to deploy a sensor in a carefully selected location (Krum et al, 2002).

APPROPRIATE AR SETTINGS AND POSSIBLE EFFECTS ON WORKERS

Not every workspace or worker necessitates a technology like AR. Paper, pencil, computer, and an online training manual are proven tools to complete many tasks, especially in office environments. However, because of the affordances of AR in that it combines the real with the virtual, there are situations where an AR system may be used to enhance the task completion process, or display and/or communication of information in conjunction with traditional technologies.

We have provided numerous examples of workplace conditions where AR would be applicable such as when:
-communication at a distance with enhanced visualization and interaction of 2D and 3D material is imperative;
-training and education while interacting with tangible objects and communicating with a trainer either in shared physical space or by distance is needed to enhance communication, increase safety and efficiency and reduce errors;
-recording, distribution, and recollection of information in 2D and especially 3D environments is needed as in a KM tool; and
-collaborative design and interaction of 3D models is necessary.

An even more important discussion involves the possible impacts of this technology on the workers who interact with AR. On the positive side, as with the affordances of the internet, workers will now have access to a wealth of information pertaining to specific job tasks. Unlike the internet, where information is found in particular linked webpages, and users must use search engines in order to locate pertinent information, AR technology allows managers and workers the ability to author their own environment by embedding the relevant information needed for task completion. This allows trainers and workers to create, track, and peruse an information database that is displayed on top of the real world. Expert knowledge is now embedded in the artifacts with which the users interact. An issue here is that although the expert knowledge used to assist a worker may be greatly beneficial to an expert, that knowledge does not simply transfer to a non-expert worker. The advantage of AR in this regard is that the information embedded is dynamic in that each worker may tailor that information specifically for individual task completion. This provides a worker with freedom to complete work with important idiosyncrasies intact. The effect on the worker here is that the AR system is not an imposing piece of technology, but as technological tool available to assist the worker. However, even with a user friendly authoring interface, it is likely that information specialists, like technical communicators and graphic designers, will be needed to mediate the flow of information from expert to novice.

Although AR may not be imposing on how a task is completed, the system does have capabilities to be imposing because each step a user completes, and the way in which that task is completed, may be recorded and reviewed. From a managerial standpoint this is an excellent feature because expert work may be presented to other workers as an educational and training piece. But this may have a negative effect on the worker because it may limit a worker's sense of freedom for fear of mistakes being recorded and reviewed by superiors. And, since the technology can assist a worker by providing accurate directions, a sense of error-free task completion may be felt by the worker.

The effect of information overload, especially in a real-time, interactive and 3D environment will most likely be an issue for some workers. Having the ability to control the amount of information being displayed will help workers, but a worker must also know which information is relevant for task completion of his specific job, and which information he may already understand. The strain on the literacy level of the worker will be great and the adaptation to such an environment is a place for future research.

In the future, AR systems, unlike any static information source, actually could counteract the problems of information overload, if the condition is recognized in time. If the human reaction to information overload was better understood and the computer was equipped with the right sensors, the AR interface could be made adaptive to the worker's stress and confusion level. Information would be presented at different speeds and in a clearly prioritized manner. Adaptive user interfaces have a great potential to enhance their own usefulness under non-optimal circumstances, but they are exceedingly hard to program. Basically, the programmer's task is to provide practical solutions to the unexpected and unforeseen. The only viable solution may be a machine-learning approach where a device accepts after-the-fact user recommendations for previous crisis situations, and attempts to infer future strategies from that data. Such systems are still in their infancy today.

In indoor or mobile AR systems where users must wear a HMD, the weight of the equipment, along with the goggles that must be worn can be cumbersome. In tasks where a worker must be precise while interacting with a tangible object it is possible that the weight of the HMD, or the strain placed on the head or neck may impede precision. In outdoor, mobile environments, workers will have to carry, along with the HMD, a significant weight of equipment equal to that of a backpack full of books.

CONCLUSION

Marshal McLuhan (1963) argued that technology and media are an extension of our bodies, and the message is in the media. If he is correct, then McLuhan would also argue that AR is the technology extended just beyond our skin and clothing, and the message that needs to be researched is how this technology will impact the distribution of information in society, the training and education of workers, and the traditional workspaces where information and knowledge are routinely created, interpreted, acted upon or dismissed. Possibly AR is the

“Ultimate Display” for certain workplace environments, but it may also be the Ultimate Information Communication Tool in the years to come. If this is the case, then researchers in both social science and computer science will need to collaborate in order to create the most efficient and usable AR technology. Education, tourism, entertainment, and medicine, along with the employment fields mentioned in this chapter are all possible locales for AR use. Specialists in these areas will need to make their information known to designers of AR systems, and AR system developers would be wise to seek out their expertise. The rise of the internet is a prime example of an information technology where once only experts were able to design how information would be distributed. Now average citizens, with the help of editing software are able to publish their information. AR technology is similar in that authoring systems will be developed to allow the worker who does not have advanced programming skills the ability to author her own AR environment.

The fields of technical communication, graphic design, interface development, and human-computer interaction will be impacted and their specialties are currently needed to ensure highly usable displays of information including virtual texts, images, icons and video playback. Research on the symbol systems used to provide information, the interaction of the user and the computer, and the impact of the technology and the information display on the user are extensions of research niches for scholars in the above fields. The research that has been conducted in these fields thus far is valuable and needs to be applied and researched in the AR environments. That information needs to be used as a basis for design and study of AR systems where the information is no longer on paper or on an online help system, but provided interactively in 3D space combining real and virtual information displayed on the real world. The empirical evidence and theories grounded in earlier technologies needs to be adopted and tested by researchers interested in enhanced display systems.

As humans we do have an amazing ability to use or create what we need in order to be successful. Creating, researching, hypothesizing, theorizing, and testing those technologies to learn more about the success of that technology as a tool for humans is a natural part of that process. AR is a next step in the evolution of human technology. It holds with it many of the technologies we have used in the past. However, it is not simply the inclusion of multiple technologies that make a new technology great; it is the ability of humans to use that technology successfully to the point that the technology disappears, and its interactions with us become blurred with our natural surroundings and reality. AR is a technology that comes with a learning curve. It is up to the decision-makers in industry if AR is the appropriate tool for their workers, and it is up to AR designers and all of us as researchers to keep producing and testing those technologies that have the ability to enhance the human mind.

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Key Terms and Their Definitions

Augmented Reality- AR supplements the real world with virtual (computer-generated) objects that appear to coexist in the same space as the real world. An AR system has 3 characteristics:

1. Combines real and virtual worlds
2. Information is interactive in real time, and
3. Registered in 3-D

Mixed Reality- An all-encompassing term that includes the spectrum of worlds modeled by computers from Augmented Reality to Virtual Reality.

Spatially Augmented Reality- AR displayed in non-mobile environments like a traditional office space by projectors. Displays may be on walls, desks, ceilings, people, other tangible objects, etc.

Mobile Augmented Reality- Refers to AR use, either indoor or outdoor, where users are able to use the system in unauthored environments either by carrying the AR equipment or by remotely accessing the virtual information. Head Mounted Displays are usually worn for mobile AR, but other displays like a hand held device or portable LCD screen may be used to display virtual information.

Head-Mounted Display- AR equipment worn on the head which houses a display technology (goggles). Displays may either be projected on the lens of the goggles or projected directly on the retina of the user.

Hand Held Display- A display technology that allows a user to see an AR world only when the display technology is held in reference to specific authored environments. This is an alternative to a Head Mounted Display and includes technologies like a portable flat screen monitor or a cellular telephone.

Virtual Retina Display- A type of display technology that works with Head Mounted Display goggles that projects an infrared ray onto the retina of the user. This projection theoretically provides clearer virtual images.