Augmented Reality

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***Abstract*—Augmented reality is an applied research area, which allows the user to percieve his environment with virtually added information. In this paper we discuss this disruptive new technology and how it is taking the consumer electronics by storm. We also discuss the motivation behind this technology , its working , applications and future scope.**

I. Introduction

Augmented reality (AR) is a term for a live direct or an indirect view of a physical, real-world environment whose elements are augmented by computer-generated sensory input, such as sound or graphics. It is related to a more general concept called mediated reality, in which a view of reality is modified (possibly even diminished rather than augmented) by a computer. As a result, the technology functions by enhancing ones current perception of reality. By contrast, virtual reality replaces the real-world with a simulated one.

Augmentation is conventionally in real-time and in semantic context with environmental elements, such as sports scores on TV during a match. With the help of advanced AR technology (e.g. adding computer vision and object recognition) the information about the surrounding real world of the user becomes interactive and digitally manipulable. Artificial information about the environment and its objects can be overlaid on the real world. The term augmented reality is believed to have been coined in 1990 by Thomas Caudell, working at Boeing.

Research explores the application of computer-generated imagery in live-video streams as a way to enhance the perception of the real world. AR technology includes head-mounted displays and virtual retinal displays for visualization purposes, and construction of controlled environments containing sensors and actuators. [http://en.wikipedia.org/wiki/Augmented$_{r}eality$]

A. Milgram's Reality-Virtuality Continuum

In 1994 Paul Milgram and Fumio Kishino defined a mixed reality as "...anywhere between the extrema of the virtuality continuum."(VC), where the Virtuality Continuum extends from the completely real through to the completely virtual environment with augmented reality and augmented virtuality ranging between. Paul Milgram's Virtuality Continuum (VC).

"The conventionally held view of a Virtual Reality (VR) environment is one in which the participant-observer is totally immersed in, and able to interact with, a completely synthetic world. Such a world may mimic the properties of some real-world environments, either existing or fictional; however, it can also exceed the bounds of physical reality by creating a world in which the physical laws ordinarily governing space, time, mechanics, material properties, etc. no longer hold. What may be overlooked in this view, however, is that the VR label is also frequently used in association with a variety of other environments, to which total immersion and complete synthesis do not necessarily pertain, but which fall somewhere along a virtuality continuum. In this paper we focus on a particular subclass of VR related technologies that involve the merging of real and virtual worlds, which we refer to generically as Mixed Reality (MR)."

B. Augmented Reality vs. Virtual Reality

Virtual reality is a technology that encompasses a broad spectrum of ideas. It defines an umbrella under which many researchers and companies express their work. The phrase was originated by Jaron Lanier the founder of VPL Research one of the original companies selling virtual reality systems. The term was defined as "a computer generated, interactive, three-dimensional environment in which a person is immersed." (Aukstakalnis and Blatner 1992) There are three key points in this definition. First, this virtual environment is a computer generated three-dimensional scene which requires high performance computer graphics to provide an adequate level of realism. The second point is that the virtual world is interactive. A user requires real-time response from the system to be able to interact with it in an effective manner. The last point is that the user is immersed in this virtual environment. One of the identifying marks of a virtual reality system is the head mounted display worn by users. These displays block out all the external world and present to the wearer a view that is under the complete control of the computer. The user is completely immersed in an artificial world and becomes divorced from the real environment. For this immersion to appear realistic the virtual reality system must accurately sense how the user is moving and determine what effect that will have on the scene being rendered in the head mounted display.

The discussion above highlights the similarities and differences between virtual reality and augmented reality systems. A very visible difference between these two types of systems is the immersiveness of the system. Virtual reality strives for a totally immersive environment. The visual, and in some systems aural and proprioceptive, senses are under control of the system. In contrast, an augmented reality system is augmenting the real world scene necessitating that the user maintains a sense of presence in that world. The virtual images are merged with the real view to create the augmented display. There must be a mechanism to combine the real and virtual that is not present in other virtual reality work. Developing the technology for merging the real and virtual image streams is an active research topic and is briefly described in Section 1.3.3.

The computer generated virtual objects must be accurately registered with the real world in all dimensions. Errors in this registration will prevent the user from seeing the real and virtual images as fused. The correct registration must also be maintained while the user moves about within the real environment. Discrepancies or changes in the apparent registration will range from distracting which makes working with the augmented view more difficult, to physically disturbing for the user making the system completely unusable. An immersive virtual reality system must maintain registration so that changes in the rendered scene match with the perceptions of the user. Any errors here are conflicts between the visual system and the kinesthetic or proprioceptive systems. The phenomenon of visual capture gives the vision system a stronger influence in our perception (Welch 1978). This will allow a user to accept or adjust to a visual stimulus overriding the discrepancies with input from sensory systems. In contrast, errors of misregistration in an augmented reality system are between two visual stimuli which we are trying to fuse to see as one scene. We are more sensitive to these errors (Azuma 1993; Azuma 1995).

Milgram (Milgram and Kishino 1994; Milgram, Takemura et al. 1994) describes a taxonomy that identifies how augmented reality and virtual reality work are related. He defines the Reality-Virtuality continuum shown as Figure 2.

The real world and a totally virtual environment are at the two ends of this continuum with the middle region called Mixed Reality. Augmented reality lies near the real world end of the line with the predominate perception being the real world augmented by computer generated data. Augmented virtuality is a term created by Milgram to identify systems which are mostly synthetic with some real world imagery added such as texture mapping video onto virtual objects. This is a distinction that will fade as the technology improves and the virtual elements in the scene become less distinguishable from the real ones.

Milgram further defines a taxonomy for the Mixed Reality displays. The three axes he suggests for categorizing these systems are: Reproduction Fidelity, Extent of Presence Metaphor and Extent of World Knowledge. Reproduction Fidelity relates to the quality of the computer generated imagery ranging from simple wireframe approximations to complete photorealistic renderings. The real-time constraint on augmented reality systems forces them to be toward the low end on the Reproduction Fidelity spectrum. The current graphics hardware capabilities can not produce real-time photorealistic renderings of the virtual scene. Milgram also places augmented reality systems on the low end of the Extent of Presence Metaphor. This axis measures the level of immersion of the user within the displayed scene. This categorization is closely related to the display technology used by the system. There are several classes of displays used in augmented reality systems that are discussed in Section 1.3.3. Each of these gives a different sense of immersion in the display. In an augmented reality system, this can be misleading because with some display technologies part of the ”display” is the user’s direct view of the real world. Immersion in that display comes from simply having your eyes open. It is contrasted to systems where the merged view is presented to the user on a separate monitor for what is sometimes called a ”Window on the World” view.

The third, and final, dimension that Milgram uses to categorize Mixed Reality displays is Extent of World Knowledge. Augmented reality does not simply mean the superimposition of a graphic object over a real world scene. This is technically an easy task. One difficulty in augmenting reality, as defined here, is the need to maintain accurate registration of the virtual objects with the real world image. As will be described in Section 1.3.5, this often requires detailed knowledge of the relationship between the frames of reference for the real world, the camera viewing it and the user. In some domains these relationships are well known which makes the task of augmenting reality easier or might lead the system designer to use a completely virtual environment. The contribution of this thesis will be to minimize the calibration and world knowledge necessary to create an augmented view of the real environment.

II. Display techniques

There are three major display techniques for Augmented Reality are headmounted displays, handheld displays, and spatial displays.

A. Headmounted

A Head Mounted Display (HMD) places images of both the physical world and registered virtual graphical objects over the user’s view of the world. The HMD’s are either optical seethrough or video seethrough. Optical see-through employs half-silver mirrors to pass images through the lens and overlay information to be reflected into the user’s eyes. The HMD must be tracked with sensor that provides six degrees of freedom. This tracking allows the system to align virtual information to the physical world. The main advantage of HMD AR is the user’s immersive experience. The graphical information is slaved to the view of the user.[14]

B. Handheld

Handheld displays employ a small display that fits in a user’s hand. All handheld AR solutions to date opt for video see-through. Initially handheld AR employed fiduciary markers, and later GPS units and MEMS sensors such as digital compasses and six degrees of freedom accelerometer-gyroscope. Today SLAM markerless trackers such as PTAM are starting to come into use. Handheld display AR promises to be the first commercial success for AR technologies. The two main advantages of handheld AR is the portable nature of handheld devices and ubiquitous nature of camera phones. The disadvantages are the physical constraints of the user having to hold the handheld device out in front of them at all times as well as distorting effect of classically wide-angled mobile phone cameras when compared to the real world as viewed through the eye. [15]

C. Spatial

Instead of the user wearing or carrying the display such as with head mounted displays or handheld devices; Spatial Augmented Reality (SAR) makes use of digital projectors to display graphical information onto physical objects. The key difference in SAR is that the display is separated from the users of the system. Because the displays are not associated with each user, SAR scales naturally up to groups of users, thus allowing for collocated collaboration between users. SAR has several advantages over traditional head mounted displays and handheld devices. The user is not required to carry equipment or wear the display over their eyes. This makes spatial AR a good candidate for collaborative work, as the users can see each others faces. A system can be used by multiple people at the same time without each having to wear a head mounted display. Spatial AR does not suffer from the limited display resolution of current head mounted displays and portable devices. A projector based display system can simply incorporate more projectors to expand the display area. Where portable devices have a small window into the world for drawing, a SAR system can display on any number of surfaces of an indoor setting at once. The drawbacks, however, are that SAR systems of projectors do not work so well in sunlight and also require a surface on which to project the computer-generated graphics. Augmentations cannot simply hang in the air as they do with handheld and HMD-based AR. The tangible nature of SAR, though, makes this an ideal technology to support design, as SAR supports both a graphical visualisation and passive haptic sensation for the end users. People are able to touch physical objects, and it is this process that provides the passive haptic sensation. [2] [11] [16] [17][18]

D. Spatial Augmented Reality

E. "See-through" Augmenter Reality

III. APPLICATION

A. Entertainment

A simple form of augmented reality has been in use in the entertainment and news business for quite some time. Whenever you are watching the evening weather report the weather reporter is shown standing in front of changing weather maps. In the studio the reporter is actually standing in front of a blue or green screen. This real image is augmented with computer generated maps using a technique called chroma-keying. It is also possible to create a virtual studio environment so that the actors can appear to be positioned in a studio with computer generated decorating. Examples of using this technique can be found at (Schmidt 1996; Schmidt 1996b).

Movie special effects make use of digital compositing to create illusions (Pyros and Goren 1995). Strictly speaking with current technology this may not be considered augmented reality because it is not generated in real-time. Most special effects are created off-line, frame by frame with a substantial amount of user interaction and computer graphics system rendering. But some work is progressing in computer analysis of the live action images to determine the camera parameters and use this to drive the generation of the virtual graphics objects to be merged (Zorpette 1994).

Princeton Electronic Billboard has developed an augmented reality system that allows broadcasters to insert advertisements into specific areas of the broadcast image (National Association of Broadcasters 1994). For example, while broadcasting a baseball game this system would be able to place an advertisement in the image so that it appears on the outfield wall of the stadium. The electronic billboard requires calibration to the stadium by taking images from typical camera angles and zoom settings in order to build a map of the stadium including the locations in the images where advertisements will be inserted. By using pre-specified reference points in the stadium, the system automatically determines the camera angle being used and referring to the pre-defined stadium map inserts the advertisement into the correct place. The approach used for mapping these planar surfaces is similar to that used by the U of R augmented reality system described in Section 2.

B. Military Training

The military has been using displays in cockpits that present information to the pilot on the windshield of the cockpit or the visor of their flight helmet. This is a form of augmented reality display. SIMNET, a distributed war games simulation system, is also embracing augmented reality technology. By equipping military personnel with helmet mounted visor displays or a special purpose rangefinder (Urban 1995) the activities of other units participating in the exercise can be imaged. While looking at the horizon, for example, the display equipped soldier could see a helicopter rising above the tree line (Metzger 1993). This helicopter could be being flown in simulation by another participant. In wartime, the display of the real battlefield scene could be augmented with annotation information or highlighting to emphasize hidden enemy units.

C. Engineering Design

Imagine that a group of designers are working on the model of a complex device for their clients. The designers and clients want to do a joint design review even though they are physically separated. If each of them had a conference room that was equipped with an augmented reality display this could be accomplished. The physical prototype that the designers have mocked up is imaged and displayed in the client's conference room in 3D. The clients can walk around the display looking at different aspects of it. To hold discussions the client can point at the prototype to highlight sections and this will be reflected on the real model in the augmented display that the designers are using. Or perhaps in an earlier stage of the design, before a prototype is built, the view in each conference room is augmented with a computer generated image of the current design built from the CAD files describing it. This would allow real time interaction with elements of the design so that either side can make adjustments and changes that are reflected in the view seen by both groups (Ahlers, Kramer et al. 1995). A technique for interactively obtaining a model for 3D objects called 3D stenciling that takes advantage of an augmented reality display is being investigated in our department by Kyros Kutulakos.

D. Robotics and Telerobotics

In the domain of robotics and telerobotics an augmented display can assist the user of the system (Kim, Schenker et al. 1993; Milgram, Zhai et al. 1993). A telerobotic operator uses a visual image of the remote workspace to guide the robot. Annotation of the view would still be useful just as it is when the scene is in front of the operator. There is an added potential benefit. Since often the view of the remote scene is monoscopic, augmentation with wireframe drawings of structures in the view can facilitate visualization of the remote 3D geometry. If the operator is attempting a motion it could be practiced on a virtual robot that is visualized as an augmentation to the real scene. The operator can decide to proceed with the motion after seeing the results. The robot motion could then be executed directly which in a telerobotics application would eliminate any oscillations caused by long delays to the remote site. More information about augmented reality in robotics can be found at (Milgram 1995).

E. Manufacturing, Maintenance and Repair

When the maintenance technician approaches a new or unfamiliar piece of equipment instead of opening several repair manuals they could put on an augmented reality display. In this display the image of the equipment would be augmented with annotations and information pertinent to the repair. For example, the location of fasteners and attachment hardware that must be removed would be highlighted. Then the inside view of the machine would highlight the boards that need to be replaced (Feiner, MacIntyre et al. 1993; Uenohara and Kanade 1995). An example of augmented reality being used for maintenance can be seen at (Feiner 1995). The military has developed a wireless vest worn by personnel that is attached to an optical see-through display (Urban 1995). The wireless connection allows the soldier to access repair manuals and images of the equipment. Future versions might register those images on the live scene and provide animation to show the procedures that must be performed.

Boeing researchers are developing an augmented reality display to replace the large work frames used for making wiring harnesses for their aircraft (Caudell 1994; Sims 1994). Using this experimental system, the technicians are guided by the augmented display that shows the routing of the cables on a generic frame used for all harnesses. The augmented display allows a single fixture to be used for making the multiple harnesses.

F. Consumer Design

Virtual reality systems are already used for consumer design. Using perhaps more of a graphics system than virtual reality, when you go to the typical home store wanting to add a new deck to your house, they will show you a graphical picture of what the deck will look like. It is conceivable that a future system would allow you to bring a video tape of your house shot from various viewpoints in your backyard and in real time it would augment that view to show the new deck in its finished form attached to your house. Or bring in a tape of your current kitchen and the augmented reality processor would replace your current kitchen cabinetry with virtual images of the new kitchen that you are designing.

Applications in the fashion and beauty industry that would benefit from an augmented reality system can also be imagined. If the dress store does not have a particular style dress in your size an appropriate sized dress could be used to augment the image of you. As you looked in the three sided mirror you would see the image of the new dress on your body. Changes in hem length, shoulder styles or other particulars of the design could be viewed on you before you place the order. When you head into some high-tech beauty shops today you can see what a new hair style would look like on a digitized image of yourself. But with an advanced augmented reality system you would be able to see the view as you moved. If the dynamics of hair are included in the description of the virtual object you would also see the motion of your hair as your head moved.

IV. Conclusion

The conclusion goes here.

References

[1] H. Kopka and P. W. Daly, *A Guide to LaTeX*, 3rd ed. Harlow, England: Addison-Wesley, 1999.