Real IT: Information Technology in Real Space

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Abstract. There are needs recently to push information technology beyond the desktop environment. It is because even decades after the proliferation of information technology, it still, by large, confine the users in its own domain. Conventional IT confined users to the desktop and virtual reality technology confined the users onto specialiced devices such as the HMD, large screen display room, or the CAVE. Our vision is to push for the ubiquity of IT beyond the mobile cell phone media. This paper discusses several requirements for the real IT vision. Spefically we are interested in the characteristics of display technologies that suit our vision. We will describe several key technologies that have been developed within this requirements, and our most recent work in this field.

Keywords: information technology, display technology, virtual reality, augmented reality, volumetric display.

1 Introduction

There has been a great deal of research and development both in the conventional IT field and also in the field of virtual reality. Many new algorithms and technologies have been invented to better support the users in the respective field. However, despite the development, we feel that the users are still confined to the domain of the field.

Conventional IT usually confined its users to the desktop environment. Its users must sit in front of a terminal and interact with the terminal in one-to-one basis. There is little support for multi-users. Even if there are several users that want to conduct a collaborative task, they have to crowd in front of one terminal, in which there can only be one person that operates the system. It is difficult for the users to see all the available information while crowding in front of the terminal and it is also difficult for them to convey their idea to the operator. This kind of setting bottlenecks the input and output of communication from and to the users.

Many researches in virtual reality technology have been focused to address this collaborative problem in conventional desktop environment. However, since VR technology usually put their users in its HMD environment, the CAVE, or large screen display room, we feel that the users are still disconnected from the real space, and from their peers. HMD and CAVE displays completely put users into a virtual reality space in which they are separated from the real space [3]. Usually in this type

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of projection system, co-location collaborative work is not supported due to the stereo rendering technique used. Collaboration with other users is usually done with a virtual representation called avatars. Furthermore, there are still no unifying interface models that support collaboration and interaction in such environments. On the other hand, large screen displays solve the problem of viewing information in a collaborative setting. The users are not crowding in front of a terminal, and information disseminated to the users is well displayed. However, we feel that there are situations when large screen displays are not enough. For example, the situations when the users are mobile, when they occupy a wide area larger than the display, or if the information that needs to be displayed are three dimensional.

1.1 Requirements for Real IT

Considering the situation described in previous section, we have developed a vision for IT technology to penetrate real spaces. The characteristic of a real space and the requirement of technology needed have been address previously by Eitoku et al. [5]. Based of such requirement, we have set the following guidelines in achieving our vision of real IT:

1. Information exists physically within the real world.
2. Not isolate users from their peers and support collaboration.
3. Not encumbering the users with special apparatus.
4. Support the need to naturally display three dimensional image

The main goal of our vision is to realize information penetration into the real space; it must co-exist within the real space in harmony. This means, ideally, the users shall not be confined to the desktop environment or to the specialized VR devices. Current technology that allows information to exist within the real world usually uses HMD as a medium to display the information [2] [8]. This breaks requirement two and three. HMD encumbered the user with its weight and cables; furthermore it isolates its user from the environment, disadvantageous for collaborative work.

2 Related Work

2.1 Projected Reality

There have been several techniques proposed to integrate information into the real world without encumbering the users with devices that disconnect them from the environment and their peers. Projection based technology has been the focus of research in this field. Using an image projector, various techniques have been developed to augment information efficiently into the real world. Raskar et al. [10] described a technique that uses projectors to augment textural information onto a real non-planar object in the real world. Furthermore, textural information could be animated and combined with a projected animation of a moving background to create an illusion of moving objects. A video demo demonstrated a situation where a physical mockup of a car was projected with textures of the painting and rotating tires. Combined with projected images of a moving background, it gave the illusion that the car is moving.

Ehnes et al. [4] took further the concept of projected reality and enabling it to project to not only static objects, but also moving objects. Using several rotatable projectors with marker based tracking system; marked static object, as well as moving objects in the environment can be augmented with information (see Figure 1). This is very useful in a situation where a wide area and several objects are available for augmentation, such as in a museum.

Projected reality is a suitable solution to augment textual or other 2D information onto the real space. However, it does not support the presentation of three dimensional images naturally, breaking requirement four that we have discussed previously. In order to display 3D data, stereoscopic display techniques using polarized glasses are required. This requires the user to wear special device. Non-glasses techniques such as using lenticular sheets have a limited field of view, thus limiting the number of participants. Furthermore, displaying 3D data on a flat 2D screen introduces accommodation and convergence problem that could result in visual fatigue and nausea. [7]

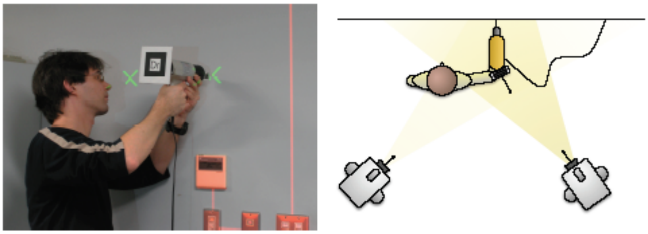

Fig. 1. Using multiple projectors and selection algorithm to augment information to the real space

2.2 Volumetric Displays

One way to display three dimensional data naturally, without accommodation and convergence mismatch, is to use volumetric display. There are two well-known types of display that are able to display information with real depth, thus eliminating the accommodation and convergence problem. Falavora et al. [6] developed a swept-volume type volumetric display called the Perspecta Spatial 3D Display. A swept volume display uses a spinning projection screen to project images at different depths. By spinning the projection screen fast enough, 3D volumetric image can be perceived by the eyes. Tanikawa and Suzuki et al. [9] developed similar system with much larger size using two plasma displays. With this size, it was possible to display human-sized 3D data; furthermore, this type of displays supports presentation to multi-users really well because it could display 3D information in 360 degrees, and special apparatus are not required.

Rotational screen displays begs the users to reach in and interact with the 3D information being displayed. However, it was not possible because the display system itself is in the way. Eitoku et al. [5] addressed this need by developing a volumetric display based on projection onto water particles thus it is possible to reach in into the display. Arrays of water drops are released in a timely fashion so that it creates vertical planar surfaces. A projector from below projects onto these planar surfaces, timed carefully so that each planar surfaces displays a cross-section of a three dimensional objects.

3 Volumetric Augmented Reality Display

As we have described previously, the first requirement of real IT is to enable the presentation of information within the real space. Projected reality system fulfilled this requirement suitably, especially in a situation where information must be displayed directly on a physical object in the real space. Although current volumetric display addressed the need of displaying 3D data naturally so it could co-exist within the real space, it did not address the need of augmenting real object. In other words, the displayed information is separate from the real object. You couldn't for example, display floating textual information over a real printer.

In 2001, Bimber et al [1] developed a mixed reality system for museum exhibition that uses half-mirror reflection technique called the Pepper's Ghost setup with active stereo projection to show real historical artifacts and the virtual representation at the same time. This system consisted of a convex assembly of half-silvered mirror and a BARCO display. The observers could see the stereoscopic virtual objects reflected off the display in the half-silvered mirror, coexisting with the physical object located inside the showcase. Because the system displayed in stereo, the virtual objects could be perceived to have a varying depth. However because the system uses active stereo projection technique, it requires the user to wear a stereo glass. Furthermore, it still suffers from accommodation and convergence mismatch problem.

We have developed an augmented reality display that is able to display volumetric 3D data augmenting the physical object.

3.1 Display System Setup

Our system setup is illustrated in figure 2. To enable physical object and 3D data to co-exist in the same space, we use the Pepper's Ghost setup. In order to display with real varying depths, we used layers of Polymer Dispersed Liquid Crystals (PDLC) film placed on the horizontal plane. A PDLC film can be turned on/off; in off condition, the liquid crystals are in relaxed state causing the layer to have opacity thus it is possible to project image onto it. We specified in our system so that at any given time, there could only be one liquid crystal layer that was in opaque state. This layer was projected with images coming from a projector. To control the depth of the virtual object's appearance, we controlled which PDLC layer was turned off. To minimize the height of the system, we placed a projector on the lower horizontal plane and we used a mirror to reflect the projection upward onto the PDLC layers. A half-silvered mirror was placed at a forty five degrees angle, while the diorama was placed behind the half-silvered mirror. With this setup, the observer would see the images from the PDLC layers inside the half-screen mirror. Since the PDLC layers were stacked physically, when it was reflected, the depth of resulting image corresponded directly on the depth of the PDLC layer. To complete the setup, we

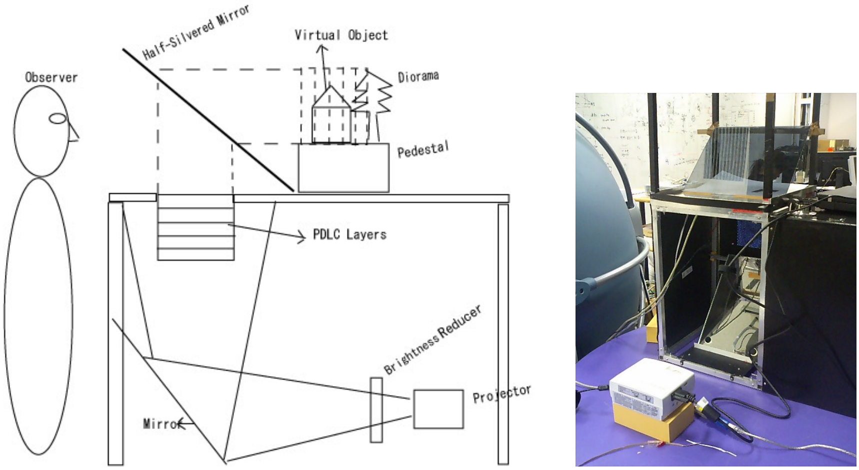

Fig. 2. General System Setup

lighted the diorama with study lamp in order for it to be visible; it was because the projector was really bright. Additionally we placed a dark film in front of the projector to further reduce the light that is coming into the user's eyes, and to prevent the diorama from being washed out due to the projector's bright light.

3.2 Liquid Crystal Layers

We used six layers of PDLC film as our projection screen. PDLC is a relatively new material that is commonly used in an interior design as a digitally switchable window. It is an array of liquid crystal droplets that can be excited with electricity. In relaxed state, the liquid crystals are randomly dispersed, and it prevents light from transmitting, thus it is opaque. When electricity is applied, the liquid crystals become excited, and they lined up properly allowing light to go through, thus it becomes transparent. In Japan, this sheet is sold under the brand UMU films (NSG UMU Products Co., Ltd). We used a particular model that when 100 volts of current is

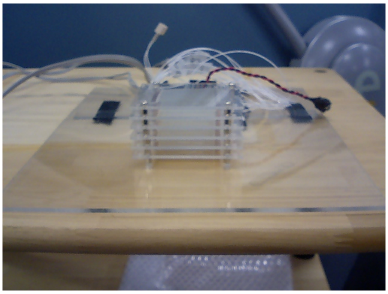

Fig. 3. UMU Film layers sized at 40mmx40mm; each spaced at 7 mm

applied, opaque state is reached with 93 percent haze ratio, and when there is 0 volts of current, it became clear with 12 percent haze ratio.

The PDLC takes 0.78 millisecond to turn from opaque to clear, and from clear to opaque it takes 6 millisecond. We project images onto the film when it turned opaque, and because we are limited by the slowest speed, which is 6 milliseconds.

For our prototype, we used UMU films that are sized at 40 millimeters by 40 millimeters. We placed the UMU film onto a clear acrylic panel that was 2 mm thick, and we set it so that each layer is spaced at 7 mm distance (including the acrylic thickness) from each other (See figure 3), and we used 6 layers altogether.

3.3 Display Rate Consideration and Rendering

There are several things to consider when calculating how fast a display can perform. In our case, we have six layers of PDLC in which each layer's flicker takes 6 milliseconds. Because we are developing a solid stack volumetric display, one frame is defined when all layers within the display have finished rendering; thus, theoretically, it takes 36 milliseconds to complete a volumetric frame. That means in one second, our display could theoretically display 27.77 frames.

However, we must also consider the display rate of the projector used in the system. Currently off-the-shelf DLP projector could display at a max of 85Hz, which it takes 11 ms to draw a frame. So with six layers in the system, the system could still display at 15 frame per second (FPS), which is still within the minimum requirement for a real time display system.

We use OpenGL graphic library to do the rendering. We specify a 3 dimensional frustum with size and resolution that is identical to our physical display which was 40mm(width)x40mm(height)x42mm(depth). Whenever a layer is opaque, we send command to the OpenGL library to draw a cross-section of the frustum.

4 Summary and Discussion

We have presented four specifications that guide us in developing display systems for realizing our vision of real IT. The most of the important aspect of this vision is that we, as the developers, must not separate our users from their environment and their peers when using they are using our system. This means that the information being displayed must be in real space, instead of in the virtual space, for example, in the CAVE or HMD; furthermore, the users must not be burdened with equipments that could increase their cognitive load when interacting or communicating with their peers. In addition, when displaying 3D data, it is important for the users to be able to experience them without focus and convergence mismatch, and preferably the 3D data could exist in the same space with the physical object for information augmentation purpose.

Our recent work of volumetric augmented reality display is in progress to address the need of displaying three dimensional data for augmenting physical objects.

We realize that in order for the vision of real IT to fully be realized, there is really crucial need to address the issue of interface. This means that we need to research a set of interface beyond mouse and keyboard that could be used in a real space along with display technologies that we have defined previously. Input and output system must be defined in order for a system to be fully functional. As part of our progress, we are planning to investigate interaction method suitable for our volumetric augmented reality display. We still start by identifying several requirements that support our vision of real IT and implementing the system according to that guideline. Ideally we would not want to use special purpose hardware that might burden the users, and the paradigm should support three dimensional interaction.

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