Augmented Reality Frameworks and Paradigms

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Introduction

With the advancement of technology, much more information can be provided to a human performing a task than ever before. This information can be instructional, entertaining, or educational and may be presented to the user in a number of different formats. Augmented Reality (AR) is a method of overlaying digital imagery on top of a person’s view of the world and occurs in real-time but requires specific hardware and algorithms that are able to track and determine the positions of objects in view. Three frameworks for performing augmented reality are ARCADE [1], ARMO [2], and ASTOR [3], each with their own benefits and consequences. The purpose of this paper is to summarize the details of each framework while providing insight on what strengths and weaknesses each possess. Lastly, the researched framework techniques and results will be compared and contrasted in a detailed discussion.

ARCADE

Augmented Reality Computing Arena for Digital Entertainment (ARCADE) is a framework designed to keep track of display parameters of an individual viewer and render a virtual image correctly and seamlessly in the field of vision. The main purpose of ARCADE is for entertainment purposes but by no means is restricted to this field. Another practical use could apply to aerospace industries where crucial repair information is displayed for a manufacturer on top of the industrial parts. This information may include diagrams and instructions that would assist the manufacturer in the task of assembling the parts. Another use for ARCADE is robot path planning where a sequence of movements are predetermined for a robot and simulated to examine the results before applying them to the actual robot.
ARCADE uses a core technology termed Video Object Tracking Engine (VOTE) to track objects’ positions and orientations. VOTE accepts various digital video input formats and analyzes the low level visual information such as colors, lighting, edges, regions, and camera parameters. By utilizing a 3D environment matrix, VOTE can track environments aspects like size and position of an object in the field of view. In addition, markers with specific color patterns are placed on physical objects to assist in object recognition and may be superimposed with alternate images.

ARCADE also incorporates technology for performing human head and face tracking for entertainment purposes. The performance of this technology is designed to be near real-time but with medium accuracy due to high priority of an interactive entertainment environment. The algorithm for face tracking is first trained using a classifier object displaying images of faces known as positive examples. The algorithm is also presented negative examples of arbitrary images. After ARCADE is trained, it will be able to recognize a human face in real-time by comparing it to the positive and negative examples it has seen in the past.

The designers of ARCADE created three pilot applications for illustrating the capabilities of the framework: ARProps, ARMirror, and ARMobile. ARProps recognizes 3D surface markers in the viewing area and replaces the underlying real-world object with a computer generated virtual object. This could be used for TV program post-production to replace an object with a digitally enhanced version. ARProps may also apply to robot path planning by recognizing the shape of the robot and overlaying a 3D outline of future steps without moving the actual robot.
ARMirror is kiosk running software for either replacing or enhancing the image of a human head in real-time. The face can either be completely replaced with an animated version or elements could be added such as hats or mustaches. Other objects besides heads could be replaced making this program applicable outside of entertainment in fields such as pilot training and aircraft manufacturing. With more information placed in front of the worker, tasks can be completed quickly and correctly without the use of paper manuals. ARMobile is another head replacement application like ARMirror except it can reside on mobile phones or other devices that have embedded cameras for the sole purpose of entertainment.

The makers of ARCADE believe augmented reality will be a major technology in the near future for entertainment as well as other uses. With the advancement of augmented reality, ARCADE hopes to create new and successful business opportunities. The ARCADE framework’s intent is to create new AR services that are easy to use, cost effective, and entertaining.

**ARCADE Assessment**

ARCADE seems to do a good job taking care of the tricky tasks of augmented reality with advanced object tracking and positioning algorithms. It has established software products that demonstrate its functionality as well as its applicability to useful tasks. In each product, the resulting augmented reality images are displayed on an external monitor where the user would have to watch this monitor if they want to see the virtual objects interact with the real world. Currently ARCADE is limited to entertainment applications but there is no reason it couldn’t be applied to other fields.
ARMO

Augmented Reality based Reconfigurable Mock-up (ARMO) is a rapid prototyping framework designed to assist in the evaluation of design products quickly and cheaply. ARMO allows a user to create shapes out of physical models and then overlay 3D models, colors, and interfaces to test the configuration before going into production using augmented reality operations. These designs could be used in design evaluation and CEO presentations before manufacturing fully functional products.

Currently CAD tools are already being used to model prototypes of designs but with the unfortunate side effect that a user cannot interact with the model physically. A rendering on a computer monitor may not be sufficient for evaluating a product because it doesn’t provide a tactile response. Overlaying a virtual image over top a physical object could eliminate this problem while saving time and money.

The developers of ARMO use blue Styrofoam to create parts of a model and connect them together. Certain parts may have markings that indicate buttons and are replaced with user interface screens. The ARMO software is able to recognize the shapes of the foam as well as the markings and digitally replace them with virtual images. This way it is easy to reconfigure without remanufacturing an entire product and the product designer only has to create the uncommon parts for design alternatives.

Using Styrofoam is an inexpensive and speedy process for creating the prototypes as opposed to industrial materials. ARMO is able to automatically detect the edges of the assembly by comparing them to candidate 3D models and when ARMO finds the corresponding 3D model, it is drawn over top the prototype accordingly.
ARMO is also able to recognize human skin based on skin color detection and labeling algorithms for when the mockup is handled. If ARMO recognizes that a finger is located near a proposed button location the action of that button is activated. Various color spaces were used (RBG, HSV, and YCbCr) and it was determined that YCbCr provided the best results.

The designers of ARMO created three experimental prototypes of personal media players where the pressing of a button would activate a screen. These prototypes were fielded to a test group of 10 people including engineering and art students. The consensus was that it was interesting to be able to create your own mock-ups and seemed as though this could save time and money when designing real products.

**ARMO Assessment**

ARMO suggests a niche usage for augmented reality but implements some ingenious methods to achieve its goal such as CAD model replacement and skin recognition. It is clear that this technology is most beneficial when the user is wearing headgear for viewing the augmented reality. This way they can look down at their mock-up and interact with it as if it was an actual electronic device. Headgear can be a nuisance to wear but shouldn’t be a problem if mobility isn’t a priority.

**ASTOR**

Autostereoscopic Optical See-through Augmented Reality System (ASTOR) is a transparent screen for viewing augmented reality with additional required equipment for the user to wear. It utilizes projectors to display on a clear surface so that the virtual objects appear as though they are part of the scenery on the other side.
Current display technology requires the user to wear head mounted gear in order to track virtual objects in the real world and can be quite intrusive. The goal of ASTOR is to develop AR solutions using projection-based techniques. ASTOR uses a holographic optical element (HOE) to create an AR system where a user can walk up to the display without any equipment and view a combination of real and virtual images regardless of his position.

ASTOR is an autostereoscopic display, which means that it can display three-dimensional images without the use of special headgear or glasses. In particular, ASTOR is a class of autostereoscopic displays that is capable of displaying multiple views. The ASTOR system uses light diffusion to create floating objects in 3D space when light is reflected from an illuminated HOE. The number of projectors used for the display determines the number of perspective views possible in the system. In order to create the appearance of 3D images, one human eye views images through a vertical slit and the other one through a horizontal slit. When these images are combined they appear to be three-dimensional.

The software for ASTOR provides calibration and perspective management. Rendering is performed using Java3D and client/server communication is established over TCP/IP using Java Remote Method Invocation. The software can be interacted with using physical buttons, sliders, and knobs.

ASTOR was set up on a proof-of-concept configuration where an operator would monitor the operation of a machine through a large safety window. A computer is located next to the glass and includes relevant data such as cutting forces, revolutions per minute, temperatures, and position. Such a setup requires a production engineer to look back and
forth and can be an inconvenience. With ASTOR in place, the values are placed directly over the parts in the machine using two projectors.

The current prototype of ASTOR has some deficiencies, however. It can only show monochrome red images and includes only one view. ASTOR uses an HOE that requires the user to focus on real and virtual objects simultaneously and suffers lateral distortion due to the horizontal-parallax-only display it uses. In the future the developers of ASTOR plan to improve each of these setbacks in a costly manner. In addition, they plan on creating more AR applications in the field of industrial machinery to demonstrate the benefits of a system like ASTOR.

**ASTOR Assessment**

ASTOR is an attractive option because it doesn’t require special equipment to wear in order to see the augmented world. The consequence of this, however, is that the user cannot interact with the environment past the screen. So while the user can see augmented reality, he cannot enter its territory. This is fine for monitoring machinery but unsuitable for tasks where the user needs to handle items in the augmented world. In addition, projection solutions can be expensive and require a lot of space to set up.

**Frameworks Comparison**

All three of the frameworks, ARCADE, ARMO, and ASTOR have their advantages as augmented reality solutions and they each have their disadvantages. When choosing an augmented reality framework, it is first important to determine how the augmented world is going to be viewed. There are three possibilities: external monitor, a head-mounted display, or an autostereoscopic screen. ARCADE uses a monitor display, ARMO uses headgear, and
ARMO projects against a screen. A monitor display is ideal for entertainment purposes because the augmented reality is only going be viewed and doesn’t usually need to be interacted with such as in movies. It wouldn’t be acceptable for ARMO because ARMO’s purpose is to allow a user to interact with an augmented image of a product mock-up that they have created. A head-mounted display is required whenever the user needs to interact with the augmented environment such as they do in this case. Head mounted displays are not necessary when the user isn’t required to interact with the environment such as monitoring machines. That is precisely what ASTOR was designed for but a monitor display like in ARCADE isn’t adequate either because that would require the operator to avert his eyes from the machine in order to see the augmented world. An autostereoscopic screen allows the operator to keep his eyes on the machine and see the overlay of instrument information at the same time.

ARCADE appears to be an augmented reality framework for more generic applications where ARMO and ASTOR were designed for specific uses. If your project doesn’t fit into the specific application domain of ARMO and ASTOR then these frameworks most likely wouldn’t be suitable for your implementation. It seems like ARCADE could be adapted for most uses as it is an all-encompassing augmented reality solution.

ARMO is the most expensive solution because it requires consumer-grade projectors, multiple computers, and most-importantly an autostereoscopic screen with a built-in see-through holographic optical element. So, unless your project involves monitoring machinery through glass or similar, this is not a very cost-effective solution. ARMO could also be expensive initially if special headgear is required but in the long run it will save you money if
you use it for its intended use. The money that is saved from creating mock-ups instead of throwaway fully functional projects would justify the start-up cost of the equipment. Again, with ARCADE using traditional equipment, it would be the least expensive but only if viewing on a traditional monitor is adequate enough for your requirements.

Both ARMO and ASTOR seem to be in their very early stages and require a good amount of effort before they can be fully realized. ARCADE is more established and has several demos that demonstrate its functionality. If ARMO or ASTOR looks like attractive frameworks to you, then it might require some waiting before they could be used on any real projects. On the other hand, ARCADE is ready to be integrated into projects in its current form. While there are some enhancements that could be made to ARCADE, it is functional and could make a great contribution to an augmented reality project.

**Conclusion**

Augmented reality is a rapidly expanding technology and has many fields that could benefit from its advancements. Augmented reality can be used to add special effects to video, replace objects in real-time, present instruction and instructions on top of machinery, project future movement of robots, create virtual devices, or simulate events. Industries such as entertainment, engineering, medical, military, and education can all benefit from the advantages of augmented reality. The possibilities seem to be endless for this exciting technology.

When choosing an augmented reality solution, it is important to choose the right tool for the job. It is necessary to understand how the application will be used and how the users will interact with it. Determine whether the user will need to watch a monitor, wear glasses, or look through a screen when selecting a framework. Also decide how intrusive the
augmented reality system can be tolerated by its users. If the user is not in a position that wearing additional equipment is an option, then this is an important factor to consider when making a decision. Hardware and software cost is another key factor to the decision process. Some solutions are not going to be adequate if the end result does not justify the cost of the equipment to construct them. After all the design decisions have been made, there are plenty of frameworks in development to assist in your effort. ARCADE, ARMO, and ASTOR are just three options in the vast realm of augmented reality and there will be several more in the years to come.
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