Apollo Beyond

Learn, Explore, Play

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Thesis Project Proposal
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Contents

Introduction

Does media that is collaborative and spatial in nature provide a superior way to study the solar system, space science, the history of space travel, and the principles behind it, which is more effective than traditional methods?

To set foot on the soil of the asteroids, to lift by hand a rock from the Moon, to observe Mars from a distance of several tens of kilometers, to land on its satellite or even on its surface, what can be more fantastic? From the moment of using rocket devices a new great era will begin in astronomy: the epoch of the more intensive study of the firmament.

--Konstantin Tsiolkovsky, Father of Russian Astronautics, 1896

The goal of ***Apollo Beyond*** is to explore a new type of interaction and how it may aid learning. Through the combination of augmented content and a tangible user interface users will be able to manipulate and interact with both physical and virtual objects. This project will seek to achieve a bridge between the physical and digital world, and provide a valuable way to learn about space science. Conventional teaching methods with regard to space science are based on 2D media; since space is a volumetric problem, 3D educational tools will enhance learning about concepts that are inherently spatial in nature. ***Apollo Beyond*** believes that no other media can provide the same experience.

Augmented Reality

Augmented Reality (AR) is a means of bleding virtual objects (often computer generated images and characters) with reality so that the virtual objects appear to blend in with and be a part of your natural environmental surroundings. A taxonomy that defines a Reality-Virtuality continuum (Fig. 1) was produced by Milgram (Milgram and Kishino 1994; Milgram, Takemura et al. 1994). Every type of media between the real world and a completely virtual one is called Mixed Reality. AR is a subcategory that lies at the end nearest the real world on the continuum. The HowStuffWorks website notes that AR's goal isn't to just superimpose graphics in a real environment, though, "but also change those graphics to accommodate a user's head- and eye- movements, so that the graphics always fit the perspective" (Bonsor 2005).

The Mixed Reality Continuum
(from Vallino 1997).

Figure 1

Due to the fact that AR is a relatively new field of study, this will only be acheived through continuation of current advanced research including the use of motion tracking data, fiducial marker recognition using machine vision, and the construction of controlled environments containing sensors and actuators (http://en.wikipedia.org/wiki/Augmented_reality).

Why Augmented Reality and the Tangible User Interface?

The Right Stuff

While both Virtual Reality (VR) and Augmented Reality deal in the spatial world of 3D objects, many complain about feelings of uneasiness experienced within immersive VR environments. Such feelings are not conducive to learning or prolonged exploration, not to mention enjoyment. AR provides the best of both worlds and alleviates this problem by grounding the user's experience in reality. The 3D items of interest are displayed in the context of the real surroundings. In addition to making the overall environment experienced more familiar, the mixing of the virtual objects with the real environment lends more credibility to the objects' existence in the user's mind, making the experience seem more real. Completely computer-generated VR environments on the other hand can often leave the user flat, where the experience is lessened by a pervading knowledge and sense of disbelief in the world around them. Also, because of the added degree of separation, non-immersive VR environments can often feel like little more than video games, which would not be accepted by many users due to lack of interest in such media.

When dealing with a subject as deeply rooted in the spatial relationships of objects as space science, one can hardly imagine a better tool for investigating its principles than AR. While other forms of media might be able to convey space science ideas, AR may be capable of delivering it in such a way as to relate it to the user's physical world and make the experience more real and thought-provoking. Augmented Reality might lend a unique feel to such experiences and engage the user in a more significant and meaningful way. Hence, it is a good choice for exploring ***Apollo Beyond's*** research question.

Tangible user interfaces are an ideal support for information visualization; as opposed to Graphical User interfaces in which users must share input devices, they are "intrinsically well suited to collocated cooperative work by virtue of their many loci of physical control…Tangible interfaces' externalization of information into physical, manipulable forms also has important implications for facilitating communications and "transparency" of interaction between multiple collocated users. These properties illustrate ways in which tangible interfaces can leverage lessons from distributed cognition. Distributed cognition describes the roles played by physical objects and the physical environment in supporting memory, learning, and interpersonal communications – all properties of direct relevance to tangible interfaces." (*Ishii, Ullmer*) The Hubble Window also supports this interaction in contrast to wearable/head mounted AR systems, which limit the view to an individual user.

Additional Reasons

On a personal note, the members of ***Apollo Beyond*** are extremely interested in this field as an area of study. While Virtual Reality is interesting, ***Apollo Beyond*** thinks it will wind up being useful in only a small group of specialized applications and, in the long run, will likely become little more than a historical footnote as a launching point for other technologies. Augmented Reality allows us to continue to live and socialize with our friends in the world to which we're accustomed while also being able to take our fantasies, our dreams, and our information with us there, too.

From a business standpoint, the visual simulation/Virtual Reality market, within which AR is currently lumped, reached $28B in 2001 and $36.2B in 2002, representing a growth of 30% (http://www.cyberedge.com/). Given the fact that AR is just in it's relative infancy, this market shows great growth potential for use in multiple applications across multiple disciplines and markets. Future uses might include tourist and navigation information stations, B2B and tradeshow product marketing visualizations/demonstrations, education, medical applications, and even manufacturing/QA design and testing.

The HowStuffWorks website suggests that "possibly by the end of this decade, we will see the first mass-marketed augmented-reality system, which one researcher calls 'the Walkman of the 21st century'" (Bonsor 2005). ***Apollo Beyond*** feels that expanding knowledge in this fascinating field would only better improve chances of success in any future business endeavors.

Project Description

The Experience

Apollo Beyond should be used by at least two users simultaneously. Therefore, there are two ways in which the exploration of space science will be presented. The user(s) will be able to study at a worktable to get information, and they will also be able to leave the table to freely walk around and view the augmented reality content through the “Hubble Window.” Essentially, one user will be allowed to freely roam the project arena (the room in which the table is located), and the other would operate the table in the manner of a mission controller. Participants can share the experience by exploring and learning together. ***Apollo Beyond*** is intended to encourage multi-user exploration by sharing the Hubble window view and workable controls, but still be flexible enough to be experienced by a single user.

Mission Control

In addition to being a work surface, the worktable will also be a computer display using overhead LCD projection, and would act like a mission control station guiding the users through an exploration of space science.For this reason the table will be called “Mission Control.” Sensors that can identify a series of tangible objects and track their location will be installed in the table. Initially the table will display a menu with three options, “Learn”, “Explore”, and “Play”. The user can choose which mode they want to use by putting an activation object next to their choice. If they select the learning mode the will be shown a general overview about space science. If they select exploration mode the table will display a map of the solar system. If they select the game mode they will be given instructions on how to carry out a moon shot and execute the sequence of events required to safely send a ship to the moon and safely return it back to Earth, all the while tracking it’s progress in Augmented Reality.

Tabletop Objects and Their Uses

Television Object

This object will bring up a window for viewing media. For example it could show historical footage like the JFK speech at Rice University about the race for space, and the first landing on the moon.

Information Object

When you place this object on a planet on the map, a window will open with information about that planet. In addition to providing information about the planet, the table can also provide instructions on the necessary steps for performing a moon shot. The user at the table would relay instructions to the user who is exploring with the Hubble Window, mimicking the actual Mission Control-to-astronaut communications model used in real space exporation by NASA. Text messages could possibly be sent back to user at table to keep him updated of the Hubble Window user's progress in game mode.

Activation Object

This object will activate the augmented reality content away from the table. It is to be viewed by the other user who is free to walk around the room and explore the solar system in 3D through the use of the Hubble Window.

Magnifying Lens Object

This object will allow the user to zoom in and examine areas of each planet in greater detail.

Stopwatch Object

If incorporated, this object might allow the user to freeze, the AR content for inspection. In addition this object could also allow the user to speed up or slow down AR animations.

Example of how the Hubble Window works (from Newman et al. 2001).

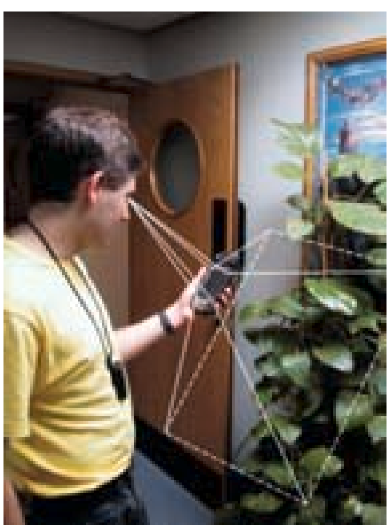


Figure 2

Hubble Window

This is a handheld computer display for viewing the AR content. The "Hubble Window" would feature a video display that shows the user exactly whatever is directly in front of it, thereby creating the effect of looking through a window. The one exception to this mirroring of reality would be that the Hubble Window display would also reveal whatever augmented content the user at the table has activated. This device will also have controls, which allow the user to perform the necessary maneuvers for a moon shot. The user at the table can read step-by-step instructions to the user of the Hubble Window. The Hubble Window will also provide haptic feedback in the form of heat/cold sensations depending on the conditions of the planet the user is investigating. Through the use of the Hubble Window, users will explore the solar system, study different aspects of each planet, learn about the physics of doing a moon shot, etc.

In addition to the Hubble Window, the user will have a utility belt with tangible tools for investigating the AR content. Each would have a function associated with them, so by taking one of the objects and "probing" the current planet being investigated in AR, feedback would be provided such as visuals, information, or sound.

Space Probes

Shovel/Drill Object
This tool is for taking core samples of planets.

Atmosphere Canister Object
This tool is for sampling the atmospheric conditions.

Microphone Object
This tool is for sampling planet sounds (simulated planet sounds).

Camera Object
This tool is for looking at views that can only be captured by camera (simulated/real photos of planets and phenomenon that man can't reach).

Temperature Object
This tool is for taking temperature readings from the planets.

The Content Description

Wan Hu

Figure 3

For thousands of years, people have looked into the sky and speculated about what is really out there. In 1865 Jules Verne wrote about the future invention of a space capsule that could carry people to the Moon. In the 20th century, man finally made the journey into space. Today, in an increasingly technological world, science education is critical. In particular, space science, which combines several scientific disciplines and impacts many other scientific fields, enables people to make informed decisions about their environment, their place in the universe, and the future of our planet (http://cse.ssl.berkeley.edu/whoweare.html - spacescience). The study of space science may also prompt current and future generations to "reach for the stars" (http://www.stsci.edu/ftp/ExInEd/electronic_reports_folder/Space_Science.pdf).

Users of ***Apollo Beyond*** will have access to historical information about space science/travel. This will include both historical anecdotes and information on early astronomers and scientists. For example, users could read about:

- Wan Hu - In the 16^{th} century he decided to take advantage of China's rocket and fireworks knowledge to travel to space in an attempt to become the world's first astronaut. As legend has it, he had a chair built with forty-seven rockets attached, and had forty seven servants light the fuses. Then there was a huge explosion. Wan Hu and the chair were never seen again (http://en.wikipedia.org/wiki/Wan_Hu).
- Gallileo - The father of Modern Astronomy.
- Kepler - The German mathematician who determined the equations for orbiting planets and satellites. He figured out that the planets moved in an elliptical motion rather than a true circle.
- Newton - He established the basic laws of force, motion, and gravitation and invented calculus. He wanted to show how the force of gravity is why planetary orbits follow Kepler's equations.
- Konstantin Tsiolkovsky - A Russian school teacher who established the basic equations for rocketry in 1903. He also determined that liquid fuel rockets would be necessary for space travel.

It will also feature more recent history topics like:

- Sputnik
- President Kennedy's man to the moon by 1969 speech, and the race for space.
- The Apollo program and the first landing on the moon.
- Skylab
- The Challenger
- The Colombia
- President Bush's return to the Moon by 2020 speech.

Users of ***Apollo Beyond*** will also have access to scientific information on the physics involved in space flight:

- Kepler's Laws of Planetary Motion
- Gravity
- Newton's Laws of Motion

Additionally, through the Hubble Window, users will be able to get a point of view that is not possible form one's normal limited perspective. They will be able to explore the circumstances behind the tides, the Solar Eclipse, the Lunar Eclipse, etc. Users will be able to see how the Sun, Moon, and Earth, interact to create these phenomenon rather than just seeing the effect (e.g. the tide rising and falling). This is a perspective which is normally unavailable. Other exporation topics could include:

- Seasons, Solstice and Equinox
- The Planets/orbits
- Moon Phases
- Constellations

In each case, the appropriate celestial bodies would be setup and aligned in the AR environment allowing the user to investigate them from a non-earthbound viewpoint of the influences that are occuring.

Project Explanation

Implementation

The project would require a small network to be set-up that would incorporate:

- The Hubble Window
- Mission Control

It is intended that the network will be based on Bluetooth technology, and that messages will be passed between the two components via the well-documented Short Messaging System (SMS). Short coded messages would be sent, parsed, and interpreted by the ***Apollo Beyond*** control programs. How these messages will be used by each of the components is detailed in the sections below.

The Hubble Window

The Hubble Window will provide the basis for the "magic window" or "magic lens" metaphor. The Hubble Window hardware would consist of:

- A mobile, wireless computing platform (likely using Bluetooth)
- A large screen display (8"-10" diag.)
- A miniature color video camera
- A set of "Space Probe" tools
- An integrated game-type controller
- And possibly some form of hardware for orientation tracking

The video camera on the back of the Hubble Window would record the real world setting before the device. AR tracking algorithms and possibly additional hardware would anchor the augmented virtual object to a real world position and stabilize this image for superimposing it over the video camera feed by the control program. The combined image would then be displayed on the screen.

"Space Probes" would be tracked by calculating proximity to the virtual planet being probed. Tracking of the probes would be done most likely using the chosen AR tracking technology. In this case, the Space Probes would be little more than iconic props with the technical functioning really being carried out by the control programs and the AR technology. Depending on the probe, the proximity of a particular probe near a particular planet will either instantiate an appropriate AR virtual sample for investigation or initiate the sending of a wireless SMS message to Mission Control to display a relevant media stream there.

The Temperature Probe would be the only Space Probe to be wired to the Hubble Window. This is so a temperature effector built into the probe's handle could be activated based upon the probe's proximity to a particular planet. The temperature effector would utilize the Peltier effect to create either a hot or cold surface against the user's skin depending on the planet's relative temperature to Earth by switching the effector's polarity. In this way, probing a planet with the temperature probe will provide the user with a physical, qualitative sensation conveying the planet's relative temperature. In addition to this, an SMS message would be sent to Mission Control to indicate that the Temperature Probe is being used with the chosen planet, and Mission Control would respond by displaying related quantitative temperature data on the main Workspace screen.

Likewise, depending on the choices made at Mission Control, SMS messages would be sent to the Hubble Window to determine which set of augmented content to display. Properties of some AR content may also be controlled through the TUI at Mission Control, such as the scale of the content being displayed or possibly the stopping or playing of AR animations in progress through a stopwatch tool.

The game controller used for the more active game elements of the project would likely be a standard game controller for the PC, PlayStation, or XBox that would be hacked, if even necessary, to provide the appropriate inputs.

Logistical and financial considerations suggest that an integrated handheld or similar unit may prove to be the optimal solution for the functions of both computing platform and display. This might be a handheld computer running Windows CE or a tablet-type computer. However, a custom-built wearable computer or modified computer might be used. The introduction of the Apple Mini has inspired some to convert the compact, powerful platform to run on a battery pack for up to 1.5 hours.

With recent advances in computers getting smaller, lighter, less bulky, and with smaller battery and lower power requirements, it is hoped that a solution can be engineered that will preclude the need for carrying cumbersome cases strapped over the shoulder or integrated into a heavy utility jacket (Fig. 4). With one of the project's sub-goals being to further work in the field towards "AR for the masses", integrated solutions like handheld computers that already incorporate the required display, computing platform, and, in some cases, cameras would be a great advantage. There are also fashion and social issues associated with HMD-type systems which may be hold-overs from many experiements in Virtual and Augmented Reality systems and personal feelings about cybernetic integration that might detract from the ***Apollo Beyond*** experience.

Why Handheld Augmented Reality?

Instead of using Head Mounted Displays (HMD), the Augmented Reality (AR) experience in ***Apollo Beyond*** would be different from many AR implementations in that it would attempt to augment the user's environment utilizing the "magic window" or "magic lens" metaphor. This approach would neccessitate that the display be handheld to some degree and portable.

With recent advances in computers getting smaller, lighter, less bulky, and with smaller battery and lower power requirements, it is hoped that a solution can be engineered that will preclude the need for carrying cumbersome cases strapped over the shoulder or integrated into a heavy utility jacket (Fig. 4). With one of the project's sub-goals being to further work in the field towards "AR for the masses", integrated solutions like handheld computers that already incorporate the required display, computing platform, and, in some cases, cameras would be a great advantage. There are also fashion and social issues associated with HMD-type systems which may be hold-overs from many experiments in Virtual and Augmented Reality systems and personal feelings about cybernetic integration that might detract from the ***Apollo Beyond*** experience.

Example of a virtual train superimposed over a real world wooden track on a handheld PC display (from Wagner et al. 2005).

Figure 4

Head Mounted Display mobile Augmented Reality (AR) versus Handheld mobile AR (from Wagner et al. 2005).

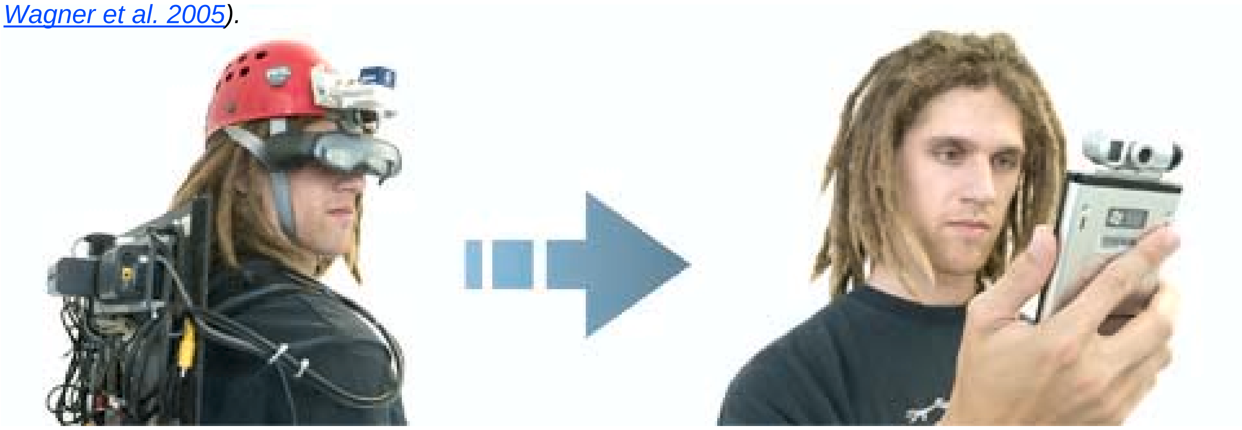


Figure 5

As mentioned, most handheld computers either already have some of the main components needed or are manufactured to easily allow for the expansion of additional hardware and sensors like those that would be required by ***Apollo Beyond***. Good, lightweight HMDs are currently selling for $300-$500 alone. The addition of camera, wireless data link, and computing platform could drive the overall price for a single Hubble Window to $700-$900 or more. For $100-$200 more, a low-end tablet PC with integrated Bluetooth, camera, display, computing platform running a version of Microsoft Windows, and standard peripheral expansion port would provide the same hardware solution without the hassle of having to fight with physical component outputs and inputs, cabling, compatibility, and encasement/housing issues while still providing a mobile large screen experience. There is also the possibility of the Apple Mini as discussed before as well as another recent development to be investigated--hacking the newly introduced PlayStation Portable (PSP). With it's integrated game controller, wireless connection, and bright display screen, the PSP might be a good option.

The Advueu V800XPT-2 tablet PC.

Figure 6

Given some people's reservations, about mobile video displays on small screens, it is likely that a low-end tablet PC or device with a similar sized screen may be the optimal solution. Low-end tablet PC's tend to save some of their costs by providing smaller screen sizes. These smaller screen sizes, however, tend to range in the 8" – 10" diagonal size, as opposed to the 3" – 4" range for PDAs and PocketPC devices, and are capable of 800x600 full screen displays. Such a size would be quite visible but would still be small enough to not be too cumbersome to handle for extended periods of time. Low-end tablet PCs average around 3 lbs in weight which is not too bad but something to be considered when taking into account that users may be holding their Hubble Window up to investigate a planet or engage in a space mission which may last for several minutes. A possible tablet PC candidate could be the Advueu V800XPT-2 (http://www.advueu.com/003/productitem.php?id=46&display=features&img=) which sells for around $1000 (Fig. 5). The HP iPaq Pocket PC h6315 (Fig. 6) would be a good PocketPC candidate, selling for around $600, (http://reviews.cnet.com/HP_iPaq_Pocket_PC_h6315/4507-3127_7-30981393.html?tag=tab).

The HP iPaq Pocket PC h6315.

Figure 7

Augmentation Technology

There are many possible options to drive the augmentation process used by the Hubble Window. For ease of execution, AR Toolkit is currently the favored choice due to its wide use in AR research, its extensive documentation, and its ease in tracking via the use of fiducial markers. However, another very attractive possibility is DART (Designer's Augmented Reality Toolkit). This toolkit differs from the AR Toolkit in that it uses Macromedia's Director to control and implement the augmented content. This would require far less programming in the initial design phases of the project's content. However, it is not yet known if DART has comparable capabilities and robustness to AR Toolkit for use in such a project as ***Apollo Beyond***.

AR Orientation & Tracking Technology

There are a number of different orientation and tracking methods for AR that ***Apollo Beyond*** could employ. Options include: magnetic trackers integrated into the Hubble Window, modified head trackers or "degrees of freedom" (dof) trackers, inclinometers and accelerometers, markerless tracking, and fiducial marker tracking using both visible and invisible markers (infrared retroreflective markers). At this point, ***Apollo Beyond*** has not chosen an AR tracking method yet. Once further research has narrowed down the choice for the actual augmentation technology to be used, an appropriate tracking method will be chosen taking into account other factors as well, such as compatibility and ease of interfacing with the software development environment.

Mission Control

Mission Control would consist of a horizontal Workspace, an LCD projector mounted over the Workspace to project imagery upon it, a number of Tangible User Interface (TUI) objects, and a single computer hooked up to a wireless network that would be responsible for three tasks:

- Tracking the TUI objects
- Transmitting and receiving information to/from the Hubble Window
- Displaying conventional 2D media as a basis to work from on the Workspace

The Workspace would be a medium-sized, table of a height that could be for either sitting or standing at. The surface would be smooth and flat to facilitate the movement of the TUI objects around its surface and work well for the purposes of displaying the images projected upon it by the overhead LCD projector.

The TUI objects would be iconic items constructed out of plexiglass, wood, or polymer clay between 2"-3" in size. They may incorporate some small electronics or magnetic parts for tracking purposes which is discussed in a following section.

The interface displayed on the workspace would be driven by the control program written in the project's chosen software development environment and would include cues, information, and windows for media.

Tangible User Interface Tracking Technology

Tangible User Interface (TUI) objects can be tracked by computer vision methods, attaching an infrared transmitter to the objects and tracking this light source, or magnetic field tracking by placing a magnet within the object and calculating its position based on the electricity induced by the magnet travelling over a number of field coils located under the table. A relatively easy to implement possibility is the use of the AR Toolkit following markers placed on the tops of the interface objects and tracked by a camera mounted above the Mission Control Workspace. This method has the added benefits of being able to easily discriminate between different objects via different markers and also quickly determining their orientation. Tracking interface object orientation might be useful for added control, i.e. rotating an object clockwise might fast forward an AR animation playing in the window while rotating it counter-clockwise would reverse it.

Why a Tabletop Interface Approach?

Historically tables have played an important role as a focal point for group interaction, from King Arthur's Round Table to Donald Trump's board room table. Tables are intrinsically collaborative working spaces They generally function in four different ways including, storage, rest-and-gesture, social focus, and display. (Gubman)
A table that is also a large computer screen is a functional solution for several reasons. People may directly manipulate data physically and digitally. Physical objects can be set out and moved on the screen's surface; multiple users can simultaneously share the space, and people can walk freely around the table. Interaction with computers usually demands a disconnection between the person that uses the machine and the rest of the world. The attention of the user is usurped by the screen in front of him, so the social aspect is disrupted. A natural interface allows normal interaction between the people in contact with the system. As a collective workspace a table inspires its users to interact with each other and the table, instead of remaining isolated from each other. It can stimulate and facilitate conversations between users, and may potentially encourage exploration. (Valli)

Current Work in the Field

"Magic Window" hardware.

Figure 8

Augmented Reality (AR) and Tangible User Interface (TUI) technologies, once strictly the domain of PhD researchers in computer science, are now growing more accessible for multimedia projects. There are a number of resources and pertinent research projects in the field of AR and TUI that will likely be drawn upon to successfully implement the ***Apollo Beyond*** project as outlined:

MIT Media Lab

"Installation" by Simon Greenwold
http://acg.media.mit.edu/people/simong/installationNew/cover.html

Using a "viewing window" and a stylus, users can draw 3D virtual forms and place them into a position in real space. Virtual coordinates are calibrated with the real viewing position to allow one to walk around the virtual object and view it from other angles.

While this project uses the "magic window" metaphor, its content is very different from ***Apollo Beyond*** and it is not setup for a mobile experience (Fig. 7). Technological elements from this project which might be applied to ***Apollo Beyond*** include:

- Use of inductive magnetic field sensors for position and orientation tracking
- Wiring and design ideas
- Virtual space and tracking coding

L'Ecole Polytechnique Fédérale de Lausanne

Real-time 3D registration.

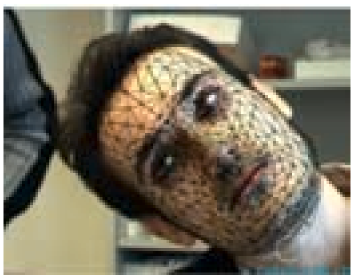


Figure 9

Computer Vision Laboratory

http://cvlab.epfl.ch/research/index.html

This lab does a lot of work related to the field of Augmented Reality and has developed robust real-time 3-D registration techniques that can handle large camera displacements, drastic aspect changes, and partial occlusions (Fig. 8). Their ultimate goal is to emulate the human ability to effortlessly detect and estimate the position of 3-D objects with respect to themselves.

Of interest is that this is a school and research lab that shares much of its work in peer-reviewed computer science journals. They even have example code available for download and use for non-commercial research purposes. Software coding elements from their work which might be applied to ***Apollo Beyond*** include:

- Stable, real-time, markerless 3D computer vision tracking
- Real-time object detection
- 3D mesh and video feature-matching

Relevant publications include:

- V. Lepetit, J. Pilet, and P. Fua. **Point Matching as a Classification Problem for Fast and Robust Object Pose Estimation**. In Conference on Computer Vision and Pattern Recognition, Washington, DC, June 2004.

- L. Vacchetti, V. Lepetit, and P. Fua. **Stable real-time 3d tracking using online and offline information.** IEEE Transactions on Pattern Analysis and Machine Intelligence, 26(10):1385--1391, 2004.

- L. Vacchetti, V. Lepetit, and P. Fua. **Combining Edge and Texture Information for Real-Time Accurate 3D Camera Tracking**. In International Symposium on Mixed and Augmented Reality, Arlington, VA, November 2004.

- V. Lepetit, and P. Fua. **Towards Recognizing Feature Points using Classification Trees**. Technical Report IC/2004/74, Ecole Polytechnique Federale de Lausanne, 2004.

- V. Lepetit, J. Pilet, and P. Fua. **Point Matching as a Classification Problem for Fast and Robust Object Pose Estimation**. In Conference on Computer Vision and Pattern Recognition, Washington, DC, June 2004.

Total Immersion

D'Fusion
http://www.t-immersion.com/

Total Immersion is a commercial software and services company specializing in real-time video and 3D images integration. D'Fusion is their premiere product and is a Commercial Off-The-Shelf (COTS) Augmented Reality solution (Fig. 9).

Features of their software which might be applied to ***Apollo Beyond*** include:

- Stable, real-time, markerless 3D computer vision tracking
- Stable, real-time, markered or registration-based 3D computer vision tracking

AR on off-the-shelf handhelds.

Figure 10

The Handheld Augmented Reality Project

"Invisible Train" by Daniel Wagner, Thomas Pintaric and Dieter Schmalstieg
http://studierstube.org/handheld_ar/applications.php

The Handheld Augmented Reality Project is a research group based out of the Vienna University of Technology and focused on realising augmented reality on off-the-shelf mobile devices (Fig. 10). Their work is geared mainly towards developing autonomous PocketPC AR devices which use fiducial marker tracking for both correct positioning and orientation of virtual objects as well as the context for the objects themselves.

The research group developed their own framework for AR on handheld devices and have a number of useful resources available for download from their website, such as AR object class libraries, etc. They also list a number of interesting related works from other research groups in the field. Their AR framework solution provides real-time video see-through 3D rendering and optical tracking with optional backend server support. Technological elements from this project which might be useful in the development of ***Apollo Beyond*** include:

- Autonomous handheld computer vision-based tracking system executing at interactive rates

- 3D scene rendering on a handheld device via a standardized graphics interface

- Workload sharing via a wireless connection and backend server

- Integration of the handheld platform's software into their AR research framework Studierstube for mutual re-use of resulting software components between workstation/notebook and PDA-based AR

Relevant publications include:
- Towards Massively Multi-User Augmented Reality on Handheld Devices (2005)
- First Steps Towards Handheld Augmented Reality (2003)

Related CSU Multimedia Thesis Projects to Date

Mobile Augmented Reality System (MARS) (2000?)

Ways in which the project might relate to challenges encountered in the development of ***Apollo Beyond***:
- General issues regarding mobile Augmented Reality

Other Software, Standards, Protocols, and Technologies

In addition to those resources already mentioned, a number of other items will likely be required to implement the ***Apollo Beyond*** project.

3D Objects and Animation

Given the fact that the California State University East Bay (CSUEB) already owns many licences for the 3D modeling and animation software package SoftImage XSI, it is foreseen that these existing copies will be used for the development of any 3D virtual spirit objects and their animations used in the project's content.

Software Development Environment

This will be determined to some degree by which set of AR software and hardware will be selected. AR Toolkit is addressable via C++. DART would be addressable using Macromedia's LINGO language. Other options may be possible such as Visual Basic.NET. The decision for which software development environment will be optimal for ***Apollo Beyond*** will be one of the last made before actually building the project. Members of ***Apollo Beyond*** have some prior familiarity with both LINGO and Visual Basic.NET. C++ is planned to be researched and learned during the summer months for personal self-improvement, and will therefore be within ***Apollo Beyond's*** skill set at build-time in case it is needed.

Creative Innovations

The creative innovations in the ***Apollo Beyond*** project are two-fold. It advances the use of mobile handheld Augmented Reality (AR) technology as a visualization and educational exploration tool. Most AR research currently ongoing in the field lean toward the use of AR as either Computer Aided Design (CAD) –type tools or for mostly entertainment purposes. ***Apollo Beyond*** aims to use AR to help visualize the difficult to understand spatial relationships within our solar system—those that often are the simple reasons behind common periodic occurences on our planet that can sometimes seem mysterious, complex, baffling, and even mystical to us when we observe them from our limited point of view here on Earth. Use of AR to address such ideas gives the user the opportunity to change their point of view and investigate such occurences in a more intuitive, free inquiry mode instead of the traditionally limited, directed, and "canned" experiences of conventional educational media. As a result, it is ***Apollo Beyond's*** hope that the space science concepts it will cover and that govern so much of our world's existence will therefore be more easily understood and have greater impact and value to its users.

YDREAMS Education and Culture

"Tangitable" technical scheme.

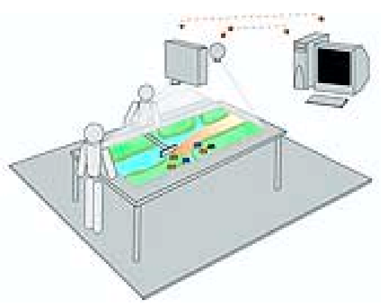


Figure 11

Tangitable
http://www.ydreams.com/ydreams_2005/index.php?page=113

YDream's Tangitable is a unique interactive installation that allows you to explore the real-time impact of pollution and waste disposal on a virtual environment by moving pieces that represent pollution, waste sources, and waste processing plants. Tangitable is designed to promote eco-awareness and planning, and to allow users to see our impact on the natural world through real-time virtual interactivity.

This project uses a tangible user interface and and a table. Elements from this project which might be applied to ***Apollo Beyond*** include:

- Tangible representative pieces
- Table with overhead projection

MIT Media Lab

Sensetable

Figure 12

"Sensetable" by Simon Greenwold
http://tangible.media.mit.edu/papers/SenseTable_CHI01.php

Sensetable is a system that tracks the positions and orientations of multiple intelligent wireless objects electromagnetically on a tabletop display..

Elements from this project which might have relevance to ***Apollo Beyond*** include:

- the system tracks objects without susceptibility to occlusion or changes in lighting conditions
- the tracked objects have a state that can be modified

Music Technology Group

Reactable

Figure 13

Reactable

http://www.we-make-money-not-art.com/archives/005227.php

Reactable allows collaborative performances by l musicians without the limits of many other screen-based interfaces. Users play the table by manipulating a set of objects placed on top of it. Each object has a unique function for generating, modifying or controlling sound. The table has with sensors, which identify and track the objects. The reacTable* also gives visual feedback by projecting a visualization of sound onto the table surface.

Elements from this project which might have relevance to ***Apollo Beyond*** include:

- objects with unique functions
- sensors in the table which track the objects

tangiTable

Figure 14

tangiTable

http://naturalinteraction.org/pastworks.html

A table with a tangible interface for children. Players can interact with maps projected on the table by moving wooden objects. It's like a collaborative tangible playground.

Elements from this project which might have relevance to ***Apollo Beyond*** include:

- tangible user interface

Audience Justification

In today's society, advanced technology is making teamwork more important within the workforce. (Gokhal 1995) The dual nature of this project may support collaborative/cooperative learning. Learners will work together to achieve shared goals of exploration, and achieving a moon shot.

In addition to fostering teamwork, the project would aim to be an instructional tool for all types of learners by providing features that appeal to visual, auditory, and kinesthetic/tactile learners. It would seek to provide value for visual learners who learn primarily through the written word, auditory learners who learn primarily through listening, and kinesthetic or tactile learners who process information through their bodies and through touch. (Hamilton 2000)

The audience for ***Apollo Beyond*** is anyone interested in learning interactively about space science. This project may increase public interest in space science and the scientific literacy of the general public. Space science stimulates imagination and interest in all types of science and exploration, which can ultimately lead to a more science and technology literate society. (National Aeronautics and Space Science Administration)

Realizability

Budget

The following items will be necessary to produce ***Apollo Beyond***:

- 3D software (free, provided by CSU-EB)
- open source AR Toolkit (free)
- Tablet PC with integrated Bluetooth ($600-$1,200)
- Cameras (free, provided by CSU-EB)
- LCD projector/mountingarm (free, provided by CSU-EB)
- Merlin software ($190)
- Miscellaneos supplies for building tangible objects ($200)
- C++.net
- 2 Computers (free, provided by CSU-EB)

Required/Potentially Useful Skills

Stephen:

- Visual Basic programming
- Plan to learn C++ (for using the AR Toolkit)

Song:

- Visual skills
- Macromedia Director (may be useful if we use DART)

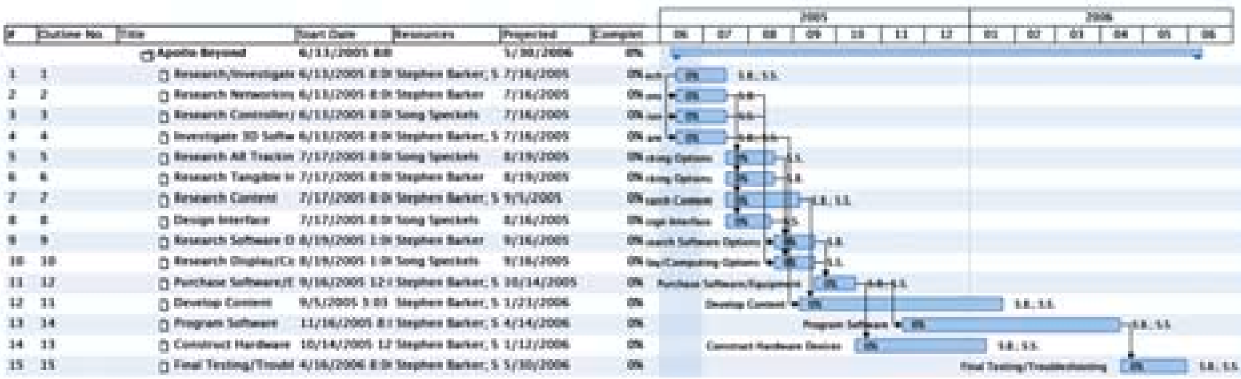
Required Research

The following research will be required between 6/13/05 and 9/16/2005:

- Networking
- AR tracking
- game controllers
- tangible interfaces
- 3D software
- space science
- Research graphics card/ processor speed

Appendix A: Gant Chart

A task dependent timeline.



#	Outline No.	Title	Start Date	Resources	Projected	Complete
		Apollo Beyond	6/13/2005 8:0		5/30/2006	0%
1	1	Research/Investigate	6/13/2005 8:0	Stephen Barker; S	7/16/2005	0%
2	2	Research Networking	6/13/2005 8:0	Stephen Barker	7/16/2005	0%
3	3	Research Controller/	6/13/2005 8:0	Song Speckels	7/16/2005	0%
4	4	Investigate 3D Softw	6/13/2005 8:0	Stephen Barker; S	7/16/2005	0%
5	5	Research AR Trackin	7/17/2005 8:0	Song Speckels	8/19/2005	0%
6	6	Research Tangible In	7/17/2005 8:0	Stephen Barker	8/19/2005	0%
7	7	Research Content	7/17/2005 8:0	Stephen Barker; S	9/5/2005	0%
8	8	Design Interface	7/17/2005 8:0	Song Speckels	8/16/2005	0%
9	9	Research Software O	8/19/2005 1:0	Stephen Barker	9/16/2005	0%
10	10	Research Display/Co	8/19/2005 1:0	Song Speckels	9/16/2005	0%
11	12	Purchase Software/E	9/16/2005 12:	Stephen Barker; S	10/14/2005	0%
12	11	Develop Content	9/5/2005 3:03	Stephen Barker; S	1/23/2006	0%
13	14	Program Software	11/16/2005 8:	Stephen Barker; S	4/14/2006	0%
14	13	Construct Hardware	10/14/2005 12	Stephen Barker; S	1/12/2006	0%
15	15	Final Testing/Troubl	4/16/2006 8:0	Stephen Barker; S	5/30/2006	0%

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