## **Purdue ECE Senior Design Semester Report**

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| **Course Number and Title** | ECE 477 *Digital Systems Senior Design Project* |
| **Semester / Year** | Fall 2013 |
| **Advisors** | George Hadley, Dr. Mark Johnson, Prof. Dave Meyer |
| **Team Number** | 5 |
| **Project Title** | Augmented Reality Simulator |

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| Senior Design Students – Team Composition | | | |
| **Name** | **Major** | **Area(s) of Expertise Utilized in Project** | **Expected Graduation Date** |
| Thor Smith | CmpE | Networking, UI | May 2014 |
| Stephen Carlson | EE | Schematic, PCB design | May 2014 |
| Steven Ellis | CmpE | Graphics, Packaging | May 2014 |
| Alec Stephen Green | EE | Signal Processing | May 2014 |

**Project Description:** Provide a brief (2-3 page) technical description of the design project, as outlined below:

1. Summary of the project, including customer, purpose, specifications, and a summary of the approach.

## We propose an Augmented Reality Simulator that allows at least one user to play an electronic game or other virtual simulation in a mobile, outdoor environment. This simulator will be divided into two parts communicating wirelessly; a central control unit will coordinate the game logic while per-player headsets will overlay appropriate game-object pixels on a semi-transparent panel that is suspended in front of the users’ eyes. Each headset will run on battery power and incorporate the user’s geospatial location and head orientation to allow the user to interact with the virtual world without the use of an external input device. This product is intended to be used for gaming and other potential simulations that require an augmented environment, especially uses which involve collaboration such as tour guides or educational aids.

1. Description of how the project built upon the knowledge and skills acquired in earlier ECE coursework.

## This course built well on the skills and knowledge provided by ECE 362, Introduction to Microprocessors. Low-level C programming techniques, embedded hardware design, and usage of on-chip microcontroller peripherals taught in ECE 362 were skills invaluable to the successful design and implementation of this project. The graphics and networking layers of this project built upon concepts taught in ECE 264 such as structures, dynamic memory allocation, and code debugging. Some of the more advanced algorithms used in game logic incorporated techniques from ECE 368 (Data Structures). In addition, a few of the signal processing lessons learned in ECE 301, Signals and Systems, were applied to the sensors used in this project to improve the quality of the data.

1. Description of what new technical knowledge and skills, if any, were acquired in doing the project.

## During this project, skills invaluable to bringing a design into reality were gained through ECE 477. For the first time, the real-world side of theoretical components was described in detail, including elements such as parasitic elements, temperature and voltage stability, and failure mode analysis. The course also did a good job in the time available of teaching students how to design a clear, readable schematic and choose parts to satisfy design requirements. PCB design was also covered in this course, a skill new to most of the team, which allowed team members to gain technical knowledge about component placement, routing, current handling capability, and design for manufacturability.

1. Description of how the engineering design process was incorporated into the project. Reference must be made to the following fundamental steps of the design process: establishment of objectives and criteria, analysis, synthesis, construction, testing, and evaluation.

## Prior to beginning the project, the team brainstormed concepts for the project, taking into account the constraints of the course. The augmented reality system was established as an area where multiple team members were interested, in addition to its applicability to satisfying the course objects of designing a custom PCB and using a microcontroller to interface with external devices. During this time, appropriate success criteria were also established to measure the outcome of the project. Analysis of past projects, including the Incredible HUD and AR Quake, provided insight into techniques needed to tackle the project and methods of improvement over previous designs. This analysis concluded that a GPS and inertial measurement unit would be needed to measure the user’s geospatial position and orientation, while a semi-transparent mirror and lens focuser would be needed to display the virtual image. All of these concerns were synthesized in the design stage, where the necessary sensors, microcontroller, and graphics processing unit were integrated into a schematic and then PCB design to electrically connect the parts. At the same time, packaging was prototyped in CAD and mocked up using baseball caps and dummy weights to test the usability and ergonomics of candidate designs. After design completion, a finished PCB was constructed and populated while a finalized product package was constructed with materials from a hardware store. Unit testing of individual peripherals, and then combined testing of system level elements, revealed no hardware problems. User experience testing of the mechanical and visual elements of the headset was performed during this time, leading to a user testimonials page being posted on the wall. Based on evaluation of the test results, the headset was refined to fix software issues to improve the user experience.

1. Summary of how realistic design constraints were incorporated into the project (consideration of most of the following is required: economic, environmental, ethical, health & safety, social, political, sustainability, and manufacturability constraints).

## **Economic:** Currently available devices performing similar functions, such as the Oculus Rift and Google Glass, were investigated prior to beginning the project to establish a reasonable design cost range. As this is a single prototype, the cost would be expected to be greater than the mass production cost of commercial units, but the cost still had to be comparable. In addition, the course provided project cost coverage of up to $300, an incentive to reduce project cost to less than that value. Cost was a major concern when deciding among components which fit specifications; the low-cost Raspberry Pi Model A was chosen to provide graphics processing power for only $25, while the inertial sensors and GPS were chosen as the lowest cost evaluation boards that could be used in a hand built prototype.

## **Environmental:** The headset component of the project was designed to be mobile, so batteries were one environmental concern. Disposable batteries create a considerable landfill impact over long usage patterns, so a rechargeable battery was used. Nickel cadmium batteries, which contain heavy metals, were discarded in favor of the lithium ion battery, which costs more but is considerably lighter and better for the environment once disposed.

## **Ethical:** Augmented reality devices display an overlay on the user’s vision which may be distracting. If a user attempts to drive a vehicle while using the system for driving directions, an accident could occur if the user fails to pay attention to the surroundings. This ethical concern is also problematic for devices like cell phones and GPS units, where texting while driving or crossing the road accounts for many injuries yearly. However, nothing in this system can detect and prevent the user from operating the system in such dangerous circumstances, since the device is mobile during intended simulations, leaving the onus on the user to use the device responsibly.

## **Health & Safety:** During use, the headset could cause motion sickness in a small percentage of the population. This issue needs careful warning messages in the user manual and product packaging, just like the messages provided with standard video game consoles. In addition, the lightweight lithium ion battery technology can pose a personal injury hazard if a fire starts during charging. A battery with an independent protection circuit, along with multiple fail-safe measures on the project PCB, minimizes the likelihood of such an occurrence.

## **Social:** Users of the augmented reality headset may suffer social rejection due to the bulky appearance of the prototype device. Therefore, every effort was made within the limits of the prototype design to make the headset packaging streamlined and lightweight. A user in an immersive augmented reality simulation may lose touch with reality, bumping into and annoying passerby or running into static obstacles and causing personal embarrassment. Such an issue, like the ethical issues of augmented reality while driving, cannot be detected or prevented by the headset and must be addressed in the user manual. Acceptance of augmented reality headsets, just like Bluetooth ear buds or self-driving cars, may become a cultural problem which diminishes with time.

## **Political:** Political concerns do not pose any relevant design constraints for augmented reality headsets.

## **Sustainability:** A lightweight packaging design to reduce user discomfort also increases product sustainability, as fewer materials and less energy is used during construction. The product was also designed to conserve power to prolong battery life between charges and increase the usable lifespan of the product before disposal when the battery wears out. Low-power sleep modes were used on the microcontroller, and the Raspberry Pi Model A and sensors were selected for low power consumption.

## **Manufacturability:** During design of the project schematic, individual components were chosen to minimize the number of external components required for implementation, decreasing the component count and therefore the time to assemble and test the project. A reduced bill of materials also decreases the number of failure modes, decreasing the failure rate and thus warranty expenses. The PCB was designed to maximize yield and ease manufacturing; wide traces and spaces, extended clearance on polygon planes, and large drill hits on vias with generous annular rings allows lower cost fabrication with higher tolerances.

1. Description of the multidisciplinary nature of the project.

## This project incorporated skills from multiple disciplines, including mechanical engineering, and computer science. Headset packaging involved product design skills normally taught in mechanical engineering; students skilled in the use of 3-D printing educated team members on how to successfully print an enclosure for the project. Incorporation of commercially available parts such as helmets and aluminum rails also involved mechanical design. Skills such as networking and graph theory are taken from computer science, aspects crucial to the multi-user aspect of the project through the central control unit.

1. Description of project deliverables and their final status.

A completed headset and central control unit were delivered on schedule, with all project specific success criteria met and the hardware fully functional as designed. Headset units were successfully able to display images based on the user’s geospatial location, and display images according to the orientation of the user’s head. In addition, the headset was capable of monitoring and reporting the battery power level to the user, and calculating and displaying the signal strength of the wireless connection to the central control unit. Finally, the central control unit was able to upload new graphics and simulation information wirelessly to the headsets without changing software on the headset. Along with the success criteria, the product packaging was also completed, with the system operating on its own battery power in a single, self-contained unit that could continue to operate when the user was moving.