Abstract:

Our project develops a personal head-up display to provide users with an "augmented reality." Based on the user's position and their head's tilt, pitch, and yaw, relevant information is displayed in their field of vision such that it appears to be part of the environment. The system consists of three main components: (1) a sensing unit, which uses an accelerometer, gyroscope, solid-state compass, and global positioning system to determine where the user is looking, (2) an embedded processing system to compute the image that needs to be displayed for the user to create the perception of an augmented reality, and (3) the head-up display that displays that image. We have designed a custom printed circuit board for the sensing unit. An embedded microcontroller performs signal processing tasks to reduce the noise from various sensors. The embedded processing system runs embedded OpenGL on Linux and uses the position information from the sensing unit to adjust the camera angle in the virtual OpenGL environment. The rendered image is displayed on semi-transparent, semi-reflective glass using a small, LED-based projector. We have implemented and tested each system component and are in the process of integrating the complete system.

I. INTRODUCTION

Our Senior Design Project consists of a portable Heads Up Display (HUD) capable of supplying the user information that complements his or her current range of vision. In order to accomplish this task, we will interface a series of measurement instruments such as a gyroscope, compass, GPS, and accelerometer connected to a microcontroller which will collect data from all the sensors. The collected data will contain information about the head’s position and orientation in the environment. The microcontroller will then send the data to a single board computer (SBC) which contains previously collected information about buildings and point of interest. Information about the environment will then be rendered on the heads up display, according to where the user is looking in the real world. This creates a situation where movements in the real world will result in a modification of the information rendered on the HUD. The labels show on the HUD will appear attached to the buildings, mimicking what a physical sign would look like.

A GPS will supply the microcontroller with positional data that will be compared to the pre-defined locations of buildings on the UMass campus. To determine what direction the user is looking we will use a digital compass. Nevertheless, the compass has three setbacks. Firstly, it is an unreliable instrument because it can be affected by any sizable metallic object in the proximity; secondly, it does not respond to rotational movement as quickly as the specifications would require; and finally, it only works properly while it rests flat on the x-y (ground) plane. To solve these two problems we will include a gyroscope that will detect angular movements that can supplement the compass data. Once the initial orientation is computed, the gyroscope, compass and accelerometer will keep track of rotational and angular changes of the user’s head, providing real time information about the user’s current field of view. The positional and rotational data will be sent to a SBC running Ubuntu 8.10 Linux, which is responsible for transposing the virtual building’s labels onto the HUD.
Below is a picture of the environment enhancement we envisioned our project delivering during early design stages.

Once completed, the heads up display should deliver building information accurate to within +/- 3° from center at 150 meter away from the building. The orientation unit will be portable, head mountable, and battery powered. The batteries should provide enough power for 3 hours of continuous use. Since errors will accumulate over time, a calibration and reset function will also be included with the unit, which will allow the user to easily recalibrate the device to his exact specifications and needs.

II. DESIGN

The project can be divided into 4 major parts. The Orientation Sensing Unit (OSU) which will acquire information about the exact position, direction, and field of view of the user. The Data Processing Unit (DPU) which will use the information about the users position and orientation, as well as information about the environment to calculate what information to display on the HUD, as well as the position of the information on the HUD screen. The HUD will be the user interface, providing information about the surrounding environment, as controlled by the DPU. Also a portable power supply will be needed to power the different the other units.

A block diagram of the different units is attached below. In the block diagram, the red lines represent power supply to the various devices while the black lines represent data flow.

The overall data flow is as follows:
Sensor => Microcontroller => DPU => HUD

A. Orientation Sensing Unit

The Orientation Sensing Unit (OSU) must provide accurate information regarding the person’s position and orientation within his environment. All of the data must be collected and forwarded to the DPU as fast as possible, to enhance the user’s experience by removing delays. In order to gather all of the information about the head’s position and orientation, the OSU uses a variety of sensors, which are polled by a Microcontroller at various intervals.

- A **GPS** device will be used to determine the person’s position in terms of longitude and latitude. The device used will be the Garmin 18 LVC which will be connected via Serial RS232 to the Microcontroller.

- A **Digital Compass** will be used to find head’s orientation. Since compasses rely on the Earth’s magnetic field, which is weak, they can be influenced by a transient magnetic field or by a large metallic object in the vicinity. The digital compass will be connected via I2C interface to the
Microcontroller. To compensate for those kinds of errors, a gyroscope will also be used, to increase accuracy.

- A **Gyroscope** will also be used to find the head’s orientation, and to compensate for any errors the digital compass might have. The gyroscope will be connected via I2C to the Microcontroller.

- An **Accelerometer** will be used to detect head movements, and find the exact field of view of the person. The accelerometer uses gravity to determine what position the head is in, by measuring how much the force is applied on each axis (X, Y & Z). The device used will be the ST Micro – LIS302DL which has high sensitivity (16.2 mg/digit) and 8 bit resolution. It will be connected to the Microcontroller via I2C interface.

- The **Microcontroller** used to gather data from the various sensors will come from the ATmega family of chips. These chips were preferred over other options because of the similarity between the different models of the chip. Code written in C for one particular model can be easily transferred to another model. At the moment, we are using the ATMega644 MCU, since this model comes with two serial ports which are necessary in order to communicate with the GPS and the DPU simultaneously. In the future, the data transfer between the OSU and the DPU might be changed to use I2C or SPI. In this case, the ATMega644P will not be indispensable. Therefore, it would be possible to downgrade to the ATMega644P.

The 4 sensors will be polled by the Microcontroller at various intervals. There are a few things to take into consideration when considering the polling rates of each sensor. Firstly, each sensor has its own update rate and some are very slow when compared with the speed of the MCU, such an example is the GPS which can only deliver one reading per second or so. A second consideration will be what is the minimum polling rate required for a smooth user experience. For example, the MCU could only require data from the compass when a movement is detected by the gyroscope (since this would be an indication of rotational change). The emphasis on reducing polling rate will depend on the power savings obtained through this strategy.

### B. Data Processing Unit

For the DPU, a single board x86 architecture computer is used. The model chosen is the Fit-PC Slim, which uses AMD Geode LX800 @ 500MHz and an embedded chipset with integrated graphics, AMD CS5536. This model was chosen because of its small size, measuring 4” by 4”, low power consumption (5-8 W), no additional cooling requirements and ability to perform as well as a net-book. The Fit-PC can be loaded with a Linux Operating System, which provides OpenGL support.

The DPU will analyze the data from the various sensors, calculating which points of interest are within the person’s field of view. Based on the relative position of the various points of interest, a 3D virtual environment will be created using OpenGL, which will be rendered on the HUD. The virtual environment will contain information about the surrounding building or points of interest and it will appear on top of the various surrounding building, which are within the person’s field of view.

### C. Head-Up Display

Once the data collected by the OSU is processed by the DPU, a video signal will be sent to a heads up display (HUD) to supply the user with the desired information. The HUD consists on a semi-transparent screen and a small projector. The screen spans all or part of the user’s range of vision and it is shaped in such a way that will reflect the projected information into the user’s eyes. Although in theory the design of the HUD is fairly simple, it is very hard to achieve an acceptable level of clarity without using special lenses and having perfectly positioned components.

Due to this issue, it would be ideal to obtain HUD hardware from third party supplier. At the moment, the only available product is on the $50,000 range. Nevertheless, we have been offered a loaner if we decide to pursue this path.
Additionally, we decided to design our own Head-Up display with the objective of being able to complete our project without the need of external funding or expensive technologies. Our design, made out of a baseball hat and handcrafted aluminum, and powered by a 3M pico-projector, turned out to work surprisingly well.

D. Power Supply
The power supply should keep the different parts of the project running. The power supply gives the user 4 hours of continuous operation through the use of a 9-Amp-hour Deep Cycle battery. The OSU uses a variety of sensors, which require a supply voltage around 3.3V with the GPS unit requiring 5V. The total power consumption of the different sensors and the microcontroller on the OSU is less than 100mW. The DPU consist of only the Fit-PC slim, which requires a AC adapter, and uses 8W peak power. The HUD uses a 3M projector and uses approximately 3W.

E. Specifications
The overall specifications for the final project would be:
- System needs to label building +/- 3º from center to maintain correct labeling from 150 meters.
- Power supply offers 3 hours of continuous use

V. Summary and Conclusion
Our project aimed at improving the user’s experience within the urban environment. The goal was to supply the user with accurate information about the surrounding building within the field of view. To achieve these goals four sensors (GPS, accelerometer, gyroscope and compass) were integrated with a microcontroller within the Orientation Sensing Unit. A mini-computer was used to calculate what buildings are within the field of view, as well as generating a virtual environment using OpenGL. The virtual environment is displayed on the HUD, giving the user the impression that the information is attached to the side of the building he is looking at.

Our prototype is able to use the GPS and find the person’s position within a given environment, as well as an accelerometer, compass, and gyroscope which can be used to calculate the exact orientation of the user’s head, relative to the horizon. The ability of the prototype to transmit data from the various sensors to a mini-computer via Serial RS232 shows that the person’s position and field of view can be obtained from the sensors. Furthermore, the virtual environment generated on the mini-computer using OpenGL shows we can generate shapes and text, which would contain relevant information for the user.

The project can be extended further by developing software applications that cover scenarios beyond our building labeling implementation. Some of these scenarios include but are not limited to: augmented reality games, civil engineering & architecture, directions, and diverse military applications.

In order to continue with this project, a more powerful mini-computer must be used. Fit-PC slim is coming with a upgraded model which uses Intel Atom processor, this should be enough computing power for most of the above mentioned applications, at least in their basic form. A second pending improvement is the reduction of the device’s weight and size. Special optics lenses can be used to reduce the distance between the projector and the projected area. Additionally, the mini-projector could be replaced all together with transparent OLED screens.
VI. REFERENCES


