A Modular 3D Holographic Interface

A Project Proposal

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1. Introduction

1.1 Objective

We live in a 3D world. The buildings we design, the art we create, and the objects we interact with on a daily basis are three-dimensional. Unfortunately our computer interfaces are not. Mouse devices, joysticks, monitors, screens and TVs provide a tremendously limited venue for interacting with three dimensions on modern devices. Almost ironically, despite technological advances in 3D sciences, the tools we use to design new objects and creations are centered primarily around 2D visualization. This is evident in design art computer apps like CorelDraw and Microsoft Paint which are essentially digital pencil and paper.

Imagine how much easier it would be to visualize and design 3D objects with a 3D tool and mechanism. With this project, you will not need to imagine. It would eliminate the need to muddle with multiple 2D perspectives in order to get a 3D perspective and give a realistic approach of how the items will be viewed in the real world. There is already a trend following the making of 3D software as seen in CAD (Computer Aided Design) software which still helps in designing objects however it's still two dimensional which is a huge limitation.

Out of the few methods of 3D display currently available, even fewer are affordable. Most forms of reliable 3D displays are expensive and at times even harmful for users. For example, 3D glasses can be harmful to glass wearers and even to most people when worn for an extended period of time. Specifically, they can be very tiring to the eye and lead to headaches since they distort images or the user's eye focus [2].

Our goal as a group is to provide a means of visualizing objects in a 3D space and to do so without the limitations of a 2D screen and interface while also avoiding eye fatigue. Providing such a solution at an affordable price while also preventing potential harm and risks to the users serves as a priority to us. 3D manipulation has started to trend in recent years and will only continue to do so in the future. Hence, the need and demand for such a method of display has never been more important than it is now.

This project's vision is to bring effective, accurate, beautiful three-dimensional I/O to modern devices. Instead of using clunky headwear, handhelds, or uncomfortable sensor gloves, we plan on using a dedicated 3D "hologram" display which can be viewed from four sides and a linked capacitive sensor array to detect hand motions around the 3D images. These sensors will function by leveraging the parasitic capacitance of the human body to detect how far away a given hand is from a metal plate without the need for touch. Our display will utilize the reflective properties of glass paneling and a standard, boring, 2D screen to project images back into a 3D space! Specifically this will feature a scaled up version of the popular phone-"hologram" devices [4]. From a user perspective, this device aims to be as simple as plug and play.

1.2 Background

Efforts are being made to transition from interacting with computers via screens to interacting with digital objects in the real world (3D space) through Google's AR project, Microsoft's Hololens & Mixed Reality projects, Facebook's Oculus and more. All these companies realize the limitations of screens and are investing in breaking that limitation in the coming years. Currently the AR, and VR markets are valued at $11bn and $8bn respectively and are expected to grow to $61bn and $34bn respectively [1] showing the huge potential for holography in the future.

The biggest challenges with all three of these technologies is creating the depth in the image and keeping visual quality [8] while also doing so at a suitable price per device at scale. Our project would essentially aim to solve or satisfy those challenges, hence the difficulty of our project.

Traditionally, doctors have viewed medical scan data on computer screens in 2D slices. Medical hologram technology will allow a complete 3D visualisation of internal organs and body parts. This will allow doctors a greater ability to examine diseases and injuries in individual patients and will lead to more accurate diagnoses and surgeries [2].

Another application would be for live performances where the musicians are not physically present, instead transmitting their image to appear before the audience.

In the area of gaming, holographic display tables which allow real-time multiplayer games are already being tested. Manufacturers are also integrating this technology into the next generation of smartphone displays, which will allow portable 3D gaming.

One of the most exciting applications of holograms is to the improvement of the educational experience. In order to engage students more fully, interactive digital lessons will be used in schools. This combination of digital and real-world information is known as mixed reality. Complex subjects can be taught using holographic images that students can interact with and examine. For example, pupils can virtually explore the ruins of ancient buildings during history lessons, or observe individual atomic particles and how they behave.

The practical uses of holographic technology have become a commonplace feature in our everyday lives. We are only seeing the beginning of the usefulness of holograms and as the innovators and developers continue to improve the technology, holograms will become an even larger part of society.

1.3 High-level Requirements

- Our device's display must be capable of both static and dynamic rendering of a 3D model with a decent frame rate of at least 24 FPS. Here dynamic rendering refers to the requirement of real-time scene calculation.

- Further, our capacitive touch module must accurately sense positional data of appendages around the display with a height range of between zero to eight inches (0” to 8”) and at maximum of twelve inches (12”) from the plates.
- Device should be able to read and take in .obj files and create 4 accurate perspective images of the object from the 3D model file.

2. Design

2.1 Physical Design

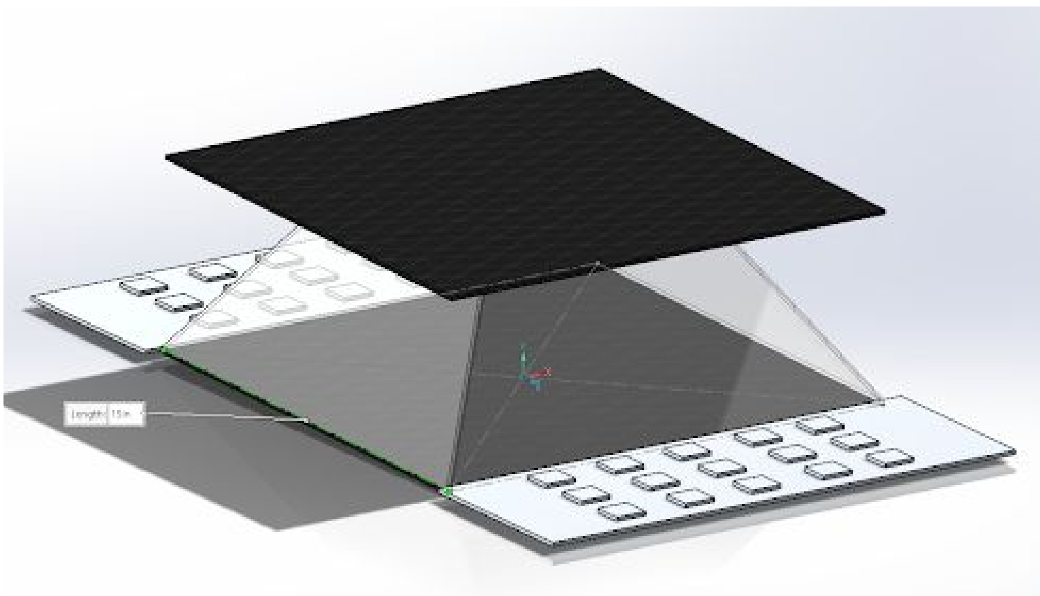

Figure 1: Mock Physical Design Render

Pictured above (**Figure 1**) is a mock-up featuring the physical aspects of our design. While the render above is somewhat lackluster, the finished product will radiate with a sleek plastic/glass-paneled display centered between two 3D capacitive sensor arrays. Final dimensions may vary slightly, however as depicted, the display will be made to fit within a 12”-15” square and the sensor arrays shall protrude from the display by up to 6”.

While not illustrated above, the top plate will include a standard 2D LCD pointed downwards towards the glass to provide the desired 3D effect (a virtual image in the center of the display). Further, the top plate will include four thin supports at its corners for stability and structure.

2.2 Block Diagram

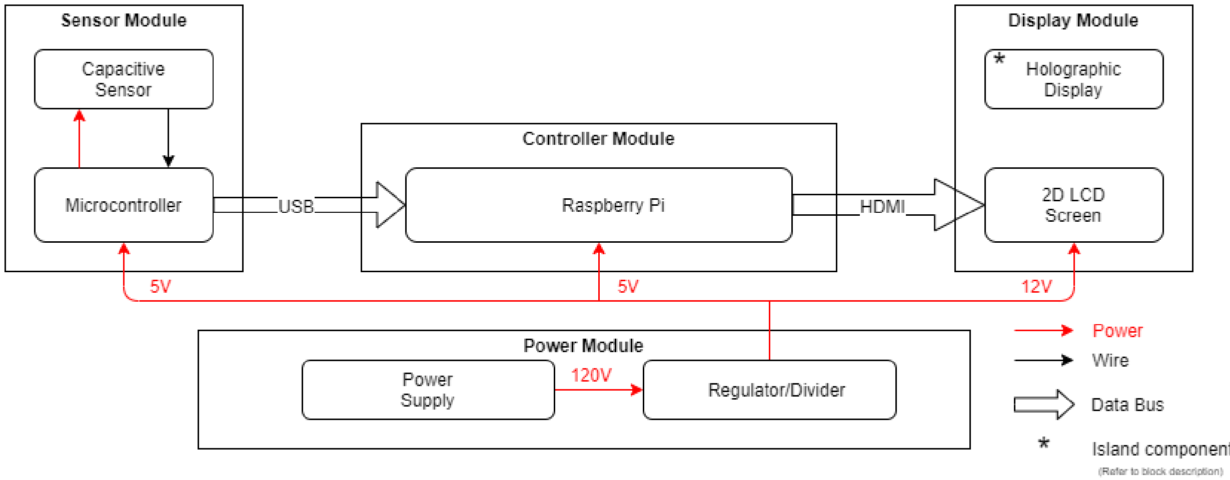

Figure 2: A High-Level Function Block Diagram depicting power, data flows & connections

As shown in **Figure 2**, our project requires 4 modules for successful operation: a power supply, a controller unit, a sensor/input module and a display module. The power supply ensures that the system can be powered continuously all day and night with the proper of 5V and 12V for the respective module voltage requirements. The controller unit consists of a Raspberry Pi, a microprocessor to run our 3D-to-2D algorithm as well as a USB port for taking in the 3D CAD file for processing then sending the final video/image to the holographic display via HDMI. The display unit comprises a 2D LCD screen that shows the four 2D perspectives of the holographic image and then is reflected onto glass pyramid structure which is the actual holographic display. Lastly, the input/sensor unit, takes in user input via a series of capacitive sensor plates that is then processed as input and sent to the Raspberry Pi to modify the final output hologram scene.

2.3 Functional Overview & Block Requirements

2.3.1 Display Module

The display module leverages the use of simple reflective technology, which consists of the two sub-modules below, to create a 3D image viewable to the user (small-scale example [4]). While this document will refer to the produced image as a hologram as is done colloquially, it is technically not a true hologram.

2.3.1.1 Holographic Display

This component will be a Square Frustum (Base square and top square ratio of 3 : 4) and angled at 45° to effectively reflect the image from the screen. This unit is what creates the hologram image by reflecting the image from the screen to the viewer. Note that this component is NOT directly connected to the screen module because it only reflects the image from the screen to create the hologram that the user sees. Thus the Holographic Display component is an island component. There is no need for it to be fixed permanently to the screen or connected in any way but we will fasten it with a frame or structure to prevent alignment issues. For the type of glass, specially coated engineered polymer based on PolyCore Technology OR Extruded polycarbonate is recommended. Alternative can be Glass, plexiglass or epoxy [5]. The material will be fully transparent and only reflective on the outer surface of the pyramid to prevent double imaging. It can be less transparent but for best user experience the thickness of the material ideally should be between 0.5mm-0.8mm to allow for best transparency.

Requirements:

- Hologram image must display by visibly reflecting 2D LCD screen images to users point of view across all 4 sides of the device

2.3.1.2 2D LCD Screen

This unit will render the hologram to be reflected off the "holographic" display (2.3.1.1) via a standard 2D screen. This subsystem will include any required video driver and 2D, LCD screen. It will take in video data via HDMI port from the Raspberry Pi which would be 4 live perspective views arranged in a way that when reflected to the holographic display it aligns to create the holographic image. The screen will be set to have the right brightness and resolution for the image to show clearly in lit environments.

Requirements:

- LCD Screen should display the video data from Raspberry Pi showing the 4 perspectives of the object

2.3.2 Sensor Module

A sensor module will handle the task of reading 3D positional data of a user's hands above the module via parasitic capacitive coupling technology. This module will also handle processing to convert raw data into useful information.

2.3.2.1 Capacitive Plate Array

This unit would be an array of capacitive plates connected in parallel made out of a good conductor (like aluminum) that will be charged and discharged repetitively in order to detect user proximity to plates.

Requirements:

- Individual conductive plates should not have electrical contact between them
- Plates should be properly insulated from all external points apart from their contact points
- When working in tandem with the microcontroller and transistor/resistor network, these plates should be able to detect a hand from 0 to 8" above each plate.

2.3.2.2 Microcontroller

The sensor controller (which will be PCB mounted) consists of supporting features required to make use of the conductive plates referenced in 2.3.2.1 - specifically a microprocessor and transistor/resistor network. It controls charge/discharge behavior of the plates, data collection and data processing.

2.3.2.2a Microprocessor(s)

This unit will charge and discharge the transistor/resistor network (2.3.2.2b) and process the raw data from the capacitive plates. It will measure the time it takes for them to recharge then calculate the distances of user hands to the plates. This final positional data will be transferred off-board to a connected computer/linker for use as human-input (Raspberry Pi in this case, see 2.3.3.1).

Requirements:

- Total number of General-Purpose IO (GPIO) pins between microprocessors should not be less than 20.
- Each GPIO pin should be able to source and sink at least 10mA at 5V +/- 5%.
- The clock period of each microprocessor should not exceed 4μs.
- The processor must be able to communicate over serial channels with the Raspberry Pi at between 9600 baud and 112500 baud.

2.3.2.2b Transistor/Resistor Network for Capacitive Sensor

Given digital signals from the microprocessor(s), this unit will charge and discharge the conductive plates.

Requirements:

- When a conductive plate is neither being charged nor discharged, current should not flow (< 0.1μA - to account for possible leakage current)
- This network must be able to discharge capacitive plates within less than 10 clock cycles of the chosen microprocessor after digital logic is asserted.
- External signal contacts (i.e. wires to capacitive plates) must be shielded to decrease parasitic capacitances/interference.

2.3.3 Control Module

This unit links the 3D HID input with the display module. This will handle arbitrary program execution/logic (e.g. a game of 3D Pong) which makes use of the sensor output, calculate appropriate rendering (3D to 2D) for the holographic display and forward these renders to the display module to be projected back into 3D space.

2.3.3.1 Raspberry Pi/Computer

A Computer, chosen to be a Raspberry Pi handles the positional input from the capacitive sensor array (treating it like a HID and reading through a USB serial port) and will map appropriate 3D object projections to the 2D, LCD screen. The aforementioned conversion will be done via standard graphics libraries (i.e. OpenGL ES) onboard. This will also be running basic program logic.

Requirements:

- Should be able to properly interface with Sensor Module and Display Module

2.3.4 Power Module

This route appropriate power to each submodule.

2.3.4.1 Wall-Adapter/Power Supply

A power supply is required to keep the system up continually. Power from a wall outlet, which is then regulated to 120Volts for the rest of the system. Used to power components from other systems reliably. This may include AC/DC converters, wall adapters.

Requirements:

- Should provide steady power throughout duration of device use
- Should provide surge protection to prevent explosions

2.3.4.2 Voltage Regulator(s)

This integrated circuit supplies the required 5V and 12V to the respective modules. This component must be able to handle the peak input from the power supply

Requirements:

- Must convert DC output from wall adapter to steady 5V and 12V (+/- 5%) supplies

2.4 Risk Analysis

The two blocks which pose the highest risk towards the successful completion of this project are the sensor module (2.3.2) and the linker/computer (2.3.3.1).

While the linker block does not consist of any hardware of our own design it poses a large number of software interfacing challenges. Working with the appropriate graphics libraries and effectively computing proper output for the LCD screen in real-time will prove challenging - especially considering the large amount of graphics processing required.

The sensor module provides the main point of failure. Based on the chosen microprocessor and total number of capacitive plates chosen, the positional resolution of hands/appendages will greatly vary. A particularly difficult challenge to tackle will be processing of raw data output from the plates. The larger number of plates we use, the larger the amount of raw data which means the more data must be processed in the same amount of time. Based on the microprocessor chosen and its clock rate, reaching an effective throughput could cause problems as well. Further, the larger the clock period of the microprocessor, the larger the charge rate of the capacitive plates must be (in order to maintain the same resolution) - this could throttle the data throughput further.

Generally, there are a plethora of variables that could greatly impede the efficacy of the sensor and interfere with the data throughput and resolution. Through empirical testing we plan on mitigating the effects of many of these.

3. Ethics and Safety

We recognise that as interesting and exciting as this project sounds there are some potential concerns in regards to safety and ethics that could be involved. We consider these and hold this important when designing, developing, and presenting this project. In order to elaborate more on our ethics and safety regulations, we touch on more specific concerns in detail.

We understand that dealing with electric components can be harmful to users, so we decided to lower the power voltages to feasible values that would prevent harm to the human body. In accordance with Article 1 of IEEE Ethics code [9], which highlights the priority of public safety, we go through great measures to guarantee the safety of those around the area and the environment in general when building and using the holographic interface. In reference to the capacitive sensor, we are going to reduce the charges and exposure of the electric field to the users by insulating the capacitive sensor with glass or plastic. By taking these measures, we help to prevent any shock risks involved with coming in close proximity with the capacitive sensors and mitigate the human exposure to electric fields. This will ensure that we are prioritizing the safety of user interaction with the project making it safe to use.

We noticed that our project appeals to a large audience so it is necessary to clarify any considerable misleading information regarding the display. For the sake of those unaware, we will explain and perhaps even put out a notice that the 3D projection of our project isn’t necessarily physical but in fact a reflection of images. It is paramount we do this inorder to uphold Article 3 of the IEEE Code of Ethics which asserts the realistic claims based on available data[9]. Furthermore, it is absolutely prohibited for users to reach towards the glass prisms where the projections reside. This acts as a precautionary measure to ensure that no injuries are sustained by possibly breaking through the glass for any reason whatsoever.

Looking into more of the ergonomic issues that may occur, there’s a possibility for anybody to develop strains in their arms and hands when working with them over long periods of time. Similar to choir conductors or juggling performers, our project users exhibit the same range of motion. Consequently, we recommend using the project in ample time intervals and taking breaks between them. Stretching the affected areas before and after use will also help prevent such wear and tear or strain from occurring.

Overall the aim of our project aligns greatly with Article 5 of IEEE Code of Ethics [9]. To improve the understanding of individuals in our society through the use of our projects in order to help visualize, plan, design and build with less restrictions and more creativity is a goal our projects strives to deliver. Conclusively, we have considered a great amount of scenarios that could fall under safety and ethics speculations. All of the guidelines we have provided are in line with the code of conducts from IEEE and ACM. We adhere to these standards and strive to use our project for the better good of enhancing and promoting productivity of our user's works.

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