Secure Testing Headset

Design Document

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Executive Summary

Development Standards & Practices Used

Materials used for the housing of the product will either conform to California proposition 65 regarding levels of toxic chemicals present or will come with a warning regarding their use. Our power supply will meet the US power plug standards and work in a standard NEMA 5-15 outlet.

We will be using C code with adhering to standard style guidelines as defined at https://www.cs.swarthmore.edu/~newhall/unixhelp/c_codestyle.html.

We may use a printed circuit board, if we do it will adhere to IPC standards found here http://www.ipc.org/4.0_Knowledge/4.1_Standards/PCBA-Checklist.pdf.

Summary of Requirements

- Headset with user interaction
- Securely receives and transmits data
- Can be used to take an exam

Applicable Courses from Iowa State University Curriculum

- Computer science 309 - provided team work experience and big project experience

(to be added to after implementation of design)

New Skills/Knowledge acquired that was not taught in courses

- Cellular vs wifi speed and US coverage
- Optics (how lenses work, corrective lenses, binocular vision)
- How to connect/use LCDs and Arduino
- 3D printing
- Existing testing software

(to be added to after implementation of design)

Table of Contents

List of figures/tables/symbols/definitions

1 Introduction

1.1 Acknowledgement

We would like to thank Rachel Schoenig on behalf of Cornerstone Strategies, Dr. Diane Rover on behalf of Iowa State University and Professor Doug Jacobson.

1.2 Problem and Project Statement

Test taking students are cheating on our clients tests in their home. We want to limit this. Our focus centers around a wearable headset capable of delivering the test while possibly monitoring the environment.

- Online tests aren't secure
- Classes are going virtual
- Current solutions still allow for people to cheat
- Tests are required to confirm that people are qualified
    - Incentive for people to cheat
        - For personal gain
        - Monetary
        - To get the test information
- Tests cost a lot of money to develop
    - Make sure questions can't be stolen & distributed
- There is an unnecessary distance between the test and camera and the student's face
    - Camera in laptop gives different view than user has
    - High density testing area makes wandering eyes easy
    - Known weaknesses, how to improve upon these
        - Camera in eye
        - Testing camera on head (cannot see below)
        - vm in background capturing/transmitting info
        - Ensure identity of test taker
        - Try to break it
        - Our solution wouldn't be as needed if increase in popularity of open book/note exams
        - Compare to existing techniques
            - ProctorU, Prometric, PSI, Proctor360
            - Record and review later
            - AI (not allowed everywhere)
            - Gaze tracking
    - Perception of security (ask users)

1.3 Operational Environment

- Expected to be used indoors
- Need to be durable, droppable
- Should be water-resistant, but not an essential requirement
- Refer to risk-mitigation section for further details on potential operational risks

1.4 Requirements

- A way to select an answer as well as progress to the next question
- A way to communicate with a secure environment that houses the test
- Charging capability
- Secure content transfer
- Users input for multiple choice
- Cheat-resistant and cheat-evident
- Comply with Question & Test Interoperability (QTI) Standards
- Reasonable price for students to afford
- Completed by end of May 2021

1.5 Intended Users and Uses

- Students
- Anyone who needs to qualify in a certification
- College entrance exams (ACT/SAT)
- College exams
- Certification exams (Pilot/BAR exam)

1.6 Assumptions and Limitations

Assumptions:

- Used only by English speakers in the U.S.
- The device will be used from remote locations (not necessarily in a testing center)
- The device will communicate with a server
- User will have wifi access

Limitations:

- Prototype cost under $1000 unless we receive outside funding (i.e. from ETG)
- The device will be a wearable headset
- The device will conform to QTI standards
- Communications between the device and a server must be done securely
- Device must be tamper-evident (we can tell if it has been tampered with) or tamper-proof
- Interaction with the test will be on the headset (no external handheld device)

1.7 Expected End Product and Deliverables

The end product shall be a device that allows for an exam to be displayed on a screen that is minimally sized. The device shall have inputs in the form of buttons and a selector wheel that will be able to select answers in the exam. The test case to prove the minimum viable product criteria has been satisfied is an exam that has no need for notes or note taking capabilities, as such the device may be enclosed but enclosure is not required. The device will not be powered by a battery for minimum viable product. The device shall be durable enough to survive minor damage and should be tamper evident so that testing security can be determined at a later date. Delivery date for the device shall be no later than May 11, 2021.

A document shall be provided that explains how to use the device. This document shall include how the inputs affect the device and how to navigate any menus that would be required. The document shall also include guidelines for emergency cases for the device such as how the device handles a disconnect from its power supply or a network connection.

2 Project Plan

2.1 Task Decomposition

Tasks and subtasks, as well as interdependence among tasks, are listed below:

- Hardware
  - Buttons signalling user response
  - Wifi connection
  - Data transfer
    - Secure data transfer
  - Power
- Screen/optics
  - Display an image
  - Update image based on user interaction (ensure high enough frames/second)
- Software
  - Receive data from a server and display
  - Quality user interface for exam

Each of the above tasks has some dependence on the other tasks as described here. The hardware to be used must be obtained before buttons can be implemented or data can be transferred to and from the device. The screen/optics must be established before the software for viewing the test is relevant. The list of items above is arranged in a way that shows loose dependencies between tasks. Certain steps can also be taken to begin work on a given task that is farther down the list (somewhat dependent on an earlier/incomplete component). For example, software may be able to be worked on before the hardware is complete assuming there is some sort of testing environment to be used in the meantime.

2.2 Risks And Risk Management/Mitigation

- Could be hacked (purchase security software)
- Our team lacks required knowledge for implementation (gain expertise from ISU experts)
- Cost of development is too great (limit features to things we can afford)
- Project requirements not adequately reflected in task breakdown (clarify tasks early and often with industry contact)
- Project is not on pace with project schedule (build in buffer time)
- Project scope is too great for given time frame (narrow scope as much as possible)

2.3 Project Proposed Milestones, Metrics, and Evaluation Criteria

The list below includes the milestones, and in parentheses is the criteria for different tasks:

- Data transfer technique
    - Data sent to headset (no lost data)
    - Data sent from headset to server (no lost data)
    - Secure transfer (no man in the middle attacks possible)
        - Notifies user and test distributor if test tampered with (successfully notifies user when man in the middle attack happens)
- Hardware (board from scratch)
    - Hardware fits inside headset
        - Headset fits on someone's head comfortably (can be worn by different people for an extended period of time)
    - Hardware connected with headset software
        - Hardware connected with server (data is sent to hardware and back to server without losing anything)
- Software (integrated into the following items)
- User interaction (buttons)
    - Button does simple task
    - Button selects an option (is displayed on screen as being selected)
    - Goes to next question
        - User can scroll up and down on a question
    - Answer saved
- Screen/optics
    - Hello world, see something on screen
    - Test questions seen
    - Interaction with exam (go to next question)
- Power Source
    - Successfully powers device
    - User notified of power status and potential issues
    - Emergency battery has enough energy to save and transmit data safely before dying

2.4 Project Timeline/Schedule

- Define problem
- Brainstorm ideas
- Narrow down to single design
- Build design
  - Screen
  - Power
  - UI
  - Software used for viewing test
  - Controls (buttons)
  - Data transfer
- Test
- Reiterate over design
- Present

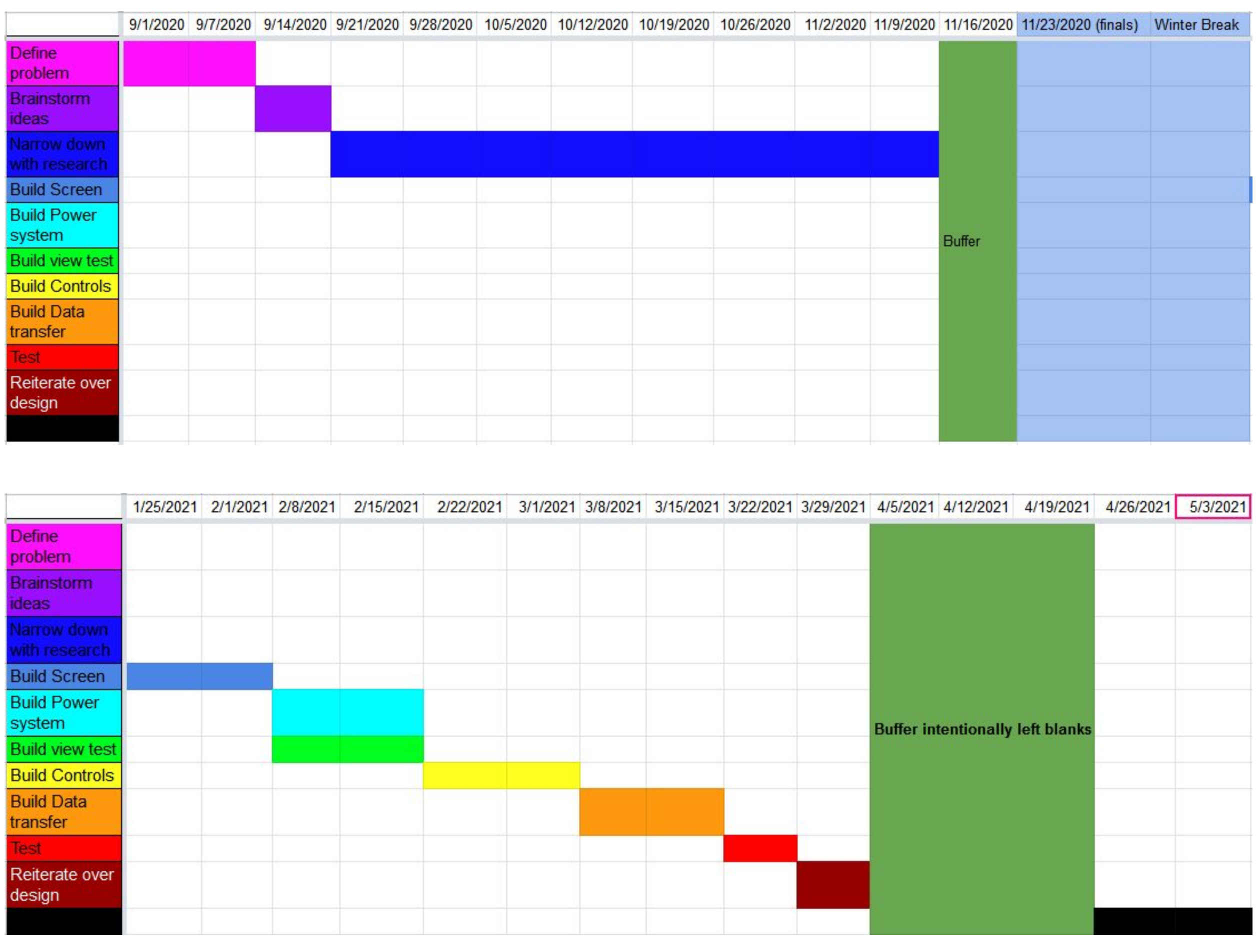

Figure 2.4.1: Gantt chart depicting project timeline

2.5 Project Tracking Procedures

We plan on using Gitlab as our code repository and to track software issues. We plan on using Trello to manage our tasks and keep track of deadlines. We will be using Webex Teams and email to communicate between team members, the industry connection, and the faculty advisor. We plan to work in an Agile environment. The metrics we will use to track progress will be whether or not the tasks are done as well as to what extent the tasks pass all unit tests.

2.6 Personnel Effort Requirements

We have various tasks, mostly split up with some tasks before the development of the product such as defining the problem and brainstorming ideas. Figure 2.6.1 shows all of the tasks and their expected time. For defining the problem, we expect it to take roughly 8 person-hours. We expect to have a meeting with our industry contact, go over the idea, and together define the problem we’re trying to solve. Brainstorming ideas is the next step before our development, we expect it to take roughly 6 person-hours, enough for the team to come together and pitch ideas all together.

The following tasks on the table, shown in Figure 2.6.1, are all for the development of the product. These times are estimations on the number of person-hours it will take to complete each portion. We expect the Screen and the Software to take 40 person-hours each, as these two tasks will be a large portion of the project. Working on Data Transfer, being able to transfer data from a server to the device securely, we expect will take 35 person-hours. Working on the UI, taking the data transferred from the server and displaying on the screen, we expect will take 30 person-hours. Implementing controls on the device we expect to take 20 person-hours. Finally we expect constructing the power systems, such as a battery, charger, and power supply for the device to take 30 person-hours.

Task	Person-Hours
Define problem	8
Brainstorm ideas	6
Build design: Screen	40
Build design: Power Systems	30
Build design: UI	30
Build design: Software	40
Build design: Data Transfer	35
Build design: Controls	20

Figure 2.6.1: The above chart determines how many hours are expected to complete each task.

2.7 Other Resource Requirements

The following list includes all additional parts required for the project:

- Headset casing (3D printed or existing)
- Screen
- Chip for connecting to server (bluetooth, wifi, etc)
- Buttons
- Battery
- LEDs (for testing purposes)
- Charging port and charger

2.8 Financial Requirements

The only monetary resources available include $1000 from the client (Cornerstone Strategies). Additional money needed would have to be requested from senior design funding, assuming that the investment would be something desirable to have for future semesters of senior design.

3 Design

3.1 Previous Work And Literature

A similar product to our current design that's out there is the Google Cardboard. According to Google, their product is an "Experience virtual reality in a simple, fun, and affordable way." In essence, it is a cardboard box with some lenses that has a slot for you to insert your phone. When running their cardboard app, and holding the device to your face, you get a VR headset device.

Figure 3.1.1: Google Cardboard device with a phone.

Pros:

- Very similar to what we want to create
- Lense setup is something that we could look at
- Very cheap device
- Develop testing software on existing platform

Cons:

- We don't need the extra overhead of VR capabilities
- Users require a compatible phone
- Loading the test onto the users phone might not be secure
- User could take out phone to allow others to view test
- User could record phone screen to share test to others

Another project that was researched during the design process was Project North Star, which was an open source AR project that kicked off in 2018, but has since been discontinued. Their goal was to create an affordable VR headset that could be mass manufactured for about $200.

Pros:

- Headset housing design in Project North Star is a useful reference
- Because of open source, many other projects are available for further research
- The original design estimated mass manufacturing of the devices at about $200 which would be valuable to reference/consider during product development
- Problems that would be encountered during development are likely ones that someone in the project community has encountered

Cons:

- Our project design scope has shifted away from AR and VR, and towards a HMD
- We don't need the extra overhead of VR capabilities
- Project North Star has been discontinued

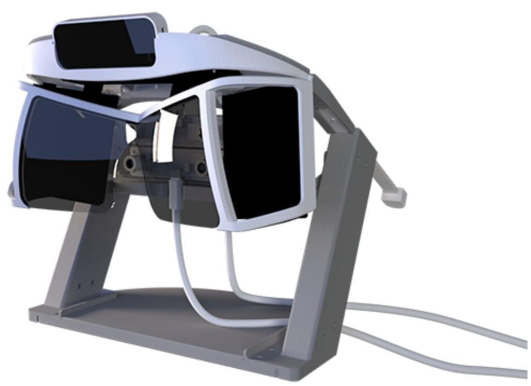

Figure 3.1.2: Project North Star Headset Design Rendering

3.2 Design Thinking

Through the “define” phase of our design thinking, we have determined that the user is a test taker. Specific types of test takers may include students in higher education or someone taking a standardized test or certification exam. The test takers need a comfortable environment to take the exam while still ensuring that the test data is kept secure. We also want to ensure that the test taker is able to interact easily with the test to minimize any stress related to the testing environment; the test taker’s focus should solely be on the exam content. We have also determined that our product is needed due to current testing circumstances during the pandemic as well as the constantly increasing use of technology for testing.

Figure 3.2.1 and figure 3.2.2 depict the ideation that took place while developing our product. Based on the figures, we narrowed down our product in the following ways. Within our security ideation, we determined that we will not be building custom architecture/OS. We will be using encryption from pre-existing resources/libraries. We will first develop the product to work over wifi, but may later add support for cellular. For our secure testing ideation, we determined that we will not be buying a pre-existing headset due to financial limitations. We will be creating a VR headset that is not immersive in the sense that the screen content will not adapt based on the user moving their head. The screen will appear as a still image of text, but can be scrolled through. We will not be using gaze tracking or any game controllers. The user will instead interact using a couple of buttons and a scroll wheel that will be on the side of the headset.

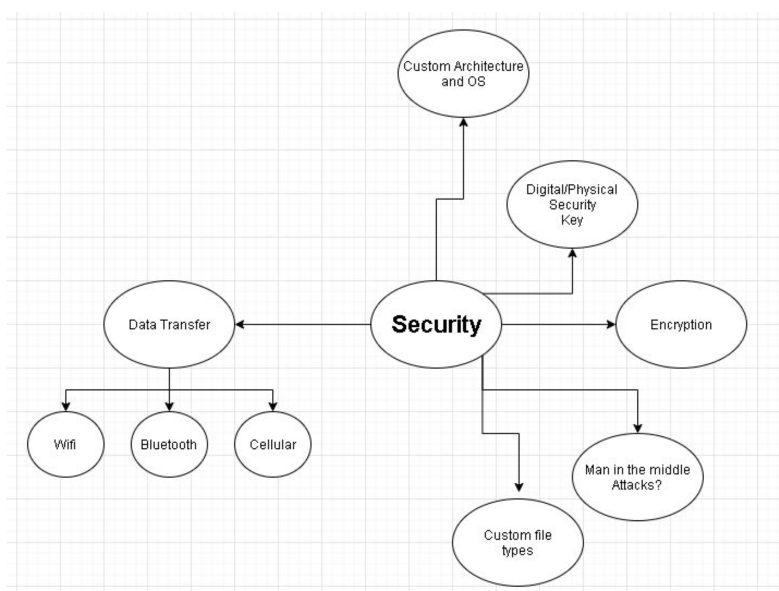

Figure 3.2.1: Ideation about security

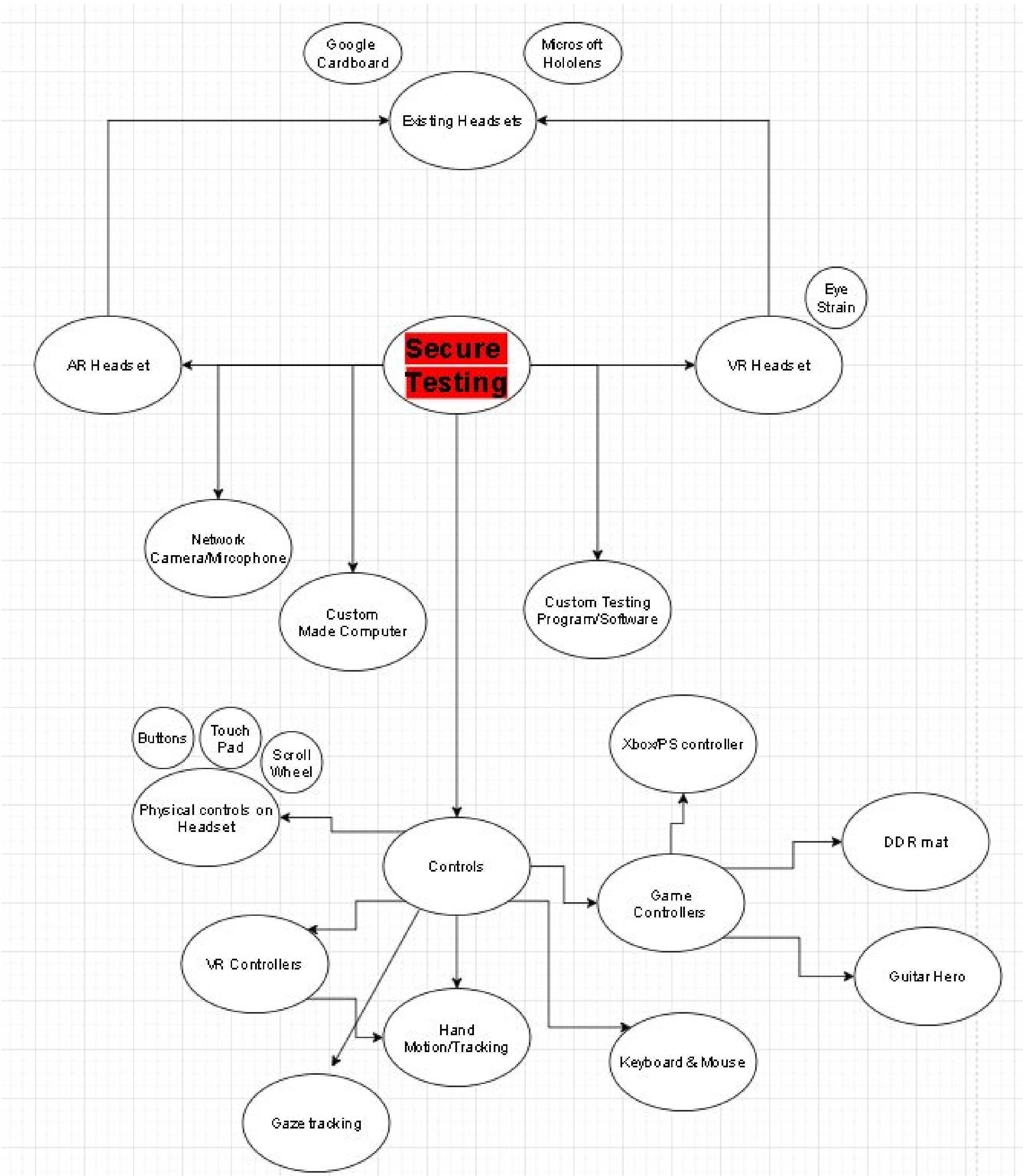

Figure 3.2.2: Ideation about secure testing

3.3 Proposed Design

Figure 3.3.1 shows the expected look of the headset. The casing will be 3D printed for the prototype, but the final product when produced on a larger scale will be made from a cast mold. The reason for the custom headset is to produce it cheaper than an existing headset that comes with additional functionality that is not needed for testing purposes. The front of the headset around the eyes will have all of the hardware, instead of having some of the equipment on the back of the head, which would require having cords connect the front and the back. The buttons and scroll wheel will be on the side of the headset. We decided on buttons directly on the headset instead of having extra handheld devices. An extra device could be at risk for being lost/disconnected from the headset. There will be an adjustable strap around the head to ensure the headset remains firmly on the user’s head. Within the headset will be two screens, one for each eye. Each screen will be a duplicate of the other. To eliminate the risk of having some type of video recording or image capture inside of the headset, there will not be excess room for anything between the user’s eyes and the inside of the headset casing. This means that user’s will not be able to wear glasses within the headset. To accomodate people with visual impairments or people who usually use glasses, there will be lenses between the user’s eyes and the two screens. The lenses will be manually adjustable so that the user can change the focus. The lens will be adjusted by moving it closer to or farther away from the screen.

We are planning on using some type of Arduino chip for the hardware as Arduino has some products that come with cellular capabilities. The Arduino we currently plan to use is called the Arduino Zero W, which includes a wifi chip that allows the headset to connect to the internet.

We will be building software that receives the test data from a secure server. The data transfer must be secure, which will be accomplished through pre-existing encryption libraries. Our drivers will need to comply with Question & Test Interoperability standards. QTI describes the standards for ensuring assessments have consistent formats, protocols, and interoperability. The test will be downloaded by the user ahead of time to ensure no dependency on the network bandwidth. The user will select the test they plan to take when ready and can scroll through the question and answer options. The user will select an option using the buttons and can then progress to the next question. The user will also be notified when the battery for the headset is running low.

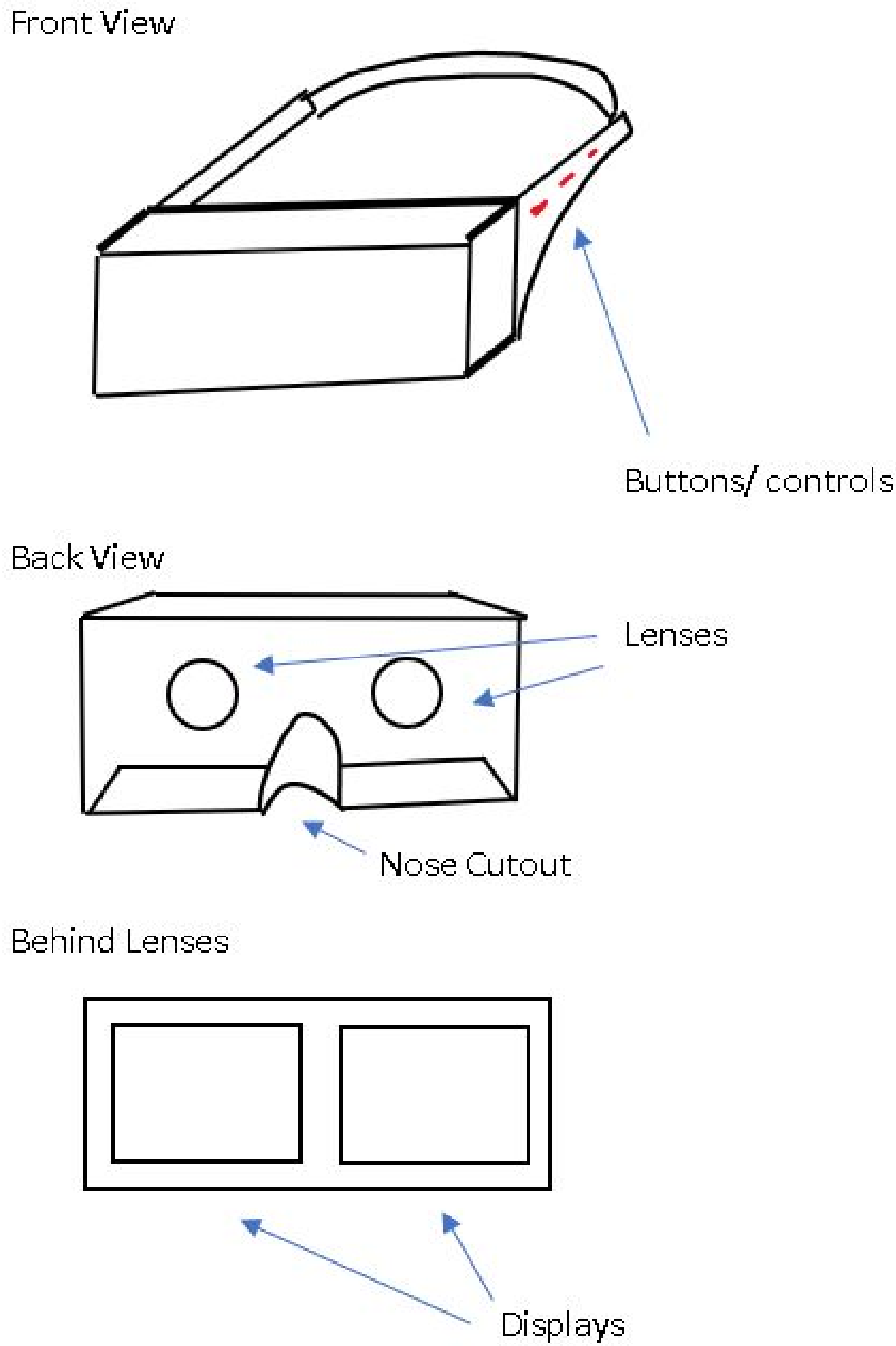

Figure 3.3.1: Sketch of headset design

3.4 Technology Considerations

Most of the existing wearable technology out there today consists of VR and AR Headsets. A lot of the VR headsets on the market currently are highly focused on the gaming industry. Software could be designed to proctor a test using a VR headset. Though these devices are slowly reducing in price, most are still hundreds to thousands of dollars.

Currently AR headsets are still much under development, and few choices are out on the market, and the ones that are are thousands of dollars.

There are very few head mounted displays or other wearable displays currently available out on the market.

There are existing remote testing solutions out there. The most popular type is a lockdown browser. Using a lockdown browser allows for students to use their existing computer to take the test, but work arounds are out there that allow students to still gain an unfair advantage, and to share the information from the test with others.

3.5 Design Analysis

The minimum viable product includes the following features: controls, display, data security, data transfer, power, and headset housing. The controls will be a scroll wheel and a few buttons. Data security will be accomplished using encryption libraries and tamper evident techniques for the hardware. Data transfer will be via wifi (or cellular for a future iteration). Power will be by a power supply and a small battery. The small battery will ensure enough power to successfully transfer test data to the server. The headset housing will hold all of the hardware and power equipment and will be built to be durable and comfortable.

After our initial analysis, we removed sensors as a component to ensure that a finished product can be produced in the allotted time. Although the minimum viable product will not be able to monitor the environment, future iterations may include sensors such as cameras, lidar, sonar, infrared, or microphones. Sensors and cameras would be used to ensure that the user was not cheating during the test. Sensor data would either be saved for processing by humans or AI could be implemented to tag specific moments of expected cheating. This AI is currently being developed in industry by certain proctoring companies, but is beyond the scope and expertise of our team and project. Future iterations may also include the following additional features: drawing tablet, built in calculator, eye tracking, hand tracking, and larger battery. The drawing tablet will allow the user to write down work while still being within the VR environment, which minimizes the user’s ability to cheat. The built in calculator will allow the user to do math calculations, which will increase the market for the product. Eye tracking and hand tracking would enable the user to interact with the test in a different way than the headset buttons and scroll wheel. The larger battery would allow the user to take a test without being connected to power the entire time.

3.6 Development Process

We intend to follow the scrum methodology as it's what we're all familiar with and is the cycle we've already fallen into with product design. We have a meeting every Monday recapping what we've done in the past week and reviewing class assignments due in the coming week along with questions for our industry contact meeting on Tuesday. Tuesday we ask those questions and work to further decide what needs to be done in the coming week and divide that up. This cycle seems to work well for everyone and in these unpredictable times it's good to have structure you can rely on.

3.7 Design Plan

Our product first and foremost has to get the test from the server and convey it to the user and take input. That's demonstrated here by the software diagram showing data moving from the server to the headsets sending and receiving program, interfacing with Tao, running through a Tao reader, receiving input from the user and then going backwards through the process. The main restrictions on our design are comfortability and security which are demonstrated in our hardware layout, not drawn to scale. All the components are kept at the front of the head to keep everything securely contained and simplify the strap on the users head. Keeping everything sealed allows for the possibility of tamper detection in future designs and by strictly limiting the input and output we minimize the possibility of secure data getting into the wrong hands or inaccurate/malicious data coming in.

Justification for our design plan, based on use cases, requirements, modules, and their dependencies, is included below.
Use cases:

- Because students are a large portion of the users, we are basing our design on producing an affordable product.
- As certification exams and college entrance exams involve test data holding high monetary value, our product needs to be very secure when transferring data between the external server and the headset. We do not want users to be able to tamper with the hardware and intercept any of the test data. As these types of exams are also relatively high stakes, we need to ensure that the users are not cheating. Future iterations of the headset will be able to detect when the headset is removed and at that point will pause the exam and not allow previous questions to be answered. Future iterations will also provide sensors or cameras that can support proctoring or monitoring of the exam environment.

Requirements:

- We need a way to select an answer as well as progress to the next question, so our design plan involves buttons on the headset that will allow user interaction. We are only supporting multiple choice questions for the minimum viable product, so buttons and a scroll wheel will be sufficient for user interaction.
- We need a way to communicate the exam to the headset, so we will be using an on chip wifi module built into the arduino. This will allow the headset to connect to the internet and receive the test.
- We need to ensure that the headset remains charged throughout the duration of the exam, so the headset will be plugged in at all times for this first iteration. Future iterations may support a power supply that enables disconnecting the headset for a period of time.
- Because we need to ensure secure content transfer, we will be using encryption techniques.
- The headset needs to be cheat-resistant and cheat-evident, so we will implement a technique in the hardware that makes it obvious that the headset was tampered with. This may be a seal or disposable seal.
- The client requests that the headset comply with Question & Test Interoperability (QTI) Standards. We will be implementing the headset using Tao Software, which already complies with QTI Standards.

Modules and Dependencies:

- Our implementation plan follows dependencies between the modules.

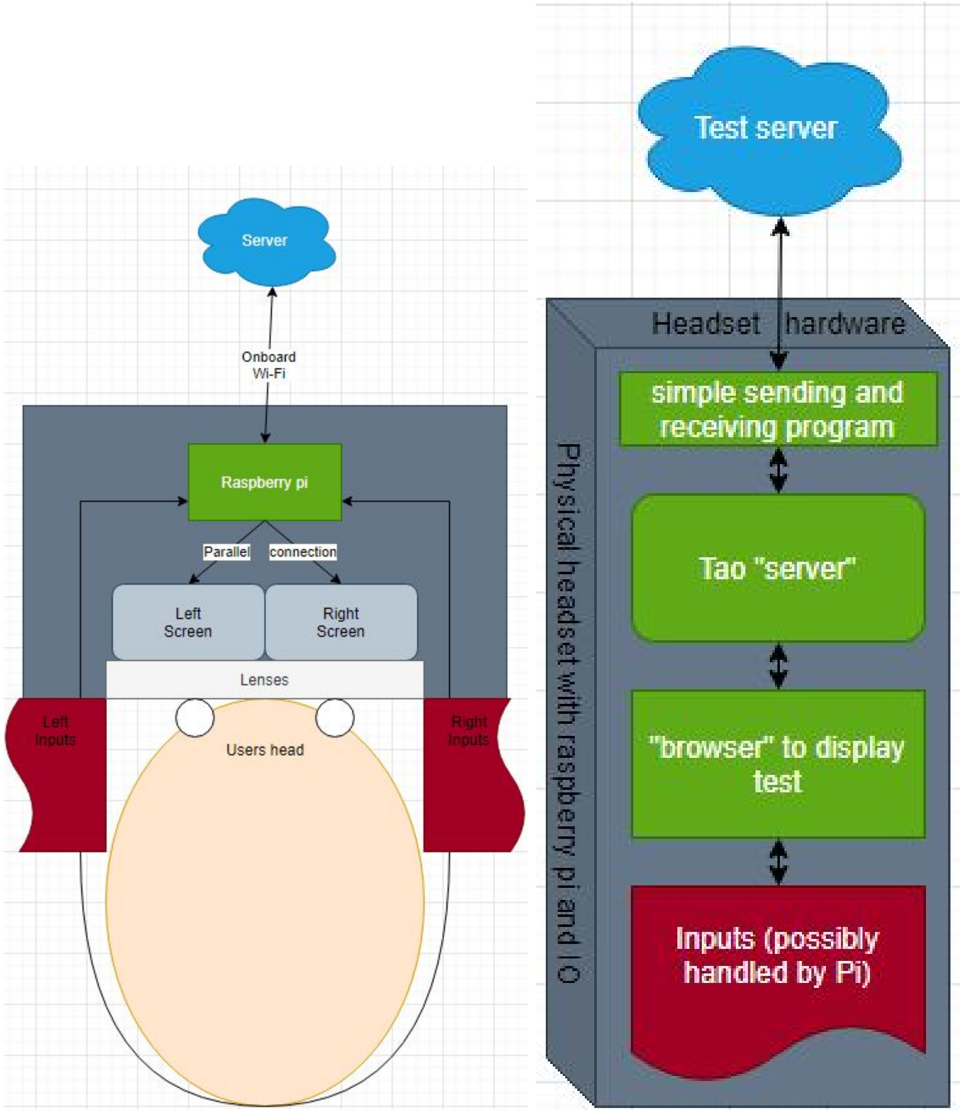

Figure 3.7.1: Hardware and software diagrams

4 Testing

4.1 Unit Testing

Hardware Unit Testing:

Power system: Checking battery functions long enough, checking all components receive power, checking consistent power levels throughout the device.

Computing system: The main chip that runs the program can output consistent signals that are expected test signals.

Input functionality: Checks that inputs can send an electrical signal, checking that the electrical signal is interpreted consistently.

Screen: Checks that screen receives power, check that power levels remain consistent.

Other Components (Unknown at this time): Checks that all receive consistent power and send consistent signals.

Image adjustment dial: Lenses move with stability along their track.

Wifi/Cellular: Component receives power and can send a signal.

Software Unit Testing:

Data Transfer: Ensure that data is successfully transferred from host to device without data loss.

Data Security: Ensure successful encryption of data that's transmitted from host to client devices.

User Interface: Ensure basic functionality of user navigation in interface.

User Input: Ensure that signals received from the hardware end are displayed correctly.

Data Display: Ensure that data is successfully delivered to the interface and is displayed to the user.

Wifi/Cellular: Ensure that the device is able to wirelessly connect, send data, and receive data.

4.2 Interface Testing

Power system to any component testing: Any component receives power at a consistent, usable level.

Computing system to screen testing: Screen can display an image loaded from the computing system and can switch to any required image as required. Screen can send error data to the computing system.

Input to computing system testing: The inputs send a consistent signal to the computing system and the computing system can reliably interpret the inputs into usable data.

Image adjustment dial to screen testing: The dial can move the focal point for the user closer or farther from the screen with stability and can show an accurate image when movement is complete.

Computing system to Wifi/Cellular module testing: The computing system can send the data to the wifi/cellular module, and the wifi/cellular module can send error messages to the computing system.

4.3 Acceptance Testing

- End-to-end testing
    - The requirements of the prototype will be tested rigorously from a use case perspective
    - All necessary use cases must be verified
    - Example use cases:
        - User can open an exam using the headset
        - User can submit answers
        - User can navigate between questions
        - User can submit an exam to be graded

- Client involvement in acceptance testing
    - The client will have authority on what use cases are necessary.
    - If there are fail points, the client will determine if they invalidate the acceptability of the prototype, and which fail points are most important to fix.

4.4 Results

- Hardware/software testing has not yet been performed, but will be executed both while the prototype is being built and after it is complete.
- Some features that were initially included in our requirements have now been pushed to later iterations, such as the inclusion of sensors to prevent cheating and the implementation of AI to detect nefarious behavior during testing.

5 Implementation

The current implementation plan is to focus on the central computer and build out from there in both hardware and software. The first stage will involve simply obtaining a microcomputer, at this time we're looking at a raspberry pi, specifically the Raspberry Pi 0W, and a screen to display on, specifically the 240x320 IPS LCD. The next step will involve getting wifi communication working on this microcomputer and figuring out how to display the screen output duplicated on two screens, one for each eye. Next we'll develop software on the device for processing the test, displaying it, and taking user input. We will at first use a keyboard and mouse to interact with the test, but further iterations will only use buttons on the headset. We plan to use open source Tao Testing software, which is a service for creating and delivering exams in a browser. We will display that browser on the LCDs that are connected to the raspberry pi. Finally, we'll just need to put everything into a casing to house the device. Once we have this prototype functioning, we will iteratively add features to the headset. Additional features will include adjustable lenses between the screen and the user's eyes, buttons instead of a keyboard/mouse, and modified Tao software.

6 Closing Material

6.1 Conclusion

This semester has largely focused on narrowing down exactly what we need to make and what it needs to do. While we never explicitly laid out goals for this semester our goals for the year are to deliver a reliable and well made prototype to our client. We feel that the best plan of action so far has been to clearly define all features and requirements of this product which at times has involved researching and explaining some fairly technical fields to a non-technical audience. We feel confident moving into the end of the semester that we will soon hammer out the last details of the design. We expect to select and order parts over winter break and spend the spring semester building and testing our product to ensure it is the highest quality possible given current conditions. This approach allows us to understand the big picture before we begin physical work and thus ensures that all requirements and obstacles are clear from the outset of next semester. We feel confident this informed position will far surpass other routes in terms of both time spent on any given increment of the design and the quality of the final product especially in areas where two seperate pieces are brought together which are often seen as weak spots in a design.

6.2 References

"Average Peak & Median Internet Speeds USA", fastmetrics.com. [Online]. Available: https://www.fastmetrics.com/internet-connection-speed-map-usa.php/. [Accessed: 12-Oct-2020].

B. Ackroyd, "A Guide to Mobile Download Speeds: 2G, 3G, 4G and 5G. What Do They Actually Mean?," *TigerMobiles.com*, 23-Jan-2019. [Online]. Available: https://www.tigermobiles.com/faq/mobile-download-speed-guide/. [Accessed: 27-Oct-2020].

"Do you even need to wear glasses with VR?: Find out if you should be wearing your glasses with your VR headset." VR Bound. [Online]. Available: https://www.vrbound.com/guides/which-virtual-reality-headsets-can-i-wear-with-glasses. [Accessed 15-Oct-2020].

GitHub. 2019. *Release TAO 3.3.0-RC02 · Oat-Sa/Package-Tao*. [online] Available at: <https://github.com/oat-sa/package-tao/releases/tag/v3.3-rc02> [Accessed 15-Nov-2020].

Jay. "How Lenses for Virtual Reality Headsets Work." VR Lens Lab. [Online]. Available:https://vr-lens-lab.com/lenses-for-virtual-reality-headsets/. [Accessed 15-Oct-2020].

"State of Mobile Internet Connectivity 2018.", gsma.com. [Online]. Available: www.gsma.com/mobilefordevelopment/wp-content/uploads/2018/09/State-of-Mobile-Internet-Connectivity-2018.pdf. [Accessed 12-Oct-2020].

T. Cooper, "Report: US States With the Worst and Best Internet Coverage 2018," *Broadband Now*, 09-Mar-2020. [Online]. Available: https://broadbandnow.com/report/us-states-internet-coverage-speed-2018/. [Accessed: 27-Oct-2020].

6.3 Appendices

Google Cardboard

Google Cardboard brings immersive experiences to everyone in a simple and affordable way. Whether you fold your own or buy a Works with Google Cardboard certified viewer, you're just one step away from experiencing virtual reality on your smartphone.

“Get Cardboard,” Google. [Online]. Available: https://arvr.google.com/cardboard/get-cardboard/. [Accessed: 16-Nov-2020].

Project north star

At Leap Motion, we envision a future where the physical and virtual worlds blend together into a single magical experience. At the heart of this experience is hand tracking, which unlocks interactions uniquely suited to virtual and augmented reality. To explore the boundaries of interactive design in AR, we created Project North Star, which drove us to push beyond the limitations of existing systems.

“Project North Star is Now Open Source,” Leap Motion Blog, 06-Jun-2018. [Online]. Available: https://blog.leapmotion.com/north-star-open-source/. [Accessed: 16-Nov-2020].