

Project Requirements Document

Version 2

OverSEA

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1 Abstract

1.1 Team Members

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1.2 Team Name

The team name is **OverSEA**.

1.3 Project Title

This project is titled **Synchronous Remote Maintenance Systems**.

1.4 Project Sponsor

This project is sponsored by NavSEA at Port Hueneme.

2 Background

We define and explore the remote maintenance problem in this paper. Currently, naval maintenance organizations will fly out experts on remote deployments to supervise and aid the maintenance, replacement, and improvement of critical navy infrastructure. The need for transportation of specialized individuals to naval ships for maintenance is costly and logistically challenging, and an opportunity exists to minimize labor and capital costs through advanced AR technology — in doing so, time and resources are saved by allowing specialists to work remotely while still following maintenance procedures and thus completing required equipment maintenance. However, there are several challenges in doing so, including the navigation of the complex environment of a Navy ship, limited bandwidth in remote locales, and the necessity for secure, encrypted communications. Other points of contention include the difficulties of communication over long distances through virtual means. A streamlined software application for aiding in the process of remote maintenance is of critical importance to ensure that modern naval vessels are kept in working condition without excessive capital cost.

2.1 Relevance

Routine maintenance of Naval ships and systems is of critical importance. The expected lifetime of these systems being in the decades provides unique challenges to maintenance personnel. Currently, specialized navy contractors and engineers travel to on-site locations in order to perform these maintenance routines. However, this process is resource intensive in both time and capital cost. In combat environments, this may not be a plausible solution, and is a logistical and security vulnerability that an enemy can exploit. Performing routine maintenance through specialist guided AR technology can ease logistical challenges,

during both peacetime and conflict. Moreover, the specialists and engineers may not be accustomed to the radically different environments of each ship they travel to, causing them to spend excess time becoming acclimatized to their working environment. The confined, chaotic nature of the inner workings of massive, multilayered naval ships may be detrimental to the productivity of these specialized employees. Maritime obstacles such as sudden storms or seasickness can also hamper the effectiveness of the specialists and engineers.

2.2 Current Methodologies

As of right now, there is no adequate solution for these problems. Current solutions using advanced technology are to connect the expert/specialist and a person aboard the Naval vessel and have the expert guide the person as to what they should do. While this method uses AR technology, it is primitive and unstable, reflecting the prototypical nature of the product involved. Current market products cannot work under poor network connectivity or under a satellite blackout. Another problem at the moment is when multiple ships need maintenance concurrently. More specifically, the time delay for sending a specialist between ships means that there is a period of downtime between each maintenance operation. Often, an entire day may be spent solely for shuffling maintenance personnel around a fleet of navy ships. Some ships will have to wait for personnel availability on other ships before they can proceed.

Currently, mixed reality models are unable to adequately address the unique issues present during remote maintenance. While existing platforms use similar technologies and platforms, they do so in a way that does not meet the needs of the end-user. Most current methods are not error-tolerant, and therefore cannot be used in a rapidly changing environment like that of a Navy ship.

3 Goals & Objectives

We intend to demonstrate how the HoloLens and other AR/VR technologies can be implemented to aid in remote maintenance. To do so, we are implementing real-time object classification and detection algorithms. We expect to use the HoloLens to detect edges of different objects in the user's line-of-sight and identify parts and machinery scheduled for maintenance. With this information, supporting documentation is automatically displayed to the mechanic, who is guided in their duties by the remote specialist. Voice commands are available for both the specialist and mechanic to smoothen the communication process. User authentication and accountability measures are enacted in order to reliably track the performance of specialists and maintenance personnel by administrative staff. Mechanics and specialists will be provided with a list of in-progress and scheduled tasks to accomplish for each working shift. As each of these tasks are finished, personnel are able to independently mark these as finished, which will be displayed to them through the HoloLens-computer interface. We expect to have a minimal viable product showcasing our solution to the remote maintenance problem within 6 weeks of the finalization of this document.

4 Implementation

To implement our proposed solution, we will use the HoloLens along with several supplementary technologies. These technologies are grouped: object detection using Vuforia, drawing with the HoloLens, computer client application, and HoloLens and computer client interaction.

For object detection, we will receive CAD models of all necessary equipment, from a centralized database on-site, which will be provided to the HoloLens-based software. The Vuforia platform application will be used to aid in object detection. Using edge detection, the HoloLens will be able to precisely identify a CAD model given the same physical item is presented by the user. With object detection and classification, the HoloLens will display the part name, required maintenance procedures, and other supplemental information to the user. With this data, the user will be able to interact with the data, pulling up videos and pdfs of required information on the side. In addition to object detection, the HoloLens will have object tracking capabilities. The user may pin a specific object, and a point object will appear. This point will track the object in a three-dimensional field, directing the user back to the object in their location. The user will also be able to create a projection of an object that will stay in a given position directed by the user.

Another component of our solution is the drawing functionality with HoloLens. Using Unity, we will include libraries, such as audio listener, finger tracking, and gesture recognition. With these libraries, the

HoloLens will be able to track the user's fingers, hands, hand gestures, and voice. The user will be able to draw in a three-dimensional plane with a variety of colors. The user will have a menu with a few options: change color, change mode, undo, clear, and draw. Once the user presses draw, they can draw with the specified color. In addition, the user can access all functionalities by stating the voice commands to add quality of life to the program.

In addition to the HoloLens application, we will have a computer client base application. This will represent the on-shore specialist who is communicating with the naval base maintenance worker. The client will be able to sign in to their account which will be used to track users calling each other. The client will be prompted to a screen where they can call other users via ids and names. The client may also receive calls, and when prompted, they will see the profile picture of the caller and will be able to accept or decline the call. When calling, the application allows the user to speak and see the other user's view. When calling a HoloLens user, the client will be able to see the HoloLens view and be able to draw on their view. The client can share their screen so that the caller may also see what they are looking at. In addition, the client can mute their microphone at any moment so that the caller will not hear them. The client will be able to zoom in and out of the view and close the call at any moment.

The last component of our project is the computer application and HoloLens application interaction. This component consists of two parts: showcasing the HoloLens view as a webcam object and hosting a server and client interaction using web sockets. The HoloLens view will be converted into a webcam source where the computer application can select the received webcam. This allows for the computer to see the HoloLens field of view. In addition, we will use websockets to implement a server on the HoloLens side and a client on the computer application side. The server will be hosted when the HoloLens user opens the application. The host will be on a specified port and ip-address. The computer application user will be able to connect to the server by entering in the specified port and ip-address. With this, the HoloLens will connect to the computer application. They both will be able to receive and send messages to one another. This functionality will be used to implement the ability for the computer application user to draw on the HoloLens user's view.

4.1 Assumptions

To implement this project, we must assume that naval ships have or will be able to provide a database with all CAD models of specific parts along with more detailed information, including but not limited to part numbers, schematics, and prior maintenance logs. We also assume that the HoloLens and associated computer is powerful enough for real-time edge detection, object detection, and classification. We must assume that the HoloLens or associated computer has a microphone for the sailor to be able to speak. We must assume that the naval ships will have a powerful enough connection that the computer application will be able to connect to the HoloLens. We assume that the naval ships have a stable environment. Because naval ships are often very unstable as they sway in the waves, they often cause incompatibility with AR/VR technologies as these technologies require the three-dimensional space to be constant. With the assumption of a stable environment, the HoloLens will be able to view the field and have its components, such as drawing, object detection, tracking, object pointers, properly functioning.

5 System Architecture

An annotated diagram of the system architecture is provided below. This diagram represents required project parameters for the Minimum Viable Product. Additional architectural specifications will be created as development continues. Additional features may require new components in the system diagram.

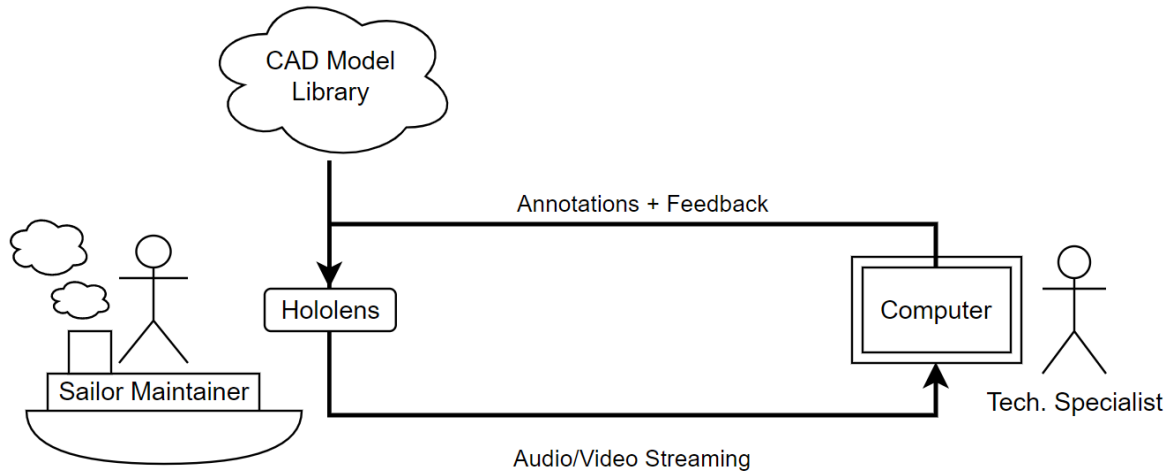


Figure 1: Generalized System Model

The diagram above represents significant data paths within the software. There are two users, the on-site HoloLens user, and the computer user, hereafter referred to as the "Mechanic" and "Specialist", respectively. The main focus is to allow object detection and classification of certain critical components that are needed for repair and/or maintenance. Currently, the HoloLens will use the Vuforia plugin to facilitate object detection. The plugin will need a CAD model to allow for detection, which can be downloaded from a third party server, provided either on-site or through a satellite connection to the on-site software system.

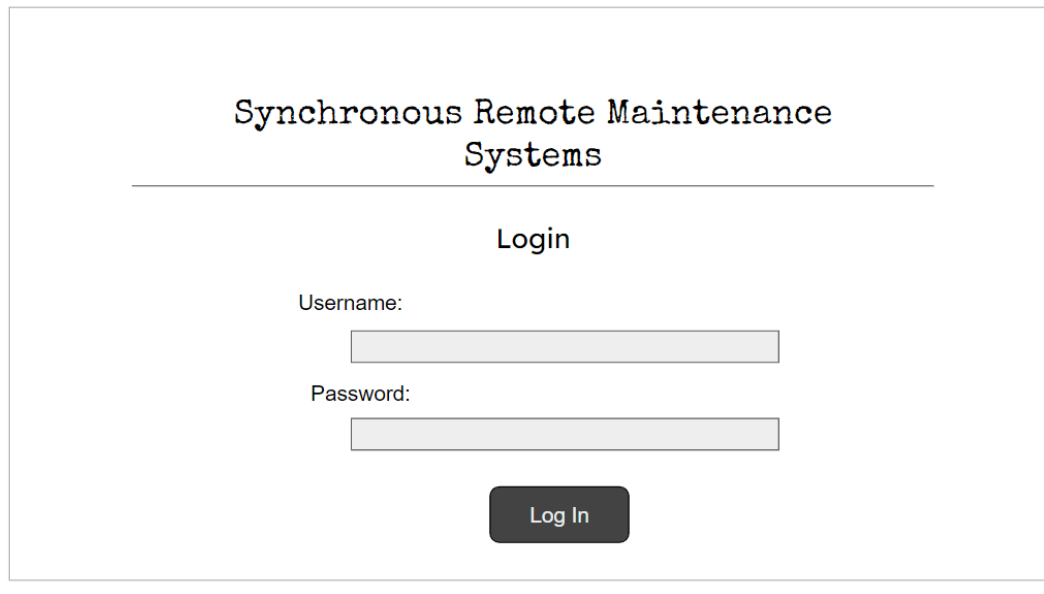
5.1 User Interaction and Design

The HoloLens user will be able to stream video and audio to the tech specialist, who in turn will be able to voice their advice/instructions to the sailor. In addition, the specialist will be able to annotate/draw on the hololens user view. The annotations/drawings will be spatially locked. Once a two-way communication between a specialist and mechanic is created, the users will be able to synchronously interact through both audio and video transmission. The specialist can provide advice to the mechanic by projecting documents into the HoloLens remotely, such as by providing the mechanic a required maintenance datasheet as required. The system will allow for a seamless disconnect once the required task is finished. The transition time between successive calls between multiple mechanics/specialists is minimized through the use of effective user interface and system design. Fallbacks are provided for high-latency or low-throughput connectivity scenarios. Credential management is implemented rudimentarily in order for secure authentication of personnel. Analytics are collected and dispatched to a central server for later processing, review, and scrutiny by administrative personnel.

5.2 Mockups

This section contains UI element mockups of the client application.

This figure shows the computer application user interface while trying to login. On this page, the user will be prompted to enter their username and password. If the username and password is on the computer application database, then they will be prompted to the active callers page. If the username and password aren't on the computer application database, they will receive an error message and be prompted to login again.



**Synchronous Remote Maintenance
Systems**

Login

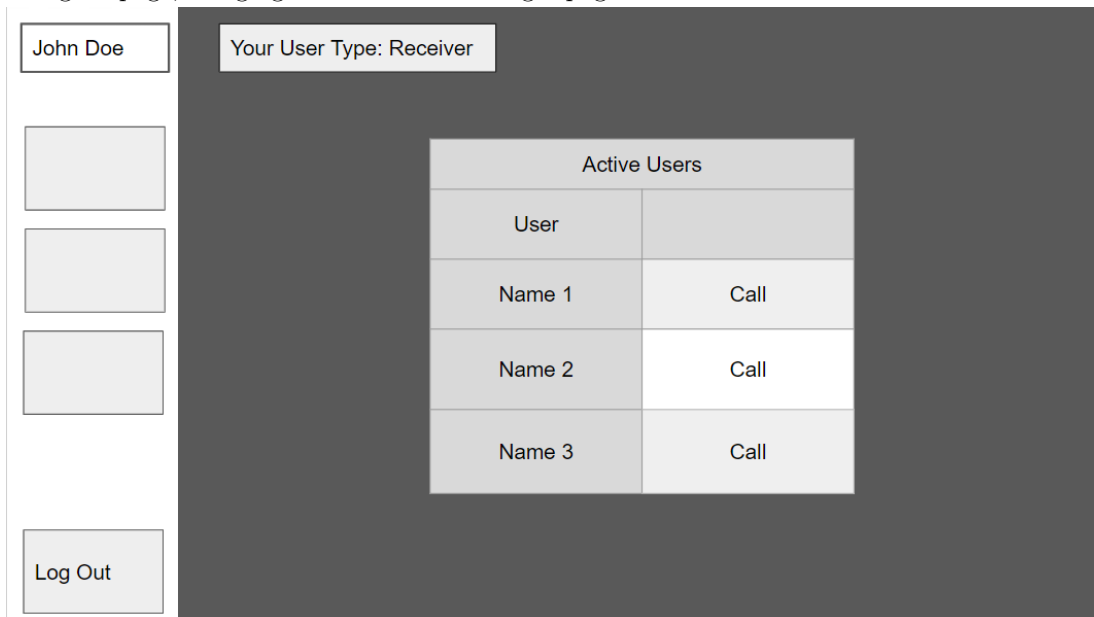
Username:

Password:

Log In

Figure 2: Client – Login Page

This figure shows the computer application user interface when the user is on the active callers page. On this page, the user will be shown all the active users on the database: their name and a button to call them. The user can press on the desired caller's call button to bring them to the call page. They may also click the logout page, bringing them back to the login page.



John Doe Your User Type: Receiver

Active Users	
User	
Name 1	Call
Name 2	Call
Name 3	Call

Log Out

Figure 3: Client – Idle Screen

This figure shows the computer application user interface while receiving a call from a HoloLens caller. On this page, the user will be shown the caller's profile picture. In addition, the user can accept the call, which brings them to the calling page or reject the call, bringing them to the active callers page.

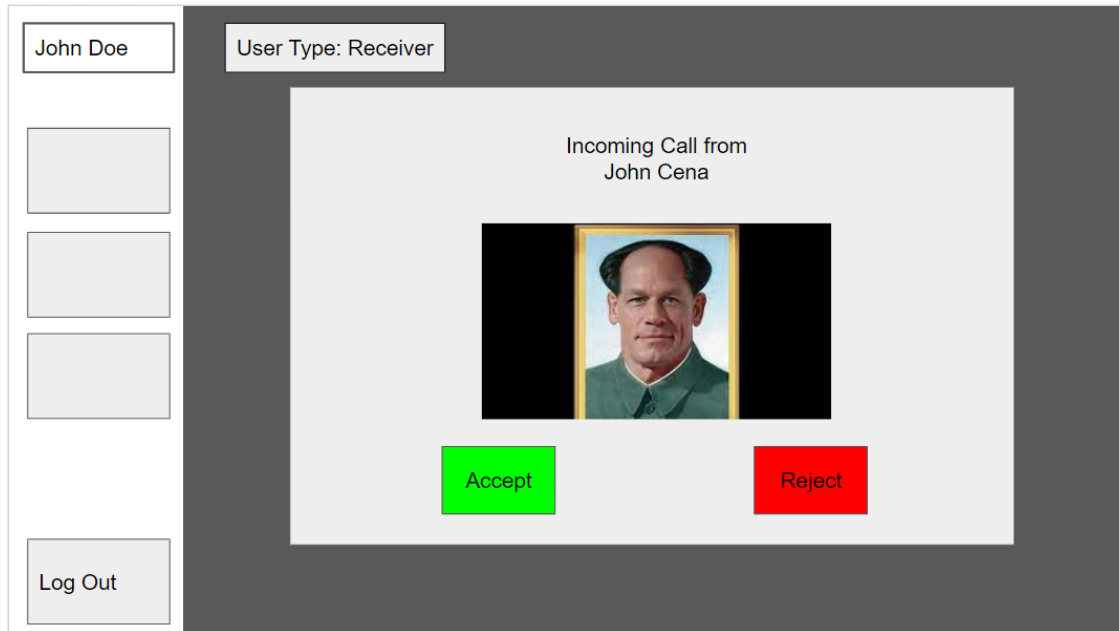


Figure 4: Client – Incoming Call Overlay

This figure shows the computer application user interface while calling with a HoloLens caller. The computer user is able to see the HoloLens view and interact with the caller in a few ways. Firstly, the user is able to draw on top of the view which will be projected to the HoloLens caller's view. The user may change mode of drawing, erase their drawings, change the colors and thickness, undo the drawing, and exit drawing mode. The user may also share their screen with the caller; they will be able to select the source of the shared screen to show the desired images. The user may also mute their microphone so that the caller cannot hear them. Lastly, the user can end the call, leaving the caller and bringing them back to the active callers page.

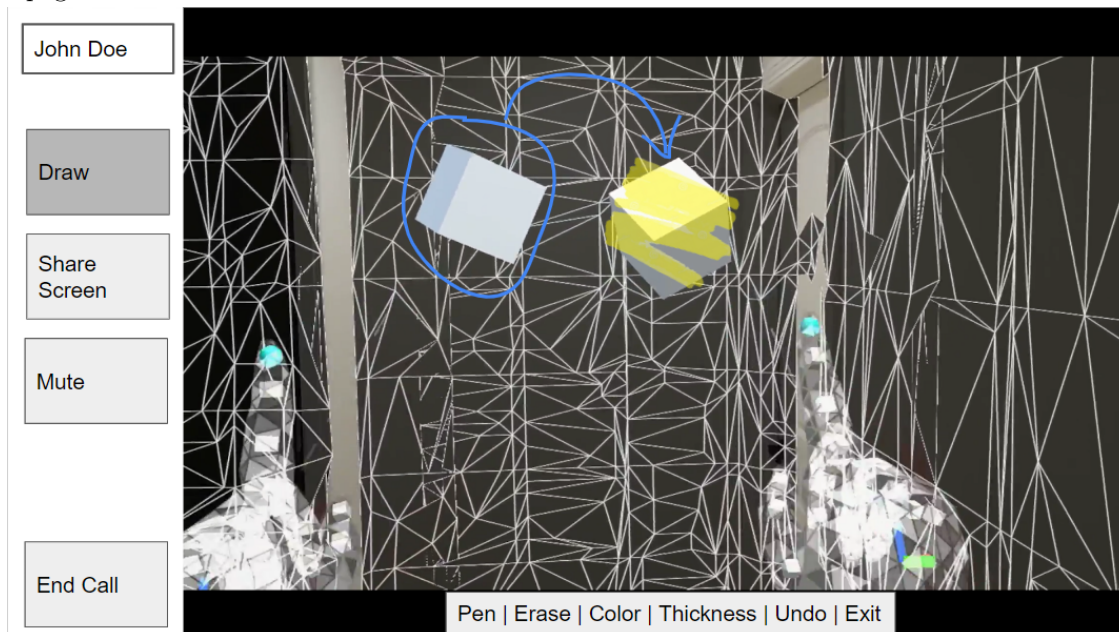


Figure 5: Client – Active Call Screen

6 System Models

Here, user interactions with our software are described, both in writing and with the help of UML/State Diagrams. Sequence diagrams are also provided for common user/system actions.

6.1 User Interactions

The user will have four main interactions: computer application login, calling, HoloLens drawing, and HoloLens object detection and tracking.

Firstly, the user will be able to login to the computer application. To do so, the user would enter their username and password respectively. If the user's credentials are present in the application database, the user will be prompted to the application. If the user's credentials are not present in the database, the user will receive an error message and will not be logged in.

Another interaction the user can do is calling. The user can be on the computer application or the HoloLens, but they have different methods to connect. For the computer application calling, the user must first login to the application. Once logged in, the user will navigate to the active users page. From there, the user can press on any user they wish to call with. Once pressing the button, the user will start calling the other user. When the call starts, the computer user will be able to draw by pressing the draw button and using their cursor to create drawing visuals. The computer user will also be able to share screen by pressing the share screen button. From there, they can choose their source to choose what they want to show the other user. The user may also mute themselves by clicking on the mute button so that the caller cannot hear them. Lastly, the user can end the call by clicking the end call button, which brings them back to the active callers page. For the HoloLens calling, the user can navigate to the active callers page. On that page, the user can click on the desired caller by pressing or using the click gesture while the cursor is pointed on the button. From there, the user will be able to hear and interact with the caller. The caller will automatically receive the user's field-of-view via the HoloLens. The user can speak with the caller, and the user can mute themselves by pressing on the mute button. The user can end the call by pressing the end call button as well.

As a HoloLens client, the user will also be able to draw. Once opening the app, the user will be prompted into the application. On the side, there will be a menu with a few options: draw, change mode, undo, clear, change color. The user may press on any of these buttons or say the option's name to navigate to this stage. When the user presses "change mode", the drawing functionality will change from normal (tracking cursor) → mesh (drawing mapped to specific area) → finger (tracking user's finger) and it will repeat in this manner. Pressing undo will revert the most recent three-dimensional space drawing. Pressing clear will remove all drawings in the entire three-dimensional space. Changing colors will cause the drawing color to change. The user can press the draw button and start drawing in their three-dimensional space with their specified color and mode. Once the user is done, they may say or press the stop drawing or say stop so that the drawing functionality will halt.

The last interaction the user may use is object detection and tracking. The user may press on a specific object which will be tracked. An arrow will pop up above the user, and it will direct the user back to the object in three-dimensional space. In addition, the user may move a hologram-like object, and it will remain stationary in the set location by the user. Lastly, the user may put any object that has its CAD model rendered into the HoloLens in the view of the HoloLens, and there will be a box tracking the object.

6.2 UML Diagrams

UML Diagrams for the software are provided below.

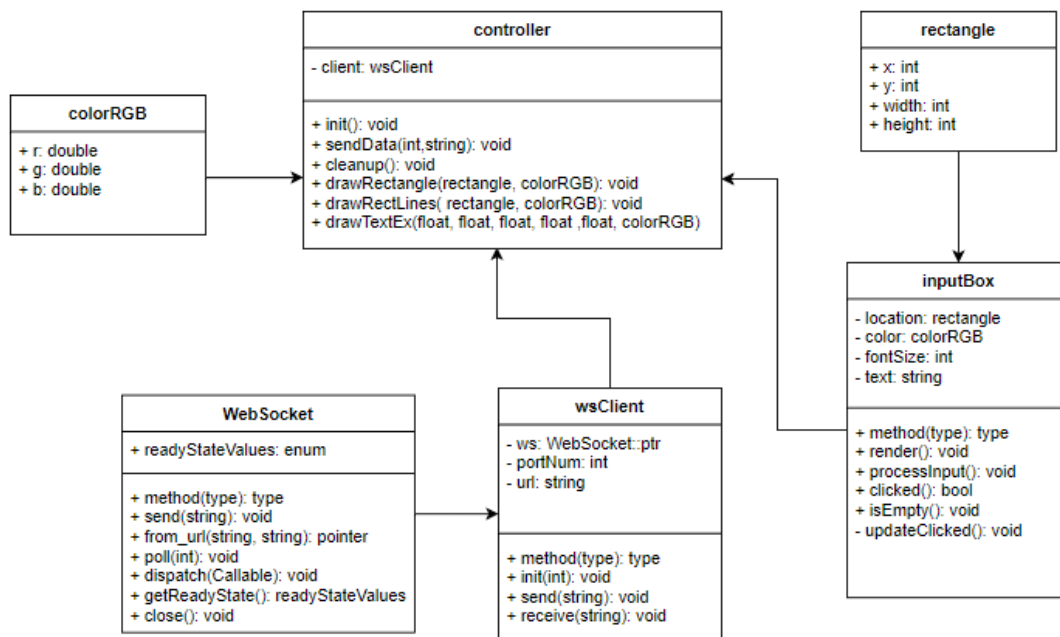


Figure 6: UML Diagram – Client

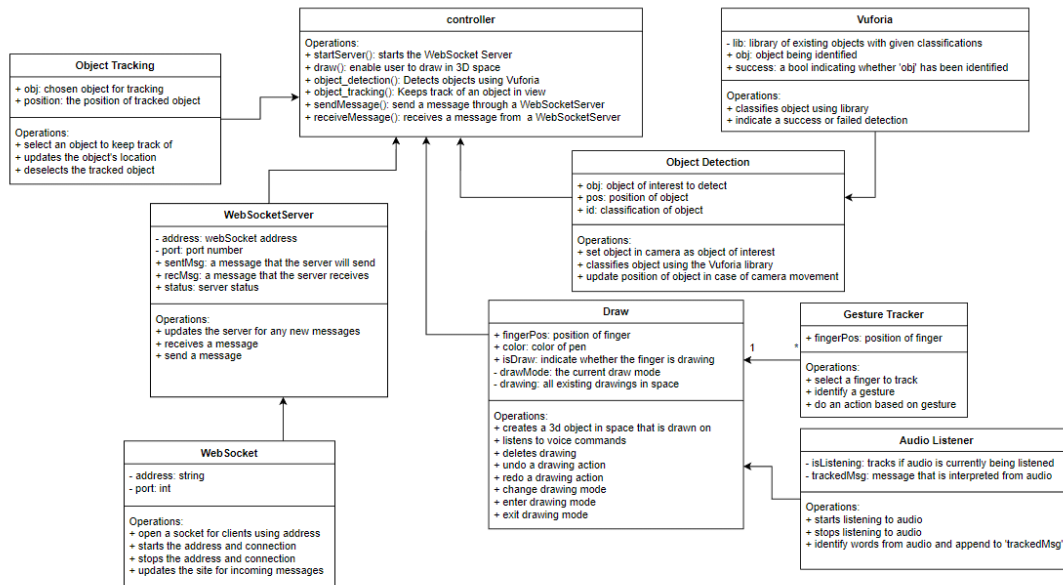


Figure 7: UML Diagram – Server

6.3 State Diagrams

State diagrams of three major components are provided below (Client, HoloLens Drawing Controller, HoloLens Object Recognition).

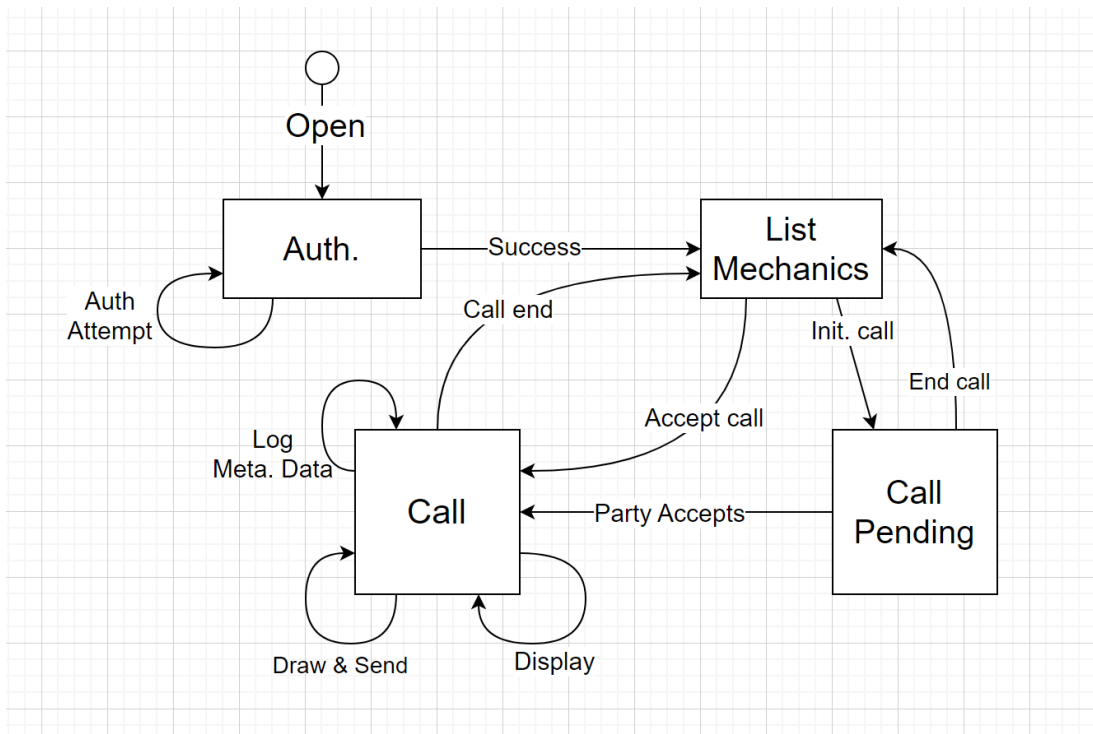


Figure 8: State Diagram – Client

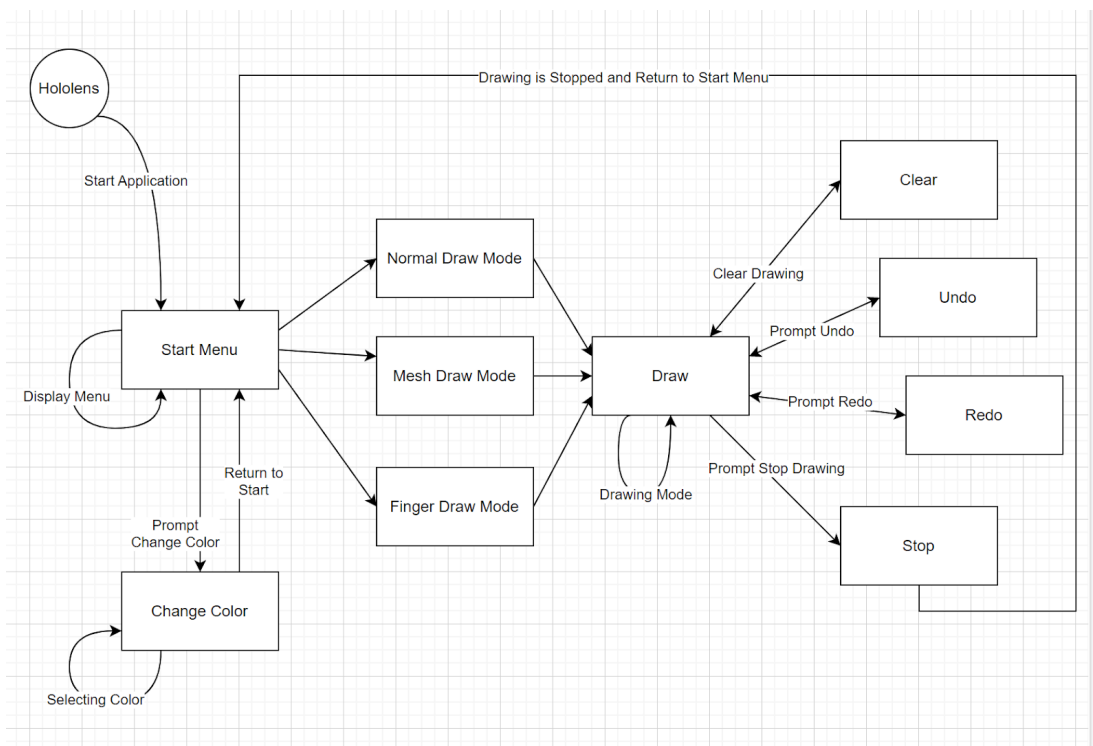


Figure 9: State Diagram – HoloLens Drawing Controller

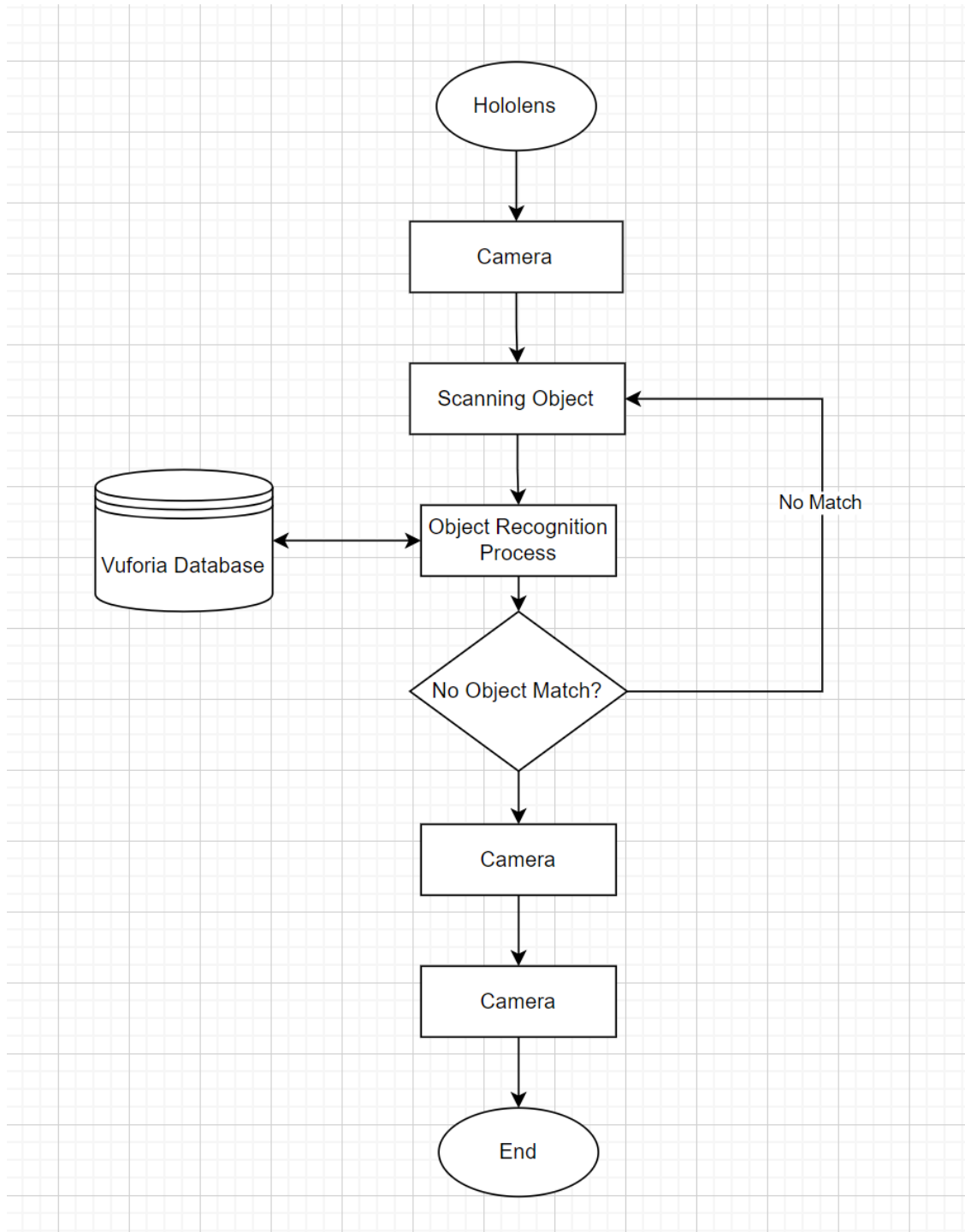


Figure 10: State Diagram – HoloLens Object Recognition

6.4 Sequence Diagrams

Sequence diagrams of three major actions are provided below (Requesting Call, HoloLens Video Export, HoloLens Drawing Renderer).

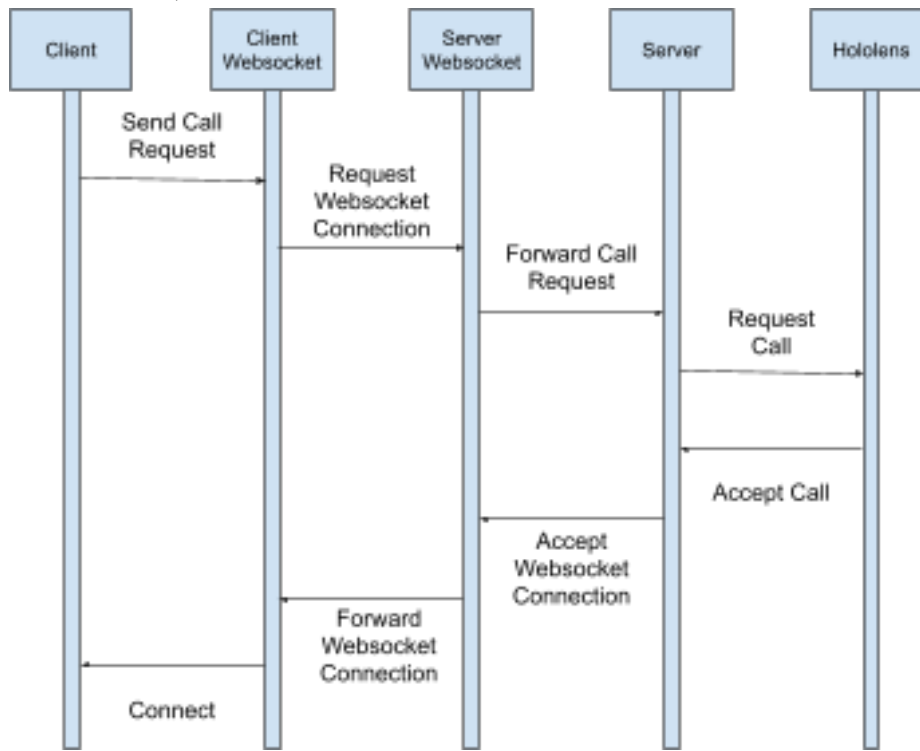


Figure 11: Sequence Diagram – Request Call

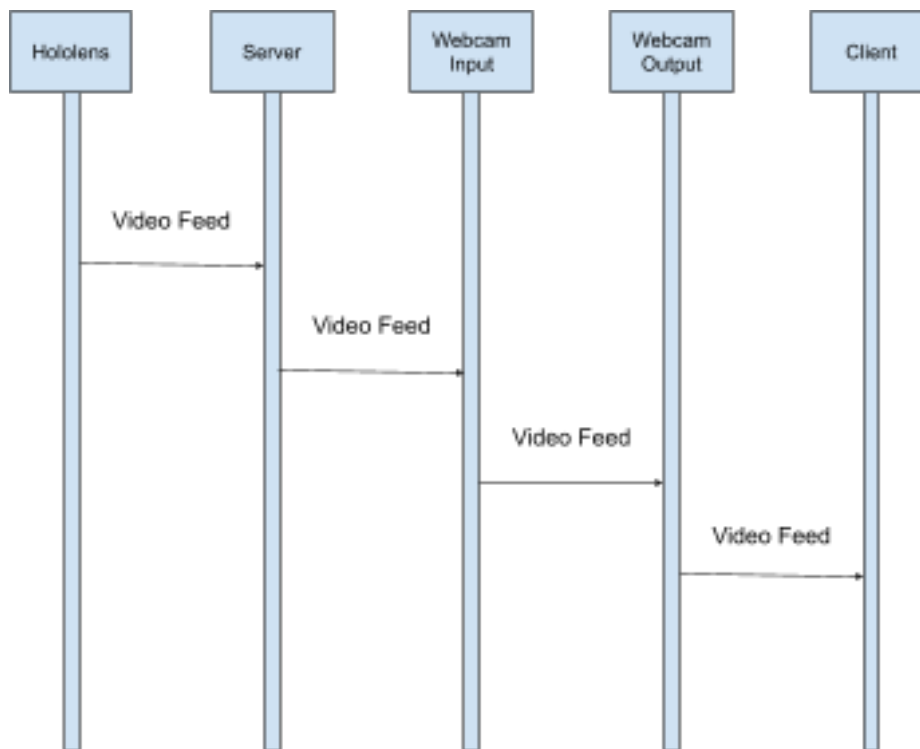


Figure 12: Sequence Diagram – Forward HoloLens Video

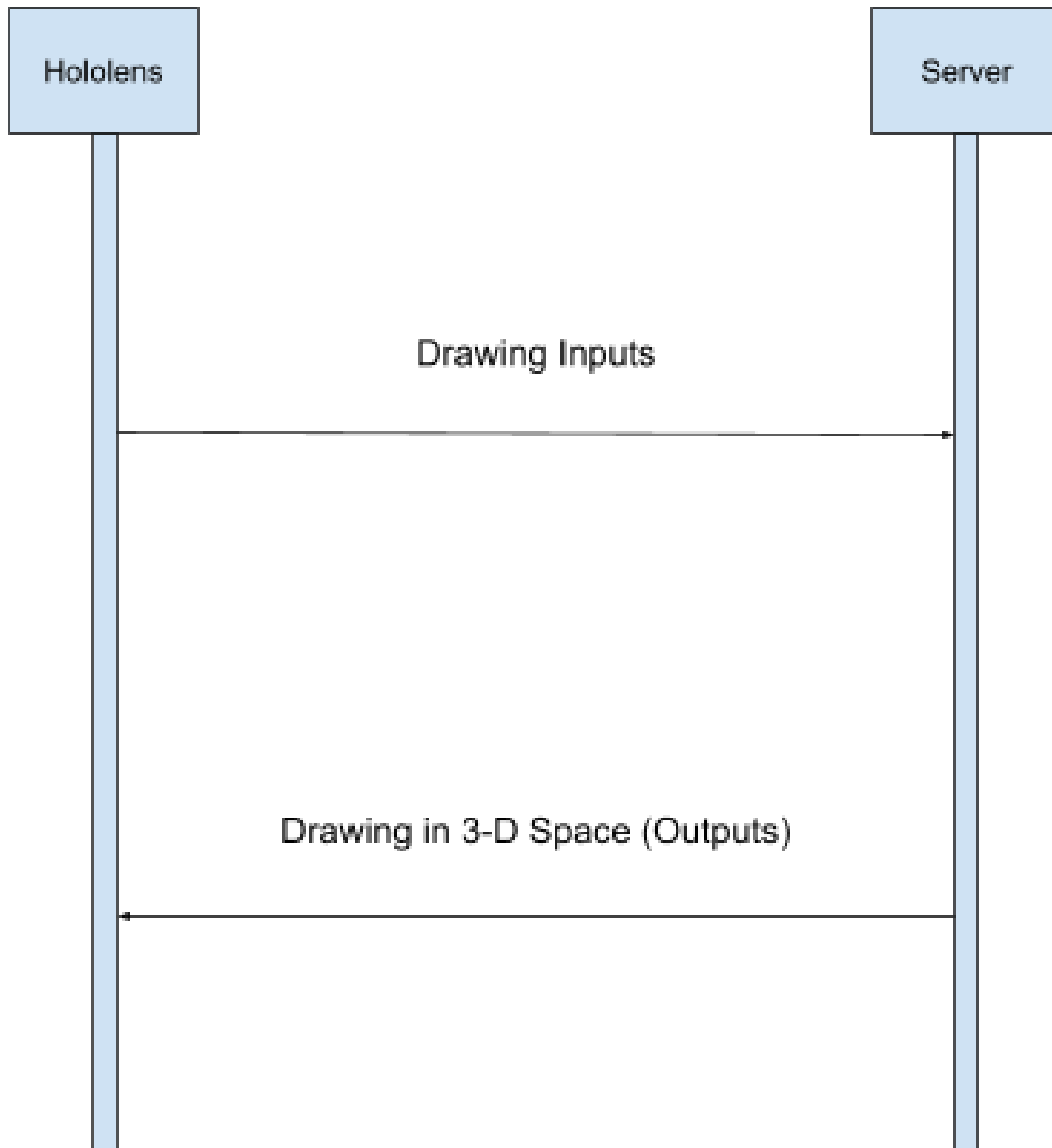


Figure 13: Sequence Diagram – HoloLens Drawing Renderer

7 Requirements

Requirements for the application are described here. These requirements are designed to facilitate the production of a Minimum Viable Product in a quick manner. Other project requirements will be created and updated as development continues. A subset of the listed user stories are specifically selected for expedited development.

7.1 User Stories

Our identified user stories for priority development are listed below. Issue links are provided for each item. [Click this link to view the kanban board.](#)

A picture of the kanban board is provided below.

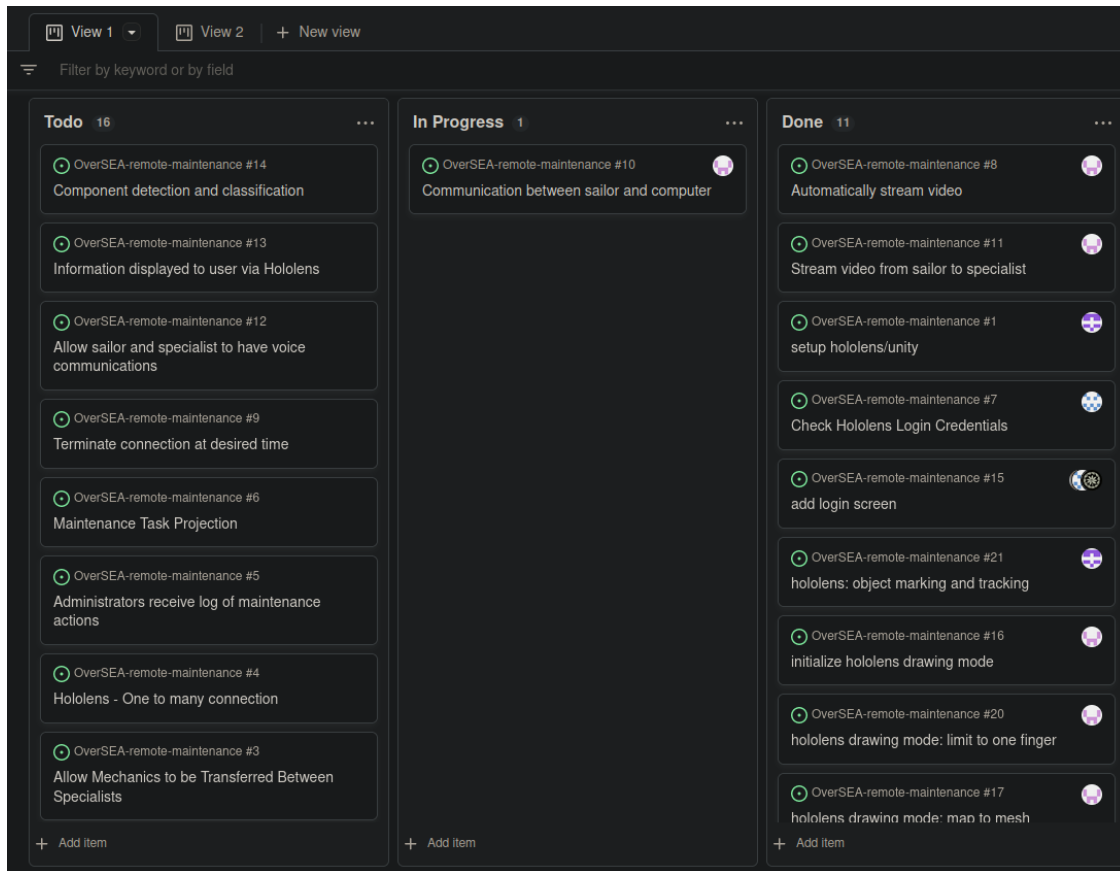


Figure 14: Kanban Board

Partially/fully implemented user stories and their progress/acceptance tests are documented on the kanban board.

1. (issue → 🚩) Users will be able to use the HoloLens to initiate communication between a sailor with the device, and a sailor at a computer.
 - (a) If there is no connection, and two users are logged in, they can use a menu to initiate a connection
 - (b) If there is a connection, the user can either continue to use that connection, or initiate a new connection.
2. (issue → 🚩) Users will be able to place an object in front of the HoloLens in order to allow the software to classify the object
 - (a) If the user places a recognized object in front of them, then the object will be highlighted on the HoloLens and the name and id number will be displayed.
 - (b) If the user does not place an object in front of them, then nothing will be highlighted or checked for in the server.
 - (c) If the user places an unrecognized object in front of them, then they will be given an error message.
3. (issue → 🚩) Users will be able to obtain information about an identified part using the software.
 - (a) If the HoloLens recognizes the object, it will display tags and information dictating whether the part needs to be repaired or not.
 - (b) If the HoloLens did not recognize the object, it will not display anything, but request that the part be scanned.

4. (issue → 🚫) Users will be able to receive aural guidance through the HoloLens-computer connection from the remote specialist
 - (a) If the user has a stable connection, the remote specialist will be able to communicate with the user.
 - (b) If the user has no or unstable connection, the remote specialist will not be able to communicate with the user.
5. (issue → 🚫) Users will be able see video from the HoloLens at the computer. This way, the specialist is able to monitor and observe the actions of the mechanic.
 - (a) If the user has stable connection, the remote specialist will be able to see the environment from the HoloLens
 - (b) If the user has no or unstable connection, the remote specialist will not be able to see the HoloLens environment.
6. (issue → 🚫) Users will be able to terminate the HoloLens-computer connection whenever they desire. They can do this by stopping the HoloLens-computer video/audio stream.
 - (a) If the user says the necessary disconnect utterance, the video from the HoloLens will be disconnected.
 - (b) If the user does not say the disconnect utterance, the video from the HoloLens will continue being streamed.
7. (issue → 🚫) Users will be able to automatically stream video from their HoloLens to the remote specialist.
 - (a) If the user has a stable connection, the user can stream the video recorded by the HoloLens to the remote specialist.
 - (b) If the user has an unstable connection, the user is unable to stream the video recorded by the HoloLens to the remote specialist.
8. (issue → 🚫) Users will be able to login with unique credentials in order to authenticate themselves on both the HoloLens and computer.
 - (a) If the user enters correct credentials , the user will gain access to the HoloLens/computer functionality.
 - (b) If the user enters incorrect credentials, the user will be prompted to enter correct credentials and not gain access to the HoloLens/computer.
9. (issue → 🚫) Selected maintenance tasks will be projected using AR for the mechanic to have visual guidance on what tasks to perform. Moreover, this projection will allow the mechanic to better understand the tasks required for them to do, without requiring the specialist to explicitly explain the process to the mechanic.
 - (a) The mechanic will automatically receive this projection through the AR display.
10. (issue → 🚫) System administrators will be provided with a digital log of all maintenance actions performed during each HoloLens/computer interaction. This allows administrators to maintain integrity in system maintenance operations.
 - (a) If the user ends the HoloLens-computer connection successfully, the log will be emailed to the system administrators in a specific format.
 - (b) If the user ends the HoloLens-computer connection suddenly (not intentionally), an email will be sent to the system administrators stating this as the case.
11. (issue → 🚫) Specialists will be able to connect with multiple mechanics remotely, without needing to exit the software application.

- (a) If the user wishes to connect with another specialist, they may end their current call and contact another specialist through the software.
 - (b) If the user does not wish to connect with another specialist, they can do nothing and continue their connection with the current specialist.
12. (issue → 🚫) Mechanics can be transferred between specialists as required to complete maintenance tasks.
 - (a) If a user has come across a problem that the specialist does not understand, they will be able to connect to a different specialist who knows the problem.
13. (issue → 🚫) System administrators will have a live list of pending and in-progress maintenance tasks in order to schedule workers efficiently.
 - (a) If a mechanic finishes a task, the admin is able to view that the task was completed on the live list. The admin is able to assign tasks to each mechanic using that live list
14. (issue → 🚫) Users will be able to log in to the client application.
 - (a) If the user supplies valid credentials, they will be logged in.
 - (b) If the user supplies invalid credentials, they will not be logged in.
15. (issue → 🚫) HoloLens users will be able to initiate a drawing mode that draws in 3D space around them.
 - (a) If the user engages this mode, the drawing mode will begin.
 - (b) If the user disengages this mode, the drawing mode will end.
16. (issue → 🚫) HoloLens users will be able to set the drawing mode to draw onto an object.
 - (a) If an object is selected, the user can draw directly onto that object in 3D space.
 - (b) If no object is selected, the drawing will not be shown.
17. (issue → 🚫) HoloLens users will be able to set the drawing mode to draw a projection of their input into 3D space.
 - (a) If the user is in this mode, the input from their drawing will be projected into 3D space using HoloLens.
18. (issue → 🚫) HoloLens users will be able to set the drawing mode to draw into 3D space at the exact position of their finger.
 - (a) If the user is in this mode, the input from their drawing will be drawn directly at the position of their finger in 3D space.
19. (issue → 🚫) HoloLens users will be able to draw with one finger at a time.
 - (a) If the user draws with no fingers, no input will be shown.
 - (b) If the user draws with one finger, input will be shown.
 - (c) If the user draws with more than one finger, only one finger will register as user input.
20. (issue → 🚫) HoloLens users can mark an object and have a hologram projected into 3D space that tracks the location and relative direction of that object.
 - (a) If an object is marked, an arrow appears showing the vector components of the direction to that object.
 - (b) If no object is marked, no arrow is shown.

8 Appendix

We intend to iterate and develop this document and our product specification as development continues.

8.1 Technologies

Our implementation revolves around the following technologies, programming languages, and platforms.

- C#
- C++
- Microsoft HoloLens
- Unity
- Unity Hand Gestures
- Unity Audio Listener
- Vuforia
- WebSocketSharp
- easywsclient
- openCV

8.2 Project Abstractions

To provide a Minimum Viable Product quickly, the following constraints are not implemented in our solution.

- Synchronous multi-HoloLens connectivity
- Network latency compensation
- Network bandwidth compensation
- Remote networking