CS189A, F22

Project Requirements Document

Version 1

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**.

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 Expected Outcomes

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. CAD models of all necessary equipment will be provided to the HoloLens-based software from a centralized database on-site. The Vuforia platform 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. We also will implement voice detection as a means of user interaction with our software, allowing the user to request videos based on verbal input. The video will be displayed on the HoloLens, and the user can rewind, skip forward, pause, and zoom in and out. The remote specialist will also be able to provide aural input to the mechanic in real-time.

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. Lastly, we must assume that the HoloLens or associated computer has a microphone for the sailor to be able to speak to the professional on shore. We also assume the users of the software have sufficient training in order to use the software at a high degree of competency.

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.

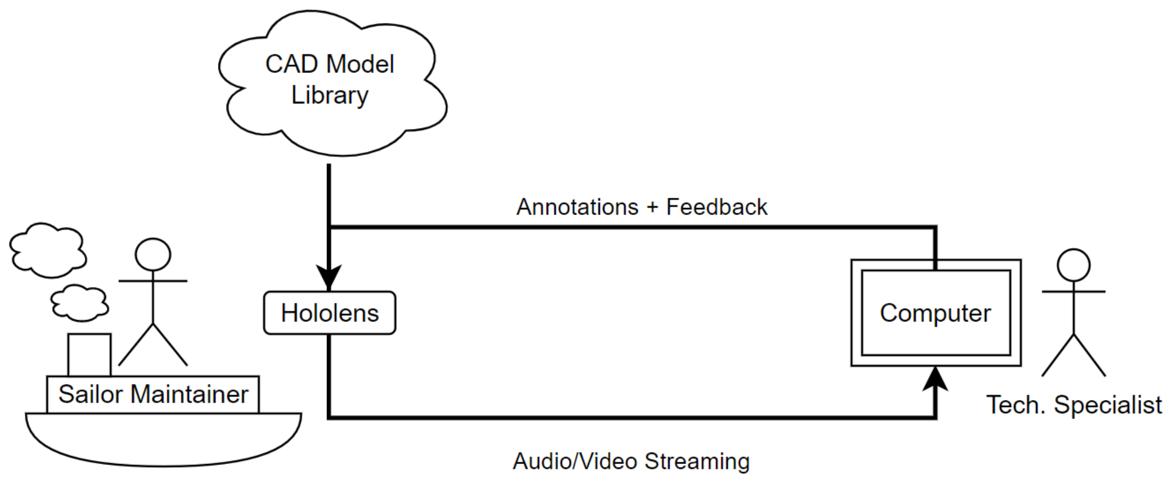

Figure 1: Generalized System Model

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.

6 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.

6.1 User Stories

Our identified user stories for priority development are listed below. Issue links are provided for each item.

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

7 Appendix

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

7.1 Technologies

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

- C#
- Microsoft HoloLens
- Unity
- Vuforia

7.2 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