PROJECT ANALYSIS REPORT

SurgeVision

"Surgery Navigation Systems "

PROJECT NAME: SurgeVision

Project Members:

HAKAN UCA

DENİZ POLAT

ABDULLAH DOĞANAY

ONUR USLU

DATE: 13.11.2024

Table of Contents

1. Introduction 2

2. Current System 2

2.1 Login System 2

2.2 Medical Data Processing 4

2.3 AR/VR Processing 5

2.4 Point Detection 7

2.5 Match Processing 8

2.6 Display Medical Data 10

3. Proposed System 11

3.1 Overview 11

3.2 Functional Requirements 12

3.3 Non-Functional Requirements 12

3.4 Pseudo Requirements 13

3.5 System Models 13

4. Glossary 14

5. References 14

1. Introduction

The SurgeVision project is an innovative surgical navigation system designed to enhance the accuracy and safety of complex hip replacements. This system leverages advanced imaging techniques by acquiring MRI or CT data from the patient, which serves as foundational input. These imaging data are converted into point clouds, followed by preprocessing steps including outlier elimination and data simplification, to optimize them for real-time usage.

Additionally, SurgeVision incorporates AR, or virtual reality glasses worn by the surgeon, enabling real-time point cloud generation directly on the patient. This on-site point cloud data undergoes similar preprocessing to ensure clarity and relevance, facilitating precise alignment with the pre-acquired MRI or CT data. The two preprocessed point clouds—derived from imaging data and real-world patient data—are then registered through a point cloud registration process, aligning the digital and physical datasets.

SurgeVision provides surgeons with an integrated, real-time visualization of the registered point clouds, enhancing spatial awareness and surgical precision. In cases where VR glasses are used, an additional camera is incorporated to collect supplemental data.

---

2. Current System

We currently do not have a system that we can base our project on, so we are developing from zero point.

2.1 Login System

1. **User (Actor)**:
    a. The User is represented as the entity that initiates the login process. They interact with the system by attempting to log in.
2. **Login System (Component)**:
    a. The Login System is responsible for handling the login requests from the User. This component likely includes a user interface (e.g., a login form) where the User enters their credentials.
    b. Once the User submits their credentials, the Login System processes this information and interacts with the User Database.
3. **User Database (Component)**:
    a. The User Database stores information about registered users, such as usernames and passwords.
    b. Upon receiving the login request from the Login System, it validates the provided credentials by checking if they match any existing records.

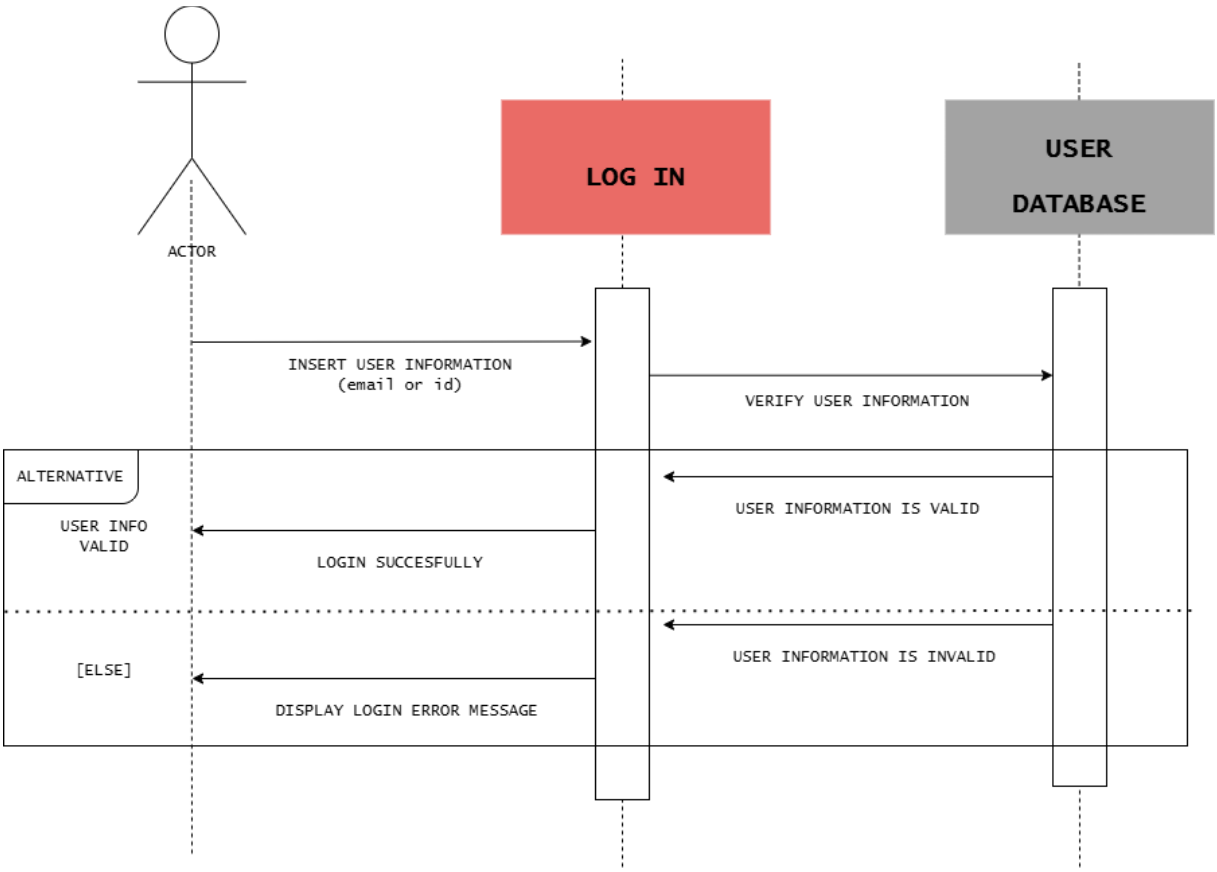
Process Flow:

1. **Step 1**: The User interacts with the Login System by submitting their login information.
2. **Step 2**: The Login System receives the credentials and sends a request to the User Database to validate the credentials.
3. **Step 3**: The User Database processes the request and checks the credentials.
4. **Step 4**: If the credentials are correct, the User Database sends confirmation back to the Login System, allowing the User to log in successfully. If the credentials are incorrect, the Login System notifies the User of the failed attempt.

Arrows and Communication:

- The arrows between components represent the flow of information and responses between the User, Login System, and User Database.
- The dashed lines in the sequence diagram indicate repeated actions or potential for repeated attempts if the login fails.

System Diagram



2.2 Medical Data Processing

1. **User (Actor)**:
    a. The User initiates interaction with the system through an interface to perform specific operations or access personal information.
2. **Interface (Component)**:
    a. The Interface serves as the intermediary between the User and the Personal Database. This component provides a means for the User to interact with the system, likely by entering or viewing data.
    b. The Interface sends requests to the Personal Database based on the User's actions and retrieves responses to display to the User.
3. **Personal Database (Component)**:
    a. The Personal Database holds the User's personal data or records. It processes requests from the Interface, such as retrieving or updating data.
    b. This component ensures the requested information is available and secure, allowing only authorized access through the Interface.

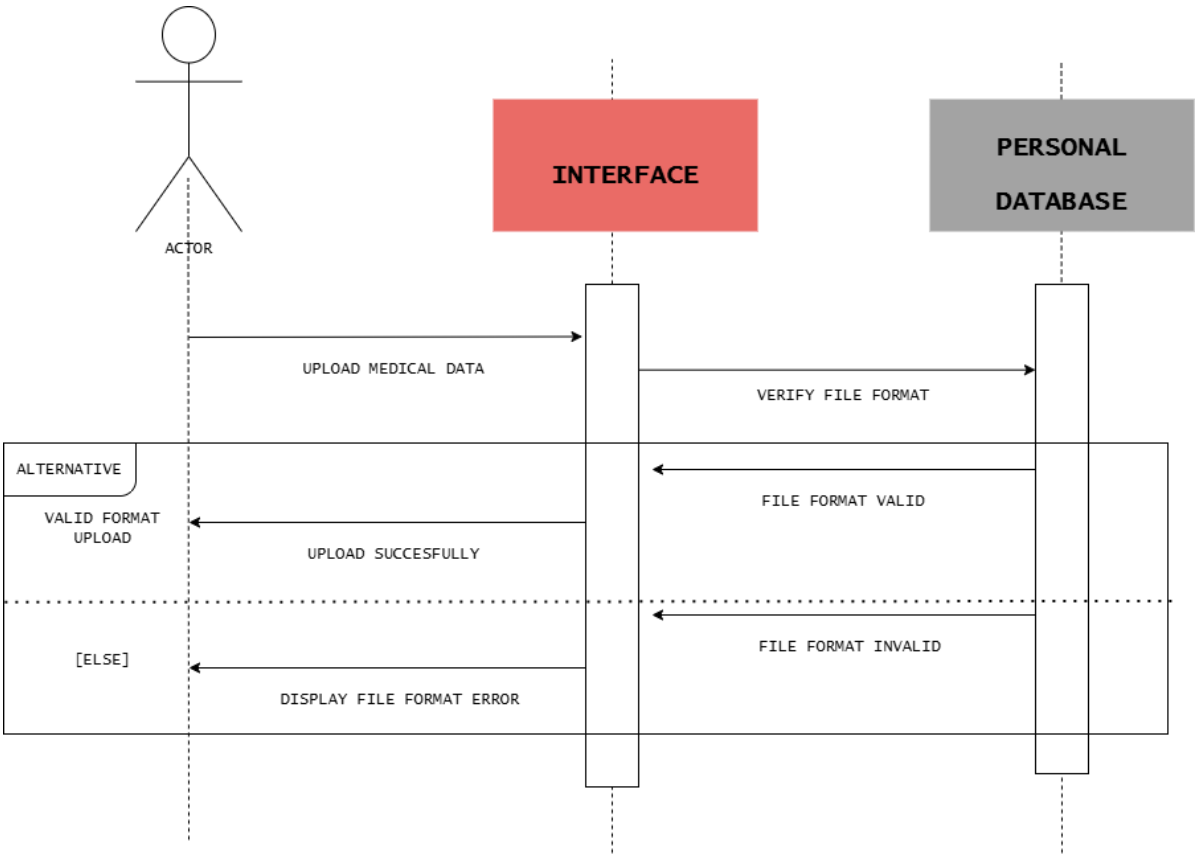
Process Flow:

1. **Step 1**: The User sends a request through the Interface, possibly to access or modify their personal data.
2. **Step 2**: The Interface receives the User's request and communicates with the Personal Database to fulfill the request.
3. **Step 3**: The Personal Database processes the request, checking for the relevant data or performing the necessary action.
4. **Step 4**: The Personal Database sends a response back to the Interface.
5. **Step 5**: The Interface displays the retrieved information or action result to the User.

Arrows and Communication:

- The arrows between components represent the flow of requests and responses, showing how the User, Interface, and Personal Database interact to fulfill data-related operations.
- The dashed lines in the sequence diagram imply potential repeated requests or interactions if the process needs to be reiterated (e.g., for repeated data access or updates).

System Diagram



2.3 AR/VR Processing

1. **User (Actor)**:
    a. The User is the primary entity interacting with the System. They might be accessing an application or environment that uses AR or VR capabilities.
2. **System (Component)**:
    a. The System acts as the main control interface for the User, handling their input and managing communication with the AR/VR System.
    b. It might represent the core application or software through which the User initiates commands or requests related to AR/VR.
3. **AR/VR System (Component)**:
    a. The AR/VR System is responsible for providing the augmented or virtual reality experience.
    b. This system processes data from the main System to create an immersive environment or project augmented content, such as overlaying virtual objects onto real-world views.

Process Flow:

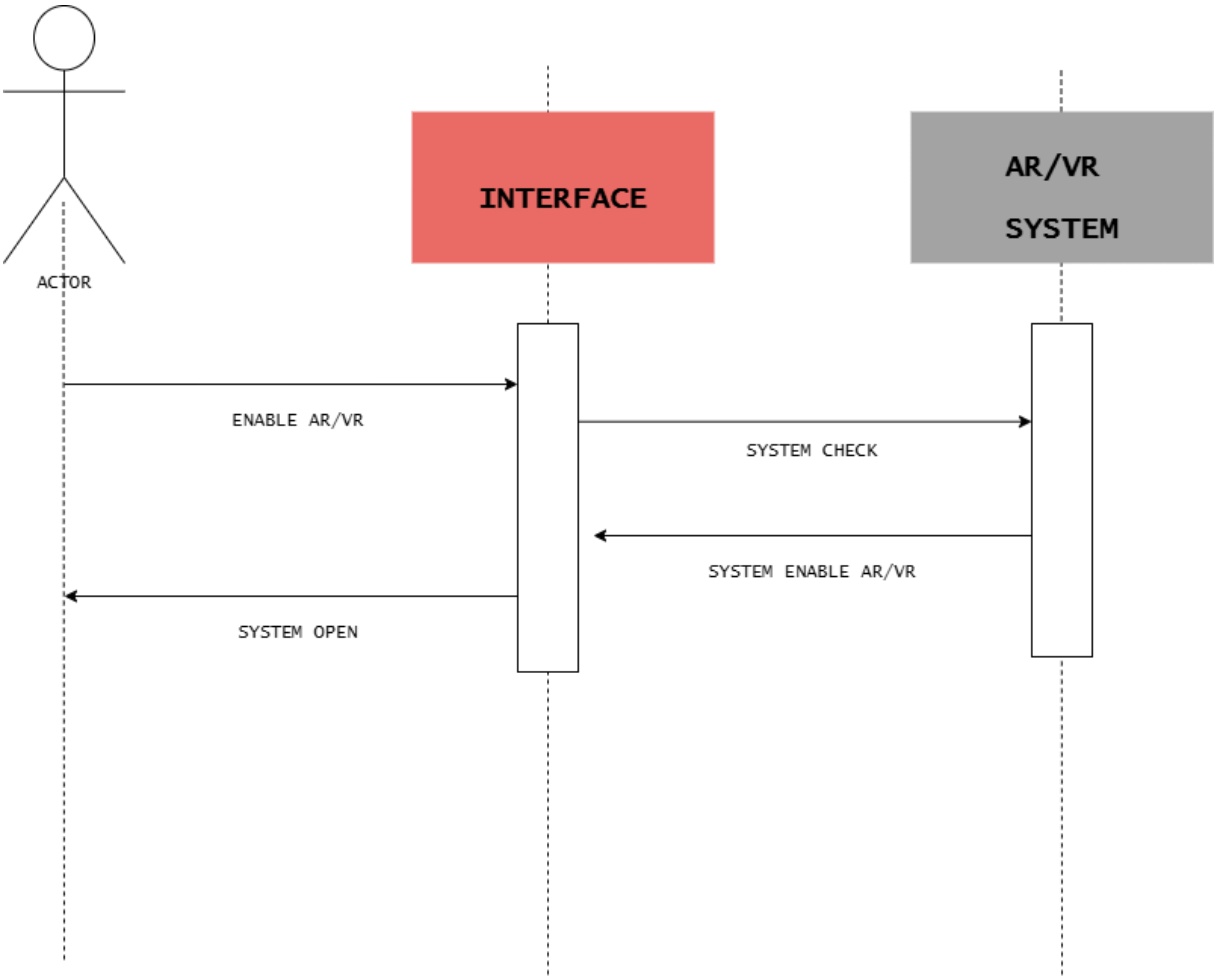
1. **Step 1**: The User interacts with the System, sending commands or inputs through the interface.

2. **Step 2**: The System processes the User's input and communicates with the AR/VR System to execute the commands. This could involve rendering a 3D environment, overlaying digital elements in AR, or processing real-time inputs from the AR/VR hardware.
3. **Step 3**: The AR/VR System responds to the System, delivering the necessary data or rendering information to create experience.
4. **Step 4**: The System then relays the response back to the User, updating the interface based on the feedback from the AR/VR System.

Arrows and Communication:

- The arrows between components represent the flow of data and control commands between the User, the main System, and the AR/VR System.
- The solid lines indicate a one-time or continuous data flow, where the User's interactions are managed by the System and executed by the AR/VR System to create the desired experience.

System Diagram



2.4 Point Detection

1. **User (Actor)**:
    a. The User initiates the interaction, intending to access or interact with personal data through an AR/VR experience.
2. **AR/VR System (Component)**:
    a. The AR/VR System serves as the interface that immerses the User in a virtual or augmented environment.
    b. This component processes the User's commands and facilitates data retrieval by connecting to the Personal Database.
    c. It might render visualizations of personal data or overlay relevant information in an AR/VR format, based on the User's requests.
3. **Personal Database (Component)**:
    a. The Personal Database stores the User's personal information and data.
    b. It responds to queries from the AR/VR System by retrieving the requested data and sending it back to the AR/VR System for display or processing in the immersive environment.

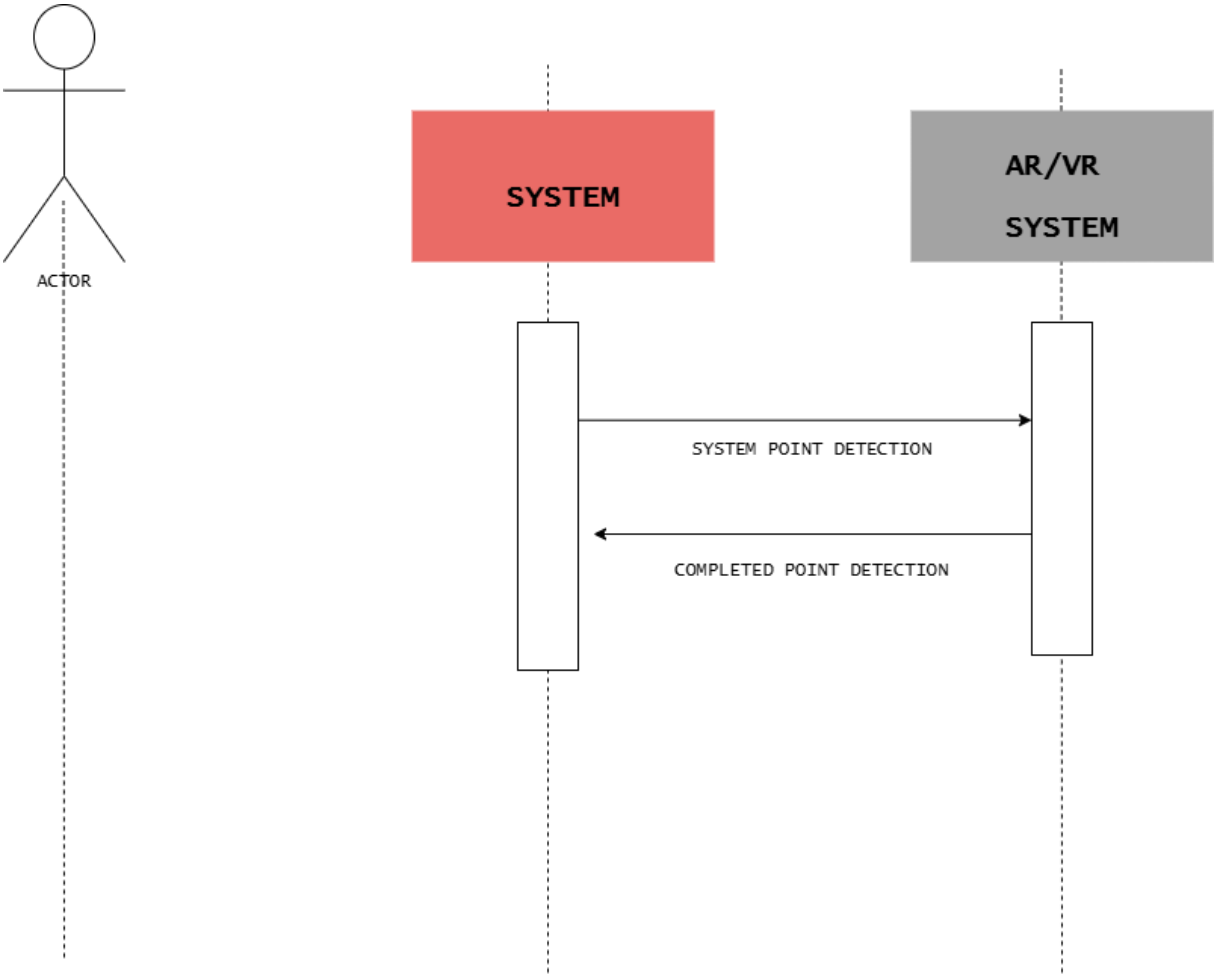
Process Flow:

1. **Step 1**: The User sends a command or input via the AR/VR System, possibly to access or view specific personal data.
2. **Step 2**: The AR/VR System processes the User's request and sends a query to the Personal Database to retrieve the requested information.
3. **Step 3**: The Personal Database locates the relevant data and sends a response back to the AR/VR System.
4. **Step 4**: The AR/VR System uses the data from the Personal Database to create an AR/VR experience that displays or integrates the personal data, which is then shown to the User.

Arrows and Communication:

- The arrows between the components represent the data flow and requests among the User, AR/VR System, and Personal Database.
- The dashed lines in the sequence diagram suggest that this process could be repeated multiple times if the User continues to interact with the system to access more data or perform additional actions.

System Diagram



2.5 Match Processing

1. **User (Actor)**:
    a. The User initiates the interaction, aiming to access their personal data through the AR/VR System. This could involve activities like viewing personal records, visualizing data, or interacting with information within an AR/VR environment.
2. **AR/VR System (Component)**:
    a. The AR/VR System acts as the primary interface through which the User experiences the augmented or virtual reality environment.
    b. It takes commands or requests from the User and manages communication with the Personal Database to fetch relevant data.
    c. The AR/VR System then renders the retrieved data in an immersive manner, enhancing the User's experience by displaying personalized information in AR or VR.

3. **Personal Database (Component)**:
    a. The Personal Database stores the User's personal information, including data that might be displayed or interacted with in the AR/VR environment.
    b. It processes data retrieval requests from the AR/VR System and provides the necessary information securely.

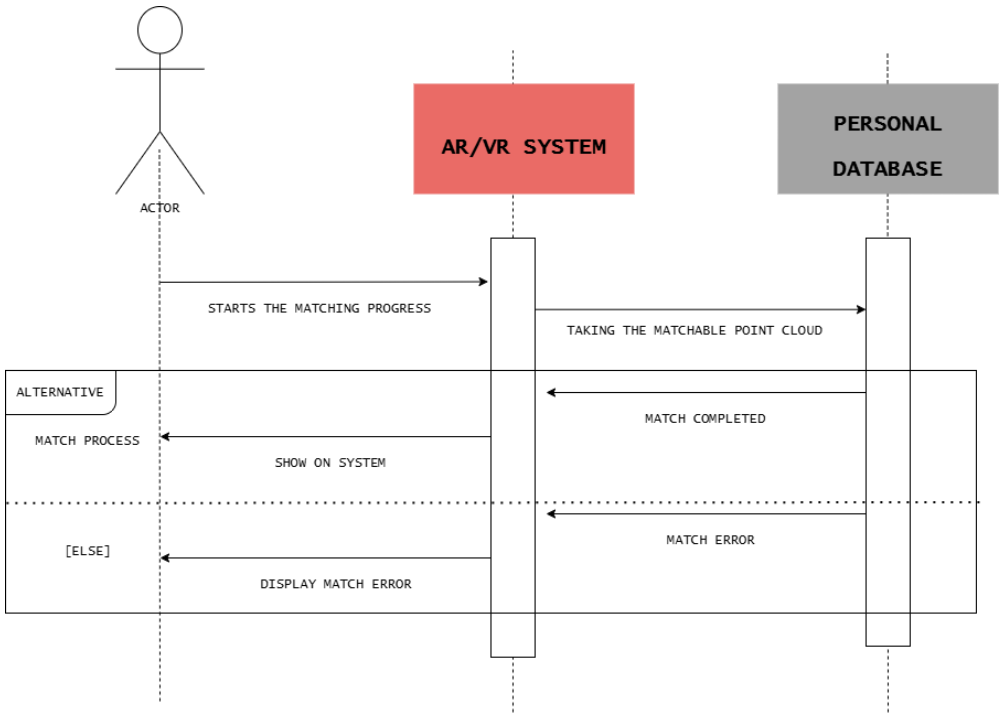
Process Flow:

1. **Step 1**: The User sends a request through the AR/VR System to access specific personal data.
2. **Step 2**: The AR/VR System receives the request and queries the Personal Database to retrieve the required information.
3. **Step 3**: The Personal Database locates the relevant data and sends it back to the AR/VR System.
4. **Step 4**: The AR/VR System uses the retrieved data to create an immersive experience, presenting the information visually to the User in the AR/VR environment.

Arrows and Communication:

- The arrows between components represent the flow of requests and data among the User, AR/VR System, and Personal Database.
- The dashed lines in the sequence diagram indicate possible repeated interactions if the User continues to access different data points or request further actions in the AR/VR environment.

System Diagram



2.6 Display Medical Data

1. **User (Actor)**:
    a. The User is the primary entity that initiates interactions with the system, likely to access or update personal data stored in the database.
2. **Interface (Component)**:
    a. The Interface acts as the middle layer between the User and the Personal Database.
    b. It receives the User's input or requests and processes them, then communicates with the Personal Database to retrieve or update data.
    c. The Interface also presents the results or feedback from the database to the User in a user-friendly format.
3. **Personal Database (Component)**:
    a. The Personal Database stores the User's personal information.
    b. It processes requests from the Interface, such as retrieving data for display or storing updated information provided by the User.

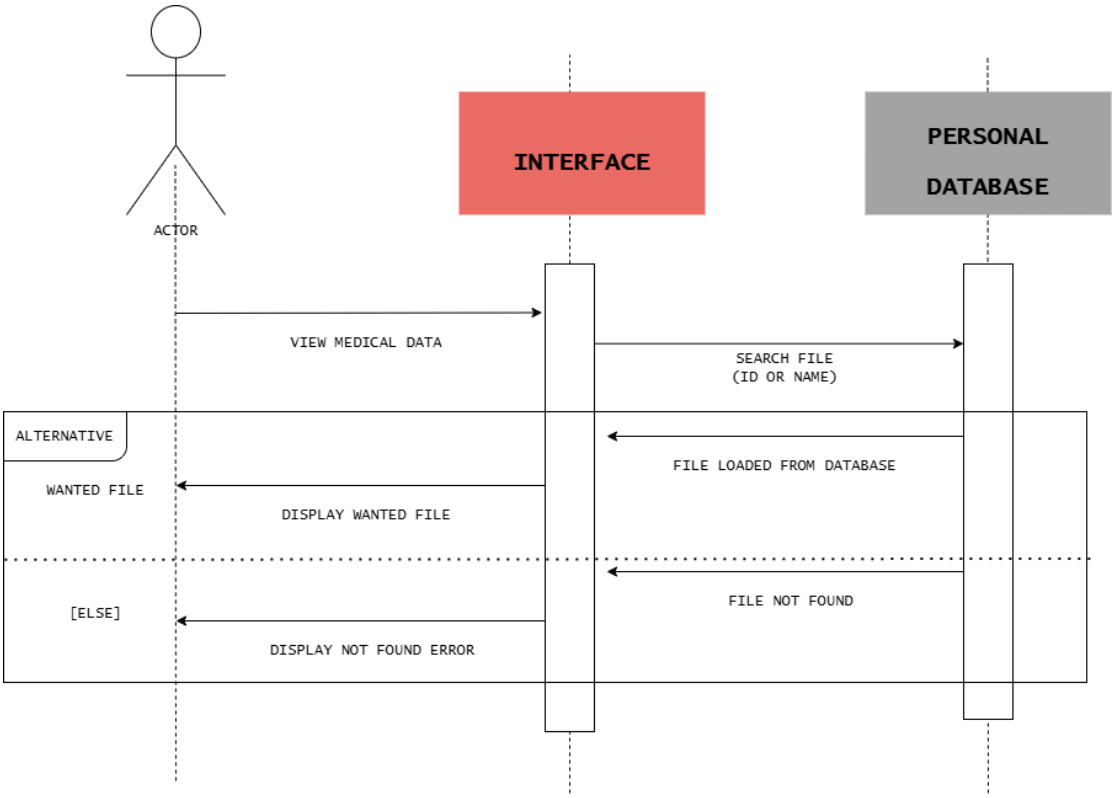
Process Flow:

1. **Step 1**: The User initiates a request through the Interface, such as querying for specific personal data or updating certain details.
2. **Step 2**: The Interface processes the User's request and sends a query to the Personal Database for the necessary data.
3. **Step 3**: The Personal Database retrieves the requested information or processes any updates and sends a response back to the Interface.
4. **Step 4**: The Interface displays the retrieved data or the result of any update operation back to the User.

Arrows and Communication:

- The arrows between the components indicate the flow of requests and responses among the User, Interface, and Personal Database.
- The dashed lines in the sequence diagram suggest that the process could be repeated if the User requires additional data access or wants to perform more operations.

System Diagram



3. Proposed System

3.1 Overview

SurgeVision is an advanced surgical navigation system designed to improve the precision, safety, and efficiency of complex surgeries, such as hip replacements. The system utilizes MRI or CT data from the patient, transforming these images into a point cloud representation that is preprocessed to remove outliers and simplify the data for optimal use in real time. Additionally, SurgeVision integrates AR or VR technology to generate a corresponding point cloud directly on the patient during surgery.

Using AR or VR glasses, the surgeon can visualize both pre-acquired and real-time point clouds. These two sets of point clouds—one derived from patient imaging data and the other generated on the actual patient—are aligned through a point cloud registration process, allowing for highly accurate overlay and guidance. The registered point clouds are then presented in a visual format that supports the surgeon in aligning and navigating the surgical site with enhanced spatial awareness.

For cases using VR glasses, an additional camera is employed to capture further data, enhancing the system's depth perception and accuracy.

3.2 Functional Requirements

- **Real-Time Image Conversion and Point Cloud Display**: The system shall acquire 3D MRI or CT images of the patient's anatomy, convert these images into point clouds, and display them in real time at a minimum rate of 25 FPS.
- **Intraoperative Point Cloud Generation**: The system shall generate a real-time point cloud representation on the actual patient using AR or VR glasses, with a minimum frame rate of 25 fps to ensure smooth visualization and accuracy.
- **Point Cloud Preprocessing**: The system shall include preprocessing capabilities to remove outliers and simplify both MRI/CT-based and real-time point clouds, optimizing them for accurate registration.
- **Point Cloud Registration Accuracy**: The system shall perform point cloud registration with an accuracy of at least 5mm, ensuring precise alignment between the pre-acquired and real-time point clouds.
- **AR or VR Support**: The system shall support the use of AR or VR glasses, allowing surgeons to visualize registered point clouds for enhanced spatial awareness and guidance during surgery.
- Alignment **Reference Functionality**: The system shall allow the marking of anatomical reference points on the patient's body, facilitating precise alignment of MRI or CT data with real-time generated point clouds.
- **User Control Interface**: The system shall provide an intuitive user interface that allows for adjustments to visualization parameters, switching between AR and VR modes, and interacting with point cloud data.
- **Additional Camera Support for VR Mode**: In VR mode, the system shall integrate with an external camera to capture additional data, enhancing the depth perception and accuracy of the point cloud overlay.

3.3 Non-Functional Requirements

- **Performance**: The system shall have a latency of 1 second or less for synchronization between real-time patient interactions and the point cloud visualization, ensuring responsiveness in the operating room. Additionally, it must support a minimum of 25 frames per second (fps) for smooth 3D rendering and interaction.
- **Reliability**: The system shall maintain high reliability throughout surgical procedures, with robust error-handling mechanisms to prevent failures or interruptions. Any software or hardware failures must be minimized to ensure continuous operation during critical surgical tasks.
- **Scalability**: The system shall be designed to support expansion beyond hip replacement surgeries, allowing integration and adaptation to other surgical procedures as needed, such as knee replacements or spinal surgeries.
- **Ease of Use**: The user interface shall be designed for intuitive use, enabling healthcare personnel to operate the system with minimal training. Controls and interactions should be streamlined to minimize the cognitive load on surgeons and support staff.

- **Regulatory Compliance**: The system shall comply with all relevant medical device regulations and data safety standards applicable to surgical navigation systems, including regional and international standards (e.g., FDA, CE marking). This ensures that the system meets the required safety, performance, and reliability criteria.

3.4 Pseudo Requirements

- **Hardware Requirements**: The system shall require specialized equipment, including high-resolution MRI or CT scanners, AR or VR glasses compatible with real-time point cloud display, and an additional camera for data collection in VR mode.
- **Software Compatibility**: The software must be compatible with commonly used MRI and CT imaging formats, allowing seamless integration with medical imaging systems. Additionally, it should support AR and VR device firmware for real-time interaction and visualization.
- **Network Requirements**: The system shall require a stable and high-speed network connection to ensure low latency in data transmission, especially between the MRI/CT scanner, AR/VR devices, and the central system interface.
- **Training**: Minimal training will be required for surgeons and operating room staff to effectively use the system, covering key functionalities such as image viewing, point cloud interaction, and system control.
- **Maintenance and Support**: Routine maintenance of hardware components (AR/VR glasses, cameras, etc.) and software updates shall be provided to ensure optimal performance and reliability. Support for troubleshooting and technical issues must be available to prevent downtime during surgeries.

3.5 System Models

3.5.1 Scenarios

- **Scenario 1**: Surgeon using real-time MRI or CT visualization on a screen to align the implant.
- **Scenario 2**: Surgeon using AR glasses for enhanced 3D view while aligning the hip joint.

3.5.2 Use Case Model

- **Actors**: Surgeon, surgical assistant, and system technician.
- **Use Cases**: Image alignment, AR interaction, point synchronization, real-time feedback.

3.5.3 Object and Class Model

- **Core Objects**: MRI Image, Contact Point, Reference Point, AR View, Control Interface.
- **Class Hierarchies**: Imaging Module, Synchronization Module, AR Interface.

3.5.4 Dynamic Models

- **Sequence Diagrams**: Displaying sequences for real-time imaging and AR interactions.

- **State Diagrams**: States include MRI processing, contact synchronization, AR overlay.

3.5.5 User Interface

- **Navigational Paths**: Menu for image adjustment, synchronization, AR toggling.
- **Screen Mock-Ups**: Primary display, control panel, AR overlay views.

---

4. Glossary

- **MRI**: Magnetic Resonance Imaging, a medical imaging technique.
- **AR**: Augmented Reality, an enhanced visual experience with superimposed images.
- **VR**: Virtual Reality, an enhanced visual experience with superimposed images.
- **CT**: Computer Tomography.
- **FPS**: Frame per second.
- **Synchronization**: Real-time mapping of physical contact to MRI coordinates.

---

5. References

- ACM Code of Ethics
- IEEE Software Engineering Code of Ethics
- Regulatory guidelines (FDA, HIPAA, GDPR)