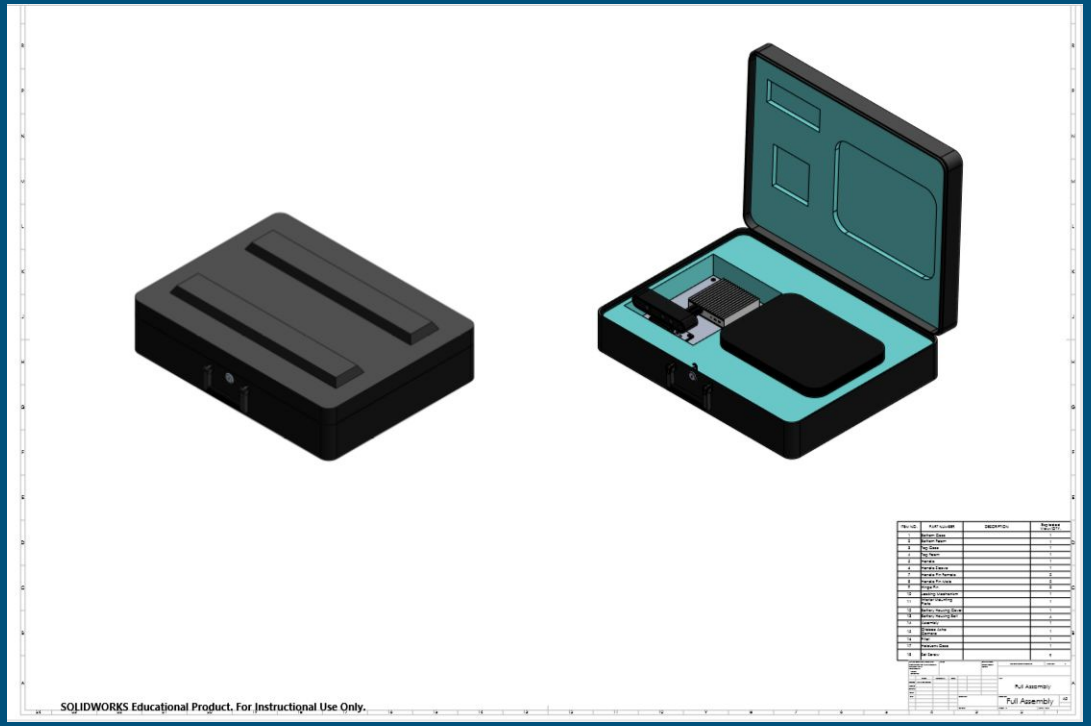
Augmented Reality Physical Therapy

Group Number: 21

Administrative Introduction

- **Sponsor**
  - Todd Sinclair, 9 Degrees of Human
- **Team Members**
  - *Alex Alvarez*: Website Front-end, Camera, HoloLens, Database
  - *Alfredo Quiroga*: Website Front-end, Camera
  - *Joe Hummel*: REST API, Website Back-end, Database
  - *Kaike Ferreira*: HoloLens, Database
  - *Logan Harvell*: HoloLens, Server, REST API
- Mechanical Engineers
  - Kayla Bitner, Geovani Colberg, Justin Velasquez, Alejandro Zelaya

Mechanical Engineer’s ARPT Case



Mechanical Engineer’s Prototype Case

Problem Statement

- Making it easier for patients to perform physical therapy exercises without having to meet with a physical therapist face-to-face
- Correctly doing exercises without supervision
- Recording data accurately for the physician
- Allowing patients to perform exercises at their convenience
- Lack of motivation to perform exercises at home

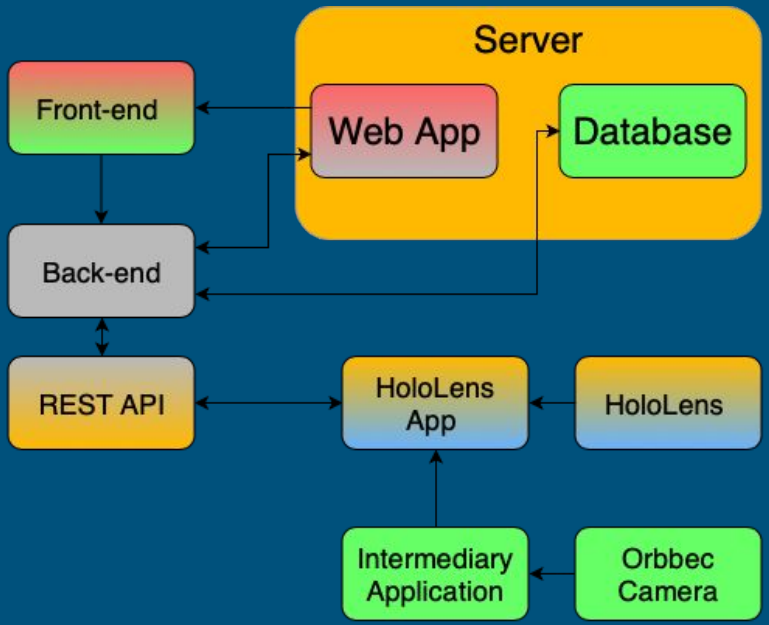
Solution

- Utilize augmented reality to promote proper exercise technique safely and accurately
- Augmented reality devices can be used at home
- By using technology data can be tracked accurately and automatically without the presence of a therapist
- Create an interactive environment to motivate users
- Using a web application for a physician to easily access patient data

Requirements

- Web application in .NET and C#
- Microsoft SQL Server Database to store patient information
- Patient data uploaded to site after exercise completion
- HoloLens application to allow patients to do exercises
- Hosted on Azure

Project Structure



Legend

- Alfredo Quiroga
- Kaike Ferreira
- Joe Hummel
- Alexander Alvarez
- Logan Harvell

Design Approach

- Orbbec Camera
  - Sends motion tracking data through a computer application
  - Utilizes a local network socket connection
- HoloLens Headset
  - Augmented reality headset for interactive holograms from Microsoft
  - Hosts and runs native application enabling and tracking home physical therapy exercises
- Server - Azure VM running Windows Server 2016
  - Database, Microsoft SQL Server
  - Web application, hosted using Internet Information Services (IIS)
    - ASP.NET MVC web application
    - REST API

Camera

The motion sensing will be done by the Orbbec Astra Pro.

Camera Application

- Astra SDK camera framework
- Written in C++ to target the Win32 platform and to run on an external Windows 10 PC to send data over the network to the HoloLens
- This application will serve as a network interface to send data joint data over the local network using IP addresses

Camera Application

- This application has the capability to also detect joint orientation as well as the depth of each joint
- It will not have a GUI and will be a simple terminal application meant to run in the computer that will be given to the users in the final product - for testing purposes we are running it on our own PCs with Windows 10

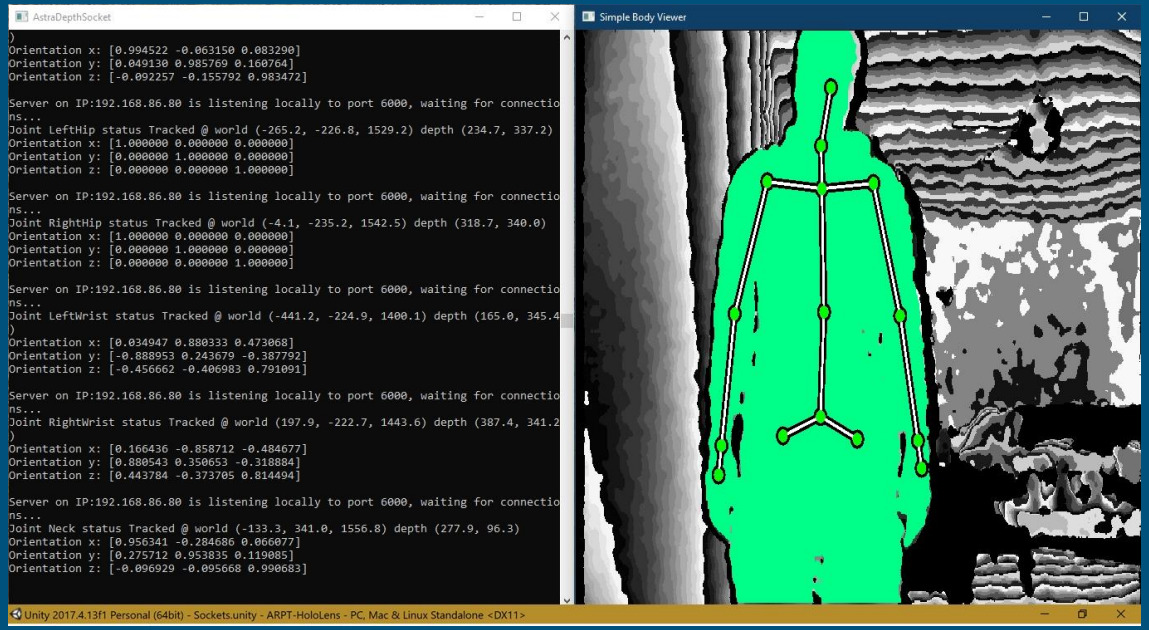
Camera Application

The camera software stores joint positions that we will use for our movement detection algorithm

```
    update_bone(joints, jointScale, astra::JointType::Head, astra::JointType::ShoulderSpine);

    update_bone(joints, jointScale, astra::JointType::ShoulderSpine, astra::JointType::LeftShoulder);
    update_bone(joints, jointScale, astra::JointType::LeftShoulder, astra::JointType::LeftElbow);
    update_bone(joints, jointScale, astra::JointType::LeftElbow, astra::JointType::LeftHand);

    update_bone(joints, jointScale, astra::JointType::ShoulderSpine, astra::JointType::RightShoulder);
    update_bone(joints, jointScale, astra::JointType::RightShoulder, astra::JointType::RightElbow);
    update_bone(joints, jointScale, astra::JointType::RightElbow, astra::JointType::RightHand);

    update_bone(joints, jointScale, astra::JointType::ShoulderSpine, astra::JointType::MidSpine);
    update_bone(joints, jointScale, astra::JointType::MidSpine, astra::JointType::BaseSpine);

    update_bone(joints, jointScale, astra::JointType::BaseSpine, astra::JointType::LeftHip);
    update_bone(joints, jointScale, astra::JointType::LeftHip, astra::JointType::LeftKnee);
    update_bone(joints, jointScale, astra::JointType::LeftKnee, astra::JointType::LeftFoot);

    update_bone(joints, jointScale, astra::JointType::BaseSpine, astra::JointType::RightHip);
    update_bone(joints, jointScale, astra::JointType::RightHip, astra::JointType::RightKnee);
    update_bone(joints, jointScale, astra::JointType::RightKnee, astra::JointType::RightFoot);
}
```

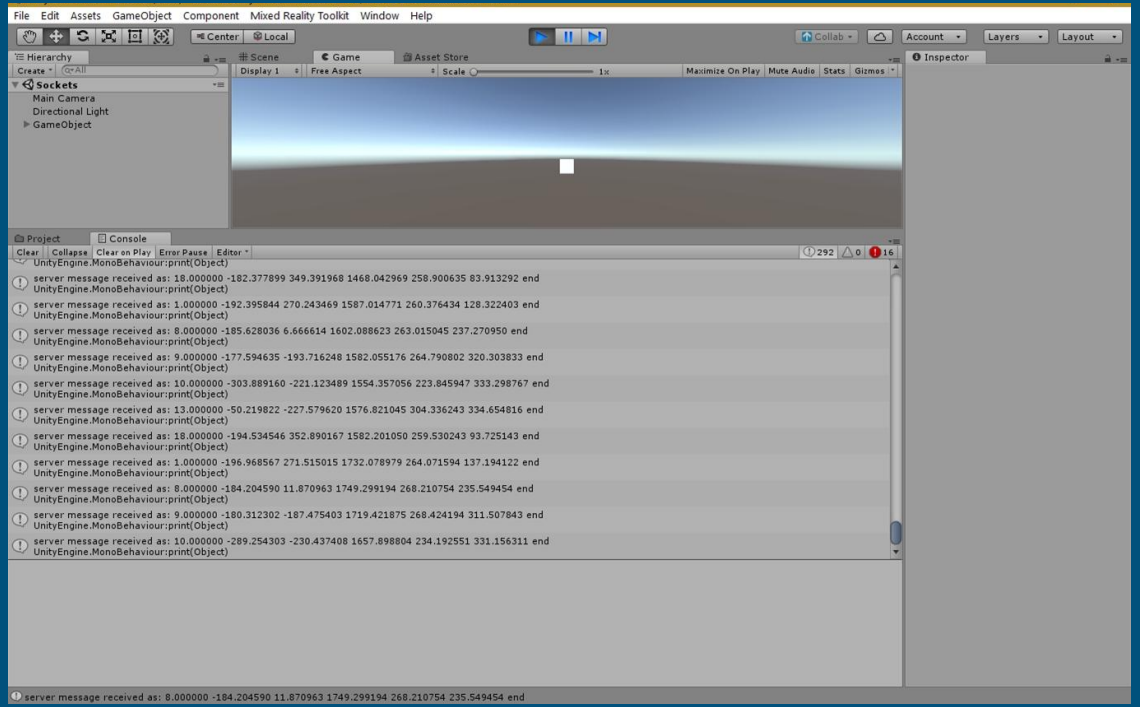
Camera Application

- Server side: detects joints and orientation and senda data and sending over the network using the TCP protocol



Camera Application

- Client Side - Joint data being received from the camera

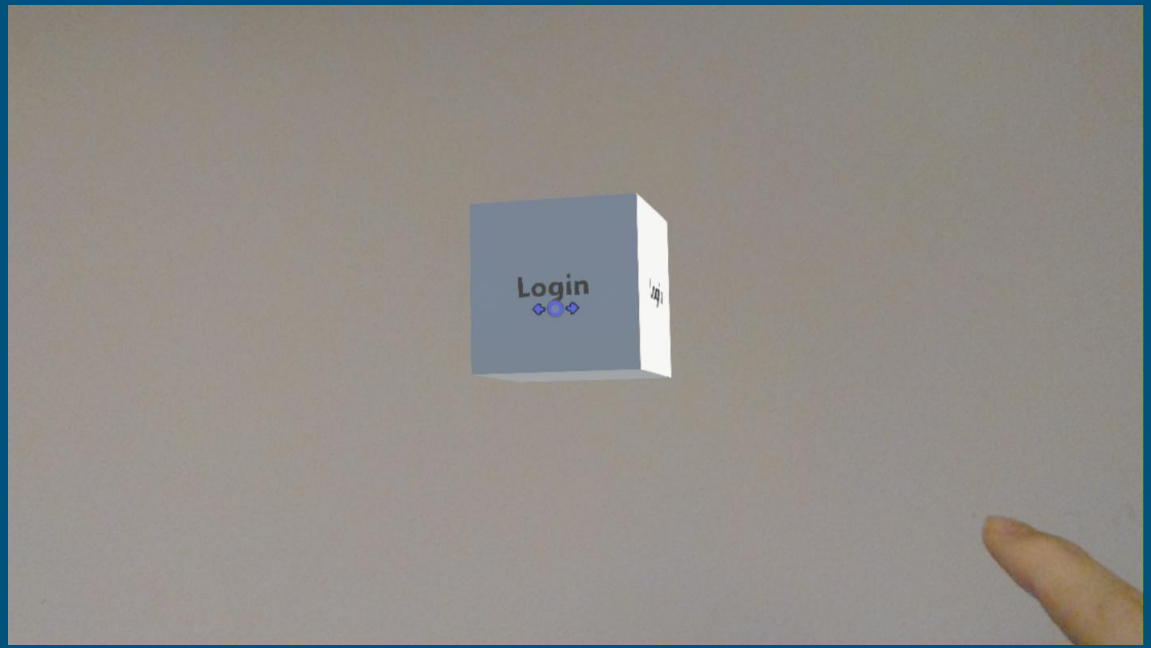


HoloLens Application

- Development
  - Written in C# with Unity3D as a Universal Windows Platform application, specifically targeting the HoloLens
  - Much of the application utilizes Unity frameworks and the HoloToolKit provided by Microsoft
  - Utilizes REST API to communicate with the web app and server, enabling data transfer
  - The HoloLens app is also capable of receiving motion tracking data from our camera application over a local network connection

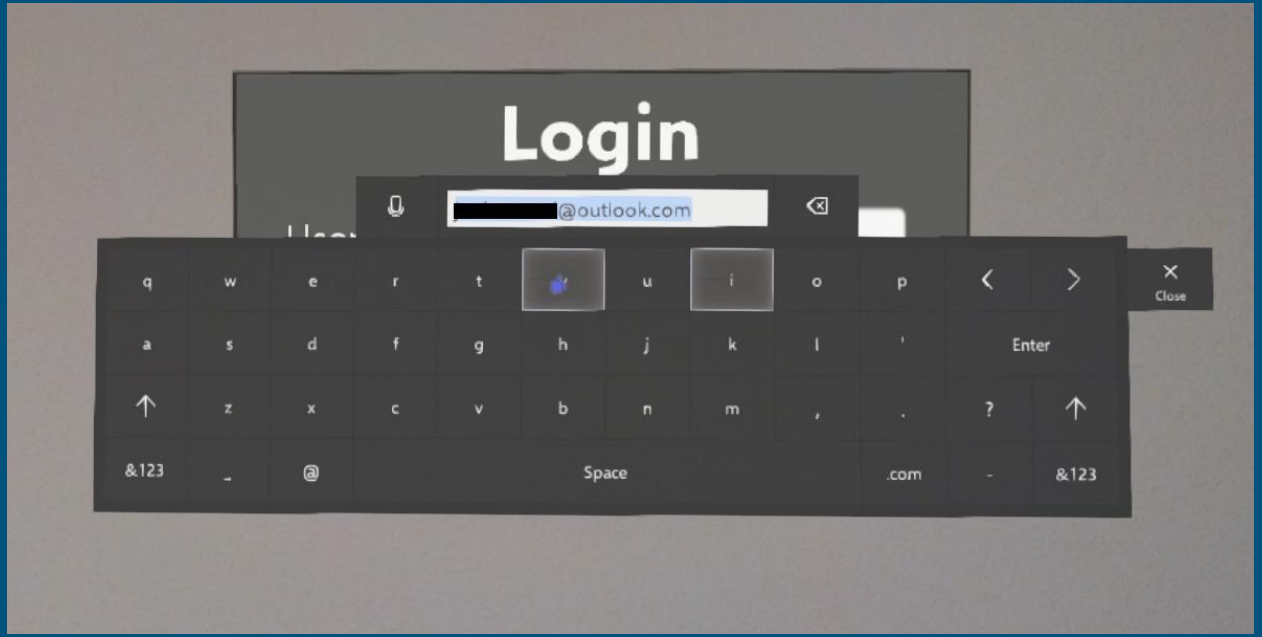
HoloLens Application Flow

- First the user is presented with a cube as the main menu interface
- The user can rotate the cube to select different options
- It remains within the user’s vision

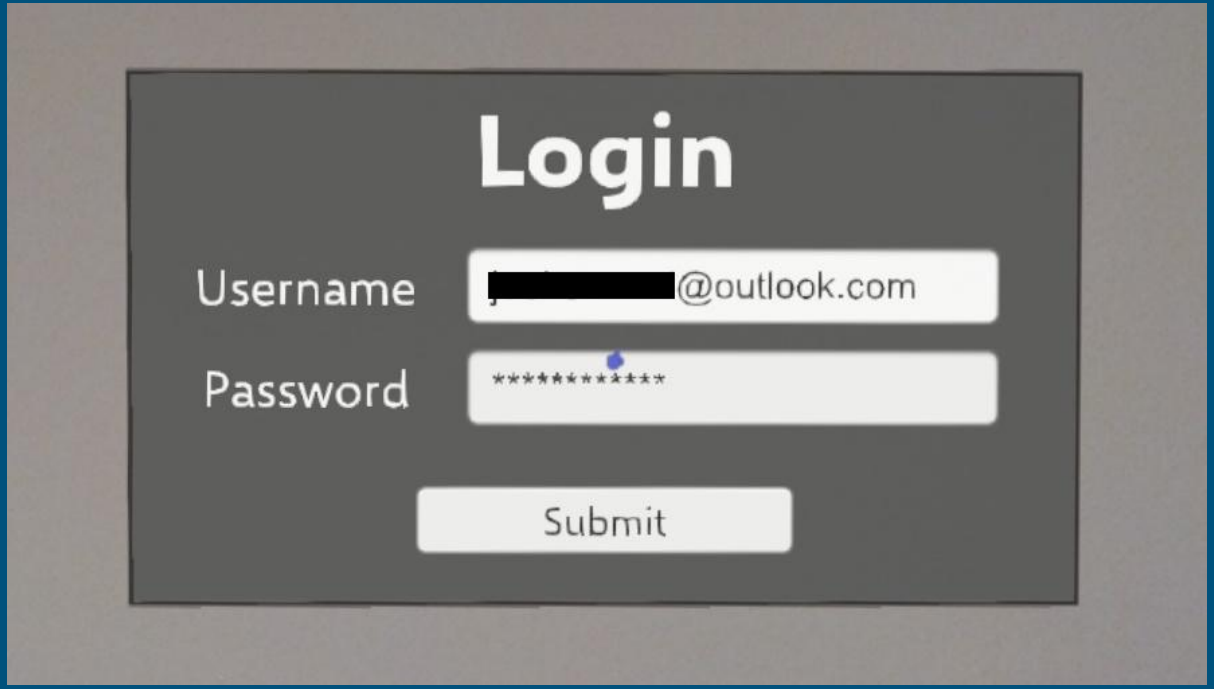


HoloLens Application Flow

- If the user is not logged in, login is the only option
- The user fills in the fields with their web application credentials
- Next an POST request is made to our REST API

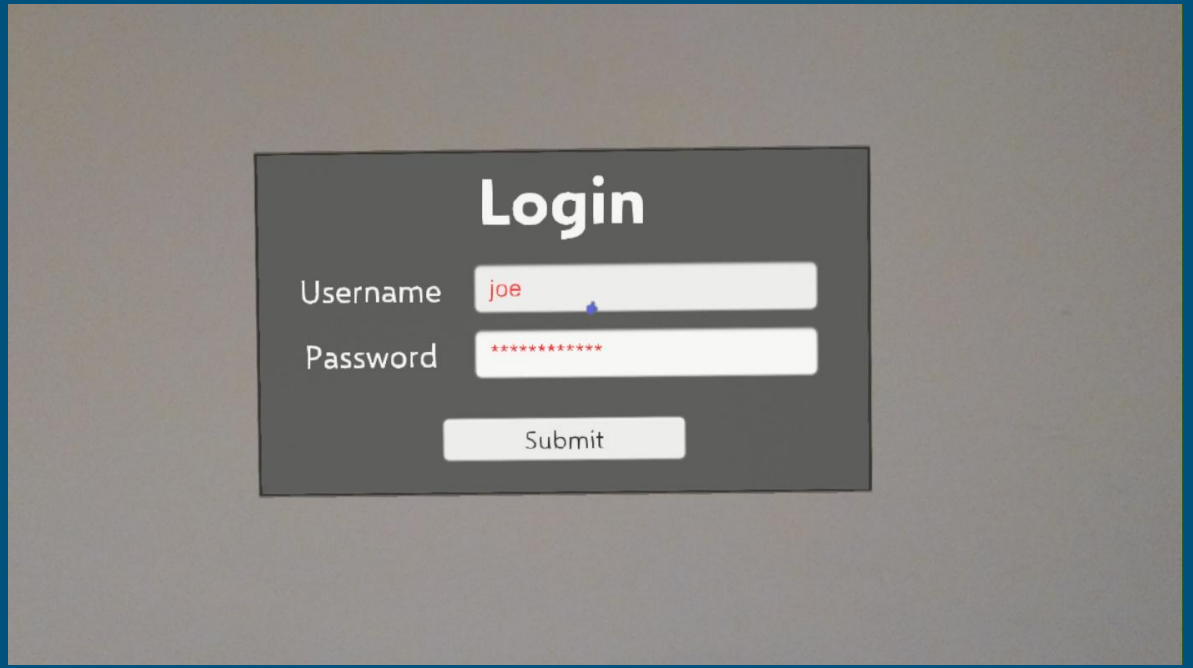


HoloLens Application Flow



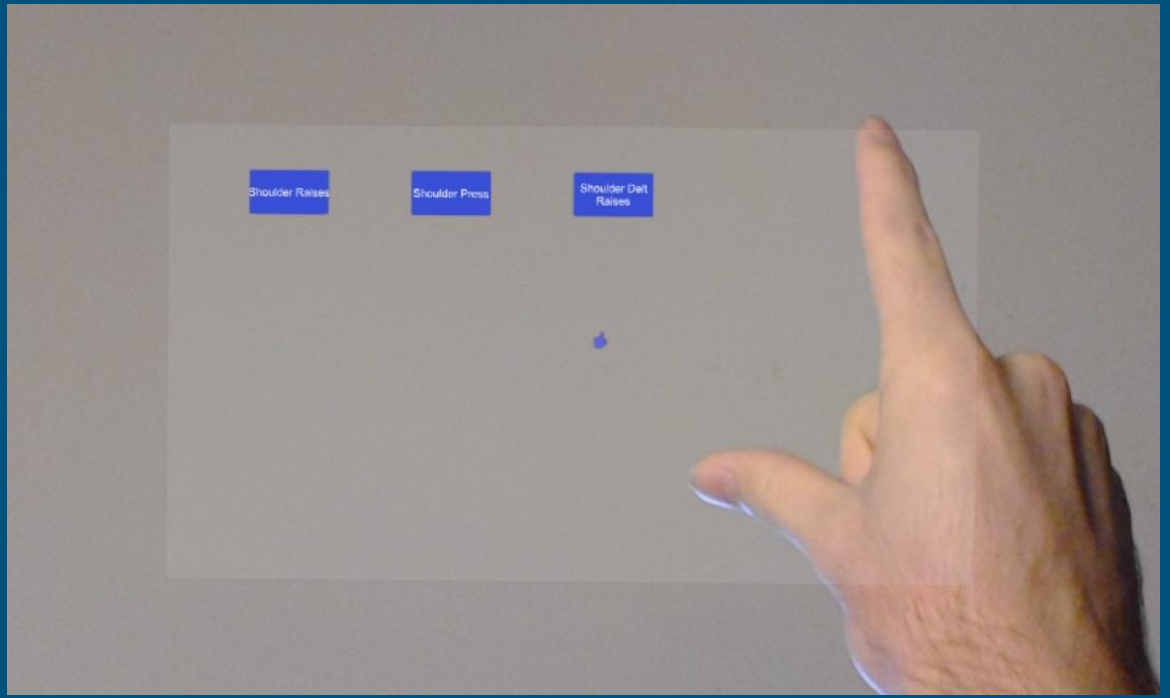
HoloLens Application Flow

- If the username and password do not match an existing user, then the text is colored red
- The user is free to re-attempt their login immediately



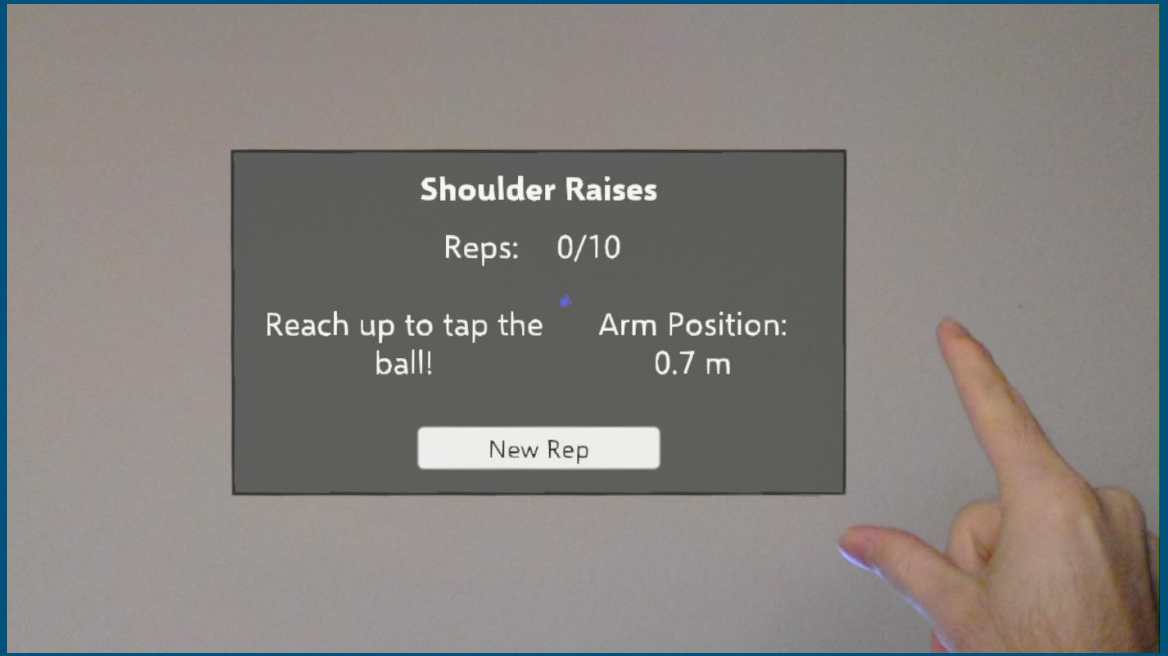
HoloLens Application Flow

- Once logged in, the user’s customized list of exercises populate an exercise menu
- In this case, there are three shoulder exercises for the patient listed

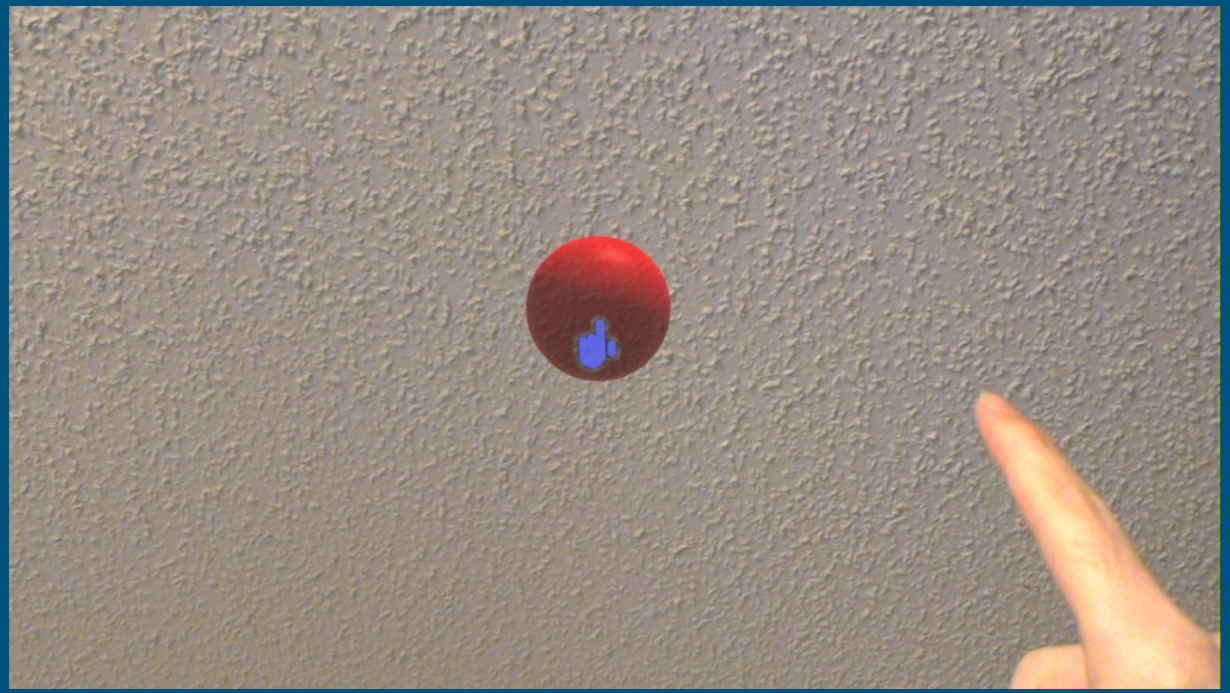


HoloLens Application Flow

- Once an exercise is selected, the user is guided through an exercise
- The prototype demonstrates Shoulder Raises, which require a user to reach above their head

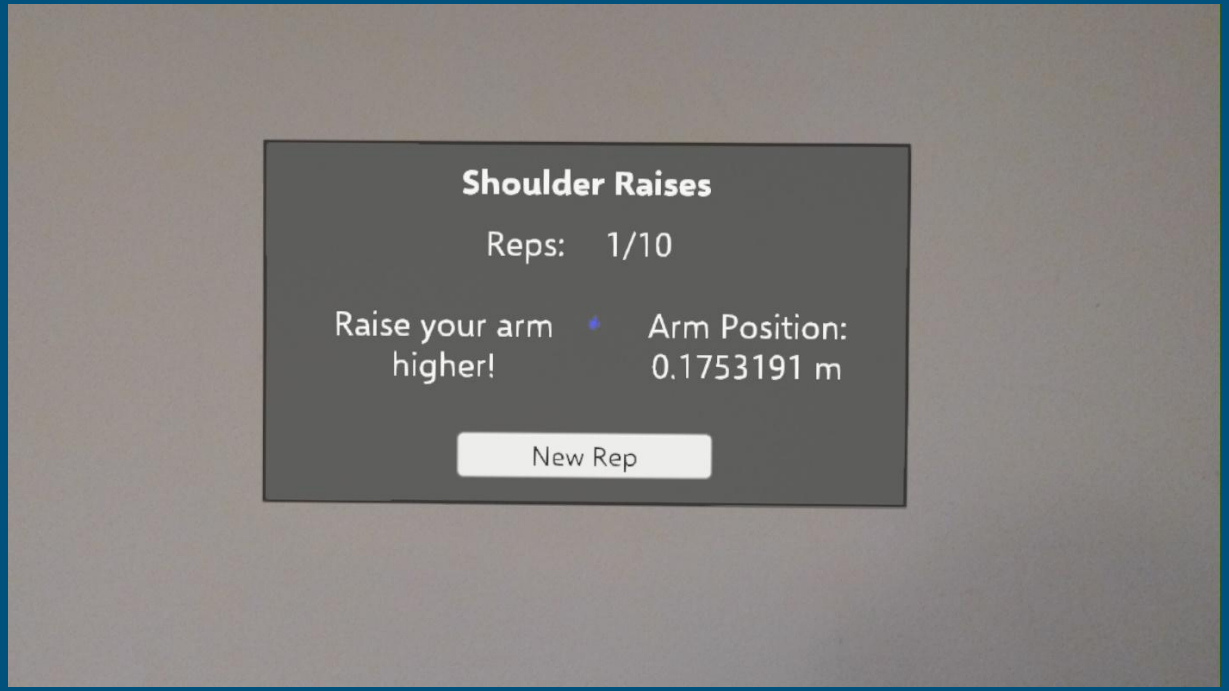


HoloLens Application Flow



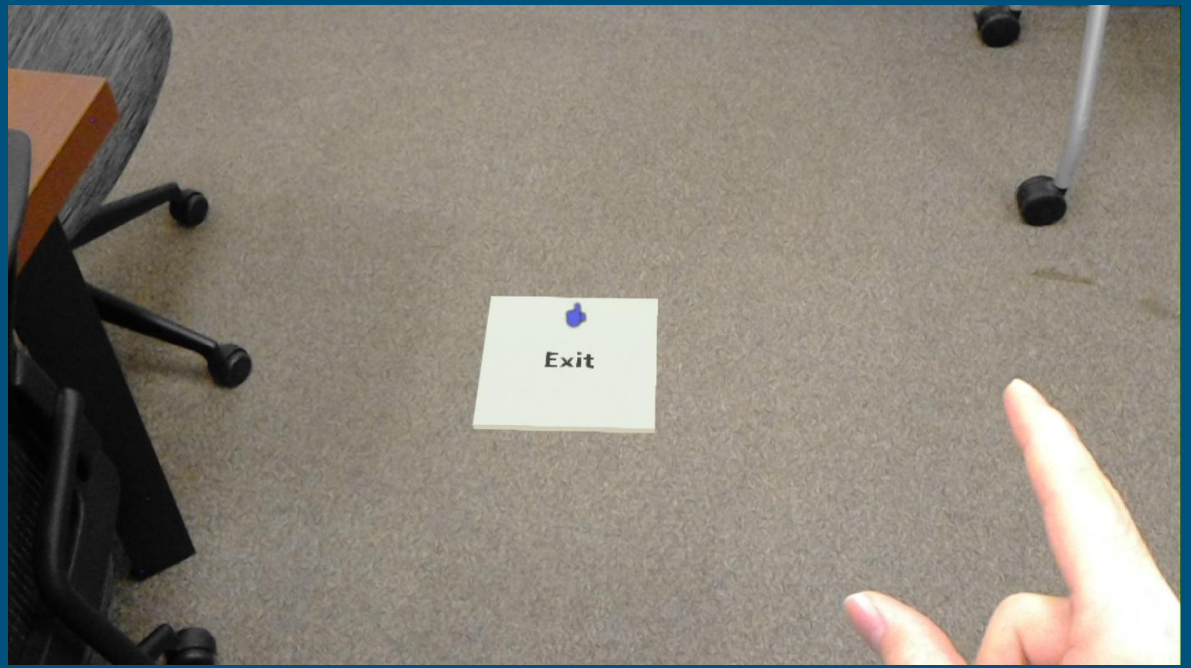
HoloLens Application Flow

- The app provides guidance when the user needs to reach higher
- Their last attempt is available for reference



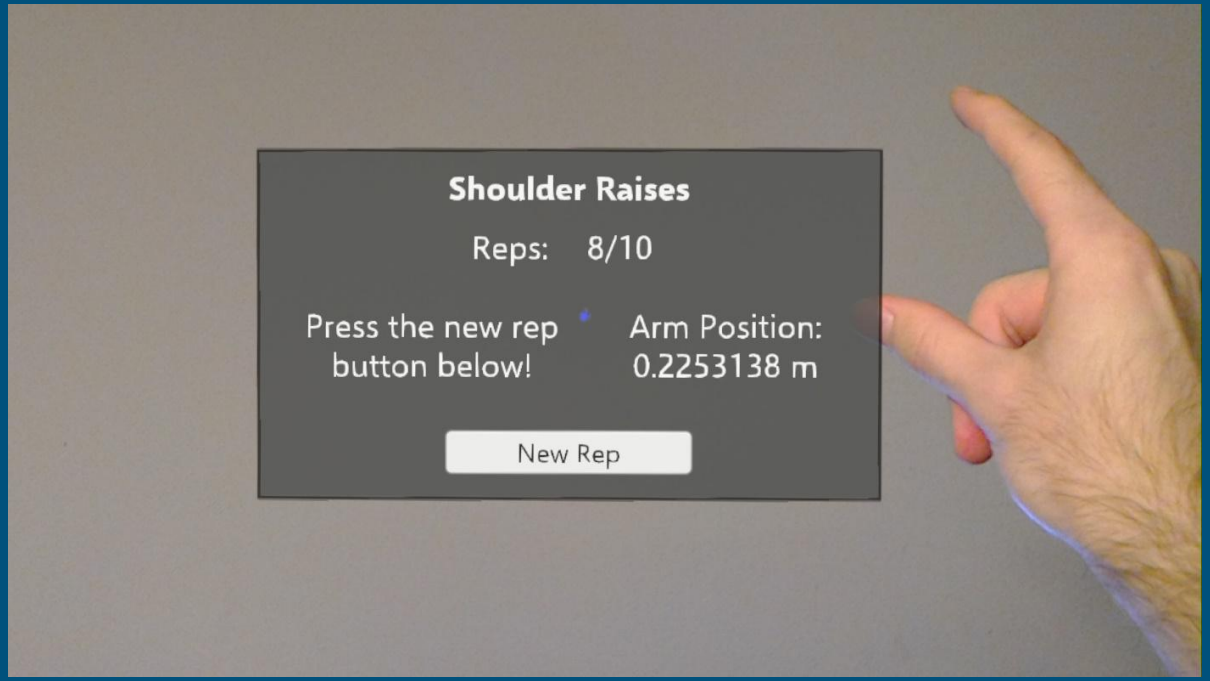
HoloLens Application Flow

- At any time the user is able to exit back to the list of exercises if needed



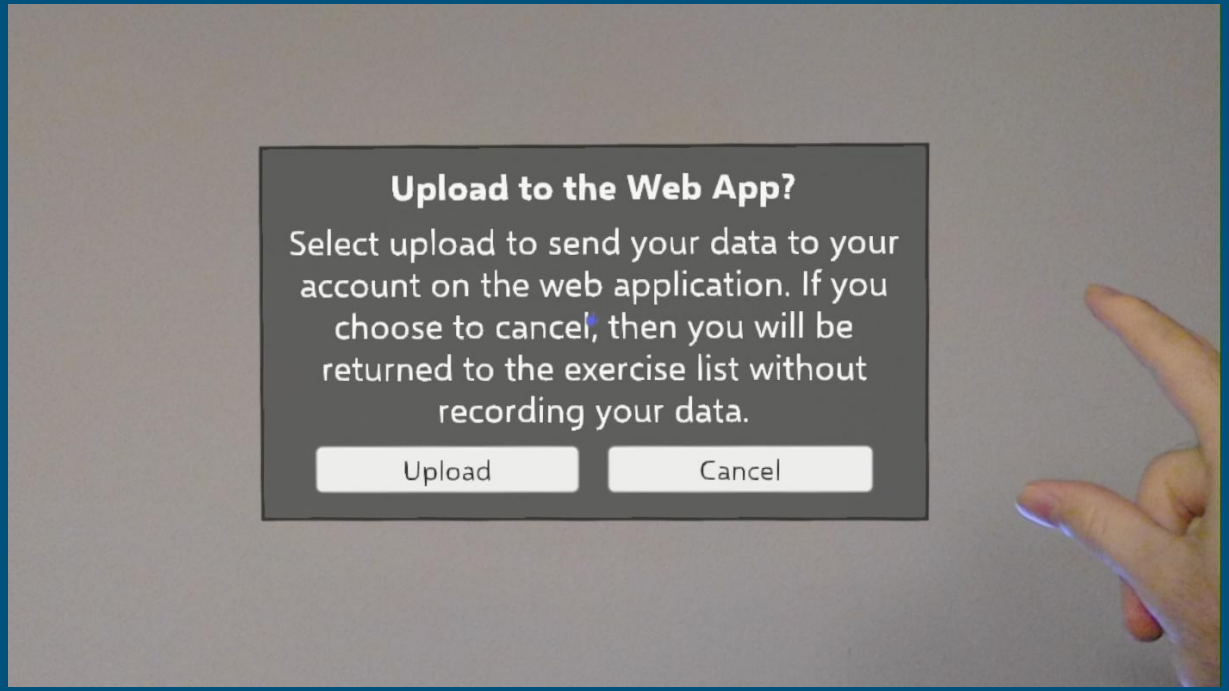
HoloLens Application Flow

- The total number of repetitions are tracked out the exercise total
- Currently, the app tries to ensure that the user lowers their reach by manually requiring a rep reset



HoloLens Application Flow

- After completion, the user may upload their stats to their account
- If so, then a POST is made to the REST API
- Both options bring the user to the exercise menu

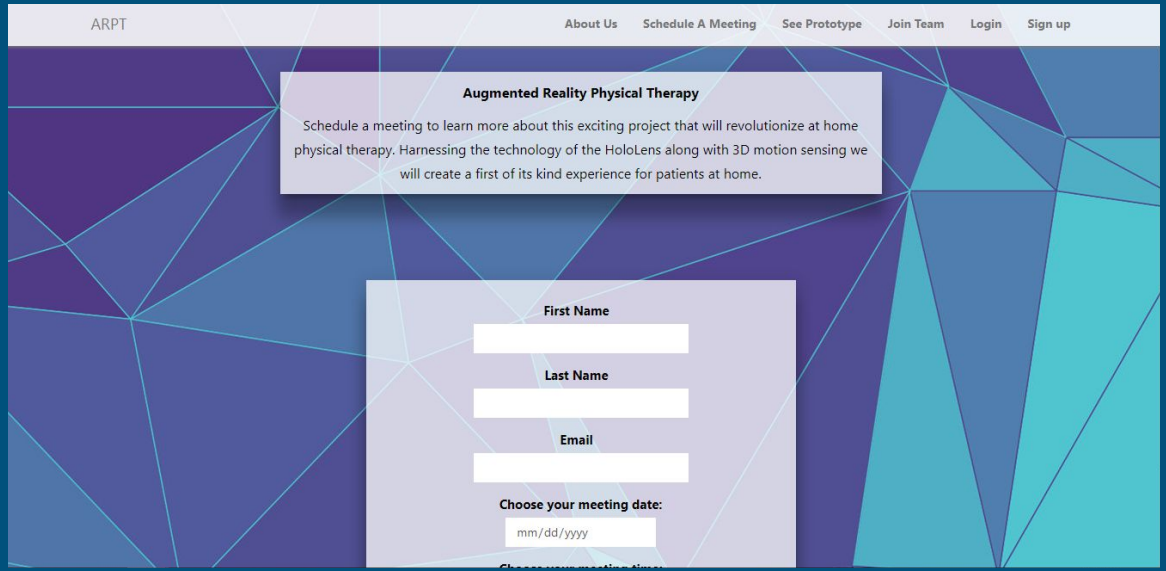


Server and Database

- Server
  - The server consists of a single virtual machine hosted on the Microsoft Azure cloud platform running Windows Server 2016
  - It is set up as a web host using Microsoft's Internet Information Services and is also set up for FTP to act as a file server
  - Also hosts the database
- Database
  - Microsoft SQL Server
  - Contains tables for users, videos, exercises, and subscriptions

Web Application Front-end

- Custom CSS and the BootStrap library helped create a fluent design interface
- Different sections of the site are separated and labeled in the navigation bar at the top



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First Name

Last Name

Last Name

City

City

State

Select a State

Password

Password

Confirm Password

Confirm Password

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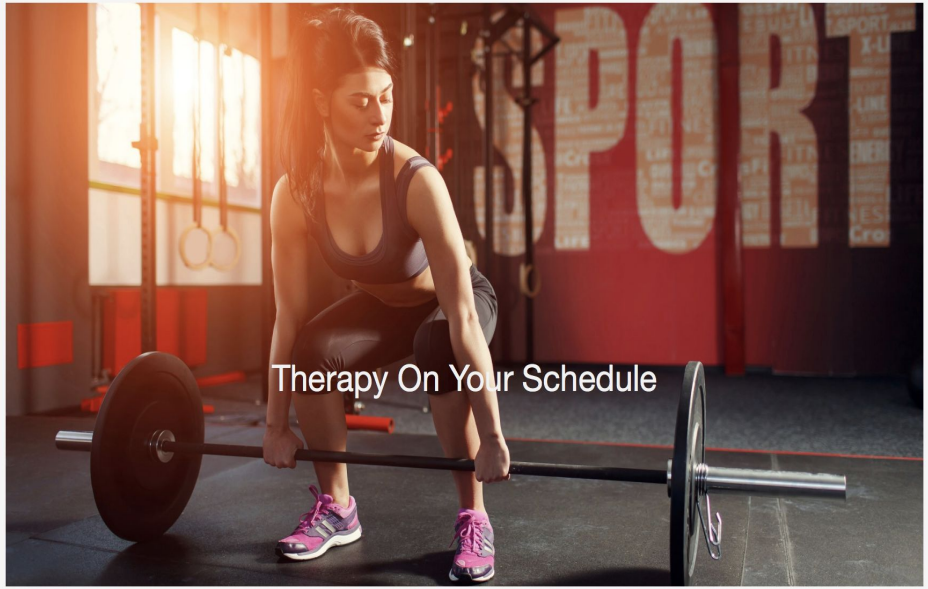
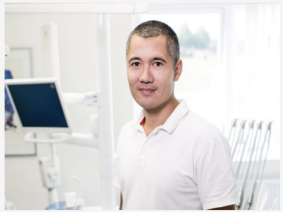
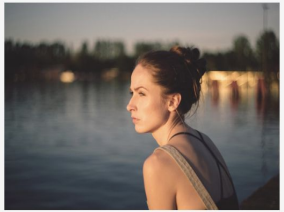




Therapist Testimonial

As a therapist the new technology of Augmented Reality Physical Therapy has helped improve the care of my patients. It has allowed us to better measure the accuracy of their at home sessions.



Patient Testimonial

It has helped me get better faster and feel more comfortable while doing exercises. The precision of being able to know right away if my exercise was done correctly has made me more confident.

Patient Testimonial

The challenging game aspect of the HoloLens made my therapy a lot more enjoyable to do. More therapists need to have this option!

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A study shows that only thirty-five percent of physical therapy patients do their prescribed exercises by their therapist on their own at home. Additionally, most of these exercises are not performed correctly.

This project attempts to tackle that problem using the Microsoft HoloLens. The project has undergone a feasibility study done by Marquette University. They concluded that the project is indeed achievable. Therefore, it is our goal to implement this technology as dynamic and economical as possible. The Microsoft HoloLens is an advanced piece of technology. It is currently only available to developers to use to create software. The piece itself is a headset that is worn by the user that provides a screen that displays augmented reality. Augmented reality establishes a computer-generated image on the user's view of the real world. The HoloLens includes multiple sensors, advanced optics, and a custom holographic processing unit. The sensors allow the user to interact with their scene. The optics generate a clear and dynamic picture for the user. Lastly, the processing unit provides a strong refresh rate and render of the display, and it has the capacity to compute high level logic.

We believe that the HoloLens is the perfect piece of hardware to use to pursuit the challenge that the physical therapists are battling. It has the ability to sense the patient, provide a field of vision, perform computations, and send that video to a database in the cloud. The HoloLens will provide the user with a scene that explains what kind of exercise they must establish. The HoloLens will then be able to advise the user if they are performing the exercise correctly. In addition to that, the physical therapist will be able to review the training videos of their patients to see their improvements

Subscribe below to get updates on this exciting project

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Michael Chang

Developer

Hi, I'm Michael Chang. I am a developer who specializes on CSS, HTML and Javascript. I'm excited to work more and learn more about design.

Jane Doe

Founder

I am Jane Doe, a web designer who loves designing and building websites. I founded this company to help bring web design to those who need it.

Jessica Smith

Graphic Designer

My name is Jessica Smith. I work mainly as a graphic designer, designing beautiful web elements, buttons, backgrounds.

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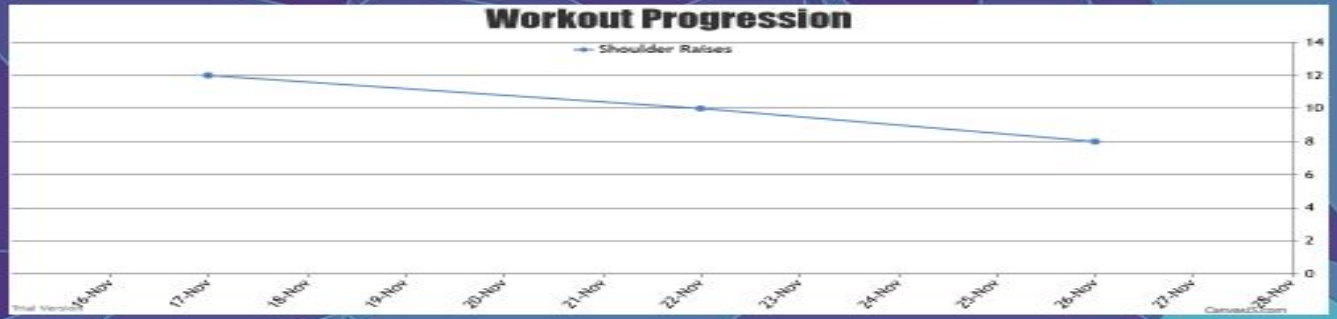
Welcome, Dr. Morgan

Patient Selection

Joe Hummel



Comments

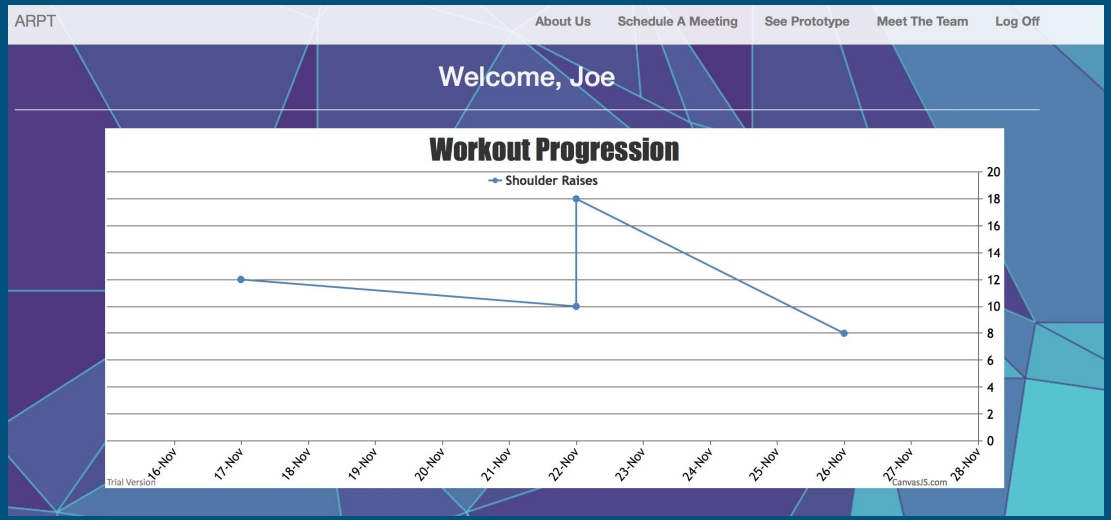
Comment	Date	Name
Testing New Comment	11/24/2018 1:50:25 PM	Joe Hummel
Testing my comment new	11/24/2018 3:00:28 PM	Arthur Morgan
Great job on the exercise. Keep gradually adding reps	11/24/2018 7:00:00 PM	Arthur Morgan
Testing therapist comment	11/25/2018 12:13:18 PM	Arthur Morgan
My new comment	11/25/2018 12:26:21 PM	Arthur Morgan
Patient comment	11/25/2018 12:28:10 PM	Joe Hummel
New comment functions	11/25/2018 1:28:03 PM	Arthur Morgan
Testing comment my new patient	11/25/2018 2:05:30 PM	Joe Hummel

Web Application Front-end

- Usability!!
- Once logged in users/patients will be able to see any comments from that the user has left
- Physical therapist will be able to see a list of their patients that use the application and the statistics of their exercises as well as make comments on the page

Web Application Front-end

- Using a graph to display patient progress.



Web Application Front-end

- Communication between patient and therapists.

Comments

Comment	Date	Name
Great job with the 8 reps!	11/28/2018 10:23:29 PM	Arthur Morgan
Thank you Dr. Morgan! I feel like my shoulder mobility is definitely improving.	11/28/2018 10:25:38 PM	Joe Hummel

Web Application Back-end

- Framework: ASP.NET Core 2.0
- Design: Model-View-Controller (MVC)
- Efficiently handles many different actions (Login, Signup, etc.)
- Takes input from the View

Security

- Hashing: Password-Based Key Derivation Function 2 (PBKDF2)
- JSON Web Token (JWT) for authentication
- Stored Procedures
- Input Validation

Budget

- HoloLens: $3,000
- Camera (Orbbec Astra Pro): $149.00
- Azure: $50/month
- Computer: ~$500 ($0 during development)

Difficulties and Accomplishments

- **Difficulties**
  - Pioneering new technology, very small foundation and prior experience to work with
  - Halfway camera change, Lack of API documentation for the new camera
  - Developing for the HoloLens has many quirks, and the documentation is quickly outdated
- **Accomplishments**
  - Server is setup and running, hosting a file server, database, and the web application and it is capable of scaling due to Azure's flexibility
  - Web Application is attractive, functional, and deployed to the server for easy access, and provides a solid foundation for future enhancements
  - HoloLens application is up and running, with working API calls and camera connection, it also established an overall user flow with a codebase prepared for tweaks and expansion
  - Camera application obtains, converts, and sends motion tracking data over a local network