Robotic Adaptive Screen Mount (RASM)

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Introduction

About 3700 people become quadriplegic every year in the US.
- Average hospital stay is two months.
- Recovery is improved with access to computer-based applications.

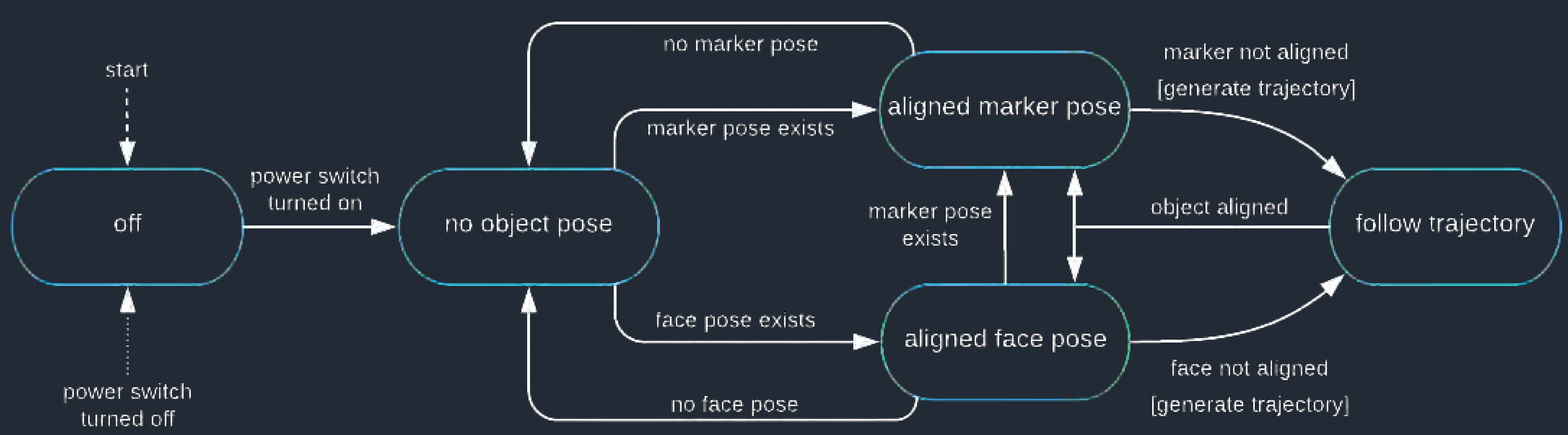
Patients with quadriplegia need eye tracking to use computers.
- Face must be aligned with the computer for eye tracking to work.

Problem: Current screen mounts are mechanically passive.
- Patient can't use computer if head involuntarily moves out of alignment with screen.

Solution: The robotic adaptive screen mount.
- Autonomously keeps a computer screen aligned with a patient's face.

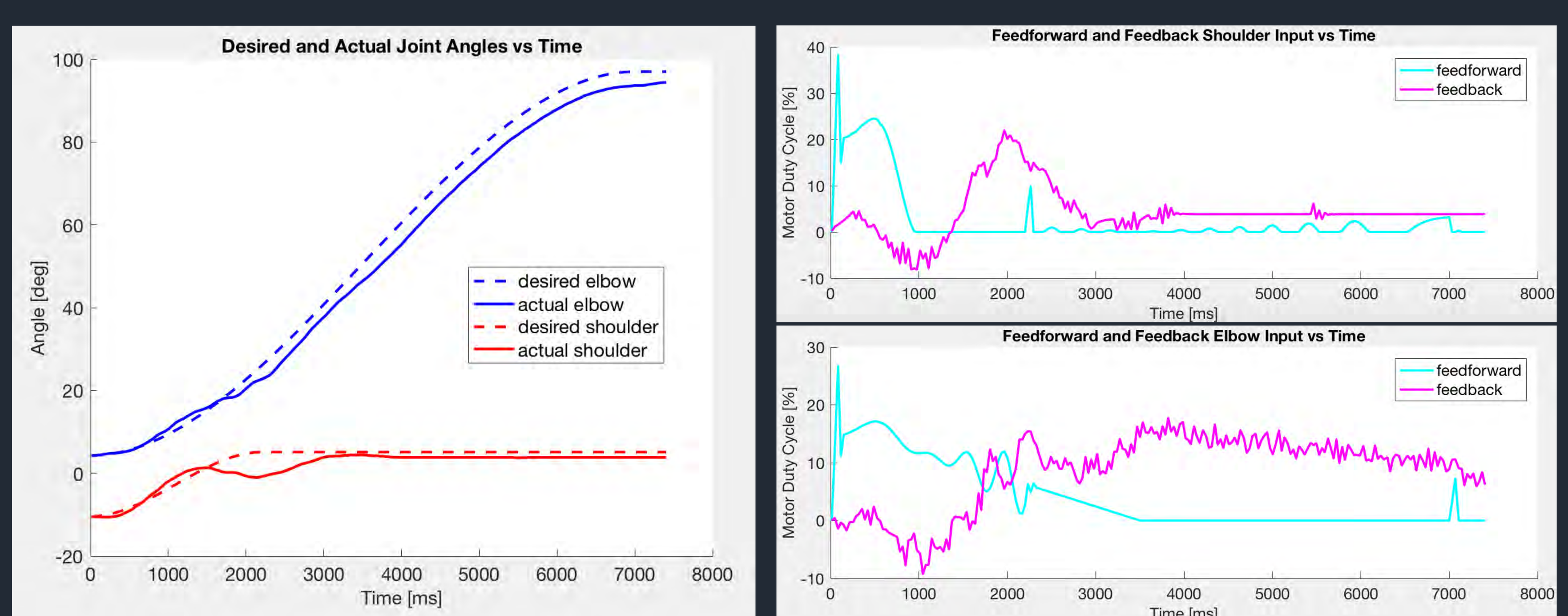
Objectives

The goal is to design and build the RASM - a six degree-of-freedom robot arm that controls the pose of a computer screen over hospital beds and wheelchairs. The position and orientation of the screen is autonomously controlled to stay in front of a face or marker. The marker is used to guide the screen to and from a patient's face. The pose of the face/marker is computed in real-time using computer vision. The RASM adheres to the autonomous behavior shown below.



Control

The control subsystem of the RASM consists of trajectory generation and trajectory tracking. The RASM uses cubic polynomial splines for the trajectory generation; and subsequently uses both feedforward and proportional-derivative feedback motor control to track the generated trajectories.



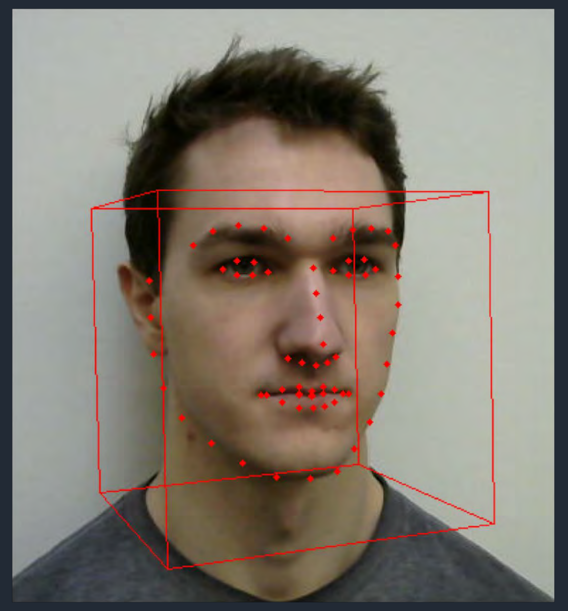
The left plot shows generated trajectories for the shoulder and elbow joints along with the actual trajectories that resulted from the RASM attempting to concurrently follow them. The two plots on the right show the feedforward and feedback control vs time for the shoulder and elbow joints that produced the actual trajectories in the left plot.

Vision

The computer vision subsystem of the RASM identifies and estimates the pose of a face and tracking marker. These poses are then used by the control subsystem to compute a goal pose. The table to the right details the accuracies and operating ranges for face and marker pose estimation.

Pose Estimation Results

Metric	Desired	Face	Marker
Range of distances from camera.	15 - 39 in	13 - 44 in	13 - 44 in
Range of yaw, pitch, and roll angles.	± 20°	± 50°	± 5°
Accuracy of yaw, pitch, and roll angles.	± 5°	± 1°	± 5°

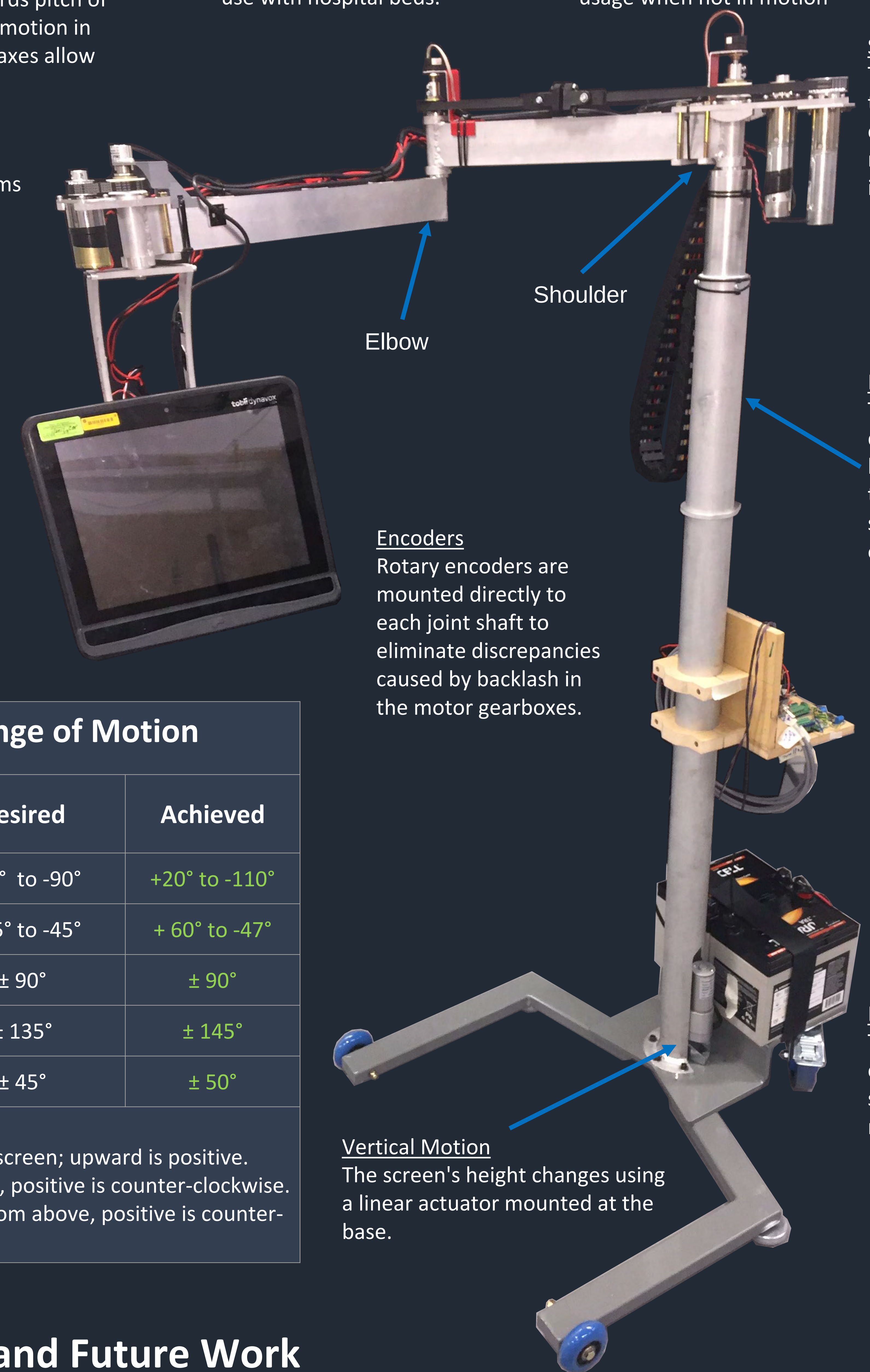


Hardware Design

Wrist Design
Curved support arms allow the screen to have an upwards pitch of 15°. The large range of motion in the pitch, yaw, and roll axes allow for a patient to be in a variety of positions.

Cantilever structure chosen for use with hospital beds.

Joints designed for zero power usage when not in motion



Shoulder and Elbow
The motors are arranged to keep the design compact and also to minimizing rotational inertia.

Pedestal
The telescopic tube design withstands the bending moment from the weight of the arm & screen through 18 inches of travel.

Encoders
Rotary encoders are mounted directly to each joint shaft to eliminate discrepancies caused by backlash in the motor gearboxes.

Base Design
The base has six points of contact with the floor for stability over a large range of screen positions.

Vertical Motion
The screen's height changes using a linear actuator mounted at the base.

Joint Range of Motion

Joint	Desired	Achieved
Pitch[1]	+15° to -90°	+20° to -110°
Roll[2]	+ 45° to -45°	+ 60° to -47°
Yaw[3]	± 90°	± 90°
Elbow[3]	± 135°	± 145°
Shoulder[3]	± 45°	± 50°

Angles referenced as:
[1] From forward-facing screen; upward is positive.
[2] When viewing screen, positive is counter-clockwise.
[3] When viewing arm from above, positive is counter-clockwise.

Conclusions and Future Work

The RASM will be a great tool for patients with quadriplegia for use during their recovery. Although substantial progress has been made on the RASM, it is still not ready for use. The ranges of motion of the RASM's joints and the face tracking both meet the desired specifications. More work, however, is needed to make the RASM's automated control system fully functional. This will be achieved by writing software that implements the behavior shown in the diagram in the 'Objectives' section. The RASM's marker tracking failed one of its metrics. We believe this issue with the marker tracking could be solved by using a marker image that is different from the one currently being used. Finally, the electrical system has several missing components. These components are meant to implement battery charging and also display information like the RASM's current control state and battery level.

Acknowledgements

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