THE UNIVERSITY of ADELAIDE

Project #2366 REFAUM

Robotic Exoskeleton for Assisted Upper-Body Motion

School of Mechanical Engineering, 2017

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Motivation:

- Every year millions of people suffer from various issues relating to upper-body muscular weakness or dystrophy
- Several of these issues require some form of rehabilitation to prevent long term muscular damage
- Current methods of rehabilitation involve the use of physical therapists and or specialist facilities which can be expensive and in high demand
- These factors have motivated the development of robotic arms and exoskeletons to provide patients with alternate solutions for rehabilitation

Project Aims:

This project aims to design and build the mechanical, electrical and control systems of a prototype upper-body exoskeleton for use with assisted motion.

The exoskeleton should:

- Replicate the human workspace
- Be portable/adjustable
- Be able to record and save move-sets
- Be able to execute these move-sets for use in rehabilitation, through repetitive motions, or for recreational activities, for example teaching the user Tai Chi routines

Research:

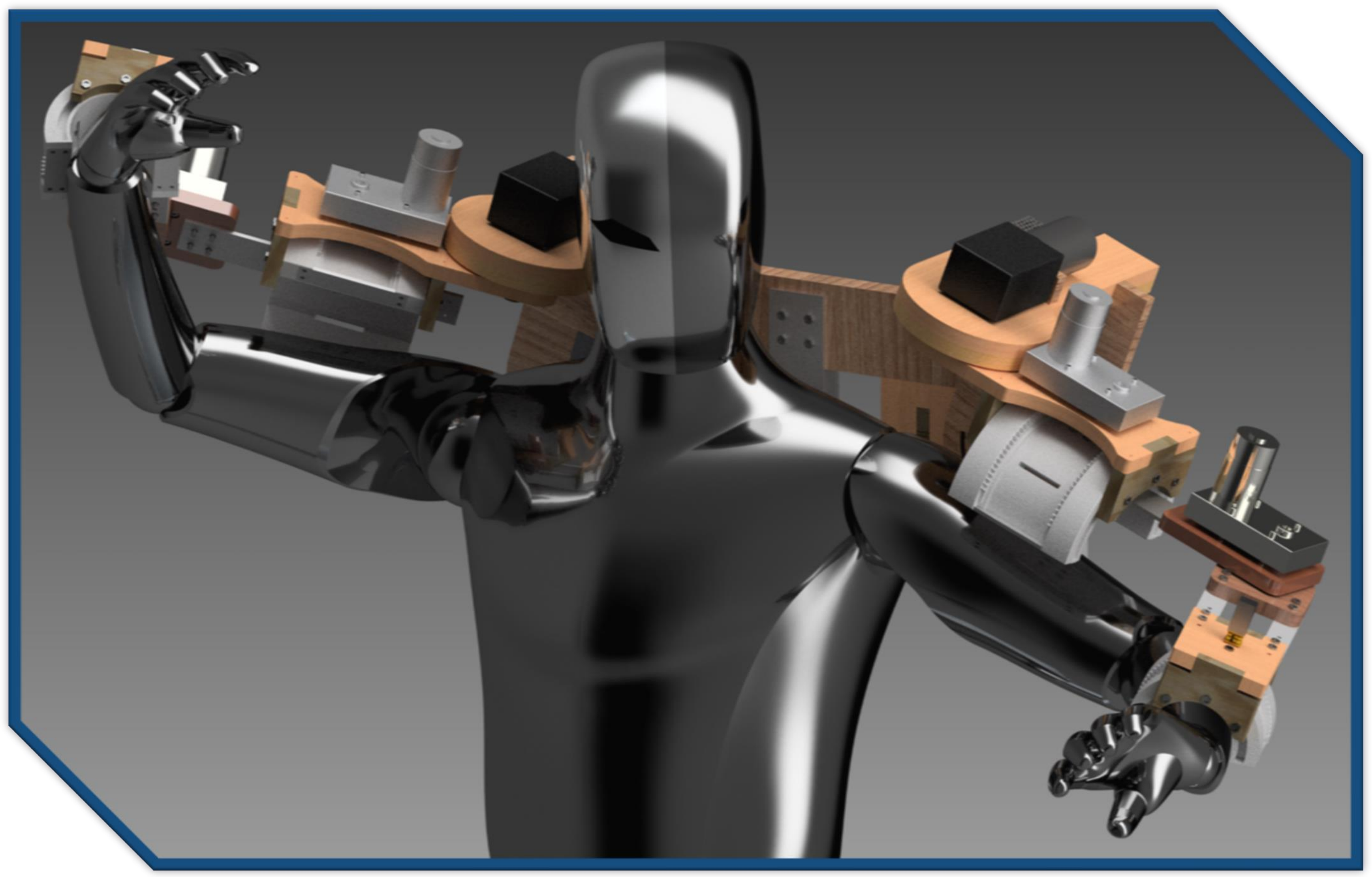
Initial research was conducted into human kinematics and dynamics, in order to determine the angular range of motion the average person could obtain as well as the force required to do so. In particular a research paper entitled "Upper-Limb Powered Exoskeleton Design" was investigated[1]. This paper contained information relating to an experiment that involved tracking the range of motion and torque of a person performing several different daily activities. The results from this experiment, shown below, were used as the basis for the mechanical system's design as well as the selection of the electrical system's actuators.

Joint	Angular Range	Max Torque	Max Actuator Torque
Shoulder Pitch	-20° to 80°	10.00 Nm	33.00 Nm
Shoulder Yaw	-20° to 140°	10.00 Nm	33.00 Nm
Shoulder Roll	-60° to 80°	3.50 Nm	7.00 Nm
Elbow Pitch	0° to 150°	3.50 Nm	7.00 Nm
Wrist Roll	-80° to 80°	0.04 Nm	0.40 Nm

Mechanical System:

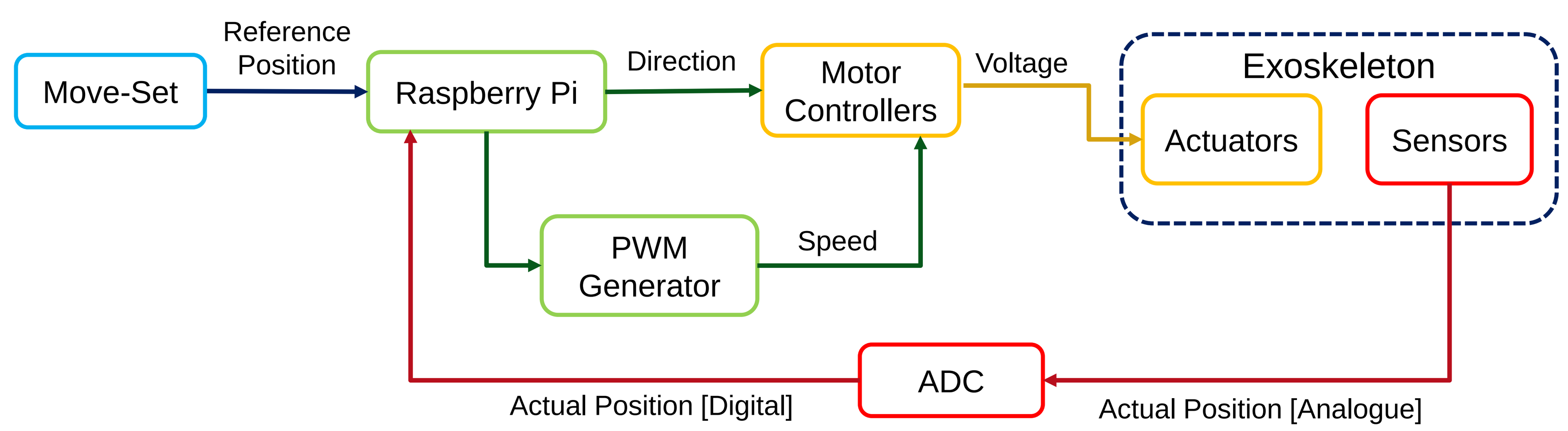
The mechanical system was designed with the angular range from the initial research in mind. It was constructed using Autodesk's Inventor and was made to have the following features:

- 5 Degrees of Freedom:
  - Shoulder - Pitch, Roll & Yaw
  - Elbow - Pitch
  - Wrist - Roll
- Modular/Symmetric Parts: To enable ease of manufacture and assembly
- Adjustable Limbs: To account for different sized patients
- Safety Pins/Stops: To prevent the limbs from moving outside of their designated angular range



Electrical System:

The exoskeletons electrical system is comprised of the sensor, actuator and controller components required to turn the recorded move-sets into physical actions.

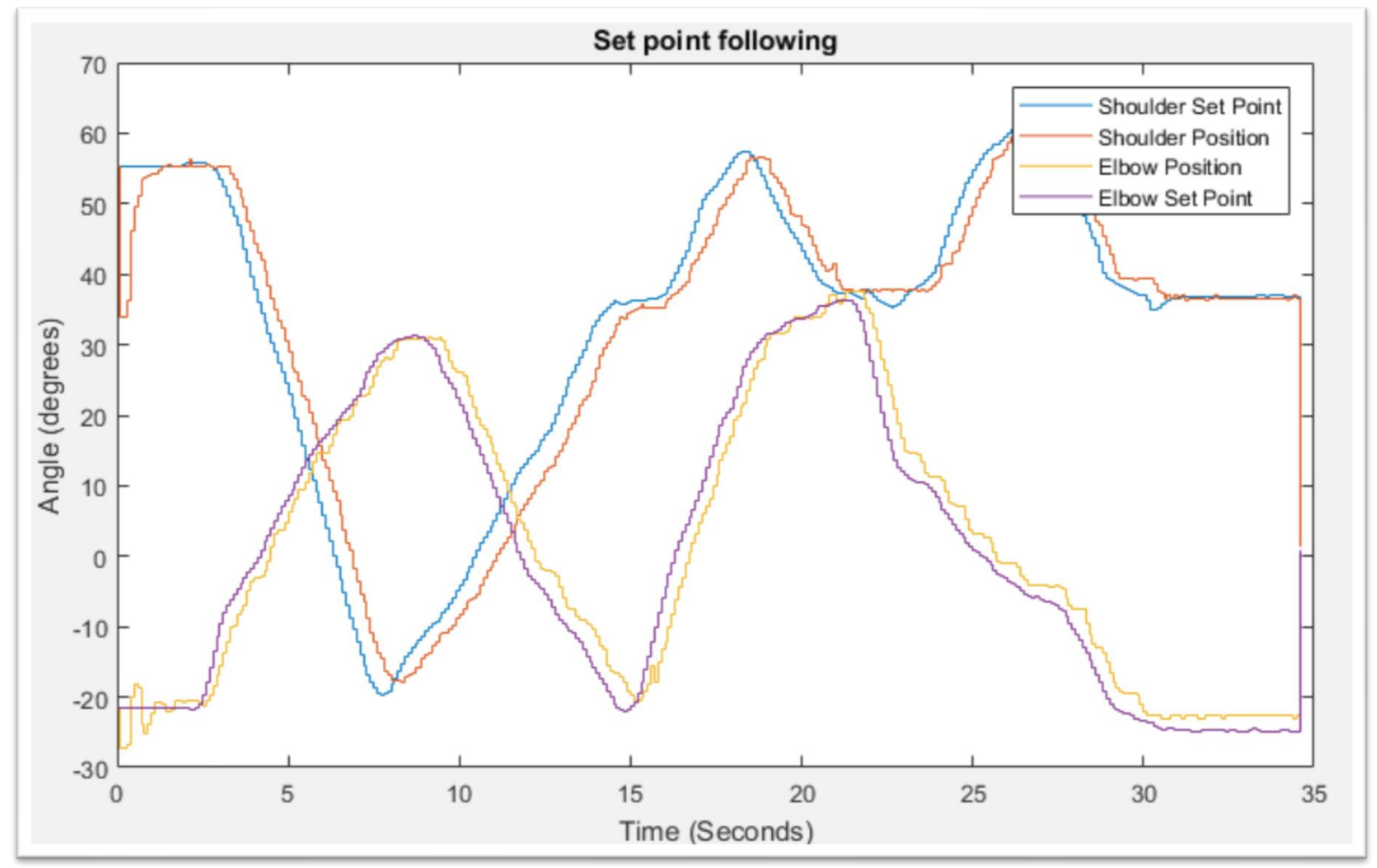


Control System:

The control system was created using MATLAB & Simulink and consists of a simple GUI that allows the user to interact with the exoskeleton in the following ways:

- Record and save move-sets
- Execute move-sets
- Enter a mirror image mode, where the right arm follows the left arm
- Animate move-sets on the host computer, using the robotics toolbox for MATLAB

Additionally, the kinematic and dynamic equations for both of the exoskeletons arms were calculated. In order to enable the use of model-based control for the set point following required to execute a specific move-set.



Future Work:

- Reduce overall weight
- Improve modularity
- Buy the additional components required to provide power to the left arm
- Power the suit using batteries
- Move the GUI from the computer to a display mounted on the right wrist
- Integrate with the lower-body exoskeleton project #2252

References:

1. Perry, J, Rosen, J, Burns, S 2007, 'Upper-Limb Powered Exoskeleton Design', *IEEE/ASME Transactions on Mechatronics*, VOL. 12, no. 4, pp. 408-417