# Subsystem Three: Controls and Decision Making

This section details the analysis, design, implementation, and results of the subsystem responsible for determining the actions required by the actuation system.

## Requirements and Functional Decomposition

The overarching purpose of subsystem three (SS3) was to determine the action that should be taken by the actuator system to minimise the error in the system.



Figure 29: SS3 Breakdown

As seen in Figure 29: SS3 Breakdown, to determine the action required in a state (given by the values determined by SS1, SS2, and SS4) the action required in any given state must be known.

To determine the general solution of what actions should be taken at any given state the controls parameters and method for the system should be derived, and then this model should be refined by practically tuning the solution.

The methodology for tuning the controls parameters of the system is discussed in kt, but the initial values to be refined are best source directly from the theory.

To determine the control parameters for the system the following method is employed:

1. Derive the equations of motion (EOM) for the system;
2. From the EOM derive the transfer function (TF) of the system (torque () with respect to angle ());
3. Transform the TF into the Laplace Domain; and,
4. Derive the PID parameters from the Laplace Domain TF.

Ultimately, five sets of controls were derived during the project: three for the 3 Degree of Freedom (DOF) lower extremity system (each joint had its own parameters), one for the continuous servomotor (which was abandoned as discussed in kt), and the positional servomotor.

The 3 DOF system was to control the lower extremity exoskeleton being constructed by the actuators and structural side of the project. However, as actual values for system parameters (masses, dimensions, moments of inertia, etc…) were never confirmed the solution had to be found algebraically.

The two systems used in testing featured their own embedded control systems, and their torque, angle, velocity, and acceleration could not be directly controlled. As such precise controls could not be derive from first principles. Instead the controls systems would need to be tuned empirically to achieve the desired system response.

## Background and Prior Art

The goal of SS3 is to model the dynamics expected of the system, establish the manipulator equations of motion, and derive the appropriate controls structure to create the behaviour required, in a stable fashion.

### Lagrange

We begin with the Euler–Lagrange equations, or Lagrange's equations of the second kind, .

### What is controls

#### Stability

### What is system response

#### Get EOM

#### Get System Response

### PID Control

## Approach and Execution

## Results and Discussion