Robotics 2

Fuzzy Logic Impedance Control

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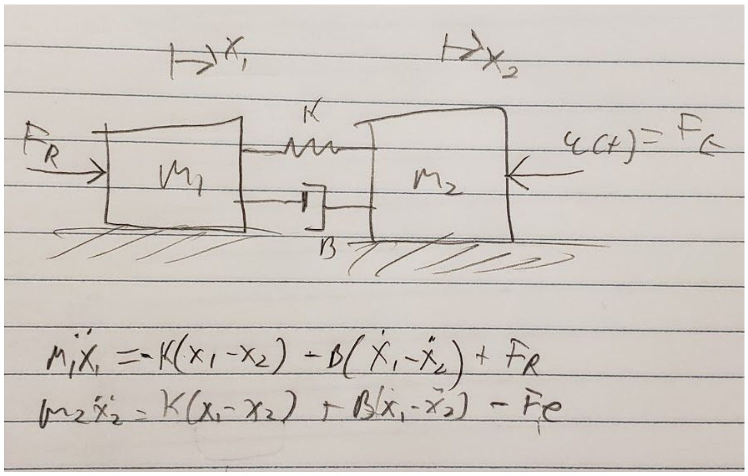
The objective of this project was to design a fuzzy logic control loop that achieves impedance control for a two degree of freedom spring-mass-damper system that is excited by a defined impulse. This system contains the robot m_1 and the gripper/sensor m_2 shown in the figure below.



Based on the requirements on your last email, we implemented this system in simulink with an initial velocity for m_2 of -1 m/s, as an initial condition in the integrator in the second mass's block diagram in addition to the constant force F_E.

For our system we implemented two fuzzy controllers that used the velocity of the second mass/gripper as an input. The output of the first controller is a force on the first mass F_R, which represents the reaction force of the robot to the environmental force and velocity, F_E, and V_2. V_2 in our case is -1m/s and the force F_R is 1 Newton. The masses of the robot and gripper are 1 kg and .1 kg, respectively.

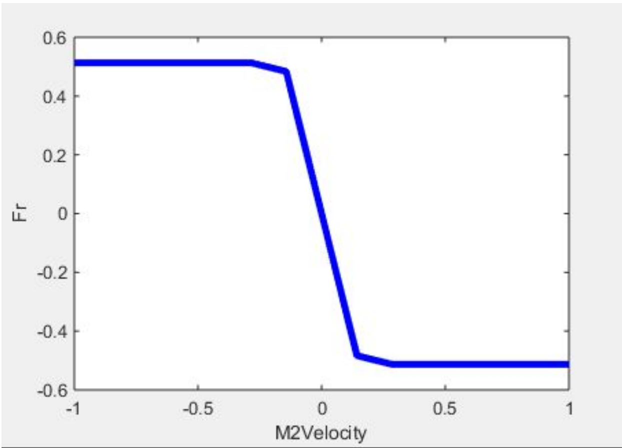
The second controller outputs a modulating signal that multiplies the native spring constant. It multiplies it by a number in the range of [0,10] to either reduce or increase the constant.

The approach used to settle the system responses leveraged a spring whose rate (spring constant) is variable by a controllable stimulus. Market research indicated that such springs are not easily available, however, one could certainly be devised, as current flow changes solid properties of metals through which they flux. Such systems with variable spring constants, or rates, would also require variable dampers as well. An alternate approach considered for settling system behavior by leveraging a damper whose damping coefficient is variable, such as that of a ferrofluid damper used in performance vehicles, where electric current is applied to the fluid to change it's viscosity and resultant damping rate.

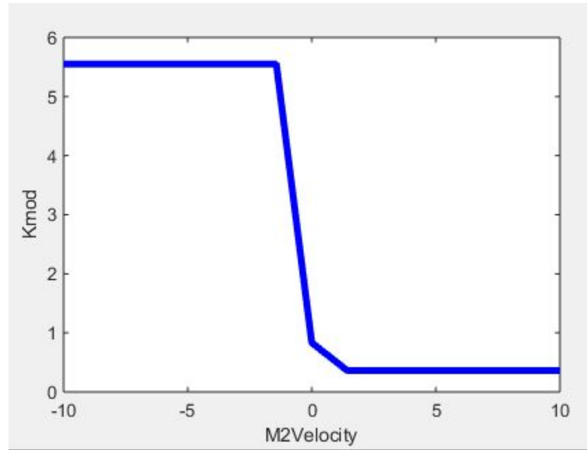
The rules of the fuzzy controllers are shown below:

1. If (M2Velocity is vpos) then (Fr is dec) (1)
2. If (M2Velocity is vzero) then (Fr is 1) (1)
3. If (M2Velocity is vneg) then (Fr is inc) (1)

1. If (M2Velocity is vneg) then (Kmod is inc) (1)
2. If (M2Velocity is vzer) then (Kmod is 1) (1)
3. If (M2Velocity is vpos) then (Kmod is inc) (1)

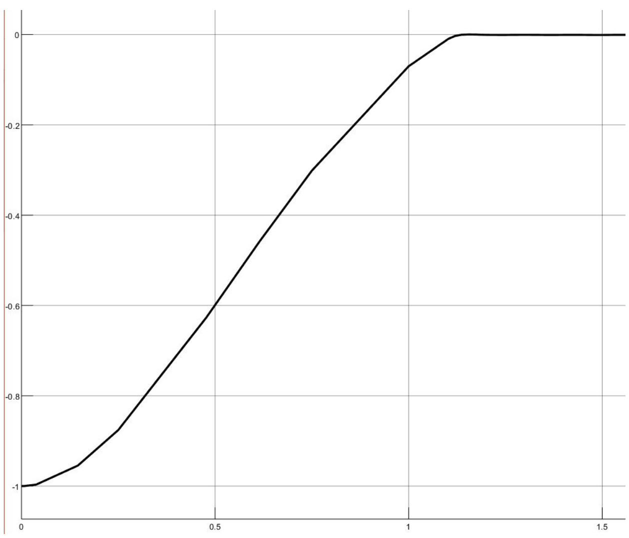


F_R **Fuzzy Rules**

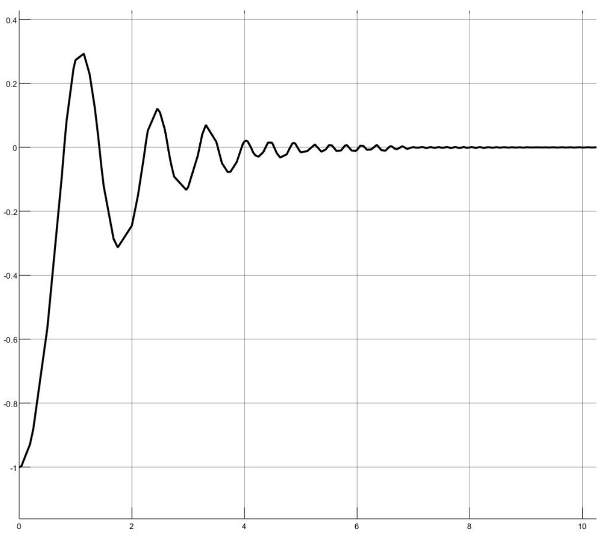


Spring Modulator Rules

The rules are logically driven, if the gripper is moving towards the robot exert a force on the robot towards the gripper, as well as its opposite. The same is for the spring modulator rules, if the gripper is moving towards the robot increase the spring constant to slow it down.
The system is controlled well just by the fuzzy controller which only adjusts the force, but adding a spring constant modulator allows the system to settle much faster, with no overshoot in the velocity of mass 2, this is show in the figures below



M2 Velocity with Spring Modulator



M2 Velocity without Spring Modulator

The settling time with the modulator is 1.2 seconds, while without it it is 6 seconds. To show this in the simulink diagram yourself, just remove input from the labeled spring controller

Many other interesting properties of the system can be shown by the scopes on the simulink diagram and we recommend you check for yourself. Interestingly the position of both masses settle, as well as the position difference. The modulating force and spring constant are also of interest, and how they change over time to maintain the zero velocity.