Senior Capstone
Small Scale Robotic Arm
Project Design Proposal

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**Project Summary**
The project consists of a small robotic arm system that has already been partially developed to mimic a hydraulic system capable of earth-moving applications. The input/output diagram in Figure 1 shows a user command input and corresponding positioning and gripper control outputs. The system is highly non-linear creating difficulty in configuring a closed loop controller design for light, medium, and heavy loads. The small robotic arm will operate with a low frequency resonant mode. Other challenges include trade off of speed versus stability. A pulley mass spring system and a gripper control system have to be built for the robotic arm. Implementing and evaluating controller designs for the robot arm make it easier to modify for different loads with varying resonant mode frequencies.

![Small Scale Robotic Arm Control Diagram](Figure 1-Input/Output Diagram)

**Objective**
One of the goals is to complete the design of the robotic arm system in order to mimic the dynamics of a hydraulic system in earth-moving applications. Part of the external load should drop when the arm reaches $+90^\circ$. This corresponds to a wheel loader dropping its dirt load. A mathematical model (transfer function) must be developed for the robotic arm system to vary operating positions. Single-loop close-looped controllers will also be compared to a two-loop controller that consists of an inner velocity loop and outer position loop. The conventional controller results will be compared to a neural network time permitting.
Modes of Operation

**Software Interface**
All controllers/filters will be implemented in software after the necessary mathematical models and control designs have been developed. A filter design will be researched in order to reduce the low-frequency resonant mode and then compared to a second-order low-pass filter. Figure 2 illustrates the overall control theory including internal software interfacing. Feed-forward, the gain compensator \((G_c)\), and the software filter will be designed in the internal software interface.

**Gripper Control**
The hardware portion will concentrate on motor functionality and sensor mechanisms that run the gripper control system. This system is attached to the end of the robotic arm and is used to pick up loads. It consists of a motor that opens and closes the clamp. A sensor may be built in order to specify when the motor opens and closes.

**Positioning**
The robotic arm swings toward any \(\pm 90^\circ\) level specified by user command. Figure 2 shows the plant \((G_p)\), which is the mathematical model that will be derived through control theory. If the user input is \(+90^\circ\), the corresponding positioning output should be \(+90^\circ\). Unity gain will be implemented so that input commands will correspond to desired positions.

![Figure 2- System Control Block Diagram of Overall Project Theory for Robotic Arm](image)

The detailed block diagram of the robotic arm is illustrated in Figure 2. The DC motor and gear train drive a aluminum rod of 45.9 cm in length with a mass of 118 grams. An additional
component, a gripper motor, will be used to carry light, medium, and heavy weights. Figure 2 shows the gears and DC motor being driven by a 200 M Hz Pentium-based computer. The input voltage is applied to an amplifier that has limits of ± 5 volts. A potentiometer is used for the position sensor to either -5 volts which would equal -90°, 0 volts corresponds to 0°, and +5 volts corresponds to +90°. Other components shown in Figure 2 include internal and external gears of the Quansar Consulting robotic arm. These gears will be driven by the DC motor. The external gears moves the arm in the ±90° position.

Figure 2-Detailed Block Diagram of Robotic Arm

System (Plant)
1) Amplifier
2) Position Sensor
3) DC motor
4) External Gears
5) Internal Gears
6) Antialiasing Filter

Software
1) 200 M Hz PC
2) A/D converter
3) D/A converter
## Tentative Schedule of Tasks

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### Equipment List

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Bibliography


Figure 3 - System Control Block Diagram

The project involves the calculations and displays for the system’s diagnostics and outputs which are shown above in Figure 3 of the system control block diagram:

1) C ⇒ Positioning
2) E ⇒ Error Signal
3) U ⇒ Controller Output
4) $U_{\text{pid}}$ ⇒ Conventional Controller Signal
5) $U_{\text{ff}}$ ⇒ Feed-Forward Signal
6) $P_f$ ⇒ Position Feedback

The various signal and block descriptions in Figure 3 are defined as follows:

1) $R(s)$ ⇒ the command input signal generated in software
2) $F(s)$ ⇒ the feed-forward compensator
3) $G_c(s)$ ⇒ the controller
4) $G_p(s)$ ⇒ the plant
5) $H_1(s)$ ⇒ the position sensor
6) $H_2(s)$ ⇒ the filter to suppress signal noise in hardware prior to A/D conversion
7) $H_3(s)$ ⇒ the filter to further suppress signal noise in software
8) $C(s)$ ⇒ the robotic arm positioning output signal