Project Deliverable
A functional description and complete system block diagram for

Non-Linear Internal Model Controller Design for a Robot Arm with Artificial Neural Networks

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11/26/07

Introduction

The aim of this senior project is to model the Quanser Consulting Plant SRV-02, use conventional system identification to develop an input-output relationship of the Quanser plant and then develop a non-linear Internal Model controller with Artificial Neural Networks(ANNs) for the system. This project deliverable summarizes research from secondary sources providing a description of the system plant physical structure, the software interface and functional description.

Physical Description

The Quanser Consulting Plant SRV-02 consists of an arm, base, and stand. The stand contains a motor driving the arm through a gear train in the base. When electrical energy is supplied to the motor the result is mechanical energy, torque, at the output shaft. The gear train moves the arm and this creates the 1st degree of freedom(DOF). There are springs attached to the arm and base. This along with friction in the rotary flexible joint forces the arm to move independently creating a 2nd DOF(Dempsey,2007). DOF's are proportional to the degree of the system plant, more on this in the functional description. The top down view of the system is shown in Figure 1 below. A side view of the system is shown in Figure 2 on the next page.

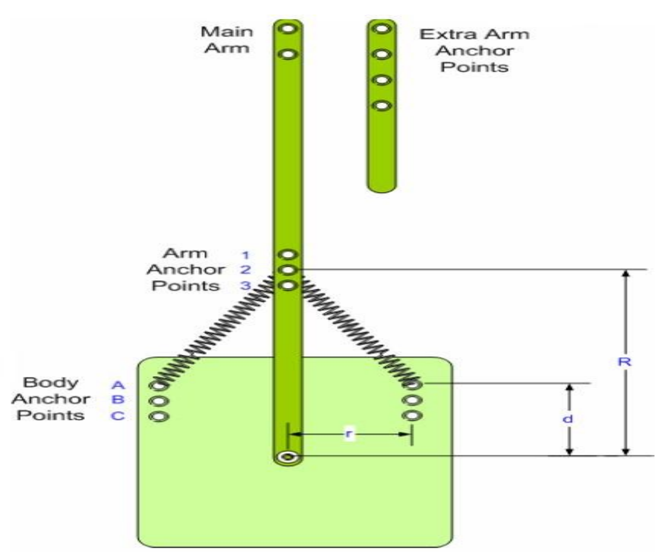

Figure 1 - Top-down view of the system showing the arm and base. Note the output shaft of the motor connected to the arm through a gear train in the center of the base(Edwards).

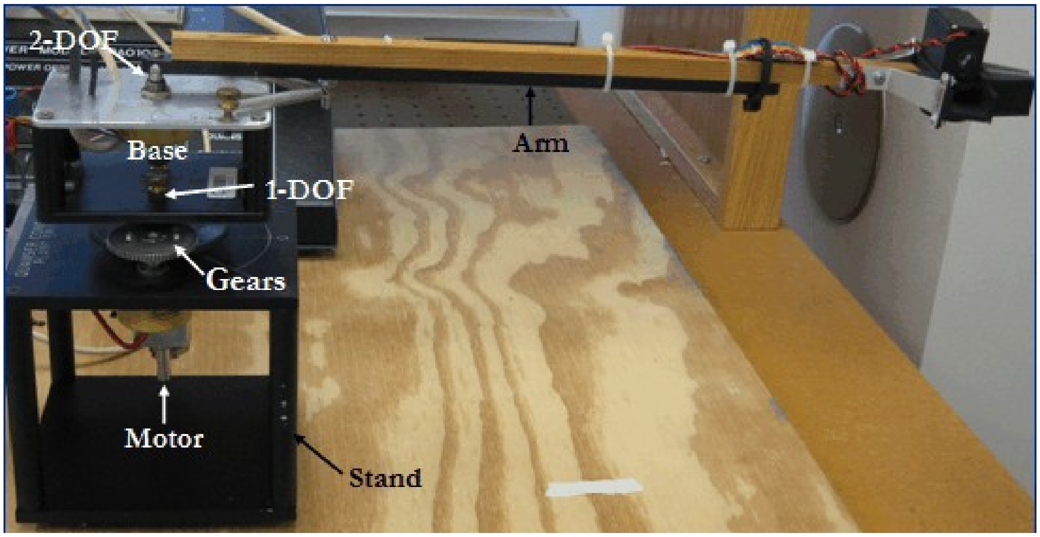

Figure 2 – Quanser Consulting System SRV-02 – Stand, base, arm and gears are shown. There are arrows pointing out where the DOFs originate (Dempsey, 2007)

The hardware shown above communicates with a 1.46Ghz Pentium-based computer with an internal A/D and D/A acquisition card. The system can be described using a low level system block diagram as shown in Figure 3 below. The system is also connected to a sophisticated power amplifier for driving the entire system shown as the amplifier in Figure 3 below.

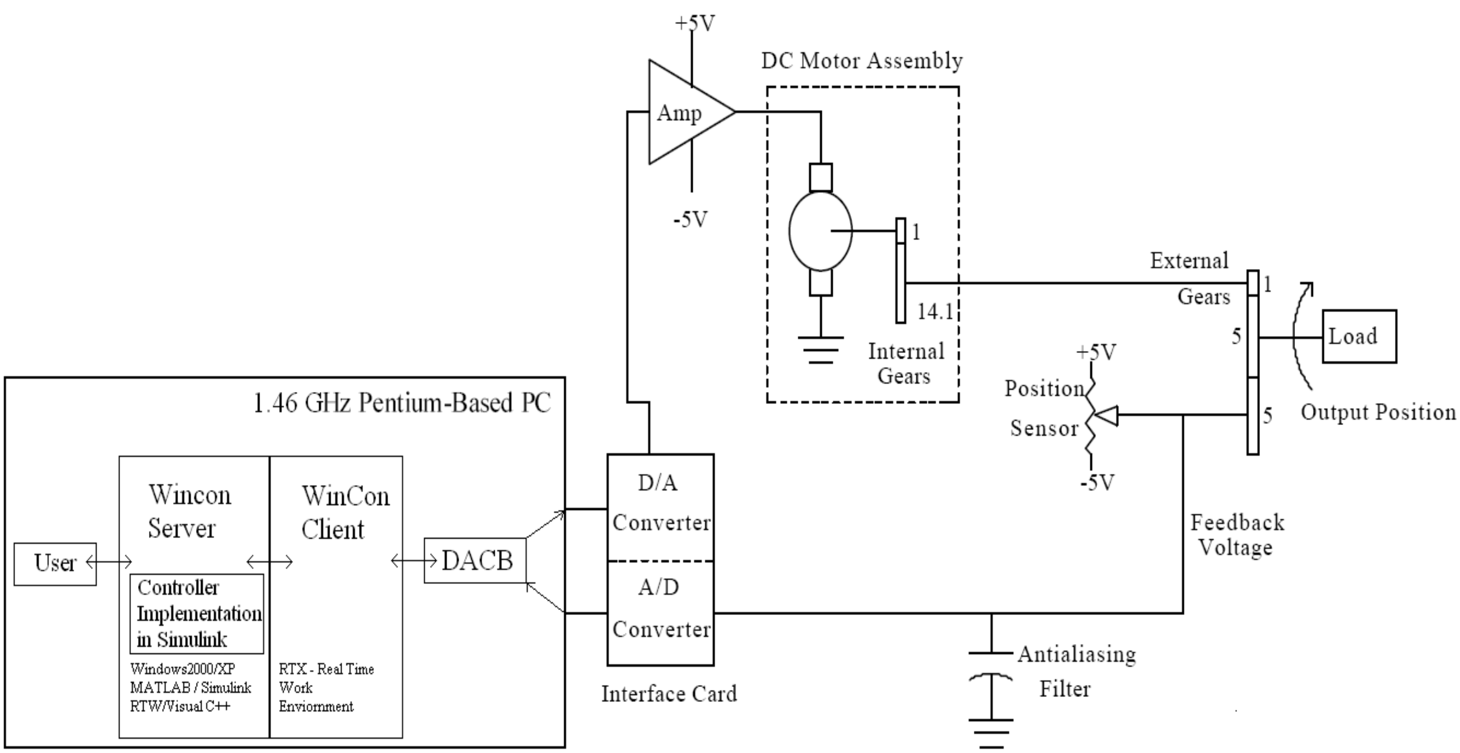

Figure 3 – Low level block diagram. Note the PC, interface card, gears, feedback voltage loop and anti-aliasing filter(Le).

Software Interface

The PC contains user interface/monitoring system for the hardware shown in Figure 4 below. As the user you are able to select various command signals and controller methods via a keyboard and monitor for real-time evaluation(Le). Real time system diagnostics and positioning output can be viewed numerically, graphically, and be collected on the monitor. All this data is determined by the feedback voltage and various sensors located in the hardware. In the feedback voltage loop the anti-aliasing filter prevents overlap in the data, due to A/D converter sampling. This filter is critical for closed-loop operation of the system.

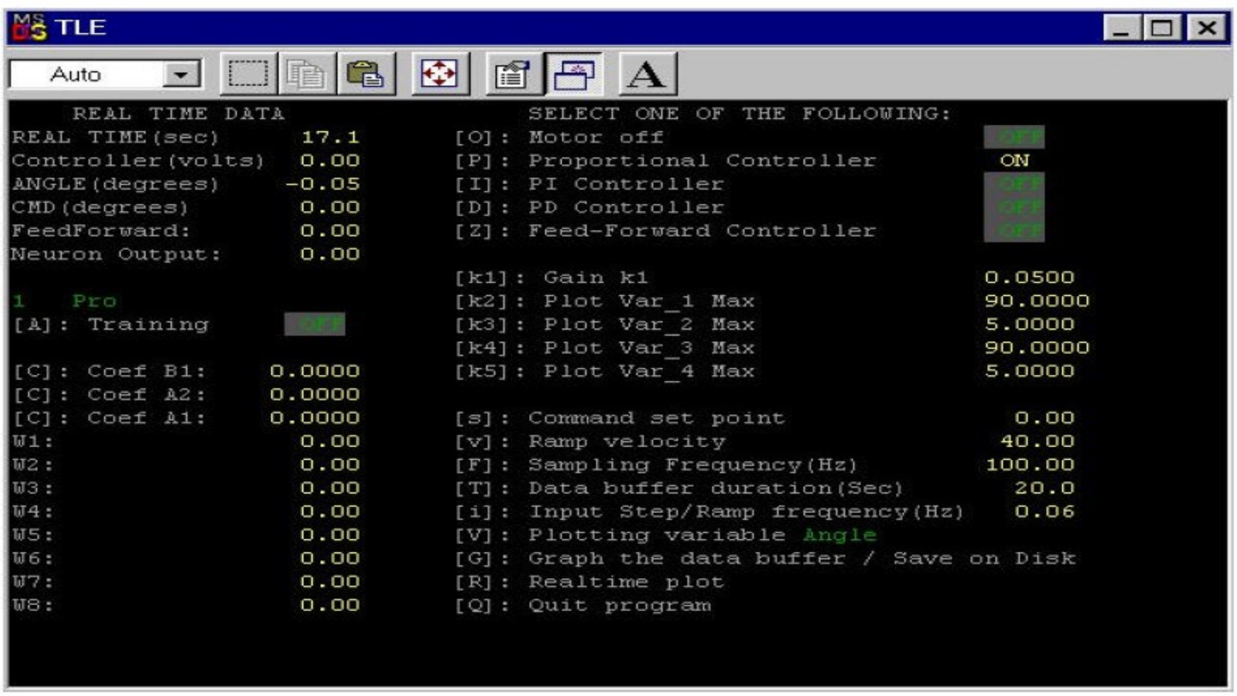

Figure 4 - User interface/monitoring system for the plant

Simulation

Another tool used in modeling and testing is the Virtual Reality(VR) Workstation developed in Matlab using the Virtual Reality Toolbox by Kain Osterholt and Adam Vaccari. The VR workstation is a flexible and accurate model of the Quanser system that can be used to generate simulation results. One is able to design any system part and build whole systems virtually. Furthermore, parent and child classes can be setup between objects such that more complex components can be created(Edwards). This object-oriented approach has a whole slew of advantages such as inheritance, encapsulation, reusability, flexibility,etc. Finally, the VR workstation can be coupled with a Matlab GUI to produce something similar to Figure 4 for simulation.

Functional Description

As stated in the introduction, the goal of this project is to design a non-linear internal model controller using ANNs for the Quanser plant. Using SimMechanics, a virtual mechanical model can be developed. Then through conventional system identification Gp(s), the process or plant model, is identified. Once Gp(s) is identified, internal model controller design may begin. Refer to Figure 5 below where Gp(s) is shown. Edwards and Smith determined that, for the level-arm configuration, the plant was a 2nd order with time delay.

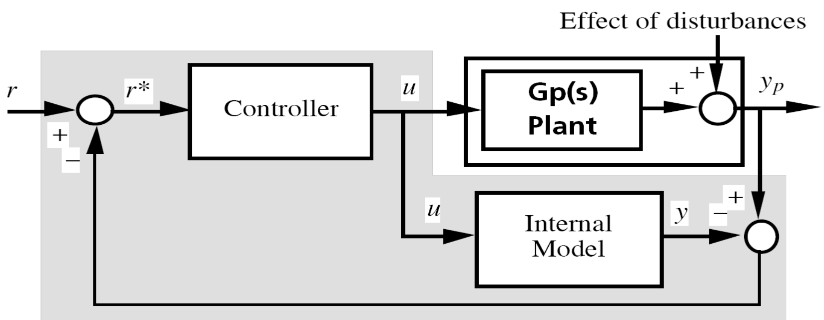

Figure 5 - Block Diagram for Internal Model Controller

The internal model controller produces the difference between Gp(s) and the 'internal model' of Gp(s) which results in the the effects of the disturbances. The disturbance is then typically minimized by a Proportional-Integral-Derivative controller labeled above simply by 'Controller'. Traditional internal models are simulated by linear system design technique. The system plant, Gp(s), is second order and non-linear. An internal model for non-linear systems needs to be simulated with ANNs.

Artificial Neural Networks are adaptive systems that can change their input-output characteristics. The internal structure of ANNs can be modified in the learning phase based on external or internal information that flows through the network. In practice, ANNs are used to model non-linear systems. The network consists of a number of inputs and a hidden layer of nodes connected to each input which process the data to generate an output. Each connection from an input to node has a variable numerical weight. In the learning phase, the output is fed back to 'tune' the numerical weights so they change to fit the proper I/O characteristics. For our case the ANN would simulate the I/O characteristics of the Quanser Plant SRV-02. Figure 6 below shows the node structure for ANNs.

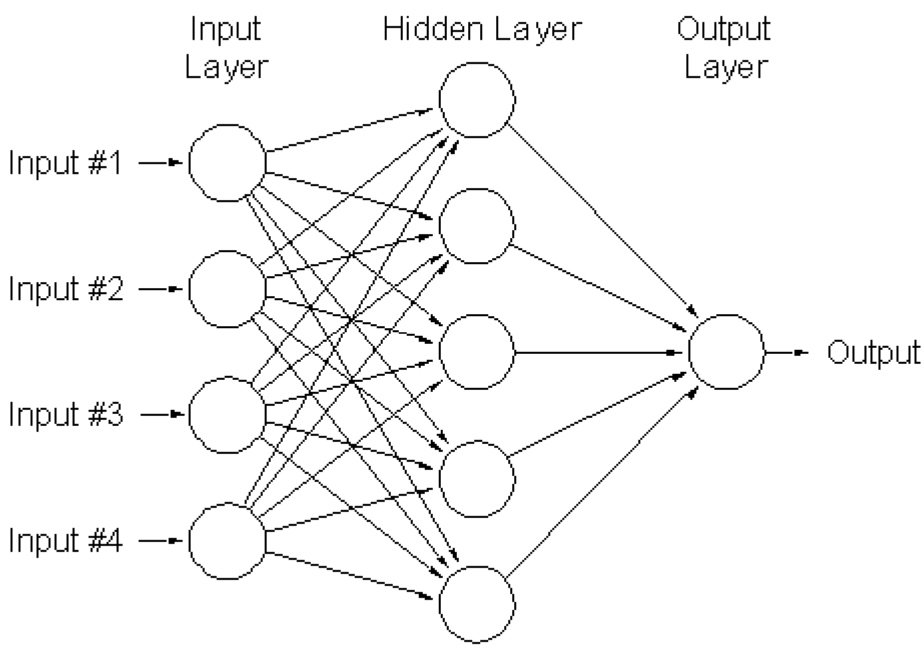

Figure 6 - Artificial Neural Network

Conclusion

The aim of this document was to topically organize information regarding the proposed work and future work on this project. The topic organization mimics the different stages of this project. The place to start would be with the physical system. Next is modeling the system and then using system identification to determine input-output characteristics of the system. Lastly, once the system has been identified it is possible to start controller design. IM controllers face limitations for linear signal processing thus ANNs are used to compensate.

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