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Adaptive Neural Control of a Gimbaled Laser Targeting System

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Abstract:

Space-based solar power is an ideal alternative to the ground-based solar system because of its round-the-clock availability. Accurately pointing the laser from space to a ground receiver can increase transmission efficiency and decrease safety risk. A superior pointing performance requires an accurate system model and controller. In this project a two-axis Gimbaled Laser Target System (GLTS) is viewed as hardware test bench of the space-based solar power transmission system.

The Adaptive Neural Control (ANC) system, first proposed by D.C. Hyland, is a neural control system within a Model Reference Control (MRAC) architecture. It is composed of five separate neural networks, two of which are used to replicate an unknown plant, while the remaining three are used to control the plant's output to match that of an ideal reference system. The system has been successfully used in hardware such as the NASA / LaRC Mini-MAST testbed and the ASTREX testbed at Airforce Philips Laboratory. It has been shown to be very effective in terms of robustness, fault tolerance, and optimality.

The objective of this research is to apply the ANC system to the problem of pointing and tracking the line of sight of a GLTS. We also examine the ANC system's resiliency, defined in terms of how the controller maintains operational normalcy in response to anomalies, both unexpected and malicious. These anomalies will be in the form of added latencies, plant parameter changes, false data injection, and sensor data alteration. We simulate the attacks on the GLTS model and determine the system's resiliency to each attack through four metrics. These metrics are recovery time, performance degradation, protection time, and degrading time. We then compare these results to that of a Proportional-Integral-Derivative (PID) controller subjected to the same attacks. Simulations show that the ANC system outperforms the PID controller in all but one case, the plant parameter change attack.

Next, the ANC system software model is translated to a hardware description for implementation on a Field Programmable Gate Array (FPGA). System replication and control simulations are run for the GLTS model. These simulations include "hardware in the loop" simulations, where the actual FPGA is used within the Matlab simulation. The results show that our hardware description of the ANC system is able to properly replicate and control the model. We implement the ANC system in hardware, on both a sequential processor, via a dSpace control board, and on an FPGA. Due to hardware limitations, we run a simplified version of the ANC system and do real time system replication of the GLTS hardware test bench. Experiments show that while the FPGA has a higher initial overshoot and slight error due to the fixed point data representation, the overall performance in terms of root mean squared reference error is approximately equal to that of the sequential processor.

Simulations show that the ANC system is able to replicate and control the linear GLTS model as well as a separate nonlinear gimbal model in the presence of noise, with no prior modeling information. Additionally, the simulations demonstrate the resiliency of the ANC system when exposed to attacks, in terms of the above metrics. Finally, hardware simulations confirm the ANC systems ability to control the GLTS model using the FPGA.