Language-Based Control of a Sphere/Tilt-Plate Mechanical System

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Introduction

The control of complex nonlinear systems can be simplified via the use of language-based control. Language-based control allows one to manage the complexity of multi-modal control systems by *quantizing the space of possible controllers,* as opposed to quantizing the control levels themselves.

Experimental Setup

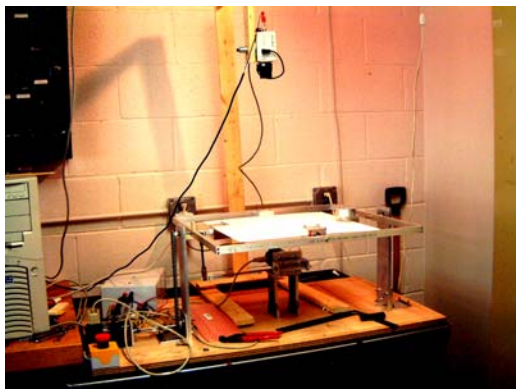

Figure 1: Photo of experimental setup

The system includes:

- 2-axis gimbaled tilt-plate
- Overhead camera with frame grabber
- 2 SilverMax smart motors
- Pentium 4 PC running RealTime Linux

Motors have built-in tunable controllers that accept commands over an 8-bit serial port connection.

The PC locates the ball based on the images obtained from the frame grabber and issues commands to the motors as necessary.

The control loop runs at 14Hz (limited by the speed of image acquisition) and alternates between sending commands to each of the motors. Image acquisition, decision-making, data processing and and serial communications are accomplished using the C programming language.

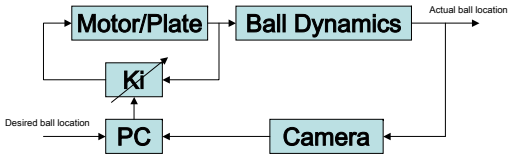

Figure 2: Control System Diagram

$$\begin{bmatrix} \dot{r}_1 \\ \dot{r}_2 \\ \ddot{r}_1 \\ \ddot{r}_2 \end{bmatrix} = \begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \cdot \begin{bmatrix} r_1 \\ r_2 \\ \dot{r}_1 \\ \dot{r}_2 \end{bmatrix} + \frac{5g}{7} \sin\alpha \cdot K_i$$

Figure 3: Linearized equations of motion for the ball. Ki can be $\{0,0,1,0\}^T$, $\{0,0,-1,0\}^T$,$\{0,0,0,1\}^T$, or $\{0,0,0,-1\}^T$

Control Strategy

•**Control the ball using strings generated from four "primitives**": use the motor controllers to limit the tilt angles of the plate to +/-α, where α is a constant.

•**Contain the ball in a small area on the platform** by repeatedly steering it to a desired location in minimum-time.

Results

1. Experimental implementation of the proposed controller.

2. A parameterization of the Containment Region by:
   - •Switching model (time Tit takes to move platform from one setpoint to another)
   - •Tilt angle α.

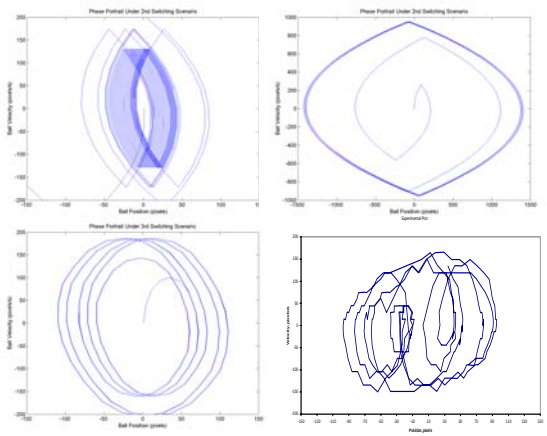

Figure 4: Phase portrait plots of the three switching scenarios and of experimental results

•The first switching scenario assumes that a switch from negative α to positive α or vice versa is made instantaneously, but there is a time delay of T seconds where the plate angle cannot be switched.
•The second switching scenario assumes that the decision to switch can be made at any time but the switch cannot actually occur until T seconds after the decision is made.
•The third switching scenario models the switch as one with a constant angular velocity, and applies this set of dynamics to the ball while the switch is occurring. The switch starts instantaneously when the decision to switch is made but the system cannot switch again until the switch is complete.

Future Work

•Explain the discrepancies between experimental results and simulations.

•Generalize the proposed control strategy to a broader class of dynamical systems.

•Explore other language-based control strategies