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Preliminary Experiments in Robot Juggling: Transputer Based Real-Time Motion Control

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Abstract

In a continuing program of research in robotic control of intermittent dynamical tasks, we have constructed a three degree of freedom robot capable of "juggling" a ball freely in the earth's gravitational field. This work is a direct extension of that previously reported in [5, 1, 4, 3, 2, 7].

The system consists of four major sections, all of which have been implemented on a network of twelve transputers.

Comments

NOTE: At the time of publication, author Daniel Koditschek was affiliated with Yale University. Currently, he is a faculty member in the Department of Electrical and Systems Engineering at the University of Pennsylvania.

Preliminary Experiments in Robot Juggling: Transputer Based Real-Time Motion Control

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In a continuing program of research in robotic control of intermittent dynamical tasks, we have constructed a three degree of freedom robot capable of "juggling" a ball falling freely in the earth's gravitational field. This work is a direct extension of that previously reported in [5, 1, 4, 3, 2, 7].

The system consists of four major sections, all of which have been implemented on a network of twelve transputers:

A transputer based real-time stereo vision system capable of reporting the position of a ball in space at 60 Hertz [6].

A juggling algorithm which continuously maps ball position and velocity (as determined by a linear state observer) to an achievable robot reference trajectory (a direct extension of [4]).

A distributed robot control architecture capable of performing low level robot control at a rate of 1Khz [8].

Adaptive model-based robot control. Improved robot tracking performance through use of smart controllers which "learn" the robot's dynamics [9].

A new 3DOF direct drive robot based on variable reluctance motors supplied by the Superior Electric Corporation.

The development of this system represents the first application of the controllers developed in [7] to a multi-axis robot, and demonstrates the capabilities of the Büghler arm and the Cyclops vision system. Both of these systems have been developed at the Yale University Robotics Laboratory to facilitate our investigations into robot control of intermittent dynamical tasks.

The system (as depicted in figure 0.1) senses ball position via the stereo vision system, and using 3-D triangulation produces an x-y-z position for the ball at 60Hz. The x-y-z position of the ball is then passed into a linear observer, which estimates current ball position and velocity at a rate much higher than the output of the vision system (this is accomplished through direct integration of the newtonian dynamics). The resulting position and velocity estimates are then processed at a rate of 1KHz by the juggling algorithm to produce commands (robot position and velocity) to the robot controller. Any of a family of robot control algorithms is then used to produce torque commands for the robot.

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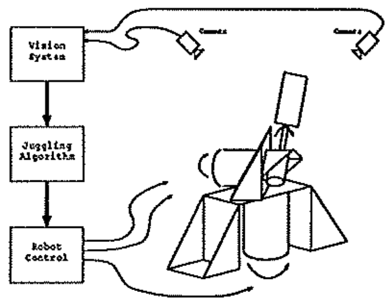

Figure 0.1: Robot juggling system

As previously mentioned the computational burden of this task has been accomplished by utilizing twelve transputers (supplied by the SGS Thompson-INMOS Corporation). Four of these are used to operate the two cyclops vision systems (one associated with each camera), and extract pixel coordinates for the ball at field rate (60Hz). One processor is then used to both perform high level vision tasks (triangulation and velocity estimation) and calculate the robot reference trajectory (evaluate the "juggling" algorithm). A single processor is then used to evaluate the robot control law. Three additional processors are then responsible for performing low-level operations on each of the three degrees of freedom, including such tasks as position and velocity estimation, safety monitoring, and phase commutation. The remaining three processors are delegated to various support tasks such as message routing, user interface, and status display.

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