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An Interactive Control Systems Simulator

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Summary

The Interactive Control Systems Simulator (ICS) was developed at Carnegie-Mellon University (CMU) for use as a laboratory environment in control engineering education. The ICS environment includes: pre-programmed dynamic systems (plants) for which the student can develop various controllers; an easy to use block diagram editor for specifying arbitrary linear control structures; a simulator which displays the time evolution of the nonlinear plant dynamics (via animated graphics) while performing the time integration of the block diagram; a comprehensive plotting package; and a disk I/O system for saving block diagrams.

ICS is implemented on the 32 bit, 68000 based HP 9836C (Pascal Operating System) scientific personal computer. Each workstation includes a high resolution color display (512 by 390 pixels), a data tablet, two 5.25 inch floppy disk drives, 1.25M of RAM, and a 10 Megabyte Winchester disk drive. Over 40 of these workstations are available for student use in three laboratories at CMU.

ICS is menu driven, employing the data tablet as the primary data input medium. Students use the locator pen to construct block diagrams, move between menu levels and invoke commands. Block diagrams are constructed by picking block elements from a menu frame and placing them in a design viewport. Blocks can be placed arbitrarily on the screen with the locator pen and are connected together by drawing paths between them. Blocks may be added, deleted, connected, disconnected, defined or inspected at any time. This complete flexibility in the construction of block diagrams makes ICS easy to learn and use.

Currently, the library of predefined plants includes a movable cart balancing an inverted pendulum, an elevator positioned by an armature-controlled DC motor, a levitation system consisting of a ferromagnetic sphere acting under the influence of a controlled electromagnet, and a two-tank reservoir system with two inputs and nonlinear flow-head characteristics. Each plant has its own set of default parameters which may be altered by the user. These parameters include the physical parameters of the plant, the nominal state for linearization, and the initial state for simulation. The user can also specify the integration step of a 4th-order Runge-Kutta algorithm, the final time of the simulation, the period at which values are sampled for plotting, and the period at which the animation is updated. The plant library is modular to facilitate easy addition of new plants.

The block elements consist of: a *plant* block representing one of the predefined plants; a *compensator* block which allows the definition of arbitrary linear dynamics in state space form; a *time function* block which acts as a signal generator (sine, cosine, step, exponential, square, and polynomial time function definitions are supported); a matrix *gain* block for scaling signals; a *limiter* block for providing signal constraints; and an *adder* block for adding signals together. A *block diagram compiler* checks the input/output dimensions of connected blocks and insures that all block fields are fully defined.

Students at CMU have responded favorably to the use of ICS as a laboratory for graduate and undergraduate courses in dynamic systems and controls. The concepts of linearization, state-variable feedback, asymptotic observers and disturbance rejection are developed in a variety of experiments. ICS is used in conjunction with CACHE, a control system analysis and design program also developed at CMU[1], to provide insight into the power and limits of linear control design techniques applied to the *nonlinear* plants. The block diagram editor and animated graphics help the students develop their intuition for the physical structures of the systems and controller designs.

References

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