Laboratory Projects in
Developing Inexpensive Control System Experiments

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At OSU we have a project that focuses on the development of inexpensive control system experiments. The lowest cost experiments we can build are temperature control experiments. We have, however, developed other relatively low-cost experiments such as the balls-in-tubes and electromechanical arcade. Below are some ideas for how to develop other inexpensive laboratory experiments.

Flexible Robot Joint/Link: One or two links could be used. Control objectives could include vibration damping and tracking. Disturbances and plant changes can be induced in a number of ways. This experiment would require methods to sense angular position, and a motor. Design of supporting electronics must be done to avoid the use of high cost amplifiers for the motor, and high cost angular sensing devices. Can you find a commercially available low-cost optical encoder that has sufficient resolution? Or, should you use a potentiometer? Would you want to measure some end-point variable such as acceleration via an accelerometer? Or, measure endpoint oscillations via a speaker/coil? What is the cost of the supporting interface electronics and data acquisition in each case? What type of motor should be used? DC motor? Stepper motor? For each case how expensive is the supporting electronics and data acquisition? You could configure the arm to be an inverted pendulum, but if you do that add some interesting disturbances (e.g., a half-filled bottle of water at the pendulum tip). Alternatively, you could build multiple-link pendulums, or multiple link robot arms with joint/link flexibility effects.

Level Control in a Tank: One or multiple interconnected tanks could be used. Tracking desired height could be the control objective. Disturbances can easily be induced (e.g., via adding liquid from another source). Controlling water level would likely be a convenient approach. What actuator should be used? A pump? What are the necessary supporting electronics for a pump? How would you sense height? An ultrasonic sensor? A pressure sensor in the bottom of the tank? Via an electronic scale that weighs the tank? Via an arm with a styrofoam ball on one end and with the other end connected to a potentiometer? What is necessary for supporting electronics and data acquisition?

Acoustics: Active noise cancellation experiments with a speaker and microphone may be inexpensive to construct. The challenges include what type of enclosure to use, the characteristics of the microphone and speakers (e.g., bandwidth, frequency response), and the data acquisition requirements.

Pressure Control: Use a container, either of fixed or variable size (e.g., via a balloon), that has variable openings (e.g., to induce disturbances). Insert a pressure sensor, design supporting electronics. Develop some type of actuation technique, e.g., via a fan or pump, along with its supporting electronics.

Humidity Control: Build a scale-model room, with windows and doors. Insert a humidity sensor. For actuation use fans, heaters, cooling elements, or a simple dehumidifier or humidifier.

Mobile Robots: There are many small mobile robots that are commercially available. See the Web. The challenge here is to build a mobile robot that is inexpensive, yet robust. Here are a set of questions to consider. Should you build a wheeled robot? Or should it be a biped, or multi-ped robot? Should it have tracks? Should it be like a hovercraft and self-elevate via fans? What will drive the motion? Motors attached to wheels? Fans? What are the requirements for the supporting electronics in each case? What capabilities will each robot have? On-board processor? Which one? How will you interface to it? Via a serial link, parallel link, or wireless ethernet? What development software will you use? What sensors will you have on-board? Ultrasonic or infrared for sensing objects? A camera? Radar? Do you need a robot arm with a grasper on the mobile robot so that it can move around and pick up things? Do you want it to be able to kick a ball like in the robosoccer competition? For the experiments you envision does the robot need to know where it is at? In some cases, this is a key limiting factor. Do you need to know position in a global fixed frame? Or just relative to objects? Could you just use ded-reckoning? Or, would you need an over-head vision system to find positions and transmit them to the robot? What is the "environment" that you are going to put the robot in? A maze? Should there be randomly placed objects to navigate around? Sometimes floor texture and color impact some of the sensors. What is the robot's objective? Could you design it to do obstacle avoidance? Search and find objects? Could you construct multiple robots, interconnect them with a wireless ethernet, and then study collective robotics problems? Could the group cooperatively move in formation? Perform cooperative search? Perform cooperative moving of an object? Plan soccer against a second team? Another game?

Mobile Agents: One of the key challenges in the mobile robots case is often how the robot knows where it is at. One solution to this is to use what could be called a "pen-plotter" approach. Before modern computers there was a device called a pen-plotter where a carriage held a pen on a piece of paper, and it was held by bars or cables and motors moved it on the x-y plane in order to draw. Encoders where used to know where the pen was at. Fast plotting required attention to dynamics of the carriage. Stepper motors were sometimes used and then the size of its step directly related to how accurately the plotter could draw. Suppose that you think of the carriage as a mobile agent that could have on-board sensors and actuators (e.g., a laser pointer) just like the mobile robot. The environment, placed where the paper in the pen-plotter system used to be, could simulate the environments that are encountered in robotics experiments. Many of the same types of problems discussed above can be studied. It may be difficult, however, to use more than two mobile agents, and it may not be as visually appealing.