EGR 215 Topics in EE Controls and Robotics

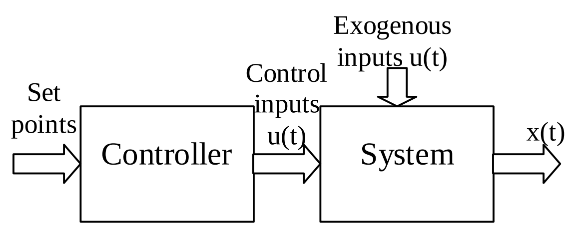
Control theory deals with a set of problems defined as changing control inputs to achieve desired outputs. For example, in driving a car, the desired output may be speed, and the input is how far the accelerator is pressed. Then control theory would determine how far to push the accelerator at any given time to attain a set speed.

Control theory is spread among many engineering disciplines at major universities like the UW. It is roughly equally shared among electrical, mechanical and aero and even astro engineering. Control theory appears in EE because electrical things need to be controlled, and also because **many controllers are built from electronic and electrical components. Today many controllers are microprocessors.**

Central to control theory is the concept of **state**. Systems are defined by a set **of state variables** x_n. **One set of values for the state variables is a unique state of the system**.

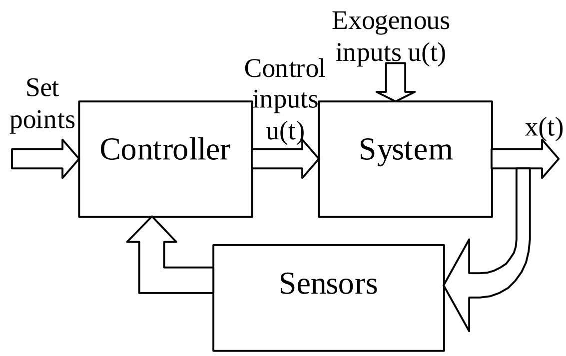
At any given time, the *rate of change* of the values of the state variables are functions of the *values of the state variables*, and of *inputs $u_n(t)$.* The inputs can be control inputs or exogenous (uncontrolled) inputs. For example, in driving, the speed of the car is the state variable, the accelerator position is a control input and the slope of the road, for example, might be an exogenous input. In this example drag causes the rate of change of speed to be a function of speed.

Control systems can be open loop or closed loop**. Open loop systems set control inputs without checking the outputs**. For example, we might know that on flat ground if you push the accelerator in half way, the car goes 55 mph. So to go 55, we push the accelerator in half way, and wait. If the car is on a hill, it won't go 55 and we won't do anything about it. (I've driven behind drivers like this!)



Open Loop

A closed loop system measures the system state and uses it to determine the control settings. For example, the driver may scan the speedometer and if speed is below 55, step on the gas a little more. When the car comes to a hill and starts to slow, the driver will notice the decrease in speed and step on the gas until speed is back at 55.



Closed Loop

Issues in control systems include design of the controller, and **controllability** (the ability to move from one state to any other), **observability** (the ability to find the values of all the state variables), **stability** (where the state variables stay bounded or blow up - amplifier feedback is an example of an unstable system) and **optimality**- the ability to move from one state to another at minimum cost. Cost can be defined in many ways.

Control can also be **continuous** or **discrete time**. In discrete time, every Δt seconds, the controller samples the state values, then computes and updates the controls. The math is a bit different from continuous time.

Finally we should mention **process control, the design of control systems to control an industrial process** like an assembly line or a refinery. Process control involves understanding the process, sensors and control theory and designing and implementing the control system.

Robotics

Robotics is found associated with controls in Electrical Engineering because robots pose some of the hardest control problems. Of course we all have an idea of what a robot is. In its broadest definition, **a robot is any machine that replaces human labor**.

Robots are also interdisciplinary. Clearly they are mechanical in nature, but they are often powered and controlled electrically. **Electric motors are important components of robots, and the control systems and sensors are electrical in nature**.

We can distinguish between **industrial robots**, which are generally stationary and perform a very limited set of tasks in a highly controlled and structured environment, **mobile robots**, in which locomotion (movement) and endurance are significant problems, and **autonomous robots**, which are expected to behave intelligently. Some things we might not think of as robots in fact show reasonable robotic capabilities. Modern passenger airplanes, for example, have autopilots which can do the takeoff, climb, cruise, descent and even the landing without human intervention, including responding in limited ways to the external environment, for example headwinds or potential collisions. However, they would be helpless if the air traffic controller wanted them to go to another landing field.

Robots are cool, and a lot of fun (consider the FIRST competition or Robot Wars). But when you take a serious look at robots, you have to start to wonder why there are not more smarter ones around, and how much they contribute to making life better. Many are remotely controlled by a human intelligence. The ones that are not don't do much that is complex. Robots have rolled over the surface of Mars and into operating nuclear reactors, but all in all the field has to be described as one of unrealized potential.