Introduction to Controls for Automotive Mechatronics
Today’s car is a rolling computer

There are 30-100 microprocessors in a car controlling various systems
The more complicated systems are not just on/off control

They are built up as control systems, not just on/off-logic systems. A control system in its simplest form is the expression of a wish and then its fulfillment.

![Diagram of control system]

The input to the control system is a wish, a desired value. For example, if this were a cruise control system for a car, this would be the desired speed.

The output is the actual value of the parameter that the control system controls. For a cruise control system, this would be the actual speed of the car.

If the control system is working right, the actual value equals the desired value.
A closer look...

How this happens is with a *feedback control loop*:

- "feedback" because the actual value is fed back through a backward-leading path and then compared with the desired value
- "loop" because, obviously, the structure of this system is a loop
Almost all control loops have this logical structure:

- There are four components (controller, actuator, “plant”, sensor)
- The *measured value* is hopefully an accurate reflection of the *actual value*. It is compared against the *desired value* to produce the *error*.
- If all is working as desired, $c = r$, so $e = 0$
Some other points

- As its basic graphical tool Controls uses block diagrams, as illustrated.

- Block diagrams have specific rules that they follow:
  - There is a single input and a single output.
  - The input is operated on by the block contents and then put on the output.
  - A block may be more complicated than it appears. It may not be just a simple block but made up of a number of blocks, like the control-system block on the third slide.

- Since almost all control loops have the standard structure as given, it is very helpful to have this structure in mind when you approach an existing system, trying to understand it:
  - The controller reacts to the error. If the error is non-zero, what you’ve got is not equal to what you want, so something must be done. The controller realizes this and sends a command to the actuator to do something.
  - The actuator is the controller’s agent for affecting the “plant”.
  - The “plant” is the thing controlled.
  - The sensor’s role is to measure the parameter of the plant that is to be controlled.
For a cruise control in a car
Voltage regulator

- The voltage coming out of the alternator should be held at about 14 VDC
- It’s controlled by changing the amount of DC current going into the rotating armature field
- This current can be adjusted using pulse-width modulation for the input current to the rotating field
Regulator vs. positioner

There are two types of control loops—a regulator and a positioner

- A regulator holds an output constant despite disturbances that try to knock it off this value
  - Desired value doesn’t change
  - There exist disturbances
- A positioner is a fly-by-wire system
  - Input (desired value) constantly changes
  - Job of controller is to track the input (make output follow input)
Throttle-by-wire

Non-mechatronic, mechanical throttle

Mechatronic throttle
Throttle-by-wire

- Sensor: potentiometer on throttle valve
- Actuator is a small DC motor on throttle valve, which controls air into engine
- Plant is throttle valve, the thing that’s controlled
- There is also a potentiometer on the accelerator pedal that sense its angle. This is turned into a desired value for the throttle valve. It need not necessarily be 1:1.
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Throttle-by-wire

- This is a positioner system. Accelerator pedal position is constantly changing with normal driving.
- The pedal itself just becomes a way to express a wish. This is true of all fly-by-wire systems. In an airplane, the yoke, stick, rudder pedals are just wish-expressing devices to set the angles of certain control surfaces on the airplane.
- Toyota introduced throttle-by-wire into the American market and there have been innumerable lawsuits surrounding it due to instances of unintended acceleration. But none of these have been proven to have been caused by throttle-by-wire. Rather they’ve been attributable to mistakes, like pushing on the accelerator pedal when it was desired to push the brake pedal, and like having the accelerator pedal get trapped under the floor mat.
- Why have throttle-by-wire at all? Allows computer control of throttle for such things as adaptive cruise control and electronic stability protection.
Mechatronic gear-shift

As you can see, this is a gear shifter with no direct connection to the transmission, so it’s shift-by-wire. Nowadays it can drive either an automatic transmission or a manual transmission without a clutch pedal. Thus the gear shift has become, again, just a means of expressing a wish.

Shift-by-Wire-Gangwahlschalter
Als langjähriger Mechatronik-Partner der Automobilindustrie hat KOSTAL nun im Bereich der Mittelkonsole mit dem elektronischen Automatikwahlhebel eine neue Herausforderung erfolgreich bewältigt.
Mechatronic gear-shift

This shows a shifting strategy for shifting up or down. Generally with up-shifting you drive the engine up to a higher speed before shifting than you would use to shift the gears to a lower gear when slowing.

The gear-shifting algorithm is event driven and is just a switching, not a controller-regulated loop as presented for cruise control or ***-by-wire.
ABS system

The way an *anti-lock braking system* works is also on/off. If a wheel is locked in braking because of low road friction, this is sensed and the braking moment on the wheel is simply released to let the wheel once again not slip on the surface. Then the braking moment is applied again. This can be done very quickly. So this is not a control system in smoothly modulated control as described for a cruise control system or a X-by-wire system.
...and I haven’t even mentioned engine control...

This is a complicated, multiple-input, multiple-output system, not a simple control loop with a single input—the desired value—and a single output—the actual value.
Mechatronic network in vehicle

All of the sensors, actuators, and microprocessors are networked together
There is not a separate processor for each loop, rather the controllers for each loop run together on a scheduled basis in the central processing unit, the central computer. The control-loop structure represents, logically, how the system works. But all the sensors and actuators are physically linked together as was shown in the previous slide.
Our focus today

- We shall focus on control loops, their structure, and how they are used to control systems
- We shall also work on building up your experience with Simulink
- You shall work through a simulation exercise using Simulink, writing a “report” on this as you go.
Some links

New York Times article about electronic car:
http://www.nytimes.com/2010/02/05/technology/05electronics.html

Clemson Vehicular Electronics Lab:
http://www.cvel.clemson.edu/auto/systems/auto-systems.html

Wikipedia on driver assistance systems:
http://en.wikipedia.org/wiki/Advanced_driver_assistance_systems

Braunschweig PDF on driver assistance systems:

Kostal shift-by-wire:
http://www.kostal.com/german/2-01-01-05.html
Some more links

- [http://www.calpoly.edu/~fowen/AutoMech/ElectronicTransmissionControl.doc](http://www.calpoly.edu/~fowen/AutoMech/ElectronicTransmissionControl.doc)
- [http://www.calpoly.edu/~fowen/AutoMech/Ottomotor-Steuerung.doc](http://www.calpoly.edu/~fowen/AutoMech/Ottomotor-Steuerung.doc)