Computer Science 773

Robotics and Real-time Control

WHAT IS CONTROL COMPUTING ?

WHAT IS THE ESSENCE OF CONTROL SYSTEMS ?

There are all manner of possible answers to that question, but I'd like to explore one which I think is particularly appropriate to people coming to the subject from a computing background. It is :

A control system is a way of programming a machine.

Anything which can usefully be thought of as being controlled must at least potentially be able to exist in several states, for the idea of control is to select one (or maybe a subset) of those states, and to devise ways of changing the system state from its present value into the chosen one, or to keep it within the chosen range once there. We must also be able to move the machine from one state to another reasonably predictably by applying some sort of control signal. Well, the control signals are our machine language, and - just as with computers - the aim is to identify a sequence of machine language instructions which, given a suitable initial state, will move the system into a required final state.

That's a view from the side of the programme. As usual, there's a dual - the view from the side of information. It might be illuminating to think of systems and information, which is bringing us into the field of cybernetics. That's entirely proper, as cybernetics is the study of control systems.

The cybernetics view suggests that feedback might be an important thing to think about. Certainly a machine which can't see the results of its actions is likely to be less interesting in its behaviour than one which can. A computer is a good (though rather specialised) example of such a perceptive machine. It performs actions which change the contents of its memory, then it can inspect its memory to determine what to do next.

Computers are not alone in being able to change their own data. Any machine which can both change its environment and sense its environment is in that position - so a robot might move things about in the space around it, and then modify its behaviour because of the changes.

TURING GOT THERE FIRST.

Turing machies are so often thought of as very primitive computers that it's easy to forget that they're not. The original model of a Turing machine is described in completely mechanical terms - it's a device which can sense instructions and the current state of a cell in its infinite tape, and can make marks on a cell to change its state if the instruction tells it to.

In mechanical terms, it's a pretty trivial device operated by just the sort of sequence control we'll talk about later in the course. What Turing's work demonstrated wasn't just that mysterious devices called computers could carry out interesting sorts of computation, but that *machines* could do it.

The picture is further obscured because nowadays if we want to build a clever machine we naturally use a computer to provide the cleverness - but that's only because we've found ways to make very powerful processors incredibly cheaply, and using a computer is the cheapest way to do the job. The interesting thing is the sort of cleverness we want in the machine, and that covers a much wider range than you find in computers alone.

Why do we study the rather artificial topic of computing, restricting ourselves to just one sort of machine ? Wouldn't it be more sensible to study the *real* subject of cybernetics ? Obviously, computing would occupy a large proportion of the syllabus, but there is a lot more to say about controlling machines than just computing.

BUT IN PRACTICE -

We regard the computer as something separate which has the specific task of producing the control input for the "real" machine. That's what the course is about.

(- and then we regard the combination of computer and machine as a machine in its own right. The definitions are recursive : a machine can be composed of smaller machines, some of which might be computers.)

EXAMPLES.

An electric motor. To control the speed you control some input voltage or current. The information input is in the form of this control, whether analogue (a DC motor) or digital (a stepper motor).

A PID controller. (That's a simple general-purpose controller which can be used in many circumstances to keep some controlled quantity constant. We'll discuss it later in the course.) The information input is the settings of three variables, the proportional gain and two time constants. The controller converts an input error signal into an output control signal. Observe that this control signal is in essence the same sort of thing as the information signal needed by the electric motor. (It might need a power amplification stage before you can use it, of course.)

A photocopier. Information input is through the language of possible button operations, perhaps supplemented by the manual operations of moving paper about from one place to another. The output is a collection of printed paper, related to a given input set of printed paper in some way specified before the operation begins. For a complicated copying requirement, one could imagine writing a programme in terms of the "language".

In studying control systems, we're concerned with the relationships between input and output in any systems of these kinds.

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March, 1998.