Computer Science 773

Robotics and Real-time Control

TRANSDUCERS

A characteristic feature of control systems is their strong dependence on interaction with the external environment. Any control system must exercise control, and must therefore send control signals to the environment; all but the simplest must also receive information from the outside for use in formulating their control actions.

A computer (well, the sort we're interested in) deals with two commodities - information and electricity. Machines, by and large, don't run on information, and use more electricity than is provided by, or acceptable to, a computer. If we're going to connect computers to machines, then, we must put something in between to convert external quantities into information and computer-scale electricity. These connecting devices are called *transducers*. We need both input and output connections. Transducers used for input are called *sensors*; those used for output are called *effectors*.

Precisely what counts as a transducer for a computer depends on where you draw lines. If you think that a transducer must convert the physical quantity directly to or from a digitally encoded form, then the range is comparatively modest; this table summarises the possibilities :

	INPUT	OUTPUT
External form	(sensors)	(effectors)
CONTINUOUS (analogue)	Analogue-digital converters, Optical encoders.	Digital-analogue converters.
DISCRETE (digital)	Conventional digital interfaces	
ON-OFF	Switches.	On-off control.

On the other hand, if you don't mind having two or more components in your transducer, the range is enormous; read on.

ACQUIRING INFORMATION : SENSORS.

Apart from operators' instructions and communications activities, which are handled by conventional means, a control system's input comes more or less directly from sensors. If there is a physical variable which you want to measure and have the measurement presented in electrical form, it has probably been done somewhere. The range of sensors in common use is vast. Very many physical quantities can be measured by instruments which give results in a form useful for control systems. (I shall assume that description to imply electrical signals, in line with the course's emphasis on electronic computers.) Any such measuring device can be used as a sensor. Most primary sensors produce a continuously variable voltage or resistance as their measurement of the physical variable. More generally, input signals may come in analogue or digital form; an analogue signal must be digitised at some stage using an analogue-to-digital converter (ADC). Signal strengths are usually measured in volts or millivolts; occasionally microvolts are more appropriate. Some sensors give corresponding fractions of amps. All these are easily interconvertible by standard electronic means. Noise might be a significant source of trouble.

Analogue data are invariably sampled - that is, the values used in the computations are generated by reading the analogue values at selected times and digitising them. In effect, therefore, the control system deals with data that are discontinuous both in magnitude and time.

EXERCISING CONTROL : EFFECTORS.

In contrast to the great variety of sensory devices, there are rather few sorts of output device which are of interest. That is not to say that only a few things can be controlled; it is rather that the required control can be effectively exercised by a few very useful classes of device - motors to move things about, switches of various sorts to redirect electrical power or signals, etc. Indeed, if we restrict our horizon sufficiently, we can say that the *sole* requirement is for an electrical signal of some specified form and power, and leave everything else to be handled by the machinery of the controlled system.

The control system's primary output is a low power digital signal, which is commonly not convenient for direct application to the controlled system. It is therefore often necessary to convert the signal into analogue form using a digital-to-analogue converter (DAC), and some form of power amplification may be necessary.

In other cases, different sorts of encoding are needed. Digital and analogue signals are just two ways to represent a number in physical form; other ways are available, and sometimes very useful. Various pulse-encoding techniques are not uncommon. They work by adjusting the ratio of "fully on" and "fully off" states of the control signal so that an appropriate average agrees with the required control value. For example, a 75% control value might be represented by a signal switched fully on for 75% of the time, and fully off for the other 25%. The essential on-off nature of pulse encoding fits in well with digital systems; there are other advantages too, as the example below illustrates.

A particular problem is the common need for continuous control of the electrical power applied to a device, which might be a large electric motor. In a low power system, the obvious solution is to connect a variable impedance element (such as a variable resistor) in series with the device to be controlled. This is not a satisfactory solution when the power required is high, because much power is dissipated in the variable impedance component : not only is this wasteful, but it must somehow be removed, usually as heat. The heat problem is avoided if the power is switched on and off by a pulse-coded signal, as no series impedance is needed. It even becomes possible to use semiconductor switches (such as triacs) without danger of their overheating. The usable pulse frequency depends on the time constants of the controlled system : with a large mechanical or thermal load, frequencies of 1 Hz or lower can be used, but it is also possible to control mains power cycle by cycle (50 Hz), and to handle even higher frequencies if need be.

ISOLATION.

Computers are built from digital electronic devices which work at low power with low voltages and small currents. They are often connected to devices in which much less docile forces, electrical or otherwise, are active. It is therefore usually necessary to ensure that the raw power of the outside world cannot get into the sheltered environment of the computer, so every interface is likely to incorporate some sort of isolating system. These can take various forms; a common method is to use an *optical coupler*, in which digitised incoming signals are converted into light pulses and detected by a photocell. Then even if something goes terribly wrong in the outside world, the effects will not reach the computer's electronics.

Alan Creak,
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