Recently I had occasion to review a control system design specification as part of a tender estimating exercise. The document had been prepared by one of the better known engineering firms in Brisbane. I was not surprised to find that every process control loop in the design made use of a PID controller even in applications where they were inappropriate. Lamenting the ubiquity of this type of controller, usually in the absence of any consideration of a more up-to-date approach, I resolved to do something about it. And that is how this article came to be.

The PID controller has three independent control terms, proportional, integral and derivative action. It might more properly be called a three-term controller if only to avoid the acronym. I frequently find myself counselling my mentee engineers to consider carefully whether they should choose to use what they deprecatingly refer to as a “pidloop”.

The three-term controller is now well past its 75th birthday having first appeared in the mid 1930’s although negative feedback control has been around since James Watt and the flyball governor. I have taken the liberty of including a photograph of technology the same age as the PID controller just to make the point.

Technology the same age as the PID controller.

The Fairey Swordfish photograph was taken by Lt C H Parnall, official Royal Navy photographer. The photograph has expired copyright.
The question frequently arises in my mind, “If the technology is so old why are we still using it?” To be honest I do not really know. This controller style is still taught in university courses as the practical controller of choice but we no longer teach navy pilots to fly biplanes to launch torpedos. Alongside the three-term controller we also teach controller tuning methods of the same vintage. The two Ziegler and Nichols methods were first published in a single paper in 1942. In contrast, my forthcoming book on controller tuning methods is running at about 200 pages so far. Such are the enormous advances in process control applications and techniques since the early 1940s. Notwithstanding the brilliant contribution Ziegler and Nichols made, nowadays, 73 years on, when you read their paper you realise how much more we know and how absurd it is to continue teaching their methods.

My feelings about the matter is that it is mainly a lack of knowledge that better and more modern techniques exist and an unwillingness to pursue the skills and knowledge required. Relevant knowledge is exceedingly difficult to find because it requires a rigorous use of classical control theory with a particular flavour applied to a great deal of operational (i.e. control room) experience and such a combination is rare both in the university classroom and in the engineering design office.

Process control is still seen by many engineers in other disciplines and by engineering managers as something of a mystery. This may be because, alongside telecommunications, it is one of the most the mathematical of all the engineering disciplines. Accordingly, from a project management perspective, investing time and money in the pursuit of better and more modern design solutions is not seen as cost effective when you can simply use the tried and tested antique which will work after a fashion. The trouble is the PID controller does not work well in today’s world any more than the Fairey Swordfish is an effective fighting machine even though the Swordfish will still fly.

I am suggesting, now, that the three-term controller is past the end of its useful life and for those who might ask, “why”, there are some very good answers. For a start, it is an analogue algorithm not a digital one.

The first three-term controllers were mechanical devices operating on gears, discs and piano wire. You can find recording thermo-hydrographs in antique shops and they use pretty well the same sort of technology. Or you could pull apart a Bourdon Tube pressure gauge and you will get the idea. The second generation controllers were analogue pneumatic or analogue electronic. Analogue controllers were used until about 1977 when the microprocessor arrived and Honeywell invented the first distributed control system. Modern distributed and programmable controllers have floating point arithmetic, elegant mathematics and artificial intelligence such as the fuzzy logic controller which is absolutely unbeatable in applications such as SAG mill control or thickener control. But still, the original three-term controller marches on, barely coping except to successfully reproduce itself in countless engineering design offices.

A second very good reason why we should cease using the three-term controller is that it simply does not work particularly well. Of the three terms in the PID controller, the proportional control action must remain the standard algorithm on which other algorithms are built. Its primary role is to handle the dynamic adjustments to the plant process.
Integral control action has but one function. It is required only to remove the steady state deviation, a simple task, and yet the penalties for using it are severe. Integral action is so destabilising that it causes frequent stoppages and wild oscillations in applications as diverse as apron feeder and conveyor belt control to surge tank and bin control. I have recently witnessed water pipeline pump stations oscillating wildly (one cycle every thirty minutes) because of the use of badly tuned PID controllers on the variable speed drives. The cycle time was caused by the interaction between pump stations a few kilometres apart. Many mines in the Pilbara suffer from apron feeder problems for the very same reason, integral action reacting against belt transit times. Integral action windup is also a frequent source of serious control problems including unexpected tripping of plant when a control loop becomes frustrated. More trustworthy techniques are now available making use of superior mathematical tools. An Australian company, Renfell Engineering (renfell.com) is marketing a copyrighted algorithm, the adaptive offset removal (AOR) algorithm as an optional replacement for integral action in its distributed data acquisition and control (DDAC) modules. This is a digital technique that doesn't have any of the bad habits of analogue-based integral action. It uses a model-based estimator to identify the source of the offset and it adaptively cancels it out.

Derivative control action was designed in the 1930s as a kind of “accelerator pump” similar to the one in a carburettor. It amplifies process noise so severely that most site-based control engineers remove it. It was originally marketed as the elusive “anticipatory” or “predictive” control under the trade name “pre-act”. In most cases it works so badly that adoption was slow at the time it was introduced. Ziegler and Nichols say that in some cases it gives good results but often it is, “worse than useless”. Derivative action is only of value in rock-solid consistent noise-free processes, and if you really need the performance then the trick is to use root-locus methods to precisely place a zero in the control loop. Modern hardware, especially actuation, is so efficient and fast that derivative control has very little to offer.

A mistake, regularly made by engineers and technicians who are unable to tune their PID controller is to introduce some artificial deadband. Artificial deadband should only be used to counteract process hysteresis such as gearbox backlash. Use in any other context will create a complete lack of control at the time it is most critically required, close to the setpoint.

Another reason we should cease using the three-term controller is that process control has moved on a long way since the algorithm was first devised. Before about 1980, industrial processes were all manual in operation. In that context, having a single loop controller that regulated temperature or flow-rate was a bonus. All the operator had to do was set the desired value and the analogue controller took care of the adjustments.

Modern industrial processes are very complex. Material is expected to feed right through the plant from beginning to end and every section has to maintain precisely matching flow-rates and feed-rates. Operators are expected to be “hands-off” and the modern plant is expected to be robust enough to handle small disturbances such as raw material variability without tripping and to still deliver consistent throughput and product quality. Our analogue 1930’s controller is out of place in such a setting.
In a modern plant, even modest modifications to control strategies deliver spectacular results. In my personal experience, I have witnessed 20% extra profit in a foodstuffs plant from a single change, 17% extra gold from a processing plant including 3.5% additional gold from a single application of feedforward control, and many similar results. Replacement of PID controllers with something better can return project payback periods that are frequently weeks, days or even hours. The main difficulty is that the results can be so spectacular that potential clients do not believe them.

Lately a colleague asked me if I could envisage a day when a large process plant contained not a single PID controller. Yes I can, but explaining the alternatives is difficult simply because it is a technical question with a very technical answer. There is a wide range of solutions, each providing an optimum control strategy to suit a specific application. There is no longer a “one size fits all” answer because of the complexity of any modern process plant. Techniques I use range from a selection of feedforward algorithms, the newly developed AOR algorithm or even the spectacularly successful fuzzy controller.

In a modern alternative design, a senior experienced process control engineer would be engaged right at the start of process concept design. They would encourage the chemical, process and mechanical engineers to envisage a fully automatic self-correcting process plant that will basically run itself. The control system would be model-based. The model would estimate controller settings and drive flow-rates, feed-rates, pump speeds and thus leave the proportional-only control to make the fine corrections. This is model-feedforward control on a plant-wide scale and far superior.

Inferential measurements from the controller adjustments can be used to determine process variations such as raw material variability, ore hardness and so forth. In a really modern approach to process plant control, the system can learn about plant behaviour and modify itself. This is a technique that has been in use in other applications for many years; the fighter aircraft that self-adjusts for battle damage, or the ocean-going yacht that rights itself after a capsize. For anyone who does not believe this is possible, do yourself a favour and watch this lecture by Raffaello D’Angelo. In particular, watch as the three ‘copters catch a ball in a net, learning on each attempt to make a better catch. The internet link is: [http://www.youtube.com/watch?v=w2itwFJCgFQ](http://www.youtube.com/watch?v=w2itwFJCgFQ).

In the end, what the process and mineral processing industries needs is a revolution in the way we design control systems: a paradigm shift, in fact. In order to do this we need access to highly skilled advanced control systems designers who come with a great deal of experience coupled with a sophisticated level of theoretical background. Engineers of that calibre do not emerge from universities as new graduates and so that implies some high quality post-graduate training.

Project managers also need to recognise that the design of a process control system for a modern process plant is no trivial task and it requires a lead engineer who is skilled at advanced control system design.
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