

Get in Control

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Early steam engines used one of the first forms of feedback control to regulate their speed. The Watt governor, developed by James Watt, used a centrifugal pendulum to stabilise engine speed, achieving course speed regulation via a system based on mathematical and physical principles.

By the beginning of the 20th century, control theory was well-established. Dynamical systems were understood, giving rise to mathematical implementations of controllers and stability analyses. By the 1920s the first form of Proportional Integral and Derivative (PID) Control was developed. And with the advent of electronics, negative feedback became widespread. Now plants could be controlled in a closed loop and with zero steady state error. PID control went on to be the most popular controller in automation. This is partly due to its simple implementation in analogue or digital form.

Notwithstanding its simplicity, PID control was found to be limited in scope. With advances in avionics and automotive engineering after the 1940s, more complex control solutions were required. Plants now comprised of several actuators and sensors and presented nonlinear behaviour. Several forms of control were developed to tackle these challenging systems: nonlinear, optimal, predictive, adaptive, H-infinity, state-space, deadbeat, sliding mode, etc.

At Cambridge Consultants, we deploy mathematicians, physicists, software, electronics, mechanical, and control engineers to determine the optimum realisation of a system from a control point of view. We have an established design methodology to take theory through to development, and our hardware and software tools enable us to quickly develop complex algorithms and develop deployment control code for microprocessors or digital signal processors (DSP). With these at hand, we are no longer limited to

simple PID control loops in microcontrollers. We can in fact design a complex control system for low-end floating point DSPs at a similar cost to PID implementations.

Our latest control system design example is a project for Caterpillar Inc. as part of a larger programme co-funded by the Technology Strategy Board. With more stringent legislation on diesel exhaust emissions of non-road vehicles, Caterpillar required intelligent solutions to reduce cost whilst achieving legislated emissions targets. We developed a control system for heavy duty diesel engines equipped with a variable geometry turbocharger (VGT) and an exhaust gas recirculation (EGR) valve. The plant is intrinsically multivariable and has strongly coupled variables. Moreover, the behaviour of the system is nonlinear and exhibits phase changes in some operating regions. We developed a multiple-input multiple-output Adaptive Model Predictive Control, where the control variables were the VGT and EGR settings and the plant output variables were intake manifold pressure, compressor mass air flow, exhaust nitrogen oxides emission and opacity. The algorithm we generated finds an optimal control law that maintained the plant outputs close to their optimised set-points and also adapts as the engine changes operating region in order to cope with non-linearities. It was proven to regulate all four variable set-points 35% better than simple PID control and we proved emissions reduction of up to 15%.

There is no doubt that the 21st century will see rapidly increasing automation in our industries and at home, with an ever-present focus on environmental impact and control. The availability of cheaper and more powerful microprocessors and DSPs means that now, even the most modest system can utilise advanced control algorithms.

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