Theory and Practice

We all know about the gap, now let's do something about it!

It's a new year and a resolution is appropriate. The theory-practice gap has existed for decades and each of us needs to bridge this gap in all we do. As control is an essential element in all multidisciplinary systems, let's start there, and begin to bridge the gap that exists between the theory of control and its digital implementation. Top Ten Lists are always popular, so here is one for classical control; call it Control Theory for the Practitioner.

1. Feedback control is a pervasive, powerful, enabling technology that, at first sight, looks simple and straightforward, but is amazingly subtle and intricate in both theory and practice.
2. In a dynamic system, changes cannot be effected instantaneously, and so an otherwise correct control decision applied at the wrong time could result in catastrophe.
3. Nonlinearities are always present, e.g., backlash, Coulomb friction, saturation, hysteresis, quantization, dead band, and kinematic nonlinearities. A linearized model can be used to approximate a nonlinear system near an operating point.
4. Stability of a dynamic system must be guaranteed. Closed-loop systems go unstable because of an imbalance between strength of corrective action and system dynamic lags. Stable systems must have adequate stability margins to work once built.
5. Stable systems have a frequency response. If a stable linear system has a sinusoidal input applied, then the steady-state output will be a sinusoid of the same frequency, however, the amplitude ratio and phase difference of the two sinusoids are frequency-dependent.
6. The open-loop transfer function is the product of all the transfer functions in the loop, i.e., controller, actuator, plant, and sensor. Compared to the closed-loop system transfer function, the open-loop transfer function is much less complex. The Nyquist criterion and the Root Locus procedure allow one to use the open-loop transfer function to predict closed-loop system performance.
7. After stability, performance is everything. Command following, disturbance rejection, insensitivity to modeling errors, and insensitivity to unmodeled high-frequency dynamics and noise are the main reasons for using feedback control, once a system is guaranteed to be closed-loop stable.
8. Time delays can be deadly. Always conserve phase, the equivalent of time delay. Integral control adds 90° of phase lag at every frequency and digital control adds time delay primarily due to D/A conversion. Imagine trying to make decisions using old information.
9. High control gain has lots of benefits, e.g., good command tracking and good disturbance rejection. However, there are three areas of concern: roll-off, saturation, and noise.
10. People's lives may be at stake. There are no "details" in control engineering, as even the most insignificant "detail" may prove to be important. Real control systems must be extremely reliable, especially if people's lives depend on them.

Maybe you know all this, but it is worth repeating. Now, let's put some of this theory into practice. On the Design News website, you will find a case study that bridges the theory-practice gap regarding something we all need to be able to do: implement speed control of a motor, with an attached incremental optical encoder sensor, using a microcontroller with a PWM output to drive an H-bridge. It doesn't get any more down to earth than that, yet this exercise uncovers gaps that are present for many of us. The microcontroller is the widely-used, inexpensive Arduino, the motor is a 12V Pitman brushed dc motor, the optical encoder is three-channel with 500 counts per revolution, and the H-bridge is the L298. MatLab/Simulink real-time code generation is used. My resolution is to continue bridging the theory-practice gap with articles and website case studies. Happy New Year!

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