How fuzzy can you afford to be?

Now, after the hype has gone, we want to take a critical look at this technology to see if it has fulfilled its expectations. Let's start by positioning fuzzy control relative to other advanced control technologies.

Levels of control

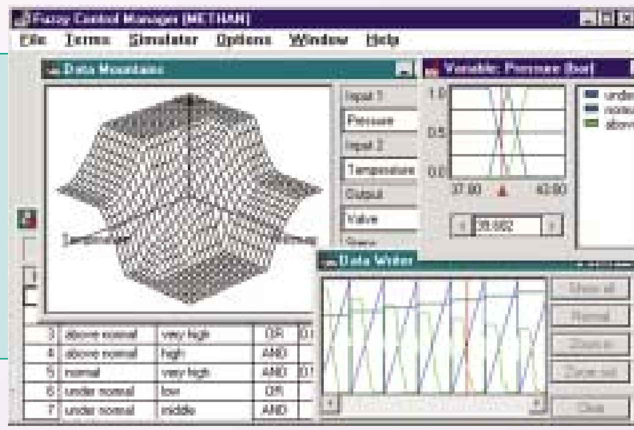
Steering a production process means fulfilling various objectives and is therefore done in a hierarchical way. The very lowest level is relatively easy to control – the basic need is to have some way to interact directly with the process.

A typical example is flow control. Clearly, it is not very difficult to reach and maintain a desired flow rate by manually adjusting the valve opening, but it is simply much more convenient to enter a setpoint and let a controller do this automatically. At this level we use mostly PI-controllers or sometimes even switches. There is no need for sophisticated controls.

The next level aims at mastering the dynamic behavior of the process. Here we have speed, level, pressure and temperature controls. In most cases the task is not very complex and therefore typically the standard PI or PID controller is sufficient. We have seen fuzzy controls and other advanced techniques being used at this level, but this is generally due to a lack of knowledge and experience in the use of PID control, rather than at a real need for advanced process control (APC) at this level

Only in a few cases is APC truly needed, and this is usually in situations where there is long dead time, or a high ratio of deadtime to time constant, or due to interactions between process variables.

Higher demands are made at the next level, the control of product quality. Here



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we usually have to deal with a relatively large number of influences. The process behavior is typically more difficult: The measurement or analysis time can cause long delays in the information update and difficult dynamic effects such as overshoot or inverse response are not infrequent.

At this level the PID-controller may struggle to deliver the required performance – and it may prove to be completely inadequate. This is the area of the main application of APC and therefore we will confine our discussion of fuzzy controls and the alternatives to this level.

Expert systems

One of the new technologies that has found a broad number of applications is expert systems (ES). These were quite popular during the 1980s. An ES is based on rules like If the temperature of the product in the reactor is too high, then we have to cool more and If the temperature of the product in the reactor is much too high, then we have to cool much stronger. These rules describe in most cases the normal interventions of the operators. They are not based on any process parameters or first principles, therefore ES applications do not require plant tests. They require, however, solid expertise.

Today, most of these applications have disappeared. We only find a few of them left in the plants. A key problem encountered with expert systems was the lack of a consistent, solid expertise – as opposed to different opinions by different operators or support staff. Tests would have delivered the needed information, but these would have taken away what was considered a great advantage of ES. Also the

Fuzzy logic was introduced in process control about 15 years ago and was welcomed with an enthusiasm never seen before. Fuzzy control became the dominant theme of many process control conferences and seminars for years.

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handling of the rules requires special algorithms or even programming languages. Finally, the improvement over manual operation was not always very exciting.

Fuzzy logic

Fuzzy control can be viewed as a refinement and expansion of expert system technology. As with expert systems, rules are used in order to determine the corrective action. However, fuzzy logic allows you to give a better meaning to such vague descriptions as 'strong cooling' or 'much stronger cooling.' Therefore we should expect better results than from ES technology.

Again, there is no need for plant tests which could be quite time consuming and/or difficult to do. However, there is still a certain (inherent and accepted) uncertainty and vagueness in the results – just as the name says. Therefore we cannot expect truly precise results. This actually is the performance limitation of fuzzy control.

And there is another disadvantage of both expert systems and fuzzy control: Both are not fully aligned with the basic philosophy of APC. The first and most important objective for the use of advanced technologies is definitely to improve operations, which is made possible and secured by means of automatic control. In other words, by simply automating the way the operator interferes with the process, without the development of improved strategies, we cannot expect to get the full advantage. Furthermore, in order to improve operations, sound knowledge of the process behavior is a key prerequisite. Both expert systems and fuzzy control are based on capturing current routines and do not inherently require or produce deeper knowledge of the process.

Model based predictive control

The situation is completely different for model based predictive control (MBPC). Here the static and dynamic behavior of the process must be thoroughly investigated and the proper descriptions of that behavior obtained – the model. Having acquired sound and quantitative knowledge of the process we are now in a position to interact much more precisely. This ultimately will not only lead to better performance of the controlled variable(s) – our primary objective – but also enable us to deliver it with smoother action on the process and therefore often with reduced consumption of the resources.

To see what that means for the industry, let us take a look at the situation in oil refineries. They are the most experienced users of APC because, for decades, their profit margins have been very small, and as a consequence of the thin margins they have exploited every means to help profitability. The performance of the key process variables has quite a strong effect on oil industry economics, and these effects and mechanisms are well known by petroleum refiners.

In most plants in other industries neither the actual dynamic performance of the key variables nor the price of the lower performance is known. This is a tremendous disadvantage. Oil refiners have investigated the benefits of APC extensively, and especially since the first oil crisis in 1972 and have made exhaustive use of it. However, most of their work is unknown to the rest of industry. They do not normally publish any 'success stories,' in order not to give away any competitive advantage.

In this extremely competitive environment fuzzy control has also been studied in depth and applied in some cases, just as expert systems before. But today there are hardly any of fuzzy or expert systems in use. With the enormous pressure on cost and therefore on control performance, MBPC has become the technology of choice wherever the PID is not suitable.

Conclusion

The above leads us to the following: The PID controller is and will be the standard controller for simpler and less demanding tasks. New technologies have not changed its leading position.

For control of more difficult situations, where PID is incapable, we have now the choice between fuzzy control and MBPC. Model based predictive control will normally deliver better results and is therefore the PID alternative of choice. Also the development effort is typically comparable to that for fuzzy control applications.

For MBPC we need to obtain a suitable process model. This is in most cases less difficult than generally believed, but there are situations where a suitable model can only be developed with very high effort or even not at all. In these cases we need to resort to fuzzy control.

From these considerations we can also see that we need to have a complete 'technology set,' a number of selected technologies ready for use in the DCS in order to be able to address any process control task for any process type and any performance demand in the best possible way. ❖

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