Fuzzy control
Facts, Japan, and Europe

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Foreword

This is a slightly updated version of an older memo in French, which was never intended to be published in a French journal, let aside in a European one. The idea was rather to settle my mind, and have an answer ready to the very many requests I recieved about fuzzy control, mainly due to the abbundant advertisement it enjoyed in the non technical press. A few things I wrote about where fuzzy control is being applied are not compltely true anymore. But I believe that globally the idea remains correct.

The original version bared a foreword acknowledging the help of Jean-Marie Nicolas and Michel Grabisch, both of Thomson-Sintra, France.

Framework and limits

The general theory of "fuzzy" logic currently enjoys a rapid developpement with many applications, specially in Japan. What I write here is narrowly confined to fuzzy **control**. This is only one of the many applications, although often advertised as the most prominent one. It is in no way the only one. I know, and say, nothing about applications to such things as knowledge representation (which was the original motive behind fuzzy set theory), expert systems and the like.

1) Fuzzy control in Japan

The basis of fuzzy control is to express a control law in terms of expert rules. The rules define the control value, or its rate of change, for some (range of) values of the measured variables or their rate of change. The specific techniques of fuzzy set theory can be seen as a systematic way of interpolating the data points.

The language used is one of sequential decisions, and as such is always applied to control problems which are fundamentally conditional sequencing problems, and where the continuous control part is completely elementary. It is symptomatic that the yardstick used to juge the efficiency of this control is always the PID. Take the often quoted example of a bathtub hot/cold water mixer. It takes into account the fact that the water that first flows when one opens the hot tap is cold, and therefore reaches the desired temperature faster than a fixed gain PID. A "success" of fuzzy control.

In its original form at least, fuzzy control shares the ideology of expert systems to automatise what an expert knows how to do, not to do things no human expert can do. The motive of research in fuzzy control is therefore not to push back the limits of what automatic control can perform, even less to *prove* things about the performance of a control mechanism, such as stability, optimality, sensitivity. As in expret systems, experimentation is the means of validation.

The single stick balancing problem is also often quoted as test case. I consider it unfair to fuzzy control. As a matter of fact, it is a simple problem, with no sequencing involved. As a consequence, for a single boom, adjusting the coefficients of a PID that would do the job is much faster than using fuzzy control, and for the double boom *with no measurement of the upper boom's angle with the lower one*, an human expert cannot do it, nor fuzzy control control either.

I think fuzzy control is a good tool where it applies, and I shall come back to that point in the next section. However it has been oversold on unjustified grounds, which obliges us to review some of the claims made.

-1) *Gentleness.*" Because it is fuzzy, fuzzy control is more gentle to the user than classical control which, for lack of fuzziness is by its essence bang bang". Do not laugh, this has often been said. It impresses the ignorants and the newsmen. The people who said that may have been themselves more ignorant of what control is than outright dishonest.

-2) *Ease of implementation.* This requires a more careful examination. The proponents of fuzzy control acknowledge that there are very many parameters to chose to setup such a control law. If the comparison item is PID, then the later is clearly easier to implement. If the comparison item is a problem that the PID would not solve (or a PID with, say, cubic terms added to it), then one has to look at the boundary of the possibilities of fuzzy control. And the simplicity is gone. (It requires something like 49 rules to balance a single stick while maintaining control of its tranlation). As a matter of fact, the very idea of what is simple depends very much on one's educational background. What *is* true is that fuzzy control lets one solve control problems with no mathematical education whatsoever. Where a more fundamental simplicity comes in is when the overall problem contains both conditional sequencing and simple continuous control. Again we shall come back to that.

-3) *Robustness.* I have seen no publication that scientifically substantiates the claim of greater robustness of fuzzy control as compared to modern control, nor any that disproves it for that matter.

-4) *Lower computational requirements.* This I consider as a false claim. The method of iterpolation used is computer intensive (all rules are continuously evaluated and their conclusions weighted according to their degree of truth in a sophisticated way). What *is* true is that this is of no real importance, because thanks to specialized chips, it is cheaply done.

A definite weakness of this approach is that the inherent complexity of the interpolation process induced makes it essentially impossible to *prove* anything about the control laws generated. Anyhow, this poof would not be in the spirit of the method : the human controller does not "prove" his know how either.

Let us quote the three reasons Dr Sugueno (scientific director of Laboratory for International Fuzzy Engineering) gives for the success of fuzzy control in Japan:

i) The carefull choice of the applications
ii) The quality and the efficiency of Japanese engineers
iii) The good fit with japanese way of thinking

We leave it to the reader to interpret these explanations. The last one should not be underestimated, coupled with an "invented here" syndrome, in a more nationalistic society than ours.

One could deduce from the above that there is little more than a regression from mathematical analysis to empirical imitation of the human operator, and disregard the whole story. I believe that this would miss the point.

2) The European response

The chalenge is less scientific than industrial. It is threefold.

The first striking fact is the wide range of *elementary* applications that have been widely quoted as success stories for fuzzy control. The good idea there is not to have included a *fuzzy* digital controller, *it is to have included a digital controller.* Japanese industry has been the first to understand that digital devices are from now on cheap and reliable, and to draw the practical consequences, that they can be put to use in cheap home appliances and other aparatus.

The response of Europe here should be to encourage our industry to use digital devices more extensively to improve consumer products.

A second remark is that qualifying simple control problems as "research" (since fuzzy control was new) has given the Japanese university scientists an opportunity to discover the pragmatic questions that standard industry had to face. What they discovered were problems were the practical difficulty to use commercially available tools was to make coexist simple continuous time controls with complicated sequencing tasks. What fuzzy control brought them was a *single language* to describe both, in terms of expert rules.

A european response might build upon the clear European lead in synchronous programming. But then such tools as the new real time languages (ESTEREL, SIGNAL, LUSTRE, to quote the three that cooperate in France) should be carefully hidden to the user, deeply burried in a system providing an elementary interface, devised to let the user solve elementary control problems of that type, with little control knowledge.

The genial feature of the Japanese fuzzy control culture has been to bring a tool well suited to their engineers (with little, if any, control engineering education) to solve **simple** problems. (And fuzzy control has been a good excuse, because it is unable to solve advanced, multivariable, control problems).

There *is* a niche for fuzzy control, or any tool sharing the peculiarities we described, (and better ones might be devised : fuzziness is not unavoidable in that respect. The real important feature is rather *rule* *based control*) that we would be foolish to ignore, mainly since larger economic dividends may be at stake with simple problems than with advanced ones.

3) Conclusion : industrial issues

The formidable advertisement that fuzzy control has enjoyed in the (mainly non technical) literature is of course not devoid of commercial aims. This is not the place to analyze them in details. Let us just recall that since consumer products are concerned, the non technical press was indeed the place were this commercial drive had to be carried out. Later will come the market for the specialized chips.

Finally, my friends in industry drew my attention to a last point which is probably not the least important one. This very article serves the purpouse of entrenching the idea that there is a completely new theory behind fuzzy control, since it is being debated in scientific circles and universities, in Japan first and now in the US and Europe. If this is a completely new theory, nothing that is constructed refering to it can fall under old patents. Therefore, Japanese industry is instantly freed from all previous patents. It is straightforward to program (approximately) a PID controller with saturation using fuzzy control. Because it will be a fuzzy controller, it cannot be challenged by an old patent. And of course this is true of many other devices.

This is a question to address for industry, not academia.