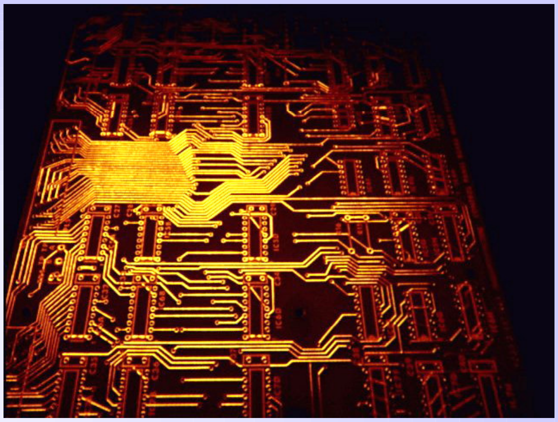

A Close Shave with Occam's Razor

A Report from the Fuzzy Logic Revolution

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PCAI

Entia non sunt multiplicanda praeter necessitatem
Entities should not be multiplied more than necessary
Roughly, Don't screw around with simplicity.

Occam's Razor
William of Occam (c.1285-1349)

Eppur si muove!
But it does move!

Galileo Galilei (1564-1642)
Said after his recantation
– that the earth does move around the sun.

As revolutions go, the fuzzy logic insurrection has been somewhat of a bust. Conducted out of the public's view, its battles are waged among academics, computer pundits, and a larger world of fading artificial intelligence gurus. Locked into battle over the name itself, both sides seem less interested in the epistemology of logic than in the surge of emotions and adrenaline released by evoking the very phrase *Fuzzy Logic*. Even its soldiers and revolutionaries have been a rather motley bunch of inept warriors. Its adherents, the revolutionaries, have long ago declared victory but are unsure of what they've won. Its opponents, the scientific establishment, simply snicker and go on writing pernicious critiques of the technology with only a minimal knowledge of its mechanics. Unfortunately, the revolution has not had its share of great martyrs, forced under pain of death or excommunication to recant their convictions with a baleful cry "But it does Work!"

Compounding the confusion, the core proponents of the technology, the founder and his band of disciples, isolated in their academic universe, confuse fuzzy logic's real nature by devising even more problematic names for the technology such as *soft computing*. Thus, we would-be architects of modern business systems (whose foundations could greatly benefit from fuzzy logic) are forced to convince cold, bottom-line oriented business executives that fuzzy logic is not fuzzy nor is soft computing soft.

But the paradigm shift moves over us with an ineluctable swiftness. A gusher of fuzzy control devices is streaming out of Japan, Korea, and Singapore: VCR imagine stabilization, antilock braking systems, dish and clothe washers, context sensitive environmental controls, real-time video noise reduction, retinal identification chips, and - in Japan - the best selling fuzzy rice cooker. Lotfi Zadeh, the inventor of and tireless advocate for fuzzy logic, speaks of a Machine Intelligence Quotient or MIQ when he explains how fuzzy logic adds increased power to ordinary appliances with little increase -- and often a reduction -- in complexity. Yet this same explosion of fuzzy control applications has given rise to the mistaken impression that fuzzy logic is some kind of engineering tool, relegated to eight and sixteen bit microprocessor chips buried in the brains of thermostats, cameras, cars, and self-cleaning refrigerators.

Nevertheless, the control applications of fuzzy logic represent only the smallest fraction of how this technology will eventually be used. Fuzzy Expert and embedded decision making systems are destined to change our daily lives and the way we work with steadily more intelligent machines and software systems. Already fuzzy decision systems have become an increasingly important part of business process modeling, knowledge discovery, and a broad spectrum of both diagnostic and predictive systems. Yet designers of intelligent systems and AI tools, in their haste to pigeonhole fuzzy logic and their inability to see, in its deep epistemological roots, a powerful engine for expressing and managing knowledge, have missed an opportunity to bring this machine reasoning paradigm to bear on today's complex, nonlinear business and strategic planning problems. To see how, in fact, fuzzy systems are emerging as crucially important business tools, we will examine three actual applications.

Substance Abuse Treatment System

A medical informatics company specializing in substance abuse treatment regiments for state and local governments, built a fuzzy Case-Based Reasoning system to meet the demands of deploying a computerized patient profiling and treatment system. With over fifteen years of patient profile, treatments, and carefully monitored outcomes, they knew that the data contained the necessary patterns linking patient profiles with successful treatments. That is, since they knew (or suspected)

$$o_p \leftarrow f(P_p, T_p)$$

that is, the outcome of patient (p) was, statistically, a function of the patient profile and the treatment, they needed to reorder the equation to,

$$T_p \leftarrow f(P_p, g(o_i) \geq \theta)$$

so that the treatment for a patient with a particular profile (P) was a fusion of the successful outcomes (that is, were the patient stayed drug free for a period greater than some threshold). They built a fuzzy rule-based system that treated the clinical history as a case repository. Figure 1 illustrates schematically how the application worked.

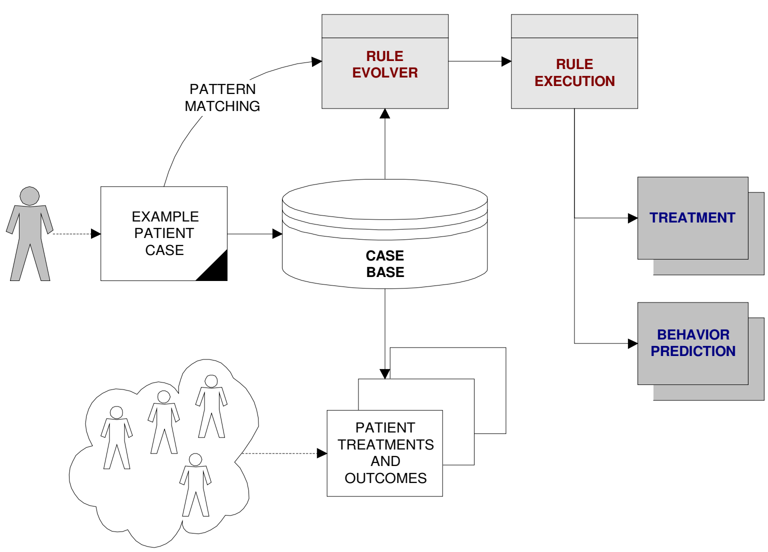

Figure 1. The Fuzzy CBR System

Using a fuzzy rule induction technique, the case base is essentially mined to find the rules that couple the proper treatment to the patient profile. This also solves one of the long standing problem with Case-Based Reasoning, finding and implementing the transformation function that takes a specific case and generates an solution case. In this case the system not only accurately predicted the correct treatments (when measured against a board of medical experts) but also predicted the long term stability behavior of the patient.

This same fuzzy Case-based Reasoning approach has been successfully used in such applications as managed health case fraud and abuse detection, cross-marketing and client profiling, criminal - actually suspect – identification, and an intelligent buyer's advisor.

Mergers and Acquisitions Analysis

The mergers and acquisitions analysts of a New York metropolitan bank routinely search large public and private database to find suitable candidates for their corporate clients. The criteria for selecting a candidate are often imprecise and subject to a fine grain interpretation by the analysts. In order to standardize the search vocabulary and provide the ability to search on the analyst's *intent* instead of a rigid boolean algebra, they implemented a fuzzy SQL processor. In this way, they can interrogate a database with such flexible and semantically powerful queries as,

```
Select companyId
From ieh001.dunnbrad
Where emplcnt is small
        And age is recent
        And revenues are large
        And profits are acceptable;
```

The where statement takes values form the database and maps them to a corresponding fuzzy set definition returning their degree of membership. In Figure 2 we can see how a column's Universe of Discourse (range of values) is decomposed into a set of overlapping fuzzy sets thus defining its semantics.

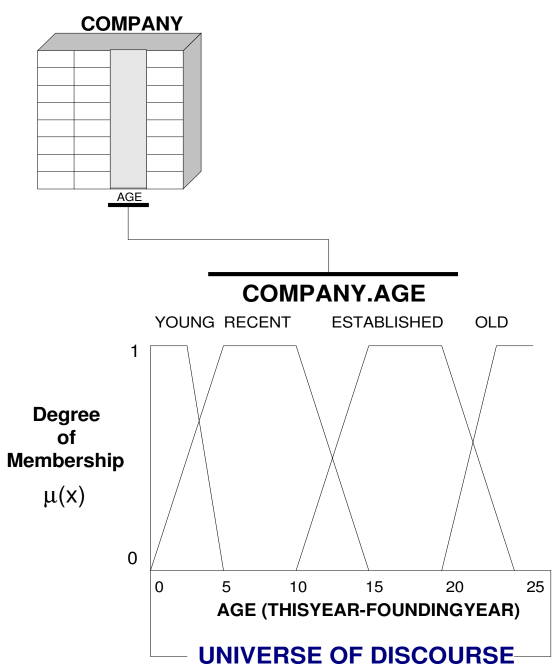

Figure 2. Defining Fuzzy sets for a Column

The degree of membership in a where clause indicates how well a data value matched the fuzzy concept. Thus, instead of a true or false result, the fuzzy query provides a degree of compatibility with the query. The combined degrees of membership for each of the where statements, in fact, generates a compatibility index, reflecting how will the selected record met the intent of the analyst's query. All the selected records are sorted in descending order by this compatibility value. Figure 3 illustrates how a FuzzySQL query system connects to the data and also to the user.

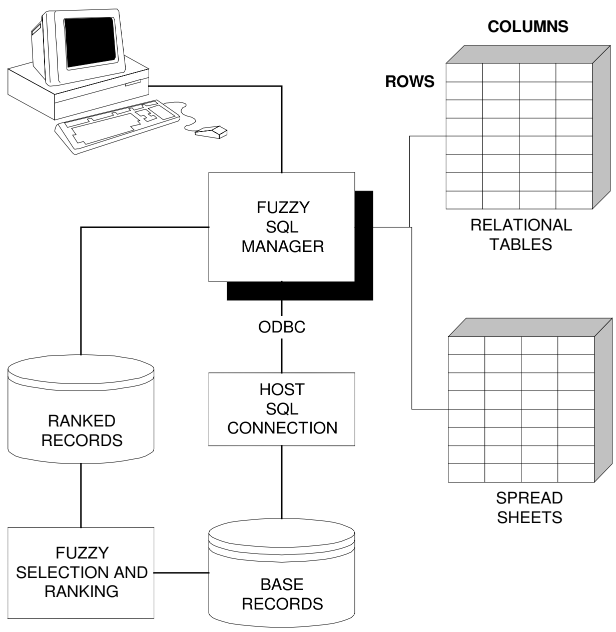

Figure 3. The Architecture of the FuzzySQL system

With its ability to find broad patterns in the data, select records that meet the intent of the user, and rank the outcome in order of its compatibility with this intent, the FuzzySQL approach has found uses in such widely different applications as project risk and estimation analysis, inventory management, drug discovery and high throughput screening in the pharmaceutical industry, and personnel and skill inventory management.

New Product Pricing

Fuzzy logic's ability to easily deal with multiple experts, accumulate evidence, and handle contradictory information makes it the ideal modeling choice for expert and decision support systems. One particularly striking example of this is the new product pricing model developed for a large British retailing firm. In this rule-based system, the expertise of marketing, manufacturing, sakes, and financial management was fused into a single pricing position. Figure 4 shows the first four rules as they actually appeared in the model.

```
Our price must be high
Our price must be low
Our price must be around 2*MfgCosts
If the Competition.Price is not very high
       Then our price should be near the Competition.Price
```

Figure 4. Fuzzy Expert System Rules

Many features of fuzzy expert systems are illustrated in this deceptively simple model. We see, in the first three rules, the inclusion of apparently contradictory statements. The third rule shows the use of a fuzzy number (2*MfgCosts) dynamically created from the data. The last rule also illustrates how fuzzy sets can he modified by hedges (not, very, near) to produce new fuzzy regions in a particular rule. The use of unconditional fuzzy statements – the first three rules -- allows the expert system to constrain the solution based on fuzzy boundaries.

Fuzzy expert system rules are run in parallel. They accumulate evidence for and against the outcome variable (in this case, *price*). When all the rules have been executed, the outcome fuzzy set is defuzzified (reduced to a single value by finding the centroid or center of gravity of the fuzzy set) to find the expected value of the outcome. Along with this defuzzification is the Compatibility Index, a measure of how much evidence underlies the solution. Thus, a fuzzy expert system can not only combine multiple conflicting experts, it can indicate how much evidence was available to support a particular conclusion.

Fuzzy Expert systems have been used widely in solving tough, if highly nonlinear business problems involving time series with complex lead and lag states. An example of such an application includes a container management and shipping system for a European consortia of shipping companies. The system found both the least expensive as well as the least risk solutions to the problem of satisfying container demands (250,000 containers of 16 different types) for 128 world wide ports. With over 9000 rules, the expert system supported fuzzy concepts such as ship loading capacities, port and depot availabilities, transit times, tariffs, container rental, and purchasing, and storage costs.

As these few example show, fuzzy logic provides an engine capable of driving a wide variety of information and knowledge based systems. Further, the use of fuzzy sets to describe the semantics of a model's knowledge, means that fuzzy systems are idea as modelers adapative feed-back systems, as tools for rule discovery from large databases, and as the core components of an advanced business process modeling language.

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Earl Cox is the founder and president of Metus Systems, a software, consulting, and training company in Chapel Hill, NC specializing in fuzzy data mining and intelligent business process modeling. Earl is the author of *The Fuzzy Systems Handbook* (1994, 1998), *Fuzzy Logic for Business and Industry* (1995), and, with Greg Paul, the award winning *Beyond Humanity: CyberEvolution and Future Minds*. His fifth book, *Fuzzy Tools for Data Mining and Knowledge Discovery*, is due from Academic Press Professional this summer.