Dempster-Shafer Theory

A question arose regarding the relationship between belief masses for single-element sets versus larger sets; some students suggested that it would be intuitive for the mass of smaller sets to sum to the mass of their supersets. However, in the example presented, the superset “one of the three is guilty” had a belief mass of only 0.1, which was less than some of its subsets. One student noted that this counter-intuitive result may be due to the normalization of the mass function (i.e. all subsets sum to 1).

Fuzzy Theory

A question arose regarding whether only triangular member functions are possible in fuzzy logic. The answer was that almost any mathematical function can serve as a member function. A student asked about the semantics of set membership when the domain of membership functions overlap; the answer was that an element can belong to both fuzzy sets simultaneously. The class then discussed whether fuzzy logic can be used in a non-traditional way. Examples provided included the use of fuzzy logic in software testing (e.g. by treating “Pass” and “Fail” as fuzzy sets) and the use of temporal fuzzy logic in the RELAX language. Finally, a student asked whether research exists on modeling states of a system as fuzzy sets that the system can occupy simultaneously. The answer given was that in fuzzy control theory, the membership degree in the set can determine the proportion of output applied to each goal. For example, if an airplane’s goal is to go up and left, the system could be in both states (going up and going left) simultaneously, weighting the output of the airplane’s actuators according to both membership functions.

Info-Gap Theory

A question arose regarding the meaning of “favorable uncertainty.” The answer given was that some system configurations might produce favorable results under specific uncertain scenarios. During the presentation, Erik noted that some researchers have sharply criticized Info-Gap Theory, for which a student requested elaboration. The answer was that some researchers have argued that Info-Gap Theory is essentially Bayesian statistics under a different name, used in applications for which Bayesian theory is inappropriate.

Derived Uncertainty Theory

The class discussed how the 99-table is derived. Erik explained that the values are subjective. For example, in a radar system, a domain expert can use the system specification to estimate a certainty level regarding the furthest distance that an object can be detected.
Uncertainty Issues

Subsequent to the presentation, the class discussed several issues related to uncertainty. Erik discussed how the representation of system state affects the complexity of uncertainty management; moreover, uncertainty management challenges can be specific to each domain. However, the majority of class discussion focused on human factors in uncertainty management. Specifically, Erik proposed that user knowledge—including crowdsourcing—could be used by systems to adapt to uncertain conditions. A question arose regarding whether “the crowd” is trustworthy, and one student noted that crowd consensus is not necessarily mere opinion; rather, crowdsourcing can be thought of as collecting information from multiple sources. The class then discussed a threat to the validity of this approach; specifically, a malicious or dominant member of the crowd could drive decision-making in their desired direction. An example given of this phenomenon was the website reddit.com, in which a core group of users can guide consensus on the site.

Finally, a question arose regarding why biological organisms are good at managing uncertainty. One student mentioned that adapting to uncertainty is just an extension of learning. Another student responded that many of the problems that we want to solve with adaptive systems already can be done by humans. The class also remarked that humans each handle uncertainty differently, and not everyone handles it well. However, there will always exist tasks that a human can handle but that we cannot codify as a program. An example given was the use of autopilot in airplanes: passengers are unlikely to ever be comfortable flying in an unmanned aircraft, because the autopilot program is unlikely to be able to handle every possible uncertain scenario.

Roadmap Discussion

The class discussed methods for reducing aleatory uncertainty. One student suggested that it cannot be reduced, only mitigated. Another student suggested that aleatory uncertainty can be reduced by constraining the environment in which the system operates; similarly, another response indicated that we can decide which parts of the environment that the system will handle based on the available sensors. Moreover, real-world examples of changing the environment exist: cloud seeding, GMOs, etc. The class next discussed how various theories can be used to handle uncertainty in dynamically adaptive systems. The class agreed that the paper explained where the theories were applicable but failed to present the limitations of each theory. Finally, the class discussed how engineers can mitigate the uncertainty that they correctly designed the components that manage uncertainty. One student suggested the use of feedback loops to self-heal uncertainty formulas; such a system could compare expected outcomes to actual outcomes and adjust its uncertainty handling mechanisms accordingly. Another student mentioned Type 2 Fuzzy Logic, in which the fuzzy membership function is itself fuzzy. A third suggestion, related to feedback loops, was to tune weights of the uncertainty formulas over time as more information becomes available. Finally, a student remarked that we can tell that a system is properly handling uncertainty simply by using it in practice.