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Soft Computing for Sensor and Algorithm Fusion

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Abstract

Sensor and algorithm fusion is playing an increasing role in many application domains. As detection and recognition problems become more complex and costly (for example, landmine detection and automatic target recognition), it is apparent that no single source of information can provide the ultimate solution. However, complementary information can be derived from multiple sources. Given a set of outputs from constituent sources, there are many frameworks within which to combine the pieces into a more definitive answer. This talk will focus on the fusion of multiple partial confidence values within the framework of fuzzy set theory.

So, the question then becomes: what methodology do we use to combine partial decision information? There are many choices, but I will focus on the use of fuzzy set theoretic mechanisms to fuse confidence from multiple sources. Two general approaches will be considered, fuzzy integrals and fuzzy logic rule-based systems. Fuzzy integrals have a long history and have been studied in the context of pattern recognition and information fusion for several years being first introduced for this purpose by Tahani and Keller in 1990. Fuzzy integrals combine the objective evidence supplied by each information source with the expected worth of each subset of information sources (via a fuzzy measure) to assign confidence to hypotheses or to rank alternatives in decision making. This is a nonlinear combination of information and the worth of the information for the decision in question, dealing with the uncertainty in both forms of data. Different fuzzy measures yield different integration operations, including averaging, linear combinations of order statistics, and many others. Measures can be found by heuristic assignment or via training algorithms.

Next, a fusion system based on a linguistic extension of the Choquet fuzzy integral will be shown. The uncertainty in the data is now expressed as a linguistic vector, i.e., a vector of fuzzy sets. The linguistic Choquet integral is used to fuse both position and confidence uncertainty in the landmine detection scenario. We demonstrate this system on the outputs from three algorithms on data collected from an outdoor test site by the GEO-CENTERS Energy Focusing Ground Penetrating Radar (EFGPR). The results show good improvement in the probability of detection and a reduction in the false alarm rate over the best single algorithm and two numeric fusion schemes.

Fuzzy logic rule-based systems provide another mechanism to fuse together the results of different features, classification algorithms and sensors. Such a system employs rules much like those that a human expert might derive. Again, uncertainty in the component parts is modeled by linguistic variables taking on fuzzy sets as values. We describe the application of a fuzzy rule-based classifiers in image processing and landmine detection.

Biographic Sketch

James M. Keller received the Ph.D. in Mathematics in 1978. He has had faculty appointments in the Bioengineering/Advanced Automation Program, the Computer Engineering and Computer Science Department, and the Electrical and Computer Engineering Department at the University of Missouri-Columbia, where he currently holds the rank of Professor. He is also the R. L. Tatum Research Professor in the College of Engineering. His research interests include computer vision, pattern recognition, fuzzy set theory and fuzzy logic, fractal geometry, and neural networks. He has been funded by several industrial and government institutions, including the Electronics and Space Corporation, Union Electric, Geo-Centers, NSF, NASA/JSC, the Air Force Office of Scientific Research, the Army Research Office, the Office of Naval Research, and the Army Night Vision and Electronic Sensors Directorate. Dr. Keller has coauthored over 250 technical publications.

Professor Keller is a Fellow of the Institute of Electrical and Electronics Engineers (IEEE) for whom he has presented live and video tutorials on fuzzy logic in computer vision, is a national lecturer for the Association for Computing Machinery (ACM), is an IEEE Computational Intelligence Society Distinguished Lecturer, and is a past President of the North American Fuzzy Information Processing Society (NAFIPS). He finished a full six year term as Editor-in-Chief of the *IEEE Transactions on Fuzzy Systems*, is an Associate Editor of the *International Journal of Approximate Reasoning*, and is on the editorial board of *Pattern Analysis and Applications, Fuzzy Sets and Systems, International Journal of Fuzzy Systems*, and the *Journal of Intelligent and Fuzzy Systems*. He is currently the Vice President for Publications of the IEEE Computational Intelligence Society. He was the conference chair of the 1991 NAFIPS Workshop, program co-chair of the 1996 NAFIPS meeting, program co-chair of the 1997 IEEE International Conference on Neural Networks, and the program chair of the 1998 IEEE International Conference on Fuzzy Systems. He was the general chair for the 2003 IEEE International Conference on Fuzzy Systems.