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HYBRID SYMBOLIC-NEURAL APPROACHES TO ARTIFICIAL INTELLIGENCE IN SPACE

Abstract

We explore a novel hybrid approach to onboard spacecraft autonomy that provides robustness to cyber-interference. Spacecraft autonomy is highly desirable as it reduces reliance on and the cost of ground station operations. As space missions extend further afield to the Moon, Mars and beyond, onboard autonomy through artificial intelligence becomes essential. Current methods exemplified by Deep Space 1 are based on temporal logic, an example of symbolic processing methods. Such methods are explicitly expressed with predictable behaviours but are brittle beyond their specific applications. More modern approaches to expert systems are Bayesian networks which incorporate probabilistic treatment. Soft computing techniques such as neural networks are fundamentally different. They are opaque to analysis but offer greater adaptability in application. Indeed, new versions of neural networks with unsupervised front ends and supervised back ends have emerged recently for machine deep learning. The use of neural networks in space systems are still in their infancy but their obscurity to analysis has been problematic. We propose hybridising symbolic processing techniques with neural networks to yield the advantages of both. It is clear that human cognition implements both neural learning and symbolic processing. There are several approaches to such hybridisation. We review some of these approaches but concentrate on hybridising Bayesian networks with neural networks. There are three aspects: (i) insertion of production rules into the neural network; (ii) online neural learning; (iii) extraction of new production rule set from the neural network. There is a natural correlation between Bayesian probability and neural weights but mapping representation of symbols into switching neurons is less clear. When these issues are resolved, there are several advantages: (i) spacecraft onboard artificial intelligence may be programmed using symbolic methods permitting analysis; (ii) these programs may be inserted into neural network form which cannot be attacked by logic bombs; (iii) the programs may learn further online to exploit neural network adaptability; (iv) new symbolic representations may be extracted from the modified neural network for analysis. This represents a powerful methodology for spacecraft autonomy impervious to cyber-attack.