MONITORING THE PERFORMANCE OF A NEURO-ADAPTIVE CONTROLLER

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Abstract

Traditional control has proven to be ineffective to deal with catastrophic changes or slow degradation of complex, highly nonlinear systems like aircraft or spacecraft, robotics, or flexible manufacturing systems. Control systems which can *adapt* toward changes in the plant have been proposed as they offer many advantages (e.g., better performance, controllability of aircraft despite of a damaged wing). In the last few years, use of neural networks in adaptive controllers (neuro-adaptive control) has been studied actively. Neural networks of various architectures have been used successfully for on-line learning adaptive controllers. In such a typical control architecture, the neural network receives as an input the current deviation between desired and actual plant behavior and, by on-line training, tries to minimize this discrepancy (e.g., by producing a control augmentation signal).

Even though neuro-adaptive controllers offer many advantages, they have not been used in mission- or safety-critical applications, because performance and safety guarantees cannot be provided at development time—a major prerequisite for safety certification (e.g., by the FAA or NASA). Verification and Validation (V&V) of an adaptive controller requires the development of new analysis techniques which can demonstrate that the control system behaves safely under all operating conditions. Because of the requirement to adapt toward unforeseen changes during operation, i.e., in real time, design-time V&V is not sufficient.

One important aspect of V&V is to analyze the *performance* of the network during design time and to monitor it after deployment. We have developed a tool ("Confidence Tool") which dynamically estimates the network performance, based upon the current inputs $\mathbf{x}$ and the training history. The confidence measure is the variance of the neural network output o, which is obtained by calculating the probability density of $p(o|\mathbf{x}, D)$ where D is the training history. Based upon a Bayesian approach [Bishop95, Neural Networks for Pattern Recognition, Oxford], we have extended this approach to handle specific neural network architectures (e.g., $\Sigma\Pi$) and to accommodate the dynamic weight update.

In this paper, we discuss this approach and present our tool, which is used in a simulation environment for controller design, tuning, and V&V, and which is currently being implemented as a monitoring tool on the flight computer of a specific manned F-15 aircraft within NASA's IFCS (Intelligent Flight Control System) project.