V&V of Neural Networks

Intelligent Monitoring Harness

NN Controller

Task: Control water level given a controllable inlet valve

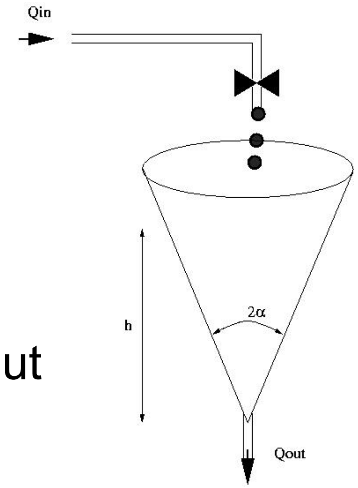
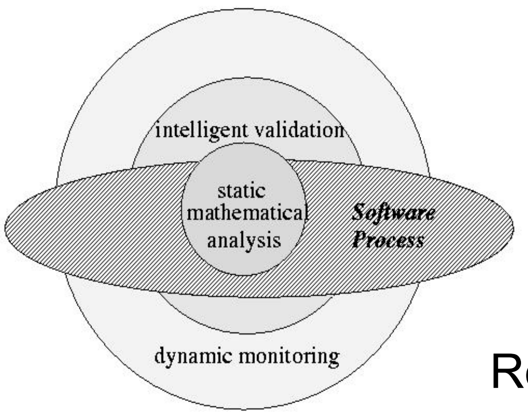
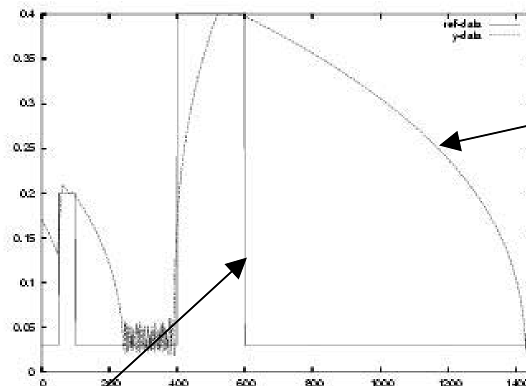


Fig. A

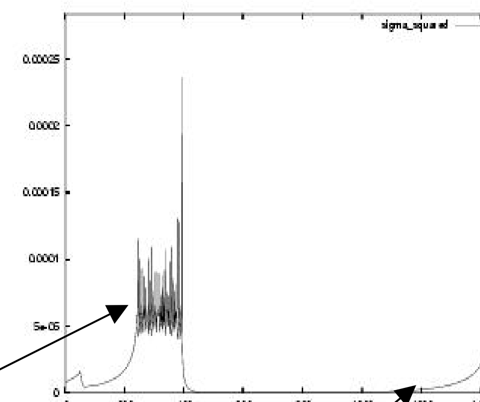




output

Reference signal

Fig. B



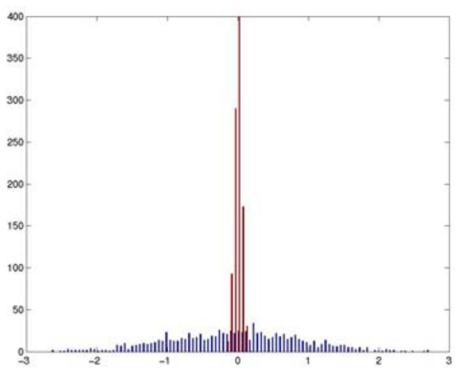


Fig. D

Small variance = high confidence

Large variance = low confidence (no reliable results)

Variance depends on how well the network is performing

Area of low confidence

Area of high confidence

Fig. C

Explanation of Accomplishment

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- **Background:** The main goal of this research is to develop methods and techniques that allow for rigorous verification & validation of neural-network based controllers. For safety-critical applications, a neural-network based controller must be verified & validated thoroughly and must pass a rigorous certification procedure; something yet to be accomplished. Even if the neural network (NN) is not used in a safety-critical area, it must be guaranteed that the neural network behaves well. The feasibility of NNs in the realm of NASA applications currently is being investigated in simulation for commercial transportation aircraft, and in flight of the Intelligent Flight Control System (IFCS) for a F-15 active aircraft. Moreover, when neural networks are used in prediction problems, it is usually desirable that some form of confidence bound is placed on the predicted value. The bound gives the range of the output of the neural network within which performance of the neural network is good/satisfactory. Our approach combines mathematical analysis and testing with dynamic monitoring to ensure robust convergence and stability. Our approach analyzes the probability distribution of the neural network output. We are developing methods for pre-deployment verification and a prototype software harness that monitors quality of adaptation during the mission.
- **Shown:** The graphs illustrate the monitoring harness on the example of a controller for a conical water tank (Fig. A). In this plant, the controller has to maintain the water level, using a controllable inlet valve. Fig. B shows a typical reference signal (the level of the water) and the corresponding neural network output. The neural network has been trained to control high water levels. Fig. C shows the variance of the output as calculated by our monitoring harness method. The variance is high in those regions which are not "familiar" to the network (low water levels). A small variance of the neural network output corresponds to a good estimate; a bad estimate has a large variance (and thus a broad bell-shaped distribution – Fig. D)
- **Accomplishment:** We presented this work at Dryden to DFRC management and collaborators from Boeing and ISR during the TQM (Technical Quarterly Meeting) of IFCS 03/05-03/06/2003. The monitoring harness technique and initial results on measuring the confidence interval of an adaptive NN were presented. Results of our analysis of Lyapunov stability (with Prof. Ken Loparo) were also presented at this meeting. The presentation was received very positively.
- **Future Work:** We are extending the monitoring-harness technique for online training of neural networks. We will be integrating this technology in the Simulink model of the IFCS.