# FAULT TOLERANAT NEURO/NEURO-FUZZY CONTROLLERS FOR AIRCRFT AUTOLANDING WITH ACTUATOR FAILURES AND SEVERE WINDS.

**Abhay Pashilkar (NAL, Bangalore), Rong Haijun ( Xian Jiatong Univ, China),**

**N.Sundararajan* & P. Saratchandran( Retd.)**

**EEE, NTU**

**Singapore**

**Email * :  ensundara@ntu.edu.sg**

**Summary :**

In this talk, we will cover some recent work carried out in our group for developing intelligent flight controllers which can handle failures and also flying under severe winds. Using neural networks and also fuzzy neural networks the controllers are able to handle actuator failures and able to perform similar to those under normal conditions.  Specifically, we will look at   1. Neural-aided controller 2. Fuzzy-neural aided controller and  3. Adaptive back stepping neural controller architectures for handling failures under severe winds for an aircraft auto-landing problem. The results indicate that good fault tolerant capabilities can be provided for existing controllers without adding more complexities and computational overhead.

## 1.      Neural –Aided Fault tolerant Controller : [ 1 ]

Modern fighter aircraft typically have physical redundancy in the control system in the form of multiple actuators and sensors. In the battlefield, the aircraft as a system must be fault tolerant to damage or loss of one or more of these components. Fist, we present a neural-aided controller that enhances the fault tolerant capabilities of a high performance fighter aircraft during the landing phase when subjected to severe winds and failures such as stuck control surfaces. The controller architecture uses a neural controller aiding an existing conventional controller (called BTFC) using a feedback error learning mechanism. The neural controller employs a dynamic Radial Basis Function neural network called Extended Minimal Resource Allocating Network (EMRAN), which uses only on-line learning and does not need *a priori* training. The conventional controller is designed using a classical design approach to achieve the desired autonomous landing profile with tight touchdown dispersions (pill box) when the aircraft is operating under no failure conditions but subject to winds. The failure scenarios considered in this study are: i. Single faults of either aileron or elevator stuck at certain deflections and ii. Double fault cases where both the aileron and elevator are stuck at different deflections.  Simulation studies indicate that the conventional controller design has only a limited failure handling ability. However, neural controller augmentation considerably improves the ability to handle large faults and meet the strict touchdown dispersion requirements, thus enlarging the fault-tolerance envelope.

Next, we present  an adaptive fuzzy control strategy for the above problem.

## 2.  Fuzzy-Neuro Fault Tolerant Controller : [ 2 ]

The strategy incorporates a dynamic fuzzy system called Sequential Adaptive Fuzzy Inference System (SAFIS) and it augments the  existing conventional controller called Baseline Trajectory Following Controller (BTFC). SAFIS is an online learning fuzzy system in which the rules are added or deleted based on the input data. Also, SAFIS incorporates an online scheme for parameter update of the membership functions. BTFC has been designed using classical control methods  under normal operating conditions with winds.

 Recently as explained earlier a neural based scheme to augment the BTFC and its performance has been shown to be superior. However, even in this neural scheme there are gaps in the fault cases where performance specifications are not met. We will show that the SAFIS aided BTFC improves the fault tolerant capabilities compared with BTFC and also the earlier neural aided BTFC performance in filling up the gaps observed earlier.

## 3.  Adaptive Back-stepping Neural Controller  : [ 3 ]

 Here ,  an adaptive back-stepping  neural  controller for reconfigurable flight control of  aircraft in the presence of large changes in the aerodynamic characteristics and also in the presence of failures. In the proposed controller, Radial Basis Function Neural networks are utilized in an adaptive back stepping architecture with full state measurement for aircraft trajectory following. For the RBF neural networks,  a learning scheme in which the network starts with  no hidden neurons and adds new hidden neurons based on the trajectory error is developed. Using Lyapunov theory,  stable tuning rules are derived for the update of the centers, widths and weights  of the RBF neural networks and a proof of stability in the ultimate bounded sense is given for the resulting controller. The fault-tolerant controller design is illustrated for an unstable high performance aircraft in the terminal-landing phase subjected to multiple control surfaces hard over failures and severe winds. The design uses the full six-degree-of-freedom nonlinear aircraft model   and the simulation studies show that the above controller is able to successfully stabilize and land the aircraft within tight touchdown dispersions.

## References :

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