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Fault-tolerant control of an unmanned aerial vehicle using optimised neural network

Tshabalala, T

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Abstract

An intelligent Fault-Tolerant Control (FTC) system for an Unmanned Aerial Vehicle (UAV) was developed to be capable of tolerating a number of different control actuator faults. The development of the control system, focused on the simulation of the system using a nonlinear flight dynamic model. The general six-degree-of-freedom flight dynamic model made use of available wind tunnel data to improve its accuracy. The system was first controlled using classical Proportional + Integral + Derivative (PID) controllers to test the basic functionality of the control system and to enable isolation of the different parts of the overall control structure. The proposed control strategy consisted of Radial Basis Function Neural Network (RBFNN)-based and Backpropagation Neural Network (BPNN)-based PID controller combined with sequential least squares Control Allocation (CA) algorithm. During normal fault-free operation the Neural Network-based (NN) controllers ensure that the system is able to attain the desired tracking performance. Once failure occurs and the NN-based control system is unable to mitigate the effects of failure, the CA algorithm redistributed the required control effort to the remaining healthy control surfaces. This system played a vital role in minimising the possibility of a fault while necessitating the reconfiguration of the control, guidance or navigation systems in the aircraft by minimising the effects of the simulated fault. The performance of this system was enhanced by optimising the allocation of control effort commanded by the virtual actuators to the physical actuators present on the aircraft. The allocation algorithm made use of secondary and tertiary control effectors. A number of control actuator failures, of varying severity, were modelled including elevator failures; aileron failures; and combined aileron and elevator failures. These failures were also tested in the presence of microburst windshear. The effects of microburst windshear were prevalent within simulations. It was found that the system was able to handle these failures. Though in the case of severe failures, the performance of the system was slightly degraded, and at some times the oscillations previously observed were reduced. The control allocation algorithm was a necessity for the system that operated using classical PID control without the neural network supervision. The proposed system can be effectively used as part of a FTC system.