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Design of an intelligent fault-tolerant control system for an unmanned aerial vehicle

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Abstract

An intelligent fault-tolerant control system for an unmanned aerial vehicle was developed that was designed 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 with the aim to implement this control strategy in an operational UAS in the future. The nonlinear flight dynamic model was a high fidelity, six-degree-of-freedom model that made use of available wind tunnel data. The model considered the general equations of motion of an asymmetric rigid aircraft within the troposphere and also considered motor, and control actuator dynamics. The proposed control strategy consisted of a model reference fuzzy logic adaption algorithm combined with a daisy chain allocation algorithm. An equivalent desired first order behaviour was used to generate an ideal response to a control input and used as a reference for the adaption algorithm to follow. The allocation algorithm made use of secondary and tertiary control effectors that were used only after the primary control surface reached its physical limits of travel. A number of control actuator failures, of varying severity, were modelled that included elevator failures, aileron failures and combined aileron and elevator failures. The results showed the proposed control system was better able to tolerate the simulated failures when compared to the unmodified autopilot. For more severe failures it was found that the control allocation algorithm was a necessity and in some cases the adaption algorithm when used in isolation, induced control instability. Tuning of the adaption rates of the adaption algorithm was found to have a significant effect on the performance of the system. In some cases the incorrect adaption rate caused degraded control performance. It was, however, concluded that the proposed control strategy did provide a degree of fault-tolerance for the failure scenarios considered. It is recommended that research into the effects of adaption rates, auxiliary control functions (such as feedforward loops) and the use of health monitoring be considered for a more practical system. It is also recommended that extensive testing be conducted with hardware in the loop simulators before this system be implemented.