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In-Flight Aircraft Performance Model Enhancement Using Adaptive Lookup Tables

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Abstract : Over the years, the Flight Management System (FMS) has experienced a continuous improvement of its many features, to the point of becoming the pilot's primary interface for flight planning operation on the airplane. With the assistance of the FMS, the concept of distance and time has been completely revolutionized, providing the crew members with the determination of the optimized route (or flight plan) from the departure airport to the arrival airport. To accomplish this function, the FMS needs an accurate Aircraft Performance Model (APM) of the aircraft. In general, APMs that equipped most modern FMSs are established before the entry into service of an individual aircraft, and results from the combination of a set of ordinary differential equations and a set of performance databases. Unfortunately, an aircraft in service is constantly exposed to dynamic loads that degrade its flight characteristics. These degradations endow two main origins: airframe deterioration (control surfaces rigging, seals missing or damaged, etc.) and engine performance degradation (fuel consumption increase for a given thrust). Thus, after several years of service, the performance databases and the APM associated to a specific aircraft are no longer representative enough of the actual aircraft performance. It is important to monitor the trend of the performance deterioration and correct the uncertainties of the aircraft model in order to improve the accuracy the flight management system predictions. The basis of this research lies in the new ability to continuously update an Aircraft Performance Model (APM) during flight using an adaptive lookup table technique. This methodology was developed and applied to the well-known Cessna Citation X business aircraft. For the purpose of this study, a level D Research Aircraft Flight Simulator (RAFS) was used as a test aircraft. According to Federal Aviation Administration the level D is the highest certification level for the flight dynamics modeling. Basically, using data available in the Flight Crew Operating Manual (FCOM), a first APM describing the variation of the engine fan speed and aircraft fuel flow w.r.t flight conditions was derived. This model was next improved using the proposed methodology. To do that, several cruise flights were performed using the RAFS. An algorithm was developed to frequently sample the aircraft sensors measurements during the flight and compare the model prediction with the actual measurements. Based on these comparisons, a correction was performed on the actual APM in order to minimize the error between the predicted data and the measured data. In this way, as the aircraft flies, the APM will be continuously enhanced, making the FMS more and more precise and the prediction of trajectories more realistic and more reliable. The results obtained are very encouraging. Indeed, using the tables initialized with the FCOM data, only a few iterations were needed to reduce the fuel flow prediction error from an average relative error of 12% to 0.3%. Similarly, the FCOM prediction regarding the engine fan speed was reduced from a maximum error deviation of 5.0% to 0.2% after only ten flights.

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