Technology Focus: Data Acquisition

Optimal Tuner Selection for Kalman-Filter-Based Aircraft Engine Performance Estimation

The new methodology reduces parameter estimation errors by more than 50 percent.

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An emerging approach in the field of aircraft engine controls and system health management is the inclusion of real-time, onboard models for the in-flight estimation of engine performance variations. This technology, typically based on Kalman-filter concepts, enables the estimation of unmeasured engine performance parameters that can be directly utilized by controls, prognostics, and health-management applications. A challenge that complicates this practice is the fact that an aircraft engine's performance is affected by its level of degradation, generally described in terms of unmeasurable health parameters such as efficiencies and flow capacities related to each major engine module. Through Kalman-filter-based estimation techniques, the level of engine performance degradation can be estimated, given that there are at least as many sensors as health parameters to be estimated. However, in an aircraft engine, the number of sensors available is typically less than the number of health parameters, presenting an under-determined estimation problem. A common

approach to address this shortcoming is to estimate a subset of the health parameters, referred to as model tuning parameters. The problem/objective is to optimally select the model tuning parameters to minimize Kalman-filter-based estimation error.

A tuner selection technique has been developed that specifically addresses the under-determined estimation problem, where there are more unknown parameters than available sensor measurements. A systematic approach is applied to produce a model tuning parameter vector of appropriate dimension to enable estimation by a Kalman filter, while minimizing the estimation error in the parameters of interest. Tuning parameter selection is performed using a multi-variable iterative search routine that seeks to minimize the theoretical mean-squared estimation error of the Kalman filter. This approach can significantly reduce the error in onboard aircraft engine parameter estimation applications such as model-based diagnostic, controls, and life usage calculations.

The advantage of the innovation is the significant reduction in estimation errors that it can provide relative to the conventional approach of selecting a subset of health parameters to serve as the model tuning parameter vector. Because this technique needs only to be performed during the system design process, it places no additional computation burden on the onboard Kalman filter implementation.

The technique has been developed for aircraft engine onboard estimation applications, as this application typically presents an under-determined estimation problem. However, this generic technique could be applied to other industries using gas turbine engine technology.

This work was done by Donald L. Simon and Sanjay Garg of Glenn Research Center. Further information is contained in a TSP (see page 1).

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18458-1.

Airborne Radar Interferometric Repeat-Pass Processing

Improvements have resolved some of the earlier difficulties.

NASA's Jet Propulsion Laboratory, Pasadena, California

Earth science research often requires crustal deformation measurements at a variety of time scales, from seconds to decades. Although satellites have been used for repeat-track interferometric (RTI) synthetic-aperture-radar (SAR) mapping for close to 20 years, RTI is much more difficult to implement from an airborne platform owing to the irregular trajectory of the aircraft compared with microwave imaging radar wavelengths. Two basic requirements for robust airborne repeat-pass radar interferometry include the ability to fly the

platform to a desired trajectory within a narrow tube and the ability to have the radar beam pointed in a desired direction to a fraction of a beam width. Uninhabited Aerial Vehicle Synthetic Aperture Radar (UAVSAR) is equipped with a precision auto pilot developed by NASA Dryden that allows the platform, a Gulfstream III, to nominally fly within a 5 m diameter tube and with an electronically scanned antenna to position the radar beam to a fraction of a beam width based on INU (inertial navigation unit) attitude angle measurements.

UAVSAR is also equipped with a set of GPS receivers that coupled with INU measurements are used to determine the antenna position to a high degree of accuracy on a pulse-to-pulse basis. The relative position error within a flight track is measured to a small fraction of a wavelength as is required for image formation; however, the absolute accuracy of the position measurements is in the 2–10 cm range limited by the accuracy of post flight processed differential GPS data. In order to make repeat-pass radar interferometric deformation maps suit-