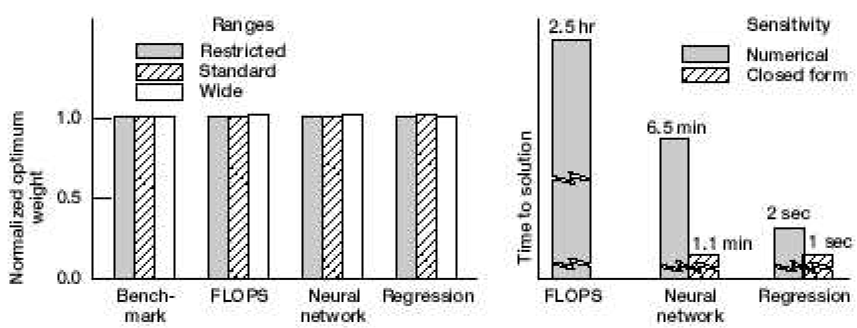
Design Process for High Speed Civil Transport Aircraft Improved by Neural Network and Regression Methods

A key challenge in designing the new High Speed Civil Transport (HSCT) aircraft is determining a good match between the airframe and engine. Multidisciplinary design optimization can be used to solve the problem by adjusting parameters of both the engine and the airframe. Earlier (ref. 1), an example problem was presented of an HSCT aircraft with four mixed-flow turbofan engines and a baseline mission to carry 305 passengers 5000 nautical miles at a cruise speed of Mach 2.4. The problem was solved by coupling NASA Lewis Research Center's design optimization testbed (COMETBOARDS) with NASA Langley Research Center's Flight Optimization System (FLOPS). The computing time expended in solving the problem was substantial, and the instability of the FLOPS analyzer at certain design points caused difficulties.

In an attempt to alleviate both of these limitations, we explored the use of two approximation concepts in the design optimization process. The two concepts, which are based on neural network and linear regression approximation (ref. 2), provide the reanalysis capability and design sensitivity analysis information required for the optimization process. The HSCT aircraft optimization problem was solved by using three alternate approaches; that is, the original FLOPS analyzer and two approximate (derived) analyzers. The approximate analyzers were calibrated and used in three different ranges of the design variables; narrow (interpolated), standard, and wide (extrapolated).



Optimum solutions for HSCT aircraft. Left: Normalized optimum weight of aircraft. Right: Central processing unit (CPU) time to solution.

Performance of the regression and neural network approximation methods for both the analysis and design of the HSCT aircraft could be considered satisfactory. For example, in the restricted range, 1-percent deviation was observed in the optimum gross takeoff weight of the aircraft. In the standard and wide ranges, the deviation increased to 2 percent. The approximation concepts significantly reduced the computing time expended during the optimization process. For the FLOPS-based optimization process, computing time was measured in hours, whereas for both approximation-based optimization processes, it was measured in minutes. Furthermore, difficulties associated with the instability of the FLOPS analyzer were eliminated with the approximation methods. However, calibrating the approximate (derived) analyzers required substantial computational time for both neural network and regression methods. For the HSCT aircraft problem, it was preferable to calibrate the approximate analyzers over a wider (standard) range and then use them to optimize over a narrower (restricted) range. Overall, neural network and regression approximation concepts were found to be satisfactory for the analysis and design optimization of the HSCT aircraft problem.

References

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