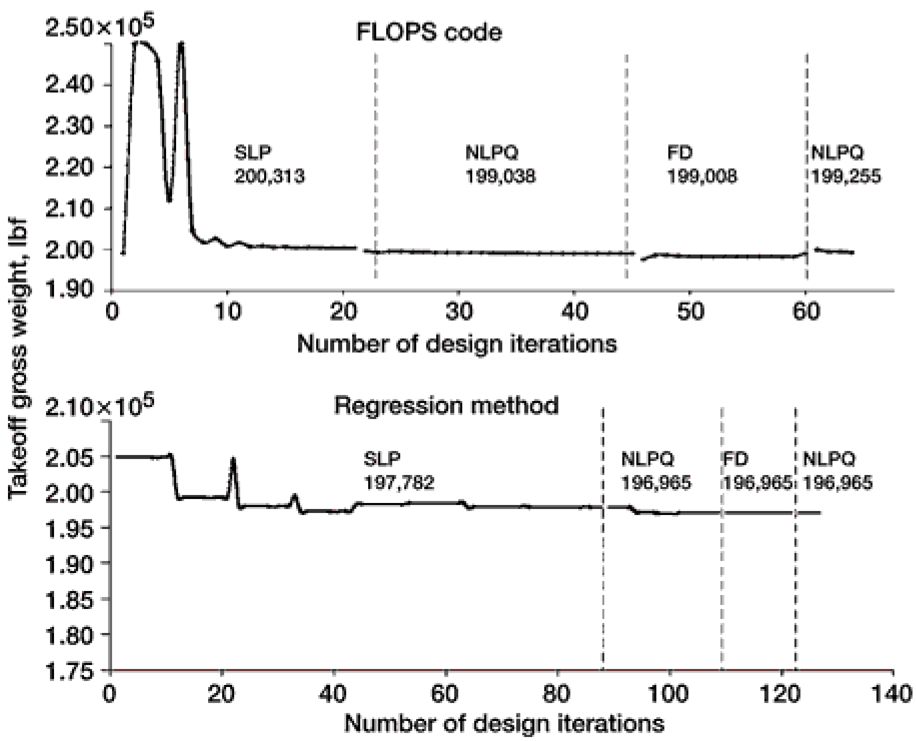
Subsonic Aircraft With Regression and Neural-Network Approximators Designed

At the NASA Glenn Research Center, NASA Langley Research Center's Flight Optimization System (FLOPS, ref. 1) and the design optimization testbed COMETBOARDS (ref. 2) with regression and neural-network-analysis approximators have been coupled to obtain a preliminary aircraft design methodology. For a subsonic aircraft, the optimal design, that is the airframe-engine combination, is obtained by the simulation. The aircraft is powered by two high-bypass-ratio engines with a nominal thrust of about 35,000 lbf. It is to carry 150 passengers at a cruise speed of Mach 0.8 over a range of 3000 n mi and to operate on a 6000-ft runway. The aircraft design utilized a neural network and a regression-approximations-based analysis tool, along with a multioptimizer cascade algorithm that uses sequential linear programming, sequential quadratic programming, the method of feasible directions, and then sequential quadratic programming again.



Optimum design of a subsonic aircraft. SLP, sequential linear programming; NLPQ, sequential quadratic programming; FD, method of feasible directions.

Long description. Graphs for FLOPS code and regression method: takeoff gross weight in pound-force versus number of design iterations. SLP: 200,313 iterations for FLOPS, 197,782 for regression; NLPQ: 199,030 iterations for FLOPS, 196,965 for regression; FD: 199,008 iterations for FLOPS, 196,965 for regression; NLPQ: 199,255 iterations for FLOPS, 196,965 for regression.

Optimal aircraft weight versus the number of design iterations is shown in the preceding figure. The central processing unit (CPU) time to solution is given in the following table. The figure shows that the regression-method-based analyzer exhibited a smoother convergence pattern than the FLOPS code. The optimum weight obtained by the approximation technique and the FLOPS code differed by 1.3 percent. Prediction by the approximation technique exhibited no error for the aircraft wing area and turbine entry temperature, whereas it was within 2 percent for most other parameters. Cascade strategy was required by FLOPS as well as the approximators. The regression method had a tendency to hug the data points, whereas the neural network exhibited a propensity to follow a mean path. The performance of the neural network and regression methods was considered adequate. It was at about the same level for small, standard, and large models with redundancy ratios (defined as the number of input-output pairs to the number of unknown coefficients) of 14, 28, and 57, respectively.

CPU TIME TO SOLUTION IN AN SGI OCTANE WORKSTATION

Task	**Regression method**			**Neural network technique**		
	Small	**Standard**	**Large**	**Small**	**Standard**	**Large**
Training, sec	0.2	0.4	0.8	59.1	136	538.8
Reanalysis,[a] msec	---	---	0.08	---	---	2.4
Reanalysis with closed-form gradient, msec	---	---	0.14	---	---	13.5
Design optimization, sec (percent of FLOPS solution time [b])	1.6 (0.78)	1.7 (0.84)	1.6 (0.78)	300.9 (15)	199.2 (9.8)	166.7 (8.2)

[a]Reanalysis with FLOPS, 3.1 sec.
[b]FLOPS solution time, 2031 sec.

In an SGI octane workstation (Silicon Graphics, Inc., Mountainview, CA), the regression training required a fraction of a CPU second, whereas neural network training was between 1 and 9 min, as given in the table. For a single analysis cycle, the 3-sec CPU time required by the FLOPS code was reduced to milliseconds by the approximators. For design calculations, the time with the FLOPS code was 34 min. It was reduced to 2 sec with the regression method and to 4 min by the neural network technique. The performance of the regression and neural network methods was found to be satisfactory for the analysis and design optimization of the subsonic aircraft.

References

1. McCullers, L.A.: Flight Optimization System, FLOPS. User's Guide, release 5.51, ViGyan, Inc., Hampton, VA, 1994.
2. Patnaik, S.N., et al.: Lessons Learned During Solutions of Multidisciplinary Design Optimization Problems. J. Aircr., vol. 39, no. 3, 2002, pp. 386-393.

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