CALIFORNIA STATE SCIENCE FAIR
2016 PROJECT SUMMARY

Name(s)
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Project Number
S0305

Project Title

Airship Hull Optimization Using Artificial Neural Network and Computational Fluid Dynamic Simulations

Abstract

Objectives/Goals

The Artificial Neural Network (ANN) has potential to help human brains solve complex computational problems. One example is the design optimization process that involves many cycles of performance simulations and design modifications. The design of airship hull belongs to this problem category. The hull shape must be optimized for low aerodynamic drag to reduce fuel consumption. Computational Fluid Dynamic (CFD) simulations provide accurate estimate of the drag. However, each CFD cycle may take hours to complete even for a simple hull shape that has rotational symmetry about its body axis. Direct hull optimization using CFD becomes computationally formidable. This project utilized the learning ability of the ANN to overcome this challenge.

Methods/Materials

A parametric representation was developed to represent the hull shape by a few parameters. Initial hull shapes and their corresponding drag coefficients obtained by CFD simulations were used to train the ANN. With the knowledge from the training set and the help of a nonlinear optimizer, the ANN then generated a hull shape that potentially had the lowest drag coefficient. CFD simulations were followed to obtain the drag coefficient of the ANN-generated hull. The new data set was added to the training set to retrain the ANN. This process was repeated until satisfactory hull shapes were obtained. The ANN code was written in Java. Open source programs OpenSCAD and OpenFOAM were used for 3D geometry generation and CFD simulations, respectively. All computations were performed on a Linux laptop computer.

Results

Four optimization trials were performed. The hull length and volume were 5 meters and 2.2 cubic meters, respectively. The free-stream air speed was 10 m/s, equivalent to a Reynolds number of 3.3 million. The first trial used nine unconstrained hull parameters for optimization and unrealistic hull shapes were produced. In the remaining trials, the hull shapes were represented by five constrained parameters. Low-drag hulls were produced by the ANN in less than 10 optimization cycles in each trial, and each optimization only required one CFD simulation.

Conclusions/Discussion

In conclusion, low-drag airship hulls were successfully obtained by the ANN-assisted optimization. Their drag coefficients were comparable to or lower than that of the NACA Model 111. This clearly demonstrated the potential of the ANN-assisted optimization method.

Summary Statement

The learning capability of the ANN was utilized to reduce the number of CFD simulations in airship hull optimization, and a number of low-drag hull shapes were successfully achieved.

Help Received

Dr. Bob Boyd of Lockheed Martin suggested directions for research and literature study, and answered my questions about airships. Mr. Peter Starodub provided guidance and monitored my progress.