CALIFORNIA STATE SCIENCE FAIR
2016 PROJECT SUMMARY

Name(s)

Shannon S.Y. Chen

Project Number

36092

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 perform complex tasks. One example is the design improvement process that involves many cycles of performance evaluation and design revisions. Sometimes, the performance can be evaluated numerically and the revision process can be automated by computer algorithms, and the task becomes a numerical optimization problem. 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 computation cycle may take hours to complete, and direct hull shape optimization using CFD becomes computationally formidable. This project addressed this challenge by applying the ANN to speed up the optimization convergence.

Methods/Materials

The main idea of the project was to utilize the learning ability of the ANN. 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 actual 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.

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 Artificial Neural Network (ANN) was utilized to reduce the number of Computational Fluid Dynamic (CFD) simulations in airship hull optimization, and a number of low-drag hull shapes was successfully achieved.

Help Received

Dr. Bob Boyd and Mr. Peter Starodub provided mentorship and guidance. Parents provided transportation and financial support.