AN UNDULATORY RIBBON-FIN DESIGN OPTIMIZATION FOR BIO-INSPIRED SWIMMING ROBOT PROPULSION USING COUPLED ANN-BGA STRATEGY

[1]Arash Taheri, [2]Meisam Mohammadi-Amin, [3]Sakineh Orangi and [2]S.Hosein Mosavi
[1]Aerospace Eng. Department, Sharif University of Technology, Tehran, Iran; email: taheri.cfd@gmail.com
[2]Mechanical Engineering Department, Tarbiat Modares University, Tehran, Iran
[3]Mechanical Engineering Department, University of Tehran, Tehran, Iran

INTRODUCTION

Many fishes use undulatory fin to propel themselves in the underwater environment. Black ghost knifefish or weakly electric fish are maneuverable swimmers, able to swim as easily forward as backward and rapidly switch swim direction, along other maneuvers using ribbon-fin propulsion (Figure 1). It is generally known that vortex shedding behind the posterior of a swimming animal is the core signature of thrust generation, as found in previous studies of anguilliform swimming. the generation of vortex rings as a means of self-propulsion has been considered prominent mainly in animals that swim using a backward jet directly emanated from their interior surfaces (e.g. jellyfish and squid). Despite lacking the high degree of cylindrical symmetry that is found in the jet-generating surfaces of such organisms, the ribbon fin is able to produce a significantly strong central propelling jet[1].

In this research, Breeder Genetic Algorithm (BGA) method is employed to optimize the ribbon-fin propulsor for weakly electric fish-inspired swimming robots using ANN (Artificial Neural Network) meta-model.

Figure 1: Albifrons (black ghost knifefish) with ribbon-fin propulsor

METHODS

In terms of new methodologies for multi-dimensional estimation, neural networks are a promising technology because of their ability to be trained and used for investigation of systems that involve nonlinear dynamics. Because of this proven capacity, neural networks have been applied in system identification. An ANN is a massively parallel distributed processor made up of interconnected processing units called neuron. In this research, we have designed a multi-layer perceptron neural network (MLPR) with one hidden layer and employed to model the relation between the propulsion force and dynamical parameters (include the sinusoidal propulsive wave frequency, amplitude and wavelength) of ribbon-fin propulsors. The results show that the ANN can model this complex relation properly.

On the other hand, because of the continuous nature of the problem variables, BGA strategy for continuous parameter optimization is used for optimization of the ribbon-fin propulsor of weakly electric fish-inspired swimming robots. In this regard, for fitness calculations the above mentioned MLPR artificial neural network trained by experimental results [2] is used to model the propulsion. For verification of the ANN meta-model, a comparison between the generalized ANN results and the results of a computational code (which was developed base on fluid drag model for estimation of fin-ribbon propulsion[3]) and the experimental results (which the ANN has not seen in the learning process) is performed. The results show that the results of the proposed ANN strategy are more accurate than the computational model.

BGAs are based on the concepts of evolution of species and selection typical of GA. however they differ in the fact that the evolution of the population is 'driven' by breeding mechanism. A very important feature of BGAs is the fact that they represent solutions as vectors of real numbers, rather than vectors of bits or integers, so they allow a representation of a phenomenon such closer to the reality than normal GAs [4].

RESULTS AND DISCUSSION

The simulation was performed using fortran 90. For training of the MLPR neural network, the results of Epstein et al. experiments were used. The ANN generalized the data set pattern and the final neural propulsion model was obtained. On the other hand, a computational code base on fluid drag model was developed. The results of ANN model was compared to the computational model as well as experminetal results. After validation of ANN model, the effects of variations of sinusoidal propulsive wave parameters were studied using the ANN-metal model. The effects were investigated using combined variations of parameters as well as single variation. The combinatory situations of variations give us more insight into behavior of ribbon-fin propulsion dynamics.

The results show the excellent accuracy of the ANN model predictions and the robustness of optimization methodology base on coupled ANN-BGA strategy. More details include the optimization methodology, ANN architecture design, discussion, graphs include comparative graphs of ribbon-fin parameter variation effects, learning history of ANN, fitness curve of BGA will be presented in details in the full manuscript.

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