Acceleration Method of Magnetic Structure Optimization Using Deep Neural Networks

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This paper proposes the acceleration method of magnetic structure optimization by Genetic Algorithm (GA) using the deep neural network (DNN). The bottleneck in the optimization of the magnetic structure using the GA is the evaluation time by Finite Element Method (FEM) calculation. In order to solve this problem, the evaluation value of each magnetic structure is estimated using DNN instead of FEM. A regression model of magnetic structure is constructed by DNN using tens of thousands of FEM calculation results. The proposed method is applied to the optimization of a linear oscillating actuator, it is confirmed that the regression model has high prediction accuracy, and outputs the results very similar to FEM calculation. By using this regression model, each magnetic structure can be evaluated without FEM calculation, and it is expected to be 10 times faster than conventional methods.

***Index Terms*—Linear Oscillating Actuator, Optimization, Finite Element Method, Genetic Algorithm, Neural Network**

I. Introduction

RECENTRY, linear oscillating actuators (LOAs) have been used in a wide range of applications [1]-[4], for example, electrical shavers electric tooth blushes, air compressors, and artificial hearts, because of their many advantages: high efficiency, simple structure easy control etc.

In order to get more efficient actuators, the various magnet arrangements are proposed [5] and the stator structure is optimized using the genetic algorithm (GA) [6]. In the case of general size optimization, there is a problem that the result largely depends on initial shape and setting of variables. Therefore, we adopt a method that can calculate optimal magnetic structure without initial shape using the GA [7]. The novel magnetic structure calculated by this method realizes high performance, but it requires very long time to calculate.

In this paper, we propose the acceleration method of magnetic structure optimization by GA using the deep neural networks (DNN). In the proposed method, a regression model of magnetic structure is constructed by the DNN. This method is applied to the optimization of LOA, the regression model has high prediction accuracy, and outputs the results very similar to Finite Element Method (FEM) calculation. By using this regression model, it shows the possibility that optimization by GA can be accelerated about ten times.

II. Optimization Method

A. Optimization using Genetic Algorithm

The optimization method for LOA divides the optimization area into sections, and computes the optimal layout with several materials as shown in Fig. 1. It is possible to get the unguessed magnetic structure in magnetization direction and ferromagnetic shape because of optimization of zero-base structure.

The material assigned to each section in Fig. 1 is optimized by GA. The materials in each section are treated as genes, the magnetic structure of LOA is the individual composed of gens, and optimal solutions are calculated by repeating crossover, mutation and evaluation for each generation.

B. Acceleration Method using DNN

Optimization by GA is one of good methods for efficiently obtaining optimal solutions from a vast search space, but because of the size of the search space, it is necessary to calculate tens of thousands of generations to obtain the optimal solution. When doing this calculation, the evaluation time of individuals by FEM calculation is the bottleneck of the optimization. In other words, by speeding up the evaluation process, it is possible to greatly reduce the time required for optimization.

In order to reduce the time taken to evaluate individuals, this paper proposes an estimation method using a regression model constructed by DNN. By creating a regression model that outputs evaluation values from gene information, individuals can be evaluated without calculation by FEM.

The DNN is used to create a regression model. The DNN is one of the machine learning methods attracting attention in recent years, and studies are actively conducted in a wide range of fields such as image recognition, voice processing, automatic driving and game of Go [8]. In this paper, the DNN learns to output the evaluation value from genetic information, and applies the learned network instead of FEM calculation.

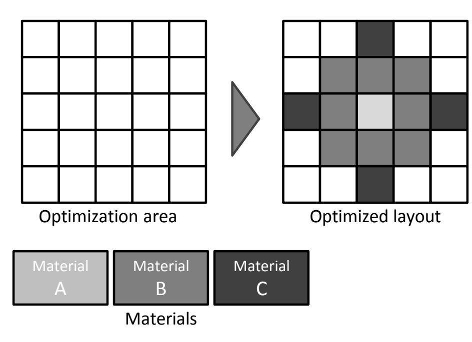

Fig. 1. Optimization method

III. Verification of Proposed Method

A. Leaning Conditions

In order to create and verify a regression model, learning of DNN is performed using genes whose evaluation values are known. For the verification of this time, we use the data that was optimized beforehand by GA using FEM evaluation. As shown in the figure 2, the optimization area is divided into 400 sections, and iron or magnet is assigned to each region. The FEM calculation results of evaluation value (teaching data) on the individual variation are shown in the figure 3. First step, DNN learns 50,000 evaluation data and then predicts 1000 individuals after learning data. Second step, FEM evaluation values of 100 individuals without 1,000 prediction results are learned additionally. After that, by repeating the second step, the FEM calculation in the optimization process is reduced to 1/10.

B. Comparison of DNN and FEM

The figure 4 shows the evaluation value by FEM and the estimation value by DNN. The graphs (a) to (d) are the results immediately after learning, after 30000 individuals, after 130000 individuals and after 230000 individuals, respectively. The estimation accuracy of the evaluation value by DNN is high, and in the conditions of (a) and (b), the correlation coefficient is 0.94 or more. Even under the conditions (c) and (d), the correlation coefficient is not as low as 0.9 or more, and the results of FEM can be qualitatively reproduced well. These results show that it is possible to replace the process of evaluation by FEM using regression model by DNN. At this time, the number of FEM calculations decreases to 1/10 as compared with the case without prediction using a regression model by DNN, which makes the optimization of the magnetic structure faster.

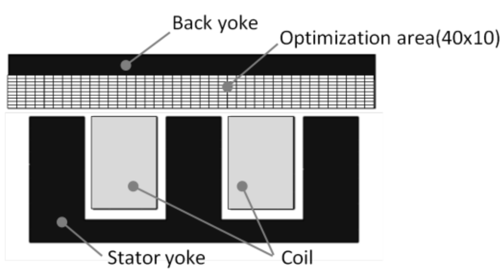

Fig. 2. Optimization model of LOA and materials

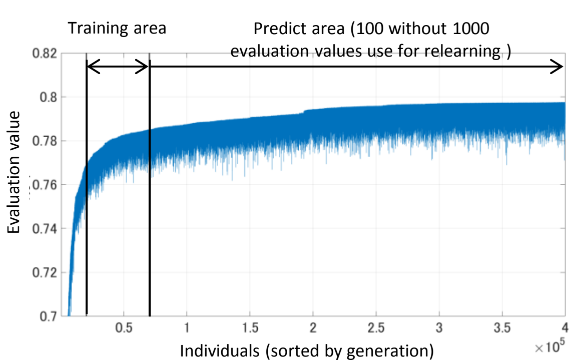

Fig. 3. Evaluation values for each generation (FEM calculation)

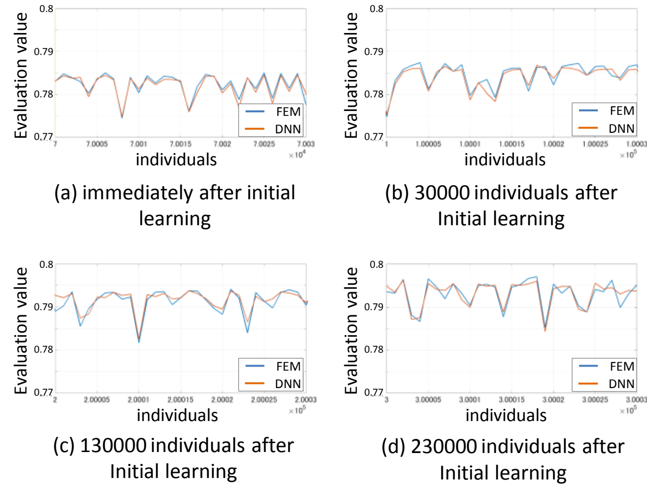

Fig. 4. Evaluation value by FEM and the estimation value by DNN

IV. Conclusion

This paper proposes the acceleration method of magnetic structure optimization by GA using the DNN. The regression model created by DNN shows a good correlation coefficient of about 0.9 or more. By using this regression model instead of FEM in evaluation process in GA, it shows the possibility that optimization by GA can be accelerated about ten times.

V. References

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