A hybrid algorithm for the synthesis of computer-generated holograms

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Abstract

A new approach to reduce the computation time of genetic algorithm (GA) for making binary phase holograms is described. Synthesized holograms having diffraction efficiency of 75.8% and uniformity of 5.8% are proven in computer simulation and experimentally demonstrated.

Recently, computer-generated holograms (CGHs) having high diffraction efficiency and flexibility of design have beenwidely developed in many applications such as optical information processing, optical computing, optical interconnection, etc. Among proposed optimization methods, GA has become popular due to its capability of reaching nearly global. However, there exits a drawback to consider when we use the genetic algorithm. It is the large amount of computation time to construct desired holograms. One of the major reasons that the GA's operation may be time intensive results from the expense of computing the cost function that must Fourier transform the parameters encoded on the hologram into the fitness value. In trying to remedy this drawback, Artificial Neural Network (ANN) has been put forward, allowing CGHs to be created easily and quickly [1], but the quality of reconstructed images is not high enough to use in applications of high preciseness.

For that, we are in attempt to find a new approach of combiningthe good properties and performance of both the GA and ANN to make CGHs of high diffraction efficiency in a short time.

The optimization of CGH using the genetic algorithm is merely a process of iteration, including *selection, crossover,* and *mutation* operators [2]. It is worth noting that the evaluation of the cost function with the aim of selecting better holograms plays an important role in the implementation of the GA. However, this evaluation process wastes much time for Fourier transforming the encoded parameters on the hologram into the value to be solved. Depending on the speed of computer, this process can even last up to ten minutes. It will be more effective if instead of merely generating random holograms in the initial process, a set of approximately desired holograms is employed. By doing so, the initial population will contain less trial holograms equivalent to the reduction of the computation time of GA's. Accordingly, a hybrid algorithm that utilizes a trained neural network to initiate the GA's procedure is proposed. Consequently, the initial population contains less random holograms and is compensated by approximately desired holograms. Figure 1 is the flowchart of the hybrid algorithm in comparison with the classical GA.

The procedure of synthesizing a hologram on computer is divided into two steps. First the simulation of holograms based on ANN method [1] to acquire approximately desired holograms is carried. With a teaching data set of 9 characters obtained from the classical GA, the number of layer is 3, the number of hidden node is 100, learning rate is 0.3, and momentum is 0.5, the artificial neural network trained enables us to attain the approximately desired holograms, which are fairly good agreement with what we suggested in the theory.

The second step, effect of several parameters on the operation of the hybrid algorithm is investigated. In principle, the operation of the hybrid algorithm and GA are the same except the modification of the initial step. Hence, the verified results in Ref [2] of the parameters such as the probability of crossover and mutation, the tournament size, and the crossover block size are remained unchanged, beside of the reduced population size. The reconstructed image of 76.4% diffraction efficiency and 5.4% uniformity is achieved when the population size is 30, the iteration number is 2000, the probability of crossover is 0.75, and the probability of mutation is 0.001. A comparison between the hybrid algorithm and GA in term of diffraction efficiency and computation time is also evaluated as shown in Fig. 2. With a 66.7% reduction in computation time and a 2% increase in diffraction efficiency compared to the GA method, the hybrid algorithm demonstrates its efficient performance.

In the optical experiment, the phase holograms were displayed on a programmable phase modulator (model XGA). Figures 3 are pictures of diffracted patterns of the letter "O" from the holograms generated using the hybrid algorithm. Diffraction efficiency of 75.8% and uniformity of 5.8% are measured. We see that the simulation and experiment results are fairly good agreement with each other.

In this paper, Genetic Algorithm and Neural Network have been successfully combined in designing CGHs. This method gives a significant reduction in computation time compared to the GA method while still allowing holograms of high diffraction efficiency and uniformity to be achieved.

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References

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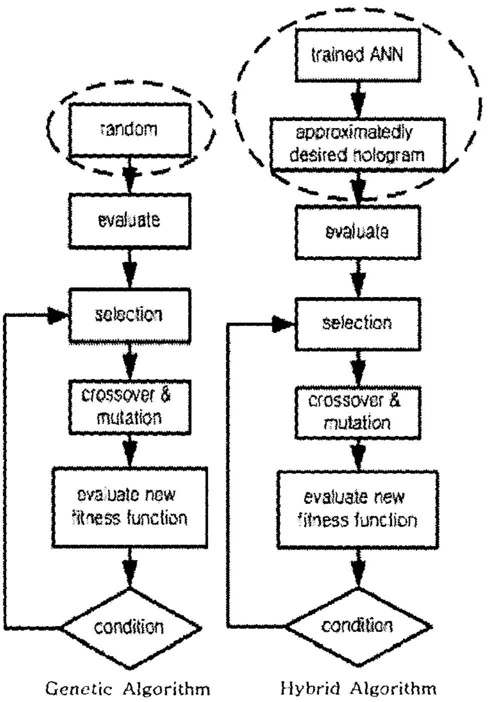

Fig.1. The difference between the GA and Hybrid Algorithm

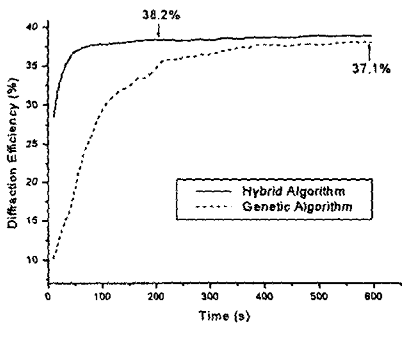

Fig. 2. Comparison in term of computation time between the hybrid algorithm and genetic algorithm

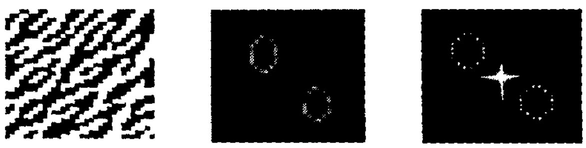

Fig.3. CGHs and its reconstructed image obtained using hybrid algorithm