Chapter 6

Summary and Further Work

6.1 Summary

The purpose of this thesis was to develop an efficient and robust design method applicable to real-world aerodynamic design problems. To achieve this goal, the real-coded adaptive range genetic algorithms incorporating with the structured coding have been developed. A comparative study of airfoil shape parameterization techniques has been also conducted for efficient design optimizations. The developed EA was successfully applied to transonic and supersonic wing designs. The following are the conclusions derived from this research.

6.1.1 Real-Coded Adaptive Range Genetic Algorithms

One of the most important difficulties in a real-world aerodynamic shape design problem comes from its highly multidimensional design space. To develop a robust and efficient EA applicable to such a design problem, the real-coded ARGAs have been developed by incorporating the idea of the binary-coded ARGAs with the use of the floating-point representation. Efficiency as well as robustness of the proposed EAs have been demonstrated by applying to a typical test function minimization problem and an aerodynamic airfoil shape optimization problem. The real-coded ARGAs consistently found better solutions than the conventional real-coded GAs do. What is more, this also eliminates prior definition of boundaries of the search regions. The design result was considered to be the global optimum and thus ensured the ability of the real-coded ARGAs in aerodynamic designs.

6.1.2 Evolutionary Algorithms Based on Structured Coding for Aerodynamic Wing Optimizations

Because the flow field is governed by a system of nonlinear partial differential equations, objective function landscape of an aerodynamic optimization is often multimodal and nonlinear. To improve EAs' capability of finding a global optimum in such a problem, a crossover operator based on the structured coding has been proposed. The coding structure of the design variables is constructed according to the epistasis information analyzed by the experimental design.

To test the ability of the developed method, it was applied to an aerodynamic shape design of a transonic wing where the wing shape was modeled using the parameter sets defined by the extended Joukowski airfoils and by the PARSEC airfoils. Aerodynamic optimizations of a transonic wing demonstrated that the crossover based on the structured coding was more efficient than the traditional one. The design results also confirmed that the PARSEC was an adequate technique for transonic wing shape parameterization. The improved Pareto front was obtained by the proposed EA based on the structured coding using the PARSEC.

6.1.3 Transonic Wing Design Optimization Based on EA

The objective of this chapter was to ensure the ability of the present EA in large-scale aerodynamic design optimizations. The real-coded ARGA coupled with the structured coding strategy has been applied to an aerodynamic design optimization of a transonic wing shape for generic transport aircraft. Aerodynamic performances of the design candidates were evaluated by using the three-dimensional compressive Navier-Stokes equations to guarantee an accurate model of the flow field. Structural constraint was introduced to avoid an apparent solution of zero thickness wing for low drag in high speeds.

To overcome enormous computational time necessary for the optimization, the computation was parallelized on NWT. EAs were proved to be suited to a parallel computation. The parallel EAs were easily implemented and they efficiently use the resources.

The designed wing had a good *L*/*D* value satisfying the given structural constraint on wing thickness. Because the structural constraint imposed a tradeoff between minimizations of the induced drag and the wave drag, the design did not have the minimum wave drag or the minimum induced drag. The straight span load distribution of the design was a compromise of this tradeoff. On the other hand, the designed wing had the allowable minimum thickness to reduce the wave drag. In addition, the designed wing had a fully attached flow so that the pressure drag was minimized. These results ensured the feasibility of the present approach.

6.1.4 Supersonic Wing Design Optimization Based on EA

A supersonic wing design optimization was demonstrated to examine the ability of the EA-based optimization. An EA incorporating with the crossover operator developed in Chap.3 was used. The adaptive-range approach was not used because this study was conducted before the development of the real-coded ARGAs.

The optimum design obtained from the present approach yielded both the minimum induced drag and the minimum volume wave drag in the given design space. This indicated the ability of the present approach for aerodynamic design of supersonic transport.

In addition, this study indicated the most important features of supersonic wing design as compared with conventional transonic wing design as follows:

1) Warp geometry based on camber line and twist angle distributions plays a more important role than spanwise thickness distribution because the thickness became simply as thin as possible.
2) Because the wing thickness constraint comes from the wing structure, a practical structural constraint will be required.

6.2 Further Work

Some possible areas for further work have arisen from this research concerning EA-based aerodynamic design methods.

In Chap. 2, the real-coded ARGAs have been developed. The practicability of this EA in single objective design problem was also proven. However, as can be seen in the aerodynamic designs in Chaps. 4 and 5, a wing design intrinsically involves multiobjective, multidisciplinary optimization. Therefore, the development of the real-coded ARGAs for multiobjective design problems will contribute to the researches in this field.

In Chap. 3, the structured coding based on epistasis analysis was proposed. The present method was successfully applied to aerodynamic wing designs. This study proposed to use one-point crossover operator to make use of the epistatic interaction structures of design parameters, but it may not be the best approach in the sense that one-point crossover cannot produce diversity in the offsprings. A promising candidate may be SBX that distributes children in the neighborhoods of each parents. By controlling the parameter u according to the epistasis information, epistatic interaction structure will be preserved.

The transonic design demonstrated in Chap. 4 showed that a wing design intrinsically involves multiobjective, multidisciplinary optimization. Because the tradeoff between minimizations of induced drag and wave drag directly related to the strength of the wing structure, more accurate structural analysis such as a finite element method is necessary. In addition, because the structural strength is generally a function of the structural weight, multiobjective optimization by a MOEA for minimizing both aerodynamic drag and structural weight will be another interesting research field.