

# Research Topics on Evolution and Learning at Honda Research Institute Europe

Yaochu Jin

Honda Research Institute Europe

Carl-Legien-Str. 30

63073 Offenbach/Main, Germany

Tel: +49-69-89011735

Fax: +49-69-89011749

Email: [yaochu.jin@honda-ri.de](mailto:yaochu.jin@honda-ri.de)

## 1. Introduction

The motivation of the research on evolution and learning at the Honda Research Institute Europe is to understand the essential mechanisms of natural evolution and learning for the design of complex and intelligent systems. Our research efforts have been made mainly in two areas. One is to study theoretic issues arisen in evolutionary design of complex systems. The other is to understand the evolution of the memory system in humans through looking at the interactions between evolution, learning and development.

Our research has been carried out in close collaboration with the academia. Current collaborators include universities in Germany, U.K., and Singapore.

## 2. Current Research Topics

### 2.1 Evolutionary optimization in the presence of uncertainties

Many challenging theoretic issues arise when evolutionary algorithms are applied to the design optimization of complex engineering problems. For example, fitness evaluations in structural design, e.g., the Honda HF118 Turbofan engine (Fig.1), is often highly time-consuming or costly. To address this problem, computationally efficient meta-models, such as neural networks and fuzzy systems, can be used together with the original fitness function. While they are computationally more efficient, meta-models can also introduce systematic errors in fitness evaluations, which may mislead evolutionary algorithms. To guarantee faster and correct convergence of the evolutionary algorithms using meta-models, proper measures, known as evolution control, must be taken during the optimization [1][2]. Besides, design variables may deviate from the optimized value and the environmental parameters may deviate from the nominal point due to unavoidable perturbations after optimization. Thus, the optimal solution achieved by the evolutionary algorithm should be robust against small perturbations. To this end, either explicit averaging or implicit averaging techniques should be introduced into the evolutionary

algorithms. In many cases, the tradeoffs between performance and robustness, quality and computational cost have to be considered [3]. If the fitness function varies continuously, the optimization problem becomes dynamic. Consequently, the evolutionary algorithm should be able to track the moving optimum [4].

Most real-world optimization problems have multiple conflicting objectives, which can be treated as a type of uncertainty in the fitness space. Our research in evolutionary multi-objective optimization has been focused on the understanding of the search dynamics of the evolutionary algorithms in multi-objective optimization and the regularity of the distribution of Pareto-optimal solutions in multi-objective optimization [5-7]. Based on these understandings, we have developed a Voronoi-mesh based estimation of distribution algorithm, which is able to model the distribution instead of a limited set of Pareto-optimal solutions. A link between multi-objective optimization and dynamic optimization has also been established [8].

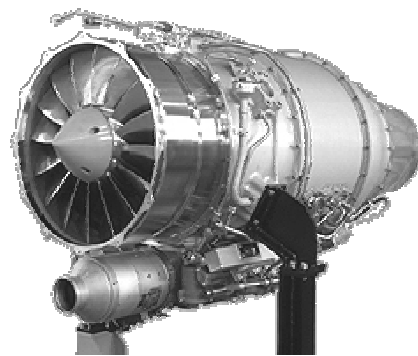


Fig.1 Honda HF118 Turbofan Engine

## 2.2. Evolution of intelligent systems

We have looked into how evolution, learning and development in the nature have worked together to evolve successfully complex intelligent systems in studying intelligent systems.

One of the most important aspects in intelligent systems is the working mechanism of the human memory and learning system. It is well recognized that the human brain is able to conduct both signal-type and symbol-type information processing. Therefore, signal to symbol transition, and vice versa, is essential in intelligent systems. As a special case, we have approached signal symbol transition by extracting interpretable fuzzy rules (symbol-type representations) from neural networks (signal-type representations) or directly from data [9-13], and by incorporating knowledge into evolution and learning [14-15].

It has been found that human memory system consists of multiple, complementary sub-systems that focus on different learning tasks [16]. Different levels in the memory system have different levels of invariance in representation. Motivated from these findings, and as the first step towards evolving intelligent systems, we have introduced multi-objectivity in evolving neural networks, which aims to simultaneously generate multiple representations of different levels of invariance, in other words, representations of a different degree of signal-symbol quality [17], see Fig. 2.

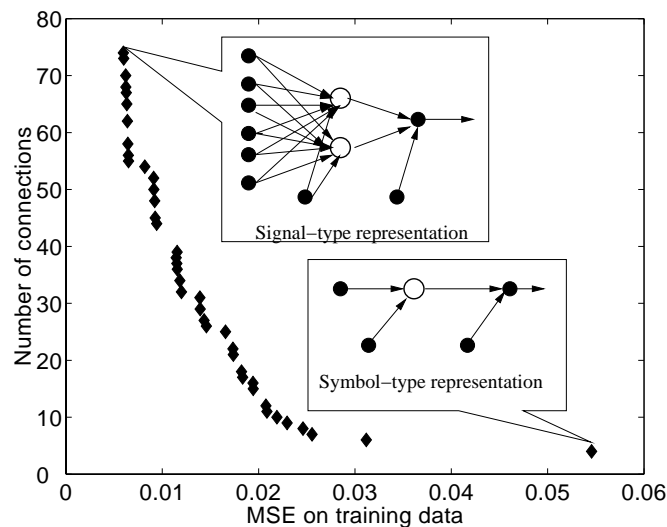


Fig. 2. Simultaneous generation of multiple representations of different signal-symbol quality.

## Acknowledgements

The author wishes to thank Prof. E. Körner, Dr. B. Sendhoff and Mr. A. Richter for their support.

## References

- [1] Yaochu Jin. A comprehensive survey of fitness approximation in evolutionary computation. *Soft Computing*, **9**(1), 3-12, 2005
- [2] Yaochu Jin, Markus Olhofer and Bernhard Sendhoff. A framework for evolutionary optimization with approximate fitness functions. *IEEE Transactions on Evolutionary Computation*, **6**(5), 481-494, 2002
- [3] Yaochu Jin and Bernhard Sendhoff. Trade-off between performance and robustness: An evolutionary multi-objective approach. In: *Proceedings of Second International Conference on Evolutionary Multi-criteria Optimization*. LNCS 2632, Springer, pp.237-251, 2003
- [4] Yaochu Jin and Juergen Branke. Evolutionary optimization in uncertain environments - A survey. *IEEE Transactions on Evolutionary Computation*, **9**(3), 2005
- [5] Tatsuya Okabe. Evolutionary multi-objective optimization – On the distribution of offspring in the parameter and fitness spaces. Shaker:Aachen, 2004
- [6] Tatsuya Okabe, Yaochu Jin, Bernhard Sendhoff. A new approach to dynamics analysis of genetic algorithms without selection. In: *Congress on Evolutionary Computation*. 2005 (accepted)
- [7] Yaochu Jin and Bernhard Sendhoff. Connectedness, regularity and the success of local search in evolutionary multi-objective optimization. In: *Congress on Evolutionary Computation*, Vol.3, pp.1910-1917, 2003

- [8] Yaochu Jin and Bernhard Sendhoff. Constructing dynamic test problems using the multi-objective optimization concept. In: *Applications of Evolutionary Computing*. LNCS 3005, Springer, pp.525-536, 2004
- [9] Yaochu Jin, Werner von Seelen and Bernhard Sendhoff. On generating FC<sup>3</sup> fuzzy rule systems from data using evolution strategies. *IEEE Transactions on Systems, Man and Cybernetics, Part B: Cybernetics*, **29**(6), 829-845, 1999
- [10] Yaochu Jin. Fuzzy modelling of high-dimensional systems: Complexity reduction and interpretability improvement. *IEEE Transactions on Fuzzy Systems*, **8**(2), 212-221, 2000
- [11] Yaochu Jin and Bernhard Sendhoff, Extracting interpretable fuzzy rules from RBF networks. *Neural Processing Letters*, **17**(2), 149-164, 2003
- [12] Yaochu Jin. *Advanced Fuzzy Systems Design and Applications*. Physica: Heidelberg, 2003
- [13] Hanli Wang, Sam Kwong, Yaochu Jin, Wei Wei, and K.F. Man. Agent-based evolutionary approach to interpretable rule-based knowledge extraction. *IEEE Transactions Systems, Man, and Cybernetics, Part C: Applications and Reviews*. **35**(2), 143-155, 2005
- [14] Yaochu Jin and Bernhard Sendhoff. Knowledge incorporation into neural networks from fuzzy rules. *Neural Processing Letters*, **10**(3), 231-242, 1999
- [15] Yaochu Jin (editor). *Knowledge Incorporation in Evolutionary Computation*. Springer: Berlin Heidelberg, 2005
- [16] H.E. Atallah, M.J. Frank, and R.C. O'Reilly. Hippocampus, cortex, and basal ganglia: Insights from computational models of complementary learning systems. *Neurobiology of Learning and Memory*. **82**, 253-267, 2004
- [17] Yaochu Jin, Bernhard Sendhoff, and Edgar Körner. Evolutionary multi-objective optimization for simultaneous generation of signal-type and symbol-type representations. In: *Evolutionary Multi-Criterion Optimization*. LNCS 3410, Springer, pp.752-766, 2005

## Biography

**Yaochu Jin** (M'98-SM'02) received the Ph.D. degree from Zhejiang University, China, and the Dr.-Ing. degree from Ruhr-Universität Bochum, Germany. He was an Associate Professor with the Electrical Engineering Department, Zhejiang University, a Visiting Researcher and a Research Associate with the Institut für Neuroinformatik, Ruhr-Universität Bochum, and a Postdoctoral Associate with the Industrial Engineering Department, the State University of New Jersey. He joined the Honda R&D Europe, in 1999. Currently, he is a Principal Scientist and Project Leader with the Honda Research Institute Europe.



His main research interests have been in fuzzy systems, neural networks and evolutionary computation with application to automatic control, design optimization, and evolution of intelligent systems. Dr. Jin is an Associate Editor of the *IEEE Transactions on Control Systems Technology* and the *IEEE Transactions on Systems, Man, and Cybernetics, Part C*. He is a Member of SIGEVO of ACM and Senior Member of IEEE.