CREATIVE DESIGN OF FUZZY LOGIC CONTROLLER

Lotfi Hamrouni, Adel M. Alimi
REGIM: Research Group on Intelligent Machines, University of Sfax, ENIS, Tunisia.
lotfi.hamrouni@hotpop.com , adel.alimi@ieee.org

Abstract: The present paper proposes a novel idea used to conceive a proper fuzzy logic controller for an industrial application. Generally, the design of fuzzy logic controller is treated as numerical optimisation problem. Genetic algorithms and neural networks are the main techniques used to adjust the values of fuzzy logic controller parameters. The majority of approaches start with an empty fuzzy logic controller, having default parameters, and make improvement over the previous one. This operation is not really a design activity; it's better called a learning process. In this work we regard the conception of a fuzzy logic controller as creative designing problem. We import from AI-creative-design community three methods: decomposition, co-evolution and emergence; we apply these techniques to combine elementary components in order to generate a fuzzy logic controller.

Key words: Fuzzy Logic Controller, Artificial Intelligence, Creative Designing.

1. INTRODUCTION

As we attempt to solve real-world problems, we realize that they are typically ill-defined systems, difficult to model and with large-scale solutions spaces. In these cases precise models are impractical, too expensive, or non-existent. The relevant available information is usually in the form of empirical prior knowledge and input-output data representing instances of the system's behavior. Therefore, we need approximate reasoning systems capable of handling such imperfect information.

In an industrial textile company called SITEX, for example, we have to develop a fuzzy logic controller (FLC) to control the color shading (nuance) of yarns to produce denims with specific shading. The shading of the denims is the change in appearance due to the color, the distortion and the orientation of the yarns. The shading is basically a difference in light reflection not a change in color or hue, therefore quantitative evaluation of the correlation between the shading of the yarns and the shading of the fabrics is virtually impossible to achieve. In addition, the available parameters of this problem do not define the solution directly; they define a set of components from which the solution is constructed. The only available parameters are: the shading of the yarns, the recipe of the washing and the shading of the fabrics.

Manually designing an FLC to satisfy such requirements is difficult if not impossible to do. Instead, we used to apply two professional learning methods: ANFIS and FuzzyTech [11][12]. Unfortunately, the results are not satisfied. We guess that the system is highly ill-defined.

In the next we propose our experience considering a fuzzy system as a creative object. We explain shortly three techniques used to model the creative design phenomena. Section two deals with the general model of co-evolution process in design, section three explains the hierarchical decomposition of an FLC, section four presents the computational modeling of emergence, section five presents the co-evolution of fuzzy logic controller and finally a conclusion.

2. FRAMEWORK OF CO-EVOLUTIONARY DESIGN

The AI-Design community regards the design as a state-space search where problem leads to solution. To be more practical, there are many versions of solution generated during the course of design, where each current one is, in general, an improvement over the previous one. This kind of synthesis of solutions can be viewed as an evolutionary system over time.

In effect, this simplified view faces a lot of challenges: (1) evolutionary design systems explore new ways to construct solutions by changing the relationships between components; (2) It can vary the dimensionality of the space by adding and removing elements; (3) It can explore alternatives instead of optimising a single option. However, the major criticism is on the assumption that the problem "or fitness function" is defined once-and-for-all. This is definitely not true for design. The central principle behind the opposing views is that design should be considered as an iterative process where there is interplay between fitness reformulation and solution generation. The evolution of both the solution and the fitness lead to the so-called co-evolutionary design (figure 1).

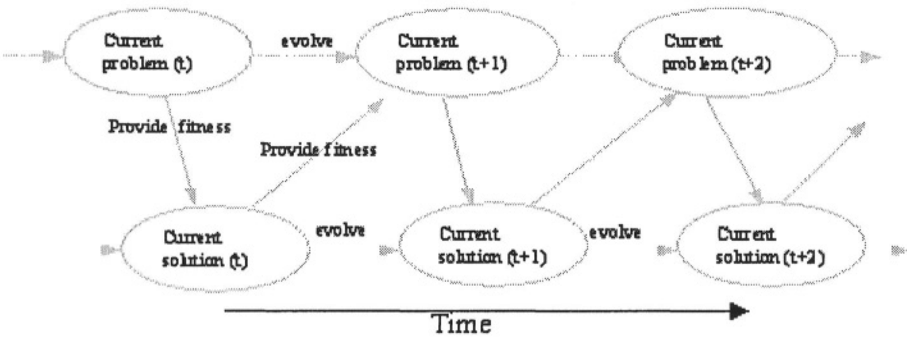

Figure 1. General framework of co-evolutionary design

3. EMERGENCE IN CREATIVE DESIGN

Emergence is another issue that recently drawn the attention of research workers in the *design community,* e.g. Gero & Yan [13], Gero, Damski & Jun [14], Edmonds & Soufi [15] etc. It is an important research issue in biology as well as in creative design. The definitions offered from the *design community* are usually applied to shape only. Hence, attempts are made to borrow definitions of emergence from other research communities to enrich our understanding. Since the *ALife* (Artificial Life) research community has also put emergence high on its research agenda.

Emergence is defined as a recognition of collective phenomena resulting from local interactions of low level units. A complex evolving representation can thus be classified as an emergent representation. In general, the methods of Gero & Schnier [16] do not specify whether the evolving representation is structure or behaviour. In figure 2, we consider the evolution of the two first level.

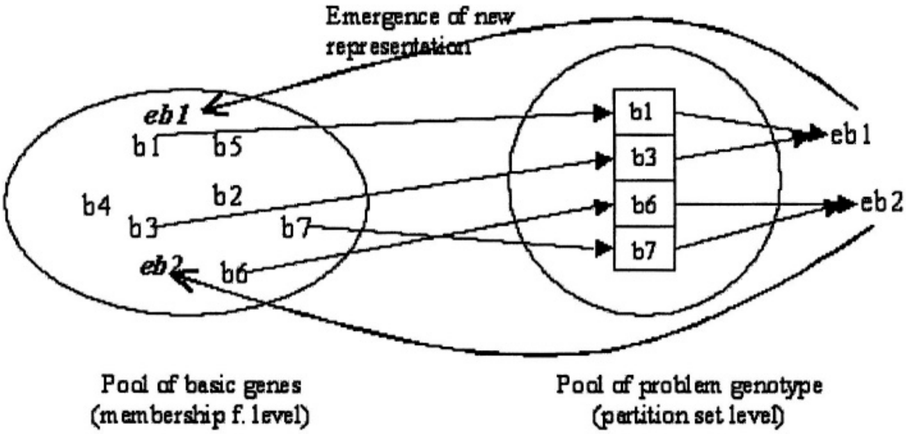

Figure 2. Direct application of evolving representation (Emergence in level 1 and 2)

4. HIERARCHICAL DECOMPOSITION OF FUZZY LOGIC CONTROLLER

Another important agenda follow, which is the decomposition of one problem into hierarchical structure, Simon [9] points out that it is only possible for complex organisms to evolve if their structure is organised hierarchically. Indeed, the generation of an object can be achieved through the recursive generation of its components until a level is reached where the generation becomes one of generating an element which is composed of basic units (Figure 2). The advantages of such a hierarchical approach are that only those factors relevant to the design of that component are considered and factors relevant to the relationships between components are treated at their assembly level. According to the evolutionary design process model offered by Gero [10], each two successive levels in the hierarchy can be considered as two state-spaces (solution-space and problem-space), the solution space can be considered to contain structure elements where the design process is to search the right combination of structure elements to satisfy the required behaviour. Co-evolutionary design process is suitably applied to model this problem design exploration; this is graphically illustrated in section 5.

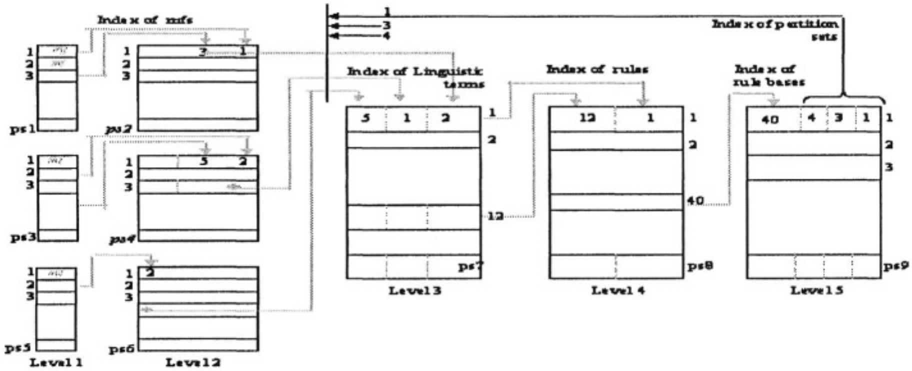

Figure 3. Multi-level decomposition of three variable fuzzy logic controller (combination and propagation)

5. CO-EVOLUTIONARY DESIGN OF FUZZY LOGIC CONTROLLER

The previous co-evolution model is applied to evolve the five levels of the decomposed FLC.

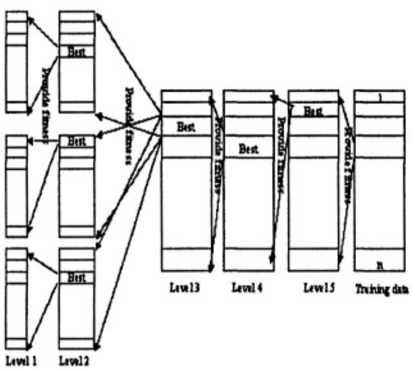

Figure 4. "Problem leads to Solution" or synthesis

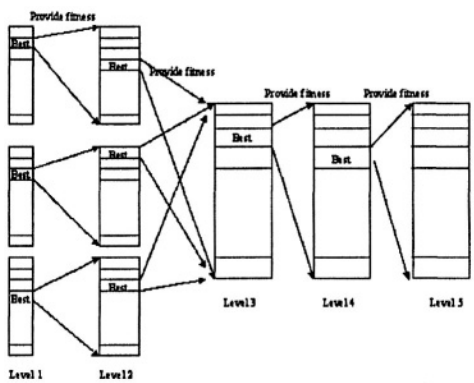

Figure 5. "Solution refocuses the Problem" or reformulation

6. CONCLUSION

In this paper, we presented briefly one novel form to design a fuzzy logic controller. By making the good decomposition of the FLC, the design becomes a combination of the basic elements. In each level of abstraction, a genetic algorithm based on the technique of co-evolution looks for the good combination. The optimization of the numerical parameters is carried out only in the first level. To validate this method, we chose to design a fuzzy logic controller for an industrial application of textile. The development of this application is in progress.

REFERENCES

[1] S. Mitra and Y. Hayashi, “Neuro-fuzzy rule generation: survey in soft computing framework,” IEEE Transactions on Neural Networks, Vol. 11, 2000, pp. 748-768.

[2] M. M. Gupta and D. H. Rao, “On the principles of fuzzy neural networks,” Fuzzy Sets and Systems, Vol. 61,1994, pp. 1-18.

[3] C. Karr, “Genetic algorithms for fuzzy controllers,” AI Expert, Vol. 6, 1991, pp.26-33.

[4] C. L. Karr and E. J. Gentry, “Fuzzy control of pH using genetic algorithms,” IEEE Transaction on Fuzzy Systems, Vol. 1, 1993, pp. 46-53,

[5] M, Regattieri Delgado, F. Von Zuben, and F. Gomide. “Hierarchical Genetic Fuzzy Systems”. Information Sciences - Special Issue on Recent Advances in Genetic Fuzzy Systems, 136(l-4):29-52, 2001.

[6] Jinwoo Kim – “A Framework for Multiresolution Optimization in a Parallel/Distributed Environment: Simulation of Hierarchical GAs” Journal of Parallel and Distributed Computing, 32(1), pp. 90-102, January 1996.

[7] H. Simon – “Problem forming, problem finding and problem solving in design”, dans Collen(A.) et Gasparski (W),, 1995, p. 245-257.

[8] M. Fustier – ‘La résolution de problèmes: méthodologie de l'action’, Paris, Editions ESF et Librairies Techniques, 1989.

[9] H. Simon “The structure of ill structured problems”, Artificial Intelligence, 4, 1973, p. 181-201.

[10] Gero, J. S. and Maher, M. L. “Modeling Creativity and Knowledge-Based Creative Design”, Lawrence Erlbaum, Hillsdale, NJ. (1993)

[11] Inform Software Corp., fuzzy-*TECH User’s Manual,* 1996.

[12] Jyh-Shing Roger Jang “ANFIS: Adaptive-Network-Based Fuzzy Inference System”, IEEE Transactions on Systems, Man, and Cybernetics 1993

[13] Gero, J. & Yan, M. (1994). Shape emergence by symbolic reasoning, *Environment and Planning B: Planning and Design* **21:** 191–218.

[14] Gero, J., Damski, J. & Jun, H. (1995). Emergence in caad systems, *in* M. Tan & R. Teh (eds), *The Global Design Studio,* Centre for Advanced Studies of Architecture, National University of Singapore, pp. 423–438.

[15] Edmonds, E. & Soufi, B. (1992). The computational modelling of emergent shapes in design, *in* J. S. Gero & F. Sudweeks (eds), pp. 173–189.

[16] Gero, J. & Schnier, T. (1995). Evolving representation of design cases and their use in creative design, *in* J. Gero & F. Sudweeks (eds), pp. 343–368.