

Analysis of evolutionary computation research through IEEE conferences

Murata, Tadahiko
Department of Informatics, Kansai University

高木, 英行
Department of Art and Information Design, Kyushu Institute of Design

<https://hdl.handle.net/2324/4486302>

出版情報 : 2002 IEEE International Conference on Systems, Man, and Cybernetics. 3, pp.236-240, 2002-10-06. IEEE

バージョン :

権利関係 : © 2001 IEEE. Personal use of this material is permitted. Permission from IEEE must be obtained for all other uses, in any current or future media, including reprinting/republishing this material for advertising or promotional purposes, creating new collective works, for resale or redistribution to servers or lists, or reuse of any copyrighted component of this work in other works.



Analysis of Evolutionary Computation Research through IEEE Conferences

Tadahiko Murata* and Hideyuki Takagi**

* Department of Informatics, Kansai University

2-1-1 Ryozenji, Takatsuki, Osaka 569-1095, Japan, murata@res.kutc.kansai-u.ac.jp

** Department of Art and Information Design, Kyushu Institute of Design

4-9-1 Shiobaru, Minami-ku, Fukuoka, 815-8540 Japan, takagi@kyushu-id.ac.jp

Abstract – Recently a large number of applications of evolutionary computation (EC) have been proposed. In this paper, we examine the number of papers relating to evolutionary computation submitted to the World Congress on Computational Intelligence (WCCI) and the Int. Conf on Systems, Man and Cybernetics (SMC). We examine applications of EC in five fields: (1) hybridization of EC with neural networks (NN) or fuzzy systems (FS), (2) application of EC in classification, recognition, and data mining, (3) application of Interaction EC (IEC), (4) enhancing technique for EC, and (5) practical application of EC. We analyze the data and make EC research trends clear.

Keywords: Evolutionary computation, IEEE conferences, hybridization, classification, interaction, enhancing technique, practical application.

I. INTRODUCTION

Soft Computing is an emerging and evolving collection of methodologies. The core methodologies of Soft Computing include neural networks (NN), fuzzy systems (FS), and evolutionary computation (EC). Soft computing algorithms have been typically inspired by natural phenomena. Therefore, soft computing provides attractive opportunities to model complexity of inference, ambiguity, uncertainty, and inheritance of information in demanding situations of real life.

Since the 1960s there has been increasing interest in imitating genetic inheritance to cope with complex real-world problems. A term to refer such techniques in common is *Evolutionary Computation*. Typical EC paradigms include genetic algorithms (GA) [1], evolution strategy (ES) [2, 3], evolutionary programming (EP) [4], and genetic programming (GP) [5]. Many EC textbooks are published [6-9] and an enormous number of applications are being attempted.

In this paper, we concentrate our attention on recent EC research in the fields of:

(A) EC for NN and/or FS [10, 11],

(B) EC for Recognition, Classification [12] and Data Mining [13, 14],

(C) Interactive EC [15],

(D) EC for Practical Applications [16],

(E) Enhancing Techniques for EC.

II. STATISTICS OF EC RESEARCH

In this section, we examine the number of papers presented in the World Congress on Computational Intelligence (WCCI) and the Int. Conf. on Systems, Man and Cybernetics (SMC). WCCI consists of three conferences: IEEE Int. Conf. on Neural Networks (ICNN), IEEE Int. Conf. on Fuzzy Systems (FUZZ-IEEE), and Congress on Evolutionary Computation (CEC). The WCCI has been held every four years since 1994.

The SMC conference is one of the largest IEEE conferences, and has made important contributions to create new scientific and technological trends and directions; some of IEEE societies, such as the Robotics and Automation Society, have the origin in the SMC Society activities. From these histories, we can see that contributors in SMC Society have keen interests to novel approaches and have eagerness to apply them to their problems. Therefore we also try to examine the development of papers relating to GA or EC in SMC.

Table 1 shows the number of papers and sessions relating to EC techniques in ICNN [17-19] and FUZZ-IEEE [20-22], and NN or Fuzzy techniques in CEC [23-25] in 1994, 1998, and 2002. We examined the titles of papers that include *evolution* or *evolutionary* and *genetic algorithm* or *GA* in ICNN and FUZZ-IEEE.

Table 2 shows that the number of papers and sessions in the proceedings of CEC held in last five years, that include keywords relating to one of the research areas described in Section I. Table 3 shows the list of keywords used to examine CEC papers.

Table 1: Relations between NN or Fuzzy techniques and EC in WCCI (1994, 1998 and 2002).

Keyword	ICNN			FUZZ-IEEE		
	'94	'98	'02	'94	'98	'02
evolution (-ary)	4	6	24	0	8	11
genetic algorithm or GA	9	8	15	9	13	9
Total	13	14	39	9	21	20
Number of Sessions	1	0	2	1	0	1

Keyword	CEC		
	'94	'98	'02
neural or neuro	8	7	22
fuzzy	2	12	9
Total	9	19	31
Number of Sessions	3	2	3

Table 2: Keywords in CEC (1998-2002).

P: the number of papers, S: the number of sessions

Keyword	1998		1999		2000		2001		2002	
	P	S	P	S	P	S	P	S	P	S
neur-	7	1	12	1	16	1	16	2	22	3
fuzz-	12	1	10	0	10	0	8	0	9	0
Total	19	2	22	1	26	1	24	2	31	3
classif- or clust-	7	0	6	1	10	1	8	0	20	0
recognition or image	5	0	2	0	7	3	2	2	11	1
mining or acqui- or extract-	5	0	4	1	4	0	4	0	7	0
Total	17	0	12	2	21	4	14	2	38	1
interact-	0	0	3	0	3	0	3	0	3	0
enhanc- or improve - or accelerat-	6	0	7	0	5	0	5	0	12	0

Table 3: The List of Keywords for Table 2.

Stem	Corresponding Keywords
neur-	neural, neuro
fuzz-	fuzzy, fuzzifying, fuzzified, fuzziness
classif-	classify, classifying, classified, classification
clust-	cluster, clustering, clustered
acqui-	acquire, acquiring, acquired, acquisition
extract-	extract, extracting, extracted, extraction
interact-	interact, interacting, interacted, interaction
enhanc-	enhance, enhancing, enhanced, enhancement
improv-	improve, improving, improved, improvement
accelerat-	accelerate, accelerating, accelerated, acceleration

Table 4: Relations between NN or Fuzzy techniques and EC in Int. Conf. on SMC in 1995, 1997, 1999, and 2001.

Keyword	'95	'97	'99	'01
GA or evolution (-ary)	34	24	80	35
NN and (GA or evolutionary)	1	2	5	1
FUZZ and (GA or evolutionary)	9	6	7	5
NN and FUZZ and (GA or evolutionary)	3	0	2	4
Total of papers relating to GA	47 (5.7%)	32 (3.9%)	94 (8.2%)	45 (7.1%)
NN and FUZZ	15	10	19	5
Total number of papers in the conference	824 (100%)	817 (100%)	1144 (100%)	638 (100%)

Table 4 shows the number of papers relating to GA or EC in SMC conferences. Although SMC conferences are annually held, we summarize the statistics on these conferences in every two years from 1995 to 2001 [26-29] and analyze their titles with the same keywords used in Table 1.

We analyze these data and make the EC research trends clear in Section III.

III. ANALYSIS OF EC RESEARCH

A. EC for NN and/or FS

This research area is roughly categorized in four types of combinations:

1. NN and GA,
2. FS and GA,
3. NN and FS,
4. NN, FS, and GA.

They are highly promoted in last decade.

To investigate the development of GA research associated with the other two methods, we examine the number of EC papers in ICNN and FUZZ-IEEE. We searched the number of keywords relating to EC in these two conferences. We also examine the number of NN or FS keywords included in paper titles in CEC. From Table 1, we can see that the number of EC applications increases in ICNN, while it does not so much in FUZZ-IEEE. Similar tendency can be seen in CEC from the right part of Table 1. That is, we can see that the NN papers is increasing in CEC 2002, while the number of FS papers decreases.

Table 2 shows the tendency in CEC in more detail. We can see that the number of NN sessions is increasing from 1 in 1998 to 3 in 2002. On the other hand, an FS session was not held in these four years in CEC.

While the combinations or hybridizations of GA with NN

are studied in WCCI, we could not find the same tendency in the SMC conferences. Table 4 shows the number of papers with titles including *genetic*, *GA*, or *evolution*. We also examine the papers relating to combination or hybridization with NN or FS.

From Table 4, we can see that the numbers of GA papers increased in 1999 and 2001. This can be seen not only in the number of the papers but also in the rate of the papers among all papers in the conference. However, the combinations of GA with NN or FS do not seem to be highly promoted in the SMC conferences. This may be because researchers submitting to SMC conferences try to show their application of evolutionary algorithms to their problems. If they try to propose their new scheme for hybridizing EC with other methods, they may submit their papers to CEC, ICNN or FUZZ-IEEE among IEEE societies, since those conferences concentrate on this research topic. However increasing in the number of applications of EC in the SMC conference will stimulate researchers' interests in this research area.

B. EC for Recognition, Classification and Data Mining

In this research area relating to recognition and classification, EC is usually employed for designing or configuring recognition or classification systems that employ NN, FS, automata and so on. Therefore many systems proposed in this research area can be seen as hybrid systems described in the previous subsection. From Table 2, we can observe that the number of papers relating to this field increased in 2002.

The research area relating to *Data Mining* is closely related to that of the recognition and classification. Recognition or classification systems with high interpretability and comprehensibility for human users can be regarded as data mining tools. Several researchers try to design compact systems using EC techniques. Every conference in Table 2 has received papers relating to this research topic.

C. Interactive EC

Takagi explains Interactive Evolutionary Computation (IEC) as an optimization method that adopts EC among system optimization based on subjective human evaluation in [15]. He introduces two main definitions of IEC. The narrow definition of IEC is "the technology that EP optimizes the target systems based on subjective human evaluation as fitness values for system outputs." He also shows the broader definition of IEC as "the technology that EC optimizes the target systems having an interactive human-machine interface."

He provides an overview of IEC-related research, and surveys several IEC applications in the following fields:

- (1) Graphic art and CG animation,
- (2) 3-D CG lighting design,
- (3) Music,
- (4) Editorial design,
- (5) Industrial design,
- (6) Face image generation,
- (7) Speech processing and prosodic control,
- (8) Hearing aids fitting,
- (9) Virtual reality,
- (10) Database retrieval,
- (11) Knowledge acquisition and data mining,
- (12) Image processing,
- (13) Control and robotics,
- (14) Internet,
- (15) Food industry,
- (16) Geophysics,
- (17) Art education,
- (18) Writing education,
- (19) Games and therapy,
- (20) Social systems.

While this research area has many fields for application as shown in the above, Table 2 indicates that the number of papers relating to IEC does not increase in these five years in CEC. Fortunately Takagi examined papers relating to IEC in [15]. We summarize Table 1 in [15] as Table 5. It shows that the number of papers in various conferences or transactions are increasing in latter half of 1990's. Especially we can see the number of papers relating to IEC doubled in 1998 from Table 5. Now this research field attracts a number of researchers.

Table 5: IEC papers (summarized Table I in [15]).

	'80-	'90-	'95	'96	'97	'98	'99	'00
Number	2	29	23	28	22	48	57	43

D. EC for Practical Applications

EC techniques are widely employed for practical applications which include engineering, designing, forecasting, economics, and so on. For example, the following sessions were held in CEC 2002 [25].

- (1) Evolutionary Computation and Biology,
- (2) Multi-objective Evolutionary Algorithms ,
- (3) Combinatorial and Numerical Optimization,
- (4) EAs and Graphics and Image processing,
- (5) Evolutionary Intelligent Agents ,
- (6) Evolutionary -Based Approaches to Multi-Agent Design,
- (7) Evolutionary Computation Applications for Electric Power Systems ,
- (8) Evolutionary Design and Evolvable Hardware ,
- (9) Games and Learning.

The titles of the above sessions show only a part of applications of evolutionary computation techniques. As shown in Table 4, the number of applications of evolutionary techniques are increasing in SMC conferences, since they can be easily applied to practical problems .

E. Enhancing Techniques for EC

Enhancing or improving the performance of EC techniques can be implemented by two ways.

- (1) Modifying scheme in EC,
- (2) Incorporating some heuristic methods into EC scheme.

As for the former way, several researchers modify the scheme in EC such as selection, crossover, mutation, elitist strategy and so on. Now we have a lot of operations for EC scheme, we should carefully select operations to construct EC method for our problems. On the other hand, several researchers are trying to enhance or improve the performance of EC techniques by incorporating some heuristic methods such as local search or a steepest descent method into the scheme of EC. Since problem-dependent heuristics are not applicable to other problems, recently problem-independent heuristics in coding, fitness inference and location of individuals in the genetic space are tried to research.

IV. CONCLUSION

In this paper, we briefly overviewed the recent tendency of EC applications in certain research fields. Looking back over the history of Soft Computing, the seeds of the NN, FS, and EC were sown in the 1960s, and they were widely but independently researched during the 1980s; as research activities increased during the 1980s, interest in fusing them

has also been rapidly increasing, and these cooperative technologies have widely and practically spread into commercial products and industrial systems during the 1990s.

We examined the papers submitted to WCCI and SMC conferences since 1994. From the data, we can see EC research area are attracting researchers now. As we can observed in Subsection III-B, C, and D, the application fields relating to classification, recognition, data mining, IEC, and practical problems are highly related to the hybridization techniques of EC with other methods. Therefore research area of soft computing will be enlarged as the number of researchers in this research area increases.

ACKNOWLEDGEMENT

This research was financially supported by the Kansai University Research Grants: Grant-in-Aid for Encouragement of Scientists, 2002.

REFERENCES

- [1] J. Holland, *Adaptation in Natural and Artificial Systems*, University of Michigan Press, Ann Arbor, MI (1975).
- [2] I. Rechenberg, *Evolutionstrategie: Optimierung technischer Systeme nach Prinzipien der biologischen Evolution* Frommann-Holzboog, Stuttgart, Germany (1973).
- [3] H. Schwefel, *Evolution and Optimum Seeking*, Wiley, New York (1995).
- [4] L. Fogel, A. Owens, and M. Walsh, *Artificial Intelligence Through Simulated Evolution*, Wiley, New York (1966).
- [5] J. R. Koza, *Genetic Programming*, MIT Press, Cambridge, MA (1992).
- [6] D. Goldberg, *Genetic Algorithms in Search, Optimization and Machine Learning*, Addison-Wesley, Reading, MA (1989).
- [7] L. Davis (Editor), *Handbook of Genetic Algorithms*, Van Nostrand Reinhold, New York (1991).
- [8] M. Gen, and R. Cheng, *Genetic Algorithms and Engineering Design*, John Wiley & Sons, New York (1997).
- [9] T. Baeck, D. Fogel, and Z. Michalewicz (Editors), *Handbook of Evolutionary Computation*, Oxford University Press (1997).
- [10] D. Ruan (Editor), *Intelligent Hybrid Systems: Fuzzy Logic, Neural Networks, and Genetic Algorithms*, Kluwer Academic Publishers, Norwell, MA (1997).
- [11] X. Yao, "Evolutionary Artificial Neural Networks," *Int. Journal of Neural Systems*, Vol.4, No.3, pp.203 – 222 (1993).
- [12] S. K. Pal, and P. P. Wang (Editors), *Genetic Algorithms for Pattern Recognition*, CRC Press, Florida (1996).
- [13] P. Adriaans, and D. Zantinge, *Data Mining*, Addison Wesley Longman Limited, London (1996).
- [14] S. Mitra, S. K. Pal, and P. Mitra, "Data Mining in Soft Computing Framework: A survey," *IEEE Trans. on Neural Networks*, Vol.13, No.1, pp.3 – 14 (2002).
- [15] H. Takagi, "Interactive Evolutionary Computation: Fusion of the Capabilities of EC Optimization and Human Evaluation," *Proc. of the IEEE*, Vol.89, No.9, pp.1275 – 1296 (2001).
- [16] Y. Dote, and S. J. Ovaska, "Industrial Applications of Soft Computing: A Review," *Proc. of the IEEE*, Vol.89, No.9, pp. 1243 – 1265 (2001).
- [17] *Proc. of the 1994 IEEE Int. Conf. on Neural Network* (Orlando, Florida, USA, June 27 – 29, 1994).
- [18] *Proc. of the 1998 Int. Joint Conf. on Neural Network* (Anchorage, Alaska, USA, May 5 – 9, 1998).
- [19] *Proc. of the 2002 Int. Joint Conf. on Neural Network* (Honolulu, Hawaii, USA, May 12 – 17, 2002).
- [20] *Proc. of the 1994 IEEE Int. Conf. on Fuzzy Systems* (Orlando, Florida, USA, June 27 – 29, 1994).
- [21] *Proc. of the 1998 IEEE Int. Conf. on Fuzzy Systems* (Anchorage, Alaska, USA, May 5 – 9, 1998).
- [22] *Proc. of the 2002 IEEE Int. Conf. on Fuzzy Systems* (Honolulu, Hawaii, USA, May 12 – 17, 2002).
- [23] *Proc. of the 1994 IEEE Int. Conf. on Evolutionary Computation* (Orlando, Florida, USA, June 27 – 29, 1994).
- [24] *Proc. of the 1998 IEEE Int. Conf. on Evolutionary Computation* (Anchorage, Alaska, USA, May 5 – 9, 1998).
- [25] *Proc. of the 2002 Congress on Evolutionary Computation* (Honolulu, Hawaii, USA, May 12 – 17, 2002).
- [26] *Proc. of the 1995 IEEE Int. Conf. on Systems, Man and Cybernetics* (Vancouver, British Columbia, Canada, October 22 – 25, 1995).
- [27] *Proc. of the 1997 IEEE Int. Conf. on Systems, Man and Cybernetics* (Orlando, Florida, USA, October 12 – 15, 1997).
- [28] *Proc. of the 1999 IEEE Int. Conf. on Systems, Man and Cybernetics* (Tokyo, Japan, October 12 – 15, 1999).
- [29] *Proc. of the 2001 IEEE Int. Conf. on Systems, Man and Cybernetics* (Tucson, Arizona, USA, October 7 – 10, 2001).