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The Significance of Genetic Algorithms in Search, Evolution, Optimization and Hybridization: A Short Review

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ABSTRACT

Evolutionary computing has facilitated numerous real life applications. Genetic Algorithms are one of the pioneer method that works on principle of natural genetics to provide search and optimization facility. Apart from search and optimization, Genetic Algorithm provides evolutionary characteristics and hybridization with fuzzy logic and neural network. The paper explains general structure of Genetic Algorithm along with advantages of Genetic Algorithm. The paper represents multiple roles offered by Genetic Algorithm. It explains role of Genetic Algorithm in search process. Multiple stages of searching solution are represented. The paper explains evolving nature of Genetic Algorithm. The paper also explains advantages of Genetic Algorithm over traditional optimization methods. Genetic Algorithm has been successful in developing numerous applications which includes machine learning and robotics, global and multi-objective optimization, classification, mathematical modeling, engineering and many more. The paper has significantly explains various roles presented by Genetic Algorithms by contributing to the development of evolutionary and intelligent hybrid systems.

Keywords

Evolution, Genetic Algorithm, Optimization, Soft Computing.

1. INTRODUCTION

Genetic Algorithms are popular and robust search algorithm based on principle of natural genetics. Apart from search characteristics, Genetic Algorithm provides quality of optimization, hybridization and parallel processing. Genetic Algorithms are widely used in engineering, scientific as well as business applications. They are successfully applied to the problems which are difficult to solve using conventional techniques such as machine learning and optimization. The paper spreads advantages of Genetic Algorithm. Genetic Algorithm owns several roles in designing different applications. This role includes search, optimization, evolution and hybridization. Soft Computing techniques are integrated techniques to find solutions for the problems which are highly complex, ill- defined and difficult to model. Genetic Algorithm is capable to handle such problems. There are numerous applications developed using Genetic Algorithms. The second section of the paper explains working of Genetic Algorithm. The general structure of Genetic Algorithm is presented and explained. The third section briefly discusses advantages of Genetic Algorithms. The fourth

section represents multiple roles associated with Genetic Algorithms. These roles include search capabilities, evolving capabilities, optimization and hybridization. The paper explains various roles provided by Genetic Algorithm. Comparison provided by traditional optimization algorithm and Genetic Algorithm is presented. The role of Genetic Algorithm is explained for hybridization with neural network and fuzzy logic. The final section of the paper justifies significance of multiple roles of Genetic Algorithm by providing summery of applications developed so far using Genetic Algorithm.

2. GENETIC ALGORITHM

In recent years, cognitive systems have gained prominence by implementing evolutionary approach to the computational modeling. The evolutionary computation is best suited to following types of computational problems that require following [1]: search through many possibilities to find a solution, large search space. Parallel approaches are highly suitable for such problems, an adaptive algorithm.

Genetic Algorithm is an evolutionary-based search or optimization techniques that performs parallel, stochastic, but direct search method to evolve the best solution. The area of GA has been traversed by three prominent researchers namely Fraser in 1962, Bremermann in 1962 and Holland in 1975 [2,3,4]. Genetic Algorithms are pioneered by John Holland in 1970's [5]. Genetic Algorithms are based on principle of natural evolution which is popularly known as "Darwinian Evolution".
GA is a population based search algorithm which consists of several components.

- Population of chromosome- Population of chromosome is basically problem representation using encoding schemes.
- Fitness evaluation: A fitness score is allocated to each solution. The individual with the optimal fitness score is required to be found.
- Genetic operations: The entire population evolves towards better candidate solutions via the selection operations and genetic operators such as crossover mutation and selection.
- Crossover and Mutation: These operators are responsible to generate new solutions.
- Selection: It is responsible to select parent chromosome from available chromosome. These parent chromosomes will be processed further to generate new children chromosomes.

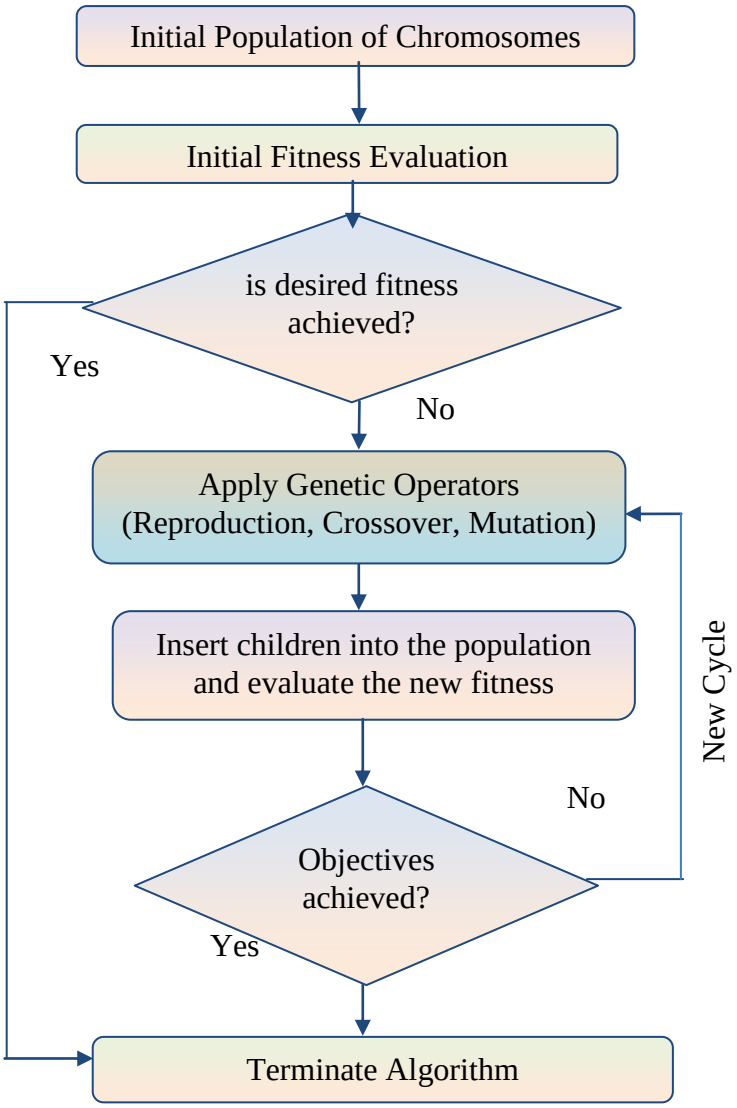

Figure 1: General Structure of Genetic Algorithm

The general structure of GA is represented using Figure 1.Better solutions will work as next generation parents whereas least fit solution will die out over successive generations. Eventually, once the population has converged and not produced offspring which are different than previous generations' off-springs, the algorithm itself is said to have converged to a set of solutions to the problem at hand.

3. ADVANTAGES

Genetic Algorithms are widely used in engineering, scientific as well as business applications. They are successfully applied to the problems which are difficult to solve using conventional techniques such as machine

learning and optimization. The major benefit of GA is that it can be used to find optimized values from large search space as well as makes system able to learn. It is observed that GA provides following major advantages [6, 7]:

- GA can be easily interfaced to obtainable simulations and models;
- GA is easy to hybridize and easy to understand;
- GA uses little problem specific code;
- GA is modular, separate from application;
- GA is capable to obtain answers always and gets better with time;
- GA is inherently parallel and easily distributed;
- GA optimizes with continuous or discrete variables;
- GA deals with a large number of variables;
- GA provides a list of optimal variables, not just a single solution;
- GA encode the variables so that the optimization is done with the encoded variables; and
- GA works with numerically generated data, experimental data, or analytical functions.

Genetic Algorithms become highly popular in the designing hybrid intelligent systems and evolutionary systems. In the field of robotics, Genetic Algorithms have been proven highly successful.

4. MULTIPLE ROLES OF GENETIC ALGORITHM

Compared to traditional search algorithm, Genetic Algorithm plays multiple roles. These roles include robust search process, evolutionary characteristics, quality of providing optimization and quality for providing hybridization with other constituents of soft computing. Due to aforementioned roles, GA is highly successful in solving real life applications. The major application areas such as combinatorial search, intelligent system design, machine learning, and evolutionary robotics have been gaining proficient results due to capabilities of Genetic Algorithm.

4.1 Role of GA in Search

GA does not require any problem specific knowledge of the search space because strings are evaluated with fitness quality and hence search is made possible through the strings which are basically constituents of its structure. Figure 2 shows process of searching solutions through fitness measures.

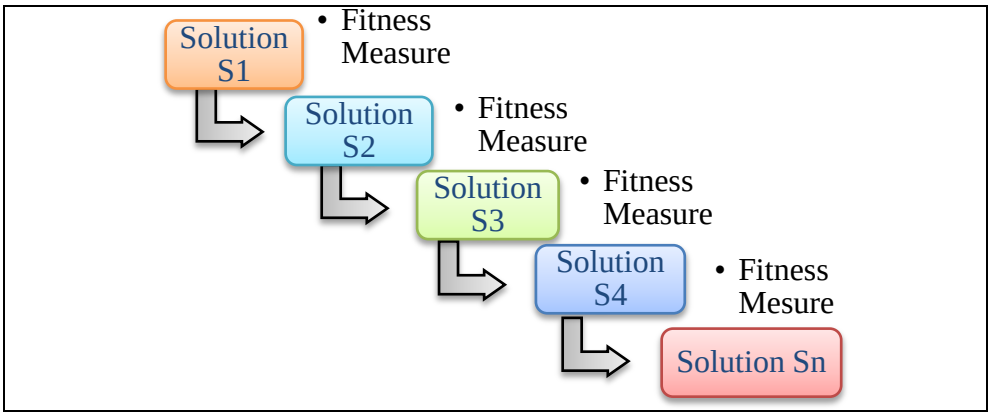

Figure 2: Search Solutions through Fitness Measure

This type of search has capability to move towards multiple directions. Here, the fitness is measured at one point of time and at the same time population can be evolved also to next generation. This way parallel processing is possible. Hence, GA is highly successful in providing solutions for parallel processing problems.

4.2 Role of GA in Evolving Solutions

The area of evolutionary computation includes the study of the foundations and the applications of computational techniques based on the principles of natural evolution. Basically, evolutionary techniques can be considered as either as search methods, or as optimization techniques [8]. There exist a number of evolutionary techniques whose main similarity is the use of a population of random or pseudo-randomly generated solutions to a problem. A number of operators are applied to the individuals of the current population to generate the individuals for the next generation population at each of the iteration. Usually, Genetic Algorithm use an operator called recombination or crossover to recombine two or more individuals to produce new individuals. Mutation or modification operators are used to create a self-adaptation of individuals. In order to select chromosome (parents) who will generate children chromosomes in next generations, selection process is designed.

The main categories of selection methods are as follows [9]:
Artificial selection: A selection process is designed such a way that it can retain or eliminate specific features according to a goal.

Natural selection: According to natural phenomena, the individual who possesses better existence qualities is able to survive for a longer period of time. In such cases, better children can be reproduced with genetic material. A selection process is similar to the Darwinian Theory of biological evolution. In natural selection process, there is no actor who does the selection. The selection is purely automatic or spontaneous without any

predefined logic. Genetic Algorithm simulates process of natural selection. Figure 3 represents steps of natural selection process.

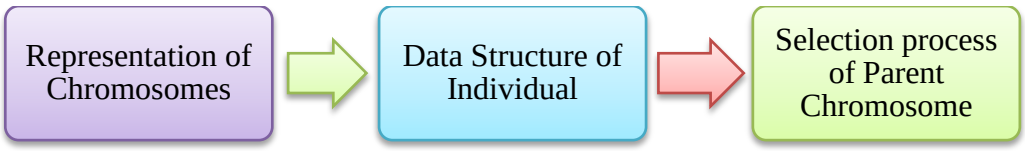

Figure 3: Steps of Simulating Natural Selection Process

4.3 Role of GA in Optimization

Optimization is the process of finding decisions that satisfy given constraints, and meet a specific outcome in terms of its optimal value. Traditional methods of optimization include both gradient based as well as direct search techniques. Being one of the prominent representatives of evolutionary computation, Genetic Algorithm satisfies the requirement providing optimum solution. The objective of global optimization is to find the "best possible" solution in nonlinear decision models that frequently have a number of sub-optimal (local) solutions [10]. In the absence of global optimization methods, feasible solutions are only the solutions. There are significant differences observed between GA and most of the traditional optimization algorithms as summarized by [11,12,13,14]:

- Traditional optimization method uses single point approach while GA uses a population of multiple points at single run;
- In traditional optimization, convergence to an optimal solution depends on the chosen initial solution while in GA, due to randomness , initial solution is always different;
- A classical algorithm is efficient in solving one problem but the same may not be efficient in solving a different problem while GA is generic in nature for similar types of objective functions;
- GA converts design space into genetic space;
- GA works with coding of parameter set rather than actual value of parameters;
- A traditional algorithm may not be efficient to handle problems with discrete variables or highly non-linear variables with constraints while GA can be robustly applied to problems with any kinds of objective functions, such as nonlinear or step functions; because only values of the objective function for optimization are used to select genes;
- Traditional algorithm can stuck at suboptimal solutions while GA can have less chance to be trapped by local optima due to characteristics of crossover and mutation operators; and
- GA uses stochastic reproduction schemes rather that deterministic ones.

The working of Genetic Algorithms for optimum solution is shown in Figure 4. Due to its random nature, the Genetic Algorithm improves the chances of finding a global solution [14]. Quite often, several applications require several contradicting criterions to be satisfied simultaneously. These problems are known as multi-objective optimization. Often those criterions are contradicting and cannot have optimum at the same time, thus improving the value one-criterion means getting worst values for another [15]. Genetic Algorithms are capable to solve problems of multi-objective optimization.

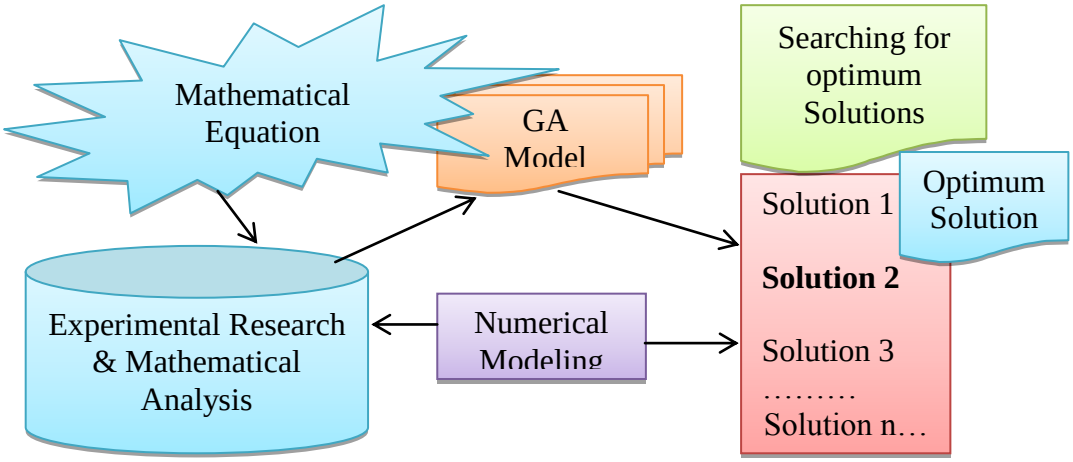

Figure 4: Working of GA for Optimum Solutions

4.4 Role of GA in Hybridization

Soft Computing (SC) is not merely a clearly defined field but also a discipline that deals with hybrid intelligent systems [16]. SC techniques are integrated techniques to find solutions for the problems which are highly complex, ill- defined and difficult to model. The family of soft computing is constructed using four prime techniques: namely Fuzzy Logic (FL), Evolutionary Computation (EC), Neural Networks (NN) and Probabilistic Reasoning (PR). Each method is capable of providing distinguished as well as sharable advantages and obviously carries certain weaknesses also. They are considered complementary rather than competitive as desirable features lacking in one approach are present in another. Recent years have contributed to large number of new hybrid evolutionary systems. There are several ways to hybridize a conventional evolutionary algorithm for solving optimization problems. Evolutionary computing is based on Evolutionary Algorithms (EA). Genetic Algorithms being one of the prominent types of EA were not specifically designed as machine learning techniques like other approaches such as neural networks but have been successfully applied to many search, combinatorial and optimization problems. However, it is well

known that a learning task can be modeled as an optimization problem, and thus can be solved through evolution which is efficiently offered by EA [17].However, one of the significant limitations of GA; shown in the Table 1 is an inability of storing and handling imprecision. In order to remove these limitations hybridization of GA with Fuzzy Logic and hybridization of GA with Neural Network is required respectively.

Table 1: Advantages and Limitations of Constituents of SC

Constituents of SC	Advantages	Limitations
GA	Natural evolution and optimization	Inability of storing and handling imprecision
FL	Approximate reasoning, imprecision	Inability of learning
NN	Learning and implicit knowledge representation	Inability for optimization
PR	Uncertainty	Inability of learning

GA-FL Hybridization

In order to have learning and dealing with imprecise knowledge handling, GA is hybridized with FL. This is popularly known as Genetic-Fuzzy Hybridization. GA is able to encode and to evolve rule antecedent aggregation operators, different rule semantics, rule- based aggregation operators and de-fuzzification methods [18]. Hence, it is considered as knowledge acquisition scheme. Due to the mentioned qualities optimization of Fuzzy Rule Based Systems (FRBSs) is made possible. These optimized Fuzzy Rule Based Systems are capable to design decisions regarding the characteristics and performance measure [19].

GA-NN Hybridization

GA has been integrated with Neural Network to develop Genetic-Neural systems. In this type of hybridization, Genetic Algorithms are used to improve performance of Neural Networks. Several important applications have been developed using this type of hybrid structures. This type of hybridization includes following ways of designing Genetic-Neural systems [20]:

- GA based tuning of connecting weights, bias values and other parameters.
- GA based tuning of neural network topologies.
- GA based preprocessing of data and interpretation of the output of NN.

GA-PR Hybridization

The aim of a probabilistic logic (also probability logic and probabilistic reasoning) is to combine the capacity of probability theory to handle uncertainty with the capacity of deductive logic to exploit structure. Integration of Genetic Algorithm with Probabilistic Reasoning (PR) has not been widely popular so far. Bayesian Network is the most popular approach of PR. In order to find optimal structure of Bayesian network for a given database of training cases, GA is utilized. Bayesian optimization algorithms are designed with help of GA-PR hybridization [18].

5. LITERATURE REVIEW OF APPLICATIONS USING GA

As a result of extensive literature survey; it has been observed that GA has been successfully applied to real life application areas [14,18,21,22,23,24,25,26,27,28, 29,30,31,32,33,34,35]. The summarized information of major applications developed using implementation of Genetic-Algorithm is represented in Table 2.

Table 2: Summarizing Major Applications of Genetic Algorithm

Application Domain	Example of Applications
Global Optimization	• Travelling Salesperson Problems consists of following: • Ex. routing of school buses, airlines, trucks, postal carriers
Prediction	• Weather Forecasting, Financial Forecasting, • Marketing & Sales
Scheduling Problems	• Effective Distribution of Resources, Examples: Timetabling problems, railway scheduling problems • Job shop Scheduling problems
Machine Learning	• Classification problems • Automated knowledge acquisition problems • Example based learning algorithms • Learning Robot Behavior
Multi-Objective Optimization	• Decision making problems in transportation planning and management
Engineering Problems	• Designing intrusion detection in network, mobile telecommunication networks, etc. • Applications in Mechanics, hydrodynamics, aeronautics, etc.
Dynamic Data Analysis	• Continuous Analysis of event such as change in stock prices, fashion industry, and any other real

	application
Classification	• Text Mining, information retrieval, Rule Discovery
Computer Games	• Real time computer games
Automation	• In Object Oriented Software Engineering, unit test cases are generated automatically • Computer automated design
Mathematical Modeling	• Graph coloring problems, artificial vision system
Hybrid Systems	• Evolutionary–fuzzy system for robotics, decision making, medical diagnostic system • Neural-Genetic-Fuzzy Modeling for control system
Media Segmentation	• Applications of media segmentation includes image, video, and music segmentation

Some of the major applications from Table 2 are explained as under:

- GAs has been successful in achieving solutions for the variety of scheduling problems which need to deal with effective distribution of resources. During the scheduling process many constraints have to be considered [22]. Genetic Algorithm has been also used to solve the train timetabling problem. The railway scheduling problem considered in this work implies the optimization of trains on a railway line that is occupied (or not) by other trains with fixed timetables. The timetable for the new trains is obtained with a Genetic Algorithm (GA) that includes a guided process to build the initial population [23].
- In the engineering of mobile telecommunication networks, two major problems can occur in the design of the network and the frequency assignment. The design of telecommunication network is of the type of multi-objective constrained combinatorial optimization problem. In order to achieve this type of optimization, GA is proposed to increase the speed of the search process; the GA is implemented parallel on a network of workstations [28].
- Genetic Algorithms are designed to play real-time computer strategy games. Unknown and non-linear search space can be explored using GA and spatial decision making strategies and population have been implemented within the individuals of a Genetic Algorithm [31].

Genetic Algorithm has been proven highly successful in large number of application areas. In order to make GA more effective and efficient, robust fitness function and effective crossover operator should be designed. GA has been providing significant advantages searching, optimization and

evolution. The most promising research area is Genetic Algorithm based hybrid systems. Hybridization of genetic algorithms have contributed a lot in designing intelligent systems, robotics, evolutionary systems, machine learning systems, etc. The solutions provided by Genetic Algorithms are very rapid, reliable and precise.

6. CONCLUSION

The paper explains Genetic Algorithm and its working characteristics. Various advantages of Genetic Algorithm are presented. Genetic Algorithms possesses several important features such as evolution, search, optimization and hybridization. The paper explains multiple roles of Genetic Algorithms. One of the major beneficial characteristics of Genetic Algorithm is to implement efficient search process compared to traditional search algorithms. Genetic Algorithms are capable to simulate process of natural evolution. The various steps of natural evolution are presented in this paper. Genetic Algorithm plays extremely important role in providing global optimization. The paper explains how Genetic Algorithm is utilized for achieving optimized outcome compared to traditional optimization methods. This paper presents advantages and limitations of major constituents of soft computing family i.e. Genetic Algorithm, fuzzy logic, neural network and probabilistic reasoning. Being one of the important constituents of Soft Computing, Genetic Algorithm is greatly advantages in designing hybrid intelligent systems. The hybrid systems have strength of each of the technique used in designing the systems. The paper highlights importance of Genetic-Fuzzy System, Genetic-Neural system, Genetic-Bayesian system. The literature survey of the applications developed so far using implementation of Genetic Algorithm includes significant real world applications. Thus, the paper justifies significance of varied roles of Genetic Algorithm by providing summery of applications developed so far using Genetic Algorithm. It also outlines future trends and research direction of Genetic Algorithms.

REFERENCES

[1] Leung, J. et al. (2011). Genetic Algorithms and Evolution Strategies [Online]. Available:http://pages.cpsc.ucalgary.ca/~jacob/Courses/Winter2000/CPSC533/Slides/04.3.1-ES-GA.ppt [Accessed: June 2013].

[2] Fraser, A.S., Simulation of genetic systems, J. Theoretical Biology, vol. 2, no.3, pp. 329- 346, May 1962.

[3] Bremermann, H. J., Optimization through evolution and recombination, in Self – organizing Syst., M.C. Yovits, et al., Eds. Washington D.C.: Spartan Books, 1962, pp. 93-106.

[4] Holland, J. H., Adaptation in natural and artificial systems. Ann arbor: The University of Michigan Press, 1975.

[5] Holland, J. H., Hierarchical descriptions of universal spaces and adaptive systems, in *Essays on cellular automata*, A.W. Bruks , Ed. Urbana: Univ. Illinois Press,1970, pp. 320-353.

[6] Williams, W., Meta-heuristic Algorithms: Genetic Algorithm: A Tutorial [Online].Available: https://www.cs.drexel.edu/~spiros/teaching/SE320/slides/ga.pdf [Accessed: May 2013].
[7] Haput, R. and Haput, L., Practical Genetic Algorithms, 2nd Edition,A JOHN WILEY & SONS, 2004.
[8] Reyes, C. and Sipper, M., Evolutionary computation in medicine: an overview, Artificial Intelligence in Medicine, vol. 19, pp.1-23, 2000.
[9] Mankad, K. B. and Sajja, P. S. (July 2012). Measuring human intelligence by applying soft computing techniques: A genetic fuzzy approach , in *Diagnostic Test Approaches to Machine Learning and Commonsense Reasoning Systems*, X.A. Naidenova and D. Ignatov, Eds. Hershey, PA: IGI Global, pp.128-153 [Online]. Available: http://www.irma-international.org/viewtitle/69407/ [Accessed July 2013].
[10] Bajpai, P. and Kumar, M., Genetic Algorithm – an Approach to Solve Global Optimization Problems, Indian J. Computer Sci. and Eng., vol. 1, no. 3, pp. 199-206, Oct.-Nov. 2010.
[11] Karry, F. O. and Silva, C. D. *Soft computing and intelligent system design: Theory, tools and applications*, 1st ed., New York, NY: Pearson, 2004, pp. 44, 64, 368,374-375,379,382,390.
[12] Padhy, N. P., *Artificial Intelligence and Intelligent System*. New Delhi, India: Oxford University Press, 2005, pp. 23,279,330-333,363,463,483-499.
[13] Rajsekaran, S. and Pai, V., Neural Networks, Fuzzy Logic, and Genetic Algorithms Synthesis and Applications. New Delhi: PHI, 2003, pp.11, 228,249.
[14] Deb, K. Revolutionary Optimization by Evolutionary Principles, [online]Available: http://www.iitk.ac.in/directions/directsept04/deb~new.pdf
[15] Andrey, P. ,Genetic Algorithm for Optimization, User Manual, Hamburg, 2005.
[16] Akerakar, R. and Sajja, P.S. *Knowledge-Based Systems*. Sudbury, MA: Jones and Bartlett, 2010, pp. 67,129,152,218,239,243.
[17] Herrera, F. (2009). Lecture Notes for Data Mining and Soft Computing- Session 6, Genetic-Fuzzy Systems- I. Dept. Computer Science and A.I., University of Granada, Spain [Online]. Available:http://www.isa.cie.uva.es/estudios/doctorado/documentacion2009/DM-SC-06-I-Genetic-Fuzzy-Systems.pdf [Accessed: Jan 2014].
[18] Cor'don, O. et al., *Genetic Fuzzy Systems Evolutionary tuning and learning of fuzzy knowledgebases*. Singapore: World Scientific, 2001,pp. 1, 2,40,79-80,87,89,130, 132-136,142-144,375-380,414-416.
[19] Puig, A.O. et al., Evolving Fuzzy Rules with UCS: Preliminary Results, *in Learning Classifier Systems*, J. Bacardit et.al., Eds.vol. 4998, Berlin, Heidelberg: Springer-Verlag, 2008, pp. 57-76.
[20] Pratihar, D. K. Soft Computing. New Delhi: Narosa, 2008.
[21] Valenzuela, C. L. Evolutionary Divide and Conquer: a novel genetic approach to the TSP, Ph.D. dissertation, Dept. Comput., Univ. London, London, England,1995.
[22] Sigl, B. et al., Solving Timetable Scheduling Problem by Using Genetic Algorithms, in Proc. 25th Int. Conf. IT Interfaces, June 2003, pp. 519 – 524.
[23] Tormos, P. et al., A Genetic Algorithm for Railway Scheduling Problems, in *Metaheuristics for Scheduling in Industrial and Manufacturing Applications*, F. Xhafa and A.Abraham, Eds. vol.128, Berlin, Heidelberg: Springer, 2008, pp. 255–276.
[24] Fidelis, M. V. et al., Discovering comprehensible classification rules with a Genetic Algorithm, in *Proc. 2000 Congr. Evol. Comput*., vol. 1, R. Dienstbier, Ed. July 2000, pp. 805-810.
[25] Ribeiro, A. et al., Automatic Rules Generation by GA for Eggshell Defect Classification, presented at Proc. European Congr. Comput. Methods in Appl. Sci. and Eng., Barcelona , Spain, 2000.

[26] Srinivas, N. and Deb, K., Multi-objective Optimization Using Non-dominated Sorting in Genetic Algorithms, Evol .Compu., vol.2, no.3, pp. 221-248,1994.
[27] William, H. K. and Yin, Y., Genetic Algorithm-Based Approach for Transportation Optimization Problems, in The Practical Handbook of Genetic Algorithms, 2nd Ed., L. Chambers, Eds. MA: Hall& Chapman/CRC Press, 2000, pp. 236-244.
[28] Meunier, H. et al., A multi-objective Genetic Algorithm for radio network optimization, in Proc. 2000 Cong. Evol. Compu., vol.1, La Jolla, CA, July 2000, pp. 317- 324.
[29] Li, W. Using Genetic Algorithm for Network Intrusion Detection, in Proc.US. Dept. Energy Cyber Security Group 2004 Training Conf., Kansas City, Kansas,2004, pp. 24-27.
[30] Quintana, D. et al., Evolutionary Rule-Based System for IPO Under-pricing Prediction, in *Proc. Genetic and Evo. Comput. Conf.*, Washington , DC, June 2005, pp. 983-989.
[31] Miles, C. and Louis, S.J., Towards the Co-Evolution of Influence Map Tree Based Strategy Game Players, in *IEEE Symp. Comput. Intell. and Games*, May 2006, pp. 75–82.
[32] Gupta, N. K. and Rohil, M. Using Genetic Algorithm for Unit Testing of object oriented software, in *Proc. First Int. Conf .Emerging Trends in Eng. and Techno.*, July 2008, pp. 308-313.
[33] Eiben, A. E. and Hauw, J. K., Graph Coloring with Apadtive Genetic Algorithm , *J. Heuristics*, vol. 4, no. 1, pp. 25-46, Jun. 1998.
[34] Rafael, B., Affenzeller , M., Wagner, S., Application of an Island Model Genetic Algorithm for a Multi-track Music Segmentation Problem, in P. Machado, Eds. Evolutionary and Biologically Inspired Music, Sound, Art and Design,pp.13-24, Springer Berlin Heidelberg, April 3-5, 2013.
[35] Spanos, A. C.,et.al., A new hybrid parallel genetic algorithm for the job-shop scheduling problem, *International Transactions in Operational Research*, Oct 2013, DOI: 10.1111/itor.12056.

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