Chapter 3

LITERATURE REVIEW OF SOFT COMPUTING IN OPTIMIZATION

3.1 LITERATURE RELATED TO GA

Rajeev and Krishnamoorthy in 1992 [17] presented a simple GA for optimizing structural systems with discrete design variables. A constrained optimization problem was transformed in to unconstrained one using penalty-based method. The paper was aimed at presenting the concept of optimization through GA in detail illustrating three bar truss problem. For this purpose all the computations for three successive generations were presented in the form of tables for easy understanding of the algorithm. Developed algorithm was then implemented for optimization of large size structure such as 160-bar transmission tower.

Koumousis and Georgiou in 1994 [18] solved mixed layout and sizing optimization problem of a typical roof truss using genetic algorithm for the layout part and logic program for the sizing optimization part. The method was applied to large-design-space problems, and near optimum solutions were found in reasonable computing time. The GA was used with roulette-wheel selection scheme, a single point crossover and a standard mutation scheme. An elitist strategy was also incorporated. The numerical results presented showed the efficiency of the method.

Shyue-Jian and Chow in 1995 [19] proposed the steady-state GAs for discrete optimization of trusses. The optimization problem was formulated as a constrained optimization problem with discrete design variables. Discrete design variables were treated by a two-stage mapping process which was constructed by the mapping relationship between unsigned decimal integers and discrete values. The authors suggested that a small generation gap and careful modification in steady-state GA can significantly reduce the computational effort and promote the computational efficiency. Several examples were solved to demonstrate the effectiveness, robustness and fast convergence of the proposed algorithm. The performance of four different crossover operators was also compared.

Rajan in 1995 [20] developed a procedure for the combined sizing, shape and topology optimization of space trusses. The sizing design variables were considered both continuous and discrete. The nodal co-ordinates were treated as continuous variables using hybrid natural

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approach for shape optimal design. In context of topology optimization element connectivity and boundary conditions were treated as Boolean design variables. The problem of getting feasible design was tackled using the penalty approach to penalize the unstable structures, null structures and structures whose performance constraints are not satisfied. The computational efficiency was improved by using two concepts: (i) using restart and (ii) identifying repeating chromosomes. The numerical examples were solved to illustrate the proposed methodology.

In 1997 Rajeev and Krishnamoorthy [21] demonstrated two improved methods for size and configuration optimization and topology optimization of trusses. The first one is a two-phase method, which in addition to arriving at better solutions compared to those obtained using earlier methods, also improves the computational efficiency in size and configuration optimization. The second method, based on a variable string length genetic algorithm (VGA), addresses the topology optimization problem, taking in to account a number of practical issues. Classical problems from literature were solved and results were compared. Features of the proposed methods, which help in modeling and application to optimal design of large truss structures, were demonstrated by solving a microwave antenna tower.

In 1997 Yang and Soh [22] proposed a new approach to optimization design concerning the configurations of structures using GA with tournament selection strategy. The tournament selection scheme was used as a replacement for the commonly used fitness-proportional selection strategy to drive GA so as to improve the fitness of each succeeding generation more efficiently. The significant reduction in the computational cost achieved in the newly proposed approach, as compared to the other GA approaches was highlighted by presenting the numerical results obtained for 18-bar plane truss, 25-bar space truss and 112 bar dome space truss problems.

Camp, Pezeshk and Cao in 1998 [23] developed a procedure incorporating a simple GA for discrete optimization of two-dimensional structures. In this study the GA based design procedure FEAPGEN was developed as a module in the Finite Element Analysis Program (FEAP). The special features of this program highlighted by the authors were discrete design variables, an open format for prescribing constraints, design checking using AISC-ASD specifications multiple loading conditions and a comprehensive AISC database of available structural steel members. Several strategies for reproduction and crossover were investigated.

In particular, a group selection scheme that does not require fitness scaling was applied. A comparison was made between FEAPGEN design search procedure and a classical continuous optimization method based on optimality criteria method. In the published work the examples of ten bar cantilever truss, one bay eight storey and three bay three storey building frames were included.

In 1998 Hadi and Arfiadi [24] carried out study on optimum design of tuned mass damper for seismically excited building structures. Multi degree of freedom structures were considered in the design process so that it makes improvement to the available design procedures where usually single mode model is considered. The H_2 norm of the transfer function from the external disturbance to a certain regulated output is taken as a performance measure of the optimization criterion in GA based procedure. It was shown that by the proposed approach, the optimum value of the mass damper can be determined without specifying the modes to be controlled.

Shresta and Ghaboussi in 1998 [25] developed a new approach of arriving at optimum design without using conceptual designs or ground structures to generate entirely new and innovative designs especially when more complex design problems are attempted. The proposed methodology was implemented using GA to evolve optimum structural shape designs, which are free to assume any geometry and topology. The sizing, configurational and topological aspects of the design were simultaneously addressed. The methodology was capable of addressing single and multiple loadings, and plane and space structures. A new string representation scheme, generalized penalty function and fitness function were introduced. Two illustrative examples of single span plane trusses were solved and the results were discussed.

Yang, Xie, Steven and Querin in 1999 [26] presented an evolutionary method for structural topology optimization (ESO) subject to frequency constraints. The bidirectional evolutionary structural optimization (BESO) method which allows the material to be added as well as removed was developed and used successfully. Three kinds of optimization objectives, namely single frequency maximization, multiple frequency maximization and structure design with prescribed frequencies were considered. Four examples were tested by BESO and ESO. The objective functions yielded by the two methods were close and BESO was computationally more efficient in most cases.

Rath, Ahlawat and Ramaswamy in 1999 [27] demonstrated a natural velocity field method for shape optimization of RC flexural member. The possibility of shape optimization by modifying the shape of an initial rectangular section, in addition to variation of breadth and depth along the length was also explored. The methodology developed by the authors uses the sequential quadratic programming (SQP) technique for the necessary shape changes and genetic algorithm to optimize the diameter and number of main reinforcement bars. The results of three design examples - a simply supported beam, a cantilever beam and a two-span continuous beam under UDL showed a significant saving (45-56%) in material and cost.

Kanwalpreet and Ramkrishnan in 2000 [28] Presented an Object oriented implementation of GA for classical problem of optimal design of truss structures form industrially manufactured sections, along with the exploration of possible new horizon of continuum topology optimization. The authors concluded that the concept of objects best exploits the generality of GAs. They showed that in object oriented terminology a "truss" class consists of structural analysis subroutines, one of which returns the relative closeness of the truss to the global optimal or the "fitness" values of the particular structural string sent to it by the routines of "genetic" class.

In 2000 Jakiela, Chapman, Duda, Adewuya and Saitou [29] applied the GA to structural topology design problems using a binary material/void design representation that is encoded in GA chromosome data structures. This representation was intended to approximate a material continuum as opposed to discrete truss structures. Four examples, showing the broad utility of the approach and representation were presented. A fifth example suggested an alternate representation that allows continuously-variable material density.

Prasad, Thampan and Krishnamoorthy in 2001 [30] proposed reliability –based structural optimization (RBSO) considering probability of distributions of random variables pertaining to load and strength parameters and system level reliability requirements. The paper briefly discussed computational and modeling complexities in RBSO using system level reliability constraints and the limitations of mathematical programming techniques. The authors proposed a modified branch-and-bound algorithm to perform the system reliability assessment of discrete structures by failure mode approach and illustrated the computational efficiency of this approach in the optimization process. They also suggested the GA based methodology for reliability based configuration optimization of trusses which satisfactorily

addressed the computational and convergence problems. It was concluded that GA based RBSO of trusses treating member sizes and configuration as design variables provides better optimal solutions for practical structures.

Krishnamoorthy, Venkatesh and Sudarshan in 2002 [31] discussed object-oriented design and implementation of core GA library consisting of all the genetic operators having an interface to a generic objective function for solving practical optimization problems. The object-oriented design, apart from giving a more natural representation of information, was shown to facilitate better memory management and code reusability. It was also indicated how classes derived from the implemented libraries can be used for practical optimization of large space trusses, where several constructability aspects have been incorporated to simulate the real-world design constraints. Strategies to model the chromosome and to code genetic operators for handling such constraints were emphasized. Strategies were also suggested for member grouping to reduce the problem size and for implementing move-limit concepts to reduce the search space adaptively in a phased manner. The object oriented methodology was tested on space trusses and the results were compared with previously reported results. The authors concluded that GA implemented using efficient and flexible data structures can serve as a very useful tool in engineering design and optimization.

In 2002 Kocer and Arora [32] formulated the problem of optimal design of latticed transmission towers subjected to normal operating load and an earthquake load. The time history analysis of the structure was also performed. Two methods were presented and evaluated for the discrete sizing variable optimization problem. The first method, called two-phase method, uses a combination of continuous and discrete optimization algorithm. The second method, called adaptive discrete assignment method (ADAM), uses only continuous optimization algorithm. The methods were shown to be applicable to any discrete variable problem that can be formulated as continuous optimization algorithm. It was concluded that the GA is very straight forward method to use for discrete optimization problems; however, it requires a significant amount of CPU time. On the other hand, the two-phase method and the ADAM do not require as much computational effort but the discrete design found with them are slightly more expensive. Also, numerical implementation of the two methods requires more effort.

Hao and Xia in 2002 [33] explored the use of GA for vibration based damage detection of the structure. The GA with real number encoding was applied to identify the damage by minimizing the objective function, which directly compares the changes in the measurement before and after damage. Three different criteria were considered, namely, the frequency changes, the mode shape changes and combination of two. A laboratory tested cantilever beam and frame were used to demonstrate the technique. Authors concluded that damage element can be detected by GA, even when the mathematical model is not accurate.

Sivakumar, Rajaraman, Knight and Ramachandramurthy in 2004 [34] presented a new approach for the size optimization of steel lattice towers by combining genetic algorithms and an object oriented approach. The purpose of this approach was to eliminate the difficulties in the handling of large size problems such as lattice towers. Improved search and rapid convergence were obtained by considering the lattice tower as a set of small objects and combining these objects into a system. A tower was considered to consist of panel objects, which can be classified as separate objects, as they possess an independent property as well as inherent properties. This could considerably reduce the design space of the problem and enhance the result. The algorithm with practical design considerations was implemented to optimize a typical tower configuration and compared with the results of a normal approach in which the full tower was considered.

Sabhahit and Hegde in 2004 [35] tested GA for its use in optimum design of prestressed concrete beam. Prismatic unsymmetrical I-section girders, simply supported at the ends and subjected to a uniformly distributed load were considered for the optimum design. The objective was to minimize the overall cost including the costs of high performance concrete, high tensile steel and a cost associated with non-tensioned steel, anchorages, form, labour work, curing and testing. The design problem was formulated as a non-linear mathematical programming problem to satisfy IS: 1343-1980 specifications. The effectiveness of the method was proved by comparing it with sequential unconstrained minimization technique. The parametric studies had been carried out to highlight the influence of various parameters, such as cost coefficients, generation number, crossover probability and mutation probability on the optimum cost.

Wang and Tai [36] in 2004 proposed an improved bit-array representation method for structural topology optimization using the GA. The issue of representation degeneracy was

fully addressed and the importance of structural connectivity in a design was further emphasized. To evaluate the constrained objective function, Deb's constraint handling approach was further developed to ensure that feasible individuals are always better than infeasible ones in the population to improve the efficiency of the GA. A hierarchical violation penalty method was proposed to drive the GA search towards the topologies with higher structural performance, less unusable material and fewer separate objects in the design domain in a hierarchical manner. Numerical results of structural topology optimization problems of minimum weight and minimum compliance designs showed the success of the novel bit-array representation method and suggested that the GA performance can be significantly improved by handling the design connectivity properly.

Woon, Tong, Querin and Steven in 2005 [37] found that success of GA-based topology optimization method for continuum structures has been limited. The authors, however, believe that the deficiencies of previous applications lie not in the GA but in the manner in which it was applied. Therefore they proposed a new GA-based method for the continuum topology optimization which yields high-fidelity solutions comparable to those produced through more well-known and established methods. The proposed method is centered on a number of novel concepts, most notably the simultaneous use of multiple genetic algorithms and the use of high-level string coding based on structural response information. The basis and methodology of the multi-GA approach was explained and key algorithms were detailed. The results obtained through the method when applied to number of structural problems were presented and discussed.

In 2005 Fu, Zhai and Zhou [38] used a simple GA with elitism for the minimum weight design of welded steel plate girder bridges. The cost of the plate girder was considered as an objective function subject to stress constraint, dimensional constraint and deflection constraint. Exterior penalty function was used to handle the constraints. Two types of plate-girder bridges were studied: a single-span bridge and a two-equal-span continuous bridge. Bridges with various span lengths, in increments of 20 ft, were investigated A parametric study was made for span lengths from 100 to 400 ft in 20-ft increments for the single-span bridge and span lengths from 200 to 400 ft in 20-ft increments for the two-span continuous bridges. From the set of optimum design data, they drew meaningful conclusions for the design variables. They concluded that the results verify engineers' past design experiences.

In 2005 Kicinger, Arciszewski and DeJong [39] carried out study on evolutionary computation in the design of the steel structural systems of tall buildings. They presented results of extensive research on both short-term, up to few hundred generations and long-term evolutionary design processes up to few thousand generations. They carried out systematic parametric design experiments with Inventor 2001. The objective of these experiments was to qualitatively and quantitatively investigate evolution of steel structural systems of tall buildings during a multistage evolutionary design process as well as the influence of various evolutionary computation parameters. Mutation and crossover rates, population size, the length of the evolutionary processes, and the importance of a symmetry requirement had been analyzed and results produced. Emergence of structural shaping patterns was also studied and several interesting patterns were found in the evolutionary design process.

Balling, Briggs and Gillman in 2006 [40] developed an algorithm based on genetic search process and used for simultaneous optimization of size, shape and topology of skeletal structures including plane frames and plane trusses. The developed algorithm finds multiple optimum and near optimum topologies in a single run. The algorithm was executed on a bridge example where it found both traditionally recognized bridge topologies as well as less familiar topologies. It was also executed on two standard test problems as well as on a plane frame example. They concluded that algorithm presents the designer with more choices and more information than algorithms that converge to a single optimum design. Method of dealing with singular and unstable topology was discussed. The key modifications made to GA, known as topology fitness and topology anticipation, were explained. These modifications enabled the algorithm to find the multiple optimum topologies.

A method of solution of shape optimization of plate/shell structures subjected to transient dynamic loads has been developed by **Sriramamurthy and Dutta in 2006 [41]**. The authors developed a surface mesh generator with boundary definition capabilities and finite element analysis module and integrated with GA code to carry out the shape optimization. The algorithm developed was observed to behave as a satisfactory shape optimization environment.

3.2 LITERATURE RELATED TO FL

In 1993 Fullér and Zimmermann [42] interpreted fuzzy linear programming (FLP) problems with fuzzy coefficients and fuzzy inequality relations as multiple fuzzy reasoning

schemes (MFR), where the antecedents of the scheme correspond to the constraints of the FLP problem and the fact of the scheme is the objective of the FLP problem. The authors showed that the solution process for a classical (crisp) LP problem results in a solution in the classical sense, and under well-chosen inequality relations and objective function, coincides with those suggested by other researchers. Furthermore, they highlighted how to extend the proposed solution principle to non-linear programming problems with fuzzy coefficients. They illustrated the approach by some simple examples.

In 2000 Chen and Shieh [43] used fuzzy decision making technique to solve multiobjective topology optimization problems. Minimizing compliance and maximizing fundamental eigen value were two objectives pursued. Linear membership functions were used for material constraint as well as eigen value objective. The membership function for the objective of compliance was a nonlinear exponentially decaying function. Increasing the decaying rate puts more weight on the objective of compliance. The effect of different finite element types on the topology was also explored. A numerical example using two different types of finite elements was given to illustrate the approach.

In 2001 Joghataie and Ghasemi [44] implemented the fuzzy membership functions in the multistage optimization technique to improve its performance for the minimum weight design of truss structures of fixed topology. In the methodology used, first, a large truss was split into several smaller substructures that are optimized separately. However to preserve the unity of the original truss, interaction-balance equality constraints were introduced to account for the compatibility of deformations and the equality of action and reaction of the forces at the point of separation of the substructures. A penalty function, containing the equilibrium equations and interaction constraints as well as other constraints was defined for each substructure. A fuzzy membership function, returning a value between 0 and 1, was introduced for each of the equality constraints to provide some fuzzy evaluation of the degree of satisfaction. The design procedure was iterative and continues till convergence. It had been found that the technique significantly improves the convergence speed at the expense of increasing the minimum weight by negligible amount.

In 2001, Simões [45] presented two-phase method for fuzzy optimization of structures. In the first phase the fuzzy solution is obtained by using the level cuts method and in the second phase the crisp solution, which maximizes the membership function of fuzzy decision making

by using the bound search method. Illustrative examples involving skeletal structures and reinforced concrete slabs were solved.

Gasimov and Yenilmez in 2002 [46] concentrated on two kinds of fuzzy linear programming problems: linear programming problems with only fuzzy technological coefficients and linear programming problems in which both the right-hand side and the technological coefficients are fuzzy numbers. The crisp problems obtained after the defuzzification were non-linear and even non-convex in general. The modified sub gradient method was proposed for solving these problems. The comparison of the new proposed method with well known fuzzy decisive set method was made.

Kaymak and Sousa in 2003 [47] stated that many practical optimization problems are characterized by some flexibility in the problem constraints which could lead to a workable solution where the goals and constraints are satisfied to a various degree. Further they noticed that fuzzy set are suitable for modeling such type of soft constraints. The weighted satisfaction of the problem constraints and goals was demonstrated by using a simple fuzzy linear programming problem. They concluded that the framework is more general and can be applied to fuzzy mathematical programming problems and multi-objective fuzzy optimization.

In 2005, Kelesoglu and Ülker [48] presented general algorithm for nonlinear space truss system optimization with fuzzy constraints and fuzzy parameters. The analysis of the space truss system was performed with ANSYS software. The algorithm of multiobjective fuzzy optimization techniques was formed with parametric dimensional language. In the formulation of the design problems, weight and minimum displacement were considered as the objective functions. 9-bar, 120-bar and 244-bar space truss examples were presented to demonstrate the application of the algorithm.

3.3 LITERATURE RELATED TO ANN

In 1991, Tagliarini, Christ and Page [49] pointed out that ANN with feedback connections provide a computing model capable of exploiting fine-grained parallelism to solve a rich class of optimization problems. They developed a systematic approach to designing NNs for optimization applications. The approach was demonstrated by designing a network that finds good solutions to a complex, nonlinear resource allocation problem – the problem of

allocating weapons to counter offensive threats. The neural solution, employing more than 46000 neural elements and more that 49 million connections was simulated on a high speed parallel processor. The network produced excellent solutions to a realistic threat scenario.

Karim and Adeli in 1999 [50] performed a comprehensive parametric study for global optimization of cold-formed steel Z-shapes beams using computational neural network model. Design curves were developed for global optimum values of the thickness, the web depth to thickness ratio and the flange width to thickness ratio.

Gupta and Li in 2000 [51] argued that traditional neural network involves long time consuming training process in order to design the layers and neurons and to find the weights for the neurons. On the other hand, mathematical programming neural network has a dynamic equation for solving the optimization problem, does not involve training and therefore, it takes less time for computations. They surveyed several MPNN models and developed new MPNN models and applied to design optimization problems in mechanical motion synthesis and structural design. It was concluded that compared to the traditional mathematical programming methods the MPNN algorithms are robust and can have global convergence properties.

Using computational neural network model developed, a comprehensive parametric study was performed by **Karim and Adeli in 2000 [52]** for global optimization of cold-formed steel I-shapes beams based on the American Iron and Steel Institute specification. Design curves were presented for global optimum values of the thickness, the web depth-to-thickness ratio and the flange width-to-thickness ratio.

A report was prepared for presentation at 10th Multidisciplinary Analysis and Optimization Conference **in 2004** by **Patnaik, Coroneos, Guptill, Hopkins and Haller [53]**. The authors of this report alleviated the deficiencies of the Flight Optimization System (FLOPS) code of subsonic aircraft through use of neural network and regression approximations. They claimed that the regression method appears to hug the data points, while the neural network approximation follows a mean path. For an analysis cycle, the approximate model required milliseconds of CPU time versus seconds by the FLOPS code. Performance of the approximators was satisfactory for the aircraft analysis.

In response to, a fully automated configuration optimization system developed to execute the entire configuration design process automatically with room of improvements in the hole representation templates and hole interpretation reliabilities by **Lin and Chao, Lin and Lin in 2005 [54]** proposed two-stage artificial neural networks based hole image interpretation techniques with improved template variety and recognition reliability.

In 2005, Sirca and Adeli [55] developed a method for the total cost optimization of pre-cast pre-stressed concrete I-beam bridge systems, by taking in to account the costs of the pre-stressed concrete, deck concrete, pre-stressed I-beam steel, deck reinforcing steel and form work. The problem was formulated as a mixed integer-discrete nonlinear programming problem and solved using the robust neural dynamics model of Adeli and Park. The practical application of the methodology was demonstrated by presenting an example. Typical network convergence curves using three different network starting points demonstrated the excellent convergence and the robustness of the optimization model.

3.4 LITERATURE RELATED TO HYBRID TECHNIQUES

In 1994, Philipp [56] carried out project work to examine how GA can be used to optimize the neural network topology, learning rate, initial weights. It was investigated, how various encoding strategies influence the GA/NN synergy. They were evaluated according to their performance on academic and practical problems of different complexity. He concluded that for weight optimization, the GANN system outperforms the traditional neural network, when small networks are used. He also claimed that a mix of crossover and mutation, high number of encoding bits and a large generation size prove to be successful. He concluded that the application of GANN system for weight optimization is reduced to the field of small networks. Regarding NN architecture optimization he concluded that architecture optimization by a GANN system comes with an extremely high computational cost.

Montana in 1995 [57] pointed out that selection of initial weight matrix for the neural network training is the key issue. The usual approach is to derive a special-purpose weight selection algorithm for each neural network architecture. The approach used in this paper was different which uses GA for the NN weight selection.

Soh and Yang in 1996 [58] investigated fuzzy controlled genetic-based search technique for structural shape optimization. An automated optimal procedure based on proposed approach

was developed and used in the least-weight design of truss structures, which includes their geometry as a design variable to be optimized. To increase the performance of the genetic-based approach for shape optimization problems, the design constraints related to member stress, joint displacement and member buckling are described by using fuzzy set theory. A fuzzy rule-based system representing expert knowledge and experience was incorporated in the approach to control its optimal search process. The effectiveness and efficiency of the proposed approach was demonstrated by solving four examples of shape design problems.

Sarma and Adeli in 2000 [59] extended the augmented Lagrangian GA of Adeli and Cheng and presented fuzzy Lagrangian GA for optimization of steel structures subjected to the constraints of AISC allowable stress design specifications taking in to account the fuzziness in the constraints. The membership function for the fuzzy domain was found by the intersection of the fuzzy membership function for the objective function and the constraint using the max-min procedure of Bellman and Zadeh. Nonlinear quadratic membership functions were used for objective function and constraints. By solving two space axial-load structures using the algorithm the authors concluded that new fuzzy GA approach increases the likelihood of obtaining the global optimum solution, improved convergence and reduced total computer processing time.

In 2000, Sarma and Adeli [60] developed fuzzy discrete multi-criteria cost optimization model for design of space steel structures subjected to actual constraints of commonly used design codes such as AISC, ASD codes by considering three design criteria: (1) minimum material cost, (2) minimum weight and (3) minimum number of different section types. The computational model starts with a continuous-variable minimum weight solution with a preemptive constraint violation strategy as the lower bound followed by a fuzzy discrete multi-criteria optimization. They concluded that solving the structural design problems a cost optimization problem can result in substantial saving compared with the traditional minimum weight solution, especially for large moment resisting structures.

Kim, Gen and Yamazaki in 2003 [61] developed a hybrid genetic algorithm (hGA) with fuzzy logic controller (FLC) to solve the resource-constrained project scheduling problem (rcPSP). For solving these rcPSP problems, they firstly demonstrated that hGA with FLC (flc-hGA) yields better results than several heuristic procedures presented in the literature. Then they evaluated several genetic operators, which include compounded partially mapped

crossover (PMX), position-based crossover (PBC), swap mutation (SM), and local search-based mutation (LSM) in order to construct the flc-hGA which have the better optimal makespan and several alternative schedules with optimal makespan.

Guruswamy and Anitha in 2004 [62] introduced a new approach towards optimal design of a hybrid proportional-integral plus derivative (PID) controller used for controlling linear as well as nonlinear system using GA. The proposed approach allows the designer to use only one well defined linear fuzzy control space with fixed structure parameters for both linear and nonlinear system. The constant PID gains are optimized using a multi objective genetic optimization and thereby yielding an optimal fuzzy controller. Computer simulations were shown to demonstrate its improvement over fuzzy PID controller without multi objective genetic optimization.

In 2004, Subbaiah, Srinivas and Mouli [63] presented a genetic training approach for a two-layer neural network to predict the solutions of various constrained optimization problems. The technique of GA was employed in designing the connection weights of an unsupervised neural network for minimizing the value of effective objective function. The methodology was demonstrated by solving numerical examples.

Nguyen, Abbass and McKay in 2005 [64] proposed the techniques to effectively stop the training or evolution of the neural networks to avoid overfitting. In this work different early stopping criteria based on (i) the minimum validation fitness of the ensemble and (ii) the minimum of the average population validation fitness, were shown to generalize better than the survival population in the last generation. The numerical experimental results suggested that using minimum validation fitness of the ensemble as an early stopping criterion is beneficial.

In 2005, Lagaros, Charmpis and Papadrakakis [65] focused on improving the computational efficiency of evolutionary algorithm implemented in large scale structural optimization problems. It was pointed out that locating optimal structural designs using evolutionary algorithms is a task associated with high computational cost, since a complete finite element analysis needs to be carried out for each parent and offspring design vector of the population considered. This work presented a NN strategy to reliably predict, in the framework of an evolution strategies procedure for structural optimization, the feasibility or

infeasibility of structural designs avoiding computationally expensive FE analysis. The prediction capabilities and the computational advantages offered by this adaptive NN scheme coupled with domain decomposition solution techniques were investigated in the context of design optimization of skeletal structures on both sequential and parallel computing environments.

Kim, Seo and Kang in 2005 [66] presented hybrid models of NNs and GAs to cost estimation of residential buildings to predict preliminary cost estimates. Data were collected about the residential buildings constructed from 1997 to 2000 in Seoul, Korea. These data were used in training each model and evaluating its performance. The models applied were Model I, which determines each parameter of BPN by a trial-and-error process; Model II, which determines each parameter of BPN by GAs; and Model III, which trains weights of NNs using GAs. The research revealed that optimizing each parameter of BPN using GAs is the most effective in estimating the preliminary costs of residential buildings. Therefore, GAs may help estimators overcome the problem of the lack of adequate rules for determining the parameters of NNs.

Natraja, Jayaram and Ravikumar in 2006 [67] highlighted that concrete mix design involves imprecision, vagueness and approximations. They developed a novel technique framed through distinct fuzzy inference modules to capture the vagueness and approximation involved in various steps of design as suggested in IS: 10262-2003 (draft code) and IS: 456-2000. A trained three layer back propagation neural network was integrated in the model to remember experimental data pertaining to w/c ratio v/s 28 days compressive strength relationship of three popular brands of cement. The results obtained through the novel technique were in good agreement with those obtained by the prevalent conventional method.