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Application of Genetic Algorithm in Construction Industry for the Optimization of Resources

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ABSTRACT

The Genetic Algorithm technique (GA) is relatively new optimization technique. In this paper we present the various applications of GA in the Construction Industry for the various purposes. Similarly we want to present the different GA methodologies which have been already applied for the same application with suitable case studies. All applications and reviews regarding with the Construction Management sector are taken in these paper. From these reviews we can broad imagine about this optimization technique and its need over them. A GA system, which is a computation model of Darwinian evaluation theory, is employed to solve different computational problems. In these review paper we present its application along with site layout planning, facilities, time-cost resource optimization, resource allocation & leveling and the multi objective problems in Construction Management with corresponding case studies and algorithm. The genetic algorithm technique finds the global optimum in relatively few evaluations compared to the size of the search space.

Keywords— Genetic Algorithm, Construction Management, Resources, Site Layout Planning, Time Cost Optimization, Optimization, Resource Leveling and Project Scheduling, Heuristic Procedures.

I. INTRODUCTION

A genetic algorithm is directed randomized searching. They drive their power from natural selection. In the broadest sense GA creates, prepares a group of collected solutions again based on their fitness in the give an environment.

A GA is a search algorithm based on natural selection and the mechanism of population genetics. Genetic Algorithm different from the traditional approaches of existing optimization techniques. The result is an efficient algorithm with the flexibility to search complex place such as the solution spaces for the solution of various problems in construction industry

There are different classes of layout problems that have been study in the literature. Site conditions such as topographical map, building towers position and respective environment are unique for each site. Optimization of facilities layout planning (which is nonlinear and discrete planning) using a scientific methodologies are difficult. It not impossible to achieve friends FLP of construction sites in has been carried out mainly through human judgments. Because of human involvement, there are no conditions that lead consistently to the same result. To overcome this GAs approach is applied here for site layout planning for various purposes. Construction site level facilities, layout is an important activity in site planning. The objective of this activity is to allocate appropriate locations and area for temporary site level facilities such as warehouses, job offices, various workshops and batch plants. Depend on the size location, and nature of the project, the required temporary facilities may vary.

A genetic algorithm works of random, yet directed, fetch globally optimal solutions. Typically set of genetic algorithms required representation scheme to encode feasible solutions to the optimization problems. Usually the solution is shown like a linear strings called a 'chromosome' whose length is varies with each application. Respective Fitness functions are applied to the steps to obtain the better solution. Chromosomes, fitness function and population are the components used in GAs methodologies.

Resource leveling problem is an attractive concept of research at every project management. There are traditional method is available for resource leveling has basic assumptions of this problem is that a network activities could not be split. If there allowance to spit the activities then there GA will be effectively used to find most optimal resource leveling. The problems regards optimizations of resource allocation and solved mainly using heuristic procedures that cannot guarantee optimal solutions (Tarek Hegazy, 1999) .There are some searches in which leveling problems solved by heuristic methodologies and genetic algorithm techniques. Resource allocation attempt to reschedule the project task, so that the Limited quantity effectively used white keeping to minimum the unavoidable extension of the project. (Banafsheh Zahraie, 2009). The task of resource leveling becomes more challenging as the demand of different resources vary throughout the project duration & as the project activities progress at different rates. The genetic algorithm used for potential meta-heuristic that is sufficiently powerful to implement an evolutionary strategy for solving different problems. Recently many researchers attempt to solve the problems with meta-heuristic methods such as genetic algorithm, simulated annealing, tabu search, ant colonies to overcome the drawbacks of exact optimal methods and priority rule-based heuristic as well as to improve the performance of the existing meta-heuristic method.

Similarly time cost Optimization problems occur in construction industry. And similar to site layout problem those are difficult to solve because it has unique solution. The current market driven economy, the ability to optimize the time-cost approach could give the profitability and even the survival of Construction Company. As usual there are several methods are used for network compression. Genetic algorithm system is helps here for solving such kind of problems. Minimizing the total project cost and total project duration is one of the most challenging tasks in the construction project planning. Evolutionary algorithms such as genetic algorithm as a advanced computational Optimization method can overcomes the drawbacks of conventional optimization methods network crashing problems. This paper contains the review of applications of genetic algorithms over the time cost Optimization studies. Time- cost trade off is a very prior and impact able aspect of construction project planning. There are tradeoff between time and cost. The pre-existing conventional methods mainly

concentrated on using heuristics or mathematical programming, this becomes more laborious that is complex for large scale activities network. A genetic algorithm is successfully adopted to solve many problems of different kinds and gives more optimal solution for large domain also.

As similar to other applications of genetic algorithms, the 'preliminary cost estimation' model construction management is also created with the help of genetic algorithm. Generally for this modeling genetic algorithm combines with Neural Networks and case based reasoning or similar components. Minimizing construction cost prediction error is the objective function of those models.

Based on chosen criteria, selection of most effective machine is very complex and Labor intensive process. A computer simulation mathematical techniques and analytical tools are here for solving this decision making computer simulation is good practical tool but it does not explore all the possible values of the robot's (machine's) parameters, thus risking missing of optimal solution (Ronie Navon, 1997). There are some applications are present by the genetic algorithm process for the design and selection of construction equipment (robot). As the above is complex decision, excavating and hauling equipments also comes under that problem. Hence genetic algorithms have a wide scope of solving multi kind of problems related to construction management.

Modified Niche Pareto genetic algorithm is mainly used for multi objective construction Optimization. Those multi objectives are maybe minimization of construction duration, cost and resource fluctuation etc. A multi objective Optimization (MOO) approach was adopted to generate scheduling solutions considering all these objectives. Time cost Optimization is also comes under multi objective problems.

A realistic construction model needs to work over the project objectives such as

1. Minimization of construction duration
2. Minimization of construction cost
3. Minimization of variation in resource utilisation during construction

There are some applied work is don't for solving such type of multi objective problems with the help of modified genetic algorithm.

Genetic algorithms (GA) also adopted in pipe network optimization for designing least cost design of water distribution network .Those network optimization problems are non-linear type problems and GA method is very efficient for nonlinear programming problems also. In addition the sampling results by GA are global optimal while by other techniques is maybe local optimal. Hence GAs reduces the risk of trapping between local optima. In this paper we put the completed work corresponds to GAs for pipe network optimization which is comparison of results, distribution network design and operation of pipe system.

II. GENETIC ALGORITHM

GAs directed randomized searching technique for optimal solution. GAs is heuristic (new and self developed) optimization technique on the principle of biology used to find the near optimal solution. A sets of genes namely 'chromosomes' composes one candidate solution. A Primary advantage of GAs lies in their capacity to move randomly from one physical Layout to another, without getting into local optima in which other algorithms often

get trapped. GAs presumes that the potential solution of any problem is unique and can be represented by set of parameters (C.M.Tam, 2001). GAs is an optimization procedure that operates on sets of design variables. Each set is called as a string and it defines a potential. Each string consists of series of characters (binary or digit numbers) shows the values of discrete design variables. For the particular solution, the fitness (goodness) of each string is the measurement of the performance of the design variables for this particular solution. The basic GAs consists of 3 operations

(1) Reproduction, (2) Crossover and (3) Mutation.

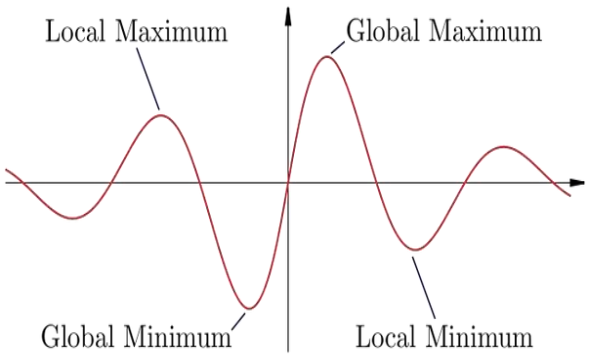

fig1. Difference of global & local optima

Here mainly GAs is applied for the following points in construction management

- Site Layout Planning
- Resource Levelling And Project Scheduling
- Time Cost Optimisation
- Preliminary Cost Estimation
- Optimisation For Multi Objective Problems
- Equipment Testing And Selection
- Pipe Network Optimisation

III. GAs for SITE LAYOUT PLANNING

There are several work is done for the designing optimal site layout planning. Seyed Rezavi Alavi, 2007 develop an integrated genetic algorithm simulation framework for site layout and construction plan optimization. Also they take a case study for applying their model, they run their model and find optimal design. Similarly 'Site level facilities layout using genetic algorithms' was done by Heng Li, 1998. They play with the 11 facilities Site Office, False Work, Labor Residence, Store Room-I, Store Room-II, Carpentry Workshop, Reinforcement Steel Workshop, Side Gate, Electrical- Water and Other Utilization Control Room, Concrete Batch Workshop and Main Gate. They design model and run for different population and find the optimal layout solution. This paper then demonstrated the robustness of the GAs approach in solving layout problems as combinatorial optimization problems that are difficult to solve by conventional methods.

There are different classes of layout problems. P.P.Zovien(2002) solves 'the site layout problem with unequal size using Genetic Algorithm'. In this proposed work they get "In Problem with higher total-object-to-site area ratio; the algorithm failed to find "good" in some classes feasible solution.

"Genetic Algorithm For optimisation supply locations around tower crane" is also contributes by C.M.Tam, 2001. They found optimal supply locations with 18% saving in current travelling time. GAs is an effective tool in handling this kind of non deterministic polynomial Optimisation.

3.1 GAs for RESOURCE LEVELLING AND PROJECT SCHEDULING

For this purpose of network crashing and the resource allocation GAs is more effectively used. Optimization of resource allocation and leveling using GAs is completed by Tarek Hegazy, 1999. They says ,Yet basic project management functions such as resource allocation, resource leveling and time-cost trade off analysis have been least improved. It is hoped that practical implementation of new approaches such as GAs justify the effort spent in proper planning and scheduling as keys to effective project management and ultimately to actual saving in project time and cost

'Use of genetic algorithm in resource scheduling of construction project' is covered by Ahmed B. Senouci (2004). They represent the hybrid genetic algorithm model complement the traditional CPM approach optimizing project schedule and total cost as it perform resource leveling the model is capable to handle large project involving large number of activities.

Onder Halis Bettemir (2015) they also developed the hybrid genetic algorithm with simulated annealing for resource constrained project scheduling (RCPS). Their computational result shows that proposed hybrid strategy improves convergence of sole genetic algorithm and provides the competitive alternative for RCPS problems. The result also a reveal the limitation of project management software for resource constrained project scheduling. Comparison of the Genetic Algorithm Simulated Annealing (GASA) with the best of the state-of-the-art algorithm indicates that he GASA provides near optimal solution.

"Resource Leveling via Activity Splitting by Efficient Genetic Algorithm" done by Seyed Hashemi Doulabi (2011). "Permutation Based Elitist Genetic Algorithm For Large Sized Resource-Constrained Project Scheduling" was comes from Jin-Lee Kim, 2008.

3.2 GAs for TIME COST OPTIMISATION

For time cost optimization in Project Management, availability of GA approach is also here. There are several work and researches by various authors for this purposes, Daisy X.M.Zheng in 2004; And 'Using improved GAs' by Heng Li in 1997 and 'Use GAs To Solve Construction Time-Cost Trade-off Problems' by Chung-Wei Feng (1997).

Time cost Optimization is very important job. Existing research shows that genetic algorithms are robust & have the capacity efficiently search complete solution spaces. Those induced the modification to improve the efficiency of basic GAs.

In paper Chung-Wei Feng (1997), their team develop new algorithm for optimizing construction time cost decisions using GAs and Pareto front approach. They say that the existing techniques using heuristic and mathematical programming are not efficient or accurate enough to solve time cost trade-off problems of real life

construction projects. And the similar way Daisy X.M.Zheng in (2004) his paper represent Novel multi objective approach that aims to optimize total and total cost simultaneously by utilizing appropriate GAs concept and tools.

3.3 GAs for PRELIMINARY COST ESTIMATION

For this perspective, genetic algorithm is also used here. G.H.kim (2005) was developed 'Hybrid Models of Neural Network and Genetic Algorithm for Predicting Preliminary Cost Estimates.' His research is on three models. Model-II & Model-III consists of GAs & other technique. Such as back propagation network (BPN) and Neural Network (NN) respectively. Research shows that back programming algorithm by trial and error uses integers, GAs use real number in optimization, thereby minimizing the possibility of trapping local optimal and improving the accuracy of estimation.

Kyong Ju Kim (2010), submit research on 'Preliminary Cost Estimation Model Using Case Based Reasoning and Genetic Algorithm.' The accuracy of early cost estimates in engineering and construction project is extremely important to both owner and project team. Previous approaches using experience, gradient search, fuzzy numbers and analytic hierarchy process are limited in their provision of optimal solutions. This paper proposes a GAs based approach as a weight generation method and has attempted to investigate the usefulness of this method by applying it to an actual bridge. In addition his study found that a case based reasoning and GAs based cost estimation model improve accuracy when it compared to the conventional model in the early stage.

3.4 GAs for EQUIPMENT SELECTION

Some researchers also regards with selection of optimal design of construction equipment for the desired work. Ronei Navon (1997) gives their contribution in 'Selection of Optimal Construction Robot Using Genetic Algorithm.' The robot's basic parameters are considered simultaneously and optimized with respect to selected criteria. They consider the parameters -

- The main configuration, namely the type of combination of the first three degree of freedom (DOF)
- The wrist configuration (the last three DOF)
- The link length of revolute configuration
-The working range the joints
- Joint velocity and acceleration

The foregoing parameters are optimized based on the following criteria- collision avoidance, percentage of coverage, dexterity, productivity, unit cost and total cost. Analysis from this research paper says that, Introducing GAs technique into robot selection can generate more economical solution, with type of motors and geometry more suited to the task. Similarly the cost can be continuously monitored in the selection process.

Excavating & Haulage equipment selection is a very complex decision making. A. Haidar takes a help of GAs applications and testing this methodology for equipment selection in 1999. Mine Industries 30 to 35% of total cost is attributes to excavation cost and 15 to 20% of his haulage cost. Hence it is important to optimal selection of those equipments. In this research they test GAs base model for 4 case studies and this model is three times successful in selecting the same type of equipment. In 2 of 4 case studies, cost of selected equipment by this GAs model is less than the cost of actual equipment used by contractor in the mine. GAs procedures Converse quickly

on optimal solution after examining only a small fraction of a search space and have been applied successfully to Complex Optimization problems in engineering.

3.5 GAs for MULTI OBJECTIVE PROBLEMS

The construction schedule must satisfy multiple project objectives that often contact with each other. The CPM was invented to achieve a higher level of scheduling co-ordination and has been a wide used for several decades. However it is a becoming outdated because of limitations such as arithmetic complexity. Since using CPM for large construction projects requires excessive computational efforts, many methods have been developed based on traditional CPM (Kyungki Kim, 2016).

Similarly Daisy X.M.Zheng, 2005 'Applying Pareto Ranking and Niche Formation to Genetic Algorithm Based Multi Objective Time Cost Optimization.' Time Cost Optimization (TCO) is one of the greatest challenges in construction industry. In this paper of genetic algorithm driven multi objective model for time cost optimization is proposed. Multi objective models are generally comes under non-linear programming and such programming is complex to optimize or solve. In this paper, based on the proposed framework, a prototype system has been developed in micro project for testing with medium sized project. The result indicates that a greater ability can be attained by the introduction of adaptive weight approach, Pareto ranking and Niche formation to the GA based multi objective TCO model

3.6 GAs for PIPE NETWORK OPTIMISATION

As a vital part of water supply system, water distribution network represent one of the largest infrastructure asset of Industrial society. Simulation of hydraulic behavior within a pressurized, looped pipe network is a complex task with effectively means solving a system of nonlinear equations.

Dragon A. Savic (1997) use 'Gas for Least Cost Design of Water Distribution Network'. In this paper author develop a computer model GANET (GAs model) for designing the optimal water distribution network. The author feel strongly that a tool like GANET should not be considered as design making tool, but also tool able to provide alternative solutions from which designer/decision maker may choose.

David E. Goldberg (1987) also applied GAs in pipeline Optimization. The method is ready for application to more difficult optimization problems civil engineering. In this paper the mechanics, power and application of GA in approximate solution of pipeline optimization problem has been examined. Author says GAs is a broad spectrum, approximate search procedure with applications in diverse problem areas.

'Genetic Algorithm Compared to Other Techniques for Pipe Optimization' by Angus R. Simpson (1994) presents the methodology for optimizing pipe network using GAs. Paper shows that GAs technique is very effective in finding near optimal or optimal solutions for a taken case study. A nonlinear programming method generates one solution. The GAs technique generates whole class of alternative solutions close to optimal. One of these alternative solutions may actually be preferred based on their measures.

IV. CONCLUSION

From the above literature it is concluded that there are wide scope for Genetic algorithm for Construction Management. There are so many numerical applications, & for them genetic algorithm is more effectively used. More than those 7 explained applications; there is also scope to this algorithm as an optimization technique. There is a need or future scope for this algorithm to take complete solutions for construction management problems under this genetic algorithm.

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