International Journal of Advanced Trends in Computer Science and Engineering
Available Online at http://www.warse.org/IJATCSE/static/pdf/file/ijatcse40912020.pdf
https://doi.org/10.30534/ijatcse/2020/40912020

Smart Review of the Application of Genetic Algorithm in Construction and Housing

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ABSTRACT

Genetic algorithm (GA) is an example of evolutionary algorithms that are bio-inspired computational methods. GA has been applied to numerous fields. It has been applied in different aspects of construction and building but that is scarcely any review that documents it. The paper reviewed the application of GA in construction and building. It was revealed that energy management is the major area of application which are further subdivided into load scheduling, prediction, and optimization. Other nonenergy applications are pricing, environment, and construction design or real estate. The review presents research information to researchers. The information can assist in the optimization of construction processes which can reduce the construction time and costs, ensure optimal allocation and use of energy, prediction of energy demands and supply in houses and incorporation of sustainability in construction and management of real estate.

Key words: Construction, energy optimization, genetic algorithm, load scheduling, pricing, real estate.

1. INTRODUCTION

Genetic algorithm (GA) is one of the most widely applied evolutionary computational methods. Evolutionary computational methods are nature-inspired methods **[1-2]**. GA is used to solve multimodal and multiobjective optimization problems **[3-4]**. It is metaheuristic and inspired by the biological process of natural selection. It is a bio-inspired method used to generate highly optimal solutions to complex and multidimensional problems **[5]**. This is done by the use of bio-inspired operators namely; mutation, crossover and selection. The problem to be optimized often arises from natural phenomena and construed as an optimization problem with an objective and or fitness function minimized subject to the given constraints. GA has been extensively modified and applied in different fields, too numerous to mention [6-10].

This paper aims to present the summary of the recent applications of genetic algorithm to construction and housing. Areas, where GA has been applied, are grouped and a framework was obtained. The research presents research information to experts in the construction and housing industries on various avenues where GA can be applied to optimize their operations.

2. GENETIC ALGORITHM IN CONSTRUCTION AND HOUSING

A smart literature review was done focusing on recent areas where GA has been applied in this context. The results were arranged systematically and a framework was obtained and presented in **Figure 1**. The framework summarized the results in a way that theoretical frameworks for future research can emanate.

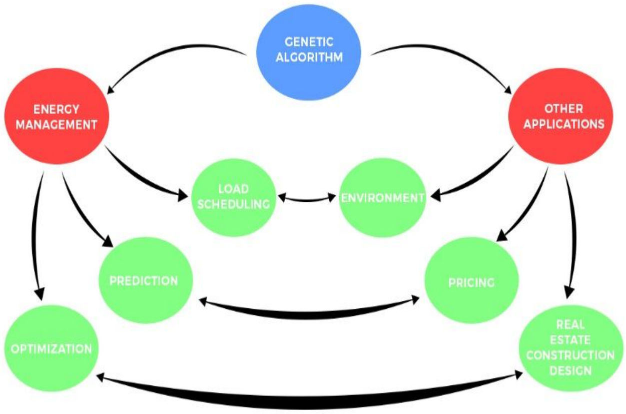

Figure 1: Genetic algorithm in Construction and housing

Two major areas where GA has been applied in this context are energy management and nonenergy (other applications. Furthermore, the present study identified that energy applications are further subdivided into three namely\; optimization, prediction, and load scheduling. On the other hand, nonenergy applications can further be divided into three namely: environment, pricing and real estate and construction design as shown in Figure 1.

3. ENERGY MANAGEMENT

Most of the application of GA here is the management of energy supplied to residential and nonresidential homes, prediction of energy use and optimization of energy used in houses. This, as stated earlier, is subdivided into three, which are load scheduling, prediction and optimization.

3.1 Scheduling and Load Management

Different risk-constrained framework solvable by the use of GA has been developed for scheduling the electric storage space heating load in residential and non-residential homes [11]. The major work of the framework is to strike a balance between cost reduction and user's thermal comfort by monitoring the different time-dependent behavior of the different loads [12].

GA and other evolutionary algorithms have been used for scheduling residential loads between peak and off-peak hours in a real-time pricing (RTP) environment [13] while maximizing user thermal comfort and minimizing both electricity cost and the peak to average ratio (PAR) [14]. This is often referred to as demand-side management (DSM) which is often overwhelmed by the scheduling of energy during peak hours. GA is often applied as a home energy management (HEM) controllers [15] to achieve minimization of energy consumption or shifting of the loads [16]. The hybrid of GA and pigeon inspired optimization in DSM to achieve a reduction in the electricity price and consumption while maximizing user comfort [17].

Also in DSM, load scheduling can be achieved via utility and rooftop photovoltaic (PV) units [18], although cautionary measures have been devised for rooftop photovoltaic (PV) to guide against issues concerning voltage [19]. GA has been applied as an optimal swapping strategy for monitoring load scheduling to minimize issues arising from an unbalanced problem in the scheduling and distribution of loads across residential homes [20]. The aftermath is the shifting of excess load from peak consumption periods to off-peak periods based on combined pricing scheme and generation from rooftop PV units [21]

The use of GA in load scheduling has been extended to hybrid residential microgrid systems which are a combination of AC and DC tied together through an interlinking bidirectional AC/DC converter (IC) [22]. This has been further extended and solved problems related to redundant resident microgrid systems [23].

GA has played a key role in scheduling load based on user demand [24], preferences, sizes of residential or nonresidential houses, smart electrical appliances in the various homes [25] under some constraints [26].

Generally as seen from the review, GA has helped in the optimal scheduling of the three major sources of power sources namely: PV generation, battery storage and the utility grid [27-28].

3.2 Prediction/Forecast

One of the major roles of government of any country is to ensure that electric power is supplied to residential homes, public establishments and business premises to drive economic growth. Electric power supplied to residential homes is managed by many private firms in a deregulated economy or exclusively managed by the government in some countries. Moreover, in some countries, it is jointly run by government and the private sector.

Genetic algorithm has been used to predict and estimate the energy performance of residential buildings. Some parameters accurately determine the consumption rate of electricity by consumers. The parameters are construed as an optimization problem and solved by using GA under some constraints. The accurate prediction of the parameters ultimately enhances efficient control of energy consumption especially in the deregulated energy sector [29]. In addition, it has been noted that poorly maintained, old or over-sized buildings tend to consume more energy and hence, more cost is expended to their management. GA was used to predict the energy to be minimized in old and poorly maintained nonresidential or commercial buildings [30] and energy generated from solar. In the use of GA to predict solar energy used by residential homes, the algorithm works just as time series analysis [31].

The use of GA in predicting energy consumption or demand helps to properly schedule of load between off and peak periods [32]. This has led to the efficient management of backup power supply and the smooth running of residential and nonresidential homes [33].

3.3 Optimization

The major use of GA is the optimization of a given phenomenon construed as an optimization problem given some constraints. Apart from energy consumption, other constraints inherent in building designs are environmental variables, technical issues [34], temperature [35] and day lightning regulation within buildings [36]. In this case, GA has been applied to architectural design in optimization of energy consumptions of residential homes [37]. This is achieved by maximizing the search capacity of GA to find sustainable design strategies that will guarantee energy optimization in buildings [38]. Examples are the application of GA in optimization of building shapes [39], building layouts and building envelope [40], which are building strategies on reduction of energy consumption. This is a much-needed relief as buildings consume 40% of global energy [41].

Optimization of load allocation in both sufficient and insufficient supplies of energy has been done using the GA [42]. GA has been applied to different sources of power supplies to residential and non residential buildings such as renewable energy [43], gas engine combined cooling, heating and power system (CCHPS) [44], grid-connected hybrid solar-wind-hydrogen CHP system [45] and grid-connected hybrid solar–hydrogen combined heat and power systems [46]. This leads to cost minimization [47]. Most of the application of GA in this context results in cost minimization or reduction. Some examples include:

a). Minimization of the total daily operating cost of a group of residential homes [48-49].

b). Minimization of life cycle costs of a hybrid energy system for residential buildings [50-51].

c). Minimization of cost per unit satisfaction [52-53].

d). Minimization of carbon emissions and total processing costs during the design process of housing parts [54] and old or deteriorating buildings [55].

e). Reduction of construction costs [56].

f). Reduction of the costs of solar energy supply to houses [57-58].

g). Minimization of users' dissatisfaction [59] and discomfort hours [60].

h). Reduction of energy demands in newly built houses [61].

i). Reduction on the environmental impact of building stock [62].

j). Minimization of wholesale risk of supplying energy to residential homes [63].

GA aids in minimization of energy consumption during an outage in a PV-battery backup system [64] and identification of optimal operation of PV-battery backup system [65]. GA has been used to solve optimally, the trade-off problem involving various constraints in the solar lease payments for large residential homes [66]. Minimizing energy consumptions in homes is a product of proper estimation of the energy demanded and supply which are done by the use of GA [67].

Generally, most of the outcome of the application of GA in optimization is to increase the probability of consumer thermal comfort in naturally ventilated rooms [68] and air-conditioned rooms [69-70] in buildings in individual homes or a collective community [71]. Apart from natural or artificial ventilation, other considerations such as the control of daylight entering residential homes have been optimized by the use of genetic algorithm [72]. GA has been used in the optimization of energy required in charging and discharging of electric vehicles in residential homes [73]. The current trend is that GA is used to implement energy optimization from the design stage to the maintenance and throughout the life cycle of the buildings [74].

4. OTHER APPLICATIONS

Undoubtedly, most of the application of GA is in the management of energy supplied to residential and nonresidential homes, prediction of energy use and optimization of energy used in houses. However, other applications exist as revealed from this review. These are classified into three: namely, environment, pricing and real estate or construction design.

4.1 Environment

Genetic algorithm is used to solve multiobjective optimization problems obtained by considering variables and constraints that will reduce to reduce the effects of climate change or extreme weather conditions on buildings and their occupants. The outcome of optimization using GA often results in designing adaptation or mitigation strategies against climate change based on the objective functions and their constraints. Hence, GA helps to determine the optimal adaptation and mitigation strategies associated with buildings, climatic and environmental variables notwithstanding [75]. Some of such climatic or environmental variables include but not limited to flooding, heat waves, heavy downpour, sunlight, extreme cold, tornadoes, hurricanes and pollution. GA has helped in the incorporation of adaptation and mitigation strategies into the design structure and layout of buildings. Examples are

a). The design of residential houses to harvest storm water [76].

b). The design of energy-efficient high-rise buildings to withstand the effect of a hot and humid climate [77]. The building ensures proper indoor thermal comfort and proper natural and artificial ventilation despite the harsh climate [78].

c). Design optimization of thickness of insulation used in buildings for different climatic conditions [79].

The use of GA has helped to reduce the computational time and cost needed in finding an optimal solution in the presence of many variables and environmental constraints leading to desirable trade-offs [80-81].

4.2 Pricing

The use of genetic algorithm in this aspect is the minimization of prices or costs related to some aspects of construction and housing. GA has been used to predict the price of new houses [82] and the price of buildings taking into consideration the location [83], spatial distribution [84], tax liability [85] and sustainability or climate change considerations [86]. The effect helps in prediction of the economic outlook of any country since real estate constitutes appreciably in the gross domestic product. The outcome presents valuable information for investors in real estate to monitor effectively the volatility or fluctuation of house prices, which can be modeled and solved using GA [87]. For example, the GA has been applied to predict the cost of building maintenance taking into cognizance, all the risks and variables in the building construction supply chain [88]. The use has also be extended to the simulation of the price of houses between buyers and sellers under different scenarios (constraints) [89].

4.3 Pricing

Genetic algorithm has aided building experts to choose the optimal construction design from several options under different constraints such as construction costs, transportation, supply chain, expertise, construction waste disposals, preservation of historical and cultural heritage [90], sustainability, topography [91] and weather or climate change consideration. This is necessary to reduce the probability of waste of manpower and scarce resources. GA helps to design decision supports systems (DSS) that can assist building experts in optimal construction decisions and to reduce waste and inefficiency [92].

GA has been applied in the management of the supply line of water distributed to residential homes. The algorithm helps to determine the optimal route and robust supply of water to residential homes [93]. In the same vein, GA has been used for allocation of facilities in residential houses, parks and community centers [94].

Development exerts pressure on urban and rural lands and trade-offs are required against several constraints to ensure maximum utilization of lands. GA has been used in this aspect to achieve optimal utilization of land for real estate development [95].

5. CONCLUSION

Two major areas of applications of genetic algorithm in building and construction emerged from this research which was conceptualized with the aid of a chart. Energy optimization is the major area where GA is applied to this context. The use of GA has helped to achieve the optimum allocation of loads and efficient management of energy consumption in buildings. GA has also helped in the prediction of energy demand and supply in residential and nonresidential buildings. Genetic algorithm has helped to solve models intended to reduce the carbon emissions and construction costs of buildings. The review also reiterated the strength of GA as seen in the management of environment and efficient management of the life cycle of buildings. GA will continue to be applied in this aspect and other similar algorithms related to genetic algorithm can also be explored [96-101].

ACKNOWLEDGEMENT

The research benefited from Covenant University sponsorship.

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