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OPTIMIZATION OF ENERGY REHABILITATION PROCESSES OF EXISTING BUILDINGS

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This paper presents a multi-optimization model usable in the buildings' retrofit strategies. The proposed method is based on a Genetic Algorithm model which finds the best solution among a considered search space composed of thicknesses and thermal conductivities of insulation materials also taking into consideration their prices. The results shows that the energy requirement for heating can be reduced with up to 25,5% by using the expanded polystyrene with a thermal conductivity of 0,036 W/m·K in case of exterior walls and the extruded polystyrene for the floor with a thermal conductivity of 0,031 W/m·K and thickness of 99,63 mm.

Keywords: optimization solution, Genetic Algorithm, wall, thickness, thermal conductivity, costs

1. Introduction

The buildings sector represents a key player in European Union (EU) energy strategy, as a major energy consumer as is continuously and rapidly expanding. The mixture of an optimal and healthy interior environment requirement, and the buildings' overall impact on countries' energy and increase of greenhouse gas emissions, emphasizes the influence of constructed environment over the entire society. These are the main reasons why methods of improving energy efficiency in buildings are continuously studied.

Considering these facts, this paper analyses and proposes a way of finding the optimal technical and economical solution for obtaining a minimum energy requirement for heating through the insulated envelope of a generic building located in Bucharest, Romania. A Genetic Algorithm (GA) was developed aiming at finding the best insulation material considering two important variables: the energy performance and the unit price, resulting in a multi-optimization problem.

The second section presents the canonical form of a Genetic Algorithm, in Holland's view, the flowchart of the standard Genetic Algorithm and a detailed

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explanation about Genetic Algorithm utilization for different optimization purposes.

The third section puts emphasis on the application of a Genetic Algorithm in case of the studied building with exterior walls insulated with expanded polystyrene and extruded polystyrene for the floor. The Genetic Algorithm model finds the best solution among a population of individuals composed of thicknesses and thermal conductivities of different insulation materials.

2. Genetic Algorithm

John Holland presented the first applications of GA, in "Adaptation in Natural and Artificial Systems" in which the biological process of adaptation was studied and emulated [1]. Fundamentally, it is based on Darwin's survival of the fittest theorem. According to this process, organisms evolve by recombining genetic material to survive in environments confronting them, thus a similar approach was translated into computational systems and used to find the best solution for a given problem. The computational model studied has the ability to "evolve" by recombining the information and transmitting it to the next generations, improving this way the overall efficiency.

The canonical form of a Genetic Algorithm, in Holland's view, includes the following steps [2]:

- create an initial population;
- fitness scores are assigned to each μ individual from the initial population;
- the best μ/2 pairs of parents are selected to create a new population;
- the children are formed by recombining each chosen pair using the crossover operator (with a crossover probability);
- with an imposed probability, the mutation is applied on the new population.

The algorithm runs until certain termination criteria are satisfied. These criteria are:

- *obtaining a value close to an expected value.* Individuals compete among them to find the optimal solution, but only those with the best results are selected and passed to the next stage. Fitness function f_i of the selected chromosomes is compared to expected value f_d. The process iterates an imposed number of times until the error falls below an imposed threshold. [3] If $|f_i - f_d| \leq \varepsilon$, then the algorithm will be stopped. The error ε is a very small number, for example $\varepsilon = 10^{-15}$ [4]
- *reaching maximum run time*. The algorithm runs for a predefined period [5].
- *reaching the maximum number of generations*. [4]

- *Early Stopping criterion*. It is introduced to prevent overfitting by stopping training if the model doesn't show improvement. The training error decreases exponentially with the increasing epochs. The algorithm runs until the validation loss stops decreasing for several epochs in a row. [6]

The scheme of the Genetic Algorithm is presented in figure 1 [7].

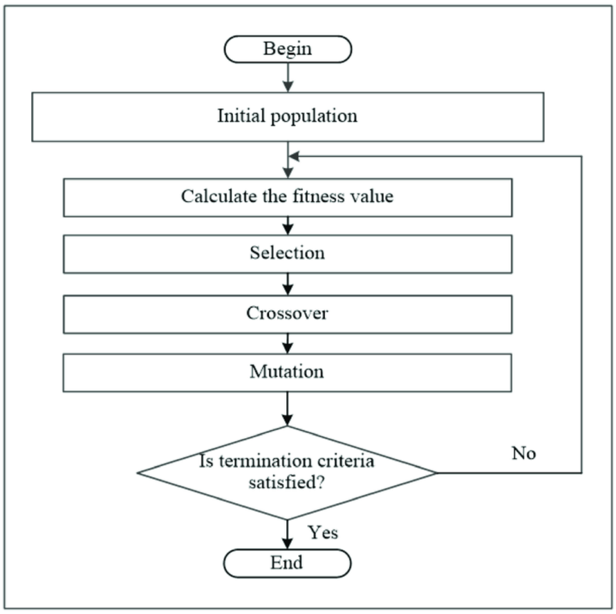

Fig. 1. Flowchart of the standard Genetic Algorithm (GA) [7]

In recent years, Genetic Algorithm was used in literature to increase the energy efficiency of existing buildings and improve the thermal comfort and indoor air quality. Most optimization problems found in literature were focused on the building envelope and on cost - renovation for residential buildings or non-residential buildings.

Several envelope design strategies were studied in case of office buildings from China, when a GA was implemented for four different climate areas. The results indicated that there was a 13% increase in energy saving after the implementation of the envelope design strategy chosen by Genetic Algorithm [8]. In Italy, the GA was used to optimize a residential apartment block envelope. The annual energy demand was reduced with 60,6% and the CO_2 emissions were minimized by 23% by using the appropriate insulation materials [9]. The GA was also implemented in Oman. The walls and the roof insulation, window’s areas, types of glazing, window’s shading and air tightness were analyzed. The simulation showed that 7,5 cm of thermal insulation has led to annual energy savings of 16,95% for Muscat city and 18,9% for Buraimi city [10].

Tuomo Niemelä, Risto Kosonen and Juha Jokisalo [11] implemented a Non-sorting Genetic Algorithm (NSGA-II) in Finland to optimize the cost of renovation of a building from 1960's. They studied the behavior of the geometry and structures of the building envelope, HVAC system, heat pump system, thermal solar system and solar photovoltaic (PV) system. The results indicated that the investments for the buildings should focus on high performance renewable energy systems.

Ugur Acar, Onder Kaska and Nehir Tokgoz implemented a NSGA-II algorithm [12] in MATLAB and performed an energy-based analysis of a residential building from Turkey considering the building envelope's U-Values, heat transfer surface and orientation. After the envelope optimization process, Pareto-Front solutions were analyzed. After Pareto optimum solutions were implemented, the building elements were investigated in terms of Life cycle cost analysis (LCC). The results showed that the optimization of the building envelope parameters could reduce life cycle cost.

Raymond D. Bingham, Martin Agelin-Chaab and Marc A. Rosensi [13] used a Non-sorting Genetic Algorithm which aimed to optimize the building envelope and renewable energy system (PV and battery electricity storage) of a residential house in The Bahamas. The optimization of the building envelope and renewable energy system led to a 30% reduction of the annual building energy consumption. Meseret T. Kahsay, Girma T. Bitsuamlak and Fitsum Tariku [14] used NSGA-II algorithm implemented in Java in the jEplus+EA (jEplus Evolutionary Algorithm) environment to optimize the configuration of the windows and, implicitly, the energy consumption. The principal variables used in this algorithm were the size of the window and location in the room. Selection of these parameters was made based on the ASHRAE standard, because a window must maximize the daylighting and natural ventilation and decrease or increase the solar radiation depending on the season.

3. Case study

3.1. Non-insulated building

The studied building is placed in Bucharest, thus the computational outdoor temperature was considered -15ºC for the heating period, as stipulated in Romanian Civil Construction Standards [15]. The average value of solar radiation intensity for the heating period was considered as stipulated in Romanian Civil Construction Standards: 77,03 W/m^2 [15]. The heating system provided thermal energy for 2184 hours per year.

The total area of the considered building's envelope is approximately 387 m^2 while its volume is 312 m^3. The exterior walls are composed of plaster and autoclaved aerated concrete. The floor has four layers: reinforced concrete, self-levelling concrete, polyethylene foam and parquet. The terrace is made of plaster, reinforced concrete and self-levelling concrete. Details on the thicknesses and thermal conductivities of the construction material can be found in Table 1.

The area of the windows is 10,8 m^2 and the door is 1,778 m^2.

Table 1

The thermo-physical characteristics of the constructive elements

Element		Area [m^2]	δ [mm]	λ [W/m·K]
Exterior wall	Interior plaster	114,62	20	0,80
	Autoclaved Aerated Concrete		350	0,80
	Exterior plaster		20	0,80
Floor	Reinforced concrete	130,00	150	2,03
	Self-levelling concrete		25	0,46
	The polyethylene foam		3	0,05
	Parquet		14	0,13
Terrace	Plaster	130,00	25	0,80
	Reinforced concrete		150	2,03
	Self-levelling concrete		25	0,46

The exterior walls were insulated with expanded polystyrene and the floor was insulated with extruded polystyrene in order to reduce the energy required for heating. Thus, a Genetic Algorithm model was developed aiming at finding the best solution among a considered search space composed of thicknesses and thermal conductivities of insulation materials considering two important conditions: obtaining a minimum energy requirement for heating at the most advantageous price of expanded and extruded polystyrene. The prices of insulation materials according to their thickness and thermal conductivity were taken from a building materials manufacturer’s websites. Moreover, the cost function was determined using a multiple variable linear regression. The steps used for developing the Genetic Algorithm are described in subsection 3.2.

3.2. The steps used for developing the Genetic Algorithm

Establishing the running parameters of the Genetic Algorithm was the first step in outlining the optimization solution. The next steps of the algorithm included the initialization of the population, establishing the stop criterion, establishment of fitness functions, and defining the processes of selection, mutation, and crossover.

3.2.1. Step 1: coding the variables and initializing the population

The variables were the thickness and the thermal conductivities of the insulation materials. The initial population was obtained by assigning an arbitrary value from the allowed range to each gene in each chromosome. The purpose of arbitrary selection is to ensure that the initial population is a uniform representation of the entire search space, so that there is not a chance that some regions in space are neglected by the process of search. [17]

The limits of the search space are defined. The minimum value of the thickness of the expanded polystyrene was 20 mm, and the maximum was 150 mm. The thermal conductivity ranged from 0,036 [W/m·K] to 0,042 [W/m·K]. The thickness of the extruded polystyrene ranged from 10 mm to 100 mm, while the thermal conductivity takes values between 0,031 [W/m·K] and 0,039 [W/m·K].

The population size was set to 20 individuals. The efficiency and the performance of the Genetic Algorithm depends on this parameter. The population is a set of chromosomes that must be large enough to be able to achieve a satisfactory number of combinations between the component chromosomes, but not too large because will increase the computational time.

3.2.2. Step 2: establishing the stop criterion

The Genetic Algorithm stops after 200 iterations, when no improvement of the solutions was obtained. The goal of the Genetic Algorithm is to converge to the minimum global error, where the optimum of the problem is. A training loop will check at end of every iteration whether the error is no longer decreasing. Once it's found no longer decreasing during five iterations, the algorithm stops [18]. In Genetic Algorithm model we implemented a counter which keeps track of the generations for which there wasn't improvement of the solutions. Initially, we set this counter to zero. Each time we don't generate individuals which are better than the individuals in the last population, the counter is incremented. If the fitness of any of the individuals is better, then the counter is reset. The algorithm terminates when the counter reaches a predetermined value. We set this value at five iterations.

3.2.3. Step 3: the establishment of fitness functions

The best adaptive individuals were those whose energy requirement for heating through the insulated envelope had the lowest value and whose price was as close as possible to the ideal established price. The fitness function aimed to evaluate the best adapted individuals.

a) The fitness function – cost

The prices of insulation materials based on thickness and thermal conductivity were taken from a building materials manufacturer's website. The ideal prices were determined as the average of the prices displayed on the manufacturer's website.

The variation functions of prices were determined by a multiple variable linear regression as detailed bellow:

$$C = (A^T \cdot A)^{-1} \cdot A^T \cdot B \tag{1}$$

Matrix A is the matrix formed by the thicknesses and thermal conductivities of the insulation materials and matrix B is composed of considered prices.

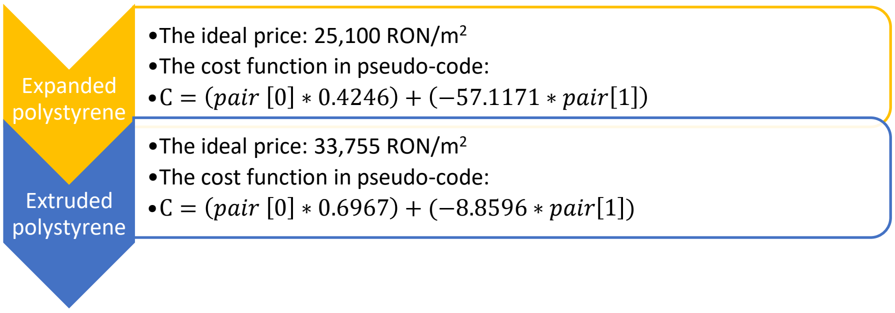

Fig. 2. The cost functions

b) The fitness function - energy requirement for heating

The expanded polystyrene was chosen as insulation material in case of exterior walls and the extruded polystyrene for the floor. The energy requirement for heating was computed using the relation (2):

$$E = h \cdot \{\Delta T \cdot H_V + [q_1 \cdot (A_1 + A_2 + A_3 + A_4) + q_2 \cdot A_5 + q_3 \cdot A_6 + q_4 \cdot A_7 + q_5 \cdot A_8]\} \ \text{[Wh/an]} \tag{2}$$

where h = the heating period; H_V = the heat loss coefficient of the building through ventilation; ΔT = temperature difference; q_1, q_2, q_3, q_4, q_5 = the unit thermal flows through the construction elements described in figure 3; A_1, A_2, A_3, A_4, A_5, A_6, A_7, A_8 = the areas of the construction elements described in figure 3.

The heat loss coefficient of the building through ventilation, H_V was determined using the relation (3):

$$H_V = \frac{\rho_a c_a n_a V}{3{,}6} \left[\frac{W}{K}\right] \tag{3}$$

where ρ_a = air density; c_a = specific heat of air; n_a = the average number of air changes; V = heated volume.

These parameters were considered as stipulated in Romanian Civil Construction Standards: $\rho_a = 1{,}2$ [kg/m^3]; $c_a = 1{,}005$ [kJ/kgK]; $n_a = 0{,}6$ [h^{-1}] [16].

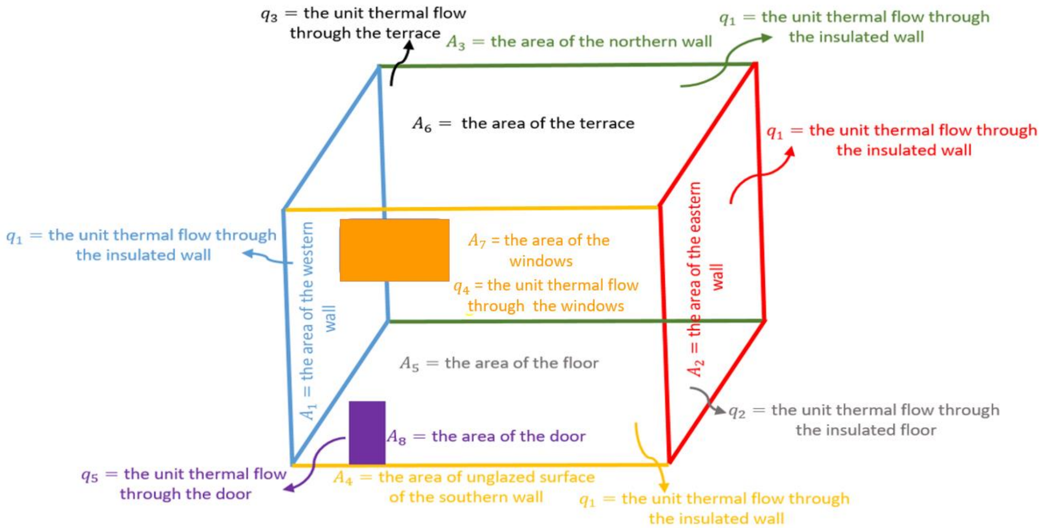

Fig. 3. The unit thermal flows through the building envelope and the areas of the construction elements

The areas of the construction elements take the values: $A_1 = A_2 = 15{,}6$ [m^2]; $A_3 = 48{,}0$ [m^2]; $A_4 = 35{,}4$ [m^2]; $A_5 = A_6 = 130{,}0$ [m^2]; $A_7 = 10{,}8$ [m^2], $A_8 = 1{,}8$ [m^2].

The unit thermal flow q_1 was computed using the Fourier conduction equation written for a wall made up of several layers:

$$q_1 = \frac{t_1 - t_2}{\frac{1}{\alpha_1}+\frac{\delta_1}{\lambda_1}+\frac{\delta_2}{\lambda_2}+\frac{\delta_3}{\lambda_3}+\frac{\delta_{izol}}{\lambda_{izol}}+\frac{1}{\alpha_2}} \left[\frac{W}{m^2}\right] \quad (4)$$

where t_1 = indoor temperature; t_2 = outdoor temperature; α_1, α_2 = film (convection) coefficients; δ_1, δ_2, δ_3 = thickness of the construction materials shown in table 1; δ_{izol} = insulation thickness; λ_1, λ_2, λ_3 = thermal conductivity of the construction materials shown in table 1; λ_{izol} = thermal insulation conductivity.

Both indoor and outdoor temperatures were considered as stipulated in Romanian Civil Construction Standards: $t_1 = 20^oC$ [19] and $t_2 = -15^oC$ [15]. The computational indoor temperatures represent the necessary condition for thermal comfort in heated rooms.

The same approach was considered for the film coefficients: $\alpha_1 = 8$ W/(m^2·K) and $\alpha_2 = 20$ W/(m^2·K). [20]

The unit thermal flow q_2 was computed using the Fourier conduction equation written for a floor composed of four layers shown in table 1:

$$q_2 = \frac{t_1 - t_2}{\frac{1}{\alpha}+\frac{\delta_1}{\lambda_1}+\frac{\delta_2}{\lambda_2}+\frac{\delta_3}{\lambda_3}+\frac{\delta_4}{\lambda_4}+\frac{\delta_{izol}}{\lambda_{izol}}+\frac{\delta_{sol}}{\lambda_{sol}}} \left[\frac{W}{m^2}\right] \quad (5)$$

where t_1 = indoor temperature; t_2 = soil temperature; α = film (convection) coefficient; δ_1, δ_2, δ_3, δ_4 = thickness of the construction materials shown in table 1; δ_{izol} = insulation thickness; δ_{sol} = the depth in the ground; λ_1 λ_2, λ_3, λ_3 = thermal conductivity of the construction materials shown in table 1; λ_{izol} = thermal insulation conductivity; λ_{sol} = thermal soil conductivity.

The soil temperature was considered t_2 = 10 ºC at a depth of 2 meters (δ_{sol}) as stipulated in Romanian Civil Construction Standards. The thermal soil conductivity was considered λ_{sol} = 1,05 W/(m·K) [16]

The unit thermal flow q_3 was calculated similarly to relation (4), except for the insulation material. The construction materials of the terrace are shown in table 1. The film coefficients α_2 = 12 W/(m^2·K). [20]

The unit thermal flow q_4 was computed using the relation:

$$q_4 = \mathrm{U} \cdot \Delta\mathrm{T} + \mathrm{G} \cdot \mathrm{g} \left[\frac{W}{m^2}\right] \quad (6)$$

where U = thermal transmittance; ΔT = temperature difference; G = solar radiation intensity; g = solar radiation absorption coefficient.

The windows used are triple-glazed, having a thermal transmittance (U-value) of 0,8 W/m^2·K and a solar radiation absorption coefficient of 0,5 W/m^2·K.

The unit thermal flow q_5 was computed using the relation:

$$q_5 = \mathrm{U} \cdot \Delta\mathrm{T} \left[\frac{W}{m^2}\right] \quad (7)$$

where U = thermal transmittance; ΔT = temperature difference.

The global heat exchange coefficient of the door is 1,2 W/m^2·K.

3.2.4. Step 4: Selection operator

The studied Genetic Algorithm used *Roulette Wheel* and *Elitism* methods in order to select the individuals for a new population.

According to the fitness of each individual, it was decided statistically which chromosome was optimal to be kept in order to create a new population. The chromosome with better fitness score was assigned the highest chance of reproduction [3]. In *Roulette Wheel* method each individual in the current population is represented by a proportional space with the value of its fitness function. By successive random sampling from this representation space of chromosomes ensures that the best chromosomes are more likely to be selected at a given step than those with weaker ones.

The Elitism method avoids the loss of the best chromosome obtained up to that step, because the fitness function of this chromosome is copied without any modification in the new population, thus the best solution obtained up to that moment is not lost. [21]

3.2.5. Step 5: Crossover operator

In case of Complete arithmetic crossover, all the genes in the chromosomes that represent the parents are combined according to a well-established rule. The rules for combining genes in pseudo-code are described in relations (8) and (9) [22].

$$c1.pair = alpha * p1.pair + (1 - alpha) * p2.pair \quad (8)$$

$$c2.pair = alpha * p2.pair + (1 - alpha) * p1.pair \quad (9)$$

where (p_1, p_2) = the parent pair that participated in the crossing process; (c_1, c_2) = the descendants; alpha = subunit positive real number.

We choose $\alpha = 0,6$.

3.2.6. Step 6: Mutation operator

Mutation occurs after the crossover operation and it has the role of introducing new genetic material into the population, with the aim of increasing the diversity of the population.

The process of mutation consists in the random replacement of one or more genes within a chromosome, obtaining more performing individuals. The mutation operator can act on any gene within of a chromosome, with a probability called mutation probability [23]. According to the literature, this probability usually has a small value between 0,001 and 0,010 [2], but they can also use higher values such as 0,033 [24].

The Non-uniform Mutation was used. Thus, a gene was randomly selected from the chromosome and replaced with a non-uniform random value that was part of a Gaussian distribution (μ, σ). In case of this mutation, the mean (μ) was zero, and the standard deviation (σ) had the value 0,5.

3.3. The result of running the Genetic Algorithm

The result after running the algorithm shown that the expanded polystyrene that fulfilled both conditions, that is, the price approaches an established ideal price while the energy requirement for heating is as low as possible, was the insulation material with a thermal conductivity of 0,036 W/m·K and thickness of 149,8 mm.

Extruded polystyrene that fulfilled both optimization problems was the insulation material with conductivity of 0,031 W/m·K and thickness of 99,628 mm. The energy requirement for heating before the walls and floor insulation was 124,371 kWh/m^2/an. This value was reduced to 92,65 kWh/m^2/an after using the expanded polystyrene in case of exterior walls and the extruded polystyrene for the floor.

4. Conclusions

This paper presents an optimization problem: obtaining a minimum energy requirement for heating in the case of a generic building located in Bucharest, at the most advantageous price. The proposed method includes a Genetic Algorithm model that decides which thicknesses and thermal conductivities fulfilled the optimization problem.

The Genetic Algorithm was implemented in the Python programming language and the PyCharm Integrated Development Environment.

The prices of insulation materials according to thickness and thermal conductivity were taken from a construction materials manufacturer's website. The variation function of prices was determined by a multiple variable linear regression. The ideal prices were determined as the average of the prices displayed on the manufacturer's website.

The ideal price in case of expanded polystyrene was 25,10 RON/m^2, while the ideal price of the extruded polystyrene was 33,75 RON/m^2.

The results show that the energy requirement for heating can be reduced with 25,5% by using the expanded polystyrene with a thermal conductivity of 0,036 W/m·K and thickness of 149,800 mm in case of exterior walls and the extruded polystyrene for the floor with a thermal conductivity of 0,031 W/m·K and thickness of 99,63 mm.

The Genetic Algorithm implemented in the Python programming language demonstrated that this algorithm can be used successfully in identifying suitable insulation materials, to obtain a minimum energy requirement for heating and reduce insulation costs in residential buildings.

A disadvantage in the algorithm was the lack of a large data set. The presented research is ongoing and, in the future will use a complex database including different insulation materials and equipment used for the energy calculation of buildings.

R E F E R E N C E S

[1] *J.H. Holland*, "Adaptation in natural and artificial systems: an introduction analysis with applications to biology, control, and artificial intelligence", 1975

[2] *G. Jones*, "Genetic and Evolutionary Algorithms", University of Sheffield, 2004

[3] *B. Carutasiu*, "Contribuții la dezvoltarea modelului matematic gray–box utilizat în analiza clădirilor cu înaltă eficiență energetică" (Contributions to the development of gray–box mathematical model used for analyzing high energy efficiency buildings - in Romanian), PhD Thesis, University Politehnica of Bucharest, Faculty of Power Enginering, 2015

[4] *M. Wang*, "Description and Application of Genetic Algorithm", Thesis for the Master of Science Degree in Mathematical Modeling and Simulation, 2012

[5] *D. Bhandari, C. A. Murthy, K. P. Sankar*, "Variance as a Stopping Criterion for Genetic Algorithms with Elitist Model", Fundamenta Informaticae 120, 2012, pp. 145-164

[6] *X. Ying*, "An Overview of Overfitting and its Solutions", Journal of Physics: Conference Series, Volume 1168, Issue 2, 2019

[7] *M. A. Albadr, S. Tiun, M. Ayob, F. AL-Dhief*, "Genetic Algorithm Based on Natural Selection Theory for Optimization Problems", Symmetry, 2020
[8] *S. Lu, J. Li, B. Lin*, "Reliability analysis of an energy-based form optimization of office buildings under uncertainties in envelope and occupant parameters", Energy and Buildings, vol. 209, 2020
[9] *A. Ciardiello, F. Rosso, J. Dell Olmo, V. Ciancio, M. Ferrero, F. Salata*, "Multi- objective approach to the optimization of shape and envelope in building energy design", Applied Energy, vol. 280, 2020
[10] *S. N. Al-Saadi, K. S. Al-Jabri*, "Optimization of envelope design for housing in hot climates using a genetic algorithm (GA) computational approach", Journal of Building Engineering, vol. 32, 2020
[11] *T. Niemelä, R. Kosonen, J. Jokisalo*, "Cost-effectiveness of energy performance renovation measures in Finnish brick apartment buildings", Energy and Buildings, vol. 137, 2017, pp. 60-75
[12] *U. Acar, O. Kaska, N. Tokgoz*, "Multi-objective optimization of building envelope components at the preliminary design stage for residential buildings in Turkey", Journal of Building Engineering, vol. 42, 2021
[13] *R. D. Bingham, M. Agelin-Chaab, M. A. Rosen*, „Whole building optimization of a residential home with PV and battery storage in The Bahamas", Renewable Energy, vol. 132, 2019, pp. 1088-1103
[14] *M. T. Kahsay, G. T. Bitsuamlak, Fitsum Tariku*, "Thermal zoning and window optimization framework for high-rise buildings", Applied Energy, vol. 292, 2021
[15] Standard roman, SR-1907-2, Instalații de încălzire. Necesarul de căldură de calcul. Temperaturi interioare convenționale de calcul, (Romanian Standard, SR-1907-2, Heating installations. Calculation heat requirement. Conventional indoors calculation temperatures - – in Romanian), 2014
[16] Metodologie de calcul al performantei energetice a cladirilor, Partea I – anvelopa cladirii, (Calculation methodology of energetic performance for buildings, Part I – building envelope - in Romanian), 2006
[17] *C. Mihăilă*, "Calculul evolutiv în probleme de alocare (Evolutionary computation in allocation problems)", PhD Thesis, Babeș-Bolyai University Cluj-Napoca, 2011
[18] *D. Kannan*, "Genetic Algorithm, Concepts and Working", Computer Science, Artificial Intelligence, 2022
[19] Metodologie de calcul al performantei energetice a cladirilor partea a IV-a – Breviar de calcul al performantei energetice a cladirilor si apartamentelor, (Calculation methodology of energetic performance for buildings, Part IV – Calculus summary of the energetic performance for buildings and apartments – in Romanian), 2009
[20] Normativ privind calculul termotehnic al elementelor de constructie ale cladirilor, Indicativ C107-2005, (Guidelines regarding the heat engineering calculation of the construction elements for buildings, C107-2005 - in Romanian)
[21] *H. Du, Z. Wang, W. Zhan, J. Guo*, "Elitism and Distance Strategy for Selection of Evolutionary Algorithms", IEEE Access, 2018
[22] *L. Dioşan*, "Inteligenta artificiala. Algoritmi Evolutivi (Artificial intelligence. Evolutionary Algorithms)". Universitatea Babes-Bolyai. Facultatea de Matematică şi Informatică, 2019
[23] *A. Hassanat, K. Almohammadi, E. Alkafaween, E. Abunawas, A. Hammouri, V. B. S. Prasath,* "Choosing Mutation and Crossover Ratios for Genetic Algorithms - A Review with a New Dynamic Approach", Information, 2019
[24] *G.E. Liepins, W. D. Potter,* "A Genetic algorithm approach to multiple-fault diagnosis", Handbook of Genetic Algorithms, 1991, pp 237–250, 1991.