Intelligent and Optimal Control of Air Conditioning Systems by Achieving Comfort and Minimize Energy

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Abstract–In this study, artificial neural networks, artificial neural network combination with genetic algorithm and neural network combination with Kalman filter were used to optimally model and control a real air conditioning system. Using the above methods, the system is first trained and after verifying the modeling accuracy, the capability of this modeling to predict the future conditions of the system is investigated. In addition to the subsystems investigated in both heating and cooling phases by mass and energy equations in Simulink simulated by Matlab software, the results of this section are finally compared with the optimal modeling results. The most important advantage of artificial neural network modeling over mass and energy equation modeling approaches is that it captures all the uncertainties and nonlinear properties of the air conditioning system due to the use of real data for modeling. It takes. Therefore, this method can optimize energy consumption in air conditioners by predicting the future conditions of the system and by precisely adjusting the time of turning on and off the main energy consuming equipment. The most important achievement of this research is more accurate and realistic modeling of the nonlinear air conditioning system.Comparing the methods used in the research for simulation methods using mass and energy equations, modeling using Bayesian trained neural network, artificial neural network modeling using MLP, modeling using neural network and genetic algorithm, modeling Using neural network and Kalman filter, the square error is equal to 0.006, 0.18, 0.056, 0.1456 and more than 0.5, respectively.

Keywords: HVAC control systems, artificial intelligence, Extended Kalman-filter, Genetic algorithm, artificial neural networks.

1. Introduction

Energy plays an important role in the politics, economy and society of every nation. In the present century, the most important asset of any society is the amount of its energy reserves, and the national security of any country depends on the presence or absence of energy resources in that country, which has raised the price of energy carriers and made managers think about the optimal use of energy. Fossil fuels and more and more wasted energy. On the other hand, the operation of a solar, wind andpower plant requires a great deal of investment in the early stages, so optimizing energy consumption both environmentally and cost-effectively is one of the most important concerns of the modern world. On the other hand, human security is one of the basic criteria for improving the quality of human life, and most of the inventions have been from the first day of human existence on earth to provide comfort in different environments and under water conditions. And air is one of the basic needs of humans [1, 2]

Harkouss et al. (2018), in an article entitled Multi-objective optimization method for buildings with clean and effective energy, found that in designing a building with clean energy, finding the best combination of design strategies is the most critical challenge that faces energy performance problems of a particular building. . In this paper, a method for multi-criteria optimization based on the simulation of the above way is presented. It consists of four stages: building simulation, optimization process, multi-criteria decision making, and the proposed solution's strength. The analysis results clearly show that, regardless

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Received: 2021.12.25; Accepted: 2022.01.31

of the weather, to design this method in a residential home, it is necessary to minimize the minimum heat load of the environment through passive strategies that are achieved with confidence [3]. Lorena Tuballa and Lochinvar Abundo (2016), in an article entitled "Review of the Development of Smart Grid Technologies," reviewed the smart grid with its general features, functions, and specifications, which provided a basic technology related to Smart Grid and research activities, challenges and Have identified issues. This shows how these technologies have shaped the modern power grid and have continued to evolve and strengthen their role in better aligning energy supply and demand [4]. Mogles et al. (2018), in an article entitled Behavioral Interaction Design of Energy Changes for a Computational Model, examined the creation of a structure to fit different types of models and the use of a simulation model as a tool for evaluation, which influences consumption decisions. According to the results, the proposed model can predict energy-saving behavior much better than existing random models and accurately estimate the effect of accepted technologies. Also, the analytical model can be turned into a decision-making system adapted to changing energy behavior [5]. Mohammadi et al. (2018), in an article entitled Integration of smart energy hubs in distribution networks considering the concept of demand response and uncertainty to a new optimization framework based on the information gap decision theory approach and a combined scenario to investigate and The study of the optimal performance of smart energy hobbies concerning economic priorities, technical limitations of the distribution network and the presence of uncertainties. Considering energy hubs equipped with innovative installations, demand-side management programs, including price response and load response services, have been made available to motivate consumers to renew consumption patterns as well as to meet the economic priorities of the energy hub.Using the results of the hybrid uncertainty modeling approach, the intelligent energy hub operator can adopt risk-taking and risk-avoidance strategies against uncertainties [6].

The issue of concern for air conditioners is the amount of energy consumed in these systems. Research shows that energy consumption in air conditioning alone accounts for 50% of the world's energy consumption. Hence, these systems also fall under the category of energy management systems. In simple terms, air conditioning controls include starting, stopping or adjusting heating, air conditioning and air conditioning, which comprises three distinct stages:

- Measuring and collecting data
- Data processing with the help of information
- Achieve a control method

The three steps mentioned in the sensor, the controller and the device are controlled [7, 8].

The first attempts at automatic control over heating, cooling and air conditioning systems were made in the late 1990s, with the aim of controlling the output by opening and closing a boiler door with a bimetallic strip. Prior to World War II, only companies using compressed air systems were responsible for controlling heating and air conditioning cooling systems in commercial and office buildings. The prevailing thinking at the time was that air-conditioning control systems were expensive and costly to install, operate and maintain, and were not worth the investment, including the constant contact with the employer to establish supervisory offices. With the introduction of electronic equipment to control ventilation, the volume and cost of these equipment were reduced [9].

After the introduction of computer-based control systems to the market, a number of companies began to work on heating, cooling and air conditioning control systems. Around the year 2000, computer-based control systems began to work seriously.

Ning and Zaheeruddin from a trained artificial neural network to control by monitoring the designated points of inlet water to cold water, exhaust air temperature and static pressure of the all-air fan system, to minimize fan and chiller energy consumption, Using a progressive artificial neural network - which is unattended - to minimize its energy consumption by applying the cost function. In this paper, neural networks are used only for optimization, and genetic algorithms or other optimization methods are not used [10].

Xian-Mei et al. used the neural network to model the air conditioning system and the genetic algorithm to optimize it, but his results were not up to date and could not predict the future of the system [11].

Labus et al. modeled "a chiller using artificial neural networks" and tried to optimize energy consumption by combining genetic algorithm with artificial neural network. This simulation is not very effective due to its partiality and its inability to use up-to-date and predictive data [12].

Tashtoush et al. modeled a room as its heating and cooling system as a dynamic system and compared the model's responses to the real state. This model also cannot predict the simulation axis [13].

Karadag and Akgobek use a neural network to model an area that has been subjected to global warming and finds that the ANN response is very close to the values obtained by numerical calculations and modeling results using mass and energy equations, Using a finite specific model is the fundamental problem of this paper [14].

Shen et al. have used a combination of genetic algorithm and artificial neural networks to optimize the parameters of injectable modeling, they have used this combination to model the data up-to-date technique employed in this project's highly technical neural network They are similar to theirs except that some optimized hybrid methods have been used in this project and in the modeling phase [15].

Liu et al. have used a combination of artificial neural networks and genetic algorithms to predict alloy tolerance. The role of genetic algorithm in his research has been as an optimizer. The results of this project show that this combination is highly capable in modeling [16].

Huang et al. used a neural network to predict the future temperature of a room, taking into account the effects of adjacent room temperature. They found that given the temperature effects of the room adjacent to the predicted results, they would be able to predict accurately and accurately. The main problem with this research is that the real space models do not use separate real models [17].

Sum et al. have tried using some simple models to investigate how the initial conditions apply to the Kalman filter trained by ANN under various conditions such as the number of input variables and so on [18].

Wang and Jin from the University of Hong Kong designed a basic model controller optimized using genetic algorithm. This controller is operated under dynamic output conditions and internal loads. In this paper, based on the prediction of the overall response of the environment and activity, energy consumption is optimized by genetic algorithm [19].

Lu et al. used fuzzy control for the HVAC system. The system is implemented and installed in a building with the help of a microprocessor connected through sensors and actuators through intermediaries [20].

Maasoumy in his article by using a step controller applied to a real air conditioning system consisting of a high-level controller and a low-level controller, taking into account the time-varying nature of the optimal controller used. Has provided comfort and convenience at a lower cost and greater efficiency [21].

Nakahara rt al. using three methods of artificial neural networks, Kalman Filter and GMDH to predict the temperature of the next day and compare the above three methods, in addition to the effect of the number of input data on the quality of advance The nose has been examined [22].

Parvaresh et al. presented a complete mathematical model of all members of a heating and cooling and air conditioning system after writing the system equations obtained from the equilibrium mass and energy equations by converting them into Laplace transformers and integrating all the members into Simulink Matlab Is simulated [23].

Macek and Marik used a qualitative method to compare new control methods applied to energy management systems such as heating, cooling and air conditioning, both in terms of operating costs and environmental conditions. Can play an important role in this regard [24].

Tigrek et al. have used adaptive and non-adaptive methods to optimize the air conditioning system considering the non-linearity of the cost function and the nonlinearity of the system under study [25].

Platt et al. used a mathematical model to model heating, cooling and air conditioning systems and then compared the function of the genetic algorithm controller and the Kalman filter on it as robust controllers [26].

Singh et al. investigated the use of adaptive control for multivariate class systems such as cooling, heating and air conditioning systems. In this paper, modeling is performed by considering the perturbations such as outside conditions, solar radiation variations and changes in thermal coefficient and its effect on indoor load, using the corresponding linear model optimized model and system performance points [27].

Anderson et al. investigated the operation of a controlled air conditioning system using advanced and intelligent control methods. Considering that intelligent control methods are confined to academic research only, he has studied the practical impact of this system on practical implementation and has found that these methods are both effective and useful in practice [28].

Kaur and Salaria, using the Bayesian neural network-based neural network method, attempted to adjust the equations of the studied system as in the simulation season using the energy-mass equations and to investigate the results [29].

Jin et al. simulate a simple model of the cooling coil using mass and energy equations and compare it with the results of experimental data. The results show the reliability of the simulation [30].

Mustafaraj et al. predicted room temperature (open office) and its relative humidity using automatic linear regression as well as nonlinear artificial neural network. Finally, he concluded that the neural network was more capable of modeling the system [31].

Xu et al. using the method of M. Robust PC for controlling the temperature of air conditioners and discusses multi-type constants and uncertainties [32].

Ruano et al. modeling and predicting the future temperature of the air conditioning system using artificial neural networks. The advantage of the approach in this project is the accuracy of the simulation of the air-conditioning system and the use of experimental data for network training [33].

2. Simulation

2.1 Air Conditioning System

In this section, we simulate the desired air conditioning system whose data are collected experimentally using various equations of mass and energy. The system is designed to simulate several components: the room, the ventilation duct, the return duct, the air conditioner, the air purifier with the ducts, the coil, the humidifier, Cooling and humidification coil, fan and filter. In the cooling mode, which is shown in Fig. 1, the return air from the room is first blended with the outside air in the mixing chamber, and the blended air enters the room after the filter passes through the air conditioning system through the ventilation duct through the fan suction line. It changes the room conditions from the initial state and the room air is then returned to the air conditioner by the return air channel.

In heating mode which is shown in Fig. 2, due to the winter environment, which is usually cold and dry, in the mixing chamber, after mixing the return air and the room air, some air cooling is reduced and the protected air enters the coil. This will save energy and reduce system depreciation. The heat coil consists of narrow tubes with fans that accelerate heat transfer. When the water enters the coil, the coils and fins in the coil are completely heated, and after the cold air collides with the outer wall of the coil, heat is transferred from the hot water to the cold air, thereby increasing the enthalpy of air, thereby. Increases in air temperature. A female moisture unit is seen in the modeling of the system, which results in an increase in the dry humidity of the inlet to the system, causing the system to reach its desired temperature and humidity as the inlet air.

In the modeling performed, the model of each component of the system is first extracted separately and after the system components are put together, the open circuit system is simulated. The model of each component of the system has three parts of heat and humidity. That is, the model of the above system is capable of analyzing dry temperature and air humidity ratio anywhere in the air conditioner or in the room. But we only use thermal modeling. The components of the system are arranged in a heated fashion such that they consist of a compartment, a heat coil, a female humidifier, an air duct, a chamber and a return air duct. The mixing chamber has four inlets and two outlets, allowing the dry temperature and the ratio of humidity to the outside and return air to the chamber. The heat coil has three inlets which in addition to the temperature and humidity ratio also include the temperature of the hot water entering the coil. The hot water in the coil inlet gives some of its heat to the cold air, leaving the coil at a lower temperature than the inlet, and the temperature and humidity ratio The outlet temperature of the female moisture enters the chamber, the temperature and humidity ratio. Blown out of the channel outlet enters the room, which is also affected by the outside air. Finally, the temperature and humidity of the chamber are returned to the mixing chamber through the return air duct.

The air conditioner provides inlet air to the system as a result of the blown air entering the chamber, while in the previous approach the air conditioner combined with the room formed the system and the boiler and chiller as the hot and cold inlet water supply. Coils are system operators that are not, of course, involved in modeling and have only control over the system. The simulated air conditioning system is single-zone type. This means that, firstly, the air outlet conditions are constant and have the same temperature and humidity for all the rooms, as well as the fan applied to the system in a single round, resulting in the flow of air passing through the inlet and outlet to the fixed room. It is not possible to adjust the temperature and coolant load in the room to adjust the air flow, but rather to control the temperature of the hot or cold water entering the coil or the water flow to the female moisture.

2.2 Control System Parameters

Control systems for heating, cooling and air conditioning range from the simplest model to a room and a thermostat to the most sophisticated form of advanced software.

- The sensor's task is to measure the actual values of control variables such as temperature, humidity and flow and transmits the information to the controller.
- The controller captures information from the sensor and processes it with intelligent signal for output of the controlled system.
- Controlled system changes variables.
- The energy source responsible for supplying energy to the system.

The main objective of the project is to reduce energy consumption by increasing the speed of system adaptation to the desired values.

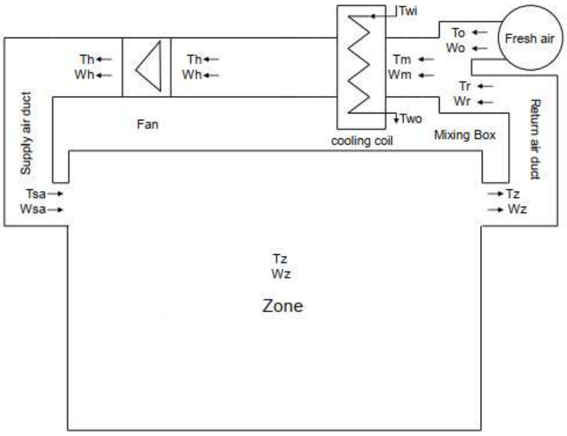

Fig. 1. Schematic of cooling fashion.

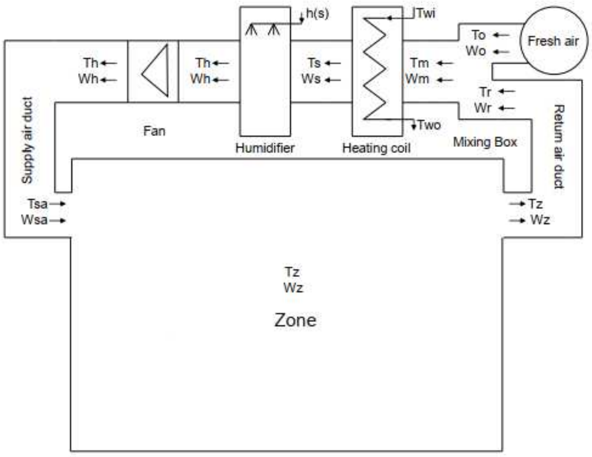

Fig. 2. Schematic of heating fashion.

2.3 Control strategies

So far, various control strategies and methods have been used to control heating, cooling and air conditioning systems. From simple controllers like PI to advanced control methods such as modern, optimal, nonlinear control and fuzzy logic based intelligent control methods, neural networks or artificial intelligence. Some of these methods are more practical and widely used in business systems.

2.4 Two-state control

Dual state controllers are the simplest type of controllers, also called cyclic or on / off controllers. If the building requires half the time the air conditioning control system is designed for, the system is activated for ten minutes then shut down for ten minutes and the cycle continues. If the building load is increased, the system activation time will increase and the shutdown time will decrease. One of the drawbacks of this short-circuit system is that it makes the system useless, that is, the system turns off before it reaches a uniform state, and if this is resolved by prolonging the system's turn-on time, it will be at the cost of dissatisfaction. The temperature will be overtime.

3. PID Controller

PID controllers are used in a variety of combinations in heating, cooling and air conditioning control systems. In these controllers, both the input and output error signals are continuous, and therefore the operators used must work continuously, so that more expensive dual-mode controllers should be used. . The PI P and PID combinations have been used in cooling, heating and air conditioning control systems. Although the PID controller performs better than dual-mode controllers, however, since PID control theory is fundamentally based on linear systems, its application to heating, cooling and air conditioning systems is mixed with nonlinear factors. It also has problems. Changes in system parameters over time should also be offset by overwhelming resets of the controller.

3.1 Advanced Control Methods

Since the oil crisis of the 1990s, which has led to a global approach to energy saving, extensive research has been conducted in the field of air conditioning systems, both in terms of comfort and energy consumption. Fulfilled in control of air conditioners.

3.2Kalman filter

The Kalman filter is one of the most successful estimation methods in practice. An in-depth discussion of this topic can be found in digital control books that examines time-varying and optimal observers. The Kalman Filter was voted the most successful and efficient theory of the year by IEEE among the various control theories. This theory, which was hardly accepted by Dr. Kalman in 1960 as a subject of a doctoral degree, after 35 years of successful application in various applications of theory of estimation, navigation and guidance, signal processing, image processing and error prediction and error correction. It achieved this degree of credibility. But the reasons for this success lie in two principles:
First, this model does not require a detailed model and is robust, meaning that although our information is less than the model under consideration, the feedback we receive from the output is accurate. So, relying on the model and

applying a higher degree of reliability than the input data, the optimal estimator will work well. On the other hand, if the outputs are highly disturbed or do not have high reliability, if a suitable model for the process can be extracted, we will still be able to estimate system state variables or filter the outputs optimally.
Secondly, there are no restrictions on performance, which means that this estimator has no restrictions on implementation on the microprocessor [31].

4. Genetic Algorithms

Genetic algorithms use Darwin's natural selection principles to find the optimal formula to predict or adapt the pattern. Genetic algorithms are often a good option for regression-based prediction techniques. These algorithms are part of soft computing methods and are classified in the evolutionary computing branch.

These algorithms were presented in Year 1995 by Holland and colleagues at the University of Michigan. The algorithm deals with a population of single components that represent possible answers to a problem. Each individual component is assigned a score of fitness depending on how well it responds to the problem.

The genetic algorithm starts with an initial population of responses and proceeds to better responses by applying genetic operators that are modeled on the nature of genetic processes in nature. Each generation of generations of new responses is called a "generation." In each generation, relatively better responses are used to reproduce new responses that correspond to the product in the natural genetic process, replacing more inappropriate responses. In this process, an evaluation or fitness function that plays the role of the environment in the genetic process of nature is used to distinguish between good and bad responses. Fig. 3 shows the flowchart of Optimization methods.

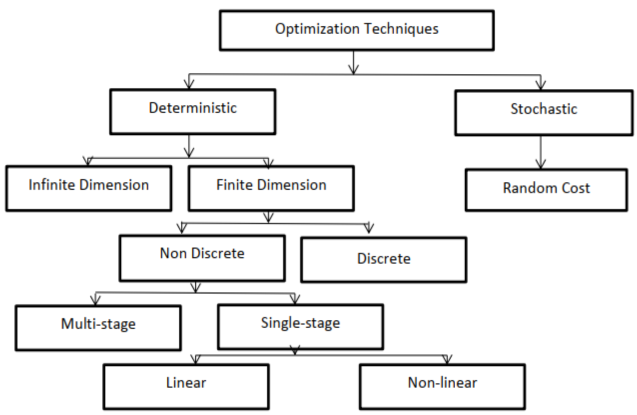

Fig. 3. Optimization methods.

4.1 Genetic Algorithm Structure

Generally, the following five basic components are needed to solve each problem using the genetic algorithm:

- Genetic representation of problem responses
- A way to generate an initial population of responses
- An evaluator function to determine the suitability of each answer
- Genetic operators to manipulate the genetic structure of the offspring at a reproductive stage
- Values for the parameters used in the genetic algorithm.

Based on these steps, a genetic algorithm would be as follows:

- Establish the initial population using the intended startup procedure and evaluate each component of the initial population.
- Combined operations until the intended stopping condition is met. This step involves the following steps:
  - ✓ One or more parents are selected for reproduction. This choice is random, but parents with the highest fitness are the most considered.
  - ✓ Selecting a genetic operator to apply to parents
  - ✓ Children are valued and accumulated for one generation and then replaced by inappropriate members of the population.

The structure of a genetic algorithm is shown in Fig. 4.

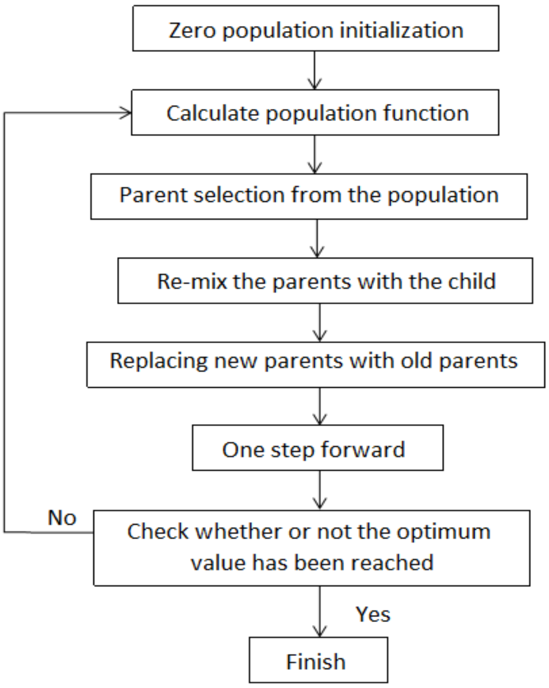

Fig. 4. The structure of a genetic algorithm.

4.2 Early population production

After deciding how to display, initial population generation is the first step in implementing a genetic algorithm. There are several ways to do this. The most common way to generate a certain number of chromosomes is to search uniformly in the search space. For binary representation, binary strings with equal probability of being zero or one, and for real representation, are real numbers with uniform distribution over a range. It is also possible to generate an initial population using better solutions by randomly generating more answers. The initial population can also be generated from previous results, human expert knowledge, or heuristics that can increase the speed of the algorithm. But in this case, it produced the possibility of losing the innovative variety that could increase the speed of the algorithm. But in this case, there is also the possibility of losing genetic diversity or causing unintended tendencies to change. In general, a small population reduces the chances of finding good answers and a large population increases computational costs.

4.3Target and fitness functions

The objective function is used to obtain a measure of response performance in the problem space. In minimization problems, the best answers are those with the lowest objective function value. This gross criterion is usually used as a preliminary step in determining the relative performance of responses in the genetic algorithm. Therefore, another function called the fit function is used to convert the values of the objective function to the relative fit criterion. In this way:

$F(x) = g(f(x))$ (1)

Where F is the objective function, g is the conversion that c onverts the value of the objective function to a negative val ue, and f is the relative fitness obtained. There are two gene ral methods for this conversion: proportionality and ranking. and a large population increases computational costs.

4.4 Mutation

In the natural process, mutation is the process by which a gene changes from a chromosome to a new structure. In the genetic algorithm, the mutation operator is randomly generated with low probability and applied to offspring. The role of mutation as a background operator is to ensure that all problem areas are resolved and the ability to recover the good responses lost during selection and rearrangement. This operator is also different for binary and true representation. In binary representation, mutation is performed by randomly changing one of the genes from zero to one and vice versa, and in discrete representations with degrees of freedom greater than two, the amount of the desired gene changes to one possible. The jump operator is applied to the actual representation by applying random changes to the range of each variable.

4.5 Replacement

After applying the genetic operators, the offspring must enter the population. There are several different strategies for replacement. While all elements of the population are replaced by produced offspring, the algorithm is called genital or non-overlapping, otherwise the algorithm will overlap. The generation gap parameter, G, which is a number in the interval (-1, 1), is used to express the overlap rate and represents the replacement ratio of the offspring in the new generation. For small values of G where the number of substituted children is one or two, the algorithm is in steady state increments. The offspring usually replace the more inappropriate members of the population, and if the number of offspring is greater than the required amount, then the best ones for replacement should be selected after evaluation.

One of the most useful alternatives is the elite selection strategy, in which case a few (usually one or two) of the best answers of each generation will go directly to the next generation. This way, it will always be the best fit to reduce it.

4.6 Algorithm stopping conditions

Since the genetic algorithm is a random search method, convergence determination is conventionally. It's difficult for her. Because the fitness for a number of generations may be constant, and then one. Find a better answer. Common conditions for stopping the algorithm are:

- A number of specified or predetermined generations have passed.
- Average population fit to a predetermined limit.
- There is little change in responses and the population converges.

4.7 Features of Genetic Algorithms

There are generally three main methods of searching for gradient, counting, and random methods. In gradient-based methods, the search for zero-gradient points is performed in all directions and localized, so it may converge to a local optimal response rather than finding a global optimal response. The necessary condition for applying these methods is derivatives. So continuity is the search space.

In counting methods a target function is applied to any point in the search space. Although these methods are simple, they have very low computational efficiency and cannot be applied to large spaces. Random methods perform random searches in search spaces and save the best evaluated points as the optimal candidates. These methods are not much better in large spaces than in object counting unless they are guided which requires information from the search space. The genetic algorithm is not really a random method but it uses choices. The main differences of the genetic algorithm with the methods mentioned are as follows:

- The genetic algorithm works on the coded representation of the parameters, not theirs, so it uses similarities in the genetic structure to find the optimal global response.
- In the genetic algorithm, instead of a response, a population of responses is considered and therefore the whole problem is considered at any one time, not just one element.
- The genetic algorithm uses efficiency information and does not use derivatives and other auxiliary information.
- Genetic algorithm uses random rules rather than definite transfer rules, which eliminates the need for knowledge about the search space.

4.8Neural Network Combination and Genetic Algorithm

Implementation of the idea of combining the neural network and genetic algorithm is shown in the figure. In this method, an initial population is randomly generated and an adaptation function based on artificial neural network model is used to calculate the appropriate ratio for all the initial population. Then select ones, two veins and mutations in the gene are used to rebuild a new generation. The operation will continue to reach the maximum number of generations and bring about population convergence. Based on the mentioned algorithm the optimization program is written in Matlab software. The flowchart of the neural network combination and the genetic algorithm is shown in Fig. 5.

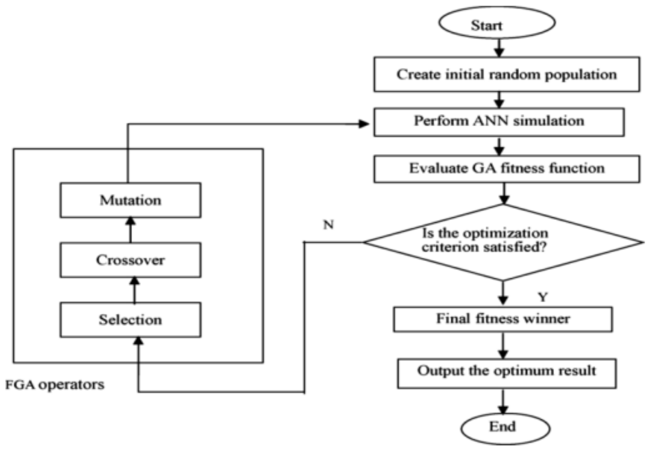

Fig. 5. the process of combining neural network and genetic algorithm.

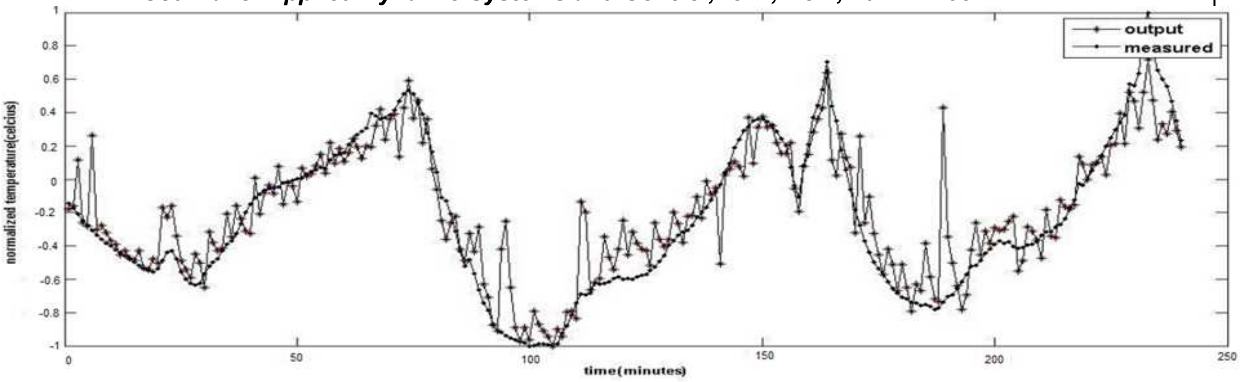

Fig. 6. Output diagrams measured and estimated by neural network and genetic algorithm.

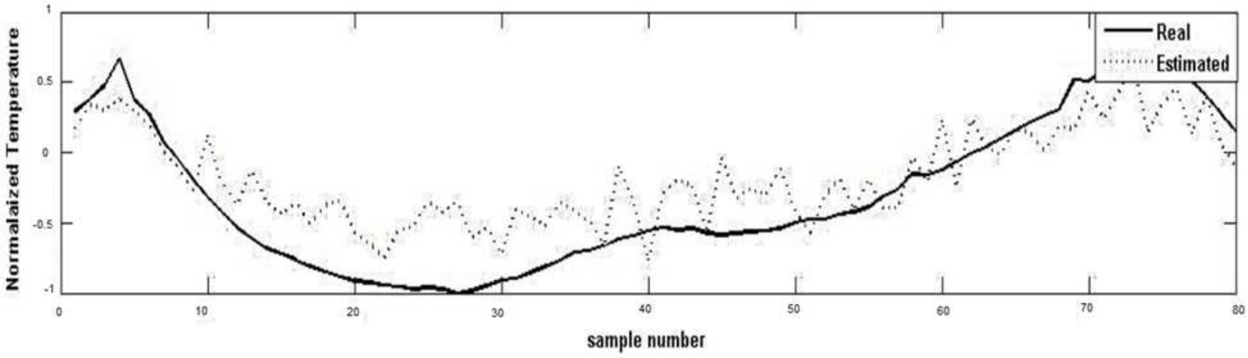

Fig. 7. Neural network testing diagram and genetic algorithm.

The Fig 6 shows that the neural network trained by genetic algorithm with relatively little error is able to simulate the desired air conditioning model and follow the output. But compared to the artificial neural network trained by the multilayer perceptual method as shown in Fig. 7 indicated that, it has weaknesses in modeling.

5. Comparing results

Even In this section, the test diagrams of the artificial neural network methods, the artificial neural network and the Coleman filter are combined and the diagrams obtained from one of the papers compared with the RBF trained neural network. As is well known, the artificial neural network diagram trained by the multi-layer perceptual feedback method has a much better ability to follow the desired outputs.

From the Figs. 8-11 it can be seen that the results of temperature prediction using trained neural network using MLP method are in good agreement with the reference diagrams [13], and the future temperature prediction capability system. The system uses the artificial neural network. But at the same time there is a clear advantage in reducing the error in the graph presented in this study. Table 1 compares the mean square errors:

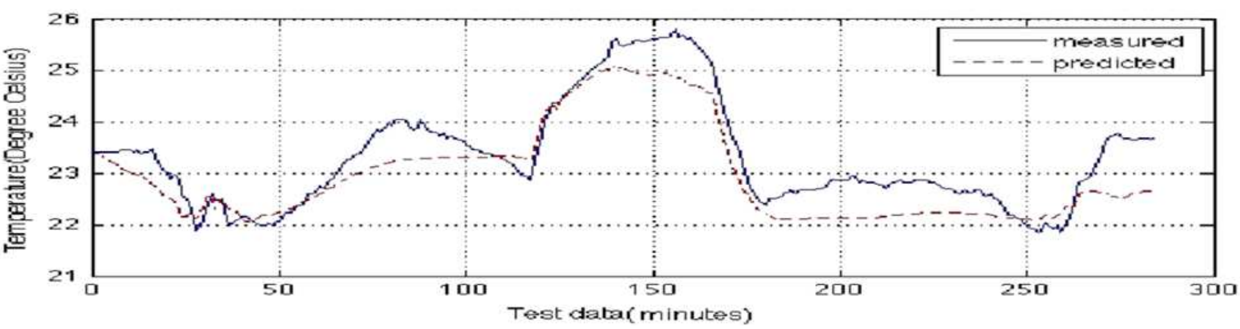

Fig. 8. Reference Neural Network Test Diagram.

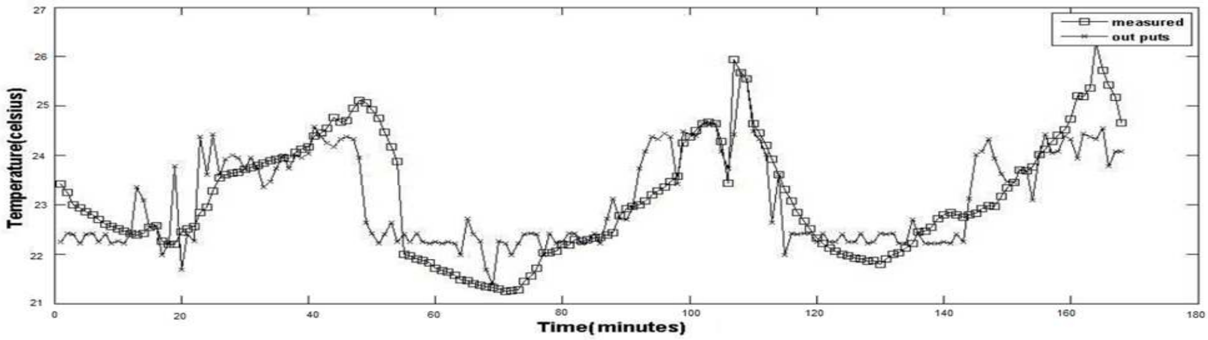

Fig. 9. Diagram derived from Bayesian trained neural network.

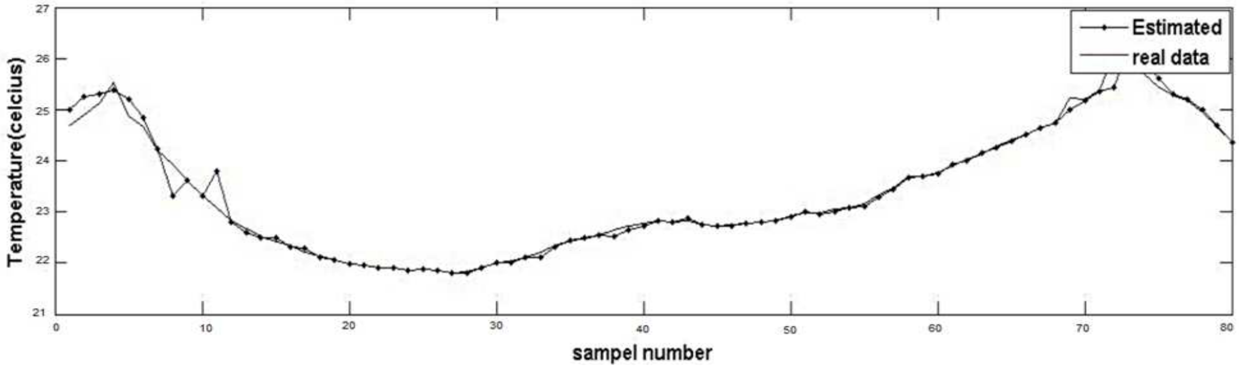

Fig. 10. Test diagram of a trained neural network using multilayer perceptual method.

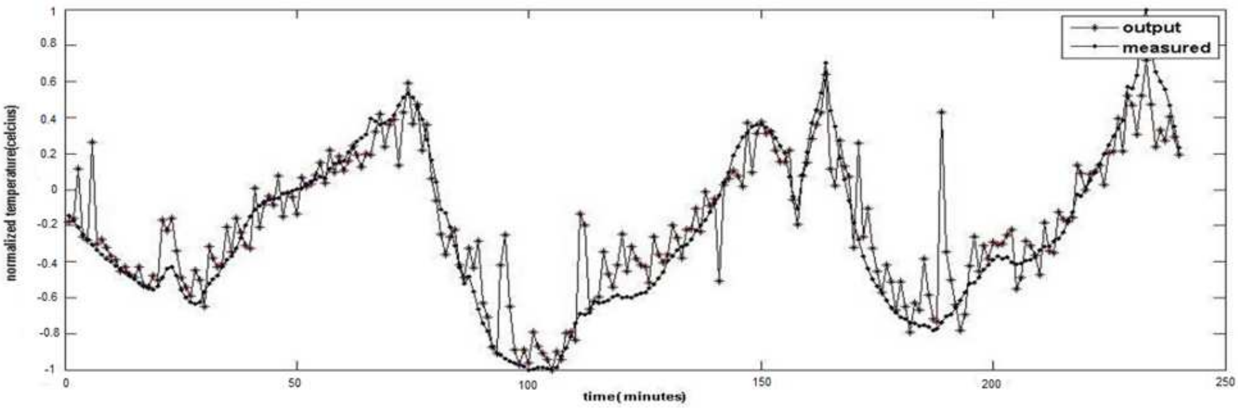

Fig. 11. Output diagram of the neural network combination and genetic algorithm.

Table 1. Comparison of the methods used in the research.

Method	Square error
Simulation using mass and energy equations	0.006
Modeling using Bayesian trained neural network	0.18
Artificial neural network modeling using MLP	0.056
Modeling using Neural Network and Genetic Algorithm	0.1456
Modeling using Neural Network and Kalman Filter	more than 0.5

As can be seen from the numbers, the lowest mean of the linear square error is related to the simulation using mass and energy equations, but this method is not capable of predicting the future temperature of the system, which is the main purpose of this study and hence comparable. Unlike other smart methods, later modeling using artificial neural network and Levenberg training method has the lowest average square error, this method, as mentioned in the graphs, yields better results than previous successful research. Updates itself and follows the measured output more accurately. Next is modeling using a combination of artificial neural network and genetic algorithm, which is ranked third in the mean linear error of 0.14. Other proposed methods are not reliable due to high error and their use is not recommended to predict future temperature of the system.

In this research, three intelligent and optimal modeling methods have been used to model an air conditioning, heating and cooling system. The results obtained from the code written in Matlab indicate that in the modeling phase of the air conditioning system using the four proposed methods of artificial neural network and synthetic neural network trained using genetic algorithm are able to simulate the system As a black box, they cover nonlinear properties of air conditioning, heating and cooling, but the combination of artificial neural network and Kalman filter, despite the use of a discrete Kalman filter to train the artificial neural network to the desired parameter number of neurons. Optimizes hidden layers, but this combination is not able Therefore, the estimate developed by the Kalman filter and the neural network cannot approach the output. For this reason, the estimates obtained from the Couleman Kalman filter and neural network are linear and cannot match the outputs despite the weight parameter being minimized. Therefore, this method is not capable of modeling the air conditioning system. In the above methods, the increase in the number of neurons in the layer does not produce a positive change in the simulation process and only produces output oscillations relative to the output. According to the results for system prediction it is better to use neural network method with four days input for neural network training (with multilayer perceptron method) and the remaining one day to test network capability in predicting future temperature of air conditioning system. to be used. It also ignores system simulations using mass and energy equations to obtain outputs using input data processed from the system transition state to the equilibrium temperature that results in weaknesses in the simulation but, in Considering this transition temperature, the resulting graph will move less slowly to new temperatures, which reduces the comparative burden of this method with other methods used in the thesis, but at the same time the results obtained from this Research is progressing in the field due to its high consistency with other research results (as seen in the confirmation section). Not reduce the mean square error of the modeling system is more capable than previous methods.

6. Conclusion

In this study, artificial neural network and its trained combination with genetic algorithm as well as its combination with Kalman filtering were used to model the air conditioning system in order to predict dry room temperature. The neural network type used was multilayer perceptron and is a Bayesian training method, the results of modeling and prediction using neural network and its combination with genetic algorithm with proper approximation able to predict future day temperature of the system. This enables the system to turn off and turn on the system's cooling and heating equipment in the first place, reducing energy consumption and, ultimately, reducing the depreciation of air conditioning equipment.

Since achieving comfort temperature and reducing energy consumption are the two main goals of this study, therefore, an acceptable approximation can be obtained from two methods of artificial neural network modeling and neural network combination and genetic algorithm for modeling the system and the neural network itself. Used to predict the future temperature of the system. If this prediction model can be combined with an air temperature prediction model that actually played the role of test temperature in this thesis, the obtained model has a good potential for reducing energy consumption, so Use the predicted temperature by future temperature forecasting software as the input measurement temperature at the test stage in this project, using the above methods to predict the output temperature and adjust the main consumer devices. Allows energy such as boilers, chillers, and so on. This can significantly reduce energy consumption while providing residents with less fluctuating comfort.

References

[1] Deng, Z. and Q. Chen, Development and validation of a smart HVAC control system for multi-occupant offices by using occupants' physiological signals from wristband. Energy and Buildings, 2020: p. 109872.

[2] Aguilera, J.J., O.B. Kazanci, and J. Toftum, Thermal adaptation in occupant-driven HVAC control. Journal of Building Engineering, 2019. 25: p. 100846.

[3] Harkouss F, Fardoun F, Biwole P-H "Multi-objective optimization methodology for net-

zeroenergy buildings," Journal of Building Engineering, 2018, 16 57–71.

[4] Lorena Tuballa M, Lochinvar Abundo M, "A review of the development of Smart Grid technologies," Renewable and Sustainable Energy Reviews, 2016 Volume 59, Pages 710-725.

[5] Mogles N, Padget J, Gabe-Thomas E, Walker I, Lee J, "computational model for designing energy behavior change interventions," User Model User-Adap Inter, 2018, 28, 1–34.[6] Ning, M. and M. Zaheeruddin, Neuro-optimal operation of a variable air volume HVAC&R system. Applied Thermal Engineering, 2010. **30**(5): p. 385-399.

[6] Mohammadi M, Noorollahi Y, Mohammadi B, Hosseinzadeh, M, Yousefi H, Torabzadeh Khorasani S, "Optimal management of energy hubs and smart energy hubs – A review," Renewable and Sustainable Energy Reviews, 2018.

[7] Afroz, Z., et al., Modeling techniques used in building HVAC control systems: A review. Renewable and sustainable energy reviews, 2018. **83**: p. 64-84.

[8] Ward, J., J. Wall, and G. Platt, HVAC control system and method. 2016, Google Patents.

[9] Wang, Y., et al., Evaluation on classroom thermal comfort and energy performance of passive school building by optimizing HVAC control systems. Building and Environment, 2015. **89**: p. 86-106.

[10] Ning, M. and M. Zaheeruddin, Neuro-optimal operation of a variable air volume HVAC&R system. Applied Thermal Engineering, 2010. **30**(5): p. 385-399.

[11] Xian-Mei, Z., L. Hao-Yan, and Z. Jin. GA in Optimized Control of Central Air-conditioning System Based on ANN Simulation. in Eighth ACIS International Conference on Software Engineering, Artificial Intelligence, Networking, and Parallel/Distributed Computing (SNPD 2007).

[12] Labus, J., et al. ANN application to modelling and control of small absorption chillers. in Proceedings of the BSO12-Building Simulation and Optimization Conference. 2012.

[13] Tashtoush, B., M. Molhim, and M. Al-Rousan, Dynamic model of an HVAC system for control analysis. Energy, 2005. **30**(10): p. 1729-1745.

[14] Karadağ, R. and Ö. Akgöbek, The prediction of convective heat transfer in floor-heating systems by artificial neural networks. International Communications in Heat and Mass Transfer, 2008. **35**(3): p. 312-325.

[15] Shen, C., L. Wang, and Q. Li, Optimization of injection molding process parameters using combination of artificial neural network and genetic algorithm method. Journal of materials processing technology, 2007. **183**(2-3): p. 412-418.

[16] Liu, W., et al., Springback prediction for sheet metal forming based on GA-ANN technology. Journal of Materials Processing Technology, 2007. **187**: p. 227-231.

[17] Huang, H., et al., A new zone temperature predictive modeling for energy saving in buildings. Procedia Engineering, 2012. **49**: p. 142-151.

[18] Sum, J., et al., On the Kalman filtering method in neural network training and pruning. IEEE Transactions on Neural Networks, 1999. **10**(1): p. 161-166.

[19] Wang, S. and X. Jin, Model-based optimal control of VAV air-conditioning system using genetic algorithm. Building and Environment, 2000. **35**(6): p. 471-487.

[20] Lu, L., et al., HVAC system optimization—in-building section. Energy and Buildings, 2005. **37**(1): p. 11-22.

[21] Maasoumy, M., Modeling and optimal control algorithm design for hvac systems in energy efficient buildings. 2014.

[22] Nakahara, N., et al. Load prediction for optimal thermal storage-comparison of three kinds of model application. in Building Simulation. 1999.

[23] Parvaresh, A., S.M.A. Mohammadi, and A. Parvaresh, A new mathematical dynamic model for HVAC system components based on Matlab/Simulink. International Journal of Innovative Technology and Exploring Engineering, 2012. **1**(2): p. 1-6.

[24] Macek, K. and K. Mařík, A methodology for quantitative comparison of control solutions and its application to HVAC (heating, ventilation and air conditioning) systems. Energy, 2012. **44**(1): p. 117-125.

[25] Tiğrek, T., S. Dasgupta, and T.F. Smith, Nonlinear optimal control of HVAC systems. IFAC Proceedings Volumes, 2002. **35**(1): p. 149-154.

[26] Platt, G., et al., Adaptive HVAC zone modeling for sustainable buildings. Energy and Buildings, 2010. **42**(4): p. 412-421.

[27] Singh, G., M. Zaheer-Uddin, and R. Patel, Adaptive control of multivariable thermal processes in HVAC systems. Energy Conversion and Management, 2000. **41**(15): p. 1671-1685.

[28] Anderson, M., et al., An experimental system for advanced heating, ventilating and air conditioning (HVAC) control. Energy and Buildings, 2007. **39**(2): p. 136-147.

[29] Kaur, H. and D.S. Salaria, Bayesian regularization based neural network tool for software effort estimation. Global Journal of Computer Science and Technology, 2013.

[30] Jin, G.-Y., et al., A simple dynamic model of cooling coil unit. Energy Conversion and Management, 2006. **47**(15-16): p. 2659-2672.

[31] Mustafaraj, G., G. Lowry, and J. Chen, Prediction of room temperature and relative humidity by autoregressive linear and nonlinear neural network models for an open office. Energy and Buildings, 2011. **43**(6): p. 1452-1460.

[32] Xu, X., S. Wang, and G. Huang, Robust MPC for temperature control of air-conditioning systems concerning on constraints and multitype uncertainties. Building Services Engineering Research and Technology, 2010. **31**(1): p. 39-55.

[33] Ruano, A.E., et al., Prediction of building's temperature using neural networks models. Energy and Buildings, 2006. **38**(6): p. 682-694.