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Optimization Approach for Energy Saving and Comfortable Space Using ACO in Building

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Abstract

In building environment energy management is still a challenging and big problem. Several methods and proposals exist in the literature for energy management, but the tradeoff between occupants' comfort level and energy consumption reduction is still required more attention to improve occupants comfort index and minimized energy consumption. In this paper, we proposed efficient optimization method for Simultaneous Comfortable and Energy Saving using ACO (Ant Colony Optimization) algorithm in Building Environment. We have given focus in two directions. First is to maximize the occupants' comfort level and second is to control the usage of power. At the end, we compared results with optimization method using ACO method using GA (Genetic Algorithm). The results show that amount of consumed energy of system using ACO algorithm is consumed less power as compare to the optimization method using GA.

Keywords: *Energy management, Ant colony algorithm, Comfort index, Energy saving*

1. Introduction

Energy efficiency in building is becoming major interest to the researchers of any scientific. That consuming less energy without compromising the comfort index is a challenging problem [1-4].

We are interest to consume less energy without compromising users comfort in building environment. Comfort index indicates occupants' comfort level. Major challenges are between users comfort index and energy consumption. The fundamental three parameters such as thermal comfort, visual comfort and air quality which determine occupants' quality lives in a building environment [5]. Temperature level is used to indicate the thermal comfort in a building. An auxiliary heating or cooling system is applied to preserve the temperature in comfortable areas of a building. The illumination level is used to indicate the visual comfort of occupants [6]. The electrical lighting system is used to manage the visual comfort. CO2 concentration is used as an index to measure air quality in the building environment [7].

There is several number of research works has been proposed before [8-10]. They used PID (Proportional Integral Derivative) controllers in order to overcome the overshoot of temperature. Other conventional controllers proposed in the literature included optimal control and adaptive control.

But these conventional controllers have some disadvantages. They need a model of the building. They are not user friendly and there are many difficulties in monitoring and controlling the parameters caused by nonlinear features.

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Other proposals in this connection are predictive control approaches [12-13], where weather predictions have been applied to heating, ventilating and air conditioning system.

In this paper, we proposed efficient optimization method for simultaneous comfortable and energy saving using ACO (Ant Colony Optimization) algorithm in building environment. We focused to improve occupants' comfort index and energy efficiency simultaneously. Then we compared results with proposed model using ACO and model using GA(Genetic Algorithm). The results of our proposed model show that higher user comfort index and minimum energy consumption compare than model based on GA.

However, there is already same optimization method using GA [3], which works and gives result correctly. Consequently, we tried to use different algorithm for the system to improve efficiency of result. ACO is that artificial technique used to develop a new method to solve problems unsolvable since last many years and inspired by the foraging behavior of ant colonies and target discrete problems. In addition, ACO is recently proposed meta-heuristic approach for solving hard combinatorial optimization problems. Artificial ants implement randomized construction heuristic which makes probabilistic decisions. ACO shows great performance with the "ill-structured" problems like network routing. Ant colonies and more generally social insect societies are distributed system that in spite of the simplicity of their individuals, present a highly structured social organization. Ant colony can accomplish complex tasks that in some cases far exceed the individual capabilities of a single ant.

2. Related Work

Energy conservation in the building is one of the challenging sectors in research field. Due to the recent technological advancements regarding building facilities and many approaches are available in designing an energy conservation system. Research on improving a building environment mainly focuses on occupants' comfort and energy efficiency. Since people spend most of their time in buildings, the environmental comfort conditions of a building are highly related to occupant satisfaction. A new control system with an intelligent optimizer is developed, which can be applied to energy and comfort management in the smart and energy-efficient buildings [4]. Hierarchical multi-agent theory is used to build this control system, which contains agent-controllers at the lower level. Particle Swarm optimization (PSO) is adopted to optimize the set points of the control system during system operations. There is a paper which is about a survey exploring state of the art control systems in building. Attention will be focused on the design of agent-based intelligent control systems in building environments. The paper presents a multi-agent control system (MACS) [5]. Adaptive learning algorithm based on genetic algorithms GA for automatic tuning of proportional, integral and derivative (PID) controllers in Heating, ventilating, and air conditioning (HVAC) systems to achieve optimal performance. Genetic algorithms which are search procedures based on the mechanics of Darwin's natural selection, are employed since they have been proved to be robust and efficient in finding near-optimal solutions in complex problem spaces. The modular dynamic simulation software package HVACSIM has been modified and incorporated in the genetic algorithm-based optimization program to provide a complete simulation environment for detailed study of controller performance. Three performance indicators overshoot, settling time, and mean squared error are considered in the objective function of the optimization procedure for evaluation of controller performance [17].

3. Optimization Approach Based on ACO Algorithm

We describe an optimization method for comfortable and energy saving using ACO algorithm in building environment. Figure. 1 describes the block diagram of the proposed control model for energy management in building environment. This model has the ACO optimizer, user comfort index, coordinator agent, fuzzy controllers, comparator, and building actuators and sensors.

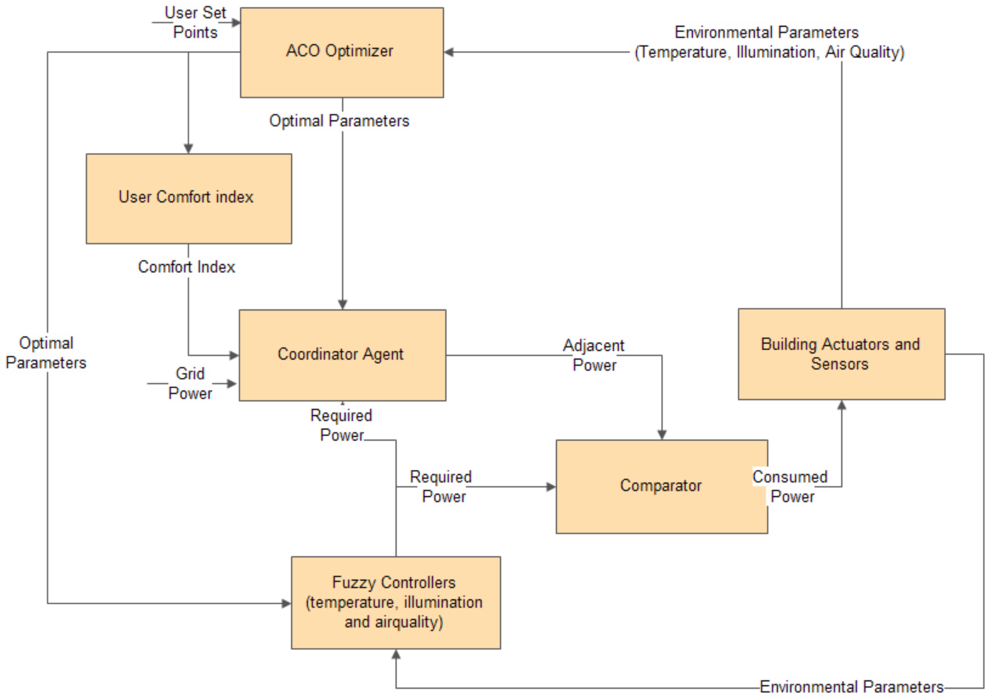

Figure 1. Proposed Optimization Method Design for Energy Management in Building

Environmental parameters such as temperature, body temperature, illumination and Air quality are input to the ACO for optimization.

ACO steps for parameters optimization:

- Position ants on different towns, initialize pheromone intensities on edge.
- Set first element of each ants tabu list to be its starting town,
- Each ant moves from town to town according to the probability p(i,j)
- After n moves all ants have a complete tour, their tabu list are full; so compute Lk and Δtkij.
- Save the shortest path found and empty tabu lists.
- Update pheromone strengths.
- Iterate until tour counter reaches maximum or until stagnation- all ants make same tour.

The comfort index can be calculated using Eq. 1 [2]:

$$\text{Comfort} = \alpha1[1 - (eT / Tset)2] + \alpha2[1 - (eL / Lset)2] + \alpha3[1 - (eA / Aset)2] \qquad (1)$$

Where “comfort” is the overall comfort level of the user and is ranged between [0,1]. α1, α2, α3 are the user defined factors which solve any possible conflict between the three comfort factors (temperature, illumination and air-quality). eT, is the error difference between optimal parameter of ACO (temperature in this case) and actual sensor temperature. eL, is the error difference between optimal parameter of ACO (illumination in this case) and actual sensor illumination. eA, is the error difference between optimal parameter of ACO (air-quality in this case) and actual sensor air-quality. Tset, Lset, Aset are the user set parameters of temperature, illumination and air-quality.

This algorithm takes as input the error between real parameters and optimal parameters of the ACO. The output of the fuzzy controller is the required power for temperature, illumination and air-quality control in the building environment. Then this required power is input to the coordinator agent.

The fuzzy controller can be calculated using Eq. 2 [3]:

$$\gamma_T = \vartheta \times P_T / K \tag{2}$$

$$\gamma_L = \vartheta \times P_L / K \tag{3}$$

$$\gamma_A = \vartheta \times P_A / K \times d \tag{4}$$

In Eqs. (2), (3) and (4) γ_T, γ_L and γ_A are the temperature, illumination and air quality increment relationship with consumed power P in time k respectively. ϑ is the weight factor to balance the relationship. The value of ϑ is between [0, 1] and "d" is the basic operation power of ventilator [3].

Coordinator agent takes as input the required power to the building from fuzzy controller, and optimal parameters from the ACO. It then adjusts the power on basis of the available power, required power and user comfort index. The adjusted power is then compare with the required power to get the actual consume power. Then actual consume power is given to the actuators to be used. The actual consume power is the minimum power to be consume in the building. This consume power is also make the occupants happy by providing the required comfort index.

The fuzzy controller can be calculated using Eq. 3 [4]:

$$PT(k+1) = PT(k) \tag{5}$$

$$PL(k+1) = PL(k) \tag{6}$$

$$PA(k+1) = PA(k) \tag{7}$$

$$PT(k)+PL(k)+PA(k)=Prequired(k) \tag{8}$$

$$Prequired(k) \leq Pavailable(k) \tag{9}$$

$$Pavailable \leq Pmax \tag{10}$$

In Eqs. (5), (6), and (7) P(k) is the required power, which is the sum of power demands from temperature, illumination and air-quality. Prequired, is the total energy source (outside grid-power or internal local power source). Pmax (k) is the maximum input power either from the power grid or from the local micro sources to the building.

Comparison component actually takes as input the adjusted power from coordinator agent and required power from fuzzy controller. It then measured the actual consumed power of the building.

Building actuators are the devices which actually use the energy inside the building. That is: AC (cooling), heater (heating), refrigerator (cooling) and oven (heating).

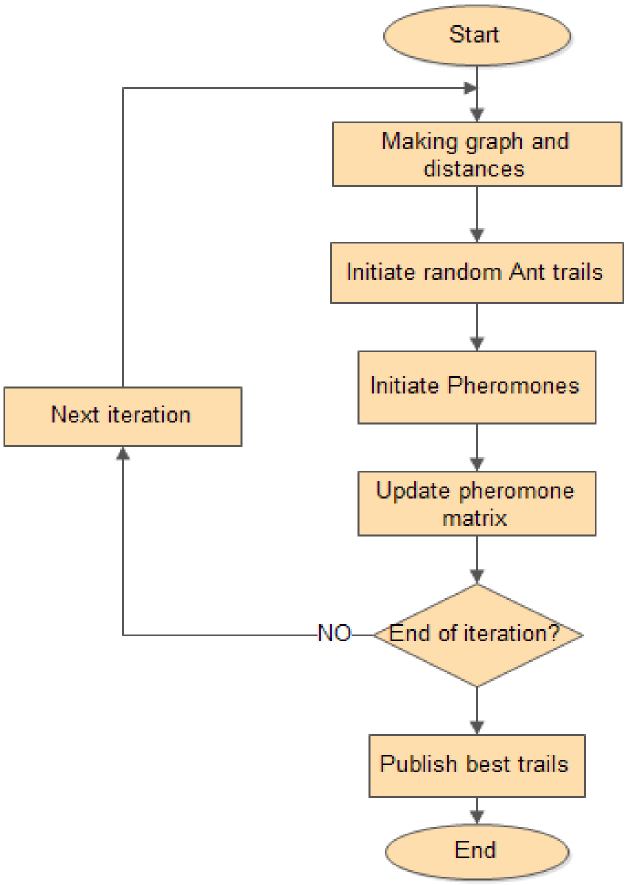

Figure 2. Flow Chart for Ant Colony Optimization Algorithm

Figure 2 illustrates work sequence of ACO, which is used by the system. Firstly, algorithm needs to make graph and give distance measurements to the graph. Secondly, we need to put Initial random ants on the trails in order to decide how many ants go through a graph. Third, put the initial pheromones on the each path of the graph and update pheromone after iteration. Last, repeat the process until we get higher result. Finally, algorithm is ready to publish the best trails.

4. Simulation and Results

Matlab/Simulink used for input/output membership functions construction. While actual simulation carried out in C# 2008. User preference set parameters range was Tset = [66-78] (Kelvin), Lset = [720, 880] (lux) and Aset = [700, 880] (ppm).

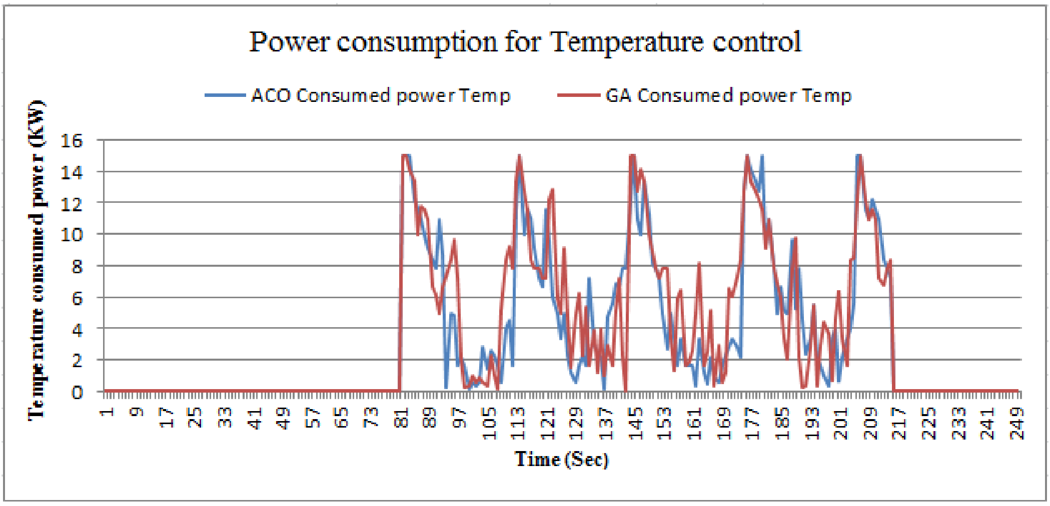

Figure 3. Power Consumption for Temperature Control

Figure 3 illustrates comparison of temperature power consumption. x-axis shows that time in seconds while y-axis shows the predicted power consumption in kilowatts. First disturbance occurs at time 81sec.

From the result, system with based on ACO method consumes less power as compared to the system with based on GA method. This is due to the fact that optimized parameters on based ACO method are more than optimized parameters based on GA method.

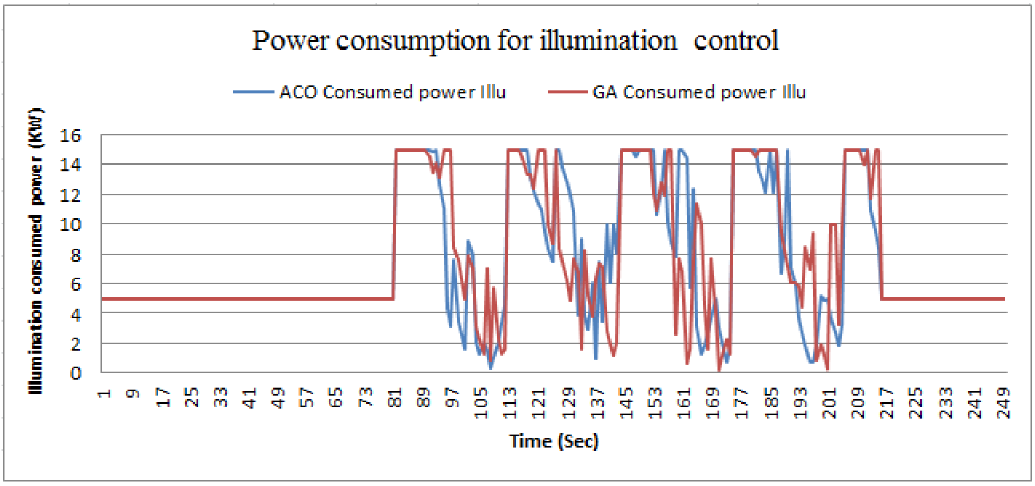

Figure 4. Power Consumption for Illumination Control

Figure 4 describes comparison of illumination power consumption. x-axis shows the time in seconds while y-axis shows the power consumption in kilowatts. First disturbance occurs at time 81sec. Similarly for illumination control, the results are same as before so this is due to the fact that optimized parameters based on ACO are more efficient than optimized parameters based on GA.

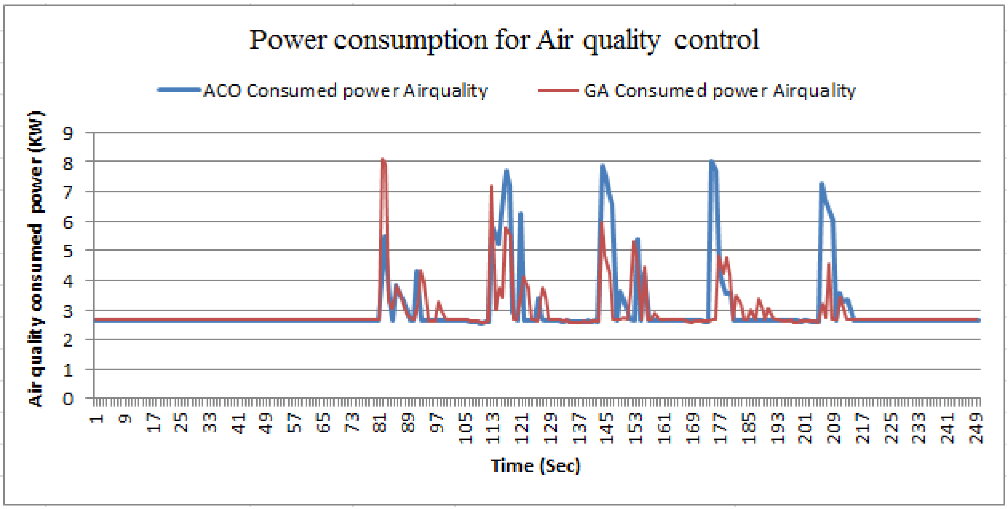

Figure 5. Power Consumption for Air Quality Control

Figure 5 illustrates comparison of air quality power consumption. x-axis shows the time in seconds while y-axis shows the power consumption in kilowatts. First disturbance occurs at time 81sec. Results are same as before so this is due to the fact that optimized parameters based on ACO are more efficient than optimized parameters based on GA.

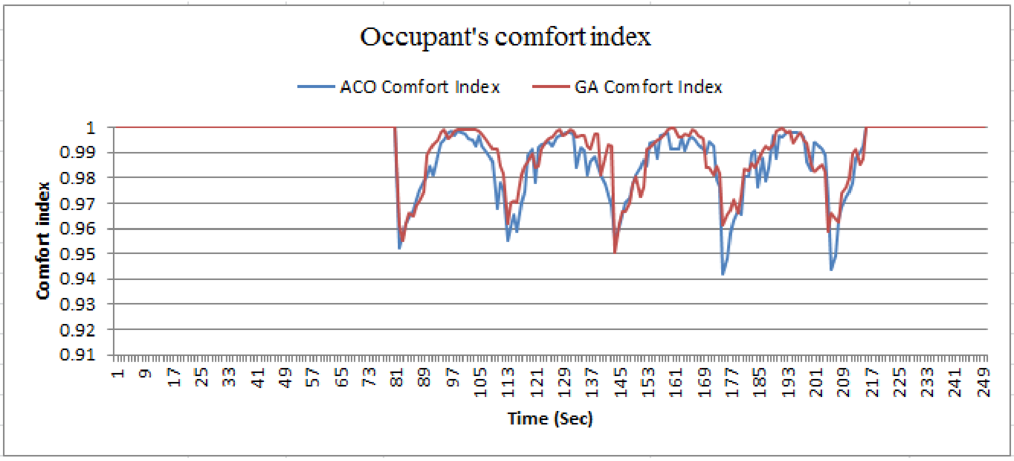

Figure 6. Occupant's Comfort Index

Figure 6 explains result of user comfort index in case of system based on ACO and system based on GA. x-axis shows the comfort index between 0.0 and 1.0 is the minimum and maximum comfort index respectively and y-axis shows the power consumption in kilowatts. First time power disturbance occurs at 82sec. At the time comfort level of ACO based system goes down to 0.952 while at the same time GA based system comfort level to 0.961. ACO based system improving comfort index as compared to GA based system.

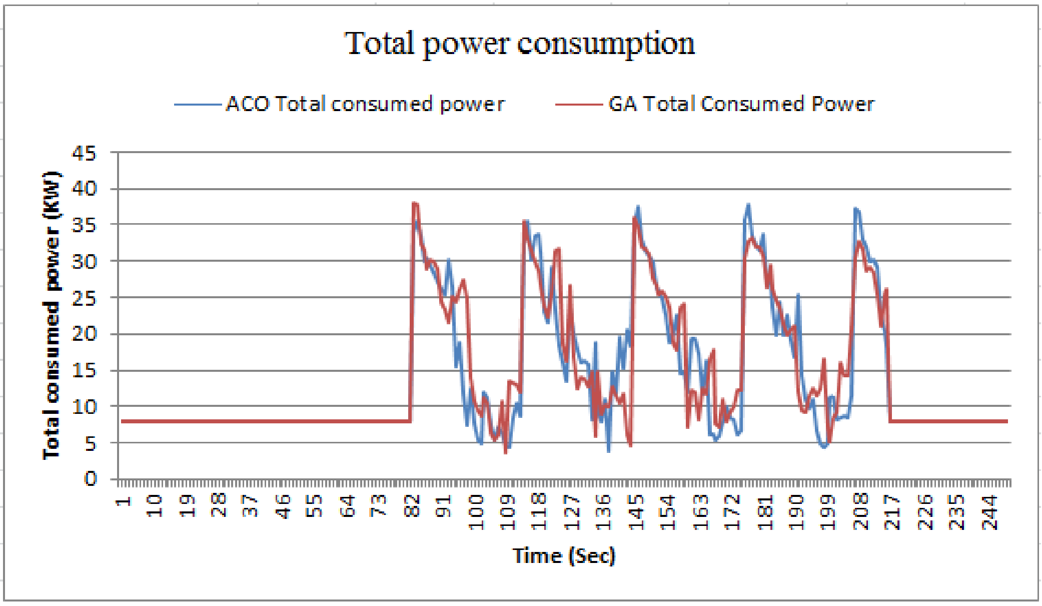

Figure 7. Total Power Consumption

Table 1. Total Power Consumption

Power consumption	ACO(KWh)	GA(KWh)
Temperature	815.9254	890.1851
Illumination	1279.009	1317.661
Air-quality	449.4082	420.723
Total	2544.342	2628.569

Figure 7 and Table 1 describe results of total power from each system. From the compared simulation result, It is obvious that total power is consumed less significantly by ACO based system.

5. Conclusion

In this paper, we proposed efficient optimization method for simultaneous comfortable and energy saving using ant colony algorithm in building environment. The problem is that we need to consume less energy without compromising user comfort in building environment. Therefore, this study proposed to increase occupants comfort index and minimizing energy consumption and comparison of two optimization algorithms. Input parameters which we optimized are temperature, illumination and air quality in the system. The proposed ACO based optimized model produces comfort index and consumed power as compared to GA based optimized model [3]. Both algorithms can produce comfort index and consumed power similarly. However, from the result, optimized model based on ACO's total results are higher than optimized model based on GA. Our proposed optimized model based on ACO improved both occupants comfort index and consumed minimum energy simultaneously.

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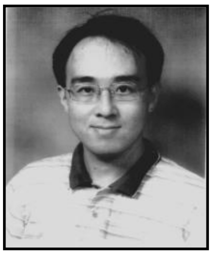

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