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Performance Evaluation of Particle Swarm Optimization on Poultry House Temperature Control System

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Abstract : *The detrimental effects of high temperature on poultry production have been investigated by several researchers due to common occurrence of environmental stressors worldwide. It has been shown that high temperature negatively affects the welfare and significantly influence the survivability and performance of the poultry production. Hence, controlling the temperature of the poultry house within thermal neutral zone of poultry birds is indispensable in order to reduce their mortality and increase production. Most of the existing techniques utilized to control poultry house temperature within the thermal neutral zone of the bird were time consuming, tedious and require a continuous monitoring. In this study, a metaheuristic technique; Particle Swarm Optimization (PSO) algorithm is adopted to achieve an optimal control of thermal requirement of a poultry housing system. PSO is a computational search and optimization method that have been empirically shown to achieve well on several optimization problems. The experimental result obtained shows that the PSO in the regulation of the thermal requirement of the poultry house is computationally efficient.*

Keywords: *Metaheuristic, Particle Swamp Optimization, Poultry House Temperature, Thermal Regulation*

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I. Introduction

Poultry flocks are particularly vulnerable to climate change because there is a range of thermal conditions within which animals are able to maintain a relatively stable body temperature in their behavioural and physiological activities [3]. Understanding and controlling environmental conditions is crucial to successful poultry production and welfare. Temperature control of poultry house within thermal neutral zone of poultry birds is essential in order to reduce their mortality and increase production [2]. When ambient temperature is high, chickens have higher energy (feed) needs than when in thermo- neutral environments. Major losses result from a less efficient conversion of feed to meat, which detrimentally impacts poultry health and productivity.

Several techniques have been utilized to control poultry house temperature within the thermal neutral zone of the bird. The traditional methods despite being effective are time consuming, tedious and require a continuous monitoring [4]. Therefore, with respect to these shortcomings, there is need for a knowledge based system that can act in controlling ventilation and temperature needs of the broiler chicken. It is also necessary for a system to sense and regulate the temperature of the environment.

Particle swarm optimization (PSO) is becoming one of the most important swarm intelligent paradigms for solving global optimization problems [1]. PSO is a population-based search technique that involves stochastic evolutionary optimization. This algorithm has unfathomable intelligence background and is appropriate for scientific research and engineering application. Therefore, PSO algorithm has triggered the widespread attention of researchers in the field of evolutionary computation, and has attained a lot of research results over the years [5]. Similarly, PSO is easy to implement and has been effectively functioned to resolve a varied collection of optimization problems. Thus, because of its easiness and effectiveness in directing huge search spaces for optimal solutions and its dominance with respect to other Evolutionary algorithm techniques; PSO algorithm is engaged in this research to achieve an optimal control of thermal requirement of a poultry housing system.

In this study, a performance evaluation of Particle swarm optimization (PSO) technique for regulating the thermal requirement of a poultry house is presented. The PSO approach for the poultry temperature regulator validate the efficacy and robustness of the optimization method.

II. Literature Survey

Particle swarm optimization (PSO) is a nature-inspired algorithm that draws on the conduct of flocking birds, social interactions among humans, and the schooling of fish. Specifically, PSO is a metaheuristic algorithm that was inspired by the collaborative or swarming behavior of biological populations [7]. In fish schooling, bird flocking, and human social interactions, the population is called a swarm and candidate solutions, corresponding to the individuals or members in the swarm, are called particles. Birds and fishes normally travel in a group without collision. Consequently, using the group information for finding the shelter and food, each particle adjusts its corresponding position and velocity, representing a candidate solution. The position of a particle is influenced by neighbors and the best found solution by any particle [6].

Particle Swarm Optimization (PSO) has been applied to solve a wide range of optimization problems, such as constrained and unconstrained problems, multi-objective problems, problems with multiple solutions, and optimization in dynamic environments. Particle swarm optimization through it application in various domain has proven to be computationally efficient in terms of effective convergence, parameter selection, simplicity, flexibility, robustness, ease of implementations [8], ability to hybridize with other algorithms and many others [6].

In PSO, individuals are referred to as particles. Each particle has a position represented by a position-vector $\bar{x}_n$ and a velocity represented by a velocity-vector $\bar{v}_n$. At each iteration, each particle changes its searching course based on: its preceding velocity $\bar{v}_n(t)$ its best position usually called *local or personal best(P_b).* it has met so far and the best position G_b attained so far by all particles in the swarm (called *global best*). That is, each particle updates its velocity and position according to equation (1) and (2) respectively [9]:

$$\bar{v}_{mn}(t+1) = \omega\bar{v}_{mn}(t) + c_1 r_1\big(P_b - \bar{x}_{mn}(t)\big) + c_2 r_2\big(G_b - \bar{x}_{mn}(t)\big) \qquad (1)$$

$$\bar{x}_{mn}(t+1) = \bar{x}_{mn}(t) + \bar{v}_{mn}(t+1) \qquad (2)$$

Where $\bar{v}_{mn}(t+1)$ velocities of particle mat iterations n,$\bar{x}_{mn}(t+1)$, positions of particle m^{th} at iterations n^{th}. $\omega$is inertia weight to be employed to control the impact of the previous history of velocities. t denotes the iteration number, c_1 is the cognition learning factor, c_2 is the social learning factor, r_1 and r_2 are random numbers uniformly distributed in [0, 1].

The Stepwise procedure of the PSO algorithm are presented below [10]:

1. Set parameter ω_{min}, ω_{max}, c_1 and c_2 of PSO
2. Initialize population of particles having positions x_n and velocities v_n
3. Set iteration n = 1
4. Calculate fitness of particles $F_{mn}(t) = f(\bar{x}_{mn}(t))$ and find the index of the best particle b
5. Select $Pbest_{mn}(t) = \bar{x}_{mn}(t)$ and $Gbest_n(t) = x_{bn}(t)$
6. $\omega = \omega_{max} - n \times (\omega_{max} - \omega_{min})/Maxnum$
7. Update velocity and position of particles
$$\bar{v}_{mn}(t+1) = \omega\bar{v}_{mn}(t) + c_1 r_1\big(P_b - \bar{x}_{mn}(t)\big) + c_2 r_2\big(G_b - \bar{x}_{mn}(t)\big)$$
$$\bar{x}_{mn}(t+1) = \bar{x}_{mn}(t) + \bar{v}_{mn}(t+1)$$
8. Evaluate fitness $F_{mn}(t+1) = f(\bar{x}_{mn}(t+1))$ and find the index of the best particle b_1
9. Update $Pbest$ of population
   If $F_{mn}(t+1) < F_{mn}(t)$ then $Pbest_{mn}(t+1) = \bar{x}_{mn}(t+1)$ else
$$Pbest_{mn}(t+1) = Pbest_{mn}(t)$$
10. Update $Gbest$ of population
   If $F_{bn}(t+1) < F_{bn}(t)$ then $Gbest_n(t+1) = Pbest_{bn}(t+1)$ and set $b = b_1$ else
$$Gbest_{bn}(t+1) = Gbest_n(t)$$
11. If $k < Maxnum$ then $k = k + 1$ and goto step 6 else goto step 12
12. Output optimum solution as $Gbest_n(t)$.

III. Methodology

In this study, an optimal control of sensor lights using Particle Swarm Optimization (PSO) is presented. A swarm optimized temperature control system is developed to provide an intelligent red light if the temperature is either above or below the normal temperature and to activate either the air conditioning system or the heater as the case may be at a point in time. Three indicators (red, green and yellow light) were used to indicate the state of temperature. These lights are interval response based on dynamic temperature inputs, thereby overcoming the inefficiencies of conventional temperature controllers, that is, a passive means of monitoring temperature.

The three control signals used in the model are green, yellow and red signals. The red signal indicate that the temperature is below or above the normal temperature. The green signal indicates that the temperature is normal while the yellow signal indicates warning signal that the temperature is either tending above or below the normal temperature. RT, GT and YT represent the red timer, green timer and yellow timer respectively. "**R**", "**Y**" and "**G**" are the red, yellow and green signals respectively.

Particle Swarm Optimization (PSO) optimizes the initial parameter as well as the random number representing the current temperature of the poultry house at a particular point in time. The output of the best randomised set of temperature from PSO regulates the poultry system temperature. Figure 1 depict the process of Particle Swarm Optimization (PSO) adopted.

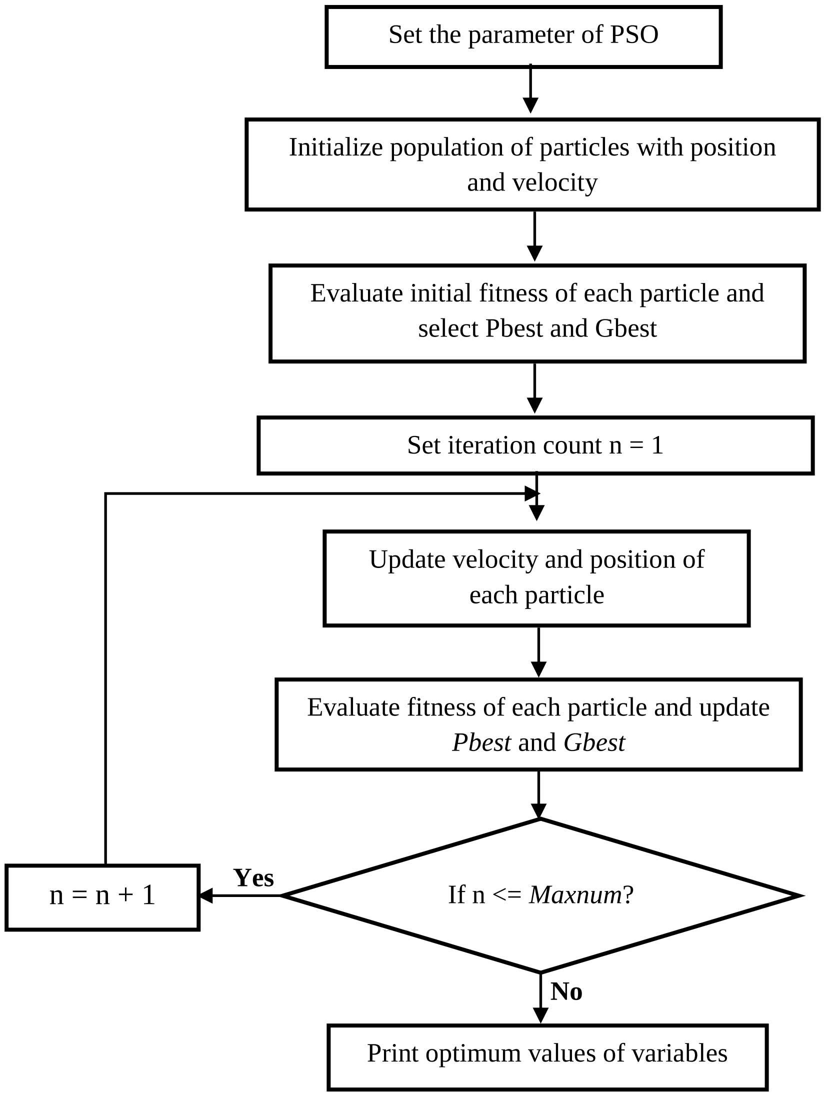

Figure 1: Particle Swarm Optimization Process

Three variables used to represent levels of temperature include:
1. **Below NT (**Below Normal Temperature): this represent a temperature values below room temperature.
2. **NT** (Normal Temperature) represent the temperature value of room temperature.
3. **Above NT** (Above Normal Temperature): this represent the temperature value above room temperature.

Figure 2 depicts the flow diagram of the program activity. The inputs which includes the current temperature and various parameters needed to control the temperature of a broiler chickens in a poultry farm were initialized. These inputs include: "**TN**" which indicates the total number of cycles and is initialized to be 10. "**C**" is the counter for the total number of cycles and is initialized to be 1. RT, GT and YT represent the red timer, green timer and yellow timer respectively. "**n**" is the counter for the iteration and it is set to 1. "**R**", "**Y**" and "**G**" are the red, yellow and green signals respectively. These parameters were presented as inputs to the Particle Swarm Optimization (PSO) algorithm for optimization. The optimized parameter from PSO regulate the thermal requirement of a poultry house. When the current temperature is greater than the normal temperature

(NT) i.e. (Temp = AboveNT) the AC is activated to lower the temperature; the red indicator "**R**" becomes ON and the red timer is increased. Similarly, when the current temperature is less than the normal temperature (NT) i.e. (Temp = BelowNT) the Heater is activated to raise the temperature; the red indicator "**R**" becomes ON and the red timer is increased as well.

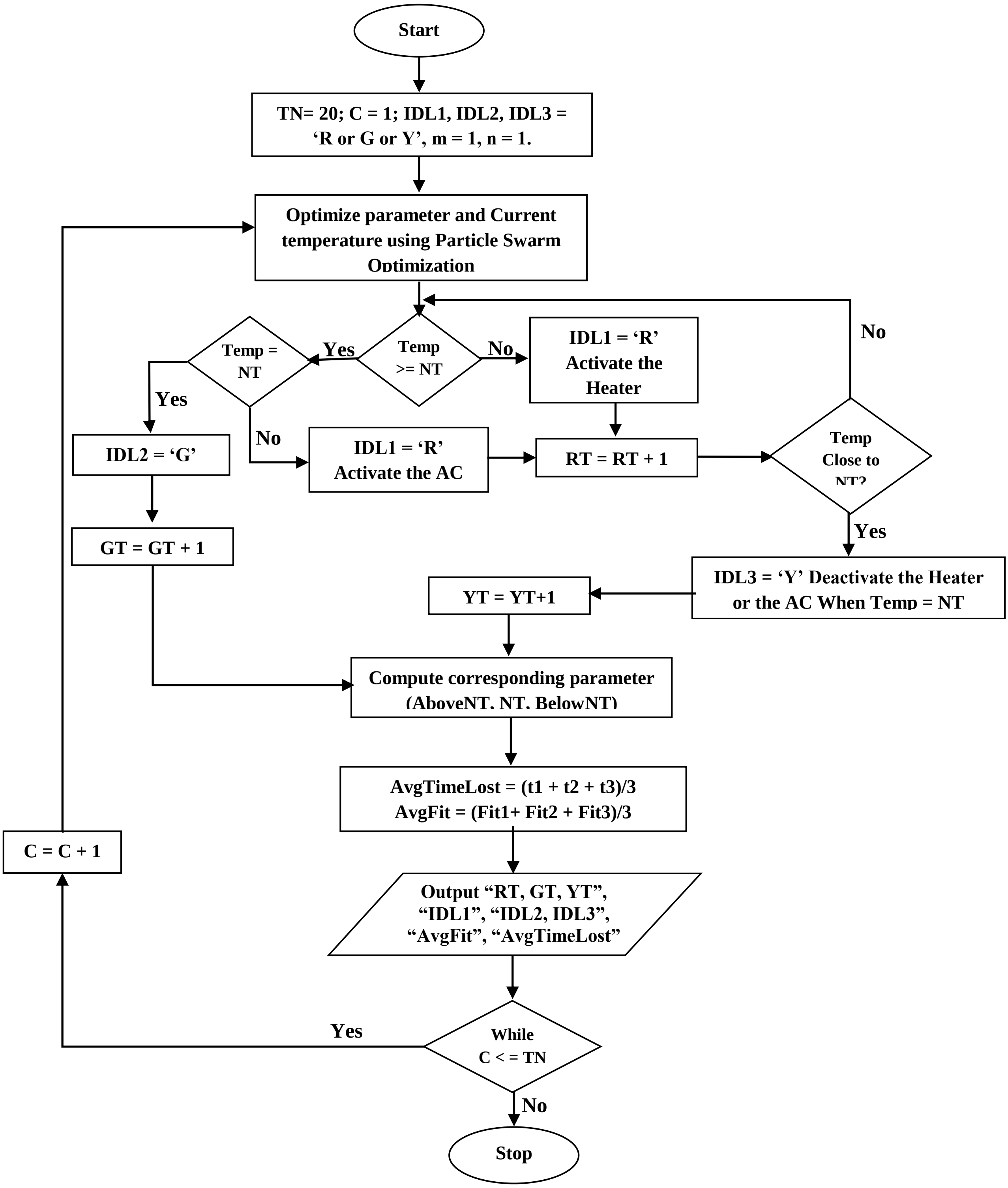

Figure 2: Program Activity of the model

At a point when the temperature is very close to the normal temperature as a result of heating or air-conditioning the warning signal is ON i.e. the yellow indicator "**Y**" and the yellow timer is increased. However, when the temperature become normal either the AC or the heater is deactivated. When the temperature is normal i.e. (Temp = NT) the AC and heater will be deactivated while the green indicator "**G**" becomes ON and the green timer is increased.

The fitness value is Ft1, Ft2 and Ft3 and the time lost in each instance are t1, t2 and t3. If the maximum criteria are met, the model outputs the temperature condition of the poultry system (AboveNT, NT and BelowNT), the average total time in each cases; the average fitness values for each cycle and the average time lost. The fitness values of each cycle are stored with the corresponding average time lost during the temperature regulation. The cycle with the least time lost has the best fitness value.

MATLAB R2012a on Windows 7 Ultimate 64-bit operating system, Intel®Pentium® CPU T4500@2.30GHZ Central Processing Unit, 4GB Random Access Memory and 500GB hard disk drive was used to implement the proposed work. An interactive Graphic User Interface (GUI) application was developed to ensure easy interaction and understanding as shown in figure 3.

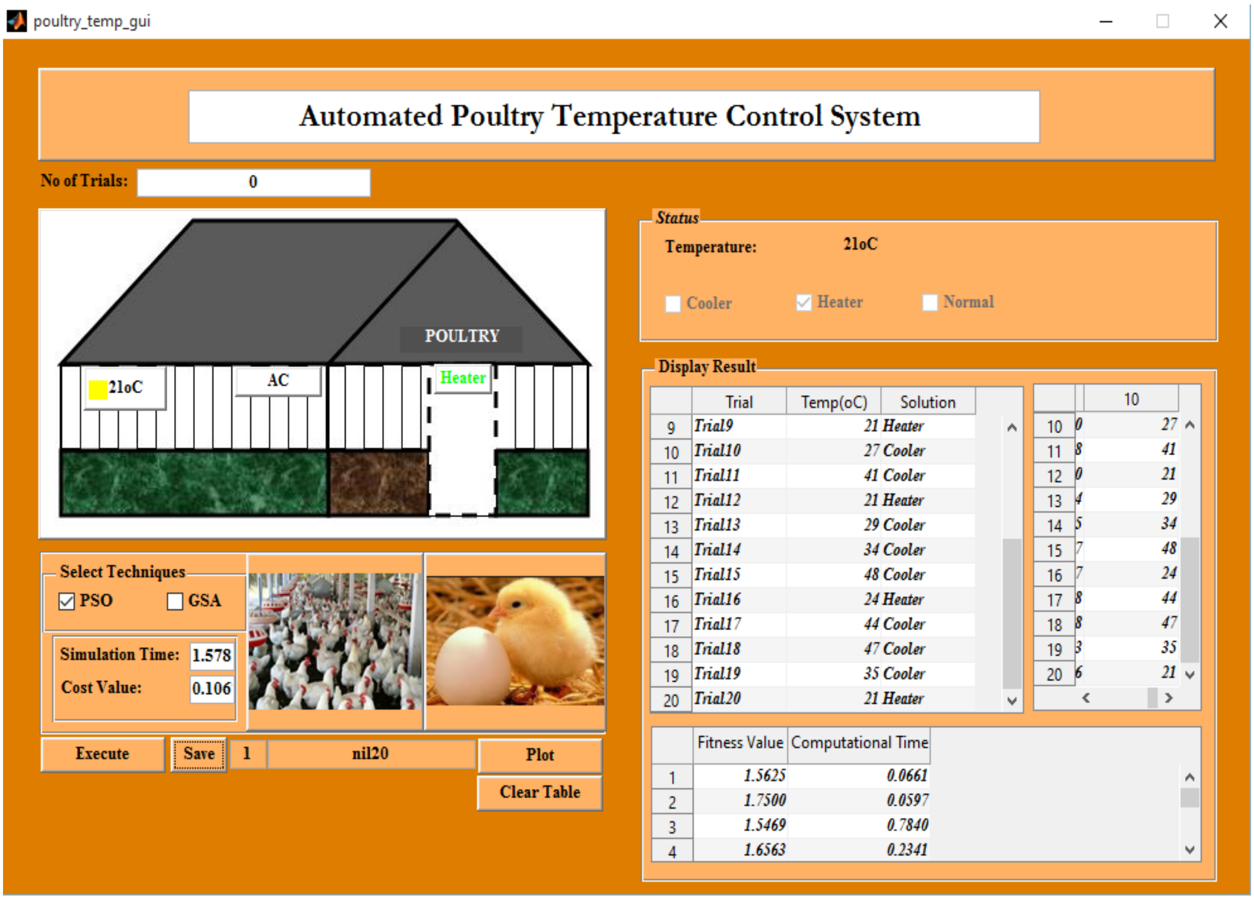

Figure 3: The GUI Application

IV. Results and Discussion

The results obtained by the application of the PSO techniques in the regulation of poultry house temperature with respect to the cost (fitness value) and computation time were evaluated as follows. Table I presents the result of simulations of the proposed model i.e. PSO in the regulation poultry house temperature for ten (10) trials in each cycle for 10 cycle. The table depict the variation of temperature of the simulated poultry house. The haphazard manner of the temperature in the table reveals how the temperature was with regulated at a point in time in a cycle. The also result reveals that the temperature regulation was mostly done by the activation of the air-conditioning system than the heater because most of the temperature value as shown in table I are above 25ºC; the normal temperature required of a poultry system. However, the heater and the air-conditioning system was activated based on the current temperature to maintain balance and to avoid heat stress.

Figure 3 depict the graph of the temperature with respect to 10 regulation attempt for the second cycle. The second circle was selected because it has the best fitness value and computation time.

Table I: Simulated PSO result for Poultry House Temperature Regulation

Trials	**Cycle 1**	**Cycle 2**	**Cycle 3**	**Cycle 4**	**Cycle 5**	**Cycle 6**	**Cycle 7**	**Cycle 8**	**Cycle 9**	**Cycle 10**
	°C	**°C**	**°C**	**°C**	**°C**	**°C**	**°C**	**°C**	**°C**	**°C**
1	45	20	39	47	42	50	26	45	42	38
2	48	27	41	32	25	28	28	34	42	33
3	23	22	35	29	34	42	46	26	21	31
4	48	25	33	28	50	33	28	42	42	40
5	39	43	29	22	35	38	50	38	36	25
6	23	28	27	25	37	34	43	30	44	28
7	28	25	39	35	33	40	36	40	26	30
8	36	25	21	32	28	34	36	34	25	44
9	49	36	50	36	21	46	46	43	20	44
10	49	25	27	48	26	23	47	26	39	50

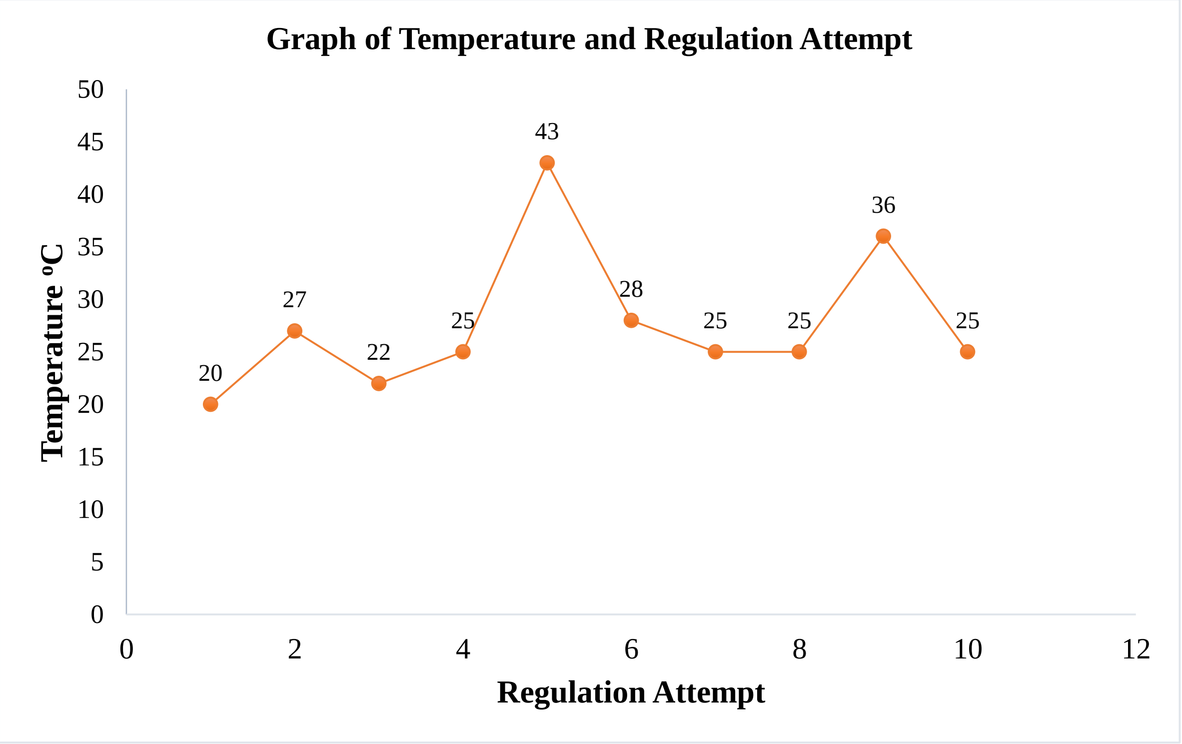

Figure 3: Graph of Temperature against Regulation Attempt

Also, Table II present the result of the proposed techniques in terms of fitness value and the computational time. The best fitness value was achieved in the second cycle with a value of 0.011 at 1.500 second. Therefore, Particle Swarm Optimization (PSO) technique in the optimization of the temperature of the poultry system is found to be efficient. Average fitness value for the 10 cycle is 0.110 at 1.628 second. This is due to the intrinsic property of PSO in its fast convergence speed. Figure4 depict the graph of the computation time and fitness value with respect to the 10 cycle.

Table II: Simulated PSO result Showing Fitness Value and Computation Time

Cycle	Computation Time (Second)	Fitness or Cost Value
1	1.766	0.232
2	1.531	0.011
3	1.500	0.276
4	1.719	0.028
5	1.813	0.067
6	1.688	0.042
7	1.625	0.055
8	1.516	0.057
9	1.516	0.040
10	1.609	0.294
Average	**1.628**	**0.110**

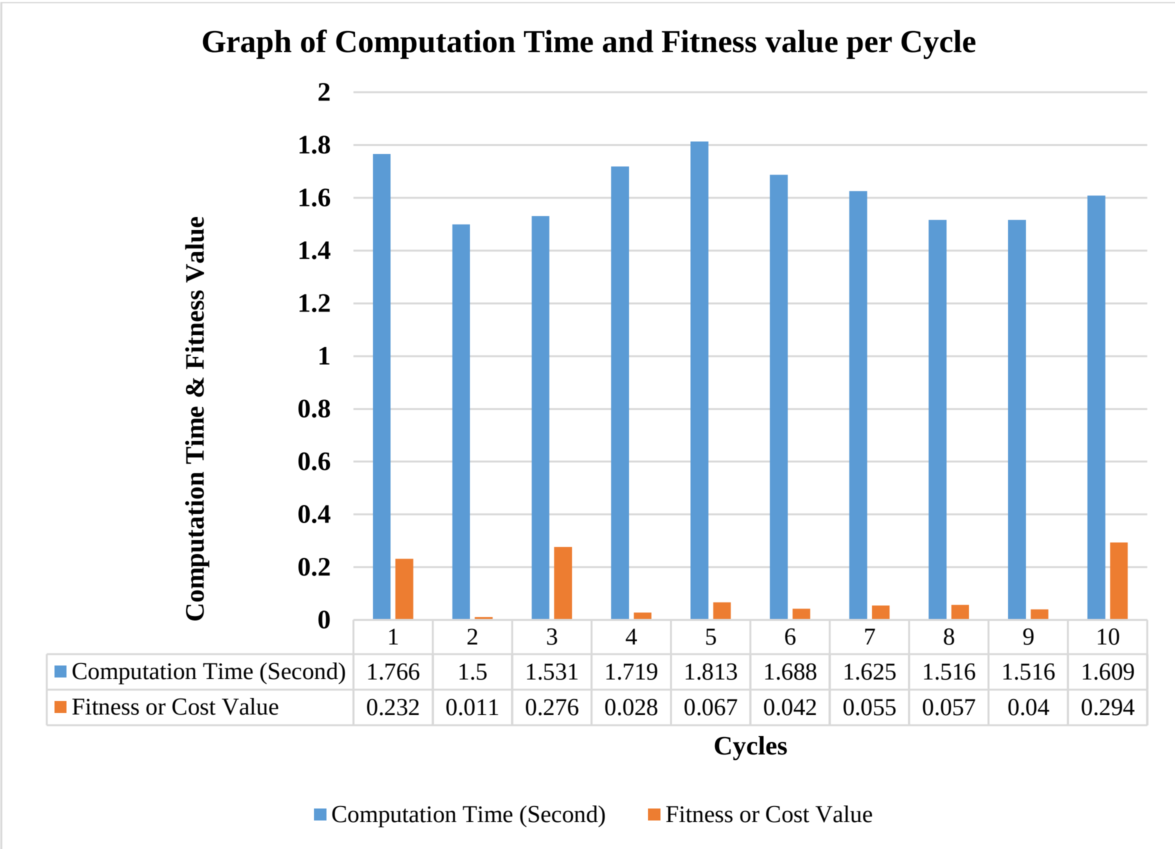

Figure 4: Graph of Computation Time and Fitness value per Cycle

V. Conclusion

This paper emphasizes on the effectiveness of controlling temperature of a poultry house with Particle Swarm Optimization (PSO)technique. The control of poultry house temperature is designed and simulated using MATLAB package programme. The experimental results obtained using the proposed method helps in the regulation of the temperature requirement of the poultry house. Therefore, Particle Swarm Optimization (PSO)technique is efficient in the control of the temperature of the poultry house for optimum production in terms of cost and computational time. It is recommended that other evolutionary search algorithm such as Ant Colony Optimization (ACO), Evolutionary Programming (EP), Genetic Programming (GP), Differential

Evolution (DE), Artificial Immune Systems (AIS), should be applied to determine their computational efficiency in the regulation of temperature requirement for poultry house.

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