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ANALYSIS AND PREDICTION OF THERMAL COMFORT USING ARTIFICIAL NEURAL NETWORK IN BAHARIA OASES

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ABSTRACT

Outdoor thermal comfort is the key for creating vibrant outdoor urban spaces. Current practice for designing outdoor thermal comfort is based on simple design guidelines, and knowledge of local wind and sun patterns. In this paper we developed a predicting Outdoor Thermal Comfort model. This prediction of thermal comfort based on air temperature, global temperature, air velocity and humidity using Artificial Neural Network in Baharia Oasis. Results show that Thermal comfort level in Baharia Oasis is better in April, and October. This research confirmed a tool that can be developed for predicting comfort across a proposed development in Baharia Oasis location; we test the proposed design changes for their success during the design phase.

Keywords: Thermal Comfort; Neural Network; Humidity; Temprature ; Velocity

INTRODUCTION

Feeling of contentment or the state of wellbeing are dragged under the definition of Comfort **[1]**. The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) describe the term "thermal comfort" as it is the condition of mind that expresses satisfaction with the thermal environment (ASHRAE, 2013a). The wider research community; architects, engineers, quantity surveyors and others in the building industry, accept this definition of thermal comfort. It is used as a basis for thermal comfort standards such the ASHRAE Standard 55 and the International Standards Organization, ISO 7730 **[2]**.

A. Factors Determining Thermal Comfort

Amount of direct sunlight

Sun supplies us with radiant energy called solar radiation. It is the sunrays intensity falling per unit time in unit area is expressed generally in Watts per square meter (W/m2). The radiation episode on a surface varies from moment to moment according to its geographic location (latitude and longitude of the place), orientation, and season, time of day and atmospheric conditions. It is the solar radiation which mostly determines whether a place is exposed to high or cold temperatures **[3]**.

Ambient Temperature

The ambient temperature is the temperature of shaded air (but well ventilated) enclosure; it is generally stated in degree Celsius (ºC). Taking into account the temperature of the site depends on several factors such as local wind as factors such as shade, body of sunny water conditions, etc. Wind low speed, and it became air from room temperature to the ground. When the wind, the higher the speeds, the feelings of the place of the surge of air at the lower temperature is endless. It affects internal temperature and comfort level too. It affects the differences in body temperature , and that, logically, also lost at the rate of convection gold from the heat acquired **[3]**.

Relative Humidity

All the ways of a man are clean in the sensitive part, verging to the dampness. The moisture vapor strives leather processing. The evaporation process is strongly influenced by the relative humidity, where the maximum temperature at which thermal balance can still be effectively maintained through evaporative cooling at different levels of relative humidity. It is strongly vary, the bending of the light of heaven is nigh unto the other end, where the temperature is at its lowest, and, increasing or decreasing it, namely air temperature shall be raised again. The drop in relative humidity around noon tends to be greatest in the summer. In areas with high humidity, the permeability of solar radiation is reduced due to the absorption and diffusion of the atmosphere. High humidity reduces water evaporation and perspiration. As a result, high humidity and high ambient temperature cause great discomfort **[3]**.

Wind Direction

A filter circulation of air temperature flows. Lower temperatures superior effects of wind chill wind speed increases. May have increased the cooling effect of the enhanced speed of the wind, this angel loves another: for he was higher than the air higher than the temperature on the speed of the wind, which, however, it is felt not comfortable with.

However, according to Szoklay (2008) **[4]** evaporation is restricted in high humidity (about 85%); thus, even air movement cannot adequately increase the cooling effect. Wind is a major consideration of the advice of the architect 's, which is broken for indoor It affects the heat in the building envelope, and the convective influencing any consolation in thoroughly execute judgment between them, as well as infiltration of the building, which makes its home in the air **[5]**.

Precipitation

But precipitation includes the forms of ICTs in the water of the rain, snow, and hail ceased, neither the dew falls. The heavy rain conditions are less likely to outside, as often happens with those of wind, and thermal comfort of micro-air less critical of other causes. However, it may be of interest to evaluate how far the canopy to the roof top, precipitation, and often infiltrate this to happen. It is the dampness that can affect also clothes and thermal treatment **[5]**.

Sky condition

The sky, a cloud shall cover, in a general way with respect to the seasons: the sun the air conditioning. It is clear, the sky, a beam of light under the conditions of the solar intensity may be increased; since it reduces the monsoon cloud cover. Then again, the top surface of the external radius losses from being known to increase when covered with clear skies cloud **[5]**.

Land structure and topography

The conditions for the transfer of energy through the building structure and the determination of the thermal reaction of people are local and site-specific. These conditions are generally summarized under the term "microclimate", which includes wind, radiation, temperature and humidity in the vicinity of a building. The presence of a building changes the microclimate by obstructing the circulation of the wind and casting shadows on the background and other buildings **[5]**.

REVIEW OF LITERATURE

[6] Measured the skin temperature of various parts of the physical body. It had been found that the correlation is robust between the temperature of finger, the gradient of the fingertip and human thermal comfort. The corresponding correlation coefficients were 0.78 and 0.8, respectively.

[7] use a Neural Networks to Predict Thermal Comfort in a tutorial Classroom The proposed method focused on the classical artificial (feed forward) neural networks (ANN) and therefore the time-series NARX feedback neural networks to realize the thermal comfort assessed using the anticipated mean vote (PMV). The sector measurements were conducted during a selected classroom of the Thai-Nichi Institute of Technology (TNI), Thailand. Two sort of ANN models were trial; a classical ANN model, and NARX model. The optimum topology of ANN.

[8] used Machine Learning Algorithms to predict Individual Thermal Comfort. The authors propose a completely unique machine learning based approach to find out an individual's thermal comfort model. This approach may be a good combination of features, and therefore the classifier learns that it takes a feature shot as input and matches the thermal sensation class (i.e. "feeling cold", "neutral" and "feeling warm"). Evaluation employing a large scale publicly available data demonstrates that when using Support Vector Machines (SVM) classifiers, the accuracy of our approach is 76.7%, over twice above that of the widely adopted Fanger's model (which only achieves accuracy of 35.4%). additionally, the study indicates that two factors, a person's age and outdoor temperature that aren't included in Fanger's model, play a crucial role in thermal comfort, which a finding is interesting.

[9] Measured with infrared thermography comfortably breaking sensor, mounted on so fast. The skin temperature was close within three selections on the surface of the occupant.

Additionally, two ways were defined to explain the recent neutral region and to estimate the occupant's thermal comfort at 95% confidence level.

Based on a data-driven method, **[10]** predict three sorts of thermal sensation: uncomfortable coolness, comfortable and uncomfortable warmth. The model was constructed with two sorts of input parameters, which are environment parameters and human thermal sensation. The results were compared with Support Vector Machines (SVM), neural networks and Linear Discriminant Analysis (LDA).

The results show that the prediction accuracy is between 73.14% and 81.2%.

[11] Studied the likelihood of characterizing human thermal comfort with average skin temperature. The skin temperature values were captured from 26 sampling points of the physical body and various mathematical combinations were explored, then the mean of 10 sampling points was selected because the most accurate metric.

[12] used SVM to construct individual's thermal comfort model. SVM and linear discriminant analysis (LDA) were combined to enhance the model efficiency and classify thermal comfort **[6]**. created a relationship between local skin temperature and human thermal comfort, with a mean square error (MSE) of but one.

Recently, 2019 the wide use of smartphones became a major source for inspiration to many researchers to develop thermal comfort models by using participatory sensing. Several recent studies **[13]** have used participatory sensing to collect individual user response on thermal perception and proposed the concomitant thermal comfort models. These models range from individualized to thermal models for groups. In **[14]**, authors proposed "Thermovote", a mobile application to reinforce occupant's thermal comfort. They used PMV and added humans as sensors to reinforce the thermal comfort. Humans' thermal sensation data are collected through smartphone app and are utilized in real-time to manage the space temperature. The authors in[15] proposed SPOT+ that provides a measure of thermal comfort by predicting the long run room occupancy and optimal temperature. Using the prediction model, SPOT+ finds an impression schedule that optimizes both energy usage and thermal comfort.

DATA AND METHODOLOGY

A. Study area: El-Baharia Oasis

El-Baharia Oasis is a natural topographic oval-shaped depression located in the heart of the Western Desert of Egypt. It is located between latitudes 27° 48′ and 28° 30′ N and between longitudes 28° 35′ and 29° 10′ E, about 370 km southwest of Cairo. It belongs to the "Giza" governorate and its capital is a small city called "Bawiti". El-Baharia is the smallest among other four oasis depressions, only 94km long and 42km wide with an approximate area of 1800 km^2. It represents one of the two main Cretaceous outcrops in the north Western Desert, where the other outcrop is at Grbel Abu Roash. This oasis is one of the most geologically important areas of the Western Desert and has attracted special attention in the four decades since the discovery of iron ore deposits in the cities of El Gedida, Ghorabi and El Harra **[16]**.

El-Baharia Oasis is a naturally excavated oval-shaped topographic depression formed from the erosion of a double plunging anticline fold assigned to the s-shaped "Syrian Arch Folding Event" during the Late Cretaceous to Early Tertiary. There are some hypotheses discussing the origin and genesis of the depression these are: 1- Wind action (Erosion). 2- Tectonic movements. 3- Tectonics and wind action. 4- Multi-controlling factors: many erosional cycles involving weathering, pedogenic, karstic, fluvial and aeolian processes **[16]**.

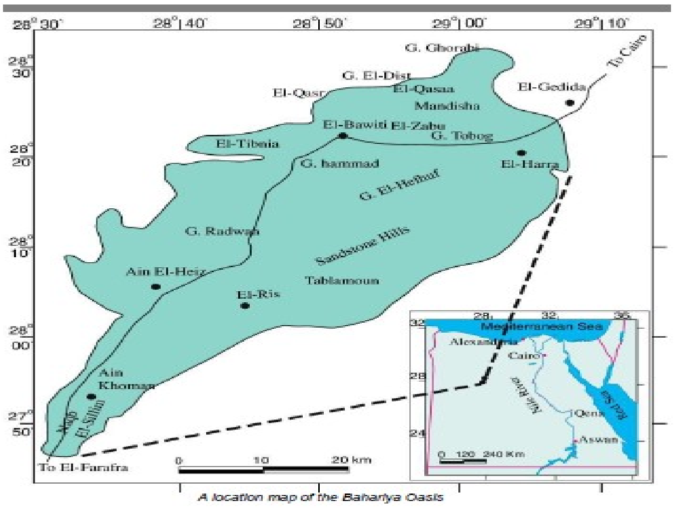

Figure 1: Baharia Oases

B. Data

In this part we will use two types of data; training data and testing data for historical study which depend upon the observation data for Baharia and Al-Kufra oases; the data Period will be from 2005 – 2019 contains the daily and monthly data for the following parameters such as: air temperatures, relative humidity and wind speed and direction in different time slots. The data source from (https://rp5.ru/).

C. Calculate Thermal Comfort

[17] present a new Equation for Estimating Outdoor Thermal Comfort; we used the collected data to calculate the thermal comfort using this equation

$$Y1 = -3.4 - 0.36v + 0.04Ta + 0.08Tg - 0.01RH + 0.96Adu$$

Where;

v: Air Velocity (m/s);

Ta: Air Temperature (C);

Tg: Globe Temperature (C);

RH: Relative Humidity (%);

Adu: Area of body skin (m2)

According to **[18]** the globe temperature can be calculated using the following equation

$$Tg = 0.01498SR + 1.184Ta - 0.0789RH - 2.739$$

Such that Ta: Air Temperature (C) ; RH: Relative Humidity (%) and SR is the solar radiation;

According to the Renewable Energy Authority of Egypt both global and direct, the average solar radiation between 7 and 8 kWh per square meter per day **[19]**.

Area of body skin(m2) is often used in clinical purposes over body weight because it is a more accurate indicator of metabolic mass (the body's need for energy), where metabolic mass can be estimated as fat free mass since body fat is not metabolically active Below are some of the most popular formulas for estimating:

Du Bois formula: [20]

$$Adu\ (Women) = 0.000975482 * W^{0.46} * H^{1.08}$$

$$Adu\ (Men) = 0.000579479 * W^{0.38} * H^{1.24}$$

Such that W: Weight and H is the Height; in the thesis we used the value of adult male from table of average BSAs as an input to the neural network.

And then we convert the value of the thermal comfort to the comfort level using the following **Table 1 [17]**.

D. Artificial Neural Network

An artificial neural network (ANN) is a paradigm of information processing that is enthused by the way biological nervous systems like the brain process information. The key element of this paradigm is the novel structure of the information processing system. It consists of a large number of strongly interconnected processing elements (neurons) that work together to solve certain problems. ANNs learn like people through examples. An ANN is configured through a learning process for a specific application, e.g. B. pattern recognition or data classification. Learning in biological systems involves adapting the synaptic connections that exist between the neurons. This also applies to ANNs **[21]**.

Table 1: Comfort Level

Value of Y	Comfort Level
-2	Cold
-1	Cool
0	Comfort
1	Slightly hot
2	Hot
3	Very Hot
4	Very-Very Hot and feel pain
5	Very not tolerable

Algorithm : Artificial Neural Network (ANN) algorithm

Start with randomly chosen weights
while MSE is unsatisfactory
and computational bounds are not exceeded,
do for each input pattern $X_p, 1 \leq p \leq P$
Compute hidden node inputs $(Net_{p,j}^{(1)})$
Compute hidden node outputs $(X_{p,j}^{(1)})$
Compute inputs to the output nodes $(Net_{p,k}^{(2)})$
Compute the network outputs $(O_{p,k})$
Modify outer layer weights

$$\Delta w_{k,j}^{(2,1)} = \eta \times (d_k - o_k) \times S'\left(net_k^{(2)}\right) \times x_j^{(1)}$$

Modify weights between input and hidden nodes

$$\Delta w_{j,i}^{(1,0)} = \eta \times \sum_k ((d_k - o_k) \times S'\left(net_k^{(2)}\right) \times w_{k,j}^{(2,1)}) S'\left(net_j^{(1)}\right) \times x_{p,i}$$

End for
End while

RESULTS

Results Analysis of Baharia Oasis

Figure 2 shows the thermal comfort level in Baharia Oasis per month, the thermal level was cold in January and December; and it was cool in February, March and November; and it was comfort in April, September and October ; and it was slightly hot and hot in other months.

Table 2 show the mean and standard deviation of the parameters used in calculation of thermal comfort (Air temperature, Humidity, Globe Temp and Velocity.

Figure 3 shows Relationship between all factors and level of thermal comfort in Baharia, we can see that:

- The level will be cold when the mean of air Temperature equal to 11.19^{0}c with standard deviation = 4.37^{0}c; Humidity = 67.24% with standard deviation = 17.31%; global temperature =5.30^{0}c with standard deviation 5.54^{0}c and finally the velocity = 1.84 m/s with standard deviation = 2.22 m/s
- The level will be Cool when the mean of air Temperature equal to 16.90^{0}c with standard deviation = 4.49^{0}c; Humidity = 53.24% with standard deviation = 16.81%; global temperature = 13.81^{0}c with standard deviation 5.55^{0}c and finally the velocity = 1.66m/s with standard deviation =1.68m/s

- The level will be comfort when the mean of air Temperature equal to 23.10 ^{0}c with standard deviation = 4.07^{0}c; Humidity = 42.12% with standard deviation = 16.15%; global temperature = 21.40^{0}c with standard deviation 5.14^{0}c and finally the velocity=1.8m/s with standard deviation =1.6m/s
- The level will be Slightly Hot when the mean of air Temperature equal to 29.16^{0}c with standard deviation 4.18^{0}c; Humidity = 29.82% with standard deviation = 12.76%; global temperature = 29.54^{0}c with standard deviation 5.47^{0}c and finally the velocity=1.89m/s with standard deviation =1.66m/s
- The level will be Hot when the mean of air Temperature equal to 35.10^{0}c with standard deviation =3.71^{0}c; Humidity = 20.66% with standard deviation = 8.29%; global temperature = 37.3 ^{0}c with standard deviation 4.80^{0}c and finally the velocity = 1.95m/s with standard deviation =1.48m/s
- The level will be very Hot when the mean of air Temperature equal to 40.40^{0}c with standard deviation 2.90^{0}c; Humidity = 13.10% with standard deviation = 5.63%; global temperature = 44.17^{0}c with standard deviation 3.68^{0}c and finally the velocity = 1.81m/s with standard deviation =1.13m/s
- The level will be very-very Hot when the mean of air Temperature equal to 44.63^{0}c with standard deviation 4.55^{0}c; Humidity = 8.21% with standard deviation = 4%; global temperature = 49.55^{0}c with standard deviation 5.65^{0}c and finally the velocity = 0.83m/s with standard deviation = 1.05m/s.

Table 3, illustrates that, there was a statistically significant positive correlation between thermal comfort level and date, air temperature, global temperature parameters and a statistically significant negative correlation between thermal comfort level and, Humidity, velocity parameters.

A. ***Prediction Model using Artificial Neural Network***

Figure 4 display the proposed model implemented to predict the thermal comfort using Neural Network; the steps of the model are:

Step 1: Data Collection (From 2005-2019): In this part we will use two types of data training data and testing data for historical study which depend upon the observation data for Bahria oases; the data Period will be from 2005 – 2019 contains the daily and monthly data for the following parameters such as: minimum and maximum temperatures, relative humidity and wind speed and direction in different time slots. (https://rp5.ru/)

The thermal comfort for Baharia oases in the future period (2020-*2050) will be calculated using the proposed prediction model.*

Step 2: Calculate thermal comfort

Step 3: Training phase

We trained the data using different neural network topology, and number of epochs until we reach to the final weights.

The model was trained a several times to get the best accuracy; the best results occurred when we trained the neural network with three layers in the first layer we picked 7 nodes; 5 nodes in the hidden layer and one node in the output layer with 50 iterations.

Step 6: Prediction phase

We use the proposed model to predict the thermal comfort level as shown in **Figure 5**.

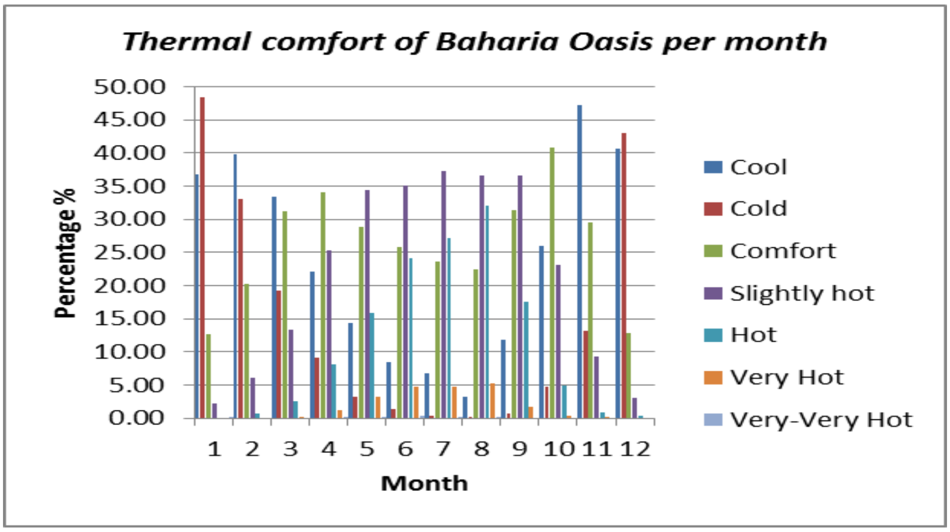

Figure 2: Thermal comforts of Baharia oases per month

Table 2: Air temperature, Humidity, Globe Temp and Velocity of Baharia per month

Month		Air Temp.	Humidity	Globe Temp.	Velocity
1	Mean	12.73	51.86	8.34	1.34
	Std. Deviation	5.60	19.34	7.78	1.58
2	Mean	15.04	44.70	11.64	1.49
	Std. Deviation	6.11	19.48	8.40	1.66
3	Mean	18.90	39.54	16.63	1.92
	Std. Deviation	6.59	21.33	9.16	2.03
4	Mean	23.08	34.35	21.97	2.02
	Std. Deviation	6.92	19.67	9.49	1.77
5	Mean	26.98	32.35	26.76	2.14
	Std. Deviation	6.70	17.82	9.11	1.82
6	Mean	29.99	33.18	30.26	2.37
	Std. Deviation	6.20	17.76	8.55	1.68
7	Mean	30.79	36.71	30.93	2.11
	Std. Deviation	5.73	18.71	8.07	1.55
8	Mean	31.13	38.64	31.15	1.82
	Std. Deviation	5.55	19.21	7.93	1.67
9	Mean	28.46	43.34	27.63	1.96
	Std. Deviation	5.62	20.65	8.10	1.56
10	Mean	24.04	48.82	21.98	1.86
	Std. Deviation	5.51	20.78	7.83	1.78
11	Mean	18.63	53.94	15.17	1.31
	Std. Deviation	5.35	20.44	7.58	1.49
12	Mean	14.36	56.81	9.88	1.38
	Std. Deviation	5.44	19.21	7.59	1.57

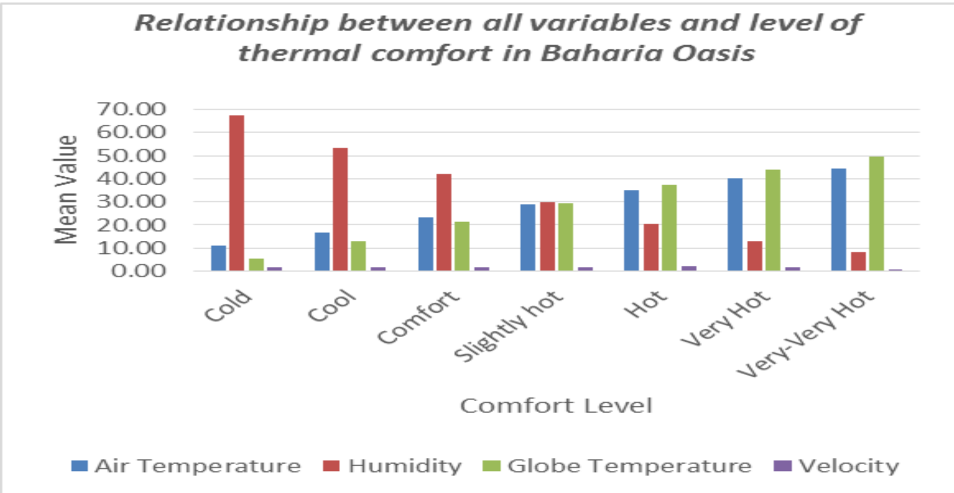

Figure 3: Relationship between all factors and level of thermal comfort in Baharia Oasis

Table 3: Correlation between Thermal comfort level and all factors

Thermal Level	Pearson Correlation	Sig. (2-tailed)
Date	.043**	0
Temperature	.558**	0
Humidity	-.200**	0
Globe Temp	.604**	0
Velocity	-.596**	0

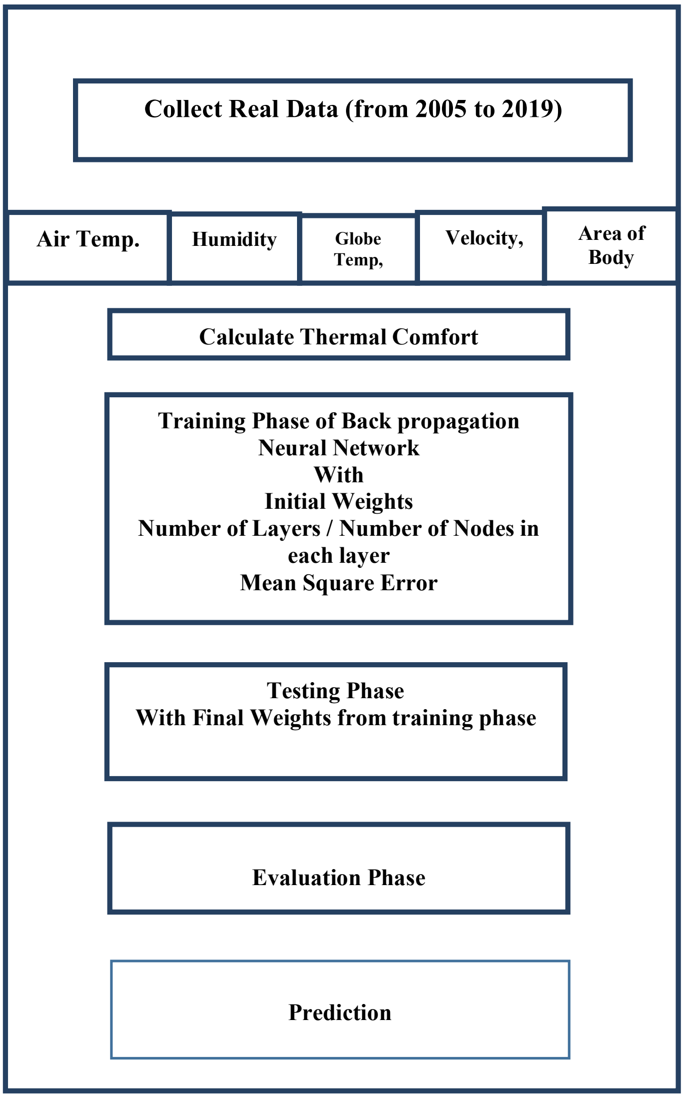

Figure 4: Proposed Model

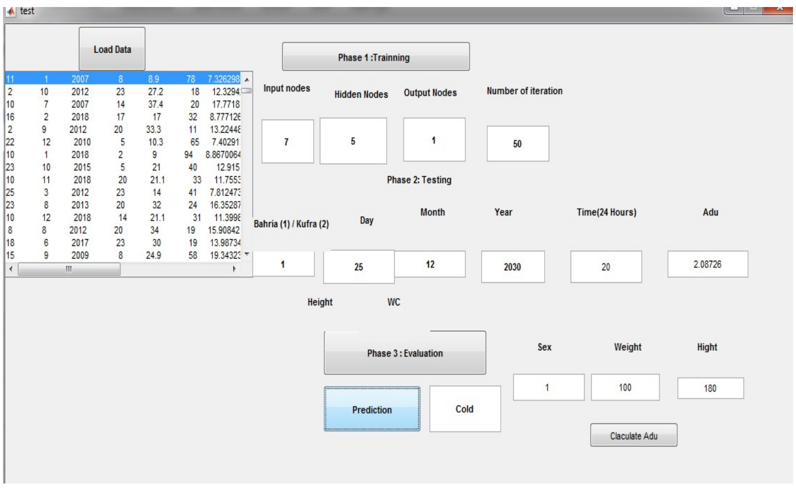

Figure 5: Proposed Application

CONCLUSIONS

The purpose of this article is to develop a process for Thermal Exterior Symmetry Comfort with a tool for use during the initial design phase of development; we use a neural multilayer network to predict thermal comfort. The proposed model can help and assist designers and experts in selecting their designs to respect the value of thermal comfort in these areas. It can also help people to save energy sources in their area besides being comfortable with.

Finally After analysing the results from data sets collected from year 2005 to 2019, we can see that the months that are comfort in Baharia oasis in average per day are March and November. As a result of the statistically significant positive correlation between comfort level and thermal temperature, Globe is a statistically significant negative correlation between temperature and thermal comfort level and air temperature, humidity.

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