International Journal of Applied Science and Research

A Novel Unified Environmental Quality Control Index based on AI Towards Smart building Optimization

Yasser M Alharbi

Electrical engineering department, Taif University, Taif, Saudi Arabia

DOI: https://doi.org/10.56293/IJASR.2022.5479

IJASR 2023
VOLUME 6
ISSUE 1 JANUARY - FEBRUARY **ISSN: 2581-7876**

Abstract: Assessment and monitoring of health and working conditions in the workplace is an important issue. Human health, safety and productivity are not only greatly affected by health and working conditions, but the equipment, machinery and materials in those environments can be affected in ways that lead to degradation. This paper presents a way to use artificial intelligence in developing a novel entity index for assessing and monitoring workplace health and conditions of use in intelligent buildings. Based on fuzzy logic, two algorithms were developed to determine the relationships and dependencies between various immediate environmental indicators and underlying environmental variables, to account for these relationships and trends, and finally to represent the indicator values for temperature, health and working conditions. A table was developed with temperature ranges and the effects on occupancy experience within those ranges. The current environmental indicators used in the previously unambiguous algorithm to generate new index values are apparent temperature (air cooling coefficient, wet bulb temperature and heat index), temperature and humidity index, discomfort index, warmth, comfort, and heat capacity. Based on Fuzzy logic, the environment variables of the algorithm are ambient temperature, relative humidity, and air velocity. After developing a complete system model using MATLAB/Simulink, further testing and evaluating the algorithm design, a model was created containing all indexed sub models, fuzzy sub model algorithms, input blocks, and data visualizations.

Keywords: Artificial intelligence, Climate control system, environmental monitoring, Smart buildings.

1. Introduction

The comfort, stress, performance and health of people in the workplace are affected not only by the ambient temperature, but also by the combined effects of the weather and variables such as ambient temperature, relative humidity, insolation and wind flow. Based on these factors, various temperature-based indicators have been developed and used to evaluate and monitor specific working environments in terms of comfort, risk and disruption [1]. These direct indicators include apparent temperature, thermal comfort, temperature and humidity indicators, actual temperature, dew point temperature, and humidity indicators. This indicator can show how the workplace temperature actually looks to the human body. It is also an indicator for protecting against risks and trends arising from the assessment, monitoring and analysis of environmental conditions in terms of human health, safety and productivity [2]. Finally, it can be used to predict and maintain optimal working conditions. Notable examples of the negative effects of an unsafe work environment include reduced productivity and heat-related illnesses such as heat stroke and other safety concerns [2].

2. Literature Review

Above all, the continuous improvement of the quality of life is directly related to the improvement of the quality of the environment. It can be achieved using intelligent monitoring, analysis, forecasting, decision-making and control systems based on intelligent tools and technologies. It can also be used in everyday life to refer to a resident of a particular area. A larger area, such as an urban area (cities), an entire state, continent or subcontinent. The complexity of these systems is high due to the interdependence of various environmental parameters [3].

Assessment of human health risks to the environment is evolving and new methods are constantly being developed. Pressures on health (good and bad) affect human health at the same time, but the impact is difficult to understand [4]. A limitation of current approaches to environmental health research is focus on different types of risks. Well-designed environmental and health research is good business. Because data collection is expensive and takes time, researchers have fewer participants and more high-quality data. Exposure or researchers may be less contagious. Data on the number of participants in this study may be more expensive with more study participants. This exchange is not possible. In addition to the main meeting, it is possible to count the number of meetings in which the study participants are interested [1-2].

Indexing, which combines multiple variables into a single variable, is a technique that can improve statistical performance to account multiple environmental pressures. This indicator can be used to identify areas with different environmental characteristics. Negative environmental exposure clusters can be identified and correlated with health outcomes [5]. These systems can be implemented using artificial intelligence (AI) technology; it can be combined with a hybrid approach. Approaches applied to AI include rule-based expert systems, machine learning techniques such as artificial neural networks (ANNs) and guided learning, data mining algorithms, and research methods such as state-based inference and genetic algorithm optimization [6] [17]. Because most environmental processes are somewhat uncertain, there are varying dependencies between environmental factors, and there are not always complete data sets (time series records or accurate time measurements). In practice) it is necessary to perform a predictive system and environmental analysis, with unverified knowledge

3. Methodology and algorithm design

Developing new environmental indicators requires the development of many fuzzy inference algorithms using knowledge databases and inference engines. The average results of both algorithms are used to assess the health and condition of the professional environment of the training space, to design the first unambiguous algorithms for intelligent systems, and to provide the data needed to develop knowledge and reasoning base. Was created for Machinery and Analysis. A range of values leading to new indicators for assessing health and the environment. First, determine the relationship and dependencies of the seven environmental indicators directly recorded on the three most important Environmental variables (environment temperature, wind speed and relative humidity), and then develop an algorithm to generate temperature values. Second, the optimal recommendations for indoor work safety (an environment in which most people are comfortable) range from 20 to 24.5 °C and a relative humidity of 20.-60%, with all applicable limits and test effectiveness has been reviewed and analyzed. Thus, a preliminary relationship is established between the proposed domains and effects and demonstrated effects for evaluating specific circumstances.

Third, MATLAB/Simulink sub-models representing the mathematical expressions of each environmental indicator will be developed, and all indicators will be tested against different combinations of basic input environmental variables: ambient temperature, relative humidity, and wind speed. The test results of each input combination should only be analyzed and studied using the actions in the first step. On this basis, the initial relationship between all indicators will be improved. In order to verify the accuracy of the results and calibrate the readings, the existing index calculators on the government website, such as [1, 2], are used. Based on all the above data analysis and the relationship established between all indicators and variables, the second one will develop a fuzzy logic algorithm to correlate the three main environmental variables (ambient temperature, relative humidity and air velocity) and generate a value in terms of temperature. Represents the evaluation of education status and environmental sanitation conditions. The working principle of the proposed system and the initial algorithm for calculating the new unique index value are shown in Figure 1.

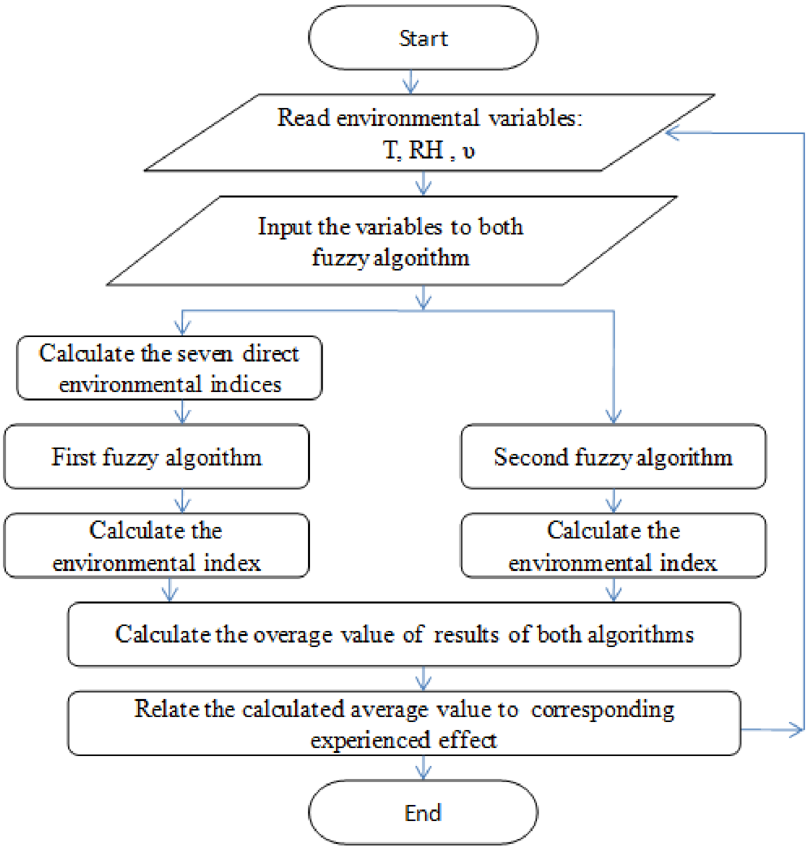


Figure 1. Flowchart diagram representing the working principle and algorithm for calculating the index value

4. The applied environmental and climatic variables, direct indices, their threshold limit values and experienced effects

In a given occupational environmental space, the basic applied environmental and climatic variables and factors that affect the human perception of the environment and their physical effects on humans are measured by direct environmental indices, including those that record the apparent temperature, thermal comfort, temperature-humidity index (THI), humidex index, effective temperature and dew point temperature. The environmental factors influencing how humans perceive their environment are mainly related to physical architectural structures, such as ventilation and lighting, building configuration, more or less natural shapes, proportion and scale including office width and ceiling height. Climatic features like a hot and dry climate also play a part. In the next sections, each of these variables, factors and indices with their limit values and experienced effects are to be discussed.

4.1. The Apparent Temperature

The thermometer measures the actual ambient temperature of the air in a space of its own, telling occupancy how overheated or over cold air is surrounding their bodies. Apparent temperature is a term used to describe the equivalent temperature perceived by a person's body. It can be determined by a set of temperature indicators used to indicate comfort, hazards, and the level of illness experienced in a given working environment related to temperature, combined with other factors and environmental weather conditions, such as humidity, temperature, radiation and wind speed. The apparent temperature is subdivided into three types, as shown in Fig. 2: heat index (HI), the wet-bulb globe temperature (WBGT) and wind chill factor. Each of these types corresponds to one of three temperature ranges: a) when the ambient air temperature point is between 10°C and 26.7°C, the apparent temperature is the ambient air temperature; b) when the ambient temperature point drops to 10°C or less, the wind chill factor is applied; and c) when the temperature rises above 26.7°C, for the apparent temperature, the HI is applied.

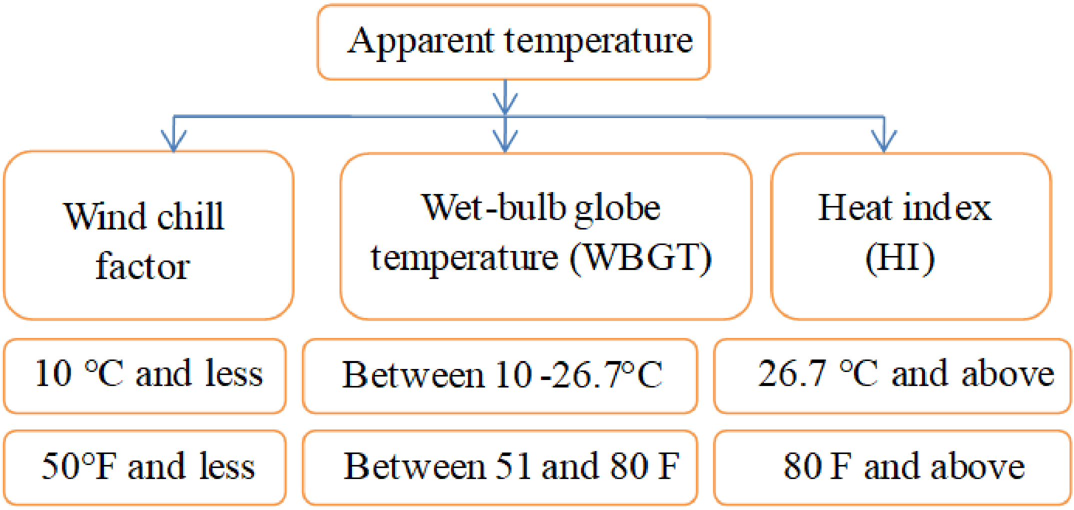


Figure 2. Types and ranges for apparent temperature.

4.1.1. The heat index (HI)

The HI is a measure used to describe and measure how hot the outside environment ambient temperature feels to the average person’s body when combined with relative humidity and exposure (stress and clothing). The HI is sometimes called the comfort heat index or humiture.

The HI is applied as an indicator for calculating the human body's comfort and risks, including heat caused illnesses such as heat stroke and dehydration, in different environments. The HI is applied only when the following three conditions exist: a) the ambient temperature point is higher than 26.7°C, b) the relative humidity rises above 40% and c) the dew point temperature is 12°C or higher. The HI is calculated as given by (1). In this equation, F is the measured temperature in degrees Fahrenheit, and H is the relative humidity. For this equation, the relative humidity needs to be converted from a percentage to a decimal by dividing it by100.

$$\begin{gathered}\mathrm{HI} = -42.379 + 2.04901523\mathrm{F} \quad + 10.14333127\mathrm{H} \\ -0.22475541\mathrm{FH} - 6.83783 \times 10^{-3}\mathrm{F}^2 - 5.481717 \times 10^{-2}\mathrm{H}^2 \\ +1.22874 \times 10^{-3}\mathrm{F}^2\mathrm{H} + 8.5282 \times 10^{-4}\mathrm{F}^2 - 1.99 \times 10^{-6}\mathrm{H}^2\end{gathered}$$

Table 1 shows the applied HI threshold limit values and applied color code zones for use in an occupational environment and their related occupant disorders. Table 6 below shows the related thermal comfort in terms of apparent temperature.

Table-1: Examples on effects of the heat index (shade values)

Temperature **Celsius (Fahrenheit)**	Zone color	Disorders of the heat index experienced by occupants
Less than 27°C (80°F)	-	No Heat Stress on occupants
27–32 °C (80–90 °F)	Yellow	**Caution**: with prolonged exposure and activity in this environment, fatigue is possible. further activity may result in heat cramps
32–41 °C (90–105 °F)	Pink	**Extreme caution**: exposure and physical activity in this environment can result in heat cramps and heat exhaustion. further activity may result in heat stroke

41–54 °C (105–130 °F)	Orange	**Danger**: sunstroke, muscle cramps and heat exhaustion are probable; Heat stroke is possible with prolonged exposure and/or physical activity.
Over 54 °C (over 130 °F)	Red	**Extreme danger**: heat stroke is highly likely imminent with continued exposure.

4.1.2. Dew point temperature

The dew point temperature is a measure used to evaluate the amount of moisture in the air and can be defined as the temperature to which the air has to be cooled in order to be 100% saturated with water vapor (100% relative humidity). Since no more vapor can be held in the air after this temperature is reached, dew will form by condensing the water vapor into liquid form (dew). If the air is further cooled, the water vapor in the air would form fog or precipitation.

The experienced comfort levels, in terms of how comfortable will feel, are shown in Table 2. A quick explanation is that the higher the dew point temperature, the greater the amount of water vapor/moisture in the air, and hence the muggier the environment will feel. The optimal recommendations for indoor occupational safety and health are between 20-24.5°C with a relative humidity of 20-60%.

The expression given by (2) is used for a simpler calculation of the dew point temperature. It gives an approximate value in degrees Celsius when relative humidity (RH) values are above 50% [7].

$$D = \frac{237.3 * N}{1 - N} \qquad (2)$$

$$N = \frac{\left[ln\left(\frac{RH}{100}\right)+\left(\frac{17.27*T}{237.3+T}\right)\right]}{17.27} \qquad (3)$$

Where T is temperature.

Table 2: The general comfort levels in terms of the dew point temperature

The DP temp. (°C)	**How comfortable it will feel-like (Experienced Comfort)**
DP <= 12.8	Dry and comfortable
12.8 - 18.3	Become sticky with muggy evenings
DP >=18.3	Lots of moisture in the air, becoming oppressive

4.1.3. The wind chill factor

The wind chill factor is the opposite of HI. HI measures how hot the ambient temperature of the external environment feels to the body of ordinary people, while the wind chill index measures how cold the external environment feels to the body of ordinary people. It takes into account the transient flow of low-temperature wind at a given wind speed and the resulting comfort or risk experienced. In other words, the air-cooling coefficient tells us how cold the wind is, and the ambient air temperature felt by the human body decreases due to the wind speed. The wind chill coefficient is also called the chill index or wind chill (also called wind chill). The wind chill factor is only applicable when both of the following conditions exist: a) the ambient air temperature is equal to or less than 40°F (4°C) and b) the ambient air velocity is 5 miles per hour (mph) or higher[8, 9].

The wind chill factor index is calculated as given by (4) and (5). Where in (2) air temperature is measured in °F, air flow speed is measured in meters per hour. Equation 3 measures air temperature in °C, while air flow speed is measured in kilometers per hour at 10 m above ground level.

$$Wild\ chill\ factor = 35.74 + 0.6215T - 35.75V^{0.16} + 0.4275TV^{1.6} \tag{4}$$

$$Wild\ chill = 13.74 + 0.6215T - 11.37V^{0.16} + 0.3965TV^{1.6} \tag{5}$$

The applied threshold limit values of the wind chill factor and experienced effects are shown in Table 3.

Table - 3. The applied Wind chill factor applied threshold limit and experienced effects.

Temperature *(Fahrenheit)*	**Wind chill factor effects experienced by workers**
Above +30	Chilly. Generally unpleasant
(+15) – (+30)	Cold. Unpleasant.
(0) - (+15)	Bitter cold. Very unpleasant/Frostbite possible
(0) – (-20)	Extremely cold. Frostbite likely. Outdoor activity becomes dangerous.
(-20) – (-60)	Frigidly cold, Exposed flesh will freeze within 30 seconds.

4.1.4. The wet-bulb globe temperature (WBGT)

The WBGT is also called the heat stress index. It is a single value that measures the combined effects of the thermal environmental occupational conditions on a human's body perception of temperature during working activities. Included factors are the ambient temperature, relative humidity, infrared radiation (usually sunlight), visibility and air flow (wind speed). Consequently, the WBGT is a measure of how hot the ambient temperature feels to a human body when the temperature is combined with ambient air humidity, direct or radiant sunlight and air flow. The wet-bulb globe temperature is applied mainly as an index for evaluating ambient occupational (e.g., industrial) environment states, conditions and situations.[8]

The WBGT index is calculated using three measurements: the globe temperature, dry bulb temperature and ambient air humidity, which is calculated by measuring the wet bulb temperature. This index can be calculated outdoors and indoors assuming the wind speed is around 3 mph and the working environment is not in full sunshine (shaded). For outdoor applications, the index is calculated for a given environment using the expression given by (6):

$$WBGT = 0.7T_W + 0.2T_G + 0.1T_D \tag{6}$$

For indoor applications, the index is calculated by the expression given by (7):

$$WBGT = 0.7T_W + 0.3T_G \tag{7}$$

When solar radiation is negligible, TG = TD, for indoor applications, the index is calculated by (8):

$$WBGT = 0.7T_W + 0.3T_D \tag{8}$$

TG: The globe temperature, which indicates radiant heat
TD: Dry bulb temperature, the actual ambient air temperature
TW: The wet bulb temperature, which indicates the humidity

The wet-bulb temperature, TW, can be calculated by (9), where T is the air temperature and H% is the dry-bulb temperature relative humidity:

$$\begin{aligned} T_w = T\,arctan[\,0.151977\sqrt{H\% + 8.313659}] + arctan(\,T + H\%) \\ - arctan(\,H\% - 1.676331) + 0.00391838\,H\%^{\frac{3}{2}} \\ arctan(\,0.023101\,H\%) - 4.686035 \end{aligned} \tag{9}$$

Table 4 lists the applied WBGT threshold limit values and color codes for use in the workplace and the recommended intensity of physical exertion.

Table-4: The applied WBGT threshold limit values and Intensity of physical exertion

WBGT (°F)	WBGT (°C)	Color	Intensity of Physical Exercise
≤ 78–81.9	≤ 25.6–27.7	White	Good conditions but Extremely intense physical exertion may precipitate heat exhaustion; therefore, caution should be taken to early recognize symptoms and take actions.
82–84.9	27.8–29.4	Green	Marginal conditions: This is a marginal heat stress limit for all personnel. Possible fatigue with prolong exposure. Body will be stressed after 45 minutes.
85–87.9	29.4–31.0	Yellow	Caution conditions: Heat related illnesses are possible with prolong exposure (heat cramps- painful contraction of muscle, weakness). Body will be stressed after 30 minutes
88–89.9	31.1–32.1	Red	Danger/High risk range: High risk of heat strike, heat exhaustion likely; Dizziness, nausea, vomiting, headache, fainting, and weakness. Body will be stressed after 20 minutes. Strenuous exercise are curtailed for all personnel
90 and Above	≥ 32.2	Black	Extreme danger/severe risk range: heat stroke highly likely; extremely high body temperature, confusion, convulsions, unconsciousness, death. body will be stressed after 15 minutes. Physical works are suspended for all personnel

WBGT (°F)	WBGT (°C)	Color	Intensity of Physical Exercise
≤ 78–81.9	≤ 25.6–27.7	White	Good conditions but Extremely intense physical exertion may precipitate heat exhaustion; therefore, caution should be taken to early recognize symptoms and take actions.
82–84.9	27.8–29.4	Green	Marginal conditions: This is a marginal heat stress limit for all personnel. Possible fatigue with prolong exposure. Body will be stressed after 45 minutes.
85–87.9	29.4–31.0	Yellow	Caution conditions: Heat related illnesses are possible with prolong exposure (heat cramps- painful contraction of muscle, weakness). Body will be stressed after 30 minutes
88–89.9	31.1–32.1	Red	Danger/High risk range: High risk of heat strike, heat exhaustion likely; Dizziness, nausea, vomiting, headache, fainting, and weakness. Body will be stressed after 20 minutes. Strenuous exercise are curtailed for all personnel
90 and Above	≥ 32.2	Black	Extreme danger/severe risk range: heat stroke highly likely; extremely high body temperature, confusion, convulsions, unconsciousness, death. body will be stressed after 15 minutes. Physical works are suspended for all personnel

4.2. Thermal Comfort

The rate and amount of heat transfer between the human body and the environment one lives or works in depends on the temperature difference between the body and the environment. In cold ambient environments, more heat is transferred from the human body to the environment. On the other hand, in hot ambient environments, the human body transfers less heat to the environment. Thermal discomfort is represented by these two hot and cold cases [10]. Most people will feel comfortable at room temperatures between 20 to 22 °C (68 to 72 °F), but this can differ greatly between individuals [11-13]. [11] definition of the thermal comfort zone is the range of conditions where 80% of sedentary or slightly active persons find the environment thermally acceptable [11].

Table- 5. Relating the thermal comfort to the Heat Index

HI in degrees Celsius °C	Thermal comfort experienced by occupants
HI < 30°C	No discomfort
30 – 40°C	Some discomfort
40 – 45°C	Great discomfort
> 45°C	Dangerous
HI > 54°C	Heat stroke imminent

Table-6. Relating thermal comfort in terms of apparent temperature

Apparent temperature in degrees Celsius °C	the thermal comfort experienced by occupants
Wind chill ≤ -35	Sever danger
-35 ≤ Wind chill ≤ -20	Extreme cold
-20 ≤ Wind chill ≤ 0	Uncomfortably cold
0 ≤ T < 15	Cool
15 ≤ T < 18	Slightly cool
18 ≤ T < 23	Comfortable
23 ≤ T < 29	Slightly Warm
29 ≤ T ≤ 32	Warm
T> 32 and Heat Index ≤ 38	Uncomfortably hot
Heat Index > 38	Sever danger

Both the temperature and relative humidity, as well as the corresponding apparent temperature (heat index or wind chill index), play a vital role in determining the experience of thermal comfort. Therefore, thermal comfort can be determined differently by applying different indices.

Determining thermal comfort in terms of the HI is as described in Table 5; relating thermal comfort in terms of apparent temperature is shown in Table 6.

4.3. The temperature-humidity index, (THI)

The THI is a useful and easy measure for evaluating the degree of discomfort in terms of the risk level corresponding to the thermal stress experienced by occupants in a warm weather environment. The index can be defined as the combined impact of both heat and the resulting stress under the combined effect of the ambient temperature and relative humidity. It was originally called the discomfort index. This index was proposed by Thom [14-16] [17], as expressed by (10). Other expressions for calculating the discomfort index are given by (11), (12) and (13). The higher the resulting value of the discomfort index after applying these equations, the higher the value of discomfort.

The discomfort index values given by (13) are similar to those of the WBGT index for indoor application, i.e., when solar radiation is negligible and TG = TD. The discomfort index is applied to characterize the heat stress in an environment and correlate the thermal sensation; the applied criteria are explained in Table 7. As shown in the table, most humans feel comfortable when the discomfort index is below 21°C and feel very uncomfortable when it is greater than 29°C. Another application of the THI is for evaluating the degree of discomfort in terms of the degree of risk corresponding to a given heat stress. Such applications were classified according to the THI values and are reported in [17, 18], as listed in Table 8.

$$THI = T_d - 0.55\left(1 - \left[\frac{RH}{100}\right]\right)(T_d - 14.44) \qquad (10)$$

$$THI = T_d - \left[0.55 - \left(0.55 * \left[\frac{RH}{100}\right]\right)\right](T_d - 58) \qquad (11)$$

$$DI = 0.4(T_D + T_W) + 15 \qquad (12)$$

$$DI = 0.5T_D + 0.5T_W \qquad (13)$$

Table-7. Characterizing the environmental heat stress and correlate thermal sensation [AXSWE40] [AXCSDE41]].[12]

DI value (°C)	***Discomfort*** **levels experienced by occupants**
Less 21	No discomfort, no heat stress is encountered
21–24	Mild discomfort: most people feel a mild sensation of heat
24–27	Moderately discomfort: people feel very hot, and physical work may be performed with some difficulties.
27–29	Most people suffer from discomfort
29–32	***Severe*** discomfort, everyone feels severe stress, people engaged in physical work are at increased risk for heat illness e.g. heat exhaustion and heat stroke.
Above 32	It is a state of medical emergency

Table-8. Evaluate the degree of discomfort in terms of the risk degree corresponding to given heat stress

THI value (°C)	**The risk degree of thermal stress experienced by occupants**
Less 27	Safe, no risks
27-32	Heat fatigue is possible with prolonged exposure and activity
32-41	Sunstroke and heat exhaustion are possible with prolonged exposure and activity
41-54	Sunstroke and heat cramps are possible
Greater 54	Sunstroke, heat stroke and heat confusion, or delirium is possible

4.4. Effective Temperature (Et)

The effective temperature (ET) index was introduced in 1923 by Houghton and Yaglou. The index was originally devised to provide a method of determining the relative effects of air temperature and humidity on comfort13.

$$ET = 37 - \frac{37 - T}{(0.68 - 0.0014RH) + \left(\frac{1}{1.76 + 1.4V^{0.75}}\right)} - (0.29T(1 - 0.01RH) \qquad (14)$$

The effective temperature index can be calculated by (14), where v is wind speed (in m s−1) at 1.2 m above the ground. The applied threshold limit values and experienced effects are shown in Table 9.

Table- 9. The applied threshold limits values and experienced effects

Effective temperature in degrees Celsius °C	**the experienced effect**
ET <1	Very cold
$1 \leq$ ET < 9	Cold
$9 \leq$ ET < 17	Cool
$17 \leq$ ET < 21	Fresh

21 ≤ ET < 23	Comfortable
23 ≤ ET < 27	Warm
ET > 27	Hot

4.5. Humidex Index

The humidex index was devised by Canadian meteorologists to measure how the average person feels in hot and humid weather, reflecting the perceived temperature combined with the ambient air temperature and air vapor pressure. The humidex index can be calculated by (15), where T, temperature, is in °C, Td is the dew point temperature measured in °C, and Vp is the air vapor pressure measured in hPa, as calculated by (16). The applied threshold limit values and experienced effects are shown in Table 10.

$$Humidex = T + 0.5555\left(V_p - 10\right) \qquad (15)$$

$$V_p = 6.11 * e^{\left(5417.753*\left(\frac{1}{273.16}\right)\left(\frac{1}{237.16+DP}\right)\right)} \qquad (16)$$

Table- 10. The applied threshold limits values and experienced effects

Humidex (°C)	Degree of comfort
20–29	No discomfort
30–39	Some discomfort
40–45	Great discomfort; avoid exertion
46 and over	Dangerous; possible heat stroke

5. System Simulation For Building The Knowledge Base And Inference Engine

In developing a new, single environmental index, two different artificial fuzzy logic algorithms were developed to acquire the data needed to develop the knowledge base and inference engine for the intelligent systems. To construct this new index, four steps were applied; these steps are described in the methodology section of this work. MATLAB/Simulink models representing the mathematical expressions for each of the applied seven direct environmental indexes were developed. For testing all the environmental indices of a given environmental variable input, a model was developed by integrating all the indices' sub-models and input of the environmental variable blocks.

Examples of the results obtained by testing the models, in terms of each index value, suggested ranges and effects, are listed in Table 11. The results of the observations, conclusions derived and all results data and knowledge were used to develop the initial knowledge base and inference engine for the fuzzy algorithm to develop the new, single index for assessing.

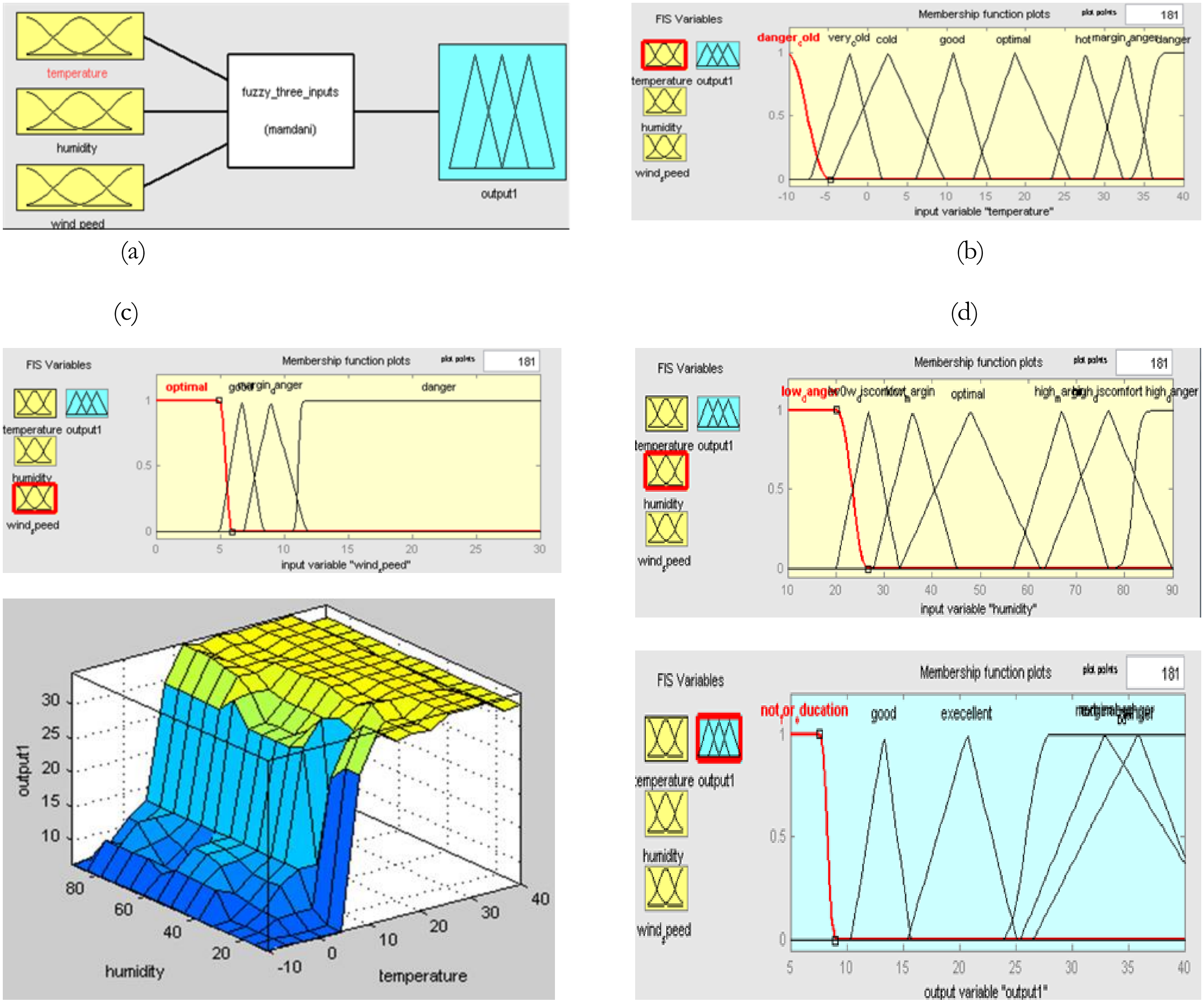
5.1. Fuzzy Algorithm Design: Building The Knowledge Base And Inference Engine

Two different artificial fuzzy algorithms are to be developed with different knowledge bases and inference mechanisms. Each algorithm is to be used to calculate a number for given environmental variables that represent the occupational environment health state and conditions. The average results of both algorithms are to be used to assess the occupational environment health state and conditions. The first fuzzy algorithm is developed to relate the input of seven direct environmental indices along with the three environmental variables and to then output one value in terms of temperature that represents the assessment of the environmental health state and conditions. Each of the direct environmental indices with ranges in terms of the threshold limit values and interpretations of these ranges for the experienced effects discussed and used to build the corresponding index's membership function and choose the linguistic variables and universe of discourse ranges.

The inputs to the first developed Simulink model with the first fuzzy algorithm are the three main environmental variables: the ambient temperature, relative humidity and air speed, which are used to calculate the numerical values of all the seven direct indices. The calculated values are then used as the seven inputs to the fuzzy algorithm.

The second fuzzy algorithm was developed to relate the three main environmental variables in terms of ambient temperature, relative humidity and air flow speed and to then output one value in terms of temperature that represents the assessment of the educational environmental health state and conditions. The developed fuzzy algorithm in MATLAB/Simulink models is shown in Fig. 3(a-f).

The designed fuzzy algorithm's membership function, the linguistic variables, and universe of discourse ranges of the three inputs and the one output are shown in Fig. 3(b-f). Fig. 4(a) shows the results when the three inputs are ramps with three increasing different slope values (temperature: slope 2, initial value 13; humidity: slope 5, initial value 35; and wind speed: slope 1.01, initial value 2). Fig. 4(b) shows the results when the three inputs are ramps with three increasing different T values (temperature: slope 3, initial value 20; humidity: slope 4, initial value 4; and wind speed:



(a) (b)

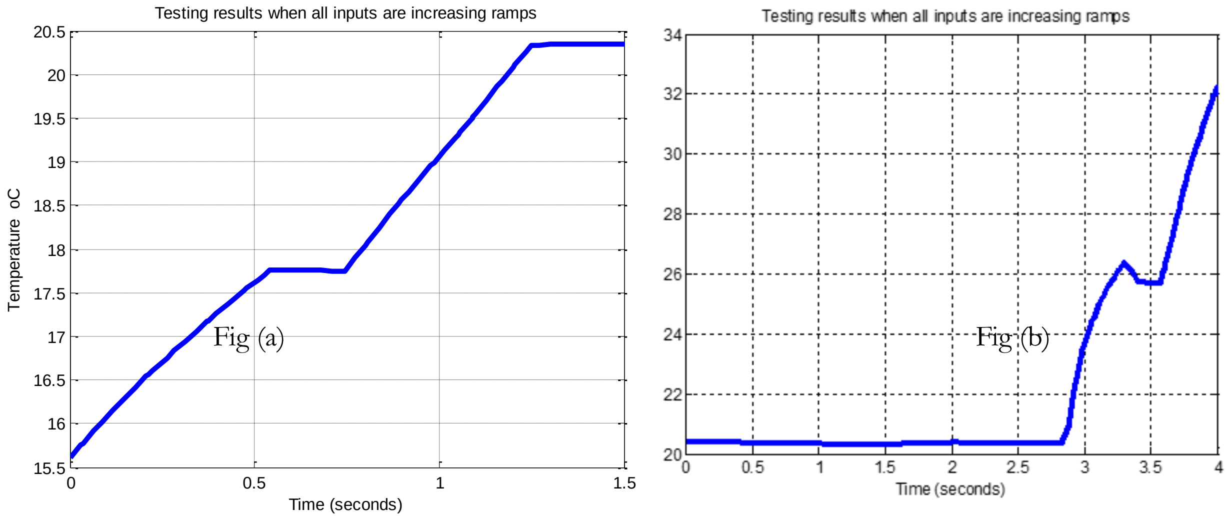
(c) (d)

(e) (f)

Figure 3.The second fuzzy algorithm's membership function, the linguistic variables, and universe of discourse ranges of the three inputs and the one output: (a) the second fuzzy algorithm, (b) ambient

temperature input, (c) humidity input, (d) air speed input, (e) membership function output and (f) fuzzy rule basis in form.

Figure 4. (a-b). Test results when the three inputs (temperature, humidity and air speed) are ramps with three increasing different slope values.



6. Overall System Design, Simulation Testing and Evaluation

The developed overall MATLAB/Simulink model shown in Fig. 5 was built by integrating all the following sub-models: all indices' sub-models, the two fuzzy algorithm sub-models and the blocks for data inputting and displaying. The model was tested for different combinations of the input environmental variables in terms of ambient temperature, relative humidity and wind speed. Examples of the results obtained by testing the overall system model in terms of the first and second algorithms' environmental assessment values, the one index value, and the interpretations in terms of suggested experienced effects are listed in Table 11.

Table 11. Examples on the results obtained by testing the models, in terms of the one index value

Test №	T (°C)	RH (%)	Air speed (v)m/s	Fuzzy(1) index value	Fuzzy(2) index value	Interpretation
(1)	18	40%	3	21.2	20.4	Excellent conditions
(2)	25	50%	5	22.1	21	Good conditions
(3)	30	50%	5	28.3	27.3	Marginal conditions, Most of students feel moderately discomfort
(4)	35	70%	5	34.1	33.4	Extreme danger, Risks of heat stress after 15 minutes

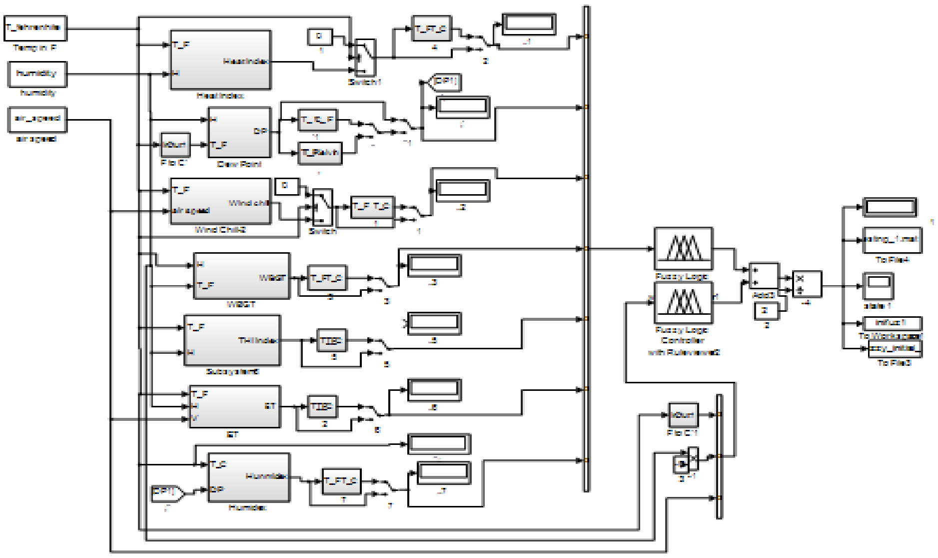


Figure 5. Overall system MATLAB/Simulink model.

Conclusion

In this work, an artificial fuzzy logic algorithm was designed to help in developing a new, single index value in terms of temperature for assessing and monitoring educational environment health state and conditions. The mutual relationship and interdependence between different direct environmental indices including the basic variables were determined and used in developing the knowledge base and inference engine.

Based on the results of testing the developed system with the designed artificial fuzzy algorithms, as well as data study, analysis, correlations and interpretations, a table was developed with temperature ranges and the resulting experienced effects by students within these ranges. The table gives and interprets an assessment of the occupational environment health state and conditions with the effects experienced by humans within these temperature ranges.

References

1. C. A. Pope III, M. Ezzati, and D. W. Dockery, "Fine-particulate air pollution and life expectancy in the United States," New England Journal of Medicine, vol. 360, no. 4, pp. 376-386, 2009.
2. S. Wing, R. A. Horton, N. Muhammad, G. R. Grant, M. Tajik, and K. Thu, "Integrating epidemiology, education, and organizing for environmental justice: community health effects of industrial hog operations," American journal of public health, vol. 98, no. 8, pp. 1390-1397, 2008.
3. D. Dunea and M. Oprea, "Fuzzy-APA: Employing Fuzzy and Neural Networks Techniques in Data Analysis of Industrial Wastewaters Monitoring," WSEAS Transactions on Environment and Development, vol. 6, no. 8, pp. 581-590, 2010.
4. A. M. Fan, G. Alexeeff, and S. B. Harris, "Cumulative risks and cumulative impacts of environmental chemical exposures," vol. 29, ed: SAGE Publications Sage CA: Los Angeles, CA, 2010, pp. 57-57.
5. U. Platt, "Air pollution monitoring systems—past–present–future," in Advanced Environmental Monitoring: Springer, 2008, pp. 3-20.
6. K. Karatzas, "Artificial intelligence applications in the atmospheric environment: status and future trends," Environ. Eng. Manag. J, vol. 9, pp. 171-180, 2010.
7. M. Lawrence, "The Relationship between Relative Humidity and the Dewpoint Temperature in Moist Air: A Simple Conversion and Applications," Bulletin of the American Meteorological Society, v.86, 225-233 (2005), vol. 86, 02/01 2005.

8. K. Blazejczyk, Y. Epstein, G. Jendritzky, H. Staiger, and B. Tinz, "Comparison of UTCI to selected thermal indices," International journal of biometeorology, vol. 56, no. 3, pp. 515-535, 2012.
9. R. Osczevski and M. Bluestein, "The new wind chill equivalent temperature chart," Bulletin of the American Meteorological Society, vol. 86, no. 10, pp. 1453-1458, 2005.
10. Y. A. Çengel and M. A. Boles, Thermodynamics : an engineering approach. New York, NY: McGraw-Hill Education. , 2015.
11. Thermal Environmental Conditions for Human Occupancy, 2017.
12. K. Ukhurebor, I. Abiodun, and F. Bakare, "Relationship between relative humidity and the dew point temperature in Benin City, Nigeria," Journal of Applied Sciences and Environmental Management, vol. 21, no. 5, pp. 953-956, 2017.
13. Z. Wang et al., "Individual difference in thermal comfort: A literature review," Building and Environment, vol. 138, pp. 181-193, 2018.
14. E. Iso, "7730: 2005," Ergonomics of the Thermal Environment. Analytical Determination and Interpretation of Thermal Comfort Using Calculation of the PMV and PPD Indices and Local Thermal Comfort Criteria. CEN (European Committee for Standardization). Geneva, 2005.
15. K. Parsons, Human thermal comfort. CRC Press, 2019.
16. E. C. Thom, "The discomfort index," Weatherwise, vol. 12, no. 2, pp. 57-61, 1959.
17. A. Abdel-Ghany, I. Al-Helal, and M. R. Shady, "Human Thermal Comfort and Heat Stress in an Outdoor Urban Arid Environment: A Case Study," Advances in Meteorology, vol. 2013, 02/21 2013.
18. C. Hunter, W. Savannah, R. Company, Aiken, C. South, and Minyard, "Estimating Wet Bulb Globe Temperature Using Standard Meteorological Measurements," 01/01 2000.
19. T. Yousif and H. Tahir, "Application of Thom's Thermal Discomfort Index in Khartoum State, Sudan," J Forest ProdIndust, vol. 2, 09/01 2013.