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Development of a new computer model for predicting thermal comfort in different climates using the Visual Basic programming language

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Abstract

A computer programme is developed using the visual basic programming language to predict the indoor and outdoor thermal comfort conditions using seven thermal comfort indices. The default data of the programme include the climatic conditions of twelve cities representing the equatorial, arid, and warm temperate climates. Additionally, the user is able to investigate other climatic conditions via entering the required input data.

The integrated indices are the adaptive model for thermal comfort, wet bulb globe temperature, and tropical summer index as the indoor indices, whereas the outdoor indices include the wet bulb globe temperature, discomfort index, heat index, and wind chill index.

The programme is thought to be a useful tool that enables researchers and designers to gain further understanding and appreciate the thermal demands of the site before starting the design process. Moreover, it enables them to evaluate the current thermal conditions, which is especially useful for retrofitting processes.

Keywords: Thermal comfort, passive design, arid climate, equatorial climate, warm temperate climate

1 Introduction

Within the architectural context, the thermal comfort indices are mainly used to assess the effect of the built environment on the thermal comfort of the occupants (Sharma & Ali, 1986) and to evaluate the thermal performance of the buildings (Djongyang, et al., 2010). This assessment is used to determine the sustainable opportunities provided by the built environment through comparing the actual and the desirable thermal conditions. Consequently, the decisions of selecting the most optimum design alternatives are facilitated (Humphreys, et al., 2013). Furthermore, the outdoor thermal indices are used in the process of designing the urban environment as the success of outdoor spaces depends mainly on the thermal sensation of the individuals presented in such spaces (Mahmoud, 2011).

In addition, the outdoor environment has an obvious influence on the thermal conditions of the indoor environments (Shashua-Bar, et al., 2012).

2 Development of THERCOM programme

The *Thermal Comfort in different Climates* programme (*THERCOM*) was developed based on the visual basic programming language to predict the thermal comfort in the free running buildings as well as in the outdoor environment. Visual Basic programming is one the core skills taught in the MSc course Renewable Energy and Architecture, at Nottingham University[1]. The conceptual idea of the programme is presented in figure (1).

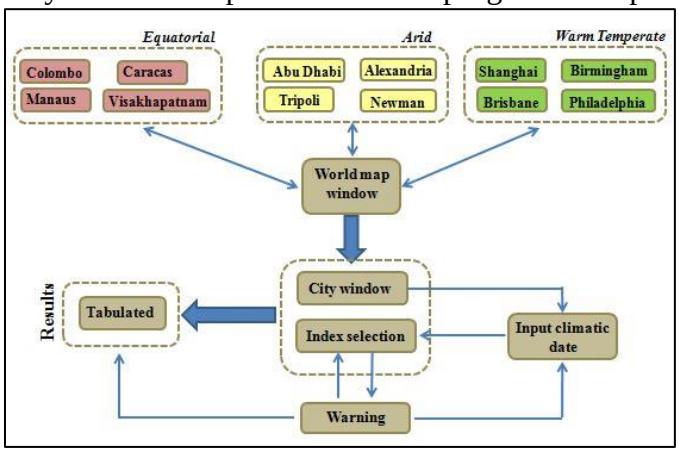

Figure 1. The conceptual idea of Thercom programme

As can be noted from the figure, THERCOM programme consists mainly from three steps which are selecting a city from four cities within each climate type, performing the calculations after feeding in the required input data and choosing the thermal index, and then viewing the tabulated results. The integrated cities, as can be demonstrated from figure (1), are:

- Equatorial climate: Colombo, Caracas, Manaus, and Visakhapatnam
- Arid climate: Abu Dhabi, Alexandria, Tripoli, and Newman
- Warm temperate: Shanghai, Birmingham, Brisbane, and Philadelphia

The welcome screen of the programme is depicted in figure (2).

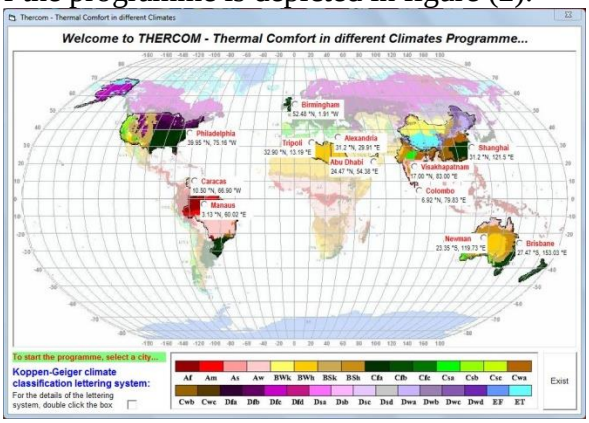

Figure 2. The welcome screen of THERCOM programme

The thermal predictions of the programme are based on hourly basis except those of the adaptive model for thermal comfort. The user is allowed to select the default input data

1 For information about the MSc course, refer to: http://www.nottingham.ac.uk/~lazmbg/MScREA/

which represents 24 hours in each of the year months for each city. Additionally, it should be mentioned that the user is allowable to investigate other cities by clearing all the input fields and entering the values of the required climatic variables manually for the city under consideration.

2.1 The integrated thermal comfort indices

Seven thermal indices are integrated within the THERCOM programme; four of them are used for the outdoor environments whereas the rest are applicable for the free running

Table 1. The monthly distribution of the selected indices

	Index	Cities	Period
Indoor indices	Adaptive model for thermal comfort	Philadelphia, Birmingham	March - Dec.
		Abu Dhabi	Oct. - April
		Newman	Feb. - Dec.
		Other cities	Jan. - Dec.
	Tropical summer index	Colombo, Caracas, Manaus, Visakhapatnam	Jan. - Dec.
	Wet bulb globe temperature	Colombo, Caracas, Manaus, Visakhapatnam	Jan. - Dec.
		Alexandria, Tripoli	May - Oct.
		Abu Dhabi	March - Nov.
		Newman	sep. - May
		Philadelphia, Shanghai	June - Sep.
		Brisbane	Nov. - March
Outdoor indices	Wind chill index	Philadelphia	Jan., March
		Shanghai	Feb.
		Birmingham	Feb., April, Dec.
	Discomfort index	Colombo, Caracas, Manaus, Visakhapatnam	Jan. - Dec.
	Heat index	Colombo, Caracas	Jan. - Dec.
		Manaus, Newman	Feb. - Dec.
		Visakhapatnam	Feb. - Nov.
		Alexandria	May - Oct.
		Tripoli	Aug. , Sep
		Abu Dhabi	April - Nov.
		Philadelphia	June, July
		Shanghai	June - Sep.
		Brisbane	Jan., Feb., Nov.
	Wet bulb globe temperature	Colombo, Caracas, Manaus, Visakhapatnam	Jan. - Dec.
		Alexandria, Tripoli	My - Oct.
		Abu Dhabi	March - Nov.
		Newman	Sep. - May
		Philadelphia, Shanghai	June - Sep.
		Brisbane	Nov. - March

buildings. The selection of the indices was based on their validity, simplicity, and applicability. The indices are displayed in table (1) in addition to their suitability in the considered cities.

For all the integrated indices, the required hourly variables are: the air temperature, wet bulb temperature, indoor temperature, relative humidity, solar radiation, and air velocity at both 10 meters height and the occupation level which was assumed as 1.5 meter. Due to the approximations in the calculations of the wet bulb globe temperature and the tropical summer index, the globe temperature was replaced by the indoor temperature. Therefore, a 3m x 3m x 3m mock-up model of concrete was generated. Furthermore, and for the adaptive model for thermal comfort, the mean monthly outdoor temperature is required.

3 Validation of Thercom programme

The predictions of the THERCOM programme for the wind chill, heat, and discomfort indices were compared with the online calculators used by the US National Weather Service Weather Forecast Office [1] and the keisan online calculator [2] respectively.

Figures (3), (4), and (5) show the agreement between the predictions of the THERCOM programme and the online calculators.

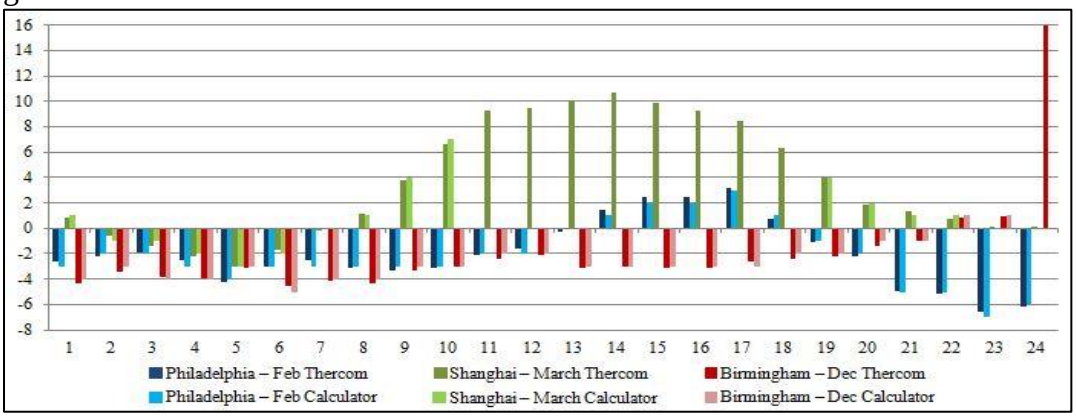

Figure 3. The predictions of THERCOM and the online calculator for the wind chill index

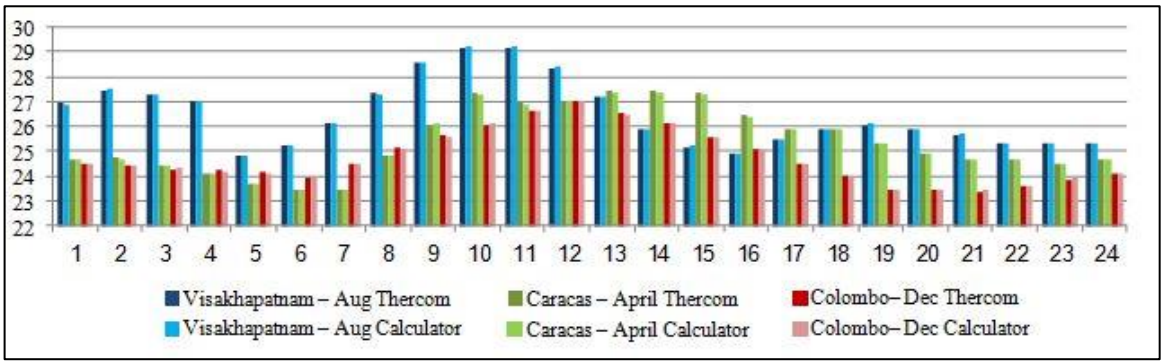

Figure 4. The predictions of THERCOM and the online calculator for the discomfort index

1 Available at: http://www.crh.noaa.gov/ddc/?n=windchill and http://www.hpc.ncep.noaa.gov/html/heatindex.shtml.
2 Available at: http://keisan.casio.com/exec/system/1351058230

For the rest of the indices, a similar approach to that mentioned by Mishra & Rampgopal (2013) was followed where the similarities in the predictions of the different indices for the one case indicate their validation.

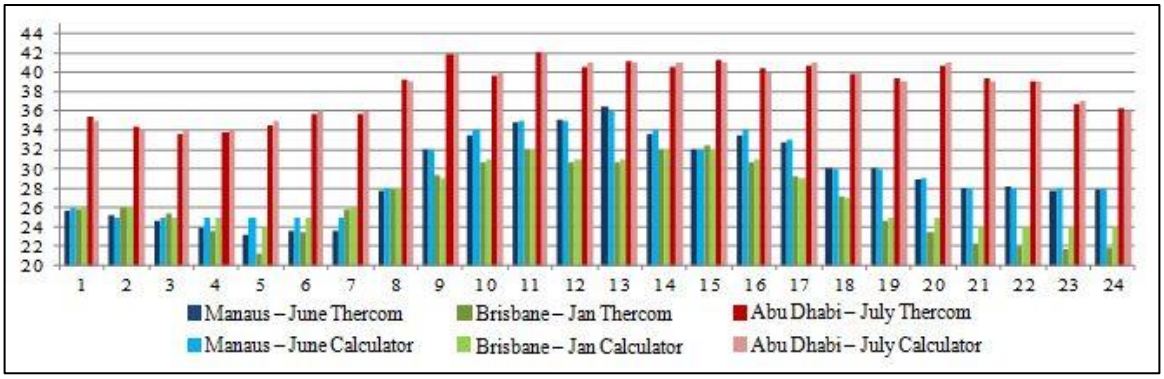

Figure 5. The predictions of THERCOM and the online calculator for the heat index

4 Case of Colombo

The predictions of the adaptive model for thermal comfort indicate the suitability of the specifications of the investigated mock-up for the climatic context of Colombo as can be noted from figure (6) where the indoor temperature falls within the comfortable range.

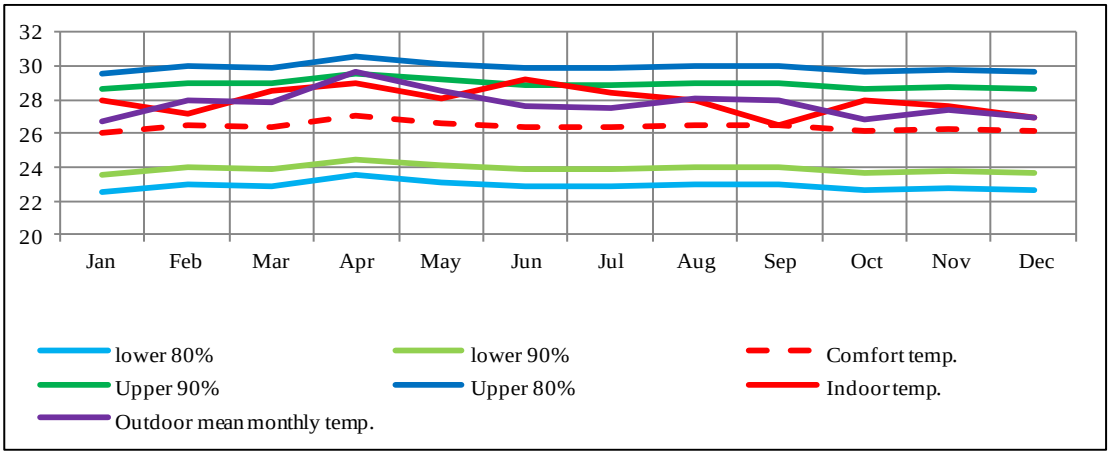

Figure 6. Predictions of the adaptive model for thermal comfort for Colombo

Figure (7) presents the hourly indoor predictions. In general, both the predictions of the wet bulb globe temperature and the tropical summer indices are similar. The former states that no precautions should be taken and the latter reports a slightly cool condition (CSC, 2012; Sharma & Ali, 1986).

The predictions of the outdoor comfort conditions, as presented in figure (8), show an agreement between the discomfort and the wet bulb globe temperature indices as their predictions were:

- Discomfort index: less than half of the population feels discomfort (Poupkou, et al., 2011)
- Wet bulb globe temperature: active exercise for unacclimatised people should be curtailed (Blazejczyk, et al., 2012)

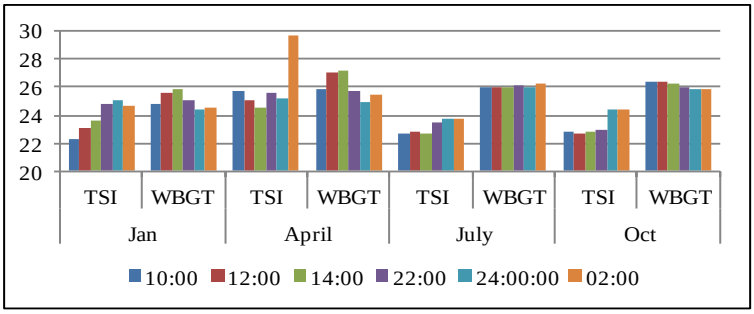

Figure 7. The hourly predictions of indoor thermal comfort in Colombo

However, the heat index predicts comfortable conditions (Blazejczyk, et al., 2012). This variation may be due to its sensitivity to the relative humidity considering its high level that exceeds 80% during the investigated hours.

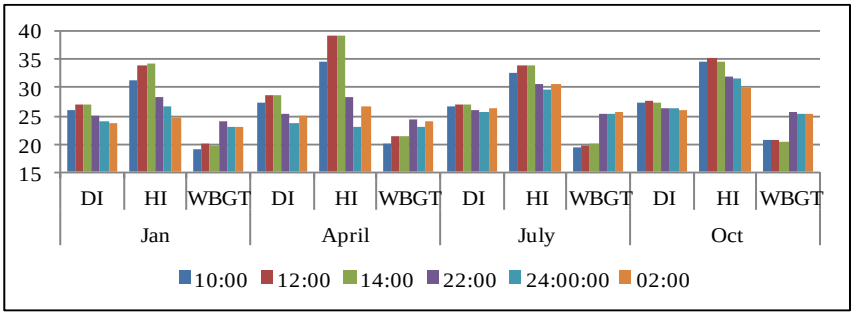

Figure 8. The hourly predictions of outdoor thermal comfort in Colombo

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