Virtual instrument for comfort factor measurement

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Abstract- This paper focuses on a description of the comfort by means of the temperature-humidity comfort index. In the attempt to describe this complex phenomena, those related to the human perception, for temperature and humidity estimation, we propose to use words of natural language. This linguistic description is not so accurate and also subjective than the numeric one obtained through usual sensors, but it is easily understood by human beings even if the concept is abstract due to it geographical context dependence. Finally, an aggregation of temperature and humidity measurements performed by a virtual symbolic sensor is presented for the qualification of the comfort index.

I. Intdoduction

Numerous indices have been developed over the years that give a measure of the human physical comfort as it relates to weather conditions [1], [2]. Kalkstein and Valimont [3], [4], [5], developed a relative index called the Weather Stress Index, which accounts for hourly apparent temperature values, but excludes other important meteorological parameters related to heat stress. A summer relative comfort index, the Heat Stress Index, has been developed to improve upon the limitations of the current, widely-used comfort indices, as well as the shortcomings of the Weather Stress Index. In addition, the index has been designed to fit seamlessly into NWS forecasts [6], allowing daily values to be calculated for time periods up to 48 hours in advance. When attempting to describe complex phenomena, especially those related to the human perception, one is often led to use words of natural language. This linguistic description is not so accurate and also subjective than the numeric one obtained through usual sensors, but it is easily understood by human beings even if the concept is abstract due to its geographical context dependence. The representation of the measurements by means of linguistic scales provides abstract information which can be integrated in decision, diagnosis or control especially with systems using symbolic coding [7], [8], [9]. If the temperature is forecast to be above 25°C, it must be combined with humidity to calculate the apparent temperature. When the temperature is at or below 10 degrees it must be combined with the wind speed to calculate the wind chill. We propose a description of the comfort by means of the knowledge of the relative humidity and of the ambient temperature. Since this symbolic sensor is an all-purpose component [10], the qualification of the comfort index is an aggregation of temperature and humidity measurements performed by a virtual symbolic sensor.

II. The comfort index definition

A. The temperature-humidity comfort index

According to the recent standards, the comfort index is defined by the relation [11]:

$$CI_{[°F]} = -42{,}379 + 2{,}05 \cdot T + 10{,}145 \cdot H - 0{,}225 \cdot T \cdot H - 6{,}84 \cdot 10^{-3} \cdot T^2$$
$$- 5{.}48 \cdot 10^{-2} \cdot H^2 + 1{,}23 \cdot 10^{-3} \cdot T^2 \cdot H + 8{,}53 \cdot 10^{-4} \cdot T \cdot H^2 - 1{,}99 \cdot 10^{-6} \cdot T^2 \cdot H^2 \tag{1}$$

where T is the ambient air temperature in Fahrenheit degrees and H is the relative humidity in percents. The equivalent formula for Celsius degrees is:

$$CI_{[°C]} = 6978,77 + 2,90 \cdot T + 1261,18 \cdot H - 0,26 \cdot T \cdot H - 22,15 \cdot 10^{-3} \cdot T^2$$
$$- 2037,79 \cdot H^2 + 1,98 \cdot 10^{-3} \cdot T^2 \cdot H + 1305,83 \cdot 10^{-6} \cdot T \cdot H^2 - 6,45 \cdot 10^{-6} \cdot T^2 \cdot H^2 \qquad (2)$$

B. The wind chill index

Prior to 2001, Environment Canada has used the following basic equations for calculating Wind-chill Temperature T_W and Wind-chill Factor [12]:

$$T_W = 33 - \left(\left(12,1 + 6,12\sqrt{V} - 0,32V\right)\left(33 - T\right)/27,8\right) \qquad (3)$$

where V is the wind speed in kilometres per hour, and T is the outside temperature in Celsius degrees.

For many years, researchers have felt that, based on scientific arguments, the wind-chill concept needed to be modified. They argued that a beaker of water is hardly a good model for heat loss from the heat-generating human body. Thus, intensive research over the past decade or two led to a new model and wind-chill formula based on modern heat-transfer theory instead of Siple's experiments. The current model is based on heat loss from an exposed human face, chosen because it is the part of the body most often exposed directly to severe winter weather. The model assumes the rest of the body to be clothed appropriately for the weather conditions. The metric formula for Wind-chill Temperature is:

$$T_W = 13,112 + 0,6215 \cdot T_a - 11,370 \cdot V^{0,16} + 0,3965 \cdot T_a \cdot V^{0,16} \qquad (4)$$

where T_a is the ambient air temperature in Celsius degrees.

III. Virtual symbolic measurement of comfort index

A. Symbolic evaluation of comfort index

To perform a symbolic measurement, it is necessary to clearly specify the relation between symbols and numbers [7], [8].

With multidimensional measurements, the definition of symbolic meanings leads to a combination between basic measurements [10], [11], [12]. The comfort evaluation needs knowledge about of temperature and humidity. If the temperature and the humidity are described by symbols as in the following sets:

S(T)={**cool, mild, warm**} and S(H)={**low_H, medium_H, high_H**} respectively,

obtaining of the information about the comfort index will imply combination of these measurements:

- the comfort evaluation is **comfortable** when the temperature is **mild** and the humidity is **medium_H**;
- the comfort evaluation is **acceptable** when the temperature is **cool**, **mild** or **warm** and the humidity is **low_H** or the temperature is **cool** or **warm** and the humidity is **medium_H**;
- the comfort evaluation is **uncomfortable** when : the temperature is **cool**, **mild** or **warm** and the humidity is **high_H**;

The new symbolic variable, the comfort evaluation, takes its value in a new set of symbols denoted S(T, H). This symbol is in fact one whose meaning is defined on the Cartesian product of the numerical sets of these two variables [9].

Let the temperature measurement set for a usual case is T = [10°C, 35°C] and the humidity measurement set is H = [20%, 80%]. The translation *tr* of the symbols for temperature are defined by:

- *tr*(cool) = [10°C, 15°C] ; *tr*(mild) = [15°C, 25°C] ; *tr*(warm) = [25°C, 35°C]

and for the humidity are defined by:

- *tr*(low_H) = [20%, 40%] ; *tr*(medium_H) = [40%, 70%]; *tr*(high_H) =[70%, 80%].

The description of the symbolic comfort measurements, *ds*, comes directly from the definition. In this manner, some concrete cases will lead to:

ds(27°C, 75%) ={**uncomfortable**}; *ds*(20°C, 50%)={**comfortable**}; *ds*(18°C, 28%) ={**acceptable**}.

B. Virtual measurement of comfort index

Figure 1 presents the minimal configuration of a system for realizing a virtual comfort index instrument. It includes a digital humidity and temperature sensor, SHT11, a signal conditioning system, SCS, and a PC.

Figure 1. Measurement system bloc diagram

      The software application for this virtual instrument has been written in LABVIEW programming software package. His components compute the numeric value of comfort index by means of the relative humidity and the temperature data, describe and compute the symbolic variable of the temperature and humidity and realize the comfort evaluation. The bloc diagram of the VI's corresponding of the numeric measurement of the comfort factor and the virtual symbolic comfort index are shows in Figure 2 and Figure 3.

      Figure 4 shows the front panel of the virtual symbolic comfort meter working and having data recordings over 100 seconds in comfortable case.

Figure 2. The bloc diagram of the numeric measurement of the comfort factor
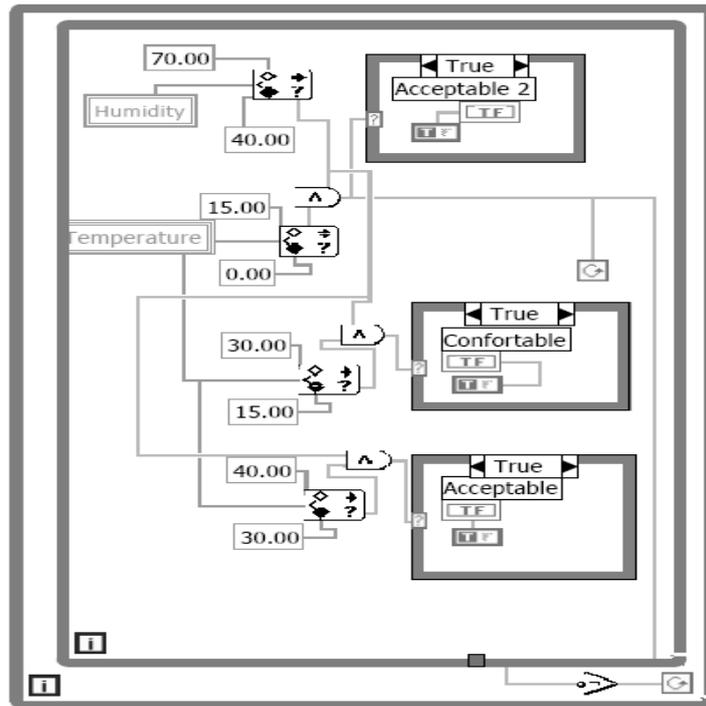
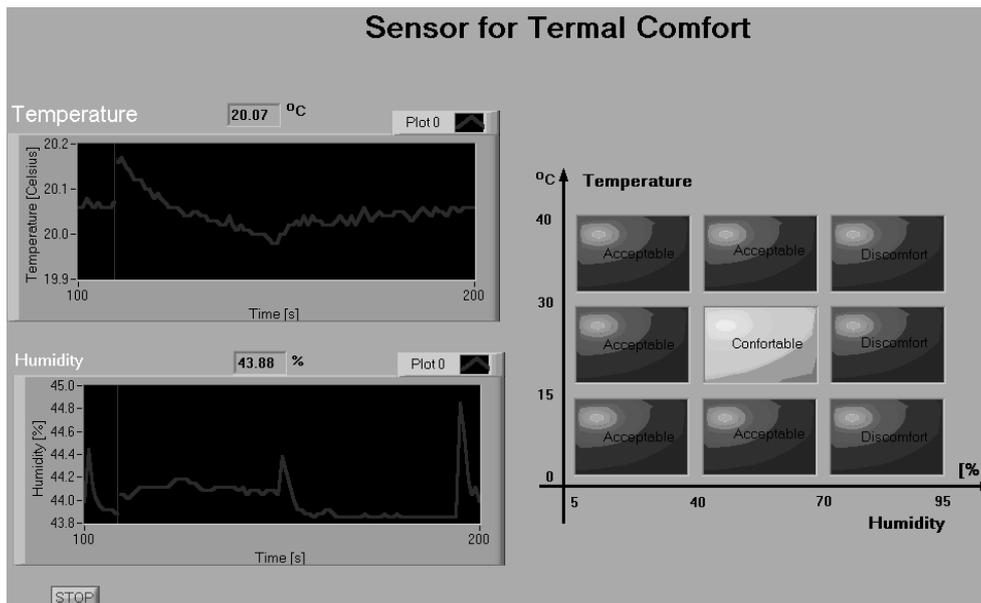Figure 3. The bloc diagram of the virtual symbolic comfort factor

Figure 4. The front panel of the symbolic comfort meter

The instrument has been calibrated by means a Paperless Humidity/Temperature Chart Recorder, EXTECH RH520.

IV. Conclusions

A virtual instrument for the comfort index measurement by means of the numeric values of the relative humidity and of the temperature can be realized. The method for qualify this phenomena is better to be in words of natural language. We have proposed a symbolic model if the comfort index terms arrangement cannot be represented by a numerical model. The presented virtual instrument can be developed in the future by combined the temperature with the wind speed for calculate the wind chill.

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