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Environmental Technology Platform Architecture For In Situ Monitoring the Thermal Comfort in Rural Environments

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ABSTRACT: *This research presents an environmental technology platform developed through the integration of air temperature and relative humidity sensors on an ecosystem in order to obtain some thermal characteristic of the Rural Environments. This sensory platform contains an expert system to detect the behaviors of environmental variables that result in risk or without risk alert to the thermal comfort for human and animal health. For this, the expert system analyses the environmental thermal conditions of the UFRA University, through temperature and humidity index (THI). Therefore, this platform is considered as a good low cost solution for thermal monitoring, which is based on in situ measurement technologies for rural environments.*

Keywords: *Environmental Technology, THI, Thermal Comfort, System Integration, Rural*

I. INTRODUCTION

The characterization of the thermal comfort of an environment has two main objectives: to identify the dominant climatic behavior of a region, and develop care strategies for human and animal health, based on information of the temperature and relative humidity, because these environmental variables are critical for welfare and survival.

The focus is on a rural area in Pará, Brazil, located about 10 km east of the city of Belem and containing the main campus of the Amazonian Federal Rural University (UFRA). The regional economy is based on agriculture, including livestock production and farming (e.g. rice, cocoa, beans). The study area has many rural workers, in addition to educators and students. This work aimed to develop a sensory platform for study the thermal comfort in UFRA area, through temperature and humidity index (THI). Expert systems that can characterize weather conditions automatically are especially important in emerging population centers, such as this one in Pará, because they lack historical records of environmental conditions that could be used for traditional pattern recognition.

Previous research related to environmental monitoring of rural areas include humidity sensor networks for forests [1], and the use of wireless sensor networks (WSN) for evaluation of animal health in closed shelters [2]. The distinctive feature of the proposed work is to develop an architecture of an IN SITU environmental technology platform that integrates the knowledge of agricultural systems, computing systems, expert systems and the environmental systems in a single study; to present an integrated solution. We present our findings by providing an overview of the complete thermal discomfort system. We hope that our work encourages others to develop similar highly integrated systems for other types of ecosystem applications.

II. MATERIALS AND METHODS

A. Environmental Technology Platform architecture

The Figure 1 shows the sensory platform (the board has dimensions with approximately 4.5 centimeters per 4.5 centimeters) developed in this work senses and logs climate variables and analyses them simultaneously. The acquired data estimates Temperature and Humidity Index (THI) and sends messages of risk or safety to a communication network. The plastic case is rated at IP56 (International Protecting Code) and provides thermal protection and mechanical shock absorption.

Fig 1 Sensory platform architecture fixed to a tree, in a height of 1.5 meters from the floor.

The SHT75 is a 14 bits digital high precision sensor of temperature and humidity, with digital data output (2-wire interface), which covers the dynamic range of -40ºC to 125ºC for the temperature, and 0 to 100% for the relative humidity.

The Zigbee (IEEE 802.15.4) module (see Figure 4) transmits the acquired data by wireless communication. This micro transceiver operates at 2.4 GHz in bidirectional mode and at half-duplex encrypted channel of data flow, and can reach up to 500 meters in open environments. The Li-Ion (Lithium-Ion) battery produces 5 Volts and current load with 8.400 milli-amperes per hour (mAh). The sensor captures information 3 times per day. With this, the platform is autonomous power for about four months, and then only need three recharges during the year. The battery takes six hours to recharge.

The embedded computer that manage all devices of the sensory platform is an 8 bits microcontroller PIC18F252, with clock of 20MHz and 2-wire interface port for communicate with the SHT75 Sensor, transmitter (TX) and receiver (RX) serial ports for communicate with the Zigbee module. The microcontroller programmed the state of low power consumption and the supervisory system activates the system through Wake-Up signal from Zigbee communication module daily at 9:00 am, 15:00 pm and 21:00 pm. The platform performs three functions when in enabled state:

Function 1. Receives data from sensor SHT75 and performs preliminary analysis;
Function 2. Computes the THI by the specialist rules given in table 1;
Function 3. Sends messages to the supervisor system that quantifies the risk of thermal comfort to rural workers and livestock.

The sensory platform availability was 350 days of the year 2012 (95.62%), in the 16 days that the system was not available due to training courses or maintenance. The sensory is easy to use. There is only an on/off button, which starts to collect and transmit data when activated by the operator. The supervisory system has intuitive interface with graph generation and analysis of data collected. The training on use of sensory platform last 4 hours; all trained operators had no difficulty to use the equipment.

B. Test site at Amazonian

The test site is located at the UFRA campus, near the city of Belém in Pará state, Amazonian region, with north latitude 1º27'34.4"S and west longitude 48º26'03.1"W, an elevation of 10m and a total area of 3.2km2, of which only about 3% is built-up. It is in the west equatorial climate. Its estimated 2012 population of students, educators, researchers and rural workers was 6.000. The temperature and humidity index was developed for the US National Weather Service and should be measured and calculated only on external conditions, never in buildings. This index commonly used for the identification of thermal comfort levels in livestock’s. The THI is calculated using the following formula [3]:

$$THI = 0.8 \times T + RH \times (T-14.3)/100 + 46.4 \qquad (1)$$

In the above formula, the THI refers to the rate of humidity and temperature and is dimensionless; T refers to the temperature measurement in Celsius degrees (°C), and RH refers to the relative humidity of the air measured in percentage (%). The Table 1 shows the ranges of THI and its influence on the thermal comfort of the environment for rural workers and livestock. An individual´s sense of thermal comfort is strongest when the heat exchange between the human body and the environment occurs without great effort; work capacity is maximum under these conditions, too. The value of the THI considered threshold between comfort and stress situations, varies according to the authors, but there is unanimity in the view that a THI of 76 is already stressful for high-milk production cows.

Table 1: Levels of thermal comfort for humans and animals

Parameters	Levels of thermal comfort
THI < 74	Adequate thermal comfort.
74 ≤ THI < 79	Warm environment in which to begin the thermal discomfort. This can cause health problems such as reduction in quality of work and life of rural workers.
79 ≤ THI ≤ 84	Very hot environmental conditions, indicating danger and may have serious consequences to the health of rural workers. This implies condition hazard to animals, indicating the need for producers to take precautions to avoid losses in production, especially for confined livestock and must be applied security actions to avoid disastrous losses.
THI > 84	Indicates extremely hot condition with very serious risk to the health of rural workers. This indicates an emergency; it is necessary be taken urgent actions to avoid loss of production.

III. RESULTS AND DISCUSSION

In 2012 the average temperature and relative humidity were 27.93ºC (82.27ºF) and 81.78% respectively (Figure 2). The temperature and relative humidity measured in the university area proved slightly greater between the months of May and October (average of temperature and humidity: 28.32°C and 79.19 %), the thermal discomfort in the UFRA Campus is estimated to have been worst during these months. In the other months of the year the temperature and relative humidity (mean of temperature: 27.7°C and relative humidity average: 83.30 %) are more mild (rarely the temperature is lower than 22ºC), on average, being the period from November to February (between years) the months with the lowest average. The temperature and humidity values of the year 2012 have to approximate values of historical data measured by the weather station located at the International Airport of Belém-Pa (9 km distant from UFRA), with north latitude 1º23'05"S and west longitude 48º28'44"W, an elevation of 16m [5].

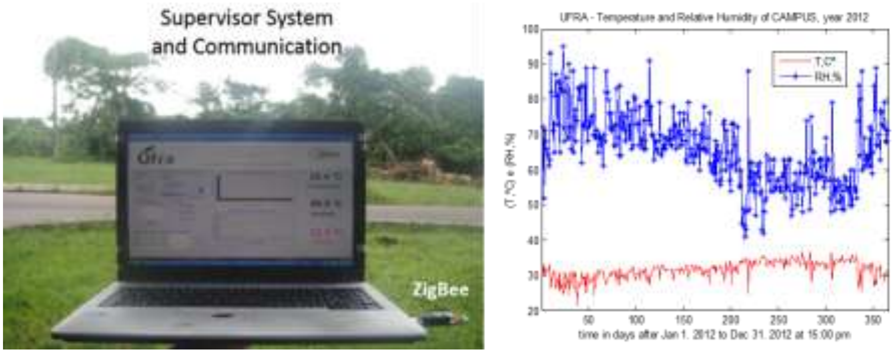

Fig 2 Supervisor shows the evolution of temperature and relative humidity at UFRA in 2012

After processing the data of temperature and relative humidity of the year 2012, with daily measurement on time critical heat at 15:00 hs for determining the THI (Figure 2), the results characterize: the months January-May and November-December with the best thermal comfort, with average of temperature and relative humidity: 30.12ºC and 75.35%. With the THI has average: 82.7, minimum: 71.9 and maximum: 85.9. The months with a tendency to decrease in thermal comfort are Jun., Jul., Aug., Sept., and Oct., with average of temperature and relative humidity: 31.57ºC and 66.93%, and the THI has average: 82.9, minimum: 75.9 and maximum: 86.3. June and October were periods of especially high thermal discomfort due to increase in temperature and decrease in relative humidity due to precipitation. The risk to the health care of rural workers and livestock is highest during these months. The months between November and May are characterized by lower risk of thermal discomfort.

IV. CONCLUSION

Spatially dense real-time environmental monitoring is critical for protecting people and livestock from the extremes of environmental variability, such as the thermal discomfort we consider here. Furthermore, monitoring builds up an archive of past conditions, which can be both to improve real-time assessment methods and to influence societal decision-making.

significant development in the understanding of climate effects on animals and rural workers, which directly influences the production quality. A better understanding of the interactions between the environment and living beings, reflected in their behavior and welfare, becomes a source of strategies to minimize the effect of climate on them [4]. The IN SITU environmental technology platform with the THI methodology, was satisfactory. The application data and the results of THI assumes values above 75 and below 82 in most of the annual records in UFRA area [5].

The in situ sensory platform described here can be used to assess the degree of thermal comfort experienced by workers and livestock in a wide variety of settings. This information can be used both to issue alerts, at time when discomfort is high, and to design strategies, such as nutritional plans, that reducing the risk to health and production due to unfavorable weather conditions.

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