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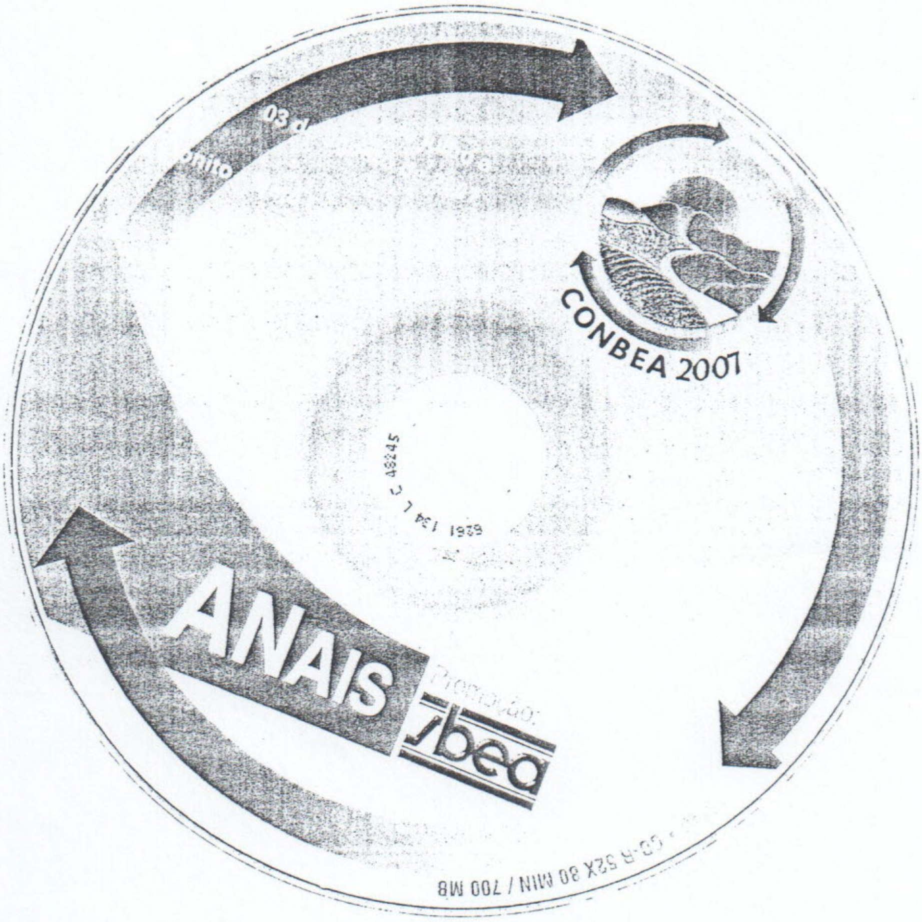
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VISUALIZATION OF THERMAL INFORMATION IN GRAIN STORAGE BIN BASED ON SENSORS AUTOMATION AND COMPUTER GRAPHIC TECHNIQUES

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ABSTRACT: This paper presents a technique for studying thermal behavior of grain storage bins, which is useful for increasing the safety margin of storage processes. The technique is based on intelligent instrumentation combined with an advanced computer graphic interface model. Validation of the method was obtained by considering the information related to spatial and temporal variability of the temperature in a case study for these bins including two dimensional and volumetric mapping for decision-making support in storage processes.

KEYWORDS: thermal visualization, grain storage, decision-making

VISUALIZAÇÃO DE INFORMAÇÕES TÉRMICAS EM SILOS DE GRÃOS BASEADA EM AUTOMAÇÃO DE SENSORES E TÉCNICAS DE COMPUTAÇÃO GRÁFICA

RESUMO: Este trabalho apresenta uma técnica que auxilia o estudo dinâmico do comportamento térmico em silos de armazenagem de grãos. Tal comportamento influencia o controle da margem de segurança durante a estocagem de grãos. Seu desenvolvimento foi realizado com base em instrumentação inteligente combinada com um avançado modelo de computação gráfica. A validação foi obtida considerando a geração de informações sobre a variabilidade espacial e temporal das medidas de temperatura e o seu mapeamento bidimensional e volumétrico, bem como a qualificação das mesmas para o auxílio à tomada de decisão no processo de armazenagem.

PALAVRAS–CHAVE: visualização térmica, armazenamento de grãos, tomada de decisão

INTRODUCTION: In the world, besides the importance of electronics applications in agriculture of new techniques during production processes, their use in storage and transportation also merits attention. In Brazil, for instance, the specific case of grain, at present about 20% of national production is lost during storage and transportation. By correcting these systems, this figure can be reduced. Thus, improvements in grain treatment and storage in, for example, the case of bins and agricultural dryers, through access to and use of reliable data on thermal variations would undoubtedly contribute, by optimizing decision-making during the aeration process, to substantially minimizing storage problems (BALSANI, 1999). Understanding the drying process in dryers or bins of agricultural products requires monitoring of, among other variables, product temperature, in addition to its quantification in order to validate mathematical models simulating grain drying. Factors governing grain quality during storage are temperature and humidity. Seasonal variations in ambient temperature may established indices unreliable owing to humidity migration or redistribution. Localized humidity increase can cause fungus and insect development, which sometimes produces toxins and makes grain unfit for human consumption, particularly at temperatures between 15°C and 38°C (30°C is ideal) those preferred by insects and acaroids. Many of the demands placed upon such agricultural processes will be met by extension of existing modeling and technology. However, an apparently monitoring system can be obtained if digital signal processing is incorporated within the sensors package together a decision making environment. The advantage of this is the possibility to converse with distributed and central processing facilities without the need for complex conversion systems. Besides, during the past decade different methods have been used for temperature monitoring in many applications, including agriculture. New sensor technologies in this area include the development of silicon-based sensors, image-based sensors, fiber-optic sensors, and new materials such as polymer, dedicated architectures and specialized software's (BRIGNEL & DOREY, 1983; HOWELL & HAMILTON, 1990; AVIRAY et al., 1990; WIDE & SOHLBERG, 2002; LIM et al., 2002). Grain-temperature monitoring during bin storage is fundamental in the decision to aerate when heated areas are detected in a grain mass through the models and concepts described in the previous discussion. This paper presents an instrumental system for visualizing thermal real-time map information in agricultural bins.

MATERIAL AND METHODS: To succeed in monitoring the temperature in grain-storage bins, instrumentation based on intelligent modules for data acquisition, together with another module having a host function was applied. In the tests, three acquisition modules were used, each of which had 8 sensors plus a host module which was connected to a computer by using standard RS-485 for serial communication, allowing information exchange between more than two interconnected devices by means of a pair of metallic wires. All the system modules (the acquisition ones plus the host module) originate in a circuit whose processor is an 80535 microcontroller. Figure 1 presents the basis in block diagram for the temperature acquisitions and host modules, respectively.

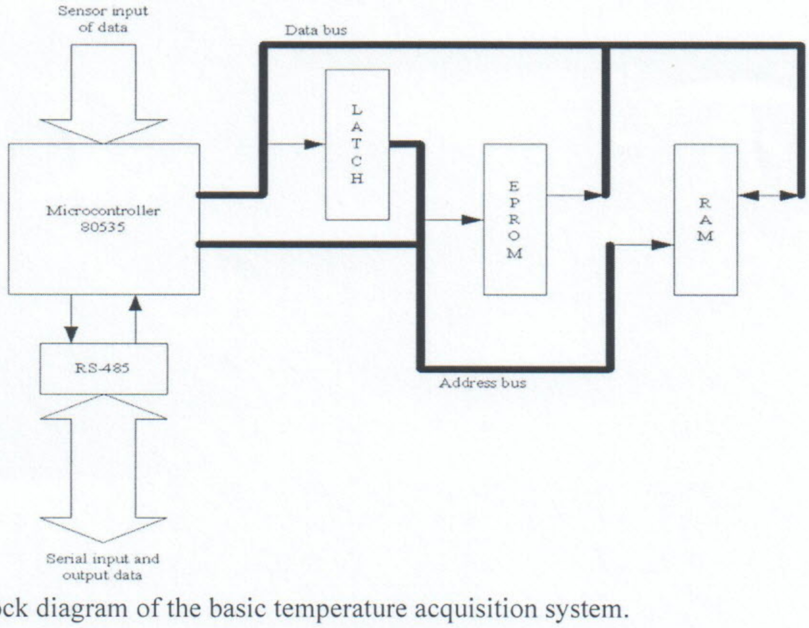

FIGURE 1. Block diagram of the basic temperature acquisition system.

The sensors utilized were miniature types PT100 in a Whetstone bridge configuration. A conditioning circuit of the signal originating in the temperature sensor through the utilization of operational amplifier LM725 configured as a differential amplifier which intensified the difference in potential in the branches of the Whetstone bridge in order to condition the voltage variation in proportion to the temperature variation reported by the sensor (between 0V and 5V), which is then applied at the entrance of the analog to digital converter of the microcontroller 80535. As an integral part of the decision-making system, an application was developed for IBM-PC computers with a Microsoft Windows platform. This was done using a Borland C++ Builder. Besides, the data received from the monitoring system, the application also requires from the user the form in which the monitors were distributed in the inside of the bin being analyzed. For the mapping process it was used interpolation by means of cubic spline method.

RESULTS AND DISCUSSION: Figure 2 shows temperatures on a gray-level scale and interpolating some known values. A thermal map or image can be obtained which makes possible improved spatial temperature variability analysis of pre-established planes. The use of these maps or images makes it much easier to understand thermal behavior in bins. Also, image sequences varying with time can be generated, obtaining in this way animations and a structure making possible temporal series analyses of thermal variations. Since the data group was selected from the base, temperatures are represented like the 2D images, on a gray-level (or pseudo-color) scale and, based on the sensor locations, voxels are rendered with an *OpenGL* library. Figure 3 illustrates a further tool option allowing visualization spatially identifying monolithic volume internal planes of grain bin temperatures.

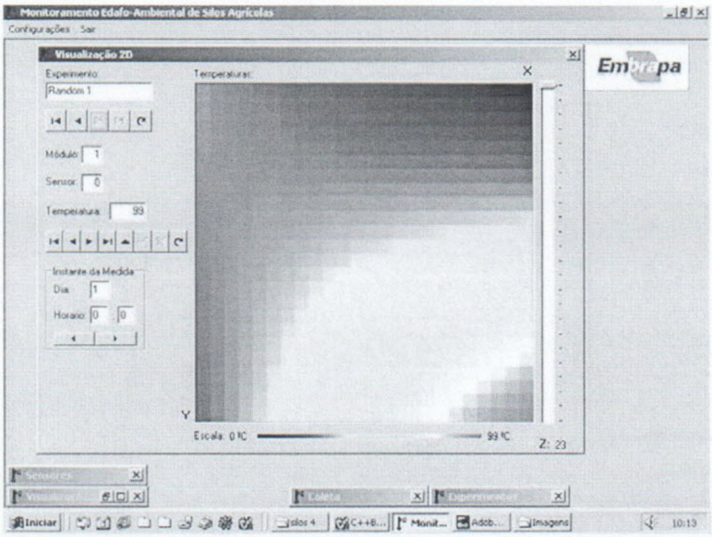

FIGURE 2. Two-dimensional gray-level representation of temperature variation in a selected plane.

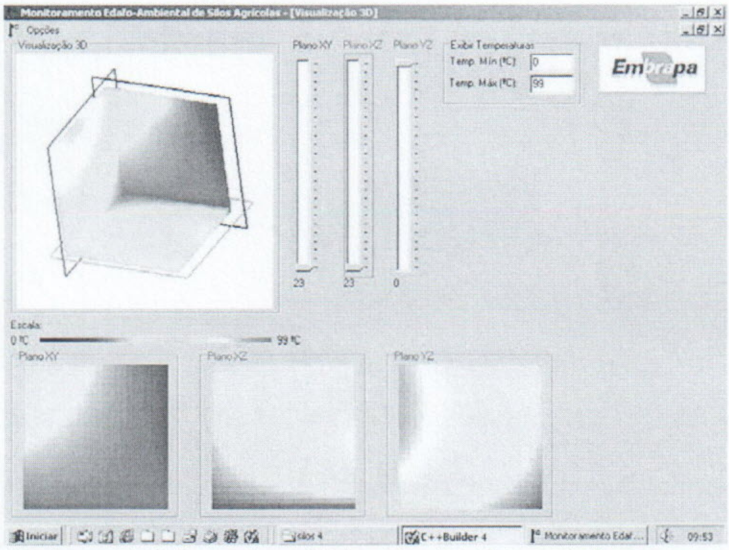

FIGURE 3. Thermal volumetric information obtained by data interpolation.

CONCLUSIONS: With the use of this technique, a new tool was developed for thermal monitoring and decision making in processes for reducing grain loss in bins. The solution proposed offers an innovational, reliable, and easy to use methodology, which makes possible efficient management of information relative to spatial and temporal variability of thermal gradients occurring in agricultural bins.

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