A scale model of a grain storage tower equipped with Micro Web Servers

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Abstract—**This paper presents a scale model of grain storage tower, i.e. a silo for drying and airing cereal grains. The scale model consists of a 2.50 m wide x 2.10 m long plant with all control and monitor capacities provided by Micro Web Servers. An application running on the Micro Web Servers enables storing all parameters in a data basis for later analysis, preferably done remotely. The implemented model aims to support a remote experimentation facility for technological education, research-oriented tutorials, and industrial applications. Given its low-cost, this remote facility can be easily replicated in other institutions to support a network of remote labs, which encompasses the concurrent access of several users (e.g. students).**

Index Terms—**Remote Experimentation, embedded web servers, Micro Web Server, Remote Monitoring and controlling.**

I. INTRODUCTION

Technology is driving newer and more innovative ideas within informatics and computer systems. Recent examples of online monitoring and control support this opinion. In fact, online monitoring and control is being widely studied and applied in many different areas such as: traffic control, Earth phenomena (e.g. earthquakes), weather, industry, and many others. In parallel and motivated by the growing popularity of the Internet, many companies working with embedded systems are now offering Micro Web Servers (MWS) that allow monitor and control operations via the Internet, at low cost. Printers, routers, and webcams are some examples of devices that support web-based configuration and status display [1]. Devices incorporating MWS carry many advantages, e.g. the ability to be remotely accessed through the Internet, using a simple Web browser. The remote access supports several new functionalities, such as: failure detection and diagnosis, firmware update and remote maintenance, among others [2]. These new functionalities may even provide a considerable reduction on maintenance costs, if the system under maintenance is built with such devices.

In the following sections we describe an example of such a system built with devices incorporating MWS. The system in question corresponds to a low-cost scale model of a silo for drying and airing cereal grains. It may be used for technology education, research, or industry-oriented

vocational training. One main advantage is its low-cost that allows an easy replication by other Institutions or Organizations.

II. MICRO WEB SERVER

The main factor for keeping the system cost low is to use low-priced devices. An additional factor that influences the system cost is the use of open source tools for developing and debugging the application run by each device. These two factors are carefully observed within the Remote Experimentation Laboratory of the Federal University of Santa Catarina (RExLab/UFSC), whose main mission is to develop low-cost and high-performance MWS, such as the one illustrated in fig. 1. The depicted Printed Circuit Board (PCB) contains a MWS, a low-cost microcontroller, an AVR-RISC memory [3], and a Network Interface Card (10baseT) connected to the microcontroller. The Network Interface Card contains: a TCP/IP stack; an HTTP server (available on open source code); and additional memory for both code and data (HTML, images, CGI, and Java) [4]. An important detail: there are drivers for the Operating System (OS) running at the microcontroller. Some additional characteristics: final price of less than US$ 30 (building parts) and a size of 85 x 95 mm. These characteristics allow using the MWS with several objects, to provide remote control and monitoring (due to its reduced size and low cost). Given the past experience acquired with this MWS (e.g. remote temperature sensing – http://computacao.unisul.br/projetos/), in small applications, we decided to build up a larger and more complex system, and made it totally controllable and observable through the Internet, by using our MWS. Our choice went for a scale model of a grain storage tower (i.e. a silo).
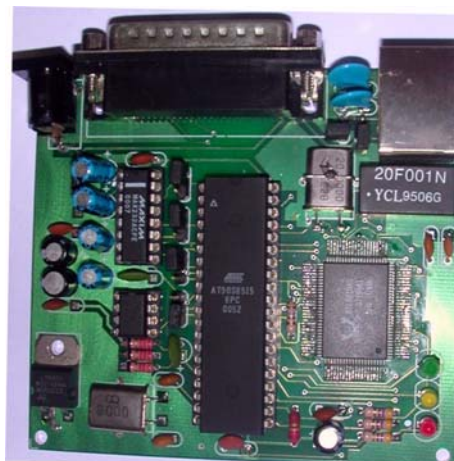

Figure 1. Printed Circuit Board of the Micro Web Server - MWS

III. THE SILO MODEL

A general view of the developed model is illustrated in fig. 2. As mentioned, the access to the silos parameters (both in terms of monitor and control parameters) is to be made through the Internet, using one MWS (i.e. typical client/server architecture). On the server side, the silos model contains one MWS that receives the temperature and humidity readings from a 10-bit, 8-channels, analogue/digital converter (ADC), connected to a series of sensors. The ADC is connected to the MWS through a serial RS-232C port. The client side is supposed to be any web browser supporting Java. The silos web interface comprises HTML with Java applets that allow a direct communication link with the MWS for the purpose of reading and controlling the models parameters. On the server side, there are CGI (Common Gateway Interface) scripts running at the MWS that interpret all requests made by the user, when accessing the silos model through the web. Before presenting the details of the model operation, we describe in the following paragraph the structure and functionally of a conventional silo.

A conventional silo is a metallic structure built on the top of a concrete basis. The silo is built on such a way that an interior air chamber is formed. One or more heaters and air pumps allow injecting hot air into the silos inside. The air trespasses the grains stored inside the silo, which impairs them from rotting. In Brazil, the most used silos are 11 metres diameter with a total storage capacity of 430 tons of grain. A detailed description of the silo operation is available from [5].
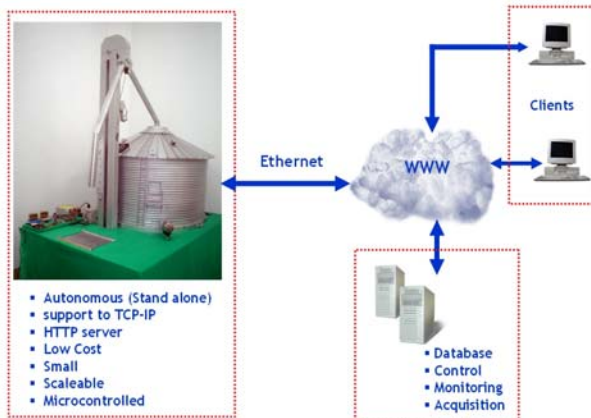

Figure 2. General view of the remote infrastructure

A. Model operation

Referring to the implemented model, the grains are dropped off into the respective silos compartment and then loaded into the internal containers by a bucket elevator standing in parallel with the silos body structure, which runs vertically (see figure 3-1 for a detailed view of the bucket elevator). The elevator drops off the grains into a tube that leads into the container. In our model, the grain is removed from the silos interior following a similar process, i.e. by controlling the direction of a servo motor (see figure 3-4 for a detailed view of its placement) it is possible to put grains into or out of the silo. Once the grain is stored inside the silo, internal sensors allow monitoring both the internal temperature and humidity. The readings may be remotely accessed using the functionalities provided by the MWS. The Parameters Control System (PCS) receives this information from the MWS in time intervals fixed by the systems administrator. In every new reading, the PCS compares the actual values with the ones defined as trigger levels. If for instance the actual temperature is higher than the limit set by the administrator, the PCS automatically turns on the aeration system. Once the temperature drops below that setpoint the PCS shuts off the aeration system (see figure 3-3 for a detailed view of its placement).

The model contains three temperature sensors (two located inside the silo and one outside) and two humidity sensors (again, one inside and one outside the silo). These sensors are connected to the ADC, which in turn is connected to the MWS that reads and displays the values. The readings are also stored by the MWS for later analysis, if needed. As depicted in figure 4, the MWS controls the aeration system, the bucket elevator and the grain flow direction through an external motors power board, clearly visible on figure 3-2. Figure 4 also depicts the grain level sensor that allows determining the used storage capacity (from 0 to 100%, in steps of 10%). This sensor is connected to one of the eight channels available at the ADC.

As all parameters are controlled and monitored by the MWS, the possibility of remotely accessing those parameters lays on the creation of a simple webpage able to exchange information with the MWS. This possibility is described in the following section.

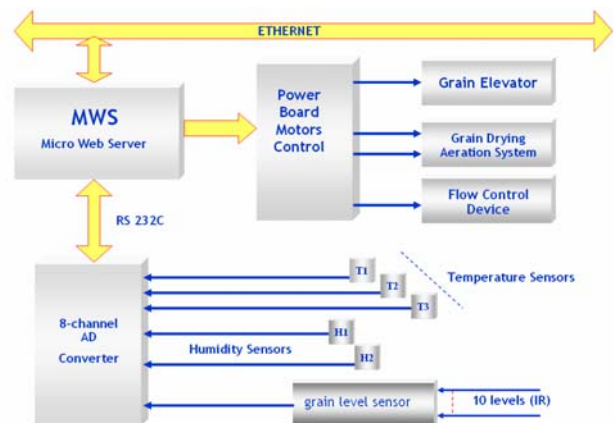Figure 3. Some details of the silo scale model

Figure 4. Block diagram of the silo control / monitoring scheme

IV. PRESENT DEVELOPMENT

The silos parameters can be monitored and controlled through a webpage located at the following URL http://computacao.unisul.br/projetos/silo/. This same page includes a visual feedback from the silos operation, provided by a webcam. Figure 5 corresponds to a print screen of a client presently accessing the system. The top left quarter contains an image of the silos interior, the tubes and the bucket elevator. The used storage capacity is also indicated (40%, on figure 5) by the colored area. The image will also show movement if the bucket elevator is working. The top right quarter contains the image returned by the webcam. The current readings (internal temperature sensor 1 and 2, external temperature sensor, internal and external humidity sensors, and level sensor) are displayed on the bottom right quarter. The control parameters (temperature setpoint, aeration system, bucket elevator, and flow direction) are displayed on the bottom left quarter.

Figure 5. Web page for controlling and monitoring the silo model

V. CONCLUSION

The implemented silos model illustrates the possibility of remotely controlling and monitoring complex (automated) systems, using a low cost approach based on MWS. Besides the cost aspect, the system is also accessible by any remote client using a simple web browser, which allows an easy and flexible use by any student or teacher. Given these two aspects, the implemented silos model can be easily replicated in other institutions to support a network of remote labs, which encompasses the concurrent access of several users for technological education, research-oriented tutorials, or even industry-oriented training.

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