A new control system for citric fruits conservation and maturation based on CAN and Internet networks

J.V. Capella[1], J.J. Serrano[1], J.C. Campelo[1], A. Bonastre[1], R. Ors[1], P. Bradbury[2]

(1) Fault Tolerant Systems Group, Polytechnical University of Valencia
(2) Polaris Technology

In citric fruits conservation and maturation systems it is very important to have faithful information about certain parameters that indicate the fruit state, and that allow to take the appropriate proofreaders actions in order to achieve an optimum controlled fruit maturation.

In front of the rudimentary control systems that are being used at the present time, the Fault Tolerant Systems Group of the Polytechnic University of Valencia together with POLARIS TECHNOLOGY S.L company, have developed a new distributed control system based on CAN and Internet networks that allows a remote pursuit and control in real time of these processes.

In each cold store, there are a strategically distributed set of sensors and actuators that are interconnected by means of a CAN network. One node centralizes the information, so that after its filtrate and storage is overturned on a backbone CAN network that interconnects all cold stores with a PC in charge of carrying out a second treatment and storage of the information and its diffusion to Internet.

Finally, each user (authenticated by means of a security system) can be connected to his installation via an Internet connection or using a GPRS or WAP mobile telephone, to see the process evolution or to modify the parameters of each cold store.

This system is completely operative and it has been already installed in different companies of several countries, obtaining very interesting results.

1 Introduction

At the present time is necessary to obtain a high quality in all type of industrial and technological processes, being included the fruits conservation and maturation sector. In this sector a control of the product evolution as much before the collection as after is being carried out more and more. In this line, it is fundamental to be able to present a product under good conditions to carry out a correct monitoring and control of the conservation and maturation process.

The systems that have been used up to now, most consisted on a manual control or in some few cases in transferred control systems of other industrial sectors (PLC's, etc.), making them expensive, not very flexible and difficult of adapting to the process.

Our objective for some time has been offering to this sector a potent and flexible solution that adapts easily to the characteristics of these applications, and everything with a reasonable price to be able to assure its installation in the companies of this sector.

About the characteristics of the monitoring and control systems of citric fruits maturation, to highlight that it is necessary the use of a distributed system because each fruit installation is integrated by diverse cold stores, each one of them with sensors and actuators dispersed in its interior.

Also, the control system should be scalable because the companies of this sector are very dynamic and they have variable necessities in the time as for storage capacity (cold stores) and with clear tendencies to the progressive amplification of their installations.

On the other hand those systems should be easily configurable and controllable since the operators of these systems are usually people with a great experience in

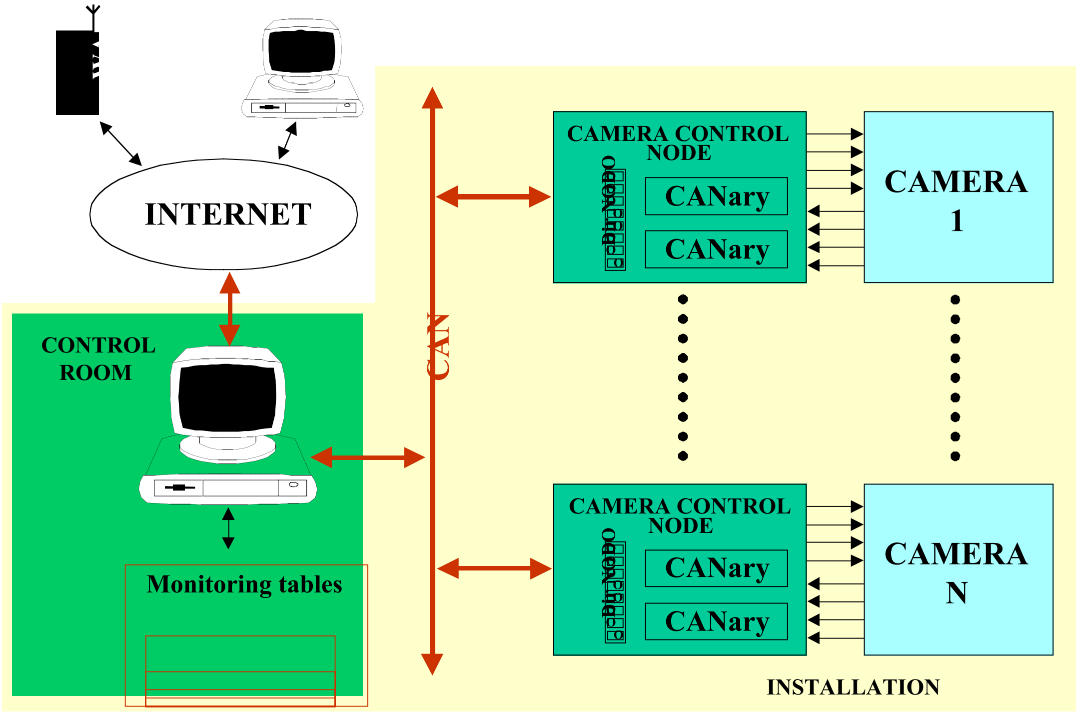

Figure 1. General scheme of an installation

topics related with the citric fruits but limited computer science knowledge.

Lastly, aspects of security and dependability should not be forgotten, what forces to facilitate to the proprietors or taken charge a sure access and in real time to the information of the state of their installations, since a system failure can cause the lost of tons of fruit, with the rising economic damage. Also, with this system they can have the same information that they would have in the case of being personally before the system but without being had to displace physically to the installation. In this manner two important benefits have been obtained, first, the tranquility of knowing in all moment (even from the home) that the system works correctly. The second it consists on the possibility of reacting quickly before any anomaly that was detected.

For everything, a distributed system with the previous characteristics has been designed and implemented [1]. This system is based on a hierarchy of networks, formed by two CAN networks [2] (one backbone or dorsal and another local to each one of the cold stores) and Internet, offering through the last one the possibility to obtain all the system information, and even the possibility to send it orders.

2 Citric fruits conservation and maturation system

2.1 Structure of a citric fruits conservation and maturation installation

These installations, as can be seen in figure 1, are constituted by one or several annexed industrial premises in whose interior several cold stores of big dimensions are harbored (able to harbor several tons of fruit). Also exists a control room and other elements like offices, conveyor belts to pack the fruit, quality control laboratories, etc.

Each cold store has a refrigeration system, forced ventilation (that consists in several fans of variable speed), an humidifier system, an ethylene injection system, as well as several sensors of temperature, humidity (absolute and relative), CO_2, etc. Also, is necessary to dispose in each cold store several sensors to measure in a more precise way these magnitudes due to the enormous proportions of the cold store (see figure 2), that which originates certain dispersion of these along all the cold store volume.

Figure 2. Photography of a cold store

2.2 Citric fruits conservation and maturation process

The citric fruits after their collection should cross a set of typical phases conducive to their conservation and maturation. These phases corresponds with the states in those that a cold store can be, and they are the following ones:

1. Reception state: the cold store is filled with the fruit that comes directly from the field, and that after its reception and cleaning is stored in big drawers that are transported to the interior of the cold store. Being therefore necessary to proceed to a cooling and homogenization of the fruit (because it is hot) until reaching the conservation temperature, passing to the following state.

2. Conservation state: In this state the cold store is maintained in some controlled conditions of temperature, humidity and ventilation, trying to stop the maturation of the fruit insofar as possible.

3. Maturation state: The fruit is submitted to a process in which by means of the progressive increment of the temperature in an atmosphere controlled with an appropriate proportion of ethylene and ventilation, a change in the fruit color takes place, as well as the fruit is located under the transport conditions. When this phase finishes, the product leaves the cold store toward the tapes of having packed and later on toward the trucks that transported it toward the smallest sale points.

4. Stop state: The cold store is empty, awaiting the new collection campaign.

5. Alarm state: The system transits to this state in an automatic way after the detection of some malfunctioning due to the lack of electric fluid or to the damage of some critical devices of the system (refrigeration system, ventilation, etc.).

3 Control system architecture

A distributed system with a hierarchy of networks has been developed to carry out the monitoring and control of the process of citric fruits conservation and maturation. Internet is in the upper level and allows a remote access to the system, so much to obtain information of the operation of the same one as to be able to modify the variables of this. The intermediate level is formed by a CAN network, called backbone, and has as mission the interconnection of all the cold stores with a main computer. Lastly, in the lower level appears a CAN network in each cold store of the installation to interconnect all the present nodes in the same one.

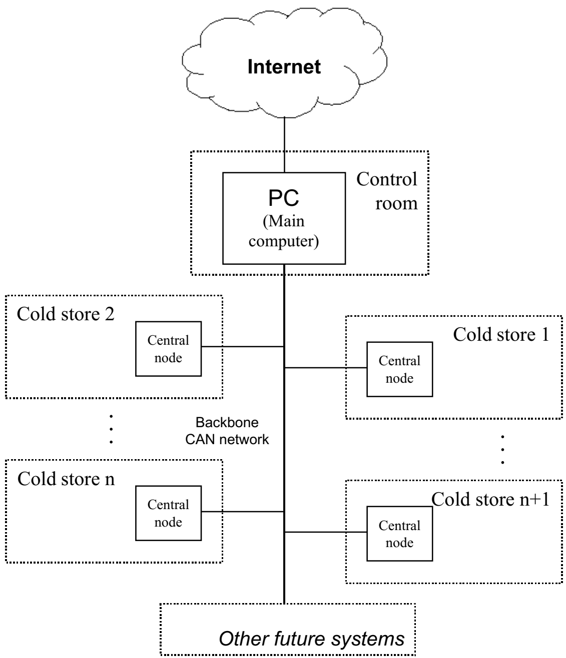

Figure 3. Hierarchy of networks and system architecture

This hierarchy, that can be observed in the figure 3, allows to divide the system in three subsystems. The first of them formed around Internet would be constituted by the main computer and any other device (PC's PDA's, mobile telephones, etc.) connected to this network. The second subsystem would be formed around to the CAN backbone network that connects the main computer and the central cold store nodes. Lastly, the third subsystem formed around to the local CAN network and composed by the central cold store node and all the S/A nodes (see figure 4), existing a subsystem of this type for each cold store of the installation.

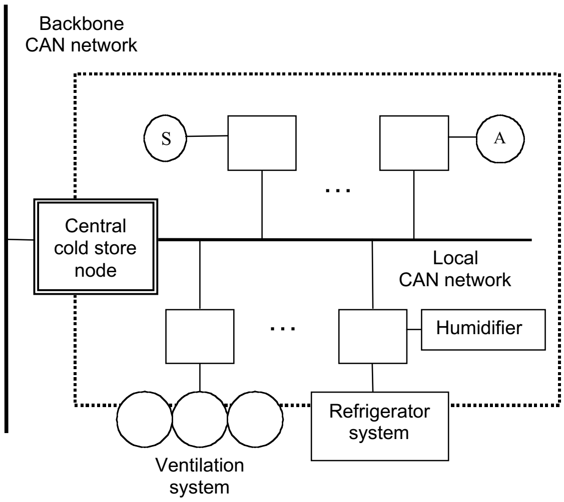

Figure 4. Central node and satellite nodes of a cold store

In the following sub-sections, the mission of each one of the system nodes is described, as well as details of its implementation and operation.

3.1 Main computer

The main computer mission is to store locally all the information of the different cold stores, and through Internet offer this information to the user and even to receive orders from the installation responsible (previous authentication).

It is a personal computer located in the control room that has access on one hand to Internet, by means of the connection that the company has, and on the other hand has a CAN network card that connects it to the backbone network.

3.2 Central cold store nodes

This type of nodes has as mission, to centralize all the cold store information, picking up this of each one of the nodes of the same one, storing it and after its processed to transfer it through the backbone network to the main computer. It should also control the cold store executing the control algorithms that it disposes, and respond to the commands that the operator sends through the main computer.

These nodes, as can be observed in the figure 5, have two independent CAN connections, one that connects it to the local cold store network and another to the backbone network. On the other hand these nodes have some micro-switches that allows to associate to these nodes an address that corresponds to the number of the cold store that they control. On the other hand it is not necessary to give the address of this node inside the local cold store network, since this is fixed and it corresponds in all the cold stores to the node “1”.

The implementation of these nodes have been carried out by means of 8 bits microcontrollers [3] (which possesses a CAN channel) and by means of a SPI link is connected to a CAN UART that provides the second CAN channel.

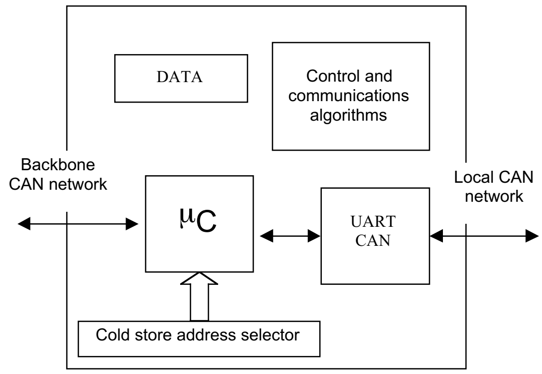

Figure 5. Central cold store nodes structure

3.3 S/A nodes

The Sensor/Actuator nodes (S/A nodes), as their name indicates are nodes that have connected the sensors and necessary actuators in each cold store, being connected directly to the different parts of the process, and being standard nodes that it is not necessary to configure.

At the moment there are implemented three types of S/A nodes:

- Sensor nodes. This nodes have three analogical inputs, sensors of humidity, temperature and CO_2 can be connected to this inputs, and the nodes send the value of these magnitudes periodically through the network. The sensors that one node has installed is indicated by means of some micro-switches –sensor presence selector– (see figure 6).

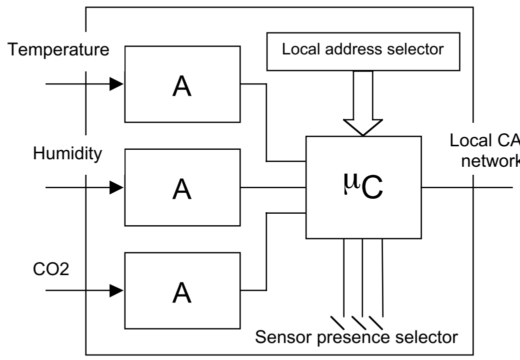

Figure 6. S/A nodes structure

- Digital I/O nodes. By means of their three digital outputs they can control elements like the refrigerator, humidifier, etc., and with their three digital inputs obtain information about elements as the door (open/close), switch (cold store on/off), besides fallen of force, etc.

  The operation of these nodes is the following one, from the cold store control node a message can be sent in order to activate / disable each one of its digital outputs, and this nodes send a message to the central cold store node every time that a change in their inputs occurs (see figure 7).

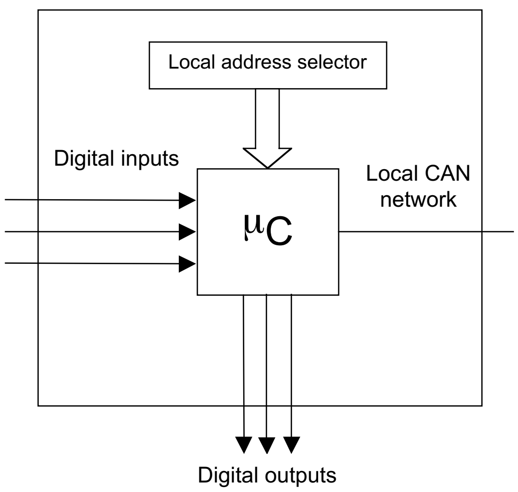

Figure 7. Digital I/O nodes structure

- Ventilation control node: It is a node that carries out the speed control of the fans. For it, as can be observed in figure 8, it has a zero crossing detector, a triac based circuit to feed the fans, and a circuit for feed the speed [4]. With these circuits and the appropriate PID control is able to locate the motor speed to the level received through the network.

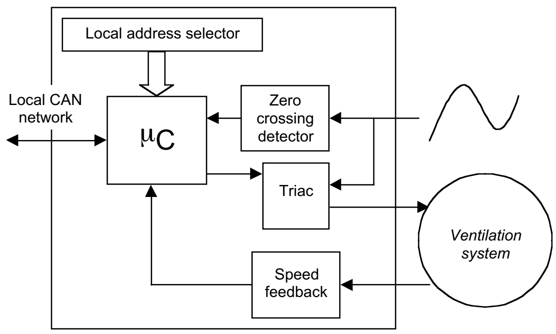

Figure 8. Ventilation control nodes structure

All these nodes have been implemented by means of Atmel CANary micro-controllers. Each node also has some micro-switches to assign them an own address inside the local network of each cold store.

On the other hand, two communications protocols over CAN have been designed. The first one for the backbone CAN network, allows the exchange of messages among the main computer and the central cold store nodes, and the second one for the CAN network of each cold store. Given the application characteristics the messages are very guided to different functionalities of each one of these systems. The message identifier is divided in two fields, in the lower part is placed the identifier of the node involved in the system (cold store address for the backbone network and node address for the local network), and the message code is placed in the upper part.

4 System implementation

Two types of programming environments exist in the system, one of higher level that is located in the main computer based on Linux to consider this operating system very robust for an application of these characteristics [5], where all the control programs are located, and it is carried out the data storage and distribution through Internet.

The control programs have been developed with the C++ language, having two functionalities, on one hand the collection of information over the CAN backbone network, their storage and later publication toward the web, and another in charge of to pick up the commands that the responsible orders and send them to the pertinent cold store.

This application of the main computer is personalized for each installation by means of a configuration file where is specified all the installation characteristics, such as number of cold stores, sensors and actuators for each cold store, satellite nodes inside each camera, etc.

The SQL server system database is used to store all the generated information, so that it is simple its distribution by means of the web server through Internet, as well as the users administration [6].

When the main computer starts up, it can be a warm start (due to a fall of tension in the system, computer reset, etc.) in which case the computer continues working in the same way that before the fall, or it can be an cold start, in this case the computer reads the configuration file, and through the CAN backbone network it configures the central cold store nodes, particularizing the operation of each one of them to the characteristics of the assigned cold store. The difference among a warm or cold start is detected by the main computer through the information that has stored in disk.

Once the central cold store nodes have received the configuration information they wait until the operator sends the start command. When the cold store is filled with fruit, the responsible sends through the main computer to this camera the order of passing to the reception phase, so that the cold store node begins to control in the appropriate way this cold store. When the conditions that determine the end of the reception phase are reached, the system passes automatically to the maintenance phase, phase in which will remain until the user orders to pass to maturation phase.

Although this obeys a normal operation, conditions like the lack of electric fluid or the mishap of critical devices can happen.

If a lack of electric fluid is detected, the cold store node passes to alarm mode, continuing with the monitoring of the system, obviously without being able to exercise any control operation on the same one. When the electric fluid returns, the node continues working the same as before the fall, but without leaving the alarm mode, with the purpose of that the operator is aware of this event and act in consequence. Later on the operator will be who orders the alarm mode exit.

In case of malfunction of some critical subsystem, the system also spends to the alarm mode and the user's intervention is expected, so that after paying the cause that causes the entrance in this mode, order to leave the same one.

The central node carries out the pertinent functions in order to the system evolves in the way that has ordered the responsible through the main computer and the backbone network. For it, the node executes the control algorithms, which obtain information of the different sensors of the system through the local cold store CAN network, calculates the appropriate control actions, and sends these through the cold store network to the actuators nodes so that these apply them. The satellite nodes operation comes defaulted from its fabrication, and they carry out the corresponding functions according to the node type.

In this manner, the nodes that have coupled sensors of temperature, humidity or CO_2 transmit periodically the value of these variables. On the other hand, the node that controls the fans receives the speed parameter and by means of a PID algorithm makes that the ventilation is adjusted to this value. Finally other nodes are in charge of activate/disable, according to the received orders, the refrigerators, humidifiers, etc. or to transmit the changes that take place in doors, switches, etc.

Optionally, certain companies request to enlarge the system, besides the cold store control, so that other systems like conveyor belts, weighing systems, etc. This is easy to implement by means of the appropriate nodes connected to the backbone network.

5 System operation

The system is designed to be controlled from an intuitive and friendly environment (these systems will be managed for personal with great experience in the maturation of citric fruits but few computer knowledge).

In the main computer based on Linux operating system the Apache web server has been installed, due to their high reliability, to serve all the information about the installation stored in the main computer to the remote or local authenticated users [7].

The HTTP protocol can be used to access this information [8], in this way the operator can be connected from any computer connected to Internet and even from the modern mobile telephones or PDA's (different versions of the graphical interface exist –some with more graphic power than others– so that it is possible to select the most appropriate in function of the device (PC, PDA, mobile phone, etc.). Also a WAP server was developed to be able to access this information with the mobile telephones that only had this protocol.

Each implemented installation is provided with an IP address, corresponding to the main computer of this installation. When the user access to this page, after to be authenticated and to select the format in which wants to visualize the information, a main page from which has a total access to all the services of the application appears, these services can be divided in two big groups, monitoring and change of operation values.

In this web page the basic information of all the cold stores is visualized (state: reception, conservation, maturation, alarm or stop, temperature, humidity, etc.) being able to select a concrete cold store, in this case the user gain access to all the information about the same one, obtaining the current value of all the cold store variables as well as a historical graph of the evolution that has had each one of them during a selected period of time. Starting from this cold store window, and previous authentication as responsible for the same one, a new window appears from which is possible to change the operation values of the different elements to control in the cold store (fan speed, % ethylene, humidity, etc.).

As it has been indicated in the previous paragraph, two user types exist in this application: an user with permissions to see what is happening in the different cold stores, and another more privileged user that is the only able to change the operation variables, being the responsible for the correct evolution of the process. This has arisen as a detected necessity in our experience in the development of these systems, when seeing that not everybody should have capacity to modify the operation system values given the disastrous repercussions that these changes could have on great quantity of fruit.

6 Conclusions

A control system for the conservation and maturation of citrus has been presented. This innovative system is fruit of the experience of the Polaris Technology S.L company and the Fault Tolerant Systems Group GSTF in applications of these characteristics.

The developed system is a distributed system formed by a hierarchy of networks with the necessary characteristics of flexibility, scalability, dependability and easy installation and operation, also provides a perfect adaptation to the necessities of this type of installations, everything with a competitive price.

This distributed system is vertebrate around two CAN networks, since this industrial network offers the previous characteristics. The nodes are implemented by means of low cost microcontrollers of 8 bits. In the nodes design it has been tried that few types of different nodes exist and each one of them has a predetermined generic operation.

Nowadays several installations of the presented system exist, in which has been able to verify in the practice the correct system operation, their installation and maintenance easiness, as well as the tranquility that this system offers to the installation responsible, since he can know in real time what is happening in his installation, even in a remote way.

References

[1] “A perspective to the design of distributed RealTime Control appplications based on CAN” Torngren, M. Proceedings of the 2th International CAN Conference (ICC’95), pp. 9-2 to 9-11. London, 1995.

[2] CAN specification, Version 2.0 Robert Bosch GmbH, Stuttgart, 1991.

[3] “Microcontroladores Intel MCS51. Arquitectura y Programación” Campelo, J.C., Perles, A., Rodríguez, F. Editorial U.P.V, 2000.

[4] “Printed Circuits Board Design Techniques for EMC Compliance” Montrose, M.I. New York: IEEE Press Series on Electronics Technology, 2000.

[5] “Building secure servers with Linux” Bauer, M.D. Sebastopol, CA: O'Reilly, 2002.

[6] “A guide to developing client/server SQL applications” Chan, A., Khoshafian, S., Wong, A., Wong, H. San Francisco: Morgan Kaufmann, cop., 1992.

[7] “Advanced Linux programming” Mitchell, M., Oldham, J., Samuel, A. Indianapolis: New Riders, 2001.

[8] “Internetworking with TCP/IP” Comer, D.E. Prentice Hall, 1996.

Fault Tolerant Systems Group
Polytechnical University of Valencia
Camino de Vera, S/N
46022 Valencia, Spain
Phone: +34 96 387 7570
Fax: +34 96 387 7579
E-mail: jcapella@disca.upv.es
Website: www.disca.upv.es/gstf

Polaris Technology S.L.
Plaza del Castillo, 8
46380 Cheste (Valencia), Spain
Phone: +34 96 251 2510
Fax: +34 96 251 2510
E-mail: philip@tpolaris.com