4^{th} IFAC International Symposium on Intelligent Components and Instruments for Control Applications

SICICA 2000

A Node, Based on Embedded PC, for Intelligent Distributed Monitoring and Control

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A NODE, BASED ON EMBEDDED PC, FOR INTELLIGENT DISTRIBUTED MONITORING AND CONTROL

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Abstract: The important automation and process control trend towards the use of more powerful distributed monitoring, supervision, and control systems, asks for the development of nodes with augmented performance, including the capability of autonomous, and even intelligent, control operation. This work deals with the design, implementation, and experimental test, of a node that, be means of an embedded PC, can exhibit powerful features. The dynamics of today's economy, favors those that can adapt quickly: so it is needed to have easy to implement, easy to modify monitoring and control systems. The node described in this paper embodies the needed elements for the direct connection of many kinds of sensors, and for a safe digital communication, with other nodes and control center, via modem. With our node, it is easy to build distributed control systems. Object oriented methodology was used to program the node. A set of messages was defined to handle externally the node itself as a object. Some intelligent features were added, in the form of rules and learning capability.

Keywords: distributed control systems, intelligent agent, embedded PC, distributed artificial intelligence

1. INTRODUCTION

Industrial production schemes are evolving and finding a variety of alternatives to be competitive. For instance, production units can be conceived as flexible (open to be redefined in a short time), and allowed to take some (creative) decisions at its particular level. A basis for this promising situation is the availability of a powerful electronic processing technology, that can be used for new distributed instrumentation systems, specially adequate for more performance and flexibility (Kopetz, 1997)..

Quality control is nowadays an important aspect of the production process, and frequently requires a sophisticated sensorial system that, in turn, need the support of a proper processing power.

Usual difficulties to be overcome in the industrial plants, when introducing sensors and computer visualization, are reliability, long distances for signal transmission, and the presence of many sources of trouble for information integrity (electromagnetic interference, noise, mechanical vibrations, etc.) This scenario calls for the use of digital communication techniques (Lewis, 1997).

Distributed systems, based mainly on digital communication, are becoming the main trend to solve industrial automation complexity, because it is a "divide-and-conquer" strategy. Distribution means some degree of responsibility delegation, giving more freedom to the control centre for high-level tasks. That requires a certain capability of the nodes of a distributed system, to be able to assume some autonomy (Koshijima, et al., 1995)..

A fast presence in the market with new products is one of the key factors for competitivity. The production system must be easy to adapt to changes, and that includes the measurement, monitoring and control equipment. The market dynamics dictate also that changes must be fast. Frequently, when a plant wants to change something of electronic and digital processing nature, a problem of technological dependence appears, having to wait for external help. Modular approaches are a way to respond to these need, but should include all the elements to avoid further deployment efforts. As a matter of fact, people without electronic knowledge find problems when new sensors, that require specific interface electronics, must be included in the monitoring system.

From the point of view of technology, the general trend is the use of PCs for everything. There is a specific adaptation of this trend for real-time on-line control purpose, in the form of embedded computers. They are becoming cheap and robust, offering advantages related to an easy programming.

Considering all these aspects, this research deals with the design, building, and experimental test of an easy to implement distributed architecture, based on nodes with an important processing capability, derived from the use of embedded computers. The augmented performance of the nodes are intended for intelligent distributed monitoring and control.

This paper describes the main facets of the node, as described below.

2. HARDWARE FEATURES

There are two fronts that the node has to handle: The interaction with the environment, through sensors and actuators (process interface), and the communication with a control centre

In this work a modular design for the node is made, in order to be able to modify in a simple way the characteristics of the process interface or the communications. In the case of communications, it can easily change from cable to any wireless method. In process interface, it can use different ICs to increase the number of channels or adapt to faster processes (figure 1).

The heart of the node is an embedded PC, This decision has been taken to obtain a powerful basis for intelligent and autonomous behavior, as well for data processing capabilities. An important advantage of having a MS-DOS

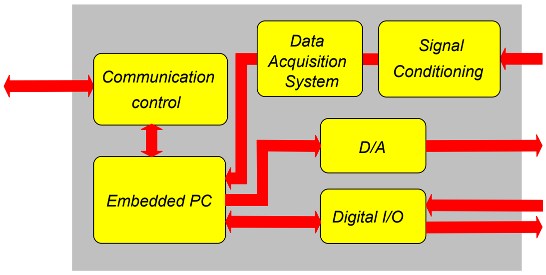

Fig. 1. Block diagram of the node architecture.

system, is that software development can be done in conventional Intel based computers, using will-known environments (for instance, Borland C++). Executable programs can be downloaded to the node for testing purposes and, once attained a satisfactory status, be kept as resident (non-volatile memory).

The data acquisition system handles 8 analog inputs with a precision of 12 bits. It is based on the MAX186 integrated circuit by Maxim (Maxim, 1993). Some features of this IC are: 8 channel single-ended or 4 channel differential inputs, single 5V supply, low power, 133 KHz. sampling rate, internal reference of 4.096 V and 4 wire serial interface. For communication with the data acquisition system, the embedded PC uses 4 lines of one of the parallel ports, controlling the timing by software.

The node has a signal conditioning block with circuits for sensor interface, so the user can connect directly to the node many kinds of measurement elements: for instance PT100 temperature sensors (variable resistance), the traditional 4..20 current loops, voltage in the range of pH sensors (milivolt), and other voltages (including variable gain amplifiers, so it can adapt the signal in a range of 0.5 V to 40 V.).

The D/A block can handle 2 analog output channels, using the MAX352 integrated circuit (Maxim (1994). The chip has the following features: 2x12bit digital-to-analog converter with output amplifiers, serial 3-wire interface, 2.5µs setting time, ±12 V output swing and ±12 V to ±15 V power supply. In the same way that with the A/D converter, 3 lines of the parallel port are used for the D/A.

In addition, the node has 6 digital inputs and 6 digital outputs.

In order to get robustness in the presence of noise, and the possibility of long-distance interconnections, the node has incorporated a modem for the communications with other nodes and the control centre.

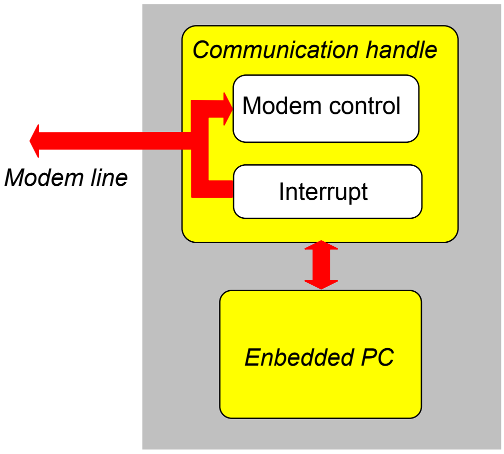

Fig. 2. Block diagram of communication handle

This solution makes simple and fast the cabling tasks (it can use telephony technology), and is open for other transmission media. The node has also the possibility of an extra channel for alarms, in order to provide an urgent way (an interrupt) for handling such cases (figure 2). This extra channel is based on the use of a 22KHz. frequency signal, that do not disturbs the data signals. For the generation of this interrupt signal, the ICL8038 integrated circuit by Harris Semiconductor (Harris, 1996) has been chosen.

3. OBJECT ORIENTED NODE

The Object Oriented methodology promotes a modular approach for software development. In particular, it is a big help for the initial analysis of the problem to be solved, and gives as a result a well structured and easy to understand code.

The node operates according to a resident program, that is organized upon an object oriented taxonomy of classes, in C++. This taxonomy has two levels: a set of classes at the bottom, that handle the process interface electronics and the modem, and an upper set of classes for the functions of the node (for instance, to keep a series of measurements on a buffer) (figure 3). This structure makes easy to change the interface circuits (new technological advances can ask for improvements in further versions of the node), with little effort by the software side.

The classes at the bottom level deal with the initialization of the converters, the reading of the analog and digital input channels, and the writing to the analog and digital output channels. For every channel, an object of the corresponding class has been instantiated.

The methods defined for these classes are very simple (for instance, only to read o write one data in the corresponding channel) in order to make easy any further changes about the ICs employed for the process interface. The methods have been programmed in assembler language.

At the high level a class that controls the whole functionality of the node has been designed, for coordinating the activity of three other classes: one for analog signals, one for digital signals, and the last for alarm management.

The class in charge of analog signals is able to store data in a buffer, to control the sampling rate, and to perform process control functions. For these activities, the class uses the services of three other classes. One is designed to control the output analog channels, remembering the last actualization. The other classes are devoted to PID control, and to any other alternative defined by the user by means of a transfer function.

For the management of alarms, it is designed a class that decides when the node must ask for an interrupt to the central control. This class is also in charge of the learning functionality.

Externally the node acts as an object. The behavior of the node, as governed by the resident program, responds to a set of messages. This set of messages was defined so the monitoring and control center uses it to configure node functions (for instance gain of amplifiers, size of buffers etc.) as a part of the distributed system, and to exchange information (for instance, experimental data obtained by the sensors connected to the node).

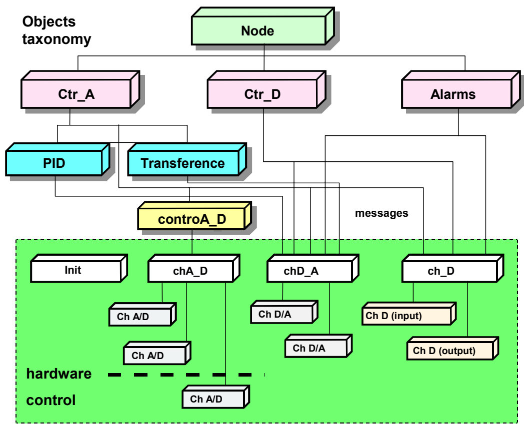

Fig. 3. Objects taxonomy.

4. ADVANCED FUNCTIONAL CHARACTERISTICS

In order to have an autonomous role in the system, the node can operate as an analog controller (PID, or with a transfer function defined by the user), and as a logic controller. During configuration, the user writes the parameters of the controller. Configuration can take place at any time.

As a PID controller, the node can perform this kind of control with respect to a constant reference, to do position control, or with a variable reference, to do speed control (in this case the reference is one of the analog inputs).

The node has some intelligent features, using rules: during the configuration of a node, the user can specify a set of rules, that chain actions to specific characteristics of the measurements obtained in real-time: In this way, the node can generate alarms, when a limit is violated, an fire an specified actions through the outputs.

The node is also able to learn. As the system works, alarms occur: the operator takes the pertinent decisions (actions), the node observe these decisions, and build the corresponding rules with a confidence degree. Rules that are frequently applied in a consistent way, are learned by the node, and assumed by the node as an autonomous behavior (that can be overridden by the user).

With the properties included in the behavior of the node, it is possible to make it work as an agent (this is a matter of further research)

5. CONCLUSION

The node has a small size, with a cost around 300 $, and can handle directly many kinds of sensors. The communications via modem are easy to establish

A prototype consistent of two nodes and a computer has been tested in laboratory. The nodes are connected to the serial port of the computer, using an adapting unit. This distributed system has been used for the monitoring and control of several experimental plants, of electromechanical, chemical and fluid handing nature. The results obtained are satisfactory indeed: the material and programming tasks to implement each solution (for each of the plants) was done easily, in a short time (typically under 2 hours).

Since distributed solutions is a general trend, there are now products with features that converge to some aspects of the system described in the paper. This happens mainly concerning communications through ports of the PC and the use of modular architectures. In particular, such products are becoming popular for data-logging and measurement (for instance, the ADAM modules). The chief difference of our system is based on the use of an embedded PC for each node. Taking advantage of the processing power given by the PC, the node can have autonomous and intelligent functions. By including an interrupt channel on the communications, the coordination of tasks in the distributed system is facilitated. Learning features make the node behave as an intelligent agent, which paves the way for an easy tuning of distributed system applications.

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