SUPPORT SYSTEM FOR SENSORIAL DATA INTEGRATION FOR A ROBOTIC WORKCELL

Jorge M. Dias, Urbano C. Nunes, A. de Almeida
Departamento de Engenharia Electrotecnica
Largo Marques de Pombal, Universidade de Coimbra,
3000 Coimbra, Portugal

ABSTRACT

Sensing information collected and processed by different levels of control as well as sensory planning strategies will be necessary to cooperate in a robotic system to be able to synthesize and execute reliable motions for operations such as grasping, manipulating and assembling parts. Among multiple problems to deal with when attempting to build such a robotic system an important one is related with the establishment of the physical connections, through adequate hardware and software design, to support the integration of the actuators and sensors. In this paper it is described hardware and software components with which it is possible to build hierarchical distributed control implementations. Particularly it is described an implementation which aims to act as a support system for sensorial data integration in a robotized environment.

Our approach consists on the use of a distributed system connecting different subsystems based on different industrial buses which follows an hierarchical model based on a high speed serial network, the BITbus interconnect [1]. The complete system integrates a supervisor controller, acting as the master, and several slave subsystems with distinct responsibilities, namely: real-time image processing, gripper sensing and actuator, conveyor controller and digital I/O system connected to the parallel I/O pins of the PUMA controller. Particularly the real-time image processing unit has a special architecture which is composed by a set of modules working under the control of a VMEbus based computer. In a typical configuration the system uses one module for image acquisition and display and several modules, each one based on a DSP processor, for image processing.

DISTRIBUTED SYSTEM ARCHITECTURE

The control system in use exhibits an hierarchical structure of the form illustrated in figure 1. It is expected that this computational structure would be useful for the following two tasks:

• To support simple automatic assembly applications in real-time. The computational structure should be powerful enough to allow the study of assembly applications with appreciable sensory problems. It should also be flexible enough in order to make easy the study of portions of the complete assembly problem by different people working at the same time. It still should be flexible in order to turn easy different case studies.

• To allow the access of the cel resources from other computational systems working out of the real-time
process at a high level hierarchy. At this level it is expected to investigate rather more complex problems such as: 3-D vision integration; path planning; fine-motion studies; grasp planning; domain modelling, etc.

![Diagram of Sensor-Based Robotic Assembly Cell](image)

Figure 1. Sensor-Based Robotic Assembly Cell Schematic

In order to achieve the first purpose the control system has been implemented following a distributed model based on a high-speed short-message channel and using slaves with a high processing capacity. For the second purpose work is under way to connect the supervisor to a ETHERNET network on which we have SUN 3/60 workstations.

To establish the communications between the supervisor and the distributed outstations it is used a serial network in a bus topology, the BITbus interconnect. This network which may be considered as a Fieltbus approach, although without to fulfil all the requirements of the Fieltbus standard [2,3,4], is physically implemented in hardware through an enhanced version of the 8051 microcontroller (referenced 8044) and in software through a real time multitasking executive. This network exhibits a good acting in handling short messages namely allowing high order rates of information transmission (up to 2.4 Mbits in half-duplex, synchronous mode). This network has enough attributes to lead to attractive solutions for a wide spectrum of local control applications, particularly at the sensor and actuator level. This is due to the above mentioned characteristics as well as its low-cost implementation. Presently the main devices of the assembly cell are:

- A PUMA 560 manipulator.
- A two finger gripper equipped with sensors.
- A conveyor belt equipped with a set of functions (ex: variable speed).
- A rotary table with pneumatic indexing.

Associated with this devices there are several sensors and actuators which in the case of the conveyor belt are the brake and the motor speed control, sensors to monitor the motor speed and miniature optical devices to detect objects on the conveyor.

The gripper is pneumatically controlled by using a pneumatic servovalve which allows continuous variation of the force applied to the handling objects. It is equipped with an optical sensor to detect the presence of objects between the fingers and proximity sensors (ultrasonic ranging and optical proximity sensors) to help in the execution of fine motions.

At the moment a piezoresistive tactile sensor is being added with which it is expected to overcome some difficulties in handling objects by getting information about the object position in the fingers.

The sensorial system of the cell still comprises vision for which it was designed special hardware to support near real-time image processing.

VISION SYSTEM

For image processing and analysis it is used a VMEbus-based system implemented in our laboratory [5]. The system is based on digital signal processors (DSP's) TMS32025 and takes a SIMD (Single Instruction Multiple Data) configuration by using several modules with a DSP in each of them. The data corresponding to the images are distributed in each one of the modules. The distribution of the data by the different image processing modules is done by an image acquisition and display board which controls a video bus implemented in the P2 slot of the VMEbus. This module can receive a signal through one of four cameras. It has a capacity for acquiring 512×512 samples of 8 bits of a CCIR video signal and a local storage capacity for two frames as well.

A BITbus controller board for VMEbus systems was implemented which allows the use of the vision system in
a BITbus architecture. The functional structure of the VMEbus-BITbus board is shown in figure 2.

![Block Diagram of the VMEbus-BITbus Board](image)

**Figure 2.** Block Diagram of the VMEbus-BITbus Board.

The board supports transmission speeds rated for 62.5 Kbits/s or 375 Kbits/s for asynchronous operations and up to 2.4 Mbits/s for synchronous mode. For synchronous mode the speed achieved depends on a value of a crystal installed on the board. Three 26-pin sites provide the board with user memory. Each one of the sites is selectable for data or application code and the address spaces for each one of the memory sites is selectable as well. Two 16-deep FIFOs provide the bidirectional path for the parallel data transfer between the board and the VMEbus. Each FIFO has 16-bits width to enable both single and double-byte block transfers. Associated with each FIFO there is one status register with up-to-date information necessary to the control of the data transfers. The board is able to handling either polling or interrupt mode transfers.

All the boards described are slave for the VMEbus and work under the control of a VME-host computer.

**GRIPPER ACTUATOR AND SENSING UNIT**

In this task the hardware in use is a VMEbus system. It comprises a master CPU board where all the processing is done, an acquisition and actuator slave board and a communication BITbus slave board. The system should be able to integrate all the information gathered from the gripper sensors in order to obtain suitable descriptions which will be useful during the execution of fine motions.

**MIUC SYSTEM**

The conveyor actuator and sensing unit as well as the digital I/O (see figure 1) are MIUC (Industrial Microcontroller of the University of Coimbra) based systems.

The digital I/O unit is connected to the I/O pins of the PUMA controller and aims at enabling an efficient use of part of the capacities of the PUMA controller. This unit knows at any time the state of all the I/O lines allowing the supervisor to monitor and to act on them. Some of the input lines were reserved to be connected to ON/OFF sensors and the remainder to be directly activated by software. Therefore, the use of the powerful REACTI instruction at the PUMA controller might be more efficiently and easily handled at the supervisor level.

The MIUC is a modular system designed around the MOS51 family of microcontrollers which aims at enabling simple control and local processing at the actuator and sensor level. The most relevant characteristics of the MIUC system are the capacity to compose a BITbus station and the ability to support a multitasking environment.

A set of boards corresponding to a variety of functions has been implemented around the MIUC parallel-bus with which is possible to accomplish diverse control and monitoring applications. It has been developed boards for: analog acquisition and actuation; motor control (DC, DC brushless and step motors); power interfaces; PWM actuators; signal conditioning, etc).

All the programs to run on these BITbus stations are compiled on the supervisor and downloaded through the BITbus channel.

**SUPERVISOR SYSTEM**

The supervisor system is set up by an IBM 386 equipped with a board dedicated to BITBUS communications and another for ETHERNET network.

**SOFTWARE CONSIDERATIONS**

The support software of the cell control distributed system is described in a simplified way by the diagram of the
figure 3 about which it can be outlined the following functional layers:

- Physical link which follows the RS485 standard.
- Data link which implements a subset of the SDLC protocol.
- Transaction layer which defines a message format that ensures the transparency in the exchange of information between the master and slave tasks.
- Cell application support layer which implements several procedures to allow the interaction of the cell actions distributed through the cell subsystems.
- Application layer

The first three layers follows the BITbus specifications. The cell application support layer aims to perform the interface between the user programs and the distributed cell resources. At the user point of view this layer appears as a set of procedures which allow him to know the state of the cell and to unchain remote cell actions in a transparent way (without knowledge of the physical configuration of the cell). For that the procedures make use of a database with information about either the physical configuration of the cell or dynamic cell status information. The set of available commands assume diverse levels of complexity which may be a simple examination of the state of an ON/OFF sensor or a command to unchain a MOVE operation by the PUMA but executed under sensorial interaction.

The cell configuration parameters are introduced interactively through an installing program. The information to be supplied by the user is of the following type:

- Name (Name of the sensor or actuator);
- Type (sensor or actuator);
- Node address (Physical address of the processing slave station);
- Is an extension (yes/no)?
- Number of the task;
- Type of the frame reference (Dynamic or static);
- Frame relating to (Name);
- Values of the components of the frame;

CONCLUSION

A distributed system has been described which aims to support the sensorial integration in a robotic environment. A BITbus architecture was chosen exploiting its features of low-cost, easy implementation and good performance in short message transfers. In another way it was used the potentialities of the VMEbus at the slave nodes which should achieve a high processing capacity.

REFERENCES

1. Intel Corporation, "The BITbus interconnect serial control bus specification", in Distributed Control Modules Databook, pp.100-147, 1984.


