MULTIPROCESSOR ROBOT CONTROLLER
An Experimental Robot Controller for Force-Torque Control Tasks

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Abstract: There is ongoing research and development in the field of hybrid position and force control of the assembly robots at the Department of Automation and Applied Informatics and the Department of Control Engineering and Information Technology, Budapest University of Technology and Economics. As result, an Experimental Robot Controller was built for the special needs of the project. Both the hardware and the software system of the controller are under continuous development. The most recent achievement is, a built in six-component force-torque sensor. The development of the software system is currently dealing with the extension of the programming environment with force-torque control possibilities. There are numerous industrial applications for force and torque control (i.e. screw driver, welder), but a flexible equipment can provide much more than just the possibility of solving a single task. This paper presents an overview of the robot controller hardware, separately detailing the force-torque sensor interface. The second part of this paper overviews the software system of the controller and the possibilities of its extensions for force control tasks.

1 INTRODUCTION

A few years ago an extended research and development project started in the field of robot control. In the project the Department of Automation and Applied Informatics and the Department of Control Engineering and Information Technologies are taking part at the Budapest University and Economics. The hardware development is continuously focusing on the Experimental Robot Controller. This is a multiprocessor control system for a NOKIA PUMA 560 manipulator. The connected power electronics and some extension cards to the central PC-based control computer were developed, supporting the research of the modern robot control algorithms. The paper first introduces the hardware architecture of the control computer In the later part the software system of the Experimental Robot Controller is shown. The distributed software system and the possibilities of the communication are introduced in the complex robot controller plant. Finally the directions of further research and development are overviewed.

2 THE EXPERIMENTAL ROBOT CONTROLLER PLANT

The research and development project was started from a quite old robot system. The manipulator was the PUMA 560 type, made by the former Nokia Robotics, the controller was made in Russia, called SZFERA-36. Its manipulator was kept, an approximately 30 year old system, and all other parts were changed. The aim was to build a low-cost control system that must agree with the following requirements: modular architecture, extensibility, easy system development possibilities, and interfacing capabilities with different sensor subsystems. The software side of the development required much of the same: open system architecture, the usability of standard development tools and techniques, and the possibility of building a configurable, modular system.

The PUMA 560 manipulator is a six-joint human arm like device. This robot arm has a widely spread, general configuration, additionally it is a very well constructed manipulator and, since the project does

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not deal with the mechanical aspects of the robot manipulators, this device was chosen.

The first task was to develop the power electronics that can connect the manipulator and the controller system. A six channel servo amplifier was build, especially optimized for precise DC drives. This part receives the ±5V reference signals from the central controller and provides the ±30V control signals for every joint. These hardware controllers are very fast, no time gap between the signals from the central controller and to the drives of the manipulator is assumed.

2.1 The Advanced Robot Controller Cards

In parallel with the power electronics, another hardware development has started. The architecture of the IBM PC was chosen for the central control computer and Gabor Tevesz has started to build a general purpose robot (DC servo) controller card. This PC extension card is called Advanced Robot Controller card. The block scheme of this card is shown in Figure 1.

One ARC card is capable of controlling four joints. In the Experimental Robot Controller there are two ARCs, each responsible only for three joints. Since the hardware build up of the manipulator provides an Euler configuration wrist, the partitioning of the first and second three joint provides further possibility of creating a simpler control software system.

Starting from the power electronics side, every ARC cards contains a Texas Instruments TMS320C31 digital signal processor with four whole featured interfaces controlling electronic drives. Together with its interfaces, the high speed CMOS 32-bit floating point processor has the following capabilities: taking the position signals and calculating the speed and acceleration of the corresponding joints; performing calibration and credibility checks using null impulses; supervising the position, speed and acceleration limits; producing the set point values for the servo amplifiers; providing synchronous movement between the joints controlled by a stand alone or by more ARC cards. The 16 MIPS and 32 MFLOPS processor has high speed static RAM for the best possible performance. This processor, using the pre-programmed boot loader, can boot from the FLASH memory or from the dual port RAM. The second method can be well used for development and test. Additionally to the drive interfaces, there is a three-wire synchronization channel built in. With the help of this feature more ARC cards are capable of acting together and coordinating multi drive systems.

The next part of the ARC card is the so called pre-processing unit. It is based on an Intel 80386EX microprocessor. This embedded processor is fully compatible with the PC environment and has a lot of integrated peripherals supporting the rich functionality. This unit can boot from the attached FLASH memory and connected to the signal processor via dual port RAM. On the other side, the communication between the host computer and the pre-processing unit goes through the ISA bus and the dual port RAM. In both directions the handling of the RAM is fully interrupt driven, in order to reach the highest possible performance. The interface could be converted into PCI for even higher speed, but it would require the complete redesign of this extension card. However, the ISA bus interface is the slowest connection in the chain, it provides enough communication bandwidth for very complex control tasks.

The central part of the robot controller is the full featured personal computer. Since the ISA bus interface is required by the ARC cards, the host CPU is an Intel Celeron 633MHz processor.

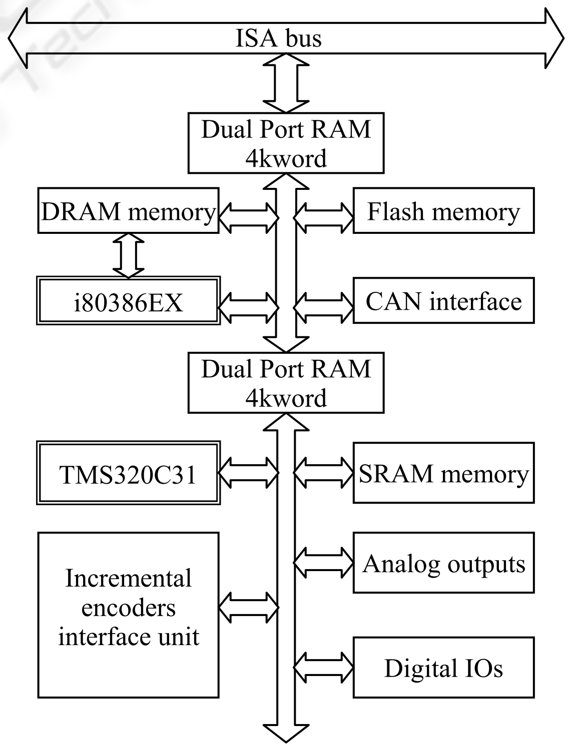

Figure 1: The block scheme of the ARC cards.

2.2 The Force Torque Sensor Interface Card

The most recent hardware addition to the Experimental Robot Controller is the six-component force torque sensor. The sensor head is built between the last joint of the robot and the end effecter. The sensor is directly connected to its electronics, the so called MiniForce unit. The tasks of this unit are to receive the signals from the strain gages, perform decomposition and produce the results of the measurement. There is a metal cage in the sensor head and the voltage of multiple gages is measured in order to provide the three components force and torque. The MiniForce unit is attached to the base of the manipulator. It contains the controlling electronics of the sensor head and it performs the analogue-digital conversion, digital signal filtering and matrix compensation, eliminating the crosstalk effects. In this configuration the effects of the electrical noises are the minimal, in the measurement system as well.

The MiniForce unit is connected through an RS422 differential line to the force torque sensor interface card. This is a PCI bus extension card directly built in the central control computer (Hankó, 2004). This unit contains one additional (to the ARC cards) Texas Instruments TMS320C32 digital signal processor. The block scheme of this extension card is shown in Figure 2. An additional CAN interface is implemented on the sensor interface card in order to provide fast and direct communication with the ARC cards. This channel provides fast and direct connection, avoiding the additional load on the host processor (the Intel Celeron processor working on the motherboard). This communication has limited bandwidth, but it is enough for exchanging the most important data.

3 THE SOFTWARE SYSTEM

In this section the whole software system of this multiprocessor control system is presented. Starting from the manipulator side, in the first line there are the digital signal processors (DSPs).

3.1 The Software of the Extension Cards

The manufacturer of this processor provides assembler, optimizing ANSI C compiler and linker for these devices. Every DSP environment is capable to start automatically from the provided FLASH memory. During the software development and test phase the DSPs can be started from the connected dual port RAMs by the host processor in the case of the sensor interface card or by the communication processor in the case of the ARC cards. This dual boot functionality is supported by the boot loader integrated in the processor and can be configured by jumpers on the corresponding extension card.

The next operational unit is the communication processor with its environment on the ARC cards. In the current version the i80386EX processors perform only data relay between the host processor and the joint processors (the DSPs on the ARC cards). The necessary computational power is provided by the other parts of the system. As mentioned above, the host system runs QNX operating system and there is ongoing development for embedding the QNX into the communication processors. In order to embed the QNX operating system, some additional BIOS functionality must be implemented. These are required for initializing the environment and starting the Initial Program Loader (IPL). The duty of IPL is to load the compressed operating system image, decompressing it in the memory, switching into protected mode and starting the QNX. With the help of this environment there will be hopefully more resources available, while the efficiency of the communication can be maintained.

3.2 The Software of the Central Control Computer

The host computer is a full featured workstation. Since the early times of this research and development project the QNX operating system is used on the central computer. This operating system is a real-time Unix-like one, developed especially

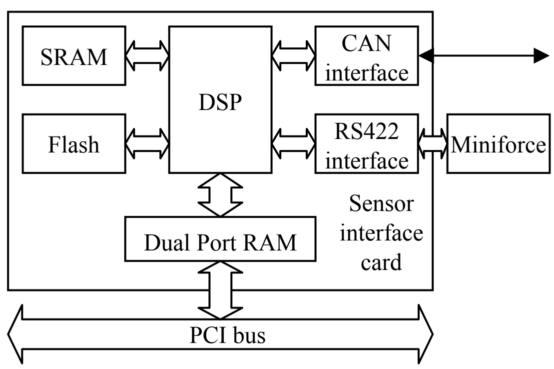

Figure 2: The force-torque sensor interface card.

for time critical process control task. The previous version (QNX v4) contained a lot of special features focusing on the primary aim, the very good real-time performance. In those times the robot control software system was very complex, containing more than ten separate, but heavily communicating processes.

Recently the whole software system was ported under the new version of the operating system, the so called QNX Neutrino. This is the 6th version (the 5th was omitted by the developer) and the whole software suite is called QNX Momentics. It contains not only the core operating system and numerous supporting utilities, but a graphical user interface (GUI) called Photon and a full featured development environment as well.

Both versions of the operating system have microkernel based architecture. The small central kernel provides only the most important services such as pre-emptive scheduling, status handling and the basic communication services. A whole desktop environment is slower in a microkernel architecture system, but the system builders and software developers have the ability to build a reduced, efficient, very fast environment. This aim is supported by the modularity and the fine tuneable scheduling mechanism. The most important change between the mentioned versions is that the process based scheduling changed to a thread based one. Another significant change is made in the philosophy, and instead of using vendor specific methods, the solutions according to the POSIX standard are implemented.

Following the evolution, the whole robot control software was rewritten last year according to the new operating system version. The process structure of the new robot control software is shown in Figure 3. The original robot plant used the Advanced Robot Programming System (ARPS) as the robot programming language. This environment was implemented using the own developed robot controller as well. Since the scheduling is now based on the threads instead of processes, the structure is quite simple. The last process, the one responsible for MiniForce communication, is the most recent software development. It was written and fitted in a few months later than the software relocation took place.

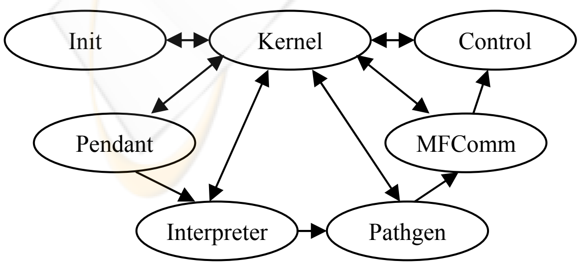

Figure 3: The process structure.

The participants of this research and development project at the Department of Automation and Applied Informatics have important achievements. The most important outcome is the integration of the sensor system and the start of the software implementation of various methods based on the capabilities of the hardware. However, there is a lot of work to be done in the field of modern robot control systems.

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REFERENCES

Tevesz, G., Bézi, I. And Oláh, I., 1997. A Low-cost Robot Controller and its Software Problems. In *Periodica Polytechnica Ser. El. Eng.* Vol. 41, No. 3., pp. 239-249

Hankó, T., 2004. Hatkomponensű erő-nyomatékérzékelő illesztése PCI buszra. (A PCI bus interface for six component force torque sensor.) Diploma work, in Hungarian, Department of Automation and Applied Informatics, Budapest University of Technology and Economics

Oláh, I., Tevesz, G., 2002. Software Problems of an Experimental Robot Controller Based on QNX Real-Time Operating System. In *Periodica Polytechnica Ser. El. Eng.* Vol. 46, No. 3-4., pp. 151-161

Oláh, I., Tevesz, G., 2005. An Experimental Robot Controller for Force-Torque Control Tasks. *The International Journal of INGENIUM 2005 (4) – Engineering Achievements Across the Global Village,* edited by Janusz SZPYTKO, Cracow-Glasgow-Radom, pp. 477-484