IST-2001-37652

Hard Real-time CORBA

Title

D3.3
Robot Control Testbed
Procurement

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Partners

Universidad Politécnica de Madrid
Lunds Tekniska Högskola
Technische Universität Wien
SCILabs Ingenieros

Summary Sheet

IST Project 2001-37652
HRTC
Hard Real-time CORBA

D3.3

Robot Control Testbed

Procurement

Abstract:

The Robot Control Testbed (RCT) has been designed to permit experiments concerning Hard Real-Time CORBA (HRTC), based on earlier experiences and equipment that has been made available from complementary projects. The more expensive parts, such as the mechanics and the drive electronics, is therefore available to no cost. The contributions of the HRTC project to the RCT in terms of durable equipment has been:

- Host computers for design, development, and evaluation.
- PC hardware for soft real-time high-level control.
- Portable computer for portable virtual testbed.
- Embedded computer boards.

Some sensors and adapter boards have been tailored by supplying companies according to the needs of the RCT, but the resulting hardware items have been available so late in the project that very little of the cost is charged the project.

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Release Sheet (1)

Release:	**0.1 Draft**
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Scope	Initial version
Sheets	All

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1 Introduction

The designed testbed is based on the robot systems made available to the project. The primary system to be used here is the one including an ABB IRB2000 manipulator, which has been completely reconfigured to permit control experiments. That is, the original control computers have been removed, hardware interfaces have been added, and our control computers have been connected. This forms a completely open controller, including servo control down to the torque control of AC motors, which requires several kHz sampling frequency for each of the six joints.

An earlier and original form of the system was based on M68k and DSP processors on a VME bus, and with synchronous RS422 communication with statically scheduled traffic to fulfil hard real-time requirements. An intermediate stage of development is to use PowerPC boards on the VME-bus. This was selected as the first safe implementation approach, using the computer boards according to item x[§].

A more promising design for the future is to use the PCI bus, because

1. That bus I getting the most common with more types of hardware available and to a lower cost.
2. The ABB (and most other brands) sold today are using the PCI bus, as for the newer Irb-2400 that is also available in our laboratories.
3. The PCI bus provides more flexible configuration, with plug-and-play support in hardware, which is attractive from a flexible real-time systems point of view.
4. The PCI bus in an electric and logic sense is also available in the mechanical PMC (PCI Mezzanine Card) form. According to unpublished information we have access to, future distributed hard real-time systems robotics products will provide PMC connectors for augmented distributed IO and processing. For ease of upgrading to future systems, PMC-based cards are preferred, assuming that PCI carrier boards are available.

From these aspects, and from observations of what is available on the hardware market, it was concluded that PMC PPC computers are preferred. The PPC-type of processors is simpler than the Intel-type when it comes to low-level programming, and also when it comes to interrupt latencies etc., the PPC is clearly preferable for high-end embedded processors. For host computers the situation is different, performance and availability of software are in favour to the Intel-based hardware.

[§] Item numbers refer to the table in Section 4: Summary of durables.

2 Overview

The physical robot, here represented by the newer Irb-2400/S4C+ system, is connected to control computers and external sensors as depicted in Figure 1.

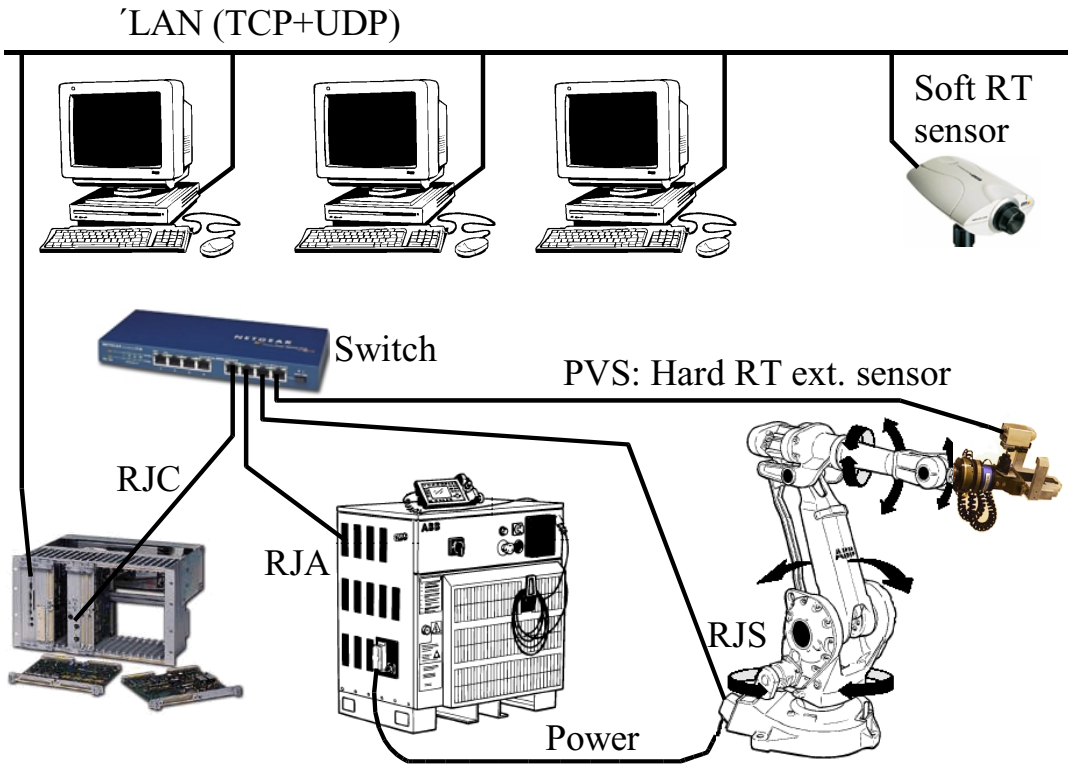

Figure 1 Robot control nodes according to the RCT design.

This in principle also applies to the Irb-2000 system, which according to the RCT Design includes the following distributed nodes:

- **Robot Joint Sensing (RJS) computer with sensor electronics.** Objects provide readings of the robot joint angles.
- **Robot Joint Control (RJC) computer with multiprocessor backplane.** Multiple CPUs that interact via shared memory over a VME or PCI bus.
- **Robot Joint Actuation (RJA) computer with drive power electronics.** Requested torque is accomplished by controlling the motor currents.
- **Process Value Sensing (PVS) node, optional, providing local HRT IO.** Force or vision sensors are typical examples.

In addition, there are host PCs used for high-level control. Details about the hardware selection now follows.

3 Equipment

The different types of testbed units will now be described technically. A summary including costs for the durables that are charged this project will then be given in the next section.

3.1 Robots

The robot of primary interest is the Irb-2000, which we have full freedom to control and to configure as needed (item 1). With the availability of the PCI-based solution, we also have the option of using the more modern Irb-2400 (item 2), which then contains the original ABB software and therefore illustrates how HRTC interfacing with legacy-controlled machines can be done. End-effectors and additional sensors (like force-torque) are also available, item 3.

3.2 Communication

Fast Ethernet was selected for the communication. For the built-in hard real-time communication this means scheduled raw Ethernet, which we accomplish by the ordinary switches according to item 4.

3.3 Robot Joint Control

For embedded hard real-time and predictable computing, the PPC is clearly preferable due to its shorter interrupt latencies. It also has a cleaner architecture and according to our experience it is also easier to work with when it comes to assembly-level debugging and device-driver development. PPC/VME-boards are available according to item 5, whereas the more powerful PPC-G4 boards that also can be used for the Irb-2400 is listed as items 6-8. Those items include the carrier boards that connect the PMC connectors to the PCI bus.

3.4 Sensor and Actuator Devices

We found the Axis ETRAX to be an appropriate special purpose processor, since it both facilitates interfacing to sensors and drives as described in the design specification, and is part of the video cameras that we intend to use for the visual feedback. The ports of the ETRAX are connected to the ABB hardware via simple interfaces that have been built to practically no hardware cost. We use the so-called developer board (100LX according to item 9) directly in the testbed. Communication is according to section 3.1

3.5 Video cameras

The Axis camera 2110 (item 10) is currently available to the project, while the next generation of cameras that permit synchronized frame grabbing for stereo vision remains to be delivered. The cost, if any, will be charged other activities.

3.6 Host computers

The host PC needed in the physical testbed, items 12 and 13, are preferably Linux-based, but for various software availability reasons we also need one

with Windows. That machine and one of the Linux ones were equipped with good 2D+3D graphics cards for appropriate visualization of motions and models.

3.7 Virtual testbed

The virtual testbed requires development and simulation tools and computers, which can be shared with the development of the physical testbed. Additionally, a portable computer is needed to make demonstration of the virtual testbed portable. An IBM with ATI-based 3D-graphics support was selected (item 11).

4 Summary of durables

The Value column contains the real or estimated value in kSEK per item. The Cost column is what amount is charged the HRTC project, in SEK for all items (if several) together.

	Description	Value	Qty	Cost
1	Irb-2000 robot with S3 reconfigured control system	200	1	0
2	Irb-2400 / S4C+ robot system	250	1	0
3	End-effectors and additional sensors	140	1	0
4	Fast Ethernet switch, Netgear FS108	0.5	2	0
5	PPC / VME, Motorola MVE2400 / 2600	20	3	0
6	PPC-G4 card; Motorola PrPMC800-1251	17.5	2	35
7	PCI / PMC	12.5	2	25
8	Multifunction digital and analog IO: PMC730	16	2	32
9	Axis ETRAX 100LX development board	3	3	0
10	Axis2110 camera (two of next generation ordered)	5	1(2)	0
11	IBM ThinkPad T30	27		27
12	Windows-based testbed host, PC P4 with ATI9700	17	1	17
13	Linux-based PCs, P4, one with Matrox Parhelia	25.5	2	51
Sum	All items:	>600	21	187

With 9.2SEK = 1EUR this results in a cost of 20300EUR, but since it is durables, which also have had to be bought late during the project, the actual costs charged the project will be well under budget.