Technical Framework for Robot Platforms in Education

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ABSTRACT: *Robotics is an interdisciplinary area involving many disciplines taught at higher education institutions. Therefore, robots offer an excellent tool for innovative teaching of a number of different engineering subjects. To apply robots in such a variety of subjects and different scenarios, the employed platforms have to meet a number of technical as well as educational requirements such as flexibility, modularity, scalability and ease of use.*

This paper describes our new educational robotics framework and how we meet the technical challenges posed in such a scenario. Modular components form a robotics kit to build flexible platforms tailored to teaching and research.

1 INTRODUCTION

As robotics is an interdisciplinary topic involving components from mechanical, electrical, control, and computer engineering, it offers an excellent basis for teaching a number of different engineering disciplines and their integration into systems. Robots provide an interesting vehicle for demonstration of basic engineering problems, and practical exercises in student projects help to develop skills like creativity, teamwork, designing and problem solving. Experiences with courses utilizing robots have been reported, for example, on Artificial Intelligence [1], software engineering projects [2], genetic programming and hardware based vision [3], data structures courses [4]. To accomplish such courses and projects involving robots, universities need platforms which are flexible and modular, yet powerful, so they can be easily customized to the requirements of different subjects.

There are several software platforms established already in the embedded and robotics world. On the embedded side, there are some small distributions available (e.g. Linux VR [5] or ElinOS [6]), but often these distributions are too specialized for a particular platform, or they are commercial solutions, reducing the flexibility needed in an educational environment. On the robotics side, there is for example the Orocos [7] system, which is a CORBA-inspired approach of a large selection of open source software for robotics related control tasks. As it is based on standard Linux desktop distributions, it is difficult for Orocos to meet embedded demands like economical use of all system resources.

The combination of the scalable processing box (SPB) and the Linux real-time environment (LiRE) developed at the L3S in Hanover [8], is designed as a Linux based open-source system, to fill the gap between a free software approach and high performance embedded computing. Besides the focus on the requirements in research and education [9], a main aspect in the creation of this system was to fulfill robotic demands. In particular, it addresses real-time requirements which are an important issue in embedded robotic systems. Especially in the field of autonomous service robotics where sensors and actuators are controlled by a network of several processing units (physical as well as logical units), real-time mechanisms are strongly demanded.

2 THE SPB AND LIRE

The SPB is a standardized, scalable, modular and easily combinable processing unit for applications in educational robotics. It provides the basic infrastructure to run software on several robotic platforms for research and education. Two main aspects took place in the development process of the SPB:

- design of the hardware modules
- development of a software architecture

The SPB is designed for Intel Pentium hardware environments with a small footprint (see Fig. 1). As this is a standard industrial approach a good availability and standardization of all components is ensured. A common set of interfaces is included in the design. Simple sensors and actuators can be connected via serial interfaces, for a more complex communication with real-time aspects a CAN interface is included and Ethernet connections are available for high bandwidth. The USB-port is available for any kind of minor data exchange. Administration can be done by connecting keyboard and VGA-monitor or via remote connection.

Fig. 1 SPB Prototypes

As the system is deployed within an educational and research context, there is the situation of multiple users working with one hardware platform (e.g. several groups of students working on one robotic systems with different tasks). This brings the problem of people interfering with each others software. To keep these problems as small as possible a compact flash card is used as boot and storage media for the SPB. Each group of users now can have their own CF-card with their own environment. To switch a robotic system from one working task to another only these cards need to be changed.

The software architecture for the SPB is based on an embedded Linux distribution named LiRE (**Li**nux **R**eal-time **E**nvironment). It was developed as part of the MoRob-project [10] at the L3S. To satisfy the real-time requirements in the subject of robotics the Linux Real-Time Application Interface RTAI [11] is included. The Installation of LiRE is kept as simple as possible. A suitable kernel and tools for the Linux environment are available as pre-compiled packages. To get a system up and running, there is a set of interactive installation scripts to configure, select, and install what is required. To handle these scripts, only normal UNIX user knowledge is necessary. As the system is totally build of *open source* software, all source code for the used programs, RTAI and the kernel are available on the internet. Therefore, the system can be setup and enhanced step by step according to special user demands in a later stage.

The software development for applications running in this environment can comfortably take place in a standard desktop Linux environment. For easy access to the system the embedded web server monkey [12] and a secure shell daemon [12] are included. The multi binary embedded tools *busybox* [12] and *tinylogin* [12] are taking care of a familiar non-graphical Linux behavior of the system.

For the handling of complex applications with strict timing constrains RTAI is used. Especially the fusion of data coming from different sensors or control algorithms of a robot are requiring a very precise real-time behavior of the system.

3 THE MOROB KIT

Modular components form a robotics kit to build flexible platforms tailored to teaching and research (see Fig. 2). The kit combines a number of advantages found in different commercial platforms. The mechanical setup is easily customizable to the requirements of the users (like Lego, but much more robust). To equip robots individually, the kit includes a selection of components, e.g. servo drives and sensor modules like odometry, laser scanner, ultrasound, inertial sensors, etc. Individual components (aluminium profiles, sensors, actuators, controllers) can be complemented to obtain reasonable kits which can be used in a variety of courses and lab exercises.

Fig. 2 The Morob Kit

4 APPLICATION EXAMPLES

First prototypes of the SPB were built at the *Institute for Systems Engineering - **R**eal **T**ime **S**ystems Group (RTS)* [13] in Hanover. Six boxes were assembled in two different configurations. A small configuration based on a PC104 board with a 266 MHz Processor and a large configuration with an EBX board running on 700 MHz (see Fig. 1).

The MoRob Kit becomes the technical base in research and educational project at the RTS and L3S. Stability, versatility and robustness in mechanics and software ensure a flexible design for a wide range of different application. The first Robot built by students (see Fig. 3) is a very agile vehicle. To navigate and for collision avoidance it is equipped with state of the art laser scanners.

The research in the area of 3D laser scanning [14] [15] at the RTS also benefits from the construction of the SPB and the MoRob kit. The LiRE running on the SPB is used as a flexible operating system in the development of a complex 3D laser sensor. The real-time processing and communication abilities enables a powerful preprocessing and distribution of the acquired data of the laser scanner. Flexibility of the MoRob Kit allows students and researchers to investigate different mechanical setups in 3D laser scanning. One possible setup it to rotate a 2D laser scanner to get 3D information, another setup can be a fixed 2D scanner and a continuous moving object to be scanned (see Fig. 4 for both setups in a showcase for Hanover Industrial Fair 2004).

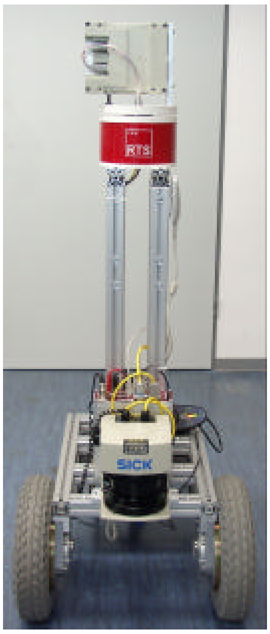

Fig. 3. A Robot built by Students

Fig. 4 3D laser scanning (HMI'04 Showcase)

5 SUMMARY AND OUTLOOK

This paper described the combination of the SPB and the MoRob Kit as a technical base for robotics in research and education. The SPB is designed from industrial standard hardware powered by the free embedded Linux distribution LiRE. It gives a flexible platform to perform research projects in the field of mobile robotics with high demands to the abilities of the processing system. For education purposes it enables students to develop powerful complex systems with their own mechanical and software design.

To keep the processing power of this modular system growing, a real-time Ethernet approach called RTnet [16] can be included. Because this provides high bandwidth and hard real-time communication within a distributed system, it enables the combination of several SPBs in a larger overall system for a more powerful processing structure. This also allows a set of different SPBs to be rearranged for different tasks. If a number of boxes is available, they can be used as single processing units for smaller student projects or it is possible to combine them for larger research jobs.

As everything is based on open source software and standardized hardware components, this approach invites students and researchers to set up their own SPBs and MoRob kits. This will keep the whole system growing and improving.

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