

RCUBE

A Platform for Intelligent Autonomous Systems

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Abstract—An intelligent robot platform for autonomous systems with vision capabilities has been developed by the University of Applied Sciences Brandenburg in cooperation with SME's. The system will be suitable as a research and education platform for universities, a basis for industrial applications and for private developers of robots. This paper presents an architecture overview and application details of the RCUBE system.

RCUBE will be available in 2 modular versions:

1. a cost-effective platform for reactive robots and private developers
2. a performant platform for intelligent robots with image processing capabilities suitable for research, development and education in the field of service robotics (Fig.1).

The system consists of 3 ready-to-program hardware modules with a basic software layer. They can be combined in different configurations. The modularity provides the flexibility to configure an RCUBE system for different application areas, but also single modules can be used in applications such as autonomous intelligent cameras or planning robots (e.g. lawnmower, vacuum cleaner). A key feature is the capability to autonomous image processing combined with sensors and actors, small size and low power consumption. RCUBE opens the way to small independent seeing robots.

1 Problem description

Small autonomous systems, especially mobile robots are a growing application area of intelligent systems. The economic commission of the UNO forecasts a boom concerning professional service robots (for instance for medical, cleaning, security purposes) and private service robots (domestic and entertainment robots) till 2005 [4]. Until now it was not possible for researchers, pupils, students and hobbyists to use a system, which is

- flexible,
- adaptable to an application case,
- easy to program and
- cost-effective,

because none existed.

For reasons of cost, time and capacity small enterprises and universities normally use widely spread basic blocks of microcontrollers (such as Basic Stamp, Handyboard, C-Control), which are not suitable for real robotic applications including manifold sensor equipment (Table 1). The main problems are to be found in the limited possibilities for connecting sensors and actors, but also performance and power consumption don't meet the needs of small and middle size autonomous systems. The building of autonomous systems turns out to be either very time-consuming or, in the case of complete solutions, very expensive. Most of the systems successfully established on the market have been developed by universities and then hived off as a product (see Eyebot, Handyboard, RCX, Real Robots).

Another drawback of the current situation for small robots is the lack of an autonomous image recognition capability. Image recognition is realized on mobile robots either via radio linked hardware or by using relatively power consuming components.

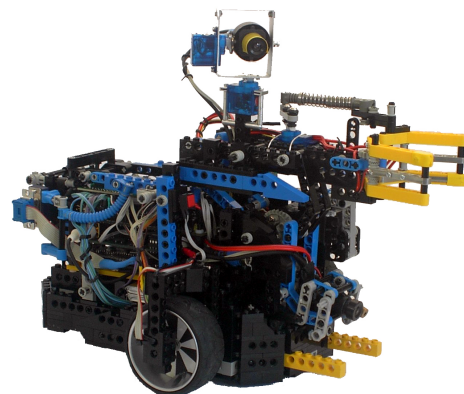


Fig.1: RCUBE robot with vision capabilities

Table 1: overview of controlling parts for reactive robots (incomplete)

system	source	sensors	actors	costs ¹	time ²
Eyebot	JokerRobotics	many	many	700	3
6.270-Board ³	self assembly	many	many	600	3
Handyboard ³	self assembly	few	many	600	3
C-Control	Conrad electr.	few	very limited	450	3
Basic-Stamp	Parallax	few	very limited	350	2
RCX	LEGO	very limited	few	260	1
Mobile-Robot	Fischertechnik	very limited	very limited	300	1
Real Robots	EagleMoss	few	very limited	200	1

2 Project

These problems and our engagement in intelligent robotics ([1], [3]) since 1996 lead the authors to the development of a modular core architecture. The project aims required the interdisciplinary cooperation of specialists from various fields, such as mechatronics, electrical engineering, artificial intelligence and computer engineering. The project "Initiative Intelligent Autonomous Systems" is supported by the "Ministerium für Wissenschaft und Kultur des Landes Brandenburg" (MWFK, Germany). The (technical) requirements to a suitable robot core were identified as follows:

- image recognition onboard
- small and modular
- low power consumption
- enough performance for running algorithms in the field of machine learning
- many ports for digital and analog sensors
- many ports for actors, such as servos, motors
- program persistence
- independent from any radio links
- software open source
- cost effective

3 Project results

In the project IIAS from 2001 till 2003 the needed hardware and basic software parts have been developed. First results were demonstrated at CeBIT 2002 [2]. The current project stage (June 2003) is fine tuning of the libraries and construction of a sample application system for demonstrating the key features of the architecture.

The architecture RCUBE consists of three modules:

- CPU board
- VIO board (Video input/output unit)
- AKSEN board (Actor/sensor unit)

which are combinable in any number and connected over a field bus with 1 MBit bandwidth. The modularity leads to interesting configuration possibilities (Fig.2) and application fields other than mobile robots.

3.1 CPU board

The CPU Board plays the role of the intelligence provider in this system, this means the location of computing power. Core component is a StrongARM processor with 200 MHz running ARM-Linux. This system is freely programmable as any other Linux machine, for instance using gcc. Libraries for communication with other modules are provided. Downloaded programs can be flashed to a nonvolatile memory.

For logging purposes or for receiving highlevel orders, a bluetooth connection with 115 KBit bandwidth is optional available. This provides a comfortable way for development and debugging. The authors suggest to make use of a radio connection only for this purpose, because the dependance of the correct function of a service robot from an interference-prone radio connection is a known issue of present solutions. For instance bluetooth, wireless LAN and german video links use the same frequencies in the 2.4 GHz wave band.

It is possible to use more than one CPU board, if more computing power is needed and the application is distributable.

3.2 VIO board

The VIO Board is a standalone image digitizing and recognition solution based on StrongARM and Linux. Up to 4 standard PAL cameras (for instance small and cheap CMOS cameras) can be connected to the board (multiplexed, 60 ms for a camera change).

The image stream is digitized with 25 fps (CCIR601 CIF 2:1, means 320x280x24) or 10 fps (CCIR601 full resolution 1:1). This is suitable for almost all applications off small mobile robots. The image stream is provided as RGB or YCbCr stream. Image recognition algorithms are freely programmable in C or C++

¹estimated material costs in Euro per robot

²man-month to construct a simple reactive robot

³developed by MIT

and connect to the image stream via a Video4Linux2 interface.

For easier development of applications, a video output of the input image stream or image analysis results, such as colored segments, is provided in real time. It is possible to use more than one VIO board if more cameras are needed.

3.3 AKSEN board

The AKSEN board provides connections for simple peripheral devices in a robotic environment, such as actors and sensors. It was designed with two main purposes in mind:

1. standalone controller for reactive robots
2. sensor and actor server in a RCUBE system

Main advantages of this new robot controller are:

- many connections for simple sensors (appendix A)
- motor drivers, universal power drivers and control outputs
- enough performance for reactive robots
- program survives and reboots after a power blackout
- small power consumption
- small hardware and software costs
- solderable by user
- native GPL C-compiler (Linux, Windows)
- distribution as module or kit

This module is usable standalone in education at highschools and universities, for hobbyists, for interactive installations in art and marketing, technical applications, which need small power consumption and flexibility, or as an universal controller for intelligent sensors. Actual stage in this subproject is outsourcing of production and distribution.

Naturally, more than one AKSEN board is possible in a RCUBE system.

3.4 Other modules

Additional modules will be developed. One of the current subprojects is the development of a mass storage device on the basis of compact flash cards. So it will be possible to save the learned experience and adapted skills over an power blackout. This module can be used in any combination with the other modules of the RCUBE architecture (think about a reactive robot with a big memory or an intelligent camera with logging functions).

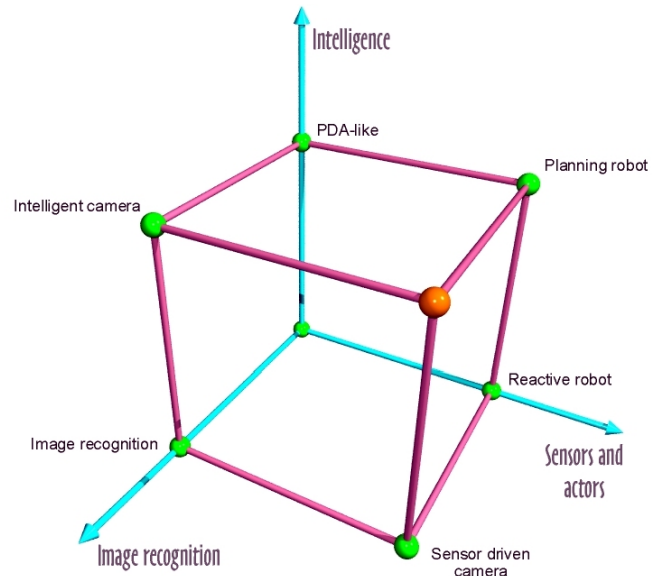


Fig.2: configuration space of RCUBE

4 Application fields

All modules are designed for low power consumption and interoperability. All modules can be used standalone or together in any number. All modules can communicate (for instance for monitoring reasons) over bluetooth with other RCUBE systems (other robots) or hosts. All modules survive a power blackout (or a long inactive period) without losing their programs, and reboot after power reoccurs (think about periodic driven, when solar powered appliances). Application specific modules can be connected to a RCUBE system over standardized field bus interfaces.

The flexible configuration of a RCUBE system provides interesting application areas (Table 2). Note that every point in the configuration space (Fig.2) stands for a possible application of the RCUBE system.

The RCUBE is suitable for teaching intelligent systems, research (rapid prototyping) in the field of ser-

Table 2: overview of application areas of RCUBE modules (incomplete)

modules used	application area
AKSEN	reactive robot
AKSEN + CPU	planning robot
AKSEN + VIO	reactive robot with vision capabilities, sensor controlled camera
AKSEN + CPU + VIO	RCUBE: core for small service robots
VIO	autonomous image recognition system
VIO + CPU	intelligent camera
CPU	PDA-like

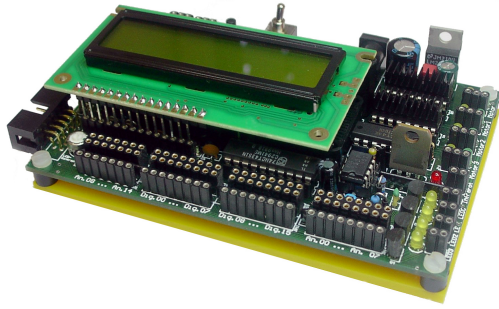


Fig.3: AKSEN controller board

vice robotics, and in smaller configurations for students and hobbyists to build their own AMR. A first complex demonstration system will be a robot with energy autonomy, capable of finding its docking station and unmodified sockets with image recognition.

5 Conclusion

The RCUBE architecture meets the needs for constructing small seeing robots and provides some interesting standalone spinoffs as the AKSEN and VIO boards. The three main modules of the architecture are developed, tested and ready for application adaption.

Appendix

A Description of the AKSEN board

Main features of AKSEN controller board (Fig.3):

- 15 analog inputs (suitable for sensors for light, infrared, obstacles, lines, voltage etc.)
- 16 digital in-/outputs (freely configurable)
- 4 motor drivers for small DC-motors up to 1A (variable in direction and rotational speed)
- 4 driver (for infrared senders or bulbs)
- 3 servo outputs (extensible by software)
- 1 output for modulated infrared (localization)
- 3 fast encoder inputs (for instance odometry)
- 4 dipswitches
- RS232 interface,
- CAN interface (optional)
- LCD display (optional)
- bluetooth connection (optional)

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