Departamento de Ciência da Computação
Instituto de Ciências Exatas
Universidade Federal de Minas Gerais

Vision & Robotics Laboratory – VeRLab

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1 Introduction

Owing to the trans-disciplinary nature of the area for which it became known from its foundation in early 1993, the Vision and Robotics Laboratory – VeRLab has been involved in leading edge research both in Computer Vision and Robotics. VeRLab is part of the Computer Science Department – DCC, of the Universidade Federal de Minas Gerais – UFMG, in Belo Horizonte, Brazil. With its 75 years, UFMG is among the top three centers of excellency in the country – both in research and in academics. For many years its graduate programs have been consistently reckoned among the best in the country across all scientific areas. The programs, which include Ph.D. and masters, are ranked from 5 to 7 (7 being the maximum) by CAPES (official government agency responsible for graduate programs in Brazil). Among the top five in the country, DCC's faculty numbers 40 PhD professors coming from the best Universities both in the US and Europe. This manifold diversity of background is one of the assets that has greatly contributed to the department's academic quality, and has also fostered the creation of several prolific research labs. The text that follows describes VeRLab's main project activities, as well as a brief description of the available infrastructure (Figure 1).

Figure 1. Some of VeRLab's mobile robots, including off-the-shelf and custom made robots.

2 Research

Robotics and computer vision are two very closely related areas. This affinity may clearly observed in mobile robotics, active vision, vision based control of manipulators, to name a few. Broadly speaking, the lab's current thrust efforts are in cooperative robotics and dynamic scene reconstruction. Further details may be found in the lab's web site.

2.1 Robotics

We are focusing on new strategies and sensory integration for mobile robot navigation, and pushing forward towards full autonomy by using exploratory procedures and real time experiment evaluation. Several robots are being used as test bed for validating navigation and path generation algorithms. We consistently make use of several sensors in the robot using a robust probabilistic framework. The techniques have been developed in such a way that they can be extended to other modalities of mobile robots, such as aerial and underwater. Methodologies for coordination and control of multiple robots have also been studied and successfully applied.

Aerial Robots

Dirigibles: since 1997 we have been working on the problem of autonomous navigation of unmanned dirigibles. Most of the work done in the lab deals with vision based techniques that make it possible for a vehicle to move autonomously in an indoor environment marked with visual beacons. This problem was approached by first modeling the aerial vehicle and then deriving the control from the identification process and the estimated parameters. This research has been developed in close collaboration with CenPRA (Centro de Pesquisas Renato Archer, in Campinas) and the GRASP LAB (General Robotics, Automation, Sensing and Perception Lab, University of Pennsylvania). The final goal is to enable the deployment of a fully autonomous dirigible for environmental applications. Our indoor blimps are equipped with micro-cameras and RF links, and are controlled by a remote computer, where the kinematics and dynamic models are processed. The video stream coming from the onboard camera is processed in real time, providing real time information to control the blimps attitude in real time. The experience acquired in the control of these small dirigibles, under controlled environmental conditions are being scaled up to be used in the navigation of the AS800, a larger blimp built at CenPRA housing several other sensorial modalities such as INS (Inertial Navigation System) and GPS.

Airplanes: we have been working on a project for the development of autonomous airplanes. The initial target is a commercially available R/C model airplane, which has significant payload for several sensors and cameras. The first task to be accomplished with this UAV is the autonomous inspection of power transmission lines. A powerful, parameterized, open source airplane simulator is now being used to derive control methodologies for the actual model UAV. The airplane is being equipped with several sensors and all the electronics are currently being integrated. This research is being performed in collaboration with the Department of Electronic Engineering at UFMG.

Cooperative Robotics

We have been looking into the problem of cooperative tasks performed by more than one robot, acting on the same object(s) or interacting in the same environment. This also includes the cooperation between mobile robots, as well as between manipulators and mobile robots. Force and torque interactions between and among robots are being studied. Recently we have been looking at cooperative sensing and communication issues that appear naturally when a group of highly instrumented mobile robots are working together. Although the evaluation of some cooperative behaviors are difficult for practical implementations we powerful home made simulators and move towards the analysis and control of groups of hundreds or thousands robots. e currently have two of them running in the lab: MuRoS and NEMO. Some of the behaviors are being evaluated in the context of soccer playing micro-robots. We have two sets of such robots, and several strategies are being tested under different configuration strategies. We have also built inexpensive holonomic robots which have been successfully used in validating a novel planning and control framework based on connected graphic approach. Recently we have acquired three Pioneer 3 robots equipped with SICK Laser range Scanner and GPS sensors that are suitable for outdoor missions. We have a project to use them in collaboration with the aerial UAVs described above. In this area, we have close collaboration with Prof. Vijay Kumar and his team at GRASP Lab. - University of Pennsylvania.

Planning and Control

We are focusing in the use of navigation Functions for motion planning and control. Navigation Functions are artificial potential functions defined over the robot configuration with a unique global minimum at the goal configuration. The main advantage of potential field based approaches for robot navigation is that the integral curves of the vector field formed by the gradient of the potential function define implicit paths from every start robot configuration to the goal configuration. In our research we apply very well know finite elements techniques to efficiently compute navigation functions. The main advantages of our approach include the possibility of dealing with complex shaped robots and obstacles.

Swarms of Robots

Large groups of robots and sensors, generically called *swarms of robots*, have received much attention in recent years. Basically, these systems try to employ a large number of simpler agents to perform different types of tasks, oftentimes inspired by their biological counterparts. We are particularly interested in planning and controlling the trajectories of swarms. One of the main concerns of these types of tasks is scalability. Systems to control and coordinate swarms of robots must be scalable from tens to hundreds of agents and must be robust to the dynamic deletion or addition of new agents. Agents should operate asynchronously and rely only on local sensing and communication, since the maintenance of a global state of the system is impractical. Furthermore, robots must be *anonymous* due to the challenges of uniquely identifying individual members within the swarm. We have been working on scalable approaches that allows a swarm of robots to synthesize shapes and patterns, converging and spreading along complex 2D curves. One possibility is to specify an implicit function and control the robots to track this function using a modified gradient descent technique. Figure 2 shows an example of an implicit function to generate the letter A and a group of simulated robots synthesizing this shape.

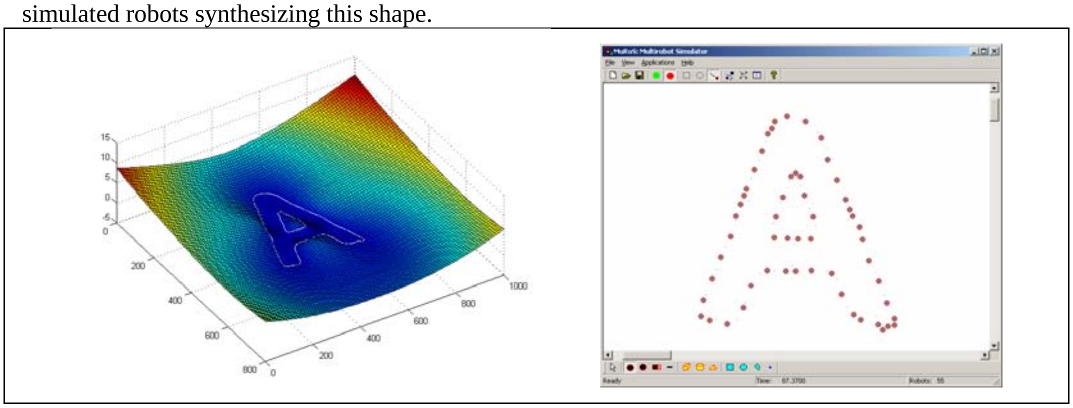

Figure 2. Simulations of 55 robots tracking the letter A. The figures on the left show the implicit function, while the figure on the right show a snapshot of the simulation (robots are the small circles).

Robot Manipulator Control Software

In order to perform applications mobile manipulation tasks, we have ported RCI/RCCL (Robot Control Interface and Libraries) to QNX, which is now open source for universities. This parameterized software is powerful in the sense that it may be used with any manipulator. It contains all necessary manipulator functions such as direct and inverse kinematics and dynamics. A small, 3 d.o.f. manipulator prototype was built, and the software was validated successfully. We are currently in the process of controlling a PUMA 560 manipulator mounted on a differential mobile platform in order to obtain a mobile platform.

Other Projects

Also, as mentioned in the previous reports, VeRLab has worked in several different projects in robotics including haptics, rehabilitation robotics, development of custom made robots (for example, a mobile manipulator to install and remove aircraft warning devices on aerial power transmission lines), etc.

2.2 Computer Vision

The main focus is on algorithms and vision systems for robotic applications, such as, but not limited to, navigation and map building. Two- and three-dimensional tracking algorithms have been developed at the lab. Due to application demands, these algorithms have implementations that run from 10 fps to near frame rate (30fps). We have successfully developed and implemented tracking, pose estimation algorithms for use in the robotics domain. An inexpensive, but sufficiently precise and robust range laser scanner was developed at the lab. This scanner can be used in three-dimensional shape acquisition and mobile robot navigation. More general computer vision problems are also being tackled at the lab. These include scene reconstruction via stereo, shape from motion, and other techniques.

3 Teaching

Graduate and undergraduate courses in Robotics and Vision are an integral part of VeRLab's activities. Courses are offered every semester to undergraduate students from Computer Science, Electrical and Control and Automation Engineering. The approach has been pragmatic in that emphasis is given projects addressing real world problems.

ROBOTICS

Three courses are being currently offered: Introduction to Robotics, Mobile Robotics and Advanced Robotics. The first course provides a general introduction to manipulation and locomotion, and the main issues and applications. Sensing, mapping, navigation, decision making, are some of the subjects covered in a very dynamic course where group of students build a autonomous robot built for an end-of-semester competition in a semi-structured environment. Great emphasis is given to the stochastic nature of real sensors and actuators. LEGO parts compose the mechanical structure, and all processing is performed by a HandyBoard where programs developed in Interactive C control the actions of the robot. Advanced Robotics touches special topics such as haptic interfaces, control, cooperation, and other recent issues in the area.

VISION

Computer Vision is taught covering the main problems of the area, starting from image processing techniques, and proceeding to feature detection, stereopsis and motion for three dimensional reconstructions. Robot vision is addressed as one powerful tool for robot localization and mapping.

4 People

From undergraduate to PhD students, VeRLab has the privilege to count with sharp young people. Since 1994, 8 PhD dissertations and over 25 MsC thesis have been successfully defended. Currently there are 6 PhD, 4 MsC graduate students and 10 work study (scientific initiation) undergraduate students from Computer Science, Electrical and Control and Automation Engineering.

5 Infrastructure

Robotics and Vision devices are expensive items, and considering the highly competitive access to research funding makes it a very strenuous endeavor the setting up and maintenance of a research lab in these areas. Since its foundation in 1992, the lab has gradually been equipped with workstations, a manipulator, several mobile robots, cameras, and other related equipment, which are listed below.

- Three Pioneer 3 robots equipped with SICK Laser Range Scanners, GPS and Sonar Sensors.
- PUMA 560, 6 d.o.f. manipulator, VAL-II and RCI/RCCL under QNX.
- LORD Parallel Jaw Gripper, with position, F/T and touch sensors in each finger.
- Nomad 200 mobile robot, equipped with color camera, ultra-sound, infra-red and touch sensors, electronic compass and wireless Ethernet.
- Indoor blimps. One with 1,4m in length, and two with 2,1m. The dirigibles are equipped with micro-cameras (color and b/w) and video RF links. Propulsion is provided by modified RC servos, remotely controlled by a computer.
- 3D linear laser scanner (developed and built in-house, imaging volume of 400mm).
- RS-170 color and b/w frame-grabbers.
- IEEE 1394 frame-grabbers
- CCD cameras (color and b&w; RS-170 and IEEE 1394 interfaces).
- Several fixed lenses with different focal lengths.
- Motorized and manual zoom lenses
- Optical bench with several precision mounting hardware.
- Calibrated light sources.
- Tripods and Mounting arms and brackets.
- Several analog RF video links.
- Workstations (SUN/Sparc running Solaris 2.8).
- Microcomputers (Pentium III, IV).
- 100Mbps LAN connected to the Internet-2.

The lab also has access to UFMG's supercomputing facility consisting of IBM and SUN parallel machines adding up to hundreds of processor nodes.

6 Collaboration

INTERNATIONAL

University of Pennsylvania – Many of the research topics described above have been developed under close collaboration with Professors Vijay Kumar, Kostas Daniiliidis, C. J. Taylor and James Gee from the GRASP LAB, at the University of Pennsylvania, USA.

University of Rochester – Prof Kyros Kutulakos (now at University of Toronto).

NATIONAL

The lab works jointly with professors from several departments within UFMG, such as Electrical Engineering, Electronic Engineering, Mechanical Engineering.

MANET – The lab is a member of a cooperative network (Manufacturing NETwork), which gathers several robotics researchers in from 18 states in Brazil. The aim of this network is to foster collaboration among the different groups in the context of joint research and industry contracted projects.

CenPRA – We also have collaboration the Robotics and Vision Laboratory from the Centro de Pesquisas Renato Archer, in Campinas, São Paulo. Since 1996 our labs have been working on the development of an unmanned aerial dirigible named Aurora.

7 Research Grants

Funding for VeRLaB's research comes from a few sources listed below. It is important to note that the DCC has invested a fair amount of resources, both financially and by mean of excellent physical and support infrastructure. UFMG has been funding the great majority of work study undergraduates under a program named PAD (Projeto de Aprimoramento Discente). Graduate students are typically funded by national and state agencies. A few projects have been recently approved and are under way, namely:

- CNPq – VideoCapture
- FAPEMIG – CORAH
- FUNBIO – Transpeixe
- CNPq/CT-INFO – SensorNet

8 Publications

Results from VeRLaB's researchers have been published in several prestigious robotics and computer vision journals and conferences both international and national such as:

JOURNALS – INTERNATIONAL

- International Journal of Robotics Research
- Autonomous Robots
- IEEE Transactions on Man, Machine and Cybernetics
- IEEE Transactions on Power Delivery
- IEEE Signal Processing Magazine
- IEEE Transactions on Pattern Analysis and Machine Intelligence
- IJCV – International Journal on Computer Vision
- Computer and Graphics Journal

CONFERENCES – INTERNATIONAL

- ICRA – International Conference on Robotics and Automation
- IROS – International Conference on Robotics and Systems
- WAFR – Workshop on Algorithmic Foundations in Robotics
- DARS – Workshop on Distributed Autonomous Robot Systems
- ICCV – International Conference on Computer Vision
- ECCV – European Conference on Computer Vision

CONFERENCES – NATIONAL

- CBA – Congresso da Sociedade Brasileiro de Automática
- SBAI – Simpósio Brasileiro Automação Inteligente
- SIBGRAPI – Simpósio Brasileiro de Computação Gráfica
- SBC – Congresso da Sociedade Brasileira de Computação
- WTF – Workshop de Tolerância a Falhas

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1 Introduction

The Robotics research at the Universidade Potiguar (UnP) has been carried out 4 years ago. The laboratory is used as a research center and supports the Robotics classes. The main aim of the Laboratory is to develop the robotic and computational vision researches. The Robotics Laboratory is currently equipped with:

- 14 Lego Robolab kits;
- 10 Robix kit;
- Webcam,
- PENTIUM class processors
- Local Area Network with fast (100Mbps) connection to the Internet-2
- An "arena" where are placed annually the Mobile Robotics Championship.

The championship is composed of several teams composed by the students of the Robotics class who build their robots to competition. Every year the championship takes place at the UnP Scientific Congress. Also in the Robotics classes, the students build manipulators robots to achieve some task like, play chess, build little wood structures, take objects away from a mat, draw objects, follow light points, etc. Some of those projects are shown in the figures presented in the page 3.

2 – Robotics Research

The next items briefly describe the main research directions in robotics research.

2.1 - Lego Robolab kits

In these researches new strategies, we are focusing on and sensory integration for mobile robots navigation, moving towards full autonomy with the usage of exploratory procedures and real time experiment evaluation. The Lego robots have been used to play soccer and rescue little dolls to a safe area.

2.2 - Robotic Vision

The focus here is on algorithms and vision systems for robotics applications, such as navigation and industrial applications. Two- and three-dimensional tracking algorithms have been developed at the lab.

2.3 – Robot Manipulators

In this research, the focus is on algorithms for robotics applications, such as playing games, playing music instruments, and robot builders. These researches aim the use of robots in dangerous tasks.

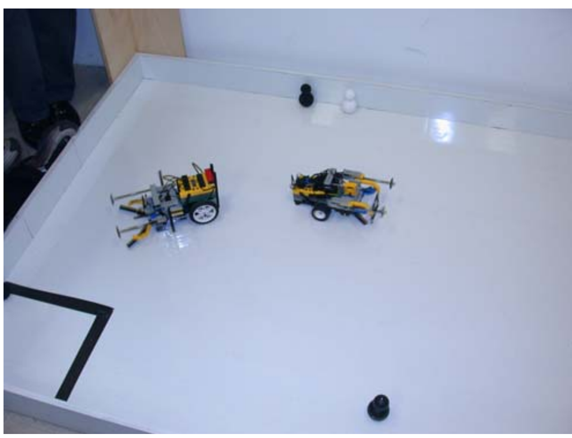
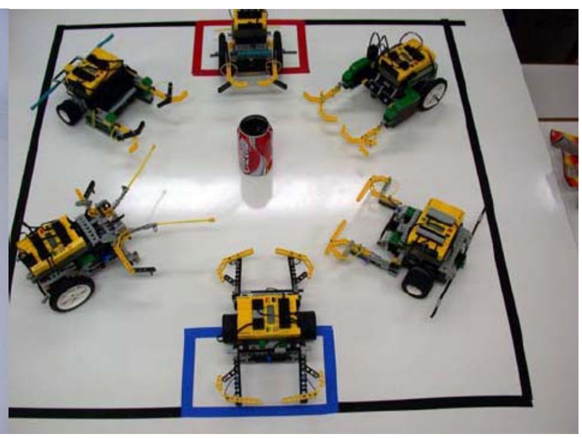
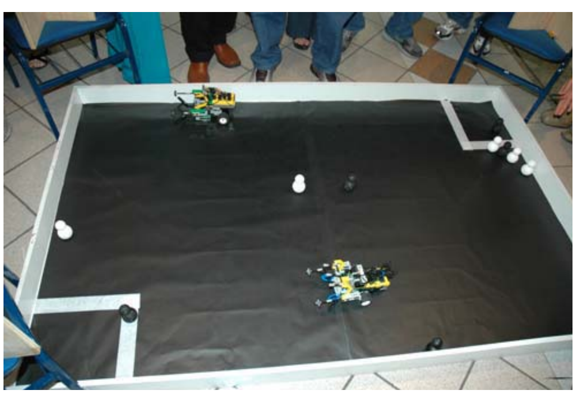
3 – Collaboration

The robotic group of the Universidade Potiguar is on to the group of research: Computational Systems, of the UnP. The research topics described above have been developed only with undergraduate students under supervise of Prof. Dr. Allan Medeiros de Martins. The group is currently composed of 04 undergraduate students.

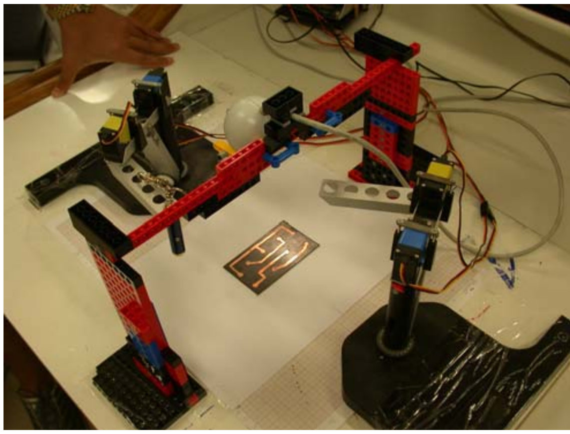
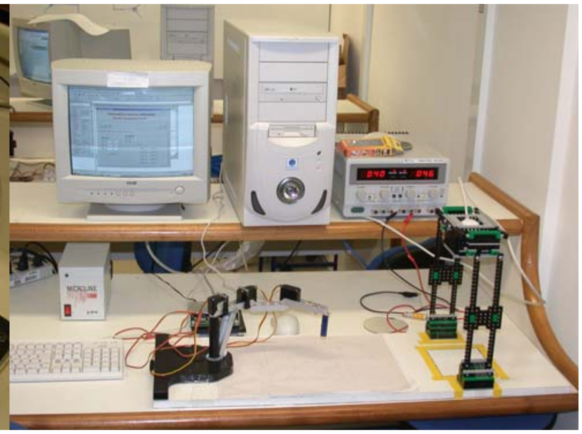
4 – Illustrations

In this section, some pictures of the research topics described above are presented projects cited in the section 2.

4.1 - Lego Robolab kits

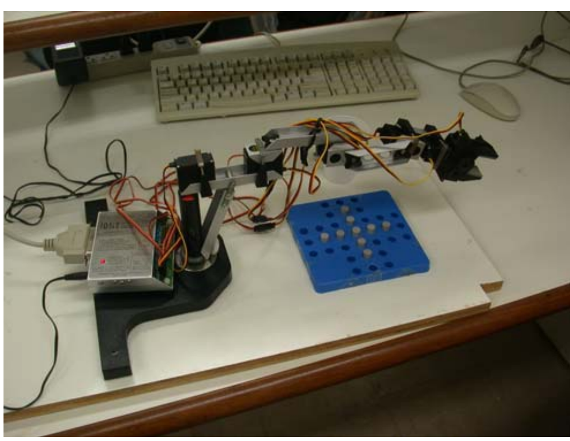
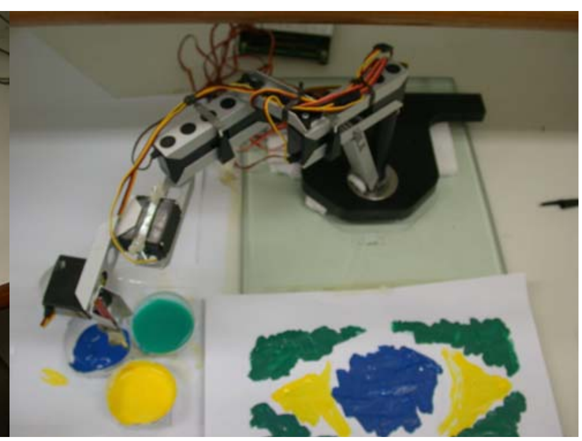




4.2 - Robotic Vision

4.3 – Robot Manipulators



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1. Introduction

The Control Systems and Automation Group was created in 1997. Since the group foundation, the research related to robotics area was focalized in the development and construction of an autonomous guided vehicle, shown in the Figure 1. The sections 2 and 3 describes the main projects developed by GACS related to robotics field.

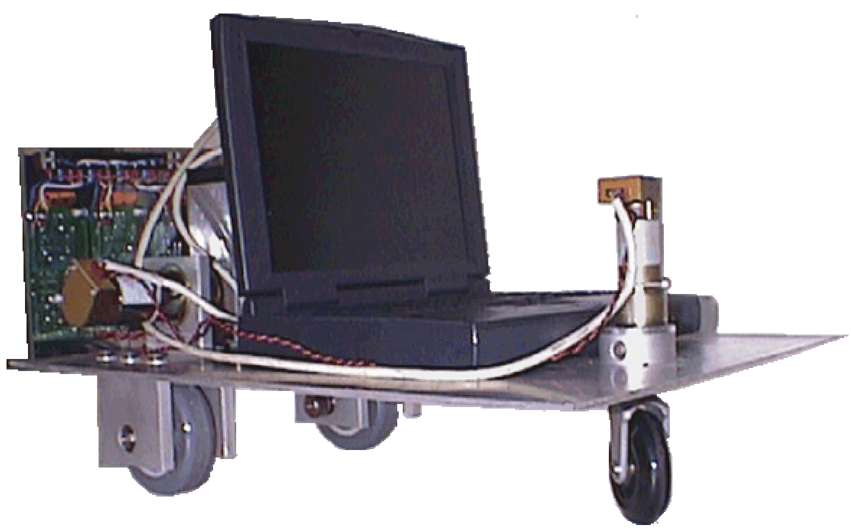

Figure 1: Mobile robot developed by GACS.

2. Robot Design

The mechanical and electrical hardware characteristics are presented, with focus on the robot's compatibility, portability and low cost. The robot design allows an interactive and visual environment for software development based on block diagrams, using the full facilities presented by the real time Matlab/Simulink. A customized hardware based on FPGA's and microcontroller, shows in the Figure 2 realize the communication between the notebook embedded in the robot, with the sensors and actuators used for navigation and trajectory control.

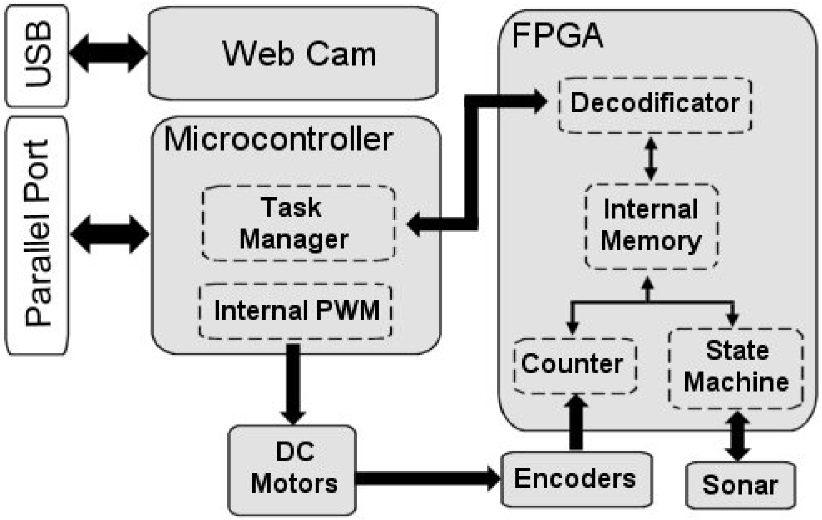

Figure 1 – Design and architecture of robot electrical hardware.

The algorithms of localization, orientation and control, are conceived and validated under a simulation. After the validation step, the real time application runs using the same simulation environment, using the communication block represented by the Mobile Robot in figure 3.

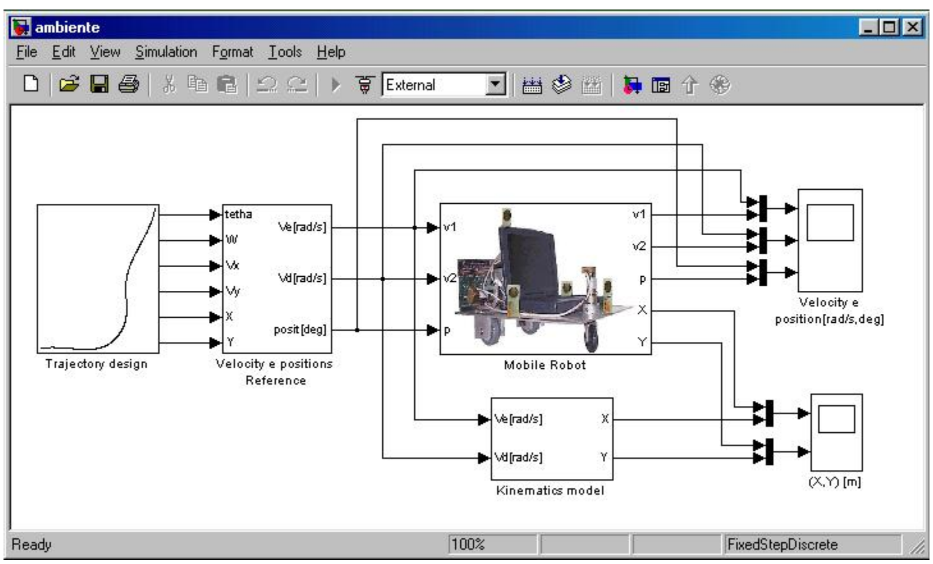

Figure 2 – Simulink real time environment.

3. Multicriteria Analysis and Synthesis of Visual Servoing (project support by CNPq – Brazil, under grant 474390/2004-7)

This project attempts to propose a new approach to the muticriteria analysis and synthesis of 3D and 2D visual servocontrol schemes. Several criteria should simultaneously be taken into account, such as convergence, avoidance of actuators' and sensors' saturations, and 3D constraints. The idea is to represent 3D and 2D servos into a unified rational systems framework. The stabilization conditions are cast in terms of Linear Matrix Inequalities that can be solved by interior point algorithms.

In particular, visual servos which aim to drive a perspective camera in front of a fixed target are considered. Dedicated spots serve as visual features, in such a way that to any configuration of their projection onto the camera image plane corresponds to a unique sensor-target relative situation. In the 6DOF case, this is so when they are at least four, coplanar and unaligned. The environment is presumably free of mobile obstacles. A noise-free model of interactions is set up first. The actuators, the sensor and the image processing system are supposed perfect and instantaneous, so that they do not explicitly appear.

The project is carried out in collaboration with Dr. Patrick Danès – Robotic and Artificial Intelligence LAB/ LAAS – Toulouse, France.

Robotics and Automation Research Group – GEAR

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Nome:	Grupo de Estudos em Automação e Robótica – GEAR
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Membros:	Prof. Fernando Camilo Paes Prof. Francisco Manoel Pinto Garcia Prof. Ion Willer dos Santos Prof. Janes Landre Júnior Prof. Luis Enrique Zárate Prof. Marcelo Becker Adriano Jotadiemel Mais Adriano Rosa Teixeira Alan de Carvalho Pousa Aristides Neto Domingues Breno Ferreira Lizardo Henrique Dutra Monteiro Leandro Colen Rocha Luiz Castilho Sanchez Luiz Flávio Vieira Brant Marcelo Fernandes de Barros Cabaleiro Marcela Esteves Vianna Marco Antônio Boato Jr. Otávio Nobre Tiago de Freitas Paulino Weber Perdigão Macedo

Introduction

The Robotics and Automation Research Group has been started in 1997, when the Robotics Lab of Pontifical Catholic University (PUC) was founded. Professors and students interested in robotics and automation from different departments and institutes of PUC began to work together using resources in this new lab. The robotics lab is currently equipped with:

- COMAU SMART S2 6 dof industrial robot;
- Two PEGASUS II, a educational platform for education in robotics;
- Laser scanner SICK LMS200 for indoor applications;
- Mobile robot for indoor (built from an scientific project);
- Mobile robot for outdoor (built from a research project (FINEP 1541/98);
- SCARA 4 dof educational robot (FAPEMIG TEC997/96 and TEC999/96);
- CCD cameras;
- MATROX frame grabbers;
- PENTIUM class computers;
- PowerPC workstation;
- LAN 100Mbps;
- POLAROID sonar 6500 series sensors;
- DSP starter kits (TEXAS INSTRUMENTS);
- PCI bus starter kit (PLX);
- PC104 CPU´s;
- Several automation sensors (inductive, encoders).

Robotics and Automation Research

At the Robotics Lab of PUC Minas, GEAR´s place, different applications of electronics, mechanical design, signal processing, instrumentation and control are used for robotics and automation projects. Following topics briefly describe the main research directions in robotics and automation research at PUC Minas.

1. Haptic Interfaces

Haptic interaction is enabled by a special sensor modality that combines sensing and action. The energy and information flow is bi-directional, so that, as the user touches and manipulates objects, he/she simultaneously changes their state and receives information about them. In our interactions with the world, haptics adds not only a compelling dimension to the information we receive, but also another means for expressiveness in our actions as well. The design of haptic interfaces to simulate virtual or real environments is a challenging problem in robotics, human-machine interface and computer graphics. The dynamic interactions among the human operator, the mechanism, sensors, actuators, the physic-based simulation, and the evaluation of the overall system bring interesting questions and important practical concerns. The focus of the research is on the design and implementation of simple haptic interface with a single degree-of-freedom. The main goal was to design and to build a haptic interface that allows the simulation of virtual environments being able to be use in teleoperation applications. Based on the desired specifications for the haptic device, we implement the mechanical prototype shown at Figure1. We also developed the electronics, the control algorithms and the virtual environment to build our 1DOF haptic interface. Some applications in industrial automation (teleoperation) and biological systems (rehabilitation with the Physiotherapy Department) have been addressed.

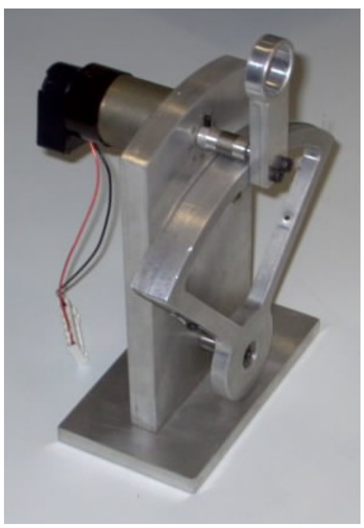


Figure 1. 1 DOF Haptic Device at GEAR – PUC Minas.

2. Software Architecture and Industrial Automation

In this research area we are interested on the integration of different parts at the manufacturing floor. Equipments as robot - SMART S2 (Figure 2), CNC machines, ethernet terminals (micro controlled systems for instrumentation) are integrated in a supervisory system. Some PLC´s are used in order to integrate all some sensors as displayed at Figure 3. It was chose the QNX Software as the operational system for real time applications. Under this operational system for real time applications a general architecture for robotics and automation has been addressed. Students from computer science and electronics engineering are working together in the specification and implementation of the GEAR Architecture. This working is following some results present by Chatila at INRIA – France.

Figure 2. SMART S2 COMAU industrial robot at PUC Minas.

Figure 3. PLC kit for system integration at PUC Minas.

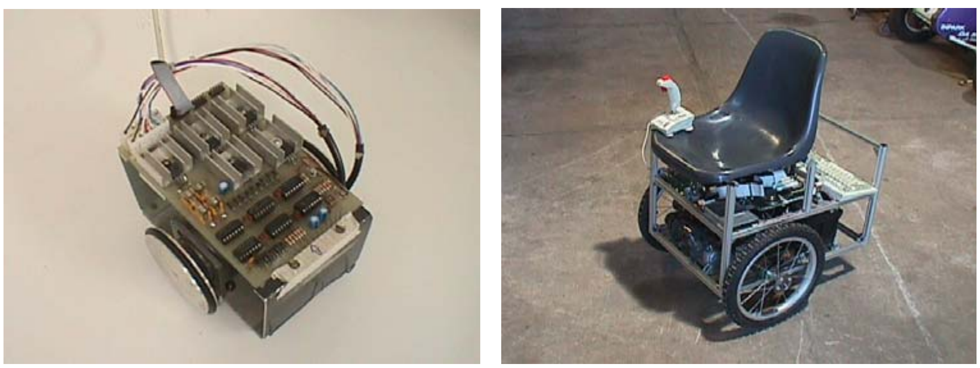
3. Embedded systems, Instrumentation, Signal Processing and Control

Many applications on signal processing and embedded systems are using Erasable Programmable Logical Device (EPLD) and Field Programmable Gate Array FPGA) devices. By using such devices the user can make the specification of the hardware during its application. A software language, the Hardware Description Language (VHDL), now defines the hardware for the application. Many embedded systems are using this technology, once the processing time is reduced to a hardware delay only (few nanoseconds). For this, the complete algorithm should be described in hardware. Following this research topic, applications for signal processing (image processing) for real time applications are developed to evaluate transformations (cosine transformation) of the incoming image (frames), or kinematics measurements by calibrating the image system. Master students on mechanical engineering are working with camera calibration and computer vision while mater student on electrical engineering are translating math functions to hardware algorithms. In order to real time signal processing applications, some experiments are implemented on the GEAR´s Lab. Figure 4 shown the inverted pendulum testbed.

Figure 4. Inverted Pendulum testbed at PUC Minas.

4. Mobile Robots

Mobile robotics is an amazing word where many issues can be addressed, for undergraduate and graduate courses. In this research topic some different issues on mobile robots has been addressed: mobile robots simulator environment, trajectory planning and obstacle avoidance. By using a high level language, the simulator allows the insertion of the cinematic and dynamical model of the robots. The algorithms for trajectory planning and obstacle avoidance will be developed and evaluated on the simulator. For instance we have different softwares for each application. In the future, just main software will be able to include, exclude, edit and change parameters for each method (potential fields, Voroni diagram, and others). For instance we have two different platforms where the students implement and can see the final result, as displayed at Figure 5. This research topic has involving many students from computer science and information science undergraduation courses. Some initial tests with the Computer Science Graduate Course are going to be implemented and evaluated on the robotics lab focusing on mobile robots.



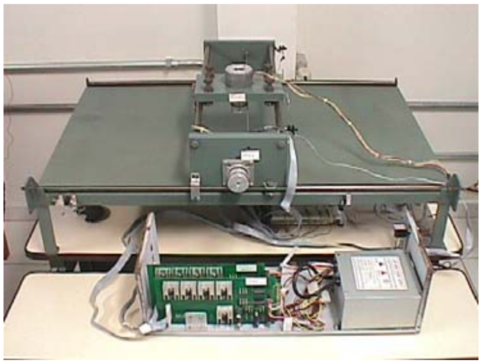
(a) (b)

Figura 5. (a) Intable and (b) outdoor mobile robots developed at PUC Minas.

5. Robot Development

As a small research lab, many solutions are homemade. Some of them using research projects: SCARA by FAPEMIG, and the AGV by FINEP. On this project, all mechanical specification was fully developed, defined the manufacturing process of each part. These hardware platforms were manufactured by using mechanical and electrical-electronics engineering. Today, graduate students have experimental testbeds because previous works on robot developments. Some works still running, improving some specific performance indices on these robots. Figure 6 presents some implementations of different robot designs developed at PUC Minas.

(a)



(b)

(c)

Figure 6. (a) 4 DOF SCARA robot, (b) 2 DOF Cartesian robot and (c) linear axis of the wind tunnel Cartesian robot.

Collaboration

We have working with different groups in robotics: Computer Science Department, Electrical Engineering and Mechanical Engineering at UFMG (Belo Horizonte – MG); Mechanical Department at ITA (São José dos Campos – SP) and UNITAU (Taubaté – SP). We are also working with Prof. Vijay Kumar, at University of Pennsylvania, at GRASP Lab.

Actually we have 4 Graduate students, 17 undergraduate students and 7 professors with projects or developments on this area.

Pontifícia Universidade Católica do Rio de Janeiro
Departamento de Engenharia Mecânica
Engenharia de Controle e Automação

Control and Automation Laboratory
Robotics Group

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1. Introduction

Robotics research has been carried out in the C&A Laboratory, involving undergraduate and graduate students from the areas of Control Engineering, Mechanical Engineering and Electrical Engineering.

Collaborators:

- Prof. Marcos Azevedo da Silveira, D.D'Etat
- Prof. Ricardo Tanscheit, Ph.D.
- Prof. Moisés Henrique Szwarcman, M.Sc.
- Prof. Mauro Schwanke da Silva, M.Sc.

M.Sc. Students:

- Felipe Augusto Weilemann Belo
- Felipe dos Santos Scofano
- Miguel Angelo Gaspar Pinto
- Pedro Ferreira da C. Blois de Assis

Undergraduate Students:

- Bruno Favoreto Fernandes Soares
- Bruno Messer
- Claudio Duvivier Neto
- Felippe Alves Moraes Garschagen
- Fernando Uilherme Barbosa de Azevedo
- Filipe Sacchi da Silva
- Gustavo de Oliveira Lima
- Ilana Nigri
- Leonardo Pedrosa Salvini
- Márcio Barros Neto Barbosa de Barros
- Mariana Fonseca Bystronski
- Rafael Caram Assemany Moreira

The C&A Lab is currently equipped with:

- Two MA2000 6-axis manipulators.
- ER-1 mobile robot, equipped with color camera, wheel encoders and infra-red sensors.
- Several small manipulators designed and built in the lab.
- Several radio-controlled two and four-wheeled vehicles designed and built in the lab.
- Computers with Pentium IV class processors.
- Robot control PC board with 8 A/D, 8 D/A and 8 encoder channels.
- Local Area Network with fast connection to the Internet.

Figure: 360° panoramic view of the PUC-Rio C&A Lab.

2. Robotics Research

The next items briefly describe the main research directions in this group.

2.1 Design and Control of High Performance Robotic Manipulators

Large robot manipulators are needed in field, service and medical applications to perform high accuracy tasks. In these applications, a large robotic system may need to have a very fine precision. Its accuracy specifications may be very small fractions of its size. Achieving such high accuracy is difficult because of the manipulator’s size and its need to carry relatively heavy payloads. Many industrial robots are unable to perform highly demanding maintenance tasks, due to fundamental physical limitations, such as joint friction. The goals of this research topic are to study novel methods for improving the performance of industrial robots under position and force control, and to design and build high-performance robotic manipulators for that purpose.

2.2 Autonomous Mobile Robots

In field or indoor environments it is usually not possible to provide service robots with detailed a priori environment and task models. In such environments, robots will need to create a dimensionally accurate geometric model by moving around and scanning the surroundings with their sensors, while minimizing the complexity of the required sensing hardware. In this research topic, algorithms are developed to allow a mobile service robot to explore and build its environment model for future navigation requirements, using a limited sensor suite such as a single monocular camera system fixed to the mobile base, wheel encoders and contact switches. Such developments would allow a low-cost robot to localize itself and navigate through a flat-floored static environment such as an office floor or apartment. Experimental results are being carried out on an ER-1 mobile robot system.

2.3 Artificial Muscles and Binary Robotics

Binary robots are systems consisting of several actuators, each of them with only two potential states. By combining the binary state of each actuator, desired positions and trajectories can be obtained. A large number of actuators is desired to increase the number of end-effector positions and orientations attainable by the robot, approaching the performance of a continuous system. In this research topic, both the potential actuation mechanisms (such as artificial muscles) and fundamental design schemes for such systems are studied.

Universidade Federal de Minas Gerais
Escola de Engenharia
Departamento de Engenharia Mecânica

Laboratory of Robotic, Welding and Simulation

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Eduardo José Lima II – Doctorate
Carlos Alberto Carvalho Castro – Doctorate
Renato Ventura Bayan Henriques – Doctorate
Mirian Verônica dos Santos – Doctorate
Frederico Ramalho – Master
Leonardo Panicali Carlech – Master
Carolina Meirelles Dantas - Master
Guilherme Campelo Fortunato Torres – Master
Guilherme Marconi Silva – Master
Hélio Coelho Guimarães Soares – Master
Sérgio Rodrigo D. Guedes – Master
Silvio Trivellato Andrade – Master
Leonardo Augusto Vieira – Master
Leonardo Horta Miranda – Master
Leonardo Panicali Carlech – Master
Alvaro Thadeu Cadete dos Reis - Undergradute
Leonardo Augusto Vieira – Undergraduate
Eduardo Maluf Zica – Undergraduate
Paulo Henrique Coelho Papatela - Undergraduate

Collaborators

All members of MANET – Manufacturing automation Network
www.manet.org.br
In Special:
Prof. Mário Campos Montenegro, PhD (UFMG)
Prof. Walter Fetter Lages, PhD (UFRGS)
Prof. José Reinaldo Silva, PhD (USP)
Prof. Teodiano Freire Bastos Filho, PhD(UFES)
Prof. Sadek Crisostomo Absi Alfaro, PhD (UnB)
Prof. Ronaldo Paranhos, PhD (UENF)

Introduction

In 1995, under the coordination of Professor Bracarense, began the implantation of the Group of Robotics, Welding and Simulation in the DEMEC/UFMG. This group has as objective to contribute for the technical and scientific improvement of professionals in the area of automation of welding processes, in the development and implementation of new technologies, besides services in robotics, welding and simulation. With the support of companies from the productive sector and from government agencies (FINEP, CNPq, CAPES and FAPEMIG) it was built the Laboratory of Robotics, welding and Simulation, a laboratory of last generation that offers the necessary and enough conditions for teaching, research and consulting in the several areas with respect to robotics, welding and simulation.

Philosophy

"To study physical, chemical, mechanical and metallurgical phenomena looking for the automation of the welding processes"

Meanly research topics and projects related to robotics

Robotic Welding with covered electrodes

In this project, studies have been made to develop the robotization of the welding with covered electrodes. This welding process is the only one that still is completely used by hand. Despite its difficulties, modeling of electrode heating and melting rate using finite volumes was developed with the objective to apply it in a control of a robot. As part of the project an old ASEA IRB6 was retrofitted. The retrofitting was developed in a partnership of the LRSS with the GCAR – Group of Control, Automation and Robotics from the Federal University of Rio Grande do Sul - UFRGS. This robot has today an opened architecture, allowing that the model be implemented in its program with the objective to use it for the welding with covered electrodes. Figure 1 shows the electrode temperature profile as obtained from the model and figure 2 the robot after retrofitting.

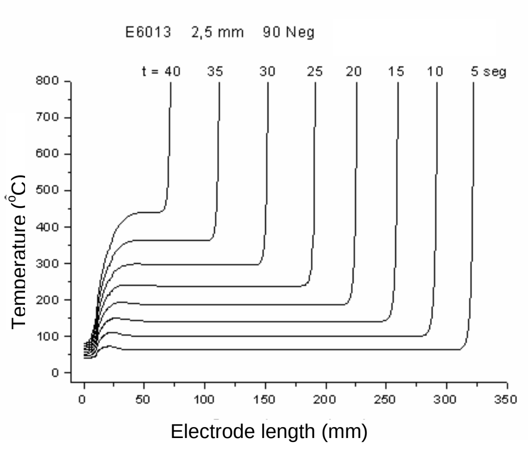


FIGURE 1 – Modeled electrode temperature profile

FIGURE 2 – Robot retrofitted

Optimization of robot welding

Many companies are already using robots for welding in Brazil. To help these companies to obtain the best performance with their robot, offline programming has been used as tool to visualize and study the best welding trajectories. Additionally, online programming, using and industrial Motoman SK6 robot, has been applied to achieve the best welding parameters. Figure 3 shows an example of offline programming where the study was developed for a company that produces scaffold by welding. Figure 4 shows the Motoman robot welding a scaffold during online programming.

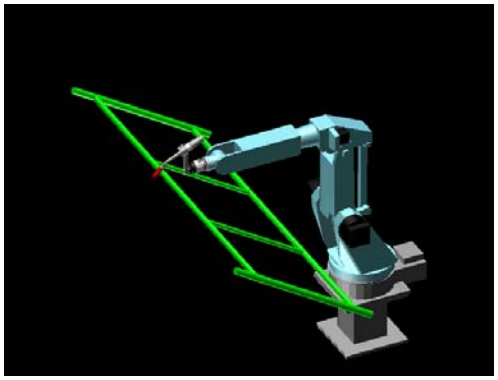


FIGURE 3 – Offline programming of a scaffold welding

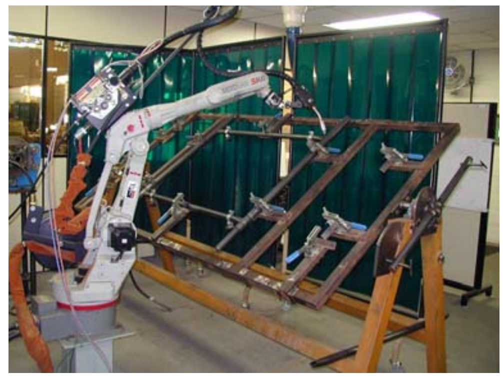


FIGURE 4 – Robot welding a scaffold

Safety in robotic welding

Having a chair in the AWS – American Welding Society - D16 committee, that deals with robotic welding, since 2000, has allowed participating in the preparation of three important documents about safety and personal training for robots for welding. The documents are: “Guide for Components of Robotic and Automatic Arc Welding Installations” **In:** AWS D16.2/D16.2M:2001, “Risk Assessment Guide for Robotic Arc Welding” **In:** AWS D16.3M/D16.3:2001 and “Specification for the Qualification of Robotic Arc Welding Personal **In:** AWS D16.4:1999.

Robotic arc welding of complex pieces using robot cooperation

Classically the robotic welding programming begins with the identification of the movements that will result in the welds, followed by the planning order and direction at which these movements will be executed. Due to the complexity of the geometry of some pieces, frequently the degrees of freedom, necessary for the robot or robots (cooperation) positioning to accomplish a welding, must be increased. A way to work with the high number of degrees of freedom is to break it in sub-systems of smaller complexity and coordinate their movements independently, in spite of the continues programming being made from the robot or robots to the weld. This project intends to change this focus. It starts from the definition of the geometric parameters and entrances that represent the weld. This inversion represents a differentiated approaching since the relative position of the torch in relation to the piece, taking information from a database that represents the no-lineal relationship among the variables of the process, is fixed before the determination of the positioning and welding sequence. After this first step the cinematic relationships and the geometric restrictions of the piece are established, being possible to obtain the coordination of the robot or robots movement. A possible tool to be used to evaluate this methodology is the offline simulation. It helps to determine possible collisions and eventual corrections in the final program to be generated for the robot or robots.

Modeling of residual stresses and distortion due to welding for robotic welding

One of the biggest problems in the welding of heavy structures is the distortion and the residual stresses caused by the welding. During the programming of a welding with robot these problems should be considered but not always are and almost always the weld are accomplished with less than 100% of efficiency. In this project a mathematical model is been developed to be incorporated in the program of robots for welding of heavy structures. That way, knowing how the distortion and the residual stresses will behave, the robot can alter its path; the welding parameters and even the welding sequence to minimize them. Sensor of voltage and LASER seam tracking will be used to confirm the alterations and, in some cases, correct them.

Application of dynamic resistance to control welding parameters during robotic resistance spot welding

Usually, in the resistance spot welding (car bodies welding for example) the spot quality is evaluated by sampling. In this project the spot quality (mechanical Resistance) was evaluated with respect to the dynamic resistance of the spots during welding. Then, monitoring current and voltage used to fabricate the spots by robots, it is possible to know if a spot is good or bad and correct it without losing the welding sequence. A database of all the spots can be recorded for future evaluation and guarantee. A partnership with SENAI-CIMATEC in Salvador, Bahia is allowing to implement this technology in a ABB 6400-24, already prepared for resistance spot welding.

Mechanized Underwater welding

The project of underwater wet welding with covered electrodes had as objective to study the weldability of steels used in offshore structures with commercial electrodes at three depths, 50, 100 and 150 meters. This project allowed in the beginning to understand the process and its problems. The depths are simulated inside of a hyperbaric pressure chamber (figure 5) and the welds are accomplished with a gravitational mechanized system (figure 6). The welds are analyzed with respect to porosity quantity and location, metallurgical aspects, arc stability, easiness of arc opening, visual aspects and mechanical properties. The mechanized system has performed the welds with high quality, allowing to say that the welds made with it, have higher quality than the welds made by hand nowadays. Recently it was noticed that the mechanized system is able to even do vertical welds. A new project is been developed to construct a new mechanized system that will allow to do also vertical welds. This system will be light and compact. The idea is to use a ROV to carry the system. The ROV will install the system and it will perform the weld. Additionally, the

ROV will inspect and record the procedure, sending the images to an inspector in a boat above. It will also allow the accomplish wet weld at higher depths.

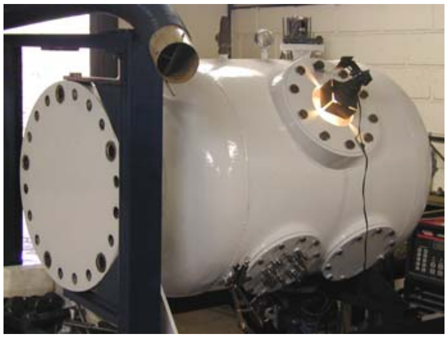
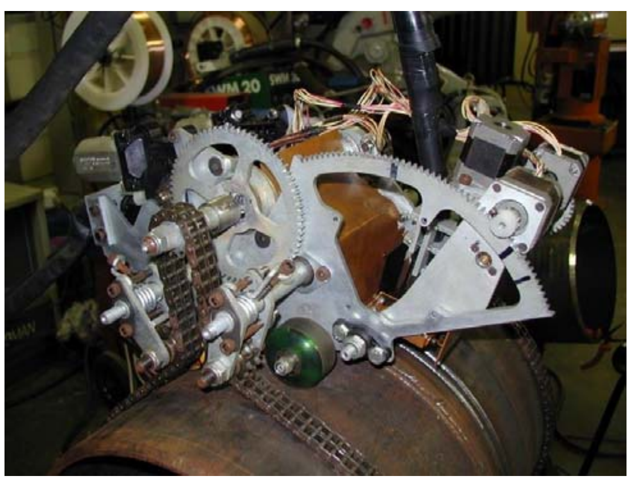


Figure 5 - Hyperbaric pressure chamber

Figure 6 - Gravitational mechanized system for welding with covered electrodes

<u>Robotic orbital welding</u>

The proposal of this project was to develop a robot for orbital welding with mechanized welding processes for pipelines. Differently from the existent systems, this one firmly holds the pipe while the carriages with the welding torch rotates around it. The major difference to the existent ones is that it is interchangeable (can be easily assembled at different pipes diameters) and the welding is all controlled. This is why the term “robotic”. Depending on the torch position in relation to the earth the welding parameters change. The use of mechanized welding processes such as GMAW and FCAW allows to work with high deposition rate, increases the production, integrity and quality of the pipes, facilitating the inspection and control. It is been studied a possibility to adapt a ultrasound transducer to the carriages allowing to inspect the welds as soon as they are made. It was noticed that there is not a system with the proposed characteristics in the Brazilian market, not even in the world market. Besides, a normalization of the weld properties must still be developed, being this the great challenger for the project.



<u>LRSS Infrastructure</u>

• *Robot KUKA KR16 with 6 DOF with a Fronius welding power source*

- *Robot MOTOMAN - SK6 robot with 6 DOF with a MOTOARC 450 HOBART welding power source.*
- *Retrofitted ASEA - IRB6 robot with 5 DOF with a KEMP welding power source.*
- *Synergic welding power source multiprocess LINCOLN Power Wave 450.*
- *Welding power for resistance spot welding, 13,5 KVA.*
- *High speed camera OLYMPUS MAC-8000, 8000 frames/ second.*
- *Test machine servo hydraulic INSTRON, 25 t.*
- *Acoustic emission system model AEDSP 32/16B and Mitras 2001 AE System made by Phsycal Acoustic Corporation.*
- *Ultrasound equipment EPOCH III model 2400 made by Panametrics.*
- *Scanning electron microscopy JEOL JSM-5310*
- *Hyperbaric chamber for 200 depth.*
- *Data acquisition systems DAS 1600 and DAQ 1600 with control boards for step motors.*

manet

ROBOTICS RESEARCH NETWORK

Some of the MANET Projects in 2005

a) Book in preparation:

Title: MANET Handbook of Industrial Robotics

Editor: Vitor Ferreira Romano (Poli/UFRJ)

CD media Editor: Renato Ventura Bayan Henriques (UFRGS)

Participants: SENAI (São Caetano do Sul), SENAI (Caxias do Sul), CIMATEC (Salvador), UFES, UFMG, UFPE, UFSC, UFRJ, UFRGS, UNESP (Bauru), UNICAMP, UnB, USP, USP (São Carlos), Instituto Superior de Engenharia do Instituto Politécnico do Porto (Portugal)

Notes: This handbook has 20 chapters in two volumes and will be available by March 2006 in Brazil and Portugal. To be published and distributed by Editora Edgard Blücher Ltda.

b) Control of Industrial Robotic Cells via Internet (demonstration)

(a) (b)

Figure 1: (a) Boat shape milling – UFRJ (b) Welding of a panel – UFMG.

Event: Globaltech – Science & Technology Fair (Porto Alegre, Rio Grande do Sul, May, 17 – 22 , 2005)

Coordinators: Vitor Ferreira Romano (UFRJ) and Alexandre Queiroz Bracarense (UFMG)

Participants:

a) Robotics Laboratory UFRJ-DEM/COPPE-PEM: *:* Vitor Ferreira Romano, Luiz Eduardo Demenicis, Sidney Augusto de Oliveira Jr.

b) Laboratory of Robotics, Welding and Simulation UFMG: Alexandre Queiroz Bracarense, Eduardo Lima II

c) KUKA Roboter do Brasil Ltda.: Patrick Polak

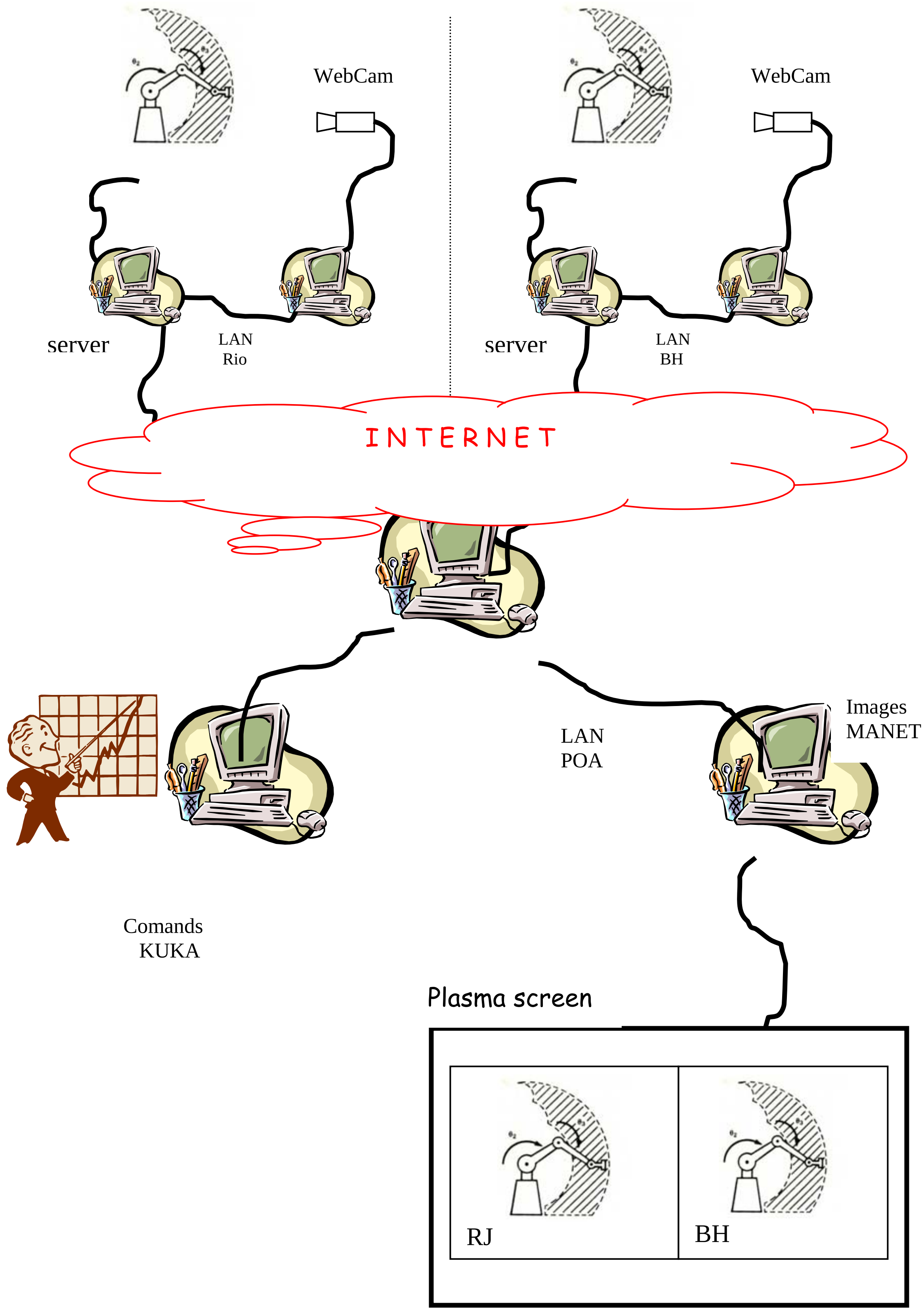


Figure 2: Demonstration scheme in POA, RJ and BH sites.

São Paulo State University (USP/SP)

São Paulo, SP

MECHATRONICS - MODELLING, DECISION AND CONTROL

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Coordinator: Paulo E. Miyagi, *pemiyagi@usp.br*
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Research Group:

- Paulo E. Miyagi , Full Professor of Department of Mechatronics and Mechanical Systems Engineering – EPSUP Escola Politécnica, University of Sao Paulo
- Fábio G. Cozman, Marcos de S.G. Tsuzuki, Diolino J. dos Santos F°, Associate Professor s of Department of Mechatronics and Mechanical Systems Engineering – EPUSP Escola Politécnica, University of Sao Paulo
- J. Reinaldo Silva, Alexandre Kawano, Amauri Hassui,; Assistenat Professors of Department of Mechatronics and Mechanical Systems Engineering – EPUSP Escola Politécnica, University of Sao Paulo
- Emilia Villani; Assistenat Professor of ITA Technological Institute of Aeronautics
- Graduate students: 18
- Undergraduate students: 20

1. Group Description

Modelling, Control and Decision in Mechatronics Engineering are the fundamental techniques and technologies for man made systems. Therefore the R&D activities of this group involves the following research areas:

- Systems integration
- Modelling and analysis of products and systems
- Control systems
- Decision making systems

The group is currently organised in Labs as follows to conduct the projects related with the above areas.

Automation Systems Lab

Co-ordinator: Paulo E. Miyagi

pemiyagi@usp.br

The Automation System Lab is interested in developing techniques and technologies for man-made systems. The research activities include not only automation of industrial production systems (manufacturing processes and continuous processes) but also transportation systems, communication systems, military defence systems, intelligent buildings, etc. In the robotics area the focus is in the programming techniques and the integration of robots in productive environments.

More details about these research topics are available if you are interested at the web site *http://www.pmr.poli.usp.br/lsa*.

Decision Making Lab

Co-ordinator: Fabio G. Cozman

pfgcozmani@usp.br

The lab focuses on automated decision making techniques, particularly techniques that involve probability theory and generalisations of probability theory. We are also interested in robotics and autonomous systems, particularly on the use of robots to enhance human life. The lab is supported by several funding institutions, including corporate partners.

More details about these research topics are available if you are interested at the web site *http://www.pmr.poli.usp.br/ltd*.

Systems Design Lab

Co-ordinator: J. Reinaldo Silva reinaldo@usp.br

The Design-Lab are interested in design methods, particularly, formal methods applied to complex systems including the complex and large scale automated and robotized systems. The lab has been working with the treatment of discrete event systems, considering formal methods related with Petri nets, vector addition and object oriented techniques.

More details about these research topics are available if you are interested at the web site *http://www.pmr.poli.usp.br/d-lab*.

Computational Geometry Lab

Co-ordinator: Marcos de S. G. Tsuzuki

mtsuzuki@usp.br

The lab does research applying computational geometry technologies in the solution of engineering problems. The used computational geometry technologies are Computer Graphics, Solid Modelling, Geometric Modelling, and Voronoi Diagram, among others. The main applications are in the development of CAD/CAE/CAM systems, and some new possible applications are robotics, medical visualisation and image processing. The concept is that geometric information can be processed through a consistent and robust way, and to reach such purpose we are using several techniques such interval arithmetic and simulated annealing, among others.

2. Research Projects (sample)

2.1 Balanced and Flexible Automation Systems

Researchers: Paulo E. Miyagi (coord.)

This project involves the systematisation of the basic techniques for design, implementation and operation of control systems for balanced automation, i.e., the development on methodologies for control systems specification of discrete event systems (systems with discrete states and instantaneous events) or hybrid systems (systems where there are discrete states, instantaneous events and continuous variables) into the contact of human centred systems and balanced automation systems.

The project are divided on the following topics:

- **Hybrid** s**upervisory systems -** This topic aims the development of a modelling, analysis and specification methodology for hybrid supervisory systems. The approach is based on modelling and analysis tools of discrete event systems such as extensions of Petri nets proper to include the treatment of continuous variables.
- **Flexible (intelligent) production systems -** This topic aims the development of methodologies and support systems for the design, analysis and control of flexible manufacturing and robotized assembling systems. These systems are considered as discrete event systems and it is investigated the effectiveness of Petri net based techniques as well as their extensions such as PFS/MFG (Production Flow Schema/ Mark Flow Graph). The focus is on the remote management of automated systems as well as the treatment of failures.
- **Integration of systems and activities in intelligent buildings -** This topic aims the characterisation and development of an integrated and modular system for management, control and monitoring of intelligent buildings with robots and computer aided sensorial

infrastructure. The approach is based on discrete event dynamic systems theory and analysis tools where the concept of open automated system has a fundamental hole.

Keywords: supervisory control, discrete event systems, hybrid systems, robot programming.

2.2 IPS - Intelligent Production Systems

Researchers: Diolino J. dos Santos F° (coord.)

Recent advances in the architecture of robots and automation systems are remarkable. The programmable controllers, formerly limited to proprietary languages, have been re-defined to use standards and open languages including high-level languages such as C and Java. The capacity, velocity and reliability of these controllers have improved to levels that can be compared to powerful computers. Also, the evolution of instrumentation concepts supports the qualitative and quantitative improvement of information that should be used by the control systems. The man-machine interface devices have improved significantly allowing user to access a vast range of information in a fast and concise manner.

In this context, robots and automation concerns with embedded control systems, which deal with decision making and complex strategies including multiple and conflicting objectives.

This research project aims to investigate and develop methods and techniques for modeling, analysis and control of Intelligent Production Systems (IPS), and includes the following themes:

- Multi-agents architecture for IPS control systems synthesis
- Control architecture for flexible production systems with multiple objectives
- Concurrent processes control of IPS

Keywords: production systems, intelligent robot systems, modelling, and control.

2.3 Decision Making Automation

Researchers: Fabio G. Cozman (coord.)

The project focuses on automated decision making techniques, particularly techniques that involve probability theory and generalisations of probability theory. These techniques are applied in robotics and autonomous systems, particularly on the use of robots to enhance human life.

The project are divided on the following topics:

- **Graphical models for probabilistic reasoning -** We have used Bayesian networks for probabilistic reasoning in various domains (for example, embedded robot systems and medical decision making), and we have developed algorithms for exact and approximate probabilistic reasoning.
- **Models that represent indeterminacy and imprecision in probability values -** Models that represent indeterminacy and imprecision in probability values using sets of probabilities (for example, probability intervals: "the probability of a sunny Sunday is between 40% and 55%"). We focus on theoretical issues regarding independence concepts and algorithmic issues regarding inference and decision making.
- **Robotics -** Robotic devices that can help the disabled and that can be used for educational purposes.

Keywords: decision making, artificial intelligence, robotics.

São Paulo State University (USP/SP)

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Mechatronics - Sensors, Actuators & Underwater Robotics

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Mechatronics - Sensors, Actuators & Underwater Robotics

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- Julio Cezar Adamowski, Full Professor of Department of Mechatronics and Mechanical Systems Engineering – EPUSP Escola Politécnica, University of Sao Paulo
- Emilio Carlos Nelli Silva, Associate Professor of Department of Mechatronics and Mechanical Systems Engineering – EPUSP
- Celso Massatoshi Furukawa, Delson Torikai, Fabio Kawaoka Takase, Flávio Buiochi, Newton Maruyama, Ricardo Cury Ibrahim, Assistant Professors of Department of Mechatronics and Mechanical Systems Engineering – EPUSP
- Graduate students: 14
- Undergraduate students: 16

1. Group Description

The research group conducts research on Mechatronic Engineering, mainly on the following topics:

- Computer controlled machines and equipments
- Micro-actuators
- Underwater robotics and actuators
- Intelligent control techniques: neural networks and fuzzy logic
- Ultrasound: transducers, non-destructive essays, acoustic localization and welding

Mechatronics provides to mechanical systems most of the recent advances achieved in the fields of microelectronics, like microprocessors, digital signal processing, memories, AD and DA converters.
Incorporating the capability to receive and process information, a mechanical system is capable to automatically adjust itself to different operating conditions. Therefore, the system becomes more flexible and offers better performance and efficiency.
The following projects illustrate the fields of interest of the laboratory.

2 Research Project in Robotics

2.1 Underwater Robotic System for Offshore Applications

Furukawa, C.M.; Barros, A.E.; Adamowski, J.C.; Maruyama, N.; Horikawa, O.
The goal of this project is the development of a robotic system for missions in deepwater fields. The first mission is related to transponder recovery. A transponder is a acoustic beacon that is left on the seefloor, and it is used in the dynamic positioning of vessels.
The underwater vehicle has to connect itself to a base on the seabed that supports the transponder and take up the whole structure. An umbilical cable is used for vehicle recovery and for semi-autonomous modes of operation.
The vehicle has an open frame structure and 8 electric propellers. An ultra-short base line (USBL) acoustic positioning systems provides position estimations with 5 cm of precision.
Sponsors: FINEP/CTPETRO
Period: since 2000
Keywords: underwater robotics, AUV, offshore equipments

2.2 Ultrasonic and Inertial Pigs for Pipeline Inspection

Furukawa, C.M.; Adamowski, J.C.; Buiochi, F.

A pig is an equipment used by the petroleum industry to inspect pipelines with sensors. The ultrasonic pig uses ultrasonic pulses to locate points of the internal wall of oil pipelines with pronounced corrosion. The pulse-echo technique is employed to measure the distance from the ultrasonic transducers to the wall of the pipeline, providing in this way an indirect measurement of the wall thickness.

Odometric and inertial position estimation is used to precisely locate the position of detected defects in a three dimensional map.

Sponsors: FINEP/CTPETRO

Period: since 2001

Keywords: non-destructive essays, pipeline inspection, inertial navigation

2.3 Development of Micropositioners and Microactuators

Silva, E.C.N.

This research project aims the development of micropositioners and microactuators. The proposed micropositioners essentially consist in a compliant mechanism multi-actuated by pieozoceramics. The microactuators essentially consists in electrothermomechanical MEMS (Microelectromechanical Systems). The project involves the design, simulation, manufacturing and experimental characterization of a proposed XY micropositioner and electrothermomechanical MEMS using load cells and optical techniques. The design of micropositioners is complex once is related to the concept of multi-flexibility, thus, a software based on the topology optimization method will be developed to design these devices in generic and systematic way. Topology optimization consists in a general computational design method that combines optimization algorithms (such as sequential linear programming) and finite element to design parts with complex topologies.

Sponsors: FAPES, CNPq

Period: since 1999

Keywords: topology optimization, piezoelectric actuators, MEMS

2.4 Fabrication and Characterization of Mini and Micro Actuators/Sensors

Ibrahim, R.C.

This research comprises the study of several types of mini and micro electromechanical devices to be used in actuation and/or sensor systems. At present, the group works with electrothermal and electrostatic actuators microfabricated using the surface micromachining technique to generate suspended structures of nickel. It also studies piezoelectric actuators of small size and medium size (ultrasonic motors). The characterizations are basically done using an optical microscope with a video camera connected to a microcomputer.

New studies are being initiated on electroplated piezoelectric films to be used in microactuators and microsensors. High aspect ratio microstructures will also be fabricated using the LIGA technique. These works are done in collaboration with the Department of Electronic Systems Engineering of EPUSP, and with the National Synchrotron Light Laboratory (LNLS, in Campinas).

Sponsor: FAPESP

Period: since 2000

Keywords: microactuator, microsensor.

2.5 Position and Velocity Control of Unmanned Underwater Vehicles

Maruyama, N.

The Unmanned Underwater Vehicles (UUVs) can be classified as Remotely Operated Vehicles (ROVs) and Autonomous Underwater Vehicles (AUVs). As a rigid body, the UUVs must be described using a twelve degrees of freedom position and velocity dynamic models. The complexity brought by the large number of degrees of freedom together with the vehicle nonlinear dynamics make them excellent systems to test more complex control techniques. Many different control techniques are being considered like: H-inf, μ-synthesis, Robust Control via Linear Matrix Inequalities, Robust Gain Scheduling .
Sponsors: FINEP/CTPETRO
Period: Since 2000
Keywords: ROV, AUV, position and velocity control.

2.6 Development of Navigation Algorithms using a Low Cost Inertial Measurement Unit with Strapdown Technology

Maruyama, N.; Furukawa, C.M.; Adamowski, J.C.

The use of Inertial Measurement Units for vehicle localization are usually accomplished by the use of Kalman Filter and Extended Kalman Filter. Using a State-Space system model it is possible by these algorithms to obtain estimates of the vehicle position and velocity. This technique allows sensor fusion (tachometer, GPS, odometer, etc.) in order to enhance the estimates. More recently, a different class of Markov Chain based filters named Particle Filters has been developed. They are Recursive Monte Carlo algorithms which allows to handle nonlinear models and Non-Gaussian noise. We are seeking to develop Kalman Filters and Particle Filters in order to estimate the position of Oil Pipeline Inspection Systems (pigs) and also the position and velocity of Unmanned Underwater Vehicles.
Sponsor: FINEP/CTPETRO
Period: since 2000
Keywords: Inertial Navigation, Sensor Fusion, Strapdown.

Instituto Tecnológico de Aeronáutica

São José dos Campos, SP

NCROMA Research Group

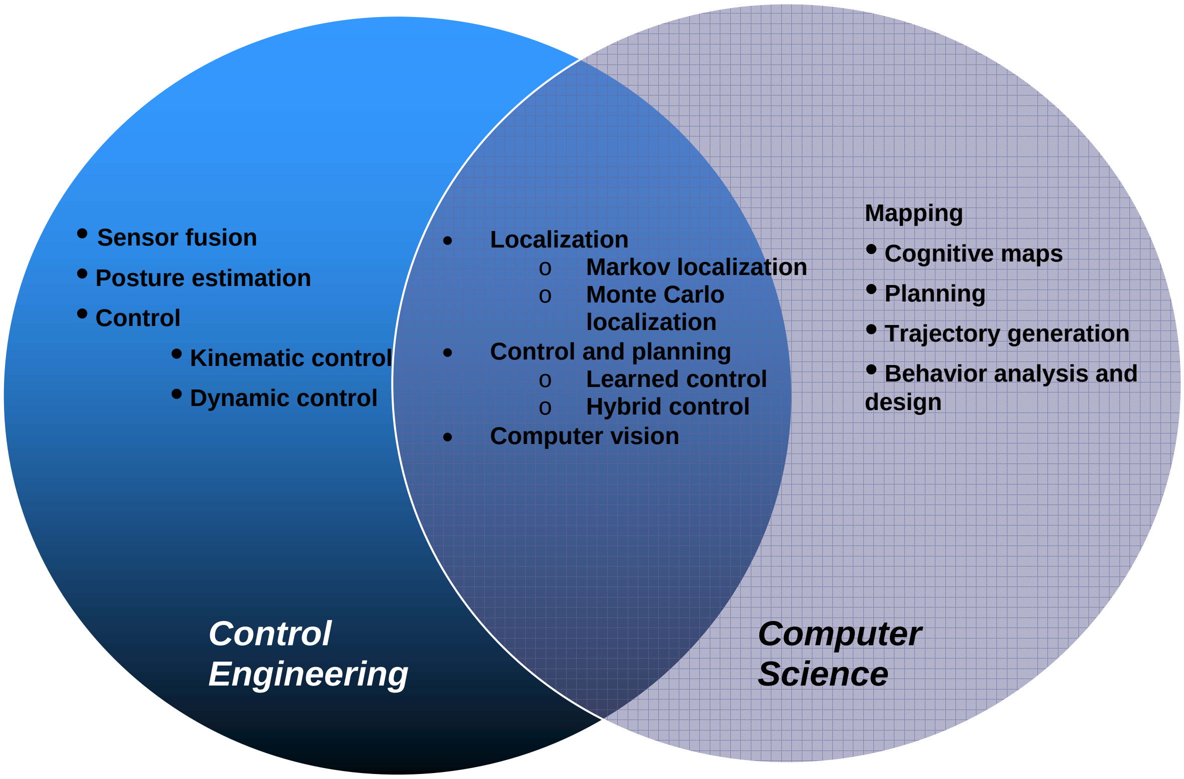
NCROMA is a research group on navigation and control of autonomous mobile robots, involving researchers from ITA Computer Science and Electronics Divisions

http://www.comp.ita.br/~ncroma

Coordinators:

Prof. Carlos H.C. Ribeiro: carlos@comp.ita.br
Prof. Elder M. Hemerly: hemerly@ele.ita.br

Main researches at NCROMA

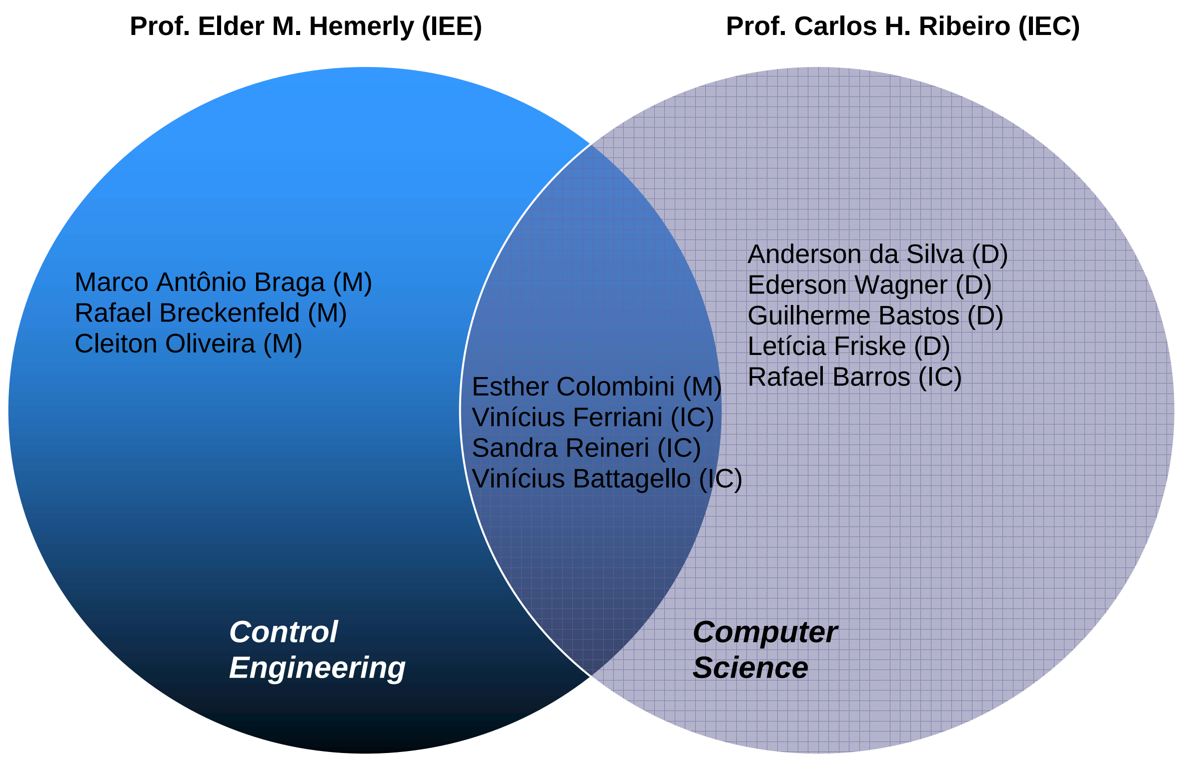


NCROMA Resources

- Magellan Pro mobile robot
  - Laser sensor, sonars, IR
  - Wireless link
  - Camera
  - On board computer
- K-Team Khepera robot
- Pioneer AT (under acquisition)
- Pioneer robot (from USP, under joint project)
- Additional hardware: electronic compass, INS, framegrabbers.
- Computers: 3 Pentium 4 1GHz, 2 Pentium PIII 800MHz, 2 Pentium PII 450MHz, 1 notebook Toshiba Satellite
- Financial support: FAPESP, CNPq, CAPES

NCROMA Members



NCROMA Current and Former Projects

- **Vibarim** (CNPq – ITA/USP):
    - Trajectory planning
    - Optimization
    - Computer Vision
- **Multibots** (CAPES – USP/ITA/ISR Portugal):
    - Robot teams
    - Trajectory planning
- **AACROM** (FAPESP – ITA/USP):
    - Behaviour coordination
    - Trajectory planning
    - Machine learning
    - Hybrid control
- **MAPPEL** (CNPq/NSF - USP/ITA/UNICAMP/Carnegie-Mellon EUA):
    - Machine learning
    - Robot teams
    - Computer vision

Campinas State University-UNICAMP

Campinas/SP

Nucleus of Informatics Applied to Education (Nied/Unicamp)

João Vilhete Viegas d'Abreu

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Nucleus of Informatics Applied to Education (Nied/Unicamp)

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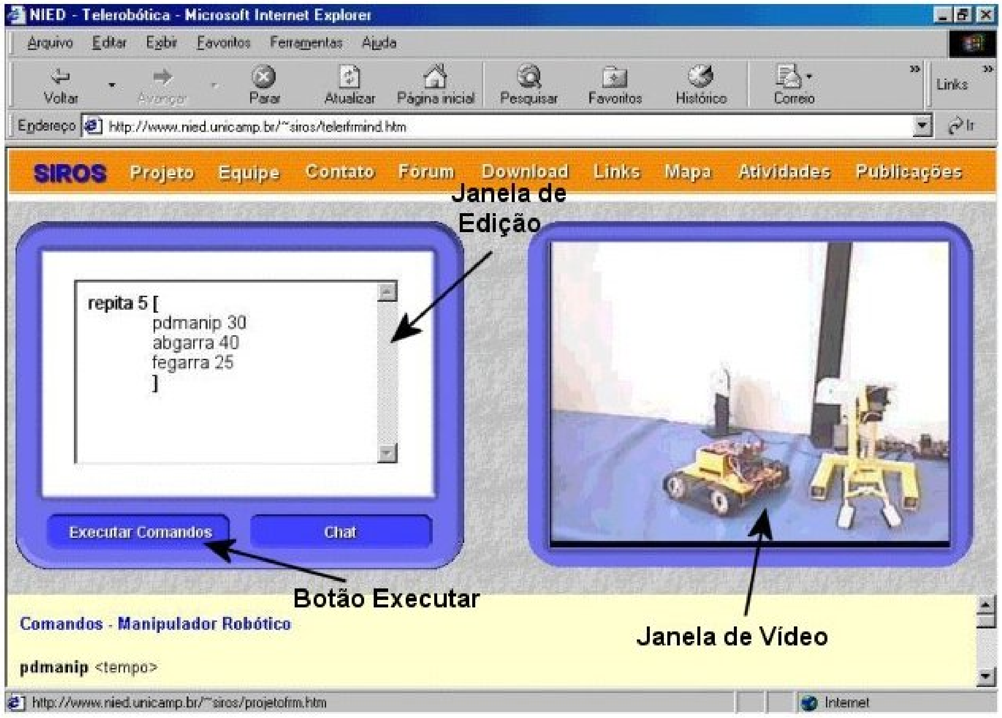
The Nucleus of Informatics Applied to Education (Nied/Unicamp), created in 1983, keeps an interdisciplinary group formed by professors and researchers (Dr. Baranauskas, MsC. Freire, Dr.Martins, Dr. Rocha, Dr. Valente and Dr. D'Abreu) of diverse knowledge areas (Computation, Engineering, Education, and Linguistics).

Throughout its history, the **Nucleus of Informatics Applied to Education (Nied/Unicamp),** has detached national and internationally by the Research Projects it leads, financed by diverse Brazilian scientific agencies (CNPq, Fapesp, Vitae Foundation) as well as international agencies (Organization of American States - OEA), establishing partnerships and collaborating with many institutions, among them: the National Program of Computers and Education (ProInfo) of the Brazilian Distance Education Secretary (SEED), Special Education Secretary (SEESP), Federal University of Rio Grande do Sul (UFRGS), PUC-SP, Foundation of Administrative Development (FUNDAP) of the State of São Paulo and Delphi-Harrison Thermal Systems from General Motors.

Nied's research activities fit in two main interrelated areas: training of human resources and the development of information and communication technologies to support the educational process.

The group has an important and large performance in the application and development of educational technology, as well as in training of human resources for this usage in the most varied educational segments. The publications of the group show innovative and pioneering results in all its acting sectors (Freire and Valente, 2001; Moraes, 2002; Valente, 1993; Valente, 1996; Valente, 1999). This academic production detaches the NIED as a national reference of excellence in its area of performance. Since, one of the others projects developed in Nied is the SIROS project, an implementation of environments for Pedagogical Robotics based on Logo.

The **Siros Project - Robotic Systems with SuperLogo** - initiated in 2000, under the coordination of Dr. João Vilhete Viegas D'Abreu, presents a set of software and hardware devices which appease resources for the elaboration of concepts and knowledge related to Pedagogical Robotics, as much in traditional as in distance way. This environment made it possible for geographically distant people to act collaboratively in programming and controlling robotic devices which are physically installed at Nied's labs. The Siros is being being by some institutions such as: Municipal Schools of Campinas, Pontifical Catholic University of São Paulo (PUCSP), Public Schools in Argentina, and by other partners of Nied in the Project OEA, described above. This project resulted some articles (D'Abreu and Chella, 2001; D'Abreu and Chella, 1999a; D'Abreu and Chella, 1999b), one master´s thesis (Chella, 2002) and one doctoral thesis (D'Abreu, 2002)



SIROS - Robotic Systems with SuperLogo

The implementation of environments for Pedagogical Robotics based on Logo constitutes one of the research lines of NIED, with the aim of building electronic/electromechanical devices which, when connected to a computer, would permit the control, in real time and out of the screen. Actually another approach was used in order to allow controling electronic/electromechanical devices using the Internet.This process consist of improving SuperLogo (a version of Logo for the Windows operating system, in portuguese) in order to enable it to control this kinds of devices in an environment called SIROS. SIROS is, an educational environment, is a reserach project objectifying, in the distance, to implement in SuperLogo software resources that make possible the user to control automatized mechanical devices. The environment allows to control devices including commercially kits and devices developed with aletrnative materials. SIROS also can be used to control RCX, a LEGO Dacta programmable brick that works similarly to a microcomputer.

UNISANTA- Universidade Santa Cecília
NPE – Núcleo de Pesquisas em Eletrônica

Santos/SP

GLPA- Grupo de Lógica Paraconsistente Aplicada

Prof. João Inácio da Silva Filho

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http://www.unisanta.br/glpa

1- Introduction

The GAPL -Group of research in Application of the Paraconsistent Logic

This group has been created with the objective of developing activities of researches in the applications areas of the Non-classic Logics, focusing the construction of Intelligent Systems based in the Anottated Paraconsistent Logic. GAPL will maintain, as well as to maintain intense academic exchange with researchers and institutions of Brazil and of other countries.The researchers of GAPL have been working in the development of Systems of Control and Automation an Robotics projects, using, mainly, the innovation of Intelligent Systems built with the fundamental concepts of the Annotated Paraconsistent Logic.

For a better administration of the Group activities the researchers are divided in two research fields interlaced with the same objective:

Group of the Paraconsistent logic used in Automation and Robotics
Group of the Paraconsistent logic used in Intelligent Systems

Group of the Paraconsistent logic used in Automation and Robotics
Members of the Group:
Prof. Dr. João Inácio da Silva Filho-*(líder)* (IEAUSP/UNISANTA)
Prof. Dr. Alexandre Rocco -*(líder)* (UNISANTA)
Prof. Msc. Marcos Roberto Bombacini (UEL)
Prof. Dr. Jair Minoro Abe (IEAUSP/FMUSP) (Membro honorário)
Prof. Msc. Cláudio Rodrigo Torres (UNIFEI)
Profa. Msc. Dorotéa Vilanova Garcia (UNESP/UNISANTA)
Prof. Msc. João Carlos Almeida Prado (FMUSP)
Prof. Fernando José Cesilio Branquinho (UNISANTA)

Group of the Paraconsistent logic used in Intelligent Systems
Members of the Group:
Prof. Dr. João Inácio da Silva Filho*(líder)* (IEAUSP/UNISANTA)
Prof. Msc. Mauricio Conceição Mario-*(líder)* (FMUSP/UNISANTA)
Prof. Msc. Jadir Denis Pinto Albino (UNISANTA)
Prof. Dr. Keiji Yamanaka (UFU)
Prof. Dr. Marinho Del Santo Junior (FMUSP)
Prof. Moisés Tavares da Conceição (UFU)
Prof. Msc. Luís Fernando Pompeo Ferrara (UNISANTA)
Prof. Dra. Neli Regina Siqueira Ortega (FMUSP)

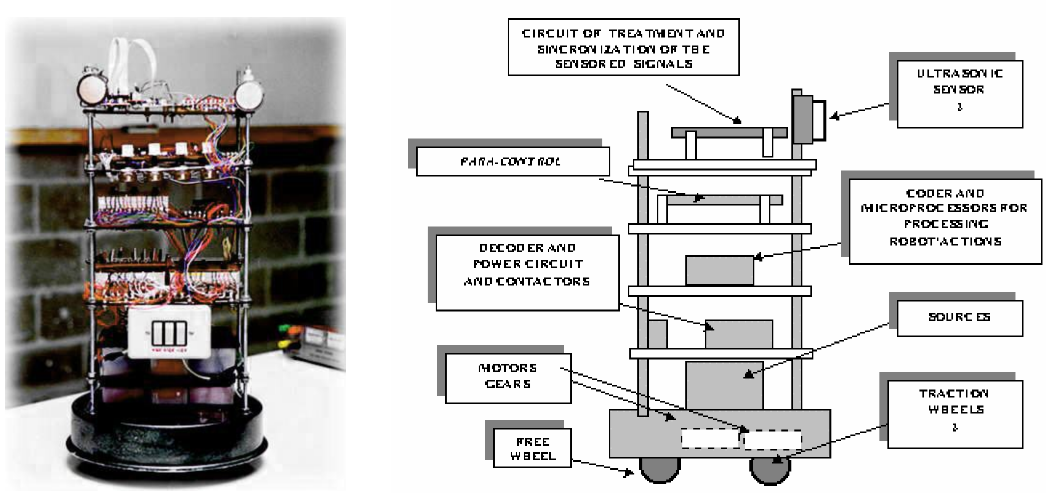
2- Robotics research

2.1 - Emmy: A Paraconsistent Autonomous Mobile Robot

Emmy is the first autonomous robot that works with a logical controller built with Paraconsistent Annotated Logic's concepts.

The paraconsistent Annotated Logics are a class of non-classic logics that allow the treatment of contradictory signals in their structure.

The control systems used in Automation and Robotics work, in general, based on classical logic. But the contradictions or inconsistencies are common when we describe parts of the real world, and these binary systems are inadequate to treat appropriately the contradictory situations. In some cases, the classic control systems are projected to ignore these situations and losing information that could be important for the increasing of the control efficiency.The control system of the robot's navigation is made by a Logical Controller paraconsistent-*Para*-Contro*l*, built in Hardware that receives and makes the treatment of electric signals based on the theoretical concepts of the Paraconsistent Logic.



(a) (b)

Figure 1 – (a) The robot Emmy – (b) The robot's main parts.

The autonomous mobile robot Emmy consists in a mobile aluminum platform of circular format with 30 cm of diameter and 60 cm of height, projected for application researches in paraconsistent annotated logics. The robot was projected in separeted modules, each one with their function in the control system. It allows a clearly visualization of the each module action working for the robot's movement. The autonomous mobile robot is destinated to traffic in a non-structured environment avoiding collision and obstacles consisting by objects that appear suddenly in its way and its main characteristic is allowing programming the robot's actions when it faces an inconsistent or vague situation captured by the sensors. The robot was named "Emmy" in homage to the great mathematician Emmy Nöether. Despite the robot's technical limitations, we think that the results were satisfactory, showing the possibility to treat uncertain situation through the paraconsistent logics.

2.2 - Parasonic: A Sensor of the Paraconsistent signals to be used in Robots

The research results demonstrate that there are a lot of difficulties to obtain a good efficiency in the control systems for autonomous movable robot's navigation. It happens because in a controller project for this kind robot should be considered several situations that can generate inconsistencies. These inconsistencies can happen in the information that the Controller receives when the robot is moved in an unknown environment. For instance: when passing by close to walls, in narrow roads, curved and in uneven lands or still in the presence of traffic, it is obtained a lot of contradiction.

The Parasonic is the result of the researches to build a device capable to capture information of the environment in form of degrees and compatible with the concepts of the Paraconsistent Logic. It is capable to capture obstacles in an autonomous mobile robot's path transforming proportional the distance measures between the robot and the obstacle in electric signals, in the form of a continuous electric tension that can range from 0 to 5 volts.

The Para-sonic is basically composed by two ultrasonic sensors POLAROID type 6500 controlled by a Microprocessor 8051. The Microprocessor 8051 is programmed properly to do the synchronization between the measurements of the sensors.

2.1 – Emmy II: A Paraconsistent Autonomous Mobile Robot With Microprocessor Control

The Mobile Robot Emmy II is a continuation of the researches developed with the Robot Emmy. This Work resulted in a *ParaControl* with more action possibility in the Paraconsistent logical control. As an innovation, the *ParaControl* presents, besides the Emmy controller characteristics (uncertainties manipulation, contradiction and paracompleteness information), the speed control in the robot's actions.

The use of the Microprocessor in the circuits reduced the robot's structure turning it more dynamic and with better answer to the interaction with the environment in his movement.

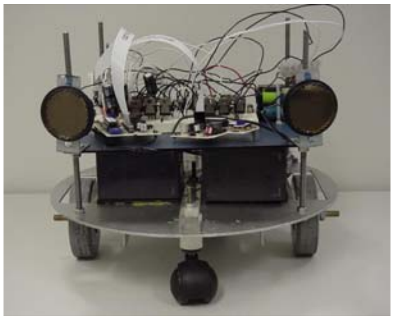


Figure 2 – The robot Emmy II

2.3- AGV - Automated Guided Vehicle

The autonomous Robot AGV is a research developed by the GAPL together with college students with the objective of building a low cost Robot performance.

Figure 3 – The robot AGV

AVG is an autonomous vehicle that moves in a certain route demarcated by a black strip. It is capable to follow a route even with the existence of curves, and to be programmed to stop in 4 places for delivery and reception of the material to be transported. For this action the robot is equipped with 7 infra-red sensor that make the verification of the route and the reading of the binary code of each one of the stop positions. The Control System for decoding the signals is done with a GAL memory (Generic Array Logic) what allows an electronic project of high income and low cost.

All these research projects in robotics presented in this work are being modified with the objective of finding new control means using the Paraconsistent Logic.