Multiact Approach for Building Web-based Educational Environments: Mobile Robotics Course as a Case Study

A. Khamis, F. Rodríguez, M. Salichs
Department of systems Engineering and Automation
Carlos III University of Madrid - Spain
E-mail: {akhamis, urbano, salichs}@ing.uc3m.es

Abstract: **This paper presents the Multiact approach, which can be used to build innovative teaching environments, which exhibit much better efficiency, cost effectiveness and more motivating courses for the students. This approach combines different activities to solve the traditional teaching constraints of curriculum, class size and limited resources and to increase the student motivation to have an active and creative role in the education process. The proposed approach has successfully been used to build a teaching environment in the filed indoor mobile robotics.**

I. INTRODUCTION

Telematic technologies (= telecommunication + informatics) are now widely used in education and training, enabling the implementation of new pedagogical paradigms (e.g. distance learning, sharing of course materials, remote and virtual laboratories). Several systems with varying capabilities and philosophies have been developed to support online education on the Web. A networked system has been employed in Michigan State University to generate personalized assignments and to provide instant feedback and on-line assistance to students in large classes [1]. WWW-based asynchronous learning environment called Mallerd is used to teach a freshman electrical and computer engineering course [2]. A technique for enabling students to benefit from the traditional classroom experience by joining classes live on the Internet or by taking lectures on demand asynchronously is presented in [3].

While there are many practical benefits in the use of Web-based education, the production of learning content, which incorporates both well organized theoretical and experimental contents, is still expensive. At the same time, new learning requirements are emerging, with a shift towards personalized learning services flexibility delivered. Thus, more cost effective learning environments are required based on open standards and reusable learning objects. The project CODEX-IP (Collaborative Language Independent Development Environment for Exemplary based Re-usable Learning objects in IP Learning Platforms) overcomes the structural problems of creating open platforms for learning by developing a cost-effective tool and methodology that enables the development and maintenance of language independent re-usable learning objects to be distributed within IP-based open learning platforms [4]. Trial-Solution (Tools for reusable, Integrated, Adaptable Learning System/Standards for Open Learning using Tested Interoperable Objects and Networking) has the objective of using open platforms and tools to develop and then validate a powerful new way of creating, delivering and managing personalized education and training [5]. WINDS (Web-based Intelligent Design Tutoring System) project aims to contributing to reorganisation of the pedagogical, cultural and functional aspects of university design education [6].

Robotics education provides an ideal field for Web-based education systems because of its flexibility. Unlike traditional fields, robotics is still an emerging area. Relatively few programs exist at the graduate level, and even fewer at the undergraduate level. The courses in existence are still new and are open to rapid change and new approaches.

Much of the current research in new robotics education environments is concerned with the use of web-based instructional activities to map traditional educational model by using the new telematic technology. Lundquist has presented online introductory course in robotics and industrial robots [7]. Many subjects related to mobile robots have been introduced in online course [8]. McKee has proposed an online environment for teaching robotics and artificial intelligence [9]. The learning taxonomy used in this project was the simple stop-look-act cycle, which provides an interactive learning. Many other researchers try to build remote laboratories to facilitate remote experimentation and hardware resources exchange. A remotel laboratory for mobile robot experiments has been discussed in [10] to provide an access to mobile robots infrastructure. Schilling has presented a model design for remote mobile robots [11]. A software architecture to build mobile robotics remote laboratories has been presented in [12]. The project TEAM (Tele-Education in Aerospace and Mechatronics) [13] and IECAT (Innovative Educational Concepts for Autonomous and Teleoperated System) [14] are two examples for virtual laboratories.

Most of the previous works have been developed to cover certain subjects by providing online experiments or online classes without providing any kind of generic tools for the remote users by which they would be able to customize the experimental content according to their needs. Some types of tools also must be provided to give the student the possibility to play an active and creative role in the education process. The face-to-face interaction between the student and the tutor and between the student and the machine is very important issue in a field like robotics.

The multiact approach tries to provide an integrated teaching environment, which combines different instructional and constructional activities. The paper is structured as follows. Section II presents the proposed multiact approach. The expected outcomes from using this approach are listed in section III. Section IV presents a case study to create a new mobile robotics fundamental course using this approach. Section V summaries student feedback, while concluding remarks are given in section VI.

II. MULTIACT APPROACH

Multiact approach tries to combine different educational activities to develop innovative teaching environment for engineering. This approach has two main parts, web-based instructional activities that are used to map the traditional teaching and learning activities and to solve the traditional teaching constraints of curriculum, class size and limited resources. The other part of this approach is the constructional activities, which give the students the opportunity to physically construct and implement the ideas driven from the course. The following subsections describe in more details the proposed activities.

A. Instructional Activities

The instructional activities of the course can be implemented based on the Web-based education model. In this model telematic technologies are used to map the traditional teaching and learning activities. In the traditional education model, lectures and laboratories are the traditional ways commonly used in any education system. This model of education is quite entrenched where the flow of knowledge in traditional systems is largely unidirectional, especially in the large classes, with the exception of occasional questions and discussion. The amount of questions and discussion is usually inversely proportional with the class size, resulting in large classes often becoming the academic analog of watching an informational video [15]. In the last decade many terms have been proposed to describe the telematic-based education systems such as asynchronous learning networks, collaborative telelearning, distance education, distance learning, distance teaching, flexible learning, technology-mediated distance learning, interactive learning and teleeducation or Web-based Education. Many instructional activities can be implemented based on web-based education model to map the traditional teaching and learning activities and to solve the traditional teaching constraints of curriculum, class size and limited resources such as the following:

1. Web-based Lectures

Online lecture is used to map the traditional classroom. J.Bourne et al proposed to organize the material of the online lecture according to well-known taxonomies in education [15]. Barrett's Taxonomy proposed that learning should be divided into four categories: literal, inferential, applicative and evaluative. Merrill's Taxonomy uses a performance-or remember, use, or find (create). The content is classified as fact, concept (classification), procedure or principle. Table 1 shows examples of learning outcomes in mobile robots as an example according to Barret and Merritt taxonomies.

TABLE 1 LEARNING OUTCOMES

Knowledge	Example	Barrett	Merrill
Recognize types of components and circuits	Given these sensorial data, determine what is the source of these data.	Inferential	Use Concepts (Classify into categories)
Linkage to real world complexity	This figure indicates that there are some measures out of the range of the lab borders. What is your hypothesis for this unexpected result?	Applicative	Use principle

2. Web-based Laboratories

A remote laboratory can be defined as a network-based laboratory where user and real laboratory equipment are geographically separated and where the telecommunication technologies are used to give users access to laboratory equipment [16].

These labs are not restricted to synchronized attendance by instructors and students; they have the potential to provide constant access whenever needed by student. By networking many remote laboratories, we can obtain a framework called virtual laboratory.

A Virtual Laboratory is a heterogeneous, distributed problem solving environment that enables a group of researchers located around the world to work together on a common set of projects. It can be used to provide a coordinated set of experiments for student with hardware facilities physically spread over different locations, but accessible via Internet. As with any other laboratory, the tools and techniques are specific to the domain of the research, but the basic infrastructure requirements are shared across disciplines. The project IECAT [14] in which we are participating is an example for virtual laboratories in the field of mechatronics and telematics. The building of such laboratories for laboratory experiments in filed such as mobile robots requires expertise in a number of different disciplines, such as Internet programming, telematic and mechatronic systems, etc. They must have live performance characteristic, not just virtual reality or simulation programs. Also an intuitive user interface is required for inexperienced people to control the robot remotely. The implementation of such laboratories is basically based on the concept of teleoperation or remote control.

3. Web-based Assessment Tools

Methods of assessment are important aspect of every course. Traditionally, handling assessments manually incurred major overhead in the marking and processing of these assessments. So, in most courses, assessments or quizzes are usually kept to the minimum necessary to accurately assess progress or competence. With the proposed telematic-based environment, it will be easy to construct systems that automatically correct and handle quizzes for the teaching staff and that reduce the time taken to carry out other forms of assessment. Evaluative tests can be used to provide online assessments. Student first takes an exam and then, based on the results of the exam, customized learning activities can be generated to reinforce the areas in which the students scored poorly. Moreover practice tests can be designed to cover the experimental issues as a simulation to traditional laboratories.

4. Communication Tools

An essential part of any learning experience is communication. Two communication mechanisms (synchronous such as text/audio/video chat, Internet telephony and videoconference and asynchronous as E-mail, newsgroups and mailing lists) are planned to be implemented to provide communication between students and teaching staff.

B. Constructional Activities

Constructionism is an active learning process in which students construct things that are personally meaningful to themselves or others around them [17]. Instead of being served information in the traditional one-way setting, students develop their own knowledge and understandings of a subject through physical construction and implementation of their ideas. The construction activities give the students the opportunity to physically construct and implement the ideas driven from the course. They consist of the following activities:

1. Off-Campus Activities

The off-campus constructional activities are active learning activities as teleprogramming, telemonitoring, telediagnostic, telemaintenance and teleperception, etc…, which can be incorporated in the remote laboratory.

2. On-Campus Activities

The on-campus activities such as designing and constructing of new prototypes or reverse-engineering existed systems can be used to provide the face-to-face interaction between the students and teaching staff and between the student and the machine, and therefore increase student motivation and decrease students feeling of isolation. These constructional activities help also to increase student creativity and working in team.

III. EXPECTED OUTCOMES

Many benefits are expected from applying this approach to build innovative teaching environment or to update engineering courses currently taught such as:

- Increased availability where instructional activities are not restricted by the synchronous attendance of students and educators.
- Increased variety and flexibility where the multiact approach tries to make a balance between instructional and constructional activities.
- Increased communication where the Web provides many communication tools by which students can talk with each other, individually or as a group, and send questions or hold conversations, oral or electronic, with their educator.
- Increased learner control where the combination of instructional and constructional activities helps to increase the feeling of control that students have over their learning experience, which in one way to increase student motivation.
- Increased creativity where constructional activities help students to construct things that are personally meaningful to themselves or others around them.
- Increased participation where the balance between telematic-based instructional activities and constructional activities helps to increase student motivation to participate in the education process.

IV. CASE STUDY

An innovative teaching environment in the field of indoors mobile robotics is currently being developed at Carlos III University based on the proposed approach. This system covers different theoretical and experimental issues of mobile robots. It is supported by instructional activities in form of online lectures, a remote laboratory, which provide the ability to do real experiments remotely, assessment and communication tools. Moreover it has many constructional activities such as off-campus activities by using teleperception and teleprogramming concepts and on-campus activities. The knowledge is presented to the remote user by using three types of tutoring tours as shown in figure 1.

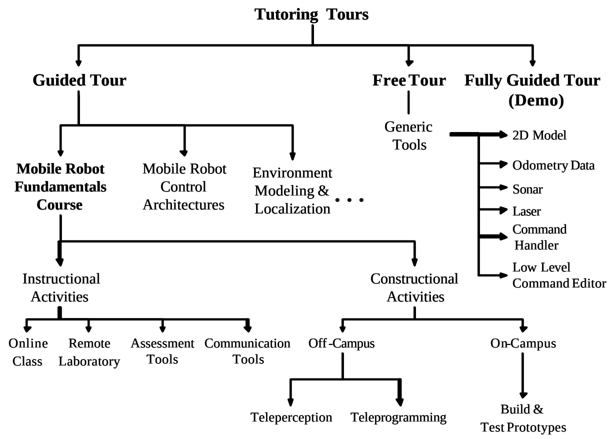

Fig. 1 Tutoring Tours

These tours are classified according to the level of guidance of the tutor into: demonstration tour, which is a fully guided tour to demonstrate basic concepts without intervention from the student, guided tour, which aims at presents different specified courses with direct interaction between the student and the tutor and free tour that is guideless tour. The following subsections describe the incorporated activities in the mobile robotics fundamental course.

A. Instructional Activities

The main objective of the developed fundamental course is to present systematic knowledge of mobile robotics.

1. Online Class

The theoretical contents have been organized based on the learning outcomes derived from the learning taxonomies explained early. The class presents the basic knowledge of robots as a general issue and indoor mobile robotics as main subject. These knowledge include introductory concepts, robots classifications, mobile robot anatomy, control architectures of mobile robots, sensors commonly used in mobile robots and mobile robots applications. The class also has been supported by FAQ pages, search engine, digital library and downloadable materials.

2. Remote Laboratory

Remote laboratories can be used to represent a coordinated set of experiments for students with hardware facilities physically spread over different locations, but accessible by students via the Internet. In the designing of these distance laboratories for robotic systems, a number of challenges must be addressed, particularly the telematics infrastructure which gives access to the experiments, as well as the user interface which provides the necessary interactivity with the remote hardware supporting the learning process of students through appropriate feedback [18]. To implement a remote laboratory a simple Internet-based remote control model is commonly used. This model is based on the simple protocol commonly used in distributed computation "The Request/Response Protocol". The client interacts with the system using any Web browser to make the request. Client requests are translated to HTTP requests, which are satisfied by the Web server. These requests are converted to high-level control requests that are received by the robot controller, which transmits them as low level control requests to execute the required task. Sensory feedback is required to give the user information about the remote robot's environment and the consequences of his/her commands.

In the remote laboratory, errors are handled by using a three stage process: autonomous detection, shared diagnosis, and manual recovery. Errors are detected by using the visualization means such as streaming video, graphical models, sensory data or connection status panels. The diagnosis task is shared by the user and the system. In recovering from the error, the user can telecollaborate with a human at the remote site or can ask the necessary privileges to be able to telnet the remote servers to reboot them.

The following experiments have been implemented to cover the experimental issue of the course:

- PC-based Direct Control

This experiment aims at familiarizing the user with the mobile robot motion control and positioning. The remote user can send direct control commands to move the robot forward, backward or to rotate it clockwise or counter-clockwise. Using many visual feedback tools (2D model, streaming video and sensory data) the remote user will be able to view the effect of the sent commands. Novel interfaces have been also implemented to remotely control the robot by using a Mobile Information Device Profile (MIDP)-enabled cellular phone and PDA.

A study has been done to measure the response time during the PC-based direct control experiment, which is the time collapsed between sending the motion commands and the motion start. Table 2 shows the response time when the experiment was ran from local site (Carlos III University of Madrid) and when it was run from remote sites (University of Applied Science - Germany and University of Reading - England).

TABLE 2 RESPONSE TIME VARIATIONS

	Min. (ms)	Max. (ms)	Av. (ms)
Spain	121	137.76	127.2
Germany	273	354	293.51
England	394	2444	1157.45

The latency and the throughput of the Internet are highly unpredictable and inevitable. There are old qualitative studies [19] that show people seem to be able to compensate for (learn) small added delays, but cannot learn large ones (>100 msec) therefore the delay will be noticed by the user but it can be accepted for such type of educative application.

- Movement Skills

Skills have been defined as all built-in robot action and perception capacities [20]. They are the robot's connection with the world. Mobile robot skills consist of the different reasoning capacities or the sensorial and motor capacities of the robot. These skills are activated by execution orders produced by other skills or by a sequencer. They return data and events to the skills or sequencers, which have activated them. A skill can send a report about its state while it is active or when it is deactivated. For example, the skill called *gotogoal* can provide information as to whether the robot has achieved the goal or not. When this skill is deactivated it might supply information about the error between the current robot position and the goal [21].

Many movement skills can be remotely activated or deactivated such as gotoogoal, orientation control, round trip, wall following and obstacle avoidance skills. Figure 2 shows a screenshot of movement skill experiment interface.

Fig. 2 Screenshot of Skill Interfaces

3. Assessment Tools

Three types of tests are designed with material organized based on the described learning taxonomies to evaluate the student. Online quizzes are used to evaluate the student's background. Time restricted theoretical tests are used to evaluate the student's knowledge in the theoretical topics of mobile robotics. Time restricted experimental tests are designed to help the student to understand the practical problems. Figure 3 shows an example for a time-restricted experimental test.

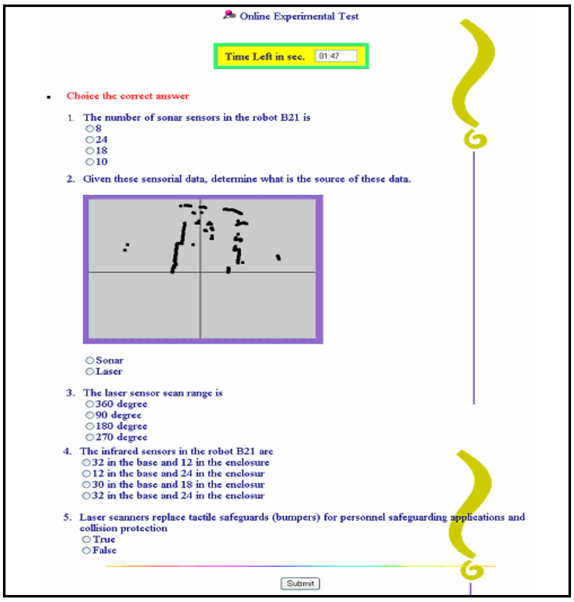

Fig. 3 Experimental Test

B. Constructional Activities

1. Off-Campus Activities

- Teleperception

The objective of this experiment is the environment perception using multi-sensor data (sonar and laser). The experiment is divided into two parts: without robot motion and with robot motion. The objective of the first part is to understand the operation of sonar and laser sensors and to be familiar with these readings. The second part aims at recognizing the real environment using sensors data. Fig 4 shows how can accumulative readings of sonar and laser sensors be used to determine the obstacle zone in the lab.

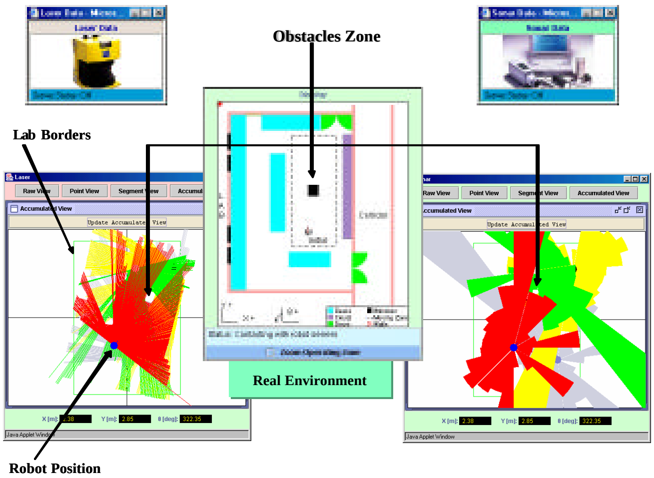

Fig. 4 Environment Perception Experiment

- Modeling & Localization

Building environment maps from sensory data is an important aspect of mobile robot navigation, particularly for those applications in which robots must function in unstructured environments. Ultrasonic range sensors are, superficially, an attractive sensor modality to use in building such maps, due mainly to their low cost, high speed and simple output. Elfes's algorithm [22] is used to generate environment maps from sonar data. In this algorithm range measurements from multiple viewpoints are combined in a two-dimensional 'occupancy grid'. Each cell in the grid is assigned a value indicating the probability that the cell is occupied.

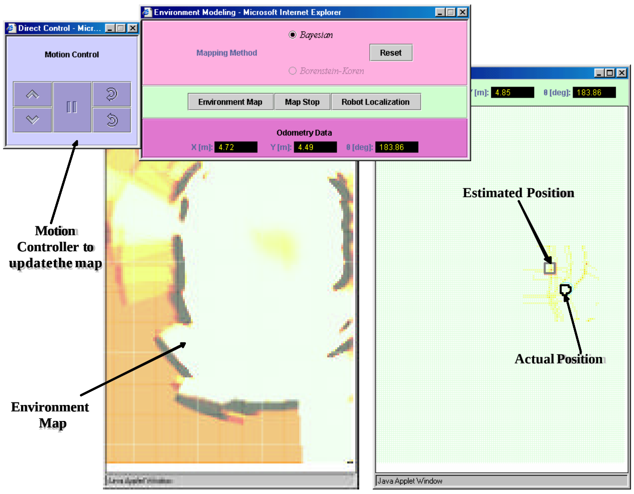

Fig. 5 Modeling & Localization Experiment

A self-localization algorithm [23] is used to estimate the robot's position by computing sets of poses which provide a maximal-quality match between a set of current sensor data and the constructed map. The remote user can compare the result of the localization algorithm with the odometry data to determine the error. Fig. 5 shows a screenshot of this experiment.

- Teleprogramming

By using a low level commands editor, the user can send low level commands via Internet to the robot's base server to perform many tasks such as adjusting the robot control parameters, increasing/decreasing robot velocity, informing about battery state, setting the Watch Dog timer which can be used for safety or diagnostic purposes, etc…

The free tour can also be used as an unguided tour, which does not determine any order and tasks at all. This tour provides generic tools to the user and let him/her to customize the experiment according to his/her needs. These generic tools include 2D model for the robot and the lab, odometry data panel, sonar data panel, laser data panel, and motion controller.

2. On-Campus Activities

Students will be asked to build robotic prototypes using lab kits such as Lego or Fischertechnik parts (including motors) as hardware components, the handy board (Motorola 88HC11 based or 16-bit Siemens 80C167) micro controller board for control, commonly used sensors and other components. Teleoperated rover also can be built and programmed by the students.

V. FEEDBACK

The proposed teaching environment has been used during the academic year 2001-2002 to update a postgraduate course about intelligent autonomous robots. Student feedback was gathered using an online questionnaire. The student responses were uniformly positive as to use of the different proposed teaching activities specially the use of the remote laboratory. Most of the student felt that the online experiments helped them to achieve a deeper and longer understanding of the subject material. Table 3 & figure 5 show examples for students' feedback obtained.

TABLE 3 STUDENT FEEDBACK

Question	Agree	Strongly Agree
The learning objective were clear	43%	57%
The course was well presented	29%	71%
The lab was easily accessible	29%	71%
The corrected exercises contained helpful comments	43%	57%
The system was essential to the course	14%	86%
The system was reliable	43%	57%
The system was easy to use	29%	71%

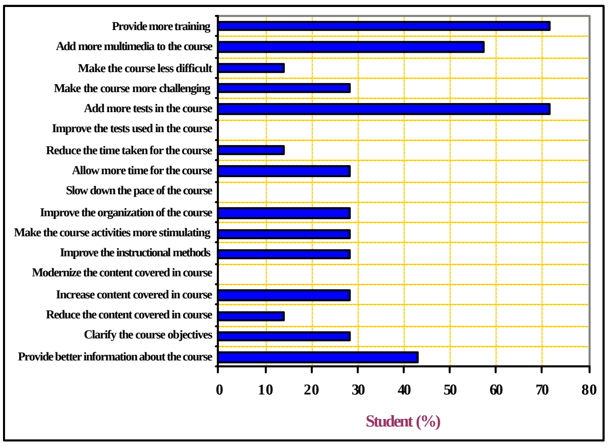

Fig.6 How would you improve this course?

VI. CONCLUSION

Multiact approach tries to combine different activities to build innovative teaching environments, which exhibit much better efficiency, cost effectiveness and more motivating courses for the students. By achieving a balance between instructional and constructional activities, student can have an active and creative role in the education process will be increased.

This approach can be used to create new course or to update courses, which are currently taught by traditional way to solve the traditional teaching constraints of curriculum, class size and limited resources. The approach has successfully been used to build a teaching environment in the filed indoor mobile robotics.

VII. ACKNOWLEDGMENTS

The authors gratefully acknowledge the funds provided by the Spanish Government through the DIP2002-188 project of MCyT (Ministerio de Ciencia y Tecnología).

VIII. REFERENCES

[1] Kashy, E., Thoennessen, M., Tsai, Y., Davis, N. and Wolfe, S. "Using Networked Tools to Promote Student Success in Large Classes", Journal of Engineering Education, Vol.87, No.4, pp. 385-390, Oct.98.

[2] Latchman, H. and Latchman, S. "Brining the Classroom to Students Everywhere". Journal of Engineering Education, Vol.88, No.4, pp. 429-433, Oct.99. Online system: http://csc.list.ufl.edu/5718/courseware/index1.html.

[3] Graham, C. and Trick, T. "Java Applets enhance Learning in a Freshman ECE Course", Journal of Engineering Education, Vol.87, No.4, pp. 391-397, Oct.98.

[4] CODEX, http://www.codex-ip.com

[5] Tria-Soultion http://www.trial-solution.de

[6] WINDS http://www.idau.unian.it/arch-winds

[7] Introductory Course in Robotics http://www.ite.his.se/ite/research/automation/course/toc.htm

[8] Mobile Robot Group, teaching, http://www.dai.ed.ac.uk/groups/mrg/teaching.html

[9] G. McKee, "The Development of Internet-based Laboratory Environments for Teaching Robotics and Artificial Intelligence", Proceedings of the 2002 IEEE International Conference on Robotics & Automation, pp. 2695- 2700, Washington, DC, May 2002.

[10] Eliane, G. and Antonio, T. "REAL: A Virtual Laboratory for Mobile Robot Experiments", Proceedings of 1st IFAC Conference Telematics Applications in Automation and Robotics, TA 2001, pp.209-214, July 24th - 26th, 2001, Weingarten, Germany.

[11] Schilling, K. (2001). Model Design for Remote Mobile Robots", Proceedings of Tele-Education in Mechatronics Based on Virtual Laboratories, July 18th - 21st, 2001, Weingarten, Germany.

[12] A. Khamis, D.M. Rivero, F. Rodriguez, M. Salichs, "Pattern-based Architecture for Building Mobile Robotics Distance Laboratories." IEEE International Conference on Robotics and Automation, 2003 (ICRA'03), May 12 to May 17, 2003, Taiwan.

[13] TEAM, http://ars-sun1.ars.fh-weingarten.de/team/index.html

[14] IECAT, http://www.ars.fh-weingarten.de/iecat/index.html

[15] J. Bourne, et al. "A Model for On-line Learning Networks in Engineering Education", Journal of Engineering Education, Vol.85, No.3, Jul.96.

[16] A. Khamis, F. Urbano, M. Salichs, "Software Architecture for Internet Mobile Robotics", SPIE's International Technical Group on Robotics and Machine Perception, Vol. 12, No. 1, March 2003.

[17] Papert, S. (1991). Situating Construction. *Constructionism*, I. Harel & S. Papert (eds.) Norwood, NJ: Ablex Publishing.

[18] A. Khamis, M. Pérez Vernet, K. Schilling, "A Remote Experiment on Motor Control of Mobile Robots", *the 10th Mediterranean Conference on Control and Automation, MED 2002*, Lisbon, Portugal, July 9-12, 2002.

[19] R. Murphy and E. Rogers. Human-Robot Interaction. Final Report for DARPA/NSF Study on Human-Robot Interaction, http://www.içaic.nrl.navy/hri/nsfdarpa/HRI-report-final.html

[20] R. Alami, R. Chatila, S. Fleury, M. Ghallab, and F. Ingrand. "An Architecture for Autonomy". The International Journal of Robotics Research, 17 (4): 315-337, 1998.

[21] M.A. Salichs, M.J. López, R. Barber, "Visual Approach Skill for a Mobile Robot using Learning and Fusion of Simple Skills", *Robotics and Autonomous Systems*, vol.38, 2002, pp.157-170.

[22] Alberto Elfes, "Occupancy grids: A stochastic spatial-representation for active robot perception", in *Proceedings of the Sixth International Conference on uncertainty in AI.*

[23] R. Brown and B. Donald, "Mobile Robot self-Localization without Explicit Landmarks". In Algorithmica (2000) 26: 515-559.