

# Robotics in Edutainment

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## Abstract

*This article describes the issues in Robotics from a viewpoint of edutainment through a series of activities in Robot World Cup Initiative and related events, such as International Robot Games Festival (in short, Robofesta) supported by Japanese government to promote creative and imaginative education programs, RoboCup Jr. which is designed for kids and younger generation to play RoboCup games with easily constructible platforms, development of small legged robots for pet in the house or games, and education project in system engineering. Finally, concluding remarks for future activities are given.*

## 1 Introduction

Robotics is an excellent domain suitable for engineering education since it needs an integration of mechanics, electronics, and computer science. The students can check the results of their achievement, and immediate feedback can be possible to fix bugs in their programs or sometimes reconsider the whole structure of their robots. As a result, they can naturally learn how to build the system and know how it works.

On the other hand, robotics has been involved into human lives from industry domain to daily life applications such as home helper or recently entertainment robots. The latter introduced a new aspects of robotics, entertainment which is intended to make humans enjoy their lives from a various kinds of viewpoints quite different from industrial applications.

Robot edutainment can be regarded as a combined domain of the above two aspects in robotics. A typical example is robot competition in which the students can be strongly motivated to design and build their robots, and make matches with them enjoying the process to get a win. The most widely known one is RoboCup [1, 2], which was originally designed as

a research project but has been widely spread out to other domains such as RoboCup-Rescue, RoboCup Jr, and so on.

In this article, we describe the edutainment issues in robotics, mainly focusing RoboCup related activities, and entertainment robotics. They are 1) International Robot Games Festival (in short, Robofesta) supported by Japanese government to promote creative and imaginative education programs, 2) RoboCup Jr. which is designed for kids and younger generation to play RoboCup games with easily constructible platforms, 3) development of small legged robots for pets in the house or games, and 4) education project in system engineering and AI course.

## 2 Robofesta

Japanese Government initiated a program called "RoboFesta" (official name is The International Robot Games Festival) to promote robot competitions for education aiming at increasing participants' understanding and experience of the symbiotic relationship between robots and humans, by bringing together the many robot contests which are held in various parts of the world and staging them together with events such as exhibitions and an international forum. The first International Robot Games Festival is scheduled to be held in 2001, summer in Osaka and fall in Kanagawa with subsequent festivals to be held every few years. For more details, please visit "<http://www.robofesta.net>".

Robofesta is expected to grow into maturity few years period as it is aiming at collaboration of very broad scope of robot competitions. Due to their emphasis of competition and hand-craft experiences, Robofesta is suitable program for promoting education related activities on robot for relatively younger generation, rather than researchers. Combined with RoboCup's

international network and coherent project plan, RoboCup and RoboFesta can closely work together to further promote robotics from research to education, and entertainment.

### 3 Entertainment Robotics

Sony AIBO is the first fully autonomous robot that was made commercially available around the world in 1999 even though the number for sale was limited. It has 18 DOFs and several types of sensors. AIBO was originally designed and developed for personal use as a pet robot, and 3000 sets were sold out in Japan in twenty minutes and 2000 sets for US for four days.

Unlike the industrial robots which need very accurate and stable control architectures, the entertainment robots do not seem to care so much about these issues. Instead, man-machine interface is the most important issue for them since personal uses are the main purpose. The appearance should be friendly and multimedia interface should be facilitated such as visual, tactile, and auditory sensors as communication aids. A kind of learning capability is needed for personal customization. AIBO satisfies these requirements, and therefore, unexpected uses such as care for autistic children has been reported.

In future, entertainment robotics will be much more often applied to art, dance, film, and other types of performances such as plays than has been so far. In addition to technical issues such as high performance speech recognition or sophisticated behavior generation with many DOFs, cognitive and emotive models seems more important as a partner with us. Designing these models and embedding them into the robots are not merely an engineering issue but also enable them to contribute to cognitive science, development, neuroscience and further philosophy by providing a means for verification of their claims. That is, we, human beings, may understand the existence of ourselves by facing with these robots.

### 4 RoboCup Jr.: RoboCup for Entertainment

The Robot World Cup Initiative (RoboCup) was proven to be an exciting new research domain involving over thousands of researchers and students from 35 countries [1, 2]. While RoboCup continue to promote advancement of robotics and intelligent systems, the exciting nature of the topic, robot competition and soccer game, made it ideal platform for engineering education. Therefore, the RoboCup Federation launched an educational initiative for educational issues in robotics — RoboCup Jr. The aims of RoboCup

Jr. are 1) Education of future RoboCuppers, 2) Creation of Robot Entertainment and Edutainment, 3) Contribution to General Science and Technology Education, and 4) Development of Infrastructure for Robot Education

In order to accomplish these goals, RoboCup implements RoboCup Jr. league and RoboCup Dream Net.

#### 4.1 LEGO Mindstorms RoboCup Jr.

In RoboCup Jr., children are given the chance to follow this exiting artificial intelligence landmark project in first person by active participation. RoboCup Jr. puts emphasis on hands-on experience and actually allowing children to use the new artificial intelligence advances to build and program their own robots to participate in robot soccer.

In order to facilitate children's possibilities of constructing of robot soccer players, the LEGO Lab from the University of Aarhus, Denmark developed easy programming environments based on recent advances in artificial intelligence and adaptive robotics. This includes the use of behavior-based systems, which allow a modular robot control structure. With modules that take care of low-level processing, children can work on a higher level to construct global strategies rather than complicated low-level control. Hence, children can program robot soccer players by putting together modules of low-level behaviors in the right manner in order to achieve the robot soccer player strategy that they are looking for. In contrast with the big LEGO Mindstorms robot soccer demonstration in Paris during RoboCup'98 which included an overhead camera and communication to the single robots, the RoboCup Jr. explored the use of fully autonomous LEGO Mindstorms robots (see Fig.1).

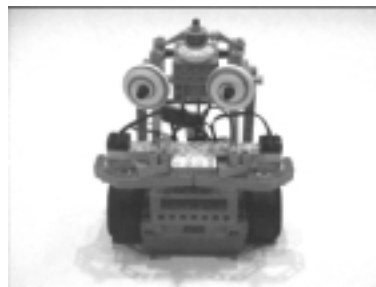


Figure 1: A LEGO Mindstorms robot

### 5 A System Engineering Project

This section describes a project course at Cornell University aimed at educating students in Systems Engi-

neering [3]. The multidisciplinary nature of the course is a great vehicle for highlighting some of the key components of Systems Engineering, including System Design, Systems and Technology Integration, Systems Analysis, and System Engineering Management. The class is comprised of twenty-four students from Mechanical Engineering, Electrical Engineering, Operations Research and Industrial Engineering, and Computer Science.

## 5.1 A project course in System Engineering

As engineering systems become more and more complex, there is an increasing need from industry for engineers who not only have expertise in a particular engineering discipline, but who also possess diverse interdisciplinary skills, can integrate system components, can ensure total system operability, and can understand the various economic forces in the marketplace. This skill set and process is often referred to as Systems Engineering (SE).

In order to effectively teach SE principles to students, a project course that embodies many of the key elements of SE, is being developed. The project entails the construction of fully autonomous, fast moving robots which will work together as a team in an effort to compete against similar teams of robots in a robotic soccer match. This yearly competition is known as the Robot World Cup Initiative (or simply RoboCup).

The soccer matches are played on a regulation size table-tennis table by teams composed of five robots. Similar to the real game of soccer, the objective is to score more goals than the opponent subject to well-defined rules and regulations. The robots are permitted to communicate to each other or to a global decision making computer via wireless transceivers. A global vision system (typically a video camera) may be used for global, robot (including the opposition) and ball position determination. Functionally the robots can be broken down into essentially three parts: electro-mechanical (the chassis, the drive unit, the passing unit, and the local sensors), communication (the wireless transceiver), and control (a microcontroller). The coordination of the robots is typically handled by a workstation, which has access to the global visual feed and which can communicate to each robot. The overall system is depicted in Fig. 2. The RoboCup is an excellent vehicle for demonstrating SE principles. We outline below some of the key aspects:

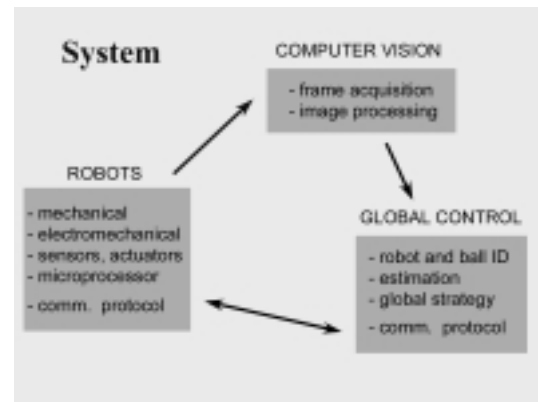


Figure 2: Schematic diagram of system

### 5.1.1 System Design and Integration

The design, construction and implementation of autonomous, soccer playing robots are challenging tasks. Not only are the individual technical problems associated with these tasks substantial, such as the design of a global vision system, mechanically robust robots, robust control systems, and robust strategies, determining the functionality of each component as it fits in with the whole system and robustly integrating these components is a formidable undertaking. Examples of system design issues are the following:

- How mechanically complex should the robots be?
- How should the decision making be distributed?
- How complex should the control algorithms be?

### 5.1.2 Systems Analysis

Analyzing the designed system, and the input this task provides to the design process, is an integral part of the project. Due to the complexity of the system, analytical studies of the system design and integration aspects of the project need to be complemented with extensive simulation: at the mechanical level (the low level control system, the dynamics and kinematics of the robots, etc.), at the decision and strategy level, and at the system level (the integration of the mechanical and strategy simulations).

### 5.1.3 Project Management

The coordination and management of the various resources available to complete the project, such as

money, time, and laboratory facilities, is an integral part of the project. Two teams of twelve students are engaged in the project. The team members are comprised of students with diverse skills and interests. For example, Mechanical Engineering students are attracted and suited to the mechanical and low level control aspects of the project, Electrical Engineering students to wireless communication and control, Computer Science students to vision and strategy, and Management students to the organizational aspects of the project. In order to successfully complete the project, the students must form effective teams, and bridge the gaps between their respective disciplines.

## 5.2 Class Organization

The class is an 8 credit, full year course. A typical load for Cornell students is 30 credits per year, thus making the project course a major time and educational commitment for the students. Approximately 60 students applied for the course, but only 24 students were selected to participate in the class due to limited resources and in order to establish well-balanced teams. Of the 24 students enrolled in the class, 16 are Master of Engineering students, while 8 are seniors. The Master of Engineering students in the class are all participating in the Systems Engineering Option at Cornell; the RoboCup project class is one of the prerequisites for this option, in addition to a Project Management class and an Applied Systems Engineering class.

The 24 students were split into two teams, Team Brazil and Team Italy. The team which wins the internal Cornell RoboCup competition being held in April 1999 will represent Cornell University in the RoboCup competition being held in Sweden in August 1999. The prioritized objectives for the project are the following:

1. For Cornell to win RoboCup 1999.
2. For Cornell to win RoboCup 2000 and beyond.
3. For an individual member's team to win the Cornell RoboCup competition being held in April 1999.

It should be stressed that the objectives as prioritized above greatly influence the team dynamics and the class atmosphere. Since the top objective is for Cornell to win the RoboCup competition, there is a substantial amount of cooperation between Team Italy and Team Brazil. As a specific example, the teams decided to pool parts of their budget and purchase one high resolution, high speed camera instead of two separate, lower resolution and lower speed cameras, to pool their

global vision efforts, and to use the same global information during the game. This would probably not have taken place if objective 3 had been prioritized as number one. Objective 2 ensures that the designs will be reusable to a certain extent and that design decisions today take into account projected future needs and technology changes.

The RoboCup lab is approximately 1000 square feet, and houses 6 high speed Pentium II Workstations, 1 high speed laptop computer, instrumentation such as oscilloscopes, power supplies, signal generators, Eprom burners, Eprom emulators, etc., and basic mechanical tools. A full machine shop is available to the students for in-house fabrication of mechanical components. Various commercial grade software packages are available to the students for design and simulation, such as Working Model 2D and 3D2, Matlab3, Pro/ENGINEER4, and OrCAD5.

## 5.3 Team Organization

Each team of twelve students is composed of a mix of individuals from various disciplines. For example, the team makeup for Team Italy is 1 Project Management student, 2 Computer Science students, 4 Electrical Engineering students, 4 Mechanical Engineering students, and one dual degree Electrical and Mechanical Engineering student. Each team is broken down into groups: Management, Artificial Intelligence, Electrical Design, Mechanical Design, Research and Development, and Simulation. Membership in a group is not exclusive; most students are members of two or more groups.

Various meetings were being held on a weekly and bi-weekly basis. On a weekly basis, a faculty member met with the team managers to discuss overall progress and administrative issues. A faculty member also met with representatives from each group, for each team, every week to discuss individual team strategies and system design issues. On a biweekly basis, a faculty member met with each group separately, for each team, to discuss detailed technical issues.

The project milestones and dates are described below:

1. Team selection and commencement of project: August 31, 1998.
2. Conceptual Design Review: October 5, 1998.
3. Preliminary Design Review: October 19, 1998.
4. Final Design Review: November 23, 1998.
5. Simulation Game: March 1, 1999 (see Fig.3).
6. Commence Final Integration: March 1, 1999.

7. Exhibition Game: April 15, 1999.
8. Cornell Championship Game: April 30, 1999. The winner of this game represented Cornell at the RoboCup competition in Sweden, and won the championship in the small-size real robot league.

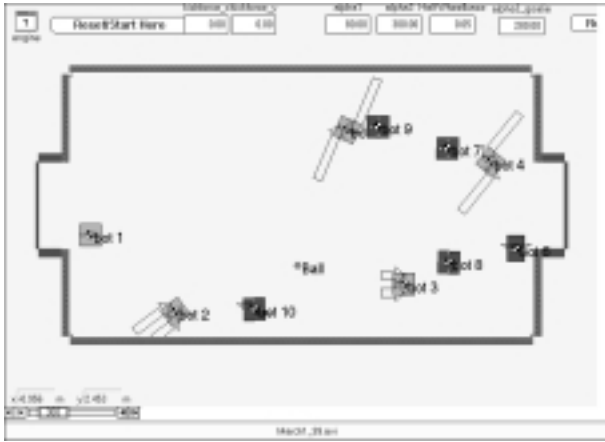


Figure 3: Snapshot of simulation game, March 1, 1999.

## 6 A course on Autonomous Systems

### 6.1 Background

This section describes a course on “Autonomous Systems” at the Computer Science department of the Flemish Free University of Brussels (VUB), Belgium. A German version of the course is held for the first time in the Fall-1999/Winter-2000 semester at the Computer Science Department of the University of Koblenz, Germany.

The VUB course on autonomous systems has a long tradition since the mid-Eighties. It is organized by the Artificial Intelligence Laboratory (AI-lab) at this university and it is thus coined by the AI-lab’s research interests and activities. The major theme in the VUB AI-lab is the investigation of the origins of intelligence, i.e., a basic research question with even philosophical dimensions. Within the last four years, the course received in addition a strong application- and hardware-oriented touch. The ideas and the environment of RoboCup play a central role in the successful combination of these two seemingly contradictory aspects of the course.

The course takes 60 hours, consisting of a theoretical lecture and practical exercises with roughly 30 hours each. “Autonomous Systems” is offered as an optional

course for students in the last two years of graduate studies in Computer Science. There is also an option for Electrical and Mechanical Engineers to attend the course and to receive credits. The average number of students is around 20. The course is held in English and it attracted several visiting students in the previous years, who based their participation on various European university exchange programs.

### 6.2 The Theoretical Lecture

Often, autonomous systems are put on a par with mobile robots. In this course, a slightly more general notion is used; namely autonomous systems as a special type of Networked Embedded Devices, which combine the three aspects of autonomous behavior, physical perception and manipulation, as well as interaction with other systems.

The investigation of such systems is of interest for two quite different reasons. First, autonomous systems play a key role in the fascinating intellectual challenge of constructively understanding intelligence; based on the hypothesis that intelligence includes inseparable aspects of the body, the mind, and the society. Second, autonomous systems bear a tremendous application potential. There is a growing interest to free human users from a permanent and explicit control of various devices. In doing so, the continuously increasing amount of networking in all kind of daily-life devices, e.g. washing-machines, cars, fridges, is playing an important role. Apart from the construction and control of such devices, the coordination of their activities, e.g. to save energy, to manage traffic, to engage in e-commerce, is still a challenging problem.

For the lecture part of the course, it is important to present the material in a clear and homogeneous manner, despite the two seemingly different background motivations for autonomous systems and the wide range of covered subjects.

The RoboCup idea and setting is the perfect glue that fits the different parts together. RoboCup is not only very useful for the practical exercises as an experimental framework, but the concept of soccer-playing robots is well suited to present the theoretic subjects of the lecture in a consistent way. The concept is easy to grasp, as everybody has a rough idea what soccer is all about, but it is still a concept which is very complex on many levels. A successful participation in RoboCup has to deal with exactly all the subjects which are listed above.

### 6.3 The Practical Exercises

The practical exercises allow the students to get hands-on experiences. They are based on a special

infrastructure, the so-called CubeSystem which was developed in the VUB AI-lab. The CubeSystem is a kind of construction-kit that allows to easily build and control a wide variety of autonomous systems. It is used in education, in basic research, and in industrial research. The core of the CubeSystem is a special computer hardware, the RoboCube [4].

In previous years, the mechanical parts for the practical exercises were based on the toy-kits of LEGO<sup>TM</sup> and Fischertechnik<sup>TM</sup>. The students devoted quite some time to the physical construction of the robots. Though some useful lessons can be learned that way, too often time is wasted on playing around with the optical appearance of the robots.

As a result, each of the four to five groups was only able to build and program one robot with rather limited sensing capabilities. Therefore, the tournament that was played at the end of the course had to be rather simple. Nevertheless, it should be related to soccer. So, the game of so-called “wall-ball” was introduced.

A wall-ball game consists of two opponents trying to outperform each other in pushing a “ball” with an active beacon towards a wall. The field is an area of 2 meters times 2 meters. Each game consists of five innings. An inning starts with the two players placed in opposing corners and the ball placed in the center of the field. Both players are marked with an active beacon (which is different from the ball-beacon). An inning ends if

- the ball touches one of the four walls surrounding the field
- a time-limit of 2 minutes is exceeded

A robot-player gets a point in an inning if and only if

- it caused the ball through pushing or shooting to touch the wall
- in doing so, the other player did not touch the ball

The player which scores the most points wins, otherwise the game ends in a draw.

It is quite interesting that the actual speed of the robot matters only to a certain degree. In the tournaments played at the end of the courses, it was much more important which robots had a reliable and stable control.

Though wall-ball allows to cover many of the important subjects related to autonomous systems, it has

still one big deficiency. It is more or less a game, where the issue of coordinating the activities of several systems is not represented.

Therefore, the practical exercises are now based on a regular RoboCup small size league set-up. So, two teams with five robots each have to play a soccer game on a ping-pong table. As this task is more complex and the time for the exercises is limited, the students start on a higher level.

They get preassembled mechanical building blocks and even robots, as well as functioning software. They have now the possibility to change certain aspects of the system and to see the effects. They are also challenged to improve the existing systems, so that different groups can play a tournament at the end of the course.

## 7 Conclusion

A series of robot competitions, education courses, and entertainment applications have been introduced as a new area of robotics in edutainment. RoboCup initiative has been taking important roles not simply by setting competitions but also expanding its activities to education and entertainment. Many researchers, students, and currently ordinary people have been involved in this new area. Although we have many issues to be solved yet, we welcome more people to enter the committee in order to share the friendship and robotics mind.

## References

- [1] Hiroaki Kitano, editor. *RoboCup-97: Robot Soccer World Cup I*. Springer, Lecture Note in Artificial Intelligence 1395, 1998.
- [2] Minoru Asada and Hiroaki Kitano, editors. *RoboCup-98: Robot Soccer World Cup II*. Springer, Lecture Note in Artificial Intelligence 1604, 1999.
- [3] R. D’Andrea. Robot soccer: A platform for systems engineering. In *American Society for Engineering Education Annual Conference*, volume 2220, 1999. Mobile Robots and Interdisciplinary Design.
- [4] Andreas Birk, Holger Kenn, and Thomas Walle. Robocube: an “universal” “special-purpose” hardware for the robocup small robots league. In *4th International Symposium on Distributed Autonomous Robotic Systems*. Springer, 1998.