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Robot soccer educational courses

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1. Introduction

Robotics encompasses multiple disciplines, including mechanical engineering, software programming, electronics and even human psychology. Robot soccer is an international project intended to promote these disciplines as well as other related fields due to increasing demand for the properly educated engineers. Basically, it is an attempt to foster AI and intelligent robotics research by providing a standard problem where wide range of technologies can be integrated and examined. The idea of introducing robot soccer and robot soccer league turned out as a great success in popularization of robotics and AI but also the other fields such as mechanical engineering and electronics.
Practical courses for the undergraduate and graduate students can be domain – focused towards a particular research field such as intelligent agents (Coradeschi & Malec, 1999; Anderson & Baltes, 2006), computer vision, artificial intelligence (Riley, 2007), control (Bushnell & Crick, 2003), etc. During the courses students are either constructing the robots, developing software for the robots or doing the both things (Beard et al., 2002; Nagasaka et al., 2006), usually divided into different research teams (Archibald & Beard, 2002, Cornell). Anyhow, they are presented with the real-life problems and have the opportunity to work on challenging project that has a motivating goal. Learning theory that supports this approach is constructionism (Piaget & Inhelder, 1966; Papert, 1980; Papert, 1986). Constructionism holds that learning can happen most effectively when people are also active in making tangible objects in the real world so we can say that experiential learning is optimal for adoption of new knowledge.
Even early works have acknowledged the need to divide robotics courses into different groups depending on their educational goal and complexity (prerequested knowledge). In his survey, Lund presented three set-ups that have been designed as a three step educational process (Lund, 1999). He considers his approach as a guided constructionism because, unlike unguided constructionism approach, it combines the constructionism approach with other methods (guidance) in order to allow the students to acquire knowledge in the most profound way. Strengthening of Educational Robotics as a pedagogic tool and integration of the Educational Robotics into the Curriculum has been subject of investigation for several years (Bruder & Wedeward, 2003; Novales et al., 2006).
Although practical courses for the university students are the most obvious choice because of generally high prerequested domain knowledge, children in elementary and secondary schools (K-12) are also targeted audience. With the current negative enrolment trends at the

technical universities and the increasing demands on the labour market, early days popularization of the technical sciences is necessary in order to provide better and more massive input for the technical sciences oriented studies. Robot soccer has the capability of attracting attention of younger population because it provides both fun and educational experiences. The term sometimes used is 'edutainment robotics' (Miglino et al., 1999; Lund, 2001). Of course, robotic soccer is not the only approach in motivating children for the robotics (McComb, 2008), but it is one of the most popular and perhaps the most comprehensive one. Choice of the platform for children and process adopting courses for their education is certainly interesting and demanding task (Baltes & Anderson, 2005). Various researchers present different modular concepts for the introduction of robotics and computer science education in high schools (Verner & Hershko, 2003; Nourbakhsh et al., 2004; Henkel et al., 2009). In fact, robot design is considered as the suitable school graduation project (Verner & Hershko, 2003). Even very young children (8 to 9 years of age) can be included in courses that can change their way of thinking and teach them basics of robotic technology as well as team work (Chambers et al., 2008).

Introduction of robot soccer courses into K-12 education has some other issues to be solved other than only adopting course difficulty level. One of the most important issues that have to be solved (other than finances) is proper education of the school teachers because they have a broad range of educational backgrounds (Matarić, 2004). Proper documentation and hardware should be available to the teachers because they are best prepared to innovate when working from a solid foundation, prepared by robotics educator, not when starting from the beginning (Wedeward & Bruder, 2002; Matarić et al., 2007). An interesting project that should be mentioned is the TERECOP project (Teacher Education on Robotics-Enhanced Constructivist Pedagogical Methods). It's overall aim is to develop a framework for teacher education courses in order to enable teachers to implement the robotics-enhanced constructivist learning in school classrooms (Arlegui et al., 2008).

As it has already been said, different age groups require an adaptive and modular approach and that was the main idea behind the concept that will be presented here. Short practical courses for three age groups have been developed and proposed: 1) younger K-12 school children (ages 13-15), 2) senior K-12 school children (ages 15-18) and 3) university students (ages > 18).

In this chapter, different modules incorporated in the practical courses are explained and curriculum, aims and tasks for each course level is described. The attention is focused on the modules integration. Although there are some commercial systems available at the market (Lund & Pagliarini, 1999; Gage, 2003; Baltes, J. et al., 2004), in order to provide courses with full range of possible learning themes as a basis for the proposed constructive education courses, development of cheap and simple robots for the robot soccer team is explained in detail.

2. Robot design

First, it should be stated that an inspiration and great help in understanding the most important problems and issues that have to be resolved during design process of a soccer robot was very detailed documentation that can be found on the Cornell University web site (Cornell). Because the robots presented in mentioned documentation are state of the art, development of similar robot for the purpose of an educational course would be too expensive and complicated. The robot presented here is much cheaper but still, it has all main components and functionality in order to fulfil educational goals and learning outcomes. Basic parts of designed robot soccer player (Figure 1.) are:

- RF two channel communication on 433/434 MHz
- 4 DC electro motors (12 V)
- Solenoid kicker which operates on 6 V
- Special made battery charger
- Microcontroller AT89C4051 with electronics
- 7.2V battery for DC electro motors and solenoid
- 4.8V battery for electronics

Fig. 1. Robot soccer player

Robot consists of four levels. The first three levels represent drive and the fourth is the control level. At the first level there are four DC electro motors with gearbox and wheels. At the same level there is also a solenoid which is used to kick the ball. At the second level the two batteries are placed. The first, 7.2 V battery, supplies four DC electro motors and the second, 4.8 V battery, supplies the electronics. Battery charger is placed on the third level. At the uppermost, fourth level, there is a microcontroller and a RF receiver. This level is also known as control level, because it contains electronics for managing electro motors. It controls their speed and orientation depending of signals received from RF receiver. This electronics also controls the kick of solenoid. RF signal is sent by RF transceiver which is connected to personal computer.

The main feature of this robot is the use of a global vision system (Figure 2). Local vision is also possible, but in order to simplify the solution, global vision option was chosen which means that only one camera is used and placed over the soccer field. The camera is connected to computer which is used for image processing and strategy planning. Computer acquires picture from the camera and recognizes the field ground, the robots and the ball. Recognition is mainly based on color segmentation because the colors of the robot teams are predefined (yellow and blue circles placed in the centre on the robot's top plate) and the ball color is predefined also (orange golf ball). Depending on the number of robots in each team, robots have additional color marks on their top so they can be distinguished by the strategy planning program. Picture background has to be green as it is the field ground. This "color rules" are set according to the rules of "small robot league" (Robocup Official Page). Software package used for the image processing and communication with the serial port is MATLAB. Image processing has to be fast and in real-time.

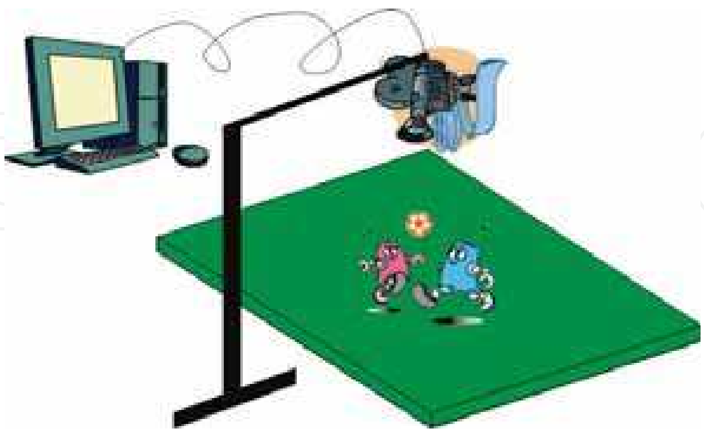


Fig. 2. Robot soccer player system using the global vision

Depending on the positions of the recognized objects, computer sends signals to the microcontrollers in robots. These signals are the upper level instructions that will be translated by the microcontrollers to the lower level instructions for the actuators.
Processed results are sent through the RF transmitter to the robot's RF receiver. Actually, RF transceivers were used, so the communication could be done in both directions. Detailed explanation of all the basic modules will be given in the following sections.

3. Robot modules

3.1 Operative module

Operative module consists of four DC motors that drive the robot and one solenoid. Motors themselves have gearboxes that reduce motor speed but also increase the torque. When choosing motor, the price was crucial and this is because the professional micro-motors for robotics are expensive. Table 1 shows the characteristics of the chosen motor. Figure 3 shows the appearance of the motor with gearbox and motor characteristics.

	No Load		Max efficiency							Stall			
Voltage	Speed	Current	Speed	Torque			Current	Output	Eff.	Torque			Current
V	RPM	A	RPM	mN-m	g-cm	oz-in	A	W	%	mN-m	g-cm	oz-in	A
12	94.7	0.023	69	28.8	294	4.08	0.06	0.21	28.0	106	1080	15.0	0.17

Table 1. Characteristics of the chosen motor

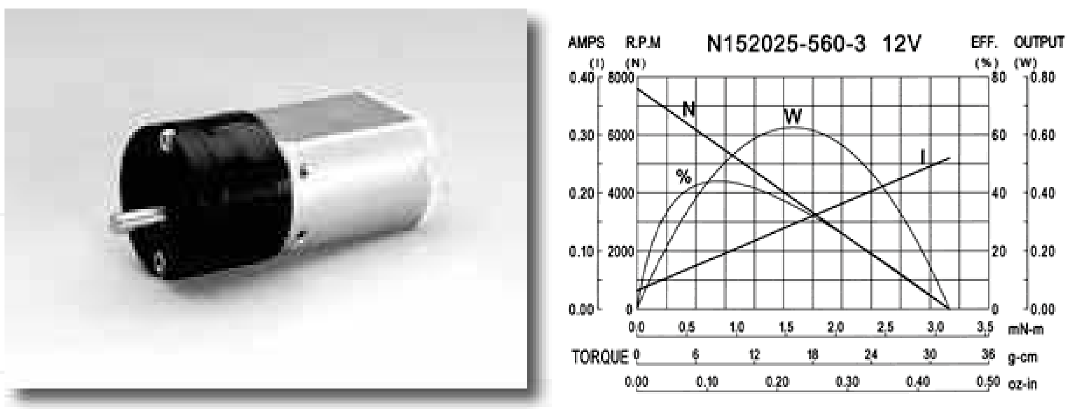


Fig. 3. Appearance of the motor with gearbox and motor caracteristis.

3.2.1. Drive motor and wheel layout

Drive motor and therefore wheel layout as in Figure 4 was chosen because the robot has to be agile and able to turn quickly around its axis. To increase the speed of robot motion forward, the front motors are set at the angle of 33 degrees.

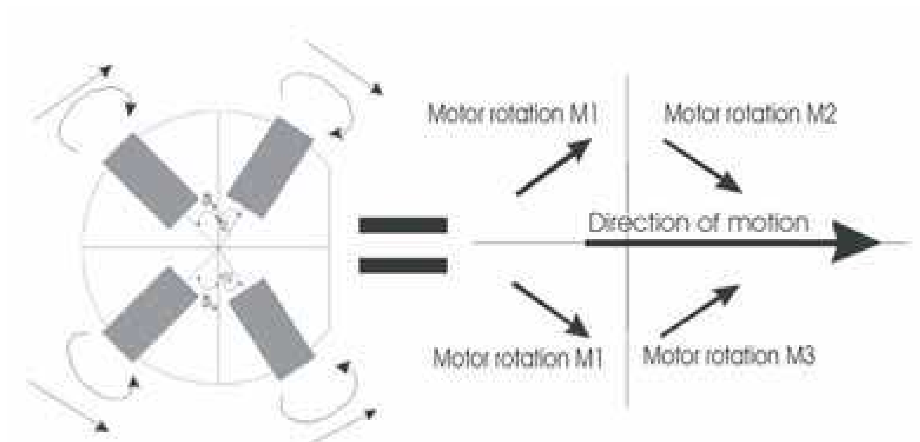


Fig. 4. Drive motor layout

Due to possibility of robot motion linearly with this set of wheels, it is necessary to use special wheels called omniwheel wheels. Although some robot soccer teams develop their own 'home-made' multidirectional wheels (Brumhorn et al., 2007), a commercial solution presented in Figure 5 is used. Wheels have transverse rollers that can rotate, so the wheel, without creating high resistance, can move vertically according to the first direction of motion.

Fig. 5. Omniwheel.

3.2. Electronics module

Electronics module has function to receive control signals and operate motors and solenoid. Receiver placed on robot receives signals from computer transmitter and forwards them to the microcontroller (Figure 6).

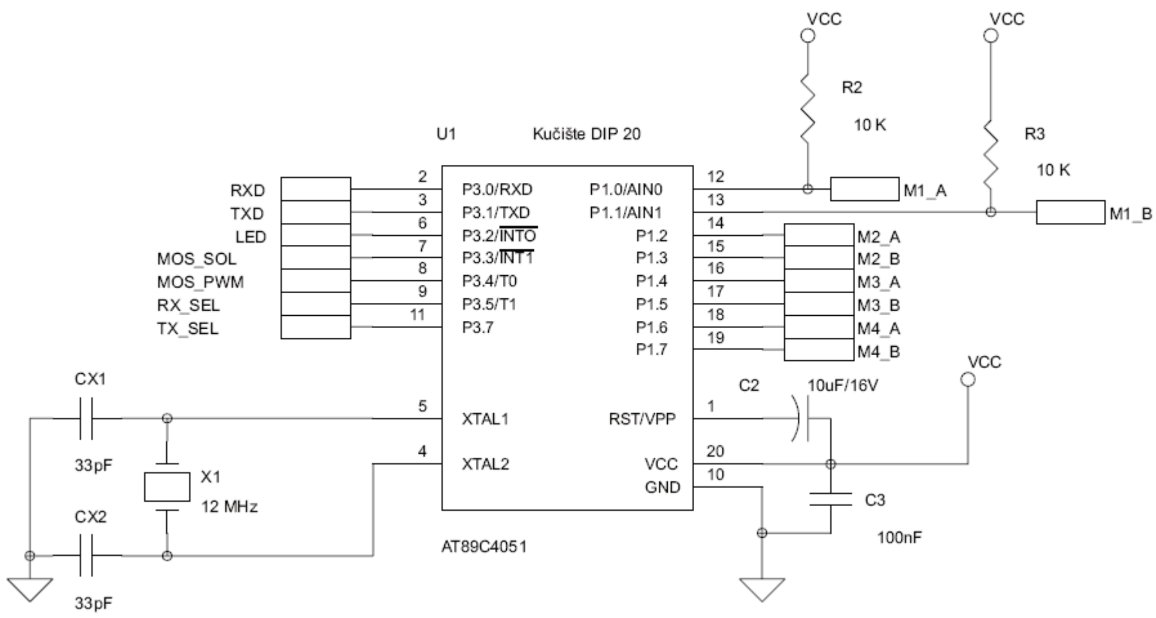


Fig. 6. Electric scheme – microcontroller

For this operation an AT89C4051 microcontroller is used and programmed. Control signals are commands for turning motors on and off in order to settle the direction of the robot motion. Input pins 2, 3, 9, 11 (Figure 6) are connected to the receiver pins 12, 14, 15, 16 (Figure 20). Microcontroller operates four motors (M1, M2, M3, and M4).

3.2.1. Motor controllers

TA7288P drivers are used to control motors speed and direction. There are four drivers, one for each motor. Electric scheme for control of one motor is shown in Figure 7.
Motor management is quite simple. Combination of A and B pins from microcontroller as a result has three functions (Table 2):
- rotate motor left
- rotate motor right
- stop motor rotation

	A	B
Rotate left	0	1
Rotate right	1	0
Stop	0	0

Table 2. Motor control function

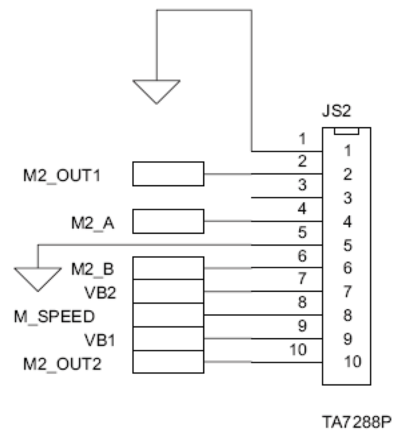


Fig. 7. M2 Motor control

Motor speed is controlled by transistor switch shown in Figure 8. Robot motion is defined by synchronized movement of all four motors. If the robot receives command "move left" or "move right", then the motors M1, M2, M3 and M4, each through its driver (Figure 7) receive orders from the table 2. Depending on these commands motors rotate and bring the robot into desired position.

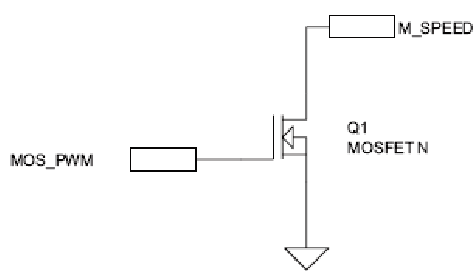


Fig. 8. Motor speed control

Motor speed (over M_SPEED pin) is common for all motors. Applying digital logic on MOS_PWM pin performs speed control. Depending on frequency of digital signal, voltage on M_SPEED pin changes. That results in greater or lesser number of revolutions of the motor.
Presented robot soccer player can move with four different speeds. Speed variation is achieved by sending four different rectangular signal frequencies on MOS_PWM. Also, robot speed depends on distance between robot and ball. If robot is far away from the ball it moves faster. In the immediate vicinity of the ball, the robot is moving slowly to be as accurate as possible.

3.2.2. Solenoid control
Solenoid is electromagnet used to hit the ball. In the immediate vicinity of the ball, the robot slows down and tries to kick ball with solenoid.

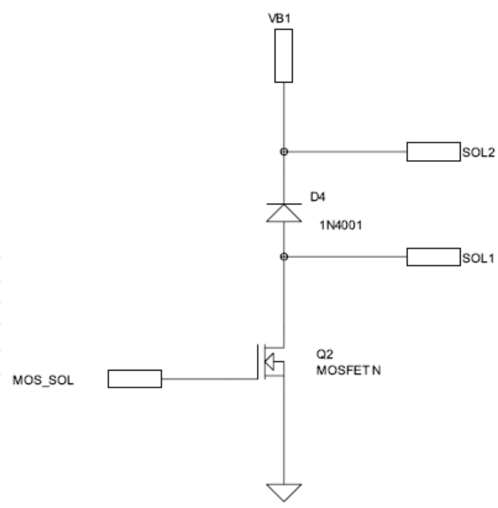


Fig. 9. Solenoid control

When the control software estimates that the robot is near the ball, it sends commands to kick it (optional). Command signal is applied on MOS_SOL pin of solenoid control. Electromagnet is activated and throws the solenoid armature; a little spring provides that solenoid return to its original position. Figure 9 shows the transistor switch that controls the solenoid. SOL1 and SOL2 are connected directly to the solenoid.

3.2.3. Power supply

Designed robot uses two battery power systems. 7.2 V battery is used for motors and solenoid and four 1.2 V batteries are connected in series and power electronics. In Figure 10 is shown the voltage stabilizer.

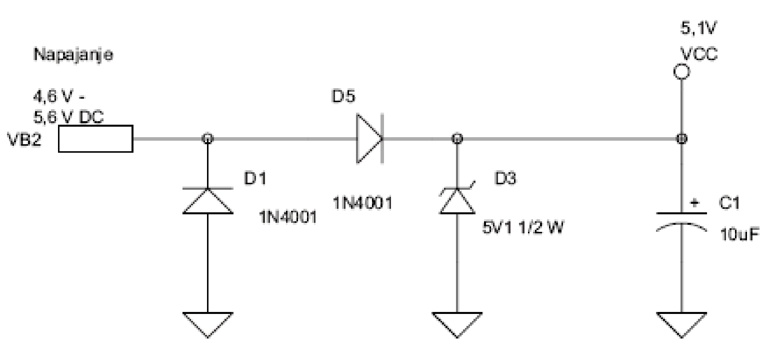


Fig. 10. Voltage stabilizer

Batteries (Figure 11) are rated at 1.2 V, four serial connected should give a voltage of 4.8 V. When batteries are full, they give the slightly higher voltage. In this case measured voltage is 5.6 V. Therefore, the stabilizer shown in Figure 10 is used. Battery charger (Figure 12 and 13) is specifically designed for this robot. There are two ways of charging. Quick 3 hours charge and slow 12 hours charge. Slow charging is safer but fast charging is option for special circumstances. This charger, of course, doesn’t need to be a part of the robot, but, if it is included as presented in our schematics, battery changing which can be quite tricky is avoided.

Fig. 11. Batteries

Fig. 12. Battery charger

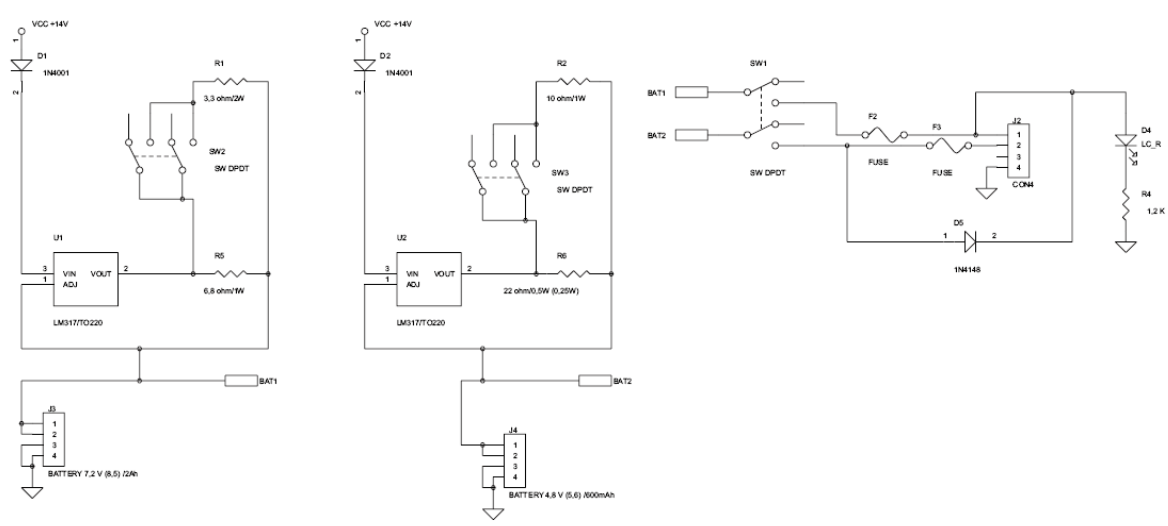


Fig. 13. Battery charger electronic scheme

3.3. Vision module
Simple local vision scheme of our vision module that uses MATLAB software package for the image processing on the central processor is presented in Figure 14.

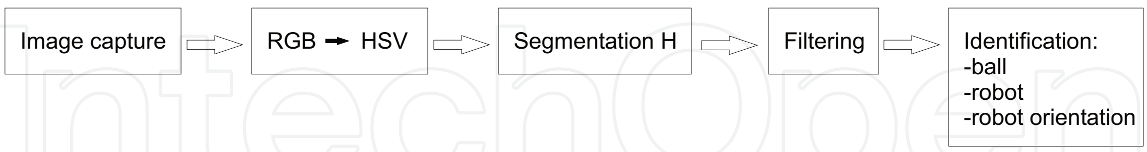


Fig. 14. robot soccer vision module scheme

3.3.1. Image capture
Image capture is the process where a color image is grabbed from the camera and placed into a memory location (buffer) on the host computer. This image must be transformed into a packed RGB image before it can be processed. Figure 15. shows simple example.

Fig. 15. Image capture example

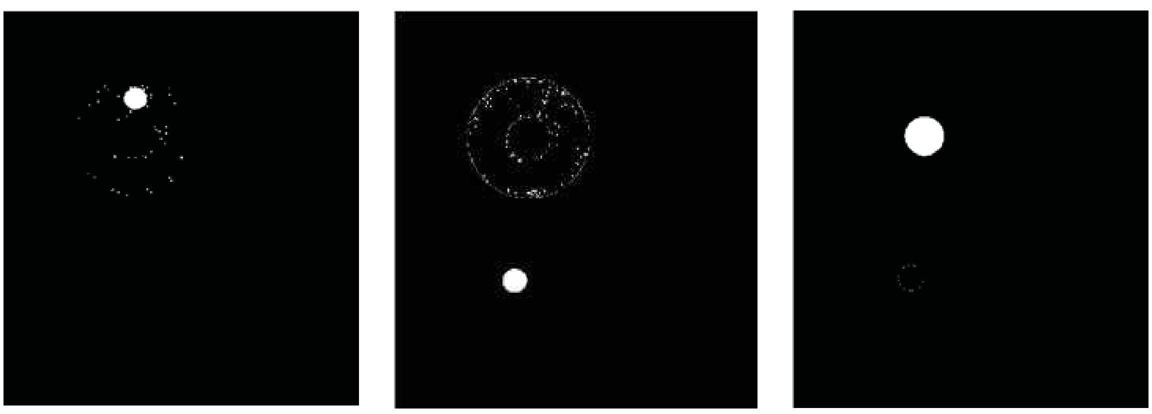
Fig. 16. H component

3.3.2. Color model transformation
Before the segmentation, image has to be converted from RGB color model into HSV color model. Generally, it can be stated that traditional RGB color space is not convenient for this

kind of applications due to the high correlation between color components. Although HSI (Hue, Saturation, Intensity) as well as HSV (Hue, Saturation, Value) color spaces has also some problems especially with the low saturation images, they are better choice for wide range of Computer Vision applications (Cheng et al., 2001; Barišić et al., 2008). After that, component H has been isolated. Component H represents hue, i.e. wavelength color. Figure 16. shows the isolated H component in gray scale.

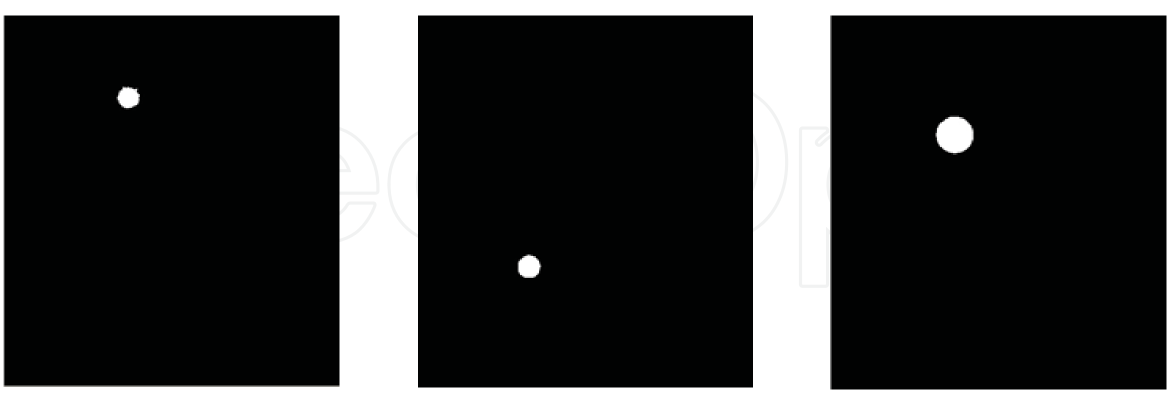
3.3.3. Segmentation

Segmentation refers to the process of partitioning an image into multiple segments. The goal of segmentation is to simplify the representation of an image into something that is more meaningful and easier to analyze. Image segmentation is used to locate objects in images.
In the case example, objects are the robot and the ball. Robot has two markers placed on its top plate. One marker indicates the robot while the other one is used to obtain information on its orientation. In Figure 17, result of region separation is shown.



a) b) c)

Fig. 17. Separated regions: a) red regions; b) ball – orange regions; c) yellow regions



a) b) c)

Fig. 18. Filtered regions: a) red regions; b) ball – orange regions; c) yellow regions

3.3.4. Image filtering

Image filtering is a process by which we can enhance images. The first step in objects analysis process is erosion. Erosion gets rid of most of the image noise and reduces the objects to those used to identify the robots and the ball. Figure 18 shows filtered regions.

3.3.5. Identification and orientation

The ball is easily identified because it has distinguishing orange color. If no ball is located it is considered missing and no location is sent to the computer.
Determining the general location of our robots is done by locating the center marker. In our case example that is the yellow regions. Red region is used to determine the orientation of the robot in relation to the ball. Figure 19 shows the position and orientation of robot and the ball.

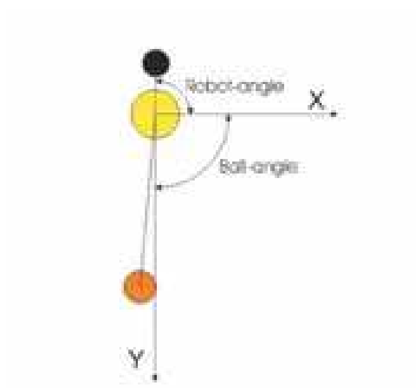


Fig. 19. Position and orientation of robot and the ball

3.4. Communication module

When robot position, orientation and distance from the ball are known, software determines what the robot should do. For example, rotate it, move forward to the ball, or kick the ball. In order to make robot do this operations, it is needed to receive predefined control commands. Although it is possible to apply Bluetooth-based control as well, in our example control commands are sent by radio transmitter and received by receiver that works on 433/434 MHz. The transmitter is connected to a computer via serial port.
Image that is obtained from the camera is processed using the image processing software on PC. Results of the image analysis are used to produce commands that are sent via the RF transmitter. RF receiver located on robot receives commands and forwards them to microcontroller. Microcontroller manages four motors and the solenoid according to the received commands. Table 3 contains set of all commands used to control designed robot soccer player and their meanings.
In Figure 20 transmitter/receiver electrical scheme is shown. For transmitter RXD, TXD, TX_SEL and RX_SEL are connected to the computer RS232 (serial) port through which computer sent commands. Same device is on robot and works as receiver. RXD, TXD, TX_SEL and RX_SEL are connected to microcontroller.

Command	Command meaning
Rotol	Rotate left
Rotor	Rotate right
Pravo	Go straight
Nazad	Go back
Stani	Stop
Udari	Hit the ball
Brzi1	Speed 1
Brzi2	Speed 2
Brzi3	Speed 3
Brzi4	Speed 4
Brzi5	Speed 5

Table 3. Commands

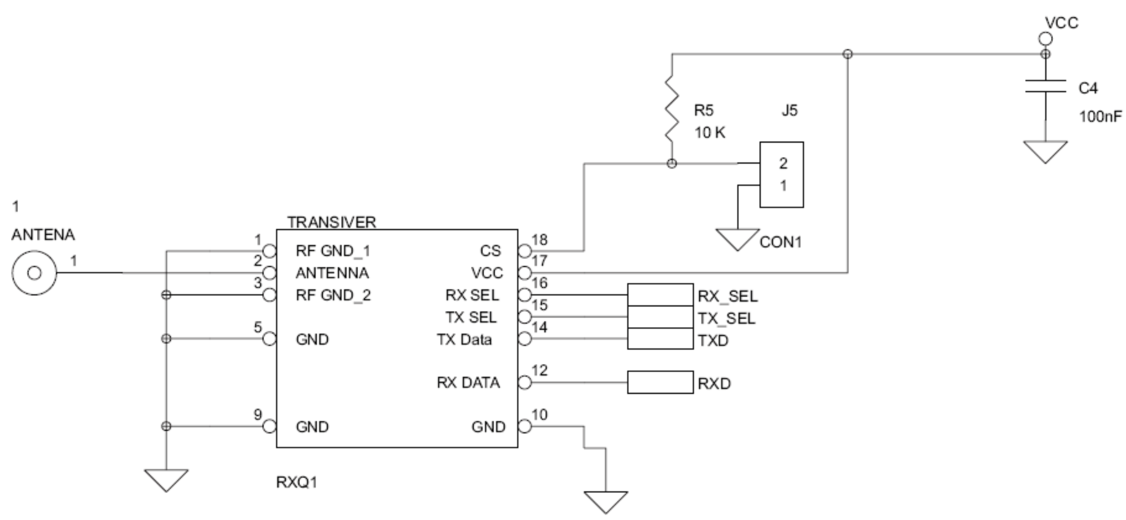


Fig. 20. Electrical scheme transmitter / receiver

4. Curriculum, aim and tasks

Because of wide educational scope provided with the robot soccer idea, instructor and designer of a particular course should be aware of various possibilities available for different groups of students. A simplified overview of the most dominant educational areas is shown in Figure 21. It should be stressed that presented schema does not include all possible areas of investigation and education as well as all possible connections between presented areas. Complexity level should be taken as provisional information because upper complexity boundaries are almost infinite. Only lover boundary of the position at which certain term occur in the figure roughly correspond to the suggested level of needed student previous education in order to attend a course.

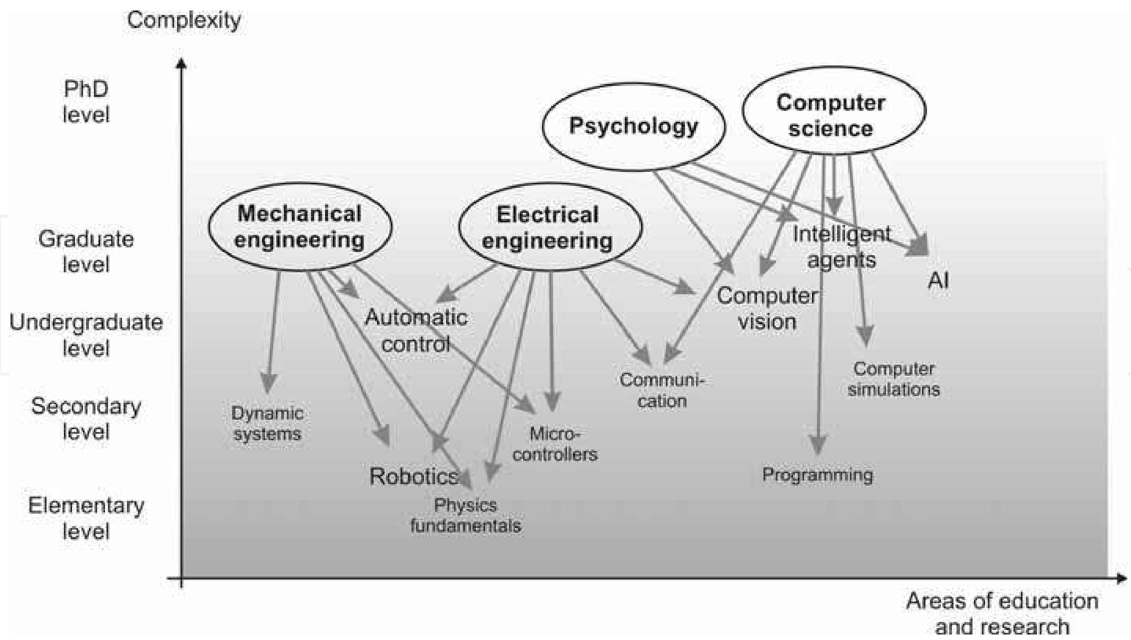


Fig. 21. Simplified chart of course complexity, level of education and area of education

Some terms in the Figure 21 overlap or can be regarded as a part of some other but the idea is to accentuate possible autonomous courses and modules that can also be further combined in order to achieve desired educational goal.

4.1 Curriculum aim

Combine acquired mechanics, electronics, informatics and programming knowledge through autonomous construction of robot soccer player.

4.2 Curriculum tasks

4.2.1 Elementary school (K-12, age 13-15)

As we already mentioned, the course is different for three age groups. The final result is the same - construction of a robot soccer player. The difference is in the amount of autonomous work, which, of course, depends on educational level of certain groups. Therefore, the elementary school students will get ready made modules that they will have to assemble in the one unit. The aim is the same, but their knowledge from this field is lower, therefore their tasks through this course will be simpler.

Educational tasks

To enumerate all the robot modules
To explain the working principle of every single module
To explain the working principle of the entire robot system

Functional tasks

To identify the each part of robot
To identify each module
To assemble robot modules into one unit

Pedagogical tasks
To develop the culture of communication and to express their own views
To acquire the habit of tidiness in the work room

4.2.2. Secondary school (K-12, age 15-18)

Secondary school students will have more complex tasks. Through those tasks, they will manufacture the certain modules by themselves. However, the programming of control functions, just like the manufacturing of image recognition software is not the main task for the students and it is playing just an informative role. In this case, students will just have to change the certain parameters inside of the computer software.

Educational tasks
To enumerate all the robot modules
To explain the working principle of every single module
To explain the working principle of the entire robot system
To explain the particular parts of the module and their role (in it)

Functional tasks
To braze the elements on ready made circuit board individually
To identify each part of the robot
To identify each part of the modules
To identify the certain modules
To assemble robot modules into one unit
To change the parameters of image processing computer software individually

Pedagogical tasks
To develop the culture of communication and to express their own views
To acquire the habit of tidiness in the work room

4.2.3. Students

The students will reach the aim by themselves. Their tasks are the most complex ones. The students will have all the required electrical and mechanical schemes, plans of robot and the prepared material. They will individually manufacture the certain module and finally they will develop the image recognition computer software.

Educational tasks
To enumerate all the robot modules
To explain the working principle of every single module
To explain the working principle of the entire robot system
To explain the certain parts of the module and their role in it
To explain the certain function of each element inside of the module

Functional tasks
To manufacture the module circuit board according to electrical scheme by themselves
To braze the elements on already made module circuit board by themselves
To identify each part of the robot

To identify each part of the modules
To identify the particular modules
To assemble robot modules into one unit
To manufacture the image processing computer software by themselves

Pedagogical tasks
To develop the culture of communication and to express their own views
To acquire the habit of tidiness in the work room

5. Curriculum schedule

Day 1:
Introducing robotics and robot soccer players to the students. Introducing to students the tasks they will need to accomplish. After the short introduction with the tasks, we start with manufacturing of the actuating module of the robot soccer player. The actuating module is the first level of the robot. It consists of a platform with four motors (with gearboxes), the wheels and a solenoid shooter.
Day 2:
Manufacturing the second and the third level of the robot.
Elementary school students: They connect batteries with ready made rechargeable circuit and assemble it all together on the metal platform which makes the second and the third level of the robot.
Secondary school students: They braze the elements of rechargeable circuit on ready made circuit board. Then they connect the batteries with rechargeable circuit and assemble it all together on the metal platform.
University students: They manufacture the module circuit board according to electrical scheme. They braze the elements of rechargeable circuit on the circuit board. Then they connect the batteries with rechargeable circuit and assemble it all together on the metal platform.
Day 3:
Manufacturing the last (fourth) level. This is the most complex level. At this level there is a controlling and receiving circuit.
Elementary school students: They get ready made module. The module is explained and described to them in detail. They assemble the module on the metal platform and put them all together in the one unit (robot).
Secondary school students: They braze the elements of the controlling and receiving circuit on ready made circuit board. Then they assemble the module on the metal platform and put them all together in the one unit (robot).
University students: They manufacture the module circuit board according to electrical scheme. They braze the elements of the controlling and receiving circuit on the circuit board. Finally, they assemble the module on the metal platform and put them all together in the one unit (robot).
Day 4:
Manufacturing the computer software or explaining the way of working for the lower levels.
Elementary school students: Explaining the way of working of the image processing and the computer vision software.

Secondary school students: Explain them the way of working and the principles of the computer vision. They autonomously change the parameters inside of the image processing computer software.
University students: With teacher's assistance, they manufacture the computer software using Matlab software package.
Day 5:
Robot activation. Synchronization and adjusting of the computer software. Demonstration.

6. Discussion

It is important to accentuate that presented courses are short-termed. Longer courses that last for one semester or even longer can handle much more topics and go in more details (Archibald & Beard, 2002; Bushnell & Crick, 2003; Baltes et al., 2004; Hill & van den Hengel, 2005) or can even allow students to manage complete robot building project by themselves (Pucher et al., 2005). If the focus of the course is shifted from building a robot towards artificial intelligence, an approach using the commercial solution of already made robots such as Khepera or LEGO Mindstorms can be used (Miglino et al., 1999; Lund, 2001). Also, size of the student group, number of available teachers must be considered before presenting course plan in order to set achievable goals.
As for the proposed and presented courses, they have been conducted for K-12 children and undergraduate and graduate students as well. In all of these courses, final result of this age levels courses are fully operational soccer robots. Each robot is made by team of 4-5 students with their mentor.
Computer vision education modules were already included as a part of the present Image processing and Computer vision course for the undergraduate and graduate students of informatics and technics at the University of Split. Another module that has already been included as a part of the Computers in technical systems course is the microcontroller programming module.
Preliminary results are encouraging, scholars are highly motivated and the response and working atmosphere is great. Members of the K-12 groups are, according to their statements, very keen on continuing with the work related with the presented problem. University students also showed great interest in the presented course modules. During the development of the system occurred some real life problems such as light and vision, noise in communication, speed of communication with PC port. Students had to deal with them or were given an insight because these are the problems that are preparing them for the actual work after graduation.
So far, curriculum described in Section 3 and 4 did not included collaboration between robots and global strategy planning. This option should be added soon especially for the undergraduate and graduate students in computer science that are listening some of the AI courses in their regular curriculum. Also, robot simulation software has not been developed yet so it has not been included here although simulators are providing significant possibilities in investigation of artificial intelligence.

7. Conclusion

In this chapter we have presented a framework for modular practical courses using robotics and robot soccer problem as an educational tool. Presented approach is flexible so it can be adapted for various age groups with different scopes of interest and previous knowledge. Some case examples have been shown. Also, we have described the robot electronics, mechanics and the whole global vision system that was developed for this purpose. Main requirements for the system and robots were: simplicity, overall price (around 300 EUR/robot + PC and a camera) and openness for further improvements.
Integration and need of interdisciplinary knowledge and its application for the successful completion of the project defined by the course aims provides possibility of collaboration between different departments and teachers. It offers the possibility to apply slightly adopted courses to different age groups. Constructive education approach and the possibility of using the presented practical course modules as a support for wide range of existing engineering courses along with a great first response from the scholars motivates authors to continue with the development of the course and its modules. Further development of the courses for the youngest children, as well as specialized AI courses, is expected in the future.

8. References

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Robot Soccer

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The idea of using soccer game for promoting science and technology of artificial intelligence and robotics was presented in the early 90s of the last century. Researchers in many different scientific fields all over the world recognized this idea as an inspiring challenge. Robot soccer research is interdisciplinary, complex, demanding but most of all, fun and motivational. Obtained knowledge and results of research can easily be transferred and applied to numerous applications and projects dealing with relating fields such as robotics, electronics, mechanical engineering, artificial intelligence, etc. As a consequence, we are witnesses of rapid advancement in this field with numerous robot soccer competitions and a vast number of teams and team members. The best illustration is numbers from the RoboCup 2009 world championship held in Graz, Austria which gathered around 2300 participants in over 400 teams from 44 nations. Attendance numbers at various robot soccer events show that interest in robot soccer goes beyond the academic and R&D community. Several experts have been invited to present state of the art in this growing area. It was impossible to cover all aspects of the research in detail but through the chapters of this book, various topics were elaborated. Among them are hardware architecture and controllers, software design, sensor and information fusion, reasoning and control, development of more robust and intelligent robot soccer strategies, AI-based paradigms, robot communication and simulations as well as some other issues such as educational aspect. Some strict partition of chapter in this book hasn't been done because areas of research are overlapping and interweaving. However, it can be said that chapters at the beginning are more system-oriented with wider scope of presented research while later chapters generally deal with some more particular aspects of robot soccer.

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