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ROBOTIC EDUCATION FOR ELECTRICAL ENGINEERING STUDENTS AT THE UNIVERSITY OF AFYON KOCATEPE

ABSTRACT

There is a demand for skilled personnel in automation technologies in Turkish Industry. Therefore some industrial automation courses as compulsory ones and a factory automation one as selective are placed in electrical department curriculum. In this study, a robotic training which is a part of factory automation course for electrical engineering students at the University of Afyon Kocatepe is presented. After graduation, students can work as an applied engineer in industry or a technical teacher at the vocational high schools. Thus robotics teaching methods and subjects are chosen more practical instead of Robotics education with cumbersome math. Also a senior level robotic application project is introduced.

Keywords: Robotic Education, Mechatronic Courses,
Robotic Application Project, Industrial Automation Courses,
Robotic Application Project

AFYON KOCATEPE ÜNİVERSİTESİ DE ELEKTRİK MÜHENDİSLİĞİ ÖĞRENCİLERİ İÇİN ROBOT EĞİTİMİ

ÖZET

Türk sanayisinde otomasyon teknolojileri alanında kalifiye personel için bir talep var. Bu nedenle elektrik bölümü müfredatı içerisine, zorunlu ve seçmeli ders olarak fabrika otomasyon ve endüstriyel otomasyon ders olarak yerleştirilmiştir. Bu çalışmada, Afyon Kocatepe Üniversitesi'nde elektrik mühendisliği öğrencileri için fabrika otomasyonunun tabii bir parçası olan robot eğitiminin ne şekilde uygulandığı sunulmuştur. Bu eğitimi alan öğrenciler fabrika sektöründe uygulamalı bir mühendis ya da meslek liselerinde teknik öğretmen olarak çalışabilirler. Böylece yöntem ve konular seçilirken yoğun matematik öğretiminin yerine robotlarla yapılabilecek uygulamalar seçildi. Ayrıca üst düzey robotik uygulama projesi tanıtıldı.

Anahtar Kelimeler: Robotik Eğitim, Mekatronik Dersi,
Robotik Uygulama Projesi,
Endüstriyel Otomasyon Dersi,
Robotik Uygulama Projesi

1. INTRODUCTION (GİRİŞ)

Nowadays technicians and engineers need a more interdisciplinary education and knowledge in work life. Consequent to the revolutionary progress in microelectronics and computer [1]. The composition of existing products has undertaken an extreme change and many new products have appeared on the market. Pure mechanical, electrical or electronic products almost do not exist any more. Obviously, this drastic change requires also an important adaptation of today's educational curriculum in engineering.

Formerly, electrical engineering curriculum generally covered electrical machines, power systems, electrical installation and lighting, and like. Nowadays, these subjects occupy a small portion of an undergrad's curriculum because developing technologies have been changing production methods and making many innovations [2].Therefore it is necessary to teach new subjects to students in the electrical departments. A lot of universities comprehends importance of new technologies and they increases number of mechatronic courses including robotics in their curricula [3, 4 and 16]. In addition balance between analytical engineering and application engineering is under interest in the publications recently [5, 6 and 7].

Industry in Turkey expects graduates of the technical faculties to possess a wide range of knowledge, because the equipment involves many devices and systems. Both graduate programs and industry need students who are ready for these technologies [8]. The new advances in factory automation, particularly in small and medium volume production factories, require high flexibility in processing and material handling equipment [9]. Since robots can offer this flexibility, they became the backbone of flexible programmable automations. Considering importance of industrial robots for the factory automation, there is a need to teach robotics courses and accomplish research related to robotics field. Therefore some industrial automation courses as compulsory ones and a factory automation one as selective are placed in electrical department curriculum. The mechatronic laboratory is equipped with a Flexible Manufacturing System included with a five axes industrial robot.

2. RESEARCH SIGNIFICIANCE (ÇALIŞMANIN ÖNEMİ)

In this study, a robotic training which is a part of factory automation course for electrical department students at the University of Afyon Kocatepe is presented. Robotics teaching methods and subjects are chosen more practical instead of Robotics education with theoretic one. Also a senior level robotic application project is introduced.

3. ROBOTIC COURSE DESCRIPTION (ROBOT EĞİTİMNİN TANITIMI)

Industry expects that engineers have knowledge and skills on different subjects such as mechanics, electrics, electronics and programming [10 and 11]. If students work in industry they should study with a lot of different subjects. Therefore, electrical engineers are encouraged to build mechanics, and to write software [12 and 13]. Before Robotic course, students should take some courses and get sufficient knowledge and skills. These are programming, fundamental mechanics, production methods, basic electrics and electronics [14]. After passing these courses, students take factory automation course as one year two semester course in the fourth year. Robotic course is given as part of factory automation course in the second semester.

After completion of fundamental courses, robotic is taught considering basic educational rules (from easy to difficult, from near to far ... etc.). Robotic course contents can be seen as in Table 1. Information about course contents is given in following subsections in detail.

Table 1. Robotic course contents
Tablo 1. (Robot kursunun içeriği)

1-FUNDAMENTAL ROBOTIC INFORMATION	a-Definition of Robot and Robotic systems? b-Robot types and Assortments c-Industrial Robots d-Robot Arms
2-PERIPHERAL EQUIPMENTS OF ROBOTS	a-Sensors b-Valves c-Pistons
3-MAINTENANCE OF ROBOTS AND SET UP ADJUSTMENT	a-Replacement of Batteries b-Adjustment of Originating points
4-ROBOT PROGRAMMING	a-Robot Motion Commands b-Simulation program c-Interface Program d-Programming with teaching box
5-INDUSTRIAL APPLICATIONS	a-Simple movement programs b-Current industrial application programs (Project work)

3.1. Fundamental Robot Information (Temel Robot Bilgileri)

3.1.1. Definition of Robot and Robotic systems (Robot ve Robotik Sistemlerin Tanımı)

At the beginning of the course, theoretical information on robots and autonomous systems are given. These are definition of robot and robotic systems, basic robot kinematics, application areas, advantages and disadvantages of robots in industry.

3.1.2. Robot Types (Robot Tipi)

Classification of robots is presented firstly. General information about Cartesian Robot, Cylindrical Robot, Spherical Robot, Scara Robots, and Jointed Robots are given. Jointed robots which we have five axes robot in the lab are taught a little more in detail.

3.1.3. Industrial Robots (Endüstriyel Robotlar)

Industrial robots and robot arms in industry for different purposes, usage areas, selection of robot for varied industrial job, movement capability of robots and mechanical specifications are taught to students.

3.1.4. Robot Arms (Robot Kolu)

Robot arms are given in detail in this part of the course. Usage of objectives, basic parts, programming, and movement area of robot arms are taught to students.

3.2. Peripheral Equipments of Robots (Robotların Çevre Ekipmanları)

These equipments are taught to student in previous courses. But these subjects are repeated and connected with robotic systems in this unit.

- **Sensors (Sensörler):** Inductive, capacitive and colour sensor …e.g. used commonly in robotic systems are explained in this section. Operation principles, structure of these sensors, selection of sensors, and integration of sensors with robots are also taught.
- **Valves(Valfler):** Fundamentals of valves, varieties of them, problem solution and industrial application with valves, valves in robotic systems are given in this part.
- **Pistons (Pistonlar):** Single acting and double acting pneumatic Pistons are introduced and operation conditions, integration with robots are taught.

3.3. Maintenance of Robots and Set up Adjustments (Robotların Bakım ve Ayarları)

Mechanic compulsions may cause some physical defections and change some adjustments. Therefore periodic maintenance is considerably important for robots used in industry. Generally it is forgotten in the industry of developing countries. Most important ones of maintenance are battery replacement and checking origin points.

- **Battery Replacement (Batarya Değiştirme):** Robots need memory batteries to keep programs written by programmers. It is necessary to replace batteries periodically not to be erased inscribed programs. Usually control unit has batteries to keep its program in memory and robot itself has batteries to save origin datum. Replacement of batteries has to be accomplished in a certain procedure. These procedures are taught to students.
- **Origin adjustment (Başlangıç Noktasının Ayarlanması):** When robots are exposed mechanic coercions or programs are downloaded for different purposes, it can be essential to change origins of robot arms. On this kind of situation new origin values should be defined. In this section this operation is instructed.

3.4. Robot Programming (Robot Proğramlama)

- **Robot Movement Commands (Robot Hareket Komutları):** Movement commands are written to control electrical motors in articulations and pneumatic systems in holder unit. Robot arms have two types of movement capability which are rectilinear and curvilinear. In the programs, approaching to target points becomes rectilinear or curvilinear. Commands are chosen according to movement variety and movement speed is adjusted by them. Also condition of holder as open or close is determined by commands.

Each robot has its own distinctive movement command. These commands are taught to students by order. Then they practice them in simulation program and robot.

- **Simulation program (Simülasyon Programı):** After fundamental knowledge of robots, students study with simulation program before studying with robot directly. They test and make necessary corrections their own small programs in the virtual enviroment which is called as "Cosimir" robot simulation program. Afterwards students start real application. Because Cosimir has same feature with robot interface program students can see their own mistakes and correct them easily.

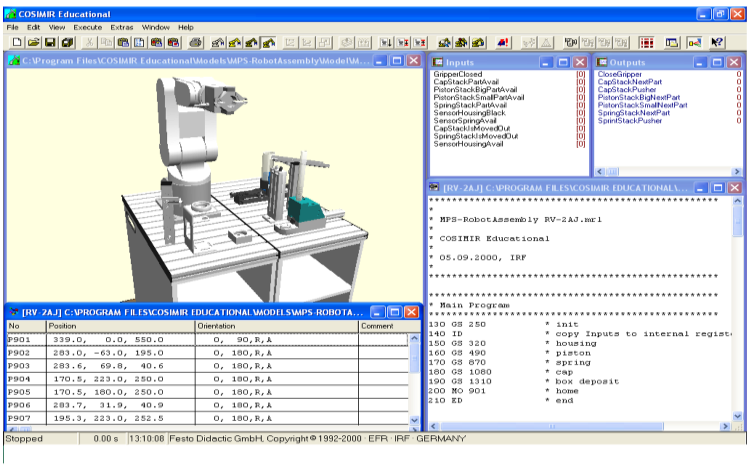

Figure 1. Cosimir simulation program
(Şekil 1. Cosimir similasyon program)

- **Usage of Interface Program (Kullanılan Arayüz Programı):** Menus and contents of interface program called "Cosirop" are introduced. Students learn how they can constitute a new Project in this section. A Project consists of two main parts: 1- Program software 2- Position table. In addition to these students learn mechanical adjustments of robot via interface program, communication between robot arm and interface program, program downloading and uploading etc.
- **Programming with Teaching Box(Öğretim Kutusu İle Programlama):** Position table can be constituted easily by means of teaching box. Robot arm is orientated desired positions via keypad on the teaching box. By memorizing of these position points is composed of position table. Furthermore, mechanical adjustments of robot can be made by teaching box.

3.5. Industrial Applications (Endüstriyel Uygulamalar)

- **Simple movement programs (Basit Hareket Programları):** Before starting advance level robot programming practices, students learn fundamental of them in this part of the robot training such as holding, dropping, handling, programming with sensors, pistons, valves, checking robot adjustments etc. Training is based on three main segments: lecturing, simulation, and application with robot. Students write short programs for different robot actions and try them with simulation and robot. They experience a lot of practice and solve a lot of robotic problems.
- **Actual Industrial application programs (Gerçek Endüstriyel Program Uygulamaları):** By means of training process until this section, students can have skill and knowledge for programming a robot arm and operating it. Before starting Project work students take an exam which contains theoretical and practical segments. Successful students can join Project works, and unsuccessful students take a feedback course. Project works are chosen as robot applications to real industrial systems. Students study as a group, each one take a Project, number of students in the group depends on difficulty level of Project. Each student is responsible his part of the Project and whole Project success. Because robotic systems will probably occupy whole Turkish industry in the future, target of this kind of education is to be ready student's real life work in the near future in the Turkish industry. Student as an intern have to work in the industry at least 60 week days in second year and/or third year summer vacation. Some students can find real industrial problems themselves. They apply robotic solution to current production system.

Project based robotic education gives students some skillfulness such as team work capability, helping each other, sharing, problem shooting, problem solving, confidence...etc.

A Project work is given following section as an example. The Project is about mosaic decoration which is a Subsection of Marble sector.

Figure 2. Flexible manufacturing sytem
(Şekil 2. Esnek üretim sistemi)

4. DENEYSEL CALISMA (EXPERIMENTAL PROCESS)

Mechatronic Laboratory in Technical Education faculty has a Flexible Manufacturing System (FMS) including an industrial robot seen in Figure 2. The FMS system is an expandable system consisting of modular production stations (MPS). MPS facilitate industry orientated vocational and further training and the hardware consists of educationally suitable industrial components. The central unit is a transport system. The FMS system is designed in such a way, that the amount and kind of MPS stations attached is of no importance. A complete processing cycle of the work-piece is always warranted. Therefore the transport system is required under any circumstances.

Each MPS can be employed individually or different number of combinations. FMS system is composed of distrubition, processing, sorting/commissioning, AS/RS and Robot stations. In the robot station, controlling the sensors and actuators of the assembly process is done directly via the robot drive unit. So this station can be used independently from other stations or a more complex process. The Robot station consists of the following:

5 axes industrial Robot (RV-2AJ) with robot controller
Slide module
Retainer module
Assembly retainer module
Magazine module
Profile plate

Figure 3. Robot station
(Şekil 3. Robot istasyonu)

4.1. A Sample Project Work (Örnek Proje Çalışması)

Most developed and pervasive industry is marble sector around Afyon where the technical faculty is in. Recently, mosaics decoration as a new sector is growing up dramatically. This sector utilizes remaining of marble industry.

Mosaics are designs or pictures created by embedding small pieces of marble into a bed of cement or other form of fixative. This form of decoration is often used for panels or on floors, but is especially effective on curved surfaces, such as ceilings and vaults. Mosaics can be found both indoors and outdoors. The art of mosaic has been practiced for thousands of years. Modern developments in materials and production techniques are evidence that mosaic is very much alive in the new millennium. Mosaic has an immense decorative potential [15].

Mosaic tiling process has been carried manually for thousands of years. Unfortunately, the manual tiling method is not a fast and flexible process as much as necessary, because, each customer has different requirements, such as colour, style, size, etc. It is very costly and also difficult to find skilful people to tile mosaic. Each mosaics style requires special mould or drawing on paper to tile the pieces in a right position and orientation.

Automation of mosaics tiling may make it possible to employ a less skilled workforce, thus culminating in the almost total decay of the ancient and glorious mosaic tradition. Therefore a computer-assisted robotic system can be constructed and applied. In order to meet customer demands, flexible robotic systems are necessity to tile various style mosaics.

After definiton of the real life problem as above, it is given a group of students for Project study. A number of testing components with two different colours are used as small marble pieces. They are stored in two different magazines. Students develop robot programs to tile mosaics for three distinctive patterns by using robot's own programming language called Melpha Basic. They follow logic in flow chart as seen in figure 3. to fulfill the project. The programs can be tried in simulation program named as Cosimir firstly and then downloaded to the robot. Result of study, mosaics can be tiled easily and no need any professional personnel. Also program is user friendly, one of the desired patterns can be chosen from control unit or from teaching box. Students know that project is realized in laboratory conditions and many problems may occur in real life applications. In order to apply real industry, it is necessary to change robot gripper according to marble mosaics at least.

4.2. Preparation Method of Program and Running (Programın Hazırlanması ve Çalışması)

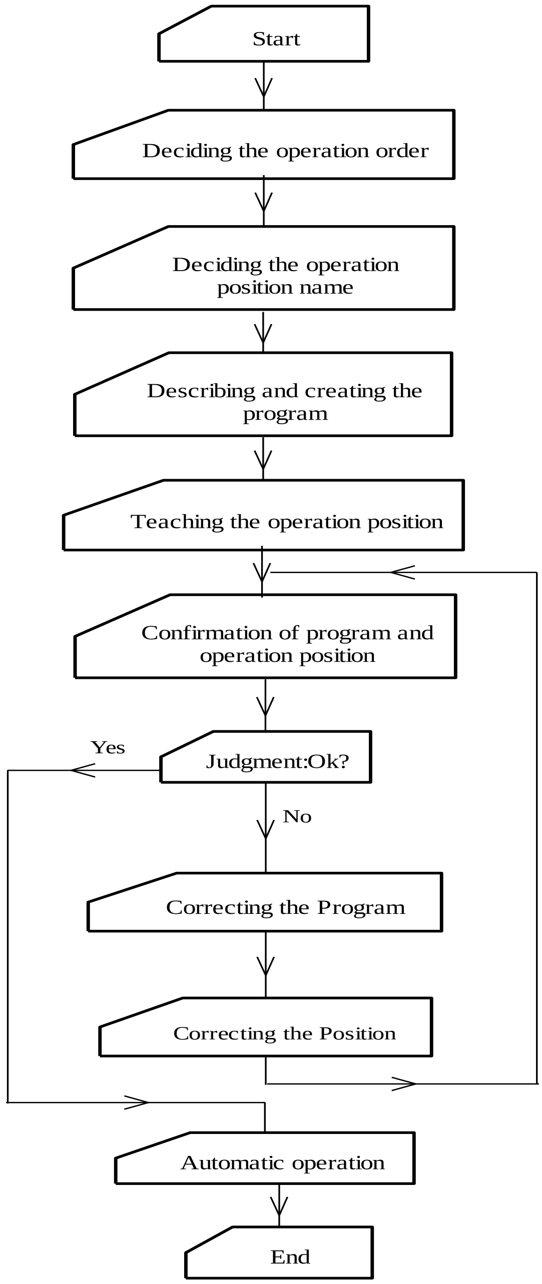

Figure 4. Flow chart of robot application process
(Şekil 4. Robot uygulama işleminin akış şeması)

Start
Decision of the work (Robot positions, holder conditions: open or close, path of robot arm)
Naming positions
Writing programs according to positions
Teaching movement positions
Checking program and positions together
Confirmation
Exactness of program
Exactness of positions
Automatic mosaic tiling

END

At the programming stage, two mosaics taking position points and tiling positions are taught to robot via by means of teaching box. These positions can be inscribed via Cosirop program instead directly. Robot arm tiles mosaic to make a pattern by moving between position points and according to movement manner written in the program. In this application, three dissimilar patterns are constituted by using two different magazine. Patterns are shown in Figure 5.1. These models are very simple ones. Programs can be developed for more complex patterns. Parts of programs for plus '+' sign, multiplication 'X' sign, and line '-' sign are given following.

- **Plus Pattern (+ Deseni)**

```
10 MVS P1        :  Move to P1 position (linear movement)
20 DLY 1         :  Waiting at P1 position for 1 second
30 MOV P2,-100   : Move to 100mm.upward position to P2 (Joint movement)
40 MVS P2        : Move to position to P2 (linear movement)
50 HCLOSE 1      : Grasp workpiece (hand close)
60 MVS,-100     : Move to 100mm.upward position to P2 (Linear movement)
70 MOV P6,-100   : Move to 100mm.upward position to P6 (Joint movement)
80 OVRD 100       : Move to adjust speed (100)
90 MVS P6       :  Move to P6 position (linear movement)
100 HOPEN 1     : Release workpiece to P6 Position (hand open)
110 MVS,-100    : Move to 100mm.upward position to P6 (Linear movement)
120 DLY 0.5     : Waiting at P1 position for 0.5 second
```

- **Multiply Pattern (X-Deseni)**

```
10 MVS P1       : Move to P1 position (linear movement)
20 DLY 1        : Waiting at P1 position for 1 second
30 MOV P3,-100 : Move to -100mm.upward position to P3 (Joint movement)
40 MVS P3       : Move to position to P3 (linear movement)
50 HCLOSE 1     : Grasp workpiece (hand close)
60 MVS,-100   : Move to 100mm.upward position to P3 (Linear movement)
70 MOV P6,-100 : Move to -100mm.upward position to P6 (Joint movement)
80 OVRD 100     : Move to adjust speed (100)
90 MVS P6     : Move to position to P6 (linear movement)
100 HOPEN 1    : Release workpiece to P6 Position (hand open)
110 MVS,-100   : Move to -100mm.upward position to P6 (Linear movement)
120 DLY 0.5     : Waiting at P6 position for 0.5 second
```

- **Line Pattern (- Deseni)**

```
10 MVS P1    : Move to P1 position (linear movement)
20 DLY 1     : Waiting at P1 position for 1 second
30 MOV P2,-100: Move to 100mm.upward position to P2 (Joint movement)
40 MVS P2    : Move to P2 position (linear movement)
50 HCLOSE 1  : Grasp workpiece (hand close)
60 MVS,-100  : Move to -100mm.upward position to P2 (Linear movement)
70 MOV P6,-100: Move to 100mm.upward position to P6 (Joint movement)
80 OVRD 100  : Move to adjust speed (100)
90 MVS P6    : Move to P6 position (linear movement)
100 HOPEN 1  : Release workpiece to P6 Position (hand open)
110 MVS,-100: Move to 100mm.upward position to P6 (Linear movement)
120 DLY 0.5: Waiting at P6 position for 0.5 second
```

A lot of programs and position lists can be saved in control panel with different names. An operator can choose a pattern on the panel and then activate robot for tiling process. This is an advantage of robotic tiling.

a- '+' pattern b- '-' pattern c- 'X' pattern
Figure 5. Simple robot application patterns
(Şekil 5. Robot uygulama örnekleri)

5. CONCLISIONS (SONUÇLAR)

There is a big gap between engineering education and industry expectations in Turkey. To fulfill this, electrical curriculum at the electrical department of Afyon Kocatepe University is developed. Number automation courses are increased and also contents of courses are quite different from classical engineering study programs. All technical courses are project based. The robot course is described in this study and one of the project works is presented as an example. Project works should be chosen real industrial problems and students should try to solve them by using automation technologies. Internship program in industry is good opportunity for project shooting. This kind of engineering study encourages students to study hard and increase self-confidence of them to work in industry. Technical education will be much more meaningful with real industrial applications.

All the aspects mentioned above are probably more important for successful work in industry than the pure theoretical background. They cannot be covered by conventional courses but can easily be addressed in real project work done in the lab.

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