Education in the field of Robotics and Automation at the Engineering Faculty of the University of Messina

Maria Gabriella Xibilia

Abstract – **In this paper the state-of the art of education in the field of Robotics and Automation at the Faculty of Engineering of the University of Messina is reported. A short description of the academic organization is given, along with topic dealt in each course and the related laboratories activities. Some experience regarding the final thesis development is also reported.**

Keywords - **Education, Automation, Robotics, System Identification, Automatic Control.**

I. INTRODUCTION

In 1999, in accordance with the guidelines laid down by the Bologna Process, the Italian university system switched from the old system (5-year Laurea degree), to the new system that split the former Laurea into two different tracks.

A credit system was established to quantify the amount of work needed by each course and exam (25 work hours = 1 credit), to enhance the possibility to change course of studies or to continue studies in a foreign country.

The first degree is the “Laurea triennale” (3-year degree) that can be achieved after three years of studies. It is equivalent to a bachelor's degree. To earn a laurea, the student have to complete the university courses and also complete a thesis, which may or not require experimental work

Students can then complete two more years of specialization which lead to the “Laurea Magistrale” (2-year degree). The "Laurea Magistrale" corresponds to a Master's Degree, and gives access to third cycle programmes (doctorates). Also in this case to earn the laurea, the students have to complete the university courses and also complete a thesis, which may or not require experimental work

The new courses started in Messina in 2000, and in particular two new 3-year degrees and two 2-year degree started at the Engineering Faculty in the Information and Communication field. Both degree contain some classes related to Automation and Robotics.

Each classes can correspond to 3 or 6 credits (cp). A 6 credit class requires a total workload of 60 hours for either lectures or labs or project works.

A list of the classes in the field of Automation contained in each degree is reported in the following:

Electronic Engineering (3-year degree)
Classes:
Basics on Automation (6 cp, 2nd year,2nd semester)

Electronic Engineering (2-year degree)
Classes:
Robotics (6 cp, 2nd year, 1st semester)

Computer Engineering (2-year degree)
Classes:
Robotics (6 cp, 2nd year, 1st semester)
System Identification (3 cp2nd year, 1st semester)

The low number of classes related to Automation is mainly due to the fact that the University of Messina is very young and also the number of structured professor is low. This has lead to introduce in the basic classes, in particular those of the 2-year degree, a wide range of topics, in order to give to the student an overview of the fundamental aspect of Automation. Some of the topics are therefore not covered in details for time limits. Despite the attention paid to this aspect, students strongly feel a big gap between theoretical and practical aspect. A further limitation is due to the lack of industries available to offer to the students stage opportunities or to propose them practical applications to prepare their final thesis. In the following section the topic dealt with in each class are dealt with in some details along with the description of the corresponding laboratory activities.

II. CLASSES IN AUTOMATION

During the 3-year degree, the basic of Automation, both as regards linear systems analysis and feedback control design are given. The same content is given in only one class in the Electronic Engineering degree, while it is split in two classes in the Computer and Telecommunication degree. Theoretical prerequisites, which are given during the first year, are matrix algebra, differential equations and Laplace and Fourier Transform.

The basic aim of these classes is to give to the students an idea of the interdisciplinary of System Theory and Automatic Control, giving examples ranging from engineering to medicine, biology and economy. This should both attract students and giving them a wider view of possible applications, even if most examples are taken from disciplines more familiar to the students, like electrical and mechanical systems. A balanced coverage of frequency response and state-space topics is given to guarantee the possibility of introducing modern control design.

A. Classes in the 3-year degree

In the following, the fundamental issues covered in the classes of the 3-year degree are listed.

Maria Gabriella Xibilia is with the Faculty of Engineering, University of Messina, Nuova Panoramica dello Stretto, 98188 Messina, Italy, E-mail:mxibilia@ingegneria.unime.it

Basics on Automation

- Definition of systems, models and system properties;
- Example of systems and models from different field of application;
- Dynamic models, differential equation and state variable forms;
- Transfer function;
- Analysis of linear time-invariant systems: stability, controllability, observability;
- Time domain responses, dominant poles;
- Frequency domain analysis;
- Properties of feedback control;
- Stability of closed loop systems, Nyquist diagram and robust stability;
- Controller design in the frequency domain;
- PID control;
- Digitization and digital control;

As regards Laboratory activities, students are introduced to the use of Matlab® and Simulink® for the analysis of dynamical system behaviour, so that they can gain a deeper understanding of the fundamental properties of systems without addressing computation issues.

Final examination consists both of a written text and of an oral discussion of the subject content.

In the graduation in Computer Engineering the basic Automation course is split in two classes, so that there is more space both for system analysis and controller design. In details, the control law design for full-state feedback and the estimator design are introduced in the System Theory class, along with stability of nonlinear systems and linearization and an overview of optimal control strategies.

As regards the Automatic Control class, the root locus is introduced as a tool both for the time domain analysis and the controller design. Students are encouraged to extensively use Matlab® and Simulink® to perform simulation both in the time and frequency domain, to observe properties like disturbance rejection, robust stability, effect of actuators saturation and so on, which are difficult to analyze without adequate software tools .

Moreover some cases of study which require a deeper expertise in control system design are briefly shown to the students to give them the possibility to enlarge their comprehension of automatic control applications and potentiality.

All the classes of the 3-year degree are based on the same educational reference that are:

- Notes written by the teachers;
- Matlab® Toolbox User Guides;
- Italian textbook: Bolzern, Scattolini, Schiavoni, Fondamenti di Controlli Automatici, Mc Graw-Hill Italia ed.

Final examination consists both of a written text and an oral discussion. Though software tools are widely used both during lessons and laboratories activities, they are not allowed during final examinations to put under evidence analytical and critical capabilities of students in control system design without skipping all the methodological issues.

B. Classes in the 2-year degree

The 2-year degree is intended to provide students with a more specialized knowledge in the different field of Electronic or Computer Engineering. As regards Automation, it should give a particular attention to industrial applications.

Unfortunately, also in this case, the number of classes is not sufficient to fill the gap between the theoretical content of the first-level classes and the practical issues of industrial automation. To try to give to the student a sufficient background to approach the job market, in the Robotic class topic related to industrial automation are also dealt.

Moreover, to cope with recent issues in control, artificial intelligence is introduced.

Topics dealt with in the class of Robotics are listed in the following:

Robotics

Industrial Automation and PLCs:

- Computer Integrated Manufacturing;
- Industrial hardware for control;
- PLCs: hardware, software and applications examples;

Industrial Robotics:

- Robots classification and industrial applications;
- Rotations representations and Kinematics;
- Dynamics (Introduction to Lagrange approach);
- Trajectories design;
- Introduction to sensors and actuators (they are dealt in more details in other classes);
- Introduction to governing unit and robot programming;
- Motion control (linear and non linear approaches);

Artificial intelligence

- Introduction to soft computing;
- Neural Networks (MLPs);
- Fuzzy Systems;
- Neural and Fuzzy control;
- Soft computing applications in control.

Educational reference are in this case:

- Notes written by the teachers;
- Matlab® Toolbox User Guides;
- Schneider Electric PLC User Guide;
- Italian textbook: Sciavicco, Siciliano, Robotica Industriale - Modellistica e Controllo di Manipolatori, Mc Graw-Hill Italia ed.

Even if the laboratory is new and most of necessary equipments are still not available, laboratory is a relevant part of the Robotic class. At the moment the Robotic laboratory is equipped only with a number of PLCs. During teaching assisted laboratory activity, students learn to program PLCs via some simple examples. To perform the final examination they have to develop their own applications, which are left totally free from the teacher, and discuss it during the examination. As an example, a simple PLC program that control the carry-ferry loading-unloading system represented in Fig.1, has been designed by students. The corresponding laboratory realizations uses simple switches instead of sensors, as reported in Fig. 2.

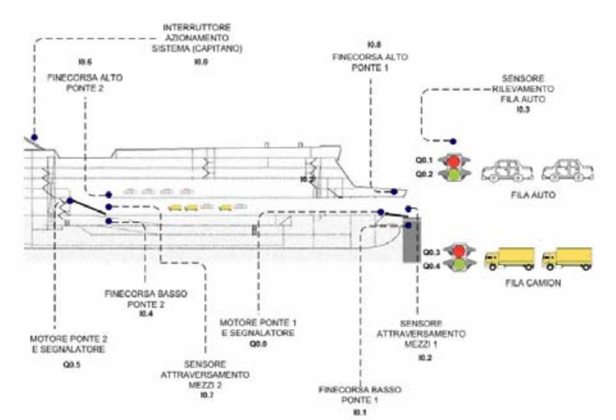

Fig. 1. Example of a student work for the Robotic laboratory.

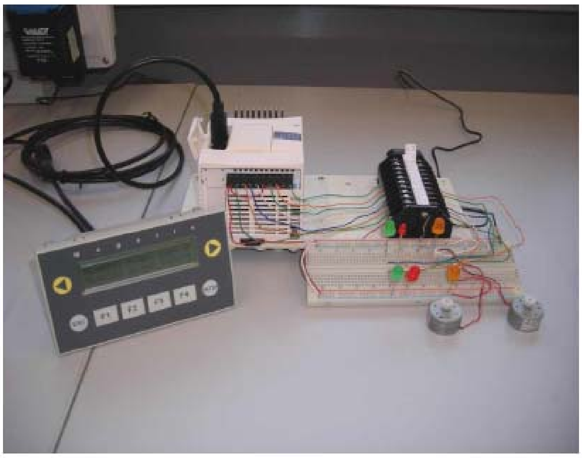

Fig. 2. Example of PLC equipment at the Robotic laboratory.

Even if, due to the simplicity of the laboratory equipment, the developed applications are far from the real-world design, students appreciate the possibility to be free to perform their experiments in PLC programming without having time limits.

In the next future, in order to equip the Laboratory for Industrial Robotics without high expenses, elements like Lego Mindstorm ® Kits will be acquired, as a starting point.

Final examination consists of an oral discussion of the subject content and of the laboratory application proposed and performed by the student.

The second class available in the 2-year degree, i.e. System Identification, is intended to encourage students to develop final Thesis in the Automation field. The class content can vary from year to year but basically consists in Theory and Practice of System Identification both as regards linear and nonlinear models. Topic dealt with in this class are:

System identification

- Introduction to system identification;
- Data processing (outliers detection, scaling, correlation analysis, PCA);
- Linear models (FIR, ARX, ARMAX,…);
- Least square method;
- Model order selection;
- Model validation;
- Nonlinear system identification by using neural networks and fuzzy systems;
- Industrial applications and Soft Sensors;
- Laboratory;

The proposed applications are selected in order to show to the students a number of practical issues emerging from industrial application of system identification. All examples are based on real-world case of study.

Laboratory activities of this class are mainly based on the use of the Matlab ® Toolboxes System Identification, Neural Networks, Fuzzy Systems and Statistics to perform Data Analysis and Processing, System Identification and Model validation starting from experimental data.

Experimental data acquired from different industrial cases of study are therefore used during guided laboratory applications and given to the students to complete their own project work.

Project work realized by the students to have access to final examination are again chosen by the students itself and mainly consists in the application of existing methodologies to industrial cases of study.

Final examination consist of an oral discussion of the subject content and of the project work.

Educational reference are:

- Notes written by the teachers;
- Matlab® Toolbox User Guides;

Due to the shortness of this course, some practical aspects are skipped and they usually emerge during the development of the project work, which requires a strict collaboration between the teacher and the students. To reduce this problem students are encouraged to work in groups to share their experiences and their expertise in the use of Matlab ®.

The knowledge acquired in the classes of Robotics and System Identification is used by the students to develop the final thesis required to graduate. Thesis usually involves some academic research or an internship in a private company. Some experiences of activities performed by the students as final thesis are reported in the next section.

III. Final Thesis

In this section some of interesting experiences of final thesis development are described. Most of the experimental thesis originates from the collaboration of the Automation group of the University of Messina whit refineries in the industrial area of Priolo Gargallo (SR) and with the University of Catania. Research activities deals with the design of Soft Sensors for industrial plants, and in particular refineries, by merging traditional methodologies and Soft Computing. Students are involved, in collaboration with the research group, both in applying recent methodologies taken from literature to industrial cases of study or in developing new methodologies designed to approach some open problems in Soft Sensor design. Research is motivated by the desire to exploit recent advances in modelling nonlinear systems, by the need to investigate the suitability of various model representations in nonlinear refineries process modelling and by adapt a number of theoretical approaches to industrial problems. An important challenge facing industries is how to increase efficiency through the use of new and intelligent technologies. Industrial process efficiency is determined by a number of factors: technology design, age and sophistication of equipment, materials of construction, mechanical and chemical constraints. Process efficiency can improved by optimizing individual processes, eliminating process steps, lowering energy consumption, monitoring and controlling process variables and reducing emissions. A possibility to reach these objectives is to optimize the process operation by exploiting all available knowledge about the process. This often requires a large number of sensors to be installed on the plant, such that the processes can be monitored and controlled adequately. Unfortunately, in process industry, measuring devices are generally required to work in a hard environment, that requires very restrictive design standards and maintenance scheduling. Moreover, some measures are available only with significant delays, thus reducing the efficiency of feedback control policies.

Mathematical models of processes designed to estimate relevant process variables can help to reduce the need for measuring devices, improve system reliability and develop tight control policies. In industrial framework they are also called Soft sensors. They are usually based on nonlinear system identification methodologies and artificial intelligence. Theoretical basis to approach experimental activities and research in this field are therefore given to the students in the classes of Robotics and System Identification. Some interesting thesis results, that allowed the research group to develop new research topics are briefly described in the following.

Thesis: “A Comparative Analysis of the Influence of Methods for Outliers Detection on the Performance of Data Driven Models”: the thesis investigated the data pre-processing step in model identification. The performance of a number of techniques useful for outlier detection was described, tested, and compared and a number of new approaches useful in industrial application was proposed. The comparison was performed by using data acquired from a real industrial plant working in a refinery in Sicily, Italy

Thesis: “Comparing regressors selection methods for the Soft Sensor design of a Sulfur Recovery Unit”: in this thesis some methods for the selection of significant regressors in nonlinear dynamic models were investigated and two new methods, based on Lipschitz coefficients and Partial Least Squares regression (PLS) techniques, were proposed.

Thesis: “Soft Sensor design for a Sulfur Recovery Unit using Genetic Algorithms”: a general design strategy, based on the automatic selection of regressors of a NMA model was developed, on the basis of the minimization of the Lipschitz numbers by a Genetic Algorithms approach.

Thesis: “Stacking approaches for the design of a soft sensor for a Sulfur Recovery Unit”: a model stacking approach is proposed to improve the estimation performance of the Soft Sensor. Neural Networks, Principal Component Analysis and Partial Least Squares approaches are used for the realization of the first level’s models and Neural Networks and PLS are used as combination approaches. The obtained soft sensor has been implemented in a refinery in order to replace the measurement device during maintenance and guarantee continuity in the monitoring and control of the plant.

Thesis: “Development of a Soft Sensors using a limited amount of experimental data”: a number of methods to alleviate the effect of small data set in system identification procedures are compared and novel methodologies have been proposed, based on the integration of bootstrap resampling, noise injection and stacked neural networks in order to improve the generalization capabilities of the model. The method has been applied to develop Soft Sensors for a Topping process and a Thermal Cracking Unit.

Student activities during the development of their thesis are guided by the entire research group, i.e. professor, Ph.D. students, technicians from refineries and professor of other universities who collaborates to the research. Interested readers can find some of these results in [1], [2], [3].

IV. Conclusions

Automation is not well covered at the University of Messina for a number of reasons. First of all, the existing degrees are mainly devoted to Electronic or Computer Engineering, so that there is no enough space for more Automation classes. Moreover the number of professors able to cover disciplines related to automation is not sufficiently high. A last reason is the lack of industries involved in Automation in the Messina surroundings.

However, basic knowledge in Automation should be part of the theoretical background of any engineer, in order to allow an easier approach to industrial employment.

In order to fill this gap it would be necessary to deal in more datails with topics like microcontrollers, embedded systems, advanced process control and nonlinear systems. A good starting point to introduce an improvement in this direction could be to increase efforts in laboratory activities. This may indeed stimulate students to acquire a deeper knowledge in practical issues of Automation even in absence of specific classes and to therefore appreciate advanced theoretical issues. A further impulse can be represented by tight contacts with industries and other public and private research groups. These relationships would allow to organize specific stage periods for master students with beneficial effects both for students and for the research group.

V. References

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