Definition and First Year of a New International Master in Industrial Processes Automation

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Abstract

The aim of this paper is to present a new international master curriculum in the field of information technologies (IT) focused on industrial processes automation (IPA), proposed by University Joseph Fourier (UJF) / University of Grenoble, France. The education objectives are set according to the latest concepts developed in IT for process automation, with clear specifications towards engineering and industry. The local and international frameworks are analyzed and the education objectives expressed according to the guidelines provided by dedicated European projects. Feedback from the first year operation of the program provides some insights for the students' enrolment, projects definition and possible ways of curriculum improvement. The proposed program architecture, contents and pedagogic approach can then serve as a motivation for new developments in IT Master programs and related curriculum design.

1. Introduction

Information technology components are increasingly used in complex engineering systems. As mentioned in [1] and promoted by the *European Embedded Control Institute*[2], the pervasive infiltration of computer systems (embedded systems and networks) in engineered products and in medicine and biology, requires transformational thinking and ideas in engineering research, education and entrepreneurship. The use of a model-based system integration methodology combined with an overall emphasis on compositional design methodology then appears as crucial issues in modern process automation. In comparison with classical programs in automatic control, the proposed curriculum [3] consequently includes advanced topics in communication networks, control-oriented modeling, supervision and real-time operation along with the more classical multi-objective and discrete-events control issues.

International exchanges and a multicultural approach to education now appear as key issues in the curriculum design. In order to fit within the Bologna process education goals and the European quality assessment in electrical and information engineering as described in [4], the following milestones are considered in the program setup and evolution: definition of the education goals and design of a structured curriculum, curriculum assessment in its institutional context, internationalization, and admission and educational standards.

The aim of this paper is to present the objectives of the new Master on IPA that has been set by UJF and its inclusion in an international and industrial environment. The specific application of the main milestones suggested by the European Commission to define a common qualification framework is described and a feedback from the first year operation is provided.

This work is organized as follows. We first present in Section 2 the main objectives of the curriculum, from an engineering point of view and at the institutional level. Section 3 details the local and international frameworks of the program, described in Section 4. Finally, specific issues concerning the first year observations and feedback are detailed in Section 5.

2. Main objectives

2.1. Modern industrial plants

The education curriculum is focused on modern industrial plants, where advanced automation is needed. This particularly implies: 1) an increased complexity and the need for communication between the systems; 2) crucial specifications in terms of safety, robustness, productivity and quality; 3) large plants involving processes that are operated at different time-scales and for which global control approaches can bring major performance improvements; 4) integrating advanced sys-

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tem theory with the latest high-tech automation devices.

These specific aspects of industrial plants are considered in the courses, lab exercises or supervised projects, which are oriented toward multidisciplinary solutions for industrial problems.

2.2. Toward the industry

In order to prepare the students for the industrial world this master is focused on developing global competencies such as team working, problem solving, concern for quality, capacity for applying knowledge in practice and capacity to learn, along with technical capabilities. The targeted positions are essentially in R&D departments and to become a specialist in control and supervision of industrial plants. As mentioned above all the main industrial sectors are concerned, which implies a multidisciplinary approach and specific capabilities to adapt to various environments.

2.3. International perspectives

The increasing need for international collaborations and business globalization in high-tech industries is answered by the fact that all the classes are given in English. The students can then acquire the appropriate terminology for the technical language used for process automation and practice their understanding and expression more thoroughly than in dedicated English classes. It also allows to open the master program for non French-speaking students and to create an atmosphere of international exchange. A chance to spend a sponsored semester in a specific partner American University is given to the best students thanks to the EU/US program "Dependable Systems International Research and Educational Experience" [5] (DeSIRE[2], Atlantis project, detailed below).

3. Local and international framework

3.1. EEATS Master program

This new master program is part of the two year (M1 and M2) engineering master degree in electronic, electrical, automatic control and signal processing (EEATS from the French acronym) offered by the department of Physics and Electrical Engineering at University of Grenoble. The University of Grenoble is composed of several institutes, among which UJF and Grenoble-INP (smaller in term of number of students). UJF covers most of the scientific fields while Grenoble-INP is focused on specific engineering topics. The EEATS Master degree is co-signed by UJF and Grenoble-INP, and provides an advanced preparation for careers in engineering or research. The areas concerned by the preparation cover broadly the field of electronic and electrical engineering from power systems to nano-technologies.

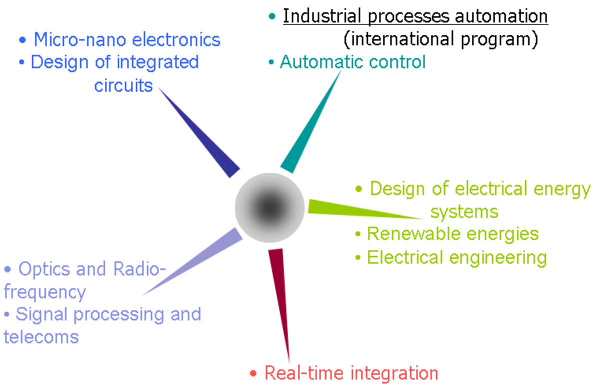

Figure 1. EEATS Master specialties in Grenoble.

Ten programs of specialization in M2 are offered to the students (see Figure 1). The specialty choice is made at the turn of the second year by the students. For admission in a program, the student should hold a bachelor degree in electronic and electrical engineering and a first year of master in an area related to the program specialization. The admission procedure reflects the implementation of the Bologna process at UJF.

The EEATS master graduates an average of 100 students per year. The facilities offered by the department include platforms for IPA or design of integrated devices. The UJF academic team has 9 professors and associate professors. All are active researchers and work in well-known research departments (G2Elab for electrical engineering, GIPSA-lab for automatic control, signal processing and speech; Neel Institute for nano-technologies, ...). The industrial background is provided by a strong support of numerous industrial companies. For instance, some engineers of Schneider Electric teach specialized courses in the areas of automatic control and protection design for industrial systems. It should also be noted that our department is at the point of being certified by *National Instrument®* as a *LabVIEW®* academy.

3.2. International environment with DeSIRE[2]

The analysis, design, implementation, administration, and assessment of international curricula will become increasingly important in the global community of the 21st century. In support of this critical issue, the European Commission and the US Department of Education have funded the ATLANTIS initiative to promote collaboration in higher education between European and American universities. Three American (Embry-Riddle Aeronautical University, Daytona Beach, FL; University of Central Florida, FL; University of Arizona, AZ) and three European Universities (AGH University of Science and Technology, Krakow, Poland; Brno University of Technology, Czech Republic; and Grenoble University, France) are presently working on the framework of a new common curriculum in real-time software-intensive control systems (RSIC) [6] as a four-year Excellence in Mobility (EIM) project. This framework is formalized with the project DeSIRE[2] "Dependable Systems International Research and Educational Experience" and the IPA master curriculum has been designed to fulfill the project objectives.

The project proposes mobility exchange of students pursuing graduate (Master level) engineering degrees in the areas supported by the consortium partners. The plan is to implement a mechanism for involving students from multilingual, geographically separated institutions in a coordinated educational and research experience exposing them to the problems, methods, solution techniques, infrastructure, technologies, regulatory issues, and design/verification tools usually not available in their home program.

Successful completion of such a semester abroad program would result in bringing three components to the home institution not possible without the proposed program:

- mobility students will be able to focus on an area of concentration not available at the home institution, due to the opportunity to take classes, get engaged with faculty and research activities, and access to unique laboratories at the host institution;
- mobility students will gain experience related to cultural immersion and to the international aspects of the program;
- home institution students, interacting in the classroom and on the research projects with the mobility students, will gain better understanding and appreciation of international and global aspects of modern world due to the transatlantic nature of the project.

4. Program description

4.1. Classes organization

The engineering topics are organized in 9 teaching units (TU) composed of classes and laboratories, as detailed in Tables 1-2. The ECTS (30 per semester) are distributed by multiples of 3 and an important weight is set on the laboratories. The total number of supervised hours (classes, labs and projects) is 400 h, which corresponds to the national standards.

Class title	**Hours**	**ECTS**
Multi-Objective Control:		
Optimal control	15	1
Nonlinear control	13.5	1
Robust control	13.5	1
Laboratories	22	3
Modeling and Real-Time Control:		
Modeling and estimation for control	24	2
Labview	18	2
Laboratories	30	2
Networks and Industrial Computation:		
Protocols and networks architectures	18	2
Safety, security and networks	18	2
Field buses	18	2
Laboratories	30	3
Mini-project 1:		
Project management	10,5	1
LEGO mini-project	10,5	1
Industrial seminars	9	1
Long project	21	3
Humanities:		
Public speaking techniques	24	3
Total	**286**	**30**

Table 1. First semester classes

4.2. Projects

While the technical seeds are provided in the classes, labs and a large amount of supervised projects (100 h) aim specifically at developing the generic and multidisciplinary competences. There are three different kinds of supervised projects:

- after four weeks of classes, a *small project* (5 weeks) begins. This project has a strong technical support from the labs and project management classes. The students integrate the technical knowledge acquired in different topics in a robotics-oriented project, with the analysis of the strengths and weaknesses of their organization;
- a *longer project* (8 weeks) follows, on a new and innovative topic associated with industrial processes automation. The technical support is reduced to regular supervision along specific guidelines in bibliographical searching, definition of a possible break-through, modeling and real-time operation;
- six *industrial seminars* (4.5 h each) are organized, where experienced engineers from large industries and SMEs are invited to present a specific case-

Class title	Hours	ECTS
Supervision of Industrial Plants:		
Safety, supervision and diagnosis	20	2
Laboratories	10	1
Advanced Discrete Event Systems:		
Scheduling, logistics and simulation	21	2
Automaton, Markov chains and petri nets	13.5	1
Mini-project 2:		
Industrial seminars	18	1
Long project	31.5	2
Industrial Internship (5 months, 21 ECTS)		
Total	**114**	**30**

Table 2. Second semester classes

study and the key points of their problem-solving strategy.

4.3. Industrial internships

The industrial internships play a major role and last for at least as long as the theoretical classes (5 months). The aim of these internships is to enhance the professional skills and provide a significant work experience for the students. Experienced engineers then contribute actively to the students' education and the master thesis defenses give an important year-to-year feedback on the strengths and weaknesses of the program. The internships can also motivate interactions between the teaching staff and the industrial engineers as each student gets an academic referee.

5. Feedback from the first year

5.1. Students application and recruitment

One of the main difficulties when starting a new Master program with international perspectives is to select the appropriate level and number of students. The recruitment process is summarized in Table 3, where the number of applicants, accepted applications, students that effectively registered and obtained diplomas are presented. We can first note that a majority of applicants are from foreign countries (Algeria, China, Cameroon, Colombia, Guinea, Iran, Korea, Lebanon, Morocco, Russia, Switzerland, Tunisia and Vietnam). The next significant group is composed of students from the local Master program (described in Section 3.1), with a few applicants from M1 EEATS programs proposed in other French universities. The last group includes the other French diplomas (M1 in other specialties and M2).

As a global remark, the total number of applicants and attending students remained approximately

	2008/2009	*2009/2010*
Applicants	**119**	**109**
- M1 EEATS	35 (30/5)	33 (30/3)
- other French diplomas	15 (4/11)	17 (0/17)
- foreign diplomas	69	59
Accepted applications	**43 (36%)**	**34 (31%)**
- M1 EEATS	28 (26/2)	16 (15/1)
- other French diplomas	3 (2/1)	4 (0/4)
- foreign diplomas	12	14
Effective number of students	**12**	**15**
- M1 EEATS	8 (7/1)	6 (6/0) + 2 (repeating)
- other French diplomas	1 (1/0)	2 (0/2)
- foreign diplomas	3	5
Graduated students	**9**	**N.A.**

Table 3. Students applications and results on a comparative basis (Grenoble / non-Grenoble)

the same between 2008 and 2009 (not counting the two repeating ones) but the academic level significantly increased. This appeared in the curriculum and as a first choice for the IPA Master among good students.

5.2. Short term project

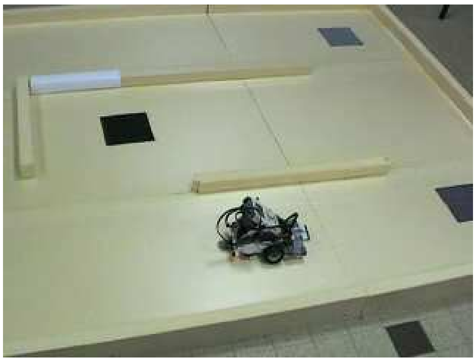

Figure 2. $LEGO^{®} MINDSTORMS^{®} NXT$ **robotics project.**

This project was organized as a 5 weeks work on a $LEGO^{®} MINDSTORMS^{®} NXT$ robot, reinforced with dedicated modeling and control labs. The objective was to develop software packages for two robots that cooperate in searching for the target in a simple maze (see Figure 2). The task for the first team's robot was to ensure a proper mapping of a specific zone, including obstacles and reference points, and send it to the second robot. The second team then had to design an algorithm that analyzes the map and drives the robot from a starting point to its destination while following the shortest path.

The students got very enthusiastic with this project and performed extensive trials at home; it resulted in a video now available on $YouTube^{®}$[7]. The second team was not able to fully complete its task, which motivated a reorganization of the class, supervised by a more experienced professor.

5.3. Long term project

The aim of this 8 weeks project was to investigate new automation solutions for the minimization of industrial processes energy consumption thanks to real-time feedback operation. This automation was based on distributed sensing capabilities, networked sensors, physical modeling for the process automation design and real-time feedback control. Three different projects were proposed:

- heat pump automation for energy savings;
- under floor air distribution (UFAD) for intelligent buildings, with two teams:
  - one focused on large-scale dynamics, involving a multi-room analysis of the problem with simplified models for each room;
  - one considering a single-room regulation, which meant that a more precise model of the room temperature distribution had to be considered.

The previous topics were highly demanding, in order to reveal the main difficulties that one may face when managing a real project. It appeared that the only group who handed in a consistent report at the end was the one which completed the project management plan seriously from the beginning and followed this plan. Most of the students had difficulties to quickly find and synthesize the large amount of information provided by the web or university library. There was also a strong tendency to remain stuck in technical details and team working sometimes appeared as a major difficulty, both for the team leader and collaborative workers. The social skills then appeared as important as the technical skills for an efficient work progress. At the end, the students greatly appreciated having their own project and to overcome technical challenges by themselves.

5.4. Internships

The five months internships were carried out on various topics and in quite different industries, as summarized in Table 4. The topics were mainly centered on modeling and control applications, with some contributions in supervision, algorithms and integrated process design. The network aspects, while not directly reflected in the internships titles, appear implicitly as necessary issues in the automation setups. The control implantations range from classical PID or logical setups in industrial automata to advanced model-based optimal or nonlinear feedback strategies.

It can be noted that most students got their internships in large industries but a significant number (one third) got enrolled in SMEs, which motivate the importance of entrepreneurial skills in addition to the classical industrial ones. The variety of addressed industrial markets appears to be a direct consequence of the need for automation in all high-tech processes with strong efficiency needs. From the education point of view, it highlights the importance of a multidisciplinary approach to engineering problems in the process modeling and control design phases.

The students' autonomy with respect to the learning process may be improved thanks to *e-learning* tools, such as *HADOC* web interface [8], which has been developed in Grenoble to explore the main concepts of the control field by the study of continuous time systems. More generic recent methods, such as the *blended learning approach* (which combines collaborative, problem-based and independent learning) described in [9] may also be of major interest in the future.

Conclusions

In this work, we described and discussed several issues related to the complex task of setting up a new IT Master program in an international environment. The specificities associated with modern IPA issues were discussed and motivated the proposed curriculum. Local and international frameworks analysis then induced the consideration of specific constraints on classes' organization and quality assessment. The feedback from the first year illustrated the difficulties associated with students recruitment, some project examples and the students adaptation in the industrial environment.

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Internship topic	Industry size	Industrial market
Conception of control laws and electronic cards for damping systems	SME	Equipment
Improvement of WinCC data exploitation and supervision development under zenOn	Large	Agribusiness / bio-pharmaceutics
Optimization of linear and nonlinear PID filters for the control of DC/DC buck converters	Large	Microelectronic
Design of an automated functional test bench for electronic cards 1016-B	SME	Automation
Development of algorithms for full electro hydraulic excavators	Large	Equipment
Validation software for ciphering algorithms	Large	Electricity
Air path modeling and control in gas motors	Large	Automotive
Bats localization and trajectory tracking	SME	Electronics
Source determination in non-homogeneous dissipative media: application to tokamaks	Large	Energy
Control of a running machin	Large	Electric

Table 4. 2009 students internships

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