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# A Glimpse on Recent Educational Activities in the Nonlinear Control Field

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**Abstract:** This contribution aims at making an overview of the most recent activities/contributions in education in the control field by members of the Technical Committee Nonlinear Systems, in order to share the best practices and ideas in the community, as well as to investigate into the level of awareness, interest and involvement of the TC members in several aspects concerning education.

*Keywords:* Nonlinear systems, Education

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## 1. INTRODUCTION

The IFAC Technical Committee TC 2.3 is focused on Nonlinear Control Systems, which are used in many applicative fields in the engineering area, and encourages related research activities and development. Specifically, the TC is engaged in promoting the development of methodologies for the analysis and the control of systems described by nonlinear difference or differential equations. This includes, among the others, problems of stabilization, regulation, tracking, disturbance rejection and output feedback control, robust control, control of constrained systems, observers, filtering, and so forth.

The TC counts almost 60 active members and 40 corresponding members who cooperate sinergically with the IEEE Technical Committee on Nonlinear Systems and Control, for research activities and services to the control community. Since 2016 the two technical committees are also engaged in promoting joint actions in education [1], [2].

## 2. SURVEY AMONG TC MEMBERS

An informal survey consisting of nearly 20 questions has been carried out among the members of the Technical Committee in order to understand the level of awareness and interest of the TC members on the following aspects in education in the control field:

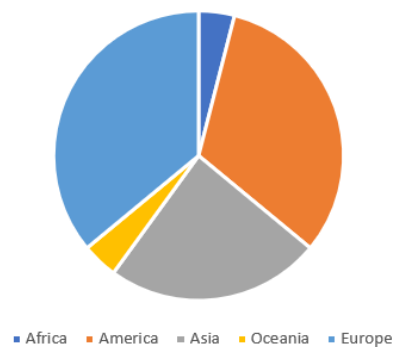
- a) actions carried out by the own institution to promote Control Engineering at the three different levels of education (undergraduate, graduate, PhD);
- b) actions to promote gender balance in Control Engineering;

- c) actions carried out by the own institution to promote mobility programs for students in the Control Engineering field;
- d) actions to promote the use of new technologies to support students with disabilities in Control Engineering educational programs.

The survey has been forwarded also to the IEEE TC Nonlinear systems and control members. We have received replies from a total of 25 members out of a total of almost 100. The statistics given hereafter refer to the 25 completed surveys.

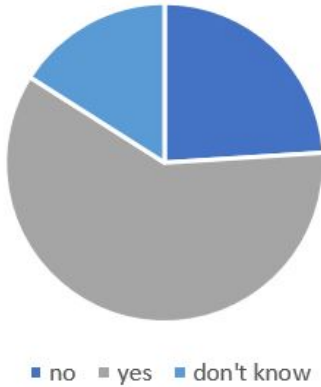
It should be also noted that while the composition of the Technical Committee in terms of Area of Residence is very heterogeneous, answers to the survey were given by members mainly from America, Asia and Europe.

Area of Residence



As already pointed out, a number of questions aimed at understanding the actions taken by the different institutions in order to promote gender balance in the engineering field.

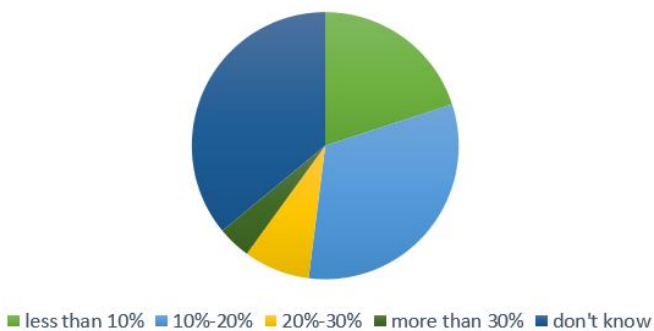
**Does your Institution schedule activities to encourage women to take a bachelor /master in engineering**



Based on the answers to the survey, the 40% of the interviewed is aware of activities from his/her own institution to encourage students to register in a bachelor/master degree in the control field in his/her own institution. Only the 48% is aware of activities carried out regularly each year by his/her institution to connect students to the labour market. The 64% of the interviewed is aware of activities in his/her own institution to encourage women to start a bachelor or a master degree in the Control field.

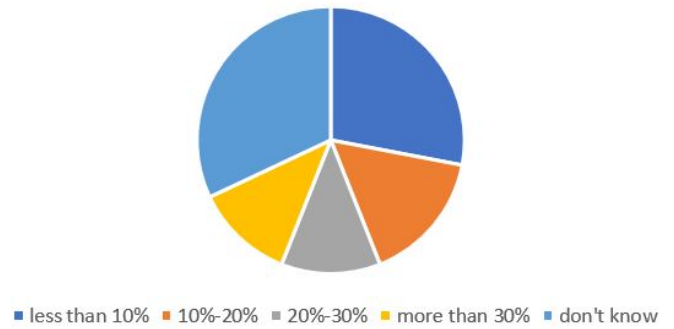
We have also asked to the interviewed to estimate the percentage of women enrolled in the bachelor degrees and master degrees with a curriculum in control engineering in their institution. Only the 12% of the interviewed estimates that this percentage is higher than 20% at the bachelor degree level.

**Percentage of women (bachelor in Control Engineering - 1st year students)**



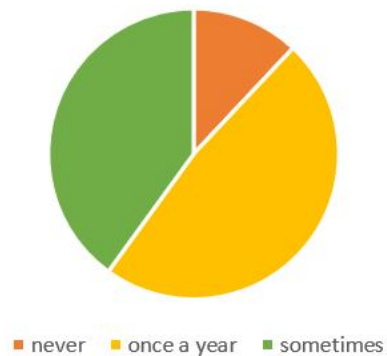
The situation sounds better at the Master degree level where the 24% of the interviewed estimates that this percentage is higher than the 20%.

**Percentage of women (master in Control Engineering - 1st year students)**



Another point of interest concerned the activities that the institutions carry out to link the academic world with the labour market. Based on the answers given by the interviewed it seems that the best practice of organizing systematically (once a year) a meeting to put in contact these two realities is not applied everywhere. As a matter of fact it turned out that almost the 50% of the interviewed is aware of systematic meetings organized in their institution to connect students with the labour market.

**Your institution organizes meetings with industries and companies to connect students with the labour market**



The results of the survey on the points so far discussed suggest that a leaflet containing information about career opportunities with a dedicated section concerning women in engineering should be created by IFAC and rendered available to the control community. In such a way it could be distributed among junior engineers to facilitate the process of job placement in the field during the events each institution schedules independently.

**3. MOBILITY PROGRAMS FOR STUDENTS AND INTERNATIONAL DEGREES**

Another aspect considered in the survey carried out within the Technical Committee, consisted in collecting information on the mobility of students. To this end it was asked to estimate the presence of foreign students in bachelor degree programs and master degree programs in the control field and to specify the kind of mobility program known to be active in the institution one belongs to.

The survey has enlightened that one of the most well known mobility initiatives for students is the Erasmus program which started in 1987 and successfully promotes since then the mobility of students engaged in University studies within European countries and now also worldwide. The Universities engaged in the program have their own agreements with partner Universities, which allow students on the different levels of education to attend courses, or carry out research activities abroad which are recognized by the sending University/Institution. Some agreements allow students to get also joint degrees, or double degrees from the two Institutions involved in the educational program.

As an example of double degree, a network of Italian and French Institutions was set up in 2000 for promoting a Multilateral Agreement [3] for the mobility of students and researchers between the two countries and for delivering a degree from both a French Institution and an Italian one, to students who have carried out a study plan or research project common to the two Institutions. The agreement concerns undergraduate, graduate and Ph.D degrees. Currently the Institutions participating to this agreement are

- in France the "Ecoles" Alliance Centrale Supélec, Polytech Nice-Sophia, ECL - Ecole Centrale de Lyon, ECN - Ecole Centrale de Nantes, Ecole Polytechnique Universitaire de l'Université Nantes, Ecole Polytechnique de l'Université Grenoble 1 - Grenoble, ENSEA - Ecole Nationale Supérieure de l'Electronique et de ses Applications - Cergy Pontoise, ESIEE - Ecole supérieure d'ingénieurs en électronique et électrotechnique Paris - Noisy-Le-Grand ISAE-SUPAERO - Institut Supérieur de l'Aéronautique et de l'Espace; the Universities: Université Paris-Sud, Université Nice-Sophia Antipolis, Université de Nantes, Université de Toulouse 3 Paul Sabatier, Université Joseph Fourier Grenoble.
- In Italy: Università di Roma La Sapienza, Politecnico di Bari, Università di Brescia, Università di Catania, Università degli Studi dell'Aquila, Università Politecnica delle Marche, Università degli Studi di Parma, Università di Roma Tre, Università degli Studi di Trento.

Another example of international cooperation and educational programme in the control field is represented by the EECI - International Graduate School on Control. EECI was founded in 2006 within the framework of the HYCON Network of Excellence funded by the European Union. The International Graduate School on Control is organized every year. The programme consists of independent modules in the control field which are eligible for 2nd Year Master Degree credits and Scientific Thesis modules. Completion of a module obtains the equivalence of 3 ECTS (European Credit Transfer and Accumulation System). In 2018-2019 a consistent number of modules will focus on nonlinear systems and methodologies and will be taught by members of the IFAC TC on Nonlinear Systems [4].

Other programs highlighted by the TC members are DAAD, Select +, Dora Plus and Overworld Programme.

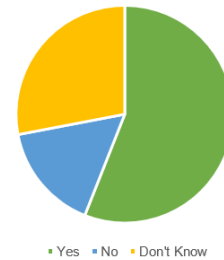
Finally a presence of foreign students greater than the 20% in his/her own institution, is estimated only by the 8% of the interviewed for bachelor degree programs in the control field and by the 24% of the interviewed in master degree programs in the control field.

#### 4. EDUCATION IN NONLINEAR CONTROL, ONLINE COURSES AND BOOKS

A number of questions of the survey focused on taking information concerning the organization of educational programs in Control Engineering in the different institutions as well as the effective presence of dedicated advanced courses on nonlinear control. Based on the answers of the interviewed the following results were obtained.

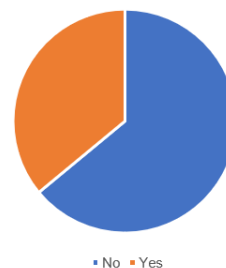
First, it turned out that to the best of the interviewed knowledge in bachelors degree programs concerning Control Engineering the first time a course in control is taught is mainly (as expected) during the second year. Secondly, advanced courses in nonlinear control are mainly taught in master degrees programs, rarely at the third year of bachelor degree programs. However only the 55% of the interviewed confirmed the presence of an advanced course in nonlinear control in his/her own institution.

In the master degree programme in Control Engineering you have courses focused on nonlinear control



As far as online courses is concerned, let us first recall that starting from 2008, an increasing number of courses on all topics is rendered available online by the most well known universities worldwide. These courses may have different characteristics: available for free for all students worldwide (MOOC), or for registered ones to a certain University, designed for an online course or traditional lectures with the use of multimedia material available online as supporting material for students.

Your Institution has also online courses in control



The number of courses and plenary talks on the nonlinear topic available on line is now increasing. As an example of few (and

non exhaustive) activities in English posted online and also concerning members of the TC Nonlinear systems we have

- The video "Control of Human Muscle via Electrical Stimulation" [5];
- The course "Nonlinear Dynamics and Chaos" taught by Steven Strogatz at Cornell University [6];
- the Lecture "Nonlinear control: a charming & adventurous voyage" by Alberto Isidori: The 2nd Wook Hyun Kwon Lecture [7];
- The course "Nonlinear Control and Estimation" taught by Christopher Kellett for the Mechatronics Engineering degree and which will be available online to students around Australia starting from 2019 [8].

The members of the Technical Committee are also involved in dissemination through tutorials and books in the control field and on interdisciplinary topics. Recent contributions are

- a tutorial on Nonlinear Modeling and Control in Biomedical Engineering at MICNON 2018 [9];
- a tutorial on Nonlinear Control Theory in Tokyo, 2018 [10];
- a tutorial on Tools for Nonlinear Control of Dynamical Networks at 2019 CCDC [11];

as well the books

- "Lectures in feedback design for multivariable systems", by A. Isidori [12], edited by Springer, meant for students following postgraduate programs in systems and control, as well as engineers working on the control of robotic, mechatronic and power systems;
- "Input-to-State Stability for PDEs", by Iasson Karafyllis and Miroslav Krstic [13], meant for applied mathematicians and control specialists researching PDEs either as graduate students or full-time academics;
- "Modeling and Control of Infectious Diseases in the Host: With MATLAB and R", by EA Hernandez-Vargas [14], edited by Elsevier, meant for researchers working in theoretical immunology, mathematical epidemiology, modeling, and biomathematics, as well as graduate students working in mathematical modelling in biology.

An IFAC webpage with information and links concerning books, online courses and online material on the different topics covered by the TCs could be created in order to be a reference for the Educational programmes in control worldwide.

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