International Journal of Engineering Research and Technology.
ISSN 0974-3154 Volume 10, Number 2 (2017), pp. 165-176

http://www.irphouse.com

Mechatronics Capacity Building in Tanzania

Francesco Braghin, Simone Cinquemani
Dipartimento di Meccanica , Politecnico di Milano
Via La Masa 1, I-20156 Milano, Italy.

Abstract

The paper deals with a capacity building project carried out by Politecnico di Milano and the three main technical universities of Tanzania aimed at stimulating high education in mechatronics and at giving professors the tools to design new mechatronics courses in the universities of the Country. This work is focused on the activities carried out at Mbeya University of Science and Technology (M.U.S.T.) where, within one week of intensive course, Tanzanian professors had the opportunity to develop a mechatronic system. The approach was aimed not just at teaching main subjects of a mechatronics course, but also at suggesting how these courses could involve university students on topics that will be a challenge for the emerging industry of the country.

Keywords: Mechatronics; robotics; capacity building.

1. INTRODUCTION

Starting from an official request of the government of the United Republic of Tanzania to support the technical education sector, the Italian government approved the implementation of a programme [3] focused on the following objectives:

- expanding access to academic engineering programmes and improving the quality of teaching and learning through training courses dedicated to staff;
- developing new engineering programmes that can better satisfy the demands of the local industrial market;
- increasing partnerships and ties with the industries through student placement services and continuous professional training;

- increasing women participation in engineering courses and employment in careers connected to technical studies.

Politecnico di Milano was in charge of capacity building training courses [4, 11]. The first phase of the project was dedicated to the assessment of existing curricula and was conducted through an initial fact-finding mission. This phase served both to identify critical issues with regard to improvements in terms of quality, relevance and effectiveness and to establish specific designated areas of interest in terms of developing curricula. Mechatronics was among the designated areas of interest. The initial analysis also served as a means of producing an assessment of the Tanzanian academic system in the engineering area, a specific overview of the three Tanzanian universities involved, and a market analysis to reduce the gap between academic curricula and the expertise demanded by the labour market. On completion of the assessment phase, capacity building was developed in three distinct stages.

1. The first phase involved a one-week visit to Politecnico di Milano by a delegation of high-level representatives from each of the three universities in Tanzania, including the rectors of the three institutes. The purpose of this visit was to show the study and learning methods and programmes used at Politecnico di Milano, the main strategic research lines and the mechanisms on which cooperation between a technical university and industries are based.
2. The second phase of capacity building consisted in three weeks of training at Politecnico di Milano for professors, researchers and administrative staff from the Tanzanian universities involved (six from each university). During the training period, the curricula regarding the areas of interest were presented to the members of the three faculties, in addition to the adopted assessment system. At the same time, the research activities of each department were presented, to show how research themes are chosen, planned, funded and developed so that the results can be published or patented. In addition, the delegation was shown the way Politecnico di Milano works to build relationships with both Italian and international industries. In parallel, visits and meetings were organized for the administrative staff, who had the opportunity to get to know the offices of Politecnico that provide services dedicated to teaching, research and relations with industry.
3. The third phase is that discussed in this paper and regards the provision of intensive courses at the three Tanzanian universities through a week-long course attended by twelve people from the three universities in Tanzania.

Overall, the project made it possible to start an innovative multidisciplinary

programme characterized by strong ties between universities and businesses, which had been absent in Tanzania's universities. In addition, the updated curricula have helped to improve the teaching systems of the universities, thus fostering the general development of the local university system. Specifically, through this project Politecnico di Milano has contributed to enhancing academic management and curricula both in academic terms and in terms of relations with local and international enterprises.

The paper is structured as follows. Section 2 introduces the aim and the objectives of the intensive course on mechatronics carried out at Mbeya University of Science and Technology (M.U.S.T.). Section 3 gives an overview of theoretical background on mechatronics, while section 4 is focused on experimental activity. Results of the course have been presented to students of secondary schools in an open-day activity (Sec.5). Attenders' evaluation is discussed in Section 6 and conclusions are drawn in Section 7.

2. OBJECTIVES AND SCOPE

As previously introduced, the third phase of the capacity building project consists of a full immersion course held at Mbeya University of Science and Technology (M.U.S.T.). The participants were selected among the professors and researchers of the three main technical universities of Tanzania (Dar-El-Salaam Institute of Technology D.I.T., Arusha Technical College and Mbeya University of Science and Technology M.U.S.T.). The course was established in accordance with the overall objectives of the project and, in particular, with the dual purpose of:

- providing participants with the basic skills and tools to design a mechatronics course at their respective universities, so that a group of engineers trained on these issues can be formed [2, 20, 9, 18, 8, 16]. This would allow to develop new relationships between academia and industries of Tanzania;
- increasing the interest of high school students to university education, in particular to mechatronics.

For this reason the course has been developed with a mix of lectures and laboratory activities. Being mechatronics multidisciplinary by its nature, the course has been structured to account for mechanics, electronics and information technology/control taking into account the tight time constraint of one week. To motivate the audience, a relevant example that helped the teaching on all these different aspects has been chosen. In particular the development of a parallel kinematic manipulator on the well-known structure of the robot delta has been taken into account (Fig.1) [12]. During the week, participants were faced with the technical and theoretical concepts to develop the device and to control it properly. Lectures were held in plenary mode (Fig.2),

while the laboratory activities were carried out in three groups according to the universities of origin, so as to create teams that would be able to develop similar activities in future [19, 14, 16, 17, 15]. Table 1 reports, in general terms, the schedule of the course topics. The last day of the course was dedicated to an open-day at M.U.S.T. Undergraduate and high school students of the Tanzanian region of Mbeya had been invited to attend. On this occasion, the participants of the course had the opportunity to explain what they had developed during the intensive week and to involve students in practical activities (Sec.5).

Table 1. Course program

	Morning	Afternoon
Day 1	Introduction to Mechatronics (Objectives and scope) and to the course	Introduction to Laboratory activity (Delta robot)
Day 2	Direct and inverse kinematics	Trajectory planning of Delta Robot
Day 3	Dynamics and actuators	Dynamic analysis and construction of Delta Robot
Day 4	Control of a mechanical system	Control of Delta robot
Day 5	Open-Day	Open-Day

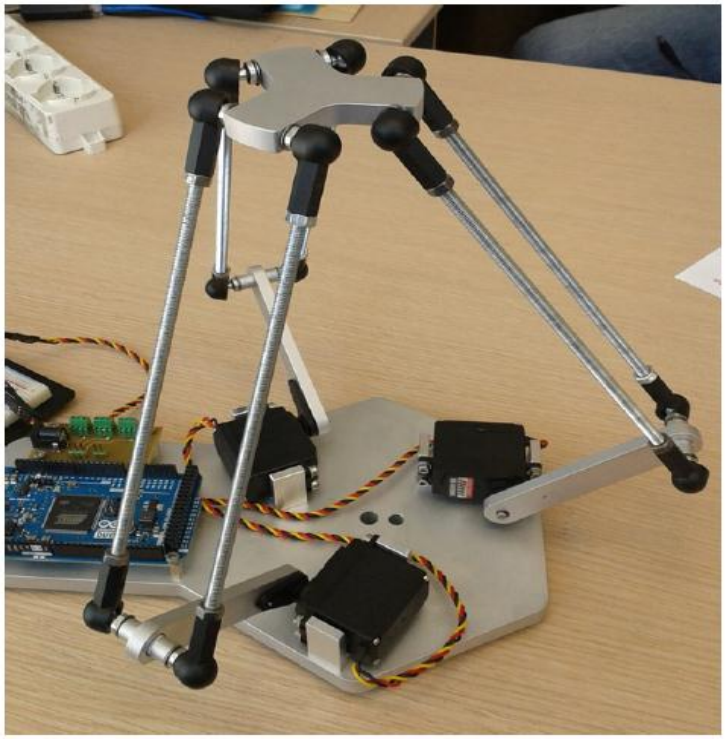

Figure 1. Delta robot developed by attenders

3. THEORETICAL BACKGROUND

The starting point of the design of any mechanical and mechatronic system is the analysis of the required tasks. This requires some basics on kinematics to carry out the synthesis of a trajectory and the definition of a motion law, as well as some knowledge on dynamics to estimate forces and torques applied on the system and evaluate gear-motors behaviour. Considering a robot, it means being able to design a trajectory in the workspace and to associate it with a law of motion, (ie. a velocity profile and acceleration) and to transpose these information to joint space, (ie. Defining the laws of motion of each motor to achieve the desired movement) through the inverse kinematics.

Figure 2. A frontal lesson

Topics of motion planning have been discussed, highlighting the effects of the law of motion on the dynamics of a system [6]. Participants have the opportunity to write some simple algorithm to manage fundamental motion laws and to create complex movements. Analysis are carried out with Octave: the choice to use a free software ensures this tool can be used by participants in their universities even after the end of the course.

Once the motion has been designed, it is necessary to assess the system dynamics, by estimating both forces and torques acting on the system so as the contribution that each motor should exert. The dynamic analysis for a simple systems can be conducted by means of analytical models and allows to evaluate the expected performance and main limitations (eg. motor torques too high), or possible improvements (eg. to increase the maximum speed).

The ability to calculate and to monitor the main kinematic and dynamic parameters, allows to optimize the performance of a machine. This type of analysis is crucial from an industrial point of view as, for example, it allows to ensure high precision, to maximize the production or to avoid overloads. Participants are divided into three groups and are asked to develop a software that is able to synthesize a trajectory and the corresponding motion curve, to perform the inverse kinematics and to check that the task is compatible with the performance and the geometry of the robot. Figures 3, 4 show the numerical analysis done by a group. The graphs in Fig.4 show the main kinematic and dynamic quantities related to the trajectory shown in the figure above.

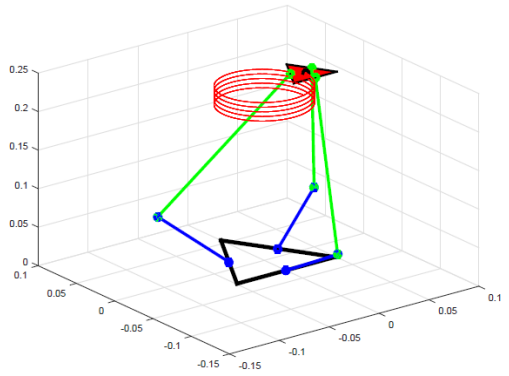

Figure 3. Desired trajectory in space.

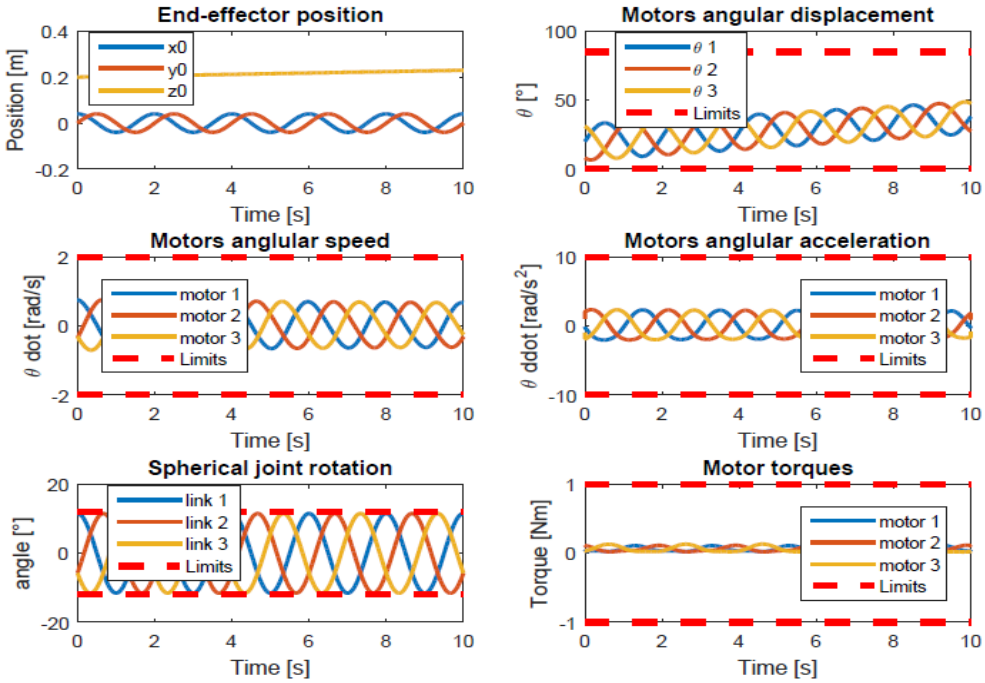

Figure 4. Numerical evaluations of kinematics and dynamics.

The last lecture is dedicated to the control of a mechatronic system. Basics of control are discussed as feedback versus feedforward, different types of controllers, concept of stability and performance indexes of a controlled system. The lecture is accompanied by a short introductory seminar on Arduino, an open-source electronics platform based on easy-to-use hardware and software. Arduino is a good opportunity for the development of low cost mechatronic systems and is widely used in universities to give students the opportunity to put into practice the theoretical knowledge acquired in control courses [13, 5, 10].

4. BUILDING A ROBOT

Lectures are complemented by laboratory activities in which participants have the opportunity to put into practice the theoretical aspects of the course by making a mechatronic device. Each group received the material to build the robot together with a manual for the construction and preliminary setup. This part of the course is specifically designed to encourage teamwork and to facilitate mutual cooperation between team members [7, 14]. Figures 5, 6, 8 show the three groups working on their delta robots. As the manipulator has been built up, teams can upload data on the designed trajectory on the Arduino board and test the robot in open loop configuration. By designing different task, participant can test the performance of the device and to evaluate optimal working condition to reduce vibration, maximize speed and precision, etc.

Figure 5. Attenders from M.U.S.T. building their robot

Figure 6. Attenders from D.I.T. building their robot

Figure 7. The group from Arusha Technical College programming the Arduino board

Figure 8. The three groups working

5. OPEN DAY

During the final day of the course, the Tanzanian researchers and professors had the opportunity to show their work at the university open day. The last year students of secondary schools in the area were invited to the event together with the university students involved in the Mechatronics course. The participants were over 300, especially thanks to the support of the local administration and the Italian Embassy that organized the transport from secondary schools to the M.U.S.T.

The open day was organized with an initial greeting by the Rector of M. U.S.T., Professor J.J. Msambichaka, and the delegate of the Italian Embassy that funded the capacity building project. With this opportunity, a video of the activities done during the project was projected, so that students would have the opportunity to appreciate the content of a mechatronics course, but also the potential and the innovative aspects that this discipline offers especially in the industrial field. A reduced version of the video is available in [1].

Then, the 12 participants of the intensive course showed their work (Fig.9). The students' curiosity and interest stimulated the participants and gave them an immediate feedback on the work they did. Moreover, to encourage the active participation and to stimulate interest, students were given the opportunity to test the manipulator their selves and to tell their mates their own experience (Fig. 10). The explanation was made in native language and was very engaging both for speakers and audiences, reaching the aim of stimulating secondary school students to higher education.

Figure 9. A course attender explains basics of mechatronics to high school students during the open day

Figure 10. At the open day high school students playing with delta robots and showing it to undergraduate colleagues

6. LEARNING EVALUATION

At the end of the intensive capacity building course, participants had the opportunity to evaluate the course and suggest any improvements. Participants were given a questionnaire to evaluate their satisfaction.

Table 1. Questionnaire

	Questions
1.	The experience was intellectually stimulating
2.	Previous skills and knowledge were sufficient for the comprehension of the laboratory experience
3.	The skills and the knowledge I developed are valuable
4.	The level of practical is appropriate
5.	The experimental activity is useful to better understand the theoretical basis
6.	Teamwork has helped me in this work
7.	I consider it an interesting experience overall

Answers were between 1 (Poor/Strongly disagree) to 4 (Excellent/Strongly agree) and are collected in Fig.11. The results confirm the common feeling perceived during the course, ie. the interest and curiosity of the participants in discovering not only new themes, but also new ways of learning and teaching. Although the short time available was a limit, all participants experienced the course very positive and began to think on how similar activity could be developed in their home universities.

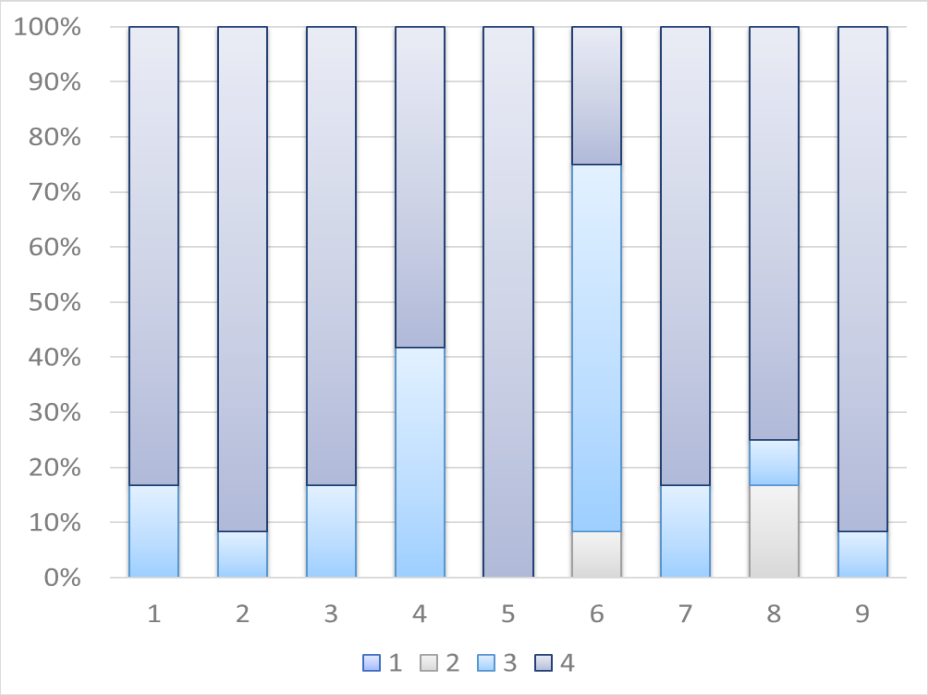

Figure 11. Answers to the questionnaire (values are expressed in percentage)

7. CONCLUSION

The capacity building activity at M.U.S.T. was addressed to future professors of mechatronics courses of the three main technical universities in Tanzania. The intensive course was very engaging for both the participants and the trainers and allowed to frame the main themes that could be addressed in a mechatronics course highlighting the multidisciplinary nature of the subject. The course was therefore carried out with the spirit of transmitting a vision of mechatronics, without pretending to cover all the facets, but rather suggesting a way in which such a course could be done.

The opportunity to extend this vision to college and high schools students in a dedicated open-day has also allowed a direct involvement of future students, stimulating them on a theme that will be of great interest to the future development of the emerging industrial reality of Tanzania.

ACKNOWLEDGMENT

The project has been carried out under the grant PA/015/2013/2014 funded by the Dar es Salaam Institute of Technology and the Italian Minister of Foreign Affairs and International Cooperation.

REFERENCES

[1] Video of the project: Capacity building in tanzania, available at https://www.youtube.com/watch?v=M5iGnkcOgho.

[2] M. Acar and R.M. Parkin. Engineering education for mechatronics. IEEE Transactions on Industrial Electronics, 43(1):106{112, 1996.

[3] Pastore-M.C. Sancassani S. Colombo, E. Storie di Cooperazione Politecnica 2011-201. 2016.

[4] P.A. Danaher, A. Davies, L. De George-Walker, J.K. Jones, K.J. Matthews, W. Midgley, C.H. Arden, and M. Baguley. Contemporary capacity-building in educational contexts. 2014.

[5] M. Del Carmen Currs-Francos, J. Diz-Bugarn, J.R. Garca-Vila, and A. Orte-Caballero. Cooperative development of an arduino-compatible building automation system for the practical teaching of electronics. Revista Iberoamericana de Tecnologias del Aprendizaje, 9(3):91{97, 2014.

[6] S. Giberti and S. Cinquemani. Motor-reducer sizing through a matlab-based graphical technique. IEEE Transactions on Education, 55(4):552-228, 2012.

[7] M. Grimheden and M. Hanson. Collaborative learning in mechatronics with globally distributed teams. International Journal of Engineering Education, 19(4):569{574, 2003.

[8] S.K. Gupta, S. Kumar, and L. Tewari. A design-oriented undergraduate curriculum in , salamimechatronics education. International Journal of Engineering Education, 19(4):563{568, 2003.

[9] M. Iribe and H. Tanaka. An integrated hands-on training program for education on mechatronics. Journal of Robotics and Mechatronics, 23(5):701-708, 2011.

[10] Y. Jang, W. Lee, and J. Kim. Assessing the usefulness of object-based programming education using arduino. Indian Journal of Science and Technology, 8:89-96, 2015.

[11] J.B. Laewen. Capacity building and development: Perspectives, opportunities and challenges. 2013.

[12] J. Lin, C.-H. Luo, and K.-H. Lin. Design and implementation of a new delta parallel robot in robotics competitions. International Journal of Advanced Robotic Systems, 12(10), 2015.

[13] G.A. Mabbott. Teaching electronics and laboratory automation using microcontroller boards. Journal of Chemical Education, 91(9):1458-1463, 2014.

[14] B.A. Oakley, D.M. Hanna, Z. Kuzmyn, and R.M. Felder. Best practices

involving teamwork in the classroom: Results from a survey of 6435 engineering student respondents. IEEE Transactions on Education, 50(3):266-272, 2007.

[15] R. Patil, J.Wagner, T. Schweisinger, R. Collins, A. Gramopadhye, and M. Hanna. A multi-disciplinary mechatronics course with assessment-integrating theory and application through laboratory activities. International Journal of Engineering Education, 28(5):1141-1149, 2012.

[16] M.J.E. Salami, N. Mir-Nasiri, and M.R. Khan. Development of mechatronics engineering degree program: Challenges and prospects. International Journal of Engineering Education, 19(4):537-543, 2003.

[17] A. Smaili and S. Chehade. Effective integration of mechatronics into the mechanical engineering curriculum: A cooperative, project-based learning model with seamless lab/lecture implementation. International Journal of Engineering Education, 21(4):739-744, 2005.

[18] J. Wikander, M. Trngren, and M. Hanson. The science and education of mechatronics engineering. IEEE Robotics and Automation Magazine, 8(2):20-26, 2001.

[19] M. Yilmaz, S. Ozcelik, N. Yilmazer, and R. Nekovei. Design-oriented enhanced robotics curriculum. IEEE Transactions on Education, 56(1):137-144, 2013.

[20] M. Yilmaz and K. Tunalp. A mixed learning approach in mechatronics education. IEEE Transactions on Education, 54(2):294-301, 2011.

BIOGRAPHY

Francesco Braghin He graduated from the Politecnico di Milano in 1997, he received the PhD in Applied Mechanics in 2001. In 2001, he joined the Department of Mechanical Engineering of Politecnico di Milano as Assistant Professor. Since 2015 he is full Professor at the Faculty of Industrial Engineering of Politecnico di Milano. He is author of about 200 scientific publications and in charge of several projects/research contracts. His latest research takes place in the field of vehicle dynamics (both road and rail) and mechatronics.

Simone Cinquemani He graduated in Mechanical Engineering from the Politecnico di Milano in 2004, he received the PhD (awarded with merit) in Mechanical Systems Engineering in 2008. Since 2008, he joined as Assistant Professor at the Department of Mechanical Engineering of Politecnico di Milano. His latest research is carried out in the field of mechatronics, in particular on active control of structures and on industrial automation. He is author of about 120 scientific publications.