Proceedings
TAEE2020

2020 XIV Technologies Applied to Electronics Teaching Conference (TAEE)

XIV Congreso de Tecnologías Aplicadas a la Enseñanza de la Electrónica

XIV conferência em tecnologias aplicadas ao ensino da eletrónica

Porto, Portugal
July 8th – 10th, 2020

Editors:

Gustavo R. Alves
André V. Fidalgo
Manuel C. Felgueiras
Ricardo Costa

TAEE2020 is organized by the Centre for Innovation in Engineering and Industrial Technology at the Polytechnic of Porto – School of Engineering

IEEE Meetings, Conferences & Events (MCE)
445 Hoes Lane
Piscataway, NJ 08854 USA
Fax: +1 732 981 1769
Email: ieee-mce@ieee.org

ISBN: 978-1-7281-6732-9

Volume Editors

Gustavo R. Alves
Email: gca@isep.ipp.pt

André V. Fidalgo
Email: anf@isep.ipp.pt

Manuel C. Felgueiras
Email: mcf@isep.ipp.pt

Ricardo J. Costa
Email: rjc@isep.ipp.pt

Centre for Innovation in Engineering and Industrial Technology (CIETI)
Department of Electrical Engineering (DEE)
Polytechnic of Porto – School of Engineering (ISEP)

Rua Dr. António Bernardino de Almeida, 431
4200 – 072 Porto, PORTUGAL
(+351) 228340532

Preface

The TAEE conference will know in its 14th edition a historical moment. Not only it is the first time that it will be organized outside the Spanish territory, but we will also have the innovative experience of holding this conference in a purely virtual format, in this year's edition.

This choice was the possible solution to a clear and global problem, which arose suddenly during the preparation of the conference. The organization applied a typical engineering approach, instinctively seeing this new problem as an opportunity, and taking advantage of the constraints imposed to experiment with new solutions to novel issues.
We tried to create a different TAEE, not better nor worse, but one that benefits from emerging communication technologies, in order to create and energize an event where we will not be physically in the same place, but we can communicate and work together in a virtual way.

The greatest motivation of TAEE will always be the strong connections, dedication and motivation of the community and it is those factors that will allow success in this new way of collaborating and working together, but at a distance. This new philosophy requires an extra effort from the TAEE association and the local organization, but particularly from all the authors and participants who were asked to do more but in less time. The response was admirable, the participation remained vigorous and contributed with an extra effort that allowed us to move resolutely and decisively to this new format.

This year we also have an interesting set of invited speakers who mix the local and sustainable vision at the Polytechnic of Porto with the different and accumulated experience of those who are long ago members of the TAEE community and also an international and innovative vision where the teaching of electronics is suggested with new tools and methodologies.

A word to the city of Porto, where unfortunately the effects of the COVID19 virus did not allow the Porto Polytechnic to receive TAEE participants as we wished. It will not be possible to visit the beautiful downtown, get to know its historic neighborhoods and cafes, navigate the Douro River or stroll on old streets and bridges. The tradition of welcoming foreigners is strong in the city of Porto and it would have been a pleasure to hold this edition of TAEE in the rooms and spaces of the School of Engineering.

We cannot forget to acknowledge all the external entities that supported this edition of TAEE, including CIETI, SPEE, IEEE and particularly CISCO, which has made itself available to operationalize this online edition of TAEE in record time.

We also sincerely want to express gratitude to all those who participated in some way in the organization of this event, contributing with some of the scarce time of their already overloaded agendas.

Finally, our wishes that the conference will be successful, that it will join in productive work and collaboration professors and researchers from Portuguese, Spanish, Latin American universities, and others who have chosen to join us. In this way, we can all present, share and discuss experiences and activities in the teaching and learning of electronics and related engineering fields, and in this 14th edition we will do so in an innovative but also valuable and exciting new way.

Porto, July 7th, 2020
André Fidalgo and Gustavo Alves
Polytechnic of Porto / School of Engineering

Organization

Centre for Innovation in Engineering and Industrial Technology (CIETI)
Instituto Superior de Engenharia do Porto, Portugal

Conference Chairs

André Vaz Fidalgo, Instituto Superior de Engenharia do Porto, Portugal
Gustavo Ribeiro Alves, Instituto Superior de Engenharia do Porto, Portugal

Programme Chairs

Manuel Carlos Felgueiras, Instituto Superior de Engenharia do Porto, Portugal
Ricardo Jorge Costa, Instituto Superior de Engenharia do Porto, Portugal

Local Committee

André Vaz Fidalgo, Instituto Superior de Engenharia do Porto, Portugal
Gustavo Ribeiro Alves, Instituto Superior de Engenharia do Porto, Portugal
Manuel Carlos Felgueiras, Instituto Superior de Engenharia do Porto, Portugal
Maria Arcelina Marques, Instituto Superior de Engenharia do Porto, Portugal
Maria Margarida Ribeiro, Instituto Superior de Engenharia do Porto, Portugal
Maria Teresa Sena Esteves, Instituto Superior de Engenharia do Porto, Portugal
Ricardo Jorge Costa, Instituto Superior de Engenharia do Porto, Portugal

Steering Committee

André Vaz Fidalgo, Instituto Superior de Engenharia do Porto, Portugal
Mª Asunción Morales Santana, Universidad de Las Palmas de Gran Canaria, Spain
Bonifacio Martín del Brío, Universidad de Zaragoza, Spain
Camilo Quintáns Graña, Universidade de Vigo, Spain
Catalina Rus Casas, Universidad de Jaén, Spain
Emilio Olías Ruiz, Universidad Carlos III, Spain
Gustavo Ribeiro Alves, Instituto Superior de Engenharia do Porto, Portugal
Inmaculada Plaza García, Universidad de Zaragoza, Spain
Javier Zubia, Universidad de Deusto, Spain
Jesús Arriaga García de Andoaín, Universidad Politécnica de Madrid, Spain
José Miguel Páez Jiménez, Universidad de Costa Rica, Costa Rica
Juan Domingo Aguilar Peña, Universidad de Jaén, Spain
Juarez Silva, Universidade Federal de Santa Catarina, Brasil
Julio Pérez Acle, Universidad de la República, Uruguay
Manuel Castro Gil, Universidad Nacional de Educación a Distancia, Spain
Manuel Rodríguez Valido, Universidad de La Laguna, Spain
Manuel Carlos Felgueiras, Instituto Superior de Engenharia do Porto, Portugal
Martín Llamas Nistal, Universidade de Vigo, Spain
Ricardo Jorge Costa, Instituto Superior de Engenharia do Porto, Portugal
Roberto Capilla Lladró, Universitat Politècnica de València, Spain
Enrique Mandado Pérez, Universidade de Vigo, Spain
César Sanz Álvaro, Universidad Politécnica de Madrid, Spain
Federico José Barrero García, Universidad de Sevilha, Spain
Fernando Pescador del Oso, Universidad Politécnica de Madrid, Spain
Francisco Javier Azcondo Sánchez, Universidad de Cantabria, Spain
Gonzalo Casaravilla, Universidad de la República, Uruguay
Jorge Juan Chico, Universidad de Sevilha, Spain
Manuel Blázquez, IES Ramiro de Maeztu, Spain
Pedro Carrión Pérez, Universidad de Castilla La Mancha, Spain
Ramón Bragos Bardía, Universidade Politécnica da Catalunha, Spain
José Miguel Ruiz Gonzalez, Universidad de Valladolid, Spain
Sergio López Gregorio, Universidad Politécnica de Madrid, Spain

Programme Committee

Alejandro Ayala, Universidad de La Laguna, Spain
Alfonso Lago Ferreiro, Universidade de Vigo, Spain
André Vaz Fidalgo, Instituto Superior de Engenharia do Porto, Portugal
Benedita Malheiro, Instituto Superior de Engenharia do Porto, Portugal
Bonifacio Martín del Brío, Universidad de Zaragoza, Spain
Camilo Quintáns Graña, Universidade de Vigo, Spain
Catalina Rus Casas, Universidad de Jaén, Spain
Delberis Lima, PUC - Rio, Brasil
Edmundo Tovar Caro, Universidad Politécnica de Madrid, Spain
Filomena Soares, Universidade do Minho, Portugal
Gabriel Falcão, Universidade de Coimbra, Portugal
Gustavo Ribeiro Alves, Instituto Superior de Engenharia do Porto, Portugal
Horacio Neto, Instituto Superior Técnico, Portugal
Inmaculada Plaza García, Universidad de Zaragoza, Spain
Javier Zubia, Universidad de Deusto, Spain
Jesús Arriaga García de Andoaín, Universidad Politécnica de Madrid, Spain
Jorge Juan Chico, Universidad de Sevilha, Spain
João Canas Ferreira, Faculdade de Engenharia do Porto, Portugal
José Carlos Alves, Faculdade de Engenharia do Porto, Portugal
José Carlos Quadrado, Instituto Superior de Engenharia do Porto, Portugal
José Manuel Ferreira, University of South-Eastern, Norway
Juan Domingo Aguilar Peña, Universidad de Jaén, Spain
Juarez Silva, Universidade Federal de Santa Catarina, Brasil
Luis Gomes, Universidade NOVA de Lisboa, Portugal
Luis Schlichting, Instituto Federal de Santa Catarina, Brasil
Mª Asunción Morales Santana, Universidad de Las Palmas de Gran Canaria, Spain
Manuel Blázquez, IES Ramiro de Maeztu, Spain
Manuel Carlos Felgueiras, Instituto Superior de Engenharia do Porto, Portugal
Manuel Castro Gil, Universidad Nacional de Educación a Distancia, Spain
Manuel Gericota, Instituto Superior de Engenharia do Porto, Portugal
Manuel Rodríguez Valido, Universidad de La Laguna, Spain
Manuel Silva, Instituto Superior de Engenharia do Porto, Portugal
Martín Llamas Nistal, Universidade de Vigo, Spain
Miguel Conde-González, Universidad de León, Spain
Miguel Valero Garcia, Universidade Politécnica da Catalunha, Spain

Pedro Fonseca, Universidade de Aveiro, Portugal
Ricardo Jorge Costa, Instituto Superior de Engenharia do Porto, Portugal
Ruben Fernandez, Universidad Nacional de Santiago del Estero, Argentina
Sergio López Gregorio, Universidad Politécnica de Madrid, Spain
Silvestre Rodríguez Pérez, Universidad de La Laguna, Spain
Susana Marchisio, Universidad Nacional de Rosario, Argentina
Susana Perez Santos, Universidad de Salamanca, Spain
Unai Hernandez, Universidad de Deusto, Spain

Invited Reviewers

Agustin Caminero, Universidad Nacional de Educación a Distancia
Alberto Yúfera, Instituto de Microelectrónica de Sevilla
Alejandro Ayala Alfonso, Universidad de La Laguna
Alfonso Lago, University of Vigo
Alicia Triviño Cabrera, University of Málaga
Alicia Perdigones, Universidad Politécnica de Madrid
Ana M. Barbancho, Universidad de Malaga
André Fidalgo, ISEP
Andrés Roldán Aranda, University of Granada
Angel Custodio, UNEXPO Puerto Ordaz
Antonio Lopez-Martin, Public University of Navarra
Antonio Barbancho, Departamento de Tecnología Electrónica
Antonio Acosta, IMSE-CNM/University of Seville
Antonio Robles-Gómez, UNED
Antonio Martin, University of Seville
Asunción Morales, Universidad de las Palmas de Gran Canaria
Begona Garcia Zapirain, University of Deusto
Benedita Malheiro, Instituto Superior de Engenharia do Porto and INESC TEC
Blanca Quintana, UNED
Bonifacio Martin Del Brio, University of Zaragoza
Camilo Quintáns Graña, Universidad de Vigo
Carlos Felgueiras, ISEP
Carlos Roche, UCLV
Carlos Jimenez, Universidad de Sevilla
Catalina Rus-Casas, Universidad de Jaén
Clara Perez-Molina, UNED
Eduardo Magdaleno, Universidad de La Laguna
Emilio Olias, University Carlos III of Madrid
Enrique Onieva, Deusto Institute of Technology (DeustoTech), University of Deusto
Enrique Mandado, University of Vigo
F. David Trujillo, Universidad de Málaga
Fátima Mª Casado Miraz, Universidad Las Palmas de Gran Canaria
Felix Tobajas, Universidad de Las Palmas de Gran Canaria
Felix Garcia Loro, UNED
Felix J. Garcia Clemente, Universidad de Murcia

Fernando Pescador, SEC
Filomena Soares, University of Minho
Francisco Arcega, University of Zaragoza
Francisco Falcone, Universidad Publica de Navarra
Francisco Javier Gonzalez-Cañete, University of Malaga
Francisco Javier Azcondo, University of Cantabria
Gabriel Falcao, University of Coimbra
Gabriel Diaz Orueta, UNED
Golberi Ferreira, IFSC
Gonzalo Casaravilla, Universidad de la República
Guillermo Glez-De-Rivera, Universidad Autonoma de Madrid
Gustavo Alves, ISEP
Hector Migallon, University Miguel Hernández
Hector Solar, CEIT
Ignacio Angulo, Universidad de Deusto
Inmaculada Plaza, University of Zaragoza
Jaime Jiménez, University of the Basque Country
Javier Garcia-Zubia, Universidad de Deusto
Jesús Sergio Artal Sevil, University of Zaragoza
Joan Oliver, Universitat Autonoma de Barcelona
João Canas Ferreira, University of Porto
Jorge Juan, University of Seville
Jose Cabrera, ULPGC
José Quadrado, IPP
Jose Angel Sanchez Ortiz, UNED Talavera
José Daniel Muñoz Frías, Universidad Pontificia Comillas
Jose I. Artigas, Universidad de Zaragoza
Jose Ignacio Garate, UPV/EHU
Jose J. Quintana, Universidad de Las Palmas de Gran Canaria
Jose Manuel Martins Ferreira, University of South-Eastern Norway
José María López-Valles, UCLM
Joseba Ezquerra, UPV/EHU
Juan Oliver, Universidad de la Republica
Juan Carlos Soto Merino, University of the Basque Country
Juan Domingo Aguilar, Universidad de Jaén.
Juan M. Santos, University of Vigo
Juan-Ignacio Vazquez, Universidad de Deusto

Juarez Bento Silva, Universidade Federal de Santa Catarina
Julian Viejo, University of Seville
Julio Perez Acle, Universidad de la Republica
Llanos Tobarra, UNED
Luis Gil, Universitat Politècnica de València
Luis Dávila, Universidad Politécnica de Madrid
Luis Zorzano, Universidad de La Rioja
Luis C. M. Schlichting, Instituto Federal de Educação, Ciência e Tecnologia de Santa Catarina
Luis Fernando Rico Riveros, Universidad ECCI
Luis Hector Porragas Beltran, Universidad Veracruzana
Manuel Castro, UNED
Manuel Perales, University of Seville
Manuel Gericota, ISEP
Manuel Blázquez, IES Ramiro de Maeztu - UNED
Manuel Silva, ISEP-IPP and INESC TEC CRIIS
Manuel Arias, Universidad de Oviedo
Manuel I. Capel Tuñón, University of Granada
Marc Porti, Universitat Autònoma de Barcelona
Maria Jose Moure, Universidad de Vigo
María Luisa Martinez, Universidad Politécnica de Madrid
Marisa Gil, Universitat Politècnica de Catalunya
Marta Prim, Universitat Autònoma de Barcelona
Martín Llamas-Nistal, Universidad de Vigo
MiguelRomá, University of Alicante
Miguel A. Prada, Universidad de Leon
Moises Diaz, Universidad del Atlantico Medio, Spain
Nicolas Medrano, University of Zaragoza
Noemí Pérez, TECNUN
Pedro Fonseca, Universidade de Aveiro
Pedro Perez, University of Jaen
Pedro Plaza, Plaza Robotica
Peña Fabiani Bendicho, Universidad de la Laguna
Rafael Pastor Vargas, UNED
Rafael De Jesús Navas-González, Universidad de Málaga
Ramon Vilanova, UAB
Raul Alcaraz Martínez, UCLM
Ricardo Costa, ISEP

Roberto Carballedo, University of Deusto
Roberto Haarth, Universidad Nacional de Cuyo
Robinson Pizzio, Federal, Institute of Santa Catarina
Salvador Alcaraz, Miguel Hernandez University
Sergio Lopez, Universidad Politécnica de Madrid
Sergio Martin, UNED
Silvestre Rodriguez Pérez, Universidad de La Laguna
Susana Marchisio, Universidad Nacional de Rosario
Susana Romero, Universidad de Deusto
Unai Hernández-Jayo, University of Deusto

Session Chairs

Session TS-1A: Trends in Education I
Scientific Chair: Juan Domingo Aguilar Pena
Technical Chair: Ricardo J. Costa

Session TS-1B: Digital Systems I
Scientific Chair: Camilo Quintáns Graña
Technical Chair: Frederico Jacob

Keynote 1: Electronics Education in the context of Sustainability
Scientific Chair: Manuel Castro
Technical Chair: Ricardo Costa

Session TS-2A: Trends in Education II
Scientific Chair: Manuel Castro
Technical Chair: Ricardo Costa

Session TS-2B: Trends in Education III
Scientific Chair: Camilo Quintans Grana
Technical Chair: Frederico Jacob

Session TS-3A: Electronics I
Scientific Chair: Catalina Rus Casas
Technical Chair: Pedro Plaza Merino

Session TS-3B: Electronics II
Scientific Chair: Manuel Gericota
Technical Chair: Frederico Jacob

Session TS-4A: Systems in Education
Scientific Chair: Catalina Rus Casas
Technical Chair: Pedro Plaza Merino

Session TS-4B: Digital Systems II
Scientific Chair: Manuel Gericota
Technical Chair: Frederico Jacob

Keynote 2: Approaching Field Programmable Gate Arrays with Deeds
Scientific Chair: André Fidalgo
Technical Chair: Pedro Plaza Merino

Session TS-5A: Trends in Education IV
Scientific Chair: Manuel Carlos Felgueiras
Technical Chair**:** Pedro Plaza Merino

Session TS-5B: Demo Session
Scientific Chair: Ricardo Costa
Technical Chair**:** Joaquim Alves

Session TS-6A: Electronics III
Scientific Chair: Asunción Morales
Technical Chair**:** Manuel Carlos Felgueiras

Session TS-6B: Trends in Education V
Scientific Chair: Unai Hernández-Jayo
Technical Chair: Ricardo Costa

Session TS-7A: Digital Systems III
Scientific Chair: Asunción Morales
Technical Chair: Manuel Carlos Felgueiras

Session TS-7B: Lab Experiences
Scientific Chair: Ricardo Costa
Technical Chair: Unai Hernández-Jayo

Keynote 3: Teaching and Learning Electronics with Remote Labs
Scientific Chair: Gustavo R. Alves
Technical Chair: André Fidalgo

Keynote Speakers

Electronics Education in the context of Sustainability

Higher education in general, and particularly in the electronics case, is at present in a very different position than several years ago. In the past, technology aimed to improve living conditions, in a way reasonably independently from their sustainability. These developments have had strong environmental implications, and it is now referred not to Development per se, but Sustainable Development. The design of functional units (e.g. cars, houses, factories) is no longer done in independent layers but in integrated and multidisciplinary projects. After fully exploring purely passive solutions, we need to move towards active solutions. Systems that traditionally working only in open loop (e.g., lighting) should now works in closed loop. Indeed, systems that are more sustainable have this behavior as a result of the massive introduction of electronics and information technologies. Thus, electronics is now seen not only as a means of increasing our comfort but as an unavoidable ally for Sustainable Development. The speech seeks to contextualize the importance of teaching electronics and presents some results from teaching experience.

Prof. Carlos Felgueiras received the B.S. and Ph.D. degrees in electrical and computer engineering from the Faculty of Engineering, University of Porto, Porto, Portugal, in 1987 and 2008, respectively. He started his professional career in 1987 as electronic designer for automation systems. Later, he was invited to supervise a test laboratory for verifying the accomplishment of European Standards in thermoelectric household appliances. He started the teaching activity in 1994 as Assistant Professor and later as Adjunct Professor and researcher in the Department of Electrical Engineering (DEE), School of Engineering (ISEP), Polytechnic of Porto (P.Porto), Porto, Portugal. His research interests include design for debug and test of mixed-signals, remote experimentation in e-learning contexts, renewable energy sources and smart buildings. Prof. Felgueiras is member of the Portuguese Engineers Association and also the Global Online Laboratory Consortium (GOLC). He has published about 90 papers and he is a member of scientific committees of several national and international conferences. (email: mcf_at_isep.ipp.pt)

Teaching and Learning Electronics with Remote Labs

Remote experimentation fits into the Technology-Enhanced Learning (TEL) domain and thus is usually applied at Educational Institutions. This keynote will first explain what is (not) a remote laboratory and the implications that follow from this debate. After classifying the different types of remote experiments, their usage inside the classroom will be described in detail, in particular in the areas of electronics, control, and telecommunications, in Engineering Education. The main purpose is to explain how remote experiments fit into a lesson plan and the educational impact they have into the students' learning process.The presented examples will also demonstrate how to design a remote lab for experiments with electronics, i.e. the sort of equipment and architectures they require for being implemented. The keynote will end with a general overview of on-going projects in the field, the current and antecipated trends of remote experimentation, and the research groups currently active in this area. 2020 is the 25th anniversary of the coining of the "remote experimentation" expression, and as such a good opportunity to revisit the path done so far.

Prof. Javier Garcia Zubia is a professor at the University of Deusto, Bilbao (Spain), for more than 30 years. He is a full professor at the faculty of Engineering since 2011. His teaching interests are Digital Systems, including digital electronics, FPGAs and SoC. His research interests fall into two domains: remote experimentation and design of advanced digital systems. He has published several tenths of articles, having an WoS h-index=13 and a GoogleScholar h-index=37. He coedited 3 books about remote experimentation and he has participated in several R&D projects, funded by the regional government, the Spanish government, the ERASMUS+ program, FP7, H2020, and NSF, among others. This intensive work has supported several invitations for delivering keynotes and receiving international recognition and awards. He has been a member of several editorial boards and program commitiees. He is a senior member of the IEEE. (email: zubia_at_deusto.es)

Approaching Field Programmable Gate Arrays with Deeds

Our experience in teaching a first year course of digital design shows that the introduction of Field Programmable Gate Arrays (FPGA) is advisable. Students demonstrate a better interest for the topics, if they can really verify the circuits they study and design. Traditional bread-board based prototyping is therefore replaced by FPGA programming, which is nowadays performed at professional level using Hardware Description Language (HDL). We are somehow critical of the current trend of introducing digital system with HDL. Our tool, Deeds (Digital Electronics Education and Design Suite) allows to configure FPGA boards for testing starting with traditional schematics-based entry, which is more compatible with the beginners' skills, and overcomes the pre-requisite of some proficiency in high-level programming languages. Deeds integrates FPGA configuration and testing into its design and simulation flow, making digital design, including microprocessor programming, demonstrable through a few commercially available FPGA boards. Tutorials and projects, designed for flexibility and self-learning, open up many possibilities to hands-on experiments and introduce the basic skills on which building HDL competences later on. Deeds was developed at DITEN, University of Genoa, and it is composed of a set of simulators and a wide collection of associated learning material, covering combinational and sequential logic networks, finite state machine design, microcomputer interfacing and programming. Deeds website: https://www.digitalelectronicsdeeds.com/index.html

Prof. Giuliano Donzellini received the Laurea degree in electronic engineering from the University of Genoa, Genoa, Italy, in 1980. After a few years as a design engineer with the Marconi firm, in Genoa, in 1983 he has been appointed Assistant Professor with the Department of Biophysical and Electronic Engineering of the University of Genoa. He has worked on automatic measurements, image analysis and process control systems, phase-locked digital systems, and speleological topographic surveying systems. Currently he is focusing on the development of simulation tools for digital electronics for educational applications (Deeds - Digital Electronics Education and Design Suite) that he exploits in his teaching activity. He has contributed his experience in several EU projects and is author or co-author of several research papers and, most recently, of the book "Introduction to Digital Systems Design" (Springer, 2019). (email: giuliano.donzellini_at_unige.it)

Table of Contents

Author List