A Cross-Disciplinary View of Industrial Electronics: Change, Chance, and Challenge

Jinhua She*, Hipólito Guzmán-Miranda†, Victor Huang‡, Allen C. Chen§, Stamatis Karnouskos¶, Larisa Dunai**, Alin Tisan††, Sho Yokota‡‡

* Tokyo University of Technology, Japan. Email: she@stf.teu.ac.jp
† Universidad de Sevilla, Spain. Email: hguzman@us.es
‡ Sage Technology Resources, USA. Email: v.huang@ieee.org
§ Innovatech Solutions Inc, USA. Email: c.j.chen@ieee.org
¶ SAP, Germany. Email: karnouskos@ieee.org
** Universitat Politècnica de València, Spain. Email: ladu@upv.es
** Royal Holloway, University of London, United Kingdom. Email: Alin.Tisan@rhul.ac.uk
‡‡ Toyo University, Japan. Email: s-yokota@toyo.jp

***Abstract*—This paper presents a cross-disciplinary view of industrial electronics for building a sustainable society. After explaining efforts and challenges from human factors, professional education, electronic systems on chip, technology ethics and society, and standards, we suggest a methodology for cross-disciplinary technology integrating the above-mentioned fields, in which the technical committees in Cluster 4, Industrial Electronics Society, play an active part.**

***Index Terms*—Cross-disciplinary technology, electronic systems on chip, human factors, professional education, technology ethics, standards, sustainable society.**

I. Introduction

The United Nations General Assembly set up the sustainable development goals (SDGs) in 2015 to achieve a better and more sustainable future. Seventeen interlinked global goals were designed and were intended to be achieved by 2030, which are: (1) no poverty; (2) zero hunger; (3) good health and well-being; (4) quality education; (5) gender equality; (6) clean water and sanitation; (7) affordable and clean energy; (8) decent work and economic growth; (9) industry, innovation, and infrastructure; (10) reducing inequality; (11) sustainable cities and communities; (12) responsible consumption and production; (13) climate action; (14) life below water; (15) life on land; (16) peace, justice, and strong institutions; and (17) partnerships for the goals [1]. Many of the goals are closely related to the ones of the IEEE Industrial Electronics Society (IES).

Changes in the economy, society, and environment can have a huge impact on how the aforementioned issues can be tackled. These changes provide us a chance for innovation. Adapting to these changes from the viewpoint of industrial electronics can be a colossal challenge. In this paper, we review the efforts of Technical Committees in Cluster 4 of IES and explain how we meet the challenges.

II. Human Factors

Human Factors is a field of practical science and technology that is indispensable for building a comfortable working and living environment and for designing safe and easy-to-use tools and systems. The concept of human factors originated from Europe in the 1850s. The research of modern human factors developed against the background of applied psychology, starting with human-error research mainly in the United States after World War II. Nowadays, the definition of human factors, which is given in the principle of human-centered design (ISO11064-1) of the International Organization for Standardization (ISO) as follows: *Human factors is an engineering discipline that considers humans and system elements as equidistant and aims to optimize the interaction among design/development, tools/equipment, environment, work/tasks, culture/customs/laws and organizations/management.*

A. Trends

Human factors contribute to the solutions of social and engineering problems. Technologies supporting an aging society are closely related to human factors. It is important to understand the human characteristics for the design of support systems to meet prescribed requirements and it is also necessary to design the behavior of systems and interfaces to suit human characteristics based on an understanding of the characteristics. The members of the Technical Committee of Human Factors, IES, have been carrying out studies to solve related problems. For example, Suzuki *et al.* presented an AI-based system that automatically identifies gross-motor skills of children and reduces the workload of childcare in kindergartens [2]. This study considered children's movements as a human characteristic and tried to understand them by classifying the motion. Chugo *et al.* developed a standing support system based on a model of human dynamics to support the daily life of the elderly [3]. The system was designed from kinematic, mechanistic, and mechanical aspects so as to adapt to the movement of a human body. Yokota *et al.* devised a low-floor-type omni-directional personal mobility that was controlled by the natural movements of a person [4]. They focused on the standing postures of a person and modeled and used them to operate the apparatus. Makino *et al.* built an AI-based system that assisted doctors to detect a pincer nail in an early stage [5]. They used a neural network to learn the gait of a healthy person and a patient, and performed the diagnosis of a pincer nail based on the gait patterns. Other systems were also developed based on principles of human-centered design in the fields of manufacturing, daily life, transportation, and social systems.

B. Future challenges

Modern human factors also integrate cognition, mentality, social characteristics, and other aspects. This ensures a wide range of outcomes to deal with problems in healthcare; communication quality; physical, psychological, and psychological handicaps; and others. Generally speaking, the problem of human factors is how to optimize interfaces between systems and people, including communication between people and systems and among people, and people's health awareness. Human perception, cognition, and behavior are complex and are not the same. Some perceptual, cognitive, and communicative characteristics were discovered in recent years [6], [7], and new challenges arise with the COVID-19 pandemic [8]. It is necessary to apply these new findings to the field of human factors.

III. Educational Perspective

The continuous evolution of technology compels universities to update their course contents yearly, as well as to adapt their teaching methodologies and platforms. This update is possible thanks to the interconnection between Universities and industries and other partners through regional, national, and international projects that allow the development of new theories and tools. This process demonstrates that the higher education system is always interconnected with the industry and with the research. That said, on the one hand, the society's need and demand for new products encourage researchers to develop new knowledge and, on the other hand, the industrial demand of engineers prepared with the latest technologies and development processes has led higher education to promote (i) professional lecturers coming from industry, (ii) Project-Based Learning (PBL) methodologies, (iii) Internships in industry, (iv) Industrial seminars/courses.

A. Future trends

A common trend that also is important for the future is that professionals coming from industry are involved in the higher education system learning processes. These professionals participate in practical and theoretical courses. The objective of such enrollment is to transmit to the students the methods and practical contents that are used daily in specific industrial areas. Often, experts from industry are invited to teach students specific topics; these allow increasing the quality of the course content, give a practical perspective of the taught concepts, and, at the same time, increase the student motivation toward the subject. These professionals often make use of practical cases and real examples that reinforce this practical and professional vision of the course [9].

The Project-Based Learning methodology developed by John Dewey is based on the 'learning by doing' concept [10]. This method, which was used since Ancient Egypt, enables to reinforce practical learning and increase student motivation and collaboration. During PBL, groups of students, supervised by an instructor, are involved in the development of specific projects from an idea to a real initial prototype, following all the stages of the development of a project. Logically, this method requires a higher level of multidisciplinary knowledge. Consequently, the students gain experience in aspects such as project planning, acquisition of raw materials, product design and development, work management, logistics, and commercialization. As part of the learning process, students also improve their communication skills. In many universities, the PBL methodology involves both university-research institution and university-industry collaboration [11]. As the PBL is oriented to solve realistic problems, the students get in contact with the stakeholders, end-users, and developers. The Industry involvement in these projects has proven to have a positive impact on student learning and motivation [12], [13] and help students to develop analytical and critical thinking, ability to manage technology and management.

The importance of having practical experience in the industry, the necessity of references, and the need of employability make students look for short internships in the industry. This practice allows them to work on a specific project or theme directly in the industry and gives them the possibility to use part of the research or development results in their final BSc or MSc theses [14]. Usually, this practice is well-coordinated between the University and the industry so that the student has two tutors, one from each part. In many Universities, different cooperation programs exist between Universities and different industrial partners coming from diverse sectors. Some of the existing programs also involve the internationalization of the practical experience in the industry, such as Erasmus+, EURES, European Project Semester, etc. Some skills strengthened by the participation of the students in this type of program are improvement of the student capacity of working in teams, decision making, ability to work in multicultural contexts, knowledge of practical problems as well to learn how to manage in a foreign environment and gain professional experience and financial remuneration.

Industrial seminars or courses involve academics that are often involved in specific research fields that are of great interest for certain industries. These facilitate that these instructors are hired or invited to teach different seminars or courses to industrial users about their field of expertise. The benefits of this dissemination action are enormous since they facilitate the transfer of recently developed technologies and knowledge to industry. Moreover, it is also beneficial for the instructor who can get industrial feedback that can enhance to optimize these developments. Also, it enables to facilitate further collaborations of great interest for future testing of new methods and technologies. From an educational per-

Preprint version of doi:10.1109/IECON48115.2021.9589742

spective, the improvement of the educational methodologies and educational contents, as well as the involvement of the education in the industry project developments are the key to success. Finally, education requires the integration of the ethical and social aspects in order to manage the societal impact. With standards, educational perspective plays the role of the definition of the lows and standards for secure and trusted online learning.

IV. Electronics Systems on Chip Approaches

Chip size reduction and price decrease due to technological evolution and economies of scale have allowed the System-on-Chip paradigm to permeate many different fields and industries [15]. This permeation of the programmable System-on-Chip technology in different fields that already were using some kind of computing can be seen from two perspectives: either to add FPGA (Field Programmable Gate Array) fabric to get more parallelism and performance in a previously microprocessor-only implementation or to add a processor to easily manage sequential tasks in a previously FPGA-only project.

A. Emergence of Free and Open-source tools for digital design

Another emerging trend is the appearance of free and open-source (FOSS) tools for digital design and verification. While some of these tools have been existing for many years (for example, the first versions of GHDL are now around 18 years old), it has only been in the latest years that significant milestones have been reached, such as support for modern verification methodologies [16], or a completely open-source design flow for the ICE40 and ECP5 families of Lattice FPGAs that covers all the steps from synthesis to bitstream generation and FPGA configuration [17].

The emergence of these free and open-source tools is also a push for vendors to release part of their flows as open-source tools, or at least some way for the users to customize their tool flows, for which Xilinx's Rapidwright is an example [18].

FOSS tools may enable unexpected ways of using the tools, as they are not subject to usage, licensing, or modification restrictions. For example, without even modifying the tools, a user can launch a huge number of instances of the GHDL simulator, limited only by available computing power and not the number of available license seats. Furthermore, since the tools allow studying and modifying their source code, this can be a further enabler for innovation. Depending on the application, the usage of multiple economic chips configured with open source tools can position itself as an alternative to solutions based on monolithic programmable System-on-Chip devices configured with proprietary toolchains.

The availability of these tools is also especially interesting from an educational standpoint, since they allow for lifelong learning both inside and outside higher education institutions, while also allowing institutions with fewer economic resources to perform project-based learning with real devices and applications. Furthermore, FOSS tools may make the difference between being able to use and implement FPGA solutions or not in developing countries, especially those with reduced or nonexistent R+D budgets and those subject to export control restrictions, contributing to technology democratization and reducing inequality. Additionally, FOSS tools can be subjected to security audits to avoid almost-undetectable supply chain attacks like [19].

A difference that open-source FPGA implementation and bitstream generation tools have with respect to open-source compilers is that the internal chip details needed for bitstream generation are not public, while the Instruction Set Architectures (ISA) of the microprocessors supported by open source compilers (such as GCC) have been published by the device manufacturers. Thus, the developers of open-source FPGA implementation tools must use probing techniques to discern which bits in the FPGA bitstream configure each specific device's primitive attribute, which is not different from what many researchers already do for academic and research projects [20], [21]. In this context, probing consists of using an already existing tool (such as the tools provided by the chip manufacturer) as a black-box, feeding it known inputs, and observing its outputs.

This allows acquiring the needed information without the need to reverse-engineer any software, which is prohibited by most End-User License Agreements (EULAs). As of today, even if the method used to obtain this information does not violate any EULAs, the fact that it is not supported or intended by the manufacturers, coupled with the diversity of Intellectual Property law particularities across the globe, creates a legal gray area where companies currently do not know if they could hit any legal issue if using these tools for production.

Standardization of the minimal information that chip manufacturers would need to provide in order to perform the implementation and bitstream generation while preserving internal chip implementation details could help alleviate this problem.

Nevertheless, free and open-source tools for digital design and verification can be used as of today, with good performance and implementation efficiency results, in both research and educational contexts, and it is expected that their importance will grow in the future.

B. AI on SoC implementation challenges

The AI development (machine learning, fuzzy logic, expert systems, and metaheuristic methods) in recent years has been possible only due to the fantastic development of the hardware platforms capable of sustaining intensive computing algorithms and, more recently, greatly increase the design flexibility making possible not only the development of software to take advantage of the hardware architecture of the computational system but also design custom hardware architecture, domain-specific architectures, to efficiently execute/process computational tasks with high speed and low energy consumption, at high performance per watt ratios. Hence, the computational platforms became more heterogeneous. Some of the algorithms that have taken advantage of the change of the calculus platform paradigm shift are the Spiking Neural

Preprint version of doi:10.1109/IECON48115.2021.9589742

Networks (SNNs) and the Deep Learning (DL) with Deep Neural Networks (DNNs).

The above-mentioned networks were successfully implemented due to the capability of the (neural) CPUs to process multiple data using the Single-Instruction-Multiple-Data (SIMD) technique or implementing neural-specific instructions set such as Intel AVX-512 or custom floating-point data format (such as the brain floating-point - bfloat16). These advantages have been many times multiplied when implemented in GPUs, for which manufacturers have developed highly optimized hardware and software framework support, such as Tensorflow, Pytorch, or Caffe. Taking data processing concurrency even further and adding the FPGAs design flexibility, successful DNN accelerators composed of many processing elements (PE) and on/off chip memory such as Swallow [22], Eyeriss [23], or Xilinx Versal AI core [24] have been reported.

However, when combining CPUs, GPUs, and FPGAs, obtaining heterogeneous computing platforms, the true computing potential is released, increasing, even more, the system performances when deploying complex/heavy computational tasks brought the development of integrated solutions such as System on Chip (SoC) or System-on-Module (SOM). The great flexibility given by being able to take advantage of each calculus platform paradigm strong points is very performance rewarding. However, each of the platforms comes with drawbacks as well, and being able to "pick and choose" the right data size and algorithm to be run on the desired platform is not yet easily achieved.

To address this problem, a few methods have been developed such as data reuse, efficient memory access, algorithm compression, or workload partition strategies which, used holistically, could improve the data throughput and power efficiency [23], [25].

Even though there has been an explosion of task scheduling methods for various computation paradigms, a "unified" approach to efficiently "break-up & allocate" computation tasks per computation platform is still an ongoing endeavor.

C. Future challenges

The ease of use and configuration of programmable System-on-Chip devices is currently an open issue for vendors who want to make all the design process easier, with the intention of making it accessible to more people, thus increasing market size. For this respect, the emergence of Higher-level languages and synthesis tools constitutes a push towards the higher adoption of these devices. In particular, these open the field of FPGA and programmable System-on-Chip design to computer programmers who already have expertise in programming languages such as C, C++, or Python. This ease of use comes with an impact on the efficiency of the generated implementations, both in area and maximum working frequency [26].

The trend of moving the electronics (including signal processing and data handling) towards the very phenomena that need to be measured may result in systems with a high number of devices, where distributed computing may happen, and in which designers may find multiple synchronization and communication challenges, as explored in [27]–[29].

With respect to the accountability of AI decisions, the electronic implementations should include accountability mechanisms that can give the operators the possibility of extracting the information about decision-making so these decisions can be reviewed.

Finally, while functional safety of the designs has always had an important role to play in aerospace, automotive, biomedical, and other fields where critical systems take major roles and where failures are expensive in personal and/or economic terms, it is expected that due to the increase in complexity of the average design, higher verification efforts will be required for industrial designs in other, non-critical areas, increasing the required knowledge and efforts needed to successfully finalize a design [30].

V. Technology Ethics and Society Perspective

With the rapid advances in technology and its prevalence in every aspect of modern life, issues that pertain to technology ethics and societal implications are raised. Especially industrialization of technology, that now is not confined to controlled industrial settings, e.g., factories, but is made available to the consumers, and often plays a critical role on decisions that impact the lives of people. In the last years, such issues are mostly exemplified by the usage of Artificial Intelligence (AI), which nowadays can be found in consumer electronics, autonomous and intelligent systems, chatbots, decision-making software in banks, courts, etc. However, several pitfalls raise alarms on how this technology is used (e.g. unlawful monitoring of citizens) as well as whether the sophisticated technology itself exhibits traits such as bias that impacts people e.g. leading to decisions that have hidden racial bias, etc. This is an interdisciplinary area of research and requires a sociotechnical approach in order to address the posed challenges. For industrial adoption, additional factors beyond the developed technology play a critical role in its acceptance [31], including business and standardization.

To understand the implications around AI and ethics, consider the rise of self-driving cars, which are expected to become massively available in the next years. Such cars would need to make decisions on behalf of their users, and as such, a key question put is on which ethical bases such decisions should be made upon. Since ethics can play a key role in the acceptance of self-driving cars [32], it means that such issues need to be properly addressed by engineers when designing, realizing, and making available such products for the public.

How to engineer such systems is not trivial [33] and requires addressing both technical as well as social challenges early enough in the lifecycle of such products. This means that engineers of the future need to have inter-disciplinary knowledge that goes beyond the technical aspects and understands the limitations and impacts the technology has, as well as on how to create systems that adhere to societal norms and regulations [34].

Preprint version of doi:10.1109/IECON48115.2021.9589742

When attempting to engineer such AI systems, there is evident the need for standards. These standards would enable the creation of technologies that can be compared and are interoperable. While several standards are available for the integration of systems, there are hardly any standards that dictate the engineering of AI systems, especially when they are in conjunction with physical forms such as intelligent robots or self-driving cars. There are some recent efforts in this area that aim to address these issues [35].

In addition to standardization, education of future engineers, which includes not only in-depth technical knowledge but also a more broad towards ethical and societal aspects, is needed. This calls for a revision of university curricula as well as lifelong learning and training programs that enable engineers to acquire not only knowledge during their studies but also be retrained to new and emerging technologies and satellite issues. Thankfully the advances in modern Information and Communication Technologies have enabled the online and mass scale of such educational and training activities e.g. via Massive Open Online Courses (MOOCs), which have been found to have a positive impact on the industry [36]. Such undertaking is more challenging than considered today by most managers and educators. To exemplify this, consider that the engineer of the future should be capable of interacting with diverse stakeholders, understand their needs, anticipate potential societal impacts, and still be capable of materializing the technical and societal needs to intelligent systems that can be deployed in real-world environments and guarantee for instance security, safety, and fairness of treatment for humans.

VI. Standards View

A. Perspectives

Extending on previous cross-disciplinary perspectives of the industrial electronics technology clusters [15], this section will focus on the integration of the IES cross-disciplinary cluster technologies on industrial electronics fields of interest. Previous discussions on directions of IES standards covered present and future technological trends focused on the vertical clusters of IES fields of interest. Expanding on recent discussions on IES fields of interest, the collaboration of cross-disciplinary technologies with the vertical fields of interest is being explored. A technology sampling of various industrial applications continues to show the need and importance of standards. From here, a methodology on using cross-disciplinary concepts to these industrial electronics verticals will be proposed, with the intent to inspire further exploration into the integration of the technical disciplines for the benefit of society.

B. Trends

The recent set of technological papers from the 2020 year series of the Industrial Electronics Magazine shows the newest trends of industrial electronics technologies covering industrial automation, industrial power generation and smart micro-grids, transport electrification, and autonomous vehicles. In almost all of the 20 articles in this yearly series, standards were dominant in the practice of the applications or it indicated a glaring need for standards. Specifically, half of the articles cite or discuss standards in the paper, while four articles cited the need for standards in the development or implementation of the applications.

Standards in automation models are needed in a wide range of applications within Industry 4.0 [37]. Basically, modeling of complex automation infrastructure requires structured approaches and development discipline, and standards are widely used, especially those already adopted by industry. Technological areas covered by this paper include industrial automation, Cyber-Physical Systems, Industrial IoT all preferring standardized approaches to integration and conformity.

Whether one realizes it or not, anyone or several or all of these cross-disciplinary approaches will be embedded in the design and development of a complex system. As systems get increasingly more complex and more encompassing into society, it cannot escape the need for social and ethical implications of the applications in today’s and tomorrow’s world.

C. Need for Standards

It is clear that with new technological trends, developments and applications are still evolving, and until the trends come into focus and stabilization, standards will not be introduced or considered. The common theme here is that new technologies and its applications look to the need for standards for stability. Two brief examples noted here show the need for standards. New solid-state technologies introduced in power transformers brought challenges in the stabilization, interfaces, and cost of this new solid-state transformer (SST) products to be integrated into existing electrical systems. This led the industry to call for SST standards for better product integration and usage. This was particularly emphasized as a need for commercial acceptance of SSTs [38].

On developing efficient wind turbines (WT) for clean energy applications, it is stressed the present most common weakness in the design and development of wind turbines is the lack of common guidelines and standards [39]. In particular, the lack of standards is focused on the light detection and ranging (LIDAR) technologies applied to WT controllers to improve their performance. It states, "the opinions of wind industry experts reveal the main issues for LIDAR technologies relate to providing common guidelines and standards as well as risk evaluation and reliability concerns".

This shows the fact is that standards are increasingly important and necessary in the new technologies exploding into today’s highly technological society, and thus society’s safety, ease of use, lowered costs both in manufacturing and consumer prices, are increasingly dependent on good and highly reliable standards and standardization. It cannot be over-emphasized that new technology trends are needed and are benefiting from standardization.

Preprint version of doi:10.1109/IECON48115.2021.9589742

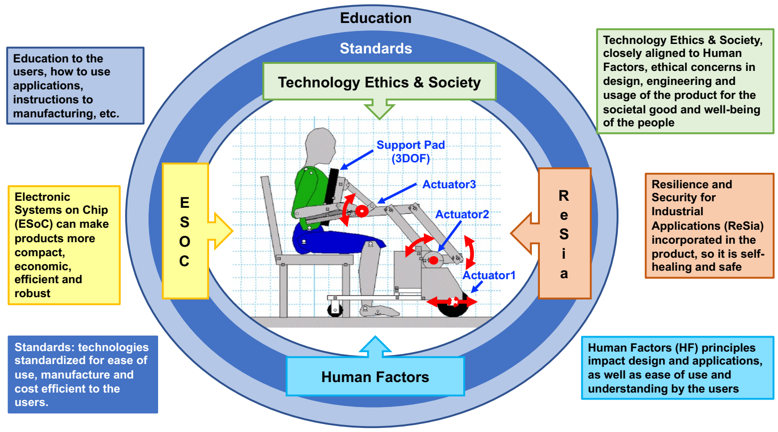

Figure 1. The proposed cross-disciplinary intra-cluster methodology via the involved IEEE IES Technical Committees

VII. Suggested Methodology for Cross-Disciplinary Technology Integration

A methodology of how integration and collaboration of the cross-disciplinary cluster technologies can immensely benefit IES vertical cluster technologies is shown in Figure 1. Cross-disciplinary aspects are important for the industry, where not only the technical results but also standards and business aspects play a key role towards the adoption of solutions [31]. Therefore, requirements, as well as considerations of additional factors beyond the pure technological ones, should be considered in order to enable the adoption of new innovative technologies.

A proposed cross-disciplinary intra-cluster methodology can be applied on a particular vertical application – starting by using a robotic walker with standing/sitting assistance [15]. Here each cross-disciplinary technology contributes to the problem at hand in the robotic walker. Human factor (HF) principles are heavily applied to impact the design and application of the robotic walker, to provide ease of use and comfort for the assisted elderly or disabled user, and to provide a clear and easy understanding of the use of the walker. In the design for the walker, many supportive and wearable elements are incorporated into the design, so electronic chips are integrated into the design due to space and weight constraints.

With increasing complexity of user applications, electronic systems on a chip (ESOC) are most likely deployed into the wearables and light-weight robotic walkers and assisting devices. Closely associated with the human factors and ESOC designs of the walker will be the consideration of resilience and safety factors (ReSia) designed into the assisted system, where factors such as self-healing considerations in both hardware and software must be built-in to ensure the ease of use and safety of the device to the elderly or disabled user, as well as 'free of concern or worries' by the user regarding the device. Closely associated with HF and ReSia will be the considerations of technology ethics and society (TES) aspects for the device and its applications. Heavy emphasis and thought on ethical considerations must be placed in the HF/ReSia/ESOC/TES aspects of the design of the product to consider gender, race, ethnicity, language and age bias and discriminatory effects.

As the designs become stabilized and useful to society, the implementation practices and design requirements can be standardized (STDS) for mass production, lower costs, and fast implementation and deployment to the consumers. Lastly, education on the use, both to the user and personnel training in production and manufacturing, will be the focus of Education (EDU). These last two cross-disciplinary technical components are shown as 'full rings' around the cross-disciplinary cluster methodology as it 'pervades' all aspects of the other technologies. This is also true for TES, which encompasses ethics and societal impact along the lifecycle of the developed products e.g. from concept to engineering, operation, and eventual disposition. With this proposed methodology, it is suggested that the cross-disciplinary cluster initiates a trial implementation with a selected vertical within IES, and reports its findings for the next article.

VIII. Conclusion

In this paper, we explained new trends, efforts, and challenges to create a sustainable society from the viewpoints of human factors, education, electronics systems on chip approaches, technology ethics and society, and standards. Since the 17 SDGs [1] are multiple cross-cutting issues, we need to carry out interdisciplinary studies with the cooperation of different fields to attain these goals. The technical committees in Cluster 4 of IES have been making a constant effort and working together to overcome the challenges. A future task is to attract young people from both industrial and academic sectors to the activities of our cluster so as to keep a sustainable growth of society.

References

[1] United Nations, "Transforming our world: the 2030 Agenda for Sustainable Development," December 2015, A/RES/70/1. [Online]. Available: https://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E

Preprint version of doi:10.1109/IECON48115.2021.9589742

[2] H. Ono and S. Suzuki, “Data augmentation for GrossMotor-ActivityRecognition using DCGAN,” in *2020 IEEE/SICE International Symposium on System Integration (SII)*. IEEE, jan 2020.

[3] D. Chugo, M. Yokota, S. Muramatsu, S. Yokota, J.-H. She, H. Hashimoto, T. Katayama, Y. Mizuta, and A. Koujina, “Standing assistance control based on voluntary body movement within safety tolerance,” in *2020 IEEE 16th International Workshop on Advanced Motion Control (AMC)*. IEEE, sep 2020.

[4] M. Suzuki, S. Yokota, A. Matsumoto, D. Chugo, and H. Hashimoto, “Simulation of omni-directional low-floor mobility controlled by inverted pendulum and human postural control model in forward-backward direction,” in *IECON 2020 The 46th Annual Conference of the IEEE Industrial Electronics Society*. IEEE, oct 2020.

[5] K. Makino, Y. Ogawa, Z. Liu, K. Yamada, H. Nishizaki, S. Shimada, T. Kawamura, and H. Terada, “Classification of a pincer nail using a recurrent-based neural network,” in *2020 IEEE/SICE International Symposium on System Integration (SII)*. IEEE, jan 2020.

[6] L. M. Contreras-Somoza, E. Irazoki, D. Castilla, C. Botella, J. M. Toribio-Guzmán, E. Parra-Vidales, C. Suso-Ribera, P. Suárez-López, M. V. Perea-Bartolomé, and M. Á. Franco-Martín, “Study on the acceptability of an ICT platform for older adults with mild cognitive impairment,” *Journal of Medical Systems*, vol. 44, no. 7, may 2020.

[7] H. Wang, X. Liu, J. Li, T. Xu, A. Bezerianos, Y. Sun, and F. Wan, “Driving fatigue recognition with functional connectivity based on phase synchronization,” *IEEE Transactions on Cognitive and Developmental Systems*, pp. 1–1, 2020.

[8] A. Gupta, A. Singh, D. Bharadwaj, and A. K. Mondal, “Humans and robots: A mutually inclusive relationship in a contagious world,” *International Journal of Automation and Computing*, vol. 18, no. 2, pp. 185–203, jan 2021.

[9] Z. Kemény, R. J. Beregi, G. Erdős, and J. Nacsa, “The MTA SZTAKI smart factory: Platform for research and project-oriented skill development in higher education,” *Procedia CIRP*, vol. 54, pp. 53–58, 2016.

[10] C. A. Maida, “Project-based learning: A critical pedagogy for the twenty-first century,” *Policy Futures in Education*, vol. 9, no. 6, pp. 759–768, jan 2011.

[11] E. Abele, J. Metternich, M. Tisch, G. Chryssolouris, W. Sihn, H. El-Maraghy, V. Hummel, and F. Ranz, “Learning factories for research, education, and training,” *Procedia CIRP*, vol. 32, pp. 1–6, 2015.

[12] L. Abeysekera and P. Dawson, “Motivation and cognitive load in the flipped classroom: definition, rationale and a call for research,” *Higher Education Research & Development*, vol. 34, no. 1, pp. 1–14, aug 2014.

[13] D. Ktoridou, E. Doukanari, E. Epaminonda, and A. Karayiannis, “Case-based learning: Offering a premier targeted learning experience for technology management students,” in *2018 IEEE Global Engineering Education Conference (EDUCON)*. IEEE, apr 2018.

[14] R. Bekkers and I. M. B. Freitas, “Analysing knowledge transfer channels between universities and industry: To what degree do sectors also matter?” *Research Policy*, vol. 37, no. 10, pp. 1837–1853, dec 2008.

[15] O. Lucia, J. She, A. C. Chen, Z. Cheng, M. Y. Chow, L. Dunai, M. Hilairet, V. Huang, E. Monmasson, K. Umetani, and S. Yokota, “Emerging trends in industrial electronics: A cross-disciplinary view,” *IEEE Industrial Electronics Magazine*, vol. 15, no. 1, pp. 127–139, mar 2021.

[16] B. Marshall, “Hardware verification in an open source context,” in *1st Worshop on Open Source Design Automation (OSDA), Workshop 10 of the Design, Automation and Test in Europe conference (DATE) 2019*, Florence, Italy, 3 2019.

[17] D. Shah, E. Hung, C. Wolf, S. Bazanski, D. Gisselquist, and M. Milanovic, “Yosys+nextpnr: An open source framework from verilog to bitstream for commercial FPGAs,” in *2019 IEEE 27th Annual International Symposium on Field-Programmable Custom Computing Machines (FCCM)*. IEEE, apr 2019.

[18] C. Lavin and A. Kaviani, “RapidWright: Enabling custom crafted implementations for FPGAs,” in *2018 IEEE 26th Annual International Symposium on Field-Programmable Custom Computing Machines (FCCM)*. IEEE, apr 2018.

[19] C. Krieg, C. Wolf, and A. Jantsch, “Malicious LUT: A stealthy FPGA trojan injected and triggered by the design flow,” in *Proceedings of the 35th International Conference on Computer-Aided Design*. ACM, nov 2016.

[20] N. Steiner and P. Athanas, “An alternate wire database for xilinx FPGAs,” in *12th Annual IEEE Symposium on Field-Programmable Custom Computing Machines*. IEEE, 2004.

[21] S. Raaijmakers and S. Wong, “Run-time partial reconfiguration for removal, placement and routing on the virtex-II pro,” in *2007 International Conference on Field Programmable Logic and Applications*. IEEE, aug 2007.

[22] B. Liu, X. Chen, Y. Han, and H. Xu, “Swallow: A versatile accelerator for sparse neural networks,” *IEEE Transactions on Computer-Aided Design of Integrated Circuits and Systems*, vol. 39, no. 12, pp. 4881–4893, dec 2020.

[23] Y.-H. Chen, T. Krishna, J. S. Emer, and V. Sze, “Eyeriss: An energy-efficient reconfigurable accelerator for deep convolutional neural networks,” *IEEE Journal of Solid-State Circuits*, vol. 52, no. 1, pp. 127–138, jan 2017.

[24] Xilinx, “Versal: The First Adaptive Compute Acceleration Platform (ACAP),” Xilinx, Tech. Rep., Sep. 2020, white paper. [Online]. Available: https://www.xilinx.com/support/documentation/white_papers/wp505-versal-acap.pdf

[25] F. Zhang, J. Zhai, B. Wu, B. He, W. Chen, and X. Du, “Automatic irregularity-aware fine-grained workload partitioning on integrated architectures,” *IEEE Transactions on Knowledge and Data Engineering*, pp. 1–1, 2019.

[26] M. Pelcat, C. Bourrasset, L. Maggiani, and F. Berry, “Design productivity of a high level synthesis compiler versus HDL,” in *2016 International Conference on Embedded Computer Systems: Architectures, Modeling and Simulation (SAMOS)*. IEEE, jul 2016.

[27] R. Krishnamoorthy, K. Krishnan, B. Chokkalingam, S. Padmanaban, Z. Leonowicz, J. B. Holm-Nielsen, and M. Mitolo, “Systematic approach for state-of-the-art architectures and system-on-chip selection for heterogeneous IoT applications,” *IEEE Access*, vol. 9, pp. 25 594–25 622, 2021.

[28] A. Al-Ali, I. A. Zualkernan, M. Rashid, R. Gupta, and M. Alikarar, “A smart home energy management system using IoT and big data analytics approach,” *IEEE Transactions on Consumer Electronics*, vol. 63, no. 4, pp. 426–434, nov 2017.

[29] G. Fedrecheski, L. C. C. D. Biase, P. C. Calcina-Ccori, and M. K. Zuffo, “Attribute-based access control for the swarm with distributed policy management,” *IEEE Transactions on Consumer Electronics*, vol. 65, no. 1, pp. 90–98, feb 2019.

[30] H. D. Foster, “2018 FPGA functional verification trends,” in *2018 19th International Workshop on Microprocessor and SOC Test and Verification (MTV)*. IEEE, dec 2018.

[31] S. Karnouskos and P. Leitao, “Key contributing factors to the acceptance of agents in industrial environments,” *IEEE Transactions on Industrial Informatics*, vol. 13, no. 2, pp. 696–703, apr 2017.

[32] S. Karnouskos, “Self-driving car acceptance and the role of ethics,” *IEEE Transactions on Engineering Management*, vol. 67, no. 2, pp. 252–265, may 2020.

[33] D. Trentesaux and S. Karnouskos, “Engineering ethical behaviors in autonomous industrial cyber-physical human systems,” *Cognition, Technology & Work*, mar 2021.

[34] S. Karnouskos, “Symbiosis with artificial intelligence via the prism of law, robots, and society,” *Artificial Intelligence and Law*, may 2021.

[35] IEEE, “Ethically Aligned Design: A Vision for Prioritizing Human Well-being with Autonomous and Intelligent Systems,” The IEEE Global Initiative on Ethics of Autonomous and Intelligent Systems, resreport, 2018. [Online]. Available: https://standards.ieee.org/content/dam/ieee-standards/standards/web/documents/other/ead1e.pdf

[36] S. Karnouskos, “Massive open online courses (MOOCs) as an enabler for competent employees and innovation in industry,” *Computers in Industry*, vol. 91, pp. 1–10, oct 2017.

[37] J. Jasperneite, T. Sauter, and M. Wollschlaeger, “Why we need automation models: Handling complexity in industry 4.0 and the internet of things,” *IEEE Industrial Electronics Magazine*, vol. 14, no. 1, pp. 29–40, mar 2020.

[38] F. Ruiz, M. A. Perez, J. R. Espinosa, T. Gajowik, S. Stynski, and M. Malinowski, “Surveying solid-state transformer structures and controls: Providing highly efficient and controllable power flow in distribution grids,” *IEEE Industrial Electronics Magazine*, vol. 14, no. 1, pp. 56–70, mar 2020.

[39] A. Shourangiz-Haghighi, M. Diazd, Y. Zhang, J. Li, Y. Yuan, R. Faraji, L. Ding, and J. M. Guerrero, “Developing more efficient wind turbines: A survey of control challenges and opportunities,” *IEEE Industrial Electronics Magazine*, vol. 14, no. 4, pp. 53–64, dec 2020.

Preprint version of doi:10.1109/IECON48115.2021.9589742