Selected Development Trends of TECIS

Peter Kopacek*. Mary Doyle-Kent **.

** TU Wien, Institute for Mechanics and Mechatronics, IHRT Favoritenstrasse 9-11/E325,A4*
A – 1040 Wien.(Email:kopacek@ihrt.tuwien.ac.at).
***Department of Engineering Technology, Waterford Institute of Technology, Waterford, X91 KOEK, Ireland.*
(Tel +353 51 302058 Email mdkent@wit.ie)

Abstract: Automation, and closely related information systems are, naturally innate, and integrated ingredients of all kinds of objects, systems, and social relations of the present day reality. This is the reason why this contribution treats the phenomena and problems of this automated/information society in a historical manner with a wider, structural framework, giving special emphasis to TECIS.

The classical International Federation of Automatic Control's (IFAC) topic of social effects is continually evolving and is moving towards human-machine cooperation. This means that automation technologies require a more interdisciplinary educated workforce. In addition developing countries need access to the newest technology to efficiently and effectively improve their industries.

This contribution benchmarks selected important development trends of the Technical committee 9.5 (TECIS). It outlines the social aspects of automation, cost orientated automation, semi-automated assembly and disassembly (end of life), mechatronics systems and robotics, cooperative robotics, engineering ethics and diversity and inclusion in automation. As well as looking forward to future development trends it also looks backwards at the history of automation in the context of TECIS.

Keywords: Social aspects, Cost Oriented Automation, SME-oriented Automation, Semi-Automated Assembly and Disassembly (EoL), Mechatronic Systems and Robotics, Engineering Ethics, Diversity and Inclusion.

1. INTRODUCTION

This contribution provides a review of the social effects of TECIS. Automation in current times means that unlimited activities are perfected by machines, independent of the intervention of direct human control. This definition involves the use of energy resources and operating without human or physical effort. In addition it requires some kind of information system, communicating the purpose of automated activity which is desired by humans, and ultimately the automatic execution of the activity, i.e., its control. This definition entails a widely extended view of automation and its relation to information systems, knowledge of the control systems themselves, in addition to the knowledge, the practice of the related human factors. The human factors include: education, health, physical and cognitive abilities, systems of cooperation and communication (i.e., language and sociology), environmental conditions, short- and long- range ways of thinking, ethics, legal systems, various aspects of private life and entertainment.

2. SOCIAL ASPECTS

Industry 4.0 is impacting how we design and manufacture on a global level. Europe, especially Germany, is integrating information, communication, and manufacturing technologies in smart, self- organizing factories. The focus for Germany's drive is to excel in smart factories and smart manufacturing. In the USA and China, the focus is on smart products, Internet platforms and the new business models that are based on these technologies. The implementation of these intelligent technologies in the USA has been given the name the *"Industrial Internet of Things."* (Gausemeier, J. and Klocke, F., 2016).

The key technologies of Industry 4.0 are: IoT, Big Data Analytics, 3D printing, Advanced (autonomous) Robotics, Smart Sensors, Augmented Reality, Cloud computing, Energy Storage, AI or Machine Learning, Nanotechnology, Synthetic Biology, Simulation, Mobile Devices, Cyber Security, Quantum Computing, Horizontal and Vertical integration and Human Machine Interfaces. (Hallward-Driemeier, M. and Nayyar, G., 2017).

As automation becomes more flexible and sophisticated, more personalization of products will be offered to customers. Flexible robotics allows the manufacturing environment keep up with changeable outputs demanded by costumers (Doyle-Kent, M., Kopacek, P., 2019). Cyber-physical systems are more complex, and the human must become the flexible problem solver and the strategic decision maker. This is facilitated by assistive technology as they are making decisions remotely. Tablets and smartphones are used to visually transmit information to the human and connect them to the processes.

The Research Council of the Plattform Industrie 4.0 (acatech) in 2019 outlined the opportunities for the development of methodological approaches to implement Industry 4.0 successfully. They state these changes must be *"accompanied by socio-technical considerations and the creation of a legal framework. These key themes are: value creation scenarios for I4.0, prospective technological trends, new methods and tools, work and society defining the legislative framework, socio-technical system and framework definitions criteria, urgency of training and skills development, fostering acceptance, extending participation, and transforming management cultures and sociopolitical dialogue."* (Hirsch-Kreinsen, H., et al, 2019).

Caldarola, Modoni, and Sacco, are of the opinion that real value in manufacturing will be when the worker is at the center of the manufactured process in in human centered systems. *"Factories of the Future 18-19-20 Work Program"* focus on human factors and human competences must be developed at the same time as technological progress. Two key factors are:

- *"Models for individual and collective sense-making, learning and knowledge accumulation.*
- *Workers interconnection with machines, processes and development of context-oriented services towards safety practices and decision making."* (Caldarola, E.G., Modoni, G.E. and Sacco, M., 2019).

In 2020 Doyle-Kent and Kopacek put forward a Socio Technical approach based on the work of Mumford. An important concept is *"that the technology (defined as machines and their associated work organization) should be equal but not superior to high quality and satisfying work environment for employees when new work systems and methodologies were being designed and implemented."* In addition, these designs should have an important democratic component. In other words, employees that will use the systems should be part of the design process so as to ensure an improved quality of life. (Doyle-Kent, M., Kopacek, P., 2020a). The ability of a company to move into this new manufacturing space depends on multiple factors and because of this high level of complexity they may require and third party to help them understand their strengths and weaknesses.

3. COST ORIENTED AUTOMATION (COA)

The main Manufacturing Systems Evolution Drivers are:

- Global growth & competition
- Knowledge Economy
- Environmental pressures
- Molecular manufacture
- Conflict over resources
- Ideology & culture, ICT- ambient & networked
- Global competition in services
- Human need
- Physical Product

Further development trends are:

- ***Environmentally Conscious Manufacturing***: Efficient use of materials and natural resources in production, Minimize the negative consequences on the environment (green manufacturing, cleaner production and sustainable manufacturing).
- ***Design for environment (DFE)*****:** Select materials that require minimum energy to produce, select processes that minimize waste of materials and energy, design parts that can be recycled or reused, design products that can be readily disassembled to recover the parts, design products that minimize the use of hazardous and toxic materials, give attention to how the product will be disposed of at the end of its useful life.
- ***Smart Factories:*** Beginning to appear and employ a completely new approach to production. Such factories allow individual customer requirements to fulfilled. Because of their flexibility last-minute changes in production are possible. The goal is production of lot size one economically.
- ***Smart products*** are uniquely identifiable, may be easily located at all times, they know their own history, current status, alternative routes to achieving their target state.

These are some of the pillars of COA.

4. SEMI-AUTOMATED ASSEMBLY AND DISASSEMBLY (EOL)

Disassembly automation emerged in 1998 with the realization of the first industrial semi-automatized disassembly cells. (Kopacek, Noe; 1994), (Kopacek, 2000). Semi- or fully automatized disassembly especially of electr(on)ic devices was not only because of the standardization by the European Commission (directive on waste from electrical and electronic equipment – WEEE) which was, at that time, a hot topic. Usually only the toxic components were removed manually and the rest of the materials were shredded and disposed of. Manual disassembly of such devices is today recognized as *'state of the art'*. Because of EC regulations and the increasing amount of electronic scrap, manual disassembly has become more and more inefficient. Hence the automation of the disassembly process has become absolutely necessary.

Flexible disassembly cells were introduced with the main modules: Industrial robots, or handling devices, with special features like high accuracy, path and force control (disassembly robots) and special gripping devices for a broad spectrum of parts with different geometries and dimensions. Disassembly tools which were especially developed for robots are as follows. *Feeding Systems* for the products to be disassembled. *Transport Systems* which are similar to the assembly cells. *Fixture Systems* for parts with different geometries and dimensions. *Manual Disassembly Stations*. *Intelligent Control Units* able to process information from extended sensors. *Component Database* including data of reusable and re-manufacturable parts. *Low Cost Oriented* vision systems for part recognition. *Various Sensors* for force and moment limitations, position, distance, etc. *Storage Systems* for tools and parts.

Aims of disassembly are:

- Reducing the need for landfill
- Isolation of pollutants and valuables
- Conservation of natural resources
- Recovery of materials and components

Usually, there is no or insufficient product information for the disassembly of the product as compared to its original assembly operation. The manufacturer has to consider how to create a new product with a view to *how sustainable is it* and how *economical is it to recover the product almost entirely at EOL*? This is one of the key factors now as compared to its design for assembly only.

Additionally, the variety of the disassembly processes are essentially wider than assembly processes, and not all parts of the product have to be recovered to achieve the highest added value.

So, the disassembly is not the logical reversal of assembly because by launching a new product, the manufacturer has to think how far robotics can be implemented for its disassembling operations. After all, this decides, on the one hand, the degree of automation and, on the other, if the technology is ready to detect and check material wear, such as aging, destruction, and corrosion for remanufacturing. (Uhlmann, 2008), (Wolff, 2018).

5. MECHATRONIC SYSTEMS AND ROBOTICS

Mechatronics as an umbrella which integrates areas of technology like measurement systems and sensors, actuation systems and drives, systems behavior, control, and microprocessor systems. This is illustrated in Fig. 1. Mechatronics brings together a number of technologies:

- mechanical engineering
- control engineering
- electrical engineering
- electronic engineering
- computer technology

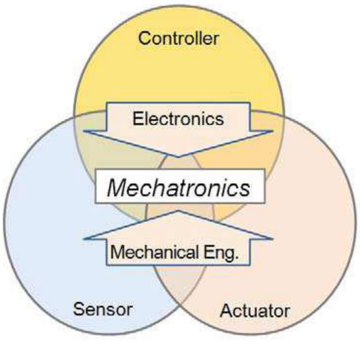

Figure 1 Pillars of Mechatronics.

Differentiated by ‘size’ there are currently different systems available or in development like:

- Conventional mechatronic systems
- Micromechatronic Systems – MEMS
- Nanomechatronic Systems – NEMS
- Femtomechatronic Systems – FEMS

Robots are often used as excellent examples of Mechatronic Systems. Robots of nanosize, Nanobotics (or Nanorobotics), are often used in demonstrations, and can act as a positive public information tool for mechatronics. The names Nanobots, Nanoids, Nanites, Nanomachines or Nanomites are also used.

The definition Nanorobots are robots with dimensions at, or below, 1 micrometer (10^{-6} m). Because up until now it was not possible to produce such robots the definition was modified to: or can *‘manipulate components on the 1 nm (10^{-9} m) to 1000 nm (10^{-6} m) size range.’*

Currently the field of robotics is rapidly evolving not only because of the latest trends in production automation.

A multi-robot system is a distributed system that consists of a collection of autonomous computers, connected through a network and distribution middleware which enables them to coordinate their activities and to share the resources. The user perceives the system as a single, integrated computing facility. Nevertheless, multiple robot systems are different from any other distributed systems because of their implicit *‘real world’* environment, which is more difficult to model.

As mentioned before a system involving several robots is a distributed system. Distribution exists in terms of spatial distribution, information distribution, as well as decision making ability. Spatial distribution exists as each robot is located in a different position. Information distribution is understandable because the information belongs to each robot, and so not all information is common to all agents. The final decision taken around the required task is always located inside each individual robot instructed to execute the tasks and this depends on its internal state.

The term collective behaviour denotes any behaviour of agents in a system having more than one agent. Therefore, cooperative behaviour is a subclass of collective behaviour which is characterized by cooperation. Cooperation is defined as the ability to work or act together for a common purpose.

Hence it follows that a multi- robot system displays cooperative behaviour if, due to some underlying mechanism, there is an increase in the total utility of the system. There are three fundamental aspects for cooperative behaviour:

- the task the robots must perform
- the mechanism of cooperation
- the system performance

In this context, one of the fundamental aspects of the robots is their capability to learn. To learn the characteristics of the surrounding environment, that is, the physical environment, but also the living beings that inhabit it. This means that robots working in a given environment have to distinguish human beings from other objects.

In addition to learning about their environment, robots have to learn about their own behaviour, through a self-reflective process. They have to learn from experience, replicating somehow the natural processes of the evolution of intelligence in living beings. (For example synthesis procedures, trying and error, learning by doing, and so on).

6. COOPERATIVE ROBOTS

Robots can accomplish different tasks in different environments, tasks that are tedious, difficult or even impossible for a human operator. If several robots are combined in order to create a multi- robot system, the range of tasks they can perform increases. This is because these systems can carry out actions that no single robot could on its own since they are always spatially limited, no matter how capable they are.

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7. ENGINEERING ETHICS

The development of relevant legislation, standards and norms which adequately meet the requirements of automation and robotics is critical to the development of new technology and its uptake in industry. Research undertaken by Doyle-Kent in 2021 titled *'Collaborative Robotics in Industry 5.0'* showed that the health, safety and wellbeing of employees in an Irish industry case study, was the most important priority of manufacturing companies in a quantitative survey of sample size of 111. A qualitative study was undertaken in this research to gain a rich understanding of the insights of Specialists in Collaborative Robotics. After a thematic review *'Theme 2'* emerged and once again highlighted the importance of meeting statuary Health and Safety requirements if new technology is to be introduced into a company and used to its full potential.

Table 1. Quotes from the qualitative case study by Doyle-Kent in 2021.

Theme 2: "There are uncertainties about meeting the statuary Health and Safety requirements by using Collaborative Robots unguarded.

- Company A's Cobots are extremely easy to program but are often put into cages for safety reasons.
- Most Cobots in Ireland are used as a fenceless robot to meet with health and safety regulations.
- These safety standards come from the industrial robot's safety standards and are evolving continuously.
- Comprehensive H&S risk assessment must be implemented before the Cobot can be installed.
- The risk assessment is the responsibility of either the machine builder or systems integrator and some are unwilling to take the risk of allowing the Cobot to run in a fenceless setup."

This study demonstrated that regardless of the features of emerging technology, legislation and perceived liability will take precedence (Doyle-Kent, 2021).

EU-OSHA is the European Union information agency for occupational safety and health. This agency contributes to the European Commission's Occupational Safety and Health (OSH) Strategic Framework 2014-2020 and, they contribute to other relevant EU strategies and programmes, such as Europe 2020. EU-OSHA's stated mission is to make the European workplaces safer, healthier and more productive, which has the effect of benefiting of businesses, employees and governments. They state that *"we promote a culture of risk prevention to improve working conditions in Europe."* (OSHA, 2021)

- Directive 85/374/EEC - liability for defective products. The Directive establishes the principle that the producer of a product is liable for damages caused by a defect in his product. A product is defective when it does not provide the safety a person is entitled to expect.

The International Organization for Standardization (ISO) is an independent, non-governmental international organization with a membership of 165 national standards bodies. They state that they, through their members, bring *"together experts to share knowledge and develop voluntary, consensus-based, market relevant International Standards that support innovation and provide solutions to global challenges."* There are currently over 23,766 International Standards covering almost all aspects of technology and manufacturing. (ISO, 2021).

At this moment in time the following ISO standards refer to robotics:

- ISO 10218-1 specifies requirements and guidelines for the inherent safe design, protective measures and information for use of industrial robots. It describes basic hazards associated with robots and provides requirements to eliminate, or adequately reduce, the risks associated with these hazards
- ISO 10218-2 has been created in recognition of the particular hazards that are presented by industrial robot systems when integrated and installed in industrial robot cells and lines.
- ISO/TS 15066:2016 Technical Specification specifies safety requirements for collaborative industrial robot

systems and the work environment, and supplements the requirements and guidance on collaborative industrial robot operation given in ISO 10218-1 and ISO 10218-2.

ISO/TS 15066:2016 is currently being updated to redefine the definition of a collaborative robot application and a new standard is being developed on the safety of mobile robots with manipulators.

In 2019 in a study titled 'Robotics Laws,' Djordievic came to the conclusion that the legal frameworks that exist currently are not fit for purpose as that do not cover the new generations of emerging robots which *"can be equipped with adaptive and learning abilities entailing a certain degree of unpredictability in their behaviour since those robots would autonomously learn form their own variable experience and interact with their environment in a unique and unforeseeable manner"*. Thus, new legislation must be developed and put into place. (Djordievic, 2019).

Doyle-Kent and Kopacek in 2020 raised several questions about what are the legal implications when humans and collaborative robots work closely together in a cell:

- *"Who would be responsible for the malfunctioning of the robot?*
- *Who would be responsible for the mistake made by a robot?*
- *What would happen if the worker got hurt by a robot?*
- *Should a robot be treated as a co-worker since it is doing part of the job?"*
- *Can human be attached to these robots, is it acceptable that people start communicating with robots and accept their recommendations and advices?*
- *Would they rely too much on them?*
- *In addition, what if something happens to a robot in this situation, how would a human react?"* (Doyle-Kent, M., Kopacek, P., 2020b)

The development of relevant legislation, standards and norms which adequately meet, in real time, the requirements of automation and robotics as they develop will be one of the most important factors.

8. DIVERSITY AND INCLUSION

All sectors, including Science Technology Engineering and Math (STEM), need diverse communities. Creating an environment where everyone has an equal opportunity to succeed is not only fair – evidence shows that diversity leads to better, more impactful scientific research. *"Enriching your employee pool with representatives of different genders, races, and nationalities is key for boosting your company's joint intellectual potential."* (Rock, D., Grant, H., 2016).

Diversity and inclusion are the vital to the long-term success of any organization. *"Employing the best talent means optimizing innovation, entrepreneurship, growth and ultimately profit margins."* (Bula, I., et al, 2020) In Industry 4.0 and 5.0 there is a requirement that engineering firms have the top talent which means ensuring engineering professionals are composed of all societal cohorts, including minority groups. This has not traditionally been the case in some countries.

Hewlett, Marshall, and Sherbin, in 2013 undertook a survey with 1,400 professionals. They investigated two kinds of diversity: inherent and acquired (Fig. 2). Inherent diversity they defined as diversity that *"involves traits you are born with, such as gender, ethnicity, and sexual orientation. Acquired diversity involves traits you gain from experience, for example working in another country can help you appreciate cultural differences."* Their research looks at '2-D diversity' and they define this as exhibiting at least three inherent and three acquired diversity traits.

Figure 2 Graphic representation of 2-dimensional diversity.

This report states that they have discovered six behaviors that can unlock innovation. In companies where diverse voices are heard they state that employees are more than twice likely to bring value driven insights and three and a half times more likely to reach their full potential. These behaviors are:

- ensuring that everyone is heard;
- making it safe to propose novel ideas;
- giving team members decision-making authority;
- sharing credit for success;
- giving actionable feedback;
- and, implementing feedback from the team. (Hewlett, S., et al 2013).

In TC.9.5 (TECIS) the above behaviors are core to our Diversity and Inclusion working group. In Bulgaria at the TECIS 2019 conference twenty-three researchers from over ten countries came together to discuss the lack of women and other marginalized groups in engineering. In 2020 a paper was presented to IFAC World Congress to outline the future direction of the working group, which includes; to support and foster greater knowledge of gender diversity in engineering education, to make a substantial contribution to our understanding of diversity issues in engineering with a view to highlighting best practices for industry. (Doyle-Kent, M., et al, 2020).

9. EDUCATION

Today`s engineering environment is more challenging than ever before. With today`s increased technical complexity and competitive pressures, the breed of managers that has evolved must confront new problems in managing complex tasks.

To manage effectively in such a dynamic and often unstructured environment, managers must understand the interaction of technical, organizational and behavioural variables in order to form a productive engineering team.

Therefore in the following the Engineering Management (EM) program at TU Wien will be described as an eductional example. (Kopacek, 2019).
The first idea for a postgraduate, executive Engineering Management MSc program at TU Wien came up in 1992 as a cooperation with the Oakland University in Rochester (MI). The main goal has been to educate managers for SME`s as well as Department Heads of large companies from the producing industry.
After some discussions and visits a general cooperation agreement between Oakland University and TU Wien was signed on January 25, 1995 in the Rectors office of TU Wien. On October 20, 1995 the first program was launched with 11 participants in Austria. The following programs up until 2005 took place in different locations in Lower Austria and Vienna. Since 2007 this program has been running in the frame work of the Continuing Education Center (CEC) of TU Wien without an agreement with Oakland University.
There is also an historical personal connection between EM and TECIS because some TC members were involved in the development of EM and were and are currently teaching in the EM program. Therefore most of the subjects of TECIS are also included in the courses of Engineering Management (Table 2).

Table 2 Keywords of TECIS – Courses of EM.

Keywords TECIS	**Courses EM**
Advanced Robotics	Technology
Cross-Cultural Aspects of Engineering	Human Factors
International Development	Management Information Systems
Engineering Ethics	Human Factors
Advances in Mechatronic Systems	Technology
Environmental Systems	Technology
Energy Systems	Technology
SME- oriented Automation	Production Systems
Technological Factors in Conflict Regions	International Law
Efficient Use of Intelligent Machinery	Production Systems
Enterprise Integration Technologies and agile manufacturing	Production Systems
Technology Innovation and Knowledge Networks	Technology
Control Systems Approaches to Conflict Resolution	Systems Engineering
Cost Oriented Automation	Production Systems
Social Networks	Human Factors
Intelligent systems and applications	IT and Production
Sustainable design and control	Systems Engineering

10. CONCLUSIONS

As pointed out earlier one of the original ideas of SWIIS was to contribute systems theory and systems engineering methods to resolve conflict situations. The SWIIS community started with the classical approaches of control engineering especially control of time continuous systems, like the theory of linear or sometimes non-linear systems, modelling, stability and optimisation. In the history of SWIIS there were some new approaches presented to several events for application of new methods from control engineering to SWIIS problems. Examples are multivariable and time varying systems as well as fuzzy and neuro methods.

Another new approach to the SWIIS problems is the use of methods from manufacturing automation time discrete systems as well as the improvement of the interdisciplinary.

Furthermore, ethics becomes of more and more interest to control engineering. The classical IFAC topic of social effects is moving more and more to a human machine cooperation. These new automation technologies require a more interdisciplinary educated people. In addition developing countries need the newest technology to efficiently and effectively improve their industries.

The influence of the conflict factor *'energy'* on stability will be studied by a new approach. Furthermore ethics, as well as social aspects and diversity are the tasks for the future.

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