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Social impact of automation trends and issues: an human centred systems engineering perspective

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Abstract: During the last decades, advanced information technologies have became more and more omnipresent to address new requirements and new needs of our e society. As a consequence of their increasing development, the social impact of information technologies, in general, and automation and control technologies, in particular, become so strong that it infers new behaviours of both humans and machines and modifies the traditional balance between technologies and society. In this perspective, systems thinking paradigm is challenging both academic and industrial communities for a better efficiency of information technologies in the human interaction loop and for a better characterisation of how both human and technologies interact with each other's. This paper addresses some systems thinking issues for an human centred systems engineering as an approach to design an automation technology as a complex "human-machine" whole in order to restore socio-technique equilibrium.

1. INTRODUCTION

During the last decades, advanced information technologies have became more and more omnipresent to address new requirements and new needs of our e society. But, their increasing development and their daily use in our professional and/or personal life impact so much the organisation of technical system and socio-technical system, that the traditional relationship between humans and machines, in the broad sense of the term, has been strongly altered. And it should be noted that this impact continues to be more and more intense as new applications of information technologies, in general, and automation and control technologies, in particular, advance.

One of the results of this increase in automation and control technologies is the emergence of new behaviours of both humans and machines that involve new balances of the mutual influence between technologies and society and that justify to revisit the traditional vision of the role that automation technologies play in our society.

Thus, ambient intelligence, infotronics technologies, embedded technical intelligence into processes and products, traceability, … are such applications of advanced technologies that come in useful for our society but whose impact implies to be deeper understood in order to be aware of their potential issues on society.

In this perspective, the evolved knowledge of the relationships between humans and technologies allows further research activities so as to encompass all issues and topics of the social impact of automation technologies when these ones become more and more ubiquitous and surround more and more Humans for any use, at any time, at any place (Zaremba and Morel, 2003)(Morel and Grabot, 2003)(Moutinho and Heitor, 2006). Thus, the study of this impact is at the core of system approaches as techno-centric approach, socio-technical approach or human centred approach (Carew *et al.*, 2007) in order to address all the aspects of the relation of automation to social environment and more particularly, the application of the potential of advanced technologies and, in particular, of control and automation technologies to the full benefit of humans and organisations (Martensson and Cernetic, 2002).

In this perspective, systems thinking paradigm is challenging both academic and industrial communities for a better efficiency of information technologies in the human interaction loop and for a better characterisation of how both human and technologies interact with each other's.

Aware of this unquestionable fusion between automation technologies and society, it can be noted that the different concepts highlighted by theses systemic approaches allow to strengthen the link between a social look and a technological look when designing an automation technology as a complex "human-machine" whole in order to restore socio-technique equilibrium.

To that end, systems engineering approaches (INCOSE International Council on Systems Engineering http://www.incose.org/) establishes practices to support different skills and abilities to engineer these complex systems as a whole of automation technologies and human behaviours within socio-technique systems and the society in large.

This led us to organise this paper as follows. Section 2 lists some recent realisations of these complex systems and their trends and issues are discussed. Section 3 stresses that there is a need to engineer an automation technology as a whole integrating both its social and technological aspects in order to improve its relation to its social environment and

underlines the perspective of an Human centred systems engineering as a rationale approach for social impact of automation issues. Section 4 presents the current and the future research activities of the IFAC technical committee on "social impact of automation" in order to encompass this new trends. Conclusion and references follow thereafter.

2. TRENDS AND ISSUES OF AUTOMATION TECHNOLOGIES

One of the major impacts observed in the application of technologies is related to the intensification of the mutual relationships between the men and technologies and the fact that this intensification seems not to have limits having regard to the unlimited capacities of technologies.

In order to make visible this interaction between Humans and hidden automation technologies, new concepts are challenging automation engineering in order to safe and secure these ubiquitous relationship which could infer non-deterministic behaviours (Nof e*t al.*, 2006) (Jämsä-Jounela and Zühlke, 2006).

Thus, the "cognitive car" (Heide and Henning, 2006) is a new innovative concept that constitutes a relevant example of the unlimited capabilities of technologies, which are expected to be providing by automation to solve traffic organisational issues and to make roads safer by preventing human failures. The idea is to equip a car with advanced automation technologies so that it forms a technological system, which can perceive itself and its environment, being able to collect and structure information in an autonomous way, and being able to inform at any time the driver on the conditions of the traffic. The proof of this concept is under development by an interdisciplinary group of researchers from RWTH Aachen University (RWTH Aachen, 2004) in Germany who have drawn up the roadmap for such an innovative project.

The concept of "Ubiquitous action" (Bruns, 2006) is an other relevant example of making visible these 'hidden' technologies in order to better close the information loop between users and automation technologies. The idea is to create a continuum of information from reality to virtuality and vice-versa by the means of hyper bond graphs techniques supporting energetic and semiotic coupling between machines and Humans. Even if working prototypes demonstrate the potentiality of mixed reality for mechatronics systems (Bruns and Erbe, 2006), this vision opens up new fields of interest for cooperative control engineering to meet the complexity of this automation world where automata and Humans will interact at equivalent, interchangeable or reversal levels for holistic purposes.

Beyond these conceptual approaches emphasizing growing interaction between automata and Humans, applications are also addressing needs of a human-centred automation (Kraiss and Hamacher, 2001) in order to put the technology in its right place and/or to better exploit human experience.

Thus, mastering complexity of plant operations in order to help operators in critical phases such as start-ups and shut-downs phases of technical installations is a key subject for industrials. In (Galara, 2006), practical facts are related that underline the necessity to better link the representation of the physics of the process and the representations of the logic of the control by automata and Humans. Following previous works (Galara and Hennebicq, 1999), the proposal is to define and develop a slang operation language based on the formalization of the best professional practices allowing to efficiently distributing actions between Human and Machine with respect to physics criteria. Automata are in this vision only a means to support and facilitate a part of the plant operation control, which should be inferred through the systems engineering process when and not before, all the process behaviour is controllable by Humans.

This better exploitation of the knowledge of Humans on machines appears as a trend in order to bring together users and automation technologies with a coherent manner.

Thus, "trace based reasoning" (Mille, 2006) is a technique able to exploit traces of computer use as experience knowledge containers for contextual and situation based problem solving. This generalisation of the classical "case base reasoning" in artificial intelligence aims to reuse past experience in a systems engineering process in order to offer the possibility to build dynamically new case structures of interactions between Human and automation technologies.

An other way to reach to this aim in a system engineering change process consists in the use of the cultural aspect of interoperability issues for managing knowledge (Whitman *et al.*, 2006). Ontological issues aim to facilitate the interoperation of knowledge leading to true semantic interoperability in order to tackle non-technical issues with regards to technical ones (Panetto *et al.*, 2006).

But, over the perspectives of ubiquitous automation and the pragmatism of Human centred automation, some scientists, in particular in the IFAC Coordinating Committee 9 on 'social systems' (Dimirovski, e*t al.*, 2006) try to reconcile social sciences with engineering sciences.

But it appears that there is a too large polarisation between technically-oriented reasoning on one hand, and socially-oriented reasoning on the other in order to efficiently apply manufacturing technologies such as enterprise resource planning systems in less automated areas such as heath-care. As a way to address this bi-polarisation to systems engineering methodologies, Human centred systems approaches intend to efficiently joint three important concepts of design, development and deployment of large-scale information technologies and the organisation of Humans in order to establish a gateway between the social and the technical (Stapleton, 2003)(Stapleton, 2006).

Nevertheless, the crucial issue of a safe, secure and ethical society in regard to the increasing development and to the world-wide diffusion of technical installations (e.g. nuclear power production, chemical process plants) and socio-technical systems (e.g. civil and military aviation, high-speed earth-bound traffic) needs to be debate in order to make efficient the social impact of automation. As underlines by (Wilpert, 2006), ethical philosophical approaches are now necessary to be systematised to taking into account these aspects of automation in order to provide potential guiding

framework to justify technology and safety oriented decisions on the basis of ethical and moral standards.

All these issues and trends are as many relevant examples which show the undeniable contribution of automation technologies to the full benefits of our society but which show also their responsibility in the emergence of new human behaviours that develop the natural capabilities of humans.

3. HUMAN CENTRED SYSTEMS ENGINNERING CHALLENGE

The growing omnipresence of automation technologies in technical and socio-technical systems has progressively exacerbated their impact on humans in their every day life and on society in large. In turn, relationships between humans and technologies are becoming more and more knowledge intensive in order to better understand how these relationships are evolving, how they can be altered purposefully and involuntary, … (Bjelkemyr and Lindberg, 2007).

For that, human-machine systems and human skills based automation topics (Stahre and Martensson, 2004) are at the core of several research activities to study the effect of automation technologies on humans and vice-versa for improving knowledge on their mutual influence. These topics aim to make sense of automation technologies for humans by developing efficient links "human-machines". Others topics ranging from human centred engineering to ethical sciences are also in this way of thinking in order to encompass all issues and trends of the social impact of automation. But, the understanding of how automation technologies play a role with humans remains a complex process since the human behaviour is complex and this behaviour is extremely different when inferred by technologies that when not. This complexity is all the more strong because sciences that are concerned by these issues are traditionally away one from the other. In fact, control engineering has developed its own methods and techniques to automatically control the more and more complex behaviour of both technical and socio-technical systems and processes. And, on the other hand, sciences related to social systems aim to the same objective but with the human sciences perspective.

But this traditional way of thinking becomes less and less traditional when considering the need to reconcile automation technologies with, in general, humans and, in particular, their users, their designers, their engineers, … In fact, the need to restore socio-technique equilibrium in order to improve the social impact of automation addresses systems thinking challenges for better efficiency of these technologies in the human interaction loop and for better characterisation of how both human and automation tend to interact with each others. This challenge enlarges the traditional setting of both automation engineering and social sciences to a systems engineering approach in order to cope with the increasing complexity of integrating information intensive technologies and Human behaviour within socio-technical systems and society in large. As systems engineering is an approach that deals with the not only technical and/or complex aspects of a system, it can be argued that it allows to strengthen the link between a social look and a technological look when designing an automation technology as a complex "human-machine" whole (Fig. 1).

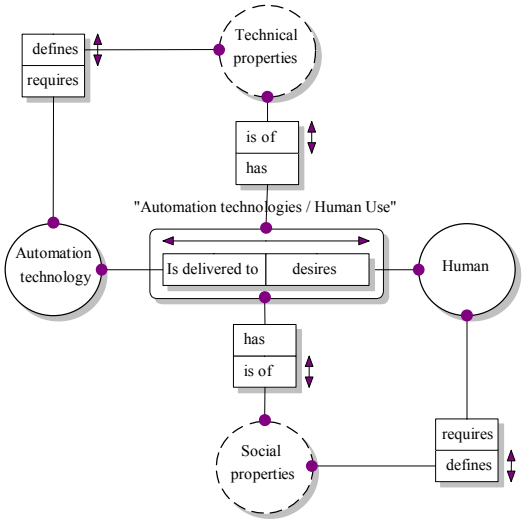

Fig. 1. Proposed model of a socio-technical automation technology using the Object Role Modeling method (Halpin, 1995)

As an emergence of human centred and systems engineering approaches, the human-centred systems engineering approach (Mayer and Stahre, 2006) aims to achieve this holistic vision of automation technologies in order to treat them within the human interaction loop emerging from the deployment of an ad hoc combination of formal and informal models of the complex behaviour of a real socio-technical system. Consequently, this socio-technical system can be considered as a system of systems (Maier, 1998) identified by both its societal and technical complexity and which exhibits particular properties as autonomy, collaboration, distribution, … To cope with this complexity, a system of systems could be noted as a candidate rationale artifact (Mayer and Auzelle, 2007) for human-centred systems engineering to bring consistency of the notion of systems to the couple automation technologies/humans. On this basis, we argue that human centred systems engineering approaches can establish practices to support different skills and abilities to engineer these complex systems as a whole of automation technologies and human behaviours within socio-technique systems and the society in large.

In conclusion, this new challenge of a systems thinking paradigm of socio-technical systems forecasts for the future to integrate automation engineering and human centred approaches (Samaras and Horst, 2005) into this human-centred systems engineering as a methodological approach to define, develop and deploy safe and secure ubiquitous automation as regards society.

As a consequence of this new challenge, education and training is a crucial way to help future engineers to understand this systems thinking paradigm and its conceptual foundations involving knowledge about complexity and systems approaches in general (Mayer and Morel, 1996) (Mayer and Lavigne, 2001) (Morel *et al.*, 2003) (Mayer and Auzelle, 2007). In particular, as any engineer is first a student

or a trainee, there is an inescapable need to help them to be aware of the social impact of the technical objects they design and engineer.

One main objective of such an education and training process is to break away from the current customs consisting in confine each science related to one aspect of the social impact of automation far one from the other. Our experience in our engineering school in organisational engineering shows that the combination of both social sciences and automation sciences can be put into practice (Fig. 2) in order to help students and trainees to grasp the conceptual framework of human-centred systems engineering concepts before to practice the combination of automation engineering and techniques and Human-centred approaches including approaches such as change management, learning theories, ethical issues, …

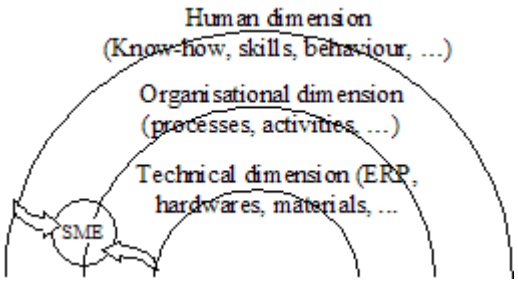

Fig. 2. Proposed education and training organisation (Mayer and Laroche, 2000) according to (Morel, 1998)

Recognising that the combination of both the social and the technical aspects of a same automation object led to a complex system, we assumed in our different research works that the different engineering areas involved in an Human centred systems engineering approach have to be taught and learnt according to the sound precepts and concepts of systems approaches needed for formally building a system as an "human-machine" whole in order to restore socio-technique equilibrium.

But, and it is perfectly evident, we must be aware also to not fall into the trap of an excessive use of education and training dedicated technologies which can led at the opposite of waited result. So, there is a crucial need to balance between e-learning and "face to face" education and training in order to emphasize the role and the benefits of information technologies in the relation between trainees and trainers.

4. CURRENT AND FUTURE WORKS ON SOCIAL IMPACT OF AUTOMATION

From the beginning of this triennium 2005-2008, this trend towards an Human-centred systems engineering approach to the issues of social impact of automation has been initiated within the IFAC technical committee TC 9.2 on " social impact of automation".

In 2006, the IFAC TC 9.2 in conjunction with others IFAC technical committees such as TC 1.3 on "discrete event and hybrid systems", TC 4.4 on "cost oriented automation", TC 4.5 on "human machine systems", TC 5.1 on "manufacturing plant control ", TC 5.3 on "enterprise integration and networking", TC 5.4 on "large scale complex systems", TC 9.4 on "control education", TC 9.5 on "supplemental ways of improving international stability" has organised the 9th edition of its series of ASBoHS (Automated Systems Based on Human Skill And Knowledge) symposiums with as guiding line to emphasize the different aspects of the social impact of automation for an adequate balance between pushing advanced automation technologies and their suitable use by e-society.

For that, the technical program of the ASBoHS'06 symposium has been defined in accordance with this objective by organising plenary sessions and regular sessions around main tracks in order to reflect the variety of forms that social impact of automation can take up. So, the 6 tracks was:

- Pacifying e-Automation and Human Capabilities in order to emphasize the changing behavioural complexity of Networking Enterprising inferred by e-Technology increasing capabilities with regards to natural behavioural Human capabilities,

- Collaborating e-Intelligence and Human Skills in order to emphasize the impact of Surface e-Intelligence emerging from cooperation between Human and Artificial Artefacts as well as between Artificial Artefacts themselves.

- Balancing e-Learning and Face to Face Education and Training in order to emphasize the role and the benefits of e-Technology in the relation between trainees and trainers.

- Ubiquitous e-Automation in order to emphasize the multiple aspects of e-Automation (Hardware and Software Artefacts), which has never been part of real life as much as today.

- Safe, Secure and Ethical e-Society in order to emphasize the multiple aspects of e-Automation in order to safe and secure Human in the e-Society and in order to respect an ethical balance in the relation between Human and e-Technology.

- Management of e-Technology in order to emphasize Human Networking through world-wide projects as a mean to manage the increasing complexity of e-Technology.

This symposium and the other actions of the TC (meeting, publications, working groups, …) (Mayer and Nof, 2006) (Mayer and Stahre, 2006) (Mayer and Stahre, 2007) are the concretisation of this new trend of the area of research of the committee and launch the activities of both the academics and the industrials involved at different levels in systems thinking paradigm and human-centred systems engineering challenges in order to make efficient the social impact of automation. This research activity on Human-centred systems engineering approaches progresses within the IFAC coordination committee CC 9 on "social systems" and has inter-relations with the others TCs of the CC9. Moreover, the content of this systems approach lead to the establishment of strong mutual actions with others IFAC TCs of the areas of control theory and technology.

5. CONCLUSION

It appears that the impact of automation on our society becomes more and more critical in the definition, the design, the development and the deployment of socio-technical systems in order to make efficient the role of advanced

technologies for their users. In fact, the actual applications of automation and the future ones as the "nomadisation" of people equipped with advanced technologies constitute new phenomena of beneficial change of our society where Humans will be ready to complete theirs tasks and to make correct decisions at any time and at any place. But, the need for better efficiency of the social impact of these technologies justifies to revisit the traditional way of thinking the mutual influence of both humans and machines in order to make sense of a real socio-technical complex whole. It is the human centred systems engineering perspective for a socio-technical equilibrium.

This is the challenge of the TC 9.2 for this triennium and for the next one just as of both academics and industrial communities. For that, TC 9.2 develops topics related to this advanced works for an Human-centred systems engineering:

- Systems thinking paradigms for an Human-centred systems engineering approaches

- Balance between pushing Automation technologies and their suitable use by the Society.

- Human-centred approach versus techno-centred approach in enterprise networking.

- Automation and safety and security issues in society.

- Education and training versus expansion of industrial and manufacturing systems.

- Automation of Human-centred systems and Society.

- Automation and machine-assisted thinking versus social security and development of society.

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