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IFAC 2002 Milestone Report for the area "SOCIAL IMPACT OF AUTOMATION"

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Abstract. Current status and forecasts are given for the IFAC subject area "Social Impact of Automation". Three broadly used approaches for dealing with these issues are identified: the traditional techno-centric, the human-centred and the socio-technical approach. From future trends in control and information technology, in society and in future impact of automation on environment, the main needs and challenges, as well as likely new applications for this area of discussion are derived. It is anticipated that the human and social aspects of automation will become in the future definitely more important than in the past. *Copyright © 2002 IFAC*

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1. CURRENT STATUS

1. a) Brief History of the Field

The field "Social Impact of Automation" addresses all aspects of the relation of automation to social environments. Officially, the field was "opened" in IFAC in 1971 by establishing a technical committee to deal with Social Effects of Automation. As stated by Withers and Rijnsdorp (1978), the initial aims were:

- to make all control engineers aware of social effects of their work,
- to involve a smaller group of interested people in a more thorough analysis of social effects and
- to provide information about new developments.

From the initial wider scope of open issues, work has been temporarily concentrated on the ideas of humanising work in manufacturing systems because of the wealth which the manufacturing sector created at that time for society. Part of endeavours for humanising work has been later focused around the Analysis, Design and Evaluation of Human-Machine Systems. This is also the title of a very successful series of symposia and conferences organised by another IFAC technical committee, called Human-Machine Systems.

Looking from the historical perspective, two important papers have to be explicitly mentioned because they can be considered as a sort of historic milestones in this field. The first one of these papers was written by Sheridan, Vamos and Aida (1981, re-published in Automatica, 1983). It explores the relationship between automation, human culture and society. The second "milestone" paper by Martin, Kivinen, Rijnsdorp, Rodd and Rouse (1990)

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discussed the appropriate approach to automation that is based on holistic consideration of technical, human, organisational, economic and cultural factors.

During the recent decade, the work in the field Social Impact of Automation is regularly reported within a couple of sessions at each IFAC world congress, at the regular symposium series of this committee ("Automated Systems Based on Human Skill"), as well as at occasional workshops of more or less regional importance.

1. b) Key Problems Addressed and Typical Applications

According to the current *scope of the technical committee* Social Impact of Automation (IFAC TC GES, 2001), the issues to be addressed include, but are not limited to:

- **social effects** of automation (i.e. effects of automation on issues such as: employment, work organisation, behaviour of people, culture, socialisation processes, norms and values, status and roles of people, wealth/powerty and other socially relevant issues);
- **socially desirable requirements** for the development of automated systems (criteria, guidelines, principles, standards and recommendations);
- **socially acceptable alternatives for design** of automated systems (a selection from best known paradigms, approaches, methodologies, good design practices, case studies):
- **environmental, health and safety implications** of automation (e.g. suggestions on how automation can help making advanced technology less hostile and less dangerous for the humankind and natural environment, how it can improve working and living conditions as well as increase safety at work, in transport or during any other human activities);
- issues of **engineering and business ethics, professional responsibility and public policy** with relation to automation (e.g. ethics in design, procurement and deployment of automation systems, ethics and responsibility in automation knowledge and control technology transfer, state regulations concerning export of automation systems to developing countries, role of worker/trade unions, etc).

The typical applications of Social-Impact-of-Automation concepts in the past were those where the consideration of these issues was seemed to be justified by some rational reasons. These applications include primarily large-scale and relatively complex systems, such as: Advanced (and Flexible) Manufacturing Systems, Aerospace (and Weapons) Systems, Air Traffic Control Automation, Automotive Control, (Chemical) Process Control and Transportation Systems.

1. c) General Approach Used for Solutions / Applications

Some different approaches, theoretical frameworks and points of observation (or perspectives) are used in dealing with the issues related to the Social Impact of Automation. Due to the interdisciplinary nature of this field, it may not be surprising that these approaches and frameworks have evolved in different professional environments, all with the aim to find proper solutions to problems that were perceived in different ways. The approaches mentioned here are able to cover almost all current key problems addressed in this field. Mainly they are used as guidelines, principles or methodologies for the design and development of socially appropriate automation (or information) systems. While in this chapter only the **basic approaches** are mentioned, the methodologies derived from these approaches are briefly described under the accomplishments and new developments in the next chapter (1.d). Looking from the very broad perspective, the following basic approaches are possible:

- the traditional techno-centric approach,
- the human-centred approach,
- the socio-technical approach and
- other approaches, such as, e.g. change-management approach, success-factors approach, different approaches of considering ethical issues, etc.

Each of these different approaches had its own evolution during the past two decades, but at a closer look, it can be seen that the approaches have often influenced each other. The traditional **techno-centric approaches** are rooted in the rationalist tradition of the Western scientific thought. Even the practitioners of the techno-centric approach acknowledge the importance of areas that are not subject to the rationalistic style of analysis. During the recent years, many extensions of such approaches have been made that strongly take into account the consideration of human and social issues.

The **human-centred approach** seems today to be dominating the design of socially appropriate automation systems. Karamjit S. Gill has very appropriately described the gradual evolution of this approach in his book "Human-Machine Symbiosis" (1996). This evolution went from the initial "human factors approach", cognitive ergonomics, human-computer interaction and user-centred approach towards the user-involved approaches. In the user-involved or participative design process, users and designers can cooperate through mock-ups or prototypes. This perspective considers design as being embodied in the work process, and attempts to support workers by providing skill-enhancing technological tools. These, in turn, enable the workers to learn by doing, to store their working expertise and even to optimise on-line their working practices. In shortest terms, the essence of the human-centred approach is probably best described by the search for finding the optimal operative symbiosis between the human and the control system.

The **socio-technical approach** builds on the Socio-Technical Systems Theory, which was considerably influenced by members of the London Tavistock Institute of Human Relations (Hanna, 1988). It focuses on analysing work processes that are strongly inter-related with the algoritms and structure of the control system to be designed. In this approach, any system composed of people and artefacts is basically considered as a "living system" which includes the notion of 'open cybernetic systems'. Such systems include humans with their working and other life activities. Specific feedback processes or loops stabilise and renew these open living systems (Brandt, Henning and Strina, 1999). The socio-technical approach offers to the designers of automation and other high-technology systems a congruent set of concepts, models, criteria and principles to guide the systems design process.

The so-called **other approaches** to dealing with the issues of Social Impact of Automation can be found in the literature as supporting efforts to assure that a control system and other parts of advanced technology are made more socially appropriate in specific phases of system development lifecycle. For example, some of the established change-management approaches can assist in increasing the acceptance of a new control or automation system by its users during the phase of system deployment (e.g., Sun and Riis, 1994; Endsley, 1994). On the other hand, consideration of success factors can help during the holistic design of automation systems (e.g. Tanaka, 1991), or to find out critical automation success factors in a specific cultural setting (e.g. Cernetic and Strmcnik, 1992). Further, still other approaches, like those about ethics, can help in education and in raising the overall awareness of responsibility of control engineers for socially appropriate technology (e.g. Schinzinger, 1998).

1. d) Recent Major Accomplishments and New Developments

Here some significant accomplishments contributed by researchers and practitioners in the field of Social Impact of Automation are briefly mentioned, to give the reader an outline of current state of the art. Part of these accomplishments and new developments relates to research (new insights, new or revised methodological elements, etc.), and part to practical studies or applications of approaches, methodology or criteria.

Before going to more specific new developments within the area of particular approaches, two important insights may be mentioned that are strongly related to the field of Social Impact of Automation. The first one relates to the wide **acceptance of complementary role of automation** and humans that has been expressed by M. G. Rodd (1993) in the following way:

> *"We are also rapidly realising the importance of automation, not as a means of putting people out of work but as a means of complementing human activities."*

The second important general insight developed during the last decade is the multilevel **structure of actors involved** in this field. This structure, in a sense orthogonal to the scope of the technical committee given in chapter 1. b), has enabled to classify in a clear way the multitude of relevant issues to be considered:

- the *individual* human operator at the work place (human-machine interaction and mental models, skills, motivation, health and satisfaction, creativity in problem-solving and design, quality of working life, safety, responsibility and blame)
- *work-groups* supported by technology (human communication, cooperation, participation in decision processes, decision-support systems, ...)
- *networks* of groups and enterprises, together with the supporting networks of information, control and transportation systems (computer-supported cooperative work, enterprise modelling and knowledge management, virtual enterprises, issues of reengineering of complex hardware and software, technology and quality management, "soft" modelling of enterprises, the Fractal Enterprise ...)
- regions and *society* at large (issues of national strategies, employment and qualification, change, education and re-learning, the roles of trade unions, gender issues, medicine, culture, conviviality and ethics ...).

In the following, some more specific accomplishments and new developments are given, structured according to the list of different approaches given before. Among the so-called **techno-centric approaches** that have been recently extended with consideration of human, organisational and social issues, two from the area of Enterprise Integration can be mentioned. For example, Theodore Williams (1999) reports on a methodology for determining the place of the human in any particular enterprise. This methodology was developed to fit into the existing and pretty comprehensive Purdue Enterprise Reference Architecture (PERA) as well as into the Generic Enterprise Reference Architecture and Methodology (GERAM). Another similar example comes from the joint Europe – USA initiative (ICEIMT, 1997) for improving the methodologies for enterprise integration. Reported by Kosanke and Nell (1999), this work deals with representing humans in the operation of virtual and extended enterprises and appears to be another step towards a better consideration of human issues in complex organisational systems supported by Automation and Control Technology (ACT).

Within the group of **human-centred approaches**, several new developments can be mentioned. In his previously mentioned book "Human-Machine Symbiosis", Karamjit S. Gill (1996), as principal author and editor, has summarised the European experience on the human-centred paradigm of systems development. The book begins with systematically introducing the foundations of human-centred systems and continues with theoretical-methodological, philosophical and practical discussion of this interesting paradigm. The book concludes with a report on a human-centred development of a commercial software system, proving that using this system development paradigm is not only to the benefit of the human user, but also economically viable. Next, Matsunaga and Nakazawa (1999) report on the human-centred development of an adaptive human-machine interface that is able to match human satisfaction. As a further example, Brandt and Cernetic (1998) discuss some practical issues of using the human-centred approach and some respective methodological elements for the design of ACT and other advanced technology systems in several European countries. Finally, Brandt, Tschiersch and Henning (2001) give a wider presentation of human-centred manufacturing systems design in its socio-technical context. This presentation is illustrated by a series of case studies from industry, service sector and research, again representing several European countries.

There are also a couple of new developments to be mentioned from the group of s**ocio-technical approaches**. In his extensive paper, Chris W. Clegg (2000) has presented and explained a complete list of 19 principles of socio-technical design. His list represents an extension of earlier formulations and is grouped into three highly inter-related categories: meta-principles, content principles and process principles. These principles may present a challenge for multidisciplinary teams to try them in the design of complex automation systems.

A similar and significant new development from the group of socio-technical approaches was reported by Grote and her co-workers (1995). They have systematically elaborated and tested in some industrial settings a socio-technical framework (called KOMPASS) that supports the analysis and development of automation systems. The KOMPASS framework comprises a method, including a set of criteria and guidelines that supports the system development team in finding the best possible design solution with regard to complementary capabilities of people and technology. The framework of KOMPASS as well as its underlying theoretical and practical aspects have been extensively described in a couple of books.

The next two new developments reported here are both well connected with the socio-technical design paradigm. First, the paper by Lena Martensson (1999) gives a discussion on opportunities available to process control operators and aircraft pilots, in order to be in control of complex systems. After reviewing available theory and design guidelines, and a brief account on six empirical case studies, the author concludes with some general guidelines for designing complex systems that may improve the safety and productivity of such systems by providing their operators (and pilots, respectively) with more opportunities for developing real operational competence. Second, the paper by Dietrich Brandt, Klaus Henning and Giuseppe Strina (1999) presents a human-oriented strategy for modelling modern enterprises and their business processes. That strategy has evolved from the practical applications and is rooted within the socio-technical system theory. Further, this strategy is expanded with concepts from the Language-Action Perspective (the basis for work-flow modelling and CSCW), the Dual Design Approach (Brandt and Cernetic, 1998, pp. 10-16), chaos theory, simulation games, mental models (Fuchs-Frohnhofen et al., 1996) and reverse/forward engineering. It is considered that all these new developments will help to design ACT that will be more human-centred and socially appropriate, without sacrificing the issues of economics and competition which are important driving forces in the globally open business world.

2. FORECASTS

2. a) Needs, Challenges, Opportunities

The developments discussed previously indicate that the needs, challenges and opportunities for the field "Social Impact of Automation" were changing with a fast pace during the last decade. Future trends can be seen in three directions:

- future *trends in technology*,
- future *trends in society* and
- trends in the future *impact of automation on physical environment* (i.e. space around people).

The technological perspective of trends is based on a selection from the possible **future directions of development in ACT**. These trends were, in part, extracted from the conclusions of the recent IFAC Technical Board Working Meeting (IFAC TB WM, 2001), from the Memorandum on the World Engineering Convention (WEC, 2000) as well as from some other sources. Similarly, the societal perspective is based on a selection of recent findings about the **future of work, future of organizations and future of societies**. These are taken from many different sources of which the papers by Meyer-Krahmer et al. (1998), Bullinger (2000) and Shackel (2000) may be specifically mentioned.

The impacts of ACT and other advanced technologies are exponentially growing, not only concerning the number of involved people (and the levels of involved social entities), but also concerning the physical space to be influenced. For instance, one may think about how automation – in different physical forms of advanced technologies – has influenced many aspects of the more or less immediate physical environment around people. All these influences are not directly aimed at any (living) social entities, but are nevertheless of great human and social concern, so that they are becoming a source of needs within the discussion area of "Social Impact of Automation".

Due to space limitations, these three lines of trends cannot be reproduced here, so the reader may look for them in the survey paper by Cernetic, Strmcnik and Brandt (2002) that is properly complementing the statements given in this Milestone Report. Elaborated from these trends, the following is a brief extract of **needs and challenges** that deserve to be discussed and solved within this area in the future:

- how to design and deploy very complex and very large ACT systems so that they are still appropriate for the human and for the society;
- how to handle the so-called "ubiquitous automation" for supporting work and leisure so that it will integrate as naturally as possible into the lives of people;
- how to provide, by means of automation, more safety for people who are using (or are exposed to impacts of) this advanced technology; particularly in cases of intentional sabotage or heavy abuse of technology;
- how to cope with the rising rate of unemployment that, again, is often caused by the increased use of automation;
- how to keep a balanced emphasis on all vital socio-technical aspects of automation, with regard to emerging advances of this technology, changing needs of its users, as well as emerging social, economic and political issues;
- how to continuously persuade and motivate control engineers about the long-term benefits of applying these principles and approaches in designing ACT systems;
- how to maintain and disseminate (a publicly accessible archive of) records of successful applications of balanced, human-centred, user-friendly and socially desirable ACT systems;
- how to find synergy among competent people in enterprises as well as professional organisations (such as IFAC and IEEE), with the aim to give these issues higher priority in professional discussions and in actual decision-making about policies, strategy and guidelines;
- how to maintain a proper balance in discussions within this field between having a necessary wide perspective of issues and disciplines and, on the other side, preserving the identity of this field within IFAC (or in other words, preserving the focus on applying the vast variety of knowledge from the other disciplines for better *automation* systems);
- how to raise the responsibility and awareness of users, managers, investors and stakeholders about the importance of these issues, with the aim that all these people will be: a) able to request from ACT providers systems that are complying with the socio-technical and human-centred design principles, b) ready to participate actively in developing socially appropriate requirements for such systems, and c) willing to pay a higher price for such systems, taking into account their greater long-term benefits.

2. b) Anticipated New Developments

A couple of new developments can be anticipated that will either have a strong impact on future research and development activities within the field of "Social Impact of Automation" or will gradually come out as results of these activities, both driven by current trends and future changes in technology and society. The social impact of these developments will have combined (compound) effects due to their mutual influencing.

First, the **areas of ACT with dominating impact on society will change**. This will have to do either with the fact that more people will come into closer contact with ACT, or this technology will have deeper social consequences. If in the past the production and military technology had the greatest impact on society, this emphasis in the future will go to the favour of greater use of ACT in other sectors. The main types of such technologies are given in the next chapter.

All these new technological applications of control systems will presumably have higher levels of intelligence and automation than it can be imagined today. Due to the abundance of embedded ACT and its widespread use by non-specialists, it will be extremely important that its functionality, human-machine interfaces and safety of such sstems will be designed such as to guarantee best possible human (customer) satisfaction and acceptance, as well as a fairly high degree of social appropriatedness.

Second, related to the forecast above, it is most likely that the criteria for human-centred and socially appropriate automation will become regular (if not even a requested) part of **requirements and functional design specification**. It can be expected that some ACT providers themselves will become interested to meet criteria for human-centredness, in order to be able to offer their customers better and more reliable control systems than their competitors. This will imply (if not even require) the **inclusion of a greater number of actors** into the design, deployment and procurement of future control technologies.

The third new development may be mentioned here that is aimed at improving the impact of advanced technology upon the natural environment. It can be hoped that the advanced technology itself, in particular the ACT, will be used in the future for **supporting sustainable development**, either directly or indirectly. This will probably occur as a consequence of two parallel trends: on one side, due to rising (ethical) awareness of individual engineers and other people responsible for the lifecycle of advanced technologies, and on the other side, due to a greater number of public regulations to do so.

2 c) Likely new applications

In relation to the anticipated new developments discussed in the previous chapter, it can be assumed for the future that the knowledge being cultivated within the field of "Social Impact of Automation" will be applied predominantly in the following types of ACT applications where the essential functions will be supported by various types of automation, decision-support and control subsystems.

a) Design of complex and/or large human-machine systems; here the term "complex" means any combination of the following attributes: great number of elements and relations, large size, high risks, variability of conditions, conflicting needs, novelty of solutions, trans-cultural implementation, etc. **Examples**: highly automated industrial processing or manufacturing plants, large trans-continental aircrafts, great ships, large off-shore oil-drilling platforms (like "Hibernia"), regional power plants, etc.
b) Design of advanced-technology systems having significant impact on a wider human population, either in regular operation or in case of potential failures, regardless whether the failure is due to the human, to the technology or to any other possible reason. **Examples**: military systems, large power-transmission systems, regional or global communication networks – all these systems implemented with an extensive amount of ACT.
c) Design of advanced technology systems controlling or strongly influencing: health of humans, security of people and property and preservation of natural environment. **Examples**: intelligent medical systems, sophisticated access-control and protection systems, pollution-prevention functions based on ACT, waste-water treatment plants with advanced control algorthms and decision support based on mathematical modelling, etc.
d) Design of automation, control or decision-support systems embedded in intelligent appliances produced in large series and used by non-specialists. **Examples**: intelligent vehicles and individual transportation systems, intelligent home appliances, home robots and other advanced comfort-enhancing functions in buildings, smart professional and hobby tools or machines, equipment for leisure and entertainment, such as e.g. those for playing robot soccer, etc.
e) Design of automation, control or information support for safety-critical (high-risk) systems, i.e. those that have (geographically) wide and highly undesirable consequences in cases of uncontrollable malfunction, abuse or natural disaster. **Examples**: nuclear plants, production of explosives and toxic or highly inflammable chemicals, cultivation of genetically modified biological material, intensive health-care or surgical support systems, etc.

2. d) Future Prospects

It can be envisioned that the traditional problems related currently to the social impact of automation will gradually grow over and beyond the original scope, towards both, the global impact of ACT as well its more direct impact on human individuals regarding their ways of living and working. Most probably, this will have wider – maybe still unforeseen implications and consequences for the socio-economic systems and the planet Earth. As also the professionals dealing with information and communication technologies and other advanced techologies increasingly recognise the significance of human and social issues of technology (see, for example IEEE SSIT, 2002), it can be predicted with a fair amount of certainty that the field of Social Impact of Automation will gain much in the importance in the future decades. It may be even argued that a better knowledge of these issues will contribute to another, still more significant breakthrough of automation and control systems into everyday work or life of individuals and organisations. Successful applications of human-centred and socio-technical design paradigms show that this can be done by helping the designers of ACT to exploit the massive potential of control theory and control engineering to the full benefit of humans and organisations.

In conclusion, it can be anticipated that the social and human aspects of automation will in the future definitely become more important than before because:

- ACT systems are becoming increasingly vital for regular functioning of many higher-level systems, e.g. in production, traffic and transport, medicine, living structures, energy production and transmission, national defence, telecommunications, various service systems, etc.
- ACT systems are becoming increasingly more complex and therefore more vulnerable in case of any failures, incidents or (natural) disasters.
- ACT systems are becoming increasingly more indispensable, powerful and influential, with greater (even global) impact on its immediate users, enterprises, societies and/or natural environment.

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