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Applied System and Control Sciences to Social Systems: Globalization Age Paradigms

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Abstract: Modern advanced information technologies resulting from automation of control and decision processes along with ubiquitous communications have a multitude of impacts on development of national economies within the global economy. Thus all kinds of social systems, being essentially human centred systems, is a cross-, inter- and multi-disciplinary challenge to systems and control researchers. Social systems in modern civilization are reviewed from the systems science viewpoint and on the grounds of recent developments in control science and technology and with regard to globalization paradigm. The innovative systems approaches employing results from hybrid systems theory and dynamical networks are needed to address the now-old challenges of combined knowledge and technology transfer world-wide for sustainable development that may remedy climate change and some of the negative socio-economic aspects of globalization.

1. INTRODUCTION

In 1736, it must have been totally unconceivable at the time what the graph based (Figure 1), solution to path-finding through bridges in Koeningsberg (Kaliningrad) of Leonhard Euler (1707-1783) might had cause or invoke in the future to come in mankind's science and technology up to nowadays. Yet it has long been recognized that graph theory evolved in time to reflect better the reality of social interactions in groups and organizations, in particular, as A. R. Radcliffe-Brown (1940) has written in his article "On social structure".

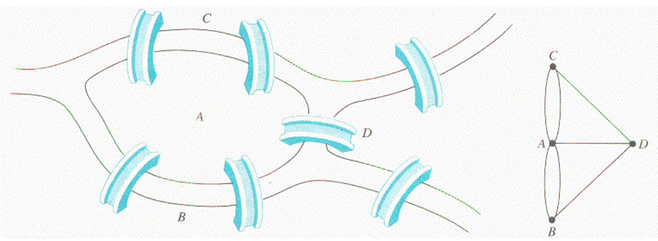

Fig. I. The 1736 path-finding problem with non-repeated path segments of Leonhard Euler (Rosen, 1999, p. 476).

Euler's multi-graph has evolved into an entire discipline (Logofet, 1993; Rosen, 1999) the most recent advances in which (Erdos and Renyi, 1959, 1960; Fax and Murray, 2004; Forester, 1992; Harrary, 1969; Kilgur et al, 1987; Sandberg, 1974; Watts, 1999) are tied up to the control of complex agent based systems and to the dynamical networks (Aizerman et al., 1977; Siljak, 1978; 1991; 2006; Tanner et al, 2002; Tao et al, 2008; Wang 2002).

The 2002 UNESCO publication *Encyclopaedia of Life Support Systems* (EOLSS) has been marked by the statement: "... a comprehensive, authoritative and integrated body of knowledge of life support systems. It is a forward-looking publication, designed as a global guide to professional practice, education, and heightened social awareness of critical life support issues…". The definition begins with the sentence "A life support system (LSS) is any natural or human-engineered system that furthers the life of the biosphere in a sustainable fashion". It should be noted that the quality of human resources is defined via education, health, poverty, disadvantaged people and human resource management. Furthermore, one of the six goals forming the basis for the design of EOLSS reads "… to elucidate sustainable development, peace, justice, equity and global security…", which clearly supports the stated title of this milestone overview report.

The research curried out by IFAC community in the broad arias of expertise covered by researchers involved in the activities of the technical committees within the coordination committee on Social Systems are supposed to give some of the answers, and even more so: considerable promising hints on how to address the underlying problems of mankind on a global scale of Earth. This way they, it is believed, will contribute substantially to a sustainable and non-endangered development of our only one world. It is their responsibility to "bridge the gap" between Figure I in the individual perception of Euler and the collective perception by OUN-UNESCO on the complexity interacting natural system (environment) along with the human system (coupling cycle individuals-government-society) and the built system (interacting economy-infrastructure). It is important to note, however, during the last 2-3 decades the global ecosystem has been so much impacted by destructive human loads that it has already reacted by patterns of global warming and climate change as well as disasters caused by impact of human societal communities (UNESCO, 2002; USGS, 2003).

Social systems observed in this study are all hybrid and large-scale, i.e. socio-economic and sociotechnical, thus their control strategies employ both numerical and linguistic information processing. Yet, the overall system must remain structurally stable in the first place hence the controlled systemic structure must retain its reachability (Siljak, 1991). Numerous methods and techniques have been developed to study “static properties” of complex control systems (Siljak and Zecevic, 2005) that go beyond reachability, including structural controllability, structurally fixed modes, and almost invariant subspaces, as well as structural decompositions of hierarchical and weak coupling variety (Siljak, 1991).

Recently, there has been a growing interest in using system graphs in “active roles” to manipulate interconnections in a network of agents to achieve desired properties and performance of the overall multi-agent system. A dynamic adjacency matrix was added to a multi-agent system in (Tseng and Siljak, 1995) to set the interconnection levels among the agents that result in a pre-assigned equilibrium. Time- and state-dependent changes of adjacency matrices were used by Feddema et al (2002) to determine if and how communication failures affect input reachability and stability of multiple cooperative robotic vehicles. Formation control graphs have been introduced by Tanner et al (2002) to model the control-related interconnections among the agents and achieve input-to-state stability in a string of leader-following agents. Fax and Murray (2004) made the use of formation graphs to obtain information exchange strategies which are robust to changes in the communication structure. Assuming that state agreement among agents is reached if states of the agents converge to a common location in the state space, Lin et al. (2005) have shown that such a state can be achieved by a switching control if the interconnection graph is sufficiently connected over time. Tao et al (2008) and Zhong et al (2008) solved respectively the exponential synchronization stabilization of complex delayed dynamical networks with general topology and also the adaptive synchronization of a case of delayed complex dynamical network is.

Social systems observed in this study also involve conflicting interests and competition hence dynamic game theory. Thus the non-cooperative game theory, including Nash equilibrium and Stackelberg incentive analyses, seems to provide the other general framework for agent-based complex systems and applications (Basar, 1986, 2007; Basar and Olsder, 1999; Eeckhout, 2000; Harsanyi, 1977; Sargent, 1993; Stirling, 2003, 2005; Stirling and Frost, 2005; Shubik, 1982). Still, given the needs for linguistic information and reasoning based conclusions, the computational kinds of representation models and processing techniques (Dimirovski, 2008; Gertler, 2007; Kacprzyk, 2006; Tseng and Siljak, 1995; Wang and Archer, 1998; Weiss, 1999; Yager 2004, 2006; Zadeh, 2006; Angelov et al, 2006) ought to be employed in addition to these two general yet mathematically rigorous frameworks (Dimirovski et al, 2006; Yang et al, 2006).

It is emphasised in here due to the paper limits, nonetheless, I had to drop out all the mathematical representation models as well as almost all the illustrations. The rest of this keynote survey is written as follows. Section 2 sheds an innovated light on scientific understanding of the hidden background of nowadays social systems and underlying phenomena that affect control and coordination in social systems. Section 3 presents some of the current key problems and establishes the main trends. Section 4 discusses recent major achievements and forecasts for the likely future trends. Conclusion and references follow thereafter.

2. INNOVATED UNDERSTANDING OF CONTEMPORARY SYSTEMS OF HUMAN AND SOCIAL BACKGROUND

2.1 A General Systems and Control Based Insight

It has been known since the early days of cybernetics that systems and control science can be indeed effectively applied to socio-economic and socio-technical systems (Brandt et al, 1999; Cestnut, 1984; Cuénod and Kahne, 1973; Dimirovski, 2001a; Stahre and Martensson, 2004; Stinchcombe, 1990), which make a category of systems that are human and society centred. This is so because systems and control science (Beniger, 1986; Buchanen, 1982; Gardner, 1985; Haddad and Chelebona, 2005; Forester, 1992) can be used to solve diverse problems (Gibson and co-authors, 1997) of decision, control, management, planning, and stability of organizational systemic structures (Arrow and Hahn, 1971; Arrow, 1990; Coales and Seaman, 1995; Gentil, 2004; Gertler, 2007; Giocoechea and co-authors, 1982; Kilgour and co-authors, 1987; Pete and co-authors, 1998; Schefran, 2001; Verndat, 1996; Wagner, 1994; Zaremba et al, 2004) that emanate from contemporary civilization and all of its life sustaining activities. As pointed out by Mansour (2001, 2002), this describes a rather broad category of systems that ought to employ qualitative modes too hence these are not amenable to pure mathematical modelling and pure maths-analytical study but rather to a consortium of relevant scientific disciplines and methods (also see Bitanti and Picci, 1996; Dormido and Morilla, 2002; Dormido, 2006; Jamshidi, 1997; Martensson and Cernetic, 2002; Neck, 2003; Romanovsky et al, 2004; Vlacic and Brisk, 2001). Yet, Siljak's methodology of *dynamic graphs* (2006) and dynamical networks as well as Nash-equilibrium non-cooperative games provide a general framework for guaranteeing the overall system design remains structurally stable (Matrosov, 2000; Siljak, 1978; Siljak and Zecevic, 2005). This in turn implies that the controlled plant retains its reachability, while allowing for employing compatible models as appropriate to solve control issues at various level of the coordinated decentralized systemic structure (Siljak, 1991). Nonetheless, it seems the issue of the non-causality of human-centred systems cannot be rigorously incorporated into the existing representation models, methods, and theories (Dimirovski et al, 2006) for now.

Indeed, to this date, many system science based studies related to social systems have assumed as such a fixed stable background per-ce, which implies that a number of society factors can safely be overlooked or cannot be accounted for by quantifiable methods. This also demonstrates, however, how crucial are structural properties such as reachability and structural stability (Siljak, 1978; 1991). However, assumptions that imply a static system model and environment are *unsound*, particularly if these assumptions are contrary to the facts. *Sound assumptions* have to observe: (i) The global environment is changing (e.g., per capita resource availability is declining); and (ii) If not addressed, these factors may exacerbate international instability and could trigger new forms and modes of global and regional instability. For instance, many actions, undertaken globally in the 20th century, to reduce socio-economic imbalances postponed problem solutions rather than creating alternative social behaviour likely to reduce underlying problems. At the same time, modern media has raised personal expectations for more people than ever before.

2.2 A Status Review of the Relevant Social Systems Area

Although the social impact of automation on the modern civilization of mankind has been enormous during the past decades and considerable investigation has taken place (Beniger, 1986; Martensson and Cernetic, 2002) the contemporary shift towards agent-based systems emphasizes the paradigm of various sorts of knowledge-based systems (Mayer and Nof, 2006). On the other hand, globalization has faced the contemporary civilization with a remarkably negative civic reaction, in particular with the red to issues of the climate change and the gap “developed-developing” (“North-South gap”), which is growing and expanding rapidly as the actual globalization process develops and as the related political and scientific discussion forums expand (Kile, 2001, 2005; Kile and Dimirovski, 2008; Kopacek and Stapleton, 2004; Kopacek, 2006). This negative civic reaction is not only internationalized, but getting more and more organised so that rumors about any kind of anti-globalization movement spread world-wide. Yet, it might be argued that the process of world-wide interaction and integration of economies (Eeckhout, 2000; Glenn and Hannan, 2000; Ljungqvist and Sargent, 2000) and other life-sustaining activity areas of the contemporary societies (Dimirovski et al., 2006) is the current and inevitable stage of the historical development of mankind with prevailing paradigm of cruel competition (Arrow and Hahn, 1971; Axelrod, 1997) actually. Moreover, it can be argued that it has been so due to the impact of information-based technologies within which control and decision technologies play a crucial role (Brandt and Cernetic, 1998; Dimirovski and Andreeski, 2006; Kacprzyk, 2006; Kopacek, 2002, 2006; Kosko, 1993; Luenberger, 2002; Special issue on Neural Networks, 2001; Neck, 2003; Stahre and Martensson, 2004; Stankovski et al., 2006; Zimmermann, 1991).

It may well be argued that, nearly twenty years after the end of the so-called bipolar world during the Cold War era, world-wide general public awareness is shifting towards a rather critical perception of modern civilization as a unipolar world (Kile, 2005; Schefran, 2001; Wagner, 1994) endangered by negative global consequences such as environmental pollution, global warming, the so-called “north-south gap”, and terrorism. Even some kind of global dictatorship cannot be excluded, the systemic structure of which remarkably resembles such known events in developed countries in the not so distant past (e.g., see Mansour, 2001; 2002). One reason for this development is the fact that modern civilization is largely European lead, on the grounds of past colonial expansion, with western oriented legal systems prevailing almost world-wide. This has left a heritage of so-called “developing” or Third-World or “disadvantageous” countries.

Nowadays, more than ever before, the responsibility of scientists with respect to society world-wide, in general, and developing countries, in particular, is rightly justified given the actual behaviour of modern civilization within the societies for which the society legislation continues to expand incomparably faster compared with the ethics of individuals, groups and societies as argued by Mansour (2002). For, according to Bertrand Russell (1945, 1975), a fundamental concept in social science and philosophy as well as in human societies is *power* with its many forms: civil authority, military, propaganda, secret service, clergy, and – above all – wealth. This fact of existence and the need for competition in human societies (Arrow and Han, 1971; Axelrod, 1997; Eeckhout, 2000; Simon, 1984; Sterman, 1989, 2000) as well as other factors of western social philosophies, largely adopted world-wide, are inducing potential for conflict thus producing social system behaviour and structure resembling inefficient non-cooperative games (e.g., Kilgour and co-authors, 1987 a, b; Myerson, 1991).

3. SOCIO-ECONOMIC AND SOCIO-TECHNICAL SYSTEMS WITHIN THE GLOBAL ECOSYSTEM: OLD NEW KEY PROBLEMS

3.1 Some Preliminary Remarks

It may well appear that the key problems of concern are of a somewhat “new-old” nature more or less. For, these are focused on known ideas of using selected branches of control system technology (Cuénod and Kahne, 1973; Dimirovski and Istefanopulos, 2004; Dimirovski, 2007; Kopacek, 2004, 2006; Sgurev and co-authors, 2004) to address issues and find some solution in areas like the following: improving business processes; increasing the economic efficiency of manufacturing production while saving energy and reducing environmental pollution; enhancing progress in developing countries; improving international stability; using systems and control education to assist more efficient society development and so on. Yet, during this triennium the world was shaken by a number of disastrous events like spreading SRS-infection, catastrophic Tzunami, apparent polar ice melting and oceans level rise. In fact, at last the global warming and climate change has become an acknowledged general alert as the non-governmental and even governmental forums show. The global ecosystem has finally been assigned proper importance and attention by the entire world.

Based on developments cited above and on global modelling research, a set of minimum conditions for sustainable global social stability in compliance with the global ecosystem have emerged (Kile, 2006; Kile and Dimirovski, 2008). These involve the qualitative variables that pre-condition all on this Earth: (1) Reduction of population and consumption to sustainable levels; (2) Balanced demand for resources with the supply of resources; (3) Re-establishing and maintaining environmental stability; (4) Avoidance evolution of zero-sum societal games to negative-sum games; (5). Reducing the economic inequality to sustainable level; (6) Build-up of social participation for underemployed people. Some may disagree with such an importance to factors (5) and (6). However this graph and its adjacency matrix are completely and tightly coupled, and moreover it is not possible to assign objectively the coupling coefficients and/or time delays among the factors because the viewpoint of each analyst is biased by his/her participation in the system. And there is no "neutral" viewpoint from which to evaluate the linkage arcs in this graph.

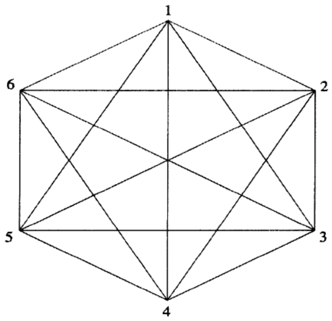

Fig. II Graph representation of the interconnected, highly interacting, factors for sustainable global social stability (Kile, 2006; node variables in the text).

Clearly, absolute equality is not realistic, yet at some level, the perceived inequality tends to destabilize societies towards dramatic events with long lasting consequences. In the recent past, many social interactions have been experienced as zero-sum games. If interactions become too competitive (e.g. like demand outpacing supply), competition can become a negative-sum game and lead to destructive behaviours (crime, terrorism, war and their combinations). Clearly, these minimum stability conditions will be difficult to achieve. But the alternative to a workable modus operandi and a move toward sustainable stability seems to be a spiral towards a contest of all against all, leading to global conflict. Meeting these challenges call for a new commitment of all societies, all people to work together for socio-economic and environmental stability as a viable path to a meaningful human future. For, only guaranteed fairness, justice and freedom for all countries, individuals and societies do represent perspectives and not just words.

Contemporary mankind societies are challenged to develop now cooperative behaviour patterns which do adapt to the global ecosystem and not vice-versa any longer. The ecosystem, albeit strongly interacting with societies, is a passive actor that can only react to how it is being used only a certain threshold hold has been surpassed but then its reaction may be beyond recovery. The way the global ecosystem has reacted in the past couple of decades strongly is seen in the patterns of global warming and climate change. Yet, ironically, if the global ecosystem fails, all societies will fail as it has already happened time an again on various parts of the globe if a regional ecosystem fails, the society associated with that ecosystem shall also fail one way or another.

Contemporary competing socio-political and religious doctrines are linked with relatively inflexible social doctrines, regrettably. Discussions of human survival should emphasize flexible aspects within competing systems to foster accommodation among doctrines. Can divergent social and religious groups, societies with confronted interests, cooperate in navigating through this dilemma? Their cooperation is indispensable in establishing a new social paradigm not seen before in the history of mankind but always dreamed of. For, a single uncooperative group might bring the world to destruction by suboptimal behaviours. In an era of suicidal behaviours so often applied world-wide this possibility cannot be overlooked.

It appeared that current problems are less due to the fact that mankind's bipolar world has disappeared and a multi-polar one has not yet been created, but rather due to an interim series of ongoing transition crises worldwide. Moreover, considerable opposition against the globalization process has been generated despite the fast progress of global networking of societies and all aspects of their life-sustaining activities: from banking and financial processes to manufacturing and production and further to communication and transportation. Another reason for this situation is a generic one: in some cases, phenomenological system identification has found successful applications to human and society centred systems (Dimirovski, 2001 a; Mansour, 2001, 2002; Russell, 1975), and it appears that not all system and control theories are equally applicable.

3.2 An Overview of the Key Problems

Ideas of using knowledge from control theory in economics in order to analyse and design systems in decision making, management and planning (e.g., see Gibson and co-authors, 1997) have emerged in the early days of cybernetics and later developed in several scientific disciplines and technologies (Levin and co-authors, 1992). The area of socio-economic systems, in particular banking and business processes and enterprise organizations as well as their operations, recently have undergone fundamental changes: (a) On the one hand, they are becoming more and more transnational due to capital mobility and global networking (e.g., Dimirovski, 2007; Glenn and Hannan, 2000; UNESCO, 2002). (b) They begin to employ highly sophisticated decision support systems (e.g., see Luenberger, 2002; Kosko, 1993) based on computational intelligence (Special Issue on Neural Networks, 2001; Zimmermann, 1991), and they shift towards networks of co-operating or competing small-and-medium enterprises (SME; Kopacek, 2004 a). Apparently, new paradigms nowadays characterise these socio-economic system structures, and this is a rather strong trend likely to continue for quite some time (Neck, 2003).

In the case of SME, in particular, increasing the enterprise efficiency, flexibility, and market responsiveness to adjust to requirements of modern supply chain dynamics and the respective management is closely related to the problems of improving the business process. It should be noted that in the area of decision and control for economic systems and business processes as well as modelling of the respective dynamics, a deep shift towards computational intelligence methods (e. g., see Kacprzyk, 2006; Kasabov and Filev, 2006; Pete and coauthors, 1998; Special Issue on Neural Networks, 2001; Wang and Archer, 1998; Yager, 2004) is under way, along with the newest theoretical advances in methodologies for dealing with perceptions and "computing with words" (Zadeh, 2006) in computing machines. Moreover, these developments are likely to lead to new uses of qualitative information in decision and control techniques for systems with a distributed information base and partially decentralised control system architectures. In addition, increasing economic efficiency of production in manufacturing while saving energy and reducing environmental pollution (Bernhardt and Erbe, 2002; Zaremba and co-authors, 2004) corresponds directly to decision and control for business processes and economic systems.

Over several decades, there has been a high level of research interest in developing methods and models based on system and control science for applications to manage risks and improve international stability within the setting of a dominantly bipolar world (Coales and Seaman, 1995; Kilgour and co-authors 1987). The current globalization process, however, has opened new and challenging problems in the transition to a multi-polar world and the management of conflicts and crises that are different from those in more recent times (Dimirovski, 2001a; Schefran, 2001). In the longer term, these are largely concerned with issues of how technology can contribute to reducing conflict risks and improving international stability (Kopacek, 2001; Kopacek and Stapleton, 2004). Also the question arises as to how advanced decision and control theories can be adjusted to decision analysis applications in social systems (Kopacek, 2004) in general and to conflict management and resolution (Kile, 2001) in particular. For instance, consider a small set of developments in the global natural environment and society which have occurred in recent decades, some of which continue into the present. These developments, according to the time frame of their major impacts, may be loosely classified into two types (Kile, 2004): (a) background changes already seen as destabilizing; (b) trends which may cause future destabilization. However, some deep research is needed to understand, and not solely identify, the latter. More than 20 years have elapsed since the first dedicated event devoted to exploring supplemental ways for conflict management and improving international stability took place using methods of systems science (Chestnut, 1984). By and large these are as relevant today as they were in the past. However, at present, the new paradigms that characterise the unipolar world point to the whole spectrum of complexities in this regard (Axelrod, 1997; Kile, 2006; Küng, 1990), which are yet to be studied and innovative methods developed and applied.

It may be observed that the issues of decision and control applications to enhance accelerated but sustainable progress in developing countries towards proper and fruitful use of automatic control technologies are somewhat specific. It should be noted that this is a process that is not yet entirely understood and still remains somewhat vague despite structural graph models. It seems as if globalization has given increased priority to the issues of the development process of mankind's present-day societies. In support this statement, observe only two cases of infrastructure systems (Dimirovski, 2001 a, b) that are highly dependent on the quality of automation and control technology embedded therein and are also safety-critical. Firstly, observe the air traffic control and management: regardless of whether it concerns a highly developed, developing or under-developed country, air traffic control and management is a globalized system and must function according to the requirements of safety-critical systems everywhere. And secondly, observe the rapidly evolving telecommunications: apart from the purely technical aspects of a highly complex and automated network system, the management and operation of trans-national (globalized) economic systems essentially depend on communications, and they have become rather vulnerable in this infrastructure.

At this point, let us recall some of the main topic areas of conferences and papers on system approaches to developing countries: management and development policies; agriculture and food; power; water and pollution control; urban planning, transport and communications; gas, oil and cement industries; methodologies; education and health; human resources; and, finally, international cooperation and development. It should be noted that, these are as relevant today as they were in the past. Therefore the objectives have been formulated and aim at promoting the development of control and automation and related systems and control topics in developing countries as well as enhancing knowledge and technology transfer for their sustainable development. The aim is to support economic progress and improve the quality of life in these countries by making a positive impact to enhance productivity, reliability and safety within the industrial processes and infrastructure systems. In particular, the word is about cost-oriented automation, power plants and systems, transportation systems, and agriculture.

During the last couple of decades, in general, education has been recognized world-wide as the crucial tool for the development of societies towards improving the quality of human resources and the quality of life itself Mayer and Nof, 2006). Education in automatic control is part of this crucial tool, which guides future generations into information-based high-level technologies (Lindfors, 2004; Dormido, 2006; Vlacic and Brisk, 2001). There are two related issues of concern: on the one hand, how can control education be made more effective and beneficial; and on the other hand, how can control be utilized to assist society to better develop its resources and potential. This area that has received particular attention world-wide during the last two decades, and its developmental prospects have been well established (e.g., see the 2005-2007 issues of Euro. J. of Eng. Education and of IEEE Trans. on Education).

The actual impact of automation on society so far experienced has suggested that some of the problems should be revisited because of the evolved knowledge on human-machine systems and human skills based automation (Stahre and Martensson, 2004). These research activities have evolved so as to encompass all issues and topics of the social impact of automation from ergonomic design of engineering work to human-oriented manufacturing systems and enterprise redesign. In brief, over time these IFAC activities have enhanced the development of several distinctive system approaches in this field: traditional techno-centric approach; human centred approach; socio-technical approach; and some specific approaches such as change management, success factors, and ethical issues.

Lastly but not least, the contemporary process outsourcing of labour is one of the recently emerged problems in the national economy of a society, which is likely to expand on a wider scale. Janos Gertler (2007) has just completed a comprehensive research in this problem within the context of its effects on the US economy. His research study has been conceptualized to focus on the so-called "3+2" sectors of the national economy: Manufacturing, Service and Government as well as direct import consumption and welfare. He has thoroughly explored and developed the respective models as well as tested them using real-world data the three fundamental balances: (i) personal (fiscal) balance, defined as the total buying power (disposable income) minus the total personal consumption; (ii) government (fiscal) balance, defined as the total tax income) minus the total government expenses, including welfare; and (iii) foreign trade balance, defined as the total exports minus the total imports, including the cost of (outsourced) foreign labour. In addition to the structural model of the primary labour outsourcing, it appears he has made new discoveries on the underlying mechanism that cause the essential impacts of the outsourcing on national economies.

4. SOME RECENT ACCOMPLISHEMENTS OF MAJOR IMPORTANCE

The essentially interdisciplinary character and nature of social systems has enhanced numerous developments of specific models and techniques. This, in turn, has contributed to systems and control science in terms of appropriate systems approaches applied to human centred and social systems that are based on exact scientific methods borrowed from control and management decision making. Positive effects from globalization may be reasonably expected only if the negative external effects are correctly confined into the decisions and activities of all people as well as into the trade-offs that form the basis of these decisions to manage the transitions of the social system in question.

4.1. An Overview on Major Recent Accomplishments

Education is essential for the overall development of the control field. Hence control education has undergone considerable evolution in order to cope with the advances in both the theory and technology of the field. From the initial focus on interactive computer-assisted teaching and training through computer-assisted learning and self-tuition, nowadays the focus of control education has shifted to studies of contemporary challenges of internet-based learning and training as well as to life-long learning (Dormido and Morilla, 2002; Gentil, 2004; Lindfors, 2004; Dormido 2006). Recently, topics of control education and training have included: developments in control laboratories; remote laboratories and experiments; simulation and animation on the web; challenges to modern curricula in control theory and engineering; teaching techniques for control theory; teaching advanced courses in control; web based courses in control; possibilities of computer networks in training, etc.

Knowledge in the area of international stability in mankind's societies world-wide, when observed as a system of interacting sub-systems, in particular, versus the issues of global development, has considerably advanced since the early 1980s. In fact, this study observation has yielded a deeper and more subtle insight into the difficulties as well as the limitations in applying results of the formal control theories. In this area of control applications, by and large, the investigations have been focused on models and methods of conflict management and resolution (Dimirovski 2001 a; Kile, 2001; Mansour, 2002), most of which employ non-cooperative game theory and dynamic group decision analysis (Kilgour and co-authors, 1987; Myerson, 1991).

The bipolar world, for which most of the knowledge on applications to international stability has been developed, however, has been replaced by a world largely in a series of transition crises, in which the accelerating pace of change and the conflicting access to technology of communities and societies have become more typical features (Axelrod, 1997; Dimirovski, 2001 a; Eeckhout, 2000; Kopacek, 2002; Schefran, 2001). An additional characterizing pattern of activities, that of striving to gain technology by any means and at any cost, has become apparent (Kile 2004; Wagner, 1994). Each example suggests that "technical solutions" to socio-economic and socio-political problems are often inadequate in accounting for interactions among background conditions, socioeconomic variables and societal behaviour. Closely related have been all contributions in the area of systems approaches to the issues of developing countries, and the IFAC concerted series of DECOM-TT events seem to have been a unique dedicated contributing development recently (Craig and Camasini, 2001; Dimirovski 2001, 2003, 2007; Sgurev at al, 2004). Technical contributions to these series may well be inferred from the sessions' titles that comprised the respective technical programs.

The above analysis shows that mankind's world-wide societies in the globalization age indeed is in transition towards a supposedly stable multi-polar world of the future. In addition, it should be noted that contemporary rather closely interacting and interconnected societies, which is supported by tremendous technology advances in the past century, have dramatically shortened the dominant time scale of the dynamics of society development. It should be observed that only to a certain extent systems science approaches have been used to clarify how transition crises do occur and evolve in time (Dimirovski, 2001 a; Sefran, 2001).

Considerable light on the potential and fetures of systems science applications to social systems has been shed by Mansour (2001; 2002).

It should be noted, however, innovated and specifically tailored techniques of both 'phenomenalistic' and structural modeling are needed in order to respond to the new challenges of applications to social systems (Dimirovski et al, 2006). The real-life experience during the last couple of decades, in particular, and indeed the entire period following World War II, is sufficient to observe how science and technology do not remain neutral, regardless of human endeavours and how humanistic they were initially conceived. The primary motivation may be tightly linked with competition and with a tendency for prestigious positions within competition at best, and hence pre-conditioned by a given human society and its features. This, in turn, enhances conflicts of interest that may lead to crises. It is apparent that new system features and paradigms, as pointed out in the preceding discussion, do require a more sophisticated use of model-representation techniques for complex systems involving qualitative as well as quantitative methods and also using discrete-event system theory,. Moreover, the involvement of soft-computing qualitative models and methods in addition to the quantitative ones seems necessary, instrumental, and more promising than initially perceived.

For quite some time, a series of symposia has been explored bridging the gap between economics and technology and engineering, and in particular how to expand systems engineering technology into applications in business and economy systems. These explorations have been encompassing and combining areas of research in econometrics, statistics, computer science, artificial intelligence and other useful tools for decision and control. In business and economic systems, from the initial focus on branch econometric models, probabilistic models and time-series analysis for optimal decision and management, the focus has shifted to agent-based techniques, AI decision support systems, and spatial data analysis for planning and control as well as financial engineering, market dynamics, pricing theory applications and integrated virtual enterprises (Luenberger, 2002; Neck, 2003). In particular, recently rather rapid new developments in theory, technology and applications have taken place and have brought about the use of so-called soft-computing (Zadeh, 1999, 2001; Yager 2004) based methods and models in decision making for managing organizations (e.g., see Wang and Archer, 1998), in modelling financial system dynamics (e.g., see Dimirovski and Andreeski, 2006; Special Issue on Neural Networks in Financial Engineering, 2001), and the respective management decision making (e.g., see Luenberger, 2002; Pete and coauthors, 1998; Special Issue on Neural Networks in Financial Engineering, 2001). This year's IFAC CEFIS 2007 reaches have gone far beyond via an innovative conceptualization based on the synergy of business and economics with financial and industrial manufacturing systems (Dimirovski and Ulengin, 2007).

The area of social impact of automation, which has emerged from explorations with initial focus on manufacturing enterprises and humanization of industrial labour, human-machine systems, and tele-operation of robotic mechanisms and systems, has shifted its focus to a deeper understanding of enterprises and human organizations as well as the transformation of industrial systems with its impact on quality of life and labour (Martensson and Cernetic, 2002). Thus this area is becoming more closely related to the area of business and economic systems and management decision making in economic systems. The research activities in human-oriented redesign have yielded outstanding results on emerging technology of automated systems based on human skills and knowledge (Stahre and Martensson, 2004). In turn, these are closely related to the recent developments in cost-oriented automation and manufacturing systems technologies (Bernhardt and Erbe, 2002; Zaremba and co-authors, 2004). Moreover, these are also closely related to SME business and economic systems (Kopacek, 2004 a, b).

4.2. Main Trends Identified

Many of the above outlined features demonstrate that societal and social system problems are generically hybrid complex and non-causal systems. Further, system properties of learning and adapting, hence sustainable evolution, are essential as well as pertinent to all sorts of systems and systemic structures that may appear in the problem and task studied with the areas of CC9. And yet further, as a rule the studied problems and tasks appear abundant in interactions due to omnipresent networked structures or networking phenomena involving both time-driven and event-driven dynamical process.

In turn, the main trends identified are presented in the sequel.

<u>Trend 1</u> – Increased interests for studying the representation of non-causal systems and the decision and control in noncausal systems by combining Math-analytical techniques with Computational-intelligence techniques, in general, and in particular with fuzzy-neural adaptive systems.

<u>Trend 2</u> – Increased interests for studying the representation of non-causal systems and the decision and control in noncausal systems by combining game theory with fuzzy system theory.

<u>Trend 3</u> – Increased interests for studying the representation of non-causal systems and the decision and control in non-causal systems by combining Petri-net theory with fuzzy system theory.

<u>Trend 4</u> – Increased interests for studying the representation of non-causal systems and the decision and control in non-causal systems by combining agent based computing structures with preference based analysis and qualitative system theory.

<u>Trend 5</u> – Increased interests for studying the representation of non-causal systems and the decision and control in non-causal systems by combining computer network theory and any one of the previous 4 trends.

At this stage it is worth pointing out some of the main topics in business and economic systems: (a) Advances in modelling techniques emphasize, among other topics, spatial data set and advanced time-series modelling; advanced econometric modelling; agent-based modelling; and financial engineering models. (b) The use of computational intelligence techniques emphasize intelligent decision support systems; application of artificial neural networks; application of wavelets; methods of genetic algorithms and genetic programming; and computational models based on evolutionary programming. (c) Advances in planning, decision and control emphasize, among other topics, the use of geographical information systems and spatial data analysis; advanced forecasting methods; advanced decision making and management; and applications of optimization and optimal control methods to regional, national and international economies.

In particular, areas of promising applications of control-related techniques are robust control theory, which recently found several interesting applications in analyzing dynamic economic systems under imperfect information, and the non-cooperative dynamic games, which were and are increasingly used to model dynamic strategic interactions between economic decision makers and in macroeconomic problems (Basar, 2007; Neck 2003). Also SME in manufacturing production (Kopacek, 2004, 2006) and in small-business financial services are gaining in importance, in particular from the point of view of the concept of virtual enterprises (Molina, 1999). Hence, both established activities as well as new challenges of methodology and substance will be within the future. Somewhat paradoxically, the introduction of concepts and methods of control theory into economics during the last four decades has been so successful that they have become part of the advanced economists' toolbox without being recognized as having originated from the control engineering community (see, for instance, Ljungqvist and Sargent, 2000, for the extensive use of control concepts).

In conjunction with manufacturing systems and enterprise integration, from the computational intelligence employing theorem-proving theory, emerged an important development that is likely to affect business and economic systems as well as the social impact of automation technology in the near future. Namely, development design and deployment of modern integrated industrial control systems has given rise to complex control systems in which the fault-tolerance property as well as availability, reliability, maintainability, and productivity placed more emphasis on the concept of performance oriented systems engineering (Morel and coauthors, 2004). In this new topic, model representations combine discrete-event and discrete-time along with continuous-time system theory in a compatible way via employing an approach borrowed from theorem-proving techniques in conventional computer science and techniques of computational intelligence (Angelov et al, 2006; Kacprzyk, 2006; Zadeh, 2006).

In addition to the main concern of creating more efficient and/or new manufacturing and production tools and of increasing economic competitiveness, the mutual influence of technology, in general, and automation and control technology, in particular, and the society has always involved the issues of humanizing labour on the one hand, and quality of life on the other. It should be noted that society environments undergo considerable changes in this globalization age. In the above forecasts and in the previous sections, it has been emphasized that both automation and control technologies play a crucial role in the overall impact of science and technology on contemporary societies. This impact process continues to be even more intense in the present networked world in the globalization age, but the social impact of automation now exhibits a strong phenomenon of world-wide propagation (Bernhardt and Erbe, 2002; Glenn and Hannan, 2000; Kopacek and Stapleton, 2004). In turn, this phenomenon should be brought into the socio-technical system approach of modelling the social impact of automation in an axiomatic way. In this regard the specific approaches of change management and success-factor need to be revisited in a broader setting, and the necessary improvements in design concepts of human-oriented manufacturing systems and integrated enterprises need to be further elaborated.

TC9.1 Economic and Business Systems

(i) The importance of robust control theory is increasing because economic and business systems are characterized by much more uncertainty than engineering systems. Hence it may well be expected that results from robust control shall be more effectively easily applicable than the results stochastic control theory, and perhaps more easily applicable too.

(ii) Application of dynamic game theory as an area where mathematical models and tools developed by engineers can yield considerably insights into economic problems that could not be obtained by more traditional economic approaches in game theory such as repeated games.

TC9.2 Social Impact of Automation

(i) Balance between pushing Automation and Information technologies and their suitable use by the Society.

(ii) Human-centred approach versus techno-centred approach in enterprise networking.

(iii) Automation and safety and security issues in society.

(iv) Social education versus expansion of industrial and manufacturing systems.

(v) Automation of health-care systems and Society.

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

TC9.3 Developing Countries

(i) Application of system engineering based approaches to combined knowledge and technology transfer for sustainable industrial development as well national and regional environment protection.

(ii) Application of system engineering based approaches to strategies for balanced national and regional sustainable development.

(iii) Combined knowledge and technology transfer in global transportation technologies and networks.

(iv) Applications of system and control strategies for rational natural recourse usage in sustainable development planning.

(vi) Applications of system and control strategies for rational management and usage of energy and water resources. (vii) Applications of system and control strategies for rationally acquiring and management of fair-share in IT products and services.

TC9.4 Control Education

(i) Re-thinking the systems and control curricula development and re-design on the grounds of the premise view on Systems & Control discipline as *the fifth fundamental, naturally emanated, science* next to Biology, Chemistry, Physics, and Mathematics.

(ii) Re-thinking the systems and control curricula development and re-design on the grounds of the impact from computer technologies and communication-network technologies.

(iii) Exploration and forecasting the far reaching impact of communication networks and networking technologies on decision and control education.

(iv) Virtual university and developmental strategies for trans-national virtual control departments.

(v) Development of enhanced methods, model, and techniques for Decision & Control Education and training via the Internet.

TC9.5 Supplemental Ways for Improving International Stability

(i) Development of system and control strategies for regional international economic and educational co-operation to enhance conflict management.

(ii) Application of non-cooperative dynamic game theory to studying and managing confrontations and conflicts.

(iii) Application of system science based approaches to study the mutual impact of regional and international stability, and vice-versa (regional versus international stability and international versus regional stability).

(iv) Development of system and control strategies for representation modelling and study of competition versus cooperation by combined math-analytical and soft-computing techniques.

(v) Resource and technology management approaches to enhance cross-boundary co-operation for ameliorating regional conflicts and confrontation.

5. CONCLUSIONS

Firstly, it may well be argued that the so-called globalization process is not just a contemporary phenomenon but rather a logical, perhaps even a natural stage, in the historical development of Mankind and its societies due to the contemporarily established technological potentials (Dimirovski et al, 2006). And it is thus believed that these features be observed within the IFAC lookforward beyond 2011. On the other hand, the world-wide real-life experience during that last two decades or so has clearly demonstrated that technology cannot be considered as neutral within the given society environments. Hence its respective background engineering sciences cannot be considered as neutral because ultimately all system engineering creations are some kind of socio-economic systems, and so are the trans-national ones in particular**.** Furthermore, by definition this coordination committee and its technical committees primarily dealing with the category of *non-causal systems*, i.e. socio-technological systems exhibiting visible or virtual *anticipation capability*, which by and large address human-centred and society-centred systems in the realm of decision and control studies.

Secondly, it has become apparent nowadays (e.g. see Zadeh, 1996, 2006; Yager, 2004, 2006; Kosko, 1993; Dimirovski, 2005, 2008) the synergy of computational power available and of systems and control theory enabled new ways to systems engineering methodologies due to model developments exploiting combined qualitative (linguistic) information in addition to the quantitative (numerical) information as an alternative representation of non-linear and uncertain dynamical processes. The emerged soft-computing modelling techniques have particularly contributed to this paradigm of combined qualitative-quantitative information processing, which is generally intrinsic to all social systems.

And thirdly, all the contemporary societies are becoming more and more networked to a considerable, and in particular so are the main infrastructure systems of business, of energy, food and water supply, and of transportation (Gertler 2007; Papageorgiou, 2004). Moreover, some of these are already networked on either continental or global scale, which in turn requires more demanding and sophisticated methodologies and techniques for decision and control as well as for coordination and management (Axelrod, 1997; Basar, 2007; Siljak, 2006). It should be noted, however, that the modelling problem of controlled dynamical processes in trans-national systems is essentially much more involved, and becoming even more so, due to contemporary communication and transportation means.

Social and societal systems in modern civilization, currently undergoing its globalization age of development, have been reviewed from the viewpoint of systems science and on the grounds of recent achievements in control and decision science a well as in information processing technology. The simple transcending of math-analytical models from large-scale system theory does not seem to be appropriate or suitable due to various in nature constraints that have to be observed (Dimirovski et al, 2006). Rather some especially derived synergy combination of computable math-analytical and soft-computing modelling techniques, fuzzy systems based in particular, is likely to have the potential of encompassing most of the essential constraints in either system representation models or in control and decision algorithms and strategies. Given these premises, upon assumption of rational expectations, considerably many and reasonably effective mechanistic system approaches, methods, and models (along with the needed algorithmic re-interpretations for computational purposes) have been developed in on the grounds of ideas from control theory and theories of networks and systems. The general system science theories provide the structural backbone to agent-based systems such as dynamic graphs (Siljak, 1991, 2006; Sterman, 2000), complex dynamical networks (Watts, 1999; Wang, 2002) and non-cooperative dynamic games (Axelrod, 1997; Basar and Olsder, 1999).

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