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Socio-Cognitive Engineering Foundations and Applications: From Humans to Nations

/a preliminary study/

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Abstract

This presentation has the character of a position paper. The author attempts to the identification and specification of socio-cognitive engineering as to a new field of research and, in parallel, as to a new systemic but redefined engineering approach which is based on interdisciplinary integrated paradigms applied to the domains of cognitive and social sciences together. The concepts of an abstract intelligence and decision-making are considered key properties of every socio-cognitive system. The TOGA meta-theory is employed to the analysis of motivations, real needs, and possible know-how of socio-cognitive engineering foundations. The socio-cognitive paradigms can be considered useful for the study of individual personal thinking, as well as, for the analysis and understanding of decisional processes on social and international levels.

Keywords: socio-cognitive engineering, meta-methodology, complexity, systems,

1. Introduction: a general vision

Socio-cognitive engineering is a new emergent object on the firmament of human technological and scientific activity fields. We may argued that it belongs to the third generation of research in the human culture.
These generations are distinguishable by the following specific techno-scientific development strategies:

- **incremental grown** of subject oriented sciences and technologies. They are self-limited by their language (conceptualization systems), observation/measurement tools and engineering approaches.
- **autonomous cooperation** between different branches of research caused by common interests and by the tentative of the unification of their objectives-oriented or interface terminology.
- **building new perspective**, common-shared top conceptualization and ontology (redefinition of basic terms from higher more abstract perspective), in such way that its become valid for many, before separated research.
- Integration of research and technology development perspectives and activity as one parallel incremental process

The primary type of such developments is a classical vision of research fields, the second represents interdisciplinary approaches and the third is an over-disciplinary systemic perspective.

In the above conceptual frame, Socio-Cognitive Engineering (SCE) requires a preparation and cooperation of inter- and over- disciplinary specialists. They missions extend the borders of classically classified research and interest areas of human culture.

Classical branches of science and engineering follow natural development and selection laws. They grown, as possibly, in separation, and enlarging cover fields of interest of their "neighbors", as well as, identifying new aspects of human life as their new research areas.
In a consequence we have physical-chemistry, mathematical-physics, socio-biology, and so on. There are evidence different perspectives on the same domain, for instance, social-psychology and cognitive sociology which enables either to increase our "explanation power", i.e. more realistic explicative models, or, from the perspective of the utility, they are concentrated on specific technologies which mirror the current economical demand of the marked. In the last case, the mechanisms of specialization and research in deep enable to increase velocity and economy of production, and increment client-tailored innovations.
Unfortunately, as we learned from the humankind history, such development has its own limits of growth [Report of the Club of Rome "The Limits of Growth",72 – see the Web], For example, following this tendency, the gasoline engine had never could be neither discovered nor developed but steam engine could be an object of the continuous perfection.

2. Meta-methodological framework

For the reasons of the large dimension of the domain of interest, its fuzziness, strong theoretical and practical heterogeneity, as well as, always yet non sufficient and congruent available knowledge, the recognition of the problem requires a novel methodological approach.
The presented study is based on the TOGA (Top-down, Object- based Goal-oriented Approach) [1], [9]. It is a systemic goal-oriented knowledge-ordering socio-cognitive methodology based on a meta-theoretical framework. It may serve as a strategy of the computational modelling and as a domain/problem independent approach for any specific ontology building.

Working hypotheses - Why a new methodology for SCE is really necessary?

Here we may distinguish two hypotheses:

1. the first is that **we really need a new systemic integrated methodology**, and
2. the second that the **TOGA framework satisfies conditions of completeness**, congruence and feasibility in order to be a first conceptual tool for SCE investigations.

- **The first hypothesis** results from the observation of continuously growing complexity and risks of real-world problems, and, in parallel, lack of systemic integrated theories which are able to copy with such large problem aggregates. They unify strategic but also numerous everyday socio-cognitive (always more human-centred) decisions.

We have learned from history, that when humans are able to conceptualize sufficiently complex requests, there emerges a necessity to build a theory and tools in order to satisfy them. We claim that we are in such a historical moment.

> *"…In seeking a solution one should consider the big success of physics in the beginning of XX century, when one coherent conceptualisation and representation system has been created and accepted by all physicists, laying the base for enormously sophisticated and successful applications of physics in other sciences and engineering. Critical to this success was the assumption of the great physicists that the really useful theory must be elegant, pretty and simple to understand. " (Gadomski, Zytkow, 1994).*

- **The second hypothesis** is based on two grounds:

1. Promising results of heuristic test applications of TOGA in different projects.

2. TOGA is an unique theoretical framework which in top-down self-growing manner intends to cope with the complexity of socio-cognitive systems.

   It is a meta-theory, therefore it is not in conflict with validated domain-dependent local theories. It only tries to see them in the systemic goal-oriented and cognitive perspective (http://erg4146.casaccia.enea.it/toga-parad.htm).
   It also includes top axioms and methods/rules how it has to be developed and how it has to be applied to the real-world problems.

From the TOGA perspective, intelligence and, more precisely, the **efficacy of management decision-making** is considered as a kernel for the solution of main problems of humanity, and a progress in the direction of computational modelling may provide a conceptual basis for a predictive simulations of numerous human activities, as well as, allow a better comprehension of old and every-day practical problems.

Some conceptual normative assumptions of the TOGA methodology [1,2,3]

The TOGA assumes the top-down **observation metaphor**, to see complex problems from a bird eye's view; this means to first identify a problem's most general context constraints which remain always true and mandatory for every successive level of its specification ("fleshing out").
Therefore in this meta-problem are involved together the properties of the both, the problem and an intelligent entity (it can be a person, an organization or a society) which tries to solve it.

KIL –Knowledge/Ignorance Levels

For this reason TOGA distinguishes formally three basic levels of our knowledge/ignorance (KIL):
- The Objects and Relations level - existence of objects and relations ,
- The Attributes Names level - existence of distinguished attributes and changes
- The Attributes Values level.

This last level only is normally applied in the current web-spread modelling methodologies.
In practice, we change level of KIL by acquisition of Information, Preferences and Knowledge (IPK).
IPK of an agent related to a selected domain of activity are distributed on the different KILs.
- We may formally tell what we, at a given current moment, know and what is unknown yet; and after a moment, after some our reasoning, we may add new elements to our IPK (Information, Preferences, Knowledge) [1,2,8].

Meta-Levels
The second aspect of TOGA is the formal distinction of goal-oriented meta-levels of problem specification. It means that every method, ontology or other conceptual tool/resource has "normal" problem dependent attributes and also a hierarchy of meta-attributes. These last concern the applicability, utility or an interface with other methods.
Using an "**observation metaphor**" we may tell whether we actually manage to see more as we approach and when we have arrived at a distance at which we may also operate/modify the domain. Of course, this "operating distance" depends on the properties of our mental tools. The observation and approach strategies may differ from case to case, but some kind "observation tools" and "acting tools" are always used.

These tools in our metaphor are our knowledge (or more precisely our IPK).
TOGA is a knowledge ordering tool, therefore it requires that the knowledge for problem solving exists. **Only in this situation** this knowledge can be goal-oriented and ordered step-by-step.
TOGA requires domain specialists in order to specify, at the beginning, the meta-attributes/ properties of their tools: *where* and *how* these tools can be used in the frame of the pyramidal top-down modelling problem.
Human mental capacities are limited by their biological carrier and incremental natural-evolution-driven solutions. The continuous growth of the number and complexity of data for real-time elaboration increases our sense of risk of losing their control and our fear of unforeseen consequences of our own and other persons/organizations errors. In this circumstance, human response was always of two types.
The first, a structuring of the environment according to known schemas, i.e. an adaptation of the world to humans needs; this led to the development of engineering.
The second, a learning new interpretative and behavioral schemes to cope more efficiently with the integrated environment, i.e. an adaptation of oneself to the world in order to use it better for the proper needs; it is called scientific research/study and education.
For the completeness of the above image we have to add the concept **"management"**:

> *Management consists of decision-making activities undertaken by one or more individuals to direct and coordinate the activities of other people in order to achieve results that could not be accomplished by any one person acting alone.* [USAID Office of Foreign Disaster Assistance, report, Web,1995]

From our, more than above, abstract perspective, management can be seen as a high level mental and communication activity which also enables an organization of the above-mentioned human responses. Management is indirect, it is characterized by acting on autonomous executors and informers by tasks emissions. Management also follows the two mentioned schemes, either by modification of subordinated units or by learning and modification of their own thinking and strategies. The main management generic missions are: confrontation of objectives with the possibilities, planning, and leading of autonomous human units to the goal achieving. In every such situation, a continuous decision-making is required.
In general, higher human mental capabilities and social knowledge are employed for living better, be safer and on the other hand, they mirror natural necessity of self-developing processes and welfare of intelligent beings. The capacity of management is considered as a one of the high-level socio-cognitive functions of the human mind that employs a meta-reasoning ability.
The managers are crucial nodes in the socio-cognitive networks of organizations.
- Usually **managers are not specialists in the domains they manage**, they use experts and executors of their tasks, but not to learn but in order to *obtain* an expertise, for instance, whether or how a method X can be applied to the problem at hand. They want to obtain only goal-oriented meta-information and meta-attributes of the knowledge of experts, about applicability and utility of the tools of executors and the competences of cooperating managers.
Consequently, in complex SCE problems we need to specify the model/(theoretical frameworks) in a top-down manner, and, at every generalisation level, we have to check if available for us methods/tools/technologies can be applied for the achieving of its/their sufficient utility.
- Of course, not always this approach can guarantee a success within predefined time limits, but it always produces useful results which either can be further developed later on or can be already sufficient for a demonstration that available knowledge or technologies are not sufficient for the achieving an expected utility.

3. The SCE ontological remarks based on the TOGA meta-theory

The area of interests of SCE covers such different fields as: psychology, sociology, physics and engineering, therefore it has to adapt their main paradigms. They are below roughly specified.

Physics paradigms:
- the simplest solution is better/"true",
- observability/measurability of attributes, events, processes and systems, and repetitiveness are necessary,
- generalization: bottom-up approach - from details to a synthesis.

Systemic paradigm:
- specialization: top-down approach - from general consensus to details.
- completeness and congruence of description on every generalization level.
- theories and models developed are valid for every domain where physics paradigms canbe applied.

Engineering paradigm:
- always goal-oriented/driven/based and
- to use available: knowledge, technologies and materials.

Cognitive paradigms (unified cognition theory):
- in every real-world problem some users/(human-agents) class must be modeled,
- a mind is abstracted from human brain and it has to be computational (symbolicthinking) intelligence does not depend on specific domain knowledge, preferences (also ethics)and available information.
- every reasoning process can be significally influenced by the properties of its carrier physical system.
- human thinking is divided on conscious and not conscious mental operations.

Social paradigms
- abstract intelligent cognitive agent properties have essential influence on the modeling of every human society/organization. Social-context is essential for intelligent beings.
- intelligence of socially interacting group is differ than intelligence of its intelligent components.

From the top perspective, the domain of SCE are systems of interacting humans and human like intelligent entities (intelligence based systems).
Here, we illustrate (Fig.1) only some ideas related to the ontological framework of SCE..

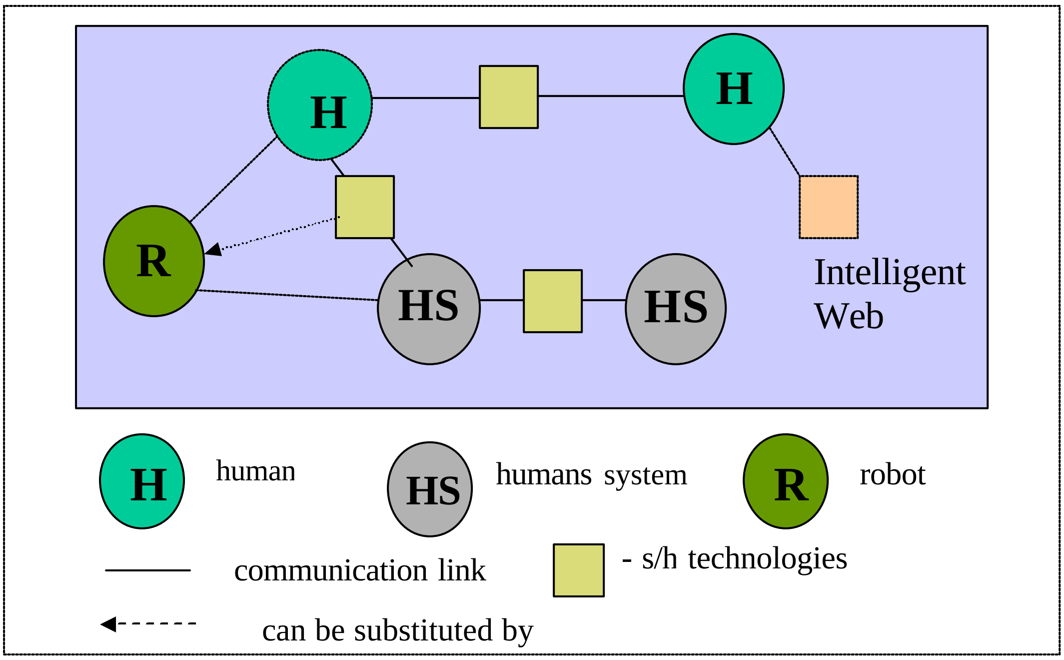

Fig.1. Top abstract objects in the identification of SC systems.

Intelligent entities (IE) are recognised as:
human individuals,
highly autonomous robots,
organizations,
associations,

communities,
society,
nations.

The basic identification criterion assumed is a capacity to autonomous, responsible decision-making. Therefore, according to the goal-oriented rule, IEs key attributes are attributes of decision-making processes and their carrier systems.

In TOGA, the structural formal scheme of the SCE domains follows the formal SPG (System Process Goal approach) framework [1], i.e. the recognition of: *systems*, *processes*, *functions*, and *goals* as independent but connected reference frames. SPG serves for a congruent and complete decomposition of the domain of activity of IE.

The cognitive perspective assumes the WAG (World, Action, intervention Goal) framework which serves for the identification of IE behavior, it is based on the interrelation between: *World of agent*, *Actions*, *Tasks* and its/his *Intervention Goal*, where all these concepts are formally defined and conceptually separated. The same conceptual schemes can be used for the specification/design processes of SCSs (Socio-Cognitive System).

The social aspects are taken under consideration starting from Universal Management Paradigm (UMP), see fig. 3, this conceptualization framework is discussed and prototypally applied to the design of an intelligent ambient by, Gadomski and Caputo [9] in the Preprints of SCEF-2003.

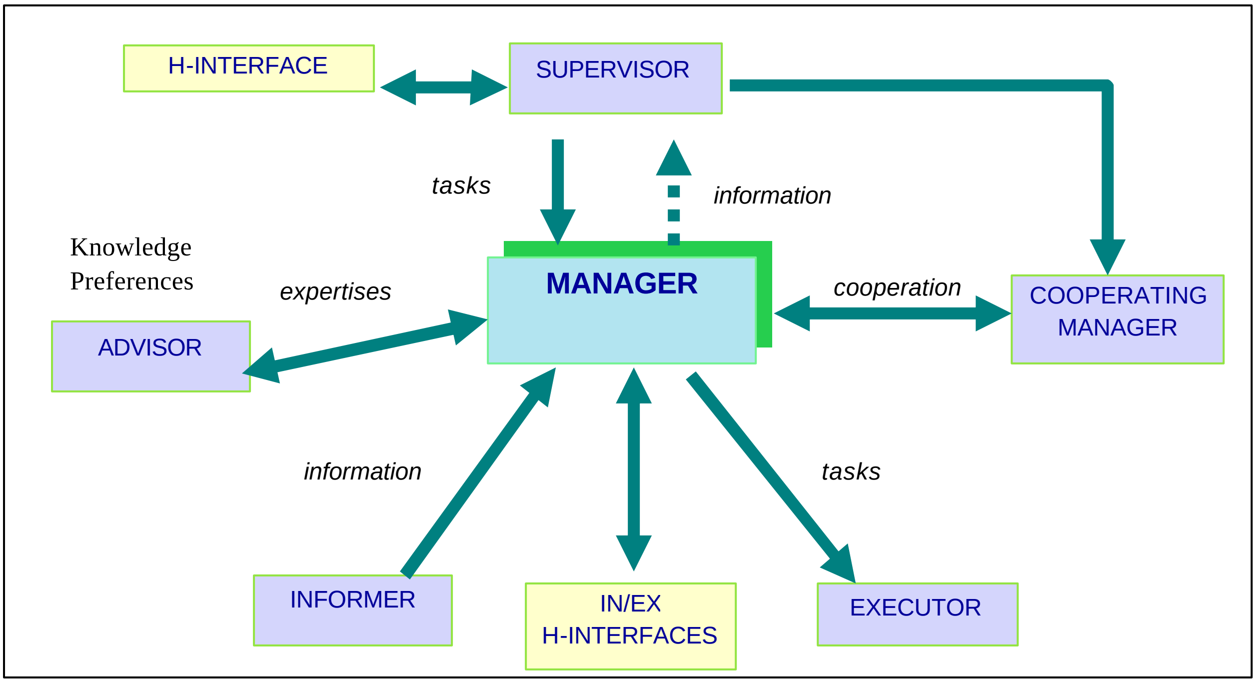

Fig. 2. Universal Management Paradigm (UMP) of TOGA, it has a pattern-based structure: subjective, incremental, recursive. UMP includes 6 canonical roles and their interrelations.

About Strategy of Socio-Cognitive Engineering

SCE is specially focused on the real-world high-risk human managerial problems. It requires an integrated effort of specialists from different fields. They needs a common systemic language. We may argued that an essential strategic factor of the social sustainable development is to cope with the subsequent socio-cognitive barriers:
technology barrier, knowledge barrier, cognitive barrier, organizational barrier, socio-political and cultural barrier (fig.3).

4. Technology, AI and Conclusions

The key factor which determines requirements for large scale technological support systems for the improving the functionality of socio-cognitive structures, is a proper estimation of the society demand on cultural, social and professional knowledge and information.

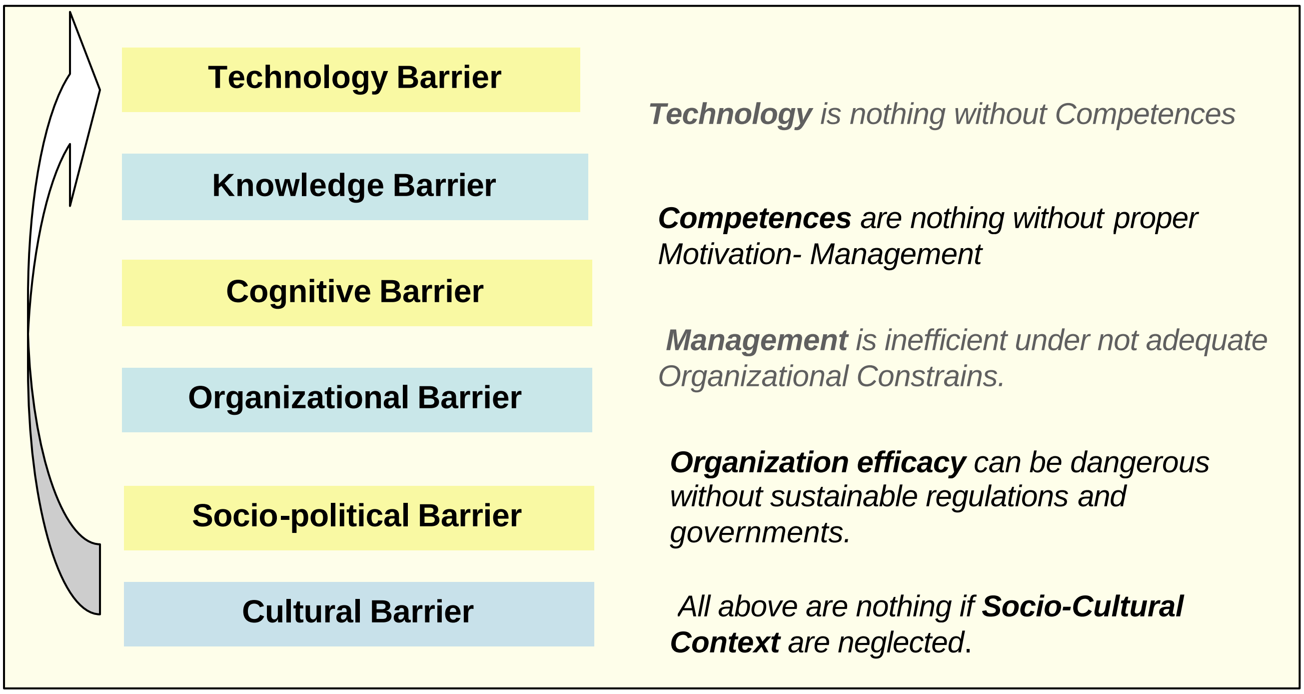

Fig. 3. To cope with all socio-cognitive barriers is an essential sustainable development strategic factor.

- Estimation of the future trends in these domains and more, identification of proper socio-cognitive factors of people, organizations and communities are essential for the design of socio-cognitive technologies.

At present, these technologies are focused on the RTD of:

- computer information and knowledge grids,
- human-computer interfaces,
- numerous specialized computer advisors (Decision Support Systems).

The review of these, software based technologies, called, human-centered design is in [5].

On the other hand, available computer technologies enable:

- implementation everything what is a formally specified,
- simulation every implemented process if the proper data are available, and
- support every mental process if its scenario is dividable on "human mental tasks" and computational reasoning tasks, with formally specified computational cognitive interfaces.

A computational method/methodology/theory is a conceptual system if its internal concepts and its interrelations are possible to express in a computer language, and which enable to transform its theoretical models into computer programs.

The foundation of AI expresses an intention to transform our available "soft" cognitive and social knowledge in computational methods/theories.

> *"Although the dream of creating intelligent artifacts has existed for many centuries, the field of Artificial Intelligence is considered to have had its birth at a conference held at Dartmouth College in the summer of 1956. The conference was organized by Marvin Minsky and John McCarthy, and McCarthy coined the name "Artificial Intelligence" for the proposal to obtain funding for the conference. Among the attendees were Herbert Simon and Allen Newell who had already implemented the Logic Theorist program at the Rand Corporation. These four people are considered the Fathers of AI. Minsky and McCarthy founded the AI Laboratory at M.I.T."* [6],

At present, after 50 years of experiences and worldwide hard work, we are discovered that the weakness of our approach was not the limitations of computer technologies, fascinating wide public by the increasing speed and memory capacity of computers [7], but lack of socio-cognitive theories of mind which should satisfy requirements of the software developers and AI potential users. The enormous complexity of a hypothetical unified socio-cognitive theory, according to the TOGA hypothesis, requires next qualitative change in human thinking, we have to learn how this type of theory is possible to construct. This situation creates new motivations in order to revise and restart the developing the system theory in more conscious and more goal-oriented manner. More precisely speaking, we are discovering that a meta-system theory and generalized engineering laws have to be build.

On the other hand, for the reason of techno-economic, psychological and cultural inertia, the world society needs a time in order to understand what really artificial intelligence means, and to think about its as a useful build-in element of the human civilization.

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