Cog-SOPHOCLES

ENEA's **SOPHOCLES** Sub-project

Contribution to the **WP1** of the **ITEA SOPHOCLES** Project, Rome, Feb. 12 2002

Technical Report

Work Package 1
of the SOPHOCLES Project

Systemic Approach for the SOPHOCLES Global Specification

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(Extended Second Edition, Version Nov. 2002)

Abstract

This report deals with a systemic knowledge conceptualization and ordering tool which can be considered as a generic methodological framework for the conceptual specification of the SOOPHOCLES Virtual Enterprise. The initial results of the SOPHOCLES Project related to the elaboration of a system conceptualization framework for the SOPHOCLES global specification (WP1, Task1) are presented.
The work includes: an analysis of the necessity and utility of a rigorous system approach, description of the TOGA methodology as a suggested tool for the design conceptual framework of the CYBER Enterprise, an analysis of socio-cognitive framework for the identification of constrains and requirements for the project. Incremental application of the unified systemic approach (complete and congruent) should significantly reinforce and add value to the distributed technology-dependent methodologies and design support tools employed in the project. The suggested cognitive IPK model should be the base for the design of an intelligent advisor for e-designers of SoC systems.

Summary

The fundamental objective of the SOPHOCLES (System level development Platform based on HeterOgeneous models and Concurrent Languages for System applications implementation) Project is a **validation of the necessary conceptual and technological tools for the development of highly advanced engineering systems**.

1. WHY SYSTEMIC/SYSTEM APPROACH?

The SOPHOCLES project is a focused on the development of a cyber networked virtual enterprise with an objective to support the activity of the design of, so called, systems on a chip.

The hypothetical SOPHOCLES Virtual Cyber Enterprise will be a complex heterogeneous system which development involves numerous technologies and specialists from different engineering and scientific areas from electronics, and software engineering up to artificial intelligence, psychology and socio-cognitive science.

From the practical perspective we can have many concrete systemic approaches, but all of them have to based on general paradigms of the system theory and system engineering.

1.1 Modern System Approach

In order to talk about a system approach in engineering we just have to use intuitively some systemic concepts even if we are not accept any specific systemic theory and we do not intend apply it. Of course these terminology used is congruent with a general systemic perspective and, for this reason, is adequate to meta-problems of the SOPHOCLES project.
Systemic concepts are developed bottom-up basing on human experts experiences and are applied top-down from highest levels of our knowledge, going down to the technical details related to particular applications of well known technologies. Ontology of SA (System Approach) is formed on highest possible abstraction and high levels of generalization available for system developers (system knowledge engineers).

1.1.1 Basic Systemic Concepts

Below, the basic meta-system and systemic concepts are defined on the base of the ISO/IEC/JTC1/ Information Technology Vocabulary updated to the current needs of the modern meta-system research. In the next part of the work a specific more formal conceptualization and systemic ontology are presented in frame of the meta-theory TOGA (Top-down Object-based Goal-oriented Approach).

Systems Science is a trans-disciplinary study of abstract organization of phenomena, described by concepts and principles which are independent of the specific domain, independent of their substance, type, or spatial or temporal scale of existence. Systems Science investigates both the principles common to all complex entities, and models which can be used to describe them in any domain, pertaining to any type of system _[Principia Cybernetica Project,95, Web].

Engineering - Goal-oriented construction of goal-oriented systems using available conceptual, technological and natural resources.

System Engineering – An engineering which efficiently, in goal-oriented manner applies systems science perspective, system knowledge, i.e. just discovered system laws, methodologies and methods to design, construction and development of wide classes of complex goal-oriented systems.

Modern system approach is focused on the **identification** and **design** problems of complex, strongly heterogeneous and human-machine-environment systems.

Integration of real-world systems and human/intelligent beings or their organizations involves "quasi-infinite" set of data which are always incomplete and uncertain.

- System Approach enables complete controllability of design processes independently on which generalization level they are specified.

Technology - A set of engineering products useful as conceptual or physical tools, components or materials for engineering.

Conceptual tools (engineering knowledge):Conceptualization systems, theories, methodologies, methods, techniques and rules useful in engineering activity.

Monitoring – Continuous acquisition of information in predetermined intervals of time from a chosen system for a predetermined purposes.

Simulation - Goal-oriented dynamic realization and demonstration of selected properties of a reference system. It can be performed in the following domains: quantitative (numerical), qualitative (modal and fuzzy logic), graphical symbols and virtual reality. It can be performed autonomously or under human supervision and control by an automatic/autonomous system (called simulator).

Diagnostic - Recognition of causes of abnormalities of a system or the causes of discrepancy between a real and expected behavior/response of a system.

Control – Modification of system state and its output by the changing of its selected attributes (control variables/parameters) according to the human or artificial system (called controller) intentions/plans.

Identification - Recognition of a system through its conceptual allocation to a certain, before known, class of systems. Identification can be done by its classification attributes, its distinguished/discovered property or by the development of a system model. Identification is a goal-oriented process.

Configuration (activity) – construction of a system only by a connection of available objects from a pre-selected domain according to their fixed properties (these objects are called components/ subsystems).

Design – a phase of the system lifecycle relaying on a conceptual construction of a system, or a construction of the description of a system sufficient for its building.

Management – an activity relaying on indirect goal-oriented modification of a system by communication of adequate tasks to autonomous execution units.

Meta-System Engineering - construction of universal conceptual tools for System Engineering, such as methods and methodologies useful for the development of every system.

In general, every System (or Systemic) approach requires a meta-system knowledge such as common trans-disciplinary language and a conceptualization system.

It is necessary to stress that new professional profiles are necessary for the modern system engineering, see for example [KMC. http://www.kmci.org/]. the main are:

System Knowledge Engineer – this profile requires:
- system engineering knowledge on generic system frames, and laws,
- modeling methods and methodologies for new class of systems,
- knowledge integration capacity, an aggregation and application of the system management strategies.

Knowledge Acquisition Engineer - the profile requires meta-knowledge necessary for searching, elicitation, acquisition of knowledge. There are many strategies for these tasks depending of the application domain, their future users and a properties of their sources. In particular most complex knowledge acquisition refers to the interviews with human experts of narrow domains/ technologies in order to recognize their cognitive mechanisms and preferences/motivations.

The above definitions should be helpful for the comprehension of more formal conceptualizations introduced in the course of this work.

1.1.2 Human Components in Modern System Approach

Modern System Engineering includes also man-machine systems and this branch of Artificial Intelligence that is focused on the development of, so called "general intelligence" [A. Newell, 1990].
The work in this direction is stimulated by concrete business criteria related to reusability of specific technologies and advantages of the standardization for advanced technology markets.
In particular, the application of the systemic cognitive perspective to the design, control and management is required when:

(a) the amount of information from the domain of interest is so big, or the information density is so high that the probability of human errors strongly increases,

(b) problem solving requires from human remembering, mental elaboration and proper application of too complex and too large for him professional knowledge,

(c) access to the data is too difficult or requires too much effort,

(d) particular interests and emotions are stronger than the human rational motivations,

(e) false decisions and faulty actions lead to dangerous unexpected situations,

(f) physical domain of intervention is not accessible for humans.

Therefore, different computer systems for autonomous execution of mental tasks, for "fitting" complex machines functions to the needs and abilities of their human users, and for supporting individual human decision making are required not only from the technological but also from economical and safety
reasons [http://www.kurzweilai.net/].

> "A cognitive psychologist running a study at the Microsoft usability labs.
> Usability studies have played a significant role in the Lumiere project. More generally, over 25,000 hours of usability studies were invested in Office '97." [MS site on the Web].

Currently, two approaches to the development of these systems are present in the literature.

The primary is a classical: in well foresight and defined situations a system (=agent) uses a fixed knowledge which is in the forms of algorithms or procedures, and it is organized in tree forms. It means, the objects of interventions, tools, and their attributes are initially established. The system can only percept the **values** (quantitative or qualitative) of invariant process variables and parameters, i.e. these values are system input and output data with invariant textual and graphical interpretations.
The second is based on the expert/knowledge-based system technology, i.e. it relies on acquisition and processing of qualitative heuristic knowledge by a meta-knowledge included in, so called, inference engines. Here, the input data are also the active part of executed calculus. In other words the system can acquist and modify rules and algorithms i.e. its own temporal "knowledge".

New and especially promising "intelligent" autonomous and decision support systems are those which are able to utilize both approaches for **supporting**, **substituting** and also **evaluating** some human mental processes.
Here, this type of computer systems is called ICA (Intelligent Computer Aagent). For example, such systems can assist plant operators or complex system designers in identifying their misconceptions and lack of understanding of plant/project status. They may play different roles dependent on the definition of the user tasks, such as: intelligent executor, advisor, controller, coordinator or tutor.
For **identification** and **specification** of a complex problem-oriented knowledge for ICA, a functional model of its human end-users is also required.

According to this, we can assume that the both above approaches should based on a more general model of an Abstract Intelligent Agent (AIA) which is able to realize goal driven interventions in an abstract environment [Gadomski,89].

Following the above assumptions, in this work we present:

- basic elements of the conceptualization theory TOGA (Top-down Object-based Goal-oriented Approach) which enables representation of the "intelligent" activities of artificial dynamic systems in a systemic perspective.

- definition of general patterns for a functional modeling of goal-oriented intelligent agents.

- formal specification framework for the representation of problem/design knowledge, problem management knowledge, and knowledge acquisition .

This meta-knowledge is necessary for SOPHOCLES Intelligent Advisor for:

- acquisition and selection of a problem oriented knowledge,
- allocation of this knowledge to the system,
- definition of a new human user communication knowledge and new cognitive
- interface functions,
- standardization of life-cycle documentations.

1.2 Utility of the System Approach to the SOPHOCLES project

At the beginning we should mention that, by the definition, SA is applicable for any artificial or natural system but not always it is really needed, useful or, in concrete situation, is economic, especially when the requested technology is well known and the design task is relatively well separated.
The business criteria for the application of SA strongly depend on the problem economical, cognitive and cultural contexts [Gadomski, 2002]. Every of them can be independently analyzed. We may mention only that the decisional criteria depend here on the objective and subjective balance between possible losses and benefits, they both are determined by such problem indicators and constrains as:

feasibility, cost, time, future reusability of technology applied, human resources motivations and capabilities, as well as, a local cultural tradition.
In general, all of them regard to such global attributes of the system of interest, as:

Heterogeneity,
Complexity and expected
Innovation Load.

In the case of the SOPHOCLES project, its general requirements presented in the project proposal strongly motivate application of a SA perspective and methodology.

Some critical systemic attributes of the SOPHOCLES project and of the hypothetical SOPHOCLES system are illustrated below.

Critical systemic attributes	**SOPHOCLES top objectives, requirements and constrains**
Heterogeneity	- Many extremely different models and technologies applied to separate functional modules. - Different domain depended conceptualizations and Terminology, - The system usability depends on socio-cognitive-technology contexts relative to different end-users which are distributed geographically and are employers of different business organizations. - Necessity of the collaboration in frame of a strongly interdisciplinary distributed and international team
Complexity	- Sophocles System requires numerous conceptual and software components with hierarchical functional structures - Sophocles System requires numerous connections on conceptual, functional, processual and structural levels - The development of inter-module interface data bases are necessary - The development of local software managers for the coordination of data flows and for system usability are required. - Synchronization of tasks in many time scales in the real-time of the design session is indispensable - Complexity of the SoC design tasks requires highly professional specialized knowledge and capabilities.
Innovation Load	- Application of advanced mathematical, software, AI, multimedia, network and cognitive: tools, methods, methodologies and technologies are the key aspect of the Sophocles system - Necessity of their validation for new design and utility tasks, and partially unforeseen yet circumstances. - The system should have incremental, selflearning properties - Interaction with end-user has to be supported by an intelligent advisor with meta-reasoning capability.

A general, the leading business hypothesis of this report, is the assumption that impossible to design and to use efficiently so complex system as the SOPHOCLES Virtual Enterprise without a rigorous systemic analysis and design, and, in consequence, without application of a socio-

cognitive perspective and modeling frames for the evaluation of the utility and context constrains of the system.
Unfortunately a proven and commonly accepted unified system theory and system engineering not exists yet. There are many systemic engineering approaches to the specification of large industrial networks, independently there are developed systemic models in economy and social science, but only few systemic theories try to copy with an integration of physical and mental phenomena. Recently, we can only mention System transition Theory [web: CLEA Center], a philosophical and engineering study of K. Palmer [Web], hypothetical physical theory of everything [Web], a modern reconceptualization of cybernetic called Autopoiesis [Maturana and Varela], and TOGA (Top-down Object –based Goal-oriented approach) being developed
In ENEA since 1860. There are many valid but partial approaches related to the representation physical systems and software realizations of agents in Artificial Intelligence. The methods suggested in Knowledge Management and Engineering are intuitive and on the low level of the formalization.
On the other hand, so called formal methods and model checking have their domain of applications mainly in software engineering but they common weak point is the problem how to transform not structured, incomplete and distributed information, knowledge and intentions to the form of formal specifications. Numerous available conceptual design tools are based on relatively formal knowledge representation methods but rather intuitive and vague indications how it should be acquired and processed to the form of the conceptual designs of complex heterogeneous systems.
In most system engineering books, system approach is presented rather as a set of weekly connected systemic laws and methods where the problem of completeness and congruence of them is rather omitted. In the above, generally known situation [see Web], the TOGA theoretical framework seems to be promising for the reason of its explicitly expressed initial criteria and normative assumptions, also mandatory to the development itself.
During last ten years, the TOGA conceptualization was successfully used as a modeling support and a tool for results validation in a few Italian and EU Projects [http://erg4146.casaccia.enea.it/wwwerg26701/gad-pape.html]. Application domains have been related to high-risk plant operator support and to the managerial decision support systems design in emergency conditions.
An application of TOGA in the SOPHOCLES project to the design of Cyber Virtual Enterprise, where a really systemic approach is highly desirable, is a validation of its applicability, utility and efficacy .
It can be useful for both, for the theory development itself and for the design of highly complex, networked, SOPHOCLES like e-design systems. In this perspective the TOGA has been proposed in the project proposal and its completing, improvement and validation, in course of the project, is congruent with project objectives.

2. TOGA SYSTEMIC APPROACH

"Everything what is finished could be done better"
[George Ridman]

2.1 Introduction and generalities about TOGA

TOGA is a system of conceptual frameworks and a methodology for complex real-world problem specifications. It also has been generalized and assumed as a foundation of a cognitive theory of Abstract Intelligent Agent.
The TOGA methodological part was inspired by Michalski, Stepp, Dontas, and Collins papers. They have proposed a main idea of the connection of an *object-based* conceptualization with *goal oriented* approach. In plausible reasoning patterns they also introduced a reasoning generalization hierarchy. The TOGA conceptualization of artificial physical systems is an integration of Lind's MFM (Multi-level Flow Modelling) framework with, generally known in physics and engineering, processual representation of physical phenomena. The *top-down*

approach is a generalization of the basic concepts of the systemic structural design methodology [E.Yourdon,1989].
The TOGA theory has been developed in ENEA since '89 [see Bibliography] and heuristically applied to different RTD projects as EC MUSTER.

TOGA is a systemic integrated approach which follows a few but basic cross disciplinary scientific and engineering paradigms.

It also assumes that our knowledge is relative but always have to be filtered and organized according to an utility function related to our goals/problems/ tasks (therefore it is called: goal-oriented).

> *"… the behavior of living organisms is typically teleonomic, that is, oriented towards a future state, which does not exist as yet"*
> [Principia Cybernerica, the Web].

Such approach must be, by definition, developed top-down. It searches consensus of the TOGA-users related to goal-oriented completeness and congruence of the system specification. Such specification is defined on high levels of abstraction and goes down applying available, but only goal-oriented , knowledge.

The TOGA meta-theory refers to the main paradigms of physics, engineering and cognitivism with a general system approach perspective, Fig. 1.

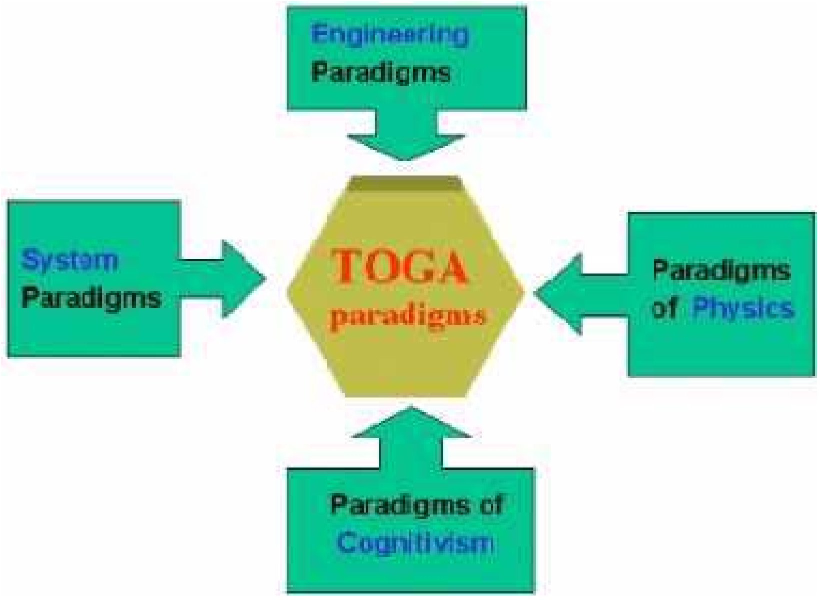

Fig.1. TOGA integrates different paradigms, the physics paradigm refers to the Thomas Kuhn's scientific method.

An fundamental TOGA assumption/axiom is the following:

In every complex real-world problem a recognition of the abstract couple:

(abstract intelligent agent, its environment)

is the key initial step for human designers or decision-makers.

They both, (AIA, En), and the interrelations between them are decomposable to the form of various intelligent agent worlds [Intelligent Agents Worlds, Gadomski,1994].

For example, even in a simple design problem, its engineer can be represented as an abstract intelligent agent (AIA) which, in a specific mental and physical environment, may intervent and modify them. This domain is called in TOGA, domain od activity (d-o-a).
All above assumptions refer to the paradigmatic conceptual frame of the TOGA theory.

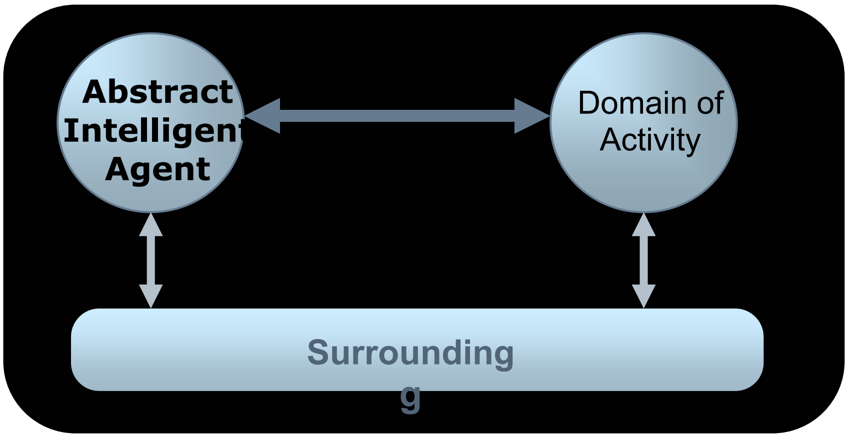

Fig. 2 It illustrates a first decomposition of the agent environment on its domain of activity and its surrounding.

2.2 TOGA Objective

TOGA intends to be a knowledge ordering tool. It assumes that we have a knowledge which is not ordered for our goal, or it is ordered for other purposes.
TOGA assumes that ontology, epistemology and philosophy as relative concepts dependent on a chosen initial couple (AIA, En), because they only are a mental property of AIA.

We could say that an additional purpose of TOGA is rather to help to understand and model robot/computer minds or another abstract intelligent system during the solution of complex design tasks, than to model humans as a biological constructs. In this sense TOGA represents a rigorous functional point of view with an operative subjectivism.
On the current level of the development, the pragmatic assumptions of TOGA does not need and does not use the concept of absolute true. It means, X is true if it is confirmed by response of the domain of intelligent agent activity - but, we should noticed, it depends on agent perceptors and also how the abstract domain of AIA activity is represented.
In particular, TOGA tries to bridge the gap between the natural sciences, the social sciences and engineering.
It have to be self-applied and self-explained (+ some axioms) because these properties are considered its meta-axioms. Its methodological rules indicate how it should be applied to any goal-oriented activity, i.e. to its self-development too.
Such theory should be:

incremental,
modular,
recursive and
repetitive
abstract system, and

it has to be activated/used only by an abstract intelligent agent.

In order to be more concrete, in the SOPHOCLES Project we intend to develop an abstract intelligent agent as a reasoning kernel of Intelligent Decision Support Systems (an intelligent advisor and artificial expert), assuming that decision-making is a main component of every auto-conscious action-oriented thinking entity.
The TOGA cognitive agent should be always goal-oriented and should think well top-down and bottom-up in an abstraction hierarchy.

TOGA is falsifiable by the analysing of other more specific theories, methodologies and methods employed in the design practice, it also means that every formal conceptualisation and commonly accepted axiomatic truths (if goal-oriented) must be expressible in and congruent with TOGA.

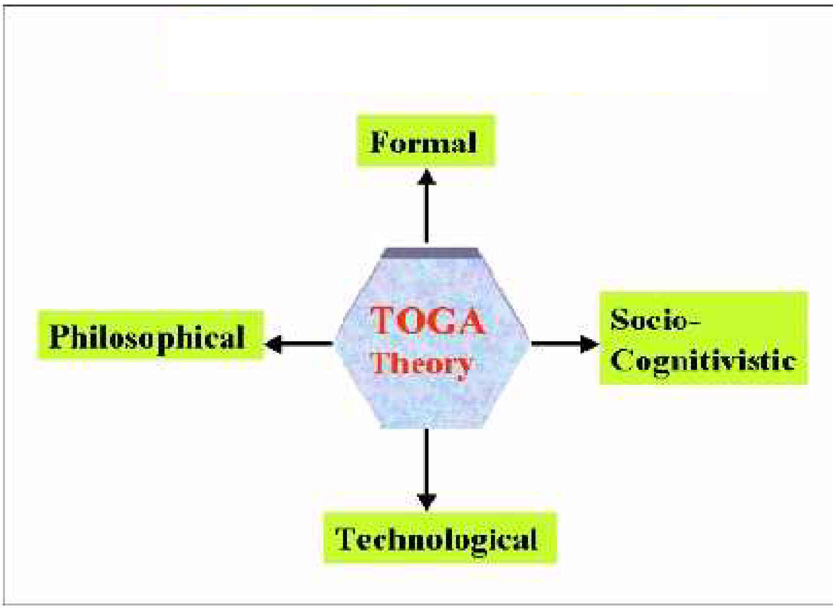

Fig.3. TOGA applications are validated in four basic contexts.

TOGA is developed in sequence of iterations by the specialization of its own formalism, decreasing vagueness of too intuitive general terminology, and to generalize too narrow meaning of the terms from specific technological domains. It is incremental and top-down therefore for its falsification a confrontation with engineering experience, a bottom-up practice are necessary. In general, TOGA accepts main concepts from Metasystem Transition Theory and is congruent with basic paradigms (meta-assumptions) of the Principia Cybernetica [see web].

Currently it is in semi-formal representation state but just useful for heuristic applications, It has been applied in many ENEA's projects. It is not finished because It is developed top-down and for its falsification a confrontation with experience and bottom-up theories are necessary.

Therefore the multi-level action-oriented decision-making which integrate rational and emotional components of conscious human thinking has been chosen as a cognitive development and validation domain of the application of the TOGA approach to the SOPHOCLES Project.

More precisely the SOPHOCLES Intelligent Advisor is focused on the development of theoretical foundations and on a demo validation of an abstract intelligent agent as a kernel of Intelligent Decision Support System for distance designers.

2.3 TOGA Meta-assumptions

The TOGA initial meta-assumptions relate to:

- **ontological axioms of a theory**; they consist of an ontology of the theory, their generic assumption is to integrate top-down approach with continuous goal-oriented constrains using a fundamental object-based conceptualization framework
- **hypothesis**; inference descriptions, generalizations of the states and laws of the world in the past, present and in the future. They are domain of falsification.
- **design assumptions**; requirements and constrains chosen arbitrarily during a design process. They are domain dependent and application-oriented

- **terminological assumptions**; definitions of arbitrarily assumed names of concepts and elements of a concept web, equivalencies and relations between terms.

In a modelling, personal experts experience and mental historical records are considered an acceptable source of information to the definition of the necessary characteristics of the model [G.Polya, 1957; A.Newell, 1972]. This assumption is especially valid for systemic cognitive constructions.
Main problems referred to this task is the lack of explicit consensus on such products, and natural consensus on their models.
For example, according to [Gadomski, 1990], verification of a real-world model/theory is based on:

- IMPLICIT CONSENSUS, in a predefined human community, when the individual motivations of one member are not known by the others;
- UTILITY CONSENSUS, when successful application of the model/theory to the solution of selected practical problems has been performed (engineering paradigm);
- EXPLICIT CONSENSUS, when an accepted theory or another conceptualisation system has been established and a proof can be/is given inside it;
- NATURAL CONSENSUS, when experimental verification of the model/theory is performed (scientific paradigm).

In this context, TOGA intents to have **utility** consensus, as a consequence, it should also has **explicit** and **natural** consensus in engineering specification and identification domains.

TOGA includes, so called, normative meta-assumptions, such as:

- structural assumptions on:
  - **-- Recursivity**
  - **-- Repetitivity**
  - **-- Modularity**

They minimize total axiomatic information employed by the theory.

- methodological assumptions, which require **completeness** and **congruence** of the problem conceptualization on every abstraction level.
- terminological assumption, to reduce the number of terms as is possible.

TOGA meta-theory is composed of three main elements:

1. **Theory of Abstract Objects** (TAO), which is the primary, domain independent, conceptualization system of AIA;

2. **Knowledge Conceptualization System** (KNOCS) is the TOGA ontology. It constitutes the second level conceptualization system, i.e. axiomatic assumptions and definitions related to: conceptualization of the real world, goal-oriented domain of activity, realization of an abstract intelligent agent (AIA), and the AIA goal-oriented activity;

3. **Methodological Rules System** (MRUS) is a rule system which indicates how to recognize and specify complex design or identification problems using TAO and KNOCS.

TOGA is a self-explanation theory, therefore our point of view on TOGA is also seen as the specification of a complex problem by an AIA. We should noticed that using top-down strategy we specialize the TOGA systemic approach using before accepted, more general (from the higher generalization level), TOGA ontology and rules.
Some basic elements of the TOGA meta-theory are illustrated in the next paragraphs.

2.4 Theory of Abstract Objects (TAO)

TAO is a mathematical construction but it is also a conceptualization system of abstract intelligent agent. It can be used for representation of perceived impressions and symbolic imaginations involved in human goal-oriented activity.

The theory refers to *abstract objects*, according to the Oxford Dictionary , abstract means "separated from matter", a conceptual product obtained by neglecting some properties of analyzed thing.

Following this, by an *abstract object* in the TAO theory is intended

***a conceptual representation of any entity or a property abstracted from its physical realization, or if it is a mental construction, abstracted from some its imaginary properties*.**

For intelligent computer agents, TAO is a primary conceptual context of symbols and images recognized physically in the ICA (Intelligent Computer Agent) environments.
TAO is based on a network concept and on fundamental elements of generally known mathematical theories, such as set theory, functional analysis, and graph theory.

Below, the basic concepts of TAO are formally presented.

Any theory can be considered as a frames system which enables structuralization and operation over a certain class of sets. In the case of TAO, any numerable set is its domain. Let this set is called *primitives set* ***Z*** or *dictionar*y.
TAO is a frames system which enables structuring the *primitives* in the forms of:

- **Objects**, specified by their n*ames, attributes names, values*, and *value domains*;

- **Relations** and relational isolated networks of objects, called *world-of-objects* (w-o-o) which:
    - can be arbitrarily divided into systems and their environments,
    - can be aggregated in universes of objects linked by r-connections.

- **Changes**, they are represented by possible operations of AIA on components of w-o-o.

The TOGA's abstract-object's frame is not defined neither by a reference to the real world nor to a programming environment, but it is a conceptual scheme which, according to the TOGA axiom, may represent formally any concept that could be described by:

object-name, attribute names and *attributes values*.

The abstract objects are assumed as elements of every conceptualization of any (physical and mental) domain of activity of intelligent system. In this sense a *process, relation, change, action* can also be considered as objects in the adequate *world of objects*[1].

Remark:
X is an entity which we/(an AIA) percepts in an unique mode and we are able to distinguish in its context/surrounding.
'X' is a formal denotation of x, for instance a character/symbol string, it is called *X name*.

Note: The terminology above used in various theories are different notions, for example,
First- order logic assumes that the World contains:

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[1] Some notational conventions:
" term " denotes an intuitively used notion of the word 'term',

Objects, such as, people, houses, numbers, theories, Donald Duck, colours, centuries,
Relations, such as, red, round, prime, , brother of, bigger than, part of, has colour, occurred after, owns,
Functions, such as, middle of, father of, one more than, beginning of, *, -.

This and other basic conceptualizations have been analysed but any other of them, seem, do not satisfy the TOGA initial requirements of completeness and goal-oriented perspective.

Definition of Object and Object Frame/(representation structure)

For an AIA, an object may be everything representable in terms of the set theory, as a ordered couple

$$('Q', A),$$

where: 'Q' is a primitive called *object name*, 'Q' $\in$ **Z**,
A is a subset of primitives a, 'a' $\in$ **Z,** called *attribute names*,
and
'Q' is not an element of A.

'Object name' and *'attribute name'* are the TAO descriptors.

Object frame (o-frame) is a metadescriptor and is defined as the ordered couple of descriptors :

(*'object name', a set of numerable 'attributes names'*).

Attribute is represented by an ordered couple ('a',w) where 'a' is an *attribute name and w is its value in a values space*, **W.**

Every object is representable as a point in **W**. The following classes of possible attribute spaces are taken under consideration:

WN - set of unordered text-expressions,
WO - set of ordered text-expressions,
WF - set of mathematical functions,
WA - set of areas in defined numerical space,
WR - numerical space.

Roughly speaking, an attribute may have qualitative or quantitative value domain.

In order to present any abstract theory we must accept its formal representations of introduced concepts. TAO is represented in two representation symbologies, mathematical and graphical.

Using mathematical notation we can represent an object Q as follows:

$$Q : \quad 'Q' \; [\, (a_1, w_1, W_1),\; (a_2: w_2, W_2), \ldots \,],$$

Where $(a_i: w_i, W_i)$ for i=1,2,... represent attributes,
W_i - denotes a domain of variability of the *i*-th attribute value in an attribute space $\mathbf{W_i}$, and
'Q' denotes an object name.

Let { Q } be a set of objects Q_1 [A_1], Q_2 [A_2], .., Q_N [A_N] and
if exists non empty subset of attributes AS such as

$$AS = A1 \cap A2 \cap \ldots \cap AN,$$

then the Cartesian product of all AS components, represented as

$\mathbf{W}_1 \times \ldots \times \mathbf{W}_m$, for i=1, ...m, is called a *common space* of object set {Q}.

Of course, the properties of a distinguished object space depend on the assumed classes of the AS set attributes.

Any form composed of an object name *'Q'* and the set of ordered couples is called *'abstract object'*,

Abstract Object Q: ('Q',A) or 'Q'(A),

where A: {('a',v)}, a: ('a',v),
and 'Q', 'a' $\in$ **Z ,**
v denotes value of the attribute a in a certain measured space.

Let a formula

$$B =_{\mathbf{U}} u$$

denotes that *something* called B has a value u in a space **U** .

In consequence, any abstract object can be also represented as follows:

$Q =_{\mathbf{Z}}$ 'Q' , where 'Q' is the name of Q , and 'Q' $\in$ **Z ,**
$Q =_{\mathbf{\Phi}} A$, where $A \in \mathbf{\Phi}$, and Φ is an element of a set of subsets of **Z,**
$A =_{\mathbf{V}} v$, where $v \in \mathbf{V}$, $\mathbf{V} = V_1 \times V_2 \times \ldots V_n$ and V_j is any strongly or weakly ordered space.

$A =_{\alpha}$ {'a'}, where $\alpha \in$ **Z.**

In this manner AIA can represent every abstract object on three levels, OL, as follows:

OL1 - *object level*, Here, AIA "knows" only that an object with name 'Q' exists:

$Q =_{\Psi}$ 'Q' , where Ψ is a subset of **Z** .

OL2 - *attribute level*, $Q =_{A}$ {'a'},

OL3 - *value level*, $Q =_{A \times \mathbf{V}}$ {'a', v },
where $a =_{\mathbf{V}} v$.

Definition of *o-relation*

Let {Q} be an object set and $Q_1, Q_2 \in \{Q\}$ then,
if $a(Q_1)$ and $b(Q_2)$ denote an attributes of object Q_1 and Q_2 respectively,
then the following expression:

$$'r'(Q_1,Q_2) : \quad 'r' [\, a(Q_1), b(Q_2) \,],$$

where (Q_1,Q_2) is an ordered couple, called *o-relation (*or shortly *relation)* between Q_1 and Q_2 , and
'r' denotes *o-relation name 'r'* $\in$ **Z.**

Definition of *system*

An ordered couple ({Q},{r}) denotes a system, Sn, iff
- all Q ∈ {Q} have a common space,
- for every (Qa,Qb), where Qa,Qb ∈{Q}, there is r[Qa,Qb] ∈ {r}, and
- for every
(r[Qa,Qb] ∈{r}) → (Qa v Qb) ∈ {Q}.

Definition of *structure*

The set {r} will be called *structure* of the system Sn: ({Q},{r}).
denotes structure if

$$\Xi : \{r\} \text{ for } Sn:(\{Q\},\{r\}).$$

On the level of attributes

$$\Xi : \{ r(A(Q))\}$$

Remark:
Structure is a *property* of every system.

Definition of *world of objects*

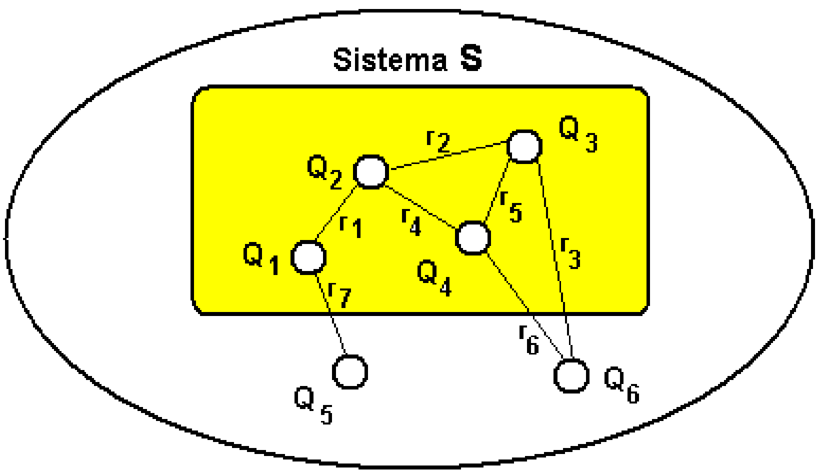
If ({Q},{r}) is a system and Qa ,Qb ∈ {Q} for every r[Qa,Qb] ∈ {r}
then this system is isolated and will be called a *world of objects*, w-o-o, also denoted by Ω.

A w-o-o ({Q}, {R}) is complete if for every attribute of every object Q ∈{Q} exists such b{Q'} and Q' ∈ {Q} then

R [a(Q), b(Q')] ∈ {R}.

Remarks:
- According to the definitions of object, relation and w-o-o, every abstract object has to be in o-relation with an other abstract object. Therefore
the minimal complete w-o-o Ω, is composed with two objects Q1(a), Q2(a) with a relation r [a]:
Ω = ({Q1,Q2},{r}). From this is possible to extract two systems:
$S_1=(\{Q_1\},\{r\})$
$S_2=(\{Q_2\},\{r\})$.

- Two objects are in a *relation* iff they have a common attribute space,



World of objects Ω

Fig. 4 An illustration of the relation between a system and a world of objects.

Definition of *r-connection* and *point of view*

Two ws-o-o can be linked by common primitives when they have different meaning/(formal function, such as object name, attribute name or relation name) in different ws-o-o. It is called *r-connection*.

For instant, if the word 'title' is a *primitive* then in one w-o-o it can be the *attribute_name* of an object named 'book' but in another w-o-o 'title' may be an object name.

For example, ‘r’(Ω1,Ω2): ‘r’(p: a , O)

means that Ω1 and Ω2 have a r-connection, where p - is a primitive and
a - denotes an attribute a defined in Ω1, and
O – denotes an object in Ω2 with the same name p,
‘r’ – is a r-connection name.

One of the new ideas included in TAO is the definition of a class of singular objects with operational attributes, and the formalization of the concept of the *point-of-view* referred to an object.

Point-of-view (p-o-v) is a relative concept. It is a possible function of a selected object into w-o-o. The representation of a selected object X from the p-o-v of another object Y includes only these attributes of X which are linked with Y by their common relations.

Let an object Q_1 is described by the attributes (a_1, …,a_n) , Q_2 is described by the attributes (b_1,…,b_m) , for n,m > 2, and among them exist only relations
r_k (a_1, b_1), r_{k+1}(a_2,b_2), then **Q_2 form the point of view of Q_1** is described only by (b_1, b_2).

It can be written as follow: PV (Q_2| Q_1) => Q_2 (b_1, b_2), where

=> denotes the result of an *operation* available for singular objects.

Definitions of a*bstraction* and *specification* operations

Abstraction and *specification* are *abstract operations* on ws-o-o performed by *singular objects.*

Singular objects are particular active objects which can:
observe, *create* and *modify*

other objects inside world-of-objects.

Singular objects can be internal or external, relatively to the ws-o-o which are the domains of their activity.
Of course, they can be considered "normal" objects in another universe of objects.
Operations on ws-o-o and on objects universes are unique attributes of the external singular object in TAO.

One of the TAO operations is an ***abstraction*** operation, Â, it transforms systems or ws-o-o in another ws-o-o.
Any w-o-o can be the base for other descendent ws-o-o obtained by an abstraction operation.
More precisely, abstraction is *from* (neglects) a specific property of system or w-o-o.
Its attributes are eliminated after abstraction operation.
Abstraction does not have reciprocal operation, i.e. the operation $\hat{A}^{-1}$ does not exist.

$$Y = \hat{A}\ X .$$

Abstraction operation reduces information X about primary objects.
Every abstract object in Ω can be obtained as a product of operations on lower, higher and parallel ws-o-o.

Definition of one w-o-o determines its relative "orthogonal" abstraction hierarchies.

We distinguish two types of abstract objects:

descendent abstract objects (dao), and
absolute abstract objects (aao).

Contrary to aao, every dao has a link with its ancestor. Another operation is a specification.

Specification increases information about objects and relations.
Specification enables decomposition of elements of w-o-o on subelements.

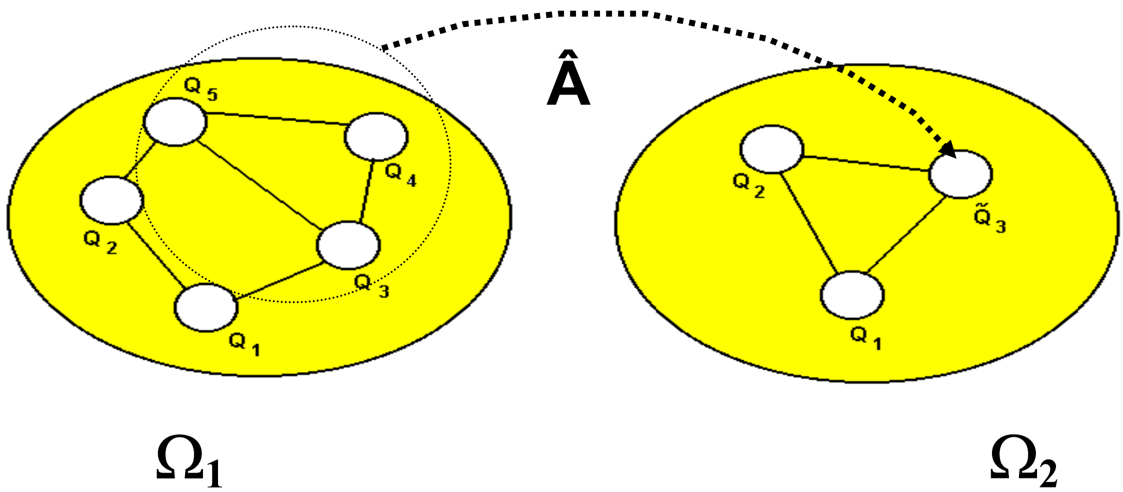


Fig. 5 An abstraction operation relating to the internal structure of a system $S(Q_3, Q_4, Q_5,)$ of the world Ω_1 .

Specification is arbitrarily done by intelligent abstract agent (a singular object in the TAO terminology).

Abstract operation is every operation performed on every information level (OL) of abstract objects , therefore a *specification* is also an abstract operation.
The problem of "abstraction" has the rich and different representations in the literature, see [Balducelli,93], [Giunchiglia,]. For example the theory of abstraction proposed by Giunchiglia and Walsh can be applied to the top-down representation of the TAO concepts.

2.5. Knowledge Conceptualization System (KNOCS)

Knowledge Conceptualization System is a meta-conceptualization toolkit. It is the second level of the TOGA ontology with axiomatic assumptions on the real-world. It gives the bases for the application of TAO and other conceptualization systems to the concrete problems and decisional situations.

Every real world problem can have many parallel particular problem oriented conceptualizations that constitute, according to the TOGA hierarchy, third domain-oriented conceptualization level.

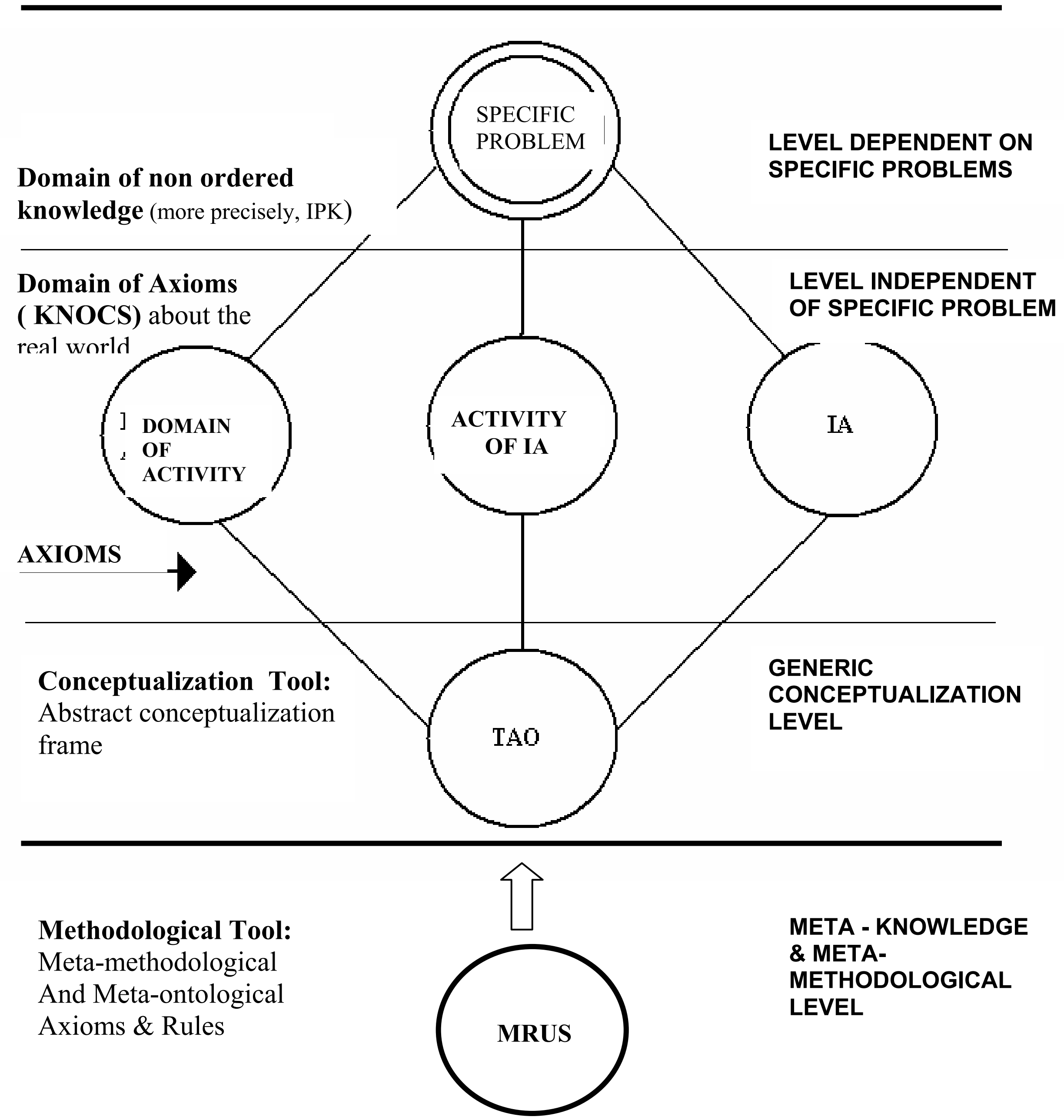


Fig. 6 TOGA Framework: Representation of three basic conceptualization levels and their management methodological tool.

KNOCS is a set of generic structured TOGA axioms and relations among them. They are presented below.

A1. Every intelligent agent, IA, exists only together with an environment, EN. The copy IAW = (IA, EN) is called *intelligent agent world*.
EN is a world of objects and it may include other IA.

Every description of IAW has to include:
Domain of activity,
Model of IA
Goal-oriented activity of IA.

A2. Every human problem can be conceptualized as an interaction between an intelligent agent (IA) and its environment.

A3. Intelligent agent is decomposable on Abstract Intelligent Agent (AIA) and its physical/software carrier (CIA –carrier of intelligent agent).
AIA is a functional system which represents an "essence" of intelligence.

AIA properties are defined top-down and also intelligence is defined using TOGA.
The relation between AIA and CIA is called *carrier relation*, Cr and is represented as the ordered copy Cr = (AIA,CIA) and graphically on the Fig. 7.

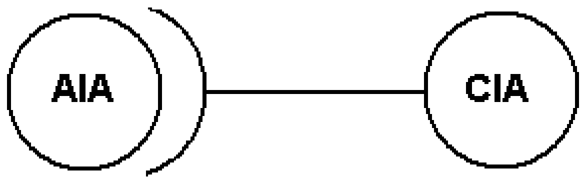


Fig . 7 Graphical representation of *carrier relation*.

Remarks: All properties of IAW and its conceptualization framework are properties of the domain of activity of another AIA called *observer*.

A4. Every product of the human reasoning activity can be conceptualized and transformed in frames of the Theory of Abstract Objects. TAO is founded on the following abstract concepts :

- *Objects,* specified by their attributes , values, and value domains.
- Relations and relational isolated networks of objects, called *worlds-of-objects.*
  Each of them is arbitrarily decomposable on a system and its environment.
- *Universes*, they are ws-o-o structured in different abstraction hierarchies and according to preselected perspectives.

TAO includes a set of operations and rules, which enable creation and modification of these concepts in any distinguished world of objects. TAO is a conceptualization system.

Definition
Conceptualization system is a frames system and the operations set which is defined on these frames.

We can notice, that TAO has an algebra property. TAO can also be seen as a generalization and extension of three existing approaches: the entity-relationship approach, the object-oriented programming/design, and the frame systems.

Remarks: *Ignorance*; it is always related to a distinguished part of IA environment. From the goal-oriented point of view, an unknown ignorance does not exists because every real ignorance has to have object property.

A5. TOGA IPK Paradigm: Reasoning is a complex hierarchical process. Its generic functional components are represented by three joined but independent relative concepts:

information,
preferences
knowledge.

A definition of the IPK (information, preferences, knowledge) process requires more precise than commonly use definitions. They are presented below.

Definitions:

Data: everything what is/can be processed/transformed in computational and mental processes. The data and **processing** consist of 'coupled definition'

Information, I: data which represent a specific property of the domain of human or artificial agent's activity (such as: addresses , tel. numbers, encyclopedic data, various lists of names and results of measurements).

Knowledge, K: every abstract property of human/artificial agent which has ability to process/transform (quantitatively/qualitatively) information into other information (such as: instructions, procedures, manuals, scientific materials, models, theories).

Preference, P: an ordered relation among two states of the domain of activity of the agent which indicates a state with higher utility. Preference relations serve to establish an intervention goal of agent.

Goal, G: a hypothetical state of the agent domain of activity which has maximal utility in a current situation. Goal serves to the choice of knowledge which should process new information.

Document: a passive carrier of different structures of knowledge and Information in human organizations, it can be physical or electronic.

Computer Program: an active carrier of different structures of knowledge expressed in computer languages.

There are two fundamental relations between Information, Preference, Knowledge and Goal related to a preselected domain of activity, D.

They can be presented in the operator formalism as follows:

$$I' = \hat{K}\, I;$$

$$G = \hat{P}\, I;$$

Where $\hat{K}$ is a knowledge operator,
I is an information about D.

And for

Pr: If Sx $\in$ Sa and Pr then Sy $\in$Sb ;

Po : Sb is better then Sa, or Sb $\succ$ Sa

P^ is a preferences operator when selects the best requested information Sy from the given $\{Pr\}$. This information describes a state of D and is denominated by G.

As we see, the I,P,K are relative terms. They are composed with data processing and choice operations which satisfy the condition that:
I and I' always relate to a before distinguished domain.

A6. Every physical domain of activity of AIA is a potential source of quasi-infinite (= practically infinite) number of information.
Here, information gathering is a continuous cognitive process. For the reason of information heterogeneity and its quasi infinity availability, information gathering and processing always require more and more mental effort and knowledge.

A7. Consciousness; Every process Ps relying on the behavior of physically realized AIA (X) in its physical environment, or on a change of a state of its IPK is conscious if X has such conceptual system where the process Ps is describable and AIA (X) can perform it.

A8. A goal-oriented conscious activity of human agents can be conceptualized by their observers (another intelligent agents) as an activity of an AIA.

A9. Every human-made real-world system in the domain of activity of AIA is describable by the decomposition of the interrelation between a System and its Goal, called SPG (System-Process-Goal Approach) [Gadomski, 1988].
SPG is funded on formal definitions of the concepts *process* and *function*, and on an object network frame divided on:

***goal layer*, *functions layer*, *processes layer* and *system layer*.**

These lavers are presented more precisely in the next paragraph of this work.

A10. Let AIA X1 includes in its d-o-a D1 another AIA (X2, D2) then in every moment, the interrelation R(X2, D2) can be described by the decomposition of an abstract interrelation between
Intervention-Goal and the state of the couple (X2, D2). It is called **WAG** (World – Action - Goal Approach).
WAG is funded on formal definitions of the concepts *process* and *function*, and on an object network frame divided on:

- **intervention-goal layer,**
- **tasks layer,**
- **actions layer,**
- **Intelligent Agent world layer.**

They are defined in the next paragraph of this work.

2.5.1 Domain modeling and System-Goal Interrelation

The first conscious representation of RW (real world) in the form of symbols is the zero-level abstract d-o-a, DA .
It includes directly acquired information about agent real d-o-a, DR .

Abstract d-o-a is divided on two parts.
The first is an *information buffer* which includes all conceptualized information obtained from human "sensorial perception".
The second contains goal-oriented descriptions of DR.

Remark: In the AI literature, these descriptions are also called 'static knowledge' or 'domain knowledge'.

DR is represented as an objects network in a discrete D3 space.

Domain three-dimensional Discrete Space (DDS)

Every system from a real domain of activity of AIA can either be specified using the *engineering design paradigm* or/and identified using the *scientific research paradigm*. In the consequence of the previously presented definitions, The basic formal "interface" between these two attempts enables to construct the couple system:

function - *carrier relation –* ***process****.*

Function is a necessary goal-oriented property of a pre-identified process or system.

From the designer perspective, when a function is defined, its *carrier process* is a concrete realization of the function.
Any arbitrarily selected artificial object from the real d-o-a of human agent, can be conceptualized by the decomposition of the interrelation between a system and its goal, Goal-System Interrelation (GSI).

The decomposition frame is an object network divided into the following network layers (= sub-networks): *system-goal layer, functions layer, processes layer,* and *systems layer,* what is illustrated in fig.8.

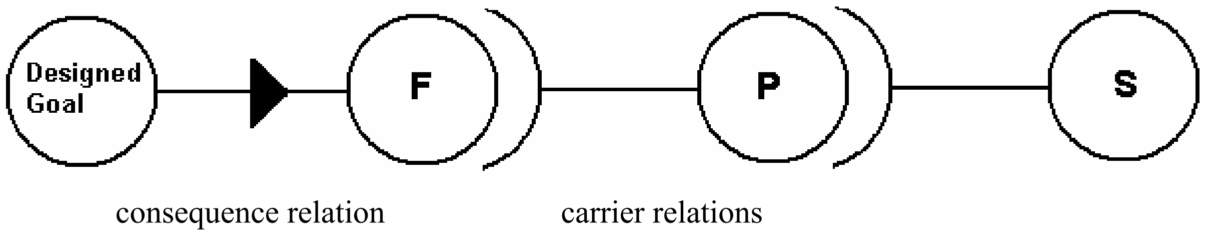


Fig. 8 Graphical representation of Goal-System Interrelation.

System-goal of a system X in an environment En, is a specification of some changes or properties of En required by the user or the creator of X, which should be/are obtained as the consequence of interactions between X and En.

For this reason, the system-goal must be expressed only in terms of the environment descriptions, and can only be established by the system creator or its user.
The *system-goal* is also called ***design-goal***.
The relations between the system-goal and functions are *cause/consequence (c/c relations)*.
The relations between functions and processes or systems are called *property/carrier (p/c relations)*.
The GSI conceptual frame allows the decomposition of the relation between a designed, modified or identified system, and its goal.

Of course, from **A6** results that every "natural" object can have an infinite number of functions and goals, i.e. they depend on the application of an analyzed object by human-agents.

From the perspective of AIA knowledge, there are three types of objects/systems/subdomains in abstract ds-o-a:

> Dt1. components driven only by physical principles; hypothetical goal is unknown for the agent,
> Dt2. fixed goal-driven components; their design-goal is known for the agent,
> Dt3. components driven by temporal intervention-goals.

In the Dt1 domain, the agent can navigate and manipulate.
The Dt2 domain is supervised and controlled by the agent according to its intervention-goals.
The Dt3 domain can also be the domain of co-operations and other social interactions.
According to the TOGA conceptualization, every perceived/conceptualized entity is represented as an object in *three-dimensional discrete space* (DDS).

- The **first dimension** is based on GSI (*Goal-System Interrelation*) divided into four layers: *goal, function, process*, *system*.

This interrelation is valid for every artificial goal-oriented system. An approach which formalizes *Goal-System Interrelation* is called System-Process-Goal Approach (SPG) and may be used for integrated plant-operator supervisory systems [Gadomski, 1988], complex engineering systems design, as well as, for the human organization modeling [Gadomski, Gadomska, 1990], [Gadomski, Nanni, 1993].

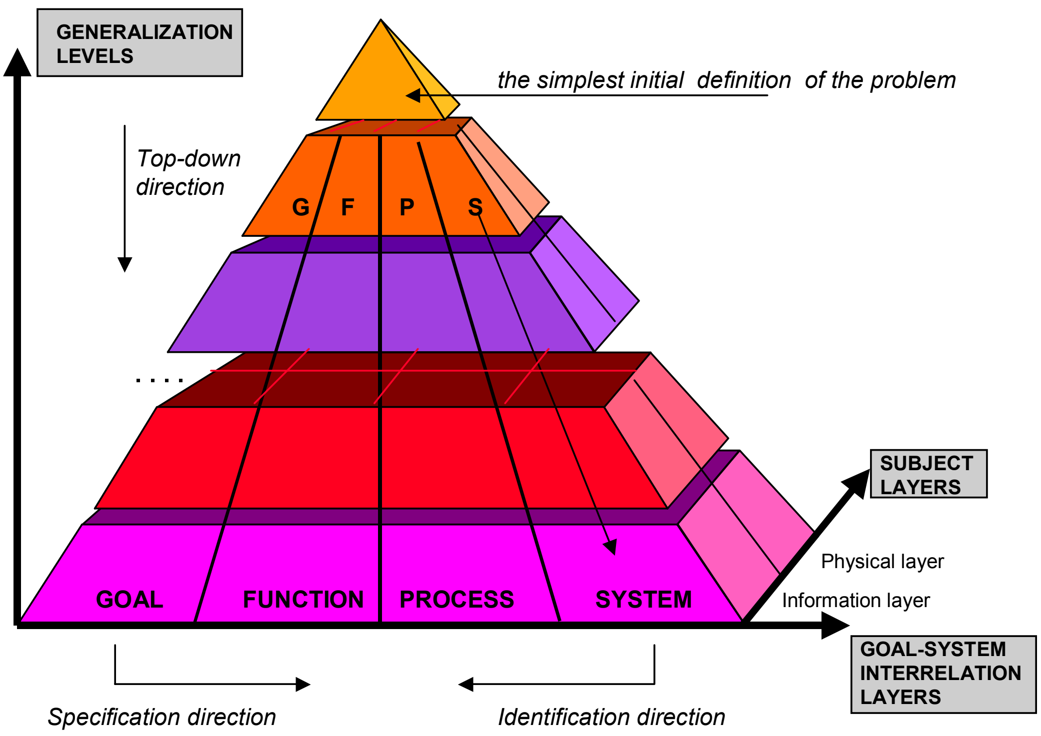


Fig. 9 An illustration of the application of the MRUS methodology to the specification or identification of complex goal-oriented system in **Domain three-dimensional Discrete Space** (DDS).

- The **second dimension** gives the possibility of setting up the domain model/representation on different *generalization levels* (GL), which can be organized arbitrarily from a simplest, initially assumed, model specification up to a details level, when the model implementation will be possible.

- The **third dimension**, called *Subject Layers*, is used for a set up of the system description in the hierarchy of abstraction, from structures of directly measured (physical) attributes to highly abstract conceptualizations, for example, material, structural, dynamic and information layers, or hardware, software and model layers.

The problem specification starts from the user knowledge collected in different conceptual systems and the initially specified goal which he/she intends to achieve.
The pyramidal, top-down problem structuring requires bottom-up goal-driven structuring of available information and evaluation of knowledge.
The requested completeness of a problem description on any GL level in the DDS space, makes the identification of problem-solver ignorance (seen as temporal black objects) necessary, and indicates the information/knowledge which should be acquired.
The problem structuring is performed top-down in the generalization hierarchy by identification of carrier systems and neighborhood processes, and by specification of functions necessary for the achievement of the assumed goal.

Fig 9 illustrates the general TOGA framework for a top-down specification of problems related to abstract or real goal-oriented systems.

The conceptualizations of the problem specification, on every GL level is verified by its confrontation with the existent data (i.e. external information related to the currently constructed GL) and with problem attributes specified on the higher GL level.

2.5.2 Intelligent Agent activity: an IAW - Goal Interrelation

This conceptualization refers to the **WAG** (World -Action-Goal) approach.

Figure 10 illustrates primary decomposition of an Intelligent Agent World (IAW).

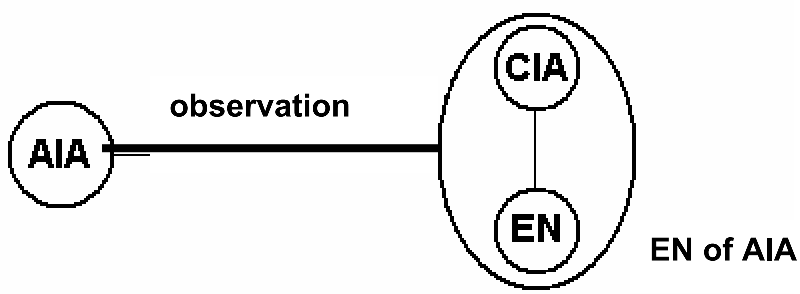


Fig. 10 From the perspective of an AIA, its environment can be seen as a couple (CIA, En).

If the d-o-a X of an AIA includes another AIA Y then X's knowledge related to a selected goal-oriented activity of Y may be conceptualized in terms of:

intervention-goals, *tasks* , and *actions* referred to the Y's world (IAW).

Where

Task is a property of an action oriented on a predefined intervention-goal, it is expressed in terms of d-o-a description, and specifies which changes have to be introduced in the AIA d-o-a for achieving an intervention-goal.

Less formal, task specifies what have to be done in the terminology if the goal definition.

Action is a specification what AIA is able to do in d-o-a for the realization of tasks, i.e. in order to achieve the predefined goal.

In other word, an action is the knowledge how in the domain context a task has to be executed by an agent.

For such reason, an *action* must depend on executor possibilities, and one *task* can be performed by execution of different alternative actions.
From the identification point of view, one selected action can be recognized as the carrier of different tasks.
Tasks (task sequence, generic scenario) are executor independent and they depend on goal constrains in predefined d-o-a.

The fig 11 illustrate formal graphical representation of the relations between IAW (Intelligent Agent World) and its temporal Intervention Goal.

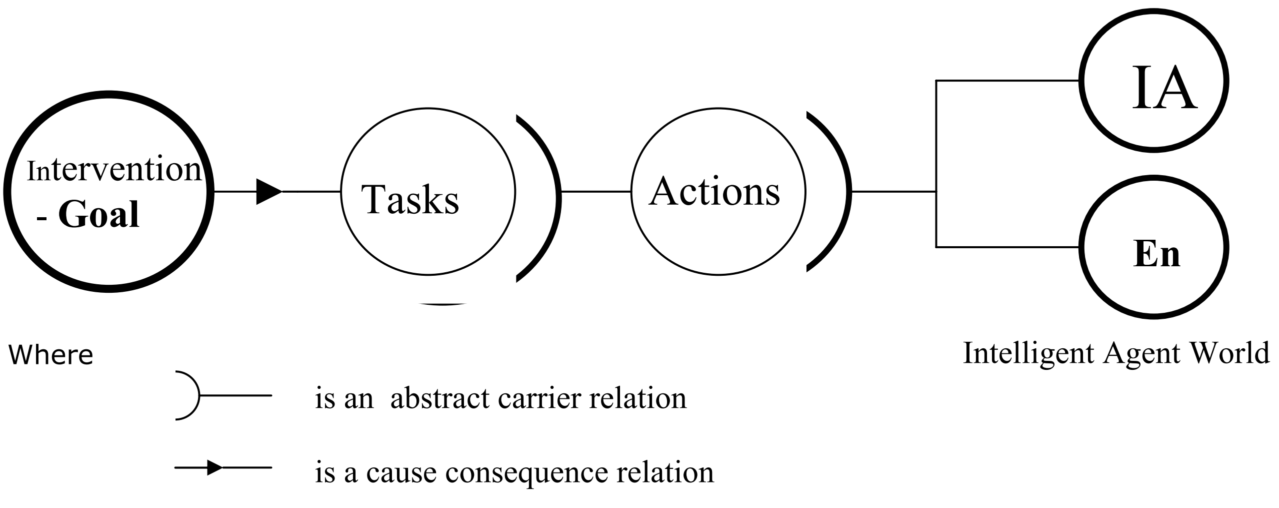


Fig. 11 The WAG conceptualization: Interrelation between IAW (IA, En) and its Intervention Goal.

Using analog to the fig. 9 presentation, the methodological approach to the interrelation: IG – IAW, is presented on the fig. 11a.

From the TOGA perspective, human organizations are Intelligent Agents. In every moment, they are describable by:

- intervention goals;
- tasks, actions to
- an their world, that is composed by IA itself and its environment.

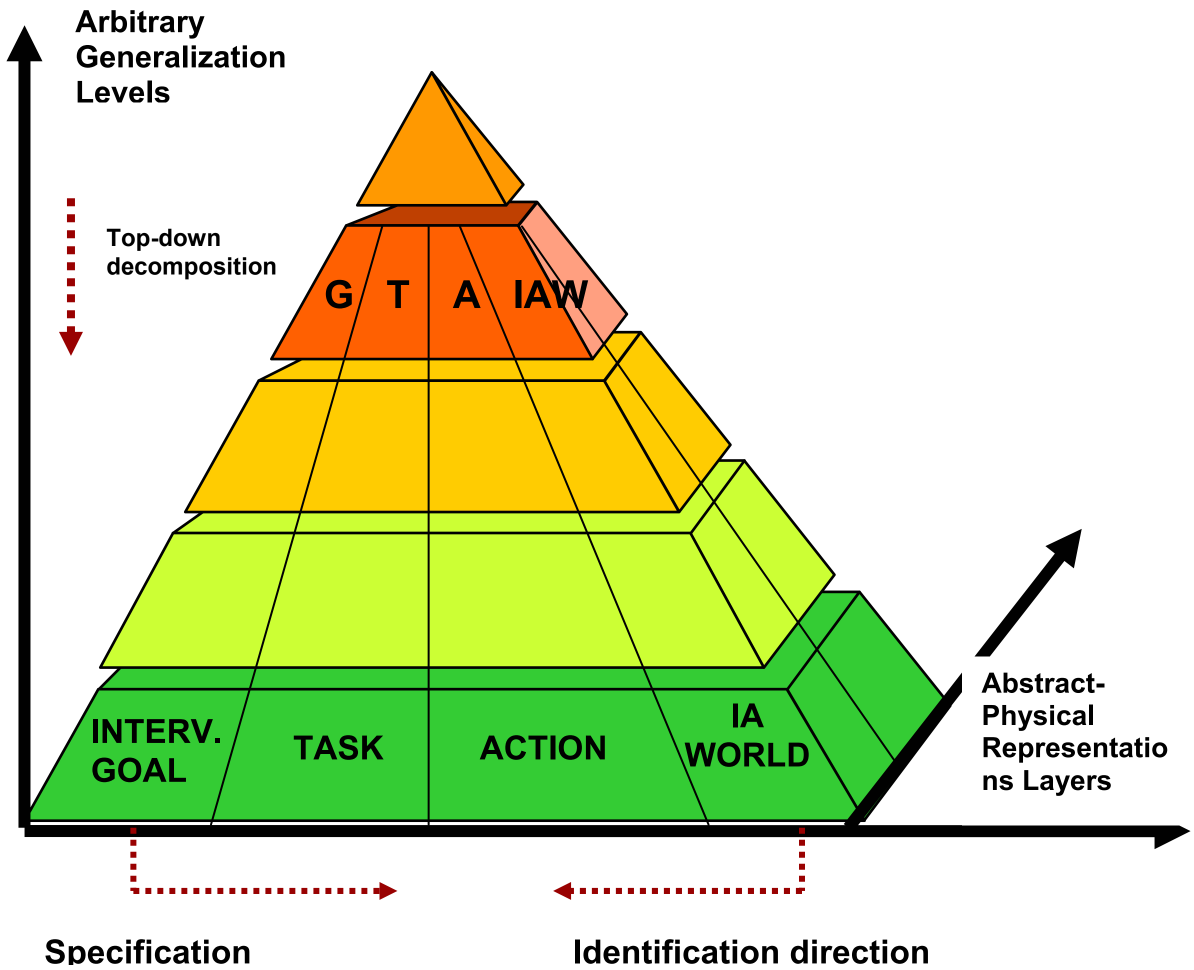


Fig. 11a . MRUS: the top-down decomposition/specialization of the **Interrelation: Intervention Goal – IAW.**

Summarizing, we can illustrate use of the above introduced concepts.
As an example let us analyze different perspectives on the notion of a knowledge management (**KM**) in the sense of classical definition of knowledge.
We may talk about: KM process, systems, activity, tasks, goal, function, and goal. Every one has a different context and different meaning in TOGA.

The KM process is a property of the system called IAW.
This system includes, as a minimum, one IA and knowledge repositories, sources and knowledge users/receivers. KM process is describable as an abstract system of knowledge processing in terms of their attributes and changes.
The KM task is a complex task which indicates which types of operations on knowledge have to be done in order to achieve a KM goal but the KM task does not indicate how they can be performed in concrete circumstances.
The KM activity is an activity of IA, it is representable as an abstract system of interrelated actions. For a concrete couple (AI, En(D)), KM actions should be executable by IA lead to the achieving of KM goal.
The KM World is the couple (AI, En(DK)), where DK denotes a knowledge domain of interest and activity of IA.
The KM system contains all active components which participate in KM activity, i.e. IA and its tools.

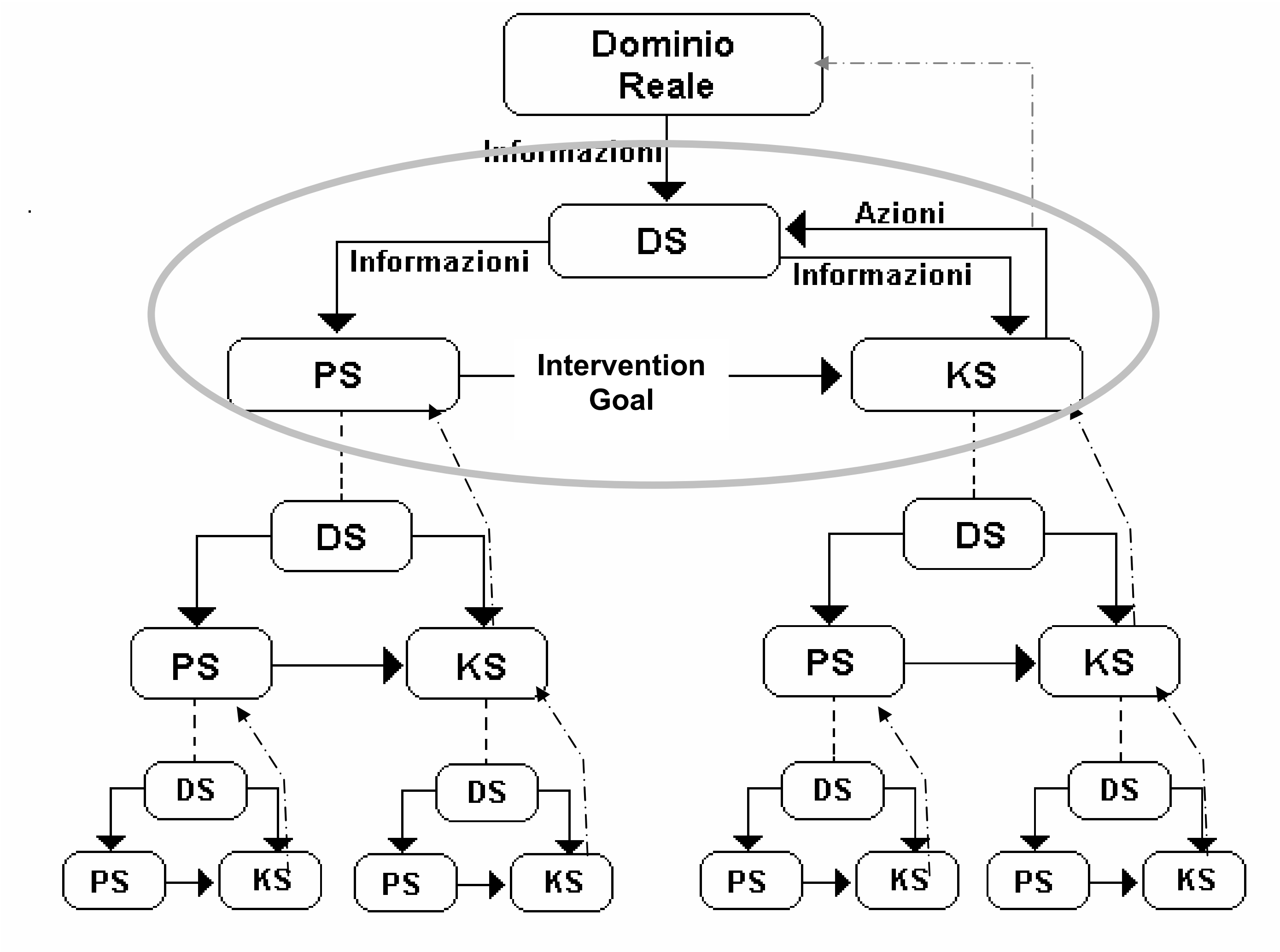
2.5.3 Intelligent agent architecture: personoid

Intelligence (artificial): The capability of a functional unit to perform functions that are generally associated with human intelligence such as reasoning and learning [ISO/IEC 1995].

According to the TOGA assumptions a specific AIA with IPK architecture is called *personoid*.

Definition
Intelligent agent is an agent with a capability to change and to evaluate its own preferences and knowledge, i.e. it has ability to learn and to change goals if the initial intervention goal is not reachable.

More precisely, using IPK conceptualization we define a generic functional architecture of the SOPHOCLES Intelligent Advisor. It is illustrated bellow in fig. 12.



Where: DS – domain representation system,
PS - preferences system,
KS - knowledge system.

Information flow
Domain reconceptualization
Action performing

Fig. 12 The IPK architecture: representation of a hierarchical, repetitive and metalevel functional structure of a personoid (the TOGA model of AIA).

More detailed specification of this module is in the SOPHOCLES ENEA's report
" Intelligent Advisor: Cognitive User Friendly Interaction" (2002), in the References.

2.6. Methodological Rules System (MRUS)

From the perspective of AIA reasoning, the Methodological Rules System (MRUS) is a methodological approach to a "top-down" and "goal-oriented" knowledge ordering for the specification of complex problems.
MRUS is based on the previously introduced conceptualization.
It assumes that at the beginning of a problem specification, the knowledge of the problem solver agent is incomplete and not goal-ordered. The problem specification activity is based on two fundamental mechanisms:

- the former is called the **top-down** mechanism, and indicates the specification direction: from very general statements on the top levels to the details which can be the elements of the problem solution;

- the latter is called the **goal-driven** mechanism; it always controls the links between the specified/identified object and the problem goal object; this mechanism creates bottom-up rules (synthesis rules).

MRUS can be a tool for checking the correctness of the goal-oriented activity of designers, and for the validation/verification of their products.

Application of MRUS to the specification of the AIA domain of activity is illustrated on figure 9.

The **SPG** and **WAG** (World -Action-Goal) methodological frameworks are supported by TAO conceptualisations.

Acts of/operations on singular objects are limited by two meta-rules:

1) *No readable up*: no singular object can read/modify objects that are at a higher w-o-o level than themselves.
2) *No write down*: no one can write objects that are at a lower w-o-o level than themselves. (This prevents the movement of information from a high security level to a low security level.)

For example, this constrains are in the Bell-LaPadula model which assigns subjects and objects to a top secret, confidential and unclassified security classes, and controls the movement of information between these classes.

At present, Methodological Rules System is a set of weakly structured heuristic rules, therefore it requires yet a concrete formal validation in the context of a sufficiently complex design project such as SOPHOCLES.

Remarks: It is useful to notice that human reasoning referred to a certain d-o-a, is based on many conceptual systems and associative processes. A mixed, not verified in "real time" changes of the conceptualization context, frequently lead to false conclusions and intuitive convictions, i.e. to the construction of not realistic goals in false or "fiction" domain-knowledge which no longer has reference to any physical or abstract d-o-a of the human agent. We can notice that every human mind is full of such types of constructions. The above situations can be omitted in the design of an artificial AIA.

3. Personoids' Society and Organization

The personoid society is a system composed of individual personoids and personoids' organizations.
In classical sociological perspective there are many models of a *society* and *organization*s. In the present work, we omit the state of the art in this field. We only illustrate its main pragmatic aspects.
Information Technology (IT) and the organization research can be together seen from two basic perspectives [Leinard.1977], [Flores, at al.,1988]:

- **IT tools for society**, i.e. computerization of various social and office activities , for instance:
  communication and information exchange by e-mail, specialized data banks, internet, managerial decisions by information systems, data processing , optimizing, simulation of social processes.

- **Society models for IT**, i.e. design of IT tools which support the design of very complex engineering systems and their aggregates, where an analogy to the similar functions of human organizations is employed to nthe modeling of MAS (Multi Agent Systems).

New AI possibilities, and, especially, agent technologies enable to extend those applications. For example, an application of abstract intelligent agents to the modeling of emergency management and environment management has been proposed in the paper [Gadomski and Gadomska, 1990].
From the autonomy and cooperation perspective, Castelfranchi deeply analyzes various social behaviors, building the models of complex interactions between various abstract-social-intelligent-agents [Castelfranchi, 1995].
Inverting the problem, for the design of an architecture for distributed intelligent artifacts, different but not all, models of an organization may be used. This context is discussed in details in the JRC Ispra report [Gadomska,1990] and the ENEA's report [Gadomska,1993]. In these works, we can notice many aspects of human organizations which could be employed in the personoids organization modeling, for example, in robotics, and in decision support systems for operators and human managers of high risk systems.
According to Max Weber (1947) [an ideal type of rational organization is *bureaucracy*, i.e. an hierarchical system based on specialization and expertness. In bureaucracy, humans are seen as purely rational instruments to achieve organization goals (foundation-goals, and temporal intervention-goals). There is no conflict between individual motivations, the members roles and bureaucratic procedures. This simplified model is not very useful for real modern human organizations, but from the perspective of personoids society it may be practically applied to the distributed cooperative decision-making. Also, the concept of actors, as an ideal representation of human roles, is involved in the identification of various visions of organizations [Freeman, 1979], [Masuch, LaPotin,1989]. Application of the personoid with build-in structural intelligence and with learning capability gives a concrete carrier for the formalization of the above mentioned models.
From the perspective of DAI (Distributed Artificial Intelligence) all human organizations are always distributed. but in the theory of organization the concepts of ***distributed*** and ***centralized*** are used in the different meaning; centralized or distributed are here power, responsibility and subordination.
From such point of view, a personoids' organization can be a centralized-hierarchical, or distributed-highly autonomous, for example, military and emergency management organizations are strictly centralized in many countries. But the modern commercial, business companies and environment-management organizations tend today or have distributed open structures. In the both cases, they are goal-oriented systems where roles of the organization nodes are dependent on common system's fundation-goals.
In contrarily to the weakly connected menu-driven systems, such as CADs and text editors, where the distributed architecture is strongly suggested, in the ADSSs (active DSS) for emergency-management, the system hierarchical functions are subordinated to the system design-goals.

We argue on mixed centralized-distributed architecture based on "cooperating" personoids. It means that we can organize personoids in human-organization-like system architecture. The solutions based on various, only agent-based system-architectures have been suggested and discussed by many authors, see for example [Gadomska,90], [Holt and Rood,94], [Gadomski and DiCostanzo, 96].
A kernel of intelligent DSSs is neither distributed nor fully autonomous in the sense of the organization theory but. the metaphor of the human organization is possible to use for the separation its internal functions. Therefore, from the software system perspective, personoids perform system *functions* according to tasks received from their manager*.* Realization of the tasks depends on their autonomy range specified in ***personoids roles***.
The role is defined by***:***

- **duties** (routine obligations),
- **responsibility,**
- **competence,** and
- **availability/access** to information/knowledge ("privileges")
- **power**, authorization/delegation/possibilities of the activation of proper decisions.

At a consequence, the behavior of personoids depends on external ***tasks*** and their own ***motivations*** (by inserted preferences) and competences (knowledge).

The formal relations between personoid roles, controlled by a supervisor/manager personoid, and the personoids' architecture is illustrated on Fig. 13.

Role can also be defined by a set R of relations between domain-state and available actions.

$$R = \{s, ac\},$$

where: ***s*** ***-*** denotes a perceived information, ***ac*** - denotes available activities.

R is divided on 3 subsets:

- first represents *responsibility* and *duties* , and is localized in the *Preferences Systems*
- second represents *competence,* and is localized in the *Knowledge System*
- third represents *power* and *access to information and knowledge*, it includes access to the domain of activity and depends on the availability of the communication channels.

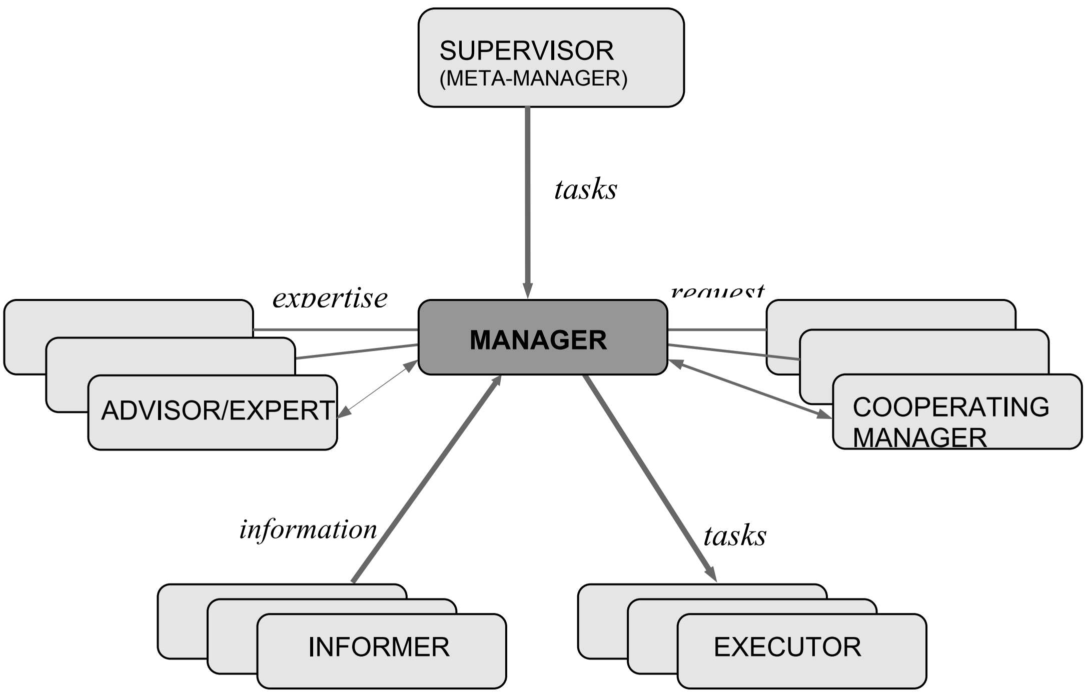


Fig. 13. The TOGA **UMP** (Universal Management Paradigm) and the Paradigm on Distributed Intelligence: A functional cluster of the *subjective recursive roles* of personoids in the POF approach [Gadomski, 1997].

Roles of intelligent agents in an organization are closely connected with the concept of its *functions.* both are goal-oriented. Every role requires from intelligent agents a capability for the activation of some set of functions planed by the system designer.
From this perspective, we may formalize *role* in the context of the interrelation between an organization *foundation-goal* and its *structure*. Here, we can use **SPG** and **WAG** (World - Action-Goal) methodological frameworks for the specification of the POF architecture.

4. SOCIO-COGNITIVE CRITERIA FOR THE SOPHOCLES SPECIFICATION

4.1 Cognitive and Engineering integrated perspective

In the field of cognitive researches the major results coming from new interdisciplinary collaborations. The importance of studying the cognition in integrated manners is now generally accepted.

"Cognitive science is concerned with the analysis of natural information processing systems (such as animals and humans). Its main concern is the investigation and modeling of human cognitive competences " [Anand Rao, 1997].

"The main concern of cognitive science is the construction of models of human thinking - models which detail the processes intervening between environmental stimuli and behavior. A shared assumption is that the mind is representational in nature and that cognitive processes can be described in terms of their function, without reference to a neural substrate.(…)" [Web: Peter Gärdenfors, 1999]

According to these authors, from the cognitivistic perspective, computers are only tools for the simulation of cognitive processes.

In parallel, the Cognitive Science's problems are faced by the Computer Science, in frame of Artificial Intelligence. According to the ISO/IEC (Information Technology Vocabulary 1995) Artificial Intelligence is

"An interdisciplinary field, usually regarded as a branch of *Computer Science*, dealing with models and systems for the performances of functions generally associated with human intelligence, such as *reasoning* and learning."

At present we can say that AI contributes to psychological research and reciprocally psychological models are going to be goal-oriented applied to the user modeling in engineering systems [P.J. Laird].

The presented work is an attempt to a synthesis of cognitive and AI theoretical perspective in the domain of the modeling of an abstract intelligent agent. This research follows the Newell and Simon research hypothesis [Web] about an artificial *general intelligence*.

Therefore this approach required an integration of :

-*Engineering perspective*, in which knowledge is applied to the construction of useful artifacts - this leads to the questions of utility and efficiency of "intelligent" problem solving mechanisms;

-*Psychological perspective*, in which a systemic and ecological [metti reference] knowledge is involved in the identification of mental processes of real acting beings. This approach tends to explain, forgive and modify human intelligent behaviors.

4.2 Intelligent Socio-Cognitive Systems Engineering

In the above contexts, Intelligent Socio-Cognitive Systems (ISCS) Engineering is a new sub-field of Socio-Cognitive Engineering (SCE) especially focused on the intelligence as the most advanced computational property of socio-cognitive systems. Socio-cognitive engineering has started, as every new human technological and engineering activity, bottom-up from the design of human-computer interfaces, cognitive ergonomy and available software engineering tools/technologies, but today from new systemic and unified interdisciplinary perspective, it should be reconceptualized and may be seen as an internal interactions' engineering between cognitive components and their structures into highly complex large aggregates of intelligence-based systems embedded in the real-world environment.
Taking under consideration complexity, large and mobile scale, heterogeneity, and always not sufficient knowledge, in order to copy with the problems of understanding and design together:

- human organizations,
- computer networks and
- human-technology culture,

all considered as intelligence-based systems, it is necessary to follow together the paradigms of:

- systemic conceptualizations (top-down approach, unified, integrated),
- engineering (goal-oriented/driven/directed/based), and
- cognitive perspective (human-like, mental functions modeling).

The key research domains of ICSE are related to the computational modeling and simulation of:

1. Socio-cognitive and cybernetic knowledge on business/governative/social organizations
2. Motivations, preferences and risk-benefits based distributed cognitive reasoning
3. Individual and collective cognitive decisions
4. Human reasoning errors, meta-reasoning, stress, emotions
5. Intelligence kernel: Cognitive abstract intelligent agents
6. Human and Computer role sharing in human-computer systems (tasks analysis)
7. Survivability of intelligent entities in hostile environments
8. Human components in a Virtual Business Enterprise
9. Socio-cognitive usability (an evaluation of organization - technology interaction)
10. Sustainable organizations and cognitive sustainability (criteria, indicators and measurement).

A short definition of Intelligent Socio-Cognitive Systems Engineering can be:

It is an engineering of highly complex large aggregates of intelligence-based systems in the real world environment.

In case of SCE its interest covers every cognition-based systems, and therefore it includes properties of artificial and natural animal cognition.

ISCS engineering is focused on the research and applications regarding modeling, simulation and the design of decision-support in the field of a management of the SHOTE (i.e. Society-Human-Organization-Technology and the Environment) internal impacts based on the integrated cognitive, systemic (top-down) and engineering (goal-oriented) paradigms.

We may assume that the objectives of socio-cognitive research & engineering are:

- to understand better and to develope and manage sustainable SHOTE aggregates
- to design SHOTE systems

- to develop software intelligent systems which should support complex engineering conceptual tasks.

4.3 Socio-cognitive Constrains: Feasibility, Business and Utility Factors

Application of the TOGA framework integrates a top analysis of such factors as feasibility, economic indicators, and utility with technological specifications of the system.

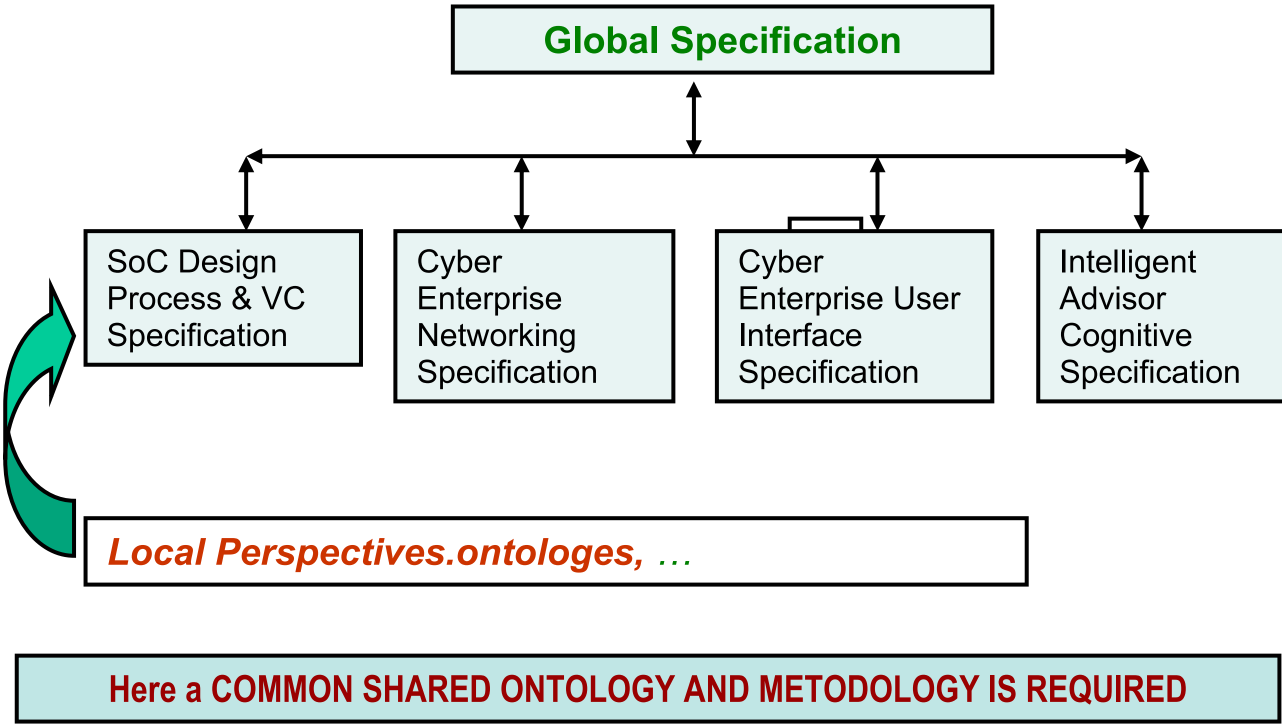


Fig 14 Basic interrelations between Local and Global Specifications in the SOPHOBLES Project.

In the local project tasks, different technology-oriented specific methodologies can be successfully developed but all of them require a standardisation effort valid non only for the project management and its results formal validation.

It is necessary to mention, that independently on local methodologies, there are available different domain independent approaches, but all of them represent specific perspectives on the global specification problem. For example we can mention many methods and tools, such as: task analysis, process representation and decomposition, systems and action graphs, workflow analysis and functional flowcharts. All of them should be possible to reconceptualize using an uniform terminology in frame of the TOGA integrated frameworks.

Summarizing, during the course of the project, an incremental application of the TOGA unified systemic approach should significantly reinforce and add value to the implementation and validation of distributed specialized technology-dependent methodologies and to design support tools employed in the project.

5. Meta-Knowledge Global Requirements Perspective

5.1. Knowledge-Based RTD Constrains

The research and development activity regarding **CHESS**s (Complex Heterogeneous Engineering Support Systems) requires from the project partners the following types of resources focused on the project objectives:

TABLE 1 Preliminary Tools Identification table

Resource type	Routine - available (Y/N)	Partially available (choice, p. develop)	For development (Y/N)
1. **scientific- technological knowledge** and capacities in explicitly recognized problem fields			
2. **technological conceptual tools** as software languages and development platforms on the two main levels: - problem oriented (high level) - implementation (basic level)			
3. **hardware infrastructures** which enable to implement and experimental validation of the solutions.			

5.2 Cooperation

Cooperation in frame of an interdisciplinary RTD project is based on a recognized local autonomy and commonly accepted collaborative tasks layer (requested and negotiated common IPK domains and resource standards).

Collaboration refers to the shared RTD effort related to the development and application of the resources specified according to the taxonomy presented in the Tab.1.

Cooperation requires a **consensus** on:
- common cooperation goal
- common ontology of the domain of cooperation
- common tasks ontology
- common task flowchart
- which tasks requires a continuous collaboration,
- definition of interfaces on functional, processual/technological and structural /(system architecture) levels.

5.3 Global Recommendations Framework: SOPHOCLES Main subsystems

Taking under consideration before presented systemic constrains, in the SOPHOCLES Project, from the perspective of: the types of knowledge requested, technologies tools and h/s involved, we have distinguished three basic specialized areas of interventions, illustrated on the fig. 15 [Technical Specification of SOPHOCLES].
They are concentrated on the development o the following subsystems (global functional components) of the project:

S1. **Sophocles Core Subsystem (SCS)** , it is a kernel of the SOPHOCLES system.

It covers all extremely complex assembling and simulation processes for the design of System on the Chip For the reason of its strongly innovative approach and, it is specified independently in more details in other SOPHOCLES documents.

S2. **Cyber Enterprise Subsystem (CES)**, it provides complete communication management service for the kernel functional components of the Sophocles system and integrate all system functionalities. It applies data bases query tools, networking and modern multimedia technologies for human – computer interfaces.

S3. **Intelligent Cognitive Advisor (ICA)**, this subsystem provides an active decision support during e- design employing human-like reasoning functions and decision-making cognitive models. ICA development is a cross-disciplinary task which is based on the hypothetical assumption that end-user professional IPK

The specific activity lines focused on the system global components above mentioned, are supported and accompanied by a meta-methodological activity focused on the global specification and ontology of the large class of **Complex Heterogeneous Engineering Support Systems** (CHESS).

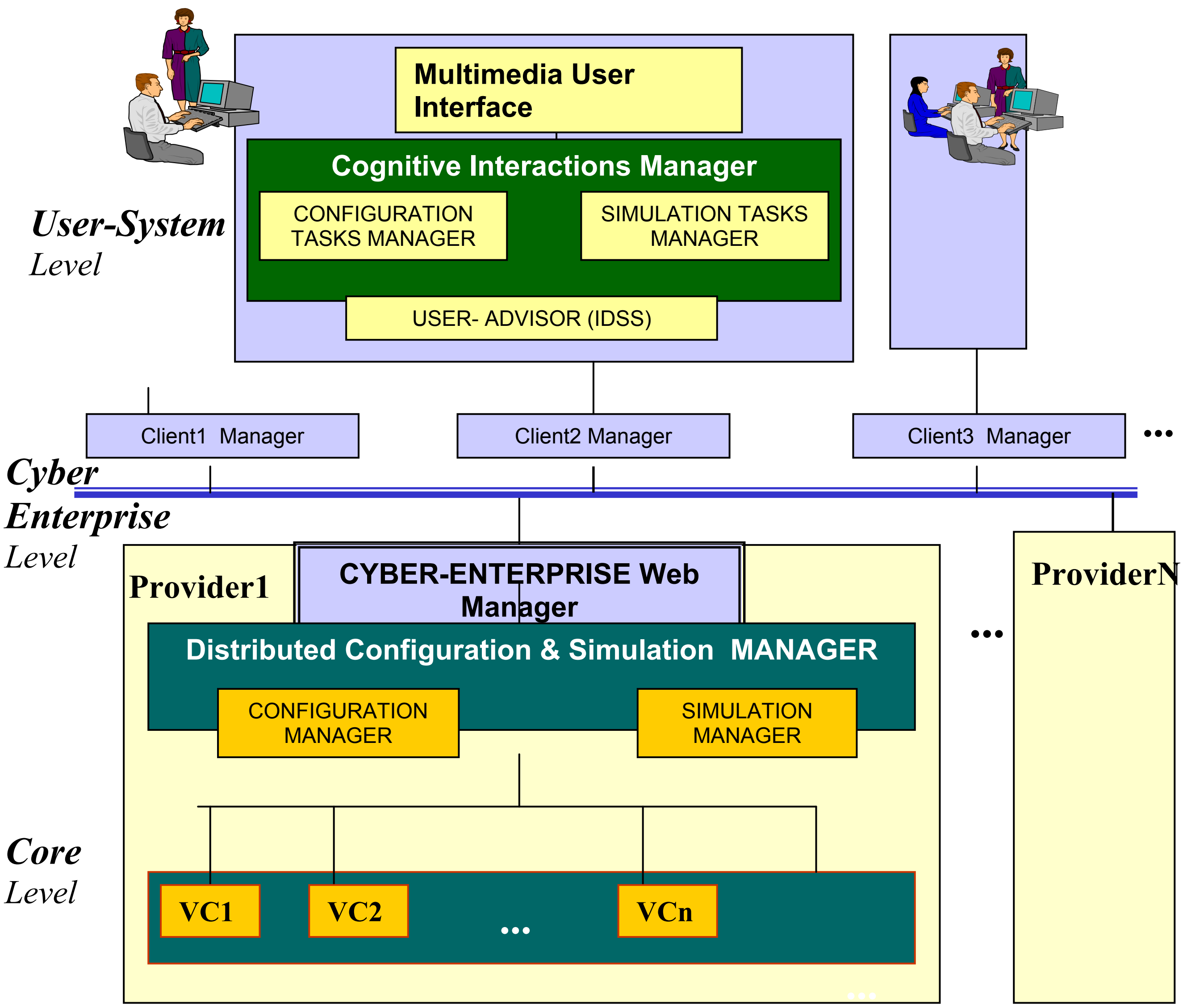


Fig. 15   Goal-oriented Functional Structure of Sophocles System (according to the ITEA Full Project Proposal, v4,2002).

S4. **CHESS** (Complex Heterogeneous Engineering Support Systems) **lifecycle - a Systemic Methodology**. This activity is parallel and regards the validation of the SOPHOCLES development progress and solution improving from the perspective of the project objectives. It is focused on an incremental development of a systemic guideline for the frameworks of global specification, performance and user-task analysis, synthesis of the studies on SOPHOCLES solutions, overall validations, and assessment of the futures strategies (these subjects are subsequently inserted in the project WPs).

We should also notice that S4. is not only a contribution to the project technical management but, in the more general perspective scale, it should produce proposals of the standards.

General User Classes of CHESS systems

The Sophocles users are from industries, research centers and
universities involved in complex networked engineering design. They are generically divided on:
•Occasional users: First-time-users, aimed at exploring Cyber Enterprise services, students
•Business users: managers and professionals involved in the economical planning of e-design projects and searching for evaluation parameters
•Routine users: such as SoC system designers, system administrators.

Other more precise taxonomy of the end-users should be done from the perspective of end-user role, where **role** (competences, responsabilities, privilliges) [TOGA Framework, Proj. Proposal 99].
It is based on the identification of the following role properties:

- Competences: what he/she is able to do, possessed models of the domain (knowledge)
- Responsibility/Duties: formally authorized initiatives, tasks and requested preferences
- Privilliges: Access to the information. It produces images of the domain. Access to execution tools (information).

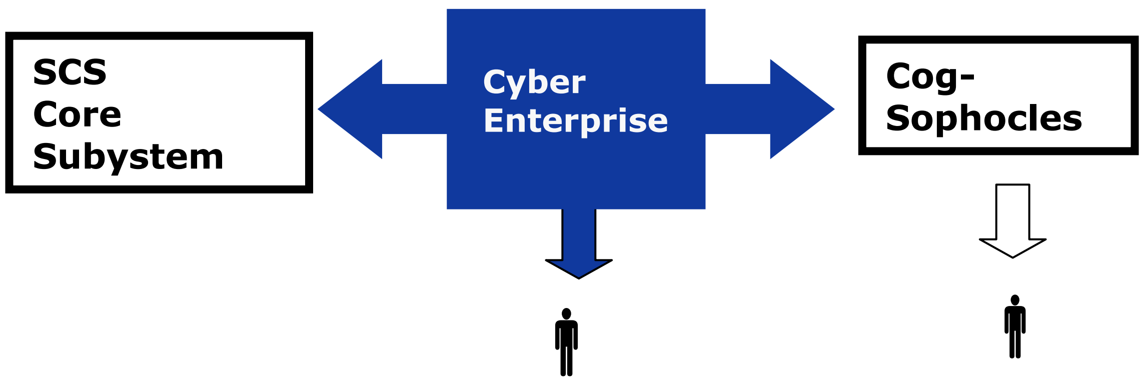


Fig. 16 The Cyber Enterprise subsystem provides all infrastructure for the SOPHOCLRS internal management.

The fig 16 illustrate localization of the end-users as clients in the structure of SOPHOCLES, where the Cyber Enterprise subsystem is a manager of the internal processes and interfaces with the users.

Application of the TOGA global specification framework requires subsequently:

1. Top-down identification of a generic scenario in form of the sequence of generic tasks
2. Association of generic tasks with subsystem functions
3. Identification of functional IPK bases required by the functions
4. Identification of available software carrier processes
5. Allocation of processes to the predefined system components
6. Identification of input-output interfaces between processes and components.
7. Allocation of the functional IPK bases to the data-bases repositories common for the subsystems.

In this phase of the project, the above heuristic procedure is followed in the Cog-Sophocles development.

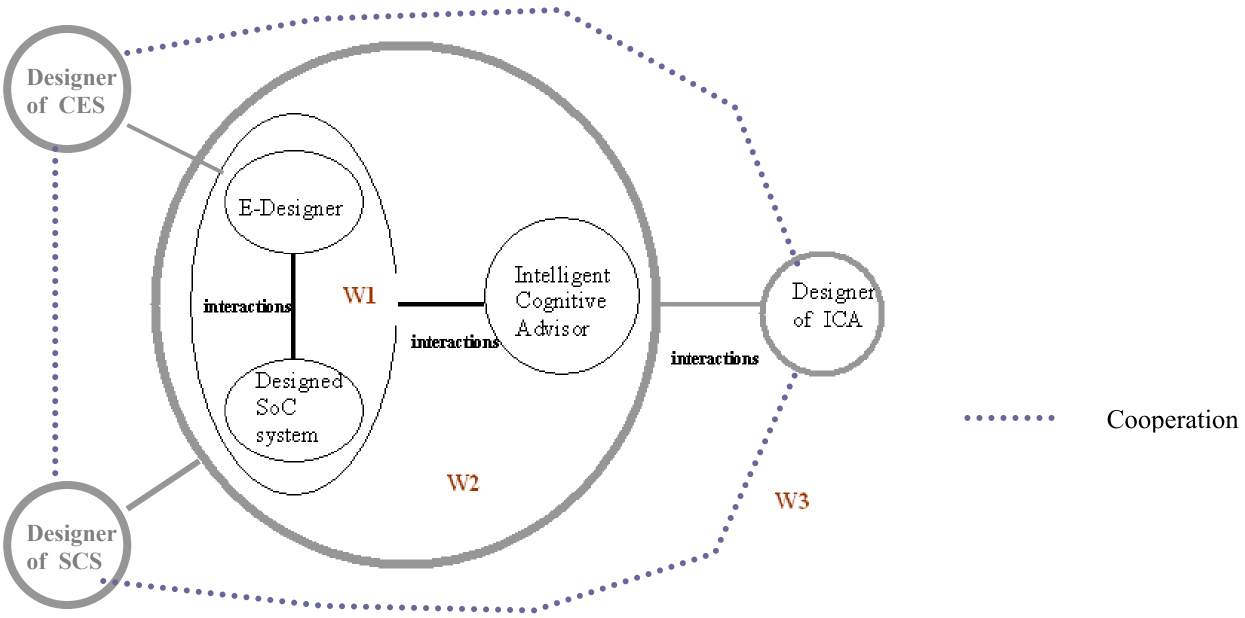


Fig 17: An ideal, functional and task-oriented representation of the SOPHOCLES Developers Worlds (W1, W2, W3).

Finally, according to the IAs world framework, Fig.17 illustrates the Worlds of the SOPHOCLES developers. All objects and interactions of the World 1 (W1) and World 2 (W2) have to be decomposed from the points-of-view of the external Designers objectives and tasks.
They formal decomposition should be performed to a level when the software system specification and implementation will be possible using available technologies.

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Annex

Application of TAO

Basic primitive/atomic concepts ***(Π)*** of a description of the domain of activity of AIA are : ***object, relation, change***, $\pi \in \Pi$, Π = (***O, R ,C***).

They are axiomatic elements of the basic conceptual web recognized "automatically" by AIA.

<u>Recognition of Primitives, Π</u>

Π elements are recognized by CIA , for example, on its subsymbolic level by the neural nets.
In this maner, which features/elements of the real world are recognized by the agent depend on CIA properties.
They are recognized and distinguished one from other with various certainty. In general, we can introduce a subjective *coefficient of recognition* (ρ) with the value domain [0 , 1]. It represents a certainty of agent that the
primitive was recognize in its d-o-a. The value ρ is specially important if the domain is real , as image, voice at symbolic communication, and so on. In abstract ds-o-a all ρ is always 1 for every π , and can be neglected, it is valid for all artificial agents.
This recognition is done by the association with a term from the agent vocabulary **Z**.
The terms from **Z** are:

1) associated with other terms,
2) instances of different conceptualization systems **C** .

Object is recognized by its surrounding.
Relation; by two objects recognized in the same recognition act (r-act)
Change; by two different primitives in subsequent r-acts.

<u>Primitive top-down and bottom-up operations</u>

One time recognized π can be *focused*, *zoomed* , *p/c abstracted* or *localized* by the agent.
We need to stress that these top-down operations are the *specification* or *identification* operations.
The both types require an external information about the specified/identified primitive.

Remark: The operation *specialization* which exists in the subject matter literature, for ex. in [AI vocabulary] relates to a concept, not to the unknown yet primitive in a certain d-o-a, therefore specialization and specification have different significations.

List of *specification* and *identification* operators:

*Focus*1 : Attributes names are jointed to the object named:

$$\underline{\Phi}_1\, Q \rightarrow Q\,(a_1, a_2, \ldots a_k, \cdot\,)$$

*Focus*2 : Values are jointed to the attributes:

$$\underline{\Phi}_2\; a_j\,(Q) \rightarrow \langle a_j , \nu \rangle_Q$$

Zoom$_1$ (in deep): Specification of decomposition elements of the zoomed primitive:

$$\underline{Z}\, Q \rightarrow \{ Q_1, Q_2, \ldots , \cdot \}_Q$$

Zoom^1 (up*)*: $\underline{Z}^1\, Q_n \rightarrow Q\, \{ Q_n , \cdot \}$

p- abstraction : It is an operator of the abstraction of a property from Q:

$\underline{\Psi}\, Q \rightarrow L$, where between Q and L is the *carrier* relation (inverse to the *property* relation).

$L \Leftarrow Q$ - represents carrier/property relation, Q is a carrier of L.

c/p relation is transitive and asymmetric: $L \Leftarrow Q \Leftarrow U$ -> $L \Leftarrow U$;
i.e. U is a carrier of L.

Definition*:* *Property* of a primitive is every its attribute which also is a primitive.

For example, the attribute *p* of the object Q is its property if

$$\underline{\Phi}_1\, p\,(U) \rightarrow p\,(a_1, a_2, \ldots a_k, \cdot\,)\,.$$

c-abstraction: It is inverse operation to *p- abstraction*:

$$\underline{\Psi}^{-1}\, L \rightarrow Q,$$

localization - of an object: $\underline{\Delta}\, Q_a \rightarrow \{R_1(Q_a, Q_1),\; R_2(Q_a, Q_2),\; R_3(Q_a, \cdot\,), \ldots, \cdot\}$.

The set $\{ Q_1, Q_2, \ldots, \cdot\}_Q$ is called the *surrounding* of Q,

- of a relation: $\underline{\Delta}\, R_a \rightarrow R_a\,(Q_1, Q_2)$, and the existence of $\{Q_1, Q_2,\}$ is necessary
- of a change $\underline{\Delta}\, C \rightarrow C(\, Q_1, Q_2, \ldots, \cdot) \;\vee\; C\,(\,R)$.

We need to stress yet that from the managerial point of view, in a predefined context, only functional properties of these operators should be known for the managers.