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Patterns for Conceptualization of Knowledge on Technological System and Human Organizations: TOGA Approach – a proposal of Standard

(invited paper)

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A Pattern for Conceptualization of Knowledge on Technological System and Human Organizations: TOGA Approach
(An extended transparent-sheets material)

Abstract

This invited paper presents a systemic perspective/patterns which enable the modelling of physical real-world artificial systems (GRAPH) from two perspective, so called "objective" represented by physicists and "subjective" represented by engineers. The first is referred to our capacities of measuring and observation of the real world and leads to identification processes. The second is goal-oriented /driven and leads to the design. In practice, both perspectives are, more or less intuitively, employed in engineering activities. The presented SPG (System-Process-Goal) Approach has been initially developed for the design of supervision systems for nuclear plants but its formal conceptualization is generalized on every technological and human-made systems. At present, it is a part of the new theoretical framework TOGA (Top-down Object-based Goal-oriented Approach) focused on the goal-oriented ordering of the knowledge available for an abstract intelligent agent.

The paper presents theoretical bases and models of the generalized SPG theoretical frame, which include object-based initial conceptualization and key relations between the subjective and objective points of views. The SPG methodology application is illustrated by examples from nuclear engineering informatics and advanced research in robotics. The obtained results suggest also the compatibility and applicability of the presented approach to the identification, design and simulation of human organizations, as well as, in the future, of the interactions of human organizations and technological systems.

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1. Introduction

The theoretical patterns which I present is a first successful step towards an integrated systemic description of artificial (goal-oriented) physical systems.

- The SPG (System –Process-Goal approach) Pattern is the proposal of a standard.

- Our question: Why it is proposed for Technological Systems and Human Organizations together?

- We may notice that technological systems and human organizations have some common abstract properties/frames and terminology.

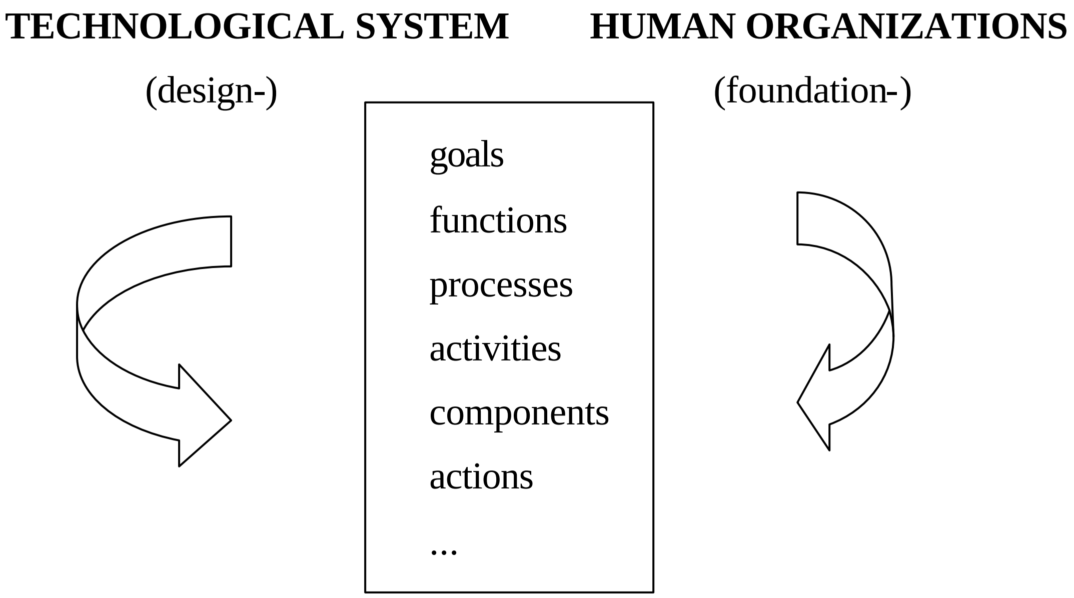


Fig. 1 Common concepts: an example of the terminological confrontation

- Their proposed generalised common conceptualization/definitions are based on the system theory paradigms and intuitive metaphors.

- Both are GAPH systems, it means, they are:

Goal-oriented

Artificial

PHysical (dynamic).

- A new integrated knowledge conceptualization framework for the GAPH type/class systems, which is here presented, is called 'SPG' (System-Process-Goal approach)

In 1986, I have proposed a general idea of SPG, at the beginning, for nuclear and high-risk-plant supervisory systems. This idea has been analyzed in ENEA for the real-time diagnostics of the TRIGA nuclear reactor [Gadomski,86].

Since 1989, in frame of ENEA's projects, SPG has been formalized and also preliminary applied for heuristic identification of highly autonomous robots [Gadomski,8]., emergency management systems [Gadomski, 8], and environment management organizations [Gadomski,8]., .
Now, SPG framework is a part of the general meta-theory TOGA (Top-down Object-based Goal-oriented Approach) [Gadomski, 89, 93].

TOGA is a meta-theory of goal-oriented knowledge ordering which includes two perspectives: "**subjective**" of an intelligent agents involved in the problem solution and "**objective**" of his "**absolute observer**".

For the reason of the possible utility of SPG, it can be presented as an independent conceptualization module for an integrated representation of any artificial dynamic systems.
For this purpose, we adopt the TOGA paradigms and axioms to the conceptualisation of a ***Domain of Activity*** of an ***abstract intelligent agent*** which includes an artificial system of our interest.
According TOGA's assumptions, every agent's ***Domain of Activity*** ***(***D-o-A***)*** is representable as a network of objects (the TAO theory [1]) .
More information about TOGA, its conceptual framework and the state of art in this subject is presented in [1].

2. Basic SPG assumptions

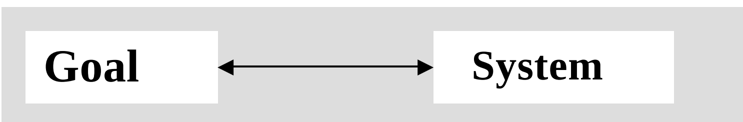
The conceptualization and application of the System-Process-Goal approach pattern requires a few initial assumptions.

Ass.1 Every GAPH either exists or is planned.

Ass.2 The ***knowledge*** on a GAPH for a problem solving is available but is not ordered or is ordered for other purposes.

Ass.3 The ***goal*** of an artificial system is always localized in the system environment and it **is conceptualized in terms of its environment description**.

Ass.4 A technological/engineering knowledge on a GAPH is representable as an abstract structure which is obtained:
- by decomposition of the interrelation between a **system** and its **goal**
- in terms of formally and uniquely defined: **systems, processes, functions** and **goals.**



- Why a formalization of this interrelation is so important?

In frame of human engineering behaviour we distinguish three basic activities: design, exploitation, modification (improvement). In all of them, the **Goal-System** abstract relation is continuously explicitly and implicitly used, what we roughly illustrate below:

- **For design:**

From a goal of a hypothetical system	to →	the realization of this physical system

- **For system exploitation**:

From the monitoring of system states	to →	the validation of the system utility (by the evaluation of the quality of goal achieving)

- **For system modification:**

From the modification modification of the goal system (constrains, efficacy)	to →	the planning of new functions and modification of the architecture.

3. Basic Conceptualization: Objects and Objects' Worlds

Here, I present only selected properties of the TOGA theory which are necessary for the explanation of the SPG pattern (a conceptual framework).

Entity *(semi-axiomatic term)* - a part/(one piece) of the domain of activity of an intelligent agent which could/may be repetitively recognised by him.

Ass. 5. Every GRAPH problem is initially conceptualised as an abstract *World of Objects*.
World of Objects (W-o-O) is a set of *objects*, *relations* between them and their *changes*.

Object

- We may recognise an entity (physical/mental) as an **object** if we are able call it by a name and if we are able to link it conceptually with other names, called attributes of it because enable to recognize (describe) this entity.

- In other way, an entity can be considered as an *object* if it is described by a set of names called **attribute names,** *an*, where an **attribute** is the ordered pair (*an*, *avalue*):

a: (*an, avalue*).

Hence, an object is representable as:

O: *Oname* {(*an, avalue*)}.

Every attribute value, denoted *avalue*, is an element of an attribute space, ***W***.

W denotes a set of either mathematical or textual expressions/symbols/stings which satisfy
most generic properties of a space in the mathematical sense [1].

Relations between objects, are denoted as $R(O_i, O_j)$.

They are constructed either on the level of object names, or on the level of their attributes.

On the level of attributes:

$R(\{a_k\}, \{a_h\})$, where $\{a_h\}$ is a subset of attributes of a h-th object.

If, in our problem, certain attribute names can also be considered as names of another objects then we can construct a hierarchical structure of *World of Objects* related to the initial objects. Such construction of Ws-o-O is called *Objects Universe*.
For example, *colour* can be used as an attribute name for physical object called *car*, and, in parallel, *colour* can be used as a name of an object in the world of abstract properties of industrial products.
In this situation we have an interrelation between two worlds of objects what is illustrated below.

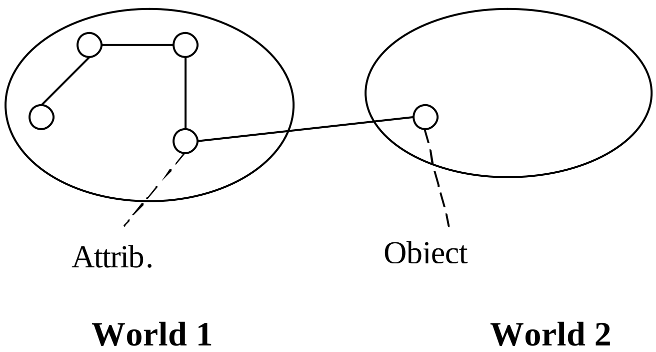


Fig. 2 An attribute of an object from **World 1** can be considered as an abstract object in a the **World 2**.

Remark: This property can be repeated on the level of textual values of the attributes.

Changes

- Changes may refer to any component of *Objects Universe* (OU) and its properties (≡ *constructs*).
They can be a property of the D-o-A or the couple (Intelligent Agent, D-o-A).
In the second case, changes are effectuated possible operations of the agent on D-o-A .

- Changes depend on the agent time scale.
- Changes are causes and effects of interactions (Intelligent Agent, D-o-A).

Every change is representable as a pair (x_n (X), $x_{(n+1)}$ (X)) , where x, X are constructs of
a preselected/pre-defined OU, and x is a property of X.

Object Meta-Classes

In frame of the TOGA's theory the following meta-classes of objects are defined:

- **Formal objects**, they are concepts of the SPG approach.
- **Real objects**, they are identified elements of the real world
- **Abstract objects**, which represent approximations of the real-world objects

and

- **Other objects** which are abstract entities representing another than SPG conceptualizations, but which can be transformed to the SPG form (ie. have the object property).

In SPG we have the following basic formal objects:

goal, function, process, system, **variable, parameter,** and **model.**

Initial Definitions of basic formal objects

SYSTEM

There are many definition of *system*, here:

System is every decomposable object which is identifiable by the recognition of a subset of its invariant attributes, called **parameters.**

- An object is decomposable if it can be presented as a network of other objects linked by some relations.

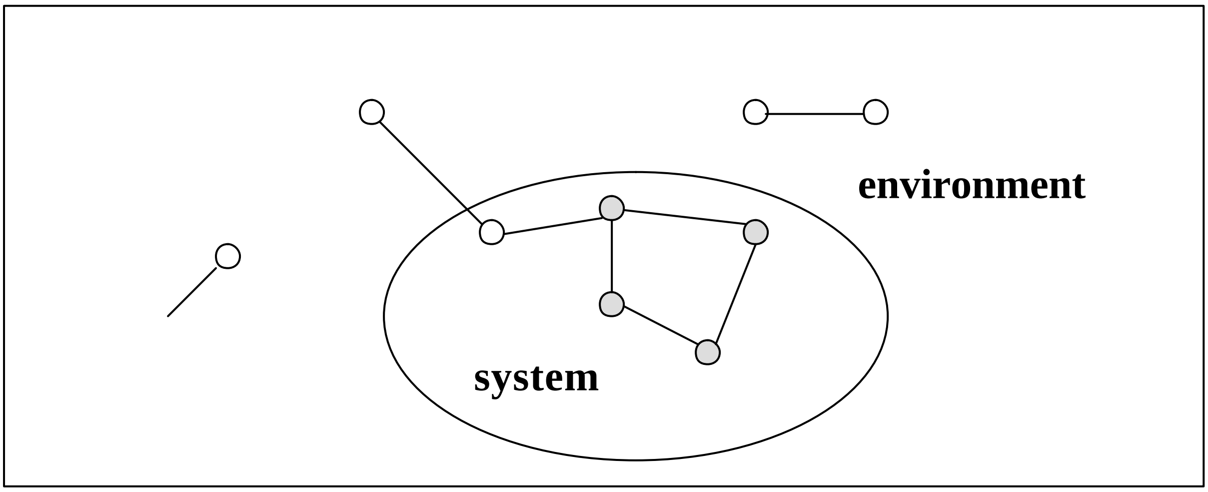


Fig. 3 A graphical illustration of a system

- Every part of a network can be considered as a system (has the system property). It always depends on our goal.
- Every part of the real-world can be considered as a system.
- Time dependent attributes of system are, of course, called ***variables*.**

GOAL – SYSTEM couple (G – S)

- In frame of SPG, knowledge on GAPH system is represented as a G – S couple.
- In the case of the design of a control or supervisory system we need more than one G – S couple.

For example, if we design a CAO (Computerized Aid for Operators) system [ ] then we need take under consideration 3 G – S couples:

The first is:

- Physically existing plant, A, with the goal G_A

and

- Its representation/description dA

We need

- CAO system, which has to be designed, it is denoted B, with the goal G_B

and

- a goal-oriented description of A, with the goal G_{dA}.

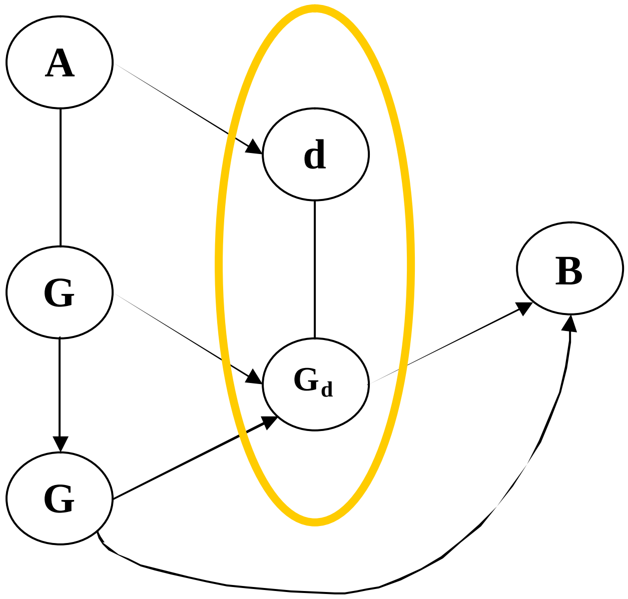


Fig.4

The couple dA-G_{dA} is a specific representation of physical system for the design of CAO.

Of course G_A is the goal of CAO system, not the goal of an A description (d).

PROCESS

In the SPG conceptualisation:

Every process can be formally represented as a mathematical operator expression:

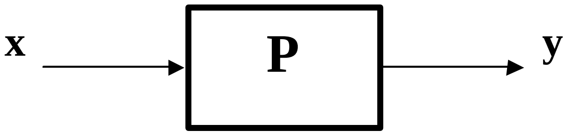
$$P : \quad y(t) = \hat{A}\ x(t)\,, \qquad \text{for } t \in (t1\,,\, t2)$$

Where: x, y are input and output variables vector,

$\hat{A}$ is the operator of the process P, it depends on parameters of the system which is "carrier" or the process P.

Every physical change can be represented by continuous or discrete mathematical function. i.e. as a process.

$$P\,(x, y, \hat{A}(p), D), \qquad \text{where } x \times y \in D \subset S_p$$



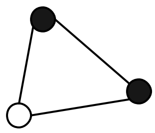
Process parameters are the attributes of a system which is a carrier of the process. Now we need to explain what_does_it_mean “carrier” relation.

CARRIER/PROPERTY RELATION

Every object is a **carrier** of its own attributes and **properties.**

> If a system X is composed with the attributes of system Y then X is a **property** of Y, and, in this sense, Y **is a carrier of** X

For example:



[redacted]

> Every **system** is a carrier of its own **structure**.

> Every **dynamic system** is a carrier of **processes.**

Remarks

– In general, one system can be carrier of many processes.

and

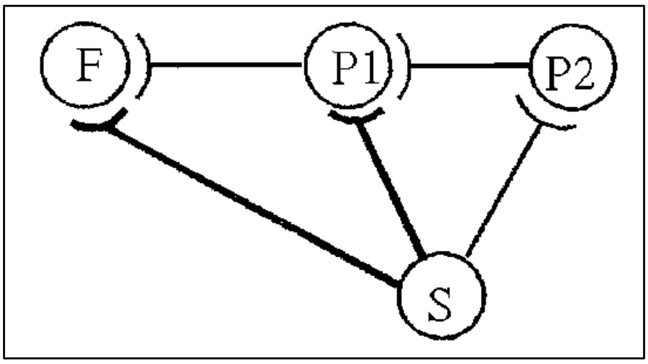
– Different physical system can be the carrier of the same abstract structure

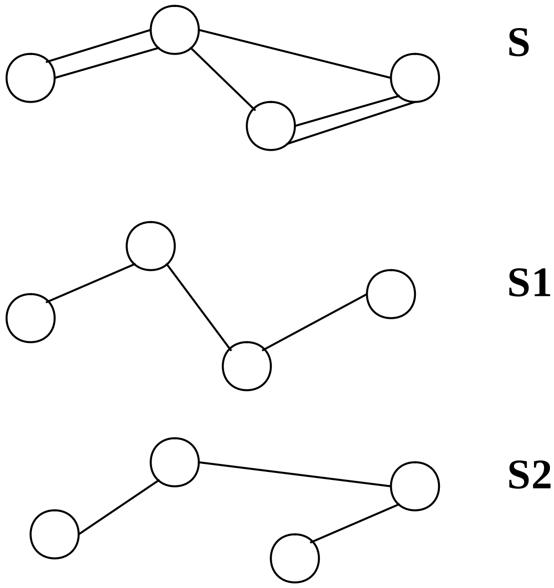
Graphical Representation	Math. Notation
	A ? B
Where A, B are objects.	

Fig. 5

Carrier relation is transitive but not symmetric, what is illustrated on the figure below.

Transitivity **Symmetry**





Hence, subsequently

F ? P1 ? P2 ? S and { S1, S2 } ? S

Fig.6

FUNCTION

From the designer and user perspective *Function* is the most important formal object of SPG

Function is every abstract object defined as a goal-oriented property of a process or a system.

For example :

- Function of thermometer is the measurement of temperature.
- Function of a car is to be a mean of transport.
- Neutron thermalization process in nuclear reactors realize an energy-production function.

In other words**:** **Function is every goal-oriented property of a system**

For an existing system : Every its function is necessary for the achieving a design-goal of this system and:

- It is activated by a system operator (human or artificial) or by the system itself

– It is realized by some processes.

For designed system : Specification of goals and the system environment are data for functional specification of this system.

Every function of a system S or a process P is described by the meta-attributes called:

status index , denoted	*Sti*,	*Sti* = 0, 1, -1
performance index ,	*Pi*	*Pi* = 1, -1
quality index,	*Qi*	*Qi* = [0, 1]
efficacy index,	*Efi*	*Efi* = [0, 1]

Status index depends on the current availability and activity of the function of interest. Its basic properties are illustrated in the table bellow.

Availability	yes	yes	no
Activity	yes	no	no
Status Index	1	0	- 1

Performance index indicates the correctness of *Sti* for one selected function, i.e, we may assume its two values scale (-1, 1), for example

1 if the function is performed according to current system-operator task or operator main *intervention goal*.

- 1 if the function has improper value of status index.

In general, the assumed performance index value scale depends on the goal requirements/constrains.

Quality index relates to the carrier process or the carrier system of the function. Its value can also be arbitrarily normalized to the interval [0 , 1]

The last function's meta-attribute is:

<u>Efficacy index</u>, it refers to the evaluation of the function-goal relation. It is important only if the goal was defined as fuzzy or a goal-quality distribution is constructed on goal attributes values.

A graphical example of goal quality is illustrated on the figure below.

Here, If $X \times Y$ is a goal attributes space with a quality function Q (x, y) defined arbitrarily by the designer or by the domain expert., then we may define a ***Goal Domain***, what is illustrated on the figure bellow.

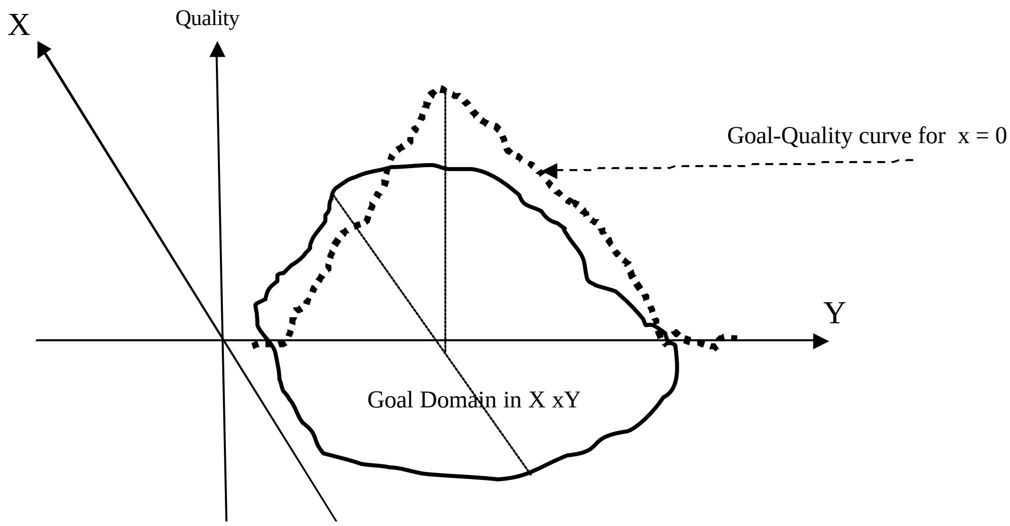


Fig. 7

Summarizing:

The function indexes describe the interrelations between functions and the system goals and processes.

These interrelations are illustrated (as abstract objects) on the following figure.

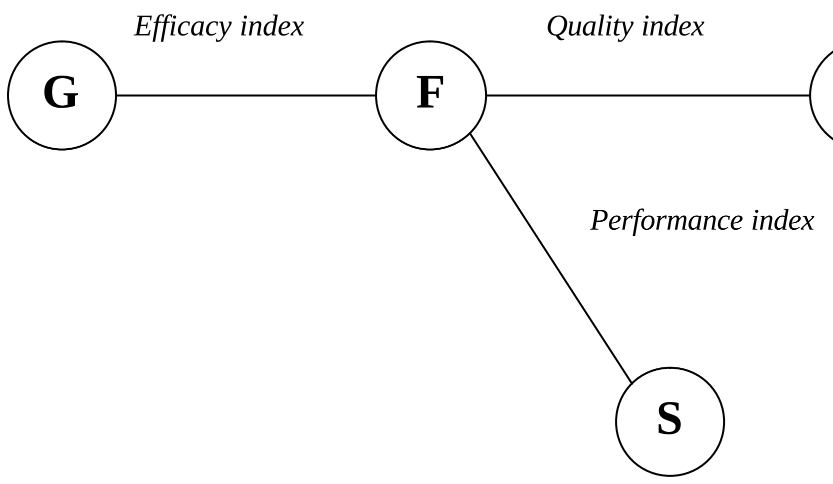


Fig.8

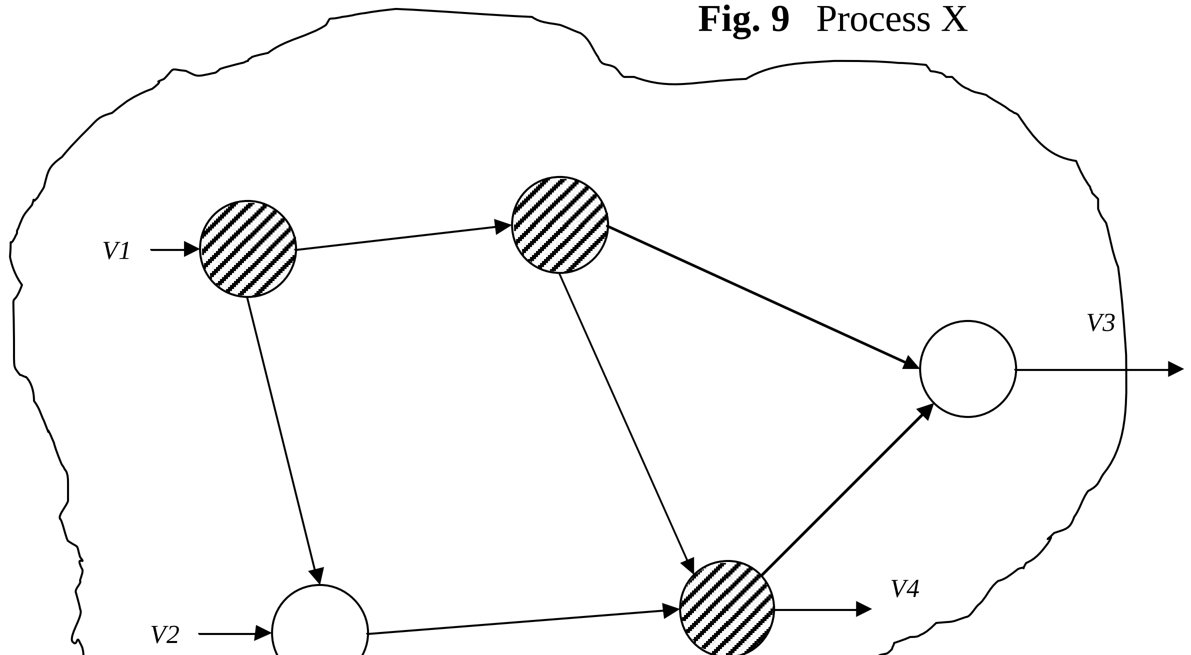
PROCESS - FUNCTION INTERRELATIONS

It is the important conceptual link between subjective and objective points of view. The nodes are the operator representation of elementary processes.

For example:

Let process X presented below is a physically existing process and it is a carrier of a function FO, from the perspective of an intelligent agent (an observer).

Fig. 9 Process X



The function FO is extracted from its carrier process on the next figure.

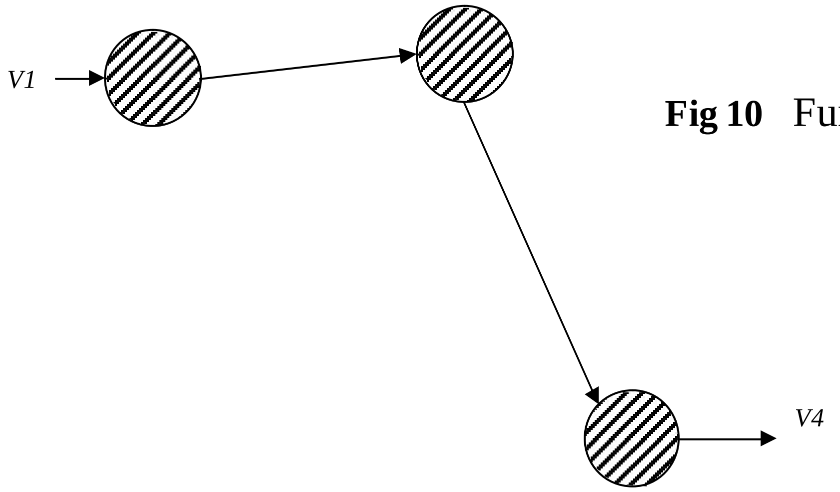


Fig 10 Function FO

Remarks:

It is easy to see that

One selected process can be the carrier of many function.

From the opposite point of view:

One function can be a property of different processes/systems.

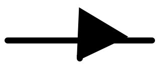
Cause/consequence Relation

***Cause/consequence* C/C relation** is the relation between **Function** and **Goal.**

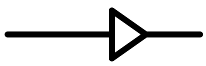
Let A e B denote abstract objects, and if the existence of A in a W-o-O implicate an existence of the abstract object B then:

A is a *Cause* of B and B is a *Consequence* of A.

Graphical representations:



Cause



Consequence

It is transitive relation, therefore a designed system is a consequence of the design goal.

Finally , SPG can be represented as:

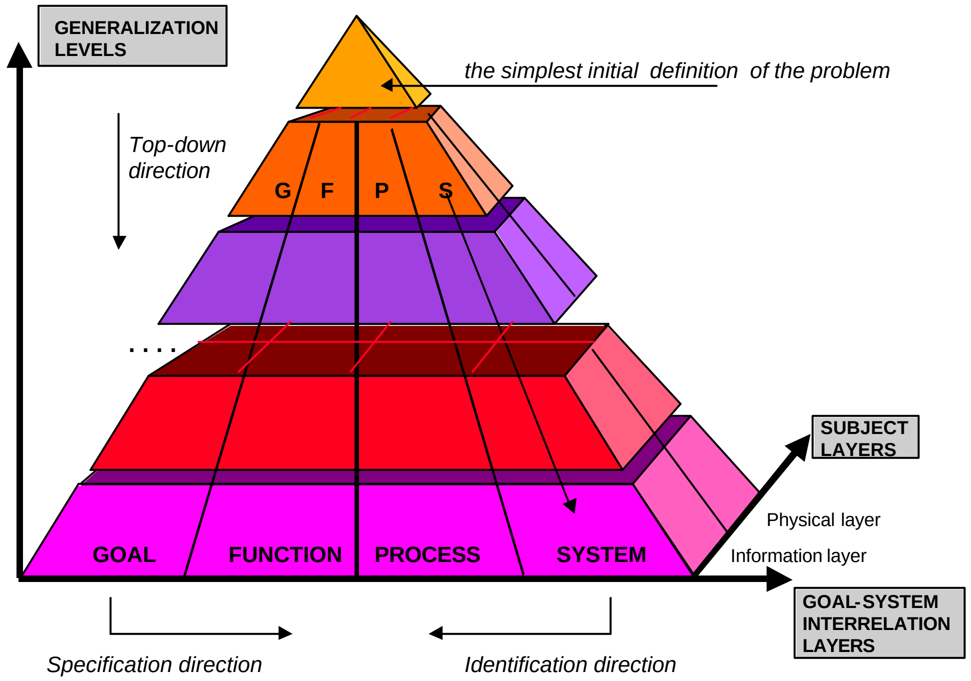
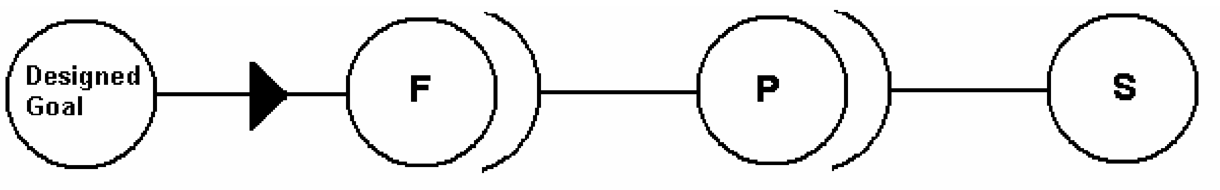


Fig. 11

Q_F = {G, F, P, S}, and in the graphical form every Goal-System interrelation can be decomposed according to the below presented relations.



consequence relation carrier relations

Fig. 12

The top-down methodological framework of the decomposition of the G-S interrelation illustrated on the successive figure.

Here we distinguish two basic engineering and research activities which are realized top-down, layer after layer.

The primary is a **specification.** It starts from an arbitrarily general description of the goal of the projected system. From the goal results functions, and they are a base for the searching of the real world processes or systems which enable their realization.

The next activity is identification, it refers to an existing system. Both of them lead to a model building.

Examples of SPG Applications

Now we present a few concrete examples of SPG applications.

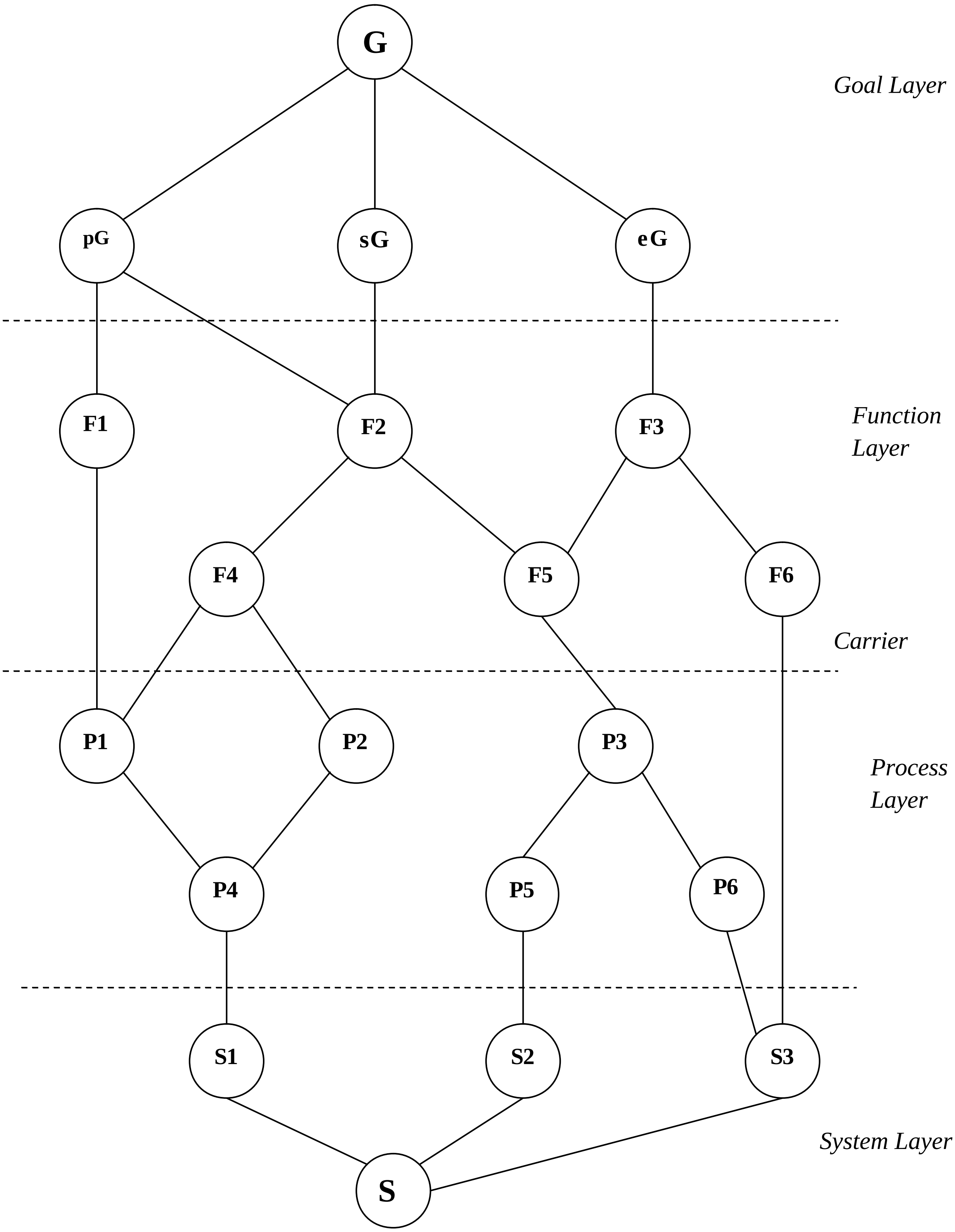


Fig. 13

. This picture illustrates an example of the G-S interrelations network according to SPG.

Bellow, the types of interrelations between four types of SPG objects are graphically represented.

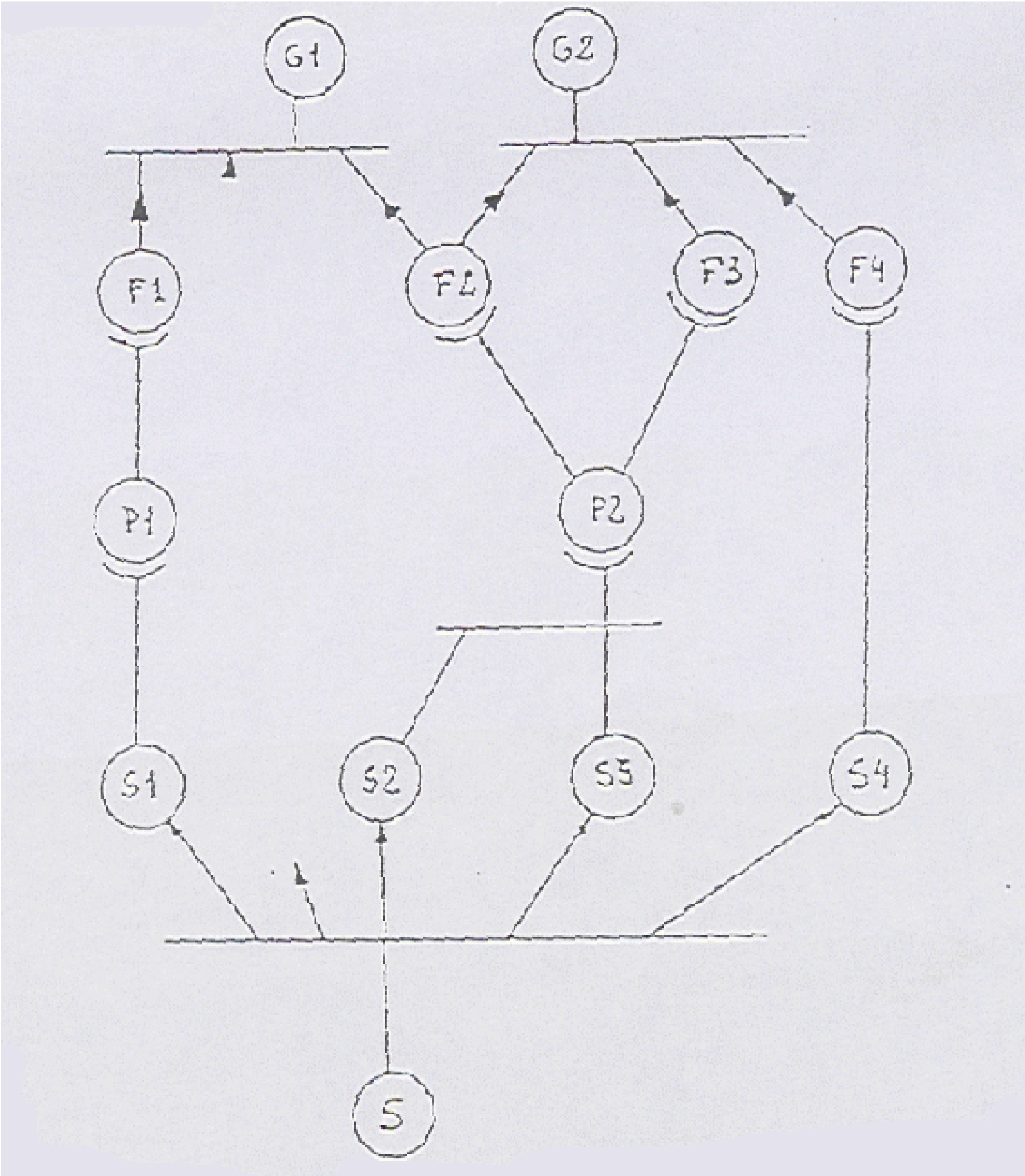


Fig. 14 An example of a Goal-System heterogeneous network (SPG).

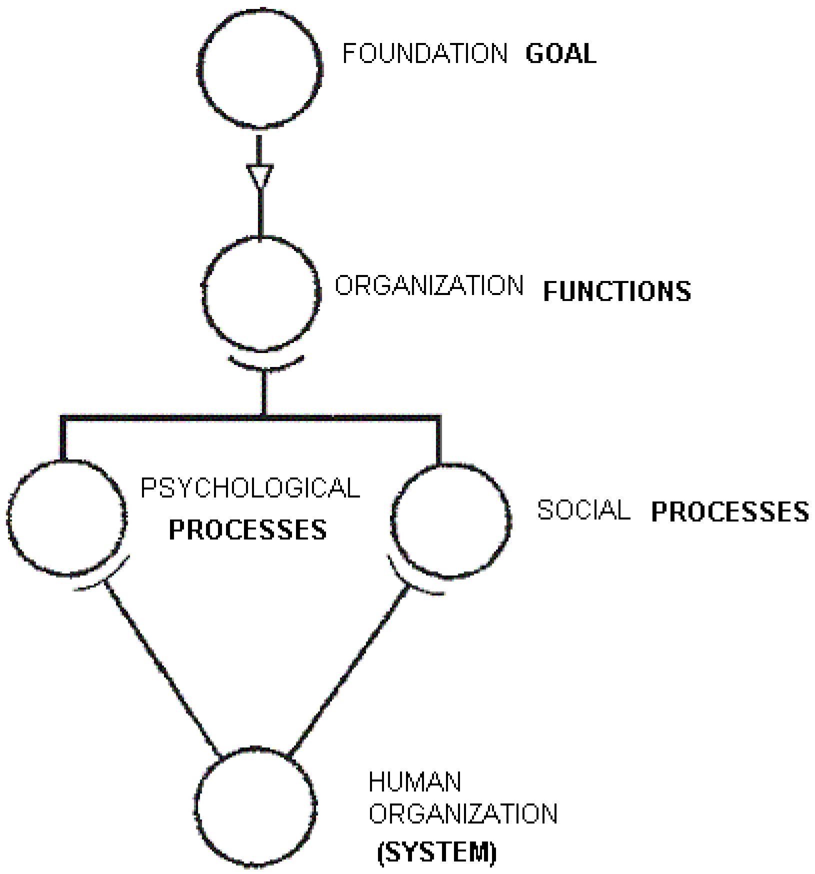


Fig. 15 This figure above illustrates the possible application of SPG for the conceptualization of a human organization.

For example, during the design of an human organization, on its every structural/responsibility level we have to choice either processes/structure or subsystems. I considered as high importance, the possibility of the representation of the human organization and technological systems together using one type a (N4, A3) graph, where:

N4 denotes number of different types of nodes:

goal, function, process, system, and

A3 denotes number of different types of arcs:

C/C, carrier, decomposition/synthesis/unification.

The main properties of such graph is easy deductible and formalizable.

Important/useful NETWORKS

On the base of the previously described SPG properties, from the TOGA perspective, every GRAPH system can also be described completely and congruently by a set of complementary and formally connected "canonical" networks.
They are:

- Functional Network , [F ; c/c] ,
- Process-Variable Network , [P, V ; pc] ,
- Variables Network , [vi ; f(vj, ...)] ,
- System Network , [Si ; sc].

In every particular situation, the choice of the network set is determined by the previous specification of the design or identification goal of the human agent (designer/scientist).

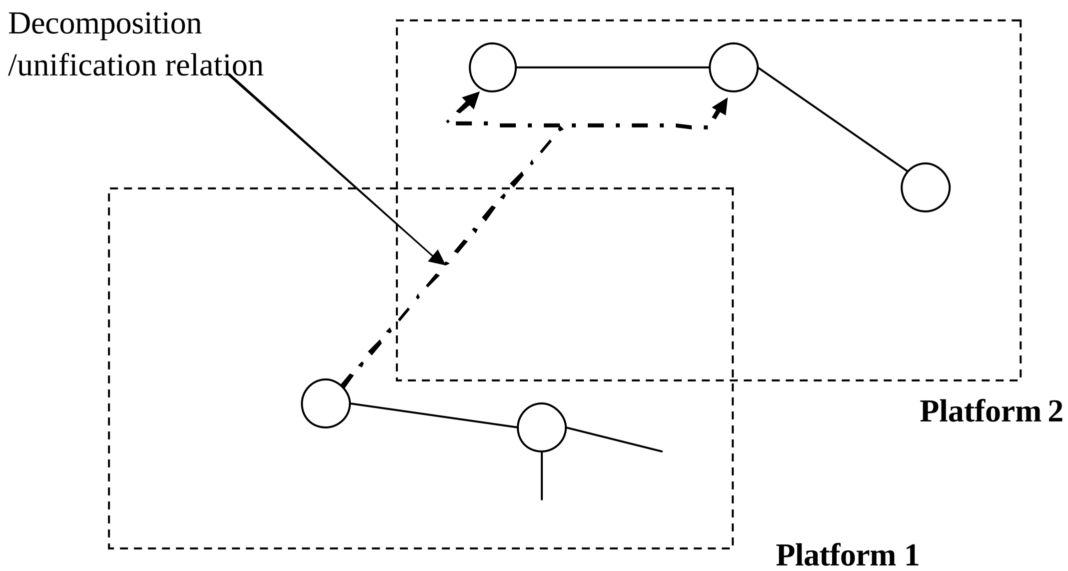


Fig. 16 An illustration of decomposition platforms of the same network

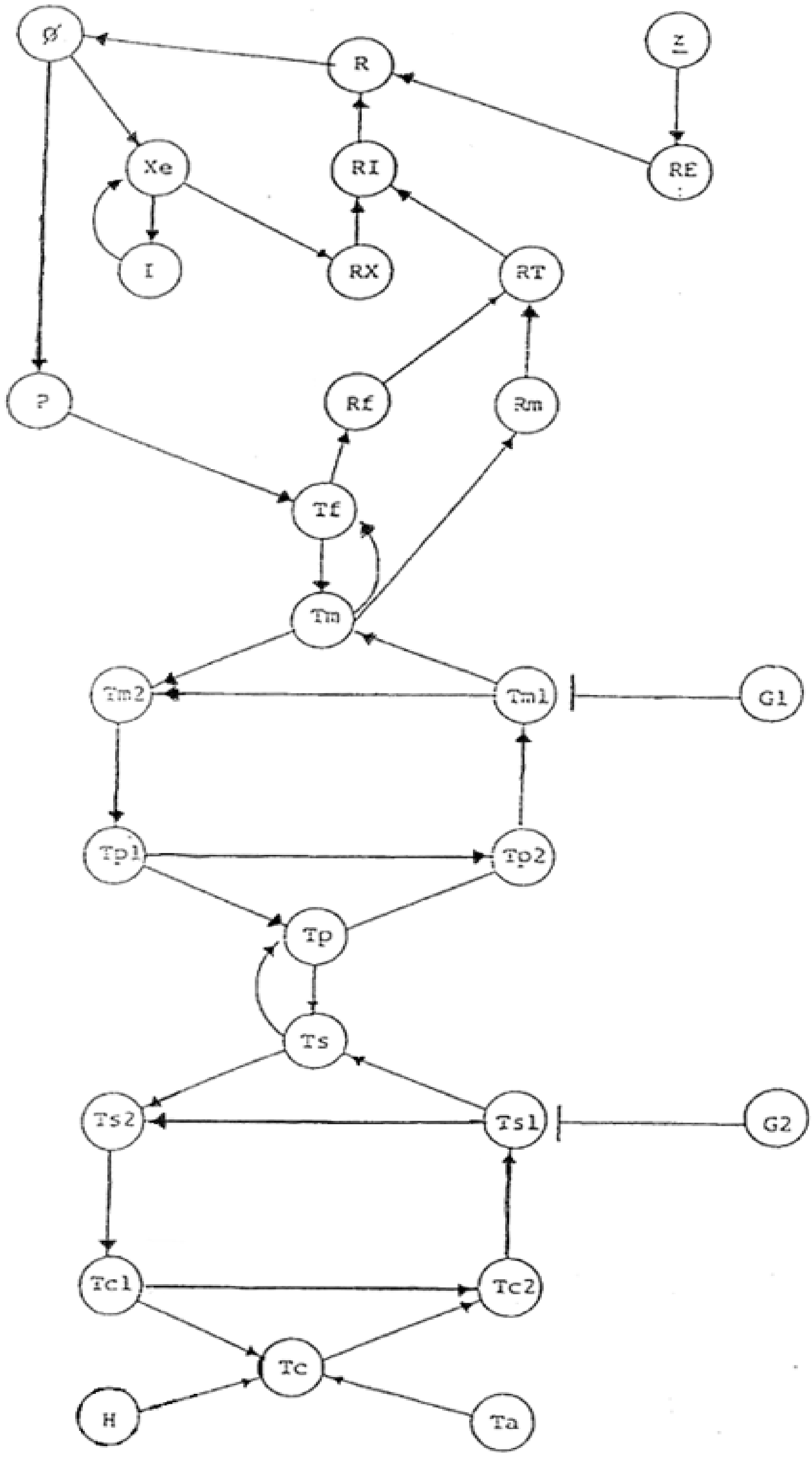


Fig. 17

Example of a variables network in the TRIGA nuclear-reactor model [ ] of the main process.

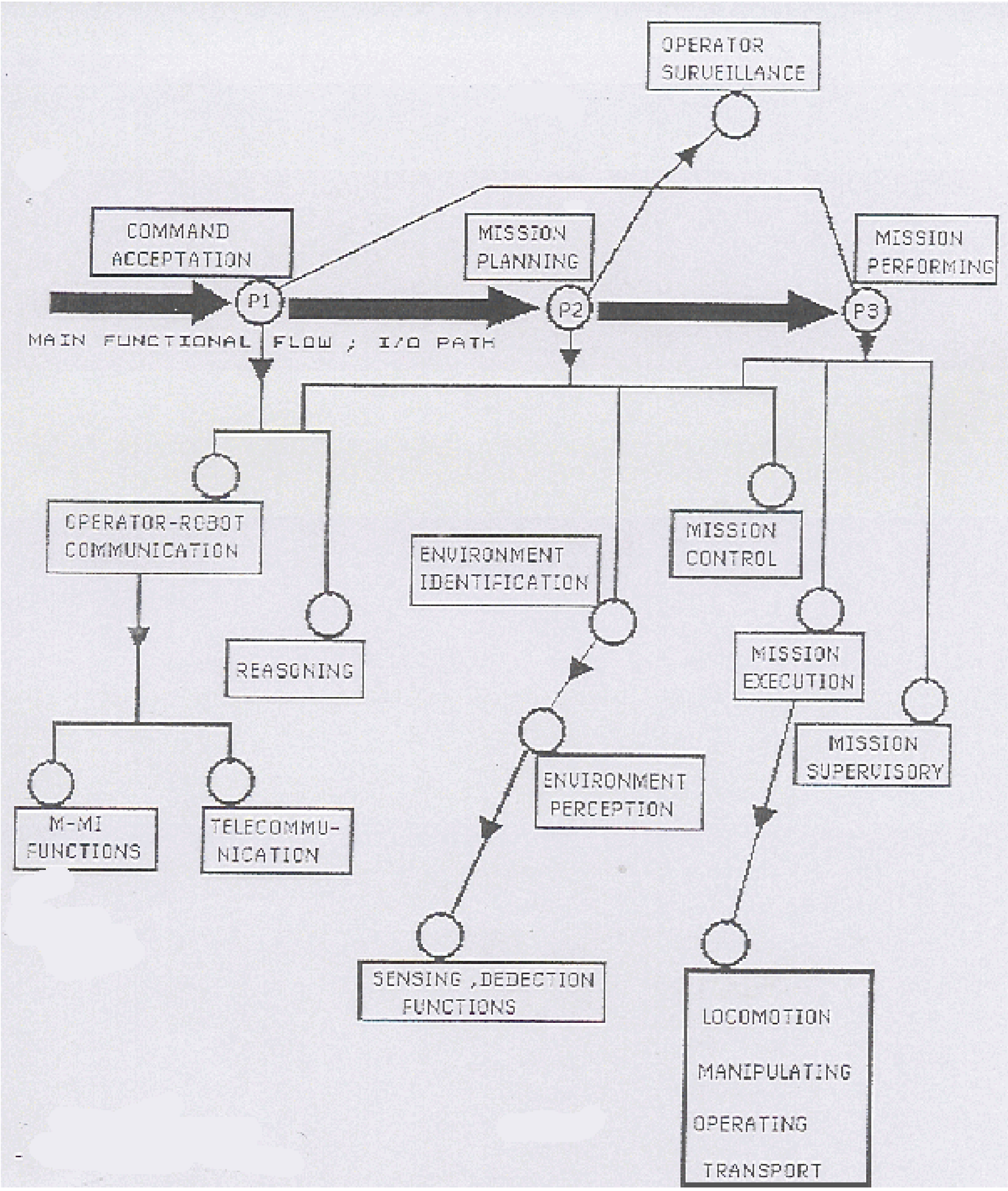


Fig. 18

Here we have another example. The above is presented the specification net of basic production-function network for the design of an autonomous robot [ ].

Connection Relation

In SPG we also have homogeneous flat relations, they are called

connection: Functional, Process & System relations

The connections relate to the objects of the same type on one chosen level of decomposition/synthesis.

There are 3 type of connections.

- **Functional Connection** between two objects X , Y indicates that the object X is a carrier of certain function fx wich is in c/c relation with fy, where fy ? Y
- **Process Connection** between two objects X , Y indicates that they have common variables vector.
- **System Connection** between X , Y indicates that X and Y have common paraneter vector, i.e. between certain system and (X , Y) exists **decomposition/synthesis** relation

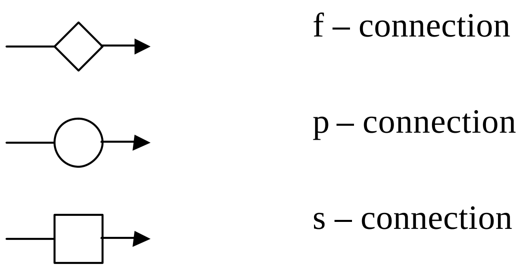


Fig. 19 Graphical representation of the types of connections

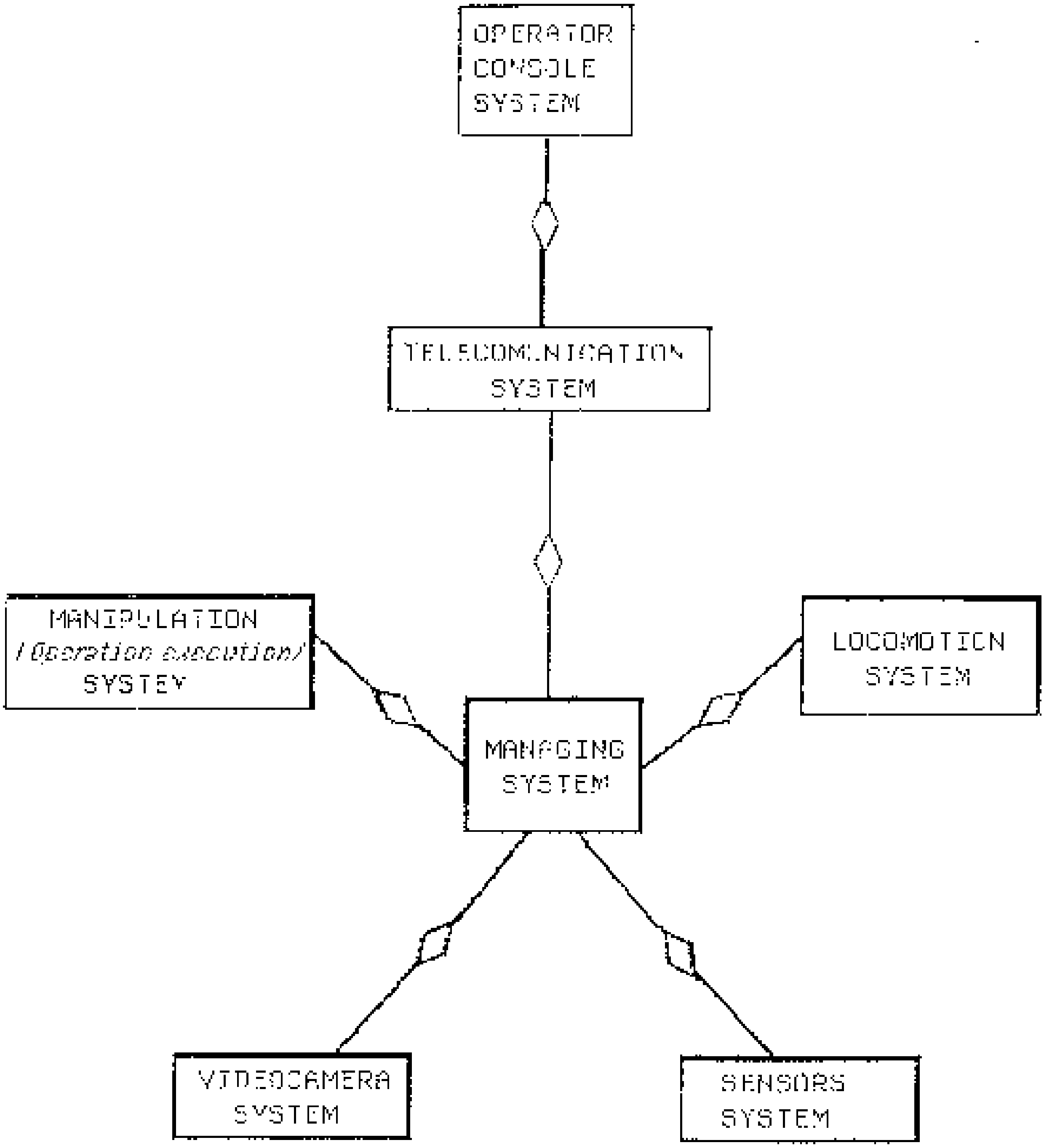


Fig. 20 Functional connections among main SAVER subsystems for one robot unit (SAVER is an ENEA project of a modular autonomous robot for non structured hostile environment) .

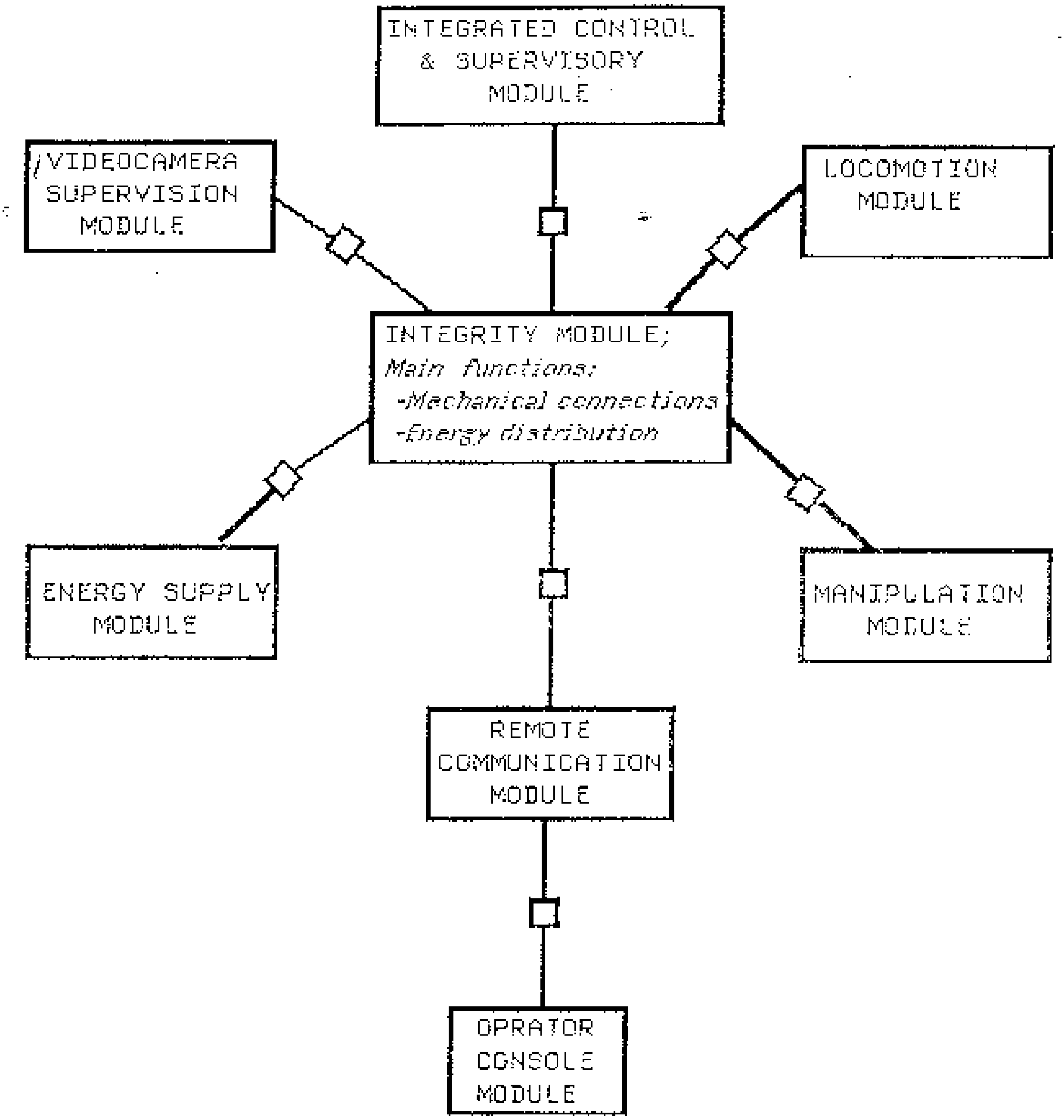


Fig. 21 Structural connections among main SAVER modules for the proposal of one robot unit.

REMARKS: Robot sensors system is distributed here among presented modules and can be visible on the second decomposition level.

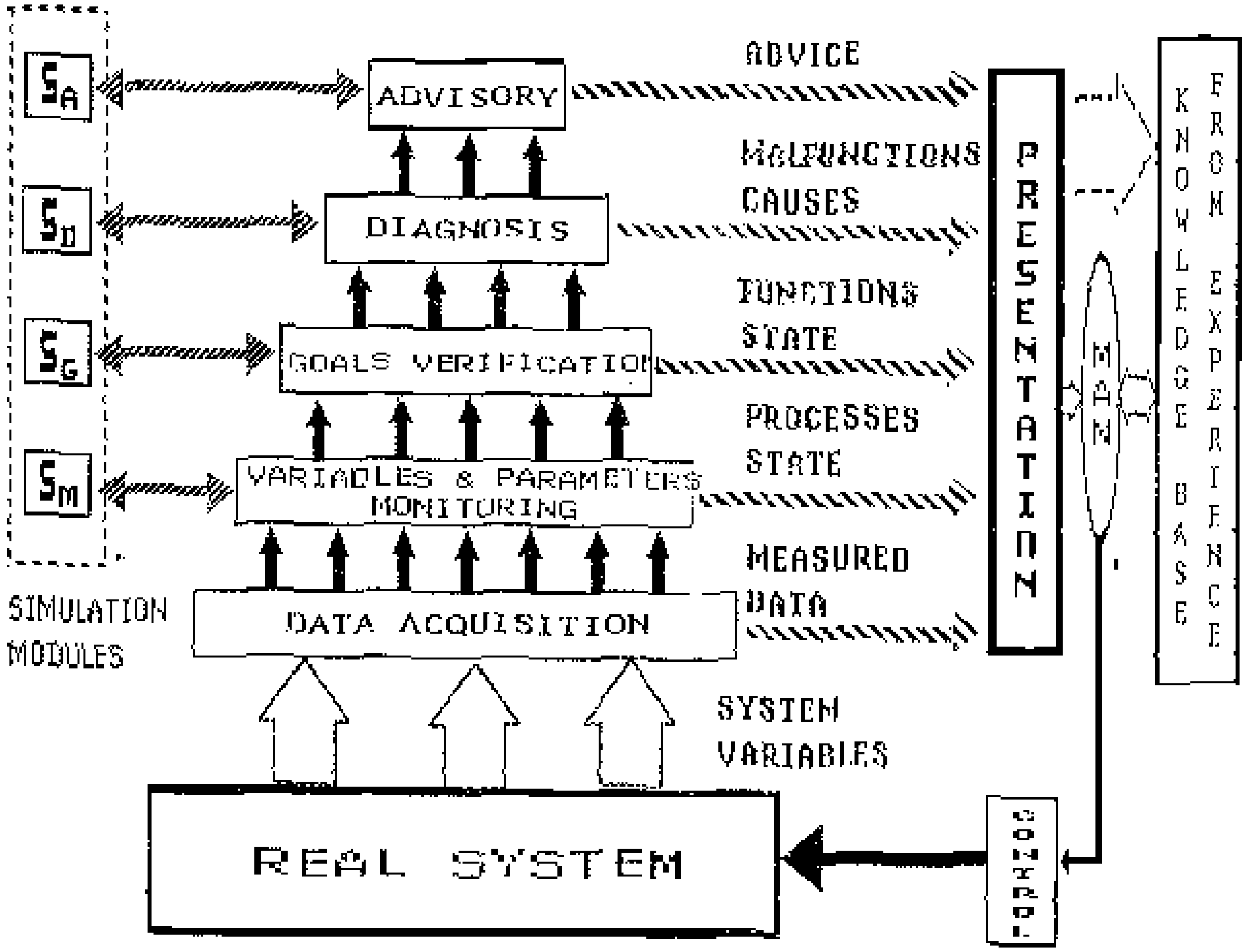
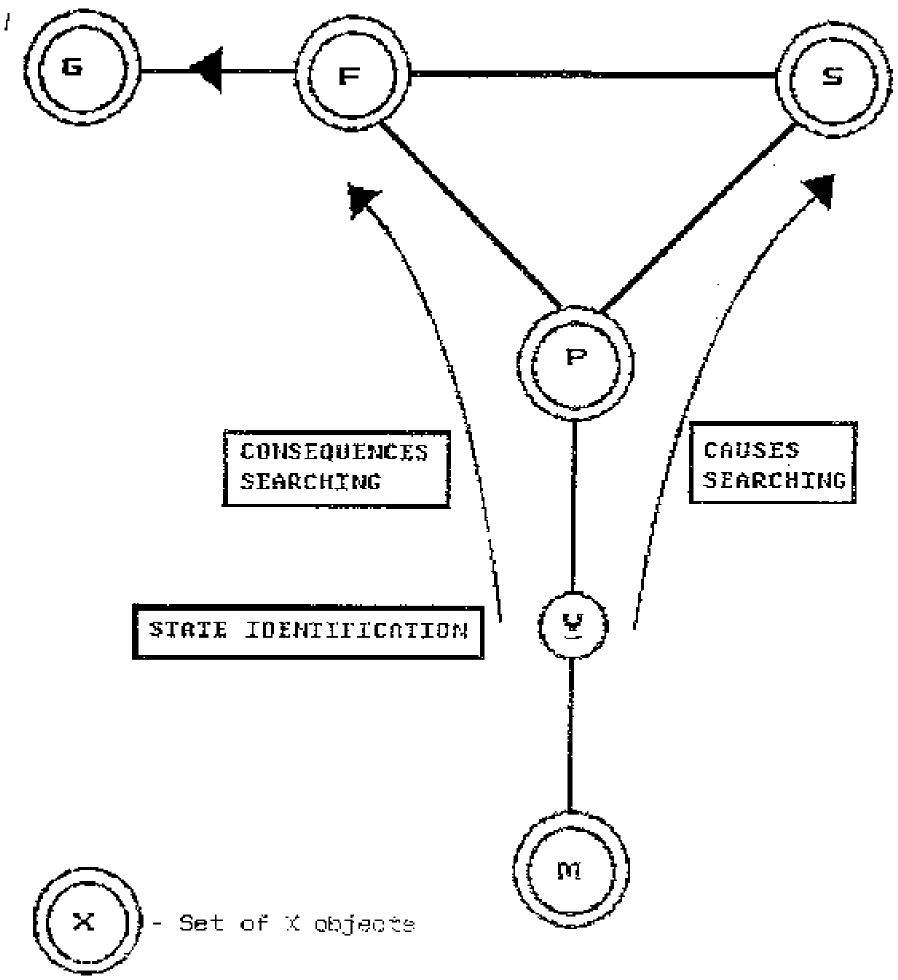


Fig. 22 Illustration of an application of SPG for a hierarchical industrial plant supervisory system.

General Strategy of System Supervisory Using SPG Approach

The figure below illustrates the consequence searching and cause searching methodology based on the SPG conceptualization pattern.

The process is started from the comparison of monitored (measured) system variables with calculated variables (model-based) from a parallel real-time simulation.



G	-	System Goal
F	-	System Function
S	-	Subsystem of system
P	-	System processes
M	-	Model of system processes
V	-	Measured variables vector

Fig. 13 SPG approach, it was also employed for the elaboration of graphical Man – Machine interfaces

- **PRESENTATION METHODS**

  Three following presentation methods have been analyzed and developed:

  – **MIMICS**
  – **MFM (Multilevel Flow Modeling - M.Lind, RISO)**

– **PSP (Process-Support-Process - A.M. Gadomski, ENEA)**

Common property of these methods is the presentation of the hierarchical decomposition of their main object which is:

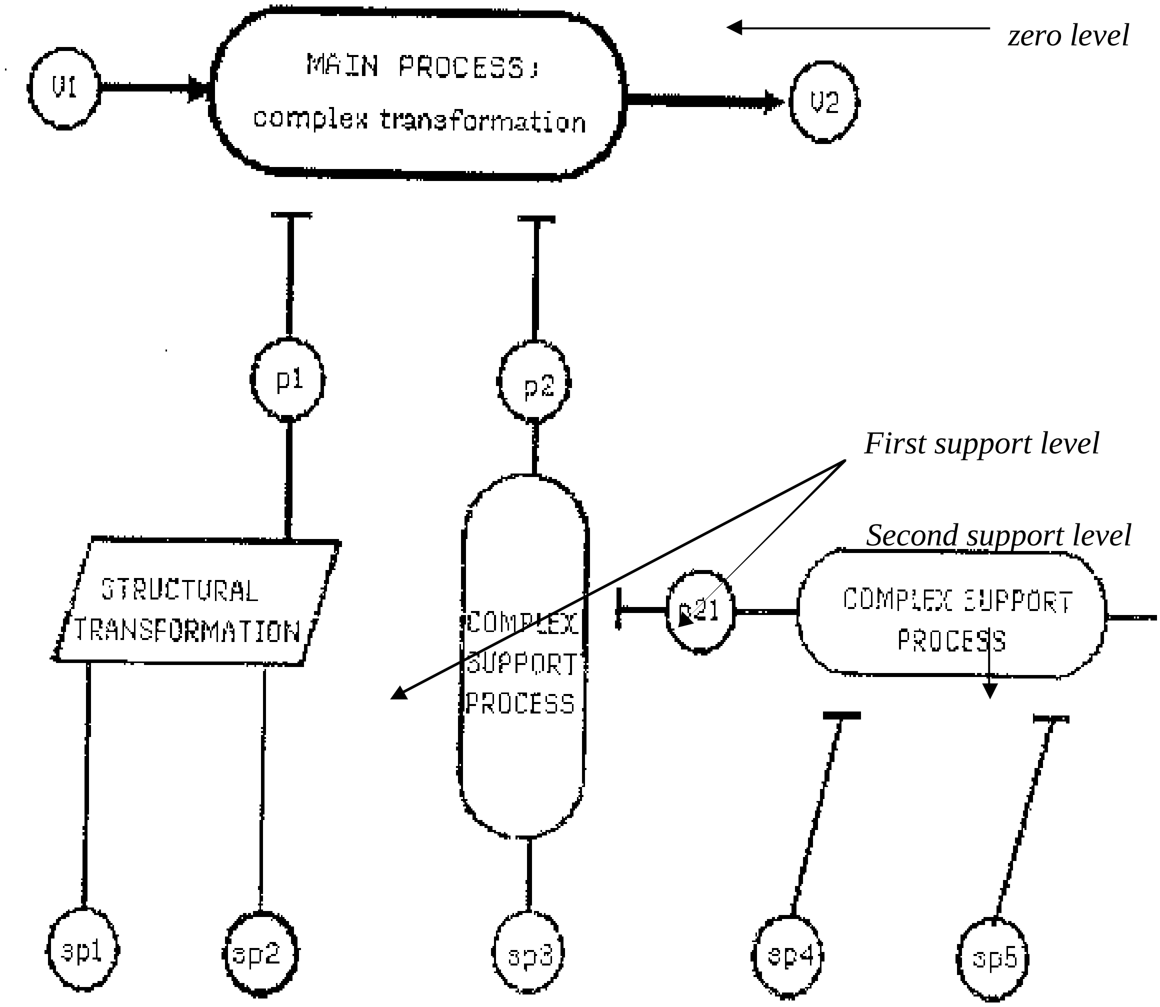
for MIMICS - general System/Structure

for MFM - Main Energy/Mass/Information Flow functions

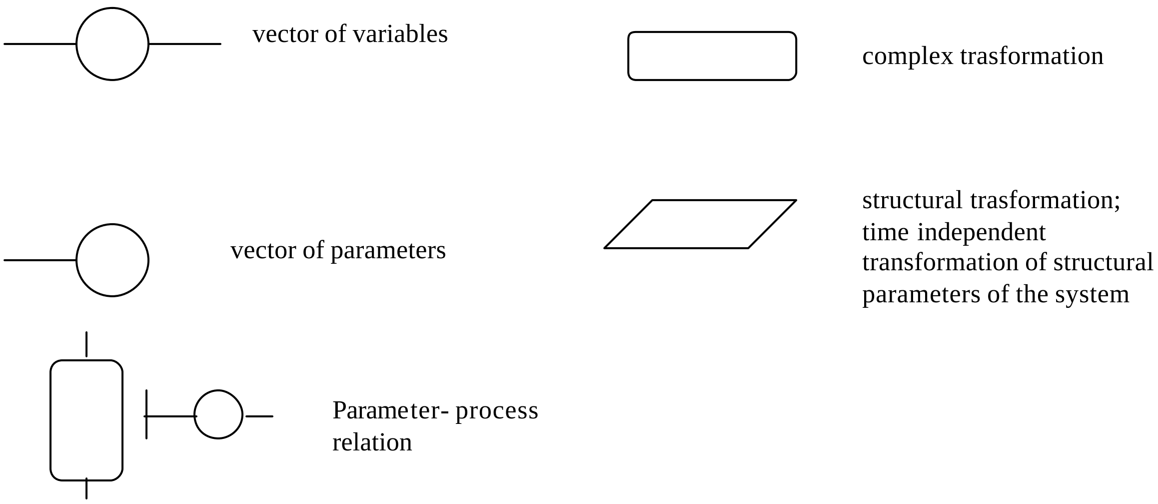
for PSP - Main System Process Flow

Process-Support-Process Method

Concept of Hierarchical Presentation of Artificial Dynamic System



The used symbols have the following meanings:



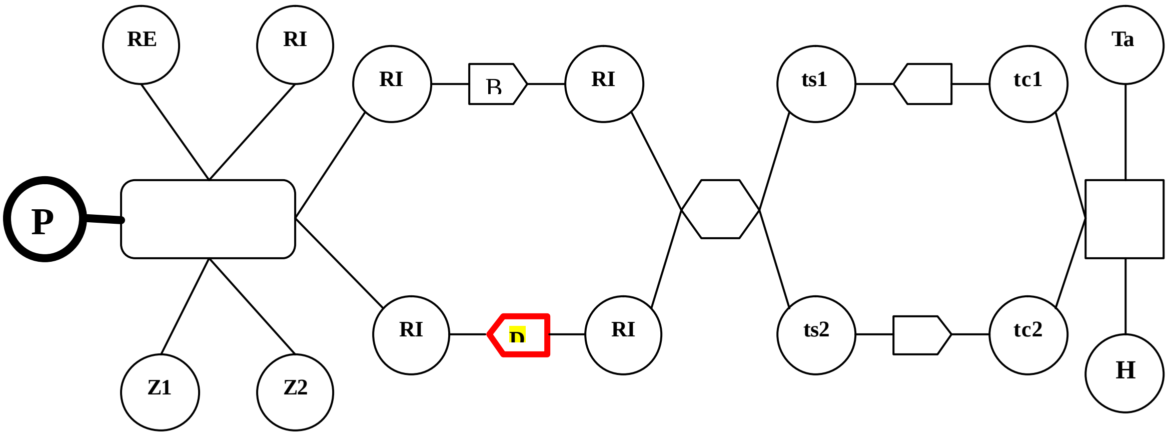
and:

V1 , V2 - Vectors of input and output variables of the main process,

p1 , p2 - Parameter vectors of the main process ;
p2 is also an output variable of the support process

sp1 – sp5 - Vectors of structural parameters which represent the basic components of the system.

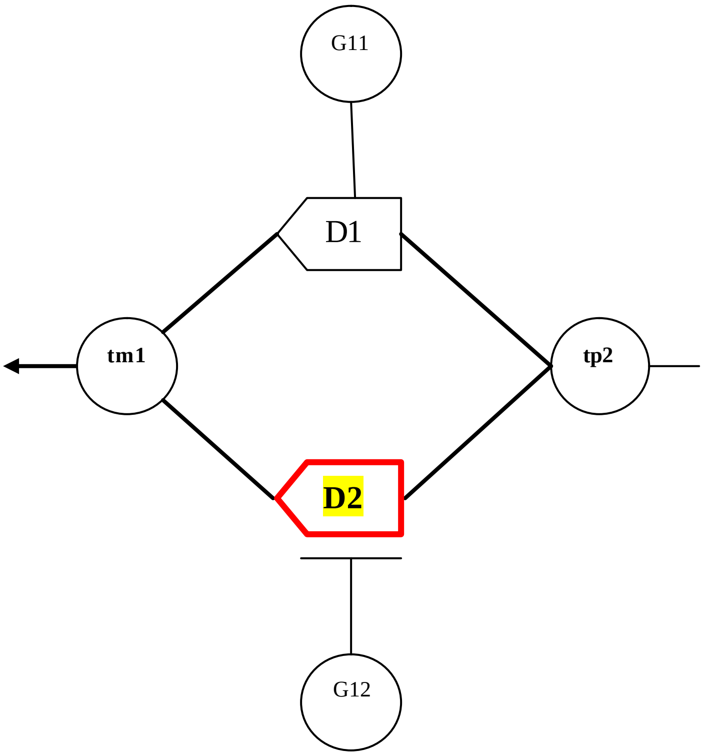
TRIGA Operator Support System, an example of the application of the Process-Support Process Method



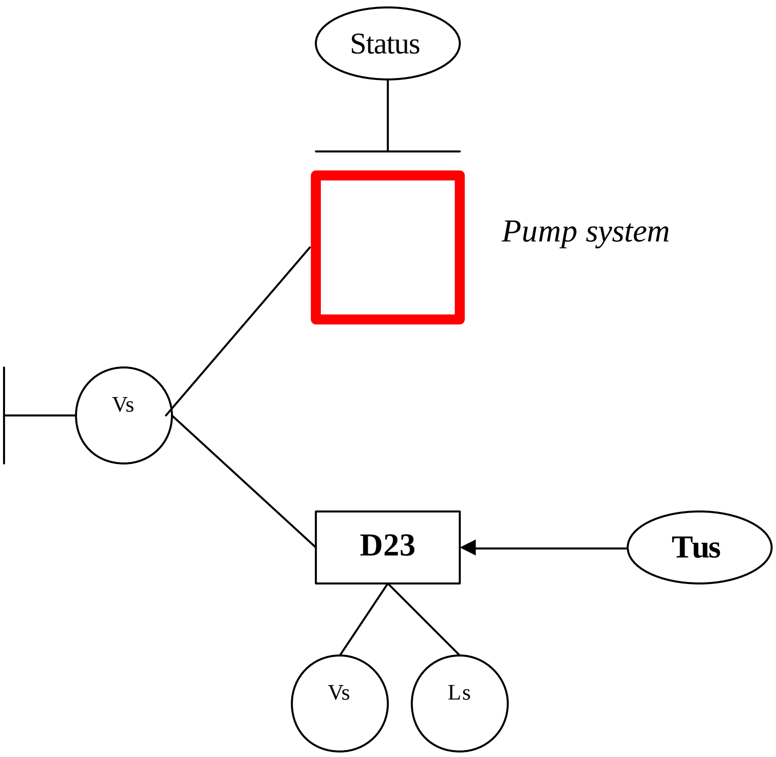
P – power production indicator

Ta – temperature of air

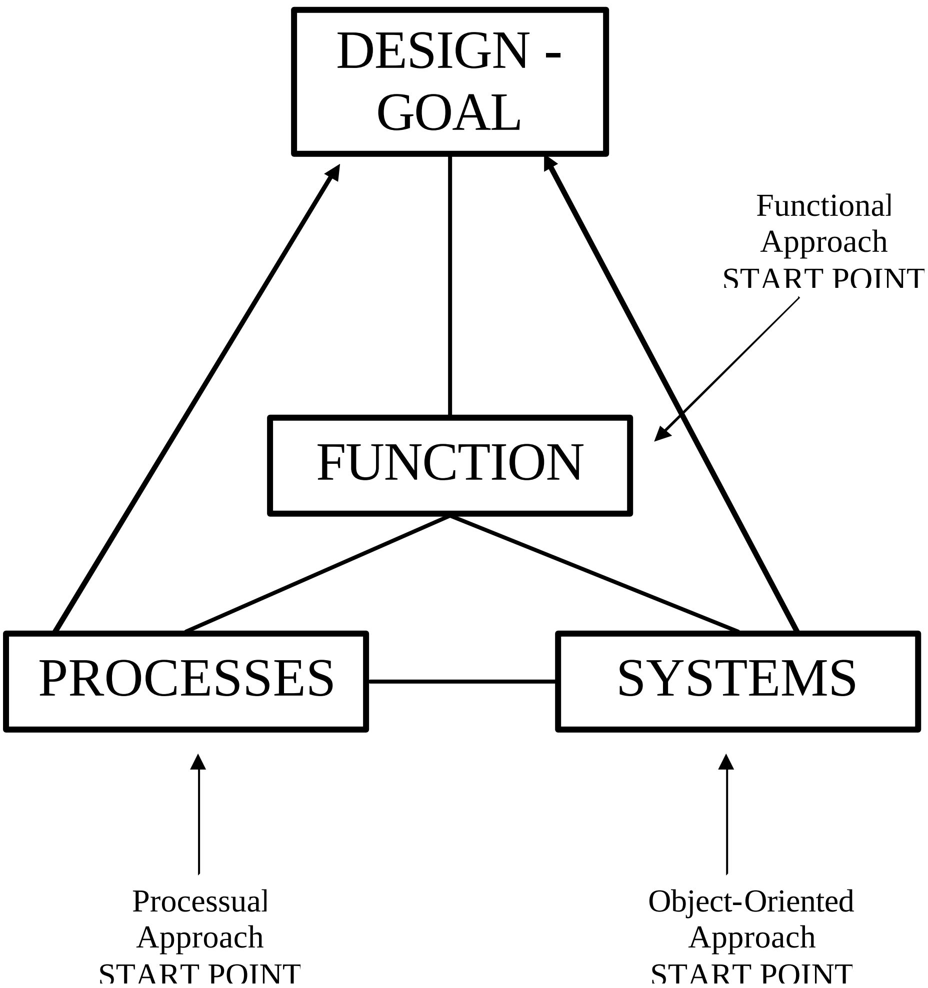
Clicking on D, a new window will open with a next level of the decomposition



With another click on the yellow zone, we put in evidence another decomposition level where we will finally find the origin of our problem on the system level.



Integrated approach to the representation of knowledge on Artificial Dynamic System *(the TOGA Conceptualization Framework)*



BASIC CONCEPTS NETWORK

CONCLUSIONS: Expected Main Domains of Applications

1. **Computer Aided Conceptual Design;**
   Theory building, specification (problem conceptualization networks) for complex industrial systems.
2. **Modeling** of a goal–oriented physical system for different purposes (such as, human everyday comprehension, reasoning)
3. **Design** of: Data acquisition
   Monitoring
   Control/diagnostic
   Supervisory systems

   especially for **high–risk plants, industrial grids** and for **navigation** systems under **time constrains.**
4. Modeling and investigation of artificial intelligent systems in fields of :
   – **Data Base Management** (“intelligent”)
   – **Robotics** (highly autonomous)
   – **Human Organizations.**
5. **Simulation** of interactions between human organizations and technological systems especially under high-risk conditions for managerial purposes.

Expected profits of the SPG standard

- transparence,
- congruence,
- completeness, and
- possibility of computer implementation.

Current status: Request of a specialization yet, practical tests and an international cooperation.

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