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## SYSTEM MODELS FOR TRIZ PROBLEM SOLVING

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### Abstract

TRIZ can be considered as specific problem solving approaches. It uses among others concepts like problem and systems. This paper is a trial to describe with general tools of system and problem modelling how model of problem and model of system evolves through ARIZ process or at least through some of its steps. The purpose of this article is to show that problem solving, and particularly, problem formulation can be described as building a system which state evolves during the process.

*Keywords: TRIZ, system models, problem formulation*

### 1. Introduction

Problem solving could be described through the systemic approach. As a problem is a description of some aspects of the world which have boundaries, and which evolve during time, it means that the traditional representations for systems could be used to specify problem solving. In this article we define the problem solving process as a system and we define its function and propose a black-box representation. Then we propose to show how the system "problem" evolves during the process of resolution, and more precisely how it could be characterized by its state, going from a cognitive, soft system to a hard, formalized one, during the phases of problem formulation.

To show this evolution we considered one case example extracted from TRIZ literature solved with ARIZ-77. We focused on the model of the three first parts of ARIZ-77 to show how the system "problem" evolves during the problem formulation phases. To do this we propose criteria to measure the boundaries of the considered system, and the level of formalization of the built system.

## 2. Problem solving process

### 2.1 A systemic description

One question is: is it possible to consider problem solving as a system? One of the basic definitions of a system is: “a set of interrelated entities” [1]. This basic assumption just implies that problem solving has to be made of entities having interrelations. Two representations are thus defined based on this definition: black-box representation and structural representation.

To define the black-box representation one of the main element to characterize is the product on which the problem solving process acts. The role of the problem solving process is to change one situation which is qualified as not satisfying. Considering the definition of problematic situation [2] as a preoccupation, inconvenience for which exists or not ability and motivation to interfere. In comparison, we consider the definition of a problem as possessing the three following characteristics:

- ability to interfere in order to change the problematic situation
- motivation to interfere to change the problematic situation
- necessity to develop a reflexion in order to synthesize a solution

The product of the problem solving process could be considered as a particular situation which has to be changed. This particular situation could be defined as “a situation in which someone feels some inconvenience, and for which means and motivation to produce changes exist but no typical solution” [3].

Thus the problem solving can be model as a process transforming one initial state of the situation, where inconvenience exists, into a final state of the situation, in which the inconvenience does not exist anymore.

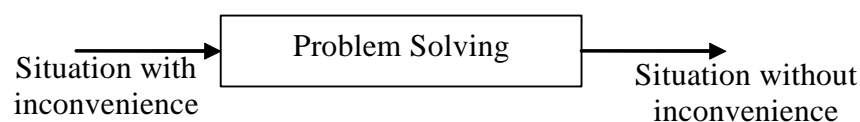


Figure 1. Black-box representation of problem solving

### 2.2 The problem-solution duality

The proposed description of black-box for problem solving underlines that the product of the process is one particular consideration of the real world. Detailing this, one can assume that problem solving is a process implying the building of a certain representation of the world in which changes have to be brought. Mainly the problem solving process is based on a 4 steps process: recognition of a problematic referent, specification of this referent in frame of the problem context, design of a concept of solution and implementation of the solution, which changes the initial referent.

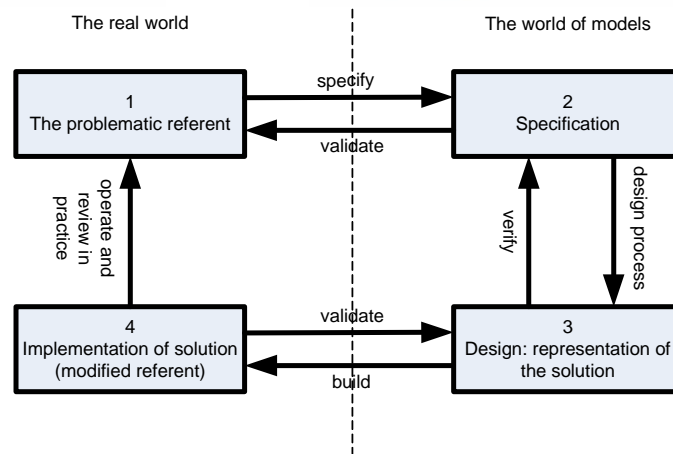


Figure 2. Description of the problem solving process

This description underlines the difference between the world and the models we use to think, understand and plan changes in the world. The world exists as it is, and a problem appears as soon as some representation of it does not fit the model we want the world to be.

$$D1: (\text{Problem}) \Leftrightarrow (\text{Desired\_State\_of\_the\_world} \neq \text{Actual\_State\_of\_the\_world}) \quad (1)$$

Thus the solution is the building of a new situation in which the state of the world is equivalent to the desired state.

$$D2: (\text{Solution}) \Leftrightarrow (\text{Desired\_State\_of\_the\_world} = \text{Actual\_State\_of\_the\_world}) \quad (2)$$

Considering these two definitions, we can then assert that Problem and Solution are two opposite propositions. It is important to define it so, as many authors seem to confuse the two concepts. This is mainly based on the fact that problem solving is a process in which the problem is re-formulated until the description of the problem enables the identification of a concept of solution [4].

### 2.3 Description of the problem solving process

If problem solving is the building of a specific representation of a referent, it also implies parallel thinking process at different level of abstractions. If trying to model these parallel thinking processes we can detail the figure 2 process as an 8 steps process.

- P1 the recognition of an unsatisfactory situation, this is the intention required to initiate a design process
- P2 the clarification of the objectives of the design process, where the unsatisfactory feeling is translated into evaluation criteria
- P3 the clarification of the difficulties why the objectives can not be reach by known ways
- P4 the formulation of the root of problem by the identification of the means for resolution
- P5 the building of a generic concept of solution
- P6 the specification of the generic principle of resolution by the identification of the specific way to implement it

- P7 the evaluation of the gap between the proposed solution and the objectives
- P8 the modification of the initial situation

As problem solving is considering and modifying a particular system, this system has to be modeled. In its first understanding, the system is the problematic referent; it means it is the real world, with no associated formal model. It is a cognitive system: "a network of subconscious notions, prejudices, preconceptions, attitudes" [1]. The generation of a solution requires to have a better understanding of the system with well defined and measurable attributes and a rigorous characterization of the interrelations between the components.

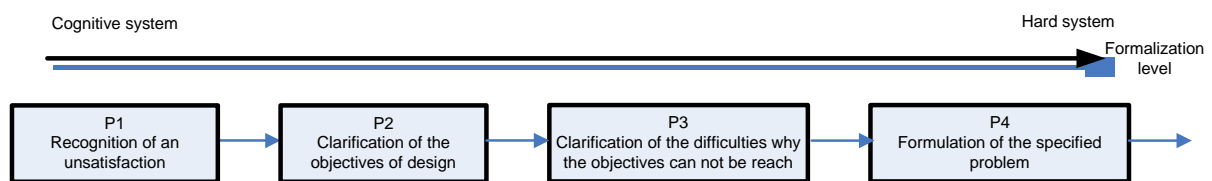


Figure 3. Evolution of the system "problem solving" during problem formulation phases

In this article we will focus on the transition from a cognitive system to a hard system, it means on the problem formulation phases of the problem solving process. Of course such analysis although have to be built for solution specification phases which surely are a kind of reverse process, going from a hard system to a cognitive one. If this analysis will be performed in near future, it has not been performed yet.

### 3. Application

To illustrate the way the problem solving process is built going from a cognitive system to a formalized one, we will consider one typical example of a problem solving case study with TRIZ extracted from [5]. The considered case study is the application of ARIZ-77 to a problem of icebreaker redesign<sup>1</sup>.

The methodology used to propose models of representation evolution is based on an ontology of TRIZ frames [6] The ontology has been defined in Protégé-2000 [7] and the proposed visualization are drawn using the Ontoviz<sup>2</sup> tab.

<sup>1</sup> Problem 5 in chapter 2-4. How the Algorithm Works. pp. 171-182

<sup>2</sup> <http://protege.cim3.net/cgi-bin/wiki.pl?OntoViz>

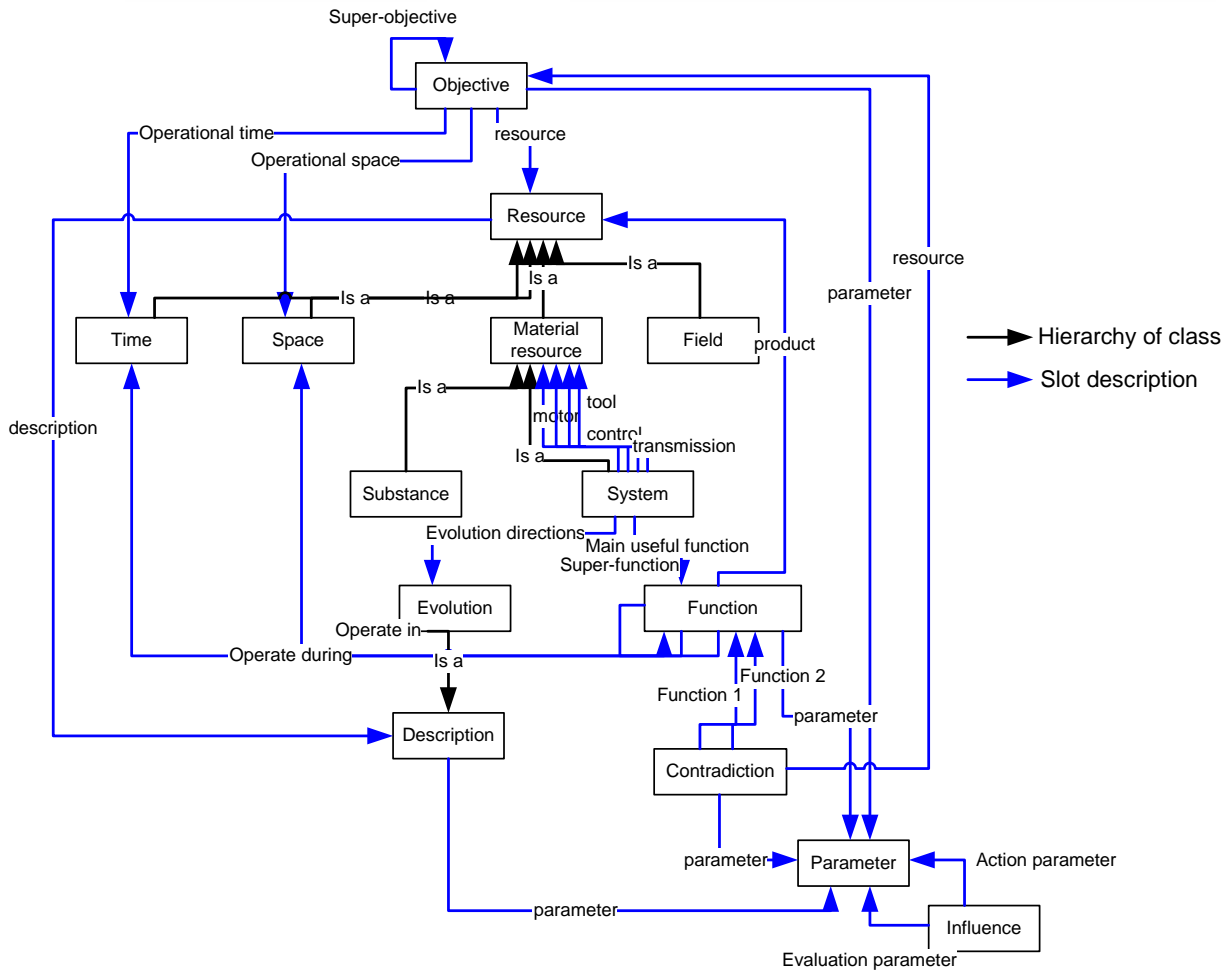


Figure 4. Ontoviz representation of the used ontology

For each of the steps will be presented the model of identified concepts, and clarified:

- The number of elicited concepts
- The number of elicited parameters
- The ratio of elicited parameters/concepts
- The number of elicited links between the concepts
- The ratio of elicited links/concepts

The objective is to show how the model evolves from cognitive to hard one. The first hypothesis on which we build our study is to say that the problem formulation process is aimed on focusing on the core of the problems, so the number of considered elements has to decrease. The second hypothesis is the problem formulation will evolve from cognitive to more formalized system, it means that the considered elements will have to more precisely elicited (so more parameters per concepts have to be elicited) and that the system will be more structured (it means that more links between the concepts will have to be characterised).

### 3.1 P1 - Recognition of an unsatisfaction

The first part of the example is the description of the situation as is initially considered. There are a lot of pieces of information, but not very well structured. As shown on figure 5, lots of elements are defined, but very few relations between these pieces of information exist.

Mainly a system is defined, its main function and working principle and some evaluation parameters that have to be increased. In addition a lot of details are given which are not proved to be useful for problem solving, but the initial description is always full of not useful information, one of the aims of problem formulation being to filter useful information.

Table 1. Analysis of the initial situation description

concepts	54
parameters	46
parameters/concepts	0,85
links	35
links/concepts	0,65

The table 1 shows that the system referring to the initial situation analysis has very large boundaries, as it includes 54 concepts. But in the same time the system has two characteristics of soft systems: the concepts have not been detailed, the ratio of parameters/concepts is quite low and the system is not structured as the ratio of links/concepts is also very low.

### 3.2 P2 – Clarification of the objective of design

We can consider that the clarification of the objectives of design mainly fits the application of the first part of the algorithm. As this first part is the clarification of the problem that has to be solved among different directions of evolution that could be considered based on the exhaustive description of the initial situation.

This step enables a first filter of the elements that have to be considered and precise some of these elements (as more parameters of the elements have been filled in). Mainly a hierarchy of systems is defined (see figure 6), a hierarchy of objectives is defined, and also the main directions of systems' evolution have been defined.

Table 2. Analysis of the first part of ARIZ-77

concepts	30
parameters	46
parameters/concepts	1,53
links	28
links/concepts	0,93

On table 2 is clearly shown that this first part of ARIZ-77 enables to restrain the focus on the study, as the number of considered concepts has dramatically decreased. In the same time, the considered system has evolved towards more formalization as the ratios of parameters/concepts and links/concepts have increased.

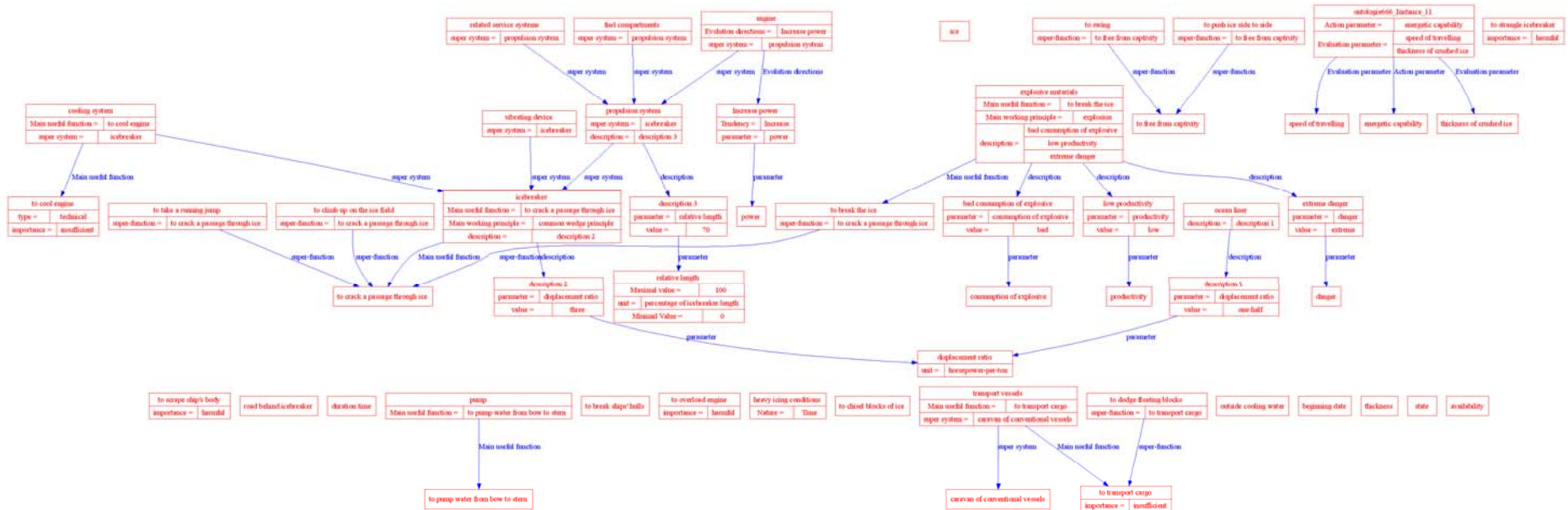


Figure 5. Ontoviz representation of the initial situation



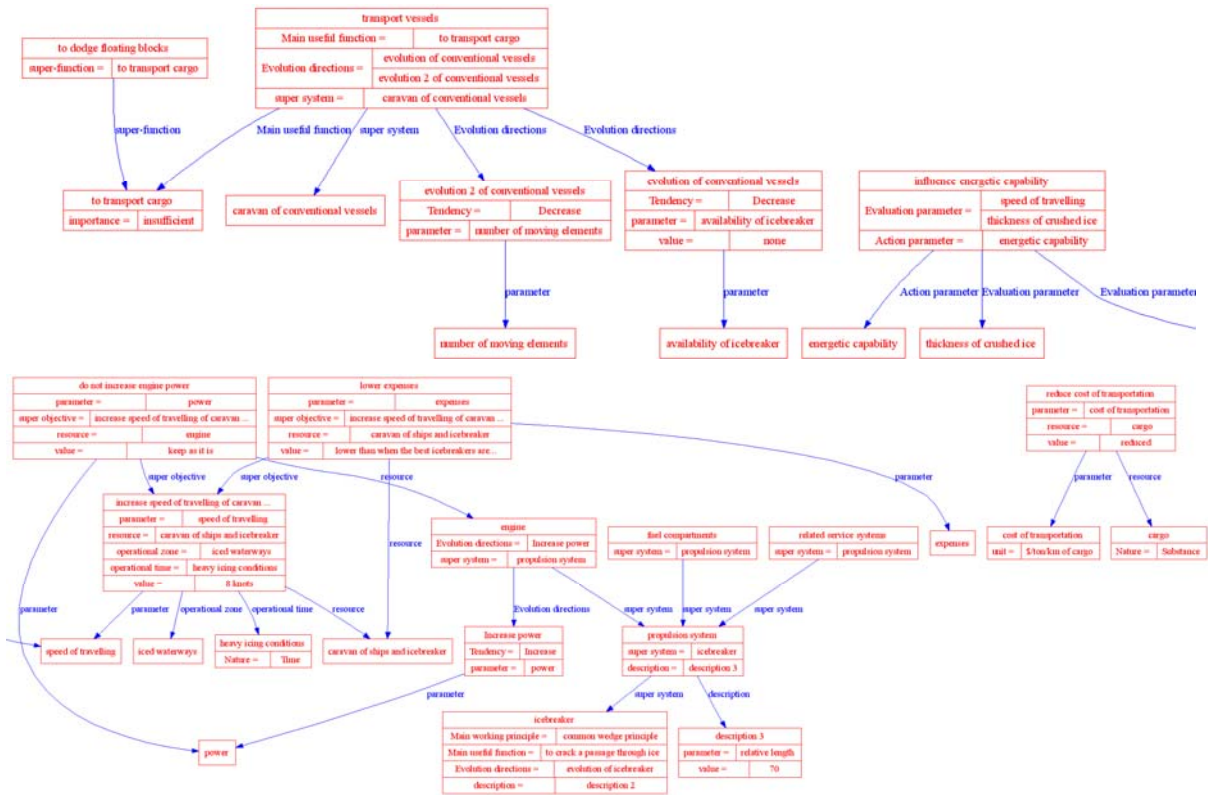


Figure 6. Ontoviz representation of the first part of ARIZ-77

### 3.3 P3 – Clarification of the objective of the difficulties to apply typical solutions

The difficulties why typical solutions can not be applied are mainly identified in part 2 of ARIZ, where the patent analysis is done and the intensification used to better understand the underlying core of problem.

Only the elements which bring some useful results have been taken into account in the model, as shown on figure 7. Thus the application of STC operators does not give useful information for each of the proposed intensification, only the interesting directions of evolution appear in the model.

Table 3. Analysis of the second part of ARIZ-77

concepts	17
parameters	30
parameters/concepts	1,76
links	17
links/concepts	1,00

The second step of ARIZ-77, as the first step, enables a decreasing of the considering number of concepts. The table 3 shows this decreasing, and it clarifies the process of problem formulation with TRIZ methods, trying to focus on the core of the problem. The considered

information is more precise and more structured, continuing the building of a harder system, as initiate in the first part.

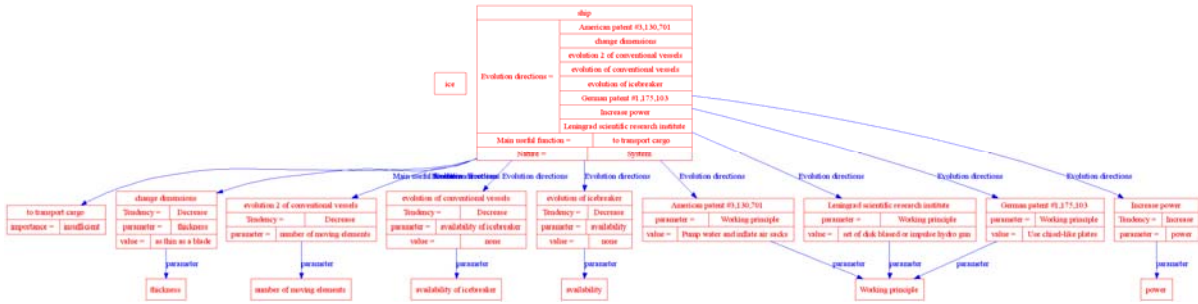


Figure 7. Ontoviz representation of the second part of ARIZ-77

### 3.4 P4 – Formulation of the specified problem

In the part 3 of ARIZ-77 some formulation of contradiction is proposed to focus on the core of problem. Also concept of solution is detailed in step 3.6, but as we are tackling only with problem formulation we have not included it in our model. Thus only the contradiction, stated as “The part of ship in contact with ice should be there to preserve the integrity of the hull, and it should not be there to press against the ice.” (cf. figure 8).

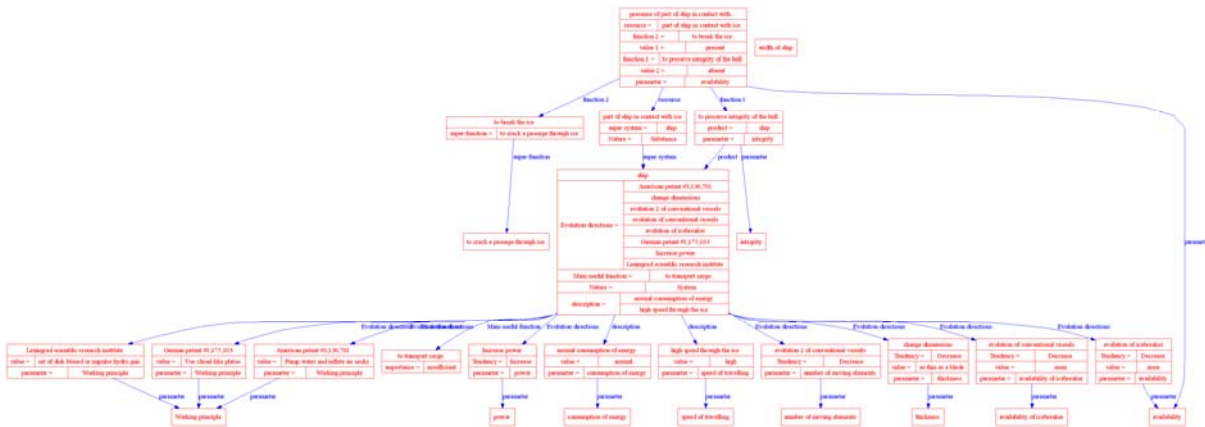


Figure 8. Ontoviz representation of the third part of ARIZ-77

Table 4. Analysis of the third part of ARIZ-77

concepts	27
parameters	47
parameters/concepts	1,74
links	29
links/concepts	1,07

The third part of ARIZ-77 is the last dedicated to problem formulation, but it also initiates the problem resolution. This tendency explains why, in opposition with the previous tendency, the number of considered concepts has increased. But the main point is that the system built is, at least, as formalized as before, as shown in table 4. With a ratio of parameters/concepts



which is nearly the same and a ratio of links/concepts which has been increased, we really face with a hard system if considering these two ratios for the initial situation description.

## 4. Conclusion

The evolution of the model throughout the different steps has shown a decreasing of the considered concepts but an increasing of the ratio parameters/concepts and links/concepts. This evolution tends to prove our hypothesis: problem formulation is a process that can be described as building a system and making it evolve from cognitive to hard system.

Table 5. Synthesis of the evolution of the system from cognitive to hard one

	Initial Situation	Part 1	Part 2	Part 3
concepts	54	30	17	27
parameters	46	46	30	47
parameters/concepts	0,85	1,53	1,76	1,74
links	35	28	17	29
links/concepts	0,65	0,93	1,00	1,07

The table 5 shows this evolution, even if the part 3 of the algorithm seems to decrease to enlarge the limits of the system, but this is mainly due to the fact that this part initiates the phases of problem resolution. The detailed analysis of these phases has not been developed yet but it seems that it is a reverse process; it means a process going from the consideration of a hard system to a cognitive one. This part of the study will be performed soon to check the validity of our hypothesis.

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