Evolution Of Systems

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Introduction

This article is an attempt to formalize my thoughts about the evolution of products or of systems in general.
It does not contain anything new. To the contrary, it just applies the assumption that "somebody somewhere has solved a problem like mine".
Altshuller proposed "trends of evolution" that are presently expanded by many authors in the TRIZ literature. In his book, Darrell Mann (1) has 31 of these trends. They are observations of the evolutions of objects. This part of TRIZ does not satisfy me. It looks more like a collection of examples of the use of some TRIZ principles (e.g. The trend of "space segmentation" or the trend of "object segmentation" show the segmentation principle at different levels in a solid).
This article tries to show TRIZ practitioners other attempts to approach the evolution with the hope that somebody will once formulate a coherent theory or at least a coherent guideline.
After introducing the general modeling of systems, the article draws from the evolution of living systems to show some conclusions useful for the TRIZ practitioner.
The way we look at the evolution of products has also an impact on the way we model the objects and their functions. Therefore, the article ends with some comments about modeling.

First part: Modeling the general system

System theory is a "theory" that started in the 1920's and was developed mainly from 1950 to 1980.
It is a kind of reaction to the Cartesian or scientist thinking of most of the technicians.
The main authors are: L. von Bertalanffy, S. Beer, K.E. Boulding, A.D. Chandler, M.D. Mesarovic, H.A. Simon, G.M. Weinberg, L.A. Zadeh and many others
A more recent book is "The Fifth Discipline" from Peter Senge.(2)
There were very few courses on "system theory" in Europe and I remember that in the 80,s there was a course by Walter Dänzer in Zürich (3)(on engineering systems), another course by Peter Checkland at University of Lancaster (4) (mainly sociologically oriented) and a course by Jean-Louis Le Moigne in Marseille(5) (philosophical point of view).

I will hereafter shortly describe the model of a "general" system according to Le Moigne.

Notes:

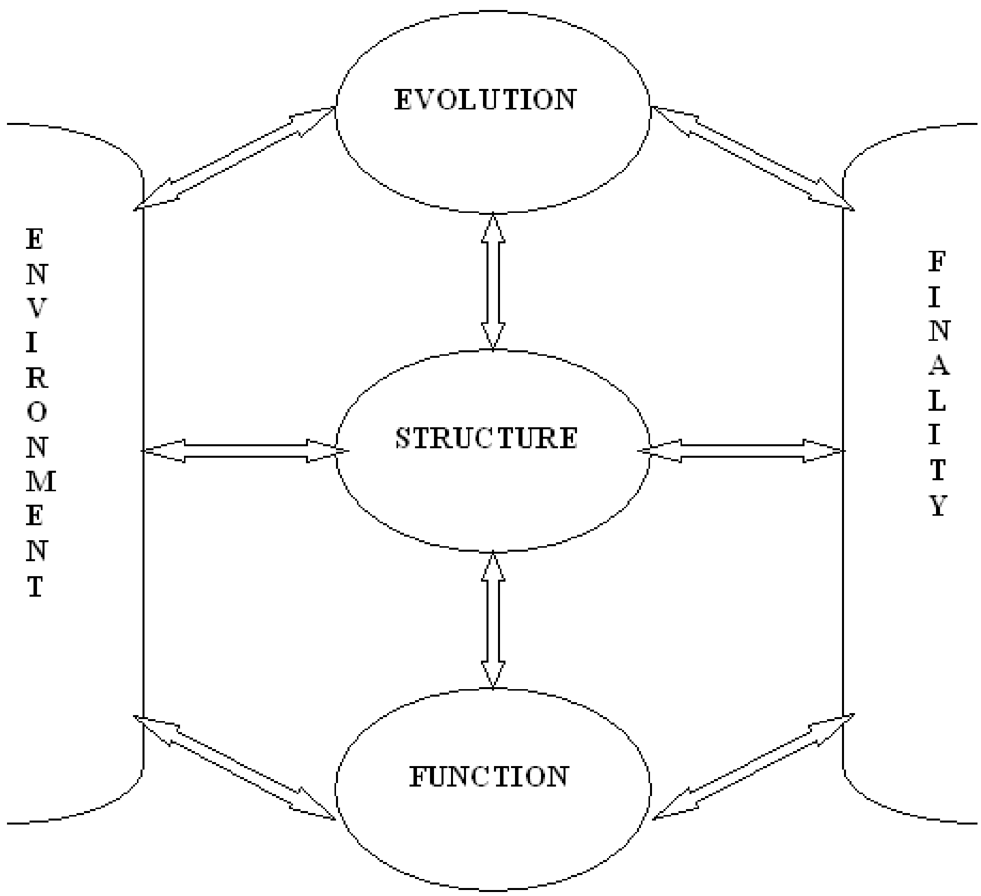
- A model is a representation of the reality. It is not the reality. It is built with some goal in mind that allows the model to take into account only the parts useful to this goal. For example in Euclid's geometry (with the goal to measure lengths, angles, surfaces etc.) the model of a triangle does not contain the color of the triangle: the model is relevant to geometry but not to the Highway Code where the color is important.

- A model can contain things that are obviously unscientific. For example, if it is helpful to simplify the model by giving some material object an "intention", it can be done (e.g.: "oil does not like water")

The "general system" model is an evolution built upon three paradigms:

- The classical mechanical paradigm representing only structures and functions.
- The statistical mechanical (thermodynamics) paradigm representing only structures and evolution.
- The structuralism paradigm representing structures, functions and evolution.

The "general system" model is represented hereafter



It contains the three boxes from the structuralism model plus two "open boxes":

- Environment
- Finality

This model makes the assumption that the system is open on its environment and that it has "finality" (a system having a finality is sometimes called "teleological system" meaning either "goal seeking system" or "purposeful system")

Finality explains why many systems (like human systems) do not only obey to causal laws but also use these laws like a good engineer to realize the project, the dream, and the finality.
That means that the structure is not the only explanation of the function or of the evolution; both can be interpreted by the projects.
Evolution is therefore not obvious (like one could think when looking at "trends of evolution") but relevant to considered projects.

From a philosophical point of view: interpreting and representing an object, as a "finalized" intervention in an environment perceives this object as created by a conflict (Heraclitus -500 BC- "The conflict is the father of all things").
Let's note that doing that we have also added a new cause to the functioning of a system: the finality, the project (beside the physical causes).
Already Aristotle (384-322 BC) had expressed that.

These last sentences just to show that somebody somewhere has already thought about.

With that model in mind we can then try to understand the evolution of systems.

Second part: evolution of living systems

Again, by looking in the literature, we can find a lot about evolution of living systems.
Lamark, Darwin, Lorenz, Teilhard de Chardin, and many others have described the evolution of living species.
However a book from 1970 (Titled "Energon") by Hans Hass (6), a German biologist has popularized some evolution of living species.
Almost every country has or had a biologist dealing with the sea (and especially with dolphins). In France it was Cousteau, in, Germany Hans Hass.
Hass coined the term "energon" as the concept of any energy acquisition system (living system, human organization etc.)
In nature, energy is something like a common currency. Every action is made to acquire energy and doing so is also costing energy. The balance has to be extraordinary positive because between the incoming energy (by eating for example) and the outgoing energy (by running for example) there is lot of energy transformations performed with low yield. And the balance has to be even more positive to take care of growth and reproduction.

Hans Hass shows twelve basic questions to evaluate the competition capability of an energon. These questions appear in the table below. We could name these questions : "efficiency criteria of a function"

Depending upon the weight given to these questions and to their answers, various evolutions have been observed in nature.

Efficiency criteria of a function

	Cost	Precision	Duration
Creation / Building	What are the costs of building the function?	What is the percentage of successful building of the function?	How much time is needed for building the function?
Functioning	What are the costs of each action of this function?	What percentage of the actions of this function is successful?	How much time lasts an action of this function?
At rest / Idling	What are the costs of the function in its idle state?	What portion of capacity survives after the idle time?	What are the durations of the idle phases?
Stopping	What are the costs to stop and reactivate the function?	What portion of capacity disappears at each stopping?	How long does it takes to stop the function?

Note :

We can try to apply this table to the function of removing a wheel from a car to replace the wheel or the tire or the brake. There are one or more bolts preventing the wheel to go its way (in the curve for example). Why is this function using bolts? Why can we not change the tire without removing the wheel? Why is the wheel not soldered to the axis? What will be the evolution of that object? The answers given to the twelve questions of the table are today satisfying most car makers and there is no need for evolution. Like Altshuller wrote, the products evolve because some problems appear (some contradictions)

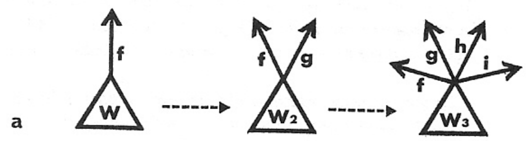
According to the table, Hans Hass describes the evolution of systems in the following manner.
He represents a function by an arrow almost like in any functional modeling and this function is "carried" by a "function carrier" represented by a triangle.

We can notice that Altshuller's representation of a function is also a triangle (an S-field).

Hereunder are the various evolutions. They have to be considered as possible steps of evolution and not as trends like in the TRIZ evolutions.

Note : the pictures are from the book of Hans Haas with permission

There are three evolutions by "change of function"

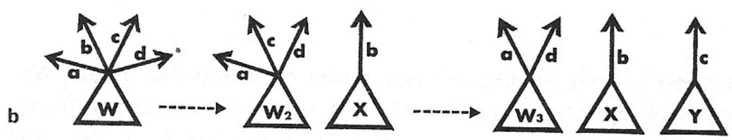


a. Functions extension

W is a "function carrier" inside a living body or inside of a company. It is producing function **f**. During its evolution it carries more and more functions (first **g** then **h** and **i**). To do that it requires some structural changes or new "functions recipes". The situation can also lead to an overload of the function carrier.

Example : In small aquatic animals, the skin takes also the function of breathing and excreting wastes.

Business example : a department performs more and more functions.(as long as the efficiency balance to perform these functions is positive : see the 12 questions)

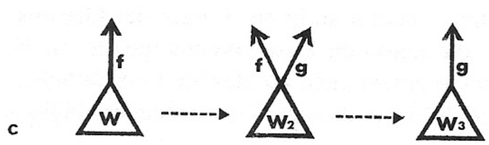


b. Functions division

W is with functions overburden (**a-d**). The various functions are hindering each other. A new function carrier **X** takes the function **b**. And the evolution continues by **Y** taking function **c**. That is an evolution to more work division, higher differentiation and higher specialization.

Example: For an animal living in air, breathing and excreting wastes can not be performed by the skin anymore. There is a conflict between these functions and the protecting function of the skin.

Business example: When a department is overburden, part of its functions are given to another or to a new department.



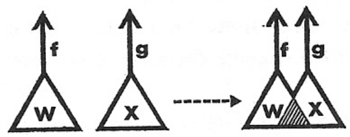
c. Functions change

It begins like a function extension. A function carrier first takes an additional function (**g**). Later in the evolution the function **f** is becoming superfluous or useless and is destroyed or regresses.

The function of a sword is "to make holes"

Swords hanging on the wall of a living room now perform a decoration function.

There are also four evolutions by "functions rationalization"

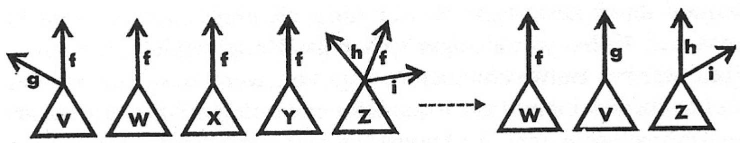


a

<u>a. Functions association</u>

W and **X** are function carriers in the same energon. They carry functions **f** and **g**. They can save something by an association (complete or partial)

Business example: Two companies are merging due to synergic effects making them more efficient on supplying more functions.



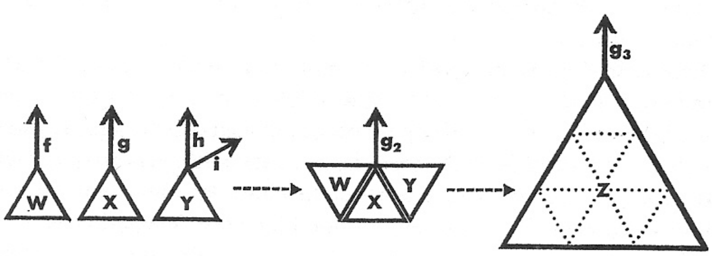
b

<u>b. Functions consolidation (fusion)</u>

Many functions carriers (**V-Z**) perform the same function (**f**) and two of them additional functions (**g, h, i**). One single function carrier taking the function f changes that situation. It can be an existing function carrier (**W**) or a new one.

Business example: The same function is performed at different places and evolves by having a central place performing the function: R&D, typing, patent evaluation, lawyers etc.)

c

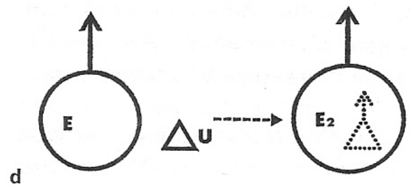


<u>c. Functions bundling</u>

Its binding to function carriers **W** and **Y** enhance the performance of function carrier **X**, resulting in a better function $\mathbf{g_2}$. At a higher integration level that gives birth to a complex organ providing function $\mathbf{g_3}$.

It is by "function bundling" that most of the complex organs of animals have been formed. It is also by "function bundling" that man has created most of the machines.

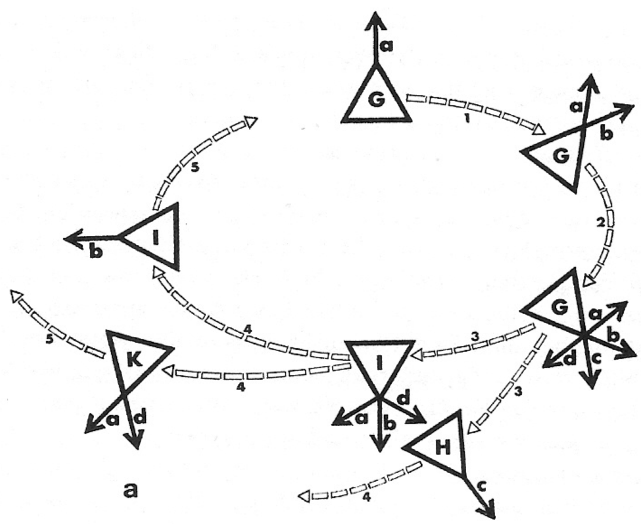
European example: Every country of Europe had its own government, police, army, justice etc.. it is evolving to new integrated organs to perform these functions.



<u>d. Functions birth</u>

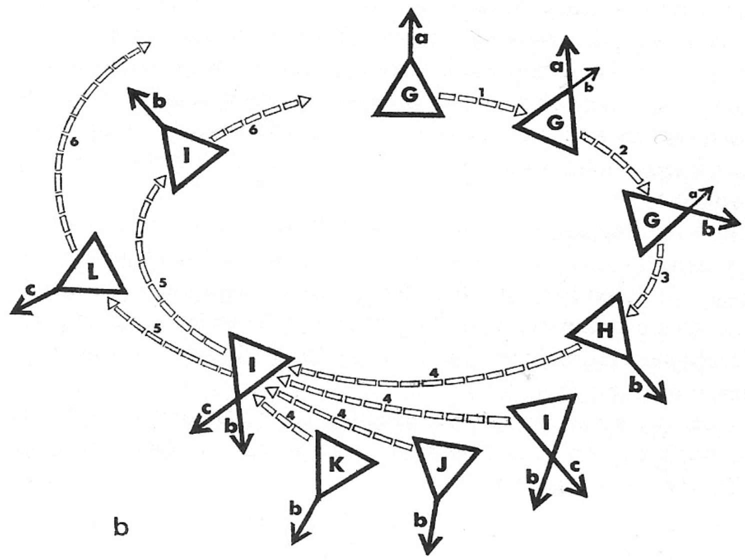
E is an energon, **U** is functionless unit in its environment. **E** takes **U** and transforms it into a function carrier

Hans Hass shows also examples of evolutions represented hereunder



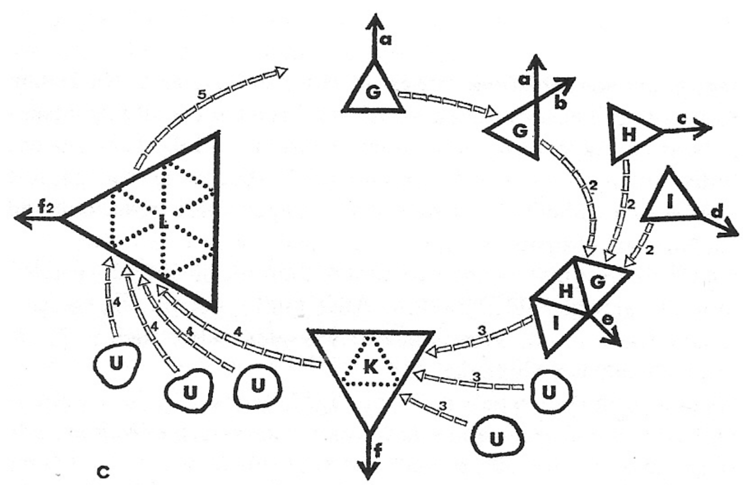
<u>a. First example</u>

Function carrier **G** performs first only function **a**. During time interval **1** it takes (function extension) also function **b** and during time interval **2** also functions **c** and **d**. It leads to an overburden and during interval **3** a function division takes place: **H** takes the function **c** and **I** the function **a**, **b** and **d**. During interval **4** another function division takes place. Function carrier **I** has then only one function any more and like **H** can continue an evolution process.



b. Second example

During time intervals **1-2-3** there appear a function change. The original function **a** looses importance and only **b** remains. During interval **4** a function consolidation appears: function carrier **I** takes from **H, I, K** the function **b** and during interval **5** it gives to **L** its function **c** (function division) and we end up with two function carrier having each only one function.



c. Third example

On a function extension follows a function bundling. Functions **a, b, c** and **d** are giving together a new function **e**. By taking useless (for them) environment units **U** they build during interval **3** and **4** a complex organ **K** with only one function (**f**). This organ can then take more units **U** to increase its function to **f2** and continue its evolution.

Notes:

- The "trends of evolution" of Hass are easier to apply to organizations when the trends of Altshuller are easier for technical objects.
- The three examples from Hans Hass are just illustrations of evolutions going in a spiral to more and more elaborate species.

- It is important to note that Hans Hass does not predict the evolution; he shows different possibilities resulting from observations.

Conclusions about the evolution

Notes:
- Following conclusions are probably more applicable to organization systems than to technical systems because the latter can be closed systems and the formers are always open systems (like in nature).
- We have to notice that the general system model puts the "evolution" of the system at a level equivalent to the level of "structure" and "function"; the evolution is not the property of a function.
- Because the most common principle (maybe not very inventive) to solve a problem is to add a function, we could also say that a trend of evolution is by adding/suppressing functions.

Conclusions:
1.- If we are in front of a system/product/organization/business, to have a fair chance to predict its evolution requires not only reviewing the TRIZ trends of evolution but also some thinking about:
- the environment in which the system is working
- the evolution of this environment
- the finality of the system
- the evolution of this finality

The twelve questions of the criteria of the efficiency of a function can therefore be helpful.

2.- Observing nature, one can see that starting from one point there are many evolutions leading to many different species. That depends from the weight given to the twelve questions and from how these species could accommodate their environment.

3.- For many technical systems however, the way they evolve is given by the intention of their designers. These people "dream" the finality of the systems and among all possible evolutions the one that will happen is the one that they want and on which they put the money to make it happen

4.- Once a system is accepted, it is very difficult to change some of its features.(the railroad track distance, the Qwerty keyboard etc.)
It seems that we first adapt the objects to us then we have to adapt ourselves to the objects. Some observers coming from another planet could say that we (humans) have adapted ourselves very good to the height of the doors.

5 - The evolution of technical systems has more possibilities than the evolution of living systems in the sense that a living system requires a physical precursor to evolve when a technical system only requires a conceptual precursor. (7)

6 - Many evolutions are made possible by the birth of a new technology (enabling technology) at the micro level (e.g. the integration of large number of transistors in an integrated circuit) It is therefore very useful to look INSIDE of the black box performing a given function to predict the evolution of the function or of the system.

7 - Finally, a good way to design a new product is to look forward and not too much backward (how it was done in the past). The value of TRIZ lies mainly in its heuristics to solve problems and less in the many observations and a-posteriori explanation of principles, trends etc.

Some comments about the modeling

There is a strong relation between the way we are looking at the evolution of systems or products and the model we have from these objects. We tend to look to the functions of what we observe and we try to find out the evolution of the structures carrying these functions or on the way to implement these functions (effect data-base). The general system has shown us that we should take into account also the finality and the environment of the system or the product. The functional approach imported in the TRIZ softwares from the Value Analysis theory has also disturbed the problem solving part of TRIZ in the sense that many TRIZ softwares are proposing "function modelers" that are sometimes not very adapted to the goal of solving a problem. In the beginning steps of ARIZ it is recommended to describe the problem in the deep details. The existing function modelers are not all fitted for that purpose. Some modelers like the one described in (8) are more adapted to describe organizations and the modelers described in (9) are good for dynamic modeling of systems.
We (engineers) all know very good modelers for time depending functions: the differential and integral calculus but we are not using them in TRIZ . Why ?.
That shows that TRIZ needs a "PROBLEM modeler" more than a "FUNCTION modeler". A simple problem modeler is the one used in IWB from Ideation, (10) because it has boxes allowing to model functions, events, criteria, intentions etc and arrows allowing to model causes, correlations, links etc. in a very easy manner.
The paradox of this modeler is that it has only few types of components but that the precision of the problem description comes from the precision that the modeler gives to what (s)he puts in these components (boxes and arrows)
The functional modeling has however a big advantage: it keeps us away from the way the functions are implemented (it fights our psychological inertia).

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