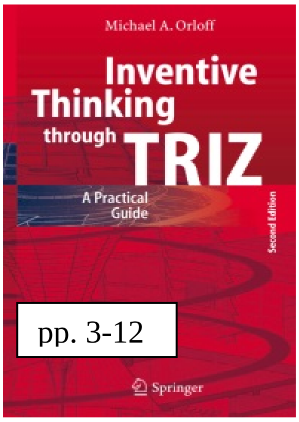

This person’s name was **Genrikh Saulovich Altshuller (1926-1998).** In the middle of the 20th century, he developed the „Teorija Reschenija Izobretatel'skich Zadač” that he then called TRIZ (Russian acronym). In English this is a „Theory of Inventive Problem Solving“. This is how he outlined new possibilities to learn inventive creativity and its practical application.

TRIZ has established itself more and more since the end of the 20th century. However, a complete textbook on the essential principles of classical TRIZ that everyone can understand has never been written until now. The book you are now reading is just such a textbook.

I hope that TRIZ will help you find the path to new possibilities and success!

2 Reinventing – the Key Concept for the Study of TRIZ

Among other things, this express study and self-taught study of TRIZ uses the following methodological procedure: Before you learn all of the necessary concepts and models, the practical functions of the theory will be demonstrated using simple examples as if you were already familiar with the essential principles of TRIZ.

These examples have been selected and are presented in such a way that they make a movement in thinking clear from the simple to the complex, from the external to the internal, from the concrete to the abstract, and from model to theory. In other words, this express study undertakes a kind of experiment with the objects that are essential factors in the theory. Students of TRIZ can then derive the key concepts of the theory from the experiments on their own.

The objects of classical TRIZ are inventions, technical systems, and their components. The essentials of the initial learning experiments are as follows:

1) Presentation of the key problem that was solved with a concrete invention;
2) Definition of the main procedure that was used to solve the problem with this invention.

The following methodological procedures will then be used later:

1) Generalization and classification of the models of the key problems and of the main procedures used to solve problems with inventing;
2) Presentation of laws for the creation of problems, prognosis, and the controlled and systematic solution of problems.

The process of inventing – this is the movement of thinking from „what already exists to what is coming[3]“. It is the construction of an intellectual bridge between what is and what is supposed to exist.

Every „bridge” is based on a certain theory. Clearly the „reliability“ of a bridge also depends heavily on the theory that provides the basis on which it is built. Classical brainstorming is an example: very few rules, essentially unlimited space to search, lots of enthusiasm and noise. Another example is classical TRIZ: systematic investigation of a task, controlled application of adequate procedures for a

[3] I am interpreting - but only directly in this context!! - a well-know expression and the title of a book by a Nobel Prize laureate, the Belgian bio-physicist Ilya Prigogine.

solution, and directed movement into the useful areas of especially successful solutions.

The basis of the teaching experiments in this study of TRIZ is a methodological procedure that I call „reinventing“.

Reinventing – is a demonstration of the process of inventing. It works as if the users already knew the principles and procedures for a solution to the problems that their inventions then address. Reinventing then functions later as a means to strengthen skills for investigating and solving problems after the essential principles of the theory have been mastered. Finally, quick reinventing can be extremely helpful when working with the analogies that are also offered for problem solving in our software (see section 21.3).

This methodological procedure stimulates associative thinking and ensures emotional acceptance and a positive perception of the theory. The student's intuition can then connect extant knowledge, skills, and experience with the key concepts of the theory on its own.

TRIZ is a qualitative theory, not a mathematical or quantitative one. The theory's formal ideas and concepts are like categories, patterns, and metaphors. The procedural methods to solve tasks - methods that consist of several steps - are called algorithms. This is also a metaphor, although it has been shown that this is a completely correct definition in the context of modern constructive mathematics.

When my colleagues reflect on TRIZ as a theory based on the above, they might suggest that it is a conceptual, phenomenological, and finally a psychological theory. In any case, the concepts of the theory reflect its axiomatic and structural principles in a more understandable, non-formal way, even if these concepts are not specifically described in scientific articles or monograms. This mode of description is the point here. The content used for qualitative models (metaphors) is also of interest. As opposed to other procedures, the models of TRIZ are constructive and can be reproduced and taught by its users.

In this textbook, we will avoid the use of formalized constructions, although we have to create and rely on just this kind of construction in our software. It is not our goal to construct formal principles for this theory. Instead, we want to model thinking qualitatively and apply practical models from this theory to real tasks. However, we will certainly not change the terminology of the theory, although we expect you to be just as critical and suspicious of this terminology as for example of words such as *assignment, departure data, solutions, result.* In most practical cases, we also don't need to define exactly which theoretical axioms and formal associations hidden in the background of these words. Intuitively we understand completely the qualitative essence and content of these words (that is - metaphors and images) with reference to certain concrete tasks.

But let's now examine the fundamental concepts of the theory.

According to its definition, reinventing is the following process (fig. 2.1).

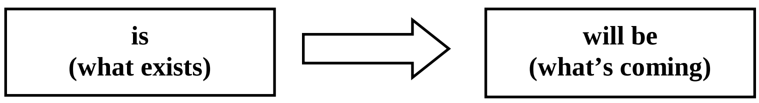

fig. 2.1. Movement of thinking from „what is” to „what's coming”

The arrow above shows thought processes - the *„flow of thought" and the „generation of ideas"* – in accordance with the theory's suggestions. Of course, reinventing in the sense of brainstorming reflects the process of brainstorming in solving tasks and assignments. TRIZ reinventing reflects the process of TRIZ in solving tasks and assignments.

How reliable do you think the following suggestions are from one of the versions of a „theory of brainstorming"**,** an example of which is shown in figure 2.2?

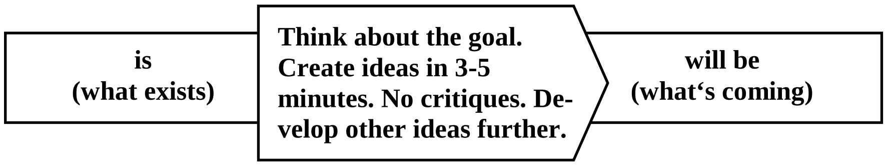

fig. 2.2. Scheme of reinventing based on brainstorming

Don't you also think that it almost seems in this scheme that the entire body of theory from military schools can be reduced to Caesar's[4] somewhat laconic method:

VENI, VIDI, VICI
I came, I saw, and I conquered.

Do you believe that this „method" teaches you to solve problems that require creativity?

What do you think about when you continue to read and see what the „stream of thought" of TRIZ is about (figure 2.3)?

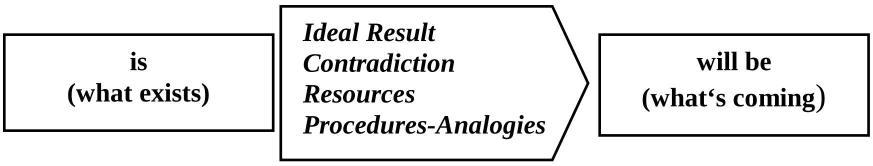

fig. 2.3. An example of reinventing based on TRIZ

Don't you associatively combine these concepts into a chain like the following one:

> ***Using available or newly transformed resources, procedures, and analogies, you remove the contradictions that prevent the achievement of the ideal result.***

I certainly thing that this chain looks like a more secure bridge for the movement „from what is – to what's coming"?! Usually I demonstrate the principle of reinventing by using a simple example, the „tip of a feather". This is an example of the development of the *working organ* of writing instruments that work with liquids.

[4] Gaius Julius Caesar (102 or 100 - 44 BC) - Roman statesman, military leader, and author

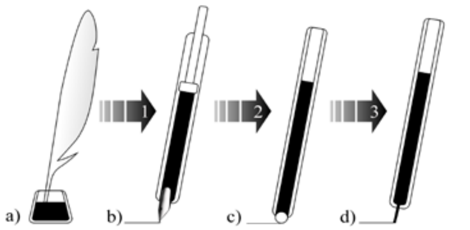

fig. 2.4. Evolution of ink writing tools: a) goose feather with ink; b) fountain pen; c) ball point pen; d) felt-tip pen

Of course, a goose feather with ink (figure 2.4a) was the most widely used means to record and transmit knowledge for ca. 2.5-3 thousand years (!) until the end of the 18th century, when the servant of the mayor of Aachen Janson devised a metal tip for the goose feather of his boss.

Then these tips called pens underwent a long construction-technical evolution.

However, the essence of writing with a pen did not change: the tip had to be dipped into ink and it could then write on paper until the ink on the pen ran out or dried out. The development of writing instruments that led to the first fountain pen (figure 2.4b) did not begin until the beginning of the 20th century (1). 50 years passed until the ball point pen spread rapidly (figure 2.4c). Then the mass use of felt-tip pens (figure 2.4d) started 25 years later. This is two times more quickly - and truly a rapid acceleration.

Let’s now use TRIZ reinventing to reconstruct the evolution of writing instruments with liquid.

Example 1. 1st transition: 3000 years from goose feather - to fountain pen. Goose feathers - even when they are equipped with a metal tip - have a major problem in that they don’t transmit ink evenly and smoothly onto paper. Either they dry out directly at the tip or they cause spots and puddles. The ink at the tip ran out quickly and the feather had to be accurately dipped into ink and carefully transferred to the paper in such a way that there were no drops.

The useful primary function of a pen as a work organ of the entire writing device is to leave an ink track on paper. Let’s call the pen an *instrument* (or even an *actor* or *inductor*, meaning the thing that initiates action). Then the track is the *product* of the pen (or even a *reactor* or *receptor*, meaning the thing that receives or takes in the action, or is produced by the inductor. The ideal track is smooth and has the necessary width. But, what happens in the pen? When there is too little ink on the pen, the track quickly becomes too thin and the pen has to be dipped in ink often. When there is too much ink on the pen, the track can get too wide or spots can occur. This is a clear contradiction between too „little“ and too „much“.

Let’s formulate the *ideal functional model:* there should be so much ink on the tip of the feather that it is possible to create a track of any length and there should also be no ink on the tip so that it cannot dry out or cause drops that then lead to spots.

The requirements presented in this kind of formulation are incompatible! But, this is reality!

There has to be as much ink available as possible during the creation of the track. We call this time when the feather completes its primary operation the *operational time*. At all other times until then, we don’t need any ink on the tip of the pen! Doesn't it seem to you that the contradiction has disappeared somewhere?! Somehow we have *solved the contradiction in time.*

It is now time to formulate the clearest version of the ideal functional model: ink moves *by itself* to the tip of the feather when the feather is supposed to create a track. There is no room at the tip of the pen to store a large amount of ink or for a mechanism to regulate the flow of ink. In other words, there are too few *spatial resources.*

Is there an empty space near the tip of the pen? Certainly there is, for example in the hollow space in the goose feather or in a special container that can be attached to the writing instrument. Then this container can be filled with ink and connected to the tip of the feather with a tube equipped „with a small valve".

We can also say that we have *solved the contradiction in space*: it is possible that there is no ink at the tip, but there is a lot of ink nearby! This idea for a solution can also be represented as a *solution to a structural contradiction*: there is a lot of ink in the *entire* fountain pen and in the entire technical system, even though there is no ink in a small *part* of the fountain pen other than during the operational time!

But, how should we approach the requirement that the ink may move *by itself* to the tip of the pen only when a track is to be created?

Let's formulate a concrete version of the ideal functional model: the pen regulates the amount of ink that moves to the tip *by itself*! This means we need a fountain pen with a locking device.

This is how it happened in reality: the tip of the pen was formed in such a way that it consists of two parts. There is a fine canal along the pen to the point where it is connected to one or more thin tubes coupled to a container that stores ink (figure 2.5).

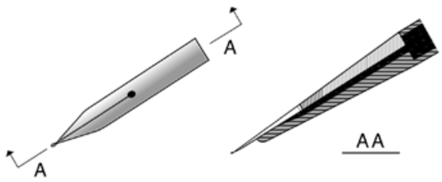

fig. 2.5. Essential construction of a pen

When the fountain pen is not in use, the canal is closed to prevent the movement of ink because both halves of the tip are very close to each other. When the pen is pressed onto paper, the parts of the tip spread and ink flows into the canal that ensues. That's it!

In short, we found a *ideal solution, an ideal final result* in the form of a tip with a locking mechanism. The energy needed for this work comes from the hand that presses on the fountain pen. When we start to write, pressure is transmitted to the tip - the locking mechanism opens. When there is no pressure, it closes!

Here we also see a *solution to a material contradiction*: *resources in construction and in the internal energy of the materials* of the pen (movable properties) and the *energy of an external source* (the resources of the hand) were used to ensure that the canal at the tip has two states (closed and open).

At first this explanation seems very long and not really clear. You are absolutely correct. There is also something else that is problematic. First, several new concepts have been introduced simultaneously. Second, there are many technical solutions to the problem of a fountain pen that can all be described with different version of reinventing that differ in the depth of their analysis. But, you will soon be able to automatically construct similar explanations on your own for real assignments, not just for teaching examples.

Example 2. 2nd transition: the ball point pen arrives 50 years after the fountain pen. It is easy to perceive that the slightest inconsistency in production or simply with time the ink can flow spontaneously and therefore can cause spots. The ink can flow by itself when the atmospheric pressure changes, especially when there‘s not much ink left. Air is not completely pressed out of the reservoir when the pen is filled with ink and there is therefore always a bit of air and a bit of pressure left. When the external pressure is lower than this remaining air pressure, pressure pushes the ink out of the fountain pen. This happened often in planes. The clothes and documents of the passengers suffered.

Let’s remember again the last ideal functional model that we just formulated for a fountain pen: ink moves *by itself* to the end of the pen only when it is supposed to produce a track.

We can now analyse the resources. Ink is a liquid like water that can therefore easily flow from the container to the pen. If the ink were thicker, it would not flow. But, this is a new contradiction: the ink *should be thicker* so that it doesn‘t flow too readily, but it should also *not be too thick* to flow easily through the work organ.

We will investigate this considerable contradiction in a *first strategic direction*: the use of „thickly flowing ink”. For 50 years, there seemed to be no way to solve this problem with normal ink.

The use of „thickly flowing ink” leads specifically to the idea of the installation of some kind of valves for the movement of ink. But, we could then no longer maintain that the ink moves to the end of the work organ *by itself*.

Here it would be logical to ask about a change in the work organ. We would need an energy source that enables us to transfer „thickly flowing ink“ or paste onto paper. The use of a valve would then clearly mean an interrupted operation and a partial transfer of paste. But, we need an uninterrupted and smooth transfer here.

We would need a few „tiny people“ who could take the paste from the reservoir and transfer it smoothly in small portions onto the paper. These „tiny people“ could then take past from the reservoir with their „shovels“, pass these on to each other towards the paper, and the pass their empty shovels in this kind of chain back to the reservoir, for example. This would cause a circular movement of full shovels from the reservoir to the paper and empty shovels from the paper to the reservoir. This is similar to the functional mode of typographical machines that use a roller to bring thickly flowing ink from one side of the roller to paper. Could we not build a writing instrument that functions like a miniature pressure machine? This is a very constructive idea!

We don’t know whether the inventors of the ball point pen, the Hungarian brothers Biro - the journalist Ladislas and the chemist Georg, thought this was in 1938. But they used this kind of printing ink as their first „thickly flowing ink“. But, they used a ball instead of a small roller (like a miniaturized printing roller). Clearly a roller would be too wide and we want to keep our thin lines. People could use a ball where the surface enabled the „tiny people" to do their work and transfer ink. The rotating ball puts the principle of an uninterrupted transfer of ink from reservoir to paper into praxis (figure 2.6). Friction with the surface of the paper causes the ball to rotate by itself! This means that the hand is once again the energy source that presses the tip of the pen with its ball onto the paper.

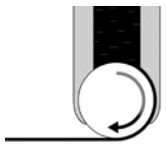

fig. 2.6. Basic construction of the work organ of a ball point pen

This is how the key idea was found by changing the *dominant resource - the material (the ink)*! This means the primary contradiction was solved *materially*. Then the inventors only need to develop a corresponding construction (*new structure*) for the transfer of paste onto paper. The contradiction was *solved materially and structurally* in a brilliant way!

Pilots in England were the first to use these new writing devices, even though it took ca. 10 years until the ball point pen finally arrived.

Example 3. 3rd transition: 25 years from the ball point pen – to the felt-tip pen. But the ball point pen was not yet perfect. The paste dried out quickly in the pen. It was sometimes squeezed out of the reservoir when the atmospheric pressure changed. This instrument caused spots, too. The hand of the writer tired quickly because more power was required than when writing with a fountain pen.

At this point, we can turn to the *second strategic direction* that was formulated for the reinvention of the ball point pen: the ink *must not flow thickly*, so that it flows freely through the work organ. *Let's intensify the contradiction*: the ink has to flow quickly and always be available at the tip of the work organ, but it must not flow out and cause spots!

It is initially clear that the ink reservoir needs to be open on both sides to balance the effects of the atmospheric pressure. By the way, this was also done with the ball point pen. But, let's continue with our investigation.

Second, the movement of ink from the reservoir to the tip (again like a fountain pen) of the work organ has to somehow be more difficult.

Analogies! Were there any *analogies in the history of writing instruments* or of similar drawing instruments?! Obviously there were! Examinations show that ink writing devices with a copper housing were used 3,300 years ago in Ancient Egypt. There was a sharpened lead tube in this housing that had an internal, fibrous reed part soaked in ink (figure 2.7).

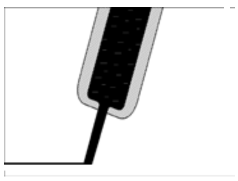

fig. 2.7. Basic construction of a felt-tip pen

The ink flowed slowly through the numerous fine capillaries of the read part to the sharpened tip of the lead tube. The ink flowed out when writing on papyrus and the subsequently hollow fibers closest to the tip could then be refilled with micro-doses of ink from the fiber capillaries!

Of course we can say today that the inventors of felt-tip pens in Japan in 1963 made use of the special *physical effect* of the movement of liquids in fine canals, i.e., the capillary effect!
But, we can also see that the reed writing tool in Ancient Egypt was certainly a predecessor of today's felt-tip pen!

The felt-tip pen offers another excellent solution to a extreme contradiction that we had already formulated, but it does this *in another strategic direction*! This solution was again found based on *material and structural resources* and with the use of a special *physical-technical effect*.

Finally we would like to turn to an effect that can be observed in the evolution of every technical system. When the developmental resources for a system of a certain type are finished, for example, for a writing instrument, then inventions from systems with an analogous purpose appear that either have a completely different functional principle or are systems that integrate extra functions with each other that were taken from two or more completely different systems.

Extra-example (beginning): the era of electronic writing instruments. Of course, we could start this section with an investigation of a few parallel developmental directions. We could start with those that are related to the development of typographic machines to produce books and newspapers or of machines that transfer drawings onto other materials. We could start with „writing" machines from mechanical and electrical systems to and including electro-static string and laser systems and with copying systems from copying paper and cameras to electrostatic toner copiers and laser systems.

But, we would like to investigate only one developmental direction for fixing hand-written or graphic information that is connected to the appearance of computers. Here we are concerned with entering information into a computer or with the transfer of text and drawings to certain lines of communication. For example, these markings can be initially made on paper and be transferred in real time during the writing process or using the words of a specialist. The task is to ensure that the lines of a representation are scanned, transformed into a digital format, saved, and transferred to a line of communication in a computer or other information sensor ***while*** this representation is being produced on paper.

But, this direction also includes a wealth of different principles based on surfaces with electro-magnetic, resistant, hollow, acoustic, infra-red, optical, laser, and combined principles to sense the local and global coordinates of the position of the writing instrument in relationship to the paper.

Fig. 2.8 shows some of the principles of scanning information that function with special electronic pens.

The electro-magnetic principle (fig. 2.8a) is based on the determination of rectangular X-Y coordinates using a system of conductors integrated into a writing tablet that sense an electro-magnetic impulse from the pen at the point where pen and conductor meet. The impulses are sent at a certain frequency, for example, 100 times per second. This means that any line can be represented as a group of points (coordinates). The frequency of scanning has to be sufficient to ensure a precise representation of a line even when writing quickly. Plus factors are simplicity and reliability as well as the possibility to turn the pages of the writing tablet. Minus factors are the necessity of a special pen and tablet where the paper cannot be moved elsewhere.

You'll find another variation of the use of electro-magnetic impulses in fig. 2.8b. The information sent by the pen is received by antennas that, for example, are installed on the ceiling in the corners of a room and form a global rectangular coordinate system. A plus factor is the chance to work at any place in the room. Minus factors are the relative complexity of the system, the use of special pens, the influence of large metallic objects, and paper that cannot be moved elsewhere.

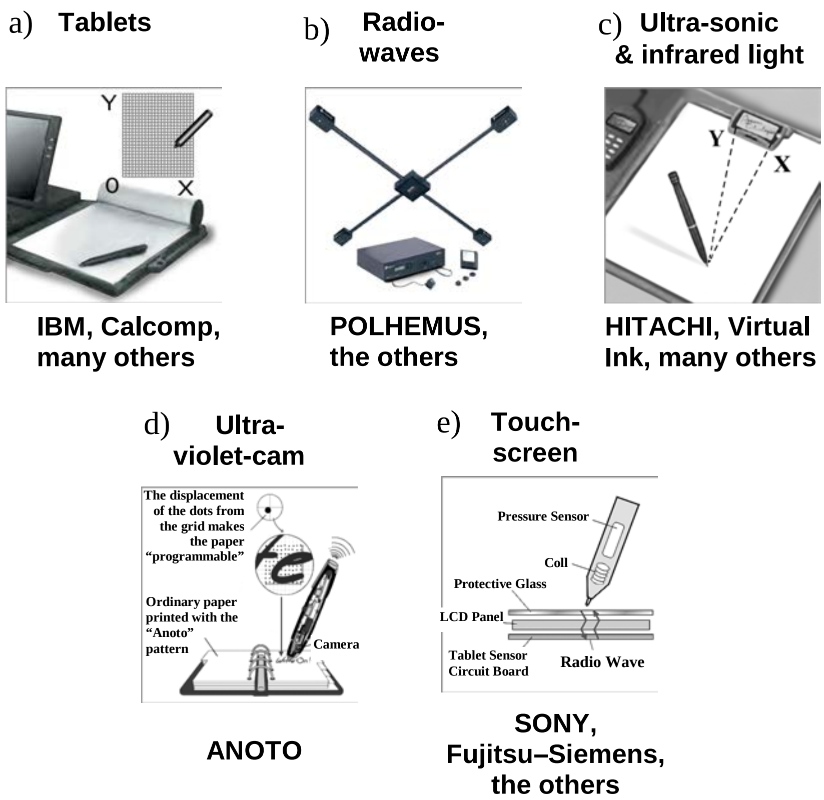

fig. 2.8. Traditional construction principles for electronic pens.

High frequency waves and/or infra-red rays are used to measure the oblique-angled X-Y coordinates as the distance from the working body of the pen to two or more sensors (fig. 2.8c). Positive factors are simplicity and reliability as well as the chance to turn the pages of the writing tablet. Negative factors are the necessity of using special pens, the necessity of attaching the sensors to the page, and paper that cannot be moved elsewhere.

A totally different principle is shown in the pen in fig. 2.8d. A compact video camera installed in the pen that functions in the ultra-violet range reads special combinations of points transferred to the paper in advance that clearly show the coordinates of the position of the working body on the paper. The positive factor is that almost all components are integrated into the pen. The negative factor is the use of special paper.

Principles for scanning coordinates based on conducting, hollow, high-frequency, or electro-magnetic tablets have been further developed in systems for drawing directly on the screens of televisions, computer monitors, and electronic blackboards in auditoriums (fig. 2.8e). Positive factors are simplicity and reliability. The negative side is that these devices are not meant to sense information on paper, although we could use the „thinking navigator“ 11 *inverse action* (see appendix 4 ***Specialized A-Navigators***) and fix the information on paper after writing by using a printer, for example.

We see that the „old“ pen has gained a new quality in the last thousand years of its development: the image can now be transferred to a computer. We have learned to enter hand-written information into a computer. This information can then be written on paper, on a blackboard, on the screen of a television, on a computer monitor, on credit cards or on the display of a mobile telephone, on special tablets that can be added to a keyboard and therefore make keyboards and mice superfluous. Dozens of principles for electronic pens were invented in the last 50 years! But, all of them had essentially the same problem: the necessity of a special pen.