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TRIZ to invent your future utilizing directed evolution methodology

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Abstract

This paper explains the concept of Directed Evolution. This concept is based on the s-curve, patterns of evolution, a structured work process and instruments. These elements are described in this article and examples of conducted work are given.

Keywords: TRIZ; Directed evolution; Ideation;

1. Overview

Genrich Altschuller, the father of TRIZ methodology discovered that systems don't go randomly, they grow based on patterns of evolution and lines of evolution as explained in this paper. Ideation International for the last twenty years has expanded the directed evolution applications where today they have 12 patterns of evolution and more than 460 lines of evolution. This development is being supported by books, technical papers, software tools and training.

A very noticeable article about Directed Evolution written by Dr. Yoni Mizrachi published in Future Magazine earlier this year [1] "Don't predict the future – invent it". To date, this powerful methodology can be applied to the evolution of:

- Organization;
- Technology;
- Products;
- Market;
- Intellectual Property;

Several projects have been completely to date demonstrating the value proposition of Directed Evolution methodology.

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2. Introduction to DE

Directed Evolution® (DE) is a technology targeting building a sustained competitive advantage through the effective management of the evolution of various artificial (man-made) systems by utilizing evolutionary patterns for technologies, markets, business, social systems, etc. The first set of patterns related to technological revolution was discovered within the Theory of Inventive Problem Solving (TRIZ) [4] that has been in development since the mid-1940s.

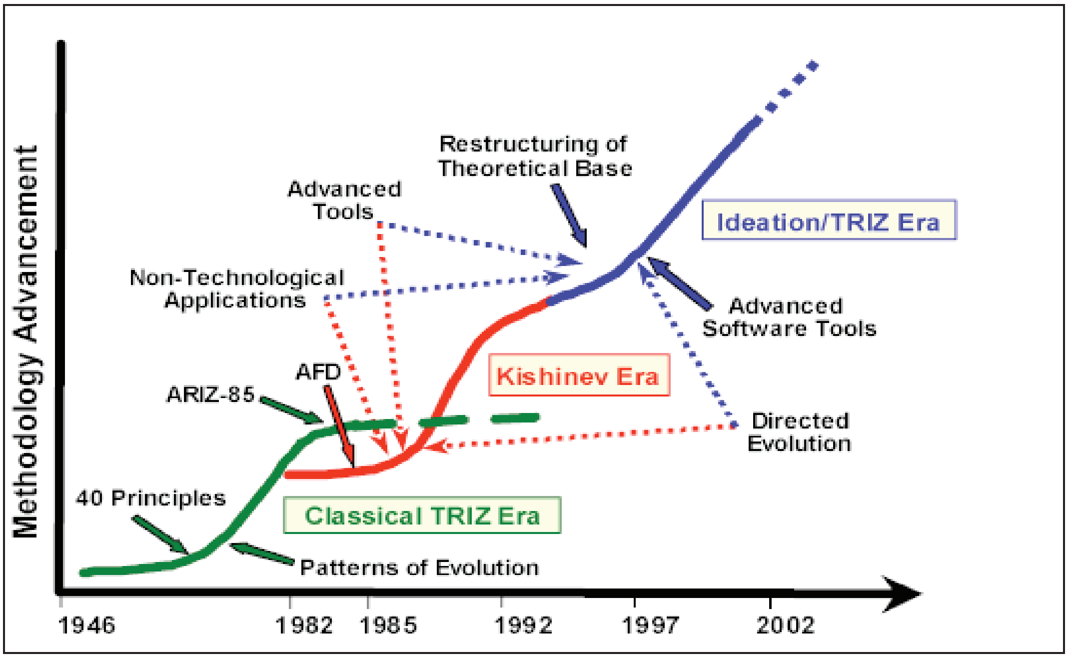

Figure 1: Evolution of TRIZ and I-TRIZ.

Directed Evolution is fundamentally different from its predecessor - Technological Forecasting [2,3] – an approach involving a set of non-related techniques such as trend extrapolation, morphological modeling, the Delphi method and others, mostly based on probabilistic modeling of future characteristics of various systems. The main deficiencies of Technological Forecasting approach are associated with the following inherent difficulties:

- Non-linear development of system's parameters making extrapolation of trends unreliable in long term.
- Delhi method (or survey) typically excludes outliers' opinions that in many cases might represent the ideas of the real visionaries, and limits its study to parameters of the given system without much consideration of the systems of higher rank.

As a result, although in the beginning much hope had been placed on the method mentioned above, most of the long term forecasts have not proven correct.

Unlike traditional forecasting, DE is based on the existence of pre-determined Patterns of Evolution discovered within the TRIZ methodology through the analysis of hundreds of thousands of innovations spanning different areas of technology. Utilization of patterns allows for identifying evolutionary directions (targets) together with proven standard ways how they could be realized (while traditional forecasting is insisting on limiting its outcome to directions leaving technical details to engineers and other professionals that could be quite puzzled how these targets could be achieved.

Taking the above into consideration, the main feature of Directed Evolution is its pro-active approach to the evolution of technology. Instead of making a prediction and waiting for it to be confirmed, the DE process uses numerous patterns and lines of evolution for the purpose of identifying possible scenarios, analyzing them, selecting the most promising ones, then planning the process of implementation.

The Directed Evolution technology was introduced in the early 1990s by Ideation International's research group under the leadership of Boris Zlotin and Alla Zusman [5]. However, their actual work on the subject goes back to early 1980s, when they made the first comparative studies of traditional technological forecasting and forecasting based on patterns of evolution related to immersion pumps. By mid 1990s, significant progress has been made, especially with the introduction of Directed Evolution® software, which incorporated powerful analytical tools and a substantial knowledge base.

3. Patterns of evolution

The *Patterns of Evolution* are described below (which includes those discovered by TRIZ originator Genrich Altshuller) together with additional patterns and over 400 additional Lines of Evolution discovered by Zlotin and Zusman and their research team.

3.1. Evolution along an S-curve

In the process of evolution, products, technologies, useful processes, organizations and other systems evolve along S-curve with specific definite stages.

Example of S-Curve in action:

In 1903 the Wright Brothers' first flight achieved an air speed close to 30 mph. Subsequently, the airplane evolved slowly through its first development stage. Human and financial resources were limited because airplanes were viewed as impractical curiosities. As a result, by 1913 airplane speed had increased to only 50 mph. In 1914 the situation changed. There were two reasons for this. The first was the start of the World War I, wherein airplanes were recognized by the military as being potentially useful. The second reason was that, by this time, improvements in airplane design had led to greater reliability. Financing and human resources were thus drawn to this new area of technology, resulting in new substantial improvements which, in turn, attracted more financial and human resources. As a result, in just four years (from 1914 to 1918), airplane speed doubled from 50 to 100 mph.

It was expected that this growth rate would continue – it declined, however. The reason for this was that the underlying concept of the Wright Brothers airplane (i.e. biplane with ropes, textiles, low aerodynamic quality, etc.) was practically exhausted. As a result, during the next 12-14 years, speed increased only to 140 mph. The next generation (representing a new Speed versus Time S-curve) began: monoplanes with metal frames having better aerodynamics, etc. Later, yet another generation – jet engines – replaced combustion engines, and so on.

3.2. Evolution towards increased ideality

Ideality is defined as a ratio of the sum of all useful functions and other benefits versus sum of all harmful functions and undesirable factors ("costs and pains") associated with useful operations and benefits.

Example of Increased Ideality:

A 100,000 kW turbo generator built in the early 1950s weighed about 200 tons. In the 1970s, a 500,000 kW turbo generator weighed about 400 tons – the power/weight ratio had increased by a factor of 2.4.

3.3. Non-uniform development of systems' elements

In the process of evolution, various system's elements evolve according to their own schedule, reaching their prime and/or maturity at different times resulting in conflicts (contradictions) that have to be removed (resolved) to ensure further overall system development.

Example of Non-Uniform Development of System Elements:

Early airplanes were limited by poor aerodynamics. Yet for many years, rather than improve the weakest link, engineers focused on increasing engine power with inadequate results.

3.4. Evolution towards increased dynamism and controllability

In the process of evolution, systems increase their ability to change and adjust to multiple conditions and/or customer requirements allowing functions to be performed with greater flexibility and variety.

Example of Evolution towards increased dynamism and controllability:

Evolution of the automotive transmission included the following steps (transitions): rigid (one speed) transmission – multispeed gearbox – gearbox with increased number of gear shifts – continuously variable automatic transmission.

3.5. Evolution towards integration/structuralization

Technological and non-technological systems tend to develop first toward increased complexity (i.e., increased quantity and quality of systems functions), and then toward simplification (where the same or better performance is provided by a less complex system).

Example of evolution towards integration/ structuralization:

Early on large animal-hunting hunters realized the advantage of carrying two rifles ready to fire (in case of misfiring). In time, hunters began binding two rifles together with a rope for convenience (integrated system). Eventually they realized that two stocks weren't needed; only two barrels. Thus, one stock was eliminated and a simplified system was designed – the two- barrel rifle appeared.

3.6. Evolution with matching/mismatching

In the process of evolution, systems' elements and parameters are matched or mismatched to improve performance or to compensate for undesired effects.

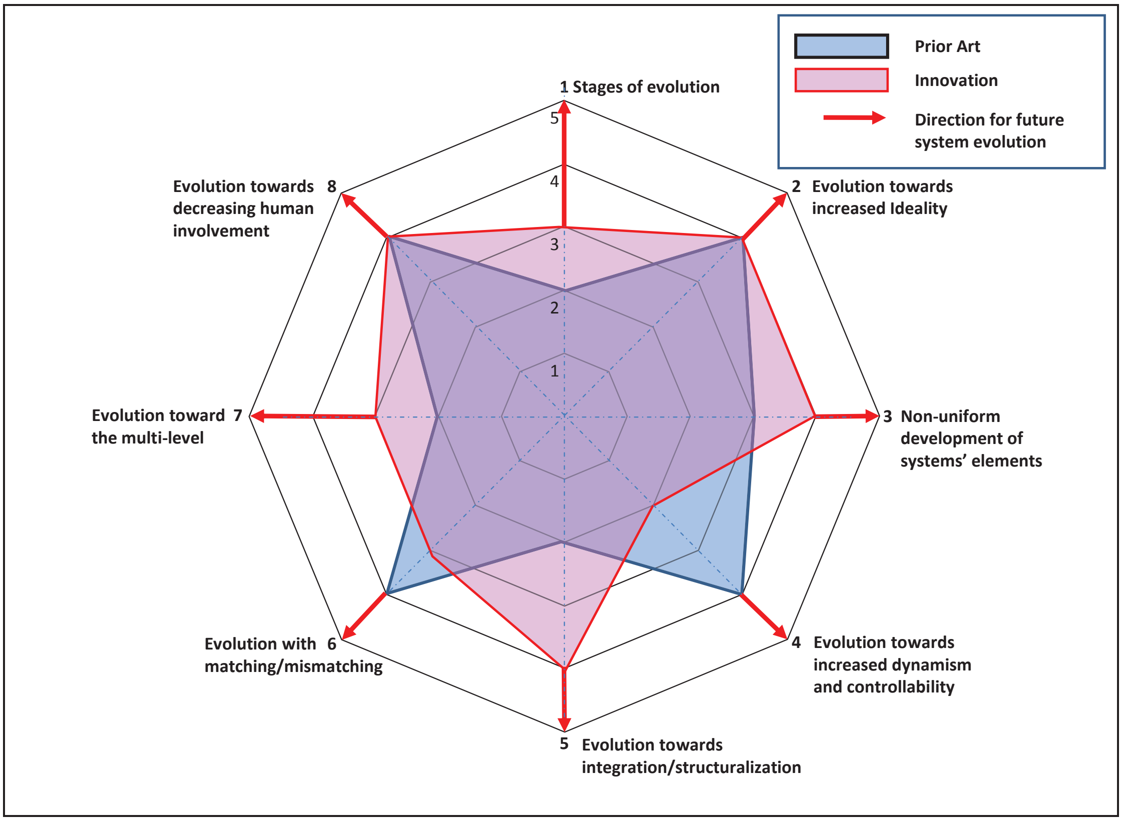

Figure 2: DE approach.

Example of evolution with matching/mismatching:

An automobile suspension system development included the following steps: Spring attached between wheels and body – Shock absorber and spring tuned to damp out impact forces – Active suspension system which automatically adjusts to road conditions.

3.7. Evolution toward the multi-level

In the process of evolution, systems tend to involve various structural levels and expanded use of interactions (known as fields in technological systems).

Example of evolution toward the multi-level:

Evolution of a cooking oven included the following steps: Large cast iron wood stove – Smaller stove fired by natural gas – Electrical stove – Microwave oven

3.8. Evolution toward decreasing human involvement

In the process of evolution, systems tend to increase the degree of automation (computerization) releasing people from performing tedious, strenuous and other functions that could be performed by machines and devices.

Example of evolution towards decreasing human involvement:

Evolution of clothes washing included the following steps:

Tub and washboard – Ringer washing machine – Figure Automatic washing machine – Automatic washing machine with automatic dispensing of bleach and fabric softener. According to this pattern, the next steps should include automatic dispensing of all necessary ingredients, including detergent, and, finally, fully-automated system, including replenishment of supplies. Patterns of evolution could be utilized for the evaluation of the level of the given technology advancement, comparison with its competitors and/or identifying next evolutionary steps (that is possessing prediction power), see Figure 1.

4. DE process

The DE process comprises the following steps:

- Analyzing the past evolution of the system of interest (whether technological, social, business, etc.) and revealing the main patterns in this evolution.
- Selecting the goals for further evolution using the DE knowledge base, which besides the requirements of the given industry incorporates information about typical needs of individuals, society, and related environments together with basic patterns of market evolution.
- Connecting the evolution of the given system with anticipated evolution of other related systems, the environment, and general technological evolution using the Ideation Bank of Evolutionary Alternatives™.[1]
- Defining how to pursue the selected directions and revealing evolutionary resources – i.e., the technologies, materials, products, processes, skills, knowledge, etc. that could be utilized in the development using the DE knowledge base, which includes patterns describing the evolution of technological and social systems.
- Identifying potential dangers and other undesired events, possible future problems, etc., both in the
- given system and its environment, using Anticipatory Failure Determination (AFD) and a special knowledge base of information about typical evolutionary dangers.

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[1] The Bank of Evolutionary Alternatives includes the results of completed and partially proven predictions for numerous important areas such as energy, food, informational technology, etc.

- Revealing and solving problems, resolving contradictions, overcoming limitations, etc. that can hinder the achievement of set goals using various instruments for problem solving including the most recent Ideation TRIZ methodology.
- Developing a logically sequenced evolutionary scenario for the given system, including a strategy for beating the competition.
- Providing reliable and effective protection of intellectual property and (if necessary) eliminating possible legal obstacles, including invalidation and designing around blocking patents.

Monitoring and continuing development of the process of implementing selected evolutionary scenario(s) of the given technological or business system, utilizing feedback for prompt adjustment.

5. DE instruments

The DE process involves the utilization of a number of tools embedded in the software, in particular:

- DE Questionnaire – a comprehensive set of questions and instructions for conducting a thorough diagnostic evaluation of the given system.
- Problem Formulator® – a software module utilizing elements of artificial intelligence for building and analyzing cause-effect diagrams describing the structure and functioning of the given system. This tool generates lists of specific control questions for system analysis and evaluation, and then creates a set of directions for evolving the system, for revealing and solving problems, revealing the root causes of undesired events, etc.
- A set of evolutionary patterns for artificial (man-made) systems,[2] including over 400 patterns and lines of technological evolution and over 100 patterns and lines of marketing and social evolution.[3]
- A comprehensive multi-layer system of approximately 1000 patterns of innovation (“operators”) for:
  - Solving technological problems.
  - Solving non-technological (business, marketing, logistics, etc.) problems.
  - Conducting Failure Analysis.
  - Conducting Failure Prediction.

6. Typical Results of a DE project

A comprehensive diagnostic analysis of the DE subject that includes:

- Documenting existing problems and contradictions – and revealing hidden ones – that hinder the effective evolution of the given system.
- Revealing the evolutionary potential and resources that allow for an increase in system ideality and provide new opportunities.
- Objectively evaluating the applicable intellectual property and developing suggestions for enhancing it and providing better protection.

Solving selected problems, generating new ideas and building alternative concepts for evolving the system, based on suggestions for selecting the most promising directions for effective strategic planning for the short-, mid -and long-term.

Predicting possible mistakes and undesired events associated with further evolving the system (for short-, mid- and long-term planning) and developing recommendations for:

- Timely prevention of potential mistakes and other undesired events.
- Early diagnostics of potential undesired events.

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[2] Unlike Classical TRIZ, which is limited to technological systems, these patterns also relate to the evolution of other systems including society, business, management, marketing, arts, medicine – practically any aspect of human life.

[3] See more about patterns of evolution in [7]

- Prompt actions capable of reducing harmful consequences from unexpected undesired events.
- Possibilities for capitalizing on undesired events such as economical crises, changes in government regulations, social changes, etc.

Providing recommendations for the effective growth of intellectual property and structuring an IP portfolio, including:

- Analyzing and "sprucing up" existing ideas and inventions, including valid and expired patents; evaluating and enhancing these ideas/inventions to ensure their best utilization.
- Adding new inventions to the IP portfolio.
- Ensuring effective protection of the IP portfolio or of its most valuable elements.

7. Selected DE projects

Automotive industry

- General prediction of the evolution of the automobile and its subsystems (brakes, doors, cables, etc.) – ongoing project conducted by Ideation research group.
- Evolution of ethanol based energy production and fuel for automobile.
- Evolution of vehicle interior, including smart automobile.
- Evolution of vehicle safety and security.

Chemical industry

- Waste processing.
- Future of micro-capsulation.
- Hydrogen fuel cells.
- New catalyst for polyolefin polymerization without heavy metals.
- New generation of chemical processing plant.
- New application for special plastics.

Other

- New evolutionary concept for endoscopic instruments (surgical instrumentation).
- Evolution of consumer products.
- Lifting mechanisms.
- New ideas for baking mixes.
- Evolution of packaging.
- Evolution of shoes.
- Prospects of globalization.
- General aspects of security.
- Evolution of timber industry.

8. Example: Evolution of washer machine detergents

In 1998, Ideation was conducting DE project on production of washer machine detergents. The purpose of the project was to analyze the evolution of detergents and come up with ideas for the next generation of detergents. This work has resulted in about 30 new concepts all related to the detergents' chemistry.

Analysis of the existing technology has shown the following limiting factors:

- Detergent is consumed during the washing cycle; to avoid its depletion in the cycle's end, an excessive amount of detergent is placed in the tank in the beginning resulting in excessive foaming.
- Excessive foaming reduced quality of washing, excess of detergent increases cost and pollution of the environment.

To resolve the issues above, continuous introduction of detergent during the washing cycle has been suggested. This concept was further developed resulting in suggesting detergent cartridges. Additional advantage could be reduced impact on the user – no detergent dust of vapor in the air, no contact with hands, etc.

Introduction of the detergent cartridges allowed for a significant changes to the marketing approach – apply the “razor and blade” or “printer and cartridge” business model; according to this model, the main equipment is sold for a lower price while the main profit is obtained via selling razors or cartridges.

A standard DE project always includes studies in evolution of the given system’s environment and super-systems including the given system as a part; special attention is paid to the other related and enabling systems that are undergoing fast growth or even marketing tornado. The simple rule here is to try to ride this tornado.

In 1998, the fastest growing technology was Internet; newly introduced America Online and Netscape Navigator allowed millions to connect and explore, so it was logical to consider how the washing machine business could benefit from this new booming technology. The result of this consideration was an idea to connect washing machines to Internet. When a cartridge is becoming low in detergent (30-20% of initial capacity), the washer automatically orders the replacement. The system is convenient for the customer and is good for the producer as it is increasing direct sales and saving on eliminating a middle man. This saving could be shared with the customers via reducing the prices which in turn can increase the company market share.

The next step is co-evolution of technology and business model. The cartridge doesn’t have to be inside the machine – it could be fixed outside of the house (similar to water meters). Then cartridge replacement could be done by a service person allowing a favorable transition from selling a commodity to becoming a service provider.

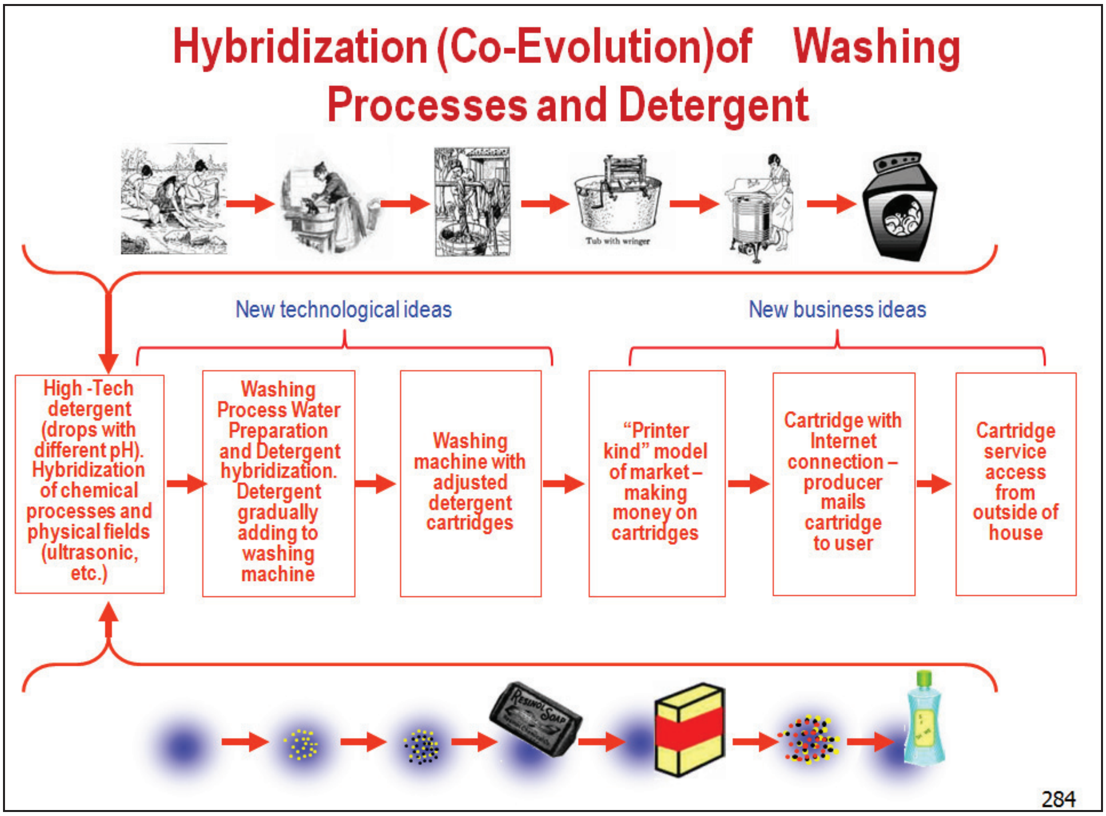

Figure 3: Example of hybridization.

The latter has an additional far reaching advantage. A typical commodity is a curse for a producer – a mass product with no patent protection very quickly becomes low margin goods because of unrestricted competition. In this case, the main competitive strategy is lowering the cost of production forcing companies to move it to the countries with low cost labor resulting in increasing manufacturing jobs loss. Transition to services saves/creates local jobs (picture below).

9. Summary

In today economical situations and global cares organizations are struggling in having a system for continues innovation that will allow to have a consistency in Research and Development that will result in having winning products that would lead the company to become technological and market leader and sustain competitive advantage. Directed Evolution methodology is the only available structured method that can provide an accurate step-by-step process on how to invent future technology, product to leap frog the competition.

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References

[1] Mizrachi, Y.: Don't predict the future invent it. World Futures, 66: 26-52, 2010, ISSN 0260-4027
[2] Jantsch, E. Technological Forecasting in Perspective (London, 1972).
[3] Martino, J. P. Technological Forecasting for Decision Making, 2nd edition (North-Holland, 1983).
[4] Altshuller, G. Creativity as an Exact Science. Gordon and Breach, Science Publishers, Inc., 1984.
[5] Zlotin, B. and Zusman, A. Patterns of Evolution: Recent findings on structure and origin. Altshuller"s TRIZ Institute Conference TRIZCON 2006. Milwaukee, April 29-May 2, 2006.
[6] TRIZ in Progress. Transactions of the Ideation research Group. Ideation International Inc., 1999.
[7] Zlotin, B. and Zusman, A. Directed Evolution: Philosophy, Theory and Practice. Ideation International Inc., 2001.