# Ele-field Analysis:

# Development of Su-field and Function Analysis.

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Key words: ele-field, su-field, ele-field analysis, function analysis, function-and-field analysis, standards of inventive problem solving, TRIZ, Evolutionary system studies.

**Problem statement.**

In 1973 G.S. Altshuller and his co-authors introduced the notion of Su-Field and created the foundation for su-Field analysis and developed a system of standards for solving inventive problems. [2,3]. Since 1987 the author of the present work performs research [6], directed at the development of TRIZ tools for further using them in non-engineering fields: in social systems, business, marketing, art, scientific research, etc. Recently this trend took the form of an independent field of research called “Evolutionary system studies”. Thus, the first task set in this work consisted in making it possible to use the su-Field analysis for non-engineering (material and non-material) systems. It is necessary to generate a kind of generalized system-based language for describing the models of inventive problems and their solutions.

The second task of the present research was associated with a number of disadvantages and internal contradictions, which exist in su-field analysis and which don’t allow to directly use the su-field analysis as a generalized language of modeling the evolution of systems.

In order to solve these problems, the notion of ele-field (elements and fields, uniting them) was introduced [13, 16] and the tools of ele-field analysis were developed. At the same time certain terms used in ele-field analysis were specified and introduced: system, field, space, feature, parameter, object, component, function, ele-field, su-field and other terms. It would be useful to get acquainted with the description of these terms (which are given at the end of the article) prior to reading this article, in order to avoid erroneous treatment of them in the course of reading the present work.

Introduction and refinement of the notions, associated with su-field analysis is an attempt to describe the tools for creation and varying the systems in a more distinct and less contradictory way. It appeared to be more complicated than we would like it to be. Of course, it would be much simpler to stay within the boundaries of such elementary notions as the ancient notions of fire, earth, water, air. However, the world appeared to be more complicated than these simple ideas. Centuries were required for the mankind to get used, for example, to such an idea, that water has been created based on two gasses. The same kind of "delirium" is generated as a result of describing systems. For example, we shall show that some object could be both an element and a field of interaction, depending upon in what system we are analyzing it. We will try to consider the issues of describing ele-fields as a generalized common language intended for describing the evolution of systems – both material and non-material.

**Ele-field as an Evolution of Su-fields.**

The elementary model of the system could be presented in the form of two elements, which are interconnected by the field of interaction (ele-field). In Fig. 1we see the model of an internal ele-field, which has the features of an element. Fig. 2 presents  the model of an external ele-field, which has the features of a field.

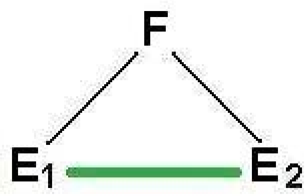


Fig. 1. Internal Ele-field (with the features of element).

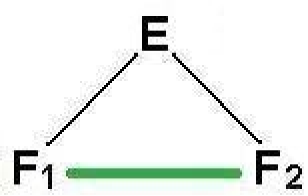


Fig.. 2. External Ele-field (with the features of field).

In spite of outward similarity, the notion of ele-field strongly differs from the notion of su-field. The first distinctive feature is that in a su-field the substance can change another substance directly and the substance can change the field without using another field. Such thing is impossible in an ele-field. For example, in an internal ele-field the direct interconnection between the elements models the function (useful or harmful) or a certain requirement and, respectively, is associated with a supersystem, for which this function or requirement are necessary. The interconnection between the elements through the field is that very feature of the elements (no less than two of them), due to which this function is performed.

***Examples.*** Ele-fields in biology: symbiosis of clown fish and actinia, pride of lions, a hoard of baboons, any ecosystem. Here are examples of ele-fields in social systems: family, tribe, company, non-profitable organizations. Ele-fields in science: Vieta theorem (connection of the polynome roots with its coefficients), the Malthus law, which connects the growth of population with food resources, illnesses and social cataclysms. In an ele-field not only certain connection between elements is maintained, but also it is described, what this connection should be used for (some useful or harmful function can be performed). For example, the theorem of triangles area could be used for identifying, which of the triangles is larger.

The second distinction of ele-field is as follows: in an internal ele-field the field is interconnected with two elements concurrently and cannot be connected only with one of them, as it is allowed in su-field structures. In this case the field of interaction should be homogeneous: it should interact with one element according to the same parameter as with the other element. The field itself cannot transform one parameter into another without an additional ele-field.

The third distinctive feature is that the fields and the elements of ele-field could be material or non-material components of the system.

The fourth distinctive feature is that the ele-field allows the two-fold analysis of element-and-field components.

***For example***, the flow of fluid (gas or particles) could be looked upon both as a substance (element), and as a field with all distributions of velocities, pressure, temperature, etc., which correspond to the field. For example, in different types of flow meters the flow is sometimes used as an element and sometimes as a field. In programming the ordinary branch statement “IF” could be looked upon both as a field of interaction of fairly different elements under different conditions and as an element, since it could contain different commands and expressions.

Ele-field models enable to describe the models of problem situations (problems) and the variants of ele-field structure evolution.

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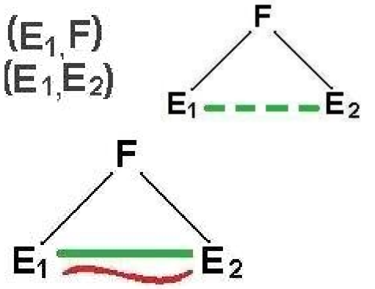
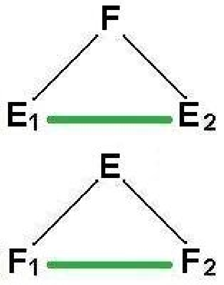
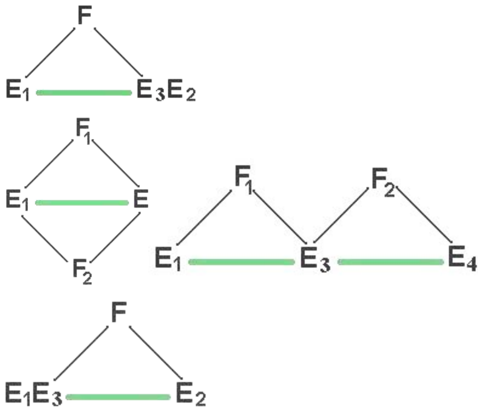
|  |  |  |
| Description of models of problem situations: no bonds, there is an insufficient or harmful bond | Ele-field: internal (with two elements) and external (with two fields) | Increase of ele-field efficiency: complex, double and chain ele-fields |

Table 1. Ele-fields: models of problems, models of solving and models of their evolution.

Ele-field modeling enables to apply the generalized system approach to solving inventive problems, which forms the foundation of TRIZ not only in engineering, but also in non-technical fields: in marketing, management, in scientific systems, in law systems, etc.

It is possible to single out the simplest ele-fields: ele-fields, which either cannot be subdivided into smaller ones, or it will lead to the variation of the field of interaction: for example, from social-and-cultural to ecological, from ecological to biological, from biological to biochemical, from biochemical to chemical, from chemical to physical.

The general logics of development of internal ele-field structures and the logics of universal system of standards could be presented in the form of the following chains of transformations (Fig.3):

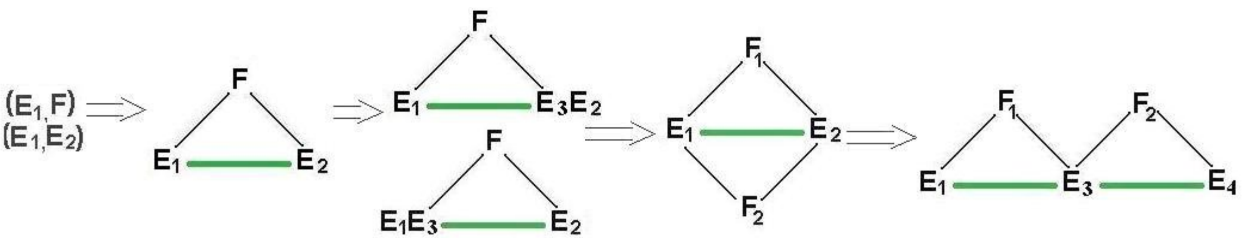



Fig. 3. General logics of development of structures of internal ele-field

With external ele-fields the following chain of transformation of Ele-field structures could be presented (Fig. 4).

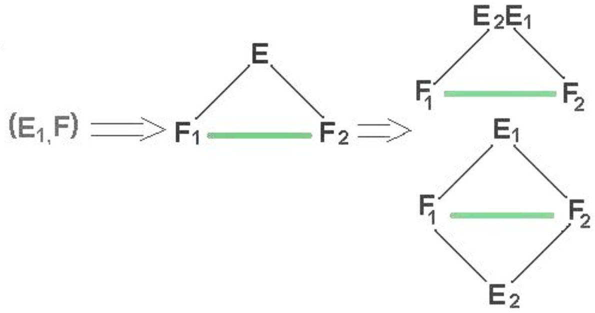



Fig. 4. Logics of external ele-field evolution

Technological processes are described through internal ele-field, in which $E_2$ is a transformed element $E_1$. For example, stamping a metal component or training a person, etc. The transformation of $E_1$ into $E'_1$ takes place in time.

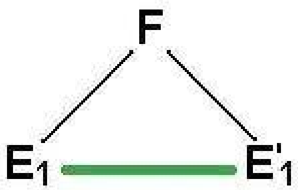



Fig. 5. Ele-field of element transformation

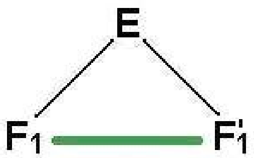



Fig. 6. Ele-field of field transformation

The transformation of a field is described through external ele-field, in which $F_2$ is a transformed $F_1$. For example, the variation of the spectrum of a ray, passing through the optical lens, or the well-known economics formula money ($F_1$) – goods (E) – money ($F'_1$), or encoding the information flow with this or that algorithm, etc.

**Ele-field as a model of a function. Ele-field-related FOS.**

Ele-field is a development of the function model. The following function model is used in TRIZ:

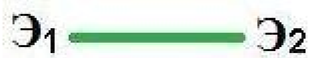



Fig 7. Function model. E1 is a subject of function (tool), while E2 is an object of function (product).

The line, which connects them is the designation of the function subject, which is directed at the variation of the function object. The action could be designated by the verb of action or be characterized by the variation of the function object parameter. It is possible to single out five actions over the function object parameter: stabilization – variation of a parameter, increase – decrease of a parameter, measuring of a parameter. There are situations, in which it is difficult to single out the direction of the action, the elements interact, influence each other, and perform the function of an object and subject simultaneously. For example, two magnets attract one another, performing the function of uniting two components into one whole object.

One more part of the function model are constraints, which are imposed upon the function performance.

Ele-field is the same function model, however, with an addition of a field (fields) of interaction, with which this function is performed. One and the same function could be implemented through different fields of interaction and different Ele-field structures. Ele-field answers three questions: Who or What? What does he (she, it) do? How does he (she, it) do it and what is the way of interacting? The model of the ele-field function could be described according to the following pattern:

- Element, subject of function
- How (and using what field) is the action performed
- Action, verb or direction, variation of the object parameter
- Element, object of function.

This wording could include refinements and constraints for each of the components of ele-field-function.

For example, a Hammer made of stone – Mechanically – Deforms (reshapes, changes the shape of) – a glass made of crystal.

In order to prepare the generalized model of the function, it is necessary to take the generalized description of the subject, object and action. It is possible to describe the generalized action in a most accurate way through describing the variation of a parameter of the function object.

Respectively, the generalized ele-field is described via generalized function, generalized field of interaction and constraints.

Since the function could be harmful, ele-field could be harmful as well.

The existence of common features between ele-field and function model enables to transfer the elements of function analysis into ele-field analysis. We shall call this kind of analysis function-field analysis of the systems.

In the same way it is possible to transfer to ele-field analysis function – oriented search (FOS) and inverse (reverse) FOS: ele-field FOS and inverse Ele-field FOS.

With ele-field FOS we can know the following: generalized object of function, generalized action, constraints and characteristics of interaction field. It is required to find the subject of the function.

> ***For example***, if we look for a generalized function for uniting the substances (increase the integrity of the objects or their coherence), we shall make use of such verbs as to vulcanize, to hammer, to fasten, to implant, etc. However, if we restrict this function only by the electric field of interaction, we shall need other verbs of action: to adsorb, to anode, to commute, to coat with chromium.
>
> Another variant of ele-field FOS takes the following form: all components of ele-field are known, but the field of interaction. For example, it is necessary to develop the design of a pulse wave sensor in the form of a wrist bracelet with a removable "head" of the microprocessor. The pulse wave signal should be transmitted to the removable microprocessor without terminals in order to provide for sealing and convenience of using the device. Thus, we obtain an incomplete ele-field model:
>
> The bracelet – transfers the pulse wave – head of the microprocessor.
>
> In generalized form:
>
> The ring on the wrist (subject) – transfers weak mechanical oscillations (action) – into a replaceable electric device (object).
>
> In this ele-field model all components are known, except the field of interaction, which provides for transmission of oscillations. The requirement to this field is known: it should transmit a very weak signal of oscillations without electric connections.

An analog for this Ele-field FOS could be flow meters of fluid, first of all moveable and portable ones, which transfer the flow data to external electric device. In our case it is possible to single out only three suitable fields of interaction: electric field, mechanical field, field of electromagnetic induction. If we take into account that no electric wires could be used for electric field in our case, while the capacitance connection require a very accurate installation of the removable part of the device, only two variants remain: either to use mechanic field or the field of electromagnetic induction.

Using the example with an ele-field of a pulse wave sensor it is possible to demonstrate, how it is possible to find and to select the required chains of physical effects (using the chains of ele-field structures) prior to taking a decision concerning what design of the device is going to be chosen. Based on the given example, we could say that in order to transmit the signal from the bracelet to removable device, we can use either a mechanical field, or the field of electromagnetic induction. In this case we know that the source field of the pulse wave is mechanical, while the final field, which is transmitted to microprocessor is electrical. Therefore, at least two chains of transformations are possible.

The first of them is as follows:

The source mechanical field of pulse wave is the transformation of it into an electromagnetic field in a bracelet – transformation into electromechanic induction and the transfer of a signal to the removable part of the device – obtainment of the electric signal in the removable part of the device.

Here is the second variant of transformations:

Mechanical field of pulse wave – transmission of mechanical force into the removable part of the device – transformation of these forces into an electric signal in the removable part of the device.

The first variant involves two transformations, while the second one implies only two of them. Taking into account the low level of source signal and the losses, which are inevitable at each transformation, the second variant seems to be more promising: the oscillations from the pulse wave should in a certain manner be mechanically transferred to the removable part of the device and only there be transformed into an electric signal, for example, using a tension gauge. Such solution was found and successfully tested.

Therefore, the analysis of the necessary ele-field chains enables to select the most efficient variant of the possible operation principle and to choose a necessary chain of physical effects required for solving the placed problem.

Inverse ele-field-based FOS implies a reverse situation: subject of the function, field of interaction and the action are known, it is necessary to find the new object of the function. For example, a portable device for estimation of the glucose level in human blood is known, which operates based on the monitoring of the impedance of the human tissue. This device could be used for estimation of humidity, degree of ripeness of food products, etc. Any other product or object could be controlled instead of the human tissue.

**Ele-field subsystems and supersystems.**

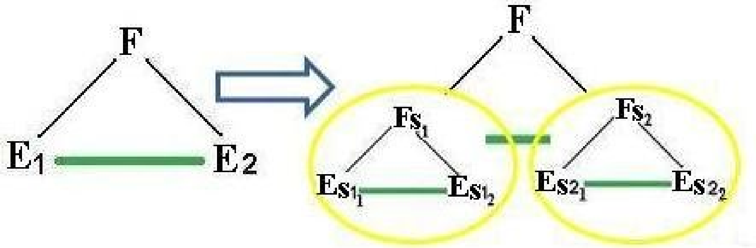



Fig. 8. Sub-ele-fields of internal ele-field.

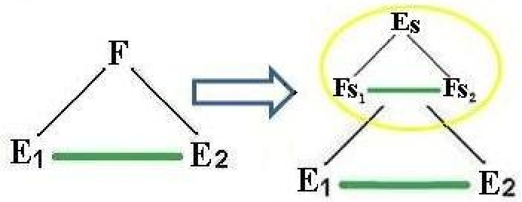



Fig. 9. Sub-ele-field of external ele-field

Elements and fields of interaction of ele-field can have an internal structure: the element can be presented by internal ele-field, while the field – by external ele-field. These structures (sub-ele-fields) are not reduced to doubled, chain or some other kind of ele-fields. This is a sub-system ele-field, in which sub-element Ef1 can differ from E1 in the same way as, for example, hydrogen differs from water or paint on the canvas differs from the artistic perception of the picture, while sub-field $F_f$. can differ from the field F in the same way, as, for example, the physical field of interaction differs from chemical bonds, while acoustic, color and tactile components differ from their total psychological action upon the human. The fields can have the same structure as the elements. For example, such fields of interaction, which are usual for TRIZ, as mechanical, acoustic, light field are in this or that way associated with fundamental fields: electromagnetic, gravitational, of weak and strong interaction. Social fields of interaction, economic and financial as well as interactions in programming – they all have a certain structure, the subsystems, of which they consist, of which they are composed.

In this case the fields of interaction of an ele-field can interact not with a certain sub-element, but with the entire sub-ele-field as a whole. For example, in a symbiosis of clown fish and actinia the interaction takes place at the level of an entire organism, both of the clown fish and actinia, not at the level of the fish fin and the tentacles of actinia. However, such interactions are also possible.

The internal structure of an ele-field could be used as a resource in inventive problem solving. For example, in electrolysis of water it is possible to use the hydrogen, which is released thereby, while in the techniques of NLP (neurolinguistic programming) it is possible to use the leading channel of the perception of the human for solving psychological problems.

The same situation exists around the transition from the internal ele-field to supersystem element $E^{s1}$ or from the external ele-field – to supersystem field $F^{F}$. The transition from ele-field to supersystem ele-field is also a resource for solving the problems of system evolution. For example, the sustainability of life of an animal or a plant could appear to be much higher in symbiosis with another animal or plant.

**Ele-fields and multitudes of elements: common features and differences.**

The systems are characterized by fairly difficult, sometimes rather entangled features, which make the system analysis rather complicated. It would be much simpler to perform the analysis, if a part of operations could be performed using a computer. To achieve this, it is desirable to utterly formalize the creation and transformation of ele-field structures. One of the possible directions of this work is the use of theory of multitudes and its apparatus for constructing and transforming the ele-fields, identification of their features. Let us try to single out, what the common features of multitudes and Ele-fields are and what differences exist between them.

MULTITUDE is one of the basic notions of modern mathematics, "a spontaneous assembly of defined and distinguishable objects? Which are mentally united into a single whole" (Georg Kantor).

What are the features, which can be called common for a multitude and ele-field (system):

- both multitudes and ele-fields have separate elements (objects, components), of which they consist;

- both in case with a multitude and in case with an ele-field the elements are united by certain bonds and features into a single whole;

- both in a multitude and in an ele-field the functions can exist and can be absent;

- multitude can consist of such elements which themselves are other multitudes, like ele-fields can consist of sub-ele-fields;

- multitude consist of indivisible elements, in the same way as the simplest ele-field does not consist of sub-ele-fields.

Here are the differences between multitudes and ele-fields (systems):

- an ele-field has one or several specific components – fields of interaction of elements;

- adding new elements to the multitude does not lead to the generation of new fields of interaction and to new features, which these elements initially did not possess, as it is the case with ele-field;

- there are assemblies of elements, based on which it is easy to create a multitude, however, it is impossible to create a complete Ele-field. For example, a multitude of material and non-material objects, the name of which begins with the letter "A";

- in multitudes the function is defined as an association of elements of one multitudes with the elements of other multitude, while in an ele-field the function is defined by the supersystem and is implemented via the association between the elements of one  ele-field;

- multitude does not depend upon the order, in which the elements are arranged, while the features of depend upon the arrangement of its elements with respect one to another;

Comparison of multitudes and ele-fields allows to treat these notions as close one to another:

- from the standpoint of theory of multitudes similar elements in an ele-field in reality, strictly speaking, are different, since they are different at least by the place of their location in space;

- if there are empty, countable and uncountable, endless, indistinct multitudes, as well as multitudes of different capacity and the operations of addition, subtraction, multiplication and division performed over these multitudes, it could be supposed that similar notion and operations could be introduced also for ele-fields.

The search for opportunities of creating a mathematical apparatus for describing ele-fields and transforming them should be continued.

**Double nature of fields and elements in ele-field analysis.**

The very fact that any element, which cannot be called simplest, could be looked upon as an internal ele-field, which has the interaction fields, while any field, which cannot be called simplest, could be looked upon as an external Ele-field, which has an element, already shows that any object (whether material or non-material) could be looked upon both as an element and as a field. In the simplest ele-fields the elements and the fields could have no features, which enabled to distinguish them (quarks, for example).

Very few people would be surprised by the fact that one and the same element could be the function subject in one function, and the function object in another function.

> ***For example***, when a hammer is manufactured on a milling machine – the head of the hammer is the function object. When a nail is hammered by a hammer, this hammer is a function subject. When using a small hammer as a tool, which transmits the strike of the heavy hammer exactly into a required place of the product, the small hammer can be looked upon as a field of mechanical action between the big hammer and the product.
>
> Another example is an electric transmission line. During the repair or when there is a protection, it could be looked upon as a product. In an energy system it can be looked upon as a tool. The electric transmission line possesses all kinds of a field of interaction between the source of electric energy and an energy user.

## Ele-field and parametrical analysis.

A tendency to enhancing formalization, unambiguity of ele-field models and the possibility of transition from ele-field models to physical effects made it vital to introduce the parametrical description of ele-field components.

We already gave an example of parametrical description in a model of function: the action performed upon an object could be presented as a parameter of function object and the directions for varying it (stabilization – variations, increase – decrease, measuring). The parameters could be physical, chemical, biological, technical (engineering), economic, social, psychological, artistic, etc. Parameters of interaction field are associated with the features of the elements, while the parameters of function – with the requirements of supersystems.

The element could also be presented as a set of parameters and association between the parameters of this element between themselves. For example, in case with a photographic camera it could be the divisibility of optical and electronic enlargement, geometric dimensions, weight, characteristics of the matrix, screen size, formats of the pictures, memory type and other numerous parameters.

The field can also be presented as a set of parameters. For example, electromagnetic field could be looked upon as a set of different parameters: field intensity, degree of polarization, rate of spreading, magnetic induction, etc.

To specific parameters relate the time and parameters of space. The space predetermines the coordinates of this or that element. Space is inseparable from the elements and the elements cannot exist beyond the boundaries of this or that space. In order to characterize space, like in case with any other feature, at least two elements are required.

On the contrary, the set of field parameters, should not include one particular coordinate of space. The field characteristic should include the length and a multitude of coordinates (at least two). Coordinates in space can be continuous (physical space) or discrete (legislation field, web-site addresses, etc.).

The element could be characterized by one point in space only, while the field should have no less than two points in space. Only one element and a multitude of interaction fields can be located in one point of space. The interaction fields connect the variation of parameters of one element with the variation of parameters of another element.

**Hierarchy and evolution of interaction fields in ele-fields.**

The fields of interaction are characterized by hierarchical structure: from simpler fields of interaction to more complicated. We assume that the first interaction fields in the evolution of the Universe are physical fields (and correspondingly – physical elements-substances). The next level of evolution are chemical interactions. Later on, the generation of life is accompanied by the formation of biological substance and the biological fields of interaction, including social-and-biological interaction – behavior of animals, generation of ecological and other systems. Later on, social and cultural systems are formed, including engineering systems.

The higher the hierarchical level of the systems, the greater the variety of interaction fields in them and the wider the scope of possibilities for one system to capture another one. The preceding system level creates resources for the generation of the subsequent system level.

From the standpoint of system capture various types of systems interaction could be singled out:

1. Reaction of capture (seizure) with the absorption (annexation) of the object of capture.

2. Reaction of capture involving exchange (including symbiosis).

3. Reaction of capture via displacement (substitution) based on the struggle for a limiting factor of the evolution.

4. Reaction of decomposition (internal capture).

5. Fruitful capture, synthesis of a new system from elements.

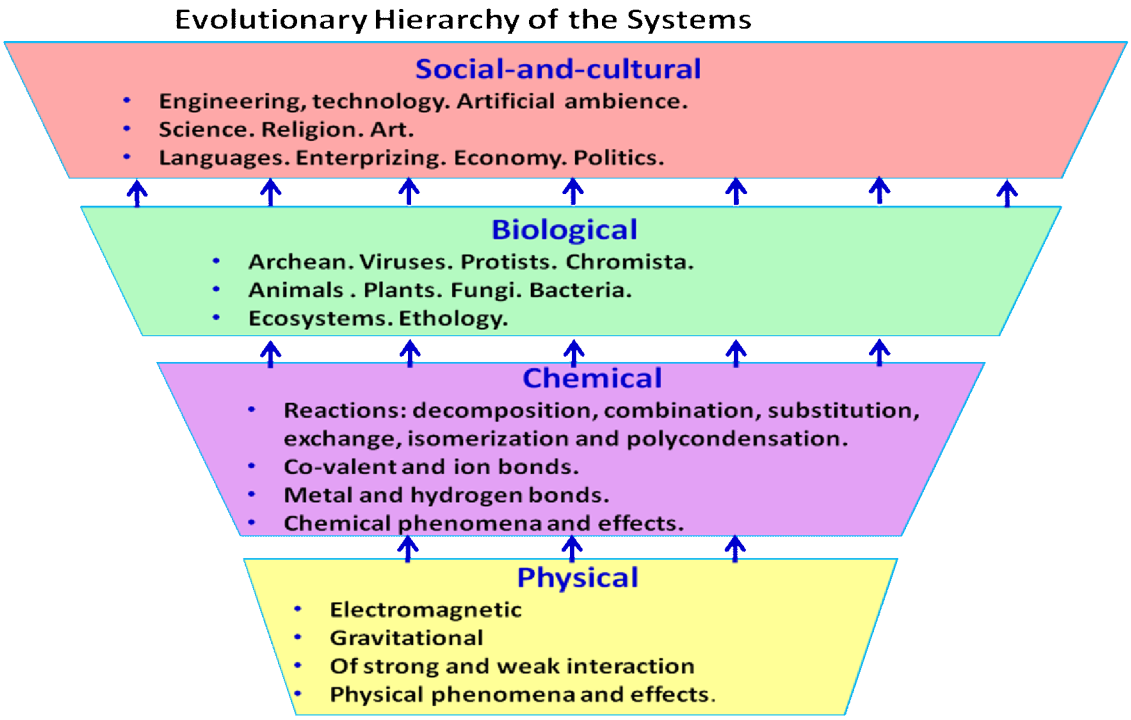



Fig. 10. Hierarchy of interaction fields of the systems

Each type of interaction is characterized by its own types of system capture. For example, for reaction of decomposition: reaction of thermonuclear splitting, reaction of chemical decomposition. Degradation and catagenesis of organisms, acquisitive type of a personality.

As it was said above, each level of field interaction has its simplest indivisible Ele-field. For example, for a social-and-cultural system this is a family-community, for an ecological system that is an ecosystem of a drop of water, for a biological system this is virus, while for a biochemical system that is cyclic molecules based on hydrocarbon bonds in case with a chemical molecule, while in case with a physical molecule these are elementary fields-particles, for example, quarks.

Any changes of bonds in ele-fields are associated with the energy processes. Each type of field association has its type of energy. With a physical level this is the energy o corresponding types of physical interaction. Chemical interactions are characterized by their own energy ties.  Energy of a living organism, living communities and ecosystems is known in biology.

The social-and-cultural fields are characterized by their own kinds of energy, which are not only reduced to other kinds of energy. The energy nature of generation and development of ethnic groups was pointed out in the publications of S.M.Shirokogorov [1] and then by L.Gumilyov [4]. In this article we are not going to analyze the details of energy-based nature of social-and-cultural systems. We shall only point out, what could be said about the energy foundations of engineering systems, as well as of economic, financial, political, psychological, art and other social-and-cultural systems.

There may be doubts concerning the energy nature of non-material systems. Each non-material system in this or that way could be reduced to information system. Information processes are associated with enthropy and energy. Synergetic processes, in particular, also form the bond between the reduction of enthropy, increase of information volume and the level of energy fields. Without going into details, characterizing these phenomena, we shall assert that the formation, preservation and destruction of any ele-field (any system) requires the energy of this or that type.

The necessity of energy forces for each case of constructing, destroying or changing the internal or external ele-field testifies to the fact that these processes cannot be instantaneous, i.e., they are necessarily characterized by inertia. Each type of interaction field should have both its own type of energy and its type of process inertia. Energy processes and inertia features characterize each (material and non-material) ele-field, any system. It is possible to assert that energy and inertia are directly associated with elements and fields, with space and time, with formation and variation of bonds in ele-fields of any type.

**Ele-and universal system of standards for inventive problem solving.**

Ele-field approach enabled to modernize the system of standards in order to use it in different fields, (not only in engineering) and without disadvantages, which characterized the previous system of standards. The universal system of standards [16] consists of 4 sections:

- synthesis of internal ele-fields;
- development of ele-field structures;
- synthesis and enhancement of efficiency of external ele-fields;

- lines of evolution of ele-fields.

It is possible to integrate functional approach, ele-field analysis and universal system of standards for inventive problem solving in the course of problem statement and analysis stage and when choosing directions for problem solving. For this purpose one can single out the following stages for analyzing a conflict or system and determining directions for problem solving:

- Singling out of the main elements of problem situation or system (engineering or non-engineering one);
- Formation of different complexes out of ele-fields and functions (useful, harmful, with insufficient level of performance, etc.); one and the same problem situation could be described using different complexes of ele-fields-and-functions
- Choosing only one problematic complex of ele-fields and functions, for which a search for solution would be conducted (it is possible to consider successively all complexes of ele-fields-and-functions that contain problem situations);
- Based on typology of formed problematic complexes of ele-fields-and-functions, determination of appropriate type of standards from the universal system of standards for inventive-problem solving.

As an example, let's describe a complex of problematic ele-fields-functions for a known problem of coloring the swirls when testing a mock-up of a parachute in a flow of water. One of the possible complexes of ele-fields-and-functions:

1. Dyeing agent – mechanically – dyes (changes the color) – swirls. Useful ele-field-and-function.
2. Dyeing agent – mechanically – deforms (changes the shape) – of the mock-up. Harmful ele-field-and-function.
3. Mock-up – mechanically – creates (changes the directions of the flow) – swirls. Useful ele-field-and-function.

Recommendations to use standard 1.2.1 (Elimination of harmful relationships via replacement, alteration or addition of elements, standard 1.2.2 (Elimination of harmful relationships via addition of filed) or to reformulate the initial problem (i.e., to eliminate the necessity of performing one or several functions – trimming) correspond to this complex of ele-field-and-functions. All these recommendations lead to obtainment of solution for the problem.

The proposed approach could be converted into an algorithm quite easily. At present the author (together with S.Sysoev) is developing software for this approach.

**Spatial system operator.**

In creation and analysis of ele-fields and systems evolution it is very important to take into account such parameters as space and time.

In an ordinary system operator space is not taken into account, which restricts the opportunities of system analysis of the situation and the object. It is proposed to use a system operator. In a spatial system operator it is necessary to take into account not only the possible changes in time and at the levels (of system, supersystems and subsystems), but also in space. It helps, in particular, to visualize the process of possible application of generalized system principles for resolving contradictions: in time, in space and via system transitions".

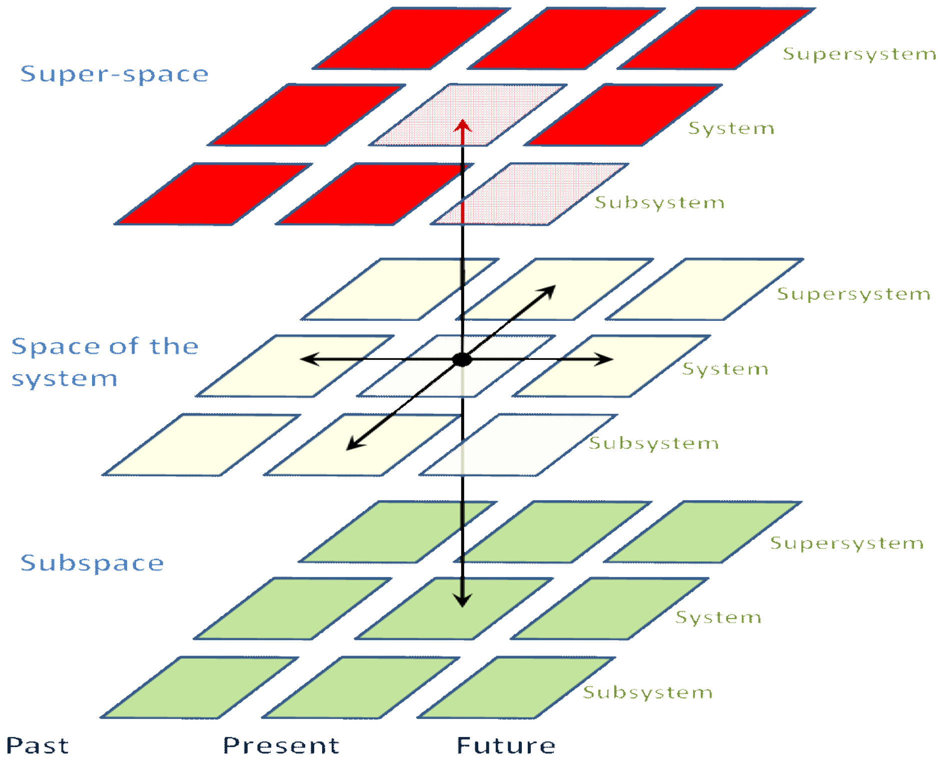



Fig. 11. Hierarchy of systems interaction fields.

For example, in biology the process of aromorphosis (transition to the new area of habitation), idioadaptation (getting used to a new kind of space) and catagenesis (simplification of the organism due to adaptation to a particular territory) are an inseparable part of evolution process of living organisms. For example, aromorphosis led to transition of fishes to amphibian, from amphibian to reptiles and, further on, to mammals and birds. Similar processes of development lines are observed in engineering and in other systems. The space-and-time (chronotopic) analysis of the conflict enables to formulate (in a very simple way) the recommended generalized system principles for resolving contradictions and the complexes of particular techniques for resolving contradictions of requirements. The table presents the dependence between the types of conflicts with the recommended generalized system principles for resolving contradictions.

Let us go back to a complex of ele-fields-functions, which describe a problematic situation as applied to the task about dyeing the swirls in testing the mock-up parachute in a flow of water.

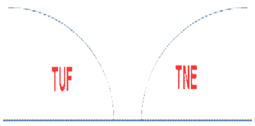
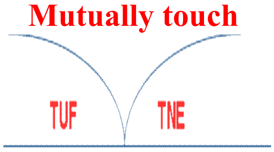
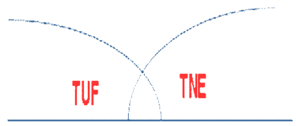
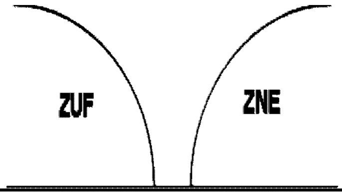
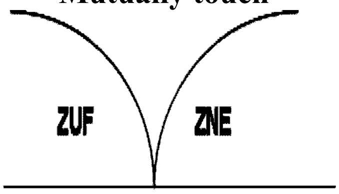
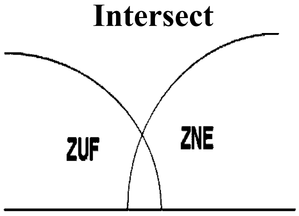
| **Time of useful function and time of non-desirable effect (TUF and TNE)**<br>**Zone of useful function and zone of non-desirable effect (ZUF and ZNE)** | **Don't intersect**   | **Mutually touch**   | **Intersect**   |
|---|---|---|---|
| **Don't intersect**   | ·In time<br>·In space (direction)<br>·In relation | ·In space (direction)<br>· In time<br>· In relation | ·In space<br>·System-based transition<br>· Physical-and-chemical and phase transitions<br>· In relation |
| **Mutually touch**   | · In time<br>·In relation<br>·System-based transition<br>· Physical-and-chemical and phase transitions | · In space (direction)<br>· In time<br>·Physical-and-chemical and phase transitions<br>· In relation | ·In space (direction)<br>·System-based transition<br>· In relation<br>· Physical-and-chemical and phase transitions |
| **Intersect**   | · In time<br>·System-based transition<br>· Physical-and-chemical and phase transitions<br>· In relation | ·System-based transition<br>· Physical-and-chemical and phase transitions<br>· In relation | ·System-based transition<br>· Physical-and-chemical and phase transitions<br>· In relation |

Table 2. Table of applying the principles for resolving contradictions.

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1. Dyeing agent – mechanically – dyes (changes the color) – swirls. Useful function. ZUF1 – contact of the dyeing agent with a swirl. TUF1 – time of conducting an experiment.

2. Dyeing agent – mechanically – deforms (changes the shape) – the mock-up. Harmful. ZNE2 – place of contact of dyeing agent with a mock-up. TNE2 – time of washing the dyeing agent.

3. Mock-up – mechanically – creates (changes the directions of the flow) – swirls. Useful. ZUF3 – contact of mockup with water. TUF3 – time for conducting the experiment.

ZUF intersects with ZNF, while TUF intersects with TNF. The recommended principles for resolving contradictions: physical-and-chemical and phase transitions and System-based transition. If the recommendations according to Table 1 of typical conflicts "prompt" what's to be done for resolving a contradiction, the Table 2 containing the application of principles of resolving contradictions prompts, how it should be done.

**Function-and-field analysis of systems.**

Functional-and-field analysis is a unification of functional and Ele-field analysis of systems. In contrast to the usual function analysis and a component-and-structural model not only functions are indicated, but also the fields of interaction of elements, which implement this function. Thus, for example, the variation of function-and-field model is possible without changing the functional model of the system, only through changing the interaction fields.

In the evolution of ele-field structures it is possible to single out two interconnected and to a certain extent contradictory tendencies.

- Tendency to trimming: enhancement of ideality through introducing the elements and fields due to existing resources, elimination of elements with preservation of functionality;
- Tendency for complication of structure: increase of ideality due to increasing functionality and interconnections within the system (deployment, increase of degree of ele-field quality);

***As an example*** let us consider the following system: a toothbrush with a case. The trimming line, which is usually implemented via methods of function analysis and trimming rules, in a given example leads to integration of the toothbrush with a case and a tooshbrush, mounted on a finger. The deployment line, which could be implemented via methods of Ele-field analysis and standards, leads to complication of system, implying the enhancement of its functionality: the body with a ultraviolet cleaning of the brush and connection to a USB port, toothbrush with ultrasound, etc.

Increase of ideality in a singled-out key problem or object could, thus, happen due to trimming and due to deployment (enhancement of Ele-field quality) of the system.

Constructing complexes of functions (useful and harmful) for the system jointly with their zones and time of useful and harmful action enables to automatically formulate not only the models of problems, but also the proposals for resolving them due to typical schemes (patterns) of conflicts and recommendations for applying the principles for resolving contradictions. In particular, it influences the rules for ranking the elements for trimming them.

One more peculiarity of function-and-field analysis is a hierarchical structure of component-structural and function-field model. Thus, the associations and functions existing between the elements could be generated at the upper and at the lower levels of the system. The models are composed for various states of the system: preservation, functioning, different modes, charging (power supply), liquidation, etc.

**Conclusions**

1. Ele-field as a universal model of system is a development of su-fields and the function model in TRIZ. The model of ele-field could be written down according to the following form: What – Using what field – Acts – Upon what object.

2. Ele-field analysis enables to create such models of developing engineering and non-engineering, material and non-material systems.

3. The formulation of model of the problem would be more efficient, if we did it through a complex of useful and harmful ele-fields-functions, implying the description of zones and field of useful and harmful interactions.

4. Parametrical approach in Ele-field analysis enables to formalize the description of ele-field and its connections with other TRIZ tools.

5. Ele-field analysis could be integrated into many analytical tools of modern TRIZ: component-structural and functional analysis, FOS, application of physical effects, ARIZ, etc.

6. Formation and variation of associations in an ele-field always take place in time, are associated with energy flows and possess the feature of inertia.

7. Spatial system operator enables to more comprehensively review the system, describe the problem and possible ways for solving it.

8. Ele-field as a universal model has rather complicated features, which require studies, also using the mathematical methods of theory of multitudes.

9. Formalization of creation and transformation of ele-fields jointly with other TRIZ tools enables to algorithmize the processes of analyzing the systems, identifying the problems and developing the recommendations for solving these problems.

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**Glossary of used terms**

Many new terms are use din this work. In order to avoid ambiguity in understanding the new terms and the ones, which are already known, I will try to discuss the most important of these terms. I will not try to offer strict definitions. It will rather be a description, which is going to be as comprehensible as I can make it to be.

**System** (from Greek *systema* – the whole consisting of parts, an assembly). Multitude of elements, staying in relations and connections one to another and forming a certain unity, on single whole. It is possible to distinguish material and abstract (non-material) systems. Abstract systems are notion, hypotheses, theories, scientific knowledge, linguistic, law, formalized, art and logical systems, etc. (http://www.russika.ru/t.php?t=3848 Encyclopedic Foundation of Russia). We shall assume that a multitude of elements, which are interconnected in a single whole, always posses features, which are not reduced to features of separate elements of this or that multitude.

**Supersystem** – multitude of mutually interconnected systems forms a supersystem. One system can concurrently be included with a multitude of supersystems.

**Subsystem** – elements, of which the system consists and which are looked upon as independent systems of a lower level.

**Element** (from lat. *Elementum* – nature, source substance), a component of a complete whole. This is what the system is composed of. In particular, it is characteristic of the element that it is possible to signify (with this or that degree of probability) the place of its location in this or that space. Elements could be material and non-material.

**Field (field of interaction)** – interconnections between the elements of a system within the boundaries of a certain space. In physics they distinguish different kinds of fields: electromagnetic, gravitational, nuclear – strong and weak. In TRIZ they use the notions of mechanical, chemical, acoustic and of the types of field interaction. In mathematics they distinguish scalar and vector fields. In linguistics we find a semantic field. In law there is a legal field. The following features are characteristic of an interaction field: it should necessarily be connected with no less than two elements, it is associated with space. Variations of parameters of one element lead (through an interaction field) to the variation of parameters of (other) elements within the frame of the space in which the field of elements interaction spreads. The fields have always an extension in space. Interaction fields can be material and non-material. Material elements can be bonded by non-material interaction fields.

**Space**. This is a fundamental notion, however, a fairly complicated one for an accurate wording. One can distinguish the Euclidean space, multi-dimensional space, vector, Gilbert, cultural, law and other kinds of space. The space is characterized by the presence of certain coordinates, which pre-determine the position of the elements and their possible travel in this or that space, extension of these elements, distance, environment, etc. The space is inseparable from the elements, which can be located in this space. For example, the formation of law elements and law space took place in the history of civilization concurrently.

**Feature**. Philosophical category, which expresses such aspect of the object, which pre-determines its similarity to or difference from other objects and is recognized in its relation to them (according to “Big Soviet Encyclopedia”). The object may take the form of material and non-material entities, systems, elements, interaction fields. The feature is a fairly complicated and rather contradictory notion. On the one hand it relates to a certain particular object, while on the other hand one can speak about the feature only in connection with another (second) object, which interacts with the first one. If, for example, electricity has not yet been discovered or market relations haven’t yet been formed, it is impossible to speak about such features of gold as electric conductivity or about its features of being a standard stock marketable goods. In practice in some cases it becomes fairly difficult to describe the features of this or that object, since there is an infinitely large number of supersystems, in which certain features of this object could manifest themselves.

**Parameter** (from Greek *Parametreo* – measure through comparison). This is a value (not necessarily a number), which unequivocally characterizes this or that feature of a material or non-material object, space or time. An example of parameters, which don’t constitute a number: color (green, blue, red, light cherry, chocolate, buffalo skin, etc.), chemical composition, structure of substance, etc.). In order to measure the value of the parameter, usually other reference objects are used, which are characterized by a standard value of this parameter: reference values of distance, weight, time, color, etc. an example of parameters of law object: name, document type, date of acceptance and of introduction of changes, date of entering into force, parameters of certain components of the document (for what persons it is intended, the duration of the punishment period, value of fine , etc.). In the same way it is possible to single out parameters of patent materials, program products and other non-material objects.

Parameter has several important characteristics:

- Parameter does not exist independently, it is always associated with this or that object and characterizes the state of this object;
- It is possible to measure the parameter value only through acting upon the object by another subject;
- Time is a parameter for processes or operations;

- Parameter could be measured using different methods, including expert evaluations;
- For one and the same parameter no less than two objects can exist, which are characterized by this parameter, parameter cannot be unique only for one system;
- Parameter can be increased, decreased, stabilized varied, measured;
- Parameters of the object can be interconnected;
- Mutual connection (interdependency) between the parameters of the object is determined by the features of this object;
- The object may be characterized by different parameters depending upon the aspects of analyzing it;
- Parameters of the object can be connected by cause-and-effect chains and create hierarchical parametrical structures;

Depending upon the aspect of analyzing the system, parameters could be:

- Physical and chemical (temperature, weight, pressure, light characteristics, acidity, etc.),
- biochemical (glucose level in blood, cholesterol level, antibody title, etc.),
- technical (productivity, reliability, accuracy of measurement, etc.),
- economic (profits, liquidity, cost efficiency, etc.),

Highly specific parameters could be used. For example, there are following special parameters for hard magnetic disks (Winchesters): Disk diameters, Number of sectors on the track, Rate of data transmission, Time of transition from one track to another, etc.

**Object**. Usually the notion of object is used in contrast to the notion of subject: subject acts upon the object or studies it. Beside such understanding of the object we shall also use another, wider understanding: a certain whole object, thing, phenomenon, entity in a virtual space, etc. The object could be looked upon as any material and non-material system, however, it can happen that the components, of which the object consists, are not singled out.

**Component** (Lat. *componens (compo-nentis)* constituent part). This is a constituent part of a material or non-material object. Element or field of interaction could be a component.

**Function** (Lat. *functio* – execution, implementation). The subject of the function changes the parameters of the function object. In this case the change is understood in a broader way: parameter of the object is increased, decreased, stabilized, varied and measured. The function of the system is preconditioned by the supersystem, it could be useful and harmful.

**Ele-field** (element-field). This is a model of material or non-material system, consisting of elements, fields and functions. Elements and fields in an ele-field shall be called ele-field components. Internal ele-field consists at least of two elements, field of their interaction and function and from the standpoint of a supersystem possesses the features of an element. The model of the internal ele-field could be described in written form in the following way: What – Using what field – Acts – Upon what object. External ele-field consists of at least two fields, an element, and a function and from the standpoint of a supersystem possesses the features of the field. The model of the external ele-field could be described in written form in the following way: Field – Using what element – Is transformed or measured – Into what field. In an ele-field the interaction field should be uniform: it can interact with one element according to the same feature as with another element. The simplest ele-field either has no sub-ele-field, or its sub-Ele-fields have interaction fields of a lower hierarchical level.

**Su-field** (substance and field) is an Ele-field for material systems, in which the elements are substances, while the fields are material (physical, chemical, biological, engineering). The substance is a material element, which has the mass of rest.

Other terms (function-and-field analysis, space system operator, etc.) are described in the corresponding sections of the article.