Thoughts on Fields
Is the Concept of Field indisputable?

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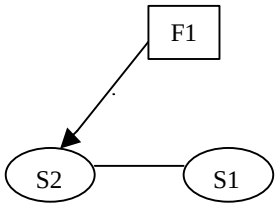
Introduction

Some of the basic concepts in TRIZ are the Substance-Field Analysis, Substance Field Resources, and the Field itself. The concept of Field differs from the one, which is customary in Physics. Further there exists diverse lists of Fields presented in various source books [1], [2], [3], [10], [11]. Remarkable differences and faulty definitions or examples also exist to confuse again the reader.
A good list of various Fields, their action in Substance-Field cases is required. Physics and other sciences are very complicated and intermingled. Hence experts on various sciences should be engaged to create an applicable and valid listing of Fields for TRIZ.
To explain the requirement, here are some thoughts for readers.

N.B.: In the following question mark(?) is used to show uncertainty in correct scientific terms in English, dubious or hard to understand definitions or the like.

Field as third element in Substance-Field Analysis

Substance-Field Analysis is one of the basic heuristics in TRIZ. The Field in conjunction with Substances gives the driving power to the system. Altshuller defined the minimum system as the following drawing



Without the Field the system does not work. The Field is the driving force to “guarantee the reaction of Substances, their mutual interaction”. Altshuller [1] names only four different forms of Field: ”electromagnetic, gravitational, the Field of strong and weak interaction”.
The definition by Altshuller describes the prevailing understanding in the 1960’s of mechanics and physics. Hence the classical Physics was divided into various sub levels:

- Mechanics
- Acoustics
- Thermodynamics
- Optics
- Electricity and Magnetism

Some other, later definitions in TRIZ

According to this Altshuller [1] defines the Field as something “that provides the energy, force, etc.” which are either scalar or vector. This definition does not correspond to the normal opinion of ‘field’ in Physics.

Later in 2000 Savransky [2] defines: *"A TRIZ field provides some flow of energy, information(?), force, interaction, or reaction to perform an effect. The presence of field always assumes presence of a substance, as it is a source of field"*.
To understand the quoted sentence is however difficult, because like all definitions this is too compact and artificial. What is "to perform an effect"? Is it the same as the "product" (end result of Substance-Field system) of the "technical system" or merely the function of the "technical system"? What about the "source of effect", does he think the substance as a higher level system?

He widens the list of Fields as

- Gravitational
- Mechanical
- Pneumatic
- Hydraulic
- Acoustic
- Thermal
- Chemical
- Electrical
- Magnetic
- Optical
- Radiation
- Biological
- Nuclear

and gives some examples of the Fields which actually are not Fields but rather some examples of consequences of the Fields or physical phenomena or merely properties of substances. Later in the appendix he gives the list of energies in

- Mechanical energy
- Thermal energy
- Energy of phase transitions(?)
- Chemical energy
- Nuclear energy
- Energies of standard physics fields

If the list has been even more thorough there is no doubt that we would have had the complete Physics. How far should we go?
When the reference source of appendix 4 in [2] is missing, a thoughtful reader has no possibilities for further study.

In the last above (Energies of standard physics field) there are the common energies as
- Gravitation interaction(?)
- Electric field
- Magnetic field
- Electromagnetic field
- Nuclear energy

whereupon a common engineer, sorry to say, has lost his interest trying to figure which are energies which fields and which listing to follow.

In a recent book Mann [3] lists the fields as
- Mechanical
- Hydraulic/Pneumatic
- Thermal
- Pressure
- Electrical
- Chemical
- Biological(?)
- Magnetic
- Weak Nuclear Attraction
- Strong Nuclear Attraction
- Optical
- Acoustic
- Olfactory(?)

And gives in "Sub-categories" again some list of material properties or phenomena of Physics.

Yuri Salamatov in his book [10] passes the question and determination of the Field with a very brief subordinate clause although uses much pages to Substance - Field reasoning and 76 Standards.

In the 'Tools of Classical TRIZ' [11] the Fields are presented in a sweet mess with listing of Scientific Effects.

In a recent book review [8] Ralph Czerepinski points out some problems in literal translations of TRIZ terminology and the correct definition of Field.

What is the referendum after all these possible definitions? Probably the fact there is a need to clarify the concepts.

There are no doubts what was Altshuller after and normally we do understand the Field in Substance-Field -drawing. If a system works, it has a function to do. A System or Process normally requires energy or force to work.

> **But we have to separate between energy, force and field from the physical properties of materials and scientific Effects or phenomena. Phenomena are in fact the end result of a working system, aren't they? They are the solution to a specific function we are looking for.**

Study of Encyclopedia

Just to remind you, let's see what the Encyclopedias [4] and [5] say.

The Classical Physics
The classical physics was divided into various sub levels as already quoted above, but mechanics further specified:

- Mechanics
  - kinematics
  - dynamics
    - statics
    - kinetics
  - hydromechanics
    - hydrostatics
    - hydrodynamics
  - aeromechanics (gases)
    - aerostatics
    - aerodynamics
- Acoustics
- Thermodynamics
- Optics
- Electricity and Magnetism

The Modern Physics include:

- Elementary particles or Super Energy Physics
  - study of particles like nucleons, electrons, positrons, antiprotons, fotons, leptons, hadrons etc.
- Nuclear Physics
  - structure of nucleus, study of these e.g. radioactivity, nuclear reaction
- Atomic Physics
  - study of electron cloud, characteristics of material
- Molecular Physics
  - molecular structure and forces between them
- Physics of Solid Material
  - crystal, liquids, gases and plasma

To confuse you more: no covering theory, which could unite all these have not yet been agreed upon.

Energy, field and effect

Energy as defined in modern Physics comprises all forms of energies, which are either potential or inertia. Potential energy includes also elastic energy due to force or heat. Energy can also be dependent on the condition as in heat.

Field is normally thought as 'field of force', gravitation, electric or magnetic force. Field is also dependent of position and time: in different places and at different times it has certain values both in quantity and direction.
Effect is some kind of influence, potency or phenomenon.

In TRIZ jargon these words, Energy, Field and Effect can have slightly different meanings.

Fields to be separated and doubtful Ones to be excluded

Electricity and Magnetism could be separated to Electricity, Magnetism and Electromagnetism as usually already done in TRIZ. Electricity is a major subject. Combined with Magnetism it creates phenomena both on Macro as well as Micro level. Further we know the Static Electricity and the Dynamic Electricity. Where there is a moving Electrical Field there is always a Magnetic Field and visa versa.

Optics studies light or in general electromagnetic radiation. Light is a kind of electromagnetic waves or the radiation of an elementary particle, photon. The energy of light can be transformed into mechanical energy through radiation pressure, into heat energy through absorption and into electric energy through optoelectric phenomenon. Optics is further divided in Geometric optics and Physical optics.

Acoustics studies sounds, acoustic waves in materials. Sound has the common features of wave motion, i.e. undulation, such as absorption, damping, reflection, refraction, diffraction and interference. Sound causes pressure and requires energy.

Chemistry is defined as a branch of natural sciences, which studies the elements of materials and the consistence of their compounds, structure, properties, reactions and their manufacture. Physical Chemistry is closely related with Physics, which forms the basis of Chemistry. So which one comes first?
Electrical Chemistry on the other hand is a sub sector of Chemistry, which studies the relationship of Electrical and Chemical phenomena. It includes among other things electrolytic dissociation, protolysis, eletrolysis, and electroforesis, Hydrogen concentration and acidity, potentiometrics, polarografia and conductometry. Corrosion is closely related.
Photochemistry studies the chemical influences of light in Chemistry.
So how to apply a Chemical Field?

Thermodynamics is a part of Physics and Physical Chemistry where energy transmission takes place as heat. The variables in Thermodynamics are volume, pressure, and temperature, internal energy and entropy, the value of which are dependent of the system condition.

A link with the Biological Fields: **Molecular Biology** is a part of Biology, which studies the effects of life on the molecular level through physical chemistry and biochemistry.
For the living organs what is needed? Is it enough to have some bioelements (H, O, C, N, and micronutrients), temperature and light? Perhaps water in addition? However, the list of micronutrients is quite an impressive one.

Olfactory means a chemical compound, which could be sensed by animals. The smell is closely related and often concurrent with taste. Smell and taste are used as means of detection and analysis in Chemistry. Hence these compounds are more likely additive substances which yield a detectable trace of a Substance in or as a Chemical Field. To understand what I mean a simple example: one cannot detect Oxygen because the material has no smell, no taste nor colour. The problem of finding a dangerous leakage is solved through addition of some Substance, which creates a compound with the former and could be smelled. So there is no need for "Olfactory" Field but better understanding of Chemistry?

Energy, force or field but not material properties nor phenomena?

For simplicity again, it would be easier to include and list the following **Fields** for TRIZ purposes as reminders for further development of Innovations and for Anticipatory Failure Determination:

- **Mechanical energies and forces**
  - basic mechanical energy/force sources as
    - gravitational force
    - centrifugal energy/force
    - hydraulic/pneumatic pressure, force
    - inertia energy
    - potential energy
    - elasticity energy (due to mechanical force or temperature)
    - adhesion/cohesion forces

- **Optics**
  - light energy

- **Acoustics**
  - sound pressure
  - undulation

- **Thermodynamics**
  - heat energy

- **Chemical energies and forces**
  - physical chemistry energy/forces
    - thermal, electrical, optical, magneto, colloid, catalysis, chemical kinetics
  - biological(?)
    - metabolic(?) energy
      - katabolic(?)
      - anabolic(?)

- **Electrical force and energy**
  - Static electricity
    - electrical field
    - potential energy
  - Dynamic electricity
    - electrical field
    - electrical energy
      - (thermal, magnetic and chemical influence)

- **Magnetic force**
  - static magnetic field
    - permanent magnet
    - field by electric current

- **Electro-magnetic field**
  - electro-magnetic field
  - radiation

- **Nuclear Physics** (usually omitted in TRIZ studies)
  - elementary particles or super energy forces
  - nuclear physics
  - atomic physics
  - molecular physics
  - physics of solid material (included)

The list as such should only contain energies, forces and 'ordinary' fields. Some physical Phenomena (or even material properties, Substances) are listed in various references [2], [3]&[11]. However these should be kept separate as substance/material properties or scientific Effects. Without this we cannot speak of 'scientific' TRIZ.

Application of Field

Let us remember where we are using the Substance-Field Analysis and the Fields. I see four major applications area**:**

1. to complement or to add the missing element to build a working system
2. to enhance system/process or to rectify a malfunctioning combination of the elements
3. to find solutions to 'mysterious' problems usually found in prototypes, i.e. Anticipatory Failure Determination, where the essential is to use Substance – Resource Analysis and collate all the potential Fields to cause the trouble.
4. to find out ways in measuring problems

Most of the 76 Standards are adding substances and adding or changing the Fields.

To find new solutions/innovations for a certain Function is subject for the search of scientific Effects and their combinations as in [6].

Discussion

1. When I started to write this article everything looked so simple and easy. Physics and other sciences seemed so well defined that is was so astonishing to find intermingled concepts and listings in References quoted. The study of basic handbooks and the encyclopedia revealed the interdependence of many techniques/sciences. This of course caused backward and forward jumping from one index to another. Hence errant and erroneous definitions are possible as well as translation of terminology.
2. In the list of Mechanical Fields there are hydraulic/pneumatic forces included. The reason is that these forces are created by mechanical/electrical energy and there is no reason to take them apart. But if we consider the various system levels they could?
3. There are also fields, forces and energy on Micro level: e.g. adhesion/cohesion and kinetics in Chemistry. Are these Fields of 'strong and weak interaction' or merely scientific Effects? Should there be a separate listing of Fields on Micro and Macro levels?
4. Some of Physical effects are very useful in finding answers to Physical Contradictions. In addition to the Separate principles and the Super and Sub level transformations there is the use of Phase transitions. It seems to me that these are often included to Fields. Should they?
5. The more complex interdependency is prevailing in Chemical and Thermal energies/fields. Thermal energy is a result of chemical reaction (if we exclude nuclear energy). On the other hand chemical phenomena are in fact a part of Physics. So what to do with these separated sciences? Or should we only use these as a reminder only in finding solutions?
6. The same applies to Optical and Acoustic energies/fields. Both of them represent in fact an energy transformation. But we can use these phenomena in finding again solutions in e.g. measuring problems?
7. Does TRIZ apply into Biology? Probably it does not. What is the correct order of evolution in Fields? Where to put e.g. the Biological? Or should we include biological fields in Chemical as above or totally exclude those? See also critiques by Peter Kaplan [9].
8. What is elementary physics and what is sophisticated knowledge from scientific scientific Effects? How much we expect a TRIZnik to know? Are the studies of senior high school scholar enough as teased by Altshuller?
9. The study of Encyclopedia might also have given other results depending the source. Are there any other classifications?
10. For clarification and more "scientific" approach, however, staying in established definitions of natural sciences would be an asset? Can we agree on the TRIZ listing?
11. Should the list be based on "old" understanding of Physics/Mechanics? This might be helpful since the listing is easy to adopt for common engineers. In Engineering we are dealing with problems that stem from quite ordinary processes or systems.

12. A scientist named Paul Kustaanheimo has studied the Gravitation. He said: ”It looks like the solution is just around the corner. When you have reached the corner, you will see that there exists still one more corner…” Is it the same with Fields?
13. For your info: I am pro TRIZ and the quoted books are great although subject to some critiques.
14. I call everybody to contribute with a positive attitude.

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