A New Approach to Su-Field (structural) Analysis

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Key words: Su-Field Analysis, Structural Analysis, substance, field, Element, Action, Knowledge, Data, Function.

1. Introduction

Su-Field analysis was developed by G.Altshuller [1]. In addition, he formulated the Su-Field increasing degree law and describes its mechanisms [2] and [3].

Expansion of the above law can be found in [4] and [5]. The expanded concept of the law was substantially changed and a forced Su-Field (Fig. 1) was introduced.

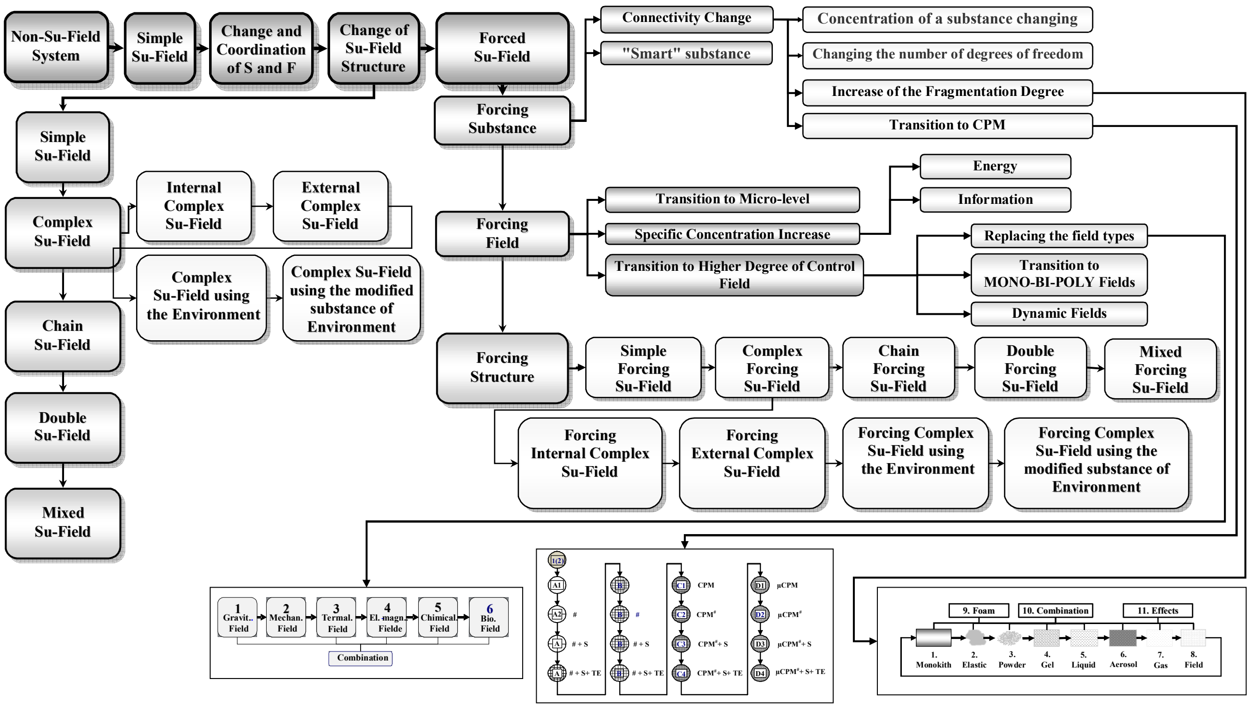


Figure 1. The scheme of the Su-Field increasing degree law

In addition, the Su-Field was renamed **El-Action**, where **El** (**Element**) stands for *Substance* and **Action** for *Field*.

The new name is more suitable in the analysis of information systems. It can be used in the analysis of all technical systems as well.

In Fig.2 the El-Action increasing degree law is shown.

Figure 2. General trend of El-Action

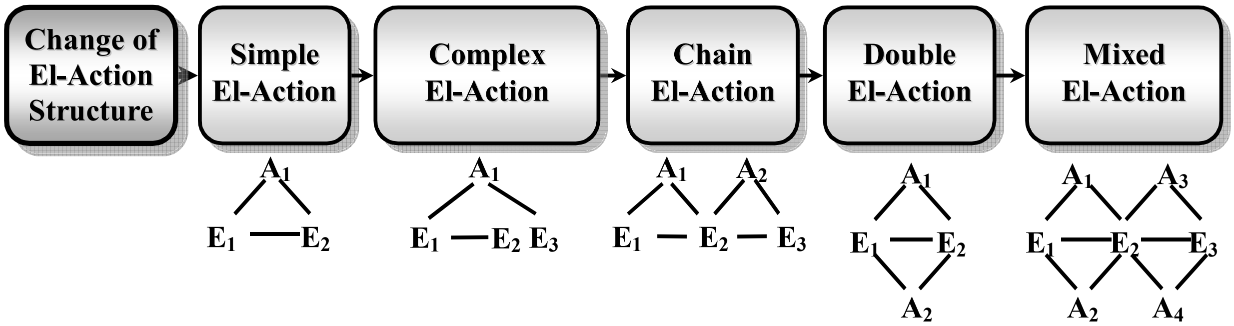


Figure 3. El-Action structure change trend

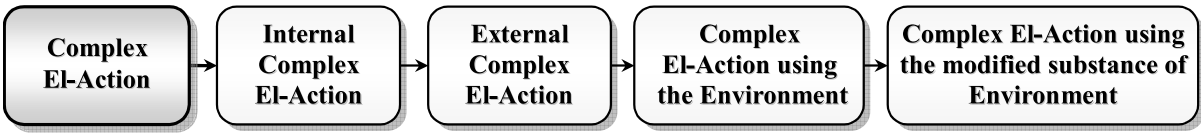


Figure 4. Complex El-Action change trend

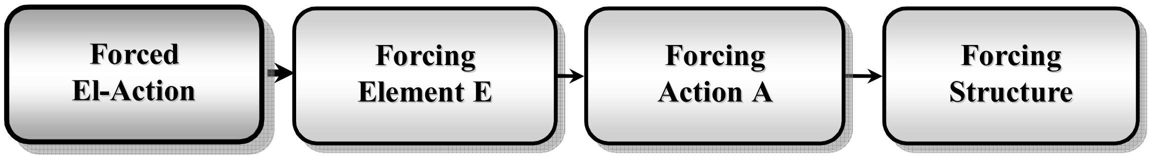


Figure 5. Forced El-Action change trend

2. The new Su-Field structure

2.1. General concepts

In this paper we introduce a new Su-Field (El-Action) structure.

The Su Field contains two components Substance and Field and the El-Action contains Element (E) and Action (A). We have added a third component **Knowledge** (**K**).

The new model, which includes Element (E), Action (A) and Knowledge (K) is called **EAK**.

The analysis method and transformation of EAK will be called **EAK Analysis**.

Knowledge (**K**) development in the system has four states:

1. Knowledge is outside the system.

2. Partial knowledge is included in the system during the design stage, while the remaining knowledge is placed into the super-system.

3. All the necessary knowledge is contained within the system, bit the knowledge control is outside of the system (in the super-system).

4. Knowledge control is performed inside the system.

Example. Need to drill a hole.

1. Knowledge outside the system.

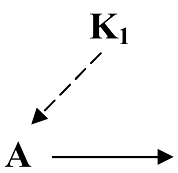
Drilled by hand. Action (A) – rotation. It acts on the Element (E) – drill. Knowledge (K) is located outside the system. The driller knows where to drill the hole and how to do it.

$$\mathbf{A} \longrightarrow \mathbf{E} \tag{1}$$

2. Partial knowledge included in the system.

Special drilling jig is used for drilling. It holds the drill at the location, where the hole should be made. The driller is not responsible for the location and punch. Knowledge about these operations is available in the jig.

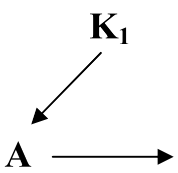
Knowledge (K) controls the Action (A) that acts on an Element (E). Knowledge of how to make a hole is outside the system (in the operator’s mind). The dotted arrow (2) indicates that we used partial knowledge.



(2)

3. All knowledge of the process is in the system.

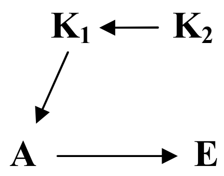
A CNC machine has all the necessary knowledge to implement technology manufacturing. Control of this knowledge (programming) is outside the system in the programmer’s mind.



(3)

4. Knowledge control is performed inside the system.

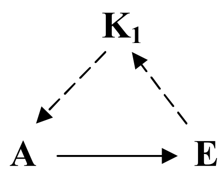
Programming must be carried out in the machine (CNC). This is the next stage of development.



(4)

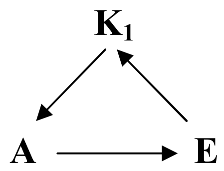
In general, the states 2-4 may be represented by more complex models.

An Element (E) may initially contain some Knowledge (K) for example the element status. In order to control element (E), it is often necessary to know its status. Then model (2) can be written as:



(5)

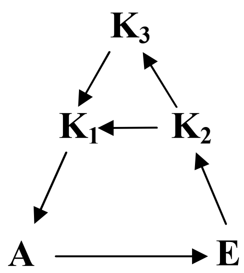
In stat 3, when control is needed for element (E), model (3) can be written as follows:



(6)

This case is typical for any self-adjusting system, such as a homing missile.

Controlling the state of an Element (E) for state 4, can be represented for as:



(7)

where:

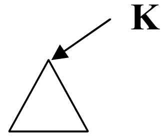
K_2 – the knowledge of the Element (E) state,

K_3 – knowledge that controls knowledge.

In the homing missile example **K_3** may be thought of as a change of purpose, the abolition of an action or self-destruction, etc.

Accounting knowledge and development patterns are modern trends in the technology. In Information Technology developing the accounting knowledge is of the utmost importance.

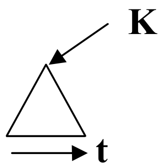
Often the Su-Fields are represented as a triangle. Same thing can be done for the El-Action. Therefore in the general case EAK can be represented as follows:



(8)

Thus, Su-Field analysis is a special case of EAK analysis, provided knowledge is ignored or not considered in the system analysis and synthesis.

To complete the picture, it is necessary to take into account changes in the elements (E), action (A) and knowledge (K) in time, i.e. their dynamic behavior. The dynamic behavior is introduced into the diagram by appending an arrow with a letter **t** (time).



(9)

We note that B. Zlotin [6] introduced process analysis (a kind of dynamic Su-Field analysis). In [7] it is suggested to have time dependent Su-Field analysis.

2.2. Patterns of the EAK development

The EAK development is carried out according to a law similar to the Su-Field increasing degree law.

Figure 6. The general trend of EAK

EAK development starts when the system does not incorporate any knowledge (K), i.e. regular El-Action development (Fig. 2-5). We name this stage as **non EAK system**.

A **simple EAK** is the stage in which Knowledge (K) is introduced into the system. The next stage is the increased controllability of the system, i.e. we can **change and coordinate the Elements (E)**, **Action (A) and Knowledge (K)**.

Coordination means that Action (A) responds to the Knowledge (K) and Element (E) responds to the Action (A). Hence, the Knowledge (K) identifies the changes in the Elements (E) and Actions (A) by controlling them.

The EAK structure is a modified form of the structures shown in Fig. 3-4 obtained by the introduction of knowledge (K).

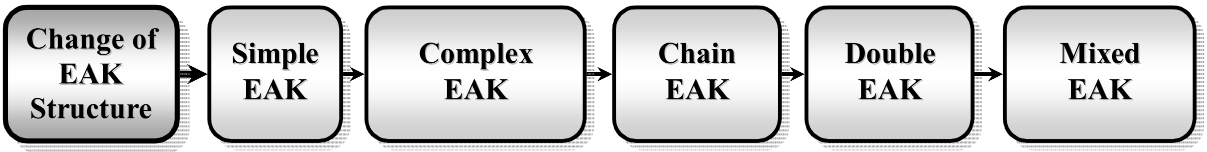


Figure 7. The trend change of EAK structure

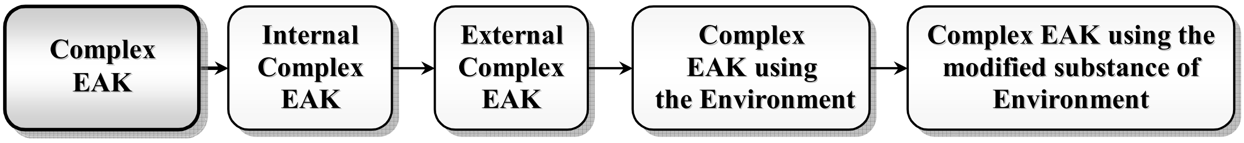


Figure 8. Complex EAK change trend

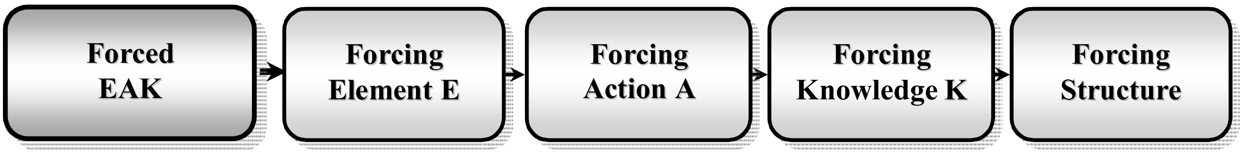


Figure 9. Forced EAK change trend

3. Patterns of control element

The pattern control element is an integral part of ***the law of control and dynamics changes degree***. Is belongs to the group of the *evolution systems laws* (Fig. 10).

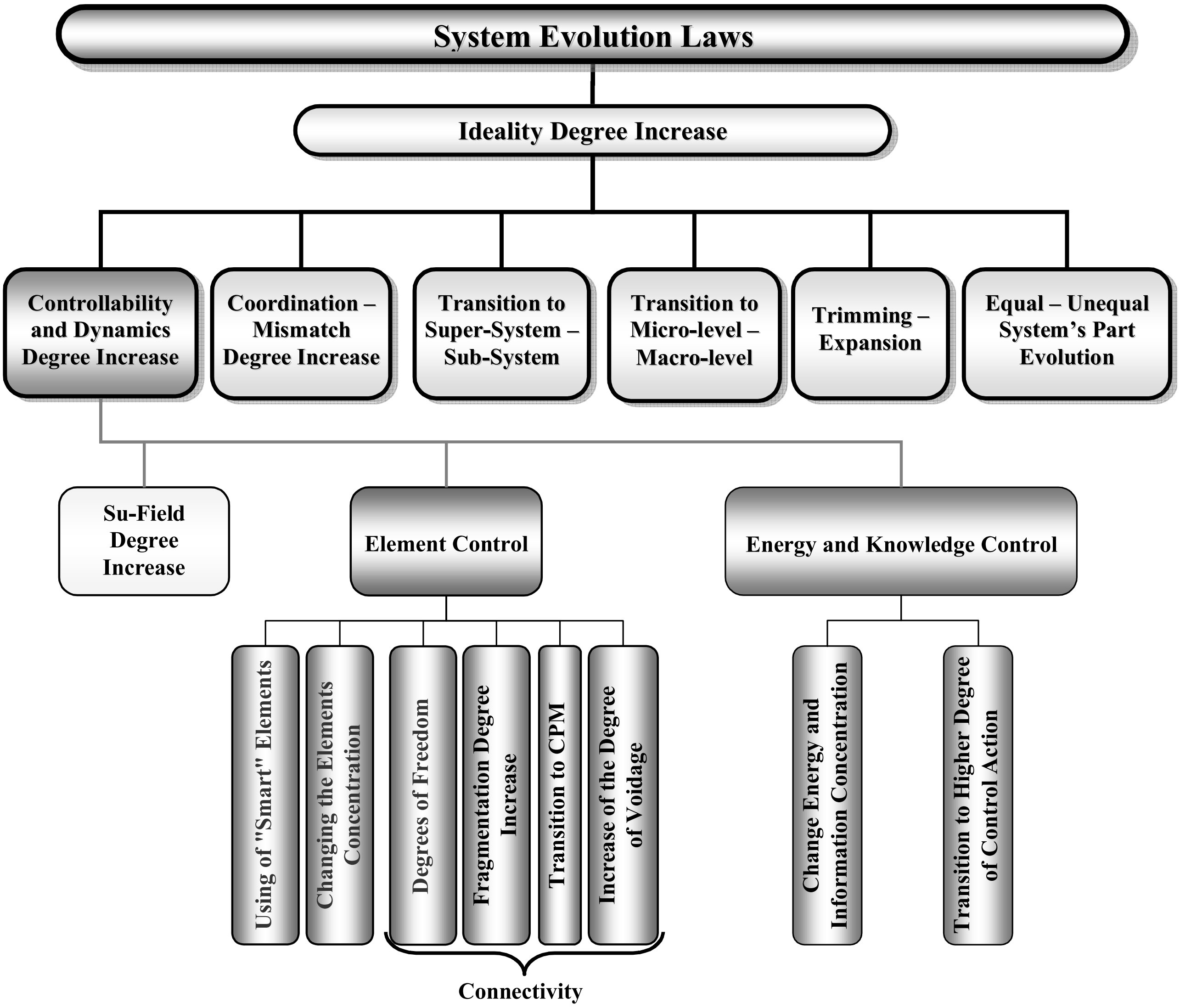


Figure 10. The structure of the technical systems evolution laws

A Control Element uses a **"smart" element**, changing **the concentration** and **connectedness of that element**.

Connectedness in physical systems include all type of connections. That is, the connection between the parts of the object, the particles of matter and up to the inter-molecular and atomic bonds.

In such physical systems, **Connectedness** can increase or decrease the ***stiffness*** or ***elasticity*** of the object along with the ***number of degrees of freedom*** in the system. Whereas in the IT or software systems, the connectedness refers to the relationship between parts of the element.

The pattern of control element is ***the adaptation of internal and external changes***, i.e. the ***changes in controllability and dynamics***.

The pattern of the control element carried out in (Fig. 10) contains the following trends:

- Use of "smart" elements,

- Changes in the degrees of the freedom number,

- Changes of an element concentration,

- Changes in the fragmentation degree,

- Transition to capillary porous materials (CPM),

- Increase in the emptiness degree.

Increasing the emptiness degree is a special case of the ***transition to the CPM***, and the transition to the CPM is a special case of ***changing the degree of fragmentation***.

Connectedness includes the following: ***changing the number of degrees of freedom number***, ***changing the degree of fragmentation***, ***the transition to the CPM*** and ***the increase in the emptiness degree*** (Fig. 10).

4. Energy and information control

The pattern of energy and information control is an integral part of ***law of controllability and dynamics increase***. The latter refers to a group of the *systems evolution laws* (Fig. 10). The pattern is that ***any system in its development tend to change the energy and information density at the proper time and place***.

Let us consider the mechanisms of energy and information density, which is primarily related to a working unit.

Energy and Knowledge Control is carried out by the trends (Fig. 11):

- **Change Concentration:**
  - **Energy,**
  - **Information,**
- **Transition to Higher Degree of Control Action**:
  - **Replacing the Action Types,**
  - **Transition to MONO-BI-POLY Action,**
  - **Dynamic Action.**

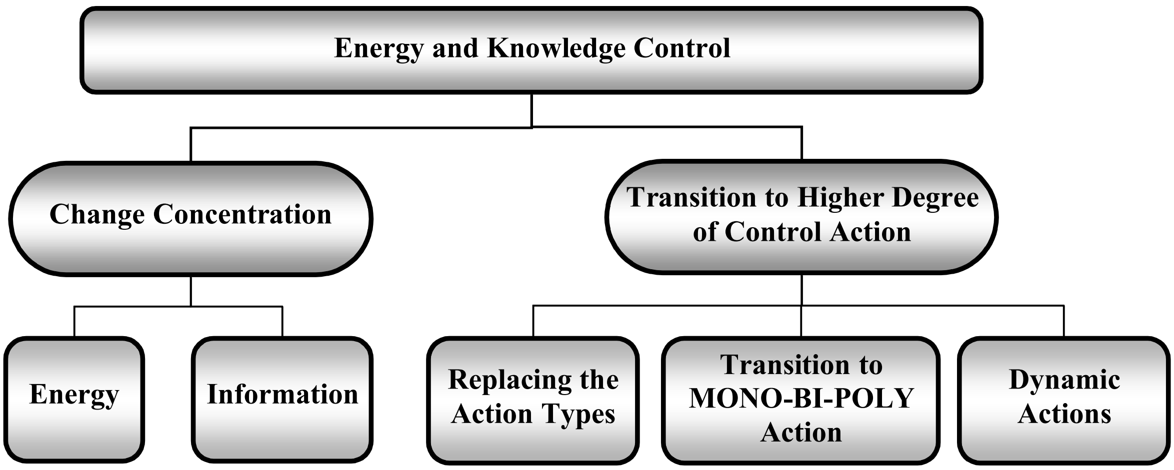


Figure 11. Energy and Knowledge Control Law

5. Patterns of knowledge development

We have identified the following patterns of knowledge development:

- The expansion – compression (convolution),
- Differentiation – Specialization,
- Combination of known knowledge and its integration,
- Intellectualization.

5.1. Extension – compression (convolution)

The tendency of expansion - compression is illustrated by the development of different theories.

Example. The development of the **electromagnetism theory**.

First, electricity and magnetism were considered as two separate forces. Then, many scientists have noticed the connection of electrical and magnetic phenomena. This the stage of the ***knowledge expansion***.

James Maxwell has linked together the electrical and magnetic phenomena, creating the classical electrodynamics. This is the stage of ***knowledge compression*** *(the four Maxwell Equations)*.

Example. The development of the **gravitational theory**.

Copernicus, Kepler, Galileo represents the stage of the ***knowledge expansion***.

Isaac Newton discovered the *law of universal gravitation*. It was a stage of ***knowledge compression.***

Further accumulation of knowledge (***extension***) showed the inaccuracy of the Newtonian theory.

The next stage of compression carried out by Einstein creating *the general theory of relativity*. It was a stage of ***knowledge compression.***

Then again a new cycle of knowledge accumulation started, for example, gravity processes on the quantum scale.

5.2. Differentiation – Specialization

When a branch of science matures, it becomes a new science by itself.

Mechanics divided into classical mechanics, relativistic mechanics, continuum mechanics. The latter is divided into the fluid mechanics, acoustics and mechanics of solids.

Each of the sections continue to divide and specialize further.

5.3. Combining of the known knowledge and its integration

Combining the knowledge from a few separate fields and generating a unified theory that can better explain certain phenomena.

For example, physics and chemistry are well-known sciences, and the combined physical chemistry studies macro chemical behavior with thermo dynamics.

Altshuller [8] described a few methods of knowledge combination.

5.4. Intellectualization

The transition from uncontrolled to controlled knowledge is due to the following chain: *adaptive (self-adjusting)* knowledge, *self-learning* and *self-organizing* knowledge, *self-evolving* and *self-reproducing* knowledge.

To date, there are adaptable, self-adjusting and self-learning systems, abile to adapt and to accumulate knowledge in learning. The development of artificial intelligence should lead to self-evolving and self-perpetuating knowledge.

This is a pattern of the future of knowledge development.

5.5. Example

Consider the process of making chocolate.

At first, the process was carried out manually. The person knew the whole process: choosing the right cocoa beans, roasting and grounding them to the desired consistency. The knowledge about the process of making chocolate was only in the employee's head, that is, knowledge was not present in the system.

The next step introduced simple mechanisms and machines. The machines had some knowledge, for example a machine (mill) to crush the cocoa beans. By this step, some knowledge was incorporated into the system. Then automation was introduced and even more knowledge was added to the system. Finally, a fully automated system that contains all the necessary knowledge for chocolate manufacturing was created.

The next step in the development requires the introduction of knowledge control of chocolate manufacturing.

For example, the system will adapt and modify the process for different grade cocoa and, particularly, adjust itself to the different cocoa beans present in the system. The system will learn the process of chocolate making and improve it. The system will reconstruct itself for different types of chocolate. The system will self-develop and create new chocolate recipes. The system will create a similar system itself.

6. Structural analysis of information processing systems

6.1. Definition

Consider the features of application for EAK analysis of information processing systems.

In information processing systems we deal with **Data** and **Functions**. In these systems, an ***Element*** is represented as **Data** (**D**) and ***Action*** – a **Function** (**F**).

A model which includes the **Data**, **Function**, **Knowledge** is called **DFK**.

Method of analysis and transformation DFK will be called **DFK analysis**.

- **Data** – incoming information to be processed by the system.
- **Function** – processing applied on the incoming information.
- **Knowledge** – aggregation of all proven, empirical or other a-priori information related to how the data to be processed.

The main difference between the Knowledge and Data is in structure and availability. The knowledge is defined during design or update of the system and exist independently of the incoming Data. When new facts or relations are discovered, the Knowledge base is updated and the processing is accommodated to include the new understanding. In certain cases, past Data forms part of the Knowledge available for processing the new Data.

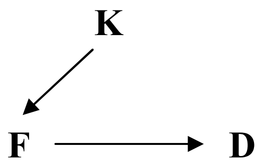
Data, Function and Knowledge are parts of DFK, and the corresponding methodology is called DFK Analysis.

6.2. DFK Analysis

The system is called uncontrolled if its function is fixed and does not depend on knowledge. Such system is referred to as an **Incomplete DFK** (7):

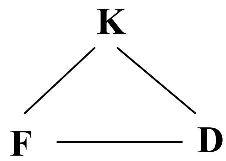
F ——— **D** (7)

Usually, some *prior* ***knowledge*** about the incoming data is available and used for adjusting the functionality of the system accordingly. Such a system forms a **Simple DFK**, shown in (8):



(8)

The system may adapt its functionality autonomously, by analyzing the incoming data and selecting the best approach to process it. This is a **Complete DFK (**or **DFK)**, presented in (9):



(9)

We believe that the proposed concept is helpful for analysis of the effectiveness and improvement of the existing solution as well as for design of the new ones.

Examples

Let's consider a system for data compression.

1. When input data type is unknown, the only reliable approach is lossless compression methods that achieve relatively low compression ratios. This system employs no knowledge and therefore it is an incomplete DFK (7).

2. When data type is known, e.g. image or audio, specific compression schemes can be applied for that type of data, like JPEG for all images or MP3 for all audio streams. Dedicated compression schemes make use of data structure to achieve much higher compression performance. The system effectiveness is higher compared with the first example. This system uses only external knowledge provided from outside, without any analysis of the input, and there it is a simple DFK (8).

3. To achieve optimal compression performance for a particular input, an image compression system analyses the input and determine the type of the image (e.g. photo, drawing, text, medical etc.) to selects an optimal method for this specific type of image. This system uses both the external knowledge provided from outside and internal knowledge collected by analysis of the input data and therefore it is an ***adaptive DFK*** (9).

6.3. Laws of DKF Degree Increase

Information processing systems tend to increase their degree of DKF according to the laws. We state here three laws of DKF degree increase:

1. Law of multistage processing.

2. Law of multiple source processing.

3. Law of accommodation.

The law of multistage processing

The law of multistage processing states: any information processing system tends *to process data in stages*. That is, as the processing complexity rises, processing is divided into several stages. There are number of distinct reasons of multistage processing:

1. *Distributed systems*. The systems where the information processing is performed by different components.

Examples: data transmission systems, client-server systems, sensor-display systems.

2. *Development optimization*. Complex systems are being divided into components, so each component can be developed and verified independently. Minimizing the interfaces between the components makes system development more efficient and faster.

Examples: virtually, all processing systems are divided into components.

According to the law of multistage processing, ***Simple DFK*** becomes ***Simple Multistage DFK***. In Simple Multistage DFK each processing stage is independent from all other stages, only data is shared. The ***Simple Multistage DFK*** transforms into ***Coordinated Multistage DFK***, where partial amount of knowledge is being shared between the stages. Finally, ***Coordinated Multistage DFK*** becomes ***Common Multistage DFK***. In Common Multistage DFK all knowledge is fully shared between all processing stages (Fig 15).

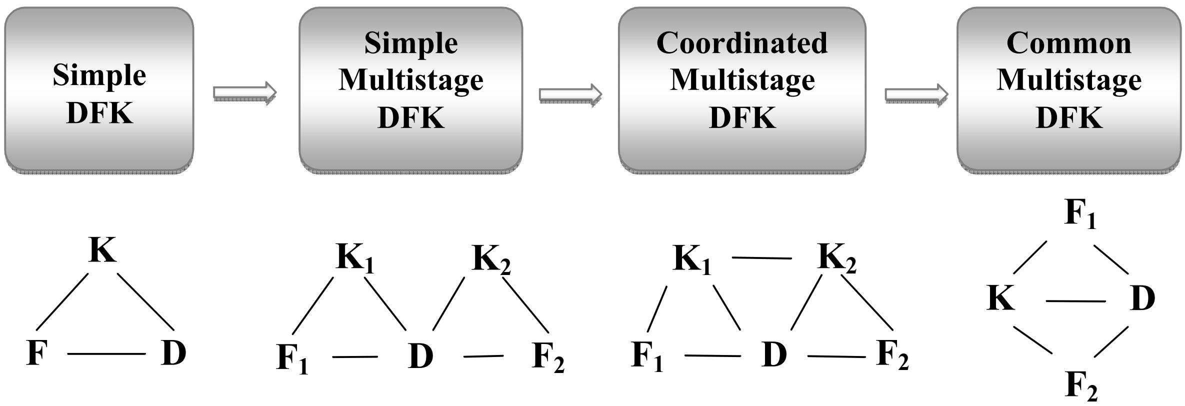


Fig. 15. Trend of multistage processing

Examples:

1. Simple Multistage DFK: Sensor/Display system. The image shown on a web page taken by camera is presented on monitor. The camera and monitor do not share any information.

2. Coordinated Multistage DFK: Data transmission system. Certain preprocessing of the data can be performed by transmitter and post-processing may be carried by receiver. Since there is a link between receiver and transmitter, some metadata about the processing can be by transmitter to the receiver.

3. Common Multistage DFK: Processing algorithm divided into subroutines can have a shared structure to contain all the knowledge.

The law of multiple sources processing

The law of multiple sources processing states: an information processing system with multiple sources tends *to process the multiple sources jointly*. That is, multiple inputs with the same or different sorts of information can be jointly process to explore the correlation between them.

Example of multiple sources of information is video capture, where both visual and audio data is captured. The relation between them can be exploited to improve speech recognition, noise reduction and video compression.

According to the law of multiple sources processing, any **Simple Multiple Source DFK** tends to become **Coherent Multiple Source DFK**. In **Coherent Multiple Source DFK** all sources of information are observed and used for processing, but the processing is performed independently. **Coherent Multiple Sources DFK** may transform to **Coordinated Multiple Sources DFK**, where knowledge is partially shared by processing subsystem on each source. Finally, **Coordinated Multiple Sources DFK** may fold into the **Shared Multiple Sources DFK** with centralized knowledge handling (Fig 16).

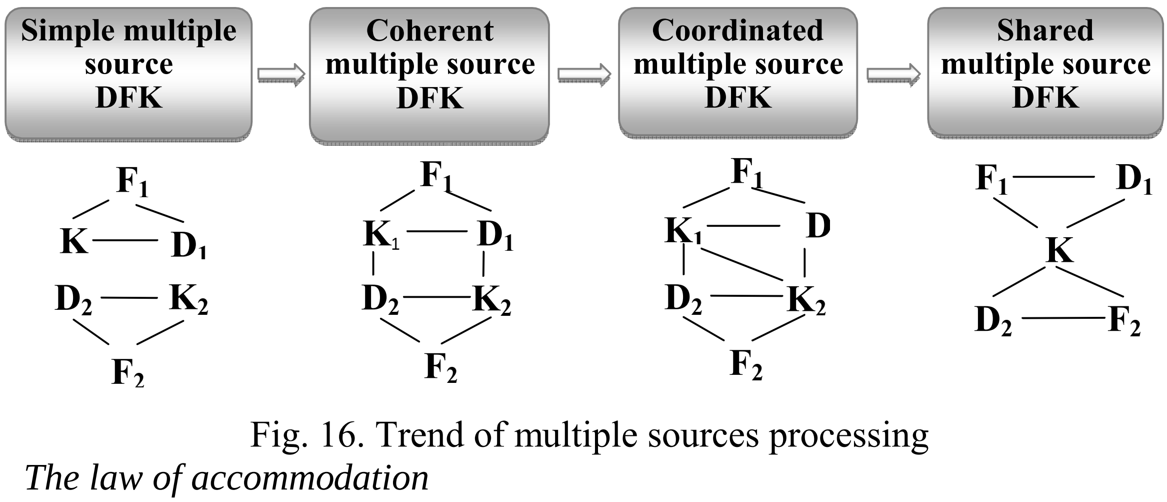


Fig. 16. Trend of multiple sources processing

The law of accommodation

The law of accommodation states: an information processing system tends to accommodate past data to improve its performance. That is, system tends to learn from information received in the past and adjust itself to produce optimal results for the incoming information.

Examples: unsupervised learning systems, like speech recognitions, search engines etc.

Static DFK is not changing in time, having constant a-priori set knowledge and functionality. Static DFK may become Learning DFK if the knowledge base changes with the incoming data. When not only the knowledge but also the function applied to the data changes with time such system is an Evolving DFK (Fig 17).

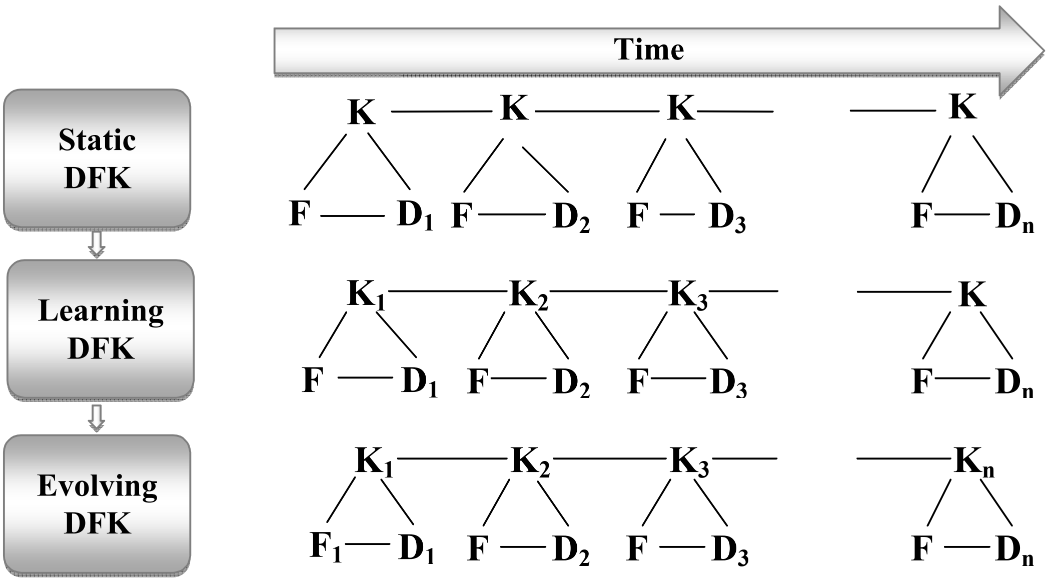


Fig. 17. Trend of accommodation

Complex DFK

The laws presented above are also applicable in combination. The example below shows Common Multistage Shared Multiple Source Learning DFK (Fig 18).

There are two sources of information D_{1n} and D_{2n}. Shared Knowledge K_n learns data behavior with each time sample. Function F_{1n} applied on D_{1n} is evolving, so the D_{1n}–F_{1n}–K_n is an Evolving DFK. On the source D_{2n} multistage processing is applied by the functions F_2 and F'_2 with a common learning knowledge K_n.

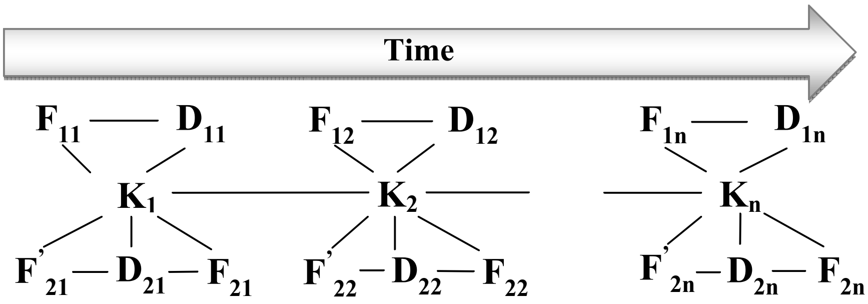


Fig. 18. Example of complex DFK

Conclusions

In this paper we propose a new Su-Field structure.

The Su-Field contains two components Substance and Field. We have added a third component **Knowledge** (**K**).

The development of information technology is the rapid today, where *knowledge* is necessary to consider in the analysis and synthesis systems.

In information systems, there is no concept of Substance and Field.

We called the Substance – "Element (E)", and the Field – "Action (A)".

The new model, which includes Element (E), Action (A) and Knowledge (K) we call **EAK**.

The analysis method and transformation of EAK will be called **EAK Analysis**.

The article describes the patterns of development of Elements (E), Action (A), Knowledge (K) and the general of EAK development laws.

Thus, Su-Field analysis is a special case of EAK analysis, provided knowledge is ignored or not considered in the system analysis and synthesis.

EAK analysis takes into account the change in the components and structure of the EAK in time.

In the information processing systems components are: Data, Function, and Knowledge. A model which includes the **Data**, **Function**, **Knowledge** is called **DFK**. New laws of design and analysis of such systems were proposed.

We believe that the proposed concept is helpful for analysis of the effectiveness and improvement of the existing solution as well as for design of the new ones.

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