České vysoké učení technické v Praze, Fakulta dopravní

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Spolehlivost Informačního výkonu

Reliability of Information Power

Summary

The presented lecture is a contribution to the task of an analysis and control of processes in complex heterogeneous Systems and Systems Alliances, for example of transportation or telecommunication nature. It is focused on the problem of Reliability of Information Power.

The backgrounds of the work are based on paradigms of Systems Theory in Klir′s interpretation [5], the understanding of Real Systems is influenced by the works of Prigogine [10] and Stonier [8], the relation of reality and information has its origin in Brillouin′s work [9] and constructive aspects of Systems theory are build on Vlček′s [15] ideas of Systems Engineering.

Unavoidable prerequisite of the work is an introduction of the core concepts:

Systems reliability at the level of interpreted System is defined as a probability of reference carrying – out of strong processes.

The process of homogenization is discussed at four basic levels, the level of multilingual translation being preferred.

The quantitative definition of Information Power is derived from the procedure of measurement of the System time changes.

At the Interpreted System level the Reliability of Information Power is defined as a probability of specified change of System time which is a response to input information. This definition cannot help us to distinguish whether Information Power has ordering or disordering effect on the System of interest.

To avoid this shortcoming a transition to the higher level of abstraction is done. This step results in the analyzing of certain representation of the information power reliability. This shift implies additional prerequisites – introduction of concepts of Systems Architecture, Identity or Interoperability. On the other hand this transition can help us to define Reliability of Information Power via the concept of Reliability of the Representation of Identity of Architecture, and even to quantify it by the speed of the approaching of the difference between an actual Identity and Strategic Identity to zero.

This abstract notion of Reliability of Information Power enables us to distinguish whether Information Power results in the increase or decrease of system entropy.

Souhrn

Příspěvkem k řešení úlohy analýzy a řízení procesů v rozsáhlých heterogenních systémech (např. dopravních nebo telekomunikačních) a systémových aliancích je tato přednáška, věnovaná problematice spolehlivosti informačního výkonu.

Práce vychází z paradigmat systémové teorie v pojetí Klirově [5], chápání reálných systémů navazuje zejména na práce Prigoginovy [10] a Stonierovy [8], vztah informace a reality vychází z Brillouina [9], použitá konstruktivní hlediska staví na Vlčkově pojetí systémového inženýrství [15], Klíčovým problémem je adekvátní zvládnutí systémové neurčitosti.

Nezbytnou vstupní podmínkou je zavedení nezbytných pojmů:

Systémová spolehlivost na úrovni interpretovaného systému je definována na základě pravděpodobnosti referenčního průběhu silných procesů.

Proces homogenizace je diskutován na čtyřech základních úrovních, přednost je dána homogenizaci založené na multijazykovém překladu.

Informační výkon je kvantitativně definován na základě jeho měření, tedy ze změn chodu systémového času.

Na úrovni interpretovaného systému lze definovat spolehlivost informačního výkonu pravděpodobností určité změny chodu systémového času v odezvu na zachycenou informaci. Toto pojetí nevede k rozlišení, zda informační výkon má na systém uspořádávací nebo chaotizující vliv.

Přechod na vyšší úroveň abstrakce znamená analyzovat obraz spolehlivosti informačního výkonu.

Tento posun předpokládá zavedení pojmů systémové architektury, identity, nebo interoperability.

To dále umožní definovat spolehlivost informačního výkonu jako spolehlivost obrazu identity architektury a kvantifikovat ji rychlostí, jíž se limita rozdílu aktuální a strategické identity blíží nule.

Toto pojetí spolehlivosti informačního výkonu již umožňuje rozlišit, zda informační výkon působí vzrůst nebo pokles entropie systému.

Klíčová slova: spolehlivost systému, informační výkon, homogenizace systémový čas, systémové rozhraní (IF), identita, architektura, multijazykový obraz systému, interoperabilita

Keywords: Systems Reliability, Information Power, Homogenization, Systems Time, Systems Interface (IF), Identity, Architecture, Multilingual Representation of System, Interoperability

Content

Reliability of Information Power

1. Introduction, motivation

A knowledge of the processes analysis and control in complex systems (for example the ones of transportation or telecommunication nature) remains still unsatisfactory in spite of significant and continuous progress in Systems Sciences and Systems Engineering.
There are several factors affecting this situation most significant being the following ones:

- Unavoidable and omnipresent **uncertainty** which is marked by different causes and modes. Uncertainty could be identified both on the levels of original / object and system / model [1].
- Complexity of the effects on systems **interfaces** [14].
- Vague identification of the relevant information subsystems and significant ("strong") information processes.
- Holistic nature of the systems resulting in poor efficiency or even the non-relevance of available, mostly reductionistic approaches.

That is probably the reason why soft methodologies are widely and more or less successfully used [16].
On the other hand, soft methodologies are too subject – sensitive and suffer from serious disadvantages:

- They cannot be expressed in regular algorithmic way.
- It is very frequently impossible to measure their efficiency or even to mutually compare different results obtained.
- The results cannot be transferred and generalized.

Strong demand for alternative "non – soft" approaches is therefore obvious.
Presented work is a contribution to the task of an analysis and control of processes in complex heterogeneous Systems and Systems Alliances. It is focused on a particular problem - **Reliability of Information Power**. Constructive approach is used.
Unavoidable prerequisite is an introduction of the core concepts, i.e.:

- Reliability,
- Homogenization, and
- Information Power.

2. Concepts

2.1. Reliability

A. Reliability of the system element or a system as a whole in the finite deterministic automaton[1] (FDA) representation can be defined as a **probability of the correct carrying out of the respective FDA mapping functions.**

An obvious scheme may be determined as follows:

- Choosing reference FDA functions.
- Defining / discovering (on the experimental background) the probability of the event the respective FDA function follows this chosen reference.

The second step is often a very difficult one.

B Reliability of a system[2] can be defined in several ways [1].
From the pragmatic point of view the following scheme is often preferred:

- Choose the process[3] of interest.
- Choose reference characteristics of this process.
- Define / discover (on the experimental background) the probability of the event that the chosen process follows the reference characteristics.

Strong and goal seeking processes are frequently of interest. Obviously the second and the third steps are both difficult and tedious.
Specification of reliability on this level needs the knowledge of:

- Systems structure[4]

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[1] **FDA := (X, Z, Z_0, Y, α, β)**
X,Z,Y are finite, non-empty sets of inputs, internal states and outputs respectively,
Z_0 (subset of **Z**) is initial (starting) state of the automaton,
α: transfer function (mapping) **Z x X→ Z,**
β: is output function (mapping) **Z x X → Y,**
Both functions (**α, β**) are not effective immediately, but they "consume" a certain quantity of time, and in such a way they originate the dynamics of the automaton.

[2] **Extended definition of the system** [15].: **S := (A/F, R/P, M, γ, δ, I)**
A/F is a set of systems elements A holding systems functions F;
R/P is a set of systems relations R described by parameters P
M is the magnitude (cardinality) of the set of systems processes
γ is the set of goal – seeking processes
δ is the set of strong (genetic) processes
I is the systems identity (see Chapter 4.1.)

[3] Process:= ordered set of events;
Event:= transition of system OR transition of systems element OR a change of systems structure OR a step of external time.

[4] Systems Structure:
St := (**A**, (a_i, a_j));
i ,j = 1,2,.......n;

- Detailed course[5] of the chosen process
- Particular reliabilities of the systems elements activated in the course of the process.

This concept of **Systems Reliability** is an equivalent to the P**robability of reference carrying - out of certain chosen process.**

C. Reliability of Complex Heterogeneous Systems (e.g. Hybrid Systems, Systems Alliances or Virtual Systems) holds some specific features:

- vague identification of a strong process of reference,
- difficult determination / measurement of particular systems elements reliabilities,
- non-regularity of significant systems interfaces,
- strong coupling among particular systems elements resulting in complex expressions of particular reliabilities as conditional probabilities,
- significant systems uncertainty.

That is the reason why the concept of Systems Reliability being expressed in terms of probabilities becomes unpractical or even useless. Instead of it a **distance** of two processes in state-space, i.e. the reference process and the actual one, can be used as a measure of reliability. There are at least three approaches within the body of Systems analysis how to measure this distance [3].
An alternative approach is based on the measuring of the distance of the process from the boundary of the "region of acceptability" in state - space).
The concept of **Structural reliability** is introduced for the mentioned cases [6].

2.2. Homogenization

An effective dynamical process of homogenization of the heterogeneous whole has important consequences to the:

- integrity of the whole
- existence of the object inside the environment
- structural properties of the whole
- dynamics of the whole with respects to the environment

All these factors form conditions to either the sustainable growth of the whole, or to the controlled decline of it.

Heterogeneity of the real object has its origin in:

- variability of the abundance of basic components of reality: mass, energy and information (M,E,I) [2,8,9],

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$\mathbf{A} \in (a_1, a_2, \ldots a_i \ldots a_j \ldots a_n)$
(i.e.: St:= Set of systems elements and doubles of connected elements.)
[5] (Detailed sequence of events)

- differences in metrics,
- effect of hidden states or variables, resulting in uncertainties,
- variability of the conditions of the activation of alternative processes.

Uncontrolled heterogeneity results in loosing the parts of the whole and, under the stress of an environment, the disintegration of the whole.
Four levels of homogenization have been recognized up to now[13,1].

2.2.1. Technological level.

At this level the process of homogenization can be reduced to the control of acceptable intervals of variables / parameters. This type of homogenisation de facto means **regularization of interface.**
The task at this level can be solved[6] within the framework of **system analysis.**
Macro - description of the process is characterized by decrease of configuration entropy.

2.2.2. Macro-physical / chemical level.

The process of homogenization on this level means **balancing of the interactions between an object and its environment**.

For a case of limited interaction object / environment and for thermodynamic description a typical situation could be expressed by relations between Energy (E) and enthalpy (F) versus entropy (S), the temperature (T) being a parameter.

This attempt can usually help to solve the stability of heterogeneous physical and chemical objects. Different possible approaches to the chosen macro-state result in uncertainty**.**

Far-reaching generalization of this approach could be done if the validity of ternary equivalence M-E-I *(mass – energy – information)* is accepted. [1,2,5,9]

2.2.3. Biological level.

Homogenisation of a whole results as well from an interplay: object – environment. Important factors of the process at this level are:

- **Competition of several objects for resources of environment**
- **Ability of duplication or multiplication of (at least one class of) objects.**
- **Two or more objects co – exist inside common environment.**

Typical process of homogenization has three distinct phases:

Reproduction → Occupation of Environment → Homogenisation

[6] (Unfortunately, quite often with serious problems)

The problem of stability of systems being homogenised by this process arises. Homogenisation via reproduction is connected with enormous decrease of configuration entropy, which is a typical marker of potential instability.
Systems tasks: **Dynamics of the Identity** is an effective tool for an analysis of homogenization processes at this level [15]. Process of homogenization of the whole is characterized by **smooth dynamics of identity** [13]. Branching of the dynamical trajectory of identity reflects the emergent phenomena, for example, reproduction.

2.2.4. Social level.
Information expressed in a set of languages is the most important factor in the process of homogenization at this level. Respective languages of certain parts of a whole differ in their alphabets, grammars and semantics. Consequently, **multilingual** character of information exchange between parts of the object / system and environment arises.
Quality of multilingual translation is a natural measure of a degree of homogenization. Integrity of the whole is causally derived from the completeness and efficiency of translation.
An important aspect of multilingual translatability in systems is "utilizing of limited resources, and / or limited time to disposal".
Specific case of this approach is "**dynamic translation**". Its nature should be characterized as a dynamical, quite often iterative or repetitive process of translation, typical with dynamic optimizing of its (frequent) alternative transition. This approach is usually demanding to the consumption of (systems) resources. On the other hand, it does not generally result in excessive decrease of configuration entropy – a positive marker for expected object / system stability. This is the reason why this approach to the homogenization is quite frequently chosen for objects of very high degree of importance.

2.2.5. Hybridization of levels

There are some wholes that consist of objects of several described levels, or their heterogeneity is of multi-dimensional nature. This is the case of <u>transportation</u>. Several dimensions should be distinguished, for example: Energy (cost) / substrate / vehicle / road / user / owner. In these cases the mutual ability of translation ("translatability") among objects of all levels and dimensions is required. That is the reason why there is general demand for universal means of homogenization. It is obvious that strong requirement for universality could be met by means of general introduction of the concepts of object language translation in multi – lingual environment (Chapter 2.2.4.) An introduction of languages of physical objects or technical artifacts could seem rather unusual, but there are no real objections. Respective languages are to be studied, recognized, understood, and introduced into common use.

2.3. Information Power

A concept of Information Power (IP) has been constructed in order to study the **problem of systems response to the certain information or to the information flow**[1,2]. Good understanding of this concept is a necessary prerequisite for further analysis. The concept is quite complex. That is why the introduction of IP cannot be too condensed.

2.3.1. Information Field

Information exchange is anchored within reality. The reality is a System composed of three entities $\mathbf{R} \in (\mathbf{M}, \mathbf{E}, \mathbf{I})$[7]. (Stonier) These elements are mutually irreducible, but there are relations of equivalence among all of them. Within the area of competence of informatics the equation:

$\mathbf{I_R} = \mathbf{I_M} \times \mathbf{I_E} \times \mathbf{I_I}$ is valid.

($\mathbf{I_M}$, $\mathbf{I_E}$, $\mathbf{I_I}$ are information reflections of M, E, I, respectively while × means Cartesian product).

Information could act as a trigger of action. The problem of an origin of relation between information and (physical) action resulting alternatively in decrease or increase of system entropy remains unsolved.

2.3.2. Specific Tasks of Messages Interpretation.

IP can be assumed as an interpretation of a message.
Interpretation can then be recognized to be a "translation" of information into the states or functions of the original system.
A message can be assumed to be shared information; containing conscious intent of the system state change or an activation of some functions of an original system which is built in the very construction of information.
The tasks are intended to solve:

- Reflections of the aim to the model (information).
- An allocation of the aim to the original objects the state of which is to be changed, or the function to be activated.
- A measure of acceptability of a message by the original object.

Problems could arise, either

- singular, or
- global (e g., in social dimension).

[7] M…mass; E….energy; I…. information

Reflections:

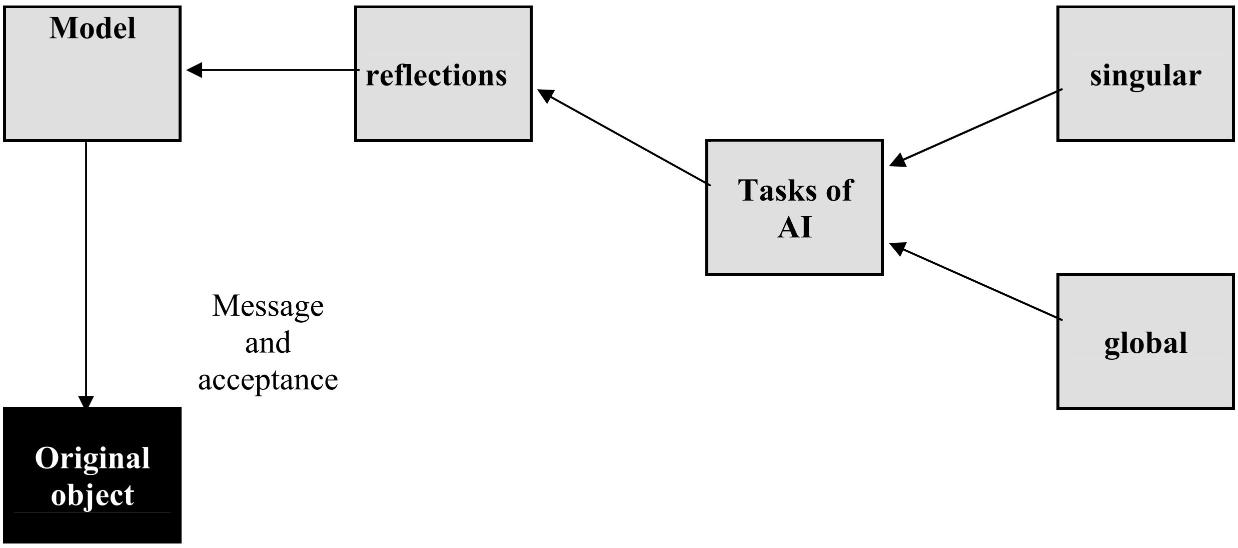


Fig. 1. Scheme of the representation of model aim

Allocations:

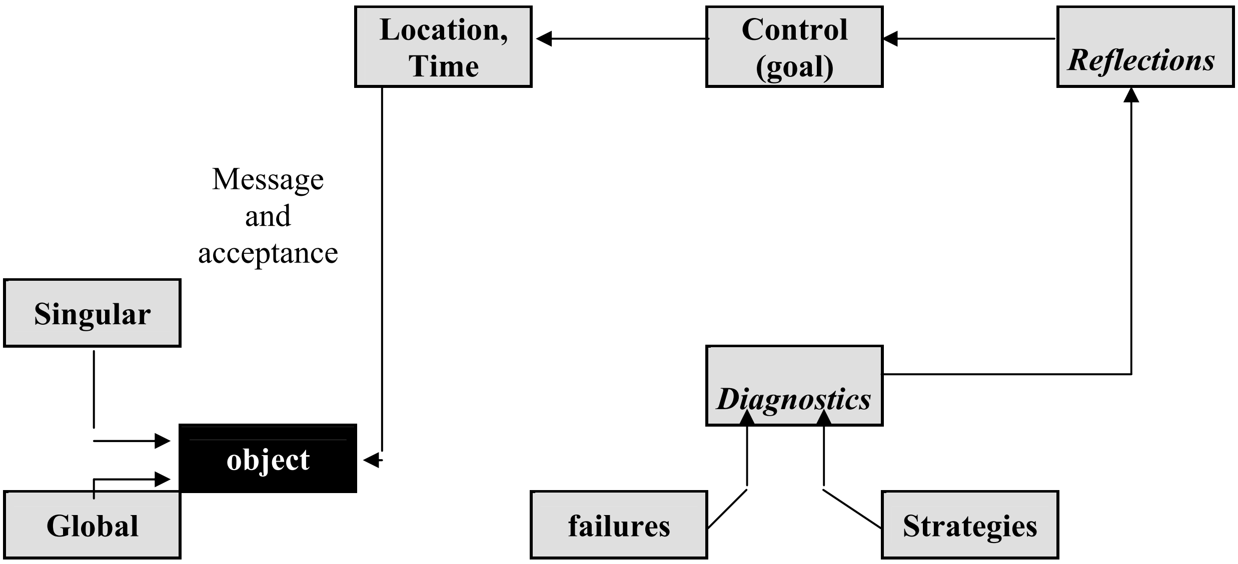


Fig. 2. Scheme of the allocation of the aim to the object

Acceptability:

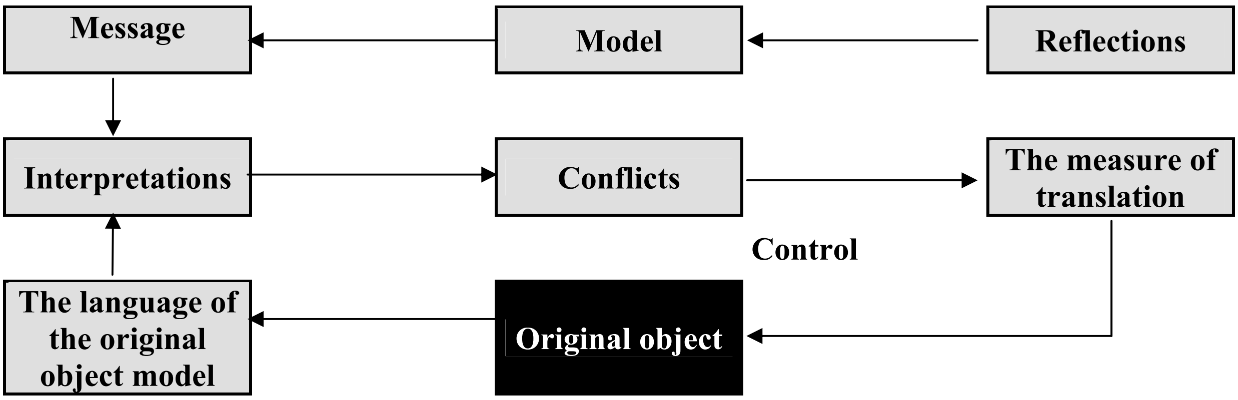


Fig. 3. Scheme of the acceptability of the message for the object

Integrated task:

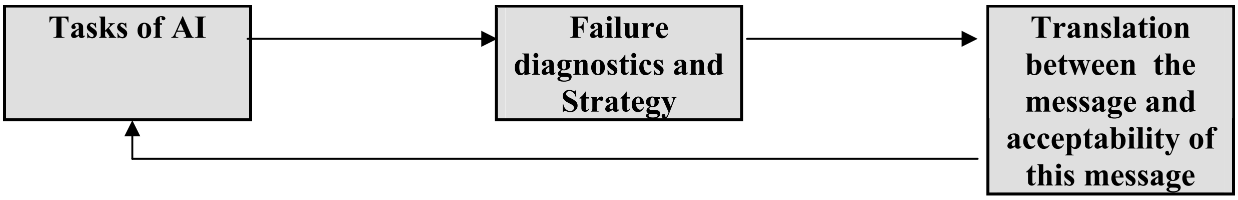


Fig. 4. Integrated task

2.3.3. Definition

Information power (IP): (measurable entity in state space **(M, E, I),** in analogy to the basic type of automaton)

$$\mathbf{IP := I \times S_0 \rightarrow S_k}, \text{ where } \mathbf{S_0 := (M, E, I)}$$

Value of IP: $|\mathbf{S_0 - S_k}|$

The alternatives of evaluation of IP [In semantics M, E, I]:

- transitions of states in state space
- changes in the contribution of $\mathbf{S_0}$ to identity
- changes of knowledge (epistemological scale)
- **IP** can also be distinguished in grades of **quality I** (data / information / knowledge /.. etc.).

Quality of IP lies within the interval between total chaos and ideal order.

2.3.4. Relation of IP and Systems time

Basic problem of systems response to certain information can be (at least in principle) solved by utilizing re – interpretation of Shannon´s concept of information, if the system is identified without explicit structure - as an automaton[8].

[8] i.e .black – box level of systems description

For the more frequent situations the structure of system is recognized, this approach is not adequate, and the utilization of the concept of IP becomes fruitful.

Measurable global effect of IP on the system is the change of the flow of System time.

Flow of System time is defined as a sequence of system events[9].

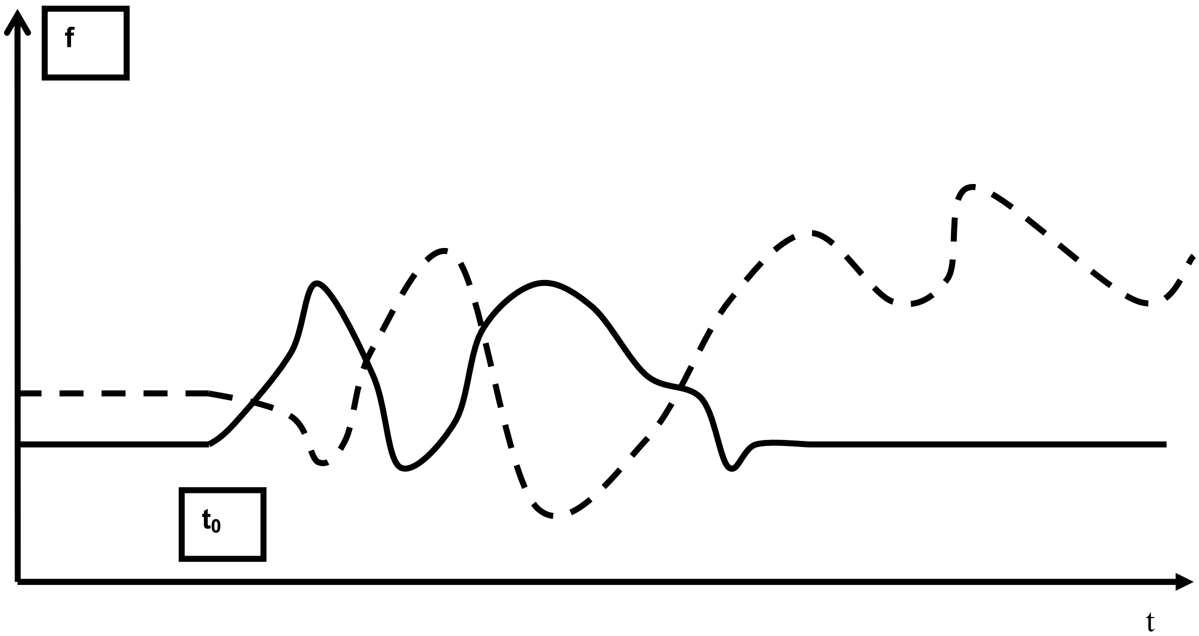


Fig. 5. An example of the system time response to the information accepted in (external time) t_0. Solid graph: time – limited response, dashed graph illustrates either chaotic behavior, or the activation of control process. (f is time dependent frequency of events)

The response of the system to certain information is a change of the instantaneous frequency of events. The response can be limited or unlimited in time. The later case can be either a result of chaotic behavior, or the result of activation of a control process.

2.3.5. Information action

Information action (IA) is a slightly modified concept to the IP. IA is also a weak analogy to the physical action. Value of IA can be (in principle) easily calculated as the sum of "excessive events" triggered by the input information.

An advantage of IA in comparison with IP is that IA can be directly associated with the efficiency of the translation of pertinent System Multilanguage.

The disadvantage of IA is that it can be hardly utilized if the response of the

[9] Event:= transition of element ∪ change of structure ∪ change of function of element ∪ *step of external time*.

Out of obvious reasons the last term – *step of external time* is omitted in this context.

System on the triggering input information is not limited in a time scale.

2.3.6. IP / ordering

Substantial output of IP analysis should be determination of the sign [10] of ordering function of IP[11]. Unfortunately even after more then 4 years of effort, this problem has remained unsolved[12].

2.3.7. Approaches to the IP analysis

There have been two basic approaches to the IP study so far:

- Multilanguage approach
- Structured approach

The Multilanguage approach is based on the notion that there is equivalence between automaton and a certain language [4]

The respective chain of thoughts could be as follows:

- Structured System is composed of ordered (connected) elements
- The elements are identified as automata
- Multilanguage composed of particular languages can be associated with the System
- Structural System relations and relations System – Neighborhood as well define constrains to the syntax of this Multilanguage and to the rules of the semantics transforms.
- IP (more accurately IA) is a measure of the efficiency of Multilanguage translation.

This approach is quite universal. The main problem of this approach from the application point of view comes from the fact that incomplete and uncertain grammars of these languages are very often met. Neither a theory, nor a set of typical tasks with these groups of grammars have been elaborated into sufficient depth.

Multilanguage interpretation can be complete, incomplete or alternative. IP is mediated in at least two languages:

- Language of the respective system
- Language of environment.

Structured approach means to dynamically analyze:

- Functions of elements
- Structure of System, inclusive respective sensitivities

[10] (+….entropy increase /-….entropy decrease)

[11] To control the processes in System it is very important to know if the effect of IP increases ordering or chaos.

[12] Possible solution (with far reaching consequences) is to introduce the fourth basic variable of reality - two valued ordering J.

- Regularities of Important complex interfaces.

3. Basic Concepts of IP Reliability

An analysis of IP means at the basic level the **analysis of reliability and efficiency of processes of the System being activated by input information.**
If the structured approach to the analysis of IP is chosen, the most important task is the **regularization of interfaces** which are activated in strong processes of the System.
Suitable model of Complex interface in the environment with significant uncertainty is constructed on the basis of the concept of Fictitious Deterministic Automaton (FDA).

3.1. Interface as a fictitious system element
For complex IF seems to be advantageous to introduce the IF as a fictitious system element ($\mathbf{A^{FIF}}$). The advantage of this approach is anchored in the richness of the concept of system element, which is generally defined as an automaton. For the sake of simplicity the finite deterministic automaton (FDA) is usually chosen. FDA can be described by a triple of sets **IN, Z, OUT** – inputs, internal states and outputs, respectively (In the set of internal states Z is further defined a specific subset – initial internal state $\mathbf{Z_0}$.), and a double of (mapping) functions: α, β. Function α transforms the Cartesian product (IN x Z) into the set of internal states Z. Function β transforms Cartesian product (IN x Z) into an output set OUT.

$$\mathbf{FDA := (IN, Z, Z_0, OUT, \alpha, \beta);\ \alpha: (IN \times Z)^{13} \rightarrow Z,\quad \beta: (IN \times Z) \rightarrow OUT)}$$

The fictitiousness of IF element reflects its important features:

- No demands on systems resources, and
- No transform of base variables or parameters, i.e. no consumption of time to carry out the functions, as well.

It is worth mentioning here, that these features are strictly valid for regular IF, while any disturbances of regularity can harm these features, as well.
Probably the simplest introduction of a **regular** IF as a fictitious systems element[14] $\mathbf{A^{FIF}}$ is:

> **Z** is an empty set,
> α is any arbitrary function without demands to system resources (in fact α is meaningless),
> β transforms IN into OUT, **β: IN→OUT**, the transform being an equivalence for all the parameters (components) of the sets (vectors) IN, OUT respectively : **OUT = IN[15].**

[13] (IN × Z), etc. means Cartesian product of respective sets.
[14] (i.e. fictitious finite deterministic automaton)

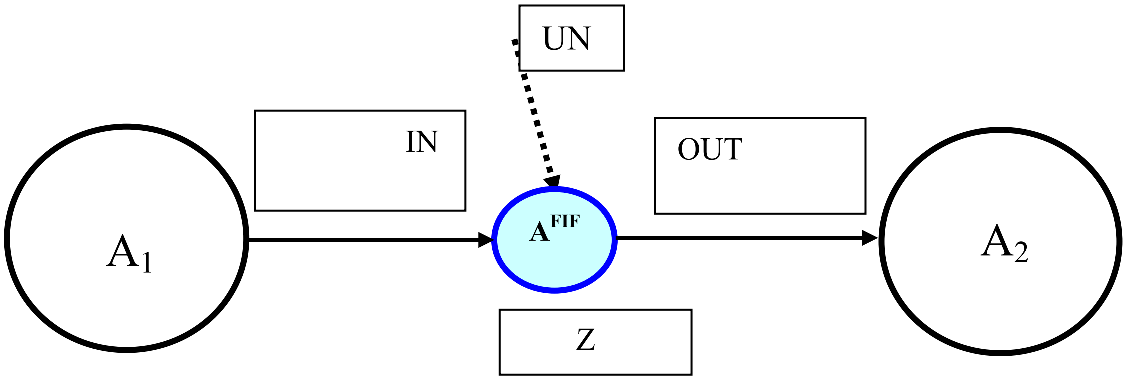
To describe the impact of irregularities and uncertainties, slightly modified model of IF is more suitable:

Let OUT = $\{a_i^{OUT}\}$ be a set of parameters a_i^{OUT} ; Let IN = $\{a_j^{IN}\}$ be a set of parameters a_j^{IN};

Let Z = $\{a_k^{Z}\}$ be a set of parameters a_k^{Z} ; $Z_0 = \{z_{0k}\}$; (i, j, k, natural numbers),

$\boldsymbol{\alpha: Z := Z_0}$ $\boldsymbol{\beta: OUT := (IN \times Z)}$

For regular IF the respective $\mathbf{A}^{\mathbf{FIF}}$ has of course the features: i = j = k; $Z_0 = \{z_{0k}\} = \{1\}$[16]



Regular interface: $\mathbf{A^{FIF}}$: $\mathbf{Z_0 = \{1\}; \alpha: Z_0 \to Z; \beta: (IN \times Z) = OUT;}$ dim(IN) = dim(Z) =dim(OUT)

Fig.6. Schematic sketch of regular interface identified as a fictitious system element.

3.2. System Uncertainty

Uncertainty (in complex systems substantial and almost omnipresent) [1,3,5,14] has many "resources" and aspects. Any effective analysis of complex systems reliability can hardly be done without careful evaluation of the impact of uncertainty to the system[17]. Thus, this is not a question uncertainty being in the focus of contemporaneous systems science.

At the beginning of the further study methodological problems arise of how to "incorporate" uncertainty into the system[18]? The significant majority of authors localize uncertainty into:

- Systems (or system elements) **functions / processes,** or

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[15] In detail: Let OUT = $\{a_i^{OUT}\}$ be a set of parameters a_i^{OUT} , Let IN = $\{a_j^{IN}\}$ be a set of parameters a_j^{IN}, (i, j, being natural numbers), then interface IF is regular if and only if :(i = j) AND $(\wedge_i(\mathbf{a_i^{OUT} = a_i^{IN}})) = \mathbf{1}$ (true)

Regular function of $\mathbf{A^{FIF}}$ therefore means plain instantaneous transition of IN into OUT.

[16](i.e.: $z_{0k} = 1$ for $\forall$ k);

[17] The problem has some analogies with the process of system identification [5].

[18] (i.e. specific model of object)

- systems **structure**, eventually to
- systems **neighborhood**.

The localization of uncertainty into the IF is not frequent[19]. Nevertheless, the author believes this is the only approach which could help us to illustrate certain nontrivial aspects of the task. To model IF we have primarily chosen an attempt described in chapter 3.1. (Interface as a fictitious system element) in which uncertainty "enters" the initial state Z_0.

3.2.1. Specification of the Task

The aim of the further part of this work is to analyze combined effect of the dimension and uncertainty of chosen IF within the system with respect to the reliability of defined[20] processes. The task is structured to the following main steps:

A. Reliability of a single (non-interacting) IF
B. Reliability of interacting interfaces.

3.2.2. Reliability of the non-interacting IF

is directly connected with the regularity of this interface. The respective relation is defined as follows.

Reliability of regular IF is equal to 1.

$$\mathbf{Rel\ (Reg\ (IF)) = 1;}$$

To specify the impact of irregularity we have to turn back to the chosen model of interface.

Assume further the same dimension of sets IN, OUT and Z,(i = j = k).

To simplify the following discussion let us suppose Z_0 is a vector, the components of which can be either 1 or 0. For the regular IF the vector $\mathbf{Z_0 := \{1,1,1,\ldots.1\}}$.

The impact of uncertainty (resulting in possible IF irregularity) could then be expressed in the simplest possible way as the existence of zero components in Z_0.

α: $\{\mathbf{a_i^Z}\} := \{\mathbf{z_{0i}}\}$ **i.e.** $\mathbf{Z := Z_0}$

β: $\mathbf{a_i^{OUT} := u_i\, a_i^{IN};\ u_i = 1}$ **for** $\forall$i, for that $\mathbf{a_i^Z = 1}$, else $u_i = \aleph$, where $\aleph$ is the number of undefined real value[21] in interval $0 \leq \aleph \leq 1$. (See Fig. 7.)

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[19] One of the reasons of this situation is probably certain semantic proximity of the concepts of interface irregularity and interface uncertainty, and consequently the possibility of misinterpretations. The most frequent concept of interface as some fictitious entity and the concept of uncertainty as a lack of information or knowledge (and also the reciprocal relation: information $\Leftrightarrow$ removed uncertainty) makes it difficult to imagine how uncertainty (i.e. quasi-entity) enters the interface (i.e. system quasi-object).

[20] (usually strong or goal – seeking)

[21] $\aleph$ is real number with undefined value in the strong sense, i.e. neither the probability density function, nor membership function within the interval <0,1> are known.

Verbally: All the components of input vector IN for which the corresponding components of initial internal state Z_0: $\mathbf{z_{0i}} = \mathbf{1}$ are directly mapped into the respective components of output vector OUT: $\mathbf{a_i^{IN}}|_{(\mathbf{zoi} = \mathbf{1})} \rightarrow \mathbf{a_i^{OUT}}$, while these components of input vector IN for that the corresponding components of Z_0 : $\mathbf{z_{0j}} \neq \mathbf{1}$ are mapped into the component $\mathbf{a_j^{OUT}}$ which has the value $\aleph$, uncertain without any a priori knowledge within the interval $\langle 0,1 \rangle$.

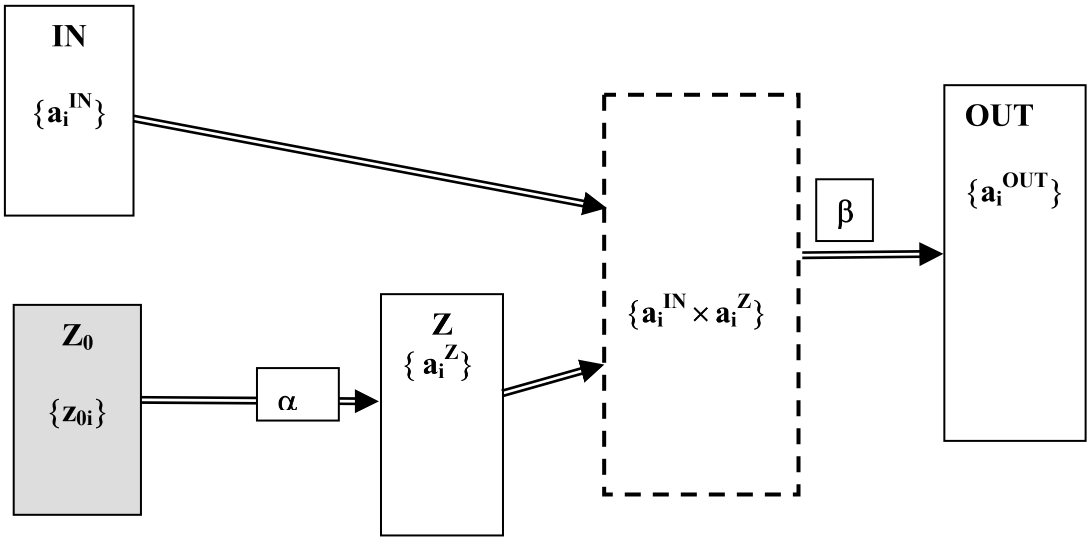

Fig.7. Model of IF function (IF represented by fictitious finite deterministic automaton)

For example: For IN:= $\{a_1, a_2, a_3 \dots a_n\}$, and Z_0:= $\{0,1,0 \dots 1\} \Rightarrow$ OUT =$\{\aleph a_1, a_2, \aleph a_3 \dots a_n\}$.

Assuming the length of vectors IN, OUT, Z, Z_0 is **n** and there is **m**[22] components of Z which are not equal to 1, **m** could naturally be an absolute measure of IF irregularity, while the relative measure of IF irregularity can then be introduced as **rir := m/n.**

Reliability of irregular IF could be expected to be monotonous non-increasing function of the rir. As the reliability (from its original definition) is probability, it is purposeful to define it within the interval $\langle 0,1 \rangle$.

Rel (Irreg (IF) = Rel(rir)

This consideration does not take into account the concept of "**acceptable degradation of IF**" (quite important from pragmatic reasons) which is quite often used within the body of Systems Analysis. This concept reflects the experience of analytics that minor irregularities of IF could often imply (in real or interpreted systems) no measurable effect on the reliability of the respective processes. The nature of this phenomenon can be linked with the redundancy of input parameters/variables (IN), and consequent possibility to reconstruct the correct values of the disturbed vector components in OUT. To introduce this

[22] ($m \leq n$; m is natural number or zero, n is natural number)

aspect of the task into the model the threshold parameter ξ[23] can be defined and the impact of uncertainty is then quantitatively expressed assuming the variable $\mathbf{z_{0i}}\ \langle 0,1\rangle$[24] . The function α in the model is modified, as well:

α: **If** $(\mathbf{z_{0i}} + \xi) \geq 1$ **then** $\mathbf{a_i^Z} := 1$, **else** $\mathbf{a_i^Z} := (\mathbf{z_{0i}} + \xi)$, while β remains unchanged:

β: $\mathbf{a_i^{OUT}} := \mathbf{u_i a_i^{IN}}$; $\mathbf{u_i = 1}$ **for** $\forall i$, for that $\mathbf{a_i^Z = 1}$, else $u_i = \aleph$, where $\aleph$ is undefined real number[25] in interval $0 \leq \aleph \leq 1$.The further results of the previous chapter remain unchanged.

3.2.3. Generalization of the model for interacting interfaces

This model of IF could be generalized assuming that interfaces within the respective system interact. The interaction means for our purposes that the measure of irregularity **rir** of the IF under study can be modified by irregularities of the other[26] system interfaces[27]. The generalization is based on the idea that instead of taking into consideration only the initial state vector $\mathbf{Z_0}$ of the IF under study (as it is done in the chapter 3.1.) the analogical vectors of neighboring IF in the same system are to be considered as well. The function α is in this case of significantly more complex nature, mapping Cartesian product of initial internal states vectors of all the interacting IF into the internal state Z of IF under study. Let the index of IF under study be $\mathbf{p} \in \langle 1,q \rangle$ and e =1,2….q. Then:

α_p: $\prod (\mathbf{Z_0})_e \rightarrow \mathbf{Z_p}$; where $\prod_q$ means Cartesian product of q sets and the arrow "$\rightarrow$" means a certain mapping rule; i.e.: $(z_{01} \times z_{02} \times \ldots\ldots \times z_{0q}) \rightarrow z_1$, etc.

Simplified version of this case illustrates the complex nature of the generalized task:

Assume two interacting interfaces, IF_1 and IF_2. The first one let be under the study.

$Z_{01} := (1,0)$; $Z_{02} := (1,0,1)$[28]; The relations are two-valued ones.

Respective (degraded) Cartesian product $(Z_{01} \times Z_{02})$ = ((1-1), (0-1), (1-0), (0-0), (1-1), (0-1));

Let us further define α_1: {(1-1):= 1, (0-0):= 0, (0-1):= 0, (1-0):= 0}, then $(Z_{01} \times Z_{02})' := (1,0,0,0,1,0)$, and $(Z_{01} \times Z_{02})'' := \mathbf{max}/_{\dim Z1}\ (\mathbf{comp}((\mathbf{Z_{01}} \times \mathbf{Z_{02}})'))$[29] = (1,1).

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[23] $\xi \in \langle \mathbf{0,1} \rangle$. An obvious generalization could be done assuming vector character of ξ $(\xi_1, \xi_2, \ldots \xi_i \ldots \xi_n)$, but this generalization is not reasonable for our purposes.

[24] (not only the binary values 0/1)

[25] $\aleph$ is real number with undefined value in the strong sense, i.e. neither the probability density function, nor membership function within the interval <0,1> are known.

[26] (neighboring)

[27] An example could be seen in the chapter 1.5.

[28] (Therefore the dimension of IF_1 is 2 and dimension of IF_2 is 3.)

[29] vector of the length of $\mathbf{Z_1}$, components of which are the maximum components of the vector $(\mathbf{Z_{01}} \times \mathbf{Z_{02}})'$

Then Z_1= (1,1) and therefore this IF is regularized.

For slightly different definition of α_1: Z1:= Z_{01}<u>AND</u>(max (comp(Z_{01} × Z_{02})') the IF remains irregular one.

This generalization makes it possible to utilize the proposed model of IF for both interacting and externally controlled interfaces. This feature is important especially in complex hybrid systems and system alliances.

3.3. Geometric re-interpretation of the model

- Let the analyzed IF consist of **n** mutually independent variables / markers. Then its dimension is **n.**
- Let all the variables of IF be renormalized[30]. Then, in geometrical view, IF could be supposed to form **n** dimensional compact body[31].
- Let <u>uncertainty</u> enter solely the studied IF, not the system as a whole. It modifies **m** variables/parameters of Z_0.

These assumptions should be expressed geometrically as the reduction of the n - volume of the IF, extracting from the core[32] the outer shell in that the OUT is totally uncertain[33]. (See Fig. 5.) For the sake of simplicity, the same coefficient **rir := m/n** of the reduction for any dimension of the IF n – volume is then utilized.

3.3.1. Model analysis

Our problem is now reduced to purely geometric task [17]:

- Let the "n-volume" of the **IF** be $\mathbf{V_{IF}}$
- Let the "n-volume" of the core be $\mathbf{V_{CORE}}$

Then the constructed variable $\mathbf{v = V_{CORE} / V_{IF}}$, being a function of **n**, **(v = v(n))** is an effective measure of the "weight" of the (regular) core for the given **n**.

The expressions for **v(n)**, for Euclidean space, typical shapes of IF and fixed γ, **ε,** respectively are as follows:

<u>Sphere</u> (with the radius r):

$$v(n) = \frac{\alpha_n (r-\varepsilon)^n}{\alpha_n r^n} = \left(1 - \frac{\varepsilon}{r}\right)^n \approx 1 - n\frac{\varepsilon}{r} + O\left(\varepsilon^2\right),$$ α_n is a constant for given n

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[30] (to the interval <0,1>, eventually taking into account the weights of the respective variables)

[31] cube or sphere (or, taking into account the weights of variables, an n – dimensional cuboid or ellipsoid)

[32] (Inner, fully certain and reliable part)

[33] (factor ℵ, no membership functions are introduced, i.e. uncertainty means total lack of knowledge)

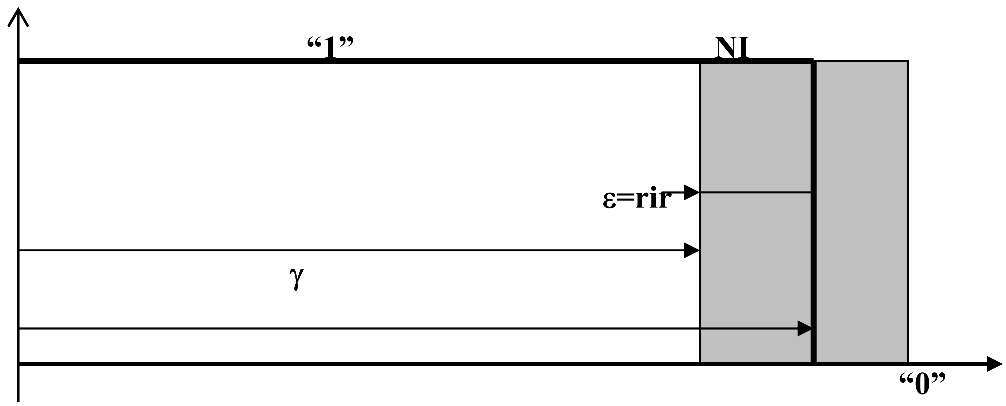

Fig. 8. Central cut through renormalized IF. "1" denotes full regularity, "0" denotes full irregularity of IF and NI denotes non-identified (i.e. totally uncertain) area of IF. ε=rir ; γ≤1; ε + γ= 1

<u>Cube</u> (with the edge a)[34]:

$$v(n) = \frac{(a-2\varepsilon)^n}{a^n} = \left(1-\frac{2\varepsilon}{a}\right)^n \approx 1 - n\frac{2\varepsilon}{a} + O\left(\varepsilon^2\right)$$

<u>Cylinder</u> (bases are (n –1) dimensional spheres with the radius r and with the height a):

$$v(n) = \frac{\alpha_{n-1}(r-\varepsilon)^{n-1}(a-2\varepsilon)}{\alpha_{n-1}r^{n-1}a} = \left(1-\frac{\varepsilon}{r}\right)^{n-1}\left(1-\frac{2\varepsilon}{a}\right) \approx 1 - \frac{2\varepsilon}{a} - (n-1)\frac{\varepsilon}{r} + O\left(\varepsilon^2\right),$$

<u>Cuboid</u> (with the edges $2a_1, 2a_2, \ldots 2a_n$....):

$$v(n) = \frac{(2a_1-2\varepsilon)(2a_2-2\varepsilon)\ldots(2a_n-2\varepsilon)}{2a_1\cdot 2a_2\ldots 2a_n} = \left(1-\frac{\varepsilon}{a_1}\right)\left(1-\frac{\varepsilon}{a_2}\right)\ldots\left(1-\frac{\varepsilon}{a_n}\right) \approx 1 - \varepsilon\sum_{i=1}^{n}\frac{1}{a_i} + O\left(\varepsilon^2\right)$$

<u>n - Ellipsoid</u> (with the axes $a_1, a_2, \ldots a_n$):

$$v(n) = \frac{\alpha_n(a_1-\varepsilon)(a_2-\varepsilon)\ldots(a_n-\varepsilon)}{\alpha_n a_1 a_2\ldots a_n} = \left(1-\frac{\varepsilon}{a_1}\right)\left(1-\frac{\varepsilon}{a_2}\right)\ldots\left(1-\frac{\varepsilon}{a_n}\right) \approx 1 - \varepsilon\sum_{i=1}^{n}\frac{1}{a_i} + O\left(\varepsilon^2\right)$$

(Where O(ε) is an inaccuracy resulting from simplifications done).

<u>Remark</u>: The expressions for cuboid and ellipsoid are de facto the same.

<u>n - Sphere</u> of radius 1.

$$v(n) = \gamma^n$$

Let us show some values for γ = 0.9 (quite moderate value of uncertainty):

n	0	1	2	3	4	5	10	20	30	50
v(n)	1	0,9	0,81	0,729	0,656	0,590	0,349	0,121	0,042	0,005

34 *Remark*: The expressions for the cube and sphere are the same for *a = 2r*.

Generalization should be done: **The n-volume of the core of IF for non-zero uncertainty is a significantly decreasing function of the IF dimension n.**

3.3.2. Discussion of the combined effect of IF dimension and uncertainty

From this model should be concluded:

a. In presence of uncertainty the increase of the dimension of the IF significantly reduces the relative weight of its regular **core**. This effect impairs the conditions for reliable function of IF. For n > 10 the IF (for quite moderate level of uncertainty $\gamma = 0.9$) has relatively too high proportion of potential irregularity for practical purposes. That is probably the reason why system analytics following the experience and intuitive background try to keep the number of markers (and therefore the dimension of the IF) as low as possible[35,36].
b. Another way to improve the conditions for achieving the regularity of IF is to (re)construct it as robust as possible. It means that the acceptable degradation of regularity of the respective IF, (expressed by the coefficient ξ**)** is to be sufficiently high. Within the artificial part of the system it could be done quite easily. The redundancy in codes or artificial system elements should be utilized, as well as time redundancy or sophistical means of predictive diagnostics. But this way is of controversial value for a "man – machine" IF, as it often assumes in fact the reconstruction[37] of both interfacing parts of the respective system.
c. Specific discussion is needed for the class of interacting IF. In this case the effect of IF conjugation could emerge. This effect could either worsen or improve the regularity of respective IF.
d. Another possible approach is the construction of combined IF variables which may help to reduce the dimensionality of respective IF consequently. This approach is promising if the variables of IF are mutually dependent. A problem then arises with **geometric interpretation** that is important for the presented approach to the IF regularity task. The author decided to evaluate the potential of **fractal geometry** for this purpose, but no satisfactory results have been obtained yet.

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[35]They can do it (to some extent), utilizing some known simplification methods [5].

[36] This approach has also some remarkable links with epistemology, for example with the old, famous and in science very useful principle of "Occam's razor": "Frustra fit per plura, quod potest fieri per paociora", or later his successors: "Entia non sunt multiplicanda praeter necessitatem" William Occam (Ockham) (1285(?)– 1349)

[37] The "reconstruction" of human component of man – machine IF implies for example demanding specific training of the operator, or multiplication of the number of human operators. Such measures could be only rarely met.

Both the presented generalized model and its geometric reinterpretation could help to study and understand certain aspects of IF behavior in complex systems and systems alliances. The effect of interaction of interfaces in complex systems and systems alliances could cast the light upon the problem, why certain multidimensional interfaces with significant degree of uncertainty "work" quite reliably in spite of the opposite results of analysis and models. The analogy with the behavior of neuron synapses is probably of deeper nature. From the coarse level of distinguish, this problem reduces to the synergy of the structure and data redundancy, and therefore can hardly be successfully investigated.

3.4. Reliability in Information Systems.

Information is considered to be an important constituent of reality. Reality is determined by information relations between mass M and energy E. Information processes arise among mass, energy and information.

Information processes should be determined by a set of qualities the most important of them being:

- Information content,
- Information flow and
- Information power.

Information flows exist between sources and users of information. They are mediated by sources of the information flows. (Telecommunication systems, media).

Information processes are performed through some information operations (or combinations of operations), such as:

- Recognition of information,
- Translation of information,
- Interpretation of information,
- Coding / decoding,
- Aggregation and clustering,
- Filtration,
- Information sorting and storing, prediction,
- Activation (utilizing information to change the state of the object within which the information system "works").

Whichever relation among mass, energy and information is considered, mutual ability of translation / interpretation is of growing importance.

Translation of information during the course of information operations could be processed only with a limited degree of accuracy. The concept of translatability should be introduced for this quality. It is possible to show that for finite real system and for finite densities of M.E.I:

$$\text{Translatability} \leq 1.$$

This statement means that errors are natural phenomena in the course of all information translation processes in real systems. Error – free translation in reality would be achieved only scarcely, in limited interval of time, on very specific occasions.
The spectrum of errors or failure causes is very wide, from probabilistic fluctuations of some minor elementary entities to human mistakes on meta-level.

3.5. Reliability of Complex Heterogeneous Systems
In Complex Heterogeneous Systems owing the significant degree of uncertainty neither the Multilanguage, nor the Structural Analysis could be done correctly, eventually real information value of such analyses could be poor[38].
For example it could be impossible to distinguish, if the change of the frequency of system time is the manifestation of the ordering or chaotization.
From the engineering point of view it seems to be obvious that reliability of the systems transition to the chaotic processes is nonsense.
As a result, either sophisticated concept of structured reliability must be introduced [6], or the shift to a higher degree of abstraction should be tried.

4. Reliability of IP – system abstraction

System approach to the reliability of information power is more complex. Reliability subjected to the proposed study is the reliability of a model, following the scheme:

$$\mathbf{(M,E,I) \rightarrow I(M,E,I)}$$

What kind of a model is? It has to be both the model of the object reliability and the model of system features of the object. Reliability of the model is then introduced as the probability of isomorphic relation: OBJECT $\leftrightarrow$ MODEL in these systems features.
System features of the original (real) object could be determined within the framework of Systems Theory as dynamical goals:

- Location inside the both specified space - time interval and state –space area (Systems Reliability Theory defines this area as a “Region of Acceptability”.).
- Strengthening or at least conservation of the position of the object in (dynamically changing) environment.

To study and to determine these goals, Systems concepts of **Architecture** and **Identity,** and to some extent also “European” concept of **Interoperability** could be utilized.

[38] This notion is a manifestation of “Zadeh′s principle”: The more complex the system under study is, the less is the number of certain non-trivial statements that could be done.

4.1. Identity

System identity is the entity, introduced by Vlček et al. [15] to express (in as compact form as possible) the relation of the complex system with the neighborhood.

The identity is defined at two basic levels: (A) Internal, (B) External.

(A) Level is constructed in the dimensions of type, uncertainty and relative weight of goal – oriented processes.

(B) Level is expressed in the dimensions that reflect the impact of the system to the neighborhood.

Quantitative construction of Identity forms a 7 dimensional vector of the components:

1. "Tuning": $\mathbf{Tu = \Sigma IF_R / \Sigma IF}$, where $\mathbf{\Sigma IF_R}$ means the number of all regular interfaces in the respective system, while $\mathbf{\Sigma IF}$ means total number of interfaces in this system
2. "Type": $\mathbf{Tp = \Sigma\delta / M}$, where $\Sigma\delta$ means the number of strong processes in the system of interest, while **M** means systems magnitude[39].
3. "Goal - weight": $\mathbf{Gw = \Sigma\gamma / M}$, where $\Sigma\gamma$ means the number of goal - oriented processes in the system of interest, while **M** means systems magnitude.
4. "Goal – stability": $\mathbf{Gs = 1 - D(\gamma)}$, where $\mathbf{D(\gamma)}$ means the averaged dispersion of goal - oriented processes in the system of interest.
5. "Extrovert orientation" : **Ex = OUT / (IN+OUT)**, where **OUT** is total number of output states[40] of the system of interest, while **(IN+OUT)** is total number of the states of the system boundary elements.
6. "Importance" (for the higher system HS) : $\mathbf{Im_{HS} = OUT}\ \delta / \delta_{\mathbf{HS}}$, where **OUT** δ is the number of output states of the strong processes of the system of interest, participating in the same time in the strong processes of the higher system HS, and $\delta_{\mathbf{HS}}$ is the total number of strong processes of HS.
7. "Coherence of goals" (with higher system HS) : $\mathbf{Cg_{HS} = OUT}\ \gamma / \gamma_{\mathbf{HS}}$ where **OUT** γ is the number of output states of the goal - oriented processes of the system of interest, participating in the same time on goal - oriented processes of the higher system HS, and $\gamma_{\mathbf{HS}}$ is the total number of goal - oriented processes of HS.

The Identity of an object can be constructed in two steps:

$$\text{Object} \rightarrow \text{specific constructed system} \rightarrow \text{Identity [3]}$$

[39] i.e. the cardinality of the set of systems processes

[40] i.e. the sum of the output boundary element states of the system of interest

4.2. Architecture

Architecture in a general sense could be introduced as a <u>constructed teleological system model</u> of the object of interest with two key features:

- Existence within specified (abstract) space
- Carrying – out defined or identified systems function.

Architecture can also be constructed as a weighted unification of a triple of system models (See scheme in Fig. 9):

1. **<u>O</u>**bject (what)
2. **<u>I</u>**nfrastructure (where, when – in relation with a higher system)
3. **<u>A</u>**im (how, why – in relation with the subject – systems analytics).

Common understanding of architecture prioritizes the second point.

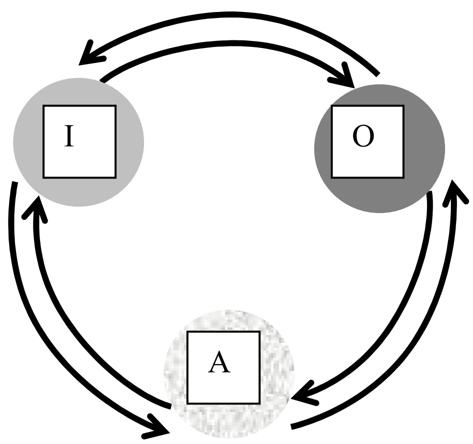

Fig 9. Scheme of the construction of architecture.

More frequent and less general pragmatic division of architectures introduces several points of view:

- General
- Logic
- Physical
- Object – oriented
- Topological

Etc.

4.3. Interoperability

This concept is quite frequent in "European" materials. It is defined within European standards as well. Unfortunately, there are many slightly different definitions which are mutually hardly compatible and they can be distinguished

at different levels as well. Interoperability of railway interlocking systems is defined quite accurately while e.g., interoperability of telecommunications systems could be understood in a slightly different manner.
Evidently the **dominant feature of interoperable systems is reliability (of representation) of standard execution of strong systems processes.**
If the problem is analyzed on the interface level of distinction, interoperability could be understood as a unique feature of the system in which acceptable degradation[41] of all systems interfaces which participate in the execution of strong processes occurs. The concept of interoperability is therefore equivalent to the at least "weak regularity" of interfaces between strong systems elements.
The specific European problem is the interoperability of the existing systems (for example of telecommunication or transportation nature). From the existing "menu" of regularization procedures[42] only the insertion of conversion element is feasible. That is probably why the reaching of the interoperability in the European context is so difficult and quite often also uneconomical task.

5. Construction of Systems Approach to the Reliability of Information Power

Systems constrains:

- "Location in space-time and state-space" and
- identity

could be integrated into the concept of **identity of architecture**.

Systems constrains:

- "Location in space-time and state-space" and
- interoperability

could be integrated into the concept of **interoperability of architecture**.

The respective sequences of representations are then:
Object → Architecture & Identity → Identity of Architecture

or

Object → Architecture & Interoperability → Interoperability of Architecture

[41] "Acceptable degradation of interface" isa well defined feature of interface within the body of systems analysis. This feature can be also called "weak regularity".
[42] (ie. reconstruction of systems element; modification of element interconnection; utilization of redundancy in functions of elements or interconnections and inserting of the conversion element)

<u>Reliability of Information Power</u> could be then recognized alternatively as:

- Reliability (of representation) of the Identity of Architecture
- Reliability (of representation) of the Interoperability of Architecture.

The first construction is more powerful and accurate. It is the consequence of the rich and more accurate semantics of the concept of Identity. Let us accept it.
Reliability of IP could be then decomposed into (the representations of) three components:

- model of space-time.
- model of the evolution of identity.
- model of the evolution of strategic state of identity.

Reliabilities of these models (and also the reliability of their chaining) could then be deduced from reliability of <u>translation</u> (interpretation) of the respective Multilanguage, and this concept could be further related with the <u>completeness of grammars</u>. The reason is obvious: These models originate in the respective system Multilanguage.
Gross scale understanding of the problem could be gained if the <u>$\Re$ function</u> is introduced and utilized.
<u>$\Re$ function</u> is the difference of (actual) identity and strategic identity of the system of interest.

$$\boldsymbol{\Re = Id\ (t) - StId\ (t)}$$

From the mathematics point of view $\Re$ is a well defined function. Both actual and strategic identity are vectors of the same dimension. Time evolution of strategic identity is usually slower then the evolution of actual identity. Both these variables depend on time.
Ordering effect of IP is expressed in the approaching of $\Re$ function to zero.

$$\lim_{t\to\infty} \Re = 0$$

Time evolution of $\Re$ expresses at this higher level of abstraction <u>reliability of IP</u>.
Situation is schematically illustrated in Fig. 10.

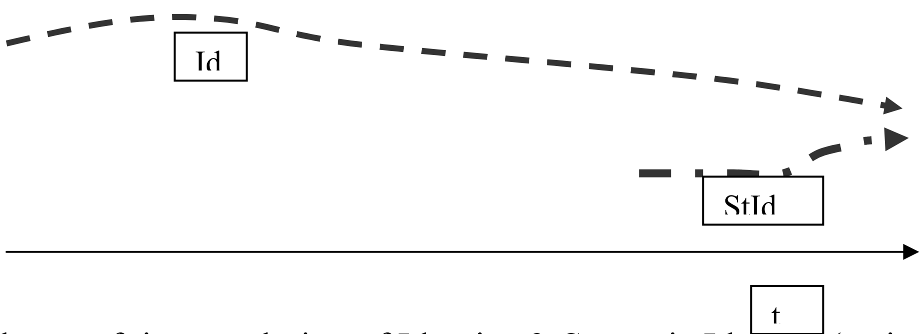

Fig. 10. Scheme of time evolution of Identity & Strategic Identity (active ordering effect of IP).

6. Discussion

At the Interpreted System level the Reliability of Information Power is defined as a probability of specified change of System time which is a response to input information. This definition cannot help us to distinguish whether Information Power has ordering or disordering effect on the System of interest.

To avoid this shortcoming a transition to the higher level of abstraction is done. This step results in the analyzing of certain representation of the information power reliability. This shift implies additional prerequisites – introduction of concepts of Systems Architecture, Identity or Interoperability. On the other hand this transition can help us to define Reliability of Information Power via the concept of Reliability of the Representation of Identity of Architecture, and even to quantify it by the speed of the approaching of the difference between an actual Identity and Strategic Identity to zero.

Serious problem of potential chaotic behavior of systems in information field has been partially solved by utilizing the evolution of $\mathfrak{R}$ function. This result is a consequence of the fact that the concept of strategic identity, constructed with the aim of supporting chaotic behavior, is a nonsense from the engineering point of view. (An assumption that the difference between identity and strategic identity decreases in the course of time is an important system goal for "well – designed" systems.)

This success is neither complete nor final. Chaotic behavior of the system in information field remains possible as a consequence of poor system identification. This is, however, a common problem of systems identification.

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Further activities:
In seventies: teaching in postgraduate courses at CTU in Prague, Faculty of Electrical Engineering
1980-1990: Seminars, consultancy and research at the Charles University, Faculty of Mathematics and Physics

Awards:
Gold and Silver Felber′s Medals of CTU in Prague; Perner′s Medal of Jan Perner University in Pardubice

Membership in professional communities / bodies:
- Union of Czech and Slovak Mathematicians and Physicists
- IEEE (USA)
- Scientific Council of the Faculty of Transportation Sciences
- Grant Agency of the Czech Republic
- Evaluating Committee of the Ministry of Transport, Czech Republic
- Branch Council of Engineering Informatics CTU in Prague, Faculty of Transportation Sciences.
- Cybernetic Society of the Czech Republic