QUANTUM INFORMATICS AND SOFT SYSTEMS MODELING

*M. Svítek**

Abstract: This paper elaborates on the area of physical information analogies and introduces new features such as the distance between wave probabilistic functions or sets of new information quantities such as strength, strength moment, strength potential energy and generalized charge. New parameters are used to define the rules for a quantum node. The knowledge cycle, which is equivalent to the Otto thermodynamic cycle, is adopted for modeling of the soft systems together with its static and dynamic information stability. Looking at the closed knowledge cycle, the evolutionary field equivalent to a magnetic field is therefore determined.

Key words: *information physics, physical-information analogies, component strength, strength moment, strength potential energy, generalized charge, knowledge cycle, quantum node, static information stability, dynamic information stability, evolutionary field*

Received: October 19, 2019 **DOI:** 10.14311/NNW.2020.30.010
Revised and accepted: April 30, 2020

1. Introduction to quantum informatics

A new class of Information Physics was introduced [1], where it was proposed that the physical entropy would be a combination of two magnitudes that compensate each other. The observer's ignorance is measured by Shannon's statistical entropy [4] and the algorithmic entropy measures the disorder of the observed system (the smallest number of bits needed to register it in the memory).

Atlan [5] defined that the system's order is a commitment between the maximum information content (possible variety) and maximum redundancy. The ambiguity can be described as a noise function, that can be manifested in a negative way (destructive ambiguity) with the classical meaning of disorganizing effect, or in a positive way (autonomy producer ambiguity) that acts by increasing the relative autonomy of a part of the system, reducing the system's natural redundancy and increasing its informational content.

We can extend Zurek's approach [1] to a complex domain, where physical entropy is a variable that can be decomposed into x- and y-axis. x-axis means the

*Miroslav Svítek; Czech Technical University in Prague, Faculty of Transportation Sciences, Konviktská 20, Prague 1, Czech Republic, E-mail: svitek@fd.cvut.cz; Matej Bel University, Faculty of Natural Sciences, Tajovského 40, Banská Bystrica, Slovak Republic

maximum variety (algorithmic entropy) and y-axis can be interpreted as a maximum redundancy (statistical entropy). This implies a certain ambiguity – bit capacity of a physical system put by Shannon, or semantic content (meaning) [17].

An alternative inspiration for the interpretation of a complex domain can come from the definition of identity [2] that can be decomposed into endogenous (regularity, goals, species) and exogenous (openness, acceptances) components. x-axis can project endogenous and y-axis exogenous components, respectively.

Quantum information science was introduced in [11] and extended to information circuits and networks in [12, 13]. In [7] a wave information flow ϕ and wave information content I were introduced. The x-axis of complex domain is the real-world part. Positive value of x-axis is an information gain (benefit) achieved by the information values (information flow, information content). On the opposite, a negative x-value shows its loss. Positive values mean that the system distributes an information flow or information content, the negative one to consume it. It is important that we can easily measure these values because they are real (endogenous) parameters.

The imaginary part is determined by y-axis and it is connected to an information environment or its system surroundings. The positive value of y-axis means a beneficial impact on its surroundings giving a clearer environment or better mood. The negative y-values means a loss of environment such as pollution or ill humor. These (exogenous) parameters are not part of the studied system because they are given by the reaction of or acceptance of its surroundings.

Within a group of components, some of them can organize the environment (y-values) to obtain the real-world results projected on x-axis. In Noetic Field Theory [6] the ordering principle of the Unified Field is not a 5-th fundamental force of physics; rather it is a force of coherence (topological switching) modeled in quantum system theory by phase parameters. Just as quantum mechanics was invisible to the tools of Newtonian mechanics, so until now has the regime of the unified field (phase synchronicity) been invisible to the tools of quantum mechanics.

The typical representation of wave probabilistic flow ψ_ϕ and content ψ_I [7] is shown in Fig. 1. For other analyzes we will use only their real values easily marked as ϕ and I.

Section 2 of the paper presents the explanation of distance between wave probabilistic functions. Section 3 extends such approach to the author's interpretation of interaction's speed between wave components. Section 4 introduces for the first time new quantities such as component strength, strength moment, strength potential energy or generalized charge. In Section 5, the new approach is applied to modeling of the quantum node with the set of its input's and output's parameters. Knowledge cycle with the static and dynamic information stability is given in Section 6 as the example of soft system modeling. Section 7 concludes the paper.

2. Distance between wave components

Let us define a quantum component c (event, function, process, etc.) in complex domain (wave probabilistic function) with its real $x = \mathrm{Re}(\psi_c)$ and imaginary $y = \mathrm{Im}(\psi_c)$ parts as follows:

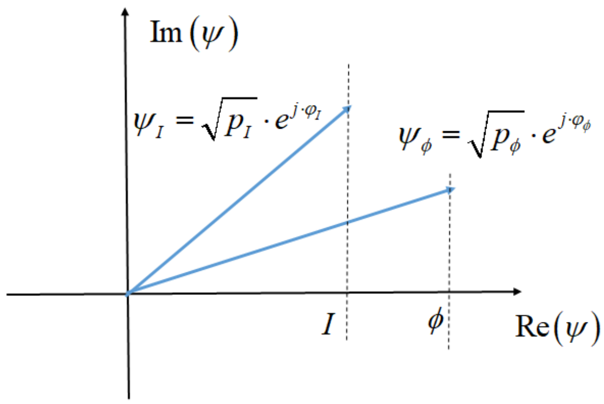

Fig. 1 *Representation of wave probabilistic flow ψ_ϕ and wave probabilistic content ψ_I.*

$$\psi_c(p_c, \phi_c) = |\psi_c| \cdot e^{j\cdot\phi_c} = \sqrt{p_c} \cdot e^{j\cdot\phi c} = \mathrm{Re}(\psi_c) + j \cdot \mathrm{Im}(\psi_c) \tag{1}$$

Value $|\psi_c| = \sqrt{p_c}$ is a c-component amplitude representing how often it occurs and the c-component phase ψ_c how it is linked to other components within system as a whole (a set of all components). Function ψ_c defines the ordering of all components and relations among them.

The *wave distance* between both wave probabilistic functions ψ_a and ψ_b can be defined as follows:

$$d = |\psi_b - \psi_a| \tag{2}$$

The parameter d expresses the square root of probability that ("a is active" AND "b is inactive") OR ("b is active" AND "b is inactive"). It corresponds to XOR logical function. It is clear that $d = 0$ means simultaneous 100 percent entanglement: ("a is active" AND "b is active") OR ("a is inactive" AND "b is inactive"). The closer wave probabilistic functions ψ_a, ψ_b are, the similar behavior pattern of a and b components can be observed. Synchronicity is the simultaneous occurrence of events that appear significantly related.

The maximal distance is given by $d = 1$ which means the simultaneous 100 percent entanglement: ("a is active" AND "b is inactive") OR ("a is inactive" AND "b is active"). The greater the distance, the more different behavior of a and b components (asynchronicity) is observed. The distance can also be understood as a measure like the physical distance between two points in space area.

Interpretation of wave distance can be e.g. through common communication. In the case of no communication, the behavior will be random. If the difference goes close to zero it means that both components are well connected and can behave synchronously. If the distance approaches one it means that the components also communicate with each other but behave as asynchronously as possible.

The disappearance of information can be arranged by thresholding the resolution of states. If a distance between states is smaller than the selected delta we

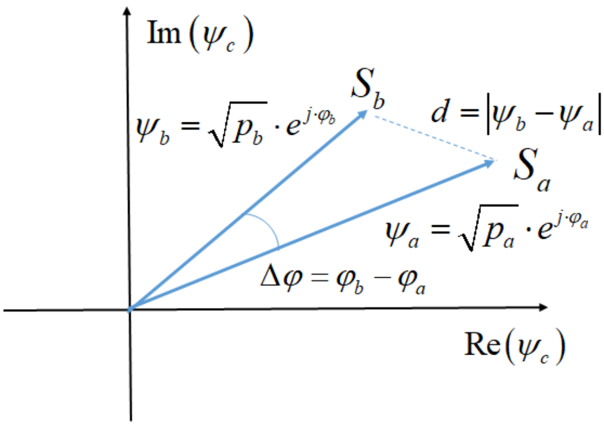

Fig. 2 *Representation of wave probabilistic functions together with the strengths of a, b components.*

consider states as indistinguishable (they merge). The information can be alternatively taken as conservative (similar to energy), but gradually entangled with other states of the system or its environment. The number of states is of course growing leading to gradual "thickening of space-time".

3. Interaction's speed between wave components

Let us consider two components a and b described by:

$$\psi_a = \alpha_a|0\rangle_a + \beta_a|1\rangle_a \tag{3}$$

$$\psi_b = \alpha_b|0\rangle_b + \beta_b|1\rangle_b \tag{4}$$

We suppose their interconnections:

$$\psi_{a,b} = \alpha_a \cdot \alpha_b|00\rangle_{a,b} + \alpha_a \cdot \beta_b|01\rangle_{a,b} + \beta_a \cdot \alpha_b|10\rangle_{a,b} + \beta_a \cdot \beta_b|11\rangle_{a,b} \tag{5}$$

This relation can be interpreted as a set of wave probabilistic functions $\alpha_a \cdot \alpha_b$, $\alpha_a \cdot \beta_b$, $\beta_a \cdot \alpha_b$, $\beta_a \cdot \beta_b$, assigned to all variants of connected a, b components. The well-known Copenhagen interpretation of quantum mechanics [10] is based on probabilities $|\alpha_a \cdot \alpha_b|^2$, $|\alpha_a \cdot \beta_b|^2$, $|\beta_a \cdot \alpha_b|^2$, $|\beta_b \cdot \beta_b|^2$. The process of the measurement (decoherence) means that a set of feasible states randomly falls in one combination with respect to its probability.

We can introduce a different point of view on interpretation of wave probabilistic functions and use the distance probabilities $|\alpha_a - \alpha_b|^2$, $|\alpha_a - \beta_b|^2$, $|\beta_a - \alpha_b|^2$, $|\beta_a - \beta_b|^2$ for further analyze. The closer wave functions are, the higher synergy between them is expected. It is analogous to the key and lock. The closer they are, the sooner we can unlock the door. If the distance is equal to one the connection can; with difficulty; happen in a short period of time because there is a low chance of two components interacting with each other. The lower distance means the higher probability that both states happen simultaneously. The distance probabilities are different than the probabilities of falling one of the states $|00\rangle_{a,b}$, $|01\rangle_{a,b}$, $|10\rangle_{a,b}$ and $|11\rangle_{a,b}$.

Based on these findings, we can hypothesize that the interaction takes place faster between wave functions that are closer to each other. This may mean the proximity is due to historical experience because this combination has occurred in the past. The speed of response can therefore play a significant role in quantum decoherence [10]. The learning process may adopt the distances among wave probabilistic functions according to frequencies of their occurrences. The more often they simultaneously occur, the closer the wave functions are and the faster (not more often) this couple of states will be selected. Historical experiences could be responsible for prior phase settings among system's components (events, functions, processes, etc.).

In the case of two hemispheres of the brain, right one is responsible for collecting the data and the left one for interpreting them (creating stories). Intuitive interconnection leads to a scenario that is unlikely but has been realized in the past. After long thought and rational comparison of different combinations, we are able to find the most probable variant [8].

A similar dependence can be observed between different sensory perceptions. For example, there may be a short distance between the wave functions assigned to vision and smell. When we remember the sense of smell, we can automatically recall a visual impression.

4. Component strength

In previous theories [14–16], we always assumed that the studied system is closed that means without the possibility of adding or subtracting energy to any component. Unfortunately, for closed systems the wave function does not cover possibilities however powerful the c-component could be after adding new energy.

Let us extend the quantum model to open systems. Based on this fact we must introduce the new parameter *component strength* S_c showing how the component is subjected to common interactions. In analogy to physics, a mass is used for gravitation interaction [18], the electrical charge is defined as an essential part of electrical field. In Standard model [10] the quark color is developed for definition of interactions as well.

Positive value of component strength $S_c > 0$ means the ability to organize; negative value $S_c < 0$ leads to disorganization (making the chaos). Component strength can be managed by many instruments such as political influences, financial power, innovation ability, new energy source, etc.

Strength moment SM_c of c-component represents its efficiency (it is a vector because ψ_c is vector)

$$SM_c \propto \psi_c \cdot S_c \tag{6}$$

This symbol $\propto$ means equality, except for a normalization constant that will be the same for all components. It will calibrate the entire quantum model. If the size of the module of ψ_c is small, even a large strength will not be reflected in the system.

The *strength potential energy* SW_c assigned to c-component can be expressed by squared strength moment (potential energy is scalar):

$$SW_c \propto p_c \cdot S_c^2 \tag{7}$$

From the physical analogy, we can define the interactions between a and b components:

$$SW_{a,b}(d) \propto \frac{S_a \cdot S_b}{|\psi_a - \psi_b|} \propto \frac{S_a \cdot S_b}{d} \tag{8}$$

The values S_a, S_b, therefore, can be understood as *generalized charges* situated in wave probabilistic space as it is shown in Fig. 2. The value $S_{a,b}(d)$ represents a link between two components (events, functions, processes). General charges with different signs repel, with positive attract.

Strength potential expresses how the observer ψ interacts with a selected a-component ψ_a

$$SP_a(\psi) \propto \frac{S_a}{|\psi - \psi_a|} \tag{9}$$

For N different components, we can rewrite the strength potential of the whole system

$$SP(\psi) \propto \sum_{a=1}^{N} \frac{S_a}{|\psi - \psi_a|} \tag{10}$$

Strength potential energy SW_c describes how the new $(N+1)$ component c perceives it due to interactions to the all other N components:

$$SW_c(\psi) \propto S_c \cdot \sum_{\substack{a=1 \\ a \neq c}}^{N} \frac{S_a}{|\psi_c - \psi_a|} \tag{11}$$

The smaller a new c-component $|\psi_c|$ the bigger influences; are caused by surrounding components it perceives. On one side, it is the energy source but on the other side, such component is fully dependent on it's surrounding (very small resilience). In case of rapid changes of outside information environment the c-component can loose the source of energy and not survive.

5. Quantum node

For more complicated structures of quantum circuit [15,16] we need to invent other rules. In Fig. 3 there is a quantum node $\{\psi, S\}$ with two inputs $\{\psi_a, S_a\}$, $\{\psi_b, S_b\}$ and two outputs $\{\psi_c, S_c\}$, $\{\psi_d, S_d\}$.

Generally, we can introduce *Strength Moment Conservation Law* that leads to the analogy of the *Information Kirchhoff's Law*:

$$\sum_{k=1}^{N} \psi_{IN,k} \cdot S_k - \sum_{n=1}^{M} \psi_{OUT,n} \cdot S_n = \psi \cdot S \tag{12}$$

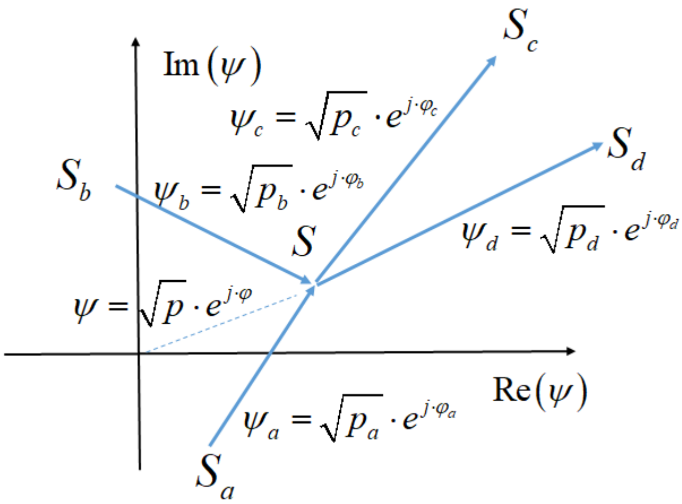

Fig. 3 *Strength Moment Conservation Law and Information Kirchhoff's Law.*

The node strength moment $\psi \cdot S$ is equal to sum of N inputs strengths moments minus M outputs strengths moments.

Let's show Strength Moment Conservation Law on the example of a small company consisting of three employees, whose mutual relations are given by functions ψ_a, ψ_b, ψ_c, where the modules show their effectiveness and phases the ability to cooperate. However, each of the employees has a different benefit for the team expressed in terms of strengths S_a, S_b, S_c. This benefit can be either a unique knowledge or a connection to a good customer.

At the same time, a group of workers consumes energy cost expressed by strength S_E and space rental price S_S. The assigned wave probabilistic functions ψ_E, ψ_S show their adequacy (modules of wave probabilistic functions) and the compliance of employees with these items (phases of wave probabilistic functions). Because it is an output from the node, the strength moments $\psi_E \cdot S_E$, $\psi_S \cdot S_S$ will have a negative sign.

The goal is to determine the performance of such a team, which leads to the application of the Strength Moment Conservation Law:

$$(\psi_a \cdot S_a + \psi_b \cdot S_b + \psi_c \cdot S_c) - (\psi_E \cdot S_E + \psi_S \cdot S_S) = \psi \cdot S \tag{13}$$

The determination of the parameters ψ and S of the quantum node is based on the normalization conditions of the wave probabilistic functions. A quantum node will be most effective if the phases are synchronized in the same direction. In this case, the potential of the team created is best used. At a higher resolution level, it is of course possible to monitor the performance of the distributed network of groups of quantum nodes created in this way.

6. Knowledge cycle

The inspiration for derivation of *knowledge cycle* came from well-known Otto thermodynamic cycle [9] that was adopted for the soft systems modeling. In the next part only real values of information flow ϕ and information content I will be used to describe the examples.

First illustrative example describes the process of the product development and its placement on the market. Let us start in the point A in Fig. 4 where we have some initial conditions – input information flow ϕ_A and input information content I_A. For construction of the initial state A, we need to transform the potential I_A into measurable information flow ϕ_B often mentioned as "know-how". This transformation is done at the cost of losses of information content because it costs some effort (money). The point B with its ϕ_B, I_B is a starting point to present the new product to an investor and ask him for additional financial support E_1 that increases the possibilities of the realization of the business plan. The financial support E_1 transforms the system into the C point ϕ_C, I_C with the same knowledge but with a higher potential for construction.

The most important part of the knowledge cycle is the realization of the business plan represented by a transition from the point C to the point D. During this phase the knowledge ϕ_C is transformed into a higher value of I_D. It is understandable that during the transition from the point C to the point D, the original knowledge ϕ_C is gradually exhausted. In the point D, we can withdraw money or use the energy obtained. Then, the system returns into the point A and it waits for new business ideas.

We can easily imagine that the company is working parallel on many other products located in different positions of the knowledge cycle. It can yield into *dynamic information stability* introduced for the explanation of living organisms [3]. The emergence and extinction of various products, or living organisms, leads to a constant balanced movement on the knowledge curve but always with other products or individuals. It is an analogy to uniform motion in Newton's equations.

The *static information stability* known as the second law of thermodynamics is characterized by maximum entropy that leads to random motion. In wave diagram (Fig. 2) it means that a sum of all random components is close to zero.

The area under points A, B denotes the input information power, the total area under points C, D the output information power and the area enclosed by the points A, B, C, D represents the gained information power (benefit).

Fig. 4 is in principle the analogy of the heat pump because the movement along the knowledge curve is counterclockwise. In this case, it is assumed that some energy is inserted inside and more energy is obtained outside. This corresponds to the product development description.

The clockwise movement in the Otto's or more generally Carnot's cycle [10] describes the thermal engine how to transform the thermal energy into movement. For us it means the use of invested money E_2 in the point D and their transformation into the information flow ϕ_C in the point C. Loss of energy E_1 is caused by unusable information. The path from the point B to the point A means practical construction of obtained information flow. This is how scientific and research institutions work.

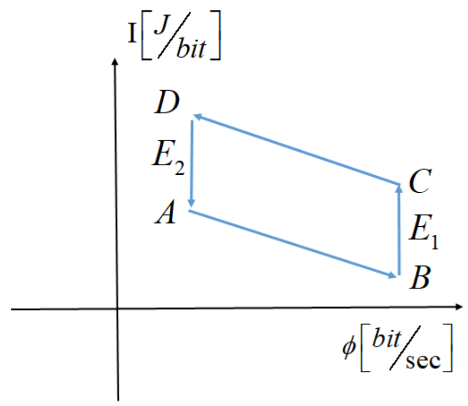

Fig. 4 *The knowledge cycle as an analogy of the heat pump.*

Looking at the closed knowledge cycle, an analogy with the magnetic field is offered. Such a field would affect other similar cycles. In Fig. 4 only one cycle is shown, but there may be more than one in parallel. The success of one cycle (larger area among the points A, B, C, D) will be reflected in the imitation of this success. It reminds one a little of the globalization of companies and the establishment of links to a number of subcontractors. In science, the emergence of a successful school around a prominent scientific personality could be explained by this theory. Such an *evolutionary field* could interpret the gradual increase in complexity in the search for new energy sources.

The evolutionary field can be analogical with the magnetic field because it has no sources and it is by-product of knowledge cycle. The circulation around the knowledge cycle (profit rate) introduces frequency and together with the area of cycle (total profit per cycle) defines the *strength of evolutional field*.

Let us take other illustrative examples of soft systems: the first one is the description of a living organism and the second one the creation of a new company. Fig. 5 shows the simplified knowledge circle with four areas. Area A is characterized by (initial) investment (negative I) and necessity for uploading of the work (negative ϕ). For the living organism this phase is typical for raising children where parents must invest a lot of money and effort to take care of them. For a new company it is the initial investment plus a lot of working hours of the company founders.

Efforts are beginning to appreciate in area B where the company is already beginning to make more and more money (positive I), even though it needs some effort, but it is shrinking. In the case of children, they are already becoming self-sufficient, but still require some effort.

Phase C is the most pleasant, because the company earns money (positive I) and gives space for extension of other activities (positive ϕ). In the case of people, it is the active age when they are financially without problems and they have the opportunity to manage all their activities.

The final phase D of the cycle is characterized by a reduction in freedom and the need for additional investment (negative I). This is typically the senior stage of life, where opportunities are diminished (smaller and smaller ϕ) and one requires some help (negative I). In the case of the company, it still produces, but the products are already subsidized. However, it is already clear that product renewal and new ideas must come so that the whole knowledge cycle will start again in area A.

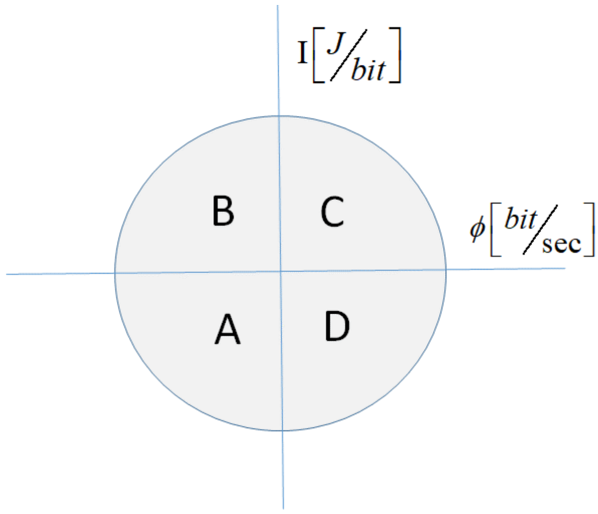

Fig. 5 *The circle knowledge cycle.*

In accordance with this principle the basic feature of life is collective behavior. Around the described knowledge cycle, at one point, there are a large number of people at different stages of life (from children to the elderly). If we look at the whole population, we still see the same picture of the circle over time, even with other actors. It's like watching a river that seems the same to us, but different drops of water flow there at any given moment. It is the principle known as kinetic stability of living population [3].

Another question is what is inside the circle (grey fill) in Fig. 5. There may be sub-elements that follow each other or cancel each other, so that the resulting circle can be created. It is equivalent to the application of an electric field to a material where positive and negative charges are created only on the surface, inside the forces are canceled out. It's the same with the magnetic field and partial currents inside the material [10].

7. Conclusion

This paper builds on previous ideas concerning physics-information analogies [14] and tries to further develop them. The unconventional approach can enrich the current view on information physics. Based on the presented ideas, it can be stated that the links between components (event, function, process, etc.) are determined by wave probabilistic functions [2, 7]. The modules of wave probabilistic functions indicate the square root of probability or the effectiveness of the components. The phases determine the organizational arrangement among them.

We have introduced positive or negative strength of components acting on its surroundings. Strength moment as a vector best describes a specific feature of each component. A component may be improbable, but have a great positive (leads to better organization of its surroundings) or negative (makes the chaos in its surroundings) effect. If the signs are different, the positive and negative effects cancel each other out. We interpret this situation as mutual attraction. With the same signs, the positive or negative effects add up according to the components' arrangements.

Each component can transform its energy into a wave field of arrangement and vice versa. For this reason we must monitor both the components' wave probabilistic functions and the components' strength for positive or negative components' manifestations.

Thanks to presented new view of information physics, we can describe the soft systems not only in "bits" but in "components dynamics" shortly "success events". This approach was previously mentioned [13] as knowledge flow in "success events per second" and knowledge content in "Joule per success event".

The new way of thinking about information physics led us to the knowledge cycle that can play an important role in soft system modeling. The examples showed how knowledge systems can be explained in this way and how static and dynamic information stability can be defined. As this is the first attempt to extend the current perception of information physics, the presented examples are illustrative only. In the next phases of research, more complex situations will be addressed.

Acknowledgement

This work was supported by the Project AI & Reasoning CZ.02.1.01/0.0/0.0/15_003 /0000466 and the European Regional Development Fund.

References

[1] ZUREK W.H. (ed.) Complexity, Entropy and the Physics of Information, Santa Fé Institute, Studies in the Science of Complexity, 8, Addison-Wesley, Redwood City CA, 1990.

[2] VLČEK J. Systémové inženýrství (Systems Engineering), Ed. ČVUT, 1999, ISBN 80-01-01905-5, (in Czech).

[3] PROSS A. What is life? How chemistry becomes biology, Oxford University Press, 2016.

[4] SHANNON C.E. WEAVER W. The Mathematical Theory of Communication, University of Illinois Press, Urbana, III, 1949.

[5] ATLAN H. Entre le Cristal et la Fumée, Essai sur L'Organization du Vivant, Seuil, Paris 1979.

[6] AMOROSO R.L. (ed) (2010) Complementarity of mind and body: Realizing the dream of Descartes, Einstein and Eccles, New York: Nova Science.

[7] SVÍTEK M.: Towards complex system theory, Tutorial, In: Neural Network World 2015, 25(1), pp. 5–33, ISSN 1210-0552, doi: 10.14311/NNW.2015.25.001.

[8] GLADWELL M. Blink -The Power of Thinking Without Thinking, Back Bay Books, Little, Brown, 2005, ISBN 0-316-17232-4.

[9] MORAN M.J., SHAPIRO H.N. Fundamentals of Engineering Thermodynamics. 6th ed. Hoboken, N.J.: Chichester: Wiley; John Wiley, 2008.

[10] FEYNMAN R., LEIGHTON R., SANDS M. Feynman lectures of physics, Addison Wesley Longman, Inc., USA, 1966.

[11] VEDRAL V. Introduction to Quantum Information Science, Oxford University Press, 2006, doi: 10.1093/acprof:oso/9780199215706.001.0001.

[12] SVÍTEK M.: Quantum System Modelling, International Journal of General Systems, International Journal of General Systems, Volume 37, Issue 5 October 2008 , pages 603 – 626.

[13] SVÍTEK M., VOTRUBA Z., MOOS P. Towards Information Circuits, In: Neural Network World. 2010, 20(2), pp. 241–247.

[14] SVÍTEK M. Physics-Information Analogies, Neural Network World 2018, 6, pp. 535–550, doi: 10.14311/NNW.2018.28.030.

[15] SVÍTEK M. Quantum multidimensional models of complex systems, Neural Network World 2019, 5, pp. 363–371, doi: 10.14311/NNW.2019.29.022.

[16] SVÍTEK M.: Wave probabilistic information power, Neural Network World 2011, 21(3), pp. 269–276, doi: 10.14311/NNW.2011.21.016.

[17] BOUCHNER P., NOVÁK M., VOTRUBA Z.: How can artificial systems rise in a tool for mind?, Neural Network World 2019, 29(6), pp. 373–379, doi: 10.14311/NNW.2019.29.023.

[18] KRIZEK M.: Do Einstein's equations describe reality well?, Neural Network World 2019, 29(4), pp. 255–283, doi: 10.14311/NNW.2019.29.017.