3(2), pp. 44-108, 2005 **ISSN 1334-4684**

INTERDISCIPLINARY DESCRIPTION OF COMPLEX SYSTEMS

Scientific Journal

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INDECS, volume 3, issue 2, pages 44-108, year 2005
Published 30 December, 2005, in Zagreb, Croatia
Released online 30 December, 2005

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Publisher: Society znanost.org. Published twice per year.
Printed by *Ekološki glasnik, d.o.o.,* Donja Lomnica (HR).
This issue is printed in 300 pieces and recorded on 200 CDs.

ISSN: 1334-4684 (printed version)
1334-4676 (online version)
1334-5230 (CD-ROM)

The publisher, Society *znanost.org*, is non-profit civil organisation that supports Journal *Interdisciplinary Description of Complex Systems* (INDECS) through project V0301P.

Journal INDECS is financially supported by Croatian Ministry of Science, Education and Sport.

INDECS publishes original, peer-reviewed, scientific contributions prepared as reviews, regular and conference papers and brief and preliminary reports.
The official web page of the journal is http://indecs.znanost.org.

Note: The accessibility of all URLs in the texts was checked one weak before the publishing date.

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GUEST EDITORIAL

The DECOS 2005 workshop was a continuation of the series of international workshops on *Complex Systems in Natural and Social Sciences* (CSNSS), which took place in Hungary (Matrafured 1995 and 2002, Tata 1996, Budapest 1997 and 2003) and in Poland (Kazimierz Dolny 1999, Zakopane 2000, Torun 2001). Its purpose was to bring together the interdisciplinary groups of researchers working on complex systems and nonlinear dynamics in sciences, economy and humanities; to provide a forum for exchange of new ideas, for discussing the emerging topics and also for gaining fresh insights into possible applications of methods of sciences to study of socio-economic systems.

The Workshop was financially supported by Foundation of *Croatian Academy of Sciences and Arts*, by *Croatian Ministry of Science, Education and Sport*, and supported by *Matrix Croatica*.

We hope that this purpose has been fulfilled, at least partially, since definitive success cannot be expected in this “never-ending story” of interchange between real life and various research domains.

The articles for the workshop have been accepted after affirmative evaluation by the Scientific Committee.

Budapest and Krakow, 1 December 2005 Katalin Martinás and Marek Frankowicz

INDECSA

Dear readers,

the publishing of this issue, INDECS 3(2), denotes the beginning of the INDECSA 2006, the process of evaluation of the best article published in INDECS in year 2005, i.e. in volume 3.

Propositions for INDECSA are given in the document available from the INDECS web page, and are written in the INDECS 2(1).

The Commission for choosing the best article for INDECSA 2006 is the following:

1. Josip Kasač, President,
2. Petra Klarić-Rodik,
3. Katalin Martinás,
4. Marek Frankowicz,
5. Armano Srbljinović.

The President of the Commission is responsible for alignment of the evaluation process with the stated propositions. He prepares the final report which includes the title and the name of the corresponding author of the award winning article, as well as relevant details of the evaluation process. The report will be available from INDECS web pages and will be included in the issue INDECS 4(1).

The award will be given to the corresponding author of the award winning article during International Conference DECOS 2006.

The money sum for INDECSA 2006 is 400 EUR.

Zagreb, 1 December 2005 — Josip Stepanić

Interdisciplinary Description of Complex Systems 3(2), 44-58, 2005

ENERGY IN PHYSICS AND IN ECONOMY

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Conference paper *Received:* 21 November, 2005. *Accepted:* 1 December, 2005.

SUMMARY

In this paper the energy concept used in economic activity is investigated. It is not a "useful" part of physical energy, but an economically defined quantity.

To reach this conclusion we first give a summary of the classification of the different concepts – all bearing the name energy. There are at least six distinct concepts to be distinguished. Three of them are scientific concepts to be differentiated. The physical (conserved) energy belongs to the realm of the first law, the energy as the ability to perform (physical, chemical) work belongs to the second law, the economic (biological) capacity for actions belongs to the (Darwinian Law).

KEY WORDS

energy, history, teaching, interdisciplinarity

CLASSIFICATION

PACS: 01.40.gb, 01.55.+b

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INTRODUCTION

Energy is a unifying concept that spans all the sciences, and is of fundamental importance in issues of social concern such as the environment and the use of fuel resources. Energy is well-known concept. Everybody has an understanding, and the majority has a well defined, contradiction free concept. As a physicist, I had a very clear notion, too. The starting of the interdisciplinary work on the relation of economics and thermodynamics lead to the realisation, that the energy concept of economists is different. The explanation was given by Veronika Poór [1] who said:

“Energy is the quantity which is conserved in physics and which is consumed in biology.”,

“That is why the physical and the biological energy are different quantities”.

A systematic survey lead to the result that there are at least six different categories of the energy. All these energy concepts have some relations (historical or factual) with each other, but from scientific point of view, they are different concepts.

ENERGIES IN THE XXI. CENTURY

There are at least 6 different energy concepts, used in different parts of science or human activity, namely the metaphysical, the psychological, the conserved, the dissipative and the important (human) energies at last but not least we must mention the

E1) ENERGY THE COLLOQUIAL OR THE ENERGIA

The first meaning of the word energy in the Cambridge Advanced Learner's Dictionary: refers to the colloquial usage [2]: „Energy (STRENGTH) is the power and ability to be physically and mentally active.” Examples: “Since I started eating more healthily I've got so much more energy. I was going to go out this evening, but I just haven't got the energy. I didn't even have the energy to get out of bed. Her writing is full of passion and energy (= enthusiasm). I'm going to channel all my energies into getting a better job. I tried aerobics but it was too energetic for me. I felt very energized after my holiday.”

It is clear, that this energy concept does not coincide with the energy of physics.

We argue, that this meaning refers to the original Aristotelian concept.

“Energeia”, which is the root of our word energy, was created by Aristotle. It is generally translated as “activity.” However, it is not necessarily an activity in the sense that we might understand it. For instance, Aristotle describes both happiness and contemplation as activities. In calling happiness an energeia, Aristotle contrasts it with virtue, which he considers to be a hexis, or disposition. That is, the virtues dispose us to behave in the correct manner. Actually behaving according to the virtues, however, is not itself a virtue but rather the energeia of happiness” [3].

By Aristotle the proper function of man is [4] is “activity of the soul in conformity with reason (*psuches energeia kata logon*) (1098a7)”. In the Poetics the word energeia, for Aristotle, refers to the paradox of producing a powerful lifelike effect through words.

In ordinary English, the word energy first appears in the 16th century. For Elizabethans, energy means the vigor of an utterance, the force of an expression, always the quality of a personal presence. A hundred years later the word can qualify an impersonal impact: the power of an argument or the ability of church music to generate an effect in the soul. The term is still used exclusively for psychic effects, although only for those engendered by either a person or a thing. It is the colloquial energy. The online etymological dictionary [5] gives: "energy: 1599, from M.Fr. energie, from L.L. energia, from Gk. energeia 'activity, operation,' from energos 'active, working,' from en- 'at' + ergon 'work' (see urge (v.))." Used by Aristotle with a sense of "force of expression;" broader meaning of "power" is first recorded in Eng. 1665. Energise "rouse to activity" is from 1753; energetic of persons, institutions, etc., is from 1796. Energy crisis first attested 1970."

Crease wrote [6]: "As late as 1842 the Encyclopedia Britannica only gave the word the briefest of entries: 'ENERGY, a term of Greek origin, signifying the power, virtue, or efficacy of a thing. It is also used figuratively, to denote emphasis of speech.'"

This energy concept is present nowadays, too, as the ability to perform an action. This energy has the property that it can be lost and can be created. There were many attempts to find the interpretation of Aristotelian energeia in physics, see as for instance [7, 8], that is to establish the relation between energeia and the energy of modern physics. Nevertheless, they are distinct concepts, and there are only some metaphoric links.

E2) METAPHYSICAL ENERGY - ENERGY AS ARCHETYPE

The 'metaphysical energy' is rather well-spread not only among physicists.. The universe of the contemporary physicist is a world of material objects, and of energy. Matter and energy have been unified by relativity theory into a single substance, 'mass-energy'. Space and time have been unified, also by relativity theory, into a single 4-dimensional entity, 'space-time'. Thus, the modern physicist sees a universe that is quite simple and elegant: mass-energy (in various forms) moving through space-time. This was clearly Einstein's view:

"Matter which we perceive is merely nothing but a great concentration of energy in very small regions. We may therefore regard matter as being constituted by the regions of space in which the field is extremely intense … There is no place in this new kind of physics both for the field and matter for field (i.e. energy) is the only reality." (cited in [9]).

The distinction between mass and energy is considered as artificial. Eddington wrote[10]: "it seems very probable that mass and energy are two ways of measuring what is essentially the same thing, in the same sense that the parallax and distance of a star are two ways of expressing the same property of location".

Russell stated the same idea in 1948, when he claimed that [11]: "it is energy, not matter, that is fundamental in physics"

After a discussion particle-antiparticle annihilation experiments in 1951, Pauli states [12]: "Taking the existence of all these transmutations into account, what remains of the old idea of matter and of substance? The answer is energy. This is the true substance, that which is conserved; only the form in which it appears is changing."

Popper reiterated this view [13]: "matter turns out to be highly packed energy."

This energy concept belongs to territory of philosophy, so we do not deal with it further.

E3) CONSERVED ENERGY

This is the energy of physics. It is taught in the Secondary Schools. The usual introduction is as follows [14]: "Energy is an abstract quantity of extreme usefulness in physics because it is defined in such a way that the total energy of any closed physical system is always constant (conservation of energy). It is impossible to overstate the importance of this concept in all branches of physics from elementary mechanics to general relativity. Energy is measured in units of mass times velocity squared, and the MKS and cgs units of energy are the Joule and erg, respectively. Other common units of energy include the Btu, calorie, and kilowatt hour.

The important quantity in physics known as work, which is the product of applied force over a distance, has units of energy. In fact, the notion that heat is a form of energy was one of the most important developments in classical physics and thermodynamics.”

The last sentence already shows the sigh of the great confusion. Heat is not a form of energy. In this respect it is similar to work. No physicist says that work is a form of energy. Work is the transfer of energy from one physical system to another, especially the transfer of energy to a body by the application of a force that moves the body in the direction of the force. It is calculated as the product of the force and the distance through which the body moves and is expressed in joules, ergs, and foot-pounds. The equivalence of heat work was demonstrated by Joule, namely to produce the same heating effect 1 Joule work or 1 Joule heat is needed. Heat, as the work, is the name for energy transfer from a system to an other. If we look for a hot body, it is not a reasonable question: “How much heat does it contain?”. Heat is not a form of energy. Heat is a form of energy transport as work.

The sound description of E3 energy was given by the Nobel Prize winning physicist, Richard Feynman, who wrote [15]: “There is a fact, or if you wish a law, governing all natural phenomena that are known to date. There is no exception to this law – it is exact so far as is known. The law is called the conservation of energy. It says that there is a certain quantity, which we call energy, that does not change in the manifold changes which nature undergoes. That is a most abstract idea because it is a mathematical principle; it says that there is a numerical quantity, which does not change when something happens. It is not a description of a mechanism, or anything concrete; it is just a strange fact that we can calculate some number and when we finish watching nature go through her tricks and calculate the number again, it is the same.”

In conclusion, the conserved energy of physics does not have form. The forms of energy in physics is a heritage of the Newtonian framework, where the total energy is written as the kinetic energy plus the potential energy and plus the internal energy. Nevertheless, the independence of this terms is not valid in non-Newtonian approach.

E4) ENERGY AS A CAPACITY TO PERFORM WORK

Energy is sometimes defined in physics, too, as the ability to do work. The energy is usually introduced by this concept in schools, as in [16]: “Energy causes things to happen around us. Look out the window. During the day, the sun gives out light and heat energy. At night, street lamps use electrical energy to light our way. When a car drives by, it is being powered by gasoline, a type of stored energy. The food we eat contains energy. We use that energy to work and play.”

Here is the explanation of Cambridge Advanced Learner's Dictionary [2]: “Energy is the power from something such as electricity or oil, which can do work, such as providing light and heat.”

“The capacity for doing work as measured by the capability of doing work (potential energy) or the conversion of this capability to motion (kinetic energy). Energy has several forms, some of which are easily convertible and can be changed to another form useful for work. Most of the world’s convertible energy comes from fossil fuels that are burned to produce heat that is then used as a transfer medium to mechanical or other means in order to accomplish tasks. Electrical energy is usually measured in kilowatt-hours, while heat energy is usually measured in British thermal units (Btu).”

In physics that energy, that is the capacity to perform work, is mentioned as the useful part of energy. It has no separate name or symbol. In biology and in ecological economics it is called as “free energy”. Nevertheless, it does not coincide with the results of thermodynamics. Lozada [17] gave a careful and detailed analysis to this problem, and stated that: “changes in free energy as traditionally defined are not, in general, related to the amount of work a system can perform (although they are so related in special cases).”

In the engineering practice that “energy” is a well-defined concept, and it is called exergy [18, 19]. Exergy is the maximum amount of work that can be extracted from a physical system by exchanging matter and energy with large reservoirs in a reference state. This work potential is due to either a potential due to random thermal motion, kinetic energy, potential energy associated with a restoring force, or the concentration of species relative to a reference state. While energy is conserved, exergy can be destroyed. The second law (formulated by exergy) is the principle of exergy dissipation.

In physics the conserved energy and the working ability controversy is “solved” by the statement, that energy is the ability to perform work, but it has available and non-available forms, suggesting that the working ability is always less then the total energy. There are cases when it is right, but it is not always the case. In thermodynamics E3, the conserved energy, U has the form:

$$U = TS + pV + \mu N, \qquad (1)$$

where the symbols are S for entropy, V for volume and the N for mole numbers, while T is for temperature, p for pressure, and the chemical potential is μ. The working ability, E4 is the exergy, defined as:

$$B = (T - T_0)S + (p - p_0)V + (\mu - \mu_0)N. \qquad (2)$$

The environment is considered as an equilibrium system, with temperature T_0, pressure p_0 and chemical potential μ_0. Exergy can be expressed by as a function of energy as:

$$B = (1 - T_0/T)U + (p_0 - pT_0/T)V + (\mu_0 - \mu T_0/T)N. \qquad (3)$$

From the formula it is clear that there maybe cases when $B < U$ and as well as there maybe cases, where $U > B$.

A numerical example to illustrate the case is as follows. Imagine 1 mol helium of temperature 15 K is in a vessel in your room. The internal energy of the gas is given by the ideal gas law:

$$U = 3nRT/2, \qquad (4)$$

where n is the quantity of gas, measured in units of mol, T is the temperature and R is the gas constant (8,31451 J/mol K). The exergy (maximum available work) in the 300 K temperature room is (roughly)

$$B = 3700 \text{ J}. \qquad (5)$$

The exergy of the gas is much larger (3700 J) then its internal energy. The “useful” energy, used in colloquial physics for exergy, is not a part of the total energy – as the later can be smaller. The exergy is not conserved, but it is dissipated. The Second Law can be formulated as the decrease of exergy.

The source of confusion is that exergy and energy are both measured in Joule units. To emphasize the differences of their nature we propose the use of extropy, which is the entropic measure of the distance form the equilibrium [20 – 22]. There is a paper on the thermodynamics of extropy in the present issue, written by Veronika Poór [23]:

$$\Pi = B/T_0 = (1/T_0 - 1/T)U + (p_0/T_0 - p/T)V + (\mu_0/T_0 - \mu/T)N. \qquad (6)$$

Does the extropy have forms? The answer seems to be positive, if we look for the introductory sentences. We can talk about the wind exergy, solar exergy. On the other hand thermodynamics says the opposite. The exergy/extropy value is assigned to a system in its environment. Expression (2) implies that there is a heat exergy, when there is a temperature difference. There is a chemical exergy, when there is a chemical potential difference. But as T, p and μ are not independent – there must be always at least two differences. So we cannot speak about the form of energy or exergy or extropy. As if there was a temperature difference, and there was no pressure difference then there must have been a chemical potential difference, too. Otherwise the positivity of exergy/extropy is not fulfilled. The form of exergy/extropy is superimposed on the actual system by a subjective valuation, as we use usually one form of the difference. The temperature difference in case of heat engines is used. The used, exploited difference is the one which is useful energy for us. Usually it is not the total exergy/extropy of the system, but only a part – which is valuable for us. This is a valued form of exergy which belongs to the biological, economic energy.

E5) USEFUL ENERGY – BIOLOGY AND ECONOMICS

The biological (economic) systems are non-equilibrium systems from the point of view of thermodynamics. We can characterize them by their extropy, which must be positive. The more developed the system the higher is the distance form equilibrium, the higher is the extropy content. Second Law states, that the extropy is always decreasing, so to sustain the state (the activity) extropy input is needed. Nevertheless not only extropy, but extropy in a usable form is needed. The oxygen and hydrogen have more extropy than water, but as Lozada [19] explained: “But suppose I am dying of thirst on a desert island. If I have hydrogen and oxygen but no catalyst (such as platinum) to make them react, I will die; if I have water, I will live.”

As Witt summarized the characteristics of metabolism [24]: “Consider, for example, the more or less complex metabolism of living organisms. The outcome of that production process is organized living substance. It is maintained by the process not least through the transformations by which energy is made available for use by the organism from carbohydrates, fats, and proteins which have ultimately arisen from the photosynthesis of radiant energy provided by sun light. The latter, together with minerals, water, oxygen, and possibly some other organic compounds, represent the ‘inputs’ to that production.”

As it is emphasized by Witts’ summary, in biology and economics only that part of exergy is considered “(free) energy”, which is useful. Biological energy comes from solar energy. The energy from the sun is stored and transported in plants and animals as chemical energy in the bonds between atoms in molecules. Some biological energy is stored in phosphate bonds in a molecule called ATP. ATP can release its energy in many useful ways in cells, but it is not very stable, so it is not be a good way to store energy for long periods of time. For transport through an organism, or for longer term storage, biological energy can be stored in chemical bonds between carbon atoms in more stable molecules called carbohydrates.

Definition given by BEIng (Biological Energy Interest group) [25]: “We use the phrase ‘biological energy’ as a convention to refer to a specific social and technological endeavor: to use the metabolic capacities of organisms to convert some combination of light, biomass, organic compounds, gases and water into useful chemical-bond energy; i.e. storable, transportable, energy yielding molecules as well as industrially useful materials. Examples include hydrogen, methane, alcohols, ammonia and bioplastics.”

Nowadays in economics the energy is considered as fuel. A substance used as a source of energy, usually by the heat produced in combustion. The modern economic energy concept becomes popular with the energy crises, which is a great shortfall (or price rise) in the supply of energy to an economy.

All living organisms including humans dissipate extropy. In any production process an important factors of production can then trivially identified: the matter or materials, i.e. substances of a certain chemical or molecular composition, which are non-equilibrium systems. This inputs are transformed. The production is the transformation of extropy from a less useful to more useful form.

This valuation leads to a thermodynamic based definition of wealth. The economic wealth of an economic agent is defined as the quantities of goods owned by the agent (X_i) times the value of the i-th type of good (ν_i)

$$Z = \sum_i \nu_i X_i \ , \tag{7}$$

where X_i is measured in natural units, (kg, cubic meters or number of items), but there is a natural unit for economic goods, it is the extropy content (Π_i is the extropy content of the i-th type material good), then

$$Z = \sum_i w_i \Pi_i \ , \tag{8}$$

where w_i is the value of the i-type extropy [26, 27].

The energy term in economics is not simply the useful part of exergy, but it contains a valuation, too. That explains the failures to derive economic values from physical (thermodynamic) considerations. On the other hand this explains the emergence of environmental problems. As the "economically" non-useful parts of extropy have (had) zero values, they did not appear in the economic considerations. A very important (material side) of economic activity was neglected.

E6) PSEUDOSCIENTIFIC ENERGY

In the last decades we can feel the ever-growing popularity of different mystic energies (cosmic, Tao, chi). A short description found in the internet is as follows [28]: "When Taoism superseded most religions where the people previously believed in ancestral spirit worship the concept of the spirit was altered to Chi. Later Taoist schools or sects introduced multiple gods associated with fertility and nature and others kept the ancestral spirit aspect. Just as there is no one interpretation of a Christian the same is true of Taoism. Many 'New Age' Westerners have studied Taoism and have taken chi as to be more of an energy like electricity. Reiki is a form of acupressure used to stimulate such energy through nodes and energy streams in the body to heal internal and external body ailments. Alternative medicine in the West has associated chi in this concept. Chinese medicine balls twice as large as golf balls or larger are held in the palm of ones hand and are rotated by the fingers. This is believed to stimulate the energy channels in the fingers and heal many ailments. Acupuncture is another way of manipulating these energy flows and nodes on the body and was established by the Taoists."

There is a confusion about the meaning of _chi. This Chinese term does not correspond to energy in modern physics. People who translate _chi that way usually refer to the old, everyday sense of vigor or vitality. It has nothing to do with the physical sense of the word [29].

Sometimes these mystic energy followers consider these energies as the real generalisation of the energy of the science. For them the secondary school education in physics, that is the Newtonian energy concept – gives the basis to understand these "mystic" energy. According to a 2005 Gallup poll, 55 % of Americans believe in psychic or spiritual healing, based on this New Age energy.

That is the point where we have to mention the "Free energy" cult [30], or with other words, the perpetual mobile constructors. In the last 150 years at least 1400 "free energy" machines were patented in USA. They claim that certain special interest groups are suppressing technologies that would or could provide energy at reduced costs, reduced pollution output, or would or could reduce the energy consumption of various devices. The knowledge given by the education is not sufficient to avoid investments into this "miracle machines". United States Patent and Trademark Office (USPTO) has made an official policy of refusing to grant patents for perpetual motion machines without a working model. One reason for this concern is that a few "inventors" have waved a patent in front of potential investors, who may believe that said patent proves the machine works.

In the next chapter a summary of the historical development is outlined. We look for the answer, how this unifying character of energy did appear. How it is possible that one concept tends to incorporate the first, the second law of thermodynamics and the Darwinian-law.

HISTORY OF THE ENERGY CONCEPTS

E2-E3 THE ENERGY CONCEPT IN PHYSICS 1807-1853

By the middle of the nineteenth century the concept of energy was being employed to provide the science of physics with a new and unifying conceptual framework, which brought the phenomena of physics within the mechanical view of nature, embracing heat, light and electricity together with mechanics in a single conceptual structure. The establishment of the mechanical view of nature, which supposed that matter in motion was the basis for physical conceptualization, as the program of physical theory, and of the concept of energy and the law of the conservation of energy as principles unifying all physical phenomena, was the distinctive feature of the conceptual structure of nineteenth-century physics [31].

The concept 'energy' stemmed from Leibniz's vis viva and Mme. Du Châtelet's demonstration that earlier experiments showing that weights dropped onto a clay floor had impact depths proportional to the square of the velocity supported conservation of vis viva rather than momentum. The energy story begins with the work of Thomas Young 1807, when he proposed energy instead of vis viva. Thomas Young, lecturing to the Royal Institution on collisions in 1807, said that: "the term energy may be applied, with great propriety, to the product of the mass or weight of a body, into the square of the number expressing its velocity", thereby tying the word, apparently for the first time, to its modern concept. But Young's "energy" was not ours. It referred only to what we now call kinetic energy and did not even use our formulation of $mv^2/2$, it was the vis viva with a new name [32]. Sometimes it is said, that Thomas Young made up the word "energy" from a Greek expression that means "work inside". Energy is something that has "work inside it". You can use that energy and get work out of it. The only problem with this explanation is that the modern concept of work appeared as late as 1829 in physics. Coriolis studied mechanics and engineering mathematics, in particular friction, hydraulics, machine performance and ergonomics. He introduced the terms 'work' and 'kinetic energy' with their present scientific meaning. Coriolis began developing his ideas in 1819 and he showed some papers to Poncelet in 1824. Both Coriolis and Poncelet published in 1829; the paper by Coriolis being "Du Calcul de l'effet des machines". Despite the two papers appearing in 1829 there was no argument as to who initiated the idea, with Poncelet acknowledging that the word "work" was brought in by Coriolis [33].

Mayer in 1842 argued that lifting a weight of one kilogram to a height of 365 meters required the same Kraft or “force” as raising the temperature of one liter of water by 10 ^{o}C. This Kraft was the conceptual precursor of energy.

Helmholtz in 1847 did not use the word energy, his paper was about the Conservation of Force (KRAFT). In 1842 Justus von Liebig attempted to reestablish the mechanical theory of animal heat. Liebig tried to do this by experiments, whereas Helmholtz took a much more general path. Having mastered both physics and mathematics, Helmholtz could do what no other physiologist of the time could even attempt – subject the problem to a mathematical and physical analysis. He supposed that, if vital heat were not the sum of all the heats of the substances involved in chemical reactions within the organic body, there must be some other source of heat not subjected to physical laws. This, of course, was precisely what the vitalists argued. But such a source, Helmholtz proceeded, would permit the creation of a perpetual motion machine if the heat could, somehow, be harnessed. Physics, however, had rejected the possibility of a perpetual motion machine as early as 1775, when the Paris Academy of Sciences had declared itself on the question. Hence, Helmholtz concluded, vital heat must be the product of mechanical forces within the organism. From there he went on to generalise his results to state that all heat was related to ordinary forces and, finally, to state that force itself could never be destroyed. His paper “On the Conservation of Force”, which appeared in 1847, marked an epoch in both the history of physiology and the history of physics. For physiology, it provided a fundamental statement about organic nature that permitted physiologists henceforth to perform the same kind of balances as their colleagues in physics and chemistry. For the physical sciences, it provided one of the first, and certainly the clearest, statements of the principle of the conservation law [34 – 35].

The problem of thermodynamics that time was articulated by Kelvin [1852], who wrote [36]: “The whole theory of the motive power of heat is founded on the two following propositions, due respectively to Joule, and to Carnot and Clausius.

- Prop. I. (Joule) – When equal quantities of mechanical effect are produced by any means whatever from purely thermal sources, or lost in purely thermal effects, equal quantities of heat are put out of existence or are generated.
- Prop. II. (Carnot and Clausius) – If an engine be such that, when it is worked backwards, the physical and mechanical agencies in every part of its motions are all reversed, it produces as much mechanical effect as can be produced by any thermodynamic engine, with the same temperatures of source and refrigerator, from a given quantity of heat.”

Clausius in his 1854 paper [37] showed that in a heat-engine operation two kinds of heat transformations occurred at the same time. In each cycle of operation, the transmission transformation took place in its natural direction (heat dropped from a high to a low temperature), while the conversion transformation proceeded in its unnatural direction (heat converted to work). He recognised the conservation law, but he called the new quantity (u) as Sensible heat. Clausius has shown that in a conversion transformation

$$\mathrm{d}Q = \mathrm{d}U + p\mathrm{d}V \tag{9}$$

where U is a state variable, dependent only on the state-determining variables t and v (temperature and volume). Nevertheless he read it, that the heat supplied to the system could become either “sensible heat”, or it could be converted into work.

ENERGY IN THERMODYNAMICS

Rankine in the 1853 – 55 papers, entitled as “Nature of the Science of Energetics” introduced the word energy to thermodynamics [38]: “Energy, or the capacity to effect changes, is the common characteristic of the various states of matter to which the several branches of physics relate; if, then, there be general laws respecting energy, such laws must be applicable, mutatis mutandis, to every branch of physics, and must express a body of principles to physical phenomena in general."

The term "energy" comprehends every state of a substance which constitutes a capacity for performing work. Quantities of energy are measured by the quantities of work which they constitute the means of performing.

"Actual energy" comprehends those kinds of capacity for performing work which consists of particular states of each part of a substance, how small so ever; that is, in an absolute accident, such as heat, light, electric current, vis viva. Actual energy is essentially positive.

"Potential energy" comprehends those kinds of capacity for performing work which consists in relations between substances, or parts of substances; that is in relative accidents. To constitute potential energy there must be a passive accident capable of variation, and an effort tending to produce such variation; the integral of this effort, with respect to the possible motion of the passive accident, is potential energy, which differs in work from this – that in work the change has been effected, which, in potential energy, is capable of being effected.

Already in the XIX. century the Beneck Foundation asked to answer the question whether Young's and Thomson's concept of 'energy' were equivalent to what Helmholtz called 'force'. There were two entries, but no first premium was awarded. The young Max Planck won the 'second premium' with a book-length essay [39] entitled "Das Prinzip der Erhaltung der Energie", Leipzig: Teubner Verlag, 1908 (1887).

ENERGETICS 1870-1945

"Energetics Movement" associated with Wilhelm Ostwald around the turn of the 20th Century. Ostwald advocated a World Government based on the use of "energy" as the universal, unifying concept not only for all of physical science, but for economics, psychology, sociology and the arts. Ostwald argued that all observable phenomena should be reduced to the principle of energy, and he proposed the development of all scientific fields in terms of energetics [40]. At first only inanimate matter was to be reduced to this principle, then the phenomena of life were included, and finally, from 1900 onwards, Ostwald attempted to account for psychological phenomena as energetic processes.

Although the energeticists are now mostly forgotten, the Cult of Energy remains deeply embedded in European culture. Over the course of the 20th century, modern physicists gradually developed our present conception of energy. Einstein had showed that mass, in itself, was energy. Energetics found its consummation and ultimate articulation in Einstein's theory of relativity, in which he formulated the famous equation $E = mc^2$, showing that matter and energy were, in fact, fundamentally equivalent. The concept of a single entity, mass energy, resolved much of the tension between competing theories of matter and the theories of energy, unifying the two concepts in larger, transcendent framework.

Our unified energy concept is the child of energetics. That is the root of the energy cult, and the root of the popular opinion that all the changes can be described as transformation of energy from one form to an other form.

This energy concept problem is not a mere grammatical problem. It is not a question that distinct concepts bear a common name. The problem is that they are not distinguished. The resulting chaos deeply effects the learning and understanding of physics in the schools. Further it has a serious impact on the handling of energy issues.

PRESENT – ENERGY PROBLEM APPEARING IN THE LITERATURE

Energy (nowadays) is the capacity to perform actions. That thing we call energy in day-to-day usage is not always the energy of science. It is not the conserved energy. Not even close! On the other hand in science it is considered that there is only one energy, the conserved one, and physics also talks about the energy forms. The confusion is well demonstrated, and well investigated in the schools. There is a serious problem with the teaching of energy in schools. It is not a school problem, as those, who did not get a solid energy concept in the school, will not have the opportunity later to get it.

Trumper and Gorsky [41] investigated the energy concept of children. They identified nine distinct conceptual frameworks, cited by Sefton [42]. Characteristics of these broad conceptions what they found that refer to capacity to perform actions. It is clear, that in spite of all the efforts of education of physics the conserved energy concept is far from the students.

In the following we give a correspondence between our classification and the conceptual framework of Tumper and Gorsky. As the two classification is based on different principles, the relation is not very solid. Nevertheless Tumper and Gorsky prove that E3 – E5 appears. Definitions belong to the evaluation of the children, and the E numbers to our classifications.

Table 1. Correspondence between work of Tumper and Gorsky and classifications of energy.

Tumper&Gorsky	**E**					
	1	**2**	**3**	**4**	**5**	**6**
1. Energy is associated with people	+				+	+
2. Things possess and expend energy	+	+	+	+	+	
3. Energy causes things to happen				+	+	+
4. Energy is an ingredient in things and can be released by a trigger				+	+	+
5. Energy is associated with activity	+	+	+	+	+	+
6. Energy is created by certain processes	+				+	+
7. Energy is a generalized kind of fuel associated with making life comfortable				+		
8. Energy is a kind of fluid which is transferred in some processes			+			
9. A scientific conception in which energy is transferred from one system to another			+			

Gregg Swackhamer gave a very concise summary of the problem, in his draft “Cognitive Resources for Understanding Energy” [43]. Here are some important statements:

- “One hundred and sixty years after its advent energy has become an indispensable concept for describing and explaining our world scientifically. Therefore it is now ubiquitous in school science curricula worldwide and regarded as of first importance universally by scientists and educators alike. Nonetheless, energy is not well understood by our students. Students graduating from secondary schools generally cannot use energy to describe or explain even basic, everyday phenomena.”
- “Energy as presented in school science is not a single, coherent concept, and it is not always consistent with the scientific energy concept. Furthermore the energy concept in the professional science education literature is not even unitary. As a result energy is not treated in consistent ways from year to year and from discipline to discipline in our schools. Today’s school science energy concept has retained and acquired connotations that contradict the modern scientific energy concept and that hinder its comprehension by teachers and students alike.“

The problem of the different connotations was already mentioned in 1914 by a Hungarian writer – Ferenc Móra [44]. Mora wrote a short article in a newspaper about Robert Mayer, with a good introduction of the First Law of Thermodynamics. He stated the grave conceptual problem as: “If I say that I do not believe in the conservation of energy than the Professors of

Physics will say that he is asinine, as he is a layman. If I say that I do believe in the conservation of energy than the Reader of this Journal will say that He is asinine, as he is a scientist."

Móra said, that he does not believe in the conservation of energy, as his energy disappeared: "Where is that Robert Mayer who can tell me where is my childhood's energy?"

This problem of understanding of energy is a problem of the schools. It is a grave problem, as the majority after the secondary school stops the education in natural sciences. My personal statistics support this result. The majority of non-natural scientists do not feel the energy concept, and the only understandable version is the E6.

The problem ican be summarised as Robin Jean did [46]: "It looks as if the first principle of thermodynamics and the word which is its stenographic token ('energy') had been allowed to be the Trojan horse for a contagion not only by ecologically and socially unsound, but also by culturally and symbolically destructive thought habits. Is perhaps the energy concept – the intellectual cathedral of 19th Century physics – a cultural equivalent of AIDS when it escapes from the lab and invades concrete life? Is the synonym-less word energy the vector of an acquired cultural immunodeficiency syndrome, as soon as it ceases to be strictly a technical term of a well-defined science, thermodynamics?"

CONCLUSIONS

E1-E6 energy concepts are basically different quantities, of different properties, which deserve a distinct name. From the list, E3-E4-E5 mean the real confusion, as they are usually measured in the same (energetic unit), and E4-E5 is considered in physics as part of E3, suggesting that the values (expressed in Joule units) satisfy the rule:

$$E3 > E4 > E5. \qquad (10)$$

This inequality is not always valid. It is valid only in some restricted cases (encountered mainly in textbooks). E3, the conserved energy is assigned to a system, the numerical value depends on the selection of the reference system. E4 refers to the actual environment, it measures the difference between the system and its environment. It can not be created. E5 refers to a human (or in biology to an organism) – it is the actual ability for action of the human. It is a valuated sum of the E4 energies. As Sung Tzu said 2500 years before in his work "The art of war" [28]: "Energy may be likened to the bending of a crossbow, decision, to the releasing of a trigger".

In this example E3 is the wood of the crossbow, E4 is the crossbow, E5 is the bended crossbow, which can be released. The E5 energy contains a valuation. It is not measured in Joule units, but in some subjective units. It is worthwhile mentioning that E5 is also a measurable, and well defined quantity in case it is connected with the economic wealth.

The following table summarises the properties of E3-E5. It compares the economic and physical and engineering energy concepts.

Table 1. Energy.

	E3 PHYSICS Total energy	**E4 Engineering Extropy**	**E5 Economy**
characteristics	neutral	neutral	valued
	abstract	abstract	human-specific
more like	mass	form	form
time behaviour	$dE_3 = 0$	$dE_4 < 0$	$dE_5 > 0$
governing law	conserved, First Law	dissipated, Second Law	can be produced, Darwinian law

ACKNOWLEDGMENTS

This work was partially supported by the Hungarian Science Foundation (OTKA) under contract number T 043522. For valuable comments and critique, thanks to Sergey Amelkin, Tamás Geszti, Attila Granpierre, Zoltán Homonnay, István Kun, Ágnes Nagy, Jean Robin, László Ropolyi, Paul Weaver and the members of the Hungarian Group for Thermodynamics. I thank for their help to Prof. Nathan Sivin and Gregg Swackhamer.

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ENERGIJA U FIZICI I EKONOMIJI

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SAŽETAK

U radu se razmatra koncept energije u ekonomskim aktivnostima. To nije "koristan" dio fizikalne energije, nego ekonomski definirana veličina.

Radi izvođenja tog zaključka prvo je sažeto izložena klasifikacija različitih koncepata – koje se sve naziva energija. Pritom treba razlikovati bar šest koncepata. Među njima su tri znanstvena: fizikalna (sačuvana) energija uključena je u prvi zakon termodinamike, energija kao sposobnost obavljanja rada (fizikalnog, kemijskog) pripada drugom zakonu termodinamike dok ekonomski (biološki) kapacitet djelovanja pripada Darwinovom zakonu.

KLJUČNE RIJEČI

energija, povijest, učenje, interdisciplinarnost

Interdisciplinary Description of Complex Systems 3(2), 59-71, 2005

COMPLEXITY, INFORMATION AND BIOLOGICAL ORGANISATION

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Conference paper *Received:* 15 September, 2005. *Accepted:* 15 October, 2005.

SUMMARY

Regarding the widespread confusion about the concept and nature of complexity, information and biological organization, we look for some coordinated conceptual considerations corresponding to quantitative measures suitable to grasp the main characteristics of biological complexity. Quantitative measures of algorithmic complexity of supercomputers like Blue Gene/L are compared with the complexity of the brain. We show that both the computer and the brain have a more fundamental, dynamic complexity measure corresponding to the number of operations per second. Recent insights suggest that the origin of complexity may go back to simplicity at a deeper level, corresponding to algorithmic complexity. We point out that for physical systems Ashby's Law, Kahre's Law and causal closure of the physical exclude the generation of information, and since genetic information corresponds to instructions, we are faced with a controversy telling that the algorithmic complexity of physics is much lower than the instructions' complexity of the human DNA: $I_{\text{algorithmic}}(\text{physics}) \sim 10^3$ bit << $I_{\text{instructions}}(\text{DNA}) \sim 10^9$ bit. Analyzing the genetic complexity we obtain that actually the genetic information corresponds to a deeper than algorithmic level of complexity, putting an even greater emphasis to the information paradox. We show that the resolution of the fundamental information paradox may lie either in the chemical evolution of inheritance in abiogenesis, or in the existence of an autonomous biological principle allowing the production of information beyond physics.

KEY WORDS

levels of complexity, the computer and the brain, algorithmic complexity, complexity and information, fundamental information paradox of the natural sciences

CLASSIFICATION

APA: 4100

PACS: 82.39.Rt, 89.75.–k, 89.70.+c

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INTRODUCTION AND THE MEMORY-DNA PROBLEM

Brain's complexity is widely considered in terms of neurons and synaptic connections, e.g. [1]. For a number of neurons $N = 10^{11} - 10^{13}$ [2], taking a value for the number of their interconnections as a few thousand per neuron $c \approx 10^4$ [3], we obtain for the measure of the brain's complexity the number $N_1 = N_{\text{connections}} = c \cdot N_{\text{neurons}} = 10^{15} - 10^{17}$. The general view is assuming a connection (synapse) represents 1 bit of information. In this way, we obtain for the information measure of the brain's complexity a value of $I_1 = I$(human brain) ~ $10^{15} - 10^{17}$ bit. Now since algorithmic complexity may be characterized by the size of the memory, we obtain that $I_1 = I_{\text{algorithmic}}$(human brain). The biggest supercomputer today, Blue Gene/L, has a memory capacity of 64 TB, corresponding roughly to $5 \cdot 10^{14}$ bit, a value not far from our brain's synoptic capacity I_1. To put the brain's algorithmic complexity into context, we mention a few related measures. Importantly, Maynard Smith [4] noted that the genetic information content of the human DNA corresponds to instructions and it is about I_2(DNA) ~ 10^9 bit. Since the instructions coded in DNA control all cellular processes [5], we may regard genetic information I_2 as acting at least at the algorithmic level or deeper, and so I_2(DNA) ≤ $I_{\text{algorithmic}}$(human organism). A third important measure is found in [6] measuring a special genetic complexity by the simplest model, in which each gene is either ON or OFF, and so a genome with N genes can theoretically encode $2N$ states. With 30 000 genes indicated to be present in the whole human genome, the arising human genetic complexity is a mere $I_3 = I_{\text{genetic expression}}$(human organism) ~ $3 \cdot 10^4$ bit. We obtained the following result: $I_1 = I_{\text{algorithmic}}$(human brain) ~ $10^{15} - 10^{17}$ bit >> I_2(DNA) >> $I_3 = I_{\text{genetic expression}}$(human organism) ~ $3 \cdot 10^4$ bit.

The first fruit of absorbing these complexity measures arises when we recognize a problem: how can it be that the genetic complexity of the human organism (including the brain) $I_2 \sim 10^9$ bit is smaller than the algorithmic capacity of the human brain, $I_1 \sim 10^{15} - 10^{17}$ bit – if the brain receives merely morphological and no algorithmic information from the environment through our senses during our lifetime? Would it be possible that the brain absorbs somehow algorithmic complexity from the environment as well? Or the complexity measures $I_1 \sim 10^{15} - 10^{17}$ bit and $I_2 \sim 10^9$ bit correspond in reality to different levels of complexity? To solve this problem (the memory-DNA problem), we will need estimations of complexity measures for the brain's dynamic activity as well as for the algorithmic complexity of the environment.

DYNAMIC MEASURES OF COMPLEXITY

Let us turn again to the computer-brain metaphor to see whether we can recognize some dynamic aspects of complexity that may be useful for further clarification. A measure of dynamic complexity is the number of operations per second. The number of operations per second in the Blue Gene/L in the third quarter of 2005 is 367 Teraflops – i.e., $3{,}67 \cdot 10^{14}$ operations per second. This is to be compared to the number of operations in the human brain per second. Let us take first operations corresponding to neural action potentials. Considering that the visual input into the brain comes through the 10^8 retinal cells, and 10^6 retinal cells are connected to the brain with axons sending 100 spikes of action potentials per second, regarded as carrying 1 bit of information each, one obtains 10^8 bit per second for the visual input into the brain. Assuming that an average neuron processes at a similar rate of operations, or 100 operations per second per neuron, we obtain for the $10^{11} - 10^{13}$ neurons a value of $10^{13} - 10^{15}$ operations per second as the number of "neural operations" in the brain, $N_1 = 10^{13} - 10^{15}$ operations per second. The close agreement of the dynamic complexity of the Blue Gene/L with that of the brain's neural complexity lends certain plausibility to attempts at modeling the brain in terms of the Blue Gene/L (The Blue Brain project, http://bluebrainproject.epfl.ch).

In reality, neural action potentials do not form a closed chain of events arising from a given initial state. Instead, they are continuously influenced by the information flow coming through the outer senses, and from internal processes extending from cellular chemical reactions up to the level of self-consciousness – by means of processes whose mathematical description far transcends the computational capacity of the Blue Gene/L. Therefore, it appears that although Blue Gene/L may be suitable to simulate brain's neural activity, it is a poor choice for modeling the brain's activity at the molecular level. Actually, Blue Gene/L is planned to simulate protein folding [7].

DYNAMIC COMPLEXITY MEASURES AT THE MOLECULAR LEVEL

To consider complexity measures corresponding to the molecular level, let us try to estimate the number of chemical reactions per second in the human organism. Certainly, the number of chemical reactions per second is larger than the number of ATP molecules produced per second. Kornberg [8] determined that the average daily intake of about 2500 kcal, corresponding to approximately 100 W, translates into a turnover of a whopping 180 kg of ATP. This number translates into $N_2 = \mathrm{N}_{\mathrm{ATP}}(\text{organism}) \sim 2\cdot10^{21}$ ATP molecule production per second in the human body. Regarding the fact that the ATP is produced in a chain of electron transfer events, and acts though energy coupling that involves the coupling of two reactions occurring at the same time, at the same place, typically utilizing the same enzyme complex, we find it plausible to assume that the rate of ATP production of $N_{\mathrm{ATP}}(\text{organism}) \sim 2\cdot10^{21}$ operations per second is smaller than the number of all chemical reactions of the human organism, $N_3 = N_{\text{chemical reactions}}(\text{organism}) > 2\cdot10^{21}$ chemical reactions per second. It is clear that both the production of each ATP molecule together with its reactants has to be timed so that the energy coupling can take effect, and that this timing is not completely pre-programmed because it depends on the cellular, intercellular, and global organizational levels. Each chemical reaction in the cell may occur sooner or later, here or there, therefore, ignoring now the question of redundancy which will be considered later below, one may count that at least 1 bit is necessary for their proper timing. Therefore the flux of biochemical reactions corresponds to a rate of information production $\dot{I}_1 = \dot{\mathrm{I}}_{\mathrm{biochem}} > 2\cdot10^{21}$ bit/s. With $6\cdot10^{13}$ cells in the body, we obtain a lower limit $\dot{I}_{\mathrm{lower}}(\text{cell}) > 4\cdot10^{7}$ bit/s. When this measure applies to neurons, we obtain that the dynamic chemical complexity of the brain exceeds by 6 orders of magnitude the complexity of the neural level.

ARGUMENTS EVALUATING THE BIOLOGICALLY UTILISED PERCENTAGE OF THE THERMODYNAMIC CAPACITY

i.) It is well known that the biological efficiency of cellular respiration is about 40 %, and that the general efficiency of the living organism is also about 40 % [9]. While in engineering such a rate of efficiency may be reached, there is a big difference that makes sense for complexity measure considerations. In machines, the energy transfer occurs through a few macroscopic degrees of freedom, corresponding to the moving constituent parts of the machine, in living organisms the energy flux does not flow automatically but is utilized by the living organism for molecular processes. Therefore in living organism the energy is continuously redistributed on microscopic degrees of freedom, on electronic excitation levels, activating just the chemical reactions the occurrence of which is useful for biological activities. Therefore in living organism a significant part of microscopic degrees of freedom corresponds to the dynamic biological information flux flowing from DNA to cellular reactions. This means that the approximately 40 % biological efficiency is related to an astronomically high information flow corresponding to the app. 40 % utilization of the thermodynamic capacity of the living organism.

ii.) Now let us estimate the thermodynamic capacity of the human organism. With a metabolism rate of L(organism) ~ 100 W the human body can mobilize an extropy flow $\Pi = L_{out}/T_{out} - L_{in}/T_{in} \sim 3{,}3 \cdot 10^{-1}$ J·K^{-1}·s^{-1} [10], and this translates in information units to $\dot{I}_2 = \dot{I}_{TD}$(organism) ≈ $3 \cdot 10^{22}$ bit·s^{-1}. This means that the lower limit of information flux we obtained above, $\dot{I}_1 = \dot{I}_{biochem} > 2 \cdot 10^{21}$ bit·s^{-1} is within an order of magnitude to the thermodynamic limit, a fit that may be regarded as quantitatively underpinning our argument. Nevertheless, we find it worthwhile to mention some further theoretical and quantitative arguments and tests on this point.

iii.) Ashby [11] pointed out that organization means conditionality, and since biological organization extends to the whole of the organism, every molecule's behavior is conditional, contingent on every other molecule's activity in the cell. There are strong indications that biological organization acts at the molecular level, e.g. [12]. Certainly, a significant part of the molecules of the cell has to follow highly specific pathways. The findings of proteomics, systems biology, and structural biology indicate that the organization of chemical reactions occurs simultaneously in intimate interactions between the molecular, cellular and higher levels. To make these complex interactions possible, Davies [13] noted that biological signals released by nucleic acids do the job to instruct ribosomes to assemble proteins, freeing protein assembly from the strictures of chemistry and permitting life to choose whatever amino acid sequences it needs. The complex of instructing biological signals influence chemical reactions of the cell in a way that is highly non-redundant. At present, little is known about how cells integrate signals generated by different receptors into a physiological response [14], yet it is clear that biological organization at the level of the cell contributes as well as higher and lower levels (corresponding to DNA, its genetic and nucletypic roles, cells, individuals, populations, species). Petricoin et al. [15] formulated that the ultimate goal of proteomics is to characterize the information flow through protein networks that interconnect the different and numerous regulatory systems of the organism. There are eleven major body regulating systems in human physiology: the circulatory, digestive, respiratory, urinatory, skeletal, muscular, integumentary, immune, nervous, endocrine and reproductive systems [16] and all of them influences each cell's chemical reactions. Regarding the non-redundant character of chemical reactions of the cells we note that evolutionary studies had shown that biology attempts to optimize resources. Therefore, it is not implausible to conjecture that biological organization may approach its thermodynamic limits, at least regarding informational resources.

iv.) Aoki [17] estimated the entropy production of the human body as 0,259 J·K^{-1}·s^{-1}. This dynamic complexity measure is to be compared with the extropy flow [10] utilised by the whole organism. A food intake of 100 W corresponds to 0,325 J·K^{-1}·s^{-1}. On the basis of these crude approximations, we derived the result that nearly 20 % of the total thermodynamic capacity of the human organism can be actually utilized for biological organization. In contrast, the general view is that the net efficiency of the utilized energy income is around 20 – 50 %, and in certain cases it may be even higher. For our present purposes, it suffices to recognize that biological organization utilizes a significant part (say 20 – 50 %) of the thermodynamic informational capacity. This result also fits well to our estimation of the complexity measure $\dot{I}_1 > 2 \cdot 10^{21}$ bit·s^{-1}, the information flux present in biochemical reactions, as compared to the thermodynamic capacity of the organism, $\dot{I}_2 = \dot{I}_{TD}$(organism) ≈ $3 \cdot 10^{22}$ bit·s^{-1}.

LEVELS OF BIOLOGICAL INFORMATION

Having obtained a quantitative and confirmed result for the dynamic chemical complexity measure, let us now consider how the levels of complexity are interrelated. Maynard Smith [4] realised that one could quantify biological information at three levels. First, at the genetic level, the biological information content is app. 2 bit per base. Second, at the selection level, a value of $\dot{I}$(evolution) ~ 0,2 bit·year^{-1} is found [18]. We add that one could expect that the appearance of the first living cells on the Earth, allegedly by abiogenetic way, would contribute to an enormous acceleration of the accumulation of genetic information, in comparison to the merely chemical evolution. Apparently, as the above obtained numerical measures of complexity show, the case is different. If the first life form has a similar complexity to the smallest genome yet found in free living organism, marine *α*-proteobacterium (Pelagibacter ubique), having a genome consisting of 1 308 759 base pairs, corresponding to app. $1{,}3\cdot10^6$ bit, than it had to evolve certainly in less than hundred million years, and so its rate of developments had to be (much) higher than $\dot{I}_{\mathrm{lowerlimit}}$(abiotic) ~ 0,013 bit·year^{-1}, a value comparable with Kimura's $\dot{I}$(evolution) ~ 0,2 bit·year^{-1}. These comparable values show a sharp contrast with plausible expectations that life is enormously more efficient in accumulating information then prebiotic processes. Third, biological information can be quantified at the morphological level. But to consider the morphological level, one has to be careful, for the genome is not a description of the adult form, but a set of instructions on how to make it. Maynard Smith emphasizes that the genome is a recipe, not a blueprint. We note that the genetic level corresponds to a complexity level at the algorithmic complexity or to a yet deeper level of complexity, regulating the algorithms. We think this is one of the main reasons why complexity sciences like cellular automata and self-organization, etc., enter into the scene: These sciences also recognize that it is possible to generate apparently complex products at the phenomenal level by means of simple physical or mathematical rules. Therefore, the real question is not what the degree of complexity at the morphological level is, but how complex an organism is at the algorithmic and at deeper levels.

MEASUREMENT OF BIOLOGICAL COMPLEXITY

Maynard Smith and Szathmáry [19, p.5] presented Table 1.1 summing up the genome sizes and percentages of coding DNA for bacterium (E. coli), Yeast, nematode, fruit fly, newt, human, lungfish, and flowering plants. They realized that when we allow for the fact that a varyingly small proportion of the DNA codes for anything, we may obtain a combined measure as a function of genome size as well as the percentage of coding DNA, a measure that makes sense. This measure, the size of the coding DNA, shows a progressive increase from bacteria to humans, with some minor exceptions only (lungfish). They noted that what this biological complexity measure tells us about structural and functional complexity is very limited [19, p.5]. On the basis of their Table 1.1, the coding part of human genome has N_{bp}(coding) ~ $6\cdot10^8$ base pairs.

COMPLEXITY JUMPS IN THE HISTORY OF LIFE AND THE PROBLEM OF ABIOGENESIS

We find it remarkable that the size of the coding DNA shows a mere hundredfold increase from bacteria to humans, from $4\cdot10^6$ base pairs to $6\cdot10^8$ base pairs. It is widely thought that terrestrial life were already present within 100 million years after the solidification of the Earth's crust. In this context, it is important to take into account the fundamental fact that the laws of physics has a very low information content, since their algorithmic complexity can be characterized by a computer program less than a thousand characters [20]. In a personal communication, Chaitin wrote [21]: "My paper on physics was never published, only as an IBM report. In it I took: Newton's laws, Maxwell's laws, the Schrödinger equation, and Einstein's field equations for curved spacetime near a black hole, and solved them numerically, giving 'motion-picture' solutions. The programs, which were written in an obsolete computer programming language APL2 at roughly the level of Mathematica, were all about half a page long, which is amazingly simple". Now one may estimate the complexity of a page as approximately $2 \cdot 10^3$ bit, since the average rate of information processing in reading is about 50 $\text{bit} \cdot \text{s}^{-1}$ [22] and so reading 1,5 pages in one minute the information content of a page is about 10^3 bit. In this way we obtain that the algorithmic complexity of physical equations is surprisingly low, $I_{\text{algorithmic}}(\text{physical equations}) \sim 10^3$ bit. Certainly, the observed flow of environmental information is enormous, but it is morphological information, and, apparently, it may arise from a much smaller algorithmic complexity through self-organization [23]. Now since we cannot expect that Big Bang (or recycling) cosmological models obtained initial conditions corresponding to an algorithmic complexity higher than the algorithmic complexity of physical laws themselves, we can estimate that the complexity measure of physics, initial and boundary conditions and physical equations included, is also about $I(\text{physics}) \sim 10^3$ bit.

This means that there is a much larger complexity jump between the early Earth without life and the first bacteria (from 10^3 bit to $4 \cdot 10^6$ bit, a jump of $J_1(10^8 \text{ years}) \sim 4 \cdot 10^3$, within about 10^8 years) than between the first bacteria and humans (from $4 \cdot 10^6$ bit to $6 \cdot 10^8$ bit, a jump of $J_2(4 \cdot 10^9 \text{ years}) \sim 150$, during $4 \cdot 10^9$ years). This fact seems strange, since chemical abiogenesis may be thought as apparently unable to accelerate the evolution of complexity much faster than life itself. The question inevitable arises: How could chemical evolution reach a twenty-seven times higher increase in complexity within a forty times shorter time period, than life, if one would expect that biological complexity increase should be relatively (much) faster? This is the problem what we count as the problem of abiogenesis.

QUANTITATIVE RELATION BETWEEN GENOMIC AND DYNAMIC INFORMATION

Maynard Smith and Szathmáry [19, p.5] noted that the number of base pairs of the coding DNA is a measure of genomic complexity that makes sense, but what these numbers tell us about structural and functional complexity is very limited. It is a general view that DNA contains the information necessary to govern biological organization, e.g. [24 – 26]. The DNA stores information that controls all cellular processes [5].

Now the requirement that the DNA information $I_2 \sim 10^9$ bit should control $\dot{I}_1 \sim \dot{I}_{\text{biochem}} > 2 \cdot 10^{21} \text{ bit} \cdot \text{s}^{-1}$ can be satisfied only if we allow that in every time-steps the activation state of any base pairs of the DNA may change. Indeed, in order to regulate and control all the cellular reactions, DNA has to represent functional information. It was Abel [27] who introduced functional sequence complexity (FSC) which is a succession of algorithmic selections leading to function, besides the random sequence complexity (RSC) that can be simplistically defined as a mathematical function of the number of equiprobable potential alphanumeric symbols that could occupy each locus times the number of loci in that sequence of symbols and the ordered sequence complexity (OSC) which is exampled by polymers such as polysaccharides. Bits of functional information represent binary choices at successive algorithmic decision nodes. Algorithms are processes that produce a needed result, whether it is computation or the end products of biochemical pathways. Such strings of decision node selection are anything but random, and they are certainly not self-ordered by redundant cause-and-effect necessity. Abel [27] pointed out that questions relating to the origin of FSC are among the most difficult in biology, if not all science. If one would ask, does the FSC originates from OSC and RSC, the best answer would probably be the slang expression: "No way!". The genetic information content of DNA does not originate from the chemical sequence of amino acids. Instead, FSC can only be quantified in its relation to biological functions actualized in the instantaneous internal and external environment. This is why FSC (and its counterpart, our dynamic complexity measure $\dot{I}_{\text{biochem}}$) is not highly redundant. Abel [27, p.65] adds: "There is a cybernetic aspect of life processes that is directly analogous to that of computer programming." We may realize that computer programming represents a yet deeper complexity level than the algorithmic complexity corresponding to the memory capacity. Analogously, the DNA complexity ($I_2 \sim 10^9$ bit) has to correspond to a deeper level of complexity than the algorithmic level of the brain (corresponding to $I_1 \sim 10^{15} - 10^{17}$ bit), and in this way we obtained a solution to the memory-DNA problem. Actually, if it is the DNA that plays the dominant role in governing cellular chemical reactions, it has to couple, coordinate and determine the timing of chemical reactions. This means that DNA corresponds to the deepest complexity level of the organism where the coordinating cellular reactions, what are themselves governed by algorithms related to couplings of chemical reactions, occurs. The complexity level of DNA corresponds to the regulation of the algorithmic complexity of cellular reaction pathways; therefore the genetic complexity is deeper than the algorithmic complexity of the memory.

Requiring that the static but deeper-than-algorithmic complexity of DNA is expressed through the mediation of activations of the $N_{\text{bp}}(\text{DNA}) \sim 10^9$ base pairs of the DNA, its information measure $I_2 \sim 10^9$ bit have to correspond to $\dot{I}_1 \sim \dot{I}_{\text{biochem}} > 2{\cdot}10^{21}$ bit·s^{-1}, and so from this requirement we became able to determine the length of the time necessary to activation of base pairs as $\Delta t \approx 4{,}2{\cdot}10^{-13}$ s. Actually, this timescale may be realistic for light-induced transfer of electrons Δt(electronic transitions) $\approx 10^{-12}$ s [28, p.6, Figs. 1-7]. This physical requirement seems to fit well with activation timescales. In this way, we obtained a conversion between the different forms of information, of its static and dynamic forms, converting $I_2 \sim 10^9$ bit to $\dot{I}_1 \sim \dot{I}_{\text{biochem}} > 2{\cdot}10^{21}$ bit·s^{-1}. It is this manner by which the DNA can fulfill the natural requirement to be differently activated in the different cells, if necessary, in each timesteps. In this way, DNA becomes able to supply the task of timing, to determine which chemical reactions should occur in the next timestep. Certainly, the DNA cannot do the timing alone, and its activity should be coherent with cellular organization supplying the necessary chemicals in the necessary places in the right moments, utilizing also a significant part of their thermodynamic capacities. But, in the way we obtained, the dynamic DNA can still preserve its key role to allow genetic control over the cellular reactions.

THE INFORMATION PARADOX: AN APPARENT CONFLICT BETWEEN PHYSICS AND BIOLOGY

While the morphological information of a circle is enormous, its algorithmic complexity is minuscule. The basic importance of the fact that simple rules may govern the appearance of high phenomenal complexity are already recognized in self-organizing systems, computer games, cellular automata [23], and it is widely thought that life's apparent complexity may appear as a product of certain yet-to-be-discovered, presumably simple physical rules.

Now Ashby's Law [11] states that "The variety of outputs of any deterministic physical system cannot be greater than the variety of inputs; the information of output cannot exceed the information already present in the input." In accordance, Kahre's "Law of Diminishing Information" reads: Compared to direct reception, an intermediary can only decrease the amount of information [29, p.14]. Moreover, it is a widely held view nowadays that the chain of physical causes forms a closed circle. The hypothesis of the causal closure of the physical

[30] maintains (roughly) “that for any event E that has a cause we can cite a physical cause, P, for its happening, and that citing P explains why E happened”. Therefore, not only Ashby’s and Kahre’s laws but the causal closure thesis is in conflict with the complexity measures found in physics and in biology. Now if the algorithmic complexity of one human brain is already around $I_1 \sim 10^{15} – 10^{17}$ bit, the information paradox consists in the fact that the information content of physics is I(physics) $\sim 10^3$ bit while that of the whole living kingdom is $I_4 = I$(biology) >> $I_3 = I_{\text{algorithmic}}$(one human organism) > $I_1 = I_{\text{algorithmic}}$(brain) $\sim 10^{15} – 10^{17}$ bit. Taking into account also that physics is hopelessly far from being able to cope with the task to govern even one human person’s biological activity $\dot{I}_1 \sim 2 \cdot 10^{21}$ bit per second, it becomes clear that at present, modern cosmological models’ algorithmic complexity is much less than the above obtained complexity measures characterizing life. Actually, the origin of biological information is widely thought to be in evolutionary biology as arising from the environment through natural selection. The problem is now: where does the high algorithmic information of the environment comes from, in a universe the behavior of which – as it is widely assumed – can be described by physical laws corresponding to a mere I(physical laws) $< 10^3$ bit? In other words: If the genome obtains its high information content from the environment, as it is assumed in evolutionary studies nowadays, how this environment could achieve an algorithmic complexity of biological size if it should correspond to the much lower algorithmic complexity measure of physics? We may realize that we are faced with a complexity paradox corresponding to the relation of physics to biology. Apparently, the informational resources of physics are far lower than the complexity measures of the brain and, in general, living organisms.

Certainly, the thermodynamic capacity of modern cosmological models allows the development of an information generation process producing information in an astronomical rate. Our Sun has a luminosity L(Sun) $\sim 4 \cdot 10^{26}$ J·s^{-1}, corresponding to a thermodynamic information capacity of $\dot{I}_3 = \dot{I}$(Sun) $\sim 10^{38}$ bit·s^{-1} [31, p.183]. There are N(stars) $\sim 7 \cdot 10^{22}$ stars in the observable universe, offering an information flux capacity $\dot{I}$(stars) $\sim 10^{61}$ bit·s^{-1}. What percentage is utilized from this astronomically high information capacity in the universe? What kinds of agents are necessary to utilize the thermodynamic capacity of the universe? The problem is: how this vast thermodynamic information capacity is utilized in the universe in the nowadays widely assumed absence of cosmic life? One could expect that the thermodynamic capacity to generate information can be utilized only by symbol-generating agents capable of generating, recognizing, handling and accumulating information. Again, it seems that abiotic processes should generate and accumulate information – in sharp contrast with the fundamental law of cybernetics (Ashby’s Law [11]); with the fundamental law of the mathematical theory of information, the Law of Diminishing Information [29]; and with the dogma of the causal closure of the physical.

In this context, an example may be enlightening. Hoyle [32] pointed out that to solve the Rubik cube by one random step in every second, it would take $1{,}35 \cdot 10^{12}$ years. The chance against each move producing perfect color matching for all the cube’s faces is about $5 \cdot 10^{19}$ to 1. Now if an intelligence is present, telling after each move if it is successful or not, reckoning 1 minute for each successful move and, say, 120 moves to reach the solution, the solution of the same Rubik cube may be reached within 2 hours. Certainly, the abiotic processes are not completely random – modifying the success ratio with and without intelligence from about 10^{16} to somewhat lower.

We point out that the production of algorithmic information seems not to be possible from phenomenal information arriving through the outer senses. The generation of genetic information from sensory data seems to be even more implausible. Although it is shown [23] that simple algorithmic rules can produce high amount of phenomenal complexity, certainly, the opposite process, the production of algorithmic information from phenomenal information is not shown to be possible yet, especially not in the absence of agents that are able to follow their own interests and not merely the laws of physics. One cannot expect that rules of games will develop from mere aggregate of phenomenal data. Mathematical operations like addition and multiplication does not arise from numbers alone. If laws could develop from aggregation of phenomena, it would be nomic emergence. Nomic emergence is something completely different from property emergence. Not only a different level of phenomena should emerge, but casual laws should also emerge simultaneously. But there is no basis "to accept emergent causal powers that magically emerge at a higher level of which there is no accounting in terms of lower-level properties and their causal powers and nomic connections" [33]. Nomic connections are based on generation of algorithmic complexity corresponding to the emergent laws. But no algorithmic complexity comes for free. Laws cannot be generated in the universe of phenomena. Although chemical symbiosis may be present in abiogenesis [4, p.35], even if it could increase the algorithmic complexity of chemical information (a process that already requires the existence of agents – and agents should be the output of chemical evolution and not its input), it could not generate genetic complexity, since the ordered sequence complexity, as Abel [27] had shown, is much simpler than the functional one and functional sequence complexity cannot be produced form ordered sequence complexity.

There exists a popular example of monkeys that can type Shakespeare's complete oeuvre on a typewriter. Actually, to type only one sentence from the Hamlet, consisting of 40 letters, each selected from 30 possibilities, it would be necessary to realize $30^{40} \sim 10^{59}$ trials. Let us assume that we have ten billion monkeys – that is, rather more monkeys than there are currently people in the world. And let us imagine each monkey hits one key per second. Let us further assume that they never stop to sleep or eat or anything else. It will still take more than 10^{49} seconds before one of the monkeys has the luck to hit on the right sequence. Now one year is about 32 million seconds, so it will take our world population of monkeys about $3{\cdot}10^{41}$ years to get there. Now how would it be possible that the absence of monkeys and typewriters, corresponding to the case of chemical abiogenesis, would accelerate the process to write an amount of information corresponding to Shakespeare's whole Hamlet, within a mere 10^{8} years? Certainly, one cannot expect that chemical evolution would be able to produce useful amount of genetic complexity in the absence of agents. Even in the presence of "inanimate agents" it seems highly implausible to expect that the accumulation rate of genetic information by chemical abiogenesis in an assumedly *physical* environment (information accumulation in physical systems is excluded by Ashby's Law, Kahre's Law and causal closure) could produce much higher jump in genetic information than the jump produced by life during its $4{\cdot}10^{9}$ years of evolution. Why should "inanimate agents", if they may exist at all, be much more efficient than living agents possessing much higher genetic complexity? Especially, if the number of regulatory genes grows approximately with the square of the total number of genes, as it is shown by genetic experiments [34].

SOLUTIONS FOR THE INFORMATION PARADOX

Within the present state of biology, it seems that there are only two ways out of the informational paradox of biology. The established way is that of the abiogenesis [19, 35, 36]. They realised a foundational work concerning the details of the chemical evolutionary process. The chemoton theory has the ambitious aim to follow chemical evolution until life's development. We think that chemoton theory is basic and will remain fundamental even when we turn our attention to a complementary aspect relative to chemical evolution: to the quantitative understanding of the origin of genetic information. In the light of the results of this paper, it seems that the problems of chemical evolution are larger now than the problem of protein folding was fifty years ago. In this case, we find it reasonable to shed some light on another important aspect of the problem that is the weak point of evolutionary theories: how to handle complexity. In this paper we try to characterize by numerical measures the process coupling autocatalytic cycles into hypercycles and co-operating hypercycles and representing genetic information. Only further developments of chemical evolution theories (see [36, 37]) may help to understand chemical evolution at the molecular level. With the present paper we would like to present a complementary global picture which may shed some light to the quantitative aspects of complexity at the algorithmic and genetic levels where coupling process occur, in the hope that the simultaneous development of progress from the aspects of molecular level and that of the global level may facilitate to bridge the gap between these levels much earlier than to proceed in one direction only.

Our proposal for answering the information paradox concerns the nature of first principles. Let us consider the important point that when complex forms develop from simple rules in self-organization, a static algorithmic complexity generates developing structures, a dynamic information of the morphological level. If the algorithmic complexity of the "simple laws" of our real world has to be much higher than that of the physical laws, then certainly we will need complex rules instead of simple rules producing biological blueprints. But perhaps these complex rules (together with their high algorithmic information content) may arise from simple laws themselves – again from a deeper level of information. The development of physics in the twentieth century had shown that physical laws arise from a much deeper concept: the concept of the first principle of physics – the action principle. Apparently, there is an intimate connection between the three levels of biological complexity, the morphological, algorithmic and genetic levels, and the three levels of science: the phenomenal level of observable phenomena, the level of laws, and the level of the first principle of physics, the action principle [38]. Morphological complexity seems to be related to the phenomenal, algorithmic complexity to the nomic level, and genetic complexity to the principal level.

The action principle is formulated by Feynman's path-integral method as arising from virtual processes covering a multitude of possible pathways and the resulting physical path will be the simple sum or integral of these paths. The integral form of the action principle contains a non-negligible surplus over its formulation in differential equations. Differential equations need definite initial conditions, while the integral formalism – virtually – includes informative interactions with a large set of the environment. Integral principles are independent from coordinates, and therefore they can cope with time-dependent boundary conditions as well. The apparent teleological behavior of living organisms may correspond to computational processes determined at the organism level, where the organism acts as an agent, following its own interests and biological needs like survival. Once the biologically favourable endpoint of a biological process is prescribed by the organism, the biological problem will be simplified, and with the help of the action principle of physics it becomes possible to determine the trajectory to be followed, and the organism can realize the biological needs by rearranging its internal physical environment.

Therefore, the solution we offer as an alternative to solve the information paradox of physics and biology is to allow agents to follow their biological needs. Agents had been introduced into biology, and they are indicated to be present already at the subcellular level [39, 40]. Szathmáry [36, 41] pointed out that there are some enzymes can adapt different shapes: in A it works as an enzyme, in B it does not. The enzyme function of hormones like adrenalin is not determined by physics at all. Nothing makes the structure of adrenalin to act like it does. Actually, adrenalin could be used as the opposite effect. An arbitrary coupling occurs between the enzyme and its function, and it is just such arbitrary coupling that is at the heart of symbolic communication that appears at agents (see also [42]).

If our results will be confirmed, it will turn out that biology cannot be reduced simply to physics, since its genetic, algorithmic and symbolic information content is much higher than that of physics. Our proposal not only allows biology to follow its own, and, necessarily, autonomous first principle not derivable from physics, but allows also to approach biology from a viewpoint that can make theoretical biology to develop into a science with exactness almost reaching the exactness of physics. The first principle of biology (the Bauer principle [43]) may be only one step only beyond the action principle of physics, and can be understood as its generalization. We propose that biological organization manifests itself in a way that decisions are made at the biological level first, and these decisions determine the endpoints of physical processes to be reached. By our proposal, biological laws can harness physical laws with the help of their enormous and effective information content.

ACKNOWLEDGMENT

It is a great pleasure to acknowledge about the inspirations, encouragement and English lecturing of a previous version of this paper to my friend, Jean Drew.

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KOMPLEKSNOST, INFORMACIJA I BIOLOŠKA ORGANIZACIJA

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SAŽETAK

Raširena konfuzija oko koncepta i prirode kompleksnosti, informacije i biološke organizacije motivirala nas je na koordinarana konceptualna razmatranja kvantitativnih mjera prikladnih za izdvajanje značajki biološke kompleksnosti. Kvantitativne mjere algoritamske kompleksnosti superračunala poput *Blue Gene/L* su uspoređene s kompleksnossti mozga. Pokazujemo da je i računalu i mozgu pridružena fundamentalnija, dinamička mjera kompleksnosti koja odgovara broju operacija u sekundi. Noviji uvidi upućuju na to da izvor kompleksnosti može biti u jednostavnosti na višoj razini, što odgovara algoritamskoj kompleksnosti. Ashbyev zakon, Kahreov zakon i kauzalna zatvorenost fizikalnih sustava isključuju nastajanje informacija. Budući da genetske informacije predstavljaju upute, nailazimo na paradoks da je algoritamska kompleksnost fizike znatno manja od kompleksnosti uputa u ljudskoj DNK: $I_{algoritam}$(fizika) ~ 10^3 bit << I_{upute}(DNK) ~ 10^9 bit. Analizirajući genetsku kompleksnost dobivamo da genetska informacija odgovara stupnju kompleksnosti višem od algoritamske, što dodatno pojačava informacijski paradoks. Naposljetku, pokazujemo da razriješenje informacijskog paradoksa može biti ili u kemijskoj evoluciji nasljeđa u abiogenezi, ili u postojanju autonomnog biološkog principa koji omogućava generiranje informacija van fizike.

KLJUČNE RIJEČI

razine kompleksnosti, računalo i mozak, algoritamska kompleksnost, kompleksnost i informacija, temeljni informacijski paradoks prirodnih znanosti

Interdisciplinary Description of Complex Systems 3(2), 72-76, 2005

A CONCISE INTRODUCTION OF THE EXTROPY

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Conference paper *Received:* 15 November, 2005. *Accepted:* 1 December, 2005.

SUMMARY

The Clausian introduction of entropy is based on an unnecessary restriction, namely that diminishing circle integral leads to a unique state variable. Eliminating that restriction a family of entropy-like function is introduced. After we have chosen one, called extropy, which has better properties as the well known entropy.

KEY WORDS

thermodynamics, entropy, extropy

CLASSIFICATION

PACS: 05.70.-a, 05.70.Ln

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INTRODUCTION

We used to describe processes with equilibrium states, and we do not ask if we can do it or not because we learned an equilibrium approach to the thermodynamics and we learned that it is the way to the non-equilibrium thermodynamics, too.

The equilibrium approach is a very good and sufficient way of teaching thermodynamics, and to give a simple skill to count with it. But there is a problem, when we want to make calculations for a process, and to describe the real world, we have to use processes in our calculations. Why aren't we able to describe a process with equilibrium states? Because process and equilibrium state are like the array and the point. With points we can only describe a line, without any direction and we can not describe an array.

Clausius did an equilibrium-approach, so he got less possibility as we can get with our non-equilibrium approach. How can we describe the processes without using formulas got from the equilibrium equations? We will show one of these methods.

To reach our goal, we have to introduce another state function, because we took advantage of the equilibrium equations in the introduction of entropy. It will be very similar to the entropy, this new state function, the difference will be, that we won't use any equilibrium equations in its deduction. The extropy was introduced and first used by Martinás et al. [1 – 3].

THERMODYNAMICAL DEDUCTION

We will use some axioms used in the equilibrium-approach of thermodynamics, but we will show, that these are true in non-equilibrium states, too.

The first axiom that we use is the first law of the thermodynamics, that

$$\mathrm{d}U = \mathrm{d}Q + \mathrm{d}W. \tag{1}$$

where U is the internal energy, Q is the heat and W is the work. The energy change is equal to the sum of thermal flow and the work done. This equation is true in non-equilibrium circumstances because its roots are in the conservation of energy.

Our second axiom is that every system is keeping to the equilibrium state, which is the state of the environment (in case of equilibrium environment). This approach to equilibrium happens in a monotonous way, where the environment is large enough to take it as a reservoir.

The problem of thermodynamics that time was articulated by Kelvin in 1852, who wrote [4]:

> If an engine be such that, when it is worked backwards, the physical and mechanical agencies in every part of its motions are all reversed, it produces as much mechanical effect as can be produced by any thermodynamic engine, with the same temperatures of source and refrigerator, from a given quantity of heat."

It leads to the Carnot-Kelvin-equation which is the following:

$$\oint \mathrm{d}Q \cdot (1 - T_0/T) + \mathrm{d}W \ \geq 0, \tag{2}$$

with dQ the heat transferred to the system at temperature T, and dW is the elementary work done by the system. From the citation follows, that this expression is equality in the reversible case and is an inequality in the irreversible case

THE INTRODUCTION OF EXTROPY

From the Carnot-Kelvin-expression, which is an equation in the reversible case, it follows that dQ(1 – T_0/T) + dW is a state function because its circle integral is equal to zero in reversible case, in the case when the original state is the same as the new. The definition of a state function is that “its value depends only on the current state of the system and is independent of how that state has been prepared. In other words, it is a function of the properties that determine the current state of the system.” [5].

If we integrate equation (2), we get the following expression:

$$\mathrm{d}Q(1 - T_0/T) + \mathrm{d}W = \mathrm{d}A, \tag{3}$$

where T is the temperature of the environment, which is taken as a reservoir and T_0 is the temperature of the system, A is the *state function*, Q is the heat and the most important, W is the work.

For the definition of the expansion work there are two possibilities: (i) $\mathrm{d}W = -p\mathrm{d}V$ with meaning that work is done on the system, or (ii) $\mathrm{d}W = (p - p_0)\mathrm{d}V$ meaning the useful work done by the system, as the $- p_0\mathrm{d}V$ part goes to the environment. In case there is only expansion type of work, we can write the following equation, considering dW as the useful work done by the system:

$$\mathrm{d}W = -(p - p_0)\mathrm{d}V, \tag{4}$$

where p is the pressure and V the volume of the system, while p_0 is the pressure of the reservoir, hence p_0 is a constant.

In addition, with the common transformation of the first law of the thermodynamics we get the following equation:

$$\mathrm{d}Q = \mathrm{d}U + p\mathrm{d}V. \tag{5}$$

If we combine (3 – 5), we get the following:

$$(\mathrm{d}U + p\mathrm{d}V)^{*}(1 - T_0/T) - (p - p_0)\mathrm{d}V = \mathrm{d}A. \tag{6}$$

Dividing it by T_0, the temperature of the environment, which is taken as a reservoir, the expression becomes

$$\left(\frac{1}{T_0} - \frac{1}{T}\right)\mathrm{d}U + \left(\frac{p_0}{T_0} - \frac{p}{T}\right)\mathrm{d}V = \frac{\mathrm{d}A}{T_0}, \tag{7}$$

with T_0 a constant temperature of the reservoir. The quantity dA is a state function, as it depends on state variables (U, V, N), and as we know the difference between state variables and state function is that the independent variables are the state variables and the dependent is the state function. So, if a function depends on state variables, it is a state function. From this chain of thoughts comes that if we divide a state function with a constant or a state variable we will get another state function. So $\mathrm{d}A/T_0$ is a state function as well as its integrate form. We will refer to it as the extropy and will denote it using the symbol Π for its integral.

$$\mathrm{d}\Pi = \frac{\mathrm{d}A}{T_0}, \tag{8}$$

$$\Pi = \frac{A}{T_0}. \tag{9}$$

If we write substitute (8) in (7), after integration we get:

$$\Pi = \left(\frac{1}{T_0} - \frac{1}{T}\right)U + \left(\frac{p_0}{T_0} - \frac{p}{T}\right)V. \tag{10}$$

That expression is valid for the blackbody radiation, as it has only two independent variables. In chemical systems the chemical potential difference also appears and the general form of extropy is

$$\Pi = \left(\frac{1}{T_0} - \frac{1}{T} \right) U - \sum_i \left(\frac{Y_{i,0}}{T_0} - \frac{Y_i}{T} \right) X_i \ . \tag{11}$$

where Y_i is the i-th intensive variable, and X_i is the i-th extensive one.

THE PROPERTIES OF EXTROPY

Let us show the similarities and differences between the entropy and the extropy. We begin with the similarities.

1. In the equilibrium state the extropy is equal to zero. Conversely, if the extropy is equal to zero then it is the equilibrium state.

2. The extropy of the system is always diminishing if the system is in a reservoir (for example in the environment). The proof is that if there is only a temperature difference, then the heat flows from hot to cold, so

$$\left(\frac{1}{T_0} - \frac{1}{T} \right) \mathrm{d}U < 0 \, , \tag{12}$$

while if there is only pressure difference, then

$$\left(\frac{p_0}{T_0} - \frac{p}{T} \right) \mathrm{d}V < 0 \, . \tag{13}$$

We can say that these differences are not a far cry, so we can keep the entropy, but the differences are significant in the following two cases.

The first case is that if the system is not in a reservoir then the energy and volume changes can be split into heat from the heat source (with temperature T) $\mathrm{d}Q^{\mathrm{A}}$ and the spontaneous heat flow between the system and the environment, $\mathrm{d}Q^{\mathrm{S}}$. Similarly, the volume changes referring to useful work $\mathrm{d}V^{\mathrm{A}}$ and to the equilibration process $\mathrm{d}V^{\mathrm{S}}$.

$$T_0 \frac{\mathrm{d}\Pi}{\mathrm{d}T} = \left(1 - \frac{T_0}{T} \right) \mathrm{d}Q^A - \mathrm{d}V^A + \left(1 - \frac{T_0}{T} \right) \mathrm{d}Q^S + (p - p_0) \mathrm{d}V^S \, . \tag{14}$$

The last two terms in (14) are always negative (see (11, 12)).

So using the extropy we can formulate the meaning of the Carnot-equation in this form: in a real cyclic process one has to compensate the extropy loss. The first two terms must compensate the dissipation.

The extropy is always positive or in equilibrium state equal to zero, so in non-equilibrium state we can write the following inequality,

$$\Pi > 0. \tag{15}$$

If we assemble the meaning of the inequalities we see that we can take the extropy as the distance to the equilibrium state.

The other case, where there is a big difference in the application is the case of the isolated system. In this case we know that the extropy is always diminishing. We can get a more comfortable description when with the choice of $1/T_0 = 0$ and $p_0 = 0$ we use the entropy.

CONCLUSION

For isolated systems entropy is the most appropriate form of the state function describing the irreversibility. For systems interacting with their environment (non-isolated) systems extropy is a more convenient form. So if we want to describe the real world, extropy is a better choice.

ACKNOWLEDGMENT

I acknowledge Dr. Katalin Martinás for useful suggestions and advice.

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UVOD U EKSTROPIJU

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SAŽETAK

Clausiusovo uvođenje entropije temelji se na nepotrebnim ograničenjima da iščezavajući konturni integral vodi na jedinstvenu varijablu stanja. Uklanjanjem tog ograničenja dolazi se do porodice funkcija sličnih entropiji. Među njima je izdvojena jedna, ekstropija, čija su svojstva u nizu procesa prikladnija od entropije.

KLJUČNE RIJEČI

termodinamika, entropija, ekstropija

Interdisciplinary Description of Complex Systems 3(2), 77-83, 2005

PARTICIPATORY POSITION

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Conference paper *Received:* 16 May, 2005. *Accepted:* 10 July, 2005.

SUMMARY

The paper deals with the problems encountered in exploring/describing cognising systems. It is argued that these are mostly an issue of epistemology and that some of the aspects of the above mentioned systems cannot be described without taking into account the researcher's participation in the process of researching (and describing).

KEY WORDS

living systems, non-trivial machines

CLASSIFICATION

APA: 2340

PACS: 89.65.-s

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THE PROBLEM OF COGNITIVE SCIENCE(S)

In the eighties, due to the explosion of computer technology, the area of artificial intelligence underwent rapid development. The capability of computers to solve tasks virtually insoluble even to the smartest of man caused general optimism and belief that the invention of computers as intelligent as their human creators or even more is only a question of time. Typical of this period was the search for (computer) algorithms to simulate intelligent behaviour. Only when it was proved in time that the intelligence of computers does not grow proportionally to the Central Processing Unit speed (does not grow at all, in fact), the researches started to consider the question of what intelligence actually is more seriously[1].

By the end of the decade, a satisfactory answer had not been found and computers which could be deemed »intelligent« had not been developed. It turned out that it is indeed relatively easy to produce the algorithms for certain tasks considered to be the indicators of high intelligence or supposed to be soluble only by "experts", like e.g. making a diagnosis on the basis of known symptoms, calculating complex differential equations or playing chess. But at the same time, certain operations so routine that we hardly even notice them in everyday life turned out to be utterly incomprehensible: e.g. the processes of cognising, language acquisition and some others. This proved that the issue of intelligence cannot be solved through a shortcut, but must be addressed by first exploring cognition and consciousness in order to solve them. To this effect, the nineties saw the growth of a new scientific discipline – that of cognitive science.

Indeed, it is more appropriate to use the term in the plural form – cognitive sciences – for it consists of differing scientific disciplines originating in various sciences. Each of them approaches the problem of consciousness and cognition in its own way. These include primarily neurophysiology, computer modelling of cognitive phenomena, philosophy of cognitive science, cognitive psychology and some other disciplines. Since than, incredible progress has been made in the cognitive sciences, providing new insights concerning cognitive phenomena in all areas. Nevertheless, there has been increasing talk of "a crisis of the cognitive sciences" in the last few years. It would appear that detailed analysis of individual elements of the cognitive system does not add significantly to the understanding of the entire phenomenon of cognition, nor render the solution of the so-called "hard problem", the pivotal question of the cognitive sciences.

Most cognitive scientists share a tacit assumption that a way out of the standstill lies in the further specialisation of the research of cognitive phenomena that will one day bring to a unified theory which will be able to satisfactory explain the phenomenon of consciousness. But the voices, warning that the crisis at hand is no mere standstill but a real crisis, are becoming louder and louder (e.g. [1] – where the authors have anticipated the problem long before it became the subject of general discussion [2, 3]). Some of the questions they are asking are: How is it possible to address the phenomenon of consciousness before we explore (or at least satisfactorily define) the phenomenon of life and the living? Can the mind and other cognitive phenomena be dealt with independently of the living system? Furlong and Vernon, for example, say: "Actually, when you ponder on it, it is indeed strange, and telling, that artificial intelligence should have been a subject of serious, detailed study before artificial life, for, actually we never assign intelligence to anything other than living systems. Did the artificial intelligencers simply but quietly assume that when their job was done their artificial intelligence systems would in fact be living systems?" [3]. The idealised concepts of intelligent talking machines are becoming less and less plausible and the intertwinement among the processes of life and cognition more and more obvious [4]. Thus, a new level of research has been formed that can be characterised with the question: ‘What is the living?’ or ‘What is life?’

From the standpoint of traditional science, the research of the phenomenon of life should be approached in the same way as the research of cognitive processes. It calls for an interdisciplinary approach, each scientific discipline tackling one aspect of the problem and trying to work on it in the same manner as on the rest of its repertory of research. The phenomenon of life can be approached from the standpoint of chemistry, biology, philosophy, anthropology or computer modelling. A chemist, for example, can deal with the chemical processes taking place inside a living organism. Naturally, he will be unable to describe the entire (chemical) conundrum at once, so he will focus on one specific chemical process in one specific kind of organisms. This breaking down of the problem into simpler components is the chief trick of the analytical-reductionist approach: if a system is too complex to be understood, it is to be divided into smaller and simpler parts. If these parts turn out to be still too complex, divide them again … and so forth, until we reach the parts simple enough for us to understand and describe.

The advantage of the analytical-reductionist approach lies in the fact that it *always* comes up with a result. If we start breaking a system down into parts, sooner or later we get a system that we can handle or describe. Unfortunately, it can happen that the results reached have virtually no connection to the initial problem any more. Thus we can gain immense quantities of data about individual parts and profoundly broaden our knowledge of them. Each detail conceals an infinity of new possibilities for further, even more specialized research and soon we get a feeling that the initial problem cannot be grasped at all, without knowing the single last detail. More often than not this makes the initial problem seem rather distant, turning it into a sort of legend bearing no connection to everyday research.

In 1971 Heinz von Foerster published his so-called “first theorem”: “The more profound the problem that is ignored, the greater are the chances for fame and succes.” [5].

However mockingly cynical this claim might appear, it is a fact that the incredible progress in, say, biology was reached exclusively by denouncing any questions concerning its foundations, the questions about the basic difference between the living and the non-living, between Jung’s *creatura* and *pleroma*.

Life is not a property, which could be satisfactorily determined by empirical parameters (which has been proved by numerous unsuccessful attempts in this direction). Rather, it manifests itself as a complex, (self-)contained and self-producing and therefore irreducible phenomenon. Life is *gestalt*, the consequence of a sensitive balance composed of numerous parts, more than just a simple sum of all of its components. Besides, it is a dynamical *gestalt* that we cannot simply “freeze” in a moment of time, as living beings can only be told apart from the non-living inside the context of time. Thus Furlong and Vernon [3, p.96] write: “And what is wrong with our conception of science in its application to Life and Mind is that the analytic reductionism which characterises the spectator consciousness stance can never capture the organisational distinctions which characterise living or cognizing beings.” No matter how detailed our description of the components be, it cannot describe the essential distinction between the living and the non-living, as this distinction appears not at the level of structure, but at the level of organisation, that is, the relation between the components [4]. In relation to this, Bateson quotes the biologist McCulloh (in [6]): “If you ask me concerning a particular cell what its function is, you've asked a question like what is the function of the second letter of every word in the English language.”

In the words of Furlong and Vernon [3, p.96]: "Scalpels and microscopes may be useful, but not for the discovery of Life and Mind, for when the analysis is done, that which is essential is gone." We cannot simply cut a living organism (literally or metaphorically) and continue treating it as a living being: *the method of research (analysis) essentially changes the properties of the living organism.*

TRIVIAL AND NON-TRIVIAL MACHINES

I believe that thinking about the puzzles of cognition necessarily takes us beyond the limits of "soft" problems that allow for the use of an analytical-reductionist approach, exact descriptions and predictability.

In the remaining part of this article, I try to prove the existence of systems, which cannot be exactly described nor predicted, even if we had at our disposal all the time and all the conceivable computational capabilities in the universe. I will use the machine metaphor and, proceeding from the work of Gell, Ashby and von Foerster (cf. [7]), explore its two categories: *trivial* and *non-trivial* machines.

Trivial machines are:

- independent of time and their history of interactions
- analytically determinable

and therefore *predictable*.

If we wish to understand the functioning of a concrete trivial machine (to determine its preceding function), we generally need as many trials as there are distinct inputs.

Non-trivial machines have internal states. The relation between the inputs and outputs of a non-trivial machine is anything but invariant. Instead, it is determined by the machine's previous operation. Thus the history of the machine's operations affects its preceding function. Ashby and von Foerster [8] prove that some of them are in principle, and others in practice, analytically indeterminable and therefore unpredictable.

Let n be the number of inputs to the machine. Let us suppose that the number of outputs is equal to the number of inputs. The number N of all trivial machines that can be synthesized is therefore $N_T(n) = n^n$, and the number of non-trivial machines is as much as $N_{NT}(n) = n^{nz}$, where z represents the number of internal states. In this case, z cannot be greater than the number of possible trivial machines ($z \leq n^n$). Thus, for trivial machines with four possible inputs, $N_T(4) = 256$ and for non-trivial machines, $N_{NT}(4) = 4^{1024}$, which means approximately 10^{620} elements. And we are still dealing with a simple machine operating only with four variable values, having only 256 internal states at its disposal. Nevertheless, even the complexity of this system is unthinkable to the point that it is absolutely impossible to analytically explore its functioning. The problem is transcomputational. According to the machine metaphor, what is to be thought of the attempts of brain modelling, a system with at least 10^{10} elements?

In sight of such complexity, the analytic-reductionist scientist would undoubtedly reach for his scalpel and try to reduce the observed system as much as possible. But some non-trivial systems have the annoying property that their parts change their characteristics completely when separated from the system. Besides, even the detailed knowledge of the functioning of all of its components does not guarantee the understanding of the entire system's operation.

Von Foerster says: "When asked, all my friends consider themselvs to be like non-trivial machines, and some of them think likewise of others. These friends and all the others who populate the world create the most fundamental epistemological problem, because the world, seen as a large non-trivial machine, is thus history dependent, analytically indeterminable, and unpredictable. How shall we go about it?” [9].

The same author can see three strategies that could be applyed: 1. ignore the problem, 2. trivialize the world, 3. develop an epistemology of non-triviality.

The most popular version is of course to ignore the problem, closely followed by the method of universal trivialisation. In the words of von Foerster: “One may call it the “Laplacian solution”, for it was Laplace who eliminated from his considerations all elements that could cause trouble for his theory: himself, his contemporaries, and other non-trivial annoyances, and than pronounced the universe to be a trivial machine …

The tremendous attraction of having to deal with something analysable, reliable and predictable, persuades one to pay for guarantees that our watches, lawnmowers, airplanes, etc., maintain their no-choice quality. The danger begins, when we extend this demand to others, to our children, our families and other larger social bodies by trying to trivialize them, that is, by reducing their number of choices, instead of enlarging it” [7].

The situation in science is similar. The danger begins, when we stubbornly stick to the analytical-reductionist paradigm, even dealing with problems, which it cannot cope with. Triviality is just an approximation. Even in the case that there exist trivial systems “out there” (and that there exists some “out there”), our cognitive system is most certainly non-trivial and so is everything that we experience. Like Newton's mechanics in physics, trivialisation is a very successful idealisation, functional in the larger part of the known world. It promises predictability and therefore safety and stability. But there is an immense expanse of indescribable forms lurking just behind the limits of triviality, elusive and intangible exactly because of their indescribability. And the moment we try to fixate some part of the non-trivial vastness, its essence has already been lost.

I believe *that the phenomenon of life cannot be treated as a trivial affair, neither can living beings be considered as mere trivial systems.* In exploring many phenomena, the observed system can undergo trivialisation, allowing for all of the benefits of the analytical-reductionist methodological paradigm. But there are also other phenomena that cannot be addressed in this paradigm and for which the non-trivial nature of the observed system ought to be taken into consideration. I think that the necessity for taking into account non-triviality does not end with the research of the phenomenon of life, but emerges at all levels of the exploration of living systems (therefore in the exploration of psychical, cognitive and, on the other hand, social systems as well).

As stated above, many phenomena can be divided into trivial and non-trivial parts. I wish to argue that the dividing line runs along the border *between the part we can satisfactorily describe as separated from the observer and the part, for which such idealisation is no longer functional*.

Including the observer into the observed system represents the basis for a *participatory epistemological position* (constructivism). The emphasis of research ensuing from this position is no longer on looking for the properties of the system, but on finding the properties of interactions between the (non-trivial) system and the (equally non-trivial) environment.

A more in-depth presentation and argumentation of the above mentioned epistemology, and the research possibilities deriving from it, is of beyond the scope of the present paper, but can be a good introduction for a debate. Let me conclude with summarizing the major differences between the classical scientific method and the described alternative in Table 1.

Table 1. Major differences between the trivial and non/trivial systems.

	Trivial systems ("classical" scientific method)	Non-trivial systems
Method	observer/researcher must not participate in the object of research	participation of the observer/researcher
	repeatability	non-repeatability
	reductionism and disregard of the "non-essential" parameters	cherishing complexity
	(linear) causality	circular (intertwined) causality
Epistemology	metaphysical realism	participatory position, constructivism
	the quest for truth	the quest for viable solutions
Ethics	objectivity	responsibility (for one's world)

REMARK

1 This division of the development into decades is, of course, a simplification. My aim is to emphasise the general direction of the developement and not its temporal dynamics.

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POZICIJA SUDJELOVANJA

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SAŽETAK

Članak razmatra problem koji se javlja pri istraživanju/opisivanju kognitivnih sustava. Zastupa se kako je to prvenstveno pitanje epistemologije te da neki vidovi kognitivnih sustava ne mogu biti opisani bez uzimanja u obzir učestvovanja istraživača u procesu istraživanja (i opisivanja).

KLJUČNE RIJEČI

živi sustavi, netrivijalni uređaji

Interdisciplinary Description of Complex Systems 3(2), 84-93, 2005

AGENT BASED MODELLING OF AID

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Conference paper *Received:* 14 September, 2005. *Accepted:* 15 October, 2005.

SUMMARY

The issue of modelling international financial aid to underdeveloped countries baffled economists for decades. The initial assumptions (that outside aid could help bolster up the internally insufficient investment, thus helping economic growth) were statistically proven wrong; most of the recipient countries did not experience rapid growth, rather an increasing dependence on foreign aid. The question arises: what causes some countries to use the aid successfully whereas most fail to do so? What is the underlying reason for this difference across regions? And how could it be modelled?

In this paper I would like to show, that a hierarchical agent-based model might be able to model the complex international cooperation among aid-giving organizations and recipient countries, so that some light could be shed on the mechanics of efficient aid distribution.

KEY WORDS

growth, aid, agent-based modelling, adaptive agents

CLASSIFICATION

ACM Categories and subject descriptors: J.4 [Computer Applications]; Social and behavioral sciences – Sociology

JEL: E17

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INTRODUCTION

Economists use modeling techniques for the same reason as practitioners of other sciences do: to describe, better understand and predict the workings of a system so complex which it is hard to fathom outright. Physicists, chemists, engineers are all plagued by the same demon: unless they simplify reality through modeling, the object of their research might not become understandable.

Since the time of Adam Smith, economists tried to advise the leaders of nations as to the "proper" path of the economy. The moral philosopher and theologist Smith developed his model to show that it is not immoral to have people work for their own financial gain; and that this greed-propelled individual behaviour is the true source of a nation's wealth [1] as opposed to the merchantilist doctrines prominent at that time. While this line of thought became the backbone of modern economics, it failed to provide an answer to the real workings of the economy as a whole.

This paper aims at showing the problems of describing the dense social net known as economy. It will be revealed through the example of financial aid, that today's economic models lack the necessary accuracy to predict the real changes in an economy caused by unforeseen forces like financial aid. An alternative way of modeling an economy will be suggested, that is supposed to have a greater explanatory and predictory power than the standard models. It will also be shown that using current technology it is possible to create such a model, and to use that model to evaluate the possible outcome of outside financial aid in a given economy.

FINANCIAL AID

The issue of financial aid is not a straightforward one. Why do the developed nations help the underdeveloped? Is it to win the goodwill of their people? To build up foreign markets for their own products? To prevent large-scale immigration? Whatever the motive, the theory is simple: giving money to low income countries will improve their quality of life.

It is obvious, that there are many moral and theoretical problems with such a statement, since it implicitly assumes that faster economic growth equals higher quality of living. In reality, many factors have to be taken into consideration (the utility function of the individuals in question[1], the aggregation of the utilities in the economy[2], etc.), but we usually disregard these, since they are not easy to describe numerically.

Even if we agree, that faster growth is better, one would have to know two things before resorting to aid: what determines growth, and how can this growth be affected.

Most models of financial aid use the neoclassical growth theory[3], that states, that stable economic growth depends on the population growth rate and corresponding capital growth rate. Based on this theory, an economy grows too slow if it does not have sufficient funds to provide the necessary capital investment to keep the country on the sable growth path. Ever since Keynes' time, it has always been understood, that savings are an increasing function of wealth [2], and investment is funded from savings. From here the theory of aid is easy to deduct: investment has to be financed from an outside force, what would allow the nation to grow faster. A nearly similar result can be deducted from Martinás' new microsynthesis [5]: the growth of money and the possible growth of capital can result in faster economic growth.

There are some problems with these theories. The greatest of them is the fact that they do not work. In some nations the outside financial aid resulted in incredible growth of both output and welfare (most notably in the East-Asian region, in Taiwan, Korea etc.), but in a rather larger number of cases, the aid had different results. Even in the best cases financial aid proved to be ineffective (as shown by Tsikata [6]), but in some nations it crowded out internal investment, increased consumption (thus reduced savings), developed aid-dependence, and in some case, Dutch disease. This gave rise to a large number of questions, most focused on why this happened, and what could be done against this.

If one examines the countries one-by-one, an other, even more relevant factor emerges. The example of Bosnia shows, that aid expenditure, while not achieving what it was meant to achieve, might result in a significant increase of welfare. The rebuilding of the war-demolished cities might show as an increase in consumption in aggregated macrovalues, but they sure did improve the quality of life. It is simply impossible to expect a nation to live in tents and spend aid on investment.

These effects seem to indicate, that it is generally flawed to assume that low income countries are best described by their GDP/capita and growth values, and that a richer description might allow better models to be constructed. With better models, aiding policies could be improved, and it would be easier to guarantee the desired effect.

AGENT-BASED MODELLING

Agent-based modelling is a computerized modeling approach that allows complex models to be constructed bottom-up. As opposed to standard modeling, the so-called individual- or agent-based models are simulations that describe the global consequences of local interactions of members of population. The individuals can represent many things; from cars in traffic through birds in a flock, to economic agents[4].

Agent-based modelling is a subset of multi-agent systems, where the complex whole is composed of several, communicating elements. Agent-based simulation differs from the general by being composed of autonomous agents.

AGENT-BASED VERSUS MATH-BASED MODELS

In an agent-based model, autonomous individual agents act in a predefined environment, and their behaviour as a whole defines the workings of the system. In the standard, math-based modeling, the behaviour of the individuals is "averaged together", and this average is described in mathematical terms. The key differences are:

- **Creation of the model**: in an agent-based model, the creator has to model the behaviour of the agents and the communication between them. In a mathematical model, one has to describe the whole system, and all interactions among the individuals have to be incorporated in the model to begin with. This means, that while in an agent-based scenario one can easily test the relevance of the agents (by comparing them to the real-life counterparts), it is hard to test the emergent macro-behaviour. In mathematical models it is quite the contrary: the model describes the macro-behaviour, which can be tested[5], whereas the underlying assumptions about the individuals remain hidden.
- **Macrobehaviour**: in math-based modelling it is easy to see, since the model describes it. In an agent-based environment, it has to be deducted from the agents' behaviour (it has to be summed somehow)
- **Changes of the outcome**: Once again, it is easier to see the direct changes in a mathematical model; however these changes might not be the relevant changes. In an agent-based system we can gather information about the changes in the members of the population, and not only in their aggregated behaviour.

All in all, agent-based models are more complex, but might be more relevant due to the fact that they are built up bottom-up, as opposed to the declarative construction of the mathematical models.

ADAPTIVE AGENTS

This is where the true power of the agent-based approach lies. Who is to say, that the agents in the system have to be described by static rules? An average agent is described by type characteristics, internalized behavioural norms, internal modes of behaviour and internally stored information about itself and other agents (state information). The internal modes of behaviour usually describes the means of communication an agent has and it's decision making rules; and it is rather easy to implement a set of rules that allow the agents to actually learn. As opposed to math-based models, the individual-based models can learn in a distributed fashion, thus more accurately describe thinking entities. In this regard it is irrelevant how they "think", but it is possible to use advanced artificial intelligence in them, namely neural networks and genetic algorithms, not only the standard if-then structures.

ECONOMIC APPLICATIONS

When discussing the issue of emergence, emergent behaviour in their book about swarm intelligence, the first example Kennedy and Eberhart bring forth is the example of an economy. They quote Smith, and his invisible hand theory, and claim that the seemingly self-organizing nature of the marketplace is nothing else but an emergent behaviour [8]. This clearly shows that the agent-based technology can intuitively be used for economic applications.

The agent-based modelling is very much like a culture-dish experiment: to begin the work, a model economy must be constructed from a set of agents. These agents represent both the economic actors and the environment (social, cultural etc. issues). After the economy is thus initialized, it is left to evolve, and the macrobehaviour emerges from the interactions of the agents, exactly as Smith described it. There can be no external interaction, only agent-agent interactions are allowed (for example, the price cannot be determined externally; it has to evolve from the decision(s) of one or more agents).

A great many issues arise when modelling an economy in this context. One of the greatest questions is: how do the agents "think", how do they behave? In some cases it is not needed that the agents behave like humans do, thus standard learning algorithms can be used. In other situations (when modelling social interactions), it is crucial that the agents behave as humans do, so new types of learning algorithms must be used.

It is also non-trivial to develop the protocols used among the agents. These protocols define the marketplaces (and off-the-market transactions) among the agents in the model, so it has great impact on the actual outcome of the simulation. A related issue is the formation of trade networks. What algorithms do the agents use to determine trade partners? Do they do it randomly? Do they incorporate past experience?[6]

The use of these experiments, however, promises to provide answers to questions which remain unanswerable in the standard terminology. These include:

- The development of cooperation among agents (does this appear in emergent behaviour?).
- The "social utility" of a society is easily calculated, since every agent's utility is known; they can be aggregated using all methods available (this makes it possible to evaluate the outcome of an action using different "preferences", social utility functions).

- The resulting income distribution, the emergent inequality in the economy (in some models, it is not easy to see the difference between social utility and inequality, but the more kind of agents we use, the more colourful the picture becomes).
- The effect of interaction networks, channels of information on the emergent economy (this is, in essence, the relationship between market structures and the emergent macroeconomic behaviour).
- The relationship between legislation and corporate capital structure (where do they get the necessary capital to invest?).

THE ASPEN MODEL

Finally it is useful to look at a rather complex agent-based economy model: the ASPEN model, Fig. 1. It is, in essence, a model of the US economy as a whole.

The early ASPEN model was a rather primitive issue; it only contained market forces: the household (composed of 1000 agents), the "firm", producing food (4 agents), and a government (1 agent). This model was run at a daily decision cycle for 30 simulation years, and it could show a 7-year periodicity in the economy [9]. This alone shows, that the microsimulation is a very powerful tool, and that the model worked according to expectations.

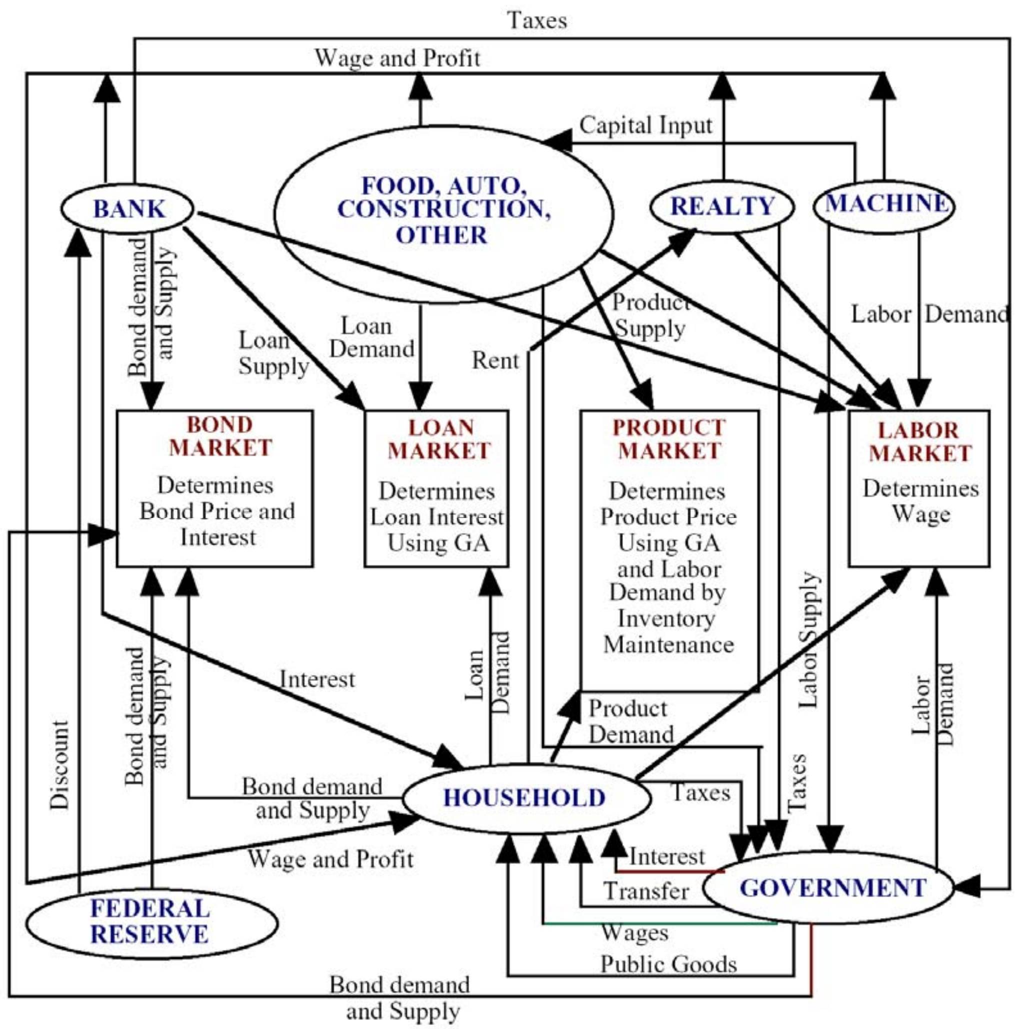

Figure 1. Interaction among agents in the ASPEN simulation [10].

This alone was a great result, but it was far from the intended accuracy. ASPEN was developed to allow:

1. examining the results of legal, regulatory and policy-changes
2. examining the various sectors of the economy independently
3. simulation of the economic agents
4. observing the economy as a whole

and the initial mode was rather far from realizing this ambitious goal.

The next step was to create a more complex model, which could fulfil the promises of the developers. This model needed a more complex structure that incorporated other sectors and the banking system, as well. Using this more complex model they have been able to predict the workings of the market with such a level of accuracy that was not possible before; thus proving the model and the concept sound.

During the past decade, computing and simulation has developed with exponential speed. The initial ASPEN model was run at the US Government's SANDIA laboratory, then housing the fastest computer in the world, the massively-parallel "TERAFLOP" computer. It had 9200 PII processors and 3.1 Teraflop peak performance. Just for comparisons' sake, the new Playstation III gaming console that is to be released coming January will possess 2 Teraflops of computing capacity. What is more, advances in GRID computing could theoretically provide unlimited processing power[7]. This allows the models to become immensely more complex, thus more lifelike.

Seeing that agent-based modelling theoretically provides the answer to many questions which remain unanswerable by other means, and also that there is a working model that has great explanatory power in a given economy, it seems clear, that such a simulation could provide the answers we need about financial aid. But how should such a simulation be constructed?

THE ABMA MODEL

The researchers at Sandia labs successfully used the ASPEN model to predict the changes in price level, output, exchange rate, and even to simulate the possible outcome of an infrastructure loss of the economy. If such a large and complex economy could successfully be modelled, it must be relatively easy to construct a model of the low-income countries that could predict the effect of financial aid. In order to do so, however, we need a structure that allows the modelling of various countries, so that there would be no need to construct brand-new models for every possible country.

BASIC STRUCTURE

The idea behind the ABMA model is simple: let us create the formal workings of a low-income country, and the specifics should appear as differences in the distribution of agents. This would allow a singular framework to be used in all experiments, yet would make possible to incorporate country-specific information in the prediction process.

As shown in Fig. 2, the soul of the ABMA model is a populator module. This takes as its input the statistical data that describes the country to be modelled, and produces the set of agents that can model the given economy. Through this method it becomes possible to use a unified model for the agents, and yet allow different countries to be modelled. The populator module would be ran only once, at the initializing stage, and after it created the necessary number and type of agents, all the changes are internal to the economy.

This process makes it possible to create Petri-dish economies that can be played with. To test any hypothesis, one only has to induce an external change to the economy, for example command the "central bank" agent to reduce the reserve ratio. After the external change had been made, the agents slowly adapt to the new situation (the "bank" type agents will increase their lending, the "corporation" type agents will increase their investment, etc ...), and the emergent behaviour will be the aggregated macro-effect.

KEY PROBLEMS

Creating a framework that would allow the description of low-income countries is a hard task in itself. It needs to possess great descriptive power, yet not contain crucial information about the countries. The country-specific information has to be coded in the composition of the agents, what might be a tougher task than it looks (since it demands, that the key differences among the countries have to be identified and simulated on agent-level).

Creating the framework might not be as hard as the description of the social systems. In an agent-based environment, the social structure is best displayed by having multiple types of "person" agents, that have different characteristics (utility functions, etc., to describe "homo economicus", "homo custodius", etc.), and the mixing of these agents in the proper ratio would result in the desired social framework. Here the question of "base" person-types arises: how should one divide up the "human" agents? Along their utility function? The education they received (implying their productivity)? Along multiple dimensions?

Another troublesome issue is the thought processes of the agents. It is pretty moot to make them think differently (so the method of "thinking" should be the same), but it is not trivial whether it can be beneficial to allow some agents to "remember" better than the others.

The creation of the "populator module" contains a large number of implicit assumptions about the modelling technology. These regard:

- input data types: the assumption is, that the key differences among countries can be deducted from statistical data. The term "statistical data" is rather vague: what kind of data do we need to be able to describe the aforementioned social system, for example? What has to be known to be able to tell apart the social framework of Zimbabwe and Timbuktu?
- data availability: is this data available? If not, can they be replaced by other data? If neither, what is to be done?
- population process: It is assumed, that by having the necessary "statistical data", it is straightforward to create the proper number and type of agents. Is it a deterministic process? Or does the populator module use a stochastic function to create the population of the Petri-dish economy?

It is easy to see, that these problems do not appear with equal weight to each and every kind of agent. The agents representing the bank sector can be relatively easily described from data by IMF. The government itself is a relatively easily describable entity. The households, however, are a lot trickier (for example they need to be described in a hierarchical fashion; their earnings and consumptions are partially individual, and partially family-based). How to create the "families of agents" is a rather complicated problem.

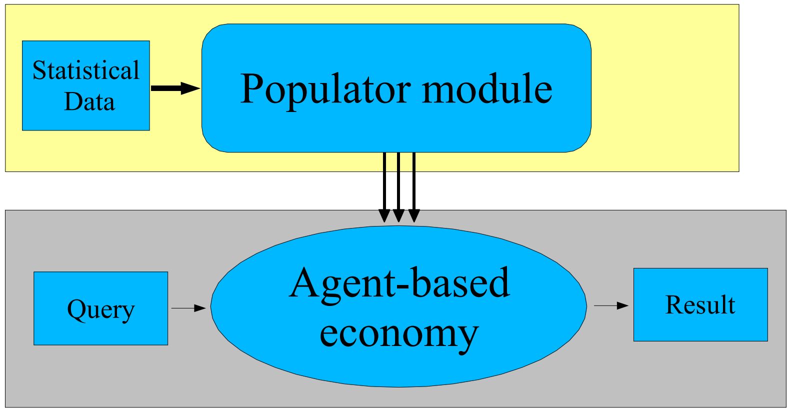

Figure 2. The ABMA model.

Last but certainly not least, it is crucial to be able to depict foreign trade. This is usually done by introducing another agent, the "rest of the world" agent. Whereas it is not a pretty solution modelling-wise, it is not really far-flung, since most low-income countries are "small" countries, meaning that they have precious little effect on the world market as a whole.

CONCLUSION

It was shown, that agent-based modelling is a radically different approach to economic modelling than the standard framework. Agent-based simulation allows the modeller to delve into the micro-workings of the economy, and gather information not only about the economy as a whole, but about the changes in the state of the individuals as well. This might allow a better evaluation of the changes (since we can directly see the changes in the utility and inequality, whereas normally these values would remain hidden in a macromodel), and could also mean better predictive ability regarding the future of our economy.

There are no computational differences in the implementation of this model. Current advances in the information technologies infrastructure make it easy to collect sufficient amount of CPU power to run such a model fast enough to gather the needed data in time.

Theoretical problems persist, however. A transparent agent-based model needs to be developed, that would allow the modeling of all low-income countries. A populator module is also needed, that would be responsible for the creation of the required number and type of agents in the economy. Finally a suitable method for indicating the various ways of providing financial aid is needed, so that the most beneficent way of providing financial aid can be found.

REMARKS

[1]My favorite example here is the hours worked. It is easy to see that if people worked more, they would produce more goods in the economy, what would make the price level lower and the products easier to export, an overall gain for the economy, resulting in faster growth. At the same time, the people would not enjoy themselves so much as before, meaning that their utility would actually decrease from this change.

[2]The two corner-solutions are the max(U_i) and min(U_i) functions; the first leading to dictatorship (only the dictator's utility matters), the last resulting in an extreme social economy, where everyone's utility would be equal.

[3]The original developed by Samuelson and Solow, described in detail in [3] and in [4].

[4]An agent can be anything that has sensors to percept its environment, and uses its effectors to act on it [7].

[5]See: aid. The model failed.

[6]It is easy to see, that this issue is not unrelated to the "thinking" of the agent. Agents using evolutionary algorithms might choose random partners and evaluate them according to a "fitness" function (more beneficial partners get higher scores, thus will be more likely candidates in the upcoming time). A neural network based agent, however, is less likely to act randomly, and will stick to satisfactory partners more than an evolutionary agent.

The true beauty of the agent-based approach lies in the fact, that it is perfectly easy to create a model economy composed of agents with different behaviours. What is more, the simulation can answer the question: which kind of "thought" is the more successful?

[7]In our case, GRID is not a solution. Whereas it is a marvellous platform to analyse the CERN data, its bottleneck is the communication channel. An adaptive agent-based simulation needs fast communication among the computing nodes, so a large capacity multi-processor system seems a better solution than a computing GRID.

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MODELIRANJE POMOĆI PUTEM AGENATA

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SAŽETAK

Pitanjem modeliranja međunarodne financijske pomoći ekonomisti se bave desetljećima. Statistički je dokazana pogrešnost početne pretpostavke kako vanjska pomoć potpomaže unutarnje, inače nedostatne, investicije čime doprinosi ekonomskom rastu jer većina zemalja koje su primale pomoć nije zabilježila brzi rast nego povećanu ovisnost o vanjskoj pomoći. Pitanja koje se nameću su: zbog čega neke države uspješno koriste pomoć dok većini to ne uspijeva? Kako objasniti tu razliku po regijama? Kako navedenu pojavu modelirati?

U ovom radu pokazujem da hijerarhijski model temeljen na agentima može omogućiti modeliranje složenih međunarodnih kooperacija između organizacija za pomoć i država primateljica pomoći, radi doprinosa razumijevanju mehanizama učinkovite raspodjele pomoći.

KLJUČNE RIJEČI

rast, pomoć, modeliranje putem agenata, adaptivni agenti

Interdisciplinary Description of Complex Systems 3(2), 94-99, 2005

MODELLING MARKETS VERSUS MARKET ECONOMIES: SUCCESS AND FAILURE

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Conference paper *Received: 19 September*, 2005. *Accepted: 15 October*, 2005.

SUMMARY

Non-linear, stochastic, thermodynamic, agent based or network modelling are powerful tools brought from other fields into economics. Applied in almost every sub-field of economics, these tools had however substantial success only in the analysis of financial markets. We suggest that the reason for this is less the insufficiency of these technical tools but rather the incapacity of mainstream economic theory to adequately represent the functioning of modern market economies. We argue that the method of mainstream economics to understand market economies by the help of simultaneous price determination on all markets fails to provide a satisfactory representation of our economies. As a result, when modelling financial markets, the final goal - a satisfactory determination of prices - is achieved; but when modelling market economies, the final goal - a satisfactory representation of modern market economies - is not achieved even if all prices are satisfactorily determined.

KEY WORDS

economic relation, market concept, credit operation, monetary economy

CLASSIFICATION

APA: 2910

JEL: E10, E13, E42

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INTRODUCTION

Non-linear, stochastic, thermodynamic, agent based or network modelling are powerful tools brought from other fields into economics. [1 – 7] Applied in almost every sub-field of economics, these tools had however substantial success only in the analysis of financial markets. The following question raises:

> *When modelling partial markets why these tools provide promising results and why these same tools fail when all markets are brought together to form a complex market economy?*

We suggest that the reason for this is less the insufficiency of these technical tools but rather the incapacity of mainstream economic theory to adequately represent the functioning of modern market economies. We argue that the method of mainstream economics to understand market economies by the help of simultaneous price determination on all markets fails to provide a satisfactory representation of our economies. As a result, when modelling financial markets, the final goal – a satisfactory determination of prices – is achieved; but when modelling market economies, the final goal – a satisfactory representation of modern market economies - is not achieved even if all prices are satisfactorily determined.

The argument is presented as follows: in a first section of the paper, we show that the major hypothesis of the ruling economic paradigm does not allow for an adequate representation of market economies, but permits adequate price determination on partial as well as on general (i.e. global) markets. This hypothesis is that all economic relations between agents can be conceived exclusively as exchange relations.

In a second section, we show that the adequate question for understanding the functioning of market economies is less the general price determination resulting from the exchange relation, but the modelling of credit-money systems resulting from the credit relation.

In a third section we show that credit-money systems cannot be represented in the terms of mainstream economics.

THE RULING PARADIGM: MAINSTREAM ECONOMICS

Following A. Smith [8], the father of economic sciences, economic science is *An Inquiry into the Nature and Causes of the Wealth of Nations*. That is to say, economic science is aiming at understanding what constitutes wealth and how individual and social wealth changes.

Mainstream economics, as all value theories, defines individual and social wealth as the sum total of commodities (i.e. useful things) [9, p.65]. In order to be able to sum up commodities to determine wealth, they must be expressed in a same unit. This is done by the help of prices, which are ratios of the given and obtained quantities. Whence the central question of analysing the exchange relation and markets (defined as the place of exchange) in this theory (the exchange operation consists in giving commodities for other commodities, because the utility that yields the former is less than the utility of the second).

However, mainstream economics does more than focusing on the exchange relation. It makes the assumption that exchange relation is the only relation between economic agents. In economics, the (pure) exchange relation is conceived as one which does not redistributes wealth. We will call this property of the exchange relation symmetry.

The exclusivity of exchange raises some problems. In fact, the system analysed in economics, called economy, is defined as all systems in any sciences, that is to say by its elements and by the relation between its elements. The elements of an economy are economic agents (being capable of making decisions to get richer), the commodities, and the exclusive exchange relation (put aside the possessing). If we consider human beings as the economic agents of the economy, then there can be no difference between exchange economies unless the list of commodities is different. But should we consider different an economy when there is no nylon sock and a year after when it is invented? Certainly not. It follows that the mainstream economic paradigm does not allow for any fundamental difference between the functioning of a barter economy with no money and a monetary economy with money.

Empirical facts show that this conclusion of mainstream economic theory [10, 11] is completely mistaken, as admitted a decade ago by the president of the European Economic Association: “We do not, as yet, have a suitable theoretical framework for studying the functioning of a monetary system.” [12, p.215].

Hence, even if the tools brought from other fields allow for an adequate solution for the price determination problem, they does not form an adequate model for the understanding of monetary systems.

In what context these tools should be applied then? We examine this question in the following section.

SUGGESTION FOR AN OTHER CORE HYPOTHESIS TO REPRESENT MONEY ECONOMIES

Following the empirical evidence, if we want to allow for a possible difference between barter and money economies, we must have at least one different economic relation in the two economies.

We suggest, as Schumpeter and others [13 – 16], that the credit relation stemming from the credit operation cannot be reduced to an (intertemporal i.e. between periods) exchange.

To show this, let us consider the following example.

Agent A gives an apple today to agent B in exchange of a recognition of debt to be paid with two apples tomorrow. This operation is simply an (intertemporal) exchange, which is considered erroneously by mainstream economics as a credit operation.

The point of the credit operation is that agent A gives an apple today to agent B in exchange of a recognition of debt to be paid not with two apples tomorrow but with a claim of two apples tomorrow, a claim for example on an agent C.

The asymmetrical character of the credit relation is straightforward: the borrower (agent B) can honour her debt if and only if she can claim to apples tomorrow from agent C. And what if agent C is unwilling to recognise the debt of two apples tomorrow on herself (a claim on herself) unless she obtains in return three apples? And what if agent C is identical to agent A?

The relation stemming from the credit operation is thus an asymmetrical relationship distinguished from the exchange relation.

In modern bank-money economies the credit operation cannot be ignored, because money is created by credit operations, as illustrated in Table 1.

Table 1. Credit operations.

Bank		Non-bank agent	
Assets	liabilities	assets	liabilities
claim on non-bank agent	money	money	debt toward the bank

As a result, if we want to construct a model of a bank-money economy, the tools brought from other fields should be used in this framework. This framework is not intrinsically refractory to allow for some difference between monetary and barter economies.

However, this modification cannot be fitted in the habitual economic framework, as we show in the next section.

BASIC NOTIONS REVISITED

Mainstream economic analysis defines individual and social wealth as the sum total of all commodities. However, a formal analysis shows that money cannot be treated as a commodity. In fact, a commodity appears as a single number in the allocation of a single agents (an asset for an agent). But bank-money appears as a pair of numbers in the allocations of two agents (an asset for the non-bank agent and a liability for the bank). Whence, bank-money cannot be treated as a commodity. It follows that individual wealth does not consist exclusively of commodities. There are also financial assets and financial liabilities (a financial asset is an asset in the allocation of one agent and it is at the same time a liability in the allocation of another agent). As a consequence, the utility concept, which evaluates exclusively commodities, cannot be used any more for the individual evaluation of the individual wealth.

Table 2 summarises the differences of the two theoretical frameworks.

Table 2. Differences between the mainstream and non-mainstream economic approaches.

	Mainstream economics	**Non-mainstream approach**
main objective	price determination	credit-money representation
economic relation	exclusively exchange	also credit
individual wealth	commodities	also financial assets and liabilities
individual evaluation of wealth	utility	not utility

CONCLUSION

More and more natural scientists by formation publish in the field of economic sciences with more success in the analysis of financial markets and with less success in the analysis of the overall economy.

We suggested that this difference is not by chance. In fact, most of the works try to answer questions formulated by mainstream economists. As we have shown, the major question formulated by mainstream economic theory, which feeds other questions, is the determination of prices. On the level of microeconomics, this question is adequate. But on a macro level, even if these questions are correctly replied, the answers do not help to understand the functioning of our modern economies. Whence the lack of success on a macro level.

Some attempts, to model the overall economy allow for the abandon of the mainstream framework [17 – 19]. However, in a context, when non-mainstream economists are also ignored, it is not surprising that interdisciplinary approaches, which often have the additional burden of not using the “official economic language” are neglected.

ACKNOWLEDGMENT

This work was funded by the Bolyai Janos Grant of the Hungarian Academy of Sciences.

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MODELIRANJE TRŽIŠTA U ODNOSU NA TRŽIŠNE EKONOMIJE: USPJEH I NEUSPJEH

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SAŽETAK

Nelinearno, stohastičko, ili termodinamičko modeliranje te modeliranje putem agenata ili mreža alati su koji se rabe u ekonomiji, a razvijeni u drugim područjima. Iako su primjenjeni u gotovo svakom dijelu ekonomije, ovi su alati pokazali znatni uspjeh samo u analizi financijskih tržišta. Kao razlog tomu predlažem prvenstveno nemogućnost vodeće ekonomske struje za prikladnim predstavljanjem funkcioniranja modernih tržišnih ekonomija, a tek u manjoj mjeri nedostatke tih alata. Obrazlažem da metoda vodeće ekonomske struje o razumijevanju tržišnih ekonomija pomoću istovremenog određivanja cijene u svim tržištima ne predstavlja na zadovoljavajući način naše ekonomije. Zbog toga, prilikom modeliranja financijskih tržišta, krajnji cilj – zadovoljavajuće određivanje cijena – jest postignut, ali prilikom modeliranja tržišnih ekonomija krajnji cilj – zadovoljavajuće predstavljanje modernih tržišnih ekonomija – nije postignut čak i ako su sve cijene zadovoljavajuće određene.

KLJUČNE RIJEČI

ekonomski odnosi, koncept tržišta, kreditne operacije, monetarna ekonomija

Interdisciplinary Description of Complex Systems 3(2), 100-108, 2005

RESEARCHING PRISON – A SOCIOLOGICAL ANALYSIS OF SOCIAL SYSTEM

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Conference paper *Received:* 9 December, 2005. *Accepted:* 15 December, 2005.

SUMMARY

The assumption that society is a complex system is a common and trivial in sociology. Most of the great sociological theories treat society as a complex system explicitly or implicitly. Because social system is always multidimensional it is easier to build such a theory than to apply it to practice. Therefore, it is still not fully explored issue, especially when theory meets empirical data. The aim of this article is to examine the complexity of a social system on the example of prison. The main issues discussed here are: the interplay of elements of the system and its consequences, dynamics of social process, influence of social change and interdependence of microsystem and macrosystem. The article presents the sociological perspective on social system.

KEY WORDS

social system, complex system, interdependence, social relations, prison

CLASSIFICATION

PACS: 87.23.Ge

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WHAT IS SOCIAL SYSTEM

Social system is a concept used relatively early in sociology by functionalists. And from the very beginning a social system was considered as complex ('the father' of sociology, August Comte regarded society as the most complex level of reality). The concept of a system indicates the society is an entity. It also points out the intrinsic social forces that rule the system and prevent it form collapsing. At the same time the systemic approach to society has been strongly criticized in sociology mainly because of organic analogies and psychological terms used to describe specific social phenomena.

To understand what it is the complexity of a social system different aspects and different levels of social phenomena must be considered. Explanation of the system might point out the dynamic or static aspect of a system. The dynamic approach to social system explores such phenomena as equilibrium, relations of the elements, conflict, development etc., while the static approach deals with such notions as structure, normative system, social control, individuals, groups, institutions, culture, and collective actions, however many of these can be analyse in both perspective.

Let us assume that society is a system. What does it mean? And what is a complex system?

At least few features are important in the definition of a social system:

- System is the entity consisting of elements which are bounded which means that components constitutes a system. The relations among the elements are themselves important parts of the system. Elements of the system might be quite heterogeneous and yet they are interrelated. The relations also may alter. Interdependence of the elements in the system is one of most important assumption for systemic approach in sociology.
- Social system is an emergent structure, a new type of social order appears on particular level of structure (individual, group, institution). System-level properties are of new quality: "system-level exists solely as emergent properties characterizing the system action as a whole" [1, p.28]. Macro-level outcomes is often the result of interdependence of social actors. The interdependence of social actors (microlevel) means that the systemic level is not merely the outcome of aggregated individuals.
- There are many sub-systems on different levels (e.g. micro and macrolevel) or areas (e.g. economic, political, religious institutions of a society). The relation between individual (micro) and systemic level (macro) is on of the crucial in sociology. The question is whether each subsystem has its own specificity and to what extent it must be taken into consideration in explanation.

COMPLEXITY OF SOCIAL SYSTEM

Complexity of social system represents different types of social phenomena and at the same time emphasises multidimensional nature of social world. Social system is formed by the characteristic of it components. One of the typical definition of complex system is as follows: complex systems are systems with multiple interacting components whose behaviour cannot be simply inferred from the behaviour of the components. This definition precisely points out the constitutive features of complex system. James Coleman proposes to explain "the behaviour of social systems by means of three components: the effects of properties of the system on the constraints or orientations of actors; the actions of actors who are within the system; and the combination or interaction of those actions, bringing bout the systemic behaviour" [1].

In order to show how complex is the social system I would like to analyse few aspects of complexity. There are many forms and types of social relations and they can generate different social forms: one can distinguish so called weak and incidental interactions, more petrified relations, up to social ties and social structure. If the system is complex then its elements are numerous and they are in mutual relations.

One can see it analysing the relations of the system. Let's examine 'few' important features of social relation itself:

- the size of the group,
- the type of relation (mutual and no mutual relations, unilateral, bilateral, multilateral relations),
- recurrence, durability and stability of relations,
- the formal and informal aspect of relations,
- the communicational aspect o relations,
- the power, dependence, and control as the dimension of relations,
- the aspect of emotional ties, interest ties etc of social relations and much more.

This particular example shows how complicated may be analysing the social relations.

Other elements of social reality may take also diverse forms. Each subsystem consists of various levels of social organisation: from simple through more complicated: individuals, social entities, groups, communities, institutions. One of the most typical examples showing how parts of a system give rise to the collective behaviors of the system is to compare the individual actions and collective actions.

The interrelations of collective actions are usually more complex and the effects of such activity are different. It must be emphasized that most sociologists would agree that action takes place at the level of individual actors and the more complex level exist as emergent properties characterizing the system of action as a whole [1 – 3]. "It is only in this sense that there is behavior of the system" [1]. If one considers the institutional aspect of social system then, again, one has to deal with patterns of behaviour, system of norms and social rules. At this point culture as a object of analysis appears. Culture is always an important part of each social system and sometimes is treated as a separate system by sociologists (it is a complex entity consisting of subsystems of values, norms, patterns of behaviour etc.).

Thus, complexity of a social system represents a multidimensional social reality. Researching social system is to answer the question which elements of that complex entity play the main role in explanation of some aspects of social reality.

A PRISON AS A SOCIAL SYSTEM

A prison as a social system is a special subject of research for several reasons. First, a prison is a relatively isolated social system and may be analysed much easier in terms of social system than other cases, especially a society as a whole is too complex system to research it directly. Second, the correctional institution is an example of total institution which consists of two communities or subsystems: the inmates and the staff. Third, this kind of institution is relatively separated and differs from other organizations in degree of control mechanisms, but it has also connections with outside environment. A macro scale perspective shows the connection between the mega system and subsystems and its consequences.

Two levels of analysis are proposed here: medium scale social system, specific social relations in prison community, and the relations between super-system (macrosystem) and sub-system (prison). The nature of the relations themselves is a separate issue. The aim of the article is to present several examples and brief analysis on social system and discuss the issue of system complexity. I believe such an investigation allows to understand the specificity of social reality and enables better research.

Researching the complexity of prison as a social system demands to explore the organisational aspect of system first. At least three aspects are important:

- type of prison,
- size of prison and prison community,
- spatial distribution and arrangements of space.

Depending on conditions of imprisonment and type of sentence there are different kinds of prisons: closed and open (in fact there are two types of open prisons: semi-open and open, but for this analysis I will ignore the difference).

The grade of confinement is crucial because it supports various type of structure, group relations and communication system. Thus one can see how one single feature (open/closed organisation) influences the system. There is diversity in connectivity among the individuals. The open system makes it easier, while the closed one does not. Consequently, the communication channels in open system are numerous and in the closed system are limited.

The other issue is the role of communication in forming collectivity, for instance community. It must be emphasised that the conditions of communication have further consequences. The quality of space distribution and social interaction generate different type of social relations and groups. In result, in closed system there are stronger social ties in cell-groups, weak ties in prison community and little mobility whereas in open system there are less integrated community, weak ties, lack of trust. Moreover, these set of conditions are conducive to specific style of behaviors of the system, for instance the probability of conflicts, the strength and resolution of the conflicts would diverge. All these features are the consequence of communications system. Figure 1 illustrates the whole process that is how the open or closed communication channels form diverse social ties.

Relation between an individual and group is of great importance. The action of the individual in group are under the influence of more complex level, that is group level. Individuals actions are determined (to some extent) by the groups. It means that “the members of solidary groups act in ways that are consistent with collective standards of conduct, norms, because they are obliged to do so” [4].

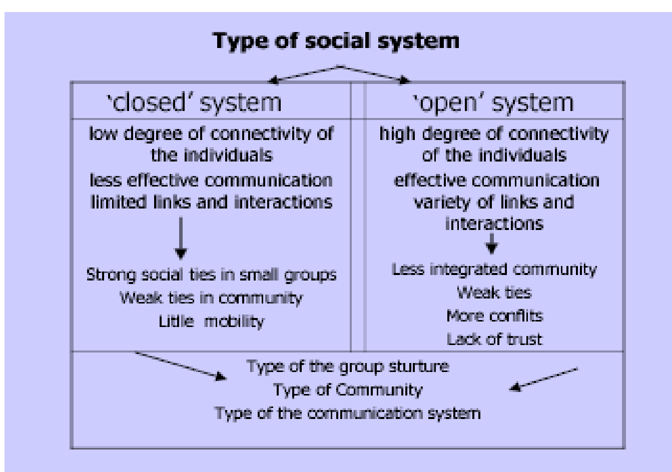

Figure 1. Forming social ties through communication channels.

All these following features are bounded to each other and this is one of the important criterion of system.

The structure of prison community is another interesting aspect of complexity of the system. The structure is one of the most important element of the system because it has the capacity for structuring other aspect of the social reality. The structure gives the interdependence to the individuals' actions and it is not only the feedback processes [1]. Actions of social actor have systemic character thanks to the interdependence.

The societal organization of prison consists of two groups: the inmates and the staff. What is more, the inmates are not homogenous collectivity, several groups may constitute it. This is in fact some simplification, but let us assume that there are two groups of inmates: the members of subculture group and the 'ordinary' prisoners who do not belong to subculture groups. Figure 2 shows the structure of community inside the prison system.

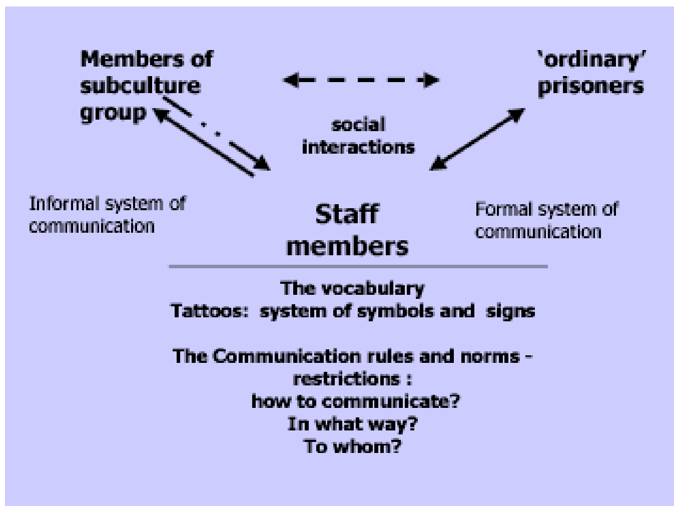

Figure 2. Prison community structure.

It is often underlined that social world being a complex system is multidimensional. It can be observed inside the prison community where the mutual relations and the structure develop several elements of the system. The social interactions among members of the subculture groups are different than the interactions between non-subculture members and the staff. There are numerous norms that rules their relations and communication.

How complex is the communication subsystem? Prison communication system contains informal and formal subsystem. Moreover, the system of communication consists of – at least – several elements such as tattoos, set of symbols and signs, the social norms that control contacts. The norms inform how to communicate? In what way? To whom? And all those elements may vary depending on type of prison system (closed or open).

The list of elements is not complete, I do not intend however at this point to analyse the whole system, thoroughly. This limited presentation is to emphasise merely the complexity of societal system.

Concluding, if complexity is a research problem it is necessary to consider several variables that determine the human behaviour and the significance of these elements for the system.

DYNAMICS OF COMPLEX SYSTEM

Social change is an example of complexity of societal system. First of all, the dynamic approach to the system reveal the connections among the elements and the results of their interplay – interdependence. Second, it enables to follow the change of the system which probably is visible only if one treats the social entity as a system. A single element may react to other element of a system starting the chain reaction in a social process. "Actions of each actor are somehow connected to those of others at an earlier point in time. This sequence of effects can continue into the future" [1, pp.29-30].

An example that illustrates how system may change is the process of adaptation to the environment. Let's consider the relations between communication system and other elements. Communication system creates several elements of social system such as the social structure, the group identity and group solidarity. An interesting phenomenon is 'prison life within the language'. Language must be consider here in boarder sense as an area where verbal acting replaces 'real' behaviours. It is of course the result of adaptation of the system to the given conditions i.e. numerous constraints. It is obvious that free acting is restricted. In such conditions inmates use verbal act as real behaviors, e.g. stigmatisation in closed small community or group is much stronger and more effective than in open society where individual mobility is high. The secret language (or precisely: vocabulary) of prisoners is another example of adaptation to environment. The reason to create such a language is the inmates' need to communicate without control of personnel in prison.

An interesting issues is how does spatial distribution affect the communication channels and change the social system in the end. Communication and language as a main area of social life become more influential as a part of the whole system. For instance the rumours, the stigmatisation, the ascribed social role or opinions would create the social structure and impose the execution of social norms. Generally, communication especially verbal contacts are the area of social action much more developed because they take over the functions of social actions [5]. The case proves that social relations, especially communication have an effect on different forms of social life and processes. Communication practices and language uses play an important role for they construct social reality within the language and beyond the language reality. The tattoos have the same role as the signs, they denote the social roles and social identities of prisoners. The subculture norms also can be treated as the effect of adaptation, most of the norms are suited to specific living conditions in the prison. Concluding, in general the prison subculture is the result of adaptation of the system.

Let us analyse closer another example: the process of the influence of the relations within social structure. Social relations form the social structure in prison. The type of the structure depends on:

- type of communications links,
- the formal structure and organisation of prison, and
- spatial distribution.

The communication competence of individuals is also important factor. For instance if an individual who has a high communication competence exchange different kind of goods (cigarettes, coffee, or even very rare goods as narcotics) such an exchange starts the process of building social position of an individual. Successful exchange and good relations generate the high position and prestige. All these variables interact in forming specific type of social structure. These factors construct the system of distribution of interest and the structure of power. Thus, social interactions form the social system. The frequency of contacts determine the quality of social relation. Frequent interactions may turns into social ties, and consequently, if there is unequal distribution of power and control, into social structure, Fig. 3.

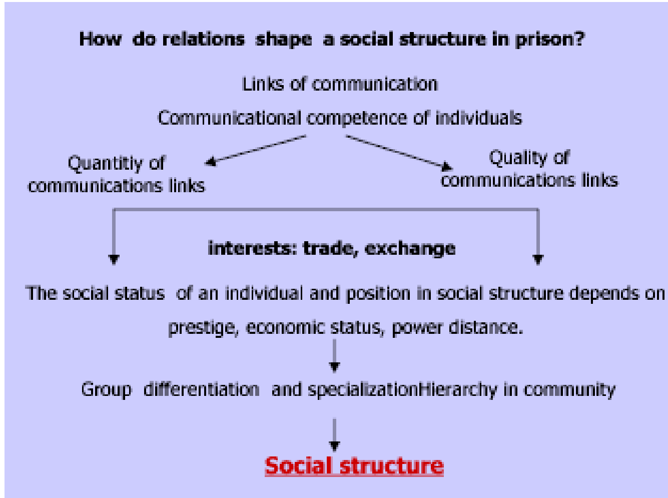

Figure 3. Role of relation in shaping prison social structure.

INTERDEPENDENCE OF MICRO SYSTEM AND MACRO SYSTEM

One of the crucial problem for sociological theory is to explain the relation between the micro and macro level. This kind of relation is understood as the connection between (macro)system and subsystem.

Let us assume that the outside social environment is the macro system and the prison is subsystem (the sub-system of prison) and that there is dependence of microsystem from macrosystem. One of the primary assumption is that the sub-system reflects the mechanisms of macrosystem, as it is its part. The dominant factors of the macrosystem become dominant in subsystem, too. And this is the case of the correctional system in Poland.

The influence of the macro-system on the prison as social system is complicated itself because the macro system consists of several subsystems: society, economic and political institutions, culture, law etc. Which sub-system might be important for prison sub-system?

Among many features the free market economy and political change would be the main factors that changed the macro system and consequently changed the subsystem of prison. The market economy altered the circumstances that govern the structure, which means that money is the main resources that redistributes the power, and influences the social relationships. As to political change, the democratisation of the system is also the feature of subsystem. The attitude towards the criminals, the politics of punishment and the law are the subject of political decisions. All these changes of the outside environment determine the conditions of imprisonment.

Political change was performed on the macrolevel by administrative decisions. The conditions of living and the rights of the inmates improved significantly after 1990 as a consequence of new regulations implemented as the macro-to–micro transition. Whereas the market economy was much more the area of micro-to-macro transformation of the prison subsystem. Gradually, new resources (money) started to shape the social reality and formed the social structure, changed the social ties, and above all introduced conflicts that destroyed group solidarity.

One of the significant and widely recognised result of free market is the change of social solidarity. Free market promotes erosion of social solidarity because it causes very often the conflicts of interests. This sometimes is perceived as the threat to social order, which is wrong. Free market supports rather new kind of social ties, and it is responsible for social change. It stimulate the new social order that implies more conflicts and less collective actions but still it is some social order.

The relation between the prison and the environment is at first glance simple: the sub-system take over the features of the mega system. But if one follows further consequences it appears that new elements may appear as the result of the specificity of the subsystem. Why is that? The particular set of features inside the prison interact with each other and can generate the specific feature of subsystem that can not be predictable merely from the features of environment. Therefore one can distinguish the two types of system that are formed by different outside environment (mega system): totalitarian prison vs free-market prison. This clear distinction illustrates the great social change of macro system. Here are the characteristics of totalitarian and democratic prison subsystem that reflects the conditions of the outside environment:

TOTALITARIAN PRISON

- the restricted system of institutional control,
- the limited access to the material goods,
- the social status depend less on one's economic status and more on social identity,
- the high level of deprivation of economic, social and psychical needs,
- the group interests and individual interest converge,
- the mobility in population of criminals is little.

'DEMOCRATIC' PRISON

- less restricted system of institutional control,
- wider access to goods,
- the social status of individual depends on one's socio-economic relation with other member of community,
- the social distance increases that divides community in much distinct way: the poor – the rich,
- the individuals' interest and group interests are in contradictions,
- the social mobility population of criminals increases (new kinds of crime).

This brief presentation specifies the main differences of subsystem that are the consequences of the macrosystem.

In democratic prison subculture gradually disappears because it is hostile environment that support the appearance and development of subculture strong community. The main function of that community was to survive. In comparison with totalitarian prison democratic prison takes over the function (or rather takes much more care) of supplying goods for the inmates. The interdependence of microsystem to macrosystem causes the change in subsystem.

CONCLUSIONS

I tried to demonstrate the complexity of social system by using example of prison. The multidimensional social reality might seem a chaotic, not systemic but in fact it has an order (which sometimes is hidden) that rules the social world. The social reality has numerous regularities. If we look at society in systemic way we are closer to discover that order. It is not easy to examine complex social system. Sociologists always are capable to research it only to some extent. So one can explore merely some aspects of complex social system. This conclusion may be not satisfying for the Reader but it is closer to truth about complex social system.

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PROUČAVANJE ZATVORA – SOCIOLOŠKA ANALIZA SOCIJALNOG SUSTAVA

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SAŽETAK

Pretpostavka da je društvo kompleksni sustav uobičajena je i trivijalna u sociologiji. Većina velikih socioloških teorija razmatra društvo eksplicitno, ili implicitno kao kompleksni sustav. Socijalni su sustavi uvijek višedimenzionalni, zbog čega je jednostavnije izgraditi odgovarajuću teoriju nego je primijeniti. Odgovarajuća problematika nije dovoljno istražena, posebno u usporedbi teorijskih rezultata i eksperimentalnih podataka. Cilj ovog članka je ispitati kompleksnost socijalnog sustava na primjeru zatvora. Glavne razmatrane cjeline su: povezanost elemenata sustava i njihove posljedice, dinamika socijalnih procesa, utjecaj socijalne promjene i međuovisnost mikro- i makro sistema. Članak postavlja sociološku perspektivu socijalnog sustava.

KLJUČNE RIJEČI

socijalni sustav, kompleksni sustav, međuovisnost, socijalni odnosi, zatvor

MANUSCRIPT PREPARATION GUIDELINES

Manuscript sent should contain these elements in the following order: title, name(s) and surname(s) of author(s), affiliation(s), summary, key words, classification, manuscript text, references. Sections acknowledgments and remarks are optional. If present, position them right before the references.

SUMMARY Concisely and clearly written, approx. 250 words.

KEY WORDS Not more than 5 key words, as accurate and precise as possible.

CLASSIFICATION Suggest at least one classification using documented schemes, e.g., ACM, APA, JEL, PACS.

TEXT Write using UK spelling of English. Preferred file format is Microsoft Word. Provide manuscripts in grey tone. For online and CD-ROM versions, manuscripts with coloured textual and graphic material are admissible. Consult editors for details.

Use Arial font for titles: 14pt bold capital letters for titles of sections, 12pt bold capitals for titles of subsections and 12pt bold letters for those of sub-subsections.

Include figures and tables in the preferred position in text. Alternatively, put them in different locations, but state where a particular figure or table should be included. Enumerate them separately using Arabic numerals, strictly following the order they are introduced in the text. Reference figures and tables completely, e.g., "as is shown on Figure 1, *y* depends on x …", or in shortened form using parentheses, e.g., "the *y* dependence on *x* shows (Fig. 1) that…".

Enumerate formulas consecutively using Arabic numerals. In text, refer to a formula by noting its number in parentheses, e.g. formula (1). Use regular font to write names of functions, particular symbols and indices (i.e. sin and not *sin*, differential as d not as *d*, imaginary unit as i and not as *i*, base of natural logarithms as e and not as *e*, x_n and not x_n). Use italics for symbols introduced, e.g. $f(x)$. Use brackets and parentheses, e.g. {[( )]}. Use bold letters for vectors and regular GoudyHandtooled BT font (for MS Windows) or similar font for matrices. Put 3pt of space above and below the formulas.

Symbols, abbreviations and other notation that requires explanation should be described in the text, close to the place of first use. Avoid separate lists for that purpose.

Denote footnotes in the text by using Arabic numerals as superscripts.

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ISSN 1334-4684 (printed)
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