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P.P. TROKHIMCHUCK
Lesya Ukrayinka East European National University

PROBLEMS OF COMPLEXITY IN MODERN CYBERNETICS AND COMPUTING SCIENCE AND WAYS OF THEIR RESOLUTIONS

Problems of complexity in modern cybernetics and computing science are discussed. Possible ways of their resolutions are represented. Two concepts of this problem (computational and system) are analyzed. First concept is connected with idea of created universal theory of calculation. Second concept has more wide scientific value: creation universal system of analysis, synthesis and formalization of knowledge. It was shown that theory of optimal informative calculation is realization of first concept, and polymetric analysis – second concept. Basic perspectives of development and application of these concepts are discussed too.

Keywords: complexity, cybernetics, computing science, informative calculations, polymetric analysis, S. Beer problem of century in cybernetics.

П.П.ТРОХИМЧУК
Східноєвропейський національний університет імені Лесі Українки

ПРОБЛЕМИ СКЛАДНОСТІ У СУЧАСНІЙ КІБЕРНЕТИЦІ ТА ІНФОРМАТИЦІ ТА ШЛЯХИ ЇХ РОЗВ´ЯЗАННЯ

Обговорюються проблеми складності в сучасній кібернетики та інформатиці. Представлені можливі шляхи їх розв'язку. Проаналізовано дві концепції цієї проблеми (обчислювальна та системна). Перша концепція пов'язана з ідеєю створення універсальної теорії обчислень. Друга концепція має більш широке наукове значення: створення універсальної системи аналізу, синтезу та формалізації знань. Було показано, що теорія оптимальних інформаційних обчислень є реалізацією першої концепції, а поліметричний аналіз - другої концепції. Основні перспективи розвитку та застосування цих концепцій обговорюються також.

Ключові слова: складність, кібернетика, інформатика, інформаційні обчислення, поліметричний аналіз, проблеми століття С. Біра в кібернетиці.

П.П.ТРОХИМЧУК
Восточноевропейский национальный университет имени Леси Украинки

ПРОБЛЕМЫ СЛОЖНОСТИ В СОВРЕМЕННОЙ КИБЕРНЕТИКЕ И ИНФОРМАТИКЕ И ПУТИ ИХ РЕШЕНИЯ

Обсуждаются проблемы сложности в современной кибернетике и информатике. Представлены возможные пути их решения. Проанализированы две концепции этой проблемы (вычислительная и системная). Первая концепция связана с идеей создания универсальной теории вычислений. Вторая концепция имеет более широкое научное значение: создание универсальной системы анализа, синтеза и формализации знаний. Было показано, что теория оптимальных информационных вычислений является реализацией первой концепции, а полиметрической анализ - второй концепции. Основные перспективы развития и применения этих концепций обсуждаются также.

Ключевые слова: сложность, кибернетика, информатика, информационные вычисления, полиметрической анализ, проблемы века С. Бира в кибернетике.

Introduction

Problem of complexity is one of central problem in modern science, including mathematics and cybernetics [1 – 17]. This problem is caused in synthetically sciences. Roughly speaking it has two aspects: system (problem of century in cybernetics according S. Beer [1, 10, 13]) and computational (problem of computational complexity [1, 2, 17]. Last problem is included in basic problems of modern mathematics (Smale problems) [1, 11].

As variant of resolution system aspect of problem complexity in cybernetics may be problem simplicity – complexity, which is included in Polymetric Analysis (PA) (universal system of analysis, synthesis and formalization of knowledge) as principle simplicity.

Hybrid theory of systems (HTS) as element of PA is created on the basis principles (criteria) of reciprocity and simplicity [1–4]. Only 10 minimal types of formalization system may be used. But number of real systems may be infinite. These systems are differed by step of its complexity. It is may be represented as answer on the one of basic question of modern theory of systems [1, 3–7, 9] about possible number of systems and its classification with point of simplicity – complexity [1, 3–6].

Therefore HTS may be represented as variant of resolution the problem of century in cybernetics according S. Beer and may be used for the resolution problem of computational complexity (theory of informative calculations, TIC) [1, 3–6].

Theory of informative may be represented as variant of resolution of computational complexity [1, 3–6].

Basic results and discussions

We begin this chapter from phrase by S. Beer [10]: "Apparently, the complexity becomes the problem of the century, just as the ability to process natural materials has been a problem of life and death for our forefathers. Our tool must be computers, and their efficiency should be provided by science, able to handle large and complex systems of probabilistic nature. This science may be cybernetics - the science of management processes and communication. The basic thesis of cybernetics can be set forth as follows: there are natural laws behavior of the large multibonds systems of any character submits that - biological, technical, special and economic." But nature of some problems may be nonprobalistic too. Therefore this problem must be expanded on problem of formalization of all science and knowledge. But modern science is the realization of the R. Bacon – Descartes concept "Science is so science, how many mathematics is in her" [1]. Development of modern science practically isn't possible without computers.

Computational complexity theory [17] is a branch of the theory of computation in theoretical computer science that focuses on classifying computational problems according to their inherent difficulty, and relating those classes to each other. A computational problem is understood to be a task that is in principle amenable to being solved by a computer, which is equivalent to stating that the problem may be solved by mechanical application of mathematical steps, such as an algorithm.

A problem is regarded as inherently difficult if its solution requires significant resources, whatever the algorithm used. The theory formalizes this intuition, by introducing mathematical models of computation to study these problems and quantifying the amount of resources needed to solve them, such as time and storage. Other complexity measures are also used, such as the amount of communication (used in communication complexity), the number of gates in a circuit (used in circuit complexity) and the number of processors (used in parallel computing). One of the roles of computational complexity theory is to determine the practical limits on what computers can and cannot do [17].

Closely related fields in theoretical computer science are analysis of algorithms and computability theory. A key distinction between analysis of algorithms and computational complexity theory is that the former is devoted to analyzing the amount of resources needed by a particular algorithm to solve a problem, whereas the latter asks a more general question about all possible algorithms that could be used to solve the same problem. More precisely, it tries to classify problems that can or cannot be solved with appropriately restricted resources. In turn, imposing restrictions on the available resources is what distinguishes computational complexity from computability theory: the latter theory asks what kind of problems can, in principle, be solved algorithmically [2, 17].

The question why the concept of computational complexity is hard for the verifiable mathematics was discussed by J. Hromkovič [16]. Therefore we must expand this problem on all science with help system with variable hierarchy or variable measure [18].

Therefore in computational sense these theories were generalized in theory of informative calculations, which is constructed on the basis of expansion quadratic forms on all possible procedure of measurement and estimation. Basic element of this theory was called as generalizing knot or functional number $N_{\varphi_{ij}}$. Basic notion of this theory generalizing informative calculations included all possible specific elements of fundamental and computing science: number of corresponding mathematical operations, their times of realization and algorithmic complexity.

Problem of creation optimal theory of calculations or informative calculations is caused of the development of modern science, including physics, cybernetics and computer science [1, 3–6]. Complexity of calculations is one of central problems of modern cybernetics and computer science [1-3]. This problem is included in famous important unresolved problems of modern mathematics (Smale problems) [1, 15].

The ways of resolution of problem complexity or creation universal theory of calculation were searched by Pythagor and Leubniz [1]. Pythagorean way was founded on the synthesis of esoteric Egyptian system and "open" Sumerian system. Leubnician way was caused to creation of modern differential and integral calculations and mathematical logics [1].

Another way resolution of this problem is theory of informative calculations [1, 5]. This theory is based on the polymetric theory (theory of variable measure or theory of measure and measurements with including procedure of measurements in measure) of measure and measurements and is one of basic element of polymetric analysis.

Polymetric analysis was created as universal system of analysis, synthesis and formalization of knowledge. PA is alternative optimal concept to logical, formal and constructive conceptions of modern mathematics and theory of information [1]. This concept is based on the idea of triple minimum: methodological, mathematical and concrete scientific.

Basic elements of this theory and their bonds with other science are represented in Fig. 1 [1].

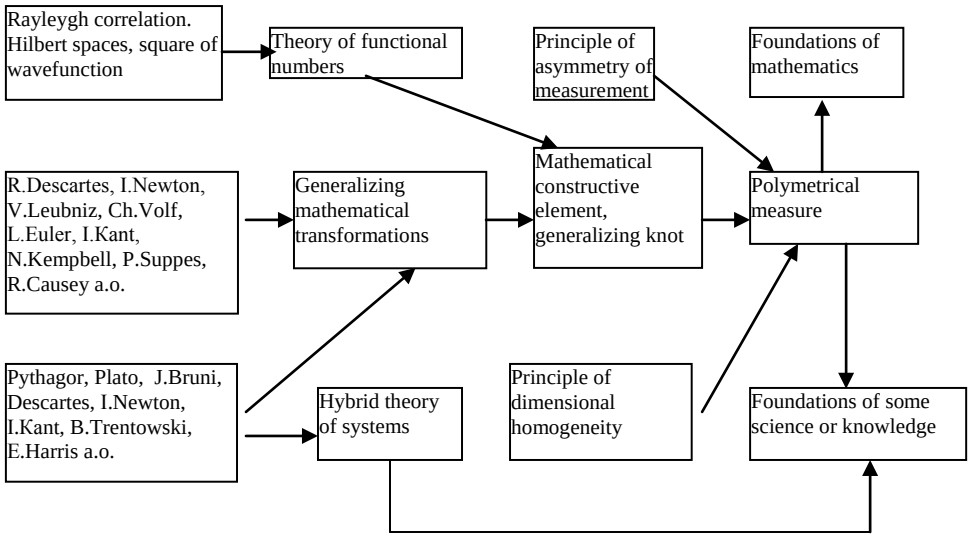

Fig. 1. Schema of polymetric method and its place in modern science [1].

Basic mathematical element of polymetric analysis is functional number (generalizing elements of quadratic forms) [1]. As in Greece mathematics number is basic elements of its system. For these numbers generalizing mathematical transformations were constructed. 15 minimal types of its transformations are existed. Informative lattice is constructed on the basis if functional numbers and generalizing mathematical transformations. Theory of informative calculations is created for this lattice. Basic principle of this theory is the principle of optimal informative calculations [1, 5].

For classification of systems of calculation hybrid theory of systems was created. This theory is based on two criterions: criterion of reciprocity – principle of creation of proper formal system, and criterion of simplicity – principle of optimality of this creation. For "inner" bond of two elements of informative lattice a parameter of connectedness σ_t was introduced. Principle of optimal informative calculation is included in criterion of simplicity.

At help these criteria of reciprocity and simplicity and parameter of connectedness the basic famous parts of knowledge and science may be represent as next 10 types of hybrid systems [1, 3, 4]:

1. The system with conservation all positions the criteria of reciprocity and simplicity for all elements of mathematical construction ($N_{\varphi_{ij}}$ and transformations) is called the *simple system.*

2. The system with conservation the criterion of simplicity only for $N_{\varphi_{ij}}$ is called the *parametric simple system.*

Remark 1. Further in this classification reminder of criteria of reciprocity and simplicity is absented. It mean that these criteria for next types of hybrid systems are true.

3. The system with conservation the criterion of simplicity only for general mathematical transformations is called *functional simple system.*

4. The system with nonconservation the principle of optimal informative calculation and with $\sigma_t = 1$ is called the *semisimple system.*

5. The system with nonconservation the principle of optimal informative calculation only for $N_{\varphi_{ij}}$ and with $\sigma_t = 1$ is called the *parametric semisimple system.*

6. The system with nonconservation the principle of optimal informative calculation only for general mathematical transformations and with $\sigma_t = 1$ is called the *functional semisimple system.*

7. The system with nonconservation the principle of optimal informative calculation and with $\sigma_t \neq 1$ is called *complicated system.*

8. The system with nonconservation the principle of optimal informative calculation only for $N_{\varphi_{ij}}$ is called *parametric complicated system.*

9. The system with nonconservation the principle of optimal informative calculation only for general mathematical transformations and with $\sigma_t \neq 1$ is called *functional complicated system*.

10. The system with nonconservation the criteriums of reciprocity and simplicity and with $\sigma_t \neq 1$ is called *absolute complicated system*.

With taking into account 15 basic types of generalized mathematical transformations we have 150 types of hybrid systems; practically 150 types of the formalization and modeling of knowledge and science [1, 3, 4].

Only first four types of hybrid systems may be considered as mathematical, last four types are not mathematically. Therefore HTS may be describing all possible system of knowledge. Problem of verbal and

nonverbal systems of knowledge is controlled with help of types the mathematical transformations and parameter connectedness [1].

HTS may be used for the classification and creation old and new chapters of all science, including computing science.

HTS may be used for the represented of evolution of systems in two directions: 1) from simple system to complex system (example, from classic to quantum mechanics) and 2) conversely, from complex system to simple system (example, from formal logic to mathematical logic) [1].

Hybrid theory of systems is open theory. Parameters of openness are number of generalizing mathematical transformations and parameter of connectedness. Thereby we have finite number of types of systems, but number of systems may be infinite. Hybrid theory of systems allows considering verbal and nonverbal knowledge with one point of view [1, 4 – 6]. Therefore this theory may be represented as variant of resolution S. Beer centurial problem in cybernetics [1].

HTS may be represented as application PA (HTS) to the problem of calculation [1, 3]. This theory was used for the problem of matrix computation and problem of arrays sorting [1, 3, 4].

HTS may be connected with problem of computational complexity. This problem was appeared in modern cybernetics for resolution of problem the transition from infinite (analytical) to discrete representation of computing procedures [1, 3, 4]. In may be connected with 4 and 5 Smale problems [1,15]

Mathematical constructive element may be represented as generalizing knot of informative lattice. Generalizing mathematical transformations are classified as quantitative and qualitative, left and right. Calculative (quantitative) transformations are corresponded to primary measurement and qualitative transformations – to derived (secondary) measurements. It allows formalizing N.R.Campbell concept [1, 8] about primary and derived measurements. Result of this formalization was named polymetric theory of measure and measurement. Basic principles of this theory are principle of asymmetry of measurement for calculative transformations and principle of dimensional homogeneity. This theory is optimal synthesis of all famous theories of measure and measurements and dimensional analysis [1]. N.R. Campbell concept is more general as “measuring” part of quantum mechanics [1, 3]. Therefore L.I. Mandelstam called Quantum Mechanics as science of derivative measurements [1, 3].

Polymetric analysis is the system of optimal formalization, synthesis and analysis of knowledge. But it is the nature of mathematics [1, 14]. For creation of theory of foundations of mathematics we must include three aspects: synthesis, analysis and formalization. This theory must be open system. Therefore Russel – Whitehead “logic” concept, Hilbert – Bernayce “formal” concept and Brauer – Heiting “constructive” concept can’t be full theories of foundations of mathematics [1]. It was cause of crisis in theory of foundations of mathematics. Therefore A.N. Whitehead made conclusion that logical concept can’t be the theory of foundations of mathematics [1, 19]. But it must be “organismic” theory[19]. Practically this concept was realized in cybernetics: theory of neuronets, systolic computers, theory of cellular automata a.o. [1]. Therefore polymetric analysis may be represented as variant of realization of Whitehead concept of “organism” mathematics and formalizing unification of proper cybernetic theories (Ivakhnenko concept of neurosets itc.)[1, 7, 11].

Attempt of association of all possible knowledge in one system on the number (arithmetical) basis was made by Platon: three types of numbers (arithmetical, sensitive and ideal). With modern point of view a arithmetical numbers are corresponded to modern pure mathematics; a sensitive numbers are corresponded to modern applied mathematics and ideal numbers are corresponded to other chapter of science and knowledge [1].

Polymetric analysis may be represented as optimal “dynamical” formalization of Errol E. Harris polyphasic concept of modern science [1, 12]. But Harris concept hasn’t universal “dynamical” mechanism of creation and evolution of science.

Polymetric measure (generalizing knot of informative lattice) may be used in monadology as monada [6]. Only Leubniz considered monad as a universal first principle [6], J. Bruni considered monad as philosophical first principle only. Therefore polymetric analysis may be represented as formalization of Leubnizian monadology and variant resolution of second her problem: search and creation of universal calculation. This problem must be resolve with help methods of theory of open system. Roughly speaking, in Leubnizian terms, we must be uniting concept of monad with concept of creation of universal calculation. But universal terms of mathematics are number and measure. This concept must be general for the creation universal system of knowledge. Therefore the polymetric measure (functional number, generalizing knot of informative lattice) is included this concept, but it include the procedure of measurement with help generalizing mathematical transformations

Polymetric analysis may be represented as renewal ancient Egyptian and Pythagorean systems (only their computational part) [1, 3, 5]. It may be answer on question: why Egyptian and Greece mathematics managed without zero [1]. But it may be represented as answer on Pythagorean phrase: “Numbers rule of the World” and variant of decoding “mathematical” part of famous Egyptian mythological table by god Thot [1].

Thus basic concepts of awakening, creation and development of synthesis with including of historical analysis of this problem are represented in [1]. Therefore with this point of view polymetric analysis is the necessary development of problem of formalized synthesis in modern science.

According to A. Ershov basic problem of modern computer science is formalization of phrase of Canadian philosopher L. Hall: “Everything comes from the head – intelligent” [1]. Therefore PA may be represented as optimal formalization of this thesis and, as effect, theoretical basis of modern computing science (informatics) [1, 3]

too. In our time theory of modern computing science must be universal system of analysis, synthesis and formalization of knowledge and it must be connected with concepts of number, measure and measurement that to comply with the most basic issues and problems of modern computer science. But it is problems of polymetric analysis. Problems of simplicity- complexity is include in the basis of this science and have many values and meanings.

Conclusions

1. Problems of complexity in modern cybernetics and computing science are discussed.
2. Some historical aspects of problem simplicity-complexity are analyzed too.
3. It was shown that this problem may be resolved with help of theory of open systems.
4. It was shown that HTS may be represented as variant of resolution problem of century in cybernetics according by S. Beer and theory of informative calculations – as variant of resolution of problems of computational complexity.
5. Basic concept and chapters of polymetric analysis are analyzed.
6. It shown, that polymetric analysis is the necessary development of problem of optimal formalized synthesis in modern science.

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