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## INTERDISCIPLINARY APPROACH TO INFORMATIONAL TEACHING ENVIRONMENT FORMATION

*В.П. Мигаль, Г.В. Мигаль.* Міждисциплінарний підхід до формування інформаційно-навчального середовища. Притаманні навчальному середовищу різні види джерел інформації породжують різноманіття інформаційних полів і потоків, що створює труднощі студентам у виборі засобів їх обробки, відображення та аналізу. Мета роботи – показати нові можливості, що надає геометризація інформаційних потоків в системі «студент – інформаційно-навчальне середовище» на міждисциплінарній основі. Вона дозволяє порівнювати інформаційні навчальні потоки з їх графічними образами – геометричними моделями, більша наглядність яких сприяє глибокому їх вивченню і аналізу за допомогою взаємозв'язаних параметрів і статистичних показників. Використання уніфікованих засобів виявлення структури інформаційних потоків і полів дозволяє аналізувати їх просторово-часову узгодженість. Це сприятиме оптимізації структури навчального середовища, адаптивність якого надасть студентам відчуття ефективності, а викладачам – нові можливості для створення інноваційних засобів для навчання і самонавчання.

*Ключові слова:* навчальне середовище, інформаційні потоки, графічні образи, структура управління, цикл функціонування, формування стресостійкості, освітні проблеми

*V. Mygal, G. Mygal.* **Interdisciplinary approach to informational teaching environment formation.** Different types of information sources that are inherent in the teaching environment generate a variety of informational fields and flows, which creates difficulties for students in choosing tools for processing, display and analysis of information. The purpose of the work is to show new opportunities that are provided due to geometrization of informational flows in the "student – informational teaching environment" system on an interdisciplinary basis. It allows comparing informational teaching flows with their graphic images – geometric models, which greater visibility contributes to their thorough research and analysis using interconnected parameters and statistical indicators. The use of unified means of exposing the structure of informational flows and fields facilitates the analysis of their spatiotemporal consistency. This will contribute to optimization of the teaching environment structure, the adaptability of which will give students a sense of efficiency while teachers will get new opportunities for creating innovative tools for teaching and self-education.

*Keywords:* teaching environment, informational flows, graphic images, management structure, functioning cycle, formation of stress resistance, educational problems

**Introduction.** The need to adapt educational space to modern realities is beyond doubt as today students have the opportunity to quickly find, update and evaluate information outside the lecture room, which opens up new opportunities for choosing place and means of study. The growth of information sources diversity generates new links between informational fields and flows, the study and analysis of which requires new approaches and management structure improvement of the educational institution. So, in order to adapt to the existing reality it is necessary to note that cybernetics as a management science considers interaction within system solely as informational. Therefore, more attention should be paid to the use of information tools for learning and the development of innovative methods that should facilitate the transition from teaching disciplines and information technologies towards individualizing learning with their help. In particular, computer training programs [1] as well as knowledge engineering technology and 3D modeling [2] are promising.

Analysis using means of pedagogical ergonomics, the methodological basis of which is systematic approach and complexity, found that growth of different types of teaching information and variety of its processing and display facilities are behind the inefficiency of teaching students. Altogether it creates additional difficulties for students in choosing information sources, which are the informational fields of the subject area, and methods for its analysis, and for teachers in structuring information and developing innovative teaching methods. Existing structures of management models of the "student – teaching environment" system do not take into account students' individuality, as

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well as are only slightly suitable for spatiotemporal coordination of informational fields and flows. In turn they are the main elements of the informational teaching environment, which structure is determined by the connections between these elements. Thus, the problems of informational teaching environment functioning and the optimization of its management structure are interconnected. Therefore, the **main purpose of this work** was to show new opportunities that are provided by geometrization of informational flows in the “student-informational teaching environment” system on an interdisciplinary basis. It aims to compare informational teaching flows with their graphic images, the greater visibility of which will contribute to deeper study and analysis.

**Current state of the problem.** The main cause of modern educational problems is the conservatism of the traditional approach to organization of training, the lack of information arrays structuring and limited means of their study [3]. In particular with such an organization of the educational environment there are difficulties in: a) identifying the diversity of interrelations between elements of the “student – teaching environment” system; b) individualizing teaching and taking into account student's opportunities and cognitive abilities; c) determining student's stress resistance. As a result problems in managing various informational flows using existing means appear. In particular spatiotemporal inconsistency of informational flows in the system has led to further search of new approaches to teaching environment organization, as well as to knowledge engineering. Today the subject of an ergonomic research of the “student – teaching environment” system functioning is an expert assessment, which is done using complex comprehensive analysis of the system from the standpoint of pedagogy, psychology, physiology, hygiene, etc. During such a research each expert uses his own terms, indicators, criteria and models. Therefore, the recommendations of these experts are not sufficiently consistent with each other, and are artificially associated into a single system of requirements for the organization of educational activity and the conditions for its implementation and mutual subordination. Consequently, such organization of the teaching environment does not contribute to teachers' creative potential growth and limits the use of high adaptive opportunities for students, in particular the further development of their individual cognitive and commutative abilities, as well as the formation of stress resistance in the students' learning process.

Thus, there is the **problem** of organizing an effective teaching environment, the **unresolved part of which is** the means of harmonizing all interconnections in the “student – teaching environment” system, which, based on the ergonomic laws of mutual adaptation [4], is essential for student's effective performance. It gives the student a sense of efficiency and functional comfort, increases motivation for learning and in modern psychology is considered as a potential criterion for successful work.

Therefore it is **relevant** and grounded to seek new approaches to the individualization of teaching through IT and ICT. It is hindered by an increase in volumes and sources of information as well as informational flows between them, which significantly increased the number of terms, parameters, indicators, criteria and models. They contribute to growing anxiety and accumulation of educational stress, which reduces the effectiveness of teaching.

Therefore there is a **contradiction** between student's individuality and adaptability on one hand and conservatism of the teaching environment organization and means of teaching on the other. As a result new problems, most of which are due to the variety of facilities of display and analysis of information, appear. Their lack of visibility and complementarity reduces the effectiveness of using new technologies in education. In order to eliminate this contradiction it is necessary to unify the teaching tools and the system's management structure, dominant elements of which are informational fields and flows. This can be realized in a more generalized ergonomic “student – informational teaching environment” system, the structure effectiveness of which is the **object of study**, and the **subject** – the facilities transforming informational flows into graphic images and their analysis.

**Research data, interpretation of results and discussion.** The analysis of publications of the management theory founders and modern researchers allows us to argue about the interdisciplinary concept of “informational flows structure”. Indeed, the founder of cybernetics N. Wiener, by introducing the concept of signal structure as a linear invariant, pointed at the similarity of management structures in objects of animate and inanimate nature, information about which in one-dimensional time-

signals functioning is almost absent. L. Vekker transferred these ideas into informational psychology and proposed code-structures that implement certain functions. And the ergonomist V. Venda used the mutual adaptation laws in formation of the structure-strategies of human activity by constructing corresponding graphic images, the so-called quadrigrams [4]. Thus, the concept of management structure is multidisciplinary, which allows it to be used in the analysis of various processes in both animate and inanimate nature. Indeed the analysis of progressive development of interdisciplinary sciences (cybernetics, ergonomics, design, system analysis, synergetics, ecology, logistics and others) shows their mutual influence and enrichment. This indicates overlapping of informational fields of these disciplines, in particular in analyzing the dynamics of dissimilar physical, biological, chemical and other processes.

In the teaching environment various types of informational flows (results of measurements and observations, Internet search, etc.), which a student processes during the study, are transformed into data in permanent form (tables, protocols, reference books, databases). Their transformation into models (structures, diagrams, graphs, functionals) enables identification and analysis of various information aspects of the corresponding processes. However, their diversity creates considerable difficulties in systematic analysis and generalization of teaching information. In particular, individual psychophysiological (cognitive and adaptive) human capabilities and acquired experience are not taken into account. Since individuality of a student and a teacher mostly shows during activity, spatiotemporal inconsistency of informational flows between the system elements often occurs in the teaching environment. Therefore in order to solve this problem such organization of training is required in which the student's choice of methods and time of study requires more self-education. This can be facilitated by complementary and interconnected tools for processing, displaying and analyzing information. Such unified means for analyzing dissimilar informational flows can be developed on a cyberphysical basis. Indeed, cybernetics considers solely informational interaction in the system, while in physics the same interaction is explored from dynamic and energy points of view. Therefore, it should be expected that the organization of informational teaching environment on the basis of this will facilitate:

- a) identification of hidden links between informational fields of various subjects;
- b) ensuring variability, coherence and complementarity of curricula;
- c) unification of teaching information structuring.

**Interdisciplinary approach to analysis of structure of informational flows.** The above mentioned analysis shows that the main problems of teaching environment functioning are:

- a) conservatism of teaching environment management structure;
- b) absence of system performance indicators;
- c) diversity of informational fields and flows, as well as educational tools;
- d) hidden spatiotemporal inconsistency of informational flows between certain teaching cycles.

The generalization of these and other features of teaching environment functioning indicates that the similarity of structure of various informational flows, which is typical for dynamics of natural processes, is needed. Indeed, in natural sciences dissimilar cyclic and evolutionary processes are analyzed, which dynamics of informational flows is described by interrelated parameters (state, speed and acceleration). These parameters have geometric content (length, steepness and curvature), which explains the informativeness of graphic images of dissimilar processes. Therefore it is not surprising that the geometrization of classical and quantum physics, biology, chemistry and ecology contributed to their development, as well as the development of new methods for analyzing the dynamics of processes of different nature (running signals, informational flows, etc.) and their reflection in the form of graphic images (wavelet-spectrograms, phase portraits, signatures, etc.).

Thus using the geometrization of informational flows it is possible to organize a more visible and harmonized informational teaching environment. For this purpose the most suitable is interdisciplinary approach to the research of functioning individuality of objects of animate and inanimate nature [5]. It lets dynamic description of their functioning to be completed by statistical one and to use fundamental laws, principles and criteria in the analysis. The methodological basis of the approach is parametric geometrization of the dynamics of physical, biological, chemical processes (responses, characteristics,

signals, etc.) in the space of dynamic events. In order to do this the one-dimensional time dependence of any parameter (running signal, information flow) after conducting double digital differentiation is presented as a three-dimensional closed trajectory of dynamic events in space (state–speed–acceleration), which is a 3D-parametric model of a dynamic system. Orthogonal projections of this trajectory are three individual graphic images, geometrically ordered configuration elements of which are signatures of the 1st and 2nd orders. Fig. 1 shows the 3D models and signatures of characteristics of dissimilar objects (spectrum of photoelectric objects, human cardiosignal, spectrum of thermal emission of the Sun ( $T=6000$  K), the mathematical model of which is the Planck formula and the physical one – blackbody standards).

Comparison of 3D models of dissimilar objects indicates that the signatures reflect:

- a) natural decomposition of information flow into dynamic, energy and information cycles;
- b) elements of signatures, which are geometrically ordered sections of their configurations and differ in steepness or curvature;
- c) spatiotemporal decomposition of the main phases of the functioning cycle.

It is important that the analysis of the indicated cycles using interconnected dynamic parameters provides complementary information about hidden links between elements of the system. Therefore it is not surprising that 3D-parametric models can be similar for dissimilar dynamic processes. Particularly remarkable is the similarity of interconnection nature of dynamic parameters, which determines configuration of the signature on the plane (speed-acceleration) that reflects the management structure (see Fig. 1 a, b, c)). This confirms the idea of N. Wiener on the similarity of principles of management in objects of animate and inanimate nature.

**Possibilities of geometrization of informational flows.** It should be noted that the representation of the signature area as the power of the corresponding microstate allows combining the dynamic and statistical analysis of informational flows, as well as using the statistical weight, entropy, and other parameters [5]. They allow determining integrative indicators of order of the functioning cycle structure and the balance of power between its main phases. In particular statistical indicators of order and balance of the antiphase

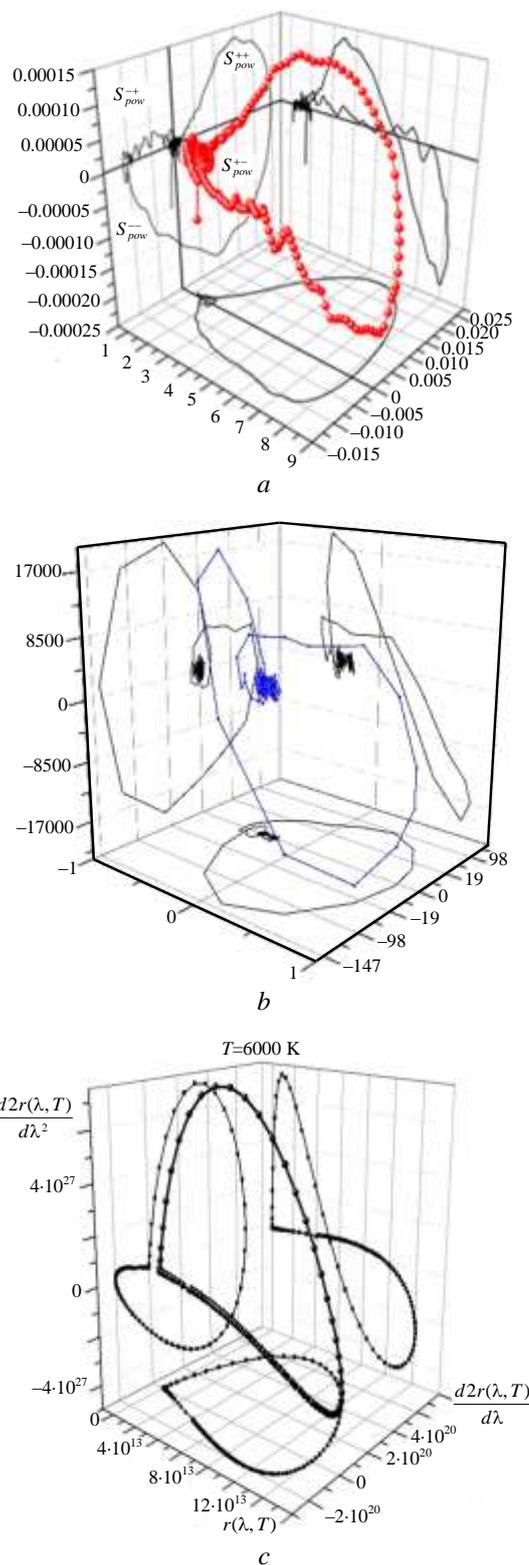


Fig. 1. 3D–models of dissimilar objects: spectrum of emission sensor (a), human cardiosignal (b), spectrum of a blackbody model at  $T=6000$  K (c)

functioning cycle components enable systematical analysis of any informational flow in the teaching environment under three complementary points of view – dynamic, energy and information. The configuration of the 2nd order signature deserves particular attention, where the structure of interconnections in the system or in its elements is depicted. This signature is located in 4 quadrants of the plane (speed–acceleration). Its configuration is a geometric model of functioning cycle of any element of the “student – informational teaching environment” system. In order to analyze the effectiveness of the functioning cycle of elements or the coordination of informational flows a controllability matrix is proposed, formed by dimensionless indicators of functioning power balance  $B_{ij}$  between main phases of the functioning cycle. The  $B_{ij}$  indicators are equal to the ratio of the areas of all signature quadrants to each other  $B_{12}=S^{++}/S^{+-}$  and so on. Hidden information about the structure of interconnections in the functioning cycle of any element of the system can be presented as a controllability matrix, which happens to be a cyberphysical model (see Table).

*Controllability matrix*

Quadrants	“+ +”	“+ -”	“- -”	“- +”
“+ +”	1	$S_{pow}^{++} / S_{pow}^{+-}$	$S_{pow}^{++} / S_{pow}^{--}$	$S_{pow}^{++} / S_{pow}^{-+}$
“+ -”	$S_{pow}^{+-} / S_{pow}^{++}$	1	$S_{pow}^{+-} / S_{pow}^{--}$	$S_{pow}^{+-} / S_{pow}^{-+}$
“- -”	$S_{pow}^{--} / S_{pow}^{++}$	$S_{pow}^{--} / S_{pow}^{+-}$	1	$S_{pow}^{--} / S_{pow}^{-+}$
“- +”	$S_{pow}^{-+} / S_{pow}^{++}$	$S_{pow}^{-+} / S_{pow}^{+-}$	$S_{pow}^{-+} / S_{pow}^{--}$	1

Thus geometrization of informational flows in one space provides qualitatively new opportunities for:

- comparative analysis of informational flows with their graphic images-signatures;
- comparative analysis of structure of dissimilar informational flows;
- structuring information arrays of different disciplines by determining the degree of their overlap, which allows to evaluate interdisciplinary connections;
- search of dynamically similar functioning cycles of systems of various nature.

**Application of the approach to the analysis of the “student – informational teaching environment” system functioning.** The works [5, 6] show that the action of external factors can lead to restructuring of the functioning cycle of various elements of the system, which is best reflected in the packaged form of signatures of dissimilar informational flows (technological, biological, etc.). Therefore analysis of the nature of changes in signatures configuration and their area in the package provides new opportunities for studying evolution of the system. In particular the nature of restructuring of the functioning cycle can determine tension and adaptability of physical (biological and other) processes. For example, in the process of analyzing the nature of changes in student's functional state under the influence of the information environment stress factors one can assess its stress resistance. Consequently, the influence of external and internal factors on the processes of mutual adaptation of the system elements can be investigated, simulated and analyzed using the approach.

In particular the application of the developed approach and its means of identification and assessment of student's stress and control of its formation in the course of training, according to the restructuring nature of the cardiocycle dynamics, proved to be effective. Let us determine the characteristic signs-markers of configuration adjustment of the cardiocycle signature, which make it possible to detect harbingers of fatigue and functional failures. Therefore it should be expected that the widespread use of the approach and the corresponding unified means of analyzing the dynamics of functioning of various elements of the “student – informational teaching environment” system will solve the problems of optimizing its organization. It is essential that it is possible to detect and analyze the spatiotemporal coherence between main phases of any informational flow, as well as to carry out complementary geometric and cybernetic modeling of the restructuring character of the functioning cycle of the dissimilar processes that are being researched. At the same time the use of interconnected

dynamic parameters and complementary statistical indicators of order and balance of the functioning cycle elements allows using the well-known fundamental conservation laws and the criteria of stability, reversibility and efficiency.

In general the developing interdisciplinary approach will contribute to further development of knowledge engineering, which can be complemented by elements of models engineering. This means that based on the proposed approach and appropriate means it is possible to create innovative teaching tools which, taking into account formation of adaptive informational and teaching environment, will facilitate solving the urgent problem of individualization of education, in particular gradually shifting from the transfer of knowledge to the student towards the development of his innovative qualities, especially the ability to perceive and create something new.

**Conclusions.** The variety of sources of information as well as informational fields and flows inherent in the teaching environment hinders the individualization of teaching. Converting these flows into graphic images makes them more visible for study, analysis and modeling, but the use of variety of terms, parameters, indicators and criteria does not contribute to the effectiveness of teaching [7, 8, 9]. Therefore in order to solve a number of educational problems an interdisciplinary approach to geometrization of dynamics of different informational flows and their analysis in one space (state, speed, acceleration) is proposed. According to it information about dissimilar processes transforms into their geometric 3D models, which: a) increases the effectiveness of teaching; b) simplifies the identification of spatiotemporal coherence of dissimilar flows; c) can detect dynamically similar cycles in various technical disciplines. The possibility of using interrelated parameters and indicators for system analysis of the structure of various informational fields and flows as well as their modeling is shown. It is essential that fundamental laws, principles and criteria are used during analysis of structure of informational flows. Therefore widespread use of the interdisciplinary approach and unified means of analysis and modeling will contribute to formation of the adaptive “student - informational teaching environment” system. It is very important that comparing the information flow with its geometric 3D model gives students a sense of efficiency while teachers have new opportunities for creating innovative tools for teaching and self-education.

Thus, with the help of interdisciplinary means of geometrization of informational flows dynamics, an adaptive “student – informational teaching environment” system can be organized, the structure of which creates more comfortable conditions for self-education and qualitative retention of material. This will increase the time and effectiveness of the virtual student-teacher interaction, as well as facilitate creation of interactive textbooks and tutorials.

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