UDC 004.8

A COGNITIVE APPROACH TO INTELLIGENT CONTROL THEORY: COMPETENCIES / LEARNING MODULES FOR DISTINCTION TASKS

[1] Prokopchuk Y., [2]Ben A., [2]Ponomaryova V., [2]Nosov P.
[1]Institute of Technical Mechanics NASU,
[2]Kherson State Maritime Academy,

Introduction and problem setting. Despite the extensive literature, the paradigmatic foundations of one or another interpretation of competencies, as a rule, are not investigated or postulated. It is necessary to methodologically correctly build a theoretical model of competence, including unconscious processes of cognition, intuition, and natural mechanisms of creativity [1, 2, 3]. Competencies should be closely linked with the genesis of the phenomenon of management, with the natural logic of distinction and management. For this, acts of cognition, types (models) of cognitive control and a model of purposeful activity should be disclosed and systematized [2].

The introduction of the concept of competence into the paradigm of ultimate generalizations - PUG (Z-tasks of discrimination, modules of competence, functional systems, etc.) allows us to define competence in a narrow and broad sense and build its various models for different types of information activity, including cognitive and educational. In applied terms, the proposed approach can be applied to the analysis and improvement of the educational process, as well as human-machine control systems for ships [4 - 7].

The main objective of this study is to develop a concept and methods for the automatic formation of human-machine learning-competency modules for multiple discrimination tasks. The concept and methods are developed within the framework of asymptotic rationality, including subjective dynamic logic.

Main research material. The basic acts of the thought process are distinctions. The "system of distinction" allows to differentiate the sequence of phenomena and events replacing each other (time), the order of location to simultaneously coexisting objects (space). This system allows you to perceive the dynamic "coexistence" and "interaction" of objects through the definition of their relationships. Let us denote the target set of discrimination objects by Z, and call the corresponding act of discrimination the Z-task of discrimination [2]. Z-tasks of distinction can be tasks of diagnostics, recognition, forecasting, choice of control, discrimination of needs, decision making (Z-task, Z-Difference, Z-Distinguishing, Z-Differentiation, Z-Control). Examples of Z-tasks of discrimination (chunking mechanism):

Z={1 - Threat; 2 – Gray Area; 3 - Non-Threat}; Z={1 - True; 2 – False};

Z ={1; 2; 3; 4} = {1-GREEN (I'm OK); 2-YELLOW (I corrected an anomaly myself); 3- ORANGE (I have data to transmit); 4- RED (Red Alert! I need help NOW!)}.

The examples show that the problems of pattern recognition and discrimination of needs are a special case of discrimination problems. The implicit formation of tools for solving the Z-tasks of discrimination, the formation of "images of tasks" is directly related to the scientific problem of "building an image of reality in the mind of an individual".

Given the "deep unconscious" [3], there is a "continuum of discrimination tasks". Each Z-task of discrimination forms its own module of learning and competence. Let us introduce an important "principle of reformulations": launching into a solution of any Z-problem leads to the automatic launch into a solution and maturation/incubation of all coarser problems defined by the sketch network. This principle underlies the phenomenon of self-actualization of discrimination tasks (most tasks do not require a "conscious" launch and control) and the phenomenon of task continuum. Note that an ideologically close principle plays a decisive role in Altshuller's theory of inventive problem solving. We also accept two principles of productivity: intuitive, unconscious experience is constantly accumulated as a "by-product" of purposefully implemented actions; the process of "recognition", "distinction", "imagination" is a continuous process.

Any learning-competency module should develop the ability of the specialist, the agent, to extract only "Meaningful Information" or "Control Information". Such information is determined, among other things, by intuitive processes of proactive control (result of natural learning based on experience). The incoming information should confirm (or not confirm) the correctness of action and safety conditions in the minimum way (most resource-economical). Control parameters can be set by "internal codes" for achieving the goal.

The term "Control Information" is borrowed from Peter A. Corning (Control information is an attribute of relationships between things and is defined as the capacity to acquisition control, disposition, and utilization of matter/energy in purposive or cybernetic processes) [8] . He considers this concept the "missing link" of Wiener's cybernetics. Indeed, the functional (content and semantic) role of information in cybernetic processes cannot be directly measured using the statistical approach of Claude Shannon, which was also adopted by Wiener (Shannon information is blind to the functional properties of information).

From a formal point of view, the information in a single finite object (for example, in a binary string) is usually measured by its Kolmogorov complexity. This information can be divided into two parts: information that takes into account the useful regularity present in the object, and information that takes into account the remaining random information. There can be several classes of models in which the regularity is expressed. This approach is also applicable to the flow of events ("arrows of time").

The selection of meaningful / control information is associated with subjective control paradigms (Subject-Oriented Control Paradigms). Such management paradigms form tasks for general AI (including assistive technologies in transport), which contributes to the successful practical application and development of AI, as well as mechanisms for controlling and neutralizing negative consequences [5]. One of the features of subjective control and decision-making systems is their implicit permanent incubation (asymptoticity), i.e. change (sometimes hardly noticeable or "almost smooth", sometimes spasmodic). This leads to non-monotonicity of solutions even to well-known tasks, frequent revision and emotional reassessment of past events-decisions, which causes instability of mental states and judgments (one of the factors affecting professional stability [4]).

The “arrow of cognition” and its attractor – “thin slice” – a set of extremely generalized heuristics or “internal codes” (the most condensed meaning within the framework of a specific task of distinction) is responsible for highlighting significant/control information within the framework of asymptotic rationality and any task of distinguishing [2]. Internal codes and precursors (probabilistic patterns) are used to solve discrimination problems: recognition, diagnostics, forecasting, control. Inner codes with large reinforcement in the database of precedents can be considered as subjective parameters of the order of development of complex situations, for example, navigation situations [5].

The full set of detail varying degrees heuristics, formed by the "arrow of knowledge", as well as the cascade (fractal) principle of refining heuristics-actions determine the subjective dynamic logic. Thanks to incubation, the mechanisms of intuition-premonitions improve and become more economical, embodied and faster, reflecting the general trend of transition from fragmented knowledge to integrated knowledge. An important component of asymptotic rationality is the final computational rationality (the maximum level of individual competence in a particular discrimination task). One of the consequences of asymptotic (emergent) rationality is a permanent jump-like change in the control system within the framework of each discrimination task (a natural mechanism of autopoietic self-optimization and, therefore, antifragility).

The dynamic logic of thinking underlies decision making under conditions of variable uncertainty, which reflects the natural desire to reduce complexity and manage cognitive load. Examples are the tasks of distinguishing objects at different distances or with variable resources. As the conditions of measurement or concentration of attention improve, decisions can be refined (the logic of “taxiing”) [1, 2]. The development of the dynamic logic of thinking is relevant, in particular, for operators of complex systems, including transport systems.

The basis of cognitive-educational and managerial competencies is an implicit-explicit mechanism for the formation of discrimination tasks and tools for solving problems - bases of own forms (bases of SF) based on internal codes of situations images and precursors [2]. The development of the task-inductor space and morphological calculations within the framework of “body-connectome-cognitome-interactome”, due to scale coherence and auto/hetero-associativity, stimulates the action of “principle of reformulations”, the phenomenon of “continuum of discrimination tasks” and intuition [2].

Thus, PUG allows you to build an "internal" or paradigm model of basic cognitive-behavioral competencies. As a result of applying such a model to educational activities, we obtain a model of cognitive-educational competencies in a general form. Therefore, on the basis of PUG, it is possible to formulate a transdisciplinary definition of concept "competence", generalizing the theoretical foundations and practice of applying the concept, both in education and in other areas of activity, including transport control [9-14].

The Z-competence module (CM), Operational Module or "knowledge asset" (unit) is a collection of all structures within the Z-task of discrimination (Units of Meaning and Processing). CM provides answers to two important questions that have caused considerable controversy among cognitive psychologists and educators: What stages does information go through during processing? How is information presented in memory?

CM is a key tool for implementing the tasks of knowledge management, competencies (Human Capital Management). The degree of CM structures formation at different points in time is different. The rate of evolution and a particular CM depends on the information-motor tension E_Z (the level of cognitive-search motivation), in particular, the frequency of solving educational, everyday or professional tasks. Partner systems, cognitive simulators, intelligent virtual environments, "intelligent webs", AI assistants and avatars can significantly speed up this process, as they are able to quickly find the ultimate knowledge structures with high intersubjective reliability.

For a formal description of learning-competency modules, we introduce the following notation (based on [2]):

$\Omega(\{\tau/T_0\},Z) = \{\alpha(\{\underline{\tau}/T_0\}, \underline{z}/Z)\}$ – base of precedents in the Z-problem of discrimination (we will consider descriptions of precedents $\Omega=\{\alpha\}$ with complete information, i.e. there are values of all tests from $\{G(\tau)\}$);

$\{G(\tau)\}$ – test domain network bank;

$\{Gv(\tau)\}$ – bank of networks of test values;

$\{Gs(\alpha)\}$ – networks of situations sketches $\Omega = \{\alpha\}$;

$\alpha(\{\underline{\tau}/T\}, \underline{z}/Z)$ – this is a separate sketch in the coordinate system $\{\tau/T\}$, z/Z (Combinatorial generalization - the ability to understand and produce novel combinations of already familiar elements - is considered to be a core capacity of the human mind);

$V(\{\underline{a}/A\}, \underline{z}/Z)$ or $V(\{\underline{a}/A\}, e/E, \{\mu\}_V, \underline{z}/Z)$ – ideal heuristics, where e/E – required resources, $\{\mu\}_V$ – implementation mechanisms with the help of society, teams, agents; tests $\{\underline{a}/A\}$ play the role of an *associative base,* $\underline{z}/Z$ - induction center;

$\{R\}_{Full}$, $\{V\}_{Full}$ – full of precursors and ideal heuristics;

$\{R^*\}_{Full}$, $\{S^*\}_{Full}$ – "thin slices" of precursors and ideal heuristics (condensed meaning is the essence of asymptotic rationality);

$\{\{S^*\}_{Min}\}_{Full}$ – the basis of the Limiting Knowledge Models based on a "thin slice" (the LKM basis is an analogue of the "thousands of brains" concept);

$\{\{\chi\}_S\}$, $\{\{\chi\}_R\}$, $\{\{\chi\}_{Min}\}$ – operational characteristics of heuristics, precursors, limiting knowledge models (costs, risks);

$\{S^\bullet, R^\bullet\}$ – socially verified heuristics and precursors;

$\{\{S^*\}_{Min}\}^*$ – critical paths on a set of knowledge models (the most commonly used discrimination strategies);

FS – functional systems (Functional Systems: the result of the implementation of limiting knowledge models), CrPaths - critical paths on a set of functional systems;

$\{f/\mu\}_A$, $\{f/\mu\}_V$ – inductors (generalized entanglement).

Heuristic triggering $V(\{\underline{a}/A\}, \underline{z}/Z)$ (inductor) not only activates the result $\underline{z}/Z$, but simultaneously triggers "maturation/incubation" and the implicit solution of the discrimination/recognition Z-problem, as well as $\{A$-Task$\}$, implementing an internal audit of information flows ("soft measurement" or "jury of intuition"; the concept of "task continuum", System 0).

Simplistically, the stages of subjective categorization, the emergence of knowledge, embodiment and confusion within the framework of the "Z-module of competence" (Z-holon) can be depicted as the following scheme ("large blocks" - «chunks»; a parsimonious cognitive architecture can account for apparent domain specificity):

Unconscious Unit | Chunk | Operational Module:

$$\Omega(\{\tau/T_0\},Z),\ \{G(\tau)\}\vee\{Gv(\tau)\} \to \{Gs(\alpha)\} \to \{R\}_{Full},\ \{V\}_{Full} \to$$

$$\{R^*\}_{Full},\ \{S^*\}_{Full} \to \{\{S^*\}_{Min}\}_{Full} \to \{\{\chi\}_S\},\ \{\{\chi\}_R\},\ \{\{\chi\}_{Min}\} \to \{S^\bullet, R^\bullet\} \to$$

$$\to \{\{S^*\}_{Min}\}^* \to \{\text{FS}\} \to \{\text{CrPaths}\},\quad E_Z \geq 0,$$

Entanglement: $\{V\} = \{V(\{\underline{a}/A\ [\{f/\mu\}_A]\}, \underline{z}/Z)\ [\{f/\mu\}_V]\}$,

$$\text{MicroConnectome} <\Omega, \{G(\tau)\}>,\qquad \Sigma_Z E_Z \leq E,$$

$$\text{CausalModel}_\Xi(\Omega, \{G(\tau)\}),\ \Xi\in\{\Xi\},$$

Stream of Solved Z-Tasks | Local 'Arrows of Time': $\{LAoT\}_Z$,

Collections of Experience Replay Data - CERD: $UnconsciousUnit \subset CERD$,

The emergence of PMZ bases and critical paths will be attributed to the main result of the 1st stage of abilities (knowledge) formation. The second and third stages are realized thanks to the practical mass solution of distinction Z-problems (the flow of local "arrows of time"). It is the stages of embodiment and operational-causal closure (emergence of the Z-holon of System 0 [3]) that characterize the highest professional experience (expert level). The embodiment allows you to dramatically reduce the cost of resources for management and increase the speed of response. All three stages together develop emotional space-time thinking within the Z-competence. The mechanism of competencies system genesis is similar to the mechanism of formation, abilities of subject, an agent.

References

1. Perlovsky L., Shkodyrev V. (2020). Physics of Mind – A Cognitive Approach to Intelligent Control Theory. In book: Cyber-Physical Systems and Control. Springer

2. Prokopchuk Y.A. (2017). Sketch of the Formal Theory of Creativity.

Dnepr, UA: PSACEA Press. 452 p.

3. Prokopchuk Y., Nosov P., Zinchenko S., Popovych I. (2021). New approach to modeling deep intuition. Materials of the 13th Scientific and Practical Conference «Modern Information and Innovative Technologies in Transport (MINTT-2021)». Kherson, Ukraine: XSMA. p. 37 – 40.

4. Koretsky O., Nosov P., Ben A., Zinchenko S., Prokopchuk Yu., Gurov A. (2022). Identification of skippers human factor by means of navigation information systems. Materials of the IV International Maritime Scientific Conference of the Ship Power Plants and Technical Operation (April 18 - 21). Odessa. Ukraine: Odessa National Maritime University.

5. Nosov P. S., Popovych I. S., Cherniavskyi V. V., Zinchenko S. M., Prokopchuk Y. A., Makarchuk D. V. (2020). Automated identification of an operator anticipation on marine transport. Radio electronics, Computer science, Control. № 3 (54). p. 158–172. https://doi.org/10.15588/1607-3274-2020-3-15

6. Nosov P., Zinchenko S., Ben A., Prokopchuk Y., Mamenko P., Popovych I., Moiseienko V., Kruglyj D. (2021). Navigation safety control system development through navigator action prediction by data mining means. Eastern-European Journal of Enterprise Technologies, Vol. 2 No. 9 (110): Information and controlling system. 55-68. https://doi.org/10.15587/1729-4061.2021.229237.

7. Nosov P., Cherniavskyi V., Zinchenko S., Popovych I., Prokopchuk Y., Safonov M. (2020). Identification of distortion of the navigator's time in model experiment // Bulletin of University of Karaganda. Instrument and experimental techniques,. № 4(100). p. 57-70. https://doi.org/10.31489/2020Ph4/57-70.

8. Corning P.A. (2007). Control information theory: the 'missing link' in the science of cybernetics. Systems Research and Behavioral Science. Volume 24, Issue 3 p. 297-311. https://doi.org/10.1002/sres.808

9. Mamenko P., Zinchenko S., Kobets V., Nosov P., Popovych I. (2022) Solution of the Problem of Optimizing Route with Using the Risk Criterion. In: Babichev S., Lytvynenko V. (eds) Lecture Notes in Computational Intelligence and Decision Making. ISDMCI 2021. Lecture Notes on Data Engineering and Communications Technologies, vol 77. Springer, Cham. https://doi.org/10.1007/978-3-030-82014-5_17.

10. Popovych Ihor, Blynova Olena, Nosov Pavlo, Zinchenko Serhii, Kononenko Oksana. Psychological factors of competitiveness of women's youth handball team. Journal of Physical Education and Sport, 21(1), 227 - 235. https://doi.org/10.7752/jpes.2021.01030

11. Zinchenko S., Tovstokoryi O., Ben A., Nosov P., Popovych I., Nahrybelnyi Y. (2022) Automatic Optimal Control of a Vessel with Redundant Structure of Executive Devices. In: Babichev S., Lytvynenko V. (eds) Lecture Notes in Computational Intelligence and Decision Making. ISDMCI 2021. Lecture Notes on Data Engineering and Communications Technologies, vol 77. Springer, Cham. https://doi.org/10.1007/978-3-030-82014-5_18.

12. Зинченко С.Н., Носов П.С., Грошева О.А., Маменко П.П., Матейчук В.Н. Управление судном в условиях внешних воздействий. Materials of the XI "Modern information technologies in transport, MINTT-2019"

May 28-30, 2019 Kherson, Ukraine. C 177-178.

13. Nosov P.S., Zinchenko S.M., Ben A.P., Nahrybelnyi Ya. A., Dudchenko O.M. Models of decision making by a navigator with implicit agreement of the COLREG rules // Науковий вісник Херсонської державної морської академії : науковий журнал. – Херсон : Херсонська державна морська академія, 2019. – № 1 (20). – С. 31-38

14. Nosov, P.S., Cherniavskyi, V.V., Zinchenko, S.M., Popovych, I.S., Nahrybelnyi, Y.A., & Nosova, H.V. (2021). Identification of marine emergency response of electronic navigation operator. Radio Electronics, Computer Science, Control, (1), 208–223. https://doi.org/10.15588/1607-3274-2021-1-20