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THE COGNITIVE MODELING TECHNOLOGY IN THE AUTOMATED EDUCATIONAL ENVIRONMENT

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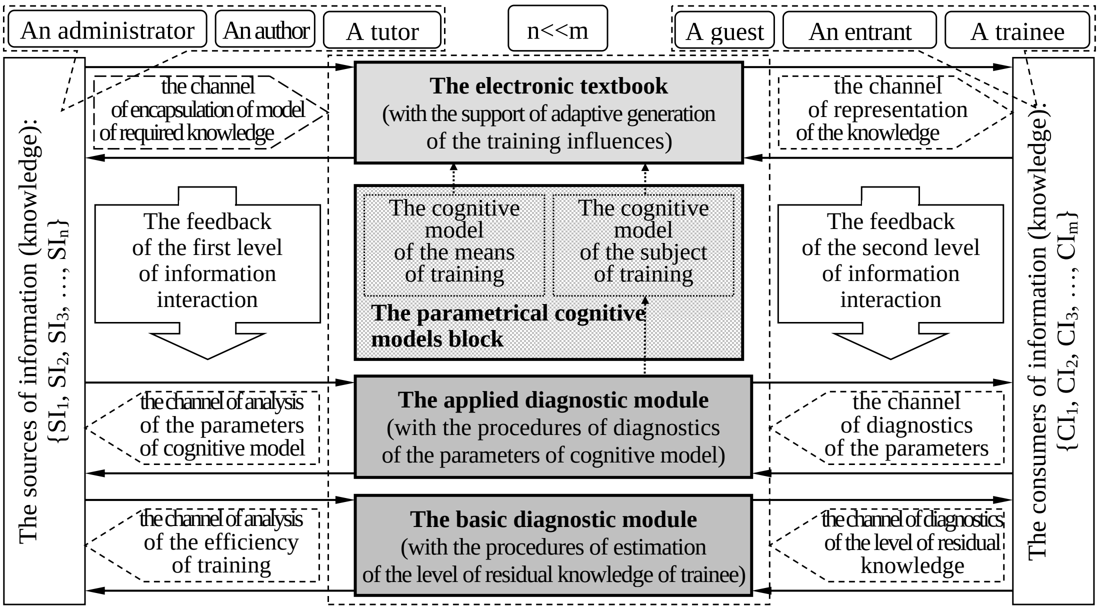
For the solving of the complex scientific problem of creation, system analysis and improving in the efficiency of functioning of the automated training with the properties of adaptation based on the cognitive models the new cognitive modeling technology is proposed, which includes: the technique of its use, the algorithm of formation of the structure of the cognitive model, the techniques of research of the parameters of the cognitive models of the subject and means of training, the algorithm of processing of a posteriori data of testing, and also the complex of programs for the automation of the tasks of research

The information-educational environment, the cognitive model, the automated training system, the cognitive modeling technology

The introduction and features of the adaptive environment based on the cognitive models

The structure of the information-educational environment (IEE) the automated (remote) training system (ART) with the properties of adaptation based on the parametrical cognitive models (CM) created by the author (pic.1) acts as a closed contour (with feedbacks) and is hybrid: it has the 2 levels of information interaction and the 6 channels of information exchange between the sources of information and the consumers of information [1, 2, 3, 4, 6].



Pic. 1. The structure of the information-educational environment of the automated training systems with the properties of adaptation based on the parametrical cognitive models

The cognitive modeling technology (CMT) is proposed in the scientific article acts as the universal in relation to the object of research and the subject area [2, 6].

CMT – the iterative cycle, providing the returns in case of revealing of the diverse errors and inconsistencies, including a sequence of technological stages, realizing the system analysis: the identification – the obtaining of information about the object of research, the conceptualization – the creating of conceptual scheme or modifying a set of concepts, the structuring – the developing of the structural scheme or the modifying of the elements of the conceptual scheme, the formalization – the building of the first and second level of the structure of the parametrical CM or the changing of the way (model) of presentation of the parametrical CM, the structural analysis – the verification of the first level of the structure of the parametrical CM or the modification of its diverse information elements (the mathematical sets), the parametrical analysis – the verification of the second level of the structure of the parametrical CM or the modification of its diverse information elements (the mathematical sets), the realization – the placement of the obtained parametrical CM at the basis of the environment of research, the revealing of inconsistencies and the causes of difficulties at the integration of the parametrical CM, the modeling – the modeling, based on the holistic approach, the solving of problems of measurement and the consideration of the nominal values of parameters, the analysis – the statistical processing of data, obtained using the parametrical CM, the revealing of diverse tendences, dependencies, regularities and relationships, and also the diverse ambiguities and heterogeneities, the subject interpretation – the interpretation of the obtained dependencies and regularities, the scientific substantiation of the obtained scientific results in the context of the subject areas, the synthesis – the accumulation of new knowledge about the dynamics of the object of research in the subject area, the addition of new scientific aspects (approaches) of consideration of the object of research. A posteriori data of use of CMT for the system analysis of IEE of ART system are given directly in the innovative author's scientific works [4, 6].

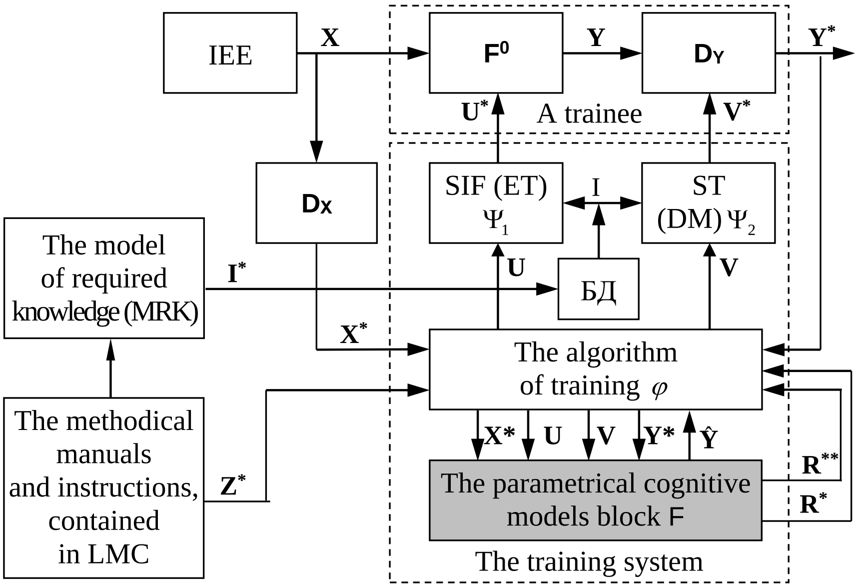
On the different technological stages of CMT the techniques and algorithms are used, realizing the various functions and support the stages of system analysis [6, 9]:

- the technique of use of CMT formalizes the sequence of the system analysis of IEE;
- the algorithm of formation of the structure of CM based on a row of the ways of presentation of CM;
- two ways to representation of the structure of the parametrical CM (the graph and structural scheme);
- the techniques of research of the parameters of CM of the subject of training and CM of the means of training;
- the algorithm of mathematical processing of a posteriori data, obtained in the course of the procedures of automated testing of the level of residual knowledge of the contingent of trainees (LRKT) and the diagnostics of individual features of personality of the subjects of training (IFPST) realized respectively by means of the basic and applied diagnostic modules (DM), included into ART system.

For the carrying out of the system analysis of the difficult of IEE of ART system CMT provides the the attraction of a row of the specialists-consultants: an expert in the subject area – the teacher, physiologist, psychologist, linguist or methodist, a cognitologist – the qualified specialist in the field of knowledge engineering, providing the correctness of the obtained structure of the parametrical CM, a system analyst – the specialist in the field of the system analysis and modeling of IEE, a programmer – the qualified specialist in the field of the languages of programming, knowing the diverse modern methods and approaches to the realization of different high-technological components of IEE of ADO system by means of the different integrated environments of programming (Borland C++ Builder).

At using of CMT, it is possible the addition of new, the removing of obsolete and the modernization of the existing methods and algorithms for the realization of the system analysis [6, 9].

In general view the structure of ART system can be formalized from the point of view of the classical theory of automatic control and presented in the following way (pic. 2).



Pic. 2. The structural scheme of the automated (remote) training system based the parametrical cognitive models

In pic. 2 the designations are entered: $\mathbf{F^0}$ – the operator of conversion the influence of environment **X** and training influence (TI) **U*** into the final condition of the trainee **Y**, SIF – the shaper of information fragment – provides the adaptive generation of TI **U*** and the control questions **V*** using the addresses in DB and the parameters of displaying $\mathbf{U_i}$ и $\mathbf{V_i}$ based on the model of required knowledge **I**, **Y*** – the resultativity of test tasks is calculated by the operator $\mathbf{D_Y}$ (sensor) based on the final condition of the trainee **Y** and the set of test questions **V***.

The task and purpose of the formation of knowledge: $\mathbf{Z}^* = \begin{cases} Q(Y^*) \to \delta, \\ T(Y^*) \to \min, \end{cases}$ δ – the required LRKT.

The algorithm of training is presented in the view: $Q(P_{n+1}) = Q(F(P_n, U_{n+1}, C_n)) \to \min\limits_{U_i, R_j} \Rightarrow U^*_{n+1}$.

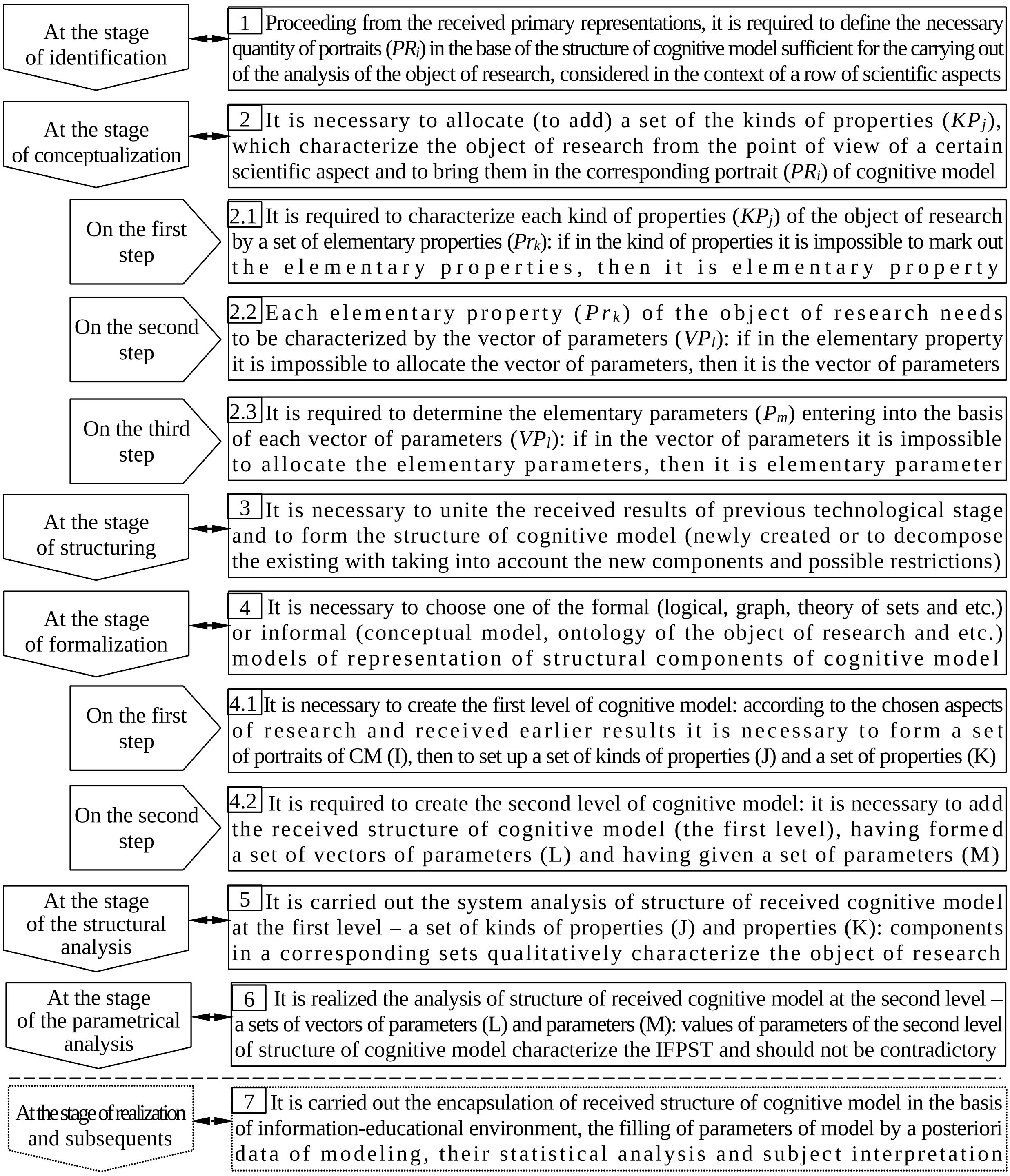
The technique of use of the cognitive modeling technology

The technique of use of CMT for the system analysis of IEE of ART system (pic. 3) formalizes the sequence and features of application of the technological stages of the iterative cycle of proposed CMT for the system analysis and the increasing of efficiency of the formation of knowledge of the trainees in IEE of ART system, and also a set of certain methods and the algorithms used on each from them.

Pic. 3. The technique of use of the cognitive modeling technology

The algorithm of formation of the structure of the cognitive models

The algorithm of formation of the structure of the parametrical CM (pic. 4) formalizes the sequence of (re)constructing of the structure of the parametrical CM based on the one from the existing models of presentation of the structured data (the logical and frame model, the semantic network and ontology) or the author's proposed models of presentation of the structured data: the oriented graph, combining the elements of the theory of sets and the multi-level structural scheme, providing the most visible presentation of the structure of the parametrical CM.



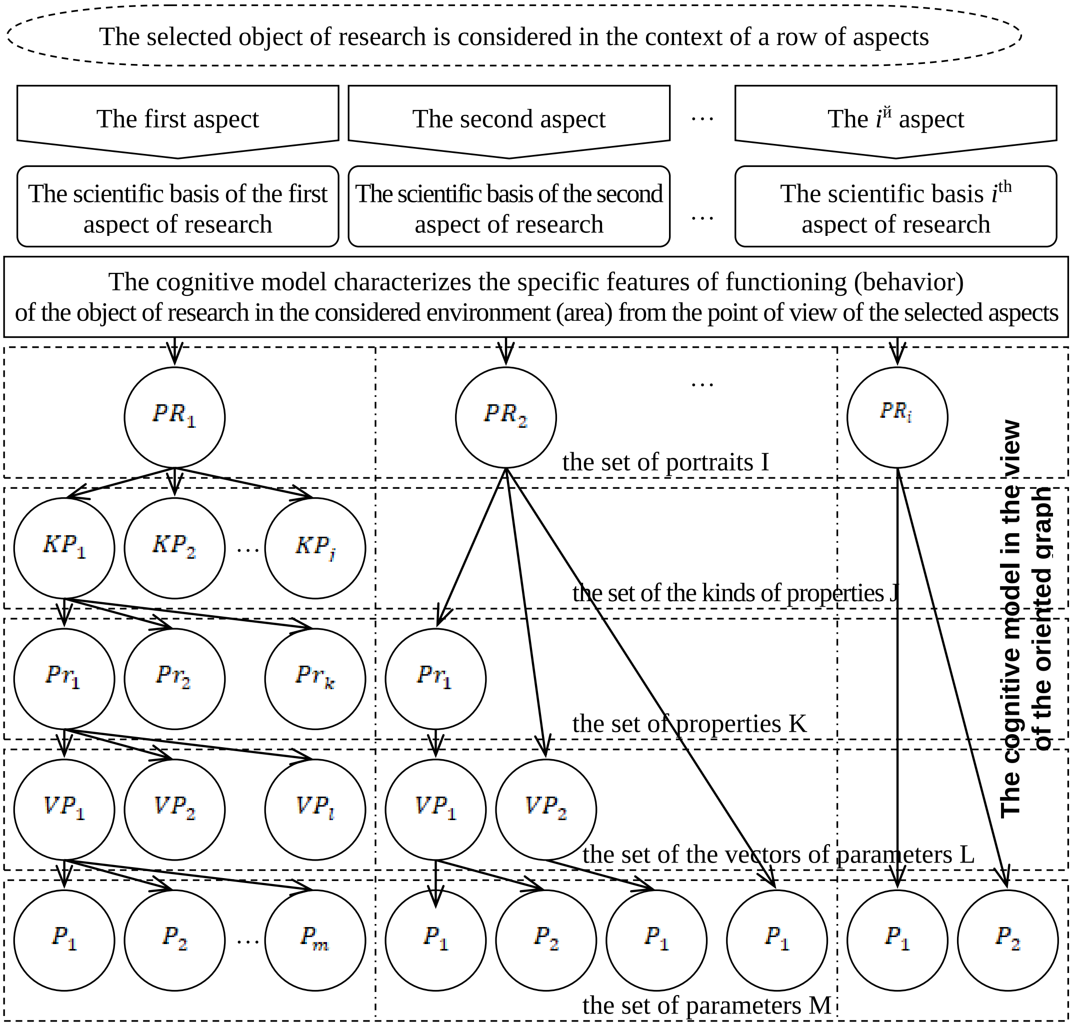
Pic. 4. The algorithm of formation of the structure of the cognitive model

The concept and ways (models) of presentation of the structure of the cognitive model

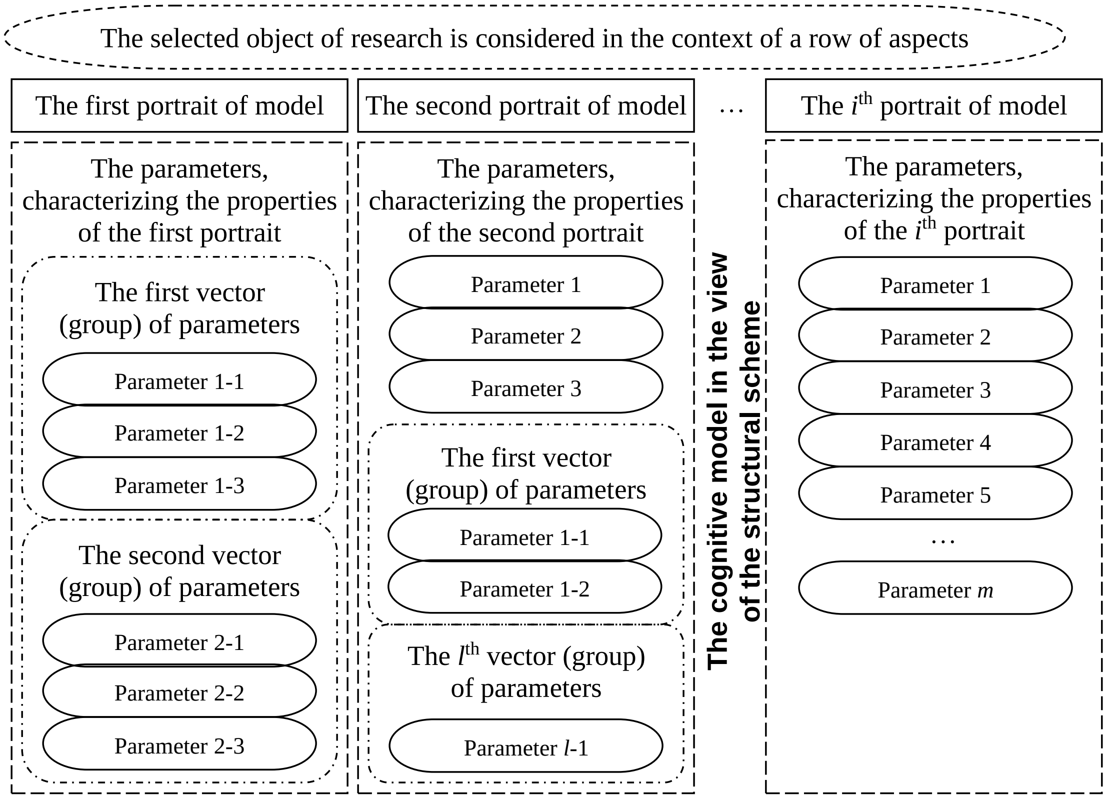
CM – the (re)constructed in width and depth a repertoire of parameters, which is echeloned on a row of portraits (PR_i) with a certain scientific justification and stratified on the several diverse mathematical sets, located on the two levels of dedicated hierarchy (structure): the set of the kinds of properties (KP_j), the set of elementary properties (Pr_k), the set of the vectors of parameters (VP_l) and the set of elementary parameters (P_m) [6]. One of the existing models of presentation of data [5] is valid to use.

At the same time the two ways (models) of presentation of the structure of CM [6] are proposed:

- the oriented graph, combining the theory of mathematical sets (pic. 5) – directly amenable to algorithmizing and program realization, is presented the collection of vertices connected by the connections, located at the different levels of the allocated hierarchy (structure);
- the multilevel structural scheme (pic. 6) – includes a row of the diverse coordinated mathematical sets of information elements, located at the different levels of the allocated hierarchy (structure), involves the complete reduction of information links, acts as a convenient way of presentation for the interpretation of the structure of CM.



Pic. 5. The representation of the structure of the cognitive model in the view of the oriented graph



Pic. 6. The representation of the structure of the cognitive model in the view of the multilevel scheme

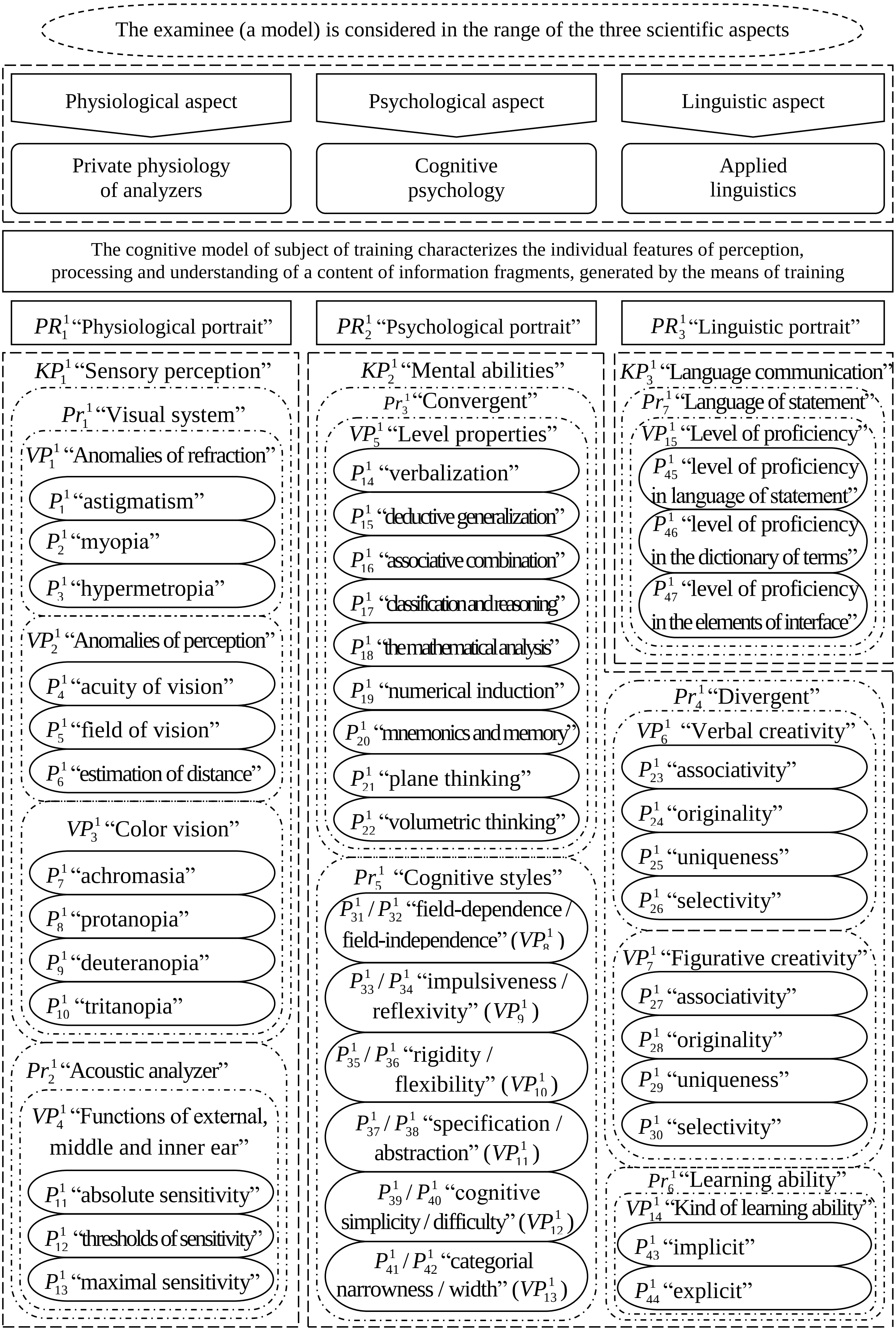
The structures of the cognitive models of the subject of training and the means of training, and also the techniques of their research and the algorithm of processing of a posteriori data

The parametrical CM of the subject of training (pic. 7) concentrates the parameters, characterizing the individual features of perception, processing and understanding by the subject of training of the content of a set of information fragments in the subject of studying [2, 3, 4, 6].

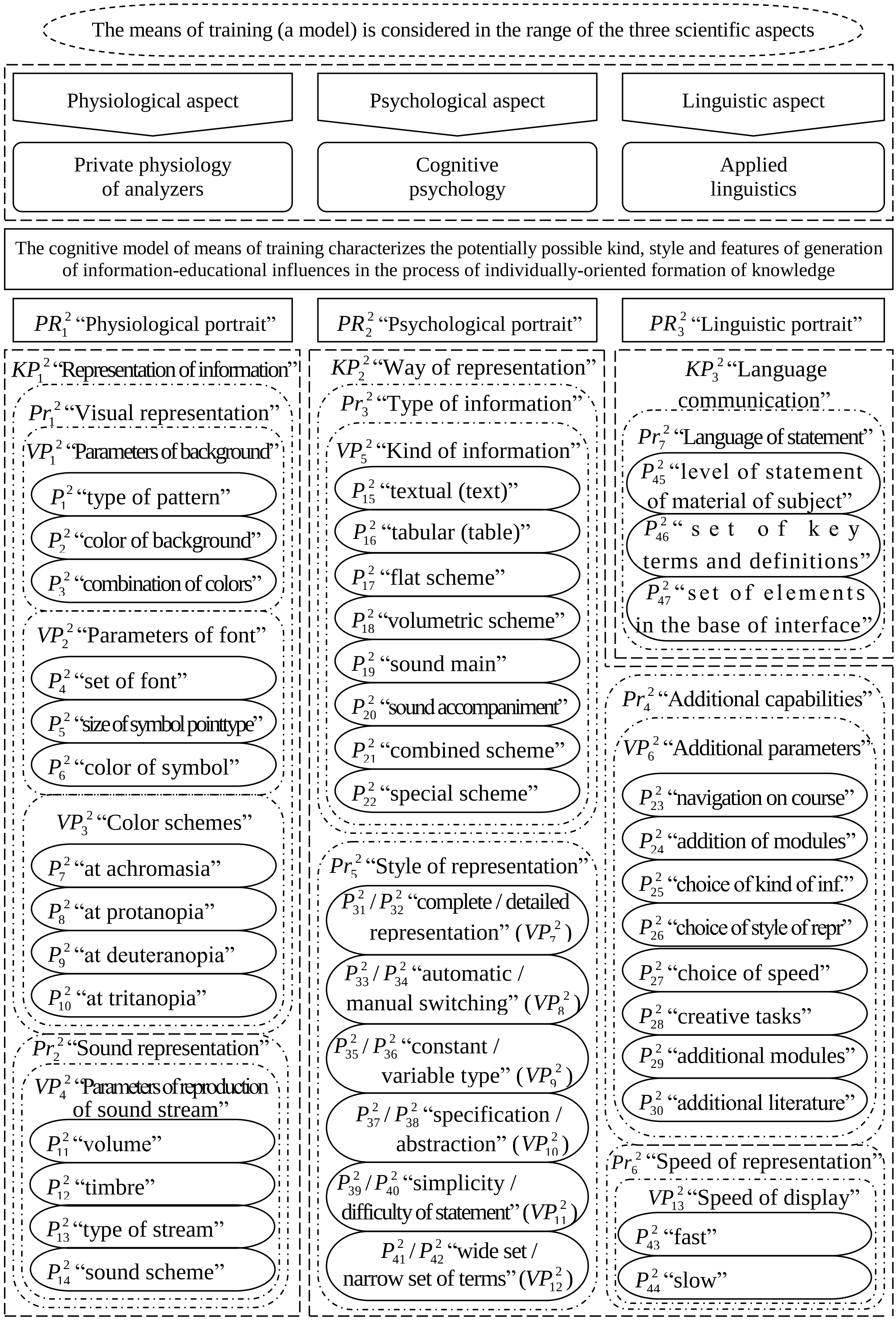
The parametrical CM of the means of training (pic. 8) concentrates the parameters, reflecting the potential technical capabilities of the adaptive electronic textbook at the realization of the individually-oriented generation of the diverse training influences by the various ways by means of the adaptive representation of information fragments processor operating on the basis of the innovative parametrical CM block [3, 4, 6, 8].

The technique of research of the parameters of CM of the subject of training (pic. 9) allows to fill and store in DB of the developed complex of programs the actual mathematical set of nominal values of the parameters, containing in the formed structure of the parametrical CM of the subject of training, to select a set of methods of their research, to provide the staging and to conduct a series of experimental researches by means of use of the applied DM [3, 4, 6, 7, 10].

The technique of research of the parameters of CM of the means of training (pic. 10) allows to configure the diverse components of the complex of programs, to add or remove the existing procedure at the basis of the adaptive representation of a sequence of information fragments processor, and also to calculate the nominal values of the parameters of displaying of the information for each certain trainee (the subject of training).

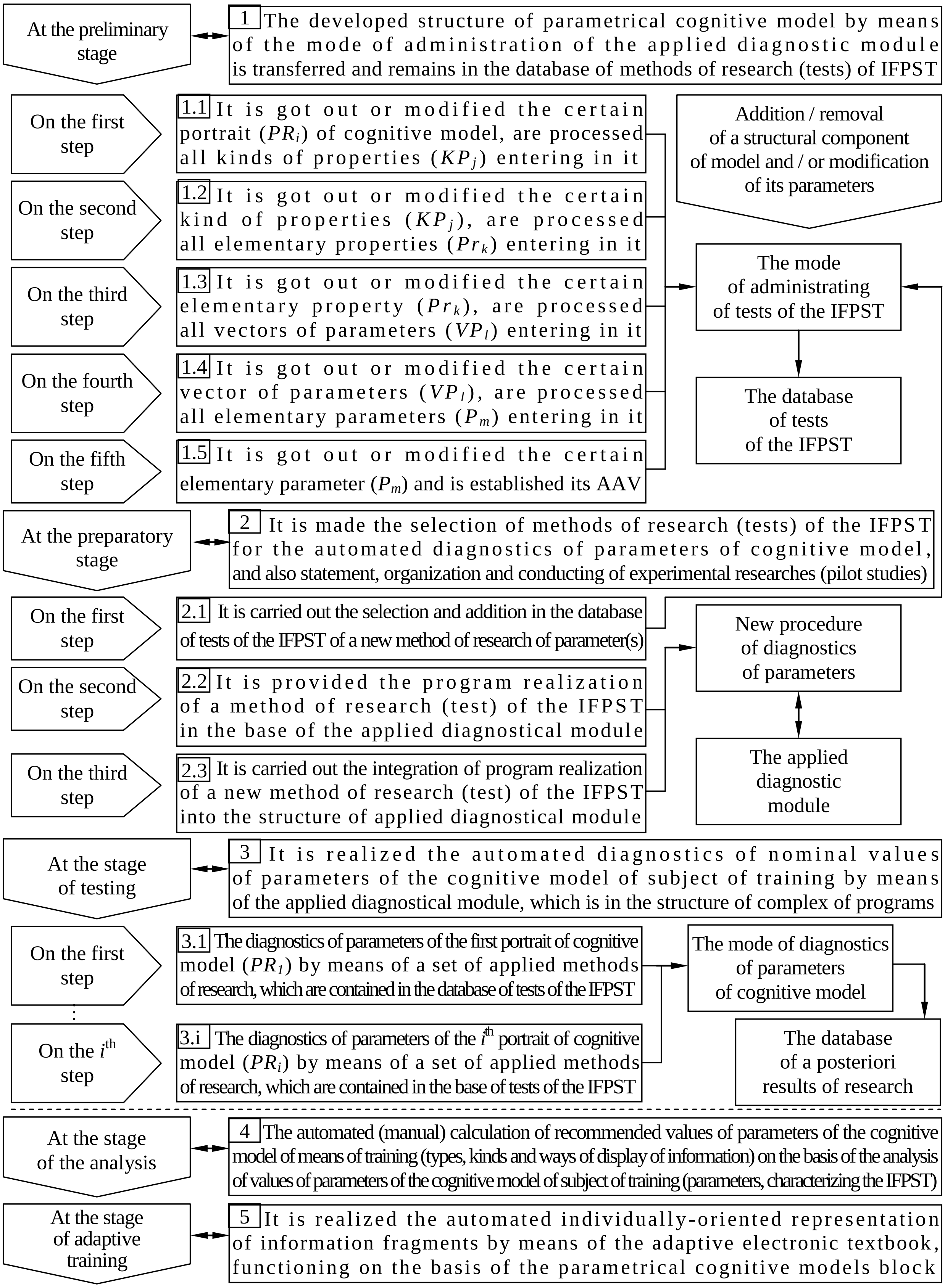


Pic. 7. The structure of the cognitive model of the subject of training

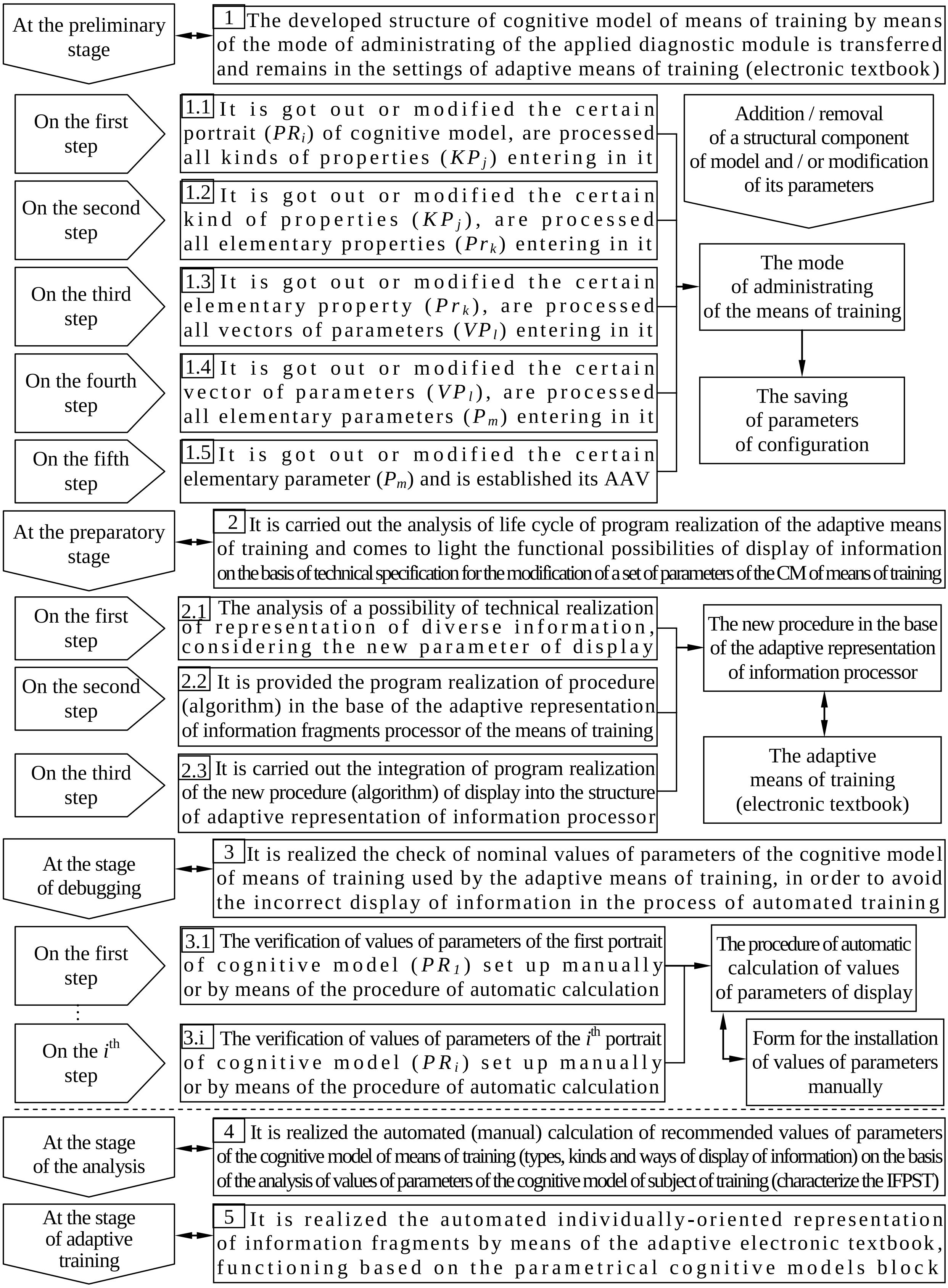


Pic. 8. The structure of the cognitive model of the means of training

The techniques of research of the parameters of CM allow to correctly configure the program complex for the automation of the tasks of research of IEE of ART system.



Pic. 9. The technique of research of the parameters of the cognitive model of the subject of training



Pic. 10. The technique of research of the parameters of the cognitive model of the means of training

The algorithm of processing of a posteriori data of research (pic. 11) allows to form the interval scale and the function of estimation, to prepare the developed software for the realization of the procedure of automated testing of the contingent of examinees, to provide the primary and secondary mathematical processing of the obtained samples of data on the basis of a set selected coefficients and statistical methods, to estimate the quality and to modify the sequence of tasks contained in the used tests and the methods of research IFPST.

At the preliminary stage ↔ **1** In the result of the analysis of question-answers structures of test is reached the calculation of indicators necessary for the conducting of testing: it is formed the interval scale and function of estimation

$$\begin{cases} b_0 = 0; \\ b_{\max} = n \end{cases}$$

On the first step → **1.1** It is defined the maximally and minimally possible number of correct answers for the procedure of estimation and formation of function of estimation

On the second step → **1.2** There are set up the lower and top threshold values of sums of correct answers (points) for the exposure of corresponding nominal values of estimates

$$\begin{cases} [b_0 = 0] - mark(nominal)=1; \\ [b_1, b_2] - mark(nominal)=2; \\ [b_2, b_3] - mark(nominal)=3; \\ [b_3, b_4] - mark(nominal)=4; \\ [b_4, b_5 = n] - mark(nominal)=5; \\ b_0 < b_1 < b_2 < b_3 < b_4 < b_5 \end{cases}$$

On the third step → **1.3** There are formed the intermediate borders of intervals on the basis of sums of correct answers (points) for the set up of intermediate nominal values of estimates (is formed the interval scale of estimation)

On the fourth step → **1.4** On the basis of interval scale the function of estimation of the diagnostical module is set up

$$\mu(x) = \begin{cases} 1, b_0 < x < b_1; \\ 2, b_1 < x < b_2; \\ 3, b_2 < x < b_3; \\ 4, b_3 < x < b_4; \\ 5, b_4 < x < b_5 = n; \end{cases}$$

At the stage of testing ↔ **2** There is carried out the preparation of software to the testing of target indicators: the interval scale and function of estimation in the mode of administrating is brought for the support of functioning of algorithmic structure

At the stage of the analysis of results ↔ **3** The saved-up a posteriori data are exposed to the statistical processing, allowing to carry out the analysis and to formulate the conclusions about current condition (level of residual knowledge of examinee and his personal characteristics)

3.1 The coefficient of difficulty of task, proceeding from which value is defined: at K>0,9 – the task is difficult, at K<0,2 – the task is easy

$$K_j = \frac{N_j}{N}$$

3.2 Total result of performance of all tasks by the i^{th} examinee

$$y_j = \sum_{j=1}^{M} x_{ij}$$

3.3 Total result of performance of the j^{th} task by all examinees

$$x_j = \sum_{i=1}^{N} x_{ij}$$

3.4 Average level of testing on results of performance of all tasks

$$\bar{Y} = \frac{\sum_{i=1}^{N} y_i}{N}$$

3.5 Average level of performance of j^{th} task by all examinees

$$p_j = \frac{x_j}{N}$$

3.6 Dispersion of total points of all examinees (subjects of training)

$$\delta_y^2 = \frac{\sum_{i=1}^{N} (y_i - \bar{Y})^2}{N-1}$$

3.7 Standard deviation of total points of examinees

$$\delta_y = \sqrt{\delta_y^2}$$

3.8 Dispersion of results of testing on the j^{th} task

$$\delta_j^2 = \frac{\sum_{i=1}^{N} (x_i - p_j)^2}{N-1}$$

3.9 Standard deviation of results of testing on j^{th} task

$$\delta_j = \sqrt{\delta_j^2}$$

3.10 Estim. of conn. of the each j^{th} task with the sum of points on all test

$$r_j = \frac{\frac{\sum_{i=1}^{N} (x_{ij} y_i)^2}{N} - p_j \bar{Y}}{\delta_j^2 \delta_y} \cdot \frac{N}{N-1}$$

3.11 Average arithmetical of independent expert estimates

$$\bar{Z} = \frac{\sum_{i=1}^{N} Z_i}{N}$$

3.12 Standard deviation of expert estimates

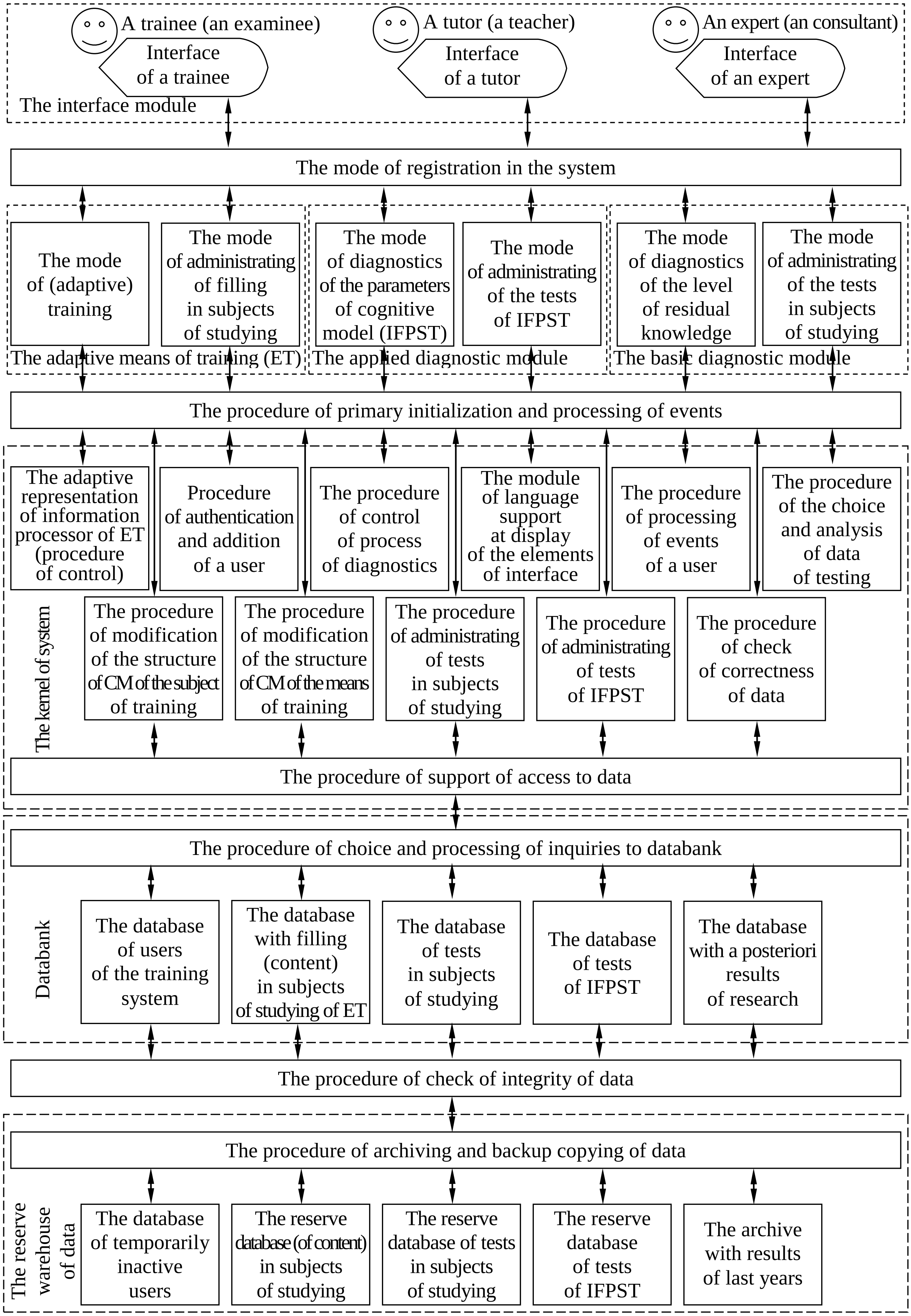
$$\delta_Z = \sqrt{\frac{\sum_{i=1}^{N} (Z_i - \bar{Z})^2}{N-1}}$$

3.13 Coefficient of correlation of results of testing and independent expert estimates (validity of test)

$$V = \frac{\frac{\sum_{i=1}^{N} (Z_i y_i)}{N} - \bar{Z}\bar{Y}}{\delta_Z \delta_y} \cdot \frac{N}{N-1}$$

Pic. 11. The algorithm of processing of a posteriori data of research

The complex of programs (pic. 12) is intended for the automation of the tasks of research of IEE, and also realizes the technology of adaptive training [3, 6, 7, 8, 10, 11].



Pic. 12. The structural-functional scheme of the complex of program

1. The practical use of the results was carried out in the learning process of “The international banking institute” (Saint-Petersburg city) and “The Saint-Petersburg state electrotechnical university "LETI"” (there are acts about the practical use 3 copyright certificates was received).
2. The estimation of efficiency of the results of research was carried out using generally-accepted indicators of efficiency (resultativity) of training (at distance): $\mathbf{K} = \{k_1; k_2; k_3\} = \left\{ Y_2 - Y_1; \frac{Y_2}{Y_1}; \frac{Y_2 - Y_1}{Y_1} 100\% \right\}$, where the coefficients k_1, k_2, k_3 respectively designate the absolute, comparative and relative indicators of efficiency (resultativity) of the formation of knowledge of the contingent of trainees [12, 13], and the results of statistical processing of a posteriori data of a series of the automated experiments are generalized in the tabl. 1.

Table 1

The results of the primary statistical analysis of the resultativity of training

The indicator	The number of the group of trainees							
	1	2	3	4	5	6	7	8
The indicators of the resultativity of training for 2004 year								
The size of sample	20	21	25	18	18	15	0	0
The average point Y_1	4,05	4,286	4,24	4,611	4,056	4,4	-	-
ASD of average point	0,686	0,845	0,779	0,502	0,802	0,507	-	-
The indicators of the resultativity of training for 2005 year								
The size of sample	24	22	24	25	24	22	23	21
The average point Y_2	4,333	4,046	4,375	4,16	4,042	4,091	4,696	4
ASD of average point	0,817	0,785	0,824	0,8	0,859	0,811	0,559	0,894
The indicators of the resultativity of training for 2006 year (with the use of CMT in the 3 groups)								
The size of sample	26	23	29	24	25	22	22	22
The average point Y_3	4,5	4,609	4,379	3,708	3,92	3,773	4,455	3,818
ASD of average point	0,707	0,656	0,775	0,751	0,572	0,612	0,858	0,853
The results of statistical analysis								
The indicators, reflecting the change in the efficiency of training for 2004-2005 year								
k_1	0,283	-0,240	0,135	-0,451	-0,014	-0,309	-	-
k_2	1,07	0,944	1,032	0,902	0,997	0,93	-	-
k_3, %	6,996	-5,606	3,184	-9,781	-0,345	-7,023	-	-
The change of ASD	0,131	-0,06	0,045	0,298	0,057	0,304		
The indicators, reflecting the change in the efficiency of training for 2005-2006 year								
k_1	0,167	0,563	0,004	-0,452	-0,122	-0,318	-0,241	-0,182
k_2	1,039	1,139	1,001	0,891	0,97	0,922	0,949	0,955
k_3, %	3,854	13,915	0,091	-10,865	-3,018	-7,773	-5,132	-4,55
The change of ASD	-0,11	-0,129	-0,049	-0,049	-0,287	-0,199	0,299	-0,041

3. In the result of the regression analysis the obtained nominal values of the coefficient of multiple correlation (CMC = 0,558) and the coefficient of multiple determination (CMD = 0.312) indicate, that 31.2% of the dispersion of the dependent variable $\hat{Y}_i$ (the estimation of LRKT) is determined by the variation of nominal values of the coefficients (predictors) K_i located in the basis of the obtained linear regression model $\hat{Y}(K_i)$.

The nominal values of initial (β**)** and standardized coefficients ($\beta^{'}$) of the linear model of multiple regression $\hat{Y}(K_i)$ are presented in the tabl. 2-3. The constant of the linear model of multiple regression is 4.653.

Table 2

The values of the initial β and standardized $\beta^{'}$ coefficients

The predictor	Vozr	K_7	K_8	K_9	K_{14}	K_{15}	K_{16}	K_{17}	K_{18}	K_{19}
The value of the initial β - coefficient	-0,006	-0,002	-0,156	0,121	0,064	-0,029	0,006	-0,074	0,025	-0,009
The standardized β - coefficient	-0,017	-0,010	-0,714	0,611	0,247	-0,104	0,034	-0,262	0,159	-0,052

Table 3

The values of the initial β and standardized $\beta^{'}$ coefficients (continue)

The indicator	K_{20}	K_{21}	K_{22}	K_{23}	K_{24}	K_{25}	K_{27}	K_{28}	K_{29}	K_{45}
The value of the initial β - coefficient	-0,026	0,001	0,035	0,013	0,009	-0,008	-0,111	-0,008	0,032	0,022
The standardized β - coefficient	-0,147	0,002	0,182	0,052	0,052	-0,113	-0,226	-0,018	0,172	0,037

The predictors in the obtained linear model of multiple regression:
$K_7 = \Pi_7^1, K_8 = \Pi_8^1, K_9 = \Pi_9^1, K_{14} = \Pi_{14}^1, K_{15} = \Pi_{15}^1, K_{16} = \Pi_{16}^1, K_{17} = \Pi_{17}^1, K_{18} = \Pi_{18}^1, K_{19} = \Pi_{19}^1, K_{20} = \Pi_{20}^1,$
$K_{21} = \Pi_{21}^1, K_{22} = \Pi_{22}^1, K_{23} = \Pi_{23}^1, K_{24} = \Pi_{24}^1, K_{25} = \Pi_{25}^1, K_{27} = \Pi_{27}^1, K_{28} = \Pi_{28}^1, K_{29} = \Pi_{29}^1, K_{45} = \Pi_{45}^1, Vozr,$
and the factor (dependent variable) is the resultativity of training Y.

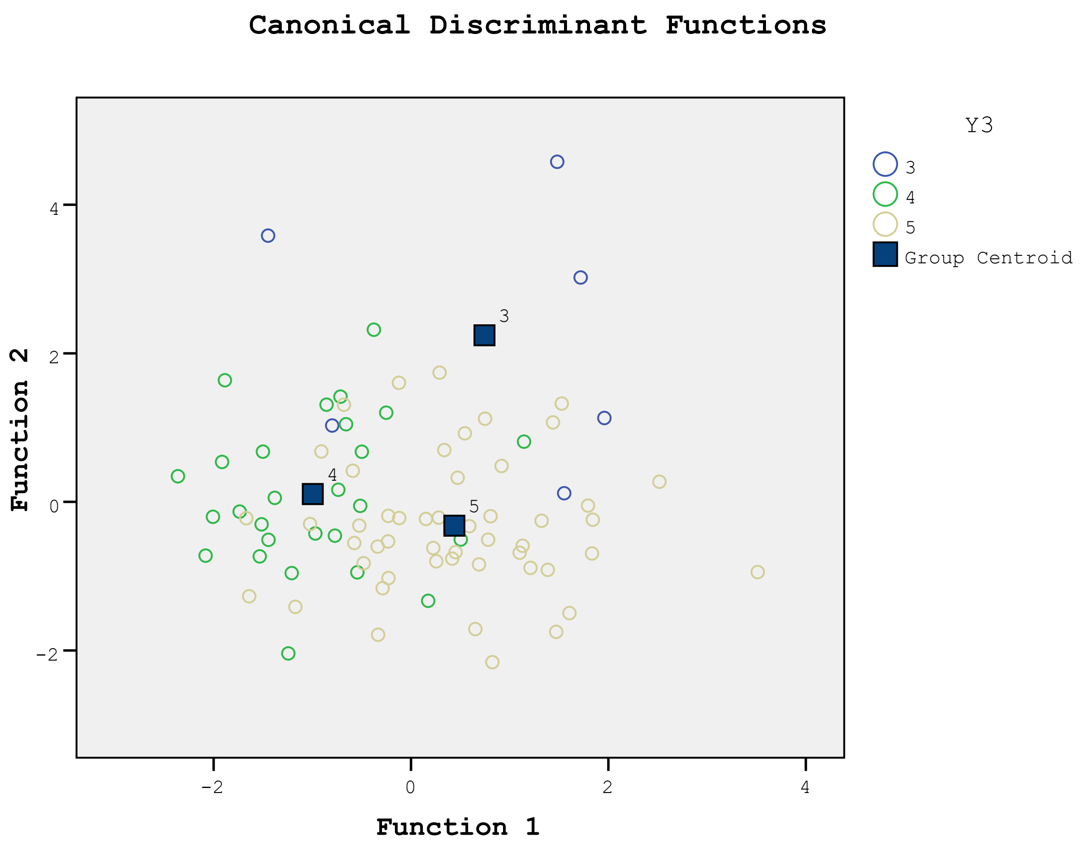
Then the algebraic equation of multiple regression takes the view:

$$\hat{Y} = 4{,}653 - 0{,}006 Vozr - 0{,}002K_7 - 0{,}156K_8 + 0{,}121K_9 + 0{,}064K_{14} - 0{,}029K_{15} + 0{,}006K_{16} - \\ - 0{,}074K_{17} + 0{,}025K_{18} - 0{,}009K_{19} - 0{,}026K_{20} + 0{,}001K_{21} + 0{,}035K_{22} + 0{,}013K_{23} + 0{,}009K_{24} - \\ - 0{,}008K_{25} - 0{,}111K_{27} - 0{,}008K_{28} + 0{,}032K_{29} + 0{,}022K_{45}$$

4. CMT allows to realize the additional contour of adaptation on the basis of the innovative parametrical CM block, and also to conder the complex system analysis of IEE, directed on the increasing in the efficiency of functioning of ART system and the resultativity of the process of the formation of knowledge of the contingent of trainees.

5. In the course of discriminant analysis the several groups of trainees were allocated in dependence from the indicator of resultativity (efficiency) of training (the estimation of LRNT): "5" – the group of "excellent-students", "4" – the group of "good-students" and "3" – the group of "mediocre-students".

Pic. 13 reflects directly the geometrical interpretation of the relative arrangement of the entered centroids of classes, which correspond to the allocated groups of trainees in the space of coordinates of two canonical discriminant functions for the system analysis.



Pic. 13. The centroids of the different classes of trainees in the space of canonical functions

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ТЕХНОЛОГИЯ КОГНИТИВНОГО МОДЕЛИРОВАНИЯ В АВТОМАТИЗИРОВАННОЙ ОБРАЗОВАТЕЛЬНОЙ СРЕДЕ

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Для решения комплексной научной проблемы создания, системного анализа и повышения эффективности функционирования среды автоматизированного обучения со свойствами адаптации на основе когнитивных моделей предлагается новая технология когнитивного моделирования, которая включает: методику ее использования, алгоритм формирования структуры когнитивной модели, методики исследования параметров когнитивных моделей субъекта и средства обучения, алгоритм обработки апостериорных данных тестирования, а также комплекс программ для автоматизации задач исследования

Информационно-образовательная среда, когнитивная модель, система автоматизированного обучения, технология когнитивного моделирования