Mathematical Modelling and Analysis
Volume 6 Number 1, 2001, pages 97–105

HYBRID MODELLING IN STRATIFIED DECISION SUPPORT SYSTEMS. II

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Received October 22, 1999

ABSTRACT

The paper studies the basic problems of Artificial Intelligence, such as integration of difference attributes of human intellect. For this purpose we have been created synergetic systems that are hybrid intelligent systems (HYIS). The paper shows the world of decision support problems and the world of modelling approaches evolution. The term 'heterogeneous problem' for decision support systems is discussed. Two models of interaction between the problems world and the methods world also the results of HYIS creating are discussed. The formalism of HYIS is introduced.

5. INTERACTION OF THE WORLDS OF PROBLEMS AND MODELLING METHODS

Let as present two models of interaction of the worlds of problems and modelling methods. They form the external world model in our constructions. The spatial picture of the homogeneous problems world W^h and of autonomous methods W^a, characteristic of the 80's is shown in Fig. 3 a). The homogeneous problems $\Pi^h = \{\pi_1^h, \pi_2^h, \pi_3^h\}$ on the W^h plane are shown by circles. Three sets, the elements of which are the methods ${}^AM^a = \{{}^Am_1^a, \ldots, {}^Am_{N_A}^a\}$, ${}^CM^a = \{{}^Cm_1^a, \ldots, {}^Cm_{N_C}^a\}$, ${}^LM^a = \{{}^Lm_1^a, \ldots, {}^Lm_{N_L}^a\}$, of manipulating with $A-, C-$ and L – knowledge on S_3, S_2, S_1 accordingly, where N_A, N_C, N_L are the number of known (developed) m^a – methods, also the autonomous models are:

$$ {}^{A}\dot{M}^a = \{{}^{A}_{1}\dot{m}^a_1, \ldots, {}^{A}_{N_{14}}\dot{m}^a_1, \ldots, {}^{A}_{1}\dot{m}^a_{N_A}, \ldots, {}^{A}_{N_{15}}\dot{m}^a_{N_A}\}, \qquad (5.1) $$
$$ {}^{C}\dot{M}^a = \{{}^{C}_{1}\dot{m}^a_1, \ldots, {}^{A}_{N_{16}}\dot{m}^a_1, \ldots, {}^{C}_{1}\dot{m}^a_{N_C}, \ldots, {}^{C}_{N_{17}}\dot{m}^a_{N_C}x, \}, \qquad (5.2) $$
$$ {}^{L}\dot{M}^a = \{{}^{L}_{1}\dot{m}^a_1, \ldots, {}^{L}_{N_{18}}\dot{m}^a_1, \ldots, {}^{L}_{1}\dot{m}^a_{N_L}, \ldots, {}^{L}_{N_{19}}\dot{m}^a_{N_L}x, \}, \qquad (5.3) $$

where: $N_{14}, \ldots, N_{19}$ – the number of models which are built for the solution of Π^h, and at the time we will assume that $\forall \pi^h_i | i \in \overline{1; N_h} \quad \exists \dot{m}^a \in \dot{M}^a = \{{}^{A}\dot{M}^a, {}^{C}\dot{M}^a, {}^{L}\dot{M}^a, \}$ and $M^a \neq$; and the most frequent case is ${}^{A}\dot{M}^a \cup^{C} \dot{M}^a =$ or ${}^{A}\dot{M}^a \cup^{L} \dot{M}^a =$ or ${}^{C}\dot{M}^a \cup {}^{L}\dot{M}^a =$, as well as the algorithms and programs interpreting of the models, are indicated by circles ${}^{A}Z, {}^{C}Z, {}^{L}Z$ in the plane W^a, i.e.

$$ {}^{A}Z = < {}^{A}M, {}^{A}\dot{M}, {}^{A}A, {}^{A}P >, $$
$$ {}^{C}Z = < {}^{C}M, {}^{C}\dot{M}, {}^{C}A, {}^{C}P >, $$
$$ {}^{L}Z = < {}^{L}M, {}^{L}\dot{M}, {}^{L}A, {}^{L}P > . $$

All these objects are knowledge carriers (in further reasoning we will consider methods and models only). The loops indicate the relations R^{AA}, R^{CC}, R^{LL} of getting new knowledge within the restrictions framework of the given knowledge type. Two worlds W^h and W^a are interconnected by the relations of correspondence between the problem π^h and the method of its solving m^a (there can be more than one). As a result of developer's activity, there appear new objects $\dot{m}^a$ (hereinafter a^a and p^a) after the correspondence relations have been determined in W^a. Obviously, $\{\dot{m}^a\}, \{a^a\}, \{p^a\}$ are also evolving with the time.

The R^{AA}, R^{CC}, R^{LL} relations are the subjects of research for individual scientific schools using this or that knowledge type. For instance, in mathematics these are the algebra rules, in logic – the modus-ponens and modus-tollens rules, in mathematical statistics – modelling algorithms, in evolution programming – a reproduction and genetic operators.

Then the model W^a looks as follows:

$$ W^a = < \hat{Z}, \hat{S}, \Omega^{ZS}, R^a >, \qquad (5.4) $$

where: $\hat{Z} = \{{}^{A}Z, {}^{C}Z, {}^{L}Z\}$; $\Omega^{ZS} \subseteq \hat{Z} \times \hat{S}$ – surjective correspondence determined all over (one-to-one in the case of the $M2$-model); $R^a = \{R^{aAA}, R^{aCC}, R^{aLL}\}$, $R^{aAA} : {}^{A}Z \to {}^{A}Z$, $R^{aCC} : {}^{C}Z \to {}^{C}Z$, $R^{aLL} : {}^{L}Z \to {}^{L}Z$. The model of the homogeneous problem world is:

$$ W^h = \Pi^h, \qquad (5.5) $$

where: $\Pi^h = \{\pi^h_1, \ldots, \pi^h_{N_h}\}$, but the external world model is:

$$ W^{ha} = < W^h, W^a, \Omega^{\pi m} >, \qquad (5.6) $$

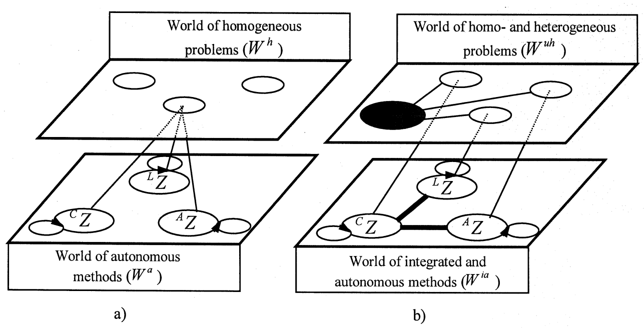

Figure 3.

where: $\Omega^{\pi m} = \{\Omega_1^{\pi m}, \dots, \Omega_3^{\pi m}\}$, $\Omega_1^{\pi m} \subseteq \Pi^h \times {}^A\dot{M}^a$, $\Omega_2^{\pi m} \subseteq \Pi^h \times {}^C\dot{M}^a$, $\Omega_3^{\pi m} \subseteq \Pi^h \times {}^L\dot{M}^a$ – the family surjective correspondences determined all over.

The other, modern picture is given in Fig. 3 b). In W^{ia} there appears a 'system response' in reply to the decomposition of π^u in W^{uh}, forming knowledge structures (methods, models, programs) outside the framework of m^a. In this case the integration means the relations R^i between m^a (heterogeneous knowledge) and forming of the structures $m^i, \dot{m}^i, a^i, p^i$ interpreting such relations. So, in W^{ia} there is no knowledge structure known in advance, which is identical to π^u. Such a structure is sought for and must be constructed. Comparative analysis of Fig. 3 a) and b) shows that variant b) is more general, does not deny the importance of the relations R^a, and enables to perfect them (overcome the disadvantages of the $m^a, \dot{m}^a$ – components) at the expense of the relations $R^i = \{R^{iAC}, R^{iCA}, R^{iCL}, R^{iAL}, R^{iLA}\}$, which already require interdisciplinary efforts.

Such relations' classification R^i is offered below: knowledge *extraction* from one of the components for the improvement or acquisition of knowledge for the other (for instance, from ANN for functioning of ES or FS) is ${}^1R^i$; knowledge *evaluation* of one component from the standpoint of the other (for instance, the use of C-knowledge for the evaluation of results and prediction of consequences of alternatives obtained by ES) is ${}^2R^i$; *including* one knowledge in another knowledge (for instance, such relations exist in FS with the Takagi-Sugeno inference engine, when the right-hand part of the 'condition-action' rules is the first-order multinomial or in GA, in which a fitness function is built-in) is ${}^3R^i$; additions of some to some other knowledge (when knowledge is given an order: a sequence, a tree, a network) is ; ${}^4R^i$; *comparison* heterogeneous knowledge is ${}^5R^i$; *argumentation* (for instance, using ES knowledge for argumentation of answers ANN) is ${}^6R^i$; *control*, when knowledge of one type actuate knowledge of the other type is ${}^7R^i$; *mapping*, when one knowledge is converted (translated) to the other is ${}^8R^i$; *role-play relations* (for instance, when FS is functioning as ANN) is ${}^9R^i$. The considered relations generalize the known hybrid intelligent system classifications.

Then the W^{ia} model is of the following form:

$$W^{ia} =< W^a, R^i >, \tag{5.7}$$

where: $R^i = \{R^{iAC}, R^{iCA}, R^{iCL}, R^{iLC}, R^{iAL}, R^{iLA}\}$, $R^{iAC} : Z^A \to Z^C$, $R^{iCA} : Z^C \to Z^A$, $R^{iCL} : Z^C \to Z^L$, $R^{iLC} : Z^L \to Z^C$, $R^{iAL} : Z^A \to Z^L$, $R^{iLA} : Z^L \to Z^A$.

Then, so far as $W^{uh} = E^u$, the external world model W^{uhia} is determined by the expression (5.8):

$$W^{uhia} =< E^u, W^{ia} > . \tag{5.8}$$

The study of R^i and integration of heterogeneous knowledge is one of the alternatives of π^u solving, the theory, methodology and technology of solving of which just begins its progress for hybrid intelligent systems [2,8-11], hybrid expert [5] and multi-agent systems [6].

Holland's successful application of the model of natural evolution to adaptive solving of improvement problems in cybernetic, possibly, will open the way to modelling of the methods world evolution, will allow to present and to study the situation when two (maybe, more) methods are selected to exchange their codes and to create a 'hybrid' which is their derivation, having a multifunction essence, as well as to step forward in the automation of autonomous method choice for π^h and searching for algorithms of forming the new decision methods for π^u.

6. HYBRID INTELLIGENT SYSTEMS

In the world practice HYIS is understood as a system in which more than one method of imitating intellectual activity of a person is used for solving a problem [2,8-11].

The HYIS formalism based on basic differences between the notions of 'analytical dependency', 'algorithm' and 'rule-oriented system', is offered below. For this purpose we will create a object controlled model of a system S in W^{uhia}, using expression [4]:

$$Y = \dot{m}(X, \Theta), \tag{6.1}$$

where: X, Y, Θ – uncontrolled input, state and operated input (i.e. control) of the object accordingly, $\dot{m} =< St, C >$ – statement about the relationships between the model inputs and its output on any suitable language, St – the model $\dot{m}$ structure, $C = (c_1, \dots c_n)$ – the parameters vector of $\dot{m}$ [4].

As far as W^{uhia} is stratified, we have (6.2 – 6.4) for S_3, S_2, S_1 accordingly:

$$Y^3 = {}^A\dot{m}^a(X^3, U^3), \tag{6.2}$$

$$Y^2_{i+1} = {}^C\dot{m}^a(Y^2_1, X^2_{i+1}, \Theta^2_{i+1}, \Gamma^2_{i+1}), \qquad (6.3)$$

$$Y^1_{i+1} = {}^L\dot{m}^a(Y^1_i, X^1_{i+1}, \Theta^1_{i+1}, {}^x\Lambda^1_{i+1}, {}^u\Lambda^1_{i+1}), \qquad (6.4)$$

where: $X^3, X^2_{i+1}, X^1_{i+1}$ – determined, uncontrolled inputs on S_3, S_2, S_1 accordingly; $\Theta^3, \Theta^2_{i+1}, \Theta^1_{i+1}$ – operated inputs (quantitative for S_3, S_2, S_1 and qualitative for S_1) on S_3, S_2, S_1 accordingly; Γ^2_{i+1} – stochastic, uncontrolled inputs on $S_2; {}^\chi\Lambda^1_{i+1}, {}^u\Lambda^1_{i+1}$ – linguistically precise and fuzzy inputs on $S_1; Y^3$ - state of object on $S_3; Y^2_i, Y^1_i$ and Y^2_{i+1}, Y^1_{i+1} – states of models at i and $i+1$ moments of the model time; ${}^A\dot{m}^a, {}^C\dot{m}^a, {}^L\dot{m}^a$, – imitation operators of changing the models states.

Let us consider the expression $\dot{m} =< St, C >$ for ${}^A\dot{m}^a, {}^C\dot{m}^a, {}^L\dot{m}^a$, in detail.

The structure ${}^ASt$ for ${}^A\dot{m}^a$ is an analytical expression (A -knowledge) in the mathematical language (algebraic, differential, integral, finite-difference and the other equations). Such a presentation is an explicit definition of ${}^ASt$. If ${}^ASt$ is obviously impossible to define, it is possible to approximate it by a multi-level forward propagation ANN (it is an implicit definition of ${}^ASt$). The parameters of the model ${}^AC$ are deterministic variables. States of object, ambiance and control are defined by the vectors $Y = (y_1, \dots, y_{N_Y}), X = (x_1, \dots, x_{N_X}), \Theta = (\theta_1, \dots, \theta_{N_\Theta})$ accordingly. The dynamics of an object can be simulated, for instance, by differential equations.

The structure ${}^CSt$ for ${}^C\dot{m}^a$ will be defined a priori, i.e. before the beginning of model experiments, by the modelling algorithm presented, for instance, in the modelling language, which is interpreted by a standard computer program. The simulation statistical modelling of an object is an incremental imitation of artificial random process $\Gamma(t)$ with usage of the C -knowledge. The statistic on $\Gamma(t)$, collected during the time of modelling, are the desirable results. The simulation models generalize the finite-difference models [4] just in the same way as any function is a particular case of an algorithm [4]. The parameters of the model ${}^CC$ are determined and stochastic variables, but the state space is not the set of the points, but the set of areas with fuzzy boundaries.

The structure ${}^LSt$ for ${}^L\dot{m}^a$ can be presented in different ways. Let us refer to the rule-oriented language. The structure is singular in this case. The structure ${}^LSt$ is unfamiliar to the developer a priori and is changed by the 'condition-action' rules collection (knowledge base- KB). For ES these rules form the AND/OR graph, which is used by the universal algorithm of KB interpretation for the pattern matching, inference and heuristic searching. The problem-solving algorithm can be presented and explained to a person only after the successful completion of interpretation. The KB in FS is drastically simplified, though it is presented by the AND/OR/COMB graph [3]. The number of the fuzzy rules in KB is one order less than it is in ES (it happens due to the fact that to describe the world approximately is much simpler than to do it exactly). The universal, high-performance algorithms of the fuzzy reasoning (Mamdani and Takagi-Sugeno) function using this KB. The simulation symbolic modelling imitates a linguistical, fuzzy nature of the experts' reasoning and it refers to the symbolic models class. This is an incremental (or one-steps) modelling in the space of the symbolic descriptions of the controlled object state as well as for ${}^{C}\dot{m}^{a}$, regardless of the time model which exists for the dynamic ES only. The model ${}^{L}C$ parameters are determined, numeric variables, precise and fuzzy linguistical variables. In ES the state is interpreted very primitively without a broad spectrum of spatial, causal, and temporary relations.

We will consider three-tuples $(\pi^{h}, \dot{m}^{a}, I^{a})$ which us called 'components', where: I^{a} – interpreter of model $\dot{m}^{a}$, for the organization of calculations of ${}^{A}\dot{m}^{a}$, as well as simulation statistical ${}^{C}\dot{m}^{a}$ and logical-linguistical modelling of ${}^{L}\dot{m}^{a}$ while solving homogeneous problems π^{h} on each stratum S_i of W^{uhia}.

Then in W^{uhia} we have *hybrid simulation process*:

$$Y_{i+1} = \dot{m}^{u}(Y_i, X_{i+1}, \Theta_{i+1}, \{{}^{i}Y^{3}\}, \{{}^{i}Y^{2}_{i+1}\}, \{{}^{i}Y^{1}_{i+1}\}), \tag{6.5}$$

where: Y_i, Y_{i+1} – states of S, X_{i+1} – input; Θ_{i+1} – control; $\{{}^{i}Y^{3}\}, \{{}^{i}Y^{2}_{i+1}\}$, $\{{}^{i}Y^{1}_{i+1}\}$, – the sets of the states of ${}^{A}\dot{m}^{a}, {}^{C}\dot{m}^{a}, {}^{L}\dot{m}^{a}$ models on S_3, S_3, S_1 accordingly (they can be 'one-element'); $\dot{m}^{u} =< St^{u}, C^{u} >$ – multi-language (hybrid) statement about the relations of model input and output.

Let us consider the three-tuple $(\pi^{u}, \dot{m}^{u}, I^{u}\ )$ into W^{uhia}. Then we will call the $\dot{m}^{u}$ *a hybrid model for solving a heterogeneous problem* π^{u} *in the world* W^{uhia}. However, this does not mean that $\dot{m}^{u}$ have only functional sense in W^{uhia}. They can execute auxiliary actions, for instance, they can extract knowledge from one component for the knowledge improvement of another $({}^{1}R^{i})$.

The formalism (6.5) puts a lot of questions. We will consider St^{u} of the model $\dot{m}^{u}$, which depends on $\hat{\pi}^{u}_{i}$ and the standard architecture chosen for its realization. This architecture, in turn, is defined by the relations R^{i} and can be formalized in different ways. One of the ways named the 'messenger metaphor', is considered below. Its essence is in the follows: the hybrid process (6.5) is imitated by the dynamic semantic network which is designed a priori for this as follows.

Let three sets of functional models-solvers (5.1), (5.2) and (5.3) of the homogeneous problems of the heterogeneous task π^{u} be given. Let us enter the following sets of auxiliary 'generator-models' ${}^{\uparrow}\dot{M} = \{{}^{\uparrow}\dot{m}_1, \ldots, {}^{\uparrow}\dot{m}_{N\uparrow}\}$ imitating appearance of dynamic objects (for instance, data, knowledge, π^{u}, π^{h}, resources, time, and etc.), 'terminator-models' ${}^{\downarrow}\dot{M} = \{{}^{\downarrow}\dot{m}_1, \ldots, {}^{\downarrow}\dot{m}_{N\downarrow}\}$ imitating the dynamic objects leaving, 'assistant-models' ${}^{+}\dot{M} = \{{}^{+}\dot{m}_1, \ldots, {}^{+}\dot{m}_{N+}\}$ imitating auxiliary operations with dynamic objects (for instance, decomposition, delay, transmission, fission, etc.).

The dynamic semantic network St^{u} will be created as follows. Let us enter the set $\Delta = \{\Delta^1, \Delta^2, \Delta^3\}$ of the 'generator-nodes' $\Delta^1 = \{\delta^1_1, \ldots, \delta^1_{N\Delta 1}\}$ 'solver-nodes' $\Delta^2 = \{\delta^2_1, \ldots, \delta^2_{N\Delta 2}\}$, 'assistant-nodes'$\Delta^3 = \{\delta^3_1, \ldots, \delta^3_{N\Delta 3}\}$, 'terminator-nodes' $\Delta^4 = \{\delta^4_1, \ldots, \delta^4_{N\Delta 4}\}$, and the one-to-one correspondences $\Omega^{\dot{m}\delta}_1 \subseteq {}^{\uparrow}\dot{M} \times \Delta^1$, $\Omega^{\dot{m}\delta}_2 \subseteq \dot{M}^{a} \times \Delta^2$, where: $\dot{M}^{a} = {}^{A}\dot{M}^{a} \bigcup {}^{C}\dot{M}^{a} \bigcup {}^{L}\dot{M}^{a}$, $\Omega^{\dot{m}\delta}_3 \subseteq {}^{+}\dot{M} \times \Delta^3$, $\Omega^{\dot{m}\delta}_4 \subseteq {}^{\downarrow}\dot{M} \times \Delta^4$ let us define. The sets of relationships $R^{St}_1 : \Delta^1 \to \Delta^2$, $R^{St}_2 : \Delta^1 \to \Delta^3$, $R^{St}_3 : \Delta^2 \to \Delta^2$, $R^{St}_4 : \Delta^3 \to \Delta^3$,

$R_5^{St} : \Delta^2 \to \Delta^3$, $R_6^{St} : \Delta^3 \to \Delta^2$, $R_7^{St} : \Delta^2 \to \Delta^4$, $R_8^{St} : \Delta^3 \to \Delta^4$, (the relationship $r \in R^{St}$ between δ_i and δ_j is defined, i.e. there is $\delta_i r \delta_j$, if the models ${}_i\dot{m}^a$ and ${}_j\dot{m}^a$ corresponding to δ_i and δ_j, are coordinated on 'output-input') and the set of dynamic objects $\Sigma = \{\sigma_1, \dots, \sigma_{N^\Sigma}\}$. Each $\sigma_i | i = 1, \dots, N_\Sigma$ (messenger) is $\sigma_i =< {}^1\sigma_i, {}^2\sigma_i, {}^3\sigma_i, {}^4\sigma_i, {}^5\sigma_i, {}^6\sigma_i >$, where: ${}^1\sigma_i$ – number, ${}^2\sigma_i$ – a node number where the object is at the current moment of the model time $t, {}^3\sigma_i$ – the node number, where the object must go, ${}^4\sigma_i$ – the moment of the model time $t_1 \geq t$ when the object must continue a motion along the network, ${}^5\sigma_i$ – the level of the object priority, and ${}^6\sigma_i$ – the information which is transferred by the object (for instance, ${}^uC, {}^AC, {}^CC, {}^LC, \pi^u, \pi^h, \{Y_i\}$ in (6.5), the hybrid strategy, i.e. the sequence of the network nodes which have been passed, that can be used for argumentation). Let us also define two sets $\Sigma^t = \{\sigma_1^t, \dots, \sigma_{N^t}^t\}$ of objects which must 'advance' at the current moment of the model time t, and $\Sigma^F = \{\sigma_1^F, \dots, \sigma_{N^F}^F\}$ of objects which must move at the moments of the time $t_1, \dots, t_n$, while $t_n \geq t_{n-1} \geq \dots \geq t_1 > t$, and $T = \{t_0, t_1, \dots, t_T\}$ of the moments of the model time, in relation to which there occurs the final set of events of the hybrid simulation process (6.5) (for instance, to occupy and free δ, detain in δ, etc.). On $\dot{M}^a, \Delta, \Omega^{\dot{m}\delta}, R^{St}, \Sigma, \Sigma^t, \Sigma^F, T$, where: $\Omega^{\dot{m}\delta} = \{\Omega_1^{\dot{m}\delta}, \dots, \Omega_4^{\dot{m}\delta}\}$, $R^{St} = \{R_1^{St}, \dots, R_8^{St}\}$ we introduce a control procedure I^u (the interpreter) as the following:

1. Initialization (i.e. generation of $\Sigma, t = 0$ and then choosing the similar amount N^Σ of the dynamic objects depending on $N^{\Delta 1}$; for them the times of motion $t_1, \dots, t_{N^\Sigma}$ are defined and they fit into Σ^F, brought in the order of growth $t_1, \dots, t_{N^\Sigma}$);

2. Has the model time expired? If yes, it is the end, otherwise go over to Step 3;

3. Choosing objects with a minimum time t_{min} of motion from Σ^F. To place the objects in Σ^t, to promote the model time to $t = t_{\min}$.

4. To move the objects from Σ^t along the network from δ_i to δ_j in accordance with R^{St}, processing events and executing programs which are interconnected with the nodes δ, and changing ${}^6\sigma_i$, until one of the following situations occurs: first, the object enters the 'assistant- temporary delay node', then t_{del} is added to t, i.e. ${}^4\sigma_i = t + t_{del}$ and the object σ_i is moving from Σ^t to Σ^F; second, the object will fall into $\delta_i \in {}^4\Delta^C$ and then it disappears from the network; third, σ_i can not fall into the necessary node and it stays in Σ^t.

5. If it is still possible to move objects from Σ^t, then go over to Step 4, otherwise go over to Step 2.

The network defined earlier can act as δ. More than one network can function in parallel. The metaphor considered generalizes individual and distributed DSS.

Eventually, the network St_i^u, can be defined as follows:

$$St_i^u =< \dot{M}^a, \Delta, \Omega^{\dot{m}\delta}, R^{St}, \Sigma, \Sigma^t, \Sigma^F, T, I_i^u > . \tag{6.6}$$

The set of networks $St_1^u, \dots, St_{N^S}^u$ the parallel operation of which is supported by the interpreter I^u can be created. Then finally we have:

$$St_1^u = < St_1^u, \ldots, St_{N^S}^u; I^u > . \tag{6.7}$$

The obtained HYIS formalism is sufficiently general and assigning different restrictions we can, for instance, imitate the functioning of hybrid systems [7], aggregate systems [1] and hybrid expert systems [5].

7. HYBRID INTELLIGENT SYSTEM REALIZATIONS

The heterogeneous problems 'Shift-daily planning of cargo operations" in the sea port – on the basis of ${}^8R^i$, 'Crop capacity planning of agricultural cultures and agricultural actions' in a bio-production system – on the basis of ${}^1R^i, {}^4R^i, {}^9R^i$ and ${}^7R^i$, as well as "Choice of measuring instruments and transmitters for engine room automation systems of sea-going transport ships' in a shipbuilder DSS – on the basis of ${}^4R^i$, are formulated and solved using the HYIS formalism.

The 'Visual Event' language and modelling system the kernel of which is debugged and is going trough laboratory testing now, is being developed for HYIS large-block, visual and object-oriented programming.

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HIBRIDINIS SPRENDINIŲ PRIĖMIMO SISTEMŲ MODELIAVIMAS. II.

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Straipsnyje nagrinėjamos pagrindinės dirbtinio intelekto problemos, tame tarpe žmogaus intelekto savybių integravimas. Tuo tikslu yra sukurtos hibridinės protingos sistemos. Straipsnyje analizuojamos sprendinių priėmimo sistemos ir modelinių artinių vystymasis. Aptariamas sprendinių priėmimo sistemų heterogeniškumas. Apibrėžtas hibridinių protingų sistemų formalizmas.