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# COMPUTER AIDED DESIGN OF HYBRID MODELS FOR AUTOMATION SHIP SYSTEMS

*The paper studies a ship engine room automatic and remote control system as a hybrid system. The terms 'real task' and 'hybrid intelligent system' are introduced. The HYIS classification and review of HYIS architectures being presented. The foundations of HYIS theory and computer aided design technology for HYIS are being shown.*

## 1. INTRODUCTION

Developing sea-going engine room automatic devices and automated systems is a target-oriented sequence of decision making design actions, as a result of which object description with a given granularity is created. Among tasks of design decision making, let us choose a class of tasks, the decomposition of which does not bring about the set of subtasks, the models of which can be created within the framework of one single method of modeling (analytical, statistical, logical, semiotic [7]). We call such tasks 'real' tasks. It is these tasks that a designer has to solve practically. Modeling of such tasks requires new methods not being abstracted with essential restrictions from the real problem-solving environment [5], but integrating the advantages of certain methods into a synergic effect system. Then such a system will be an instrument of overcoming insufficiency and drawbacks of each individual method. As M.Minsky, a well-known authority in the field of artificial intelligence technologies, recently mentioned, the time has come to build systems beyond the individual components frameworks. He stresses the importance of individual modules and the necessity of integration methodologies.

Integration is not a new notion in the system theory and the theory of artificial intelligence [4]. It has been studied for about 20 years. However there is an obvious lack of theory and technologies. We have been developing the theory and creating the technology of a possible way of integration, i.e. hybrid intelligent systems (HYIS) [4,6]. In 1997 we stated developing a hybrid model for decision making support of a designer, working with automatic systems for sea-going ship engine-room [3]. The results obtained will allow us to pass over from a 'do-it-yourself', individual hybrid development to a mass, industrial kind of activity.

## 2. CLASSIFICATION OF ARCHITECTURAL TYPES OF HYIS

World information technologies practice makes use of the following meaning of the term HYIS: a hybrid intelligence system is a system employing more than one human intellectual activity simulation method. Such methods are called components (techniques). Creating the theory of HYIS, we have limited the framework of our research to a three-level stratified system. We have chosen the neural network (NN), the genetic algorithm (GA), the simulation (statistical) modeling (SM), the expert (ES) and fuzzy systems (FS) as components. Creating the technology (Fig.2), we have chosen cognitive and functional HYIS architectural types (Fig.1).

The **cognitive hybrid** realizes the principle of redundancy and that of parallel, independent work of two functional components when solving the same problem displaying at the same

time the solution process.
**The translational hybrid** realizes the principle of translation of structure created in one technique into the structure of another technique. As a rule the structure obtained is not completed from the functional point of view.
**The chainprocessing hybrid** realizes the principle of using functionally completed components as parts. The hybrid is formed from of two components one of which is the main processor and the other is the preprocessor or postprocessor.

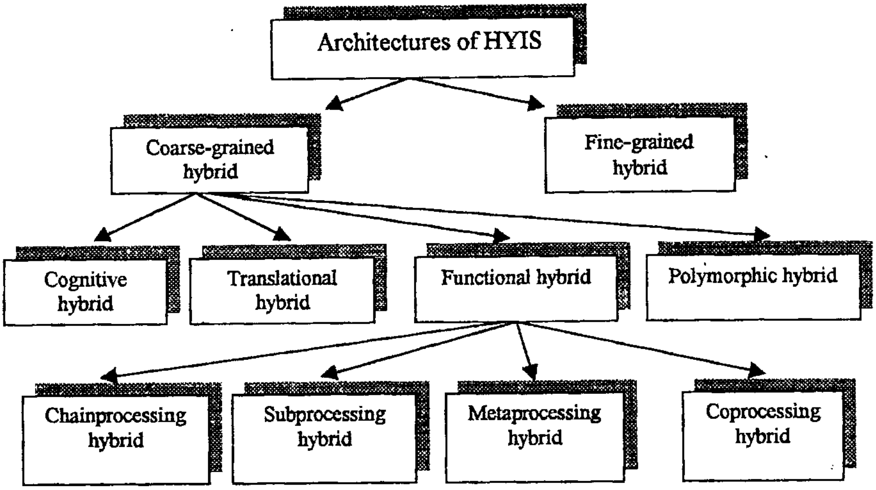


Fig.1

**The subprocessing hybrid** realizes the principle of using functionally completed components as parts. One of the components is included into the other (the latter being the main problem solver).
**The metaprocessing hybrid** realizes the principle of using one processor (the purely controlling one) and $n \geq 1$ components fulling some functional task.
**The coprocessing hybrid** realizes the principle of using components that are equal partners when solving a task. Each component can send information to every other component, can interact with every component processing subproblems of the problem.
**The fine-grained hybrid** realizes the principle of using small modules ('grains') the library of which is functionally full for the development of any HYIS class.
**The polymorphic hybrid** realizes the principle of using the architecture of one technique, but doing this, it achieves the functionality of the other techniques. These HYIS ('chameleon-like' systems) simulate functionally or emulate various techniques and change their own external characteristics (functioning) retaining its architecture.

## 3. REVIEW OF PROJECTS FOR THE CTEATION HYIS

The interest to hybrid systems and HYIS in Europe and all over the world is enourmous. Reviews of publications in the field can be found in [1,2,4,6]. Below there is a short review of projects developed at present.

The HAREM project (a Hybrid Architecture for Risk Evaluation and Management) is devoted to solving the problems of integration of the symbolic and the connectionist approach in artificial intelligence by making up a competitive hybrid system. Such a system, in the opinion of the authors, must have an environment for module designing of neural networks and the two-level knowledge-based system . Theory and methodology of combining neural networks with the basic knowledge level is worked out as the models required for adapting the neural network structure to an applied problem.

The MIX project (Germany, France, Spain, Czech) solves a problem of symbolic-and-connectionist integration and that of increasing the multi-aspectness of hybrid systems by means of combining various presentations, reasoning and learning schemes; the task of increasing the power of hybrid system inference; making clear what the theoretical influence is of the symbolic-and-connectionist integration on machine learning, on the choice and combination of methods for learning, sharing of confidence, assimilation of knowledge; increasing expandability and applicability of the hybrid modeling results to problems of the external world.

The HANSA project (European Community Esprit 111 – Project 6339 – Heterogeneous Application geNerator Standard Architecture, United Kingdom) solves the problem of development of architectral principles and software for HYIS design. The purpose of the project is to create an open environment for the application development tools. The project is based on two main elements. The first element is an object-oriented communication architecture of the cross-platform type; it allows components in hybrid application to exchange information. The second element is generators using the cross-platform for communication and the utility library (databases, spreadsheets, expert system shells, neural network and genetic algorithms) for developing an application.

The MURI project (Multiple University Research Initiative "Integrated Approach to Intelligent Systems", University of California, Berkeley; Cornell University; Stanford University, USA) is devoted to integrated applications creation for mobile robot systems. Soft computing is used for integrating of fuzzy logics, neural network, probabilistic reasoning and a genetic algorithm. Each component is matched by its class of the tasks solved.

The project HANSA is the closest to the goals and tasks of the present paper. The overwhelming majority of other projects as well as the results obtained by Russian and foreign researchers, are devoted to particular hybrids solving practical tasks. They either do not touch upon problems of HYIS technology or they automate only some of the technological stages.

## 4. THEORETICAL FOUNDATIONS OF HYBRID INTELLIGENT SYSTEMS

The HYIS is a system which includes $n \geq 2$ functional components $K = \{K_i\}|i \in \overline{1;5}$ using knowledge presented in the general semantic memory $S$ and connected with this memory and with each other by the intercomponent interface $J_\mu$ and executing an hybrid strategies $H_c$ in the state space $C$:

$$H =< K, J_\mu, S, H_c, C > . \quad (1)$$

A functional component $K_i$ is a formal deductive system :

$$K_i =< L_i, W_i, G_i, \Theta_i >, \quad (2)$$

where:

$L_i$ - set of basic expression facilities of processor input language,

$W_i$ - set of rules for building syntacally correct programs,

$G_i$ - syntacally correct programs,

$\Theta_i$ - production rules executing $\Theta_i : G_i \rightarrow G_i$.

Information processing by $K_i$ is simulated by its processor $\Pi_i$. The HYIS semantic memory is:

$$S =< L_s, W_s, G_s, Z_s, \Omega_s, X_s, \Sigma_s >, \qquad (3)$$

where:

$L_s$ - basic elements for knowledge presentation of $K_i$,

$W_s$ - syntax rules for creating of semantically correct $G_i$,

$G_s$ - problem domain knowledge $G_s = \{G_{s_1}, G_{s_2}, \ldots, G_{s_n}\} | 2 \le n \le 5$,

$Z_s$ - knowledge about component functioning $Z_s = \{Z_{s_1}, Z_{s_2}, \ldots, Z_{s_n}\}$,

$\Omega_s$ - update rules of $W_s$, etc. $\Omega_s : W_s \rightarrow W_s$ for new of $K_i$,

$X_s$ - learning rules and supplement rules of $G_s$ by knowledge from external environment, etc. $X_s : G_s \rightarrow G_s$, $X_s = \{X_{s_1}, X_{s_2}, \ldots, X_{s_n}\}|$,

$\Sigma_s$ - rules of knowledge negotiation with external environment $\Sigma_s = \{\Sigma_{s_1}, \Sigma_{s_2}, \ldots, \Sigma_{s_n}\}$.

Intercomponent interface provides information exchange between $S$ and $K_i$, and also (through the semantic memory) between $K_i$ and $K_j | i \ne j$ in accordance with $h_c \in H_c$:

$$J_\mu = \{J^i_\mu\} \Big| i \in \overline{1, n}, \quad J^i_\mu =< \Xi_\mu, \Delta_\mu, O_\mu, \Phi_\mu >, \qquad (4)$$

where:

$\xi^i_\mu : G_{s_i} \rightarrow G_{s_j}, \xi^i_\mu \in \Xi^i_\mu$ – rules of knowledge extraction from $G_{s_i}$,

$\delta^i_\mu : G_{s_i} \rightarrow G_{s_j}, \xi^i_\mu \in \Delta^i_\mu$ – update rules of $G_{s_j}$ in accordance with the results of $G_{s_i} | i \ne j, j > i$,

$o^i_\mu \in O^i_\mu$ – update the algorithm of $\Pi_i$ (for example, the change of forward chaining to backward chaining in ES),

$\phi^i_\mu \in \Phi_\mu$ – reflect the $\Pi_i$ results into the state space $C$, save the number of active $K_i$ and the active knowledge fragment into $S$.

## 5. COMPUTER AIDED DESIGN HYIS TECHNOLOGY

The scheme of technology of development of coarse-grained HYIS in interactive mode is shown in Fig. 2. This technology uses the object-stratified approach to the presentation of problem-solving environment with a limited number of levels-strata: S1 - situational, S2- streamal and S3 - parametrical). The S1 stratum is the most explicating presentation of the design object in the form of resources, their characteristics and relations. With this stratum problems of organization of automatic and remote control of engine room plants are solved (the selection, co-ordination and placement of equipment, placing communication links and power supply sources, etc.). The S2 stratum is an abstract presentation of the object in the form of stream schemes (information, hydraulic, energy, reliability and other). With this stratum the characteristics of flows, and the service is observed and problems of calculation of capacity, refusals, evaluations of the operation of the object as mass service systems are solved. The S3 stratum is the most abstract object presentation in the form of the cybernetic black box. Financial, economic, marketing parameters are observed here. The problems of optimization of financical and economic parameters, the choice of partners on the automation system market, forecastings of design situations and many the others are solved here. The detailed strata presentation is considered in the report. Each of them is matched by methods of modeling (S1 - NN and GA; S2 - SM; S3- ES and FS) of which are presented in Fig. 2 as processors (Π) and programs (P). The stratum contains its identifier, task and modeling methods specificators, the conceptual model, the knowledge field, data- and knowledge-base of problem-solving environment and subproblem solving program. The base of possible hybrid strategies and the current (interpreted) hybrid strategy is saved as the metaknowledge; the interpreted HYIS behaviour; amount of strata; the number and names the processors functionning in HYIS; the scenarios of master-programs while forming the HYIS; statistics on HYIS functioning. The technology has a set of master-programs interacting with the user and semantic memory and executing the functions of information processing in different modes. The stratum specificator forms a hierarchy of semantic memory from one (not hybrid mode), two or three strata. The task specificator forms in the dialogue with the user a task description including its structure. The conceptualizer builds a conceptual model of the application domain for the task solved on all (or one) strata. The method specificator defines a method which will be used on each stratum for solving the task. The model constructor uses the conceptual model, the method specification and builds the model and the scheme of program (P) on each strata. It can not be yet processed by the interpreter. The hybridizer works in the dialogue with the user choosing strategy of HYIS from the metaknowledge and using information saved on strata and, assigning the intercomponent interface, creates HYIS and saves its strategy in the metaknowledge. The interpreter works with the decision-making person in the task-solving mode using one of HYIS presented by the metaknowledge in the form of a hybrid strategy. The interpreter interprets the strategy and organizes the co-ordinated functioning of the processors and the interfaces. The learning master learns NN. The argumentation master explains, justifies or motivates the obtained task solution.

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