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The Pilot-Aircraft Intelligent Interface Concept

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Abstract: - The paper deals with the topical problem of increasing the effectiveness of weapon systems by constructing and providing the sophisticated man-machine interface. The man is still principal and the most important part of the man-machine system and the effectiveness of such system is first and foremost induced by the capabilities of human operator. To exert the human aptitude the appropriate intelligent man-machine interface (IMMI) is used. The main part of IMMI is the situation assessor and recognizer (SAR) providing actual information about state of man, machine and environment in form of values of situation variables. The SAR is the mapping from set of measured variables to the situation variable set and concurrently it is the model of man, machine and environment behavior. The SAR is constructed as a knowledge-based system using approaches and methods typical for Artificial Intelligence or for Intelligent Control as a branch of Cybernetics.

Key-Words: - intelligent control, intelligent system, knowledge system, man-machine interface,

1 Introduction

Contemporary systems used in warfare are characterized by increasing level of both technical and combat capabilities. It poses growing demands for man-operator as a central part of such system to be able to control the system exploiting its capabilities to the best advantage. Military systems are often operating under conditions of enemy counterworking. Therefore man (crew) is hourly under stress and overloading and in life and health hazard. Such situation extremely affects the behavior of man-operator and the level of enforcing his aptitude. Of course, the quality and effectiveness of human activity are qualified by intellectual prerequisites and they are formed in well-organized training process, but in real warfare situation, the most important is the way of man-machine collaboration and communication. For this purpose very sophisticated man-machine interfaces (MMI) are being designed.
The design of appropriate MMI is very important for control of such MM system like the system Pilot – Aircraft. The example is the ACS (Adaptable Cockpit System) project dealing with the advanced IMMI construction for pilots of modern fighters.

2 Intelligent MMI

In general, the man-machine interface serves to transfer and present information from machine to man and to provide control values and commands from man to machine, i.e. the interface operates with signals of various physical substances. The process of information or knowledge transfer from man to machine and backward is not only converting one but more complex procedures have to be provided to present information to man-operator in such way that makes possible him to solve necessary tasks more effectively. Taking into account changing situation of system, i.e. alteration of tasks of system, variable environment of system, counterworking of enemy and changes of system capabilities and properties in course of combat activity, the advanced man-machine interface must embody such important feature as being adaptive.

2.1 Adaptation of MMI

The adaptiveness of system is oriented to improving conditions for man control activity according to the changing situation, to save the man-operator and to increase the effectiveness of entire system.

There are five main groups of possible measures how to adapt system interface is in adaptive interface concept:

- Reconfiguration of structure of information and knowledge presented to pilot, i.e. selection and arranging the actual information, presenting it in appropriate form and representation language, time aligning of presented information.

- Warning signals concerning identified changes in system situation, i.e. enemy counter attack, defect of machine-part of system.
- Warning signals concerning identified state of man (including so called biostate of man) characterizing the level of actual man abilities to solve tasks and control the system.
- Active support to man in solving his decision and control tasks, i.e. the interface is to involve some decision-support subsystems.
- Helping the man by assuming some of his tasks in phase of combat activity when the man is overloaded or when his capabilities are decreased.

To provide any adaptation process it is necessary to imbed appropriate adaptation loop based on evaluation of momentary state (or situation) of system and its environment. Moreover the tasks to be solved for the providing of adaptation process may not be trivial therefore the system like this is usually synthesized using principles and approaches that are typical for cybernetic discipline: Intelligent control of systems (ICS). In this case we can talk about **the Intelligent Man-Machine Interface (IMMI)**.

2.2 IMMI analysis and synthesis

The main ICS principles used for the IMMI analysis and synthesis lead to fundamentals as:

- The IMMI system is presented as a **knowledge system**; all parts of the system are presented as a knowledge submodels; all system tasks are presented as a manipulation with knowledge or information;
- The main task of the IMMI system is to provide the adaptation actions as a response on the actual state of some situation, i.e. this system can be described in a form of **mapping M_A** from **Situation Set S** to **Adaptation Action Set A** according Fig 1. The mapping M_A from **A** to **S** is the **Law of Adaptation** determining when is necessary to provide appropriate adaptation action. The mapping from A to S is the **Law of Adaptation (M_A)** determining when is necessary to provide appropriate adaptation action.

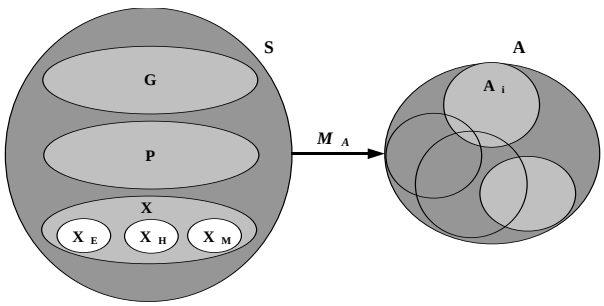

Fig. 1: The Set Representation of the Law of Adaptation

- The situation set **S** involves subset **G**, that presents values bearing knowledge about the goal and about the qualitative criteria, **P** are a set of important system characteristics, **X** is the state set involving values expressing information about the *state of human operator* (X_H), about *machine part of system* (X_M) and about *system environment* (X_E). The set **A** involves groups of values representing adaptation actions listed above.
- The most general knowledge representation language used for the IMMI description could be the **IMMI relation structure** corresponding to previous figure. The system is expressed by relation (function) in form of

$$A = M_A(S) = M_A(G, P, X). \qquad (1)$$

This relation is the knowledge model of interface adaptation and the adaptation process is then a procedural interpretation of this knowledge model.

- In the most simple form it is possible this relation represent by means of a set of statements (pieces of knowledge) about relations between some elementary situation $\sigma_i \in S$ from situation set S and any corresponding adaptation action $\alpha_j \in A$ from action set A. The causal relation of the IMMI system is presented in another simple form in Fig. 2,

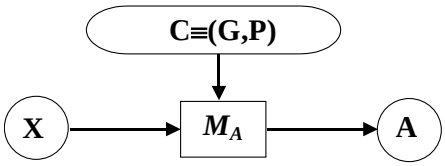

Fig. 2: IMMI system representation

where the input of system is state of system $x \in X$, output is action $\alpha \in A$ and values $g \in G$ and $p \in P$ are taken as **context values** $c \in C \equiv (G \times P)$.

The IMMI model is structured according the important parts of the system, three main parts or knowledge submodels could be found in the IMMI knowledge model. They are **the human operator model**, **the machine model** and the **environmental model**, that are presented in a form of **mappings M_P**, **M_H**, resp. **M_E** . The decomposition of the whole IMMI system can lead to a triple of relative autonomous systems with separate input sets X_E, X_H and X_M, common action set A and with contextual binding.

The C_E, C_H and C_M are sets of respective context values and we can see, that the input and output of one model could be a context for the other one, but the structure of the knowledge ACE system could be more complex.

2.1.1 Sub-subsection

The IMMI system has a knowledge structure of the **common knowledge system** (CKS) or arbitrary expert system. It involves three important subsystems.

- **Knowledge base**, that is the structured set of pieces of knowledge about the system expressed in useful knowledge representation language. This knowledge represents a static model of system and it has mostly declarative character. It represents mapping from A to S.
- **Base of data or base of facts,** that involves a set of more simply represented pieces of knowledge about the task to be solved. The knowledge has declarative character, too. This base of facts involves both actual S and A variables, i.e. characterizes the state of adaptation process of IMMI.
- **Inference or control mechanism** is a set of knowledge pieces having a procedural character. It provides the process of solving the task and expresses its consecution. The inference mechanism is model of the system behavior (system motion), i.e. it provides the adaptation process of IMMI.

The common knowledge system belongs to group of general system approximators (and to group of general function approximators of course as well). That means the Law of Adaptation could be represented by any other system approximator, e.g. by set of rules of any production system, by fuzzy logical system, by set of differential equations, by any artificial neural network, etc.

To design the IMMI four main part of system must be determined, i.e.

- **Action set A specification**, i.e. determining of possible and useful adaptation measurement and its technical realization.
- **Situation set S specification**. It means that the group of appropriate constituent variables characterizing the situation of system must be chosen. These variables could present
- **Situation set S identification.** To adjust the situation set for providing the adaptation process the effective procedures for extracting the information from measured data variables must be implemented.
- **Law of adaptation synthesis.** It means to find the mapping from S to A and express it in appropriate language i.e. to represent it by any useful system approximator.

It is evident that the adaptation process of IMMI is based on two substantial procedures:

Identification of situation (identification of S). It involves such procedures as data collecting, expressing it in appropriate language, data interpretation, assessing and recognizing. The result of these procedures is actual value of each situation set variable.

- **Determining of adaptation actions** (applying the law of adaptation) and providing them.

  That means the IMMI is composed from two important parts, two knowledge subsystems in serial connection, se Fig.3. One of them is the subsystem for reasoning and providing the adaptation law of the IMMI - RPA. For identification and setting up of the situation set the Situation Assessor and Recognizer (SAR) is applied.

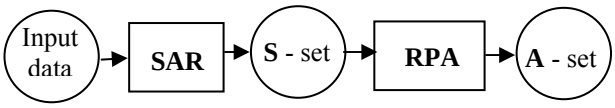

Fig.3. Knowledge structure of IMMI

3 The SAR system of the IMMI

The SAR is the knowledge system converting the information involved in measured input data to values of the S-set variables that represent the knowledge model of actual situation. I.e. it represents the mapping from measured variables to S-set. The SAR is important part of IMMI, because of the adjusting the S-set is necessary condition for providing the adaptation process. As to S-set structure discussed above, the important parts (knowledge models) of SAR are

- Model of human operator – pilot,
- Model of machine – i.e. aircraft
- Environmental model.

All parts SAR are acting concurrently and they are usually implemented in common computational environment.

3.1 The SAR-Pilot Model

The pilot model has three important parts, i.e.

- Bio-psychic model, expressing the instant bio-psychic state of pilot representing by such values, as: actual load (physical load P, visual load E, stress load S), measure of fatigue F, measure of health capability H, etc.
- Behavioral model, expressing the rules of the normal pilot behavior in course of mission.
- Mission model, involving the information about planned mission, rules and constraints for providing the tasks of mission. This model determines the desired behavior of pilot.

The pilot model is the important source of information for adaptation of intelligent cockpit concerning to improve condition for pilot activity.

3.2 The Aircraft Model

The aircraft model describes the properties and functioning of the technical part of MM system, i.e. of aircraft, its communication, navigation and weapon subystems and other technical equipment. This model serves to determination of technical state of aircraft and for evaluation of pilot control process.

3.3 The Environmental model

The environmental model express knowledge about the state and properties of environment. This model involves such part, as

- Knowledge about weather and of its influence on the system behavior and control process,
- Knowledge expressing the actual condition for fulfilling the mission including the rules for activities in group of aircrafts,
- Information about enemy activities, occurring the enemy means, locking on by enemy radar, etc.

3.4 Notices to SAR Design and Implementation

In process of analysis of system domain and of the SAR synthesis the following fundamentals were accepted:

- Whole SAR is represented in unique knowledge frame and implemented in unique computational environment
- For representing the knowledge model of SAR the rule-based system is used.
- The SAR system is designed as an open system, in first phase was represented in very simple form, in next phases the system is being improved using the evolutionary synthesis principles.
- For implementing the knowledge base of SAR the appropriate MySQL database environment is used, for procedural part of SAR C++ is used.

4 Conclusion

Because of the modern military systems are based on the collaboration of man and machine, the synthesis of intelligent man-machine interface is very actual topic. The design of sophisticated interface is very important way of increasing the effectiveness such man-machine system, enhancing its combat force and improving of protection human–operator life and health. The approaches to the intelligent man-machine interface construction issue from general cybernetic principles formulated in cybernetic discipline Intelligent Control. Therefore the structure and tasks of IMMI is very similar for various kinds of warfare system. At present the development of the IMMI is namely oriented to applying advanced approaches and methods to analysis of man behavior and properties, to synthesis of sophisticated law of interface adaptation and to solve necessary tasks of knowledge processing and utilizing by the best way. The very important and urgent application of IMMI synthesis is in domain of aviation.

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