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Design of Neuro-Fuzzy Process for Smart Robots Locomotion

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ABSTRACT. For construction of intelligent navigation system for mobile SR (Smart robots) in fuzzy environment with dynamic and static obstacles the computational method based on Neuro-fuzzy technology is used. Structure of Neuro-fuzzy system of orientation, its elements and the general principle of the activity is suggested.

KEY WORDS: Smart robot, neuro-fuzzy technology, navigation system fuzzifier, vision and training systems.

I.INTRODUCTION

In an unknown and frequently changing dynamic environment, the SR should do the same movements as a human in a similar environment. Recently, for designing control systems working in uncertain environment, it was considered purposeful to use new effective methods of Soft Computing technology [1-5]. Hence, for construction of navigation system with required autonomy, with the ability for reasoning and work in real time it is necessary to use the neuro-fuzzy technology, being one of the important directions of Soft Computing technology.

Therefore, an intelligent system for navigation of an Intelligent Robots in an uncertain and dynamic environment can most effectively be created on the basis of combination of the two modern technologies-fuzzy logic and Neuro-Computing.

Problem of creation of intellectual robots is an extremely thorny scientific and technical task the decision of which includes grounded choice of their kinematic chart and construction, determination of composition of necessary equipment, synthesis of the control system. One of the most effective ways of rational construction of intellectual robots is connected with the use of conception of the modular constructions collected from the limited row of models elements. Its natural development creates potential pre-conditions for development of intellectual robots with module organization of all aggregate of basic functional subsystems; executive mechanical subsystem; subsystems of sensitization; intellectual control system and it programmatic - algorithmic providing. Intellectualization of the processes of control of functional traffics is the main feature of modern stage of development of the mechanotronic modules of intellectual robots of the systems. Basic attention is spared to development of fundamentally new generation of the multi-coordinated modules, in which the integration of three components is carried out - electro mechanics, electronic and computer and also there is a possibility of getting a great number of co-ordinates of the module. Technical realization of intellectual MM of motion became possible due to stormy development of the microprocessor’s systems oriented to the tasks of traffic control.

II. STRUCTURE OF THE SMART ROBOT SYSTEM

The multi-ordinated mechanotronic modules of motion allow to get on an output a great number of linear and angular motions.Permanent perfection of the technology of production conduces to the stable decline of cost of vehicles facilities, which made them cost-effective for practical introduction of multi-ordinated mechanotronic modules to the present tense.The generalized structure of multi-ordinated mechanotronic modules of smart robot of the system is resulted on a fig. 1.

The Device of computer control (DCC) on the base of input information, entering from the top-level of control and on circuit to feedback from sensor, gives out in time controlling electric signals on multi-ordinated executive modules. The power gain of data signals and their inflexion occurs in power converters. Then, the executive modules work out the corresponding efforts (power and moments) for sections of the robot that provides goal-directed motion of eventual links of robot - its working organ.

We will consider the examples of between block interfaces, which most often meet in the robots with the computer management, broadly applicable in automated production. The Interface I1 presents itself the complex of networks vehicle programmatic facilities for the interface of computer control units with a computer network, or interface "man-is robot" if the purpose of management of the mechatronic system is set directly by a man-operator. Modern man-machine interfaces are executed in the manner of boards and handles of remote control (for instance, for programming of industrial robots by method of the education) of sensory display devices of data display in the systems of virtual reality.

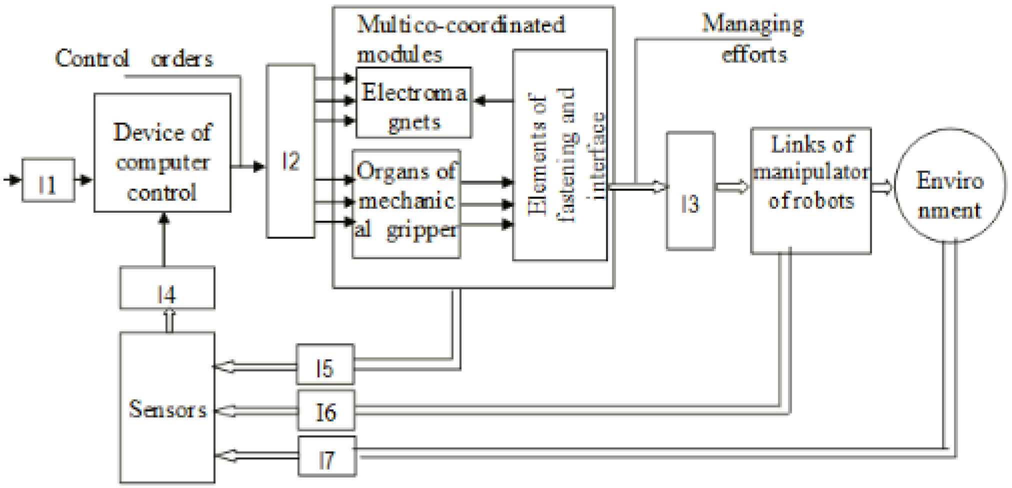

Figure 1. Generalized structure of the multi-ordinated module of movement of intelligent robot.

The Interface I2 usually consists of numerically-analogue transformer and amplifying-transforming device and serves for forming managing electric tensions for the executive modules.

The Interface I3 presents itself, as a rule, mechanical transmissions, linking executive modules with links of the robot. Structurally such transmissions usually include reducing gears, muffs, flexible connections, etc.
Interface I4 on the entrance of DCC is built on the basis of analog digital transformers in the case of use of sensors in the mechanotronic module with an analog output signal.

Interfaces of sensors I5, I6 and I7 depending on physical character of entrances and condition of system can be divided into electric and mechanical. Joining devices of feedback of the modules refer to mechanical(photo of impulsive, codes revolvers and other), tactile sensors , and also other facilities of sensitization and information about motion of the modules ,links of robot. It should be noted that connection of all elements with computer control unit foresees not only the vehicle interface but also proper software for organization the exchange of information in the real-time mode.

It is possible to select three directions of intellectualization of multi-ordinated mechanotronic modules:

- development of the integrated interfaces binding a managing controller to the computer of top level, single vehicle-programmatic managing complex (interface I1);
- creation of the intellectual power modules of management by integration of managing controllers and power transformers (interface I2);
- development of intellectual sensors of the mechanotronic modules which additionally to the ordinary measuring functions carry out computer processing and signal shaping on the flexible programs (interface I3).
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Principle of construction of the multi or dinated mechanotronic modules of linear motion is based on the supply of mobile part (anchors) of electromagnet by a few organs of mechanical gripper, which are managed separately. The multi-coordinated modules includes control unit, block of electromagnets and permanent magnets, organs of mechanical gripper (otherwise are the guided muffs) and elements of fastening and interface. The electromagnets serves for transformation of input electric signal in mechanical moving of recurrently forward action, and organs of mechanical gripper and elements of interface- for the transmission of motion to the organs of motion of the intellectual robot. Permanent magnets are mobile parts of electromagnets. The number of organs of mechanical gripper corresponds to the number of mobile links of robot. The recurrently-forward moving on the output of electromagnet is transformed in the aggregate of linear and angular motions of organs, motions of robot, coupled by organs of mechanical gripper and interfaces.

Construction of the multi-coordinated modules is resulted with three independent coordinate linear moving.
Basically the multi-coordinated modules , consists of an output rod, magnetic core winding, working organ of mechanical grippe, permanent magnets, fixative organ of mechanical gripper and corps.

Mechanotronic module has four electromagnets (in general case the module can have more than four electromagnets), which have a cylindrical form and mandrels from permanent magnets. Working organs of mechanical gripper are hardly attached to mobile permanent magnets and intended for the transmission of recurrently-forward motion of the mobile parts of electromagnets to output rods, which in turn are connected with links of robot and bring them in linear motion.

The fixing organs of mechanical gripper are attached to the body of the module7 and serves for emergency stop of an output rod. Each rod, executed from non-magnetic material, corresponds to two workers and one fixative organs of mechanical gripper. Every group of the same types of organs of mechanical gripper has hard mechanical connections.

Controlling signals enter on each organ of mechanical gripper separately and in the result rods 1 accomplish the coordinate moving independently from each other.

Direction of the coordinate displacement depends on the law of change of controlling signals entering from computer controlling device.

III. METHODOLOGY

Neuro-fuzzy technology is used to implement the meta operators. Methods of Soft Computing are based on computing methods which can work with fuzzy and uncertain information and enables finding a purposeful solution with less cost. It is known that various kinds of fuzzy control are realized on the basis of rules in linguistic form .The various variants of inferences are suggested [6].
Type 1: Applying function MIN for estimations of precise input, the degree of accomplishment of conditional part of rule is calculated as

$$\mathrm{M}_i = \mu_{A_{1k_{i1}}}(x_1)\,\mu_{A_{2k_{i2}}}(x_2).....\mu_{A_{mk_{im}}}(x_m) = \prod_{j=1}^{m} \mu_{A_{jk_{ij}}}(x_j)$$

Then the output of the right part of rule and procedure of defuzzification is performed:

$$y_1^{'} = \frac{\mathrm{M}_1\mathrm{B}_{11}^{'} + \mathrm{M}_2\mathrm{B}_{21}^{'} + ... + \mathrm{M}_r\mathrm{B}_{r1}^{'}}{\sum_{i=1}^{r}\mathrm{M}_i}$$

Here: $\mathrm{B}_{i1} = \mu^{-1}_{\mathrm{B}_{is_{1i}}}(y_1)$

Type 2: In this case monotony of membership function for estimations of fuzzy output is required. In this connection the procedure of defuzzification is complicated and described by formula (1).

$$\mathrm{B}_{i1}^{'} = \frac{\int_{-\infty}^{+\infty}\left\{\left(1-\prod_{i}\left(\mu_{\mathrm{B}_{is_{1i}}}(y_1)\right)\right)y_1\right\}dy_1}{\int_{-\infty}^{+\infty}\left\{\left(1-\prod_{i}\left(\mu_{\mathrm{B}_{is_{1i}}}(y_1)\right)\right)\right\}dy_1} \tag{1}$$

Type 3: Method of Takagi-Sugeno.
Because of a set of fuzzy rules, participated in decision-making process, the computing a conditional output will be very reliable and stable against noise.

For the functional optimization of quality of empirical adjustment of knowledge base, some changes in the conclusions of experiments are required.

For the solution of the navigation problem of the intelligent robot the application of Neuro-fuzzy system is necessary to take into account the following ideas. The environment of the robot is uncertain and dynamic and the environment includes set of objects changing their sizes and states. And consequently in case of missing the knowledge about the environment the control and decision-making is possible on the basis of information from the vision system only. This system can provide only limited information of the environment. Despite of this the camera system is used for finding the safe distance up to an obstacle in a way to the goal.

For collision-free movements in the dynamic environment the control system should periodically address to the vision system. Speed of the moving is adjusted dependent on change of the state of the environment and speed of the robot. Movement of the robot is initiated by commands coming to the servomotor from the control system and these commands determine movement of the robot to the left, to the right, forward and stopping the robot.

IV. EXPERIMENTAL RESULTS

The architecture of the control system providing purposeful behavior of SR, working in a complex dynamic environment characterized by uncertainty (fig.2), is suggested in work [7-14].

At the first level of architecture of SR control system, the basic function of the scheduler consists of the automatic decision to move intelligent robot on the basis of the corresponding data and knowledge.

Direct behavior of SR is realized as the part of the subsystem of navigation, taking place on II level. The control system at this stage formalizes control commands on the basis of a trajectory of the plan found at the first level and knowledge of reflex activity kept in the knowledge base, the current situation of the visual information and fuzzy coordinates of SR. The sequence of these commands provides realization of the plan. Commands transform to effectors signals, passing through subsystems at third (III) level.

Creating the system of planning and navigation of Smart Robots, it is necessary to take into account, that the environment of actions of these robots is uncertain, dynamic, partially or not-structured. The Smart Robot should understand the structure of the environment, create a trajectory of optimum transition from any location to the one by creating a map of environment on the basis of development of the uncertain sensor information and perceiving both static and dynamic obstacles on its way and should move on the basis of this trajectory.

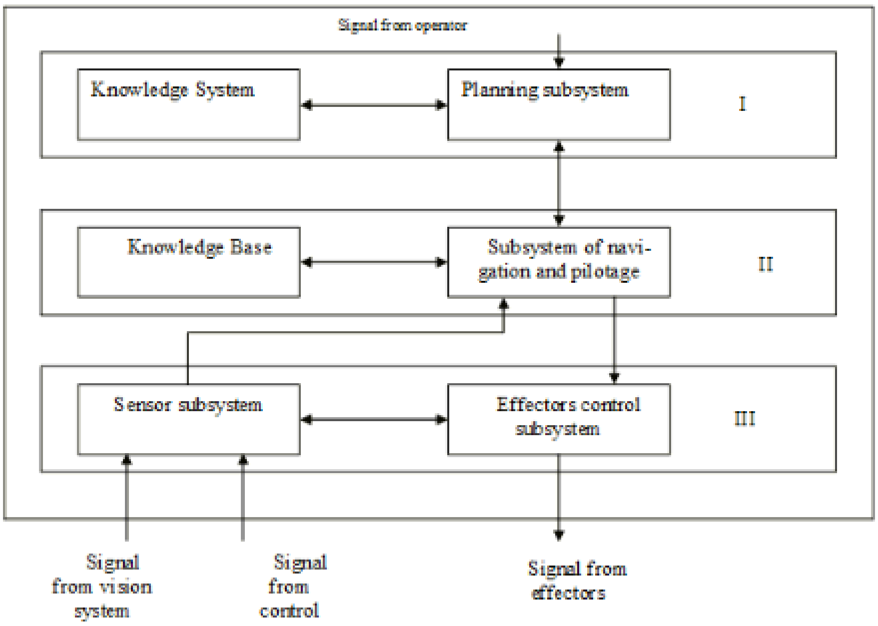

Figure2. The architecture of the fuzzy control system for intelligent robot

In this case the scheduler of Smart Robot, should create sequence of operators (in initially uncertain environment) providing movement of the robot from a point B to the point C. Generated operators are executed by navigation system of SR. It is assumed that SR is equipped with devices of orientation and technical vision. At this level input parameters of SR are visual information and its current parameters. The purpose of navigation system of SR is in on-line mode, during short time under the given plan to move the IR from a point B to a point C, avoiding both static and dynamic obstacles. In general as a whole the control of IR is reduced to the planning of its purposeful movement, to navigation and to adaptive stabilization. In a chain of these hierarchical problems the solution of latter problem takes into account such synthesis of algorithm of adaptive control that they could get into the reality planned trajectory of Intelligent Robots in the uncertain environment. General structure of control system of SR is shown in fig.3. The structure of the control system consists of the following blocks:

- Vision system (VS).
- The device for calculation of direction to goal (DCDG).
- Distance fuzzifiers (F).
- The block for control formalizing control commands (BFCC).
- System of training (ST).
- The servomotor of the Robot (SM).

DCDG can do an estimation of the goal in different ways: By vision system;On the basis of the information transmitted to it (robot coordinate system and current coordinates of the goal).

It receives a signal from the goal (a sound or an electromagnetic signal) and determines the relation to the goal, knowing the direction of this signal. Request the direction to the goal from the operator. DCDG receives signal, BFCC creates a control command, and this command is sent directly to the servomotor of the robot. Fuzzifiers are determining the relation between fuzzy input variables and control commands used in rules.

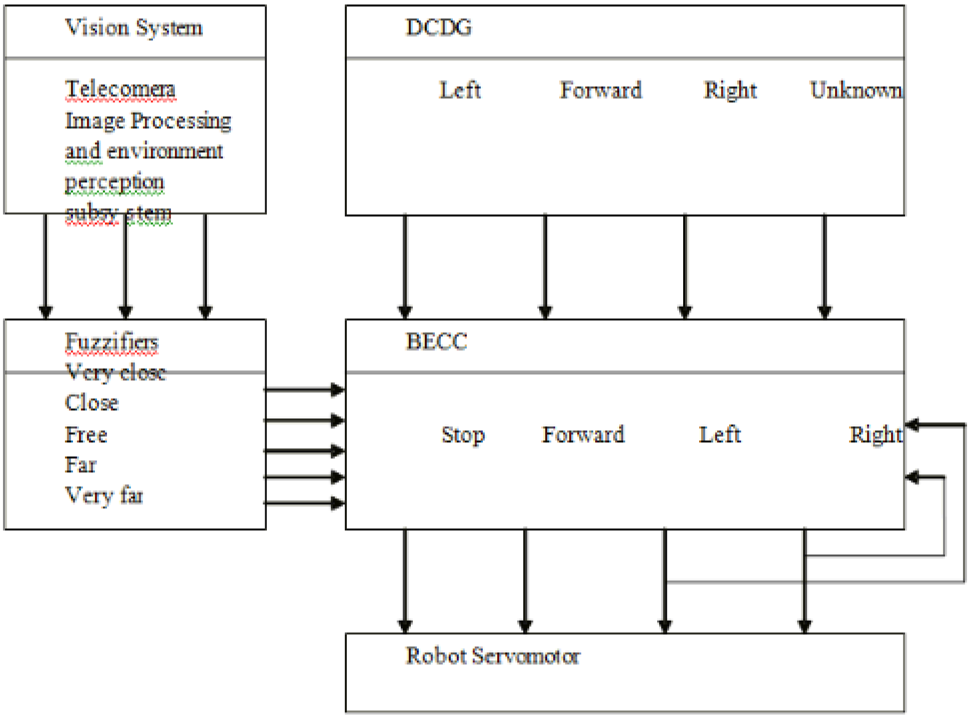

Figure 3. General structure of the navigation system of mobile robot

In this case the input fuzzifier evaluates distance up to an obstacle measured by sensor or received from the vision system. Thus, the number of fuzzifiers is the same as the number of input estimations used for the environment of the robot. If in front of the robot there is no obstacle the signal from the fuzzifier is equal to zero. If there is an obstacle BFCC will modify the moving of the robot such that it avoid the obstacle still keeping the direction to the goal. The second (hidden) layer of neurons in neural network of BFCC shows fuzzy rules, number of neurons shows number of rules. In classical fuzzy mechanism of extraction the output neurons is processed by function MIN (AND). In algorithm of training this function is replaced by other function, allowing mathematical processing]. Formalization of neural knowledge base of BFCC, that is, appropriate adjustment of parameters of the network is possible with use of experimental data. These decisions are confirmed by the operator. During the training, fuzzifiers are adjusted for use of set of linguistic concepts corresponding to the numerical estimation of distance received from vision system because these concepts depend on the sizes of the robot and objects and speed of obstacles (from intensity of changing of the environment).Simulating both the environment and IR are enabled by the computer program. The program arbitrary generates obstacle (with the different sizes).In Fig. 4 the path past by the robot in different conditions of the goal and the robot is shown. Despite of the simplified vision system of the robot, minimum number of rules, linguistic terms and possible control commands for navigation, the behavior of the robot was very intelligent.

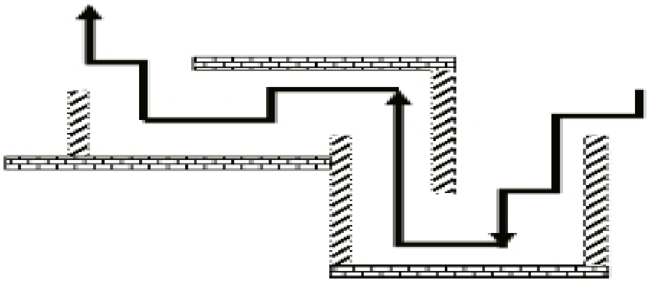

Figure 4. Orientation path of Smart Robot

V.CONCLUSION

For providing collision-free navigation of Intelligent Robot in an environment with dynamic and static obstacles an intelligent system based on Neuro-Fuzzy technology is suggested. Minimal number of fuzzy rules and linguistic terms, and commands were used for navigation. Simplicity of realization of the navigation system proves the Neuro-Fuzzy technology to be very useful in designing efficient, reliable, and fast control systems.

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