Soft Computing Robot Navigation
Case Study

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Abstract

This contribution presents Soft Computing Robot Navigation for mobile robot SCORCAS, a Case Study. The Navigation uses fuzzy logic experienced on mobile robot systems. Fuzzy logic is applied in analogous way into three sub-systems:

i. Sensor, consisting of five autonomous sensor sub-systems: visual, acoustic, tactile, thermal and inertial;

ii. Sensor fusion that comprise all the robot stimulus in environment image representation;

iii. Path planning – responsible for trajectory generation.

These systems are implemented into experimental prototype. Some results are reported.

Keywords: Soft Computing, Fuzzy System, Robot Navigation.

1 Introduction

This contribution presents Soft Computing Robot Navigation for mobile robot SCORCAS, a Case Study. It is necessary step in our project dedicated to Intelligent Technology Application in Robot Navigation Field. From great variety of soft computing models we chose fuzzy logic representation. The aim of the publication is twofold:

i. To show growing potential of fuzzy logic in real object implementation of robot navigation;

ii. To create the basis and pave path for more profound investigation in the field pertain to the next generation of Mobile Soft Computing Agents dedicated to mobile robot navigation [1].

As far as the Fuzzy Navigation Strategy is based on well known Fuzzy Inference Engine our achievement can be sought more in application aspect of this intelligent technique than in any new sophistication in the field. We show the main stages in realization of multi-sensor navigation system dedicated to mobile robot implementation: some peculiarities of mobile construction, architecture of the control and navigation system, sensor fusion technique, program realization, and some preliminary results of SCORCAS.

Among many navigation tasks of mobile robots such as: optimal trajectory planning; obstacle avoidance; smooth trajectory formation, control with time and spatial constraints, etc., we turn the spotlight on the first, since it comprises in some sense all the others. The main peculiarities of this task can be summarized as follows:

i. Uncertain still dynamically changing working environment that require effective sensor system in combination with some intelligent approach;

ii. Fairy constraint artificial sensor systems of nowadays robots. Although we involve: visual, acoustic, tactile, thermal and inertial sensors, which in some extent mimic human beings: sight, hearing, tactile, thermo, and vestibular sensing, they are incomparable imperfect in comparison with those of human beings;

iii. The same is situation with effectors that in our case are implemented by means of double caterpillar, reversible system and additionally mounted rotating tower that would correspond to human neck functions of human being. Again the human abilities prevail in many times;

iv. Even human being activity is constrained in two dimensional space they are able to assess and perform actions in the third dimension without problems (refer paddling);

The most attractive feature of live systems, unreachable of artificial ones by now, are their ability of emotional actions, which act in emergency situations. It is processed by another informational channel that bypass normal brain controlled activities and is an order faster that the last. Surprisingly enough this channel is 300 000 years older than consciousness brain activity, but practically proven during many centuries. This is nature gift left from prehistory times, eternal dream for every explorer.

There are many investigations in the field of intelligent navigation technique, concerning one or other of the problems already marked. For examples [2], [3], and [4] present: static fuzzy based model, schema oriented, and intention based navigation systems. Ref. [5], [6], and [7] demonstrate another approach: fuzzy localization on landmarks, genetic based approach, and Kalman filter combining intelligent agents, whereas [8] and [9] stress their attention to intelligent learning: reactive, supervised, and hierarchically, all based oh fuzzy logic. In contrast to all these investigations our system applies five sensing systems mentioned in point ***ii***. The paper is organized as follows: Section two presents the robot structure: mechanics, robot control and navigation system, as well as sensor system. In Section three we describe intelligent control system, whereas Section four refers to a Case Study. Paper ends with discussion about future trends of the project.

2 Presenting the Robot Structure

2.1 Mechanical and Information Structure

As an experimental tool we have chosen a kid toy tank construction consisting of a head (tower), platform, and base unit. The head has two grades of freedom to mimic human neck swivelling and joggling. It carries the all sensor systems. Platform controls and performs communication tasks. Base unit is placed in movement by two independent caterpillar direct current drive units. Mechanical and Information Structure is shown in Figure 1. A combination of velocity and direction of movements of both caterpillars produces controllable smooth rotation over centres placed on cross direction line. Depending on velocity and direction, the centre of rotation is moved from left to right infinities. When the centre of rotation is in infinity, the tank moves straight line in fore or back direction. The smooth movement of the centre from left to right infinity causes left/right rotation with decreasing/increasing radius of rotation. If a radius coincides with the geometrical centre of the tank, the last spins at a place in clock/contra wise directions depending on the directions of both caterpillars. By this way the tank possesses exclusively flexible dynamic features.

2.2 Robot Control Organization

A simplified robot control organization scheme is shown in Figure 1. Navigation strategy is generated in highest level. After generation of appropriate optimal paths they are distributed in two tasks: base unit control and head control. A middle synchronization level is used to coordinate these tasks.

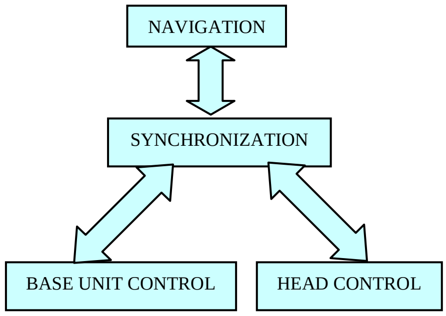

Fig. 1 Robot Control Organization

2.3 Robot Control and Navigation

Robot control system is three layers hierarchical, shown in Figure 2:

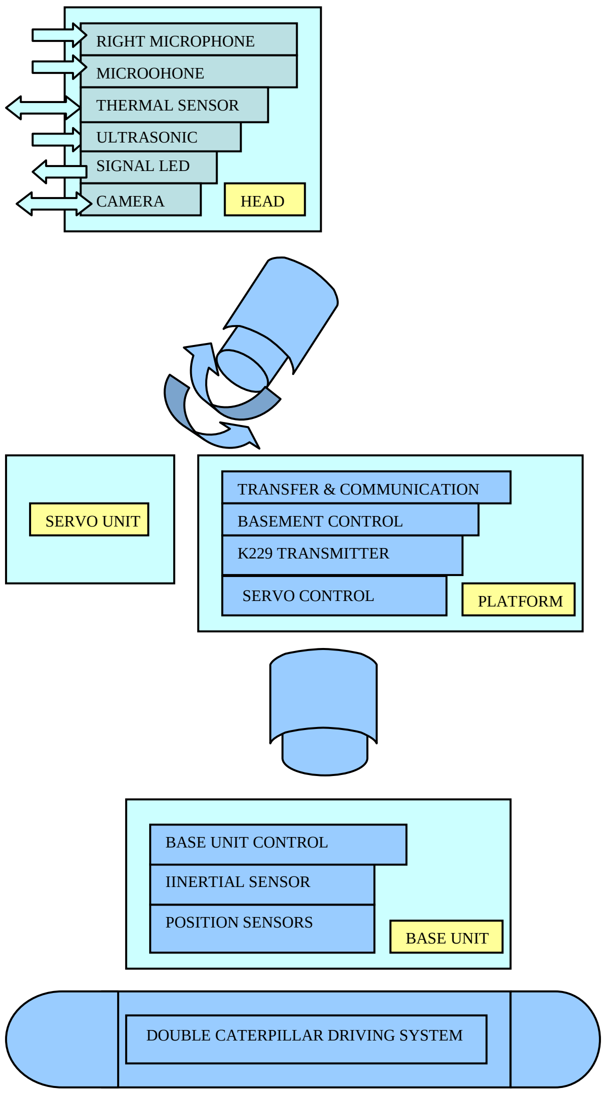

Fig. 2 Robot Control and Navigation System

- ***i.*** The lowest consists of two independent control units. One for direct drive of caterpillar DC motors, which are precisely control by specialized modulation controller. The other - for control of swivelling and joggling head movements;
- ***ii.*** The second level is responsible for synchronization of left and right drivers as well as coordination concerning motion control;
- ***iii.*** The highest is tactic and strategic level defining trajectories. Every trajectory is defined by time dependant steady states. They are transferred by wireless connection. The task of this level is robot navigation. It is implemented via PC using Intelligent Soft Computing Technology. States are transferred to the lowest level of control system of the robot.

2.3 Sensor Processing System

Since every sensor system is autonomous, the whole information is processed in parallel. The raw data are normalized within (0, 1] semi closed interval, then fuzzified using the same granulation of triangular fuzzy sets representation. This way of granulation is chosen for simplicity although some other possible representation could turn out to be more useful. For now it is left for next investigation. A conventional inference mechanism of all the fuzzy systems is chosen. Every fuzzy stimulus system is one in - one out system. It task is to transfer stimulus into its corresponding fuzzy representation. Inputs are three terms granulated stimuli and outputs are five granulated assessment of quality in respect to the defined strategy. The inputs are presented by 'low', 'middle', and 'big' terms, whereas their counterpart quality assessments are: 'good', 'middle', and' 'bad' with two additional intermediate terms; 'good-middle', and 'bad-middle'. All in/out terms have triangular shape definition. An example of visual fuzzy inference system is given in Figure 3. and Figure 4.

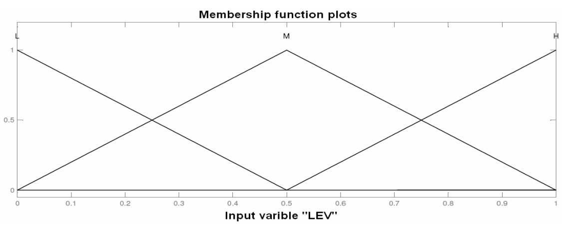

Fig. 3 Fuzzy input visual stimulus

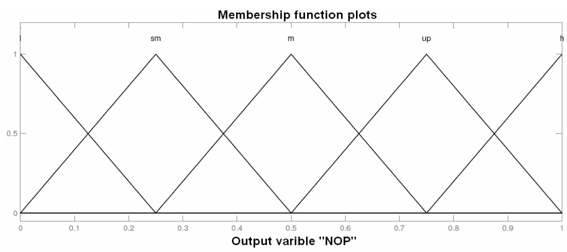

Fig. 4 Fuzzy output visual stimulus

Hence we have five simple inference systems. Everyone is presented by its fuzzy rule base with nine rules - fully exhaustive representation. In such a way we involve qualitative instead of quantitative stimuli assessment. The reason is to enlighten a process of their sequel fusion.

2.4 Sensor Fusion System

The sensor information data are transferred via transmitter to control PC; there an information fusion is performed. Existence of five sensor system requires sophisticated fusion mechanism able to process on line the information. We apply fuzzy information fusion of the pre-processed sensor data, which are outputs of the sensor processing systems. The scheme of information fusion is shown in Figure 7. After quality assessment of every sensor data they are ready for fusion. The fusion is performed using the same fuzzy logic technique. This is five in - two out fuzzy inference machine: five quality assessment of every sensor as inputs, and two decisions for both left and right drivers. In/out granulation is shown in Figures 5. and 6.

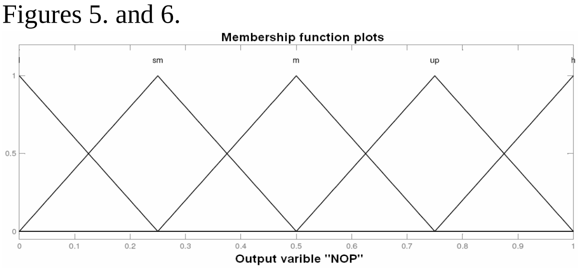

Fig. 5 Quality assessment of input for visual stimuli

Here inputs are presented by five stimulus granules of its quality: 'good', 'good-middle', 'middle', 'bad-middle', and' 'bad'.

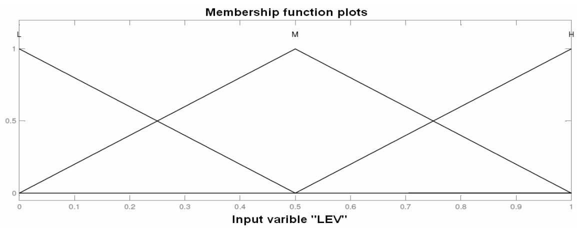

Fig. 6 Fuzzy output of fusion system

Outputs are granulated in three quality assessments for each left and right drivers, i.e.: 'good', 'middle', and' 'bad'.

3. Intelligent Control System

Control System comprises three sub-systems:

- ***i.*** Fuzzy Data Representation;
- ***ii.*** Path Planning.;
- ***iii.*** Navigation.

All the systems utilize similar fuzzy inference technique presented in Figure 7. On this stage the tower is controlled independently from caterpillar motions. It needs only synchronization with base unit control system and high priority action in emergency situations.

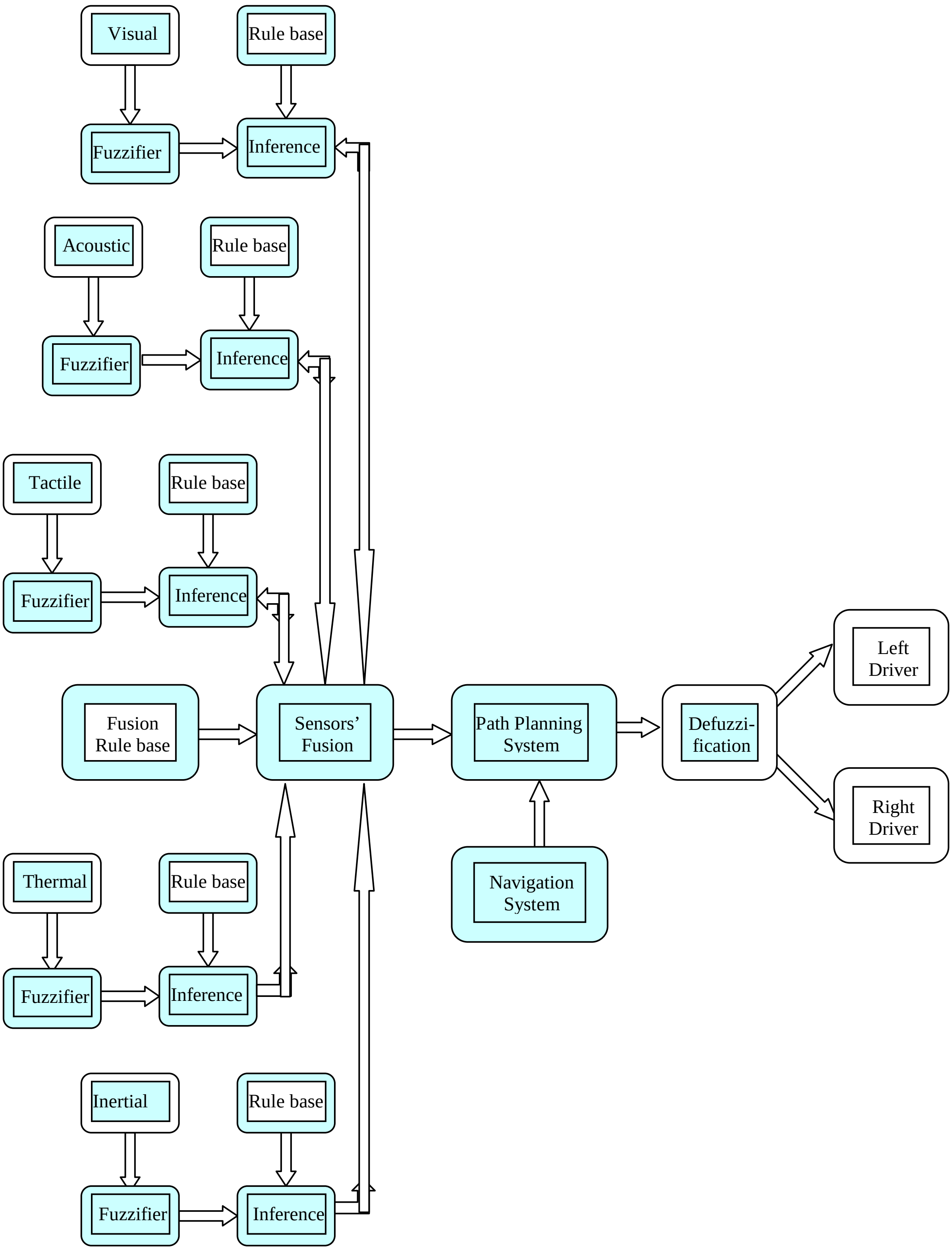

Fig. 7.Scheme of information fusion

Fuzzy Data Representation has five analogical subsystems. They are combined to produce current environment image of the robot position. Each of them consists of four blocks:

i. Input data that normalized measurements,
ii. Fuzzifier. It granulates crisp measurements in an unified for all sensors universe of discourse;
iii. Rule base that defines fuzzy inference assessment mechanism;
iv. Inference block that extracts fuzzy quality representation for every sensor measurement.

Path Planning System creates program motion based on current image and Navigation System. It interprets Navigation System inferences into short term goals. Then these goals are defuzzified and supply both left and right caterpillar drivers shown in Figure 7. Planning System also creates program motion in accordance with current image and Navigation System. Navigation System forms short (tactic) and long (strategic) goals of path planning, which supply Path Planning System. Navigation System utilises generalized environment image created by Fuzzy Representation System after data fusion. The fusion is realized in abstract five dimension space of sensed stimuli on the basis of vision, acoustic, tactile, thermal, and inertia sensors. At this stage we investigate a free trajectory without obstacles avoidance although the power of the system would be shown it its full strength in more complex tasks. Every stimulus obtains one of three fuzzy quality assessments after fuzzification of measured sensor values as: 'low', 'middle', and 'big'. We accept triangular atomic terms representation of fuzzy sets evenly distributed in their universes of discourse. Their fusion defines generalized quality assessment as point in five dimension space. The points present in its turn the quality of robot position in respect to our requirements, the next robot position and measurements. The next measurement produced short term prediction of motion on the basis of the best ambient measurements. The robot makes step in this direction. Every new measurement offers motion to the nearest goal from all the measurements. So far the robot works in a fee environment, i.e. without obstacle avoidance. It performs full scanning of working space of all distances and gives the full map of investigating field. On the tactic level Navigation System realizes zigzag motion as a result of short term planning. It offers motion in selected way optimal in respect to final goal implementation. The motion is a string of straight lines lying in the comfort zones of the investigated polygon. Strategic level is dedicated to perform compromise decisions of all the tactic point decisions for reaching of priority motion goal. The goal may be sought in curve of motion, shortest path, maximal speed, etc. when we involve obstacles and their optimal avoidance. To fulfill such goal the Navigation System performs compromises deteriorating quality in almost every step of planning. We used techniques similar to dynamic programming. The idea behind it is that optimal path is composed by optimal sub-trajectories connecting final and starting points in reverse direction. For this purpose already found strategic and tactic trajectories are estimated step by step in reverse direction from the goal to start point to define the true compromise trajectory. It is made by the following way: the last step of optimal strategic trajectory is compared with existing nearest around it. Here a compromise assessment of both, taking into account desired optimal one, is made. Since they have different representation a fuzzy systems is due to be involved again for such assessment. It consists of fuzzy rule base that calculates the final trajectory line based on both quality assessments. The quality of strategic steps are defined in terms of tactic one and as an output we obtain required compromise of optimal step. The new step is accepted as representative of calculated trajectory and the procedure is repeated until exhausting of the whole string of trajectory steps to initial point. As you can imagine the robot motion starts with short orientation in ambient environment, which corresponds to the studying and planning of human being in uncertain environment and its following motion.

4.....Case Study

In Figure 8 is shown a prototype of the robot.

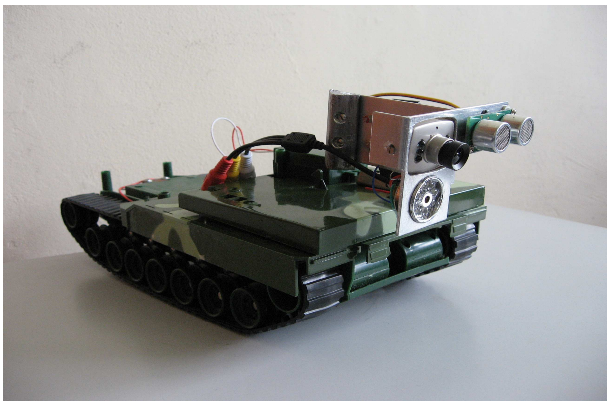

Fig. 8 A robot prototype

An experiment of robot motion in obstacle free polygon is presented in Figure 9.

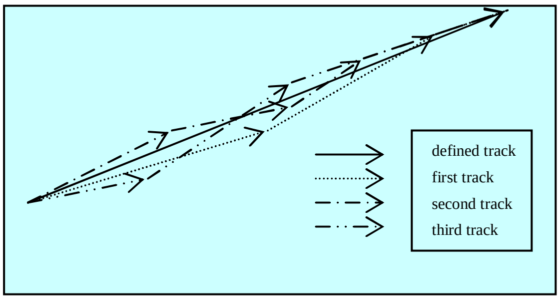

Fig. 9 Experimental robot trajectories

As you can see the differences between defined (ideal track) and combined strategic/tactic motion: the first, second, and third tracks are not significant for this specific application. The reason is that sensor information is gathered in obstacle free polygon, where sensor measurements are taken from the ambient environment outside polygon. Hence a compromise technique of back propagation corrections is realized among less contradictory variants. The situation is drastically different in case of obstacles existence into polygon, where compromises are heavy and there exists also forbidden trajectories. They principally have to be involved in priority cycle for their avoidance and elimination.

4 Discussion

The investigation demonstrates distributed application of relatively simple fuzzy rule base of systems for assessment, fusion, tactic and strategic decision making and control action performance. It is shown a solution of the task for generation of optimal trajectory as a compromise between real admissible by sensor system and ideal postulated as optimal by smoothness, speediness and other considerations. It turns out that there no complication of the task in case of obstacles existence, even in some cases they can simplify decision making as a sequence pruning of some required trajectories and their replacement with only possible ones.

Upcoming tasks:

i. Obviously, some more profound investigations are need in complicated spatial environment. It is very interesting the influence of: kind, type, and number and displacement of obstacles onto speed and quality of performance;

ii. The next task will be incorporation of searching with constraints in our multisensor system, especially suitable for different types of sensors: visual, acoustic, tactile, thermal and inertial;

iii. Improving of synchronization and organization. Up to now they are realized with distributed processing of information of autonomous sensor systems. So far, an improvement of synchronization and organization of the systems is sought in distributed information processing of autonomous units. They are incorporated into control PC for defining and processing of fuzzy variables. So far as the system uses a specialized programmable controllers all these functions can be imbedded in them, which will gain additional autonomy of the robot;

iv. All the while up to now these solutions mimic only Soft Computing Agents for using of single type protocol. As far as information processing is remote and inference systems are created beforehand, there no need they to be capsulated in a kernel of Soft Computing Agent, but future unification of these systems using and their protocols is excellent possibility for realization of simple Soft Computing Agents

v. Involvement of Soft Computing Agents organization would mean full compatibility and applicability of divers systems and different tasks. This is the path of standardization of these new solutions in independent platforms;

vi. Another important direction of investigation is involvement emergency system mimicking emotional tract of human activity, and why not in the conventional brain imitating artificial system of control loops. Even Latin emotional stands for movement, speed, which supposes improvement of the systems in respect to speedy and quality performance of robot reactions. It is referred already to creation of artificial feeling robot systems.

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