mgr inż. Janusz Będkowski
prof. dr hab. Andrzej Masłowski
Przemysłowy Instytut Automatyki i Pomiarów

MOBILE ROBOT ATRVJR APPLICATION FOR RISKY SCENARIO

Presented paper shows the result of the implementation of the intelligent controller for the autonomous mobile robot ATRVJr applied for risky scenarios. The implemented algorithm based on artificial neural network fuzzyART shows an advantage while working in real environment with the unknown structure and provided not completed information. The main task for controller is to achieve the maximum speed in order to maximizing the prediction problem. The controller manages the damage of the sensor of the robot, due to the goal can be achieved by mobile platform in case of sensor problem. Presented experiments shows the advantages of the controller and proof the need of the usage artificial neural network to implement intelligent control unit for achieving the goals in risky scenario.

APLIKACJA MOBILNEGO ROBOTA ATRVJR DO ZADAŃ W RYZYKOWNYM I NIEZNANYM ŚRODOWISKU

Praca przedstawia wynik opracowania inteligentnego sterownika autonomicznego robota mobilnego ATRVJR przeznaczonego do działania w niebezpiecznym, nieznanym środowisku. Zastosowany algorytm decyzyjny oparty na sztucznej sieci neuronowej fuzzyART wykazuje właściwości przydatne w przypadku scenariusza z sytuacją niebezpieczną oraz podczas niekompletnej informacji o środowisku. Założeniem budowy sterownika jest osiągnięcie maksymalnej prędkości robota przy maksymalizacji jakości predykcji sterownika. Sterownik jest przy tym odporny na uszkodzenia sensorów robota, dzięki czemu może dokończyć realizację zamierzonego zadania w sytuacji awarii. Przeprowadzone eksperymenty pokazują zalety sterownika i tym samym udowadniają potrzebę zastosowania sztucznej sieci neuronowej do realizacji postawionego problemu.

1. INTRODUCTION

The very essence of the research projects in the area of multi mobile systems applications for risky environment [1, 2, 3, 4] is to integrate disparate elements involved in a crisis situation into an info-structure that will allow information to be exchanged readily between all of those elements: crisis centres, relevant forces dealing with the crisis (fire fighters, de-bombing squads, police, etc.), platforms and sensors.
The goal of the development of an intelligent autonomous mobile robot ATRV-Jr is to achieve the new functionality of the control unit and demonstrate all its' capabilities as a mobile platform with own autonomy. The basic idea of intelligent control unit building's is an approach of the following constraints: damage management, adaptability, working with random and the noisy information, parallel processing with low level energy consumption (fig. 1).

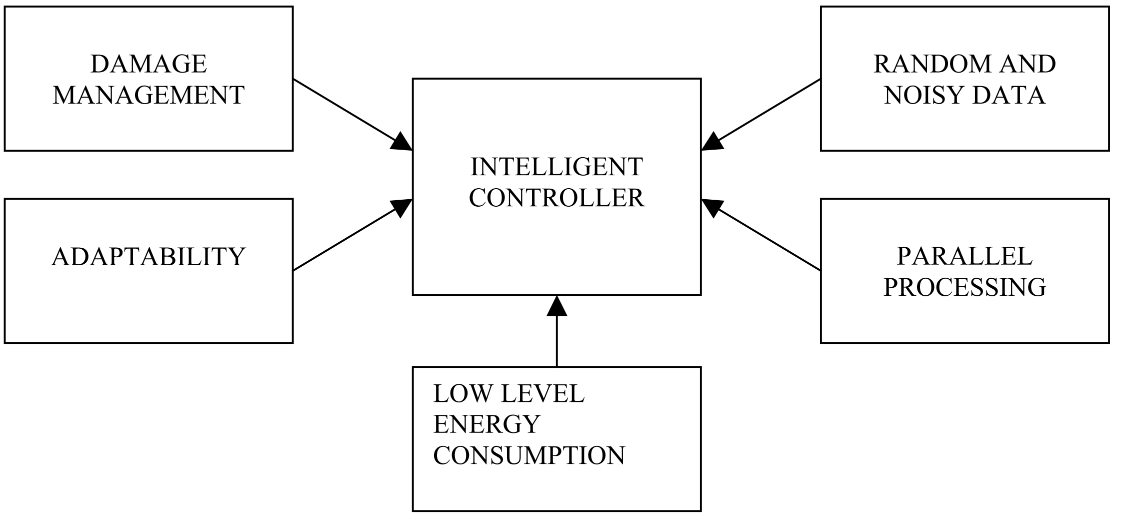

Fig. 1. The scheme of the intelligent controller

The human-inspired behavior is taken into the consideration, therefore the control of the mobile platform maps the human like decisions into the robot motion control. The following pictures shows the ATRVJr mobile platform controlled by described intelligent control unit.

The vehicle (fig. 1) is compact (0.8 m length x 0.55 m height x 0.64 m width), but powerful with a payload of 25 kg (55 lb). With its rFLEX Control System, the ATRV-Jr. can be programmed to complete sophisticated guidance manoeuvres with minimum programming steps. Obstacle avoidance is achieved with 17 sonar sensors positioned around the perimeter of the vehicle. Computations and I/O control are done by a Pentium III class PC running Linux (a UNIX OS). The onboard computing power allows the ATRV-Jr. to quickly process large amounts of information; a trait necessary for autonomous robots. It features multiple serial communication ports, thus allowing a host of input and output options.

Fig. 2. The indoor ARTV-Jr robot

Damage management is based on implementation of robust algorithm and duplication of the functionalities. Behavior based obstacle avoidance algorithm is based on the fuzzy sets theories, therefore it is robust in case of noisy data which is generated by improper functioning of the ultrasonic sensors. The SLAM algorithm as the first candidate, is based on traditional odometry and sonars, and second candidate is match scanning algorithm based on laser range finder LMS SICK 221. Therefore control unit has 2 inputs of the self local localization algorithms. Each device has its own control unit called server, which serves its' functionalities. In case of hardware damage, the system is able to reconfigure and serve at least the best configuration to achieve the goal. Each device such as odometry, compass, sonars, video camera and other sensors has an associated program – server with the built-in mechanism called supervisor. This way, the control system is conscious of the usable functionalities of the mobile platform. Presented approach is the main goal of the implementation of the damage management unit.

Adaptability is obtained by implementing robust algorithm based on artificial neural network fuzzy ARTMAP with some modifications. Due to those modification provide real time respond of the network in real environment [5, 6]. Mobile robot motion is determined by the behavior based algorithm fuzzy ARTMAP. Fuzzy sets are used to code the information from ultrasonic sensors. The robot path of motion without collision should be as long as possible at the maximum speed. The time of making decision determines the system quality and should be as short as possible. The general idea of the fuzzy ARTMAP was described in [7]. The system is able to learn new association between the set of coded ultrasonic sensor results into the set of the coded values of motors velocities. Algorithm has high generalization, and adaptability, therefore it approaches the goal.

Working with random and the noisy information is achieved by using intelligence computing applied in visual processing, building knowledge of the environment, and self localization algorithms. The noise removal from image operations can be implemented as CNN- Cellular Neural Network [8]. CNNs are often used as fast image processors because they are very efficient in applications such as a noise removal, edge and corner detection, hole filing, operations of mathematical morphology – dilation, erosion. Building knowledge of the environment is obtained by implementation fuzzy ARTMAP neural network. Self localization algorithm is based on robust graphical operation used in match scanning problem.

Parallel processing with low level energy consumption is obtained by using CORBA (Common Object Request Broker Architecture). CORBA is a mechanism in software for normalizing the method-call semantics between application objects that reside either in the same address space (application) or remote address space (same host, or remote host on a network). Each server associated with appropriate device runs independent from others. Therefore each program from control unit works parallel. The problem with synchronization and action selection has to be obtained [6]. The parallel layer architecture is taken under the consideration. Using CORBA mechanism as framework of communication between sensors and main computer of the robot allow to fast reconfiguration of sources of information about environment when same sensor isn't work and back to normal work of a robot. This technology allow to introduce a small multi-agent system on the board of the robot, by creation many servers which owners are sensors.

The intelligent control system is proposed. Robot is able to avoid obstacles, follow along the wall, follow the path, self localize, reconstruct the local map, reconfigure functionalities. System of the mobile robot ATRV-Jr is increased by adding the module of the robot Inspector localization using pattern recognition algorithm. The first goal is to obtain the robot Inspector position on the map build by robot ATRV-Jr by information from vision system and specialized software. Second goal is based on the robots cooperation idea, therefore the autonomous robot ATRV-Jr is used to transmit its camera image observing the teleoperated robot arm grabbing obstacle. Presented approach helps in indoor environment inspection. For the future robot ATRV-Jr will have universal interface probably in CORBA which allow for creating network of cooperating robots. For example build map of environment as common part of local map building by robots for itself, following by main robot during inspection, etc.

2. ARTIFICIAL NEURAL NETWORK FUZZYART

Input vector a (fig. 4) is defined as result of fuzzyfied 17 ultrasonic sensors data. Output b is the robot motors linear velocity. The fig. 3 shows the fuzzy sets which are used in coding input stream. The dimension of the input vector of the intelligent control unit is 104. Therefore it is high dimensional problem for classification purpose [6]. The extremely fast growing data base of the neural network determines the limitation of the usage in real time mode. To reduce the number of categories the vigilance parameter was tuned while the learning process occurs.

The artificial neural network fuzzyART scheme is shown in fig. 4. During the supervised learning, ART_a receives a stream $\{a^{(p)}\}$ of input patterns and ART_b receives a stream $\{b^{(p)}\}$ of input patterns, where $b^{(p)}$ is the correct prediction given $a^{(p)}$. These modules are linked by an associative learning network and an internal controller that ensures an autonomous system operation in real time [7].

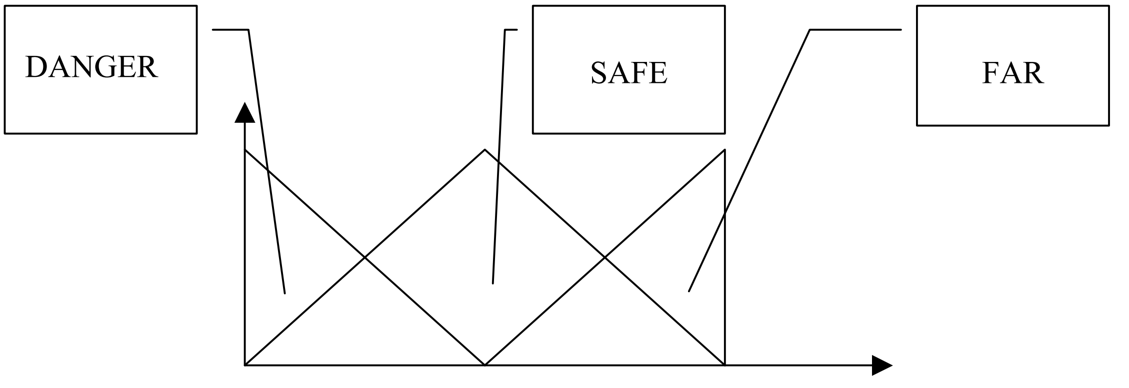

Fig. 3. The fuzzy sets used to code input stream of the 17 ultrasonic sensors

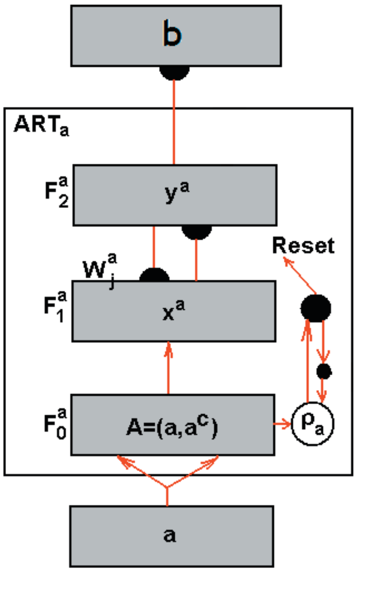

Fig. 4. Fuzzy ARTMAP architecture

The **ART_a** complementary coding preprocessor transforms the M_a-vector **a** into the $2M_a$-vector **A=(a, a^c)** at the **ART_a** field F_0^a. **A** is the input vector to the **ART_a** field F_1^a. Match tracking raises the **ART_a** vigilance ρ_a to just above the F_1^a to F_0^a match ratio $|x^a|/|A|$. This triggers an **ART_a** searching, which leads to the activation either the **ART_a** category that correctly predicts **b** or to a previously uncommitted **ART_a** category node.
Parameter ρ_a calibrates the minimum confidence that ART_a must have in a recognition category (hypothesis) that is activated by an input $a^{(p)}$, in order to accept that category instead of searching for a better one through an automatically controlled process of hypothesis testing. As in ART 1, lower values of ρ_a enable larger categories to form. These lower ρ_a values lead to broader generalization and higher code compression. A predictive failure at b increases the minimal confidence ρ_a by a least amount needed to trigger hypothesis testing at ART_a, using a mechanism called match tracking. Match tracking sacrifices the minimum amount of generalization necessary to correct the predictive error.

3. EXPERIMENTS

The robot trials were executed in PIAP laboratory of mobile robotics systems. The basic goal was to achieve the obstacle avoidance, high generalization of the mobile intelligent control unit and ultrasonic sensor damage management. The system is implemented in ATRVJr mobile platform equipped with 17 ultrasonic sensors and 2 high torque DC motors. The intelligent controller was trained in supervised learning mode. The teacher was showing robot how to avoid obstacles, goes into the narrow tunnel, smooth break in case of existing obstacle in front of robot. The revolutionary learning was taking into consideration to boost the training procedure. Therefore the robot is replacing old datum while the training process. This fact determines that the robot has to be programmed by precisely designated supervised learning procedure.

2.1. Experiment 1 – damage management

The following experiment is based on the damage management approach. The fuzzyART algorithm has built a mechanism of the value maximization of the predicted respond. Therefore, the two cases were taken into consideration. First, all robot was trained zig zag movement in the narrow tunnel. The red line shows the robot trial for described case. Second trial was executed from the same starting point but with simulated damage of one ultrasonic sensor (sensor was acquiring all the time 0 value with random noise of the measurement). The blue line shows the robot trial. Experiment shows the ability of neural network to manage the sensor damage event.

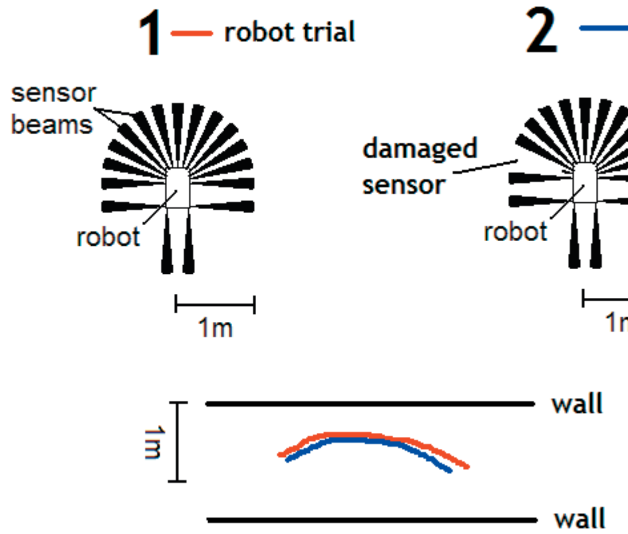

Fig. 5. The experiment of the sensor damage management given by artificial neural network fuzzyART

2.2. Experiment 2

The second experiment is based on the goal of the smooth break execution in front of obstacle. The robot controller was trained to achieve goal autonomously. Two parameters of vigilance parameter were taken into consideration. For the vigilance parameter equals 0.9 the robot responds immediately because the data base is small, but the respond is not adequate to process the training. Robot to much generalizes input signals by the error system respond in the point of view of smoothness control quality. Second vigilance parameter equal 0.99 determines the over fitting artificial neural network to the trained data set. In this case the data base is large, hence the robot is able to break smoothly. The time of respond for the second case is acceptable and determines the advantage of the chosen value of the vigilance parameter.

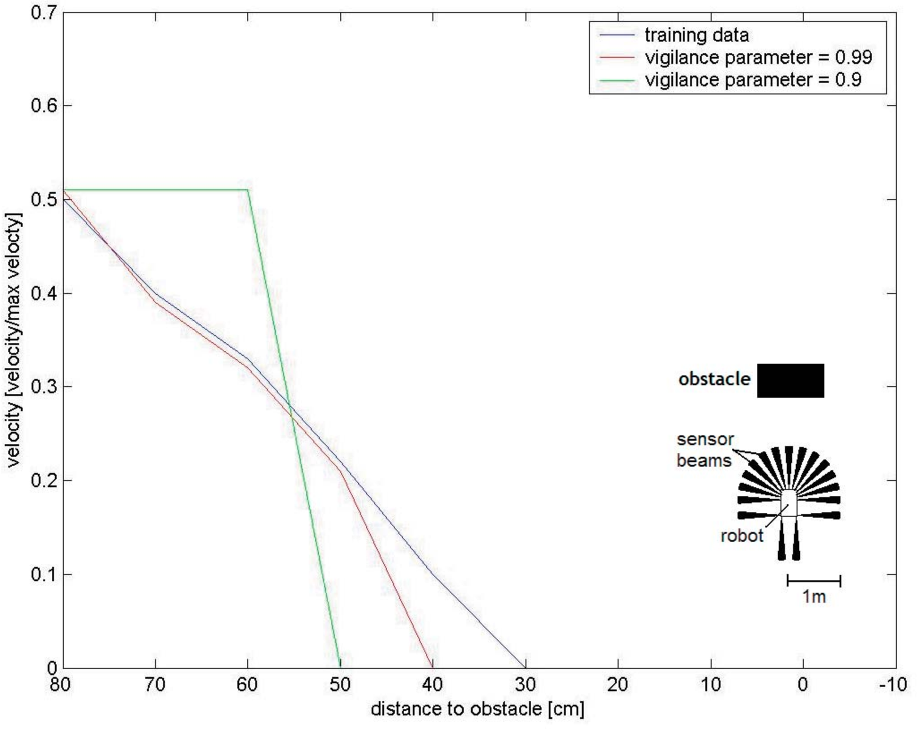

Fig. 6. The result of the experiment with training intelligent control unit how to break smoothly in front of obstacle

3. CONCLUSION

The goal of implementation the intelligent autonomous mobile robot applied into risky scenarios is achieved. The advantages of the artificial neural network fuzzyART are used in building the intelligent controller giving the damage management, working with noisy data and adaptability. Using CORBA mechanism as a framework of communication between sensors and main computer of the robot allow to fast reconfiguration of sources of information about environment when same sensor isn't working and back to normal work of a robot. This technology allow to introduce a small multi-agent system on the board of the robot by creating many servers which owners are sensors.

Presented experiments show the ability of the ATRVJr autonomous mobile robot to achieve goals in the risky environment. The intelligent controller allows to execute the low level tasks even when the input vector is not adequately corresponding with trained situation. This fact determines an advantage of using artificial neural network in low level tasks execution.

4. REFERENCES

[1] Masłowski A., Intervention Robotics - Experience in Poland, Key-Note paper, Int. Workshop RISE'2006, 19-21 June 2006, Brussels, Belgium

[2] Masłowski A., *Intelligent Mobile Robots supporting Security and Defense*, Proc. of the Int. Conference IMEKO TC-17 Measurement and Control in Robotics, NASA Space Center, Huston, Texas, U.S.A., 2004,

[3] Masłowski A., *Applied Intelligent Service and Surveillance Robotics*, Key-note paper , IMEKO TC-17 15th Int. Symposium on Measurements and Control in Robotics, 08-10 Nov. 2005, Brusseles, Belgium.

[4] Vision and Chemiresistor Equipped Web-connected Finding Robots, Project STREP 6FP EU, Contract No. 045541, 2006-2009 (Project WP2 Leader A.Masłowski)

[5] J. Będkowski, S. Jankowski: Autonomous mobile robot fast hybrid decision system DT-FAM based on laser measurement system LMS, *Proceedings of SPIE -- Volume 6347 Photonics Applications in Astronomy, Communications, Industry, and High-Energy Physics Experiments 2006, Ryszard S. Romaniuk, Editor, 63472Z (Oct. 13, 2006)*

[6] Będkowski J., Fast hybrid classifier DT-FAM Decision Tree Fuzzy Art Map for high dimensional problems in mobile robotics, *Proceedings of the Sixteenth International Symposium on measurement and Control in Robotics ISMCR 2007 June 21-23, 2007 Warsaw Poland.*

[7] G. A. Carpenter, S. Grossberg "A self-Organizing Neural Network For Supervised Learning, Recognition, and Prediction" *IEEE Communications Magazine,* September 1992

[8] Janusz Będkowski, Stanisław Jankowski, Mobile robot „Kasia" with early vision based on CNN. *Proceedings of SPIE -- Volume 6159, Photonics Applications in Astronomy, Communications, Industry, and High-Energy Physics Experiments IV, Ryszard S. Romaniuk, Editor, 61592X (Apr. 26, 2006)*

Research works supported by Ministry of Science and Higher Education Project No. O N504 2848 33 " Control and Supervising Web-connected Surveillance and Rescue Mobile Robots" (Project Leader A.Masłowski)