The Architecture of the Neural System for Control of a Mobile Robot

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Abstract

Building autonomous mobile robots has been a primary aim of robotics and artificial intelligence. Artificial neural networks are capable of performing the different aspects of autonomous driving, such as collision-free motions, avoiding obstacles, mapping and planning of path. This paper describes the global architecture of the neural system for autonomous control of a mobile robot. Such neural system has the ability for self-training and self-organizing. The purpose of this paper is to present the key ideas and approaches underlying our research in this area.

1: Introduction

Development of artificial intelligent systems, which are capable to carry out functions of biological beings, is an old dream of humanity. The ability of biological systems to training, self-organizing and adaptation has large advantage as compared with artificial systems. The advantage of computer systems is the high speed of the spreading of signals and the possibility to use large volume of knowledge stored by humanity in various areas. The development of the artificial neural systems, which connect the advantages of computers with the advantages of biological beings, creates the conditions for evolution of artificial systems to a new qualitative stage. Mostly researches in the area of artificial intelligence are based on the theory of neural networks and are directed at the decision of concrete problems. There is a gradual accumulation of knowledge for creation of universal neural systems. One of the areas, where the creation of "an artificial brain" has large practical and theoretical importance, is the robotics. Mobile robots with capabilities to autonomously reach a target location despite of obstacles are designed for a broad range of applications:

- Transport robots for material transfers in industrial production [1,2]
- Vehicles for planetary surface investigation in the framework of space exploration [3]
- Rovers carrying an equipment for inspection and repair in dangerous environments [4].

This paper is focused on description of an intelligent neural system for the control of a mobile robot. Such system is developed according to the INTAS project (Intelligent Neural System for autonomous control of a mobile robot). Compared to other project activities, the proposed neural system has the ability for self-training and self-organizing and behaves itself as a person during orientation in environment.

2: The Control System architecture

The global architecture of the neural system is represented on Figure 1. It consists of different neural modules, which are combined in an intelligent system. The neural system solves the following tasks:

- Performs data fusion
- Reactive control of the mobile robot while moving in the unknown environment
- The formation of the global route map in the process of the motion in the unknown environment
- The choice of the optimal route and generating

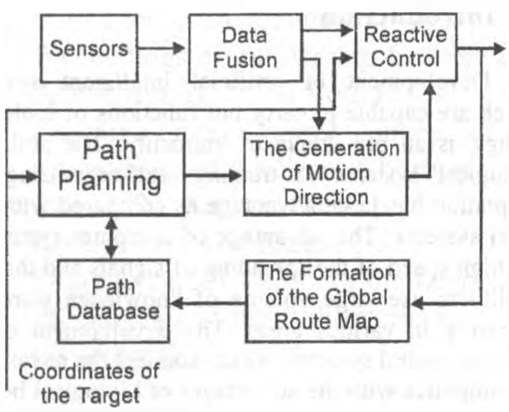


Figure 1. The Control System architecture

The neural system must provide the following demands:

- Robust control in case of inexact information from sensors
- Training with the supervisor
- Self-training and self-organizing
- Capability for real time action

One can see on Figure 1 the information from different sensors is combined by data fusion module. As a result we have the local environment map. The local environment map is used for reactive control and for unpredicted obstacle avoidance, if the working environment is known. Reactive control takes place if the working environment is unknown. In this case, the planning stage has no sense. The inputs to the neural system are the final goal position and the sensor data.

In the process of the robot motion the neural system memorizes the path. For this purpose is used the arrangement of the indicators from start point to target. Each indicator contains direction, which defines how the robot should reach next indicator, a distance between neighbor indicators etc. As a result of robot motion in the unknown environment mapping is performed. Mapping is the process of constructing a model of the environment during motion in the space. As a result of mapping the formation of the global route map and of path database takes place. The path database stores all possible paths and relevant environment data.

Now let's examine the case if the robot motion is performed in the known environment. In this case the path planning module identifies the optimal route for a specific motion action in the actual environment and generates the direction of the motion in the key points (indicators) of the path. For this purpose the path planning module uses a path database to form an optimal solution allowing to reach the target with minimal cost. The neural system performs the reactive control between the key points of the possible route.

Such neural system has ability for self-training and self-organizing. In this case self-training and self-organizing is realized both on the reactive level and on the level of path planning.

3: The hardware platform and sensor fusion

Most of the software has been developed using a mobile robot "WALTER" [5]. The robot, shown on Figure 2, is the LABMATE® mobile robot with a video camera, infrared scanner and ultrasonic transducers. Its maximal velocity is 1000 mm/s. Different sensors have different perceptual characteristics. As a result of data fusion is turned out the local environment map in the angular interval of 180° and in the review radius of 2.4 meter. The SN288827 Polaroid ultrasonic sensors report distances between 300 mm and 10 m (frequency 45 kHz). As infrared scanner is used the RS2-180 (Leuze electronic). The mobile robot has been designed for indoor environments. An RS-232 radiomodem interface is used to communicate between the SUN Sparc station and the robot microcomputer.

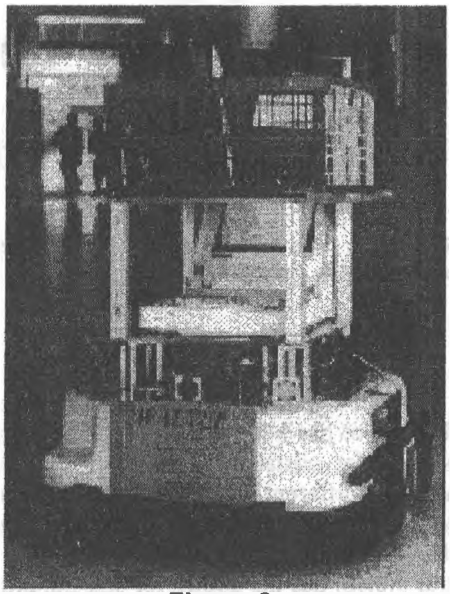


Figure 2.

The analytical approach and neural network are used for data fusion from the ultrasonic sensors and infrared scanner. The analytical approach is as follows: the ultrasonic sensors identify quite exactly the linear distance and the infrared scanner identifies quite exactly the angular distance to an obstacle. The environment map is formed as a result of the simple processing of such an information. The neural network can be used for the sensor error decrease. It consists of 3 layers and is trained on the base of experimentally prepared data. For training is used the backpropagation algorithm with an adaptive step [6]. The outputs of this block is the local environment map which is considered to be input information for the reactive module.

4: The reactive level

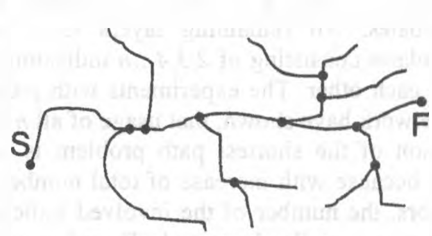
The reactive module consists of various types of neural networks. It provides the robust control of the mobile robot. The reactive module solves the following tasks:

- The selection of optimal interval of motion in environment with obstacles.
- The definition of an optimal direction in the chosen interval of motion

The optimal interval of motion is considered to be the nearest to the target. This interval is characterized to linear (R_L, R_R) and angular (W_L, W_R) distances. The optimal direction is such direction of motion, which ensures minimal angular distance up to the target in the chosen interval of motion. For this purpose the neural networks are used. If one trains a neural network by correct output data in case of inexact input information, it will provide the robust control of the robot. The neural system can itself collect the training data and learn during the interaction of a robot with the environment. As a result the self-organizing of a mobile robot is provided.

5: The formation of the global motion map

It is performed during motion in the unknown environment. The process of map formation is based on memorizing key points of the territory. As key points are used the indicators determining the way of archiving other key points of territory by a robot along the selected path. During examination of unfamiliar territory the transport network (Figure 3) is formed in memory of the planning system. And then the robot uses this information for achieving the target in different parts of territory.



•- *an route indicator;*
S – start point; F- final point.
Figure 3.

In general the algorithm of territory map formation and planning consists of following steps:

1. If there are two possible motion direction (for example, forward and back), the mobile robot is controlled only by reactive navigation system (robot moves along the corridor in the labyrinth).

2. If there are more then two possible motion directions and there is no any indicator in the current robot position, the planning system creates a new indicator and describes the link to previous indicator as a traversed distance, motion direction to achieve the previous indicator etc. The similar link is created for previous indicator to archive the indicator in current place of the robot from this previous indicator in the future. The navigation system chooses a direction according to the attraction force directed on the target.
3. If there is an indicator on "intersection of roads" in current robot position and there is at least one unknown motion direction, the navigation system tries to examine this direction because there is a possibility to achieve the target using shorter route, but the robot does not known about it yet.
4. If there is an indicator on "intersection of roads" in current robot position and all possible directions are known, the neural networks of best path planning forms an optimal route to the indicator, which is nearest to the target.
5. The indicator is also placed at dead-end situation in a labyrinth.
6. If between two known indicators there is no a free path, the links between them are removed, i.e. territory map is continuously modified.
7. All items are repeated on each step of motion.

6: The generation of the optimal route

It is performed by a neural network solving the shortest path problem (Figure 4). Conceptually it consists of n layers, where n is a number of the indicators memorized by planning system. Here the 1st layer is selecting: it selects a best route from $n-1$ routes-candidates. All remaining layers form the routes-candidates consisting of $2,3,4 \ldots n$ indicators separately from each other. The experiments with proposed neural network have shown, that usage of all n layers for a solution of the shortest path problem is an extreme case, because with increase of total number of the indicators, the number of the involved indicators in the path is essentially decreased. Therefore we used the following equation for determination of number of layers of the neural network:

$$E = \min\left\{\left\lfloor 2 \times \sqrt{n} \right\rfloor + 1, n\right\} \tag{1}$$

where n is a total number of indicators placed on the territory map.

During we obtained the equal results in comparison with widely reputed Dijkstra's algorithm. However our neural network solved the problem slower because it modelled analogue system. Therefore it is difficult to compare the performance with various pure numerical algorithms.

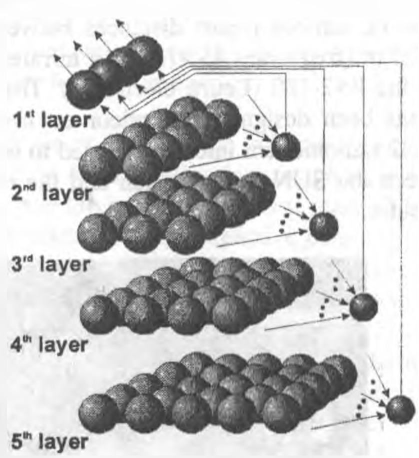


Figure 4. The architecture of the neural network for the problem of 5 cities.

7: Conclusions

An intelligent neural system for the control of a mobile robot has been presented. The ranging system was used for obstacle detection. The neural system consists of different neural networks, which are combined in an intelligent system. This paper describes the global architecture of such a system. The proposed neural system has the ability for self-training and self-organizing. The software will be tested thoroughly using various mobile robots.

8: Acknowledgements

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