An Architecture of Hybrid Neural Network based Navigation System for Mobile Robot

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Abstract

This paper presents novel hybrid architecture of control system of mobile robot oriented on navigation tasks and based on hybrid neural network MLP-ART2. Using of this model allows movement to target avoiding the obstacles almost without assistance of human operator after just small learning.

1. Introduction

There are two approaches to development of mobile robots. First of them is classical one based on logic and representation of knowledge about environment and behavior. This approach has sufficient disadvantages: a) it can be used only in case of controlled and known environment and b) it is not oriented on perception of visual images from environment and so it is very difficult to use of real objects of environment in interaction with robot. But its advantages are a) relatively easy interaction between human and robot and b) opportunity of programming of robot behavior. Second approach is so-called reactive approach based on using of neural networks and associative memory for learning of behavior in preliminary unknown environment [1]. It was inspired by neuroscience and biology. This approach has any difficulties for using because in this case it is impossible to interact with robot by natural language (or similar) and to program of robot behavior. In this case most important problem is learning of meanings of different images (patterns) perceived by robot. These meanings may be used for programming of behavior or reference on ones in natural language interaction. Hybrid approach is most interesting in development of intelligent robots because ones accumulate all achievements of AI, and task of implementation of "real" AI is connected with creating of robots.

In wide world hybrid approach based on neural networks to control of mobile robots is developed in last some years [2-8]. One of such hybrid architecture is suggested in this paper. It is based on two-level performance of information processing in mind [9] and model of associative memory of intelligent system, proposed in [10]. In corresponding to this performance, in [11] was suggested control system of mobile robot including symbolic and image levels. This architecture is oriented on usage of natural language for control of robot to move in labeled point of space.

As neural network for clustering of information the model ART-2 (model "Adaptive Resonance Theory" for analog value [12]) was selected and associative memory was based on table. Experiments with simulation of this architecture show the opportunity and suitability of this architecture for using for interaction with user to get aims for moving by language similar to natural. The model ART-2 was selected because it provides incremental and fast learning without dividing two phases: learning and training. But it might be expected that this model will be not enough appropriate in dynamical interaction with environment in case of moving of mobile robot because ART-2 suffers from category proliferation problem because uses primary features of images obtained from sensors. So by choose of vigilance threshold we can get either large sensitivity to changes in signals and producing of too large number of clusters or loss of sufficient information. This case just was found in simulation of mobile robot as shown below. So we suggest some modified novel architecture for navigation tasks based on hybrid neural network MLP-ART2 proposed by authors earlier [13, 14]. This hybrid model allows reducing of sensitivity of ART-2 to changes in environment thanks to preliminary processing of signals by multi layer perceptron (MLP) transforming primary features to secondary ones.

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2. Architecture of control system

Proposed modified architecture, based on hybrid neural network MLP-ART2 is shown in figure 1.

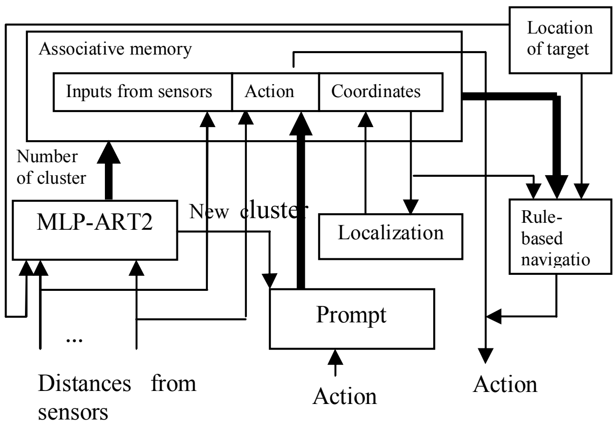

Figure 1. Proposed architecture of control system

This architecture is oriented on solving of navigation task, i.e. moving of robot to target with interaction with environment to avoid obstacles. To solve this task it is possible to employ different criterion for estimation of robot behavior, e.g.:

1) maximize time until collision with obstacle,
2) maximize distance traveled until collision with obstacle
3) minimize rotational velocity, maximize translational velocity,
4) minimize error between control action of a human operator and robot controller in the same situation.

Our architecture and experiments with it aim to provide minimal assistance of human operator during movement of robot after any small learning. Robot must basically to make decision without help using unsupervised learning based on ART. Just sometimes (essentially in beginning) it may to ask user how to act and stores associations between new cluster created by neural network MLP-ART2 and selected action appropriate for current situation. Could say that in this architecture we propose semi supervised learning. Supervised learning is needed when robot can't to recognize situation and make decision. And hybrid neural network with preprocessing by MLP aims to reduce number of such situations.

3. Simulation

To evaluate the proposed system, experiments are conducted based on program simulation of mobile robot in 2D space for solving of navigation task, i.e. moving to target avoiding the obstacles. These experiments were provided by special program MRS developed in Delphi for simulation of mobile robots in two-dimensional simplified environment.

In our simulation following base primitives are assumed to be applied for interaction of robot with environment:

1) dist(i) – value of distance getting from i-th range sensor (one of 12 sensors);

2) *target_dist* – distance from target;

3) *target_dir* – direction to target (in degrees);

4) *robot_dir* – direction of robot's movement (in degrees);

5) *move* – command to robot "move forward in one step";

6) *turn(a)* – command to robot "turn on angle *a* (in degrees)";

7) *stop* – command to robot to halt;

8) *intersection* – situation when the target is not looked by robot directly because obstacles;

9) *target_orientation* – command to robot "turn to target direction";

10) *input* – input vector for neural network consisting of values 1 for 12 sensors, 2, 3 and 4. Length of this vector is equal 15;

11) *work_NN(input)* – start of neural network *with associative memory*, returns value of needed turn of robot in degree. The value 0 is corresponding to retain of current direction of movement, TARGET is corresponding to turn to target;

12) *ask* – prompt value of angle for rotation of robot in degree. One of possible value is SAME. It means that user agrees with value proposed by robot;

13) *current_state* – last recognized cluster or selected number of direction of movement;

14) *direction(i)* – direction corresponding to *i*th recognized cluster.

Robot has 12 distance sensors allocated uniformly on the round body.

Lower we give two algorithms: of simulation of robot behavior and simulation of our hybrid neural network.

You can see that in the algorithm of robot two kinds of making decision are implemented – rules and neural network. Neural networks ere not used when robot may see directly target without obstacles and when robot is too closely in front of obstacle. Otherwise, neural network with associative memory is employed.

The experiments were conducted with two kinds of neural network – ART-2 and MLP-ART2. Respectively in first case in algorithm *work_NN* the updating of weights for MLP is absent. The experiments were conducted with different values of vigilance parameter *r* and number of iterations of EBP in MLP. Parameters of MLP are following: number of hidden neurons is 10, number of output neurons is 5 and the activation function is exponential sigmoid with parameter 1.

Algorithm of simulation of robot behavior

```
While (target_dist > 20) and not stop
    move;
    get values from sensors;
    delta = 0;
    min_distance = min(dist(0),dist(11));
    if min_distance <25 then
      if dist(0)<dist(11) then
          delta = 30
        else
          delta = -30;
      end if
    end if
 if min_distance < 5 then
         stop
   end if
   if abs(delta)=30 then
      turn(delta)
     else
      if intersection then
             Preparing vector input for NN;
             delta = work_NN(input);
             if delta = TARGET then
                  target_orientation
                 else
                    if delta <> 0 then
                         turn(delta)
                    end if
             end if
          else
             target_orientation
      end if
   end if
end while
```

End of algorithm of simulation of robot behavior

Algorithm *work_NN*

Input: input vector consisting of normalized values distance *dist(i)* from 1 for 12 sensors, *target_dist, target_dir, robot_dir*. Length of this vector is equal 15. Vigilance threshold *r*.

Output: value of angle for rotation of robot (direction).

```
Calculation of outputs of MLP and outputs of ART-2
(distances between input vector of ART-2 and centers
of existing clusters);
If minimal value of outputs of ART-2 > r then
      Delta = Ask;
      r = 1.2 * minimal value of outputs of ART-2;
      If delta <> SAME then
           Creation of new cluster (with number i) with
              center equal input vector of ART-2
                (output vector of MLP);
           Direction(i) = Delta;
        End if
     Else
        Delta = direction from i-th row of associative
                memory, where i is number of recognized
        cluster;
        Update weights of ART-2;
End if
If (minimal value of outputs of ART-2 ≤ r)
       or (delta=SAME) then
     Update weights of MLP.
     If current_state = i then
          Delta = 0;
        Else
          Delta = Direction(i); Current_state = i;
     End if
End if
```

End of algorithm *work_NN*

In figure 2 one screenshot of experiments are shown. There are 1) the trajectory of robot moving from left start point to right point which is position of target, 2) obstacle as green rectangle and 3) yellow positions of robot where it could not select direction from associative memory itself and requested prompting (supervised learning).

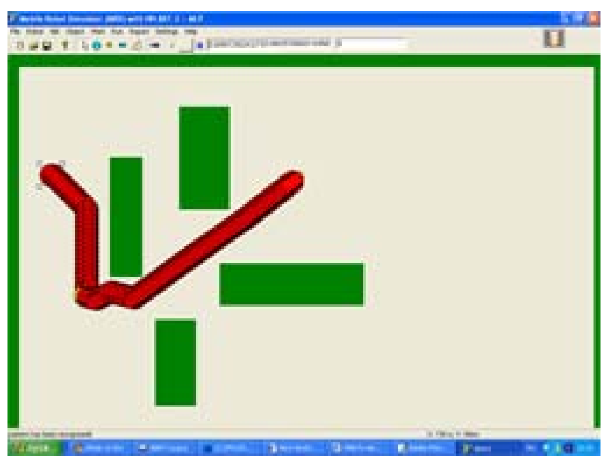

Figure 2. Screenshot of one experiment

The conducting experiments show that in case of using model ART-2 without previous processing of signals from sensors the robot often asks user "what to do". In contrast to it the model MLP-ART2 reduces number of such situations essentially after some learning and filling of associative memory by associations between created cluster and appropriate action. For configuration of environment with one obstacle and determined position of target shown in figures just 5-7 clusters are creating during learning and it is enough for practically autonomous behavior of robot independent on start position. And just one iteration for learning of MLP is enough. Of cause to achieve the absence of assistance of user may be used random selection of new direction or rules using for avoiding close obstacles.

However experiments show that sometimes the trajectory of movement is far from optimal essentially when environment includes many obstacles.

4. Conclusions

In this paper we suggest and experimentally evaluate the novel architecture of control system for navigation task of mobile robot. It is based on hybrid neural network MLP-ART2 and simple rules for navigation in specific situations. This architecture is further development of previous one suggested for interaction between robot and user by natural-like language oriented on navigation tasks. Experiments show that using of model MLP-ART2 dramatically reduces number of situations when robot ask "what to do" although sometimes trajectory of movement is far from optimal. Probably more optimal trajectory with keeping of semi-supervised learning may be achieved by careful future development of navigation rules and collaboration between ones and associative memory. In future we plan to investigate more complex implementation of rules as knowledge based system cooperated with model MLP-ART2 through black board similar to mechanism proposed in [15].

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