Adaptive robot control technique for dynamic environments

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Abstract

This paper presents the technique of adaptive robot control for dynamic environments. The technique is designed for low cost sensors that make the developed system applicable for economic models of robots. This approach is based on the hierarchy method of robot control, that came from behavior based robotics. For detection of moving objects we use ultrasonic-infrared sensor detection approach and obstacle objects grid mapping. Low-level robot control behaviors based on fuzzy logic.

Experiments were carried out on the simulation exhibition model. The result is successful in substitute high-end sensors on low cost with implementation of adaptive behavior control algorithms.

The developed technique was implemented on real Robot-Guide, that was created in the BrSTU-Robotics student laboratory of Brest State Technical University (Fig. 1).

1. Introduction

Autonomous mobile robot control is actual direction in researches. Modern systems can control robot in different ways: global navigation such as GPS, local navigation with high end sensors such as laser scanners, with low-cost sensors such as infrared ranger finders, with inertial sensors, line navigation, robot vision based navigation. There is no universal approach for this task.

Modern mobile robot must be multifunctional if it works autonomously. Such essential functions of autonomous robots are low battery behavior, goal search and following behaviors, special functions such as lifting and transportations of products at a warehouse. Tasks planning problems appear when a robot has many fuctions. Common solution is to build task planning module, that will choose the necessary behavior every time-cycle.

Robot guide platform (Fig. 1) was created in BrSTU-Robotics laboratory for hockey championship at 2014 in Belarus. Main task of the robot is to show exhibits for visitors in main hall. Robot will work in the indoor exhibition which is full of moving people – dynamic environment. All this tasks require multifunctional control system to solve them. This paper will describe about robot control aspects under this robot.

Fig.1. Robot-guide created in BrSTU Robotics laboratory.

2. Previous works

Tasks of the guide control require sensors module building. This part was developed and tested in previous work [1].

Hierarchy behavior control is one of the methods of behavior-based robotics control. Such control suggests a judge that should choose current behavior (Fig. 2).

The main feature of the hierarchy control is dividing all robot functionality for levels [2]: tasks, subtasks and low-level actions (Fig. 3). Low-level actions are chosen by subtask judge and run for current iteration of time. Implementation of this functions may based on fuzzy logic. It provides flexibility, simple and powerful control. G. Narydas, R. Simutis, V. Raudonis outline how to build hierarchy control on robot Khepera II [3]. A.Fatmi,

A. Al Yahmadi, L.Khriji, N. Masmoudi implemented this approach on real robot and show in experiments successful work of the method [4]. S. Thongchai, S, Suksakulachi, D. M. Wilkes, N. Sarkar presented navigation based only on ultrasonic sensors and controlled by sense-plan-act method [5]. They implement algorithms only on simulation.

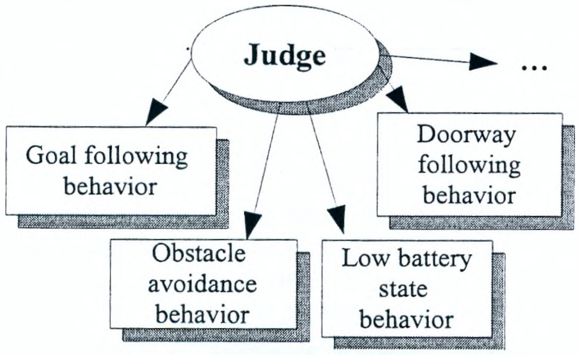

Fig.2. Judge behavior variants.

All those methods not take into account dynamic environments, where may be located tens of moving people. Such robot for dynamic environment must has correct sensors model [1], have special algorithms for respond to emerging threats of collisions.

Lindsay Kleeman and Roman Kuc examined in detail the approach based on ultrasonic sensors [6]. Chong and Kleeman work added accuracy odometers and various variant of Kalman filter for navigation and mapping problems [7]. In those works authors implement robot control for dynamic obstacle avoidance problem, but experiments was only in simulations and robot didn't autonomous and multifunctional.

3. Dynamic objects analysis

Ultrasonic-infrared sensor fusion method was used for dynamic obstacle detection. Assessment algorithm can detect obstacles on 180 degrees around the robot. Iterations of the algorithm are:

1. Read, filter and mapping ultrasonic sensors data. Created new obstacle objects (Fig. 3).

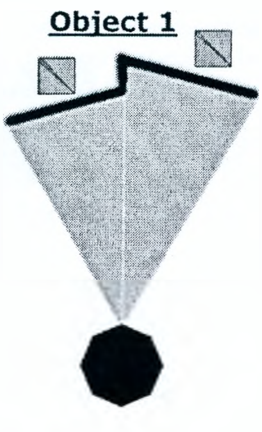

Fig.3. Ultrasonic sensor data from 1st step.

2. Robot make reading, filtering and mapping sensor data. Obstacles rectification (Fig. 4).

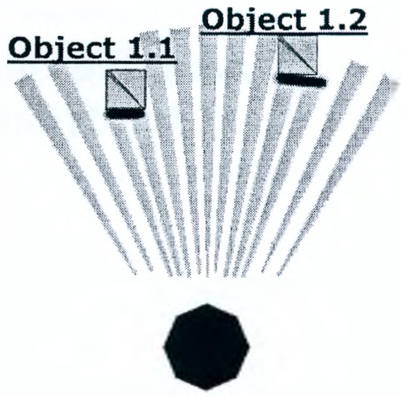

Fig.4. Infrared sensor data from 2st step.

3. Get current robot angle speed $\upsilon_{yaw\_robot}(t)$, angle direction α, and line speed $\upsilon_{x\_robot}(t)$.
4. Calculates objects speed (Fig. 5).

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If (detected obstacle was exist before)
        ϑ_x(t)= ϑ_x(t − 1) − ϑ_yaw_robot(t)
        ϑ_yaw(t)= ϑ_yaw(t − 1) − ϑ_yaw_robot(t)
Else
        For all new obstacles create new objects
        If object has parent
                ϑ_x, ϑ_yaw as parent values
        Else
                ϑ_x, ϑ_yaw as zero
        EndElse
EndElse
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Fig.5. Object speed calculation pseudo cod.

Speed vectors of objects were took on this step, as illustrate on Fig. 6.

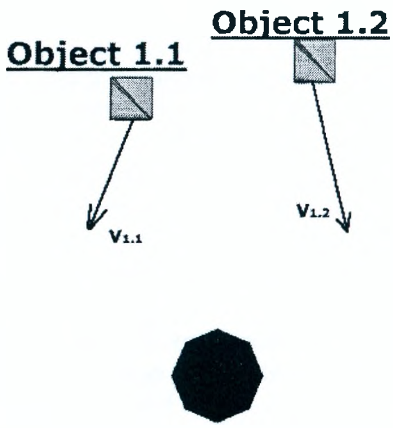

Fig.6. Calculated obstacles speed vectors.

Robot rectification is based on infrared sensors data. This approach distributed in mapping, when ultrasonic sensors detect all obstacles around the robot, and infrared data specify sensors information about obstacles [8, 9]. Algorithm divides object on two or more parts, when item line have a break. The size of the break is a little more then size of the robot - 60cm. Each of new obstacles is assigned with parent object speed. Such passage is enough for robust robot driving. This approach allows robot work with static and dynamic objects simultaneously.

4. Robot guide planning

The robot guide task model for the exhibition represents by graph (Fig. 7).

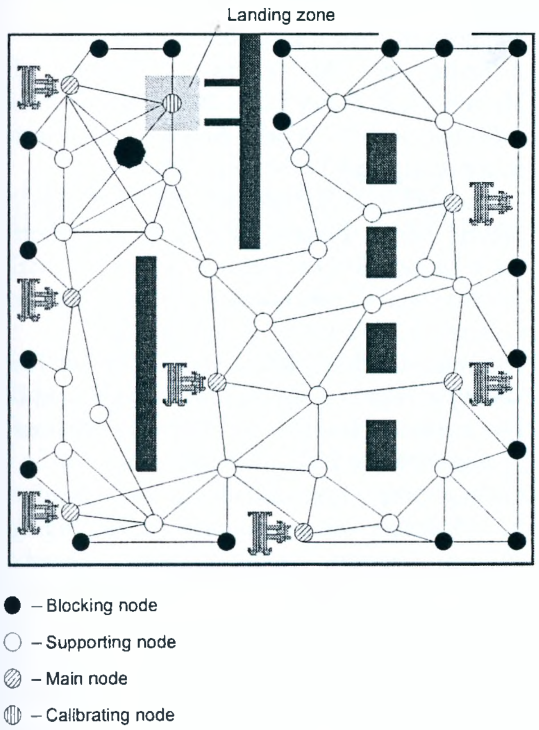

Fig.7. Robot guide navigation graph model.

Main nodes are indicates important places like exhibits, landing zone. Supporting nodes are intermediate places for robot planning. Calibrating nodes are places where located camera that establishes exact position of the robot. Blocking nodes are forbidden places like glasses doors or walls, that can't detects by infrared sensors.

The Guide environment model must be build by operator at first and will modify with robot in future. That requires additional configuration when preparing the robot to work.

5 Hierarch control method

First step of hierarchy model building is distinguish all tasks of the robot. There are navigation in the indoor environment, communication with visitors with multimedia pad and sound loudspeakers, hardware initialization and self monitoring, entertainment functions. All functions may execute independent and simultaneously.

The second is decomposition for the problem of navigation (Fig. 8). Goal finding and path following are subtasks by which robot may moving at the exhibition from one exhibit to another. All others tasks have same decomposition.

Robot motion control based on fuzzy logic which choose direction of robot moving and neural networks, that corrects robot motion [1].

5. Simulation results

For simulation experiments we use player/stage simulation tools [9], that provides ability to model dynamic environment - world with many moving objects [10]. Robot guide exhibition was build for testing of the robot guide algorithms (Fig. 7).

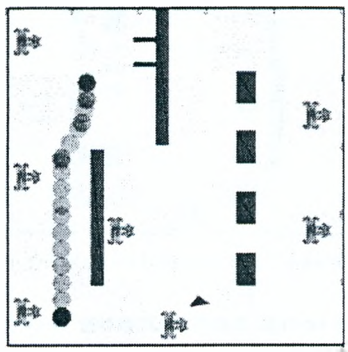

Fig.9. Robot way from landing zone to 2nd and 3rd exhibits.

Robot start his way from landing zone and visit exhibits from 2nd to 7th, missing 1st. Visiting of 2nd and 3rd exhibits is shown on Fig. 9.

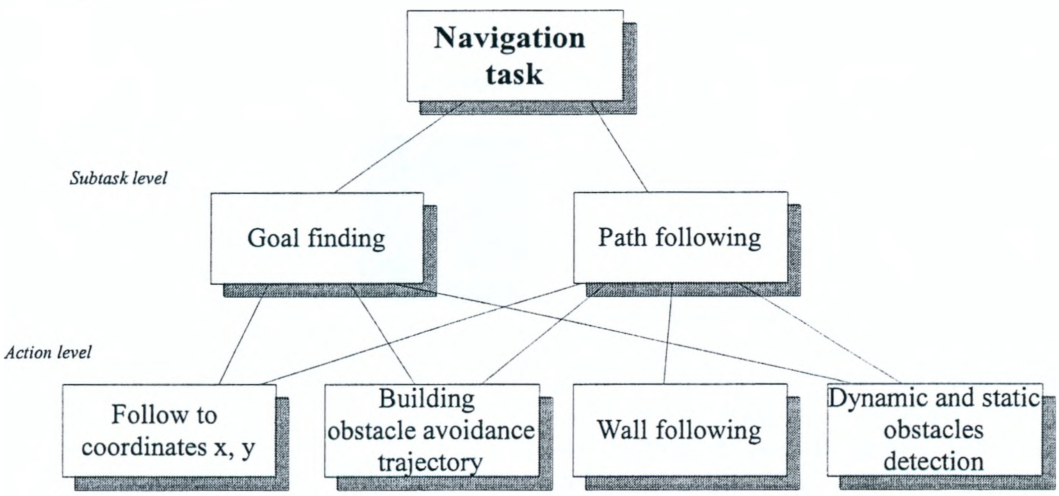

Fig.8. Hierarchy control navigation task decomposition

Then robot moves to 4th exhibit, and after meets triangle moving obstacle (Fig. 10). The robot successful changes trajectory and avoids collision. At Fig. 11 was shown end of the robot tour by visiting 6th and 7th exhibits.

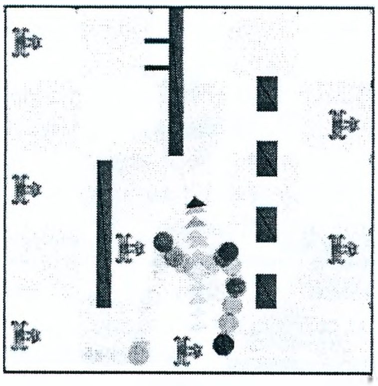

Fig.10. Between 4rd and 5th robot successful avoid triangle moving obstacle

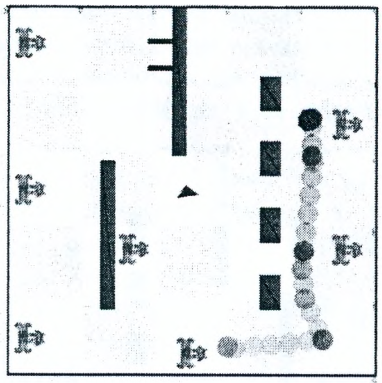

Fig.11. Robot way to 6th and 7th exhibits.

6. Conclusions and future work

Hierarchy navigation method was successful in simulation experiments and now configuring to work in real world on Robot Guide. Dynamic analyze algorithm make navigation successful when robot meet moving to him object.

Future works will to make experiments with robot in real world and to improve of developed algorithms.

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