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INTELLIGENT MOBILE ROBOT FOR INDOOR ENVIRONMENT

Abstract: *In this paper we present a navigation module of our experimental mobile robot AURO that utilizes sensor-based behavior and reactive control mechanisms to avoid collisions in the real indoor environment. The hybrid control architecture combines a low level reactive behavior with high level path planner. The robot is equipped with odometry sensors, tactile sensors and scanning ultrasound range finder.*

1. INTRODUCTION

The aim of mobile robot research in our institute is to develop an intelligent mobile system which to perform transportation task in a real indoor environment as a factory, hospital or store building with a flat floor. In the early stage of research we studied the problems of world modelling, global path planning methods and robot motion control for the known robot workspace. The modular hierarchical control architecture was chosen for the robot control [1] with modules path planner, world map, pilot, localization and motor control. The module path planner is a high-level planning system for planning the collision-free path in the known environment using the map from world map module. Pilot module calculates the parameters of the local trajectory and sends command to the motor control module. Localization module uses the internal readings and odometry data for the computing the absolute robot. The robot executes the pre-planned path from given start point to the goal point.

In the case of moving in real indoor environment a mobile robot needs sensors to acquire information from that environment. There are many different types of change that can occur within a real environment: people may be standing or walking in front of the robot, doors may be open or close, furniture may be rearranged, sensors may fall out of calibration. The map of indoor environment is generally incomplete since only static objects can be included. In such cases, the robot must be able "to map" its environment during the motion and re-compute its path as new information is added to its map. For this purpose the mobile robot uses the sensor subsystem. The sensor information from its could be used to build up a local world model in the close vicinity of the robot to avoid collisions with this unexpected obstacle or to react on current events. In this paper we will present our research results with experimental mobile robot that utilises this sensor information in sensor-based robot behavior for reactive control mechanisms to avoid collisions efficiently in the real indoor environment. We describe a navigation module using the sensor-based behavior for accomplish the movement in the real environment. The design of the module is extension of the our control system [1] for the robot motion in the known environment.

2. REACTIVE ARCHITECTURE OF THE CONTROL SYSTEM

The navigation problem for autonomous mobile robot has been considered using two well-known approaches: functional and behavior based decomposition of the task. The first uses a "Sense-Model-Plan-Act" technique, where sensors are used to build the world map. Then a path is planned based on this map and followed by the robot. The second approach is based on breaking up the control task into basic behaviors [3]. These behaviors react directly to sensor information yielding intelligent emergent behavior. Our main research purposes are focused on the development of a low cost mobile robot to be used for the automatic transport of small objects in an indoor environment. The goal was to achieve satisfactory performance using as little hardware for perception and computation as possible. Our robot AURO is based on the tricycle platform. It has ultrasonic range finder, rotating from 0° to 360°, three tactile sensors on the bumper and odometry sensor for position estimation purposes. From this point of view the control system architecture for AURO motion in unstructured environment was proposed as is shown in Figure 1. We use the hybrid type [4] of the control architecture which combines a low level reflexive behavior with a high level path planner.

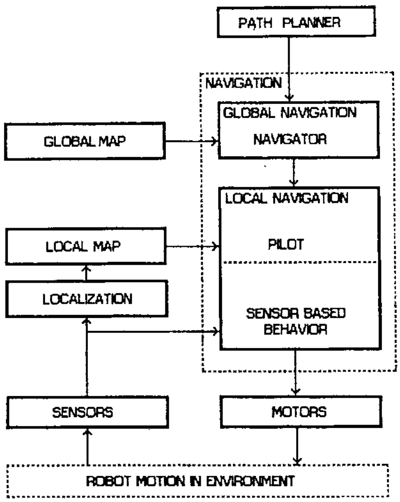

Figure 1. Architecture of control system

The given task "transport object from S to G" from the high level is accepted and executed by this control system. The Path Planner module determines the robot's path from an initial to a goal position. The proposed off-line planner uses an apriori Global Map that contains knowledge about the workspace. Available apriori workspace information such as a floor plan may serve as the basis for this map. The path planner uses the findpath algorithm with generalized Voronoi diagram (GVD) technique [2] which generates a set of reference path points between the start and final robot's positions. These points input as a nominal path to the Pilot module which calculates the parameters of the local trajectory in the robot reference frame and send an incremental position command to the servosystems of the Motors module. A Localization module [6], [10] continuously estimates the AURO absolute position in the world frame based on the internal sensor readings and odometry data. AURO executes the pre-planned path while any unforeseen situation is not accepted by Sensors module. In order to enable the AURO to react to unforeseen situation during the motion a Sensor-based Behavior module is located between the Pilot and the Motors module. As shown in the Fig. 1 this module is placed on the lowest level of control architecture and must enable the AURO to react to unexpected situations during the autonomous execution of a given path. This type of module provides a dynamic link between perception and action and is used as a reaction to actual sensory data. The module allows to AURO automatically select appropriate behavior and to adapt its motion dynamically based on the demands of the environment in performance. Motivation for this solution of the obstacle avoiding problem was to provide the robot with function identical or even similar to humans or animals behavior. The biological systems already successfully achieve the task. We use the collection of "reflexes" as the models developed to simulate these behavioral systems.

3. NAVIGATION IN INDOOR ENVIRONMENT

In order to navigate successfully in real environment the path planning needs to be highly flexible and reactive. On the other hand the robot's target should be reached in a nearly optimal manner in the sense specified by a human operator, e.g. the shortest, the safest, the most adventurous, etc., path. These navigation characteristics are obtained by dividing the navigation task into global and local part as shown in Fig.1.

3.1. Global navigation

Initially the global part uses results from the GVD technique and global map information to pre-plan the robot's path according to the user specifications. It will generate a minimum number of subpath based on a given optimalization criteria and the state of the global map between the given start and final robot's position in the real environment. A subpath is a straight-line or circle segments given by begin and endpoint co-ordinates. The local part provides the guidance of the robot by the previously calculated control points. It consists of a Pilot and Sensor-based behavior modules. The Pilot uses the local map and the subpaths to calculate the parameters of the local trajectory (the forward/backward distance and steering angle change in accordance to the subpath control points) and it transforms the trajectory into the robot's frame of reference for the purpose of control and path tracking. The sensor data should be added in order to take into account unmodeled objects or unexpected situation, so that the Pilot can find a new path to meet the original one. If it is not possible to find a path in the local map the global path planner is asked to find an alternative path from the current place to the goal position.

3.2. Local navigation

Two fundamental actions are considered in this part: the tracking of the trajectory established by the Pilot and the real-time avoidance of unmodeled obstacles. Different AI strategies are being used to implement this part [7], [8], [9]. For this purposes we use sensor-based behavior and fuzzy logic method and neural network approach is in work and testing phase just now.

The sensor-based behavior consists of a set of individual motor action each of which reacts to actual sensory information gleaned from the environment when robot moves. There are designed to be computationally very efficient. Each of behaviors is realized as software functions that are used to describe the set of interactions the robot can have with world. These function are stored in the behavior library as is given in [5].

In present state of solution following collection of behaviors are included:
emergency stop - hard stop of robot in any case of emergency
backing - this reflex stops the robot when a contact with other object took place and backtracks the robot about given threshold distance.
obstacle detector - the result of this reflex is stopping the robot when an object appears inside its security zone, defined depending on the linear and angular speeds of the robot.
obstacle avoider - deflect always the robot steering to opposite side from the nearest object
wall following - using information from the range finder sensor this reflex keeps the robot following the contour of obstacle, at fixed threshold distance
sonar orientation - using sonar information to reinitialize the position and orientation of the robot.
safe direction - chooses the heading angle of robot in the free motion corridor
stay on the path - maintains the robot as near as possible to the prescribed path
goal attraction - this behavior directs the robot towards a specific goal.

The choosing the heading angle for behavior safe direction is shown at the Figure 2. Here the maximum direction with competent angle in the measured range profile is safe for the actual motion closer to the goal direction. At the Figure 3. are shown representative situations that will be used in the strategy of obstacle avoider by neural network approach.

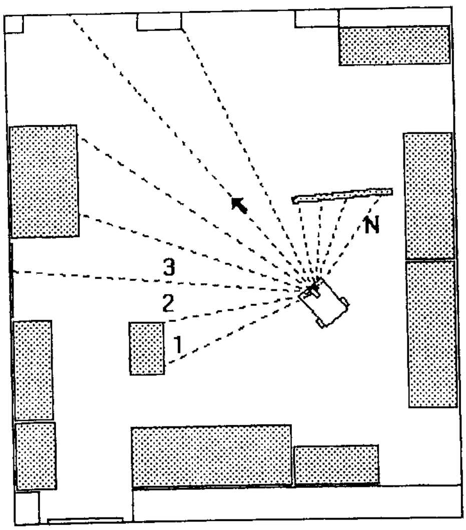

Figure 2. Behavior safe direction

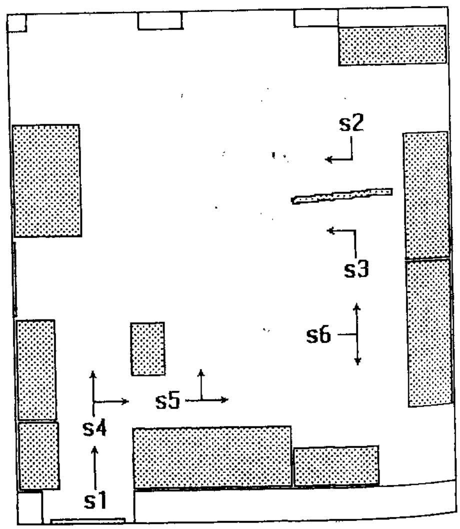

Figure 3. Representative real situation

The output of each individual behavior is some action command. This action command is acccepted by the motor control module and immediately sends to the robot actuator; there are e.g.: forward, backward, left, right, speed, stop, brake. The message received from robot can be follows: motor_active, motor_end, odo_state, sonar_state, pause, crash.

Selection of the behavior in the case collision avoidance problem is realized by fuzzy logic [4]. The output variable is the numeric value, that classified which of the behavior will be executed in actual situation.

4. EXPERIMENTAL RESULTS

4.1. Experimental mobile robot description

AURO is built up as a prism platform with three wheeled configuration, which has a length of 850 mm, a width of 500 mm, and a height of 750 mm. It consists of single steerable drive wheel at the front and two passive rear wheels. Two stepper motors are used for driving and steering the front wheel, see Fig. 4. It has a capability of motion in longitudinal directions and rotation around the robot's reference point and it can reach a maximum speed of 0.3 m/sec. The drive wheel as well as the passive wheels is equipped with shaft encoders used for odometry measurement. For sensing the environment it has ultrasonic scanning range finder, rotating from 0° to 360° and three tactile sensors on the bumper.

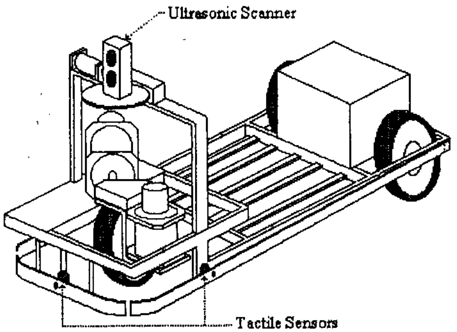

Figure 4. The schema mobile robot AURO.

4.2. Simulation results

A Figure 5. shows the simulation of a behavior obstacle avoider in the task "transport object from S to G". There is the floor plan of the corridor and two laboratory rooms with walls, obstacles and doors that is stored as a global map in 2D world model.

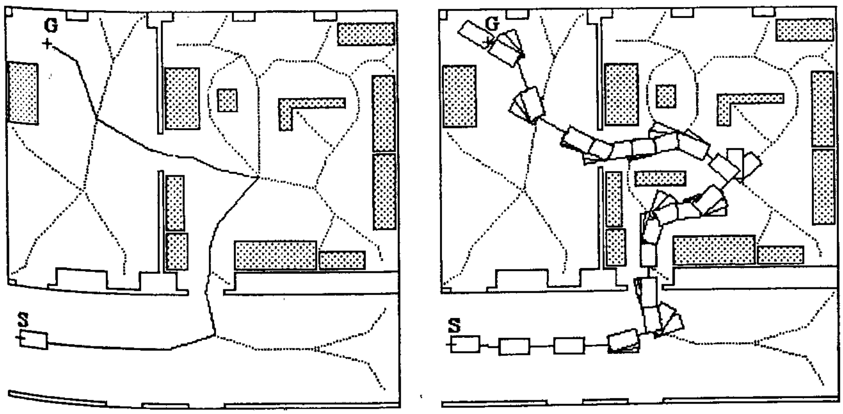

Figure 5. Expected robot behavior

For this scenario the path planner finds by GVD technique the path. The navigator generates from reference points of the path the actual subpaths for the given start and goal points S, G respectively. It sends this path as the file of reference points to the pilot. Pilot takes the information and with the local map generates the control points for motor control. If any unforeseen situation is not accepted by sensors the prescribed path is executed automatically. In the case of unexpected situation the sensors module sent the interrupt vector and pre-processed sensor data to the sensor-based behavior module. Competent sequence of the motor commands as a result of behavior from sensor-based behavior module is executed as a reaction to the event. The simulation of behavior obstacle avoider is presented. Here the new obstacle appears on the pre-planned path. Robot with your behavior avoids this obstacle. The object is avoided and different controls via point are generated to reach the goal.

CONCLUSION

In this paper the control architecture of our mobile system has been presented with emphasis on the integration of global planning and local robot behavior. The set of robot behavior has been given. Behaviors are proposed as means for control of a mobile robot at the lowest level. The simulation and first experiments in real environment demonstrate the viability of this methodology. The objective of the future research is to develop mechanisms for learning and adaptation that can be used by a robot to survive in a complex environment.

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