Application of a Mobile Robot for Environment Map Completion

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Abstract: - In the presented paper an application of a mobile robot using an ultrasonic range finder for environment information gleaning and local map building is described. The data collected by range finder from any fixed point are limited by physical properties of ultrasound waves. Only those parts of surfaces are detected for which the impact wave direction appears to right angles. Therefore the sensor data from different positions must be combined to obtain complete representation of the environment. In this paper an algorithm of map completion is presented. Experimental results are presented too.

Key-Words: - mobile robot, robot sensors, ultrasonic range finder, environment map

1 Introduction

Information of environment has substantial importance for mobile robot navigation. The robot should move among obstacles without collisions. As is described in [1], the following situations may take place: 1) The environment is known a'priori and its map is supplied to robot by human operator. All obstacles are static, start and goal points are defined. Updating of robot's localization may be required in this case. 2) The incomplete map of the environment is given. Range sensor data are used for completion and precisioning the map and for robot positioning within it. 3) The case of completely unknown environment.

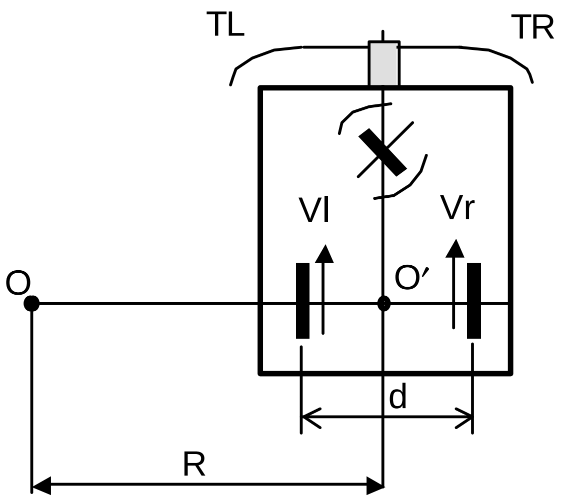
Sensors are important sources of information of the global environmental conditions. In principle the map may be created from data acquired by robot's visual system, laser range finder, ultrasonic range finder, or another kind of sensors. Ultrasonic sensors are known as robust and cheap distance sensors suitable for this application.

In the Institute of Control and System research - Bulgarian Academy of Sciences (ICSR - BAS) a prototype of Autonomous Mobile Agent (AMA) with supported systems and algorithms for intelligent behaviour in an unknown environment was developed, namely Laboratory Autonomous Mobile Robot LAMOR. LAMOR is used for testing of the developed algorithms for mobile robot control, namely path planning, navigation, obstacle avoidance and map completion using data collected from environment by scanning ultrasonic range finder. LAMOR is described in section 2. An application of the LAMOR for gleaning of information from working environment and experimental results is shown in section 3.

2 Description of the Laboratory Autonomous Mobile Robot LAMOR

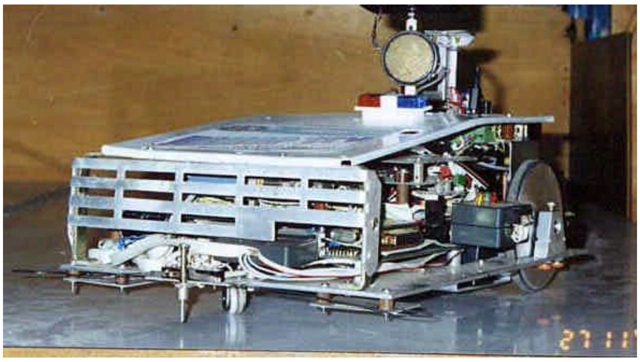
LAMOR is depicted in [3,4]. The robot construction is shown on the Fig.1. LAMOR is mobile robot with two fixed directional wheels in its wheel configuration, with differential steering, and one passive wheel. LAMOR has a length of 400 mm, a width of 260 mm and a height of 220 mm. It can reach a maximum speed of 0.05 m/sec. Till now the sensor's subsystem consists of tactile whisker's proximity sensors - left TL and right TR, an ultrasonic scanner US and sensors control unit. The ultrasonic scanner US is mounted on a vertical axle which passes through the middle point O′ of robot's rear axis. The point O′ is driving center and reference point [1,2] of the robot. The point O (fig.2) is fixed in the laboratory frame of reference when (Vr = const, Vl = const) and coincides with the local center of curvature of the robot's path or it is very far when the robot's path is nearly straight line. The distance measurement from the ultrasonic scanner is between 0.3 m and 10.6 m with an accuracy +/- 0.03 m. The minimum scanning angle step is Pi/100 radians, starting from -120° to +120° in the horizontal surface.

The architecture of LAMOR control system is depicted in Fig. 2 and described in detail in [3,4]. For the control of LAMOR a modular hierarchical control architecture was chosen with two main parts- 1) high level control system, realised on an external stationary host computer and containing modules “apriori knowledge”, “path planner”, “pilot”, “reflexive module” and 2) low level control system, realized on LAMOR and containing modules “sensors”, “sensors servicing & motor control”, and “driving unit” The task of the “path planner” module is to determine the collision-free LAMOR´s path from an initial to a goal position. The proposed off-line planner uses an apriori world map that contains partial knowledge about the workspace. The module “pilot” calculates the parameters of the local trajectory, transforms the local trajectory into a set of incremental position commands that are passed via communication to the on-board microcomputer, namely “sensors servicing & motor control” module. The “reflexive module” must enable LAMOR to deal with some unexpected situation like an unexpected obstacle on the robot’s path [3]. LAMOR has an RS232C interface for communications with the high level control system.



$$R = OO' = d\frac{Vr + Vl}{2(Vr - Vl)}$$

a



b

Fig.1. a)LAMOR platform
b) The mobile robot LAMOR

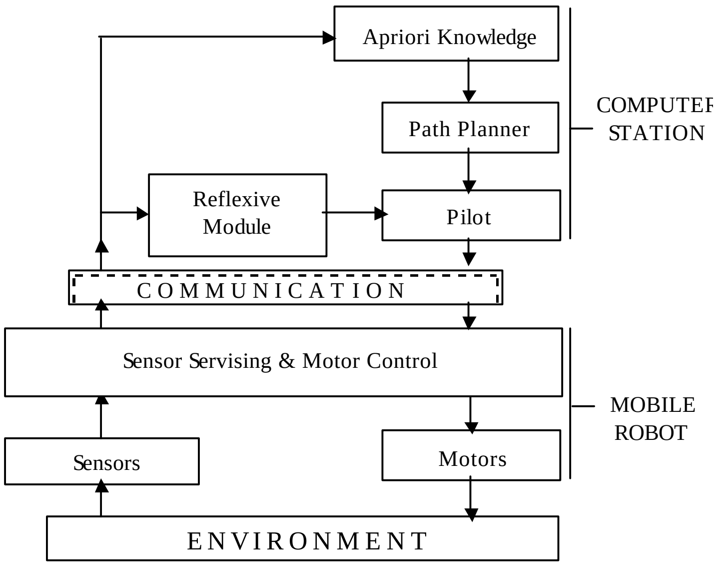


Fig. 2. The architecture of LAMOR control system

3 Gleaning of Information from Environment using LAMOR

3.1 Peculiarities of the Depth Readings Obtained from a Rotating Sonar

For the purpose of data acquisition LAMOR uses an ultrasound range finder. Depth readings are obtained from the rotating sonar in cylindrical co-ordinates, i.e., as depth at a particular angle. As a consequence of the detection mechanism in the sonar, the depth reading refers to the depth to the nearest reflecting surface anywhere in the sonar beam’s circular footprint. When the beam reflects from a flat surface at a non-perpendicular angle, the sonar returns the distance along the short edge of the beam.

Knowledge of this physical process is used in interpreting the sonar depth readings [5]. But the range information from a sonar system has much uncertainty. When sound waves strike an object, any detected echo represents only a small portion of the original signal. The remaining energy reflects in scattered directions and can be absorbed by or pass through the target, depending on surface characteristics and the angle of incidence of the beam. Instances where no return signal is received at all can occur because of specular reflection at the object's surface, especially in the ultrasonic region of the energy spectrum. If the transmission source approach angle meets or exceeds a certain critical value, the reflected energy will be detected outside the sensing envelope of the receiver. In cluttered environments sound waves can reflect from (multiple) objects and can then be received by the sensor (multipath effect) or by other sensors (crosstalk). Borenstein and Koren [6] proposed a method that allows to deal with these phenomena.

3.2 Coordinates Transformation

The rangefinder operates in robot's frame of reference which changes its position with respect to the environment when robot moves. The map of environment must not depend on the robot motion therefore all range finder information must be transformed into the environment frame of reference. For this purpose a coordinates transformation method described in [1] may be used. Described below coordinate transformation method is similar to one given in [1]. The sonar readings are converted from robot-centred polar co-ordinates to a world-centred Cartesian co-ordinate system (See fig. 3) in accordance to the following formulae:

$$
\begin{aligned}
x' &= +(x - x_0)\cos\Delta f + (y - y_0)\sin\Delta f \\
y' &= -(x - x_0)\sin\Delta f + (y - y_0)\cos\Delta f \\
x &= x_0 + x'\cos\Delta\phi - y'\sin\Delta\phi \\
y &= y_0 + x'\sin\Delta\phi + y'\cos\Delta\phi \\
x' &= r_P \cos g_p \\
y' &= r_p \sin g_p
\end{aligned} \qquad (1)
$$

where:

- (X_0, Y_0) means the coordinates of the reference point O′ of the robot in the laboratory frame of reference (X,Y);

- Δf is the heading angle of reference vector pointing forward along the longitudinal axis of symmetry of the robot;

- (X′,Y′) means the axes of the robot bound coordinate system. X′-axis coincides with the robot reference vector;

- r_P is the distance of a point on the surface of obstacle found by the range finder;

- g_p is the angular position of r_P.

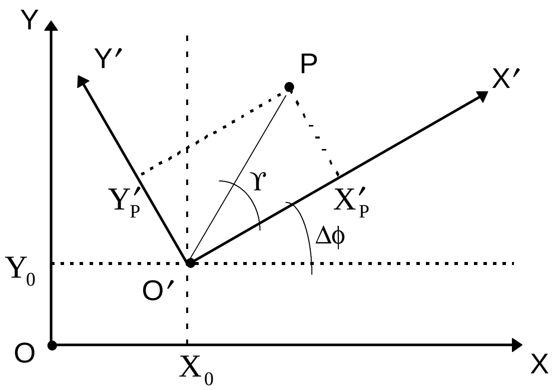
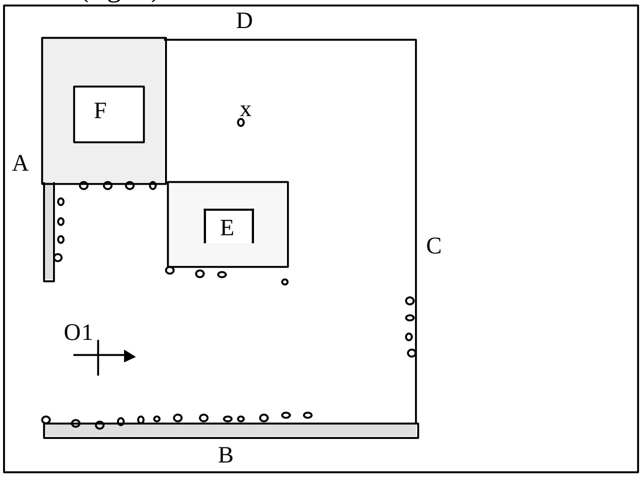
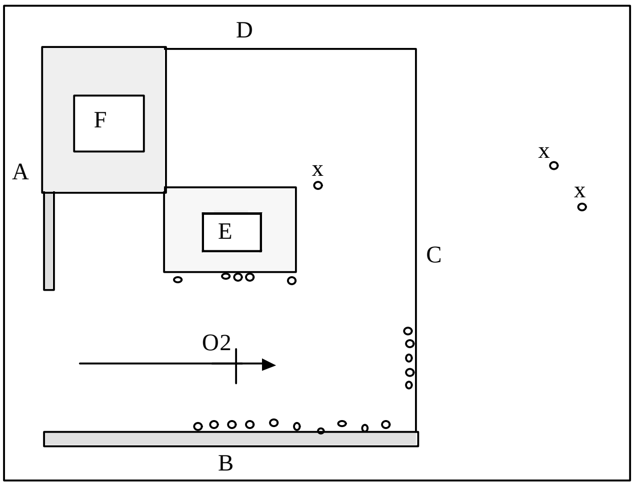


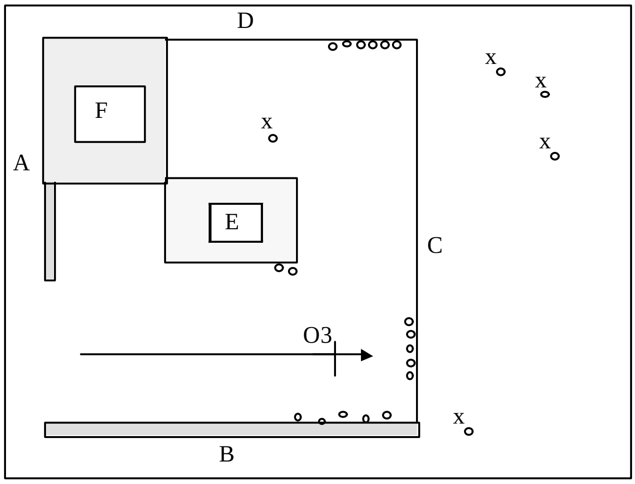
Fig. 3. Coordinates transformation

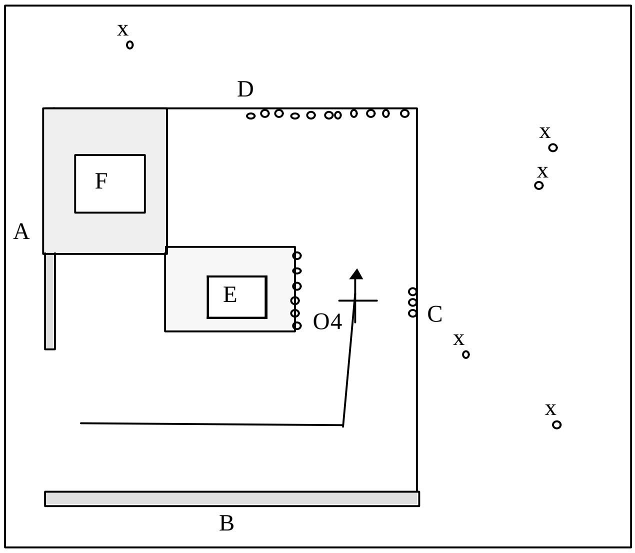
3.3 Gleaning of Information from Environment and Map Completion

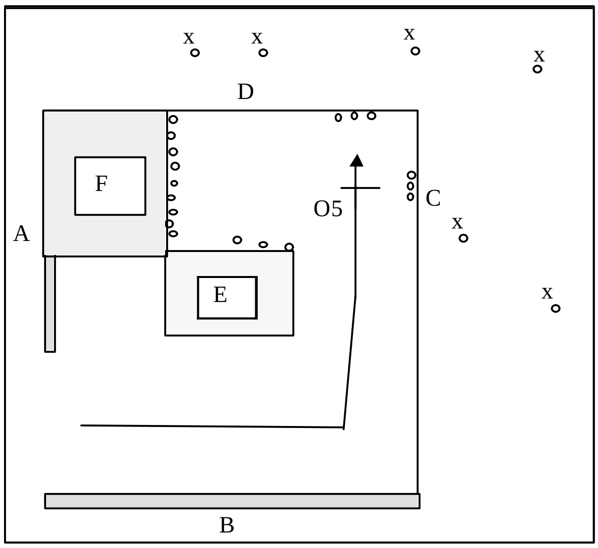
Due to physical properties of ultrasound waves the information acquired from any fixed position is very sparse. Therefore the map must be constructed linking together the sequences of measurements acquired from different successive positions along the robot's path. It is necessary to move the range finder relative to the objects that should be mapped. The updating of the environment map is then based on the range data collected as the robot moves in short steps along the known path. At the end of each step a complete scanning of the environment is performed. The results from measurements are depicted in Fig.4. There is a floor plan (1.5m x 1.5m) with walls A, B, C, D, rectangular object E (0.45m x 0.3m), and a rectangular object F (0.5m x 0.6m). The walls A, B as well as the walls of the object F are rough. The walls C, D as well as the walls of the object E are smooth. The path of the robot is defined by a set of co-ordinates of reference points in laboratory frame of reference. The full information of robot instant position must be known. Range finder data are collected in the robot's frame of reference by scanning a space around the robot's instant position Oi and are stored into a structured file. A transformation of all points found by range finder to laboratory coordinate system is performed by (1) and result are stored. Afterwords the robot passes to the new position. Successive positions of the range finder are O1, O2....On. Range finder has localised points on the surfaces labelled by circles. One may see that there are some situations for which the nearest object is not detected, and sometimes even a phantom object is detected (labelled by “x”) due to the multipath effect (fig. 4).











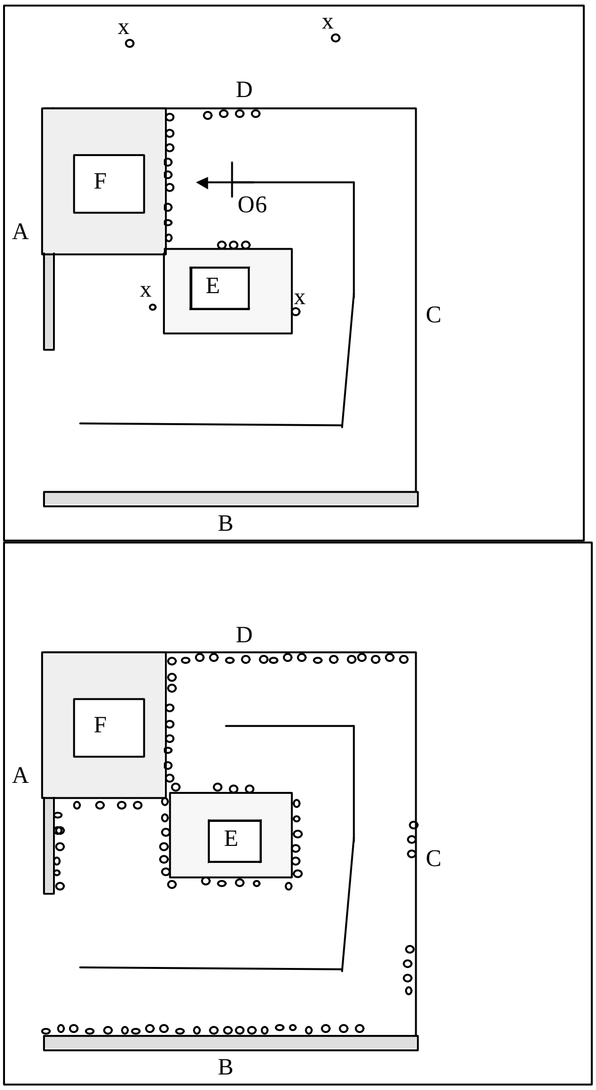


Fig.4. Experimental results

The last picture of fig. 4 shows the full path of the robot O1 – O6 as well as the ultrasonic readings O1 – O6 after they have been processed and combined.

4 Conclusion

The algorithm of construction of the environment map is developed, based on range finder acquired information. The intelligence of advanced autonomous mobile robots that is required to perform complex tasks is based on advanced features of a robot control system, such as sensor data gathering, information processing, task planning, etc. The development of features such as sensor data gathering and fusion, intelligent information processing, supervising and reasoning gives the mobile robots a large spectrum of applications.

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References:

[1] Uher, L., D. Janglova, J. Povazan. Environment Map From Range Finder Data, *Proc. 6th International Symposium on International Measurement Confederation "Eurotech '96"*, Brussels, 9-11 May 1996, pp. 221-226.

[2] Cselenyi, . J., Szilveszter Kovach, Lajos Pap, Laszlo T. Koczy. New Concept in the Fuzzy Logic Controlled Path Tracking Strategy of the Differential Steered AGVS., *Proc. 5th International Workshop on RAAD'96,* Budapest, June 10-13 1996, pp. 587-593.

[3] Manolov, O., Sv. Noykov, G. Georgiev. Control of Mobile Robot with Reflexive Behaviour., *Proc. of the National Conference "Autonatica and Informatics'97"*, Sofia, Bulgaria, 13-16 Oct.1997, Vol. 5, pp. 33-36.

[4] Manolov, O., Sv. Noikov, P. Bison, G. Trainito. Indoor Mobile Robot Control for Environment Information Gleaning., *Proc. of IEEE Intelligent Vehicles Symposium 2000,* Ritz-Carlton Hotel, Dearborn, MI, USA, October 3-5, 2000.

[5] Crowley,J. Navigation for an Intelligent Mobile Robot. *IEEE Journal of Robotics and Automation,* Vol. RA-1, No.1, March 1985, pp. 31-41.

[6] Borenstein, J., H.R.Everett, L.Feng. *"Where am I?" Sensors and Methods for Mobile Robot Positioning.* The University of Michigan, 1996, 282 p.