Environmental Modeling Based on Ultrasonic Ranging

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Abstract. In order to deal with the conflict of the robot high-performance implementing the task in an uncertain environment, environmental modeling method based on ultrasonic ranging was adopted. By the complex environmental modeling mean of combining the methods of grid and geometry, relying the measurement data of the adjacent multi-ultrasonic and the correlation among the data, the environmental modeling was established effectively. The modeling characteristics analysis showed that: the robot can easily make obstacle avoidance, path planning and decision-making in the grid-based modeling. The accuracy of the modeling is high, and it can detect and update the complex regional expediently. The environmental modeling based on ultrasonic ranging can effectively solve the problem of mobile robot implementing the tasks efficiently in the actual complex environment.

Introduction

Environmental modeling is the basis of robot navigation control algorithm, in the actual complex environment, and mobile robots rely on their own sensor system to realize the environment map construction. In order to make the robot perform the tasks efficiently in an uncertain environment, the robot needs to have the ability of independently creating and updating the environmental model. Map is a model of the environment, and the map created must solve three basic problems: (1) Map representation; (2) Robots roam in the environment and record the perception data of the sensor, which is the robot navigation; (3) Maps are updated according to the environmental information, solving the problems of description and processing to the uncertain information.

Modeling Methods and Ideology Based on the Adjacent Multi-ultrasonic Sensor

Common Modeling Method· Common methods of environmental modeling using ultrasound are as follows: grid-based map[1-2], geometric map, topological map[3-5], visibility graph map [6] and free-space -method [7-9] [13].

(1) Grid-based modeling method. The entire environment is discretized into many square cells of the same size, and then estimated each cell whether the obstacle exists based on the measurement information of the ultrasonic sensor, the estimated results are showed by the uncertainty form, and can easily achieve robot localization and navigation.

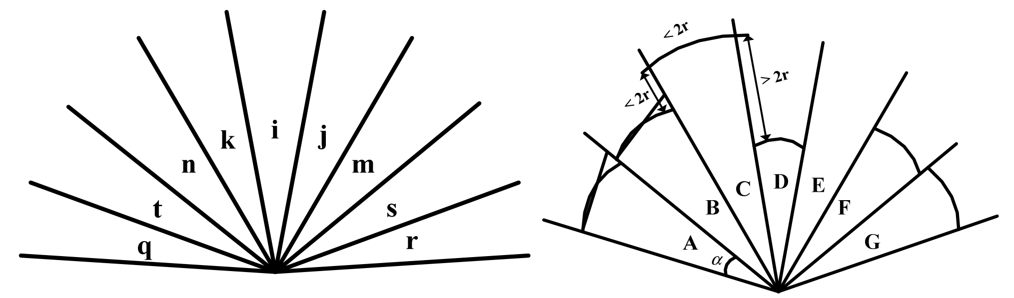
(2) Geometric-based modeling method. Location estimation and target recognition are convenient, focusing on the location information of easily perceived in the environment to identify the characteristics of the target (or abstract feature points). Positioning and navigation of the mobile robot are mainly through the matching identification of the characteristics target (or abstract feature points), to indirectly obtain the position information of its own.

In this issue, the robot used the composite environmental modeling method of combining grid and geometry.

Modeling Idea of the Adjacent Sensor. The main task of the robot is traversing the reachable region of the environment in present subject. Therefore the obstacles in the environment are required to model accurately and real-time. The subject relies on the measurement data and correlation of the adjacent multi-ultrasonic sensor, and building the obstacle models using geometric features, and then converts into the grid map.

The modeling idea of adjacent sensor is: the environment is divided into three features of wall, faults and corner; according to the measurement values of the adjacent multi-ultrasonic sensors, calculating the forward obstacle belonging to one of the above-mentioned three characteristics; according to the mutual relations as well as the characteristics of the adjacent sensor, building the obstacle models using the straight-line model, and the linear model of the local obstacles is got; according to local linear model, the local grid model is established.

Sensor Number and Definitions. Traversal robot in this subject uses 7 groups of ultrasonic sensors, which is simplified as shown in Fig.1(a), and numbered. The measurement data of the *i*-th ultrasonic sensor is d_i. The characteristics of each sensor sector and the mutual relationship of the two adjacent sectors interval can be divided into the following categories: continuous type: $d_A \le d_B \le d_A \cos\partial$; interval type: $d_B \cos\partial < d_C \le d_B + 2r$; gap type: $d_C > d_D + 2r$; open type: the ultrasonic sensor E did not detect the object or exceed the measurement largest range set in the measurement region.



a sensor number b. the relations of the sensor ranging

Figure.1 the simplified model of ultrasonic sensors

Modeling Process

By establishing the obstructions contour of the ultrasonic sensor within the sector which is satisfied the conditions, to achieve the modeling of the obstacle contour within the scope of the entire observation. Rely on the measurement data and data correlation of the adjacent multi-ultrasonic can build the environment model effectively.

The following mainly discusses the measurement data relationship of the ultrasonic sensors C, D and E, and builds the model within the sensor D:

(1) Continuous - continuous modeling method

If the measurement data of the ultrasonic sensors C, D, and E satisfies the conditions of the continuous type, and $d_E > d_D > d_C$, the modeling is: make the reverse extension line of the arc tangent of the sensor C over the left boundary point d of the sensor D, as shown in Fig.2(a); (2) If the measurement data of the ultrasonic sensors C, D, and E satisfies the conditions of the continuous type, and $d_D < d_C, d_D < d_E$, the modeling is: respectively connect the boundary point c and e of the arc sector with the sensor C and E over the arc midpoint d of the sensor D, as shown in Fig.2(b); (3) If the measurement data of the sensor C, D and E satisfies $d_c < \mathrm{d_D}, d_E < d_D$, the modeling is: make the reverse extension line of the arc tangent of the sensor C and E over the left and right boundary point of the sensor D. Where *a* and *b* in Fig.2 is the obstacle of the walls with better straightness, and *c* is the corner of the case.

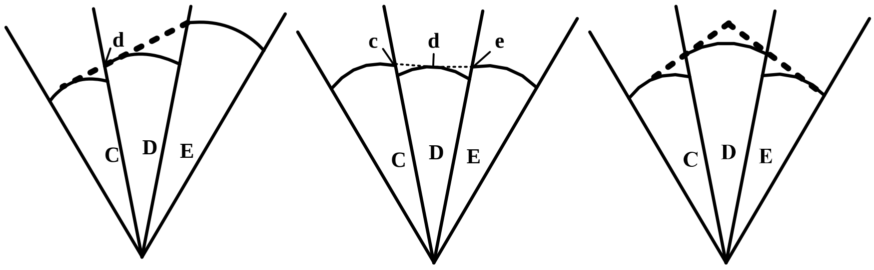


Figure 2 wall modeling

(2) The modeling approach of continuous - interval, continuous – gap, continuous - open

The situation mainly causes by appearing fault of the obstacle, and the breakpoint exists in the arc of the sensor D, so the sensor D can not building the modeling completely. Two cases are discussed: (1) If $d_C < d_D$, the modeling is: make the reverse extension line of the arc tangent of the sensor C over the boundary point d of the sensor D, as shown in Fig.3(a); (2) if $d_C > d_D$, the modeling is: make the tangent of the sensor D over the boundary point of the circular arc of the sensor C, as shown in Fig.3(b).

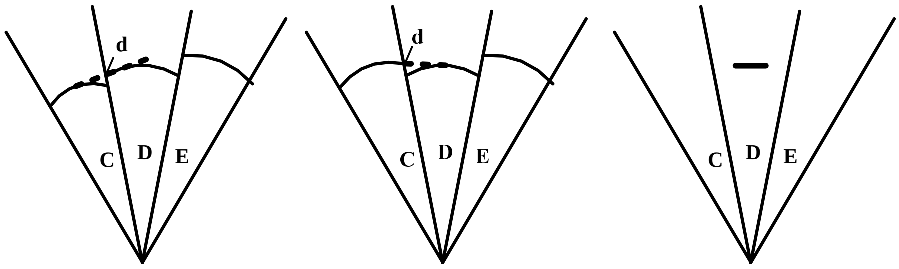


Figure 3 unilateral fault   Figure 4 bilateral fault

(3) The modeling method of interval - interval, interval - gap, interval – open, gap - gap, gap - open

For the case of faults on both sides, the ultrasonic sensor D contains a breakpoint, simply making a short line as the modeling of obstacle in the centre of ultrasonic arc with the ultrasonic sector discussed.

If the robot encounters a fault, it will have to rotate or turn, to further measure the obstacles near the fault.

Modeling Establishment and Update

Local Model Establishment. The group of lines obtained in accordance with the above modeling method describes the obstacle profile obtained by the robot probing, then we can create a grid model of local environment according to the straight-line model. Specific methods are:

(1) Initialization grid unit

The region of the traversal robot in a probe is the semicircular area with the circle center of robot, the radius of ultrasonic maximum detection range. Build the inference grids model of the semicircular region, and the occupancy values of all cells are set to 0.5, that is, all are the unknown cells, and then the occupancy values of the cell covered by the robot body are set to 0.

(2) Calculate the occupancy value of each unit according to the straight-line model

M presents the readings of the adjacent sensor to be treated, and $P(c)$ presents the occupancy value of unit c. $P(sr)$ and $P(\overline{sr})$ respectively denote the probability of sensor specular reflection and without the specular reflection, then $P(sr)+P(\overline{sr})=1$, according to the total probability formula:

$$P(c\,|\,M)=P(c\,|\,M,\overline{sr})\bullet P(\overline{sr})+P(c\,|\,M,sr)\bullet P(sr) \tag{1}$$

Two cases to discuss:

1) Without specular reflection: then $P(sr)=0$, $P(\overline{sr})=1$, then the Eq.(1) simplifies as $P(c\mid M)=P(c\mid M,\overline{sr})$. First, the straight-line model corresponding to the sensor is mapped to grid model, specific methods: point-by-point comparison method and digital integration method. Taking into account the processing performance of the 8-bit microcontroller, the method of point by point comparison interpolation principle is adopted to make linear model map to grid model. Shown in Fig.5, the unit of the straight line passing through is the unit for obstructions.

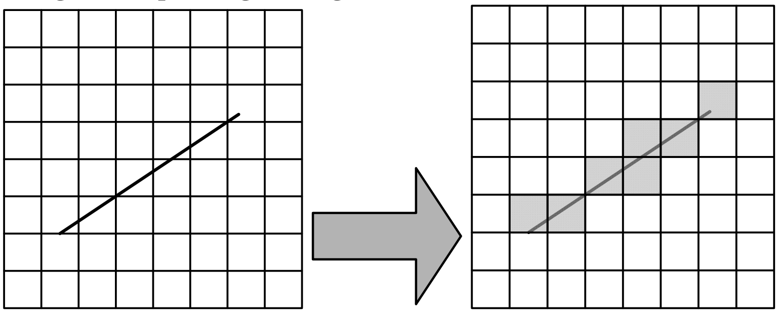


Figure 5 linear model maps to grid model

The units between R_{min} and the obstacles units are set free unit in the sensor sector discussed. Then calculated $P(c|M,\overline{sr})$ according to the empirical formula (2).

$$P(c\mid M,\overline{sr})=\begin{cases}\max(0.6,1-(\dfrac{d_i-R_{\min}}{R_{\max}-R_{\min}})^2),\text{ c - obstacles cells}\\ \min(0.4,(\dfrac{d_i-R_{\min}}{R_{\max}-R_{\min}})^2),\quad\text{c - free units}\end{cases}\tag{2}$$

2) Specular reflection

The open-type sensor may occur specular reflection, to simplify the calculation, set $P(sr)=P(\overline{sr})=0.5$. If specular reflection does not occur, the occupancy value $P(c|M,\overline{sr})$ of cell c is calculated in accordance with the formula (2); if specular reflection occurs, then the obstacle distribution within the sensor sector is unknown, and the probabilities of all cells within the sector occupied by the obstacle are the same, that is the constant S. Therefore, the formula (1) becomes:

$$P(c|M)=0.5\times(P(c|M,\overline{sr})+S)\tag{3}$$

According to the above method, the occupancy value of each ultrasonic sensor is estimated and local environmental inference grids model can be established based on the linear model.

The Global Model Establishment and Update. The establishment and update of the global model are as follows:

(1) Model initialization, the entire unit is set to "unknown unit";

(2) Robot detects in the current location, and the local linear model of the probe is established, and thus the local inference grids model is established;

(3) Use the local inference grids model to update existing global inference grids model;

(4) Determine the next observation unit in accordance with the path planning, and move to the unit.

Robot repeats steps 2-4, and the grid map of the entire environment can be obtained. Local inference grids model updates to global inference grids model, using the following method:

For the any cell C in the global inference grids model, the current occupancy value is P (c, k), when a new observing produces a new estimated value P (c, k+1) for its occupancy values, then the estimated values after the observations is:

$$P(c,k+1)=\begin{cases}P(c,k+1), & \text{if } |P(c,k+1)-0.5|>|P(c,k)-0.5| \\ P(c,k), & \text{else}\end{cases} \quad (4)$$

Features Analysis of the Model. Compared with the general linear model and grid model, the creation method of the composite model has the following characteristics:

(1) Overcome the shortcomings of low angular resolution of an ultrasonic sensor, and the case of specular reflection with the ultrasonic sensor is considered in modeling, thus the accuracy of the model is improved.

(2)Global inference grids model has the advantage of common grid model, and the robot can make obstacle avoidance, path planning and decision in a grid model conveniently.

(3) The update of environment model is followed by the update of grid model. Compared to ordinary linear model, grid model is easier to update.

(4) Combining linear model and grid model can complete the detection and update for the complex region conveniently in the grid model.

For some complex area, the robot should take the initiative to complete multiple observations to solve the problem of inaccurate modeling brought by the ultrasonic specular reflection phenomenon.

Summary

Ultrasonic sensor has the advantage of low cost, fast acquisition information, high range resolution, light weight, small size, and easy installation etc., and gets a wide range of applications in the intelligent robot sensing system [10-12][14-15]. The study of map creation method based on ultrasonic sensors of the traverse robot was done, the method combined the advantages of the linear model and the grid model to ensure the real-time and completeness of the map established in this subject.

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