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Using 2-D laser scanner and omni-directional vision for mobile robot localization

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Abstract: The paper discusses a new mobile robot localization method by means of fusion of a 2-D laser scanner and omni-directional vision. This 2-D laser scanner, which manufactured by SICK optics, can measure precise distance and direction of reflecting points, and this omni-directional vision, which we developed, can identify some landmarks by extracting the blob information from the image. The data extracted from both sensors are different in character, so they compensate each other in the fusion method. A RoboCup middle size league soccer robot (goalkeeper) is chosen to test the algorithm, experimental results are provided.

Key words: mobile robot; omni-directional vision; laser scanner; fusion; localization

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激光和全维视觉融合的移动机器人自定位

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摘要: 讨论了通过二维激光传感器和全维视觉传感器提取数据融合技术进行移动机器人定位的新方法. SICK optics 公司制造的二维激光传感器能精确地测量出反射点的距离和方位,我们自己设计的全维视觉系统能从图像中提取场地标记物的色块信息,这两种传感器提取的数据有各自不同的特征,因此在本文所给出的融合方法中它们能优势互补. RoboCup 中型组的足球机器人(守门员)被选择来验证算法,最后给出了试验的结果.

关　键　词: 移动机器人; 全维视觉; 激光传感器; 融合; 定位
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1 Introduction

An important problem in mobile robotics is localization[1]. Normally, a mobile robot uses external sensors to respond to its surrounding environment and determine its position. There are many requirements for these external sensors. First of all, accuracy is important to more precise localization, and wider view are necessary for more robust localization[2]. For achieving better environment recognition, sensor fusion is one of efficient way. However, each sensor must have sufficient capability to achieve the most efficient environment recognition[3].

Vision sensors are getting used for mobile robots easily because of recent improvement of cameras and processors. And also, a special mirror attaching to a camera was developed and it became easy to get omni-directional view from a single image. The omni-directional image can provide some landmarks information of the environment around the robot. However, it is difficult to know precise distance information of the landmarks from the image, hence no information about shape of the environment can be given.

A 2-D laser scanner is the most popular sensor for indoor mobile robots, because it is simple and gives precise distance and direction information directly. It provides denser scans and more accurate measurements as compared to other sensors like ultrasonic and infrared rangefinders. The measure-

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ment provides clear features for an ordinary indoor environment such as line segment, corners break points. So 2-D laser scanner can recognize the polygonal obstacles of the environment easily and accurately. But unfortunately, it can't easily recognize objects which have not obvious features such as line segment and corners break points, hence it is unable to known entire feature of the environment[4].

In this paper, we discuss a new method of mobile robot localization. If the objects nearby the robot are polygons, we can use the data extracted from the laser scanner for localization and data extracted from the vision to verify. If the objects nearby the robot have not obvious features such as line segment and corners break points, we can firstly use omni-directional vision to extract segment information and recognize these objects, and then we can use data extracted from the laser scanner to get the precise distance and direction information.

2 Sensor modeling

2.1 2-D laser scanner

We use the 2-D laser scanner manufactured by SICK optics. The LMS200 calculates the distance to the object using the time of flight of pulsed light. An extremely short pulse of light (infrared laser beam) is transmitted towards an object. Part of the light is reflected back to the unit a fraction of a second later. A rotating mirror deflects the pulsed light beam to many points in a semi-circle. The precise direction is given by an angular sensor on the mirror (laser RADAR). A large number of coordinates measured in this way are put together to form a model of the surrounding area's contours. Using the serial interface of the unit, measurements are transferred in real time to a host PC.

In all our experiments, 2-D laser scanner provides 180°coverage with 0.5°angular resolution. The range resolution is in the order of mm.

Detecting all the line segments, corners, and break points in a certainty environment is an easy task. The sensor provides a polar range data set in the form of (d, θ), where θ is the angle from 0°to 180°in step of 0.5°and d is the range value. A model is defined to detect the corners and break points by comparing the relation of any data point with its neighbor points. In the total of 361 points of laser data per scan, break points are those points satisfying the following conditions[5]:

$$\begin{cases} \mathrm{abs}(d_i - d_{i-1}) > \mathrm{abs}(d_{i+1} - d_i)L; \\ \mathrm{abs}(d_{i+1} - d_i) > K \quad (i = 2, 3, \cdots, 360), \end{cases} \tag{1}$$

where d_i is the distance of data point from the robot position, returned by laser scanner, L and K are predefined constants, L is a coefficient to express the relation of neighbor laser point, K is a least threshold for the break point, as shown in Fig.1.

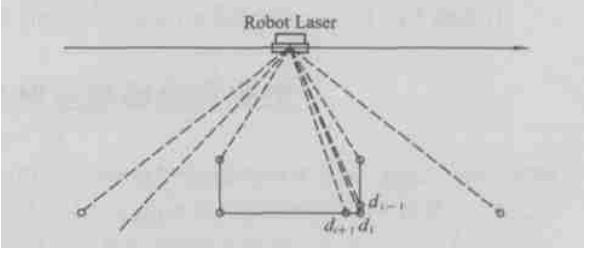

Fig. 1 The corners and break points detection

2.2 Omni-directional vision

The vision system, which developed by ourselves, consists of an acrylic cylinder with a small color CCD camera inside and the spherical mirror on the top. A OSB based frame grabber (LINX, ZR3504TQC chips) which delivers the images directly to the main CPU memory.

We can use landmark detection method to get the view angles to these objects. On the 2-D map of the environment, both the left and right edges are considered as landmarks[6]. Because of the spherical omni-vision, an object of rectangular shape looks like a sector in the image, as shown in Fig.2. The vision program converts at most eight boundary points of each blob of special color into the polar coordinates to get the ranger of sector.

3 Fusion of 2-D laser scanner and omni-directional vision

Here, we propose a simple sensor fusion method of the 2-D laser scanner and the omni-directional vision. Those laser and vision information can complement each other based on the directional

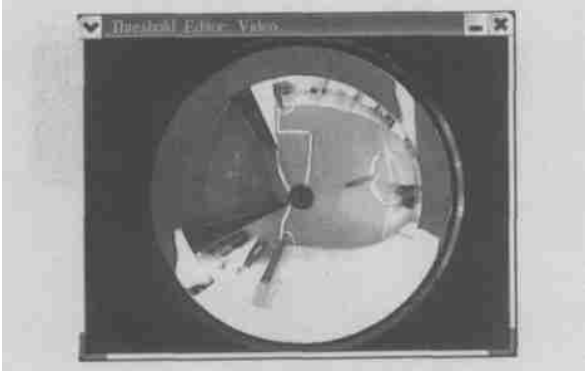

Fig. 2 A sample image

informations. Therefore the fusion makes mobile robot possible to do much better environment recognition and self-localization.

As explained before:

a. The 2-D laser scanner can provide precise directions and distance to line segments, corners and break points at the reflecting plane;

b. The omni-directional vision can provide directions of some landmarks in the environment.

So detected reflecting points in 2-D laser scanner and detected blobs in vision are fused to give environmental feature information based on the direction with following methods:

a. If the objects nearby the robot are polygons, we can use the data extracted from the laser scanner for localization and data extracted from the vision to verify;

b. If the objects nearby the robot have not obvious features such as line segment and corners break points, we can firstly use omni-directional vision to extract segment information and recognize these objects, and then we can use data extracted from the laser scanner to get the precise distance and direction information.

4 Experiments

Experiments were carried out in standard RoboCup land. There are two corner flagposts and one goal. So mobile robot can use these three landmarks to do self-localization. Standard RoboCup land behind the goalkeeper shown as Fig. 3.

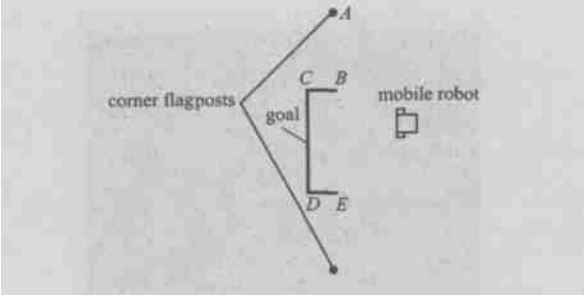

Fig. 3 Scheme of experimental environment

4.1 2-D laser scanner process

For RoboCup, instead of a net, a wall is placed around and behind the goal. The depth of the goal is at least 0.5 m. So the 2-D laser scanner can easily recognize it and measure the precise distance and direction of the reflecting points such as B, C, D, E, shown as Fig. 4.

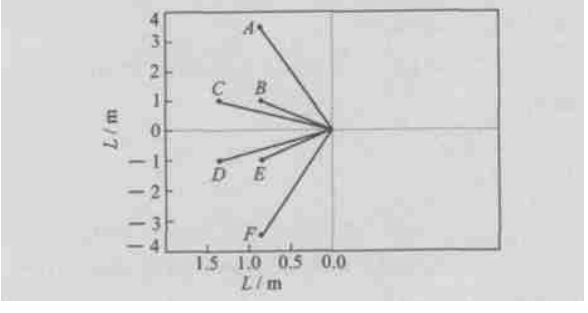

Fig. 4 Experimental result in the 2-D laser scanner

The corner flagposts are cylinders with a diameter of 20 cm and height of 1 m. If there is a person (i.e a umpire) nearby the corner flagpost, the laser scanner can't recognize which is the corner flagpost or the person. distinguish between the flagpost and the person.

Resultant detected reflecting points in the experiment are shown as Fig. 4.

4.2 Vision process

In the vision, the camera takes an image using the omni-directional mirror and then process the image to extract blob information. Resultant directions to detected blobs in the experiment are shown in Fig. 5.

4.3 Fusion

At the part of fusion, the detected blobs in omni-directional vision and the detected reflecting points in 2-D laser scanner are fused based on the direction information.

The fusion algorithm is as follows:

Initialize state of robot position

Fig. 5 Blob extracted by the omni-directional vision

```
deltangle = 0.5
for i = 1 :361 do
   Laser scanning
end for
if FoundGoalTowPost() then
   Localization by the data extracted from the laser scanner;
   Verify by the data extracted from the vision;
end if
else
   if OnlyFoundGoalOnePost() then
      Get the blob information of the cornerpost by vision;
      Get the direction information of the cornerpost;
      Get the precise distance information by laser;
      Localization;
   end if
end else
Updating the state of robot position
```

Result fused data in experiment shown as Fig. 6.

From the result of experiment, the method of fusing the distance and direction information extracted from the 2-D laser scanner and the blob information extracted from the omni-directional vision can obviously improve the robustness and precision in mobile robot localization.

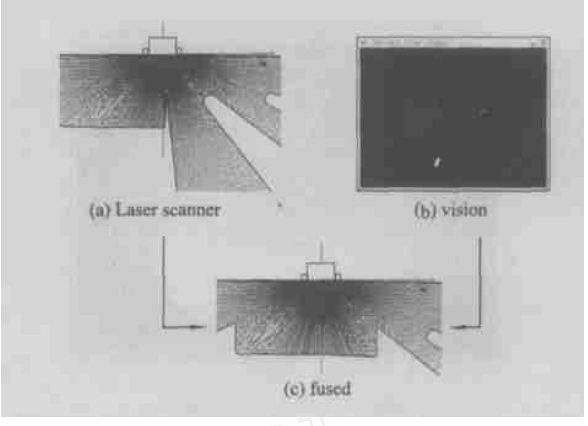

Fig. 6 Fused experiment result

Further work will be focused on real-time localization estimate and simultaneous map-building.

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