Proceedings of the 7th RoboCup IranOpen International Symposium and the 5th Joint Conference of AI & Robotics

Date of conference: April 12, 2015
Held in Iran, Islamic Azad University, Qazvin Branch
<table>
<thead>
<tr>
<th>رقم</th>
<th>عنوانمقاله</th>
<th>صفحه</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mars image segmentation with most relevant features among wavelet and color features</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Web Query Classification Using Improved Visiting Probability Algorithm and BabelNet Semantic Graph</td>
<td>9</td>
</tr>
<tr>
<td>3</td>
<td>An efficient hybrid approach based on K-means and generalized fashion algorithms for cluster analysis</td>
<td>14</td>
</tr>
<tr>
<td>4</td>
<td>Mobile Robot Navigation using Sonar Vision Algorithm applied to Omnidirectional Vision</td>
<td>22</td>
</tr>
<tr>
<td>5</td>
<td>Multi-view tracking using Kalman filter and graph cut</td>
<td>30</td>
</tr>
<tr>
<td>6</td>
<td>Developing Intelligent Full-scale Predictive Model of an Industrial Walking Beam Furnace Process Using Neural Networks</td>
<td>36</td>
</tr>
<tr>
<td>7</td>
<td>Enhanced Comprehensive Learning Cooperative Particle Swarm Optimization with Fuzzy Inertia Weight (ECLCFPSO-IW)</td>
<td>45</td>
</tr>
<tr>
<td>8</td>
<td>Polynomial Based Optimal Trajectory Planning and Obstacle Avoidance for an Omni-Directional Robot</td>
<td>53</td>
</tr>
<tr>
<td>9</td>
<td>Optimal Trajectory Planning for an Omni-Directional Mobile Robot with Static Obstacles: A Polynomial Based Approach</td>
<td>60</td>
</tr>
<tr>
<td>10</td>
<td>Word Concept Extraction Using HOSVD for Automatic Text Summarization</td>
<td>67</td>
</tr>
<tr>
<td>11</td>
<td>Consensus of Heterogeneous Multi-Agent Systems Using Static Output Feedback</td>
<td>74</td>
</tr>
<tr>
<td>12</td>
<td>A feature selection method based on minimum redundancy maximum relevance for learning to rank</td>
<td>82</td>
</tr>
<tr>
<td>13</td>
<td>A note on Pearson Correlation Coefficient as a metric of similarity in recommender system</td>
<td>89</td>
</tr>
</tbody>
</table>
Mobile Robot Navigation using Sonar Vision Algorithm applied to Omnidirectional Vision

MohammadHosseinBamorovatAbadi
Faculty of Computer and Information Technology Engineering, Qazvin Branch, Islamic Azad University, Qazvin,Iran
Email:M.bamorovvat@ymail.com

AhmadFakharian
DepartmentofElectrical, BiomedicalandMechatronicsEngineering QazvinBranch,IslamicAzadUniversity Qazvin,Iran
Email:ahmad.fakharian@qiau.ac.ir

MohammadrezaA.Oskoei
FacultyofMathematicsand ComputerScience UniversityofAllamehTabatabai ShahidBeheshtiAve.,Tehran,Iran
Email:oskoei@atu.ac.ir

Abstract—This paper presents a sonar vision algorithm applied to omnidirectional vision. It provides autonomous navigation for a mobile robot in an unknown environment. It uses omnidirectional images without any prior calibration and detects static and dynamic obstacles. It estimates the most intended path based on visual sonar beams in front of the robot. The proposed method was tested on a mobile robot in indoor environment. The experimental results show acceptable performance considering computation costs.


I. INTRODUCTION

The purpose of mobile robot navigation, moving in a structured or unstructured environment, and is transferred to the target. Vision-based mobile robot navigation, in a structured environment, without having any prior knowledge of the environment, a very powerful capability for robots is considered. A major advantage of image-based navigation systems, no need to have other sensors, and thus reduce the cost. Omnidirectional vision sensor for mobile robots are valuable because they are just in a frame provide full visibility of the surrounding environment of the robot [1]. This is important because knowing the positions of objects in the surroundings of the robot, will help robots to perform tasks such as matching or intuitive navigation map. 360 degrees field of view reduce visual perceptual bad view. In addition, use of omnidirectional vision system in a very dynamic environment and a burst of consecutive images of the environment around the robot, provides easy to use tracing techniques, to follow the desired objects.

Fig. 1. An example of the image captured by our catadioptic system.

The rest of the paper is as follows. In the section II, we’ve talked about special omnidirectional system, which created. In the section III, we have explained, the sonar vision algorithms. Also in this section, we describe the algorithm for estimating the path, avoiding collisions with obstacles and also remove the light reflection from the surface. In the section IV, we present
how the robot navigation. Then in the section V, presents the experimental results and discuss them. Finally, Section VI presents the conclusion and future plans we have.

II. OMNIDIRECTIONAL VISION

Since in this project we used omnidirectional camera for mobile robot navigation and purpose of the system is guided robot to specific locations in a way that does not collide with obstacles and objects ahead and have the ability to avoid a collision, thus have an omnidirectional camera if can observe uniform picture from surroundings of the robot and objects is good. The sanctions that Iran has been involved in recent years, as well as high cost omnidirectional vision system to buy from abroad and To obtain this kind of vision technology so we decided to take a different mirror catadioptric visual system design and build. we use [1, 4, 5] to build our mirror. For this reason, we have implemented our design, build and optimize omnidirectional vision system, with financial support, the Science and Technology Park of Gilan. This research was conducted by Grant No.2306 and Grant No.1591 and generously funded by the Science and Technology Park of Gilan. Technical designed of our mirror is in figure 2. Figure 1 show an example of the image captured by our catadioptric system.

In this paper we present a method for visual sonar, which was presented by Boyan Bonev and colleagues have used [3]. In this work, we only have to estimate the direction and to avoid colliding obstacle with visual sonars used.

III. SONAR VISION

the help of equation 1, sonar vision production and then we estimated path and the obstacles identified. Since our image is black and white, each pixel has a value of 255 was the first visual sonar, as it will prevent detection. To calculate the final motion vector that represents the path is correct and unobstructed path we took advantage of the unit vectors. As such, we've created a vector of motion using visual sonar vectors. Unit vectors added together and all the sonar target point representing the path is open and unobstructed to obtain. Then we point the ultimate goal and direction from the point of origin to the point of final motion vector drawing that represents us. Calculating a path through the following equations:
In this work, we developed a method based on sonar vision rings of the omnidirectional image inspired provided that known as the OmniVisual sonars (OV-sonars) introduced in [3]. The omnidirectional sonar including virtual beams [2, 3], which is a circle from the center and all the way up to the point where a gradient of the image would continue. The important thing is that we have not done any calibration on the camera image and the images are processed directly in the mirror and get to navigation. In this method, we directly use the image all the way to the navigation and images does not become to the panoramic image or the birds eye image. Therefore, processing speed has gone up as a result of the reaction of the robot path goes up against obstacles.

According to [3] k-th sonar $V_k = \{v_1, ..., v_r\}$ shows of r pixel of the omnidirectional image. any pixel $v_i$ tally with:

$$v_i = I_o \{i \sin \alpha + C_x, i \cos \alpha + C_y\}$$

$$\alpha = k.2\pi/N_s$$

where $I_o$ is the main 2D omnidirectional image with semidi-ameter r and center in $(C_x, C_y)$ and $N_s$ is the number of sonars proceed for each image. Figure 1 determine method of producing a visual omnidirectional sonar.

To do this, first we detect of the image edge with Sobel edge detection algorithm. Then the gray image with an appropriate threshold are converted to black and white image. Then with

$$V_{xi} = V_{x2} - V_{x1}$$

$$V_{yj} = V_{y2} - V_{y1}$$

$$f_k(x, y) = V_{xi} + V_{yj}$$

In this work, we predict the path for navigation, and along the way we will use the method of obstacle avoidance. An important point is that in all phases of navigation, just the way we use visual sonar. For obstacle avoidance we use the method in which Boyan et al [3] have proposed to have developed and innovative approach to predict the path will produce the visual sonar. Figure 3 define that how we obtain the unit vectors of a visual sonars. In figure 4-A method of visual sonar vectors to obtain the final vector and 4-B an example of a visual sonar vectors and obtain the final route are shown.

A. Obstacle Avoidance Based Sonar Vision

To identify obstacles and deal with them in accordance with [3] we use 17 visual sonar. But changes in the scattering sonar created (Figure 5-A).

We have to create a semi-spherical sonar, were inspired by [6]. But in the experiments, we found that there are problems in navigation. So we created our own special sonar. See figure 5. We have formed the sonar because: 1-Generally, no obstacles behind valuable for navigation, thus the behind barriers would not affect to navigation. 2-The vector that represents the outcome of the move, when there is no obstacle nowhere, the final vector selects straight forward if there is no obstacle in the way when Boyan scattering sonar, not choosing the right track. 3-When forward path is completely blocked, the resultant vector indicates the reverse direction, in case if sonar in semicircular form, do not choose a path. 4-In this case, do not need our
The robots have a circular shape. Figure 5 A and B display our sonars. Figure 6 A and B display semicircle sonars. As you see despite the length of the final vector is small but just right direction is detected. In the section III-B you will see how we will solve this problem.

According figure 7, you can see that in the case of Sonar are fully when there is no obstacle in the final vector is zero. In the figure 6, you can see that when the Sonar semicircle despite a correct diagnosis in the absence of an obstacle course but when there is an obstacle in the path can not be detected correctly. In the figure 5, you can see that when the sonar are as follows: in both cases, unobstructed and obstructed, the resultant vector, correctly detects the correct path.

\[ w(i) = V - S \] (5)

B. Direction Estimation Based Sonar Vision

We used an innovative method for estimating path. To do this we use a lot of visual sonar, to estimate the path. Unlike [3] that a large number of visual sonar to detect small obstacles sees fit, we hypothesized that the large number of sonar due to the resultant vector, recognizes the right track and will determine the path, and we will show the right path to take. The reason for this claim is that due to the large number of sonars, despite dealing with small obstacles, but the end result Sonar on the right track and will be open. To do this, we created a visual sonar for every 2.5 degree. To complete the picture 360 degrees, we took the 144 sonar use. The tests found that the estimated path of the robot do not need back sonars, as well. Therefore, to estimate the direction of 108 sonar, we use the form in figure 8. As you see in 8 - A the best direction estimated when there is no obstacle and correct path estimated when obstacle is in the robot forward.

C. Remove The Light Reflected From The Surface

Usually this happens on the surface gloss with light sources and the issue of domestic environments, are very common. Landscape reflected light is like an obstacle. To solve this problem, we decided to detect reflected light, and we forget them. In [3] boyan said that a pixel belongs to a reflected light when the HSV color space has a low saturation value (S), and a high value (V) is. Gradient of pixels with large difference V - S do not need be considered as an obstacle. So unlike [3], only the value w(i) with a certain amount of more than 100 tests were compared. If the number is above 100, it is not a barrier, and if the difference is below 100, the obstacle is detected.
Where \( v(i) \) and \( s(i) \) are value and saturation of pixel \( i \) in the HSV color space.

In all experiments and implementations in both the path and the minimal estimate of the barrier, the algorithm used to remove the light reflected from the surface. The following figure shows an example of the implementation of this algorithm. As you can see, all three pictures show the moment of testing. In figure 9 - A picture is related to the obstacle avoidance, and image 9 - B, the estimated path is. In both cases, the reflected light is detected correctly. In figure 9 - C, the reflection of light on the floor you can see a complete form.

IV. Navigation

We use a very simple method for robot navigation. To obtain the direction of the robot, we average the final angles of estimation an obstacle avoidance vectors to obtain the angle of the robot motion. Equation 6, use to obtain the final vector of estimation vector and obstacle vector as well. Algorithm 1, also, show how robot navigation in our project.

\[
J^* = \sum_{x,y} A(x,y)
\]

In this algorithm, when the final vector angle is between -2 to 2, is moving forward. Otherwise, the robot rotates to the right or to the left. As you can see, our motion algorithm is very simple. However, despite this simplicity, very accurate, and in almost all cases, the robot has detected the correct path. Also nowhere with not hit any obstacle. Neither fixed nor prevent movable barrier.

Algorithm 1 Navigation

INPUT: \( \alpha \) ← Angle where path estimate is achieve
INPUT: \( \beta \) ← Angle where obstacle avoidance is achieve
OUTPUT: \( SA \) ← Turn speed
OUTPUT: \( SF \) ← Forward speed

Begin

\[
\text{if } 2 < (\alpha + \beta)/2 < 90 \text{ then}
\]

\[
SA = 0.2, SF = 0
\]

\text{end if}

\[
\text{if } -2 < (\alpha + \beta)/2 < -90 \text{ then}
\]

\[
SA = -0.2, SF = 0
\]

\text{end if}

\[
\text{if } -2 < (\alpha + \beta)/2 < 2 \text{ then}
\]

\[
SA = 0, SF = 0.2
\]

\text{end if}

End

V. Experiments and Results

In this chapter we present our experiments on the robot ATRV-JR was tested. Figure 10 shows the image of the robot. Omnidirectional mirror that used in these experiments, it was designed and built by our initiative. The mirror using a simple digital camera, an
omnidirectional vision system has become. Omnidirectional mirror that was used in these experiments, it was designed and built by our initiative. The mirror using a simple digital camera, an omnidirectional vision system has become.

Laptop computer experiments we use it, have the following characteristics:
Model: DELL Studio XPS 1340
Central Processing Unit (CPU) : Intel(R) Core2 Duo P8600 @ 2.40 GHz
Physical Memory X 2 2 GB = 4GB Software:
Software, given the time constraints of the process is planned in C++. Visual library of digital camera was used to record, OpenCV under the ROS have been implemented. Operating system on which the software runs, Linux Ubuntu is. The interface for the robot, the environment is ROS.

The experiments were performed at ambient, indoor environments are Qazvin Islamic Azad University Department of Electrical, Biomedical and Mechatronics Engineering. Figure 10 shows the image of the corridor and robot when the tests were being conducted.

Test results: Processing time, (the estimated path and the lack of an obstacle), as well as the implementation of control commands to move the robot, is approximately 100 milliseconds.

Figure 12 shows the vector angle of the end result, which is sent to the robot motion. 96.9% of the cases, the deviation is below 10 degrees, and only 3.1%, is more than 10 degrees. Also, in cases of 81.3%, below 5 degrees, and at 18.7%, is more than 5 degrees. Because of the large deviation, robots

Fig. 12. Result of the angle where path estimate and obstacle avoidance achieve for a corridor. 96.9% of the cases, the deviation is below 10 degrees, and only 3.1%, is more than 10 degrees.
are not placed in the right direction at first, to test whether the robot detects the right direction, or not? Because of the large deviation in the end, because it is also a movable barrier (human) we pass to the next robot, which is to be determined whether the robot is able to detect a moving obstacle, or not? As is known, the beginning and the end, the direction is detected, and prevents properly diagnosed, and robot smoothly and quickly returned to the mainstream.

Figure 11 depicts the movement of the robot in the test environment. As is known, the robot is able to correctly discern the correct path, and continue to move along the corridor. Also, barriers to properly diagnosed, and then the path is correct. After crossing the barrier, again in the right direction, the momentum has continued.

VI. Conclusions and Future Work

In this paper, we have developed a method, which is capable of robot navigation in different environments. First, we examine the environment, and estimate the path. Then stationary and moving obstacles and barriers identified, and they leave behind. Both methods, with the help of sonar vision algorithms, have been conducted.

These methods are based on omnidirectional images. Due to the omnidirectional vision system, ease of installation and received a full, 360-degree images of around the robot is in a single frame. This method can be used in different environments, with no previous knowledge of the environment. This can be done by any of the omnidirectional vision system, and without any calibration and change the picture mode. Also, this method has low computational cost. By combining this method and omnidirectional vision system, and due to the low computational cost, almost robots in all cases, be able to identify the correct way, and the route, fixed and moving obstacles easily detected, and avoid dealing with them.

This would greatly improve, previous forms of this method, the uncertainty as it was. Especially in indoor, light reflected from the surface is detected by a particular method, and it was

**Fig. 10.** An image of a robot and interior corridors.

**Fig. 11.** Plot of a trajectory performed by the robot
not chosen as a barrier, and to ease the path continues. It is still uncertain, and this method can not be trusted 100%.

The disadvantage of this method is that the robot motion is periodic, the robot does not move smoothly and continuously. Another drawback of this method is dependent on the ambient lighting. A major drawback of this method is dependent on edge detection. In environments that can not be properly edge detection, this method will be in trouble. In continuation of our research, we are looking at ways that can reduce dependence on edge detection and improve the problem [7]. Also working on other control methods for this kind of robot motion, becomes softer [8].

ACKNOWLEDGEMENT

We would like to thank Mohammadreza Shahabian Alashti, Seyed Navid Nabavi, Mohammadreza Beyad and Farshid Abdollahi for many useful suggestions related to this work.

REFERENCES


