Proceedings of the 17th World Congress
The International Federation of Automatic Control
Seoul, Korea, July 6-11, 2008

Environment Measurement and object Recognition for Autonomous Mobile Robot's Navigation in Automated Shipbuilding

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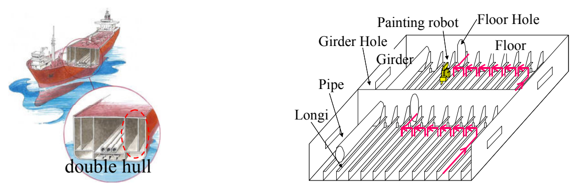
Abstract: Nowadays many parts of shipbuilding process are automated, but the painting process is not, because of the difficulty of automated on-line painting quality measurement, harsh painting environment and the difficulty of robot navigation. However, the painting automation is necessary, because it can provide consistent performance of painting film thickness. Furthermore, autonomous mobile robots are strongly required for flexible painting work. However, the main problem of autonomous mobile robot's navigation is that there are many obstacles which are not expressed in the CAD data. To overcome this problem, environment measurement, obstacle detection and recognition are necessary. In this paper the environment measurement and object recognition algorithms are introduced

1. INTRODUCTION



(a) double hull (b) painting automation

Fig. 1. Double hull structure of ship and painting automation

Although many processes of ship building have already been automated, the construction period is frequently delayed by some bottleneck processes. The representative one among them is painting process. In that process, a ship body is painted in several layers, each of which is has minimum thickness criterion. The painting process is very important because the paint film protects the ship body from being rotten by sea water. Therefore duration of a ship body is not insured by defective paint film. The reason of this bottleneck process is in difficulty of making painting film of proper thickness. One may avoid thickness insufficiency by spraying paint enough times, but too much spraying causes other problems: it is waste of resources, and wrinkling may occur after drying. Because the human labors engaged to paint ship bodies only rely on their feeling and experience in estimating the film thickness, the film quality fully depends on their skillfulness and usually is not consistent. This situation raises necessity of painting automation. By inserting robots for painting process, it is expected that it will not be a bottleneck anymore because they will provide consistent performance, once they are adjusted. But there are still many issues in automating the painting process. One thing is the complexity of the inner structure of ship bodies. International Maritime Organization (IMO) made a law at 2005, in which a ship must have double hull structure as shown in Fig. 1(a) for safety and protection of the environment. This complex inner structure prevents robots from moving freely, therefore, elaborated robot moving mechanism and path planning algorithm are required. The other is illumination problem. Because no illumination is provided inside the structure and there are dense paint particles in the air, vision based algorithms for robot navigation, which are popularly used, cannot be adopted in this case.

Fig. 1(b) shows a schematic diagram of inner structure of a ship body and a mobile robot working in the block of double hull structure. In the block there are many obstacles such as anode, pipe and ladder which are not included in the CAD information. To navigate inside block automatically avoiding the obstacles and paint the wall, the mobile robot should be able to detect obstacles and recognize them.

2. THE DEVELOPED SENSING SYSTEM

All blocks are covered tightly, so there is lack of natural illumination. Therefore, for sensing the environment, only active vision sensors such as laser structured light, moiré method (Lee et al., 2007) and range finder can be used. In this paper, an active vision sensor system with laser structured light. The size of sensor system is 180×256×100mm. Three rotation stages are mounted for panning and tilting motion which is for scanning process.

3. PROPOSED OBJECT RECOGNITION ALGORITHM

Almost all block shapes are expressed in the given CAD information. However, pipe, ladder and anode which are

978-1-1234-7890-2/08/$20.00 © 2008 IFAC 10.3182/20080706-5-KR-1001.1691

temporally equipped objects for labor's working locate inside block, which is not expressed in the CAD information. So, for efficient painting process and robot navigation, obstacle detection and recognition process are necessary. Additionally, the processing time must be short for real time robot navigation. Here, we introduce a new object detection and recognition algorithm.

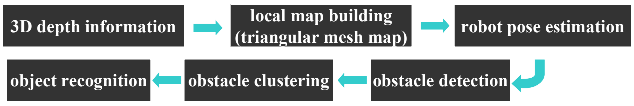


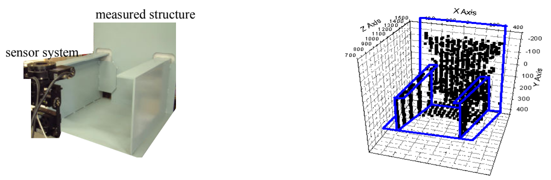
Fig. 2. Flow chart of proposed object recognition algorithm

Fig. 2 shows the flow chart of proposed object recognition algorithm. The proposed algorithm consists of five steps : 1) local map building by using triangular mesh map 2) robot pose estimation by using particle filter (Gustafsson et al. 2002) 3) obstacle detection by using spatial filtering 4) obstacle clustering by using minima rule (Katz et al., 2003) 5) object recognition by using Principle Component Analysis (PCA) (Zhujie, 1994) and Neural Network (NN). The novelty is that the measured 3D range data is transformed into intensity information, and then adopts the PCA and NN algorithm for transformed intensity information to reduce the processing time and make the data easy to handle which are disadvantages of previous researches of 3D object recognition.

4. EXPERIMENTAL RESULTS

1.1 3D environment measurement

Through scanning process using rotation stages, we can acquire whole 3D depth information as shown in Fig. 3(b), where the scanning range is between -20 degree and 20 degree, and detected at each 1 degree. The scanning time is less than 30sec.

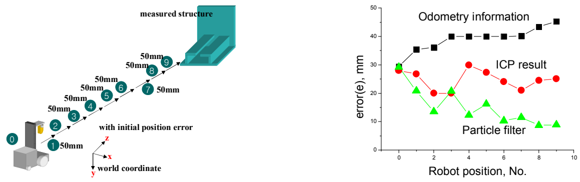


(a) measurement environment (b) measurement result

Fig. 3. Measurement environment and sensing result

1.2 Robot pose estimation by using particle filter

In Fig. 4, the robot localization by using particle filter is more accurate than other methods. The initial position has error so that the odometry information and Iterative Closest Point (ICP) result cannot detect the robot position accurately. The error means the distance between true position and measured position of mobile robot. The true position of robot was detected by laser sensor whose accuracy is 1mm. As shown in Fig. 4, the detected robot position by using particle filter is near to true value. The processing time for robot localization is less than 20 sec.

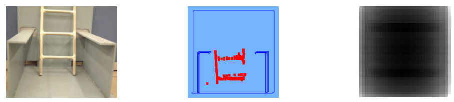


(a) robot path (b) localization error

Fig. 4. The result of robot localization

1.3 Object recognition by using PCA and NN

Fig. 5 shows the experimental results for ladder. If the result [y_1 y_2 y_3 y_4] of NN indicates [0 0 1 0] as shown in Fig. 5(d), the object is recognized ladder. In Fig. 5 (b), we can see the measurement error which is shown as isolated point, but in our algorithm in clustering process these errors can be except. As a result, we can know that our proposed algorithm is well operated for ladder basic. The object recognition time is less than 10 sec and the recognition rate is over than 95%.

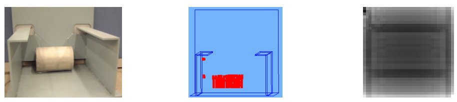


0 0 1 0

(Ladder)

(a) real env. (b) obstacle detection (c) PCA result (d) NN result

Fig. 5. Example 1 of object recognition



0 1 0 0

(Horizontal Cylinder)

(a) real env. (b) obstacle detection (c) PCA result (d) NN result

Fig. 6. Example 2 of object recognition

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