

3D Vision Based Local Obstacle Avoidance Method for Humanoid Robot

Do-Young Lee, Yan-Feng Lu, Tae-Koo Kang, In-Hwan Choi and Myo-Taeg Lim*

School of Electrical Engineering , Korea University, Seoul, 136-713, Korea
 (Tel : +81-2-3290-3243; E-mail: {mlim, dozero4}@korea.ac.kr) * Corresponding author

Abstract: In this paper, a 3D vision-based local obstacle avoidance system is designed and developed on a humanoid robot so that it can decide avoidance direction and walking motion effectively. We use a panorama environment map using speeded up robust feature (SURF) which is a robust image detector and descriptor to handle the obstacles which exist beyond the field of view. Moreover, we propose an avoidance direction decision method and a fuzzy logic based avoidance motion selection method. The robot decides the avoidance direction and avoidance walking motion for the obstacle by itself under information such as the size of objects and avoidance spaces. The proposed system is applied to the humanoid robot which we have built up with a Time of Flight camera. The results of the experiments show that the proposed method can be effectively applied to decide the avoidance direction and the walking motion.

Keywords: Obstacle avoidance, geographical measurement, avoidance motion selection, Humanoid robot

1. INTRODUCTION

Humanoid robot has recently evolved into an active area of research and development. Many related researches, such as autonomous walking, obstacle avoidance, stepping over the obstacle, walking up and down to the slope and stairs, have been studied. The works [1][2] presented the vision guided foot planning system to avoid the obstacles with the Nao and the HRP-2. These systems get the environment information from the top view installed above the humanoid robot. The work [3] presented the stereovision based locomotion planning which can modify robot's waist height and an upper body posture according to the size of the available space.

In this paper, we focus on the obstacle avoidance using vision system. Especially, we deal with a field of view problem and external path planner problem. The field of view problem occurs whenever humanoid robot faces to the large size obstacles so that humanoid robot can't precisely estimate the obstacles size and decide appropriate reaction. Therefore, we propose Surf based Panorama Environment Map (SPEM) for the problem.

In addition, external path planners which furnish information regarding the walking path and obstacles have been used to make humanoid robot predefine goal position [4]. However, this assumption that the path planner knows all information regarding walking environment in advance is not appropriate if humanoid robot walks under the unknown environment. We propose Avoidance Direction Decision (ADD) and Avoidance Motion Selection (AMS) methods to overcome these problems. The ADD calculates the complexity for the avoidance direction so that a humanoid robot can decide the avoidance direction itself. The AMS system also decides a walking motion of humanoid robot for the obstacle avoidance using obstacle information from 3D vision system.

This paper is organized as follows. In Chapter 2, we introduce the system architecture of humanoid robot. In

Chapter 3, 3D vision based local walking planning system is introduced. In Chapter 4, the results of experiments focusing on verifying the performances of the proposed system is given. Chapter 5 concludes the paper by presenting the contributions and the future works.

2. SYSTEM STRUCTURE OF OBSTACLE AVOIDANCE METHOD

In this paper, 3D vision-based humanoid robot is designed to implement the proposed obstacle avoidance method.

The system block diagram of the obstacle avoidance method is described in Fig. 1, where one 3D vision system is installed on the humanoid robot to obtain the information of environment so that ADD system and AMS methods based on fuzzy logic can be proposed.

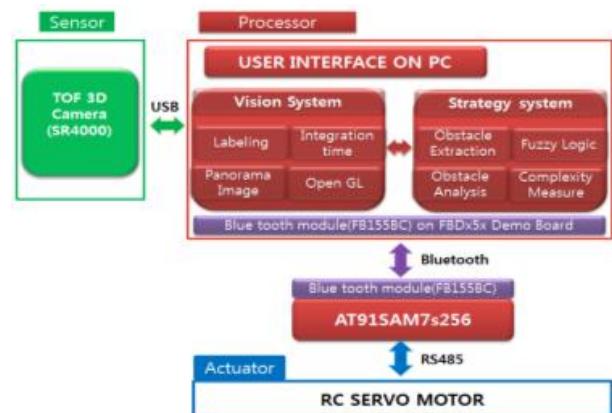


Fig. 1 System block diagram of obstacle avoidance system for humanoid robot.

In the vision system, the Time of Flight 3D Camera is installed on the one-dimensional waist mechanism so that the visible area of the robot is expanded by the mechanism to obtain its environment image.

3. LOCAL WALKING PLANNING SYSTEM

3.1 SURF based Panoramic Environment Map

SURF is a new feature extraction algorithm which is proposed recently. It approximates or even outperforms previous proposed schemes such as SIFT with respect to repeatability, distinctiveness, invariance and robustness [5][6]. The remarkable characteristic of SURF is its rapid speed. It can be used on a robot platform so that we use SURF to achieve the panorama image.

Panorama environment map can be obtained by using the SURF. We show the flow diagram of our stitching process in Fig. 2 [7].

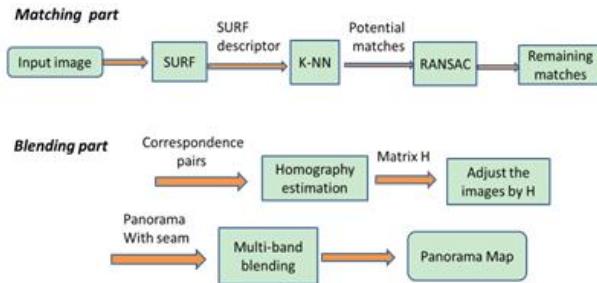


Fig. 2 Flow diagram of panorama stitching system

3.2 Obstacle Extraction and Analysis

From the SPEM, we can extract the obstacles and analysis their information. In order to extract the obstacles, we have to detect the blob in 3D panorama image. The blob detection proceeds using the labeling method. Preprocessing is needed like the level-set division because the labeling proceeds under the binary image condition.

Let θ and ϕ be an angle onto xz and yz plane and r be a distance from camera to obstacle respectively. Furthermore, the angles for each pixel position can be estimated using Fast Normalized Cross Correlation [8]. Each corresponded point is considered as the angular position from -30 to 30 degree with an interval of 10 degrees. The angle at each point can be calculated from the SPEM using linear interpolation as follows:

$$\theta = \begin{cases} (\mathbf{A}_{i+1} - \mathbf{A}_i) / (x_{\mathbf{A}_{i+1}} - x_{\mathbf{A}_i}) \times (x - x_{\mathbf{A}_i}), & \mathbf{A}_{i+1} > \mathbf{A}_i > 0 \\ (\mathbf{A}_i - \mathbf{A}_{i+1}) / (x_{\mathbf{A}_i} - x_{\mathbf{A}_{i+1}}) \times (x_{\mathbf{A}_i} - x), & 0 < \mathbf{A}_{i+1} < \mathbf{A}_i \end{cases} \quad (1)$$

$$\phi = \begin{cases} (\mathbf{B}_{i+1} - \mathbf{B}_i) / (y_{\mathbf{B}_{i+1}} - y_{\mathbf{B}_i}) \times (y - y_{\mathbf{B}_i}), & \mathbf{B}_{i+1} > \mathbf{B}_i > 0 \\ (\mathbf{B}_i - \mathbf{B}_{i+1}) / (y_{\mathbf{B}_i} - y_{\mathbf{B}_{i+1}}) \times (y_{\mathbf{B}_i} - y), & 0 < \mathbf{B}_{i+1} < \mathbf{B}_i \end{cases}$$

where, $A = \{-30, -20, -10, 0, 10, 20, 30\}$ and $B = \{-17, 0, 17\}$. To calculate the obstacle information such as size or location, we have to transform from spherical to cartesian coordinates.

Fig. 3 shows the method that location and width of the obstacle is calculated geometrically.

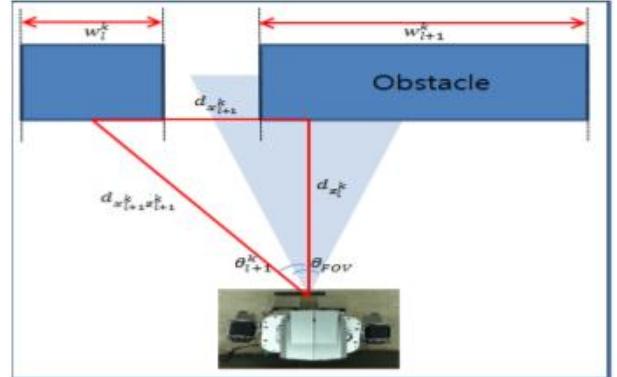


Fig. 3 Obstacle analysis: location and width calculation

3.3 Avoidance Direction Decision

Obstacle information we get from obstacle extraction and size estimation is used as the input data to decide the direction for avoiding obstacle. To decide the avoidance direction, we define the Avoidance Direction Decision (ADD) as follows:

$$ADD = \begin{cases} \sum_{k=1}^m \sum_{l=1}^n 2^k + 2^{\frac{\pi}{2} - \theta_l^k} + w_l^k, & \theta_l^k > 0 \\ \sum_{k=1}^m \sum_{l=1}^n 2^k + 2^{\frac{\pi}{2} - \theta_l^k} + w_l^k, & \theta_l^k < 0 \\ \sum_{k=1}^m \sum_{l=1}^n 2^k + w_l^k, & \theta_l^k = 0 \end{cases} \quad (2)$$

As shown in equation (2), geographical measure is determined by three factors such as distance, width of the obstacle, and angle. Therefore we get the final decision as follows:

$$Direction = sign(\sum_{all\ obstacle} ADD) \quad (3)$$

3.4 Fuzzy logic based Avoidance Motion Selection

After we decide the direction to avoid the obstacle, walking motion has to be selected depending on the environment condition such as width of obstacle and open space for avoidance. Therefore, we propose the Fuzzy Logic based Motion Selection method.

In order to perform the fuzzification, width difference between obstacle width and robot width, and space difference between avoidance space width and robot width are set up as the input variables.

Walking motion type consists in seven motions, ST, SS, SF, RS, RF, TS and TF which are combination of two motions in sidestep(S), forward(F), rotation(R), and turning(T). Table 1 shows the fuzzy rule table for the walking motions.

Table 1 Fuzzy Rule Table

w_{rs} w_{ro}	Very narrow	Narrow	Wide
Short	Stop	SS	SF
Normal	Stop	RS	RF
Long	Stop	TS	TF

4. EXPERIMENT RESULTS

We implemented our approach on the humanoid robot we built with installed TOF camera. The robot's chest provides disparity images (176x144) at 30frames per second (fps).

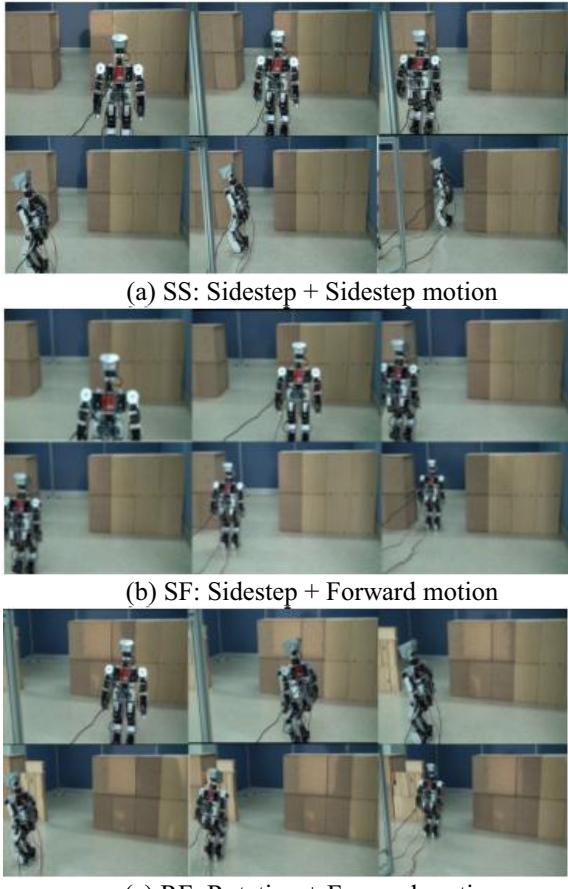


Fig. 4 Obstacle Avoidance Walking under Various Obstacle Conditions.

For testing our method, we set up an obstacle environment containing obstacles of different size and avoid space. Experiment space is 2.7m x 3m and there is a type of artificial obstacle which is 23.7cm(W) x 32.4cm(H) x 30cm(D) respectively. This obstacle is used in various shapes by combining the obstacle, so we can set up the obstacles with various width and space.

We evaluated the decision and control performance under the various obstacle conditions with the obstacle width and avoidance space. Experimental results are shown in Fig. 4 which shows the image sequences for results under SS, SF, RF respectively. There are, however, some problems that the robot isn't able to control walking efficiently due to slip and hardware defect. In order to solve this problem, the robot needs control algorithm for stable walking.

5. CONCLUSIONS

In this paper, we introduced the 3D vision based obstacle avoidance method for humanoid robot. The

proposed method is based on the panorama image and fuzzy logic. The panorama image can be a solution for the field of view problem that may be cause of the incorrect decision or perception of environment. Fuzzy logic system dynamically decides the walking motion depending on the obstacle conditions using the information from the panorama image.

The proposed system generates the path to avoid the obstacles by considering the environment condition such as size of obstacles, distance from the humanoid robot to obstacles. These systems don't need the path planner which has all information regarding the obstacle location and path information in advance.

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