

Object Tracking of Mobile Robot using Moving Color and Shape Information for the aged walking

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Abstract

A mobile robot with various types of sensors via ubiquitous networks is introduced. We designed a mobile robot composed of TCP/IP network, wireless camera and several sensors in an environment, and show object avoiding and tracking methods necessary for providing diverse services desired by the people. To avoid obstacles(objects), active sensors such as infrared rays sensors and supersonic waves sensors are employed together and measures the range in real time between the obstacles and the robot. We focus on how to track a object well because it gives robots the ability of working for human. This paper suggests effective visual tracking system for moving objects with specified color and motion information. The proposed tracking system includes the object extraction and definition process which uses color transformation and AWUPC computation to decide the existence of moving object. Active contour information and shape energy function are used to exactly tract the objects with shape changes. Finally, real time mobile robot avoiding and tracking objects is implemented.

Keywords: Object tracking, Moblie robot, Moving color and shape information

1. Introduction

In resent years, vast telecommunication infra is furnished and internet is not for special person. Building a ubiquitous network infrastructure for our society by utilizing the latest information technologies (IT) is a key issue in realizing an safe, secure, exciting, and convenient society in the 21st century. On the other hand, interactive robots living together with people in non-industrial application areas have appeared recently. Such ubiquitous robot applications including various services such as disaster rescue, home use, health care, transportation, education need to integrate various sensors, the ubiquitous network technology and robot technology. Among the technologies, we focused on how to avoid and track a object well because it gives robots the interactivity and the basic ability of working for human in real life. In this paper, avoiding technology employed several infrared rays sensors and supersonic waves sensors together and measures the range in real time between the obstacles(or wall) and the robot. To track a object, a wireless camera system was installed in the mobile robot and the image processing technology is implemented in the server computer on the network. This paper mainly describes on the visual object tracking method in ubiquitous. In visual object tracking, handling changes of viewpoint or object aspect has still been challenging[1]. This paper aims for robust object tracking method. we extract the group of candidates for

objects using the color distribution and the motion information and decide final object regions using a signature parsing algorithm and finally suggests the tracking method for detected object regions. The methods can be summarized as follows. First, the normalized RGB color distribution and moving color information are combined for robust separation between the object and the background. Second, this method shows that the objects are segmented and extracted well using signature parsing method, regardless of the shape variation. Third, recovering noises and unexpected variation is important for robust object tracking, the major control points of shape information are defined to the boundary region of the moving object to guarantee the tracking performance. Finally we show one application of mobile robot avoiding obstacles and tracking the special object.

2. Mobile Robot System

Figure 1 shows mobile robot system designed in this research. Mobile robot integrates various information from sensors such as infrared rays sensors, supersonic waves sensors and wireless cameras and send them to the server computer. The server computer calculates the range from obstacles or objects with active sensors in avoiding mode and detects object's shape and color with a wireless camera in tracking mode. Finally the computer sends control signals to the robot.

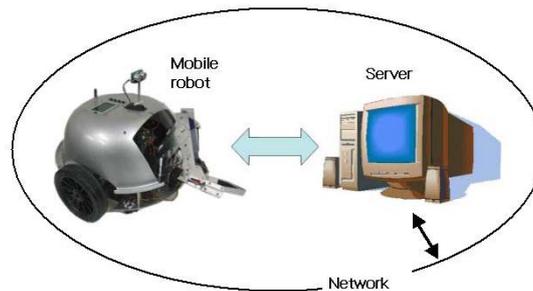


Figure 1. Mobile robot system

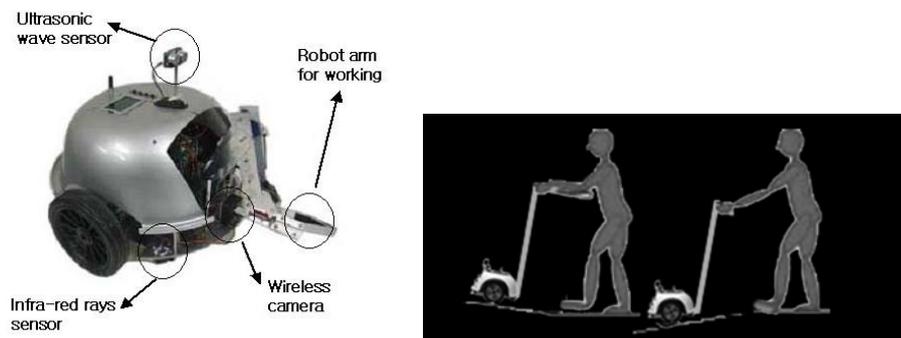


Figure 2. The structure of mobile robot and application

The structure of mobile robot and application example for older people is shown in figure 2. It employed a wireless camera on the lower part behind the robot arm. It sends image data to the server computer in real time and they are used to avoid obstacles and track the specified objects.

3. Extraction of the Object Region

3.1 Normalized color transform

The input image is used for the object's color transform using the intrinsic color distribution. Since the color information is very sensitive to the brightness value of the pixel, each color component is normalized with the brightness value[2]. If $R(x, y)$, $G(x, y)$ and $B(x, y)$ are the color component values of each pixel position, the intensity of the pixel is given by $I(x, y) = R(x, y) + G(x, y) + B(x, y)$. The normalized color components $r(x, y)$ and $g(x, y)$ of each pixel position at (x, y) is defined as follows.

$$r(x, y) = R(x, y) / I(x, y), g(x, y) = G(x, y) / I(x, y) \quad (1)$$

The specified object color distribution in the normalized (r, g) domain can be approximated by the 2D Gaussian distribution. The 2D Gaussian model is used as the GOCD (generalized object's color distribution) with generalized mean value and standard deviation. The input color image can be transformed into a gray level image $Z(x, y)$ which shows the enhanced object regions whose intensity value suggests the possibility of being object color.

3.2. Moving color transform using AWUPC

To exploit the object's motion information, motion detection measurement using unmatched pixel count (UPC) is used. The UPC is a block-based method and has simple computational operation[3]. The proposed AWUPC operation is defined as (2) where $Z(x, y, t)$ is the GOCD transformed image and $U(i, j, t)$ is the UPC motion detected image. The AWUPC operation emphasizes only the region with a motion in the skin-color enhanced region.

$$AWUPC(x, y, t) = Z(x, y, t) * \sum_{i=x-N}^{i=x+N} \sum_{j=y-N}^{j=y+N} U(i, j, t) \quad (2)$$

where

$$U(i, j, t) = \begin{cases} 1, & \text{if } |Z(x, y, t) - Z(x, y, t-1)| \leq V_{th} \\ 0, & \text{otherwise} \end{cases} \quad (3)$$

Then, to decide the threshold value in (3), a sigmoid function [4] is introduced to induce a object's colour weighted threshold value and is shown as (4)

$$V_{th} = \frac{255}{1 + e^{\frac{Z(x, y, t) - \frac{255}{2}}{2}}} \quad (4)$$

Where $Z(x, y, t)$ is an input pixel value at time t and α is a coefficient that decides the slope of threshold curve of sigmoid function. The effectiveness of object color weighted threshold value can be described as follows. The input pixel's value defines the probability of faces. A region that has high probability of the specified objects may be combined with a low threshold value to detect objects very well even when a slight motion. On the contrary, a region with low probability of the objects should be combined with a high threshold value to be decided as the object only when it has a large motion.

3.3. Segmentation of the moving object

The signature analysis method is implemented repeatedly to extract and decide the final moving objects on the preprocessed images[5]. First, the signatures on each vertical and horizontal direction are calculated. The signatures are obtained as follows.

$$S_h(i) = \sum_j^M f(i, j), S_v(j) = \sum_i^M f(i, j) \quad (5)$$

where M and N are the size of input image, $S_h(i)$ is the horizontal sum of the image strength(pixels) on each row(i), $S_v(j)$ is the vertical sum of the image strength(pixels) on each column(j). The transition points are defined where the sum of the image strength changes from 0 to positive value or from the positive value to 0. These transition points form lines on each horizontal and vertical directions and the lines are defined 'band'. These horizontal bands are virtual lines across to the transition points horizontally. The horizontal and vertical bands form the rectangle subregion(box) which provides the candidate region for tracking objects. All objects we are detecting exist in any of these candidate subregion(box).

4. Tracking Moving Object

4.1 Shape information function for objects

To obtain the position and the shape information of the tracking objects, the shape information function is defined briefly and used for the initial clues to track the object in the next image frame. The function is defined as follows.

$$S_{obj} = A_{obj} + C_{obj} \quad (6)$$

S_{obj} is the shape information function of a object and A_{obj} is the sum of pixels which is higher than the specified threshold of the moving color pixels in each segmented subregion. C_{obj} means the distance between the center of the subregion and the object's edge points in each x and y direction. This information includes the area and the contour information from the center of the object, which is the important clues to estimate the similarity of the tracking object between image sequences.

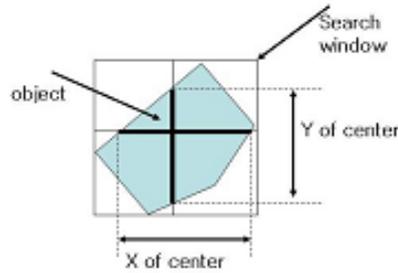


Figure 3: C_{obj} : the distance between the center of the subregion and the object's edge points in each x and y direction

4.2 Correspondence problem

To solve the correspondence problem between the objects in the previous and the present frames, the shape information function is combined with the weighting function which means the total energy of the object region. The combined equation is used to decide the similarity of corresponding object in each frame. The variation of the shape information function between each sequence is defined by following equation.

$$\begin{aligned} \Delta Shape(i, j) &= Shape^t(i) - Shape^{t-1}(j) \\ (i = 1 \dots N, j = 1 \dots N) \end{aligned} \quad (7)$$

The variation of the object distance between frames is defined in (8)

$$\Delta DIST(i, j) = DIST(i^t, j^{t-1}) \quad (i = 1 \dots N, j = 1 \dots N) \quad (8)$$

where DIST is as follows.

$$DIST(i, j) = \sqrt{((x_i - x_j)^2 + (y_i - y_j)^2)} \quad (9)$$

The final correspondence is decided by total function change, $C_{or}(i, j)$

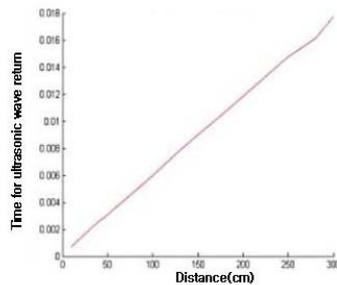
$$\begin{aligned} C_{or}(i, j) &= k \times \Delta Shape(i, j) + l \times \Delta Dist(i, j) \\ (i = 1 \dots N, j = 1 \dots N) \end{aligned} \quad (10)$$

where k and l are the weighting parameters of each shape and distance value. If we suppose N to the number of objects, $N \times N$ function are generated. Finally, the object i at time t corresponds to the object j at time $t-1$ which minimizes the $C_{or}(i, j)$ result.

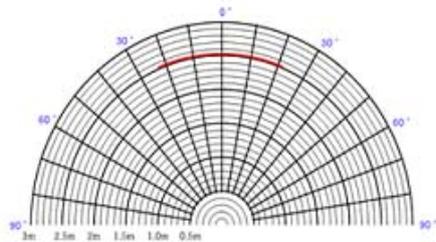
5. Experiment

5.1 Range Estimation using sensors

In this experiment, avoiding technology employed several infrared rays sensors and supersonic waves sensors together and measures the range in real time between the obstacles(or wall) and the robot.



(a)The change of time for wave return according to the range



(b) graphical representation for range and angle

Figure 4. Range estimation and representation using ultrasonic wave sensors

The mobile robot employed 1 ultrasonic wave sensor(SFR04) and 3 infrared rays sensors(GPD2D12) and used Atmega 128 for MCU. Figure 4(a) shows the relation between the range and the time for ultrasonic wave return is linear. We can estimate the range from obstacles by calculating the time for ultrasonic wave return caused by interrupt signal. Figure 4(b) is graphical representation for the range and the angle of obstacles from the robot. The range is limited from 10 to 300 cm

5.2 Extraction of the moving color

Table 1 shows that the pixels of interest more than the specified threshold of the improved image gather in small area regardless of the changes of the different color and the illuminant variation.

The distribution of the specified pixel group varies in 10% regardless of the changes of the conditions.

Table 1. Object's area changes on different condition

Illuminant Color	250lx	300lx	350lx	400lx
	sample 1	2234	2187	2093
sample 2	2389	2366	2271	2240
sample 3	2290	2261	2206	2139

5.3. Experiments for object tracking

Figure 5 shows final object tracking results which include the image segmentation using moving color information, binary operation and signature parsing method. For each subregion, the number of effective pixels for object is obtained and only the effective subregions having enough pixels for the moving object are regarded as effective area for object and the contour box information remains only on the effective subregion as shown in figure 6.



Figure 5. Image segmented subregion

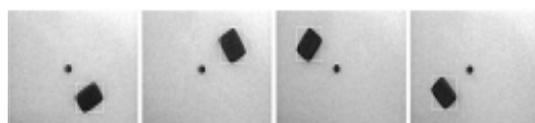


Figure 6. Effective sub region including objects

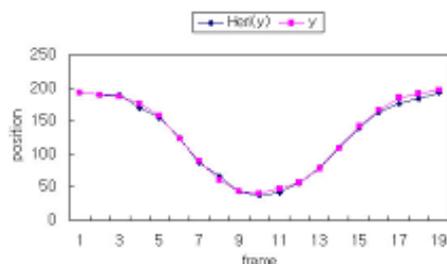


Figure 7. The result of position estimation on y axis(measured(y) vs. calculated(Heri(y)))

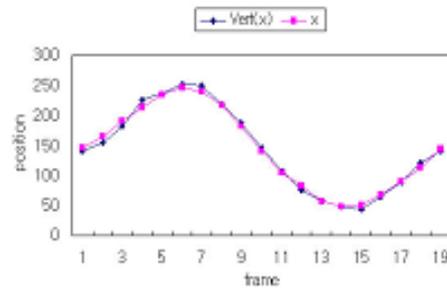


Figure 8. The result of position estimation on x axis(measured(x) vs. calculated(Vert(x)))

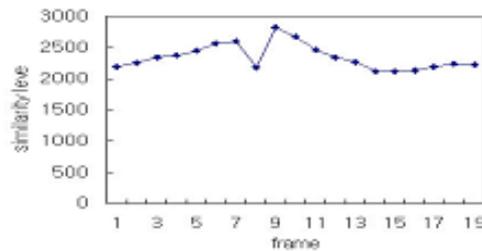
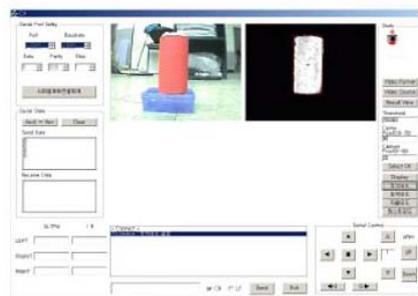


Figure 9. The variation of shape information function on each frame

To evaluate the suggested algorithm, simulated object running hardware is designed and its running track and exact position on each time are predefined to compare with the calculated object position. The result of the position between the measured value and the calculated value is shown in figure 7 on x axis and in figure 7 on y axis. Figure 9 shows the variation of shape information function on each frame which do not exceed 20% in variation on all frames.

Figure 10(a) shows the practical object tracking software which includes object detection and communication methods between the mobile robot and server or client PC and figure 10(b) shows how to grab the object using object tracking algorithm.



(a)

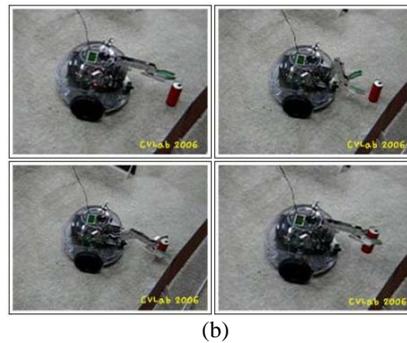


Figure 10. The practical object tracking software (a) and the steps for object grab(b).

6. Conclusion

A mobile robot with various types of sensors via ubiquitous networks is introduced. We designed a mobile robot composed of TCP/IP network, wireless camera and several sensors in an environment, and show object avoiding and tracking methods necessary for providing diverse services desired by the people. To avoid obstacles(objects), active sensors such as infrared rays sensors and supersonic waves sensors are employed together and measures the range in real time between the obstacles and the robot. We focused on how to track a object well because it gives robots the ability of working for human. This paper suggests effective visual tracking system for moving objects with specified color and motion information. The proposed tracking system includes the object extraction and definition process which uses color transformation and AWUPC(Adaptive Weighted Unmatched Pixel Count) computation to decide the existence of moving object. Active contour information and shape energy function are used to exactly tract the objects with shape changes. Finally, real time mobile robot avoiding and tracking objects is implemented to verify the effectiveness of the technique

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