# New Wavelet Based Algorithm for Real Time Visual Tracking

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*Abstract*— **in this paper, we propose a new technique in wavelet domain for real time object detection and tracking in a sequence of images.**

**The object to be tracked is identified in the first frame. Our proposed algorithm consists of two phases: the first, wavelet based edge detection is used to form ground boundary map. Then, Object dimensions estimation is implemented to determine probabilistic object areas. finally, target detection based on finding best match using feature vectors is applied. We defined dispersion of wavelet detail coefficient in object area as feature to be matched. Also we proposed a new color model for images to be used in processing algorithm. Our experimental results show that the algorithm is robust and fast. It is also insensitive to changing illumination condition and size of target.**

## I. INTRODUCTION

Tracking a moving object is useful in many problems, like collision avoidance, surveillance, gesture recognition, distance education with live teach, searching sport clip, mobile robot techniques, etc.

This paper describes a new real time algorithm for tracking user-selected object in a sequence of images by mobile robot.

The object to be followed is identified to the system. This application include the use of moving camera mounted on mobile robot and tracking of moving object differing in their looks and real-time operation in a changing environment.

For detection interested object in search window, this paper uses template matching, which measure the degree of similarity between reference object and the search window.

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The images to be matched are required to go through a number of operation before the similarity is determined. These operation include feature extraction, similarity measurement and searching for the best match. Some methods directly use image pixel gray scale values as feature. Although the pixel-base methods are simple to implement, they are very sensitive to any changes between images, like changing illumination conditions.

At the high-level feature based methods, image features such as points, lines and regions are extracted from the image . The Discrete wavelet transform has properties that makes it an ideal transform for the feature extraction, including: insensitive to changing illumination conditions and object-to-sensor distance, efficient representation of abrupt changes and precise spatial information, ability to adapt to high background noise, ability to adapt to changing local image statistics, and existence of fast processing algorithms.

In our new wavelet based algorithm the feature selection in wavelet domain has been exploited for detection and tracking.

The content of this paper is organized as follows: Section II presents our algorithm for intelligent object detection. In section III the experimental results will be presented. Finally, in section IV the future work for development of a tracking system based on the proposed algorithm will be described.

## II. AUTOMATIC OBJRCT DETECTION

In this section, we introduce our proposed algorithm to detect and track a moving object. Detection is the first stage in this algorithm, because if an algorithm can detect moving object in each frame, it will be able to track it. This algorithm has three parts: 1) the first, edge detection is applied to the original image in wavelet domain, consequently, ground boundary is distinguished, 2) the size of object is determined in each frame by computing the distance between camera and object in everyone of the frames, 3) dispersion of wavelet coefficients as feature vector is applied to matching algorithm to provide detection ability to algorithm.

*A. Edge and ground boundary map detection*

Edge detection is a fundamental issue in image analysis. In this section, we discuss wavelet based approach for the detection of edges in an image. an approach based on wavelet transform has been proposed for edge detection in 1992 by Mallat. In this method the input image is decomposed in multiple levels with out down sampling, as resolution needs to be preserved. For each subbands a threshold value is estimated according to the noise variance and used for soft-thresholding to reduce noise. The points of sharp variation (edges) include modulus maxima in high pass subbands, and the local maxima are detected to produce single-pixel edges. The level of decomposition can be selected considering the requirement of detail desired in the edges. The following step is applied on resulting edge image to detect ground boundary . Result of using wavelet based edge detection shown in fig. 1 below.

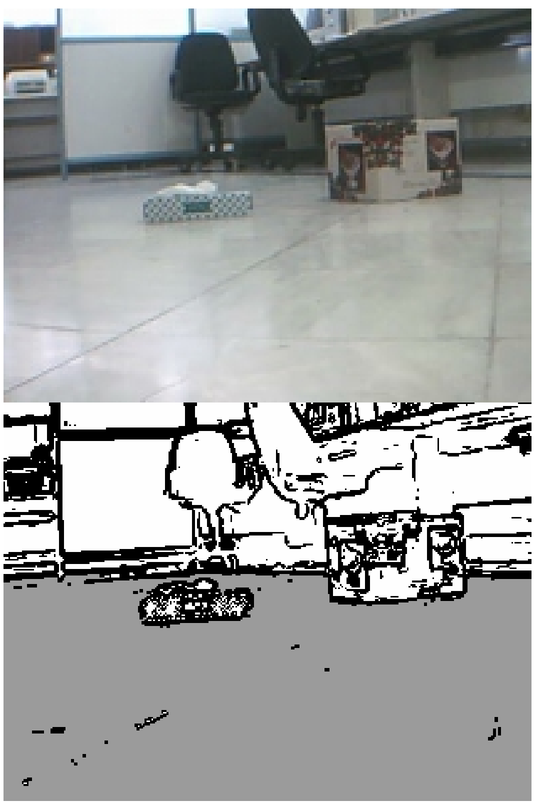

Fig. 1. Result of using wavelet based edge detection. upper: Original image. lower: Edge image

Finding obstacle and ground is necessary part of navigation. Finding ground can be useful to detect obstacles. To obtain ground boundary in edge image, we assume that some points are as ground (like lowest row in an image). This hypothesis can be considered from last frame and also robot speed. By region growing of this pixels all ground boundary can be detected.

In resulting image, because of changing illumination conditions and wavy ground texture, each pixel that considered as ground boundary is not necessarily real boundary. So, we should eliminate undesired pixel. Therefore, we use region growing algorithm again, to solve this problem.

In this algorithm the number of group pixels belong to each area are counted and if this number is less than defined threshold value, this area must be eliminate, otherwise this area is remained as boundary. In this paper, threshold level was set 50 pixels. Fig. 3 . shows the results of this algorithm.

Fig. 2. Ground boundary map detection, red points show ground boundary between objects and walls

*B. Dimension Estimation*

Dimension estimation provide certain desired capability for an intelligent image analysis procedure to understand dimensions of target area (the area that encases the target object). At first, we define the center of object area in the lowest-middle point as object center pixel. Then, we can measure dimensions of interested target area that it’s center may lie in the ground boundary pixels. According to the last section, it is clear that some points of object edge locate on the ground boundary. On the other hand, finding the ground boundary decreases a considerable amount of search areas.

To determine the dimensions, we create a table that involves dimensions of object area in certain places and also their own corresponding object center pixel. Dimensions of the object at each pixel in the image can be determined using linear interpolation operation. On the other hand, interpolation can be used to calculate the real distance of an object using data is listed at the table. In this procedure, It is important that for our mobile robot moving over the ground, there is no relative change in position of the ground from the camera.

This part is implemented manually as preprocessing step.

### *C. Wavelet based feature extraction*

More recently, wavelet-based methods for detection and enhancement tasks have received considerable attention within the image processing community[12].

The general approach in wavelet-based algorithms is to compute the decomposition wavelet of the image and process the wavelet coefficients[15]. Thus, the undecimated wavelet transform(UWT) has been used for finding wavelet coefficients due to the shift invariant property. Also it will ease feature selection procedure, because the subbands in the decomposition will have the same size as input image.

The interesting feature points should satisfy the conditions of:

- Insensitive to rotation, translation
- Insensitive changing size and illumination
- Robust to noise
- Classify the target within other details.

Therefore, in our proposed method called "dispersion of wavelet coefficients of the desired area", that explained next, only a single feature is used to represent the object.

### *D. Dispersion Factor*

Recall that ground boundary is distinguished, and then the desired areas (the area that encase the object) are considered in each pixels of ground boundary with specified dimensions. Each point of ground boundary can be enclosed by a window called "the probabilistic object area".

Dimension of object area is determined using Dimension estimation system. We need the algorithm to detect the target object between the probabilistic objects in the current frame. For this reason dispersion coefficient factor based on wavelet transform is defined. This factor depends on distance variety between edge center and any existing edge in around the object. In fact this factor specify object texture. The algorithm starts with decomposition in the original image to create a wavelet pyramid using the undecimated wavelet transform(UWT). The number of the levels and the filters are chosen based on the content of the video. We choose the number of wavelet decomposition levels to be two and use Daubechies' 2.6 biorthogonal filters.

the subband images are created containing: LL,LH,HL,HH details images. In second step, new subband image is created by adding the magnitudes of the AC bands of the lowest resolution (LH+HL), denote $\rho$. We define the center of an object $(c_x, c_y)$ as

$$
\begin{aligned}
c_x &= \Big(\sum_{(i,j)\in O} \rho_{i,j} \cdot i\Big) / \Big(\sum_{(i,j)\in O} \rho_{i,j}\Big); \\
c_y &= \Big(\sum_{(i,j)\in O} \rho_{i,j} \cdot j\Big) / \Big(\sum_{(i,j)\in O} \rho_{i,j}\Big);
\end{aligned} \qquad (1)
$$

and the dispersion factor of an object $f$ in wavelet domain as

$$
f = \frac{\Big(\sum_{(i,j)\in O} \sqrt{\big(\frac{i-c_x}{\rho_x}\big)^2 + \big(\frac{i-c_y}{\rho_y}\big)^2} . \rho_{i,j}\Big)}{\Big(\sum_{(i,j)\in O} \rho_{i,j}\Big)} \qquad (2)
$$

where O is the set of coordinates of an object area and $\rho_{i,j}$ is the value of the new subband image (created above),at position (i,j), $p_x, \rho_y$ are dimension of $\rho$, then we can detect the target object by comparing the dispersion $f$. Basically, object detection is based on feature vector containing dispersion factor value. note that this feature of object is insensitive to, translation, changing size and illuminate condition.

we can track the objects by comparing the dispersion f. Besides simplicity, another advantage of this tracking algorithm is that it can track fast movement while some existing methods have difficulties.

To illustrate the whole algorithm, a block diagram is given in Fig. 3.

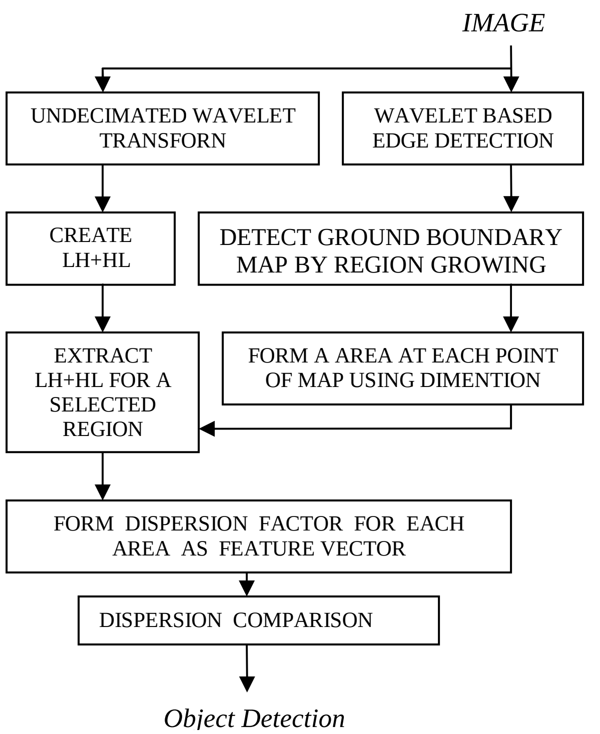


Fig. 3. Block diagram of our proposed wavelet based algorithm for Object detection

### *E. The New Optimal Color Model*

Recall from the discussion in last section that we applied the dispersion algorithm to the original image. the original image can be represented in RGB,HSV or gray scale format. In the following discussion, we described the new color model with single term to generate suitable image . This new model first is designed in this project.

We do know, the HSV model describe the image by its hue, saturation, and brightness. That hue is a color attribute that describes a pure color, whereas saturation gives a measure of the degree to which a pure color is diluted by white light. Brightness is a subjective descriptor that is practically impossible to measure. It embodies the achromatic notion of intensity.

The HSV model decouples the intensity component from the color-carrying information in a color image.

The HSV model we are about to present, is an ideal tool for developing image processing algorithms. But there is some problems in HSV model. For example, the hue component in HSV model can not detect any difference between red, black and white colors. also we need three factor to determine a color . due to the fact, it is assumed that a new single term color model (T) can be obtained using the hue, saturation and intensity component.

In order to see how the created new model (T) can be determined also from a given HSV model, consider TABLEI, which shows a tested plan for combination of the HSV components. By using the T color model, all color are separated from each other.

Before the dispersion algorithm discussed in section II to be implemented in input image , the input image in RGB color format convert to HSV format and then the corresponding T value obtained using the TABLEI. Then the earlier algorithm is applied.

The new color model along with wavelet based dispersion factor provides a very effective way to generate strong feature for object detection.

TABLE I
THE NEW T COLOR MODEL IN VARIOUS COLOR

| COLOR | H | S | V | T |
|---|---|---|---|---|
| white | 0 | 0 | 1 | $\frac{S}{10}-\frac{V}{10}+.027$ |
| black | 0 | 0 | 0 | 0 |
| gray | 0 | 0 | $.32\langle V\langle .95$ | $.032-\frac{V}{10}$ |
| red | 0 | $.05 < S \le 1$ | $.32 \langle V \langle 1$ | $1.068+\frac{V}{10}-\frac{S}{10}$ |
| blackish | H | - | $V < .25$ | 0 |
| whitish | H | $S < .1$ | - | $\frac{S}{10}-\frac{V}{10}+.022$ |
| $H \ne 0$ $.1 < S$ $.25 < V$ | $H \ne 0$ | $.1 < S < .5$ | $.25 \langle V$ | $H-\frac{S}{5}$ |
| $H \ne 0$ $.1 < S$ $.25 < V$ | $H \ne 0$ | $.5 \le S \le 1$ | $.25 \langle V$ | H |

Error vector can be computed by the difference between feature vectors of input image and user selected object. We compare the error vectors of an input image in RGB, HSV, gray scale and T formats. The results are shown in Fig. 4. We can see, in the new T model color the desired error and minimum error occur in the same place. In fact, this results express the performance of the new proposed color model and dispersion factor in object detection.

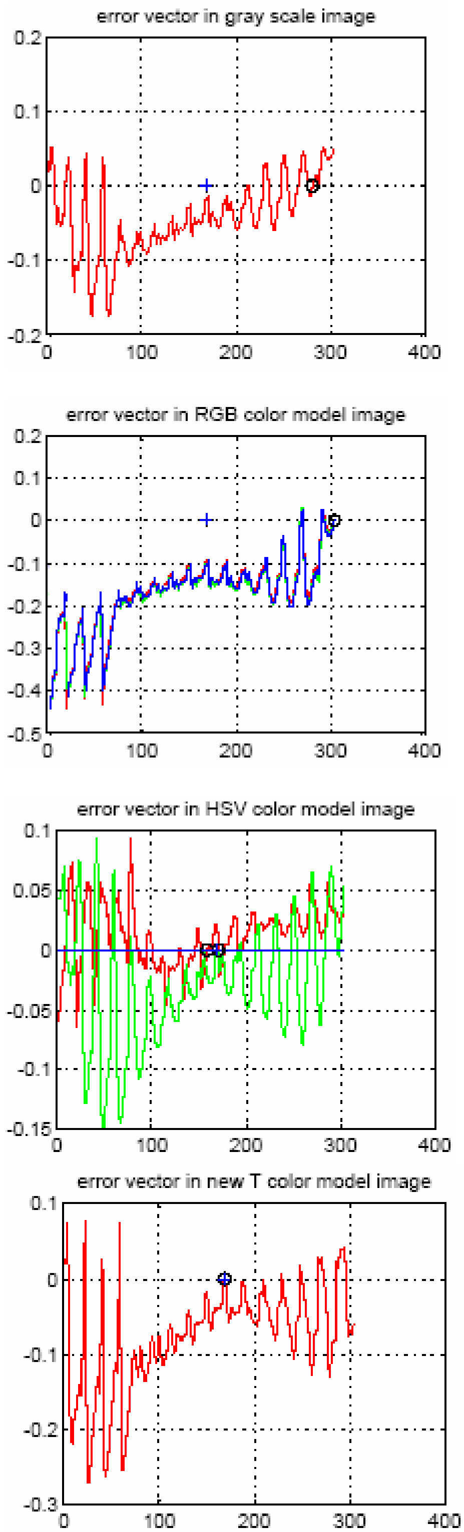


Fig. 4. comparison of the error feature vectors in the gray scale, RGB, HSV and T color model image, shown from upper to lower. Circular marker shows the place of minimum absolute error and plus sign marker shows the desired error in specified color model.

## III. EXPERIMENTS AND RESULTS

The performance of the proposed algorithm has been evaluated by conducting experiments in object tracking by mobile robot. The algorithm has been implemented in a PC running Windows XP operating system with Pentium IV 3GHz full cash processor and 1GB of RAM memory. Considering 240 by 320 pixels search window. we have been able to process 15 frames per second . In our experimental studies, Fig. 5. shows the sample results for tracking.

Fig. 5. Tracking the target object in the “mobile” sequence, where we have various conditions.

## IV. CONCLUSION

A new intelligent algorithm in wavelet domain for real time object tracking have been proposed. In this paper real time object tracking have been achieved using a special search method for finding best match between target object and search area. this search method along with the size and illumination invariant property of dispersion factor and the new color model make it possible to successfully track a target. Our experimental results show this. Suitable feature vector for reference object have been formed using wavelet based denoising and edge detection . This algorithm is fast, which will make it possible for having real time tracking by mobile robot. In future study, we will try to develop an algorithm by adding other features to feature vector to achieve more accurate results in complex environment.

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