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SideWalk Detection Algorithm
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Abstract

In this paper, we present the development of an computer vision algorithm which can detect sidewalks based on line detection. The main functions of algorithm are inducing pedestrians to follow right ways to across sidewalks. Most sidewalk detection algorithms are using color histogram analysis to extract the area of sidewalk. However, our algorithm is based on the line detection because there are various kinds of patterns and colors used in detecting sidewalks all over the world. The development of the algorithms is performed using a Walking Assistance Mobile Application for visually impaired people and can be used in no extra device and technology.

Categories and Subject Descriptors (according to ACM CCS): I.3.3 [Computer Graphics]: Picture/Image Generation—Line and curve generation

1. Introduction

As the technology has been renovated each day, more convenient life for ours are also required. In our society, there are some obstacles that visually impaired person have to be suffered in living in high dense urban. Walking in road, as a pedestrian, it's so hard to them to go straight with no visual guide to help recognizing sidewalk's circumstance. To solve this problem, there are some sidewalk detection method, one by Seng(Seng, John S., and Thomas J. Norrie. "Sidewalk following using color histograms." Journal of Computing Sciences in Colleges 23.6 (2008): 172-180.) and there are many paper about sidewalk detection. But they are extracting data based on color models of histogram and analysis that to get information. Thus, in the situation of color models won't work properly, such as existing some obstacles at sidewalk or image's color is not fixed, it's reliability has been damaged. So, we determined to develop sidewalk detection algorithms based on line detection method and set two main focus of the algorithm.

First is that the algorithm is need to be based on line detection. To cope every situation that occur in real world's sidewalk such as fallen leaves, i disarranged blocks and so on, we constructed the sidewalk detecting algorithm's as linear based. We get the linear features of the image that has more reliability to be a sidewalk and analysis the most data to get more accuracy and less elapsed time. We reduced it's time complexity by combining brief algorithm's result which operated in each video frame and analysis by some statistical regression method. It's result are more accurate than just adopting single complicated function to each input video frame and more faster than just doing complicated algorithm to each video frames. So we made some brief formula that testify the line's reliability and features to find whether the lines' are worth to regard as sidewalk or not.

Second is that the algorithm should work in real-time, as designed for visually impaired person and used in walking. In order to cope with each situation, it required that it's elapsed time be less than user's walking time and it be no spurious response and have high accuracy rating in finding sidewalk result and result's trend. In case of some spurious response happened, users only to believe program and follow the way what said to be result of algorithms. So if the conclusion is not suited for actual sidewalk, it is going to be a big problem and the algorithms' performance will be discussed. Also, if sidewalk's tendency is trembled as every steps of user, it is hard to user to recognize what is actual following path, as there exist so many path as they walk. In short, it is necessary to reduce elapsed time as work in real-time and to improve algorithms accuracy not to confuse user by final result.

So in order to achieve this two purpose, with the help of

computer vision, we have developed a Walking Assistance Android Application(WAAA) for the visually impaired. In order to develop WAAA, therefore, we need algorithms that can detect sidewalks and extract the surrounding noise. At first, we planed to use color histogram analysis to detect sidewalk. We studied various algorithms concerning sidewalk detection, and we found a algorithm which based on color histogram analysis. And it works reliably on the ideal sidewalk situation, which there are only one pattern and color, also no unexpected noise. But it turned out that, in reality, it donâĂŹt work well. Because sidewalk can be covered partly with the shadow of trees, some kind of obstacles, other pedestrians or abnormal pattern and color. For this reason, we need to make another algorithms that donâĂŹt use color histogram as much as we can. Finally, we decided to make an algorithm based on line detection. Through this solution, we could solve limitations which are caused by color histogram.

In this paper, we focus on the line detection and tendency of real-time images. We have studied how visually impaired people are walking on the sidewalk and what can usually happen in real world. It means that there are many fallen leaves. There are some pedestrians and many colors of blocks. Besides, there might be some corners where people must turn the direction at sidewalks. So, we made algorithms to solve these problems by line detection.

In our method, by comparing the subsequent video frames with that of real-time's, we increase the reliability of direction. It has little to do with machine learning, but it looks for accumulated input data set and evaluates the actual direction of pedestrian wants just like machine learning does. The goal of this algorithm is to detect the direction of users and he or she should follow. It gives users the information on which ways are better to follow and how to do that. As this algorithm is applied to WAAA, visually impaired people can recognize the correct direction and can make a decision about his or her way.

2. Related Work

There are some algorithm that can detect lines in real-time. Such as sidewalk, automobile's lane. Algorithms for drone and automobile are actively discussed. Such as color based road following algorithms and so on like [HE04, Color-based road detection in urban traffic scenes].

In previous ones, there are mostly depends on colors of images. A benchmark road follower system, SCARF [SENG08, Supervised Classification Applied to Road Following] also uses Gaussian color model too. However, There are many limitations in applying algorithms in real world. So, we gave up using the road detection system using Color Histogram and utilized edge detection along with road shape model to detect road areas in an image. Adopting this system, we made a blueprint in our research. Contrary to their studies, we used line detection and linear regression to get reliable line in ours and accumulated the tendency lines and found the direction of user.

We first had to apply some filter to reduce noise of the image. Tomasi [TOMAS98, Bilateral filtering for gray and color images] has presented the Bilateral filter by way of reduce noise of the image. It is smoothing filter for images that is characterized by being non-linear, edge-preserving, and noise-reducing. G Deng [DENG93, An adaptive Gaussian filter for noise reduction and edge detection] has present an adaptive Gaussian filter for noise reduction and edge detection. In order to get more specific information of image, although Bilateral filter has more time complexity than Gaussian's, we adopted the previous one. Tomas has present the way to use this filter in RGB or other color model images.

After applying filters, we need to find contours of the image. To detect the image's edge, we choose Canny detection method by J. Canny [CANNY86, A computational approach to edge detection.] Canny detection has got a two threshold to find contours. By adjusting two weighting value, it find edges by Sobel edge detector. After that, it check each edge's magnitude is maximum. If it is maximum, it only apply it and connect with other edges. It has got low error ratio, no spurious response, and well localized algorithm. It's result has mainly affected by this parameter. But defining two threshold's value is not easy. So P Bao [BAO05, Canny edge detection enhancement by scale multiplication.] has suggested scale multiplication to enhance the quality of detection. In our algorithm, we resized the image frame and set value by some test.

To adjust appropriate threshold, video frame's color is need to be equalized. Histogram Equalization(HE) method is well known algorithm to revise image. Shah [SHAH15, A REVIEW ON IMAGE CONTRAST ENHANCEMENT TECHNIQUES USING HISTOGRAM EQUALIZATION] arranged this method to use. We equalized the video frame before applying The filter. The image is well-ordered by resizing and equalizing method. There are some adaptive filters. But our work is real-time image processing and needed to be operated in less time complexity. So we just set the threshold as a constant value by evaluating before the program run.

In order to detect sidewalks, we have to find some lines in the image. There are many algorithms that find images's line. But our algorithm is primarily based on the Probabilistic Hough Transform. Probabilistic Hough Transform(PHT) by Kiryati [**?**, A probabilistic Hough transform] and Progressive Hough Transform(PPHT) by Barinova [BARINOVA12, On detection of multiple object instances using hough transforms] are good way to detect line features in the image. It is a technique which can be used to isolate features of a particular shape within a image. By adopting this function to contours, we get line features of each image frame. Succeeding finding lines of image, we verified each line's reliability by some equations.

Finally, we get two most reliable lines on each video frame and accumulated it. Subsequently, we do linear regression on stacked lines. Seber [SEBER12, Linear Regression Analysis] has arranged some linear regression method. Such as Ordinary Least Squares(OLS), Generalized Least Squares(GLS),

Total Least Squares(TLS) and so on. Despite the fact that GLS and TLS is more reliable for analyzing data, we chose OLS to get relatively less elapsed time to be real-time processing. It is popular and powerful estimator whose result line has to go through average of the points. We, so as to, adopted OLS estimator to apply regression in get better results.

3. Our Method

The main key of our algorithm is summarizing. We apply small patch and accumulated each result. Then we summarized the result and get results. It is quite effective than just do high-accuracy algorithm to each video's frame. We reduce much time by adopting this method to get data. It is economical for doing just little time-complexity procedure and summarizing. Thanks to linear regression analysis, we easily get total data from accumulated one and it's suit well for real-time processing such that program like this.

Before we applied the algorithm, there were some steps to go through. We got the video frame by server. But, to use this video frame, the video frames must be converted to contours image. In order to minimize elapsed time, we applied Bilateral filter to exclude frames' unexpected noises. After applying it, we applied Canny Detection to find contours of the images. Also, we used Probabilistic Hough Transform to get lines of the images. After that, we measured the reliability of each line. And the most reliable two lines are results. But, two lines must be different from each other. So, we set equation of M like this.

$$M_{ij} = K_i + m_j \quad (i = 0,1)\,(j = 0,1) \tag{1}$$

Equation (1) simply represents the range of line's slope. M is the discriminant of line that represent the upper-bound and lower-bound of the should not be required image's slope. We set value like this. K is the weighted value and it would be defined as follow by given test. As we calculate line as our track, we use DMS(Degree-Minute-Second) notation rather than using radian.

$$K_0 = 10, \quad K_1 = -10 \tag{2}$$

To set the slope's range, we set K as the constant value which make the candidate of slopes. As lines' slope is described as DMS notation width of range is defined by each line's slope. And there are more candidates of line where test line's slope is high. To get reasonable path, it is required that angle of slope is close to 90 degree. Lines are required to contrary with each other by it's direction and used to estimate the sidewalk's actual way by finding vanishing point which made of each side's line that assumed to be sidewalk.

If slope of two lines are too close, it means there are no need to consider these lines because they are almost one line in high probability. Else, if some new line has come in the situation of it's slope is not included in existing line's range, we define the situation as worthwhile and check line's reliability more. We check line by checking it's responsibility. We only compared a new line with two lines that already exist. Since we wanted to check all reliability, we apply this equation in all each input line.
In order to be reliable, it is required to be long and should be exclusive for each. Also, as we just need result that involves two line which it's slope must be exclusive.

Also, we suggest that input image's tendency are likely to refer sidewalk's border. So, we imply some linear regression method that contains two variables, the slope and length. The result of algorithm is pair of lines. So, we need to convert line's reliability not only of them, but with some other line. To give them more accuracy, we set some adopted parameter and evaluated them. Now we set the loss function of two line.

$$A_{ij} = \beta((l_i + l_j)^2 - l) + (1-\beta)D(m_i, m_j) \tag{3}$$

$$S(\beta) = Var(A_{ij}) \tag{4}$$

In constructing loss function, we calculate matrix's variance. If algorithm's result are correct, it's mount should be aroused. Also, we adopt linear regression method. We get implicit derivatives of this function by weight parameter that concerning length factor to get minimum data of loss function's result. It's parameter are easily changed to improve its quality, so we, at first, coordinate the parameter to suit with input data. So se set the P as average of matrix A.

$$P = \frac{\sum_{i=0}^{n}\sum_{j=0}^{n} A_{ij}}{n^2} \tag{5}$$

P is related to parameter and represent average of data in matrix A. So, function S is shown at this form of by calculating deviation.

$$S(\beta) = \sum_{i=0}^{n}\sum_{j=0}^{n} (A_{ij} - P)^2 \tag{6}$$

Now, we get implicit derivative of S by parameter. And variables that x, y, X, Y are shown as following equations.

$$\frac{\partial S(\beta)}{\partial \beta} = 2\sum_{i=0}^{n}\sum_{j=0}^{n} ((x^2 + x - 2X + 2Y)\beta + 2y - 2Y) = 0 \tag{7}$$

$$x = (l_i + l_j)^2 - l, \quad y = D(m_i, m_j) \tag{8}$$

$$X = \frac{\sum_{i=0}^{n}\sum_{j=0}^{n} x}{n^2}, \quad Y = \frac{\sum_{i=0}^{n}\sum_{j=0}^{n} y}{n^2} \tag{9}$$

Equation (7) present implicit derivative of loss function. To get critical value of it, we can set parameter as related to input data only. And if needed, we can change parameter to get more quality. After calculating it, we can finally set the loss function.

Now, we should define function D to get result of S. While

D get two function as variable, we can assume that two line's average angle is close to pedestrian's direction and result of linear regression method. So we define function D as this form.

$$D(m_i, m_j) = |m_i + m_j - 2 * m_{avg}| \tag{10}$$

In short, we search the slope of all lines by using linear regression method. By adjusting ours, we can develop useful loss function between two lines. This function's parameter are needed to be set before the function is called. But, the parameter's are calculated by linear regression method. Although There are some necessary to be changed by image's width and height, we resize it's size.

After applying method that calculate line's reliability with tendency of image, we use linear regression to reduce some trivial errors and simple vibration of user. We use OLS(Ordinary Least Square) method to get line's tendency. In this process, we can get our direction that can be assumed by our previous path model and know whether our path is fit in sidewalk.

$$O(n^2) \tag{11}$$

The algorithm's ti me complexity is mostly influenced by situation which affect linear vector's size. By using some regression method, we just obtain it's time complexity mostly manufactured by which regression models to take. If we choose Theil-Sen Estimator or Gradient Descendant and so on that refers to more complicated regression model, we have to give up getting real-time processing. Thus, we choose just simple and strong model that compute our algorithm.

In real-time detection, there have presented an some unknown situation that can damage our result. So, we finally use some linear regression method in combination of direction and confidence of each result. Adjusting this method, we assure that result show the direction of frame. There are some point that accuracy and performance time of algorithm needed to be compromised. Especially in real-time processing, performance time must be reduced to get meaningful result. So, there are many ways to deal with such that problems. But, we suggested that it is better to use simple algorithm and integrate with regression or some method is more efficient than using complex algorithm structure to define each frame. It is more economical and change it's elapsed-time more easily and suitable.

4. Results

We use OpenCV library to express our algorithm. As the computing system are enhanced every day, we just evaluate ours by comparing with other.

<test result>

As the result show that it's accuracy and time-complexity are developed than previous algorithm and able to deal with actual phenomenon. So, we use some mathematical method to extract particular key-point and get more accuracy by using some regression model to combine many of result rather than using high-accuracy but more time-complexity algorithm. And our algorithm are nothing to do with color histogram or another external factors so that it can be used in many various circumstance.

5. Conclusion

Comparison to previous work. Supervised Classification Applied to Road Following(SCARF) use gaussian color model to describe situation. It is useful in road detection as most of road's color are strictly fixed. But there are some problems in adapting algorithms to sidewalk detection. So, we present new algorithm by using line detection and some regression method. To get access with large variety of situation, we use line detection rather than color model. There are some benefits in each ways. If color model don't suit well in given situation, using this algorithm to get more accuracy data is good choice. Limitations. Our model are computing by only strict line. If the given situation is so much curved, our model are not much work effectively. And in the situation of too much error, line detecting algorithm could not work properly. And also, our method are mostly do with camera vision. We suggested that there are some ways to compute in using accelerator to get user's actual direction.

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