A Study of Object Recognition for the Efficient Management of Construction Equipment

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ABSTRACT: Measuring the process of construction operations for productivity improvement remains a difficult task for most construction companies due to the manual effort required in most activity measurement methods. There are many ways to measuring the process. But past measurement methods was inefficient. Because they needed a lot of manpower and time. So, this article focus on the vision-based object recognition and tracking methods for automated construction. These methods have the advantage of efficient that human intervention was reduced. Therefore, this article is analyzed the performance of vision-based methods in the construction sites and is expected to contribute to selection of vision-based methods.

Keywords: Object Recognition; Equipment Management; Automated Construction

1. INTRODUCTION

In the construction industry, the necessity of efficient project management came to the fore to gain a great deal of profits with less investment due to the principle of economy since construction environment progresses such as construction materials, construction techniques, extension of construction scale and the development of construction equipment etc. but it has a fundamental feature that it is difficult to conduct the project management due to the changes of site conditions and uncertainties. Besides, the studies that were previously conducted have been progressed focusing on the schedule management of a construction project and there is a limit in the increase of productivity only with those studies. And since work factors of a construction site are changed depending on the status of construction progress, there is a limit in the measurement of data that can be collected under the same conditions and as a result, there are many difficulties in the aspect of a progress plan (Seo, Hyung-Beom et al. 2006).

To overcome these problems, the studies are being progressed for efficient acquisition of data. The technology of construction automation based on perception of objects was on the rise for efficient acquirement of data. There are many reasons in the necessity of construction automation but the major parts can be summarized into reduction of construction costs, reduction of construction period, improvement of productivity and security of workers' safety etc (Hasegawa, 1999).

In a site that equipment was invested, it is necessary to maintain the analysis data on the investment cost through many kinds of records to judge the capacity of each piece of equipment and to prepare for the problems that will occur in the future by recording thoroughly labor input time, real operating time, achievements of construction, repaired places and repair time etc. However, since the analysis data for equipment are collected by direct observation, there are many difficulties in maintaining the accuracy with low efficiency. Therefore, if data etc. regarding operation types of equipment and the work amount are collected, it could be helpful for improvement of productivity and increase of efficiency of process management of a project.

The studies with a theme of object recognition using imaging equipment have been conducted in the papers such as (Chi and Caldas, 2011), (Gong et al, 2011) for efficient acquisition of data on the current construction equipment. In the two papers, the study on the recognition of construction equipment at a construction site has been progressed through image difference algorithm using the change of pixel value within an image and the efficient acquisition of data is possible with the application of this technology. However, there is a high possibility in the above studies that a phenomenon that an object is not recognized and a problem that it is recognized as a different object upon application in the real sites. If this limitation of the existing studies is overcome, the base to control the work sequence, time and methods of equipment and workers can be established on the basis of the technology of object recognition in an image. If that is done, it will be possible to manage equipment and workers efficiently and the improvement of productivity and an efficient process plan of construction industry can be expected through this.

That is why this study conducted the application of Speeded Up Robust Features algorithm and its verification which is a method that is more stable and less affected by the surrounding environment than the change of pixel values in an image that was used for the existing study.

2. SURF Algorithm

2.1 SURF (Speeded Up Robust Features)

The SURF which is an algorithm of extraction of a feature point is largely divided into the extraction of a feature point and the description of a feature point. First, in the extraction of a feature point, whether there is a corner is judged by using a determinant of approximated hessian matrix as shown in Formula 1. At that moment, the corner is the case that the value of the matrix is greater than 0, and which is also called as a maximum.

$$H_{\approx} = \begin{bmatrix} D_{xx} & D_{xy} \\ D_{xy} & D_{yy} \end{bmatrix} \tag{1}$$

D constituting the approximated hessian matrix means an approximate expression of the second order partial derivative of Gaussian kernel, and each approximate expression is convoluted into an image with a form of a filter as shown in Figure 1. At that moment, -2 for the black area, 1 for the white area and 0 for the grey area are applied as weight.

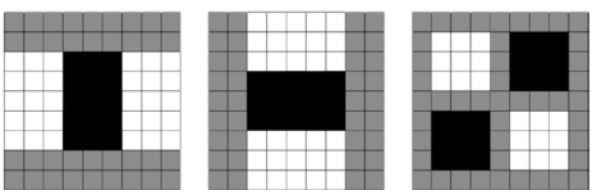

Figure 1 Filter of Approximated Hessian Matrix (D_{xx}, D_{yy}, D_{xy})

As the scale of filters is constantly increased as shown in Figure 2, a corner with various scales can be detected.

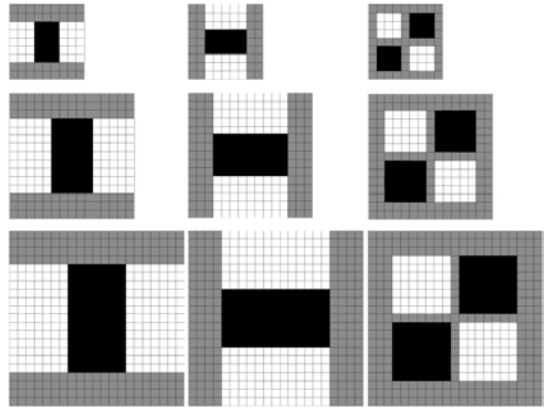

Figure 2 Changes of Scale of Filters (D_{xx}, D_{yy}, D_{xy})

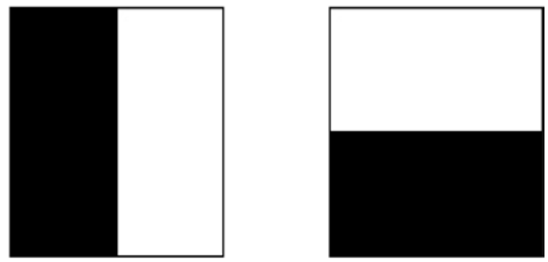

Figure 3 Harr Wavelet Filter (x direction, y direction)

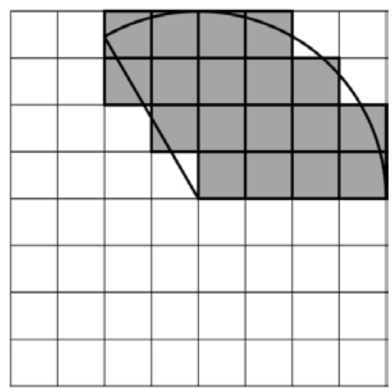

Figure 4 Feature Using Gradient and Sliding Window Calculation of Point Direction

The direction of a feature point is calculated by using the value of pixels around the location of a feature point that is detected in the description of a feature point. This uses the magnitude and orientation of the gradient which is a result of convolution into Harr Wavelet Filter that corresponds to the first derivative in the direction of x and y as shown in Figure 3. Unlike the filter of the approximated hessian matrix, the weights of 1 for the black area and -1 for the white area are applied, the scale is fixed with 2x2.

The range of values of pixels that a gradient is calculated varies depending on the scale of a feature point, and the calculated gradients correspond to the rectangle of Figure 4. And the fan-shaped sliding window focusing on the location of a feature point generates numerous vectors by adding all gradients inside window with rotation of 360°. The orientation of the largest vector among these vectors becomes the orientation of a feature point.

The feature point that its orientation is calculated consists of a descriptor with a vector type which is the final phase. This calculates the gradients of 20x20 by using the surrounding pixel values based on the location and orientation of a feature point as shown in Figure 5. At that moment, the arrow means the orientation of a feature point. And then the calculated gradients are divided into 16 gradients of 5 x 5.

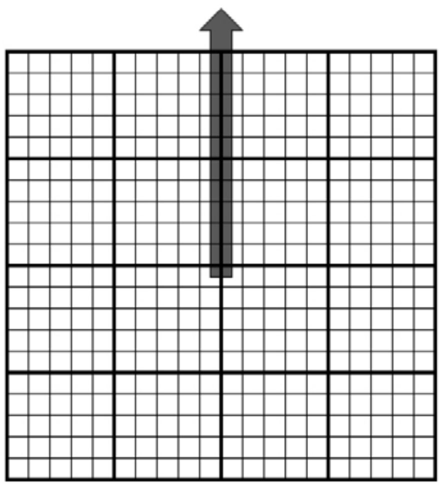

Figure 5 Division of Gradient for Composition of Descriptor

Table 1. Gradient Composition of 64-Dimension Descriptor

dx		*dy*	
$\Sigma\ dx$	$\Sigma\ \lvert dx\rvert$	$\Sigma\ dy$	$\Sigma\ \lvert dy\rvert$

Table 2. Gradient Composition of 128-Dimension Descriptor

dx $\geq$ 0		dx < 0		dy $\geq$ 0		dy < 0	
$\Sigma\ dy$	$\Sigma\ \lvert dy\rvert$	$\Sigma\ dy$	$\Sigma\ \lvert dy\rvert$	$\Sigma\ dx$	$\Sigma\ \lvert dx\rvert$	$\Sigma\ dx$	$\Sigma\ \lvert dx\rvert$

The sum of gradient of 5 x 5 is calculated after being classified as shown in Table 1. At that moment, dx means a gradient in x direction and dy means a gradient in y direction. In other words, the total 4 values are calculated by calculating the sum of the value that all are added and an absolute value after dividing the gradient according to x direction and y direction. In the remaining 5 x 5 gradients as well, if this is identically applied, the total 64 values are calculated and it comes to compose a 64-dimension descriptor by using it.

As shown in Table 2, if it is classified by considering the magnitude of a value as well as the orientation and an absolute value, the total 8 values are calculated. The descriptor that is made by using it becomes 128-dimension. The convolution work which is the most repetitive one in the detection and description of a feature point of SURF mainly consists of an operation that calculates the sum of pixel values. That is why if the convolution is performed at an integral image that is calculated by using the original image as shown in Formula 2, it can be calculated with fast speed regardless of the size of a filter.

$$I_{\Sigma}(x,y)=\sum_{i=0}^{i\leq x}\sum_{j=0}^{j\leq y}I(x,y) \tag{2}$$

2.2 Features of Construction Sites

Since construction sites are exposed to external environment, they sensitively react to the changes of natural environment and it strongly represents one-time production that a single building is produced at a single site. As the construction progresses, the materials for use are changed in construction sites and subsequently the environment in a site is changed and they have complicated environment due to construction materials and construction equipment and workers etc.

2.3 Features of Construction Equipment

The types of construction equipment are various and they are composed of noticeable colors and it is possible to transform a certain part of the appearance of equipment. Even though there is no transformation of the appearance, the types are variously observed depending on the direction of construction equipment and similar colors with the color of the appearance of equipment are distributed at the surroundings. And due to the nature of complicated construction sites, the overlapping phenomenon that the appearance of equipment is covered by many obstacles frequently occurs.

3. Experiment

Looking at object recognition algorithm of the existing studies, the object recognition using difference image is used many times. Difference image is an algorithm using the change of pixel values in an image and is a method suggested at the initial stage among object recognition algorithms. Since it uses the difference of pixel values between image frames, it is sensitive to the resolution of an image and shows a sensitive reaction to the change of intensity of illumination. Besides, in case that an object is covered or an object stands still without any movement, there is a difficulty in recognition.

Therefore, the object recognition was progressed by changing the cover of an object and intensity of illumination.

Figure 6 Object Recognition Using SURF (General Intensity of Illumination, No Cover)

Figure 6 is the result of object recognition using SURF and the experiment conditions are the cases that both the change of intensity of illumination and the covering of an object didn’t occur and it is possible for the precise object recognition as shown in the figure.

Figure 7 Object Recognition Using SURF (General Intensity of Illumination, Covered)

Figure 7 is the result of recognizing an object using SURF and the experiment conditions are the cases that there is no change in intensity of illumination and only the covering of an object occurs and it can be found that it is possible to recognize an object considerably exactly without noise.

Figure 8 Object Recognition Using SURF (Change of Intensity of Illumination, No Cover)

Figure 8 is the result of recognizing an object using SURF and the experiment conditions are that intensity of illumination is changed but the covering of an object doesn’t occur and it is possible to recognize an object exactly as shown in the figure.

Figure 9 Object Recognition Using SURF (Change of Intensity of Illumination, Covered)

Figure 9 is the result of recognizing an object using SURF and the experiment conditions are that intensity of illumination is changed and the covering of an object occurs and it is unstable compared to Figure 6 but it is possible for the considerably exact object recognition.

4. CONCLUSIONS

In case of object recognition using difference image that is used for the existing studies, it sensitively reacts to slight change of intensity of illumination or shaking of a camera so it can be found that noise occurs severely. And in case of changing the experiment conditions, it can be verified that there are many difficulties in recognizing an object along with noise when intensity of illumination is changed and the covering occurs. To solve these problems, it was experimented by using Speeded Up Robust Features algorithm.

In case of recognizing an object by using Speeded Up Robust Features, an object to be recognized could be exactly recognized and it was verified that constant recognition results could be drawn regardless of shaking of a camera or change of intensity of illumination and whether it is covered or not.

However, in case that a considerable portion is covered or a severe change of intensity of illumination occurs in a moment, there were some cases that it was impossible to recognize an object.

Therefore, the studies that can improve the performance of object recognition should be progressed through building database of object information or fusion of algorithm in the future studies.

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