A Distance Estimation Method using Intra-frame Optical Flow with Interlace Camera

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ABSTRACT

There has recently been much research on estimates of location using optical flow, which is a well-known for estimating distances. However, since high computational power is needed to calculate optical flow, it cannot be adapted to high-speed movement. This paper proposes an intra-frame optical flow, which is a new method of estimating distances using an interlace camera. It estimates high-speed moving objects accurately because it uses two successive images with a very short scanning interval extracted from one image captured by an interlace camera. The result obtained from evaluation confirmed the effectiveness of our method.

Categories and Subject Descriptors

I.4.0 [IMAGE PROCESSING AND COMPUTER VISION]: GeneralImage processing software

General Terms

MEASUREMENT

Keywords

distance estimation, interlace camera

1. INTRODUCTION

To achieve location-aware applications, we need a low cost and flexible method of estimating location that tracks objects moving of high speeds. There are many methods of estimating location using GPS[1], visual markers[3], and electric wave intensity[2]. However, GPS only provides approximate positions and other methods require environmental infrastructures. Example methods where no infrastractures are used are those using wearable sensors[4] and optical flows with wearable cameras[5]. The former researches proposed a system that could estimate the relative location by using a pedometer. However, since it was highly dependent on the walking characteristics of human beings, it was difficult to apply to disabled people or robots. The latter researches estimated movement by processing images captured by a camera. However, the use of optical flows has problems with estimation errors especially where a camera or an target object is moving of high speed.

This paper proposes a new method of estimating relative distances using intra-frame optical flows by using an interlace camera. Our method estimates a relative position only with an interace camera. Moreover, since it uses two successive images with a very short scanning interval captured by an interace camera, it can be adapted to high-speed movements.

The rest of this paper is organized as follows. Section 2 explains the proposed method in detail, and Section 3 presents our evaluation results. Finally, we summarize the paper in Section 4.

2. PROPOSED METHOD

2.1 Optical Flow

An optical flow is a vector that means the distance and the direction of movement for each pixel in two successive images. There are several methods of calculating the optical flow vector. We employed the Lucas-Kanade method, which is well known lightweight method. It divides one image into multiple domains, and it calculates the difference in luminosity and time differentiation in luminosity between the partial domains of successive frames.

Supposing the distance estimation by optical flows is performed on software, the system captures images continuously with the camera and estimates the migration distance by comparing two successive images, as shown in Fig. 1. Here, each processing time L_1 includes the time for capture, the time for storing the images, and the time for calculating the distance. At this time, the frequency of picture acquisition is $f_1 = (1/L_1)$. If the computational power of the PC or the frame rate of the camera is poor, L_1 becomes longer because the calculation of optical flow requires many computational resources. Thus, in such environments, it is difficult to estimate the migration distance of an object that is moving at high speed.

2.2 Estimates of Distance Based on Interlace Camera

We could estimate the distance during high-speed movement with the proposal method, by using optical flows with

Figure 1: Calculation interval with progressive camera

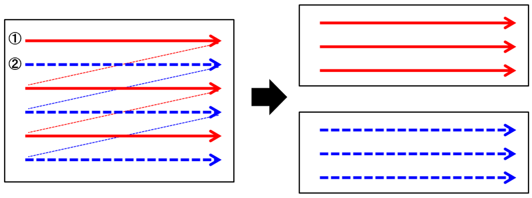

Figure 2: Characteristics of interlace scanning

the features of the interlace camera.

When a camera takes an image, it starts scanning from the upper left and moves horizontally to the right. Then, it moves onto the next lower horizontal line. An interlace camera firstly only scans odd lines and then even lines. For example, when the frame rate of the interlace camera is 30fps, its frame rate is virtually 60fps if we consider that the odd-line scanning and even-line scanning images of the interlace scan are different images, as shown in Fig. 2. We call these images odd-line scanning image and even-line scanning image.

Moreover, as shown in Fig. 3, the interlace camera takes two images with a very short scanning interval d_1, which is much shorter than L_1. At this time, the frequency with which distance is estimated virtually $f_p = (1/d_1) = f_1(L_1/d_1)$. This clearly means that our method can be more easily adapted to high-speed movement of objects than conventional methods. Moreover, interlace scans have another advantage in that the system can do sufficiently accurate estimates even where the PC or perform poorly when the capturing interval is too long to use a non-interlace camera. This is because d_2 becomes longer in this situation but d_1 is still very short.

2.3 Algorithm

Fig. 4 shows the flow of our method. The detailed processing for each step is shown in the followings:

1. Image capture: The system captures an image with the interlace camera. We assume it captures an RGB image of 640×480 pixels for simplicity.

2. Resolution conversion: It resizes the image into 240×480 pixels using the nearest neighbor method.

3. Gray scale conversion: The image is converted to a gray scale image to enable simple processing.

4. Division into two images: The system divides the image into odd-line scanning and even-line scanning images.

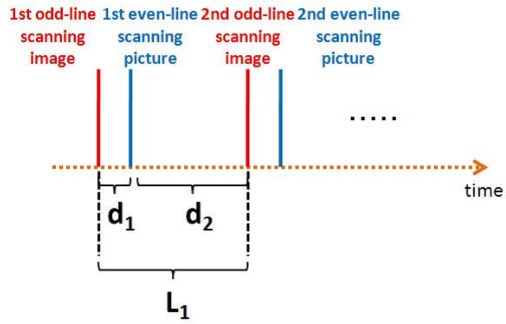

Figure 3: Calculation interval with interlace camera

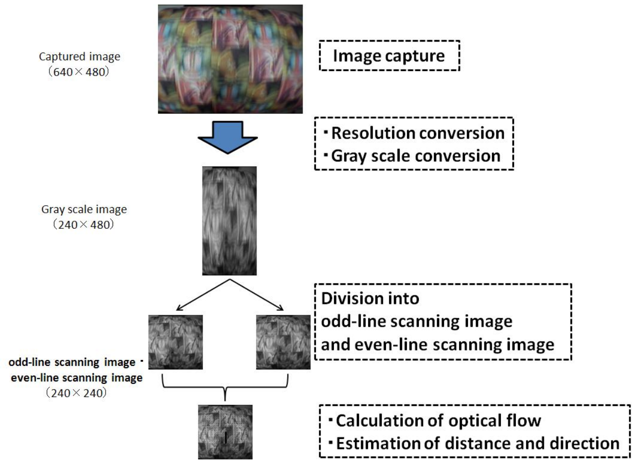

Figure 4: Flow of processing

5. Optical flow calculation: Each image is divided into 10×10 local domains, and the system calculates the optical flow using the even-line scanning and the odd-line scanning images by using the Lucas-Kanade method for each domain. The optical flow of the frame is extracted by accumulating all the estimated optical flow vectors in one frame.

2.4 Extension to Estimates of 3D Distances

We assumed our camera would be attached to airplanes or robots to detect their positions. The system can detect the three dimensional position from horizontal movement, the rotation of the camera itself, and vertical movement. s

Estimation of vertical motion

When a camera approaches the ground, optical flow vectors radiate from the center of the camera because the ground in a camera increases. The system calculates the distance of movement R by measuring the average length of the flow vectors. $R > 0$ means that the camera approaches the ground and $R < 0$ means that it is leaving the ground.

Estimation of rotation

Generally, there are three kinds of rotations; pitch, roll, and yaw. As explained above, because we only assumed a case where the camera was rotating facing the ground, we will de-

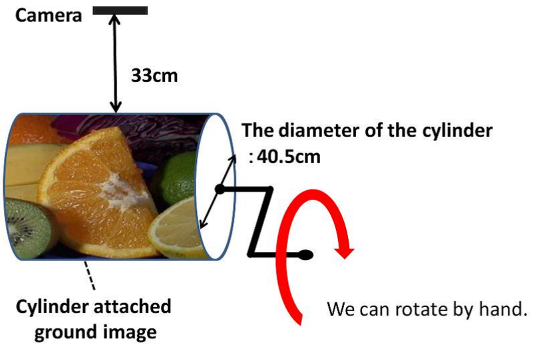

Figure 5: Setting for experiment (1)

scribe a method of calculating yaw. The system calculates the degree of rotation θ by measuring the average angle from the start point and end point of the vectors in polar coordinates. $\theta > 0$ means that the camera is rotating clockwise and $\theta < 0$ means that it is rotating anticlockwise.

3. EVALUATION

In this section, we discuss our evaluation of our method by actually measuring the accuracy with which distance is estimated. The interlace camera we used was the CARD 7RL made by RF, Inc., which has a 270,000 pixel 1/4-inch color CCD. The resolution of the camera is 680×480 and the captured images are sent to the PC via a USB port. The CPU the PC used was an Athlon(tm) 64 Processor 3500+ with a frequency of 980 MHz and a memory of 960MB. The illumination intensity of the room was about 1000lux.

For comparison, we used a non-interlace camera that had the same specifications as the camera used to evaluate the proposed method. The evaluation conditions involved the proposed method and the method for compared it with using the same programs, and these systems extracted data simultaneously.

3.1 Horizontal Direction

Fig. 5 outlines the experimental apparatus. We installed a cylinder around which an image was attached. This image was a standard picture often used by image processing and contained the image-processing library OpenCV that Intel Corp. makes available. We compressed it to 348KB (2446×2446 pixels, 64.71×64.71cm). The circumference of the cylinder was 127.17cm. The camera was fixed 33cm above the cylinder so that the whole background image could be fully photographed with the camera. Note that 1 cm on the cylinder was equivalent to 9.5 pixels on the captured image. We turned the cylinder clockwise for three turns in this environment and extracted data for the estimated optical flow vector and frame rate. We evaluated the size of the optical flow vector by changing the speed of which the cylinder revolved. We did this process 90 times.

Fig. 6 plots the results. The average frame rate was 5.87 fps. From the results in the y direction where the optical flow vector should be detected, the critical speed with the proposed method was about 55.0[cm/s] and the critical speed with the method we compared it with was about 25.0[cm/s]. This means that the proposed method can support more high-speed movement than the method we compared it with. When checking data in the x direction that should have been 0, the value of the vector was detected although this was small compared with that is the y direction. This was considered to be error due to the experimental apparatus, and there was almost no difference between the two methods.

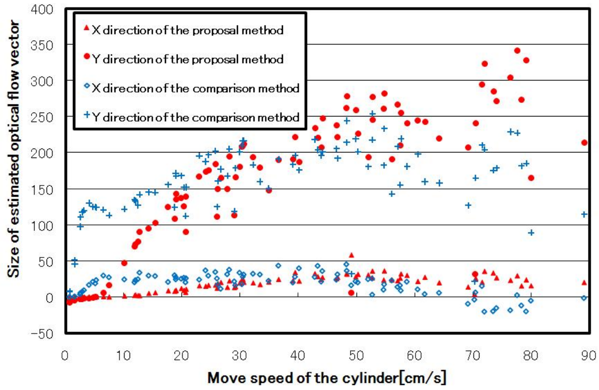

Figure 6: Results from experiment (1)

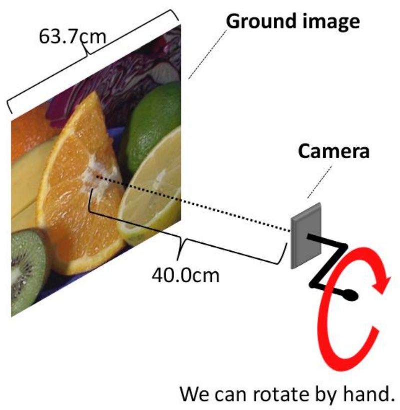

Figure 7: Setting for experiment (2)

3.2 Rotational Direction

As outlined in Fig. 7, we attached the camera to handmade rotating equipment, and we placed an image 40cm from the camera so that all the background image could be photographed with the camera. We used the same image as we had in the other experiments, which was 3081×3081 pixels and 81.51×81.51cm. Note that 1 cm on the cylinder was equivalent to 5 pixels on the captured image. We rotated the camera to the right for three turns and extracted data for the estimated optical flow vector and frame rate. We repeated these operations 120 times, by changing the revolving speed.

Fig. 8 plots the results obtained from evaluation. The average frame rate was 5.70 fps. The results indicate that the critical speed of the proposed method is about 370.0[°/s], and the critical speed of the method we compared it with is about 170.0[°/s]. This means that the proposed approach

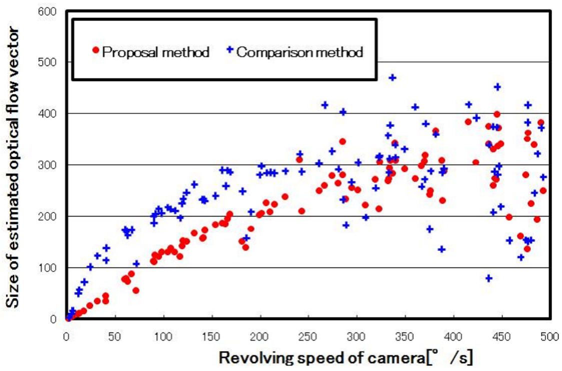

Figure 8: Results from experiment (2)

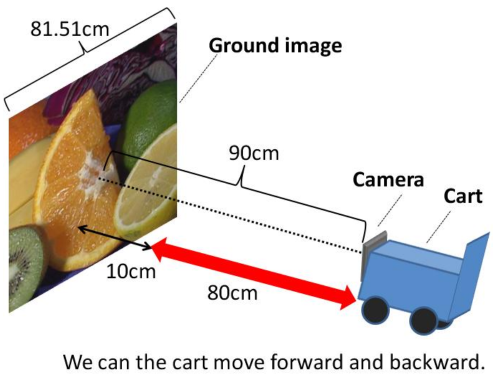

Figure 9: Setting for experiment (3)

can support more high-speed movement than the method we compared it with, as same as that in the previous evaluation.

3.3 Vertical Direction

As outlined in Fig. 9, we attached the camera at height of 70cm above the ground on a cart, and we placed the background image. At this time, the center of the camera and the center of the background image coincided. The picture was 3081×3081 pixels, and 81.51×81.51cm. We moved the cart 90cm from the background image to 10cm. Note that when the camera was the furthest from the image, 1 cm on the cylinder was equivalent to 30 pixels on the captured image, and when the camera was nearest from the image, 1 cm on the cylinder was equivalent to 240 pixels. We repeated these operations 90 times, by changing the movement speed.

Fig. 10 plots the results obtained from evaluation. The average frame rate was 5.78 fps. The results indicate that the critical speed of the proposed method is about 40.0[cm/s], and the critical speed of the method we compared it with is about 20.0[cm/s]. This is the same tendency as in the other evaluation results.

4. CONCLUSION

In this paper, we proposed a method of estimating the distance using an interlace camera and the intra-frame optical flow. Since our method could be used to estimate relative distance by two successive images with a very short scanning interval captured by an interlace camera, our system could be adapted to high-speed movement. The results from evaluation confirmed it was more effective than a conventional method we compared it with.

In future, we intend to improve the algorithm to obtain more accurate estimates, and we plan to implement several applications such as autonomously controlling a small model helicopter carrying a camera and an air mouse using a camera.

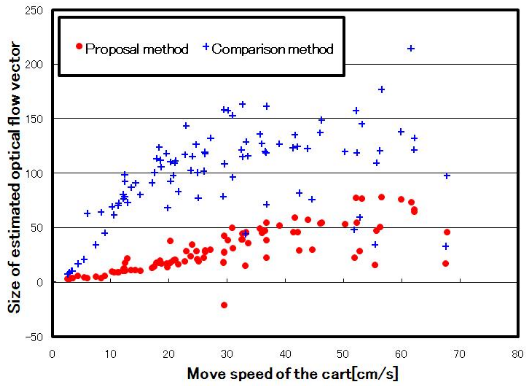

Figure 10: Results from experiment (3)

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