# Intra-frame Scan: a Method for Estimating Object Movements using an Interlace Camera and Visual Markers

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## ABSTRACT

Recently, there are many researches on location-dependent services, such as a navigation system where the system estimates the location of participants in event spaces and navigates them. There are methods for estimating absolute position such as a method using GPS and a method using RFID tags. However, they have problems on the installation cost and environmental restrictions. Therefore, the relative position estimation is strong candidate that is low cost and can be broadly adapted. Although there are existing relative position estimation methods using wearable sensors, they have problems on the cost of managing multiple sensors. There is a method using an optical flow of camera image. However, since it needs high computational power for calculating an optical flow, it cannot respond to a high-speed motion. In this paper, we propose a new method of the relative position estimation using simple markers and an interlace camera. Since our system estimates relative distance by two successive images with a very short scanning interval captured by an interlace camera, our system adapts the high-speed movement.

## Categories and Subject Descriptors

H.4 [Information Systems Applications]: Miscellaneous; D.2.8 [Software Engineering]: Metrics—complexity measures, performance measures

## General Terms

Delphi theoryMEASUREMENT

## Keywords

distance estimation, interlace camera

## 1. INTRODUCTION



Due to the recent miniaturization and technical advancement of computers, there is increasing demand on applications that provide services based on the place and the state of user. To fulfill the requirements, there are many researches on the location estimation of people or objects. For example, there is a navigation system for event spaces, which estimates the location of participants by camera to navigate them[1]. In order to put such application in practical use, it needs a location estimation method with low cost, flexible, and can adaptable to high-speed movement of objects.

As examples for the former method, there are many approaches using GPS[2], environmental infrastructure, such as RFID tag[3], visual markers[5], or electric wave intensity[4]. The method using GPS cannot be used indoors and it gives a rough position. In the methods using environmental infrastructures, they have problems on the installation cost and environmental restrictions. As the latter methods, there are methods using wearable sensors[6] and an optical flow with wearable camera[7]. Tenmoku et al. proposed a system that estimates the absolute location by using a pedometer, which estimates the relative migration distance using infrared rays by IrID LED[6]. In this method, the installation cost of infrastructure is reduced compared with the case where absolute location estimation is used independently. However, it is difficult to apply the method to a disabled person, a robot, etc, because this method is specialized to walking people. Braillon et al. proposed a method using an optical flow for objective pursuit and navigation[7]. The optical flow does not require the installation cost of infrastructure since it estimates a movement by processing an image captured by camera. However, the optical flow has problems of high computational cost and estimation errors that degrade the accuracy of location estimation, when a camera or an opponent object moves in high speed, the method using optical flow cannot the estimate relative migration distance exactly.

In this paper, we propose a method for estimating relative movement distance with low cost. Using an interlace camera and simple markers, our method can adapt a high-speed movement with two images at a very short scanning interval from the interlace image. Since the markers in our system do not include position information, the installation cost becomes low. Moreover, it does not need multiple wearable sensors but only a camera to acquire the relative position.

The rest of this paper is organized as follows. Section 2

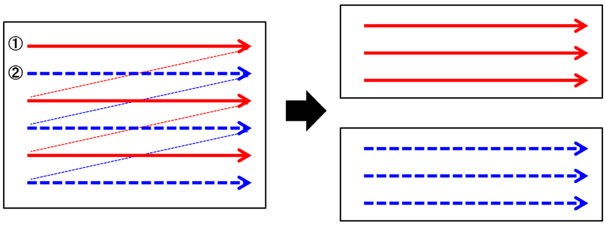


Figure 1: Characteristic of interlace scan


Figure 2: Distance estimation by progressive camera

explains the proposed method in detail, and Section 3 shows our evaluation results. Finally, we summarize the paper in Section 4.

## 2. RELATIVE DISTANCE ESTIMATION USING INTERLACE CAMERA

In order to realize the general-purpose location estimation in ubiquitous computing environments, it requires the low installation cost of infrastructure and it should support the high-speed object movement. Therefore, we propose a method that estimates the relative distance by recognizing movement of markers. Our method utilizes the feature of interlace camera, which one image is expressed from two images with a very short scanning interval.

### 2.1 The Characteristics of interlace camera

When a non-interlace camera takes an image, it starts scanning from the upper left point and moves horizontally to right. Then, it goes on to the next lower horizontal line. All lines are scanned in a progressive way. In case of using an interlace camera, the line scan is done in a similar manner, but firstly only odd lines are scanned and then even lines are done. For example, when the frame rates of a non-interlaced camera is 30fps, the frame rates of the interlace camera is 60fps if we consider that the odd-line scanned image and even-line scanned image of interlace scan are different images as shown in Figure 1.

When a non-interlace camera is used in estimating the migration distance of an object, a system captures images continuously by the camera and estimates migration distance by comparing two successive images as shown in Figure 2. In that case, each processing time $L_1$ includes the capturing time, the time of storing image, and the time of distance calculation. At this time, the frequency for picture acquisition is $f_1 = (1/L_1)$. If the throughput of PC or a camera is

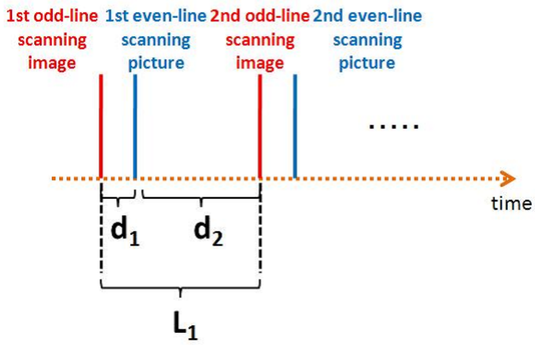


Figure 3: Distance estimation by interlace camera

not enough and if we use an algorithm for estimating migration distance with much computational complexity such as the optical flow, the time to capture an image becomes long. Thus, it is difficult to estimate the migration distance of the object that moves in high-speed because $L_1$ is too long in such an environment.

The above-mentioned problem is solved by using interlace scan. As shown in Figure 1, an interlace camera expresses one image from two images with a very short scanning interval. Therefore, if only the system can capture one image, the system gets two successive images called an odd-line scanned image and an even-line scanned image. As shown in Figure 3, when the system estimates the migration distance using interlace camera, it captures one image, and performs calculation($d_2$) of estimation by comparing obtained two successive images. At this time, the scanning interval between two successive images is much less than a half of the scanning interval in non-interlace camera. This is because $d_1$ does not include any cost for storing an image and calculation. At this time, the frequency of distance estimation is $f_p = (1/d_1) = f_1(L_1/d_1)$. Therefore, in the same environment, the frequency of estimation is $L_1/d_1$ times faster than that in the conventional method. It means that our method can adapt to high-speed movement of object compared with the conventional method. Moreover, the interlace scan has another merit that the system can perform estimation even in the case where PC and a camera have poor performance in which the capturing interval is too long for using non-interlace camera. This is because migration distance can be calculated by capturing one image.

### 2.2 Algorithm for migration distance estimation

The migration distance estimation in our method is performed as the steps shown in Figure 4. The detailed procedure of each step is shown in the following sections.

As shown in Figure 5, we assume an environment where an interlace camera moves in parallel with the ground covered with many black circular markers. First, our system captures an image with an interlace camera, and then the image is binarized simply by fixed threshold in order to perform marker detection easily.

#### *2.2.1 Camera image acquisition*

All the following processings are performed for each odd line image and even line image. After the binarization, our

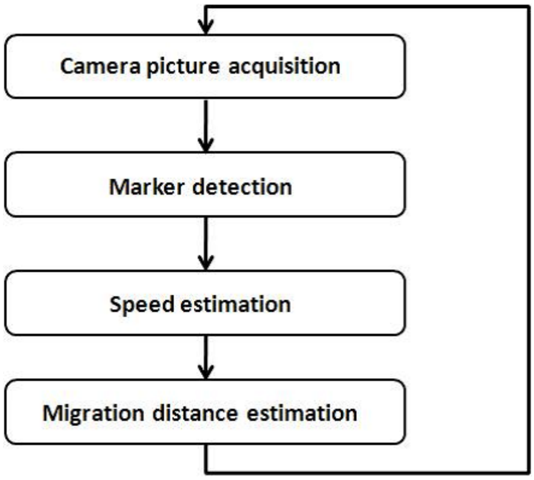


Figure 4: Flowchart of migration distance estimation

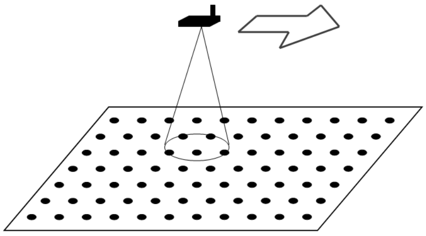

Figure 5: System configuration

method detects the possible area for markers by detecting the set of continuous lines that the total count of white pixels on the line of y-direction is below $Th$ (Figure 6-$< 1 >$).

Next, for accurate calculation of center position for each marker, our method makes small boxes based on the middle point of each possible area. The size of box is 128 x 96 pixels and it arranges 5 boxes longitudinally (Figure 6-$< 2 >$). Then, our method applies the same procedure described as Figure 6-$< 1 >$ to x-coordinate and y-coordinate in each box (Figure 6-$< 3 >$, $< 4 >$), and it gets the central position for each marker.

Finally, our system performs integrates too close (within $R$ pixels) two central points because they should be considered the same marker divided into two windows (Figure 6-$< 5 >$).

### 2.2.2 *Velocity estimation*

When an interlace camera moves on a marker, the marker on the captured image has blurred by the time lag between the odd-line scan and the even-line scan as shown in Figure 7. By preliminary experiment, it is confirmed that the size of blur is in proportion to the movement speed of camera. Therefore, the movement speed of camera can be estimated by this relation. When multiple markers are detected in one frame image, our system calculates the average velocity from the results of calculating velocity for all markers. It contributes the accuracy improvement for distance estimation.

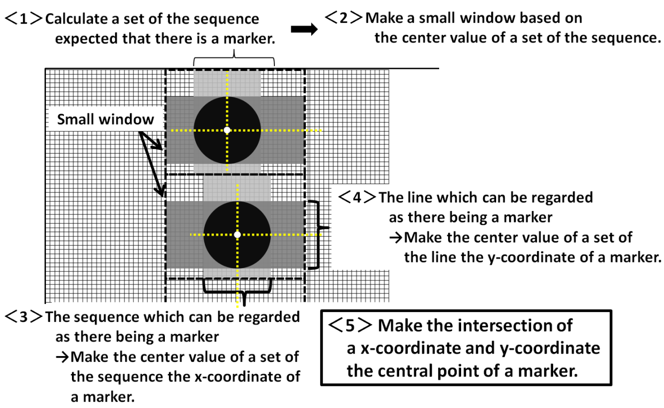


Figure 6: The method detecting a marker

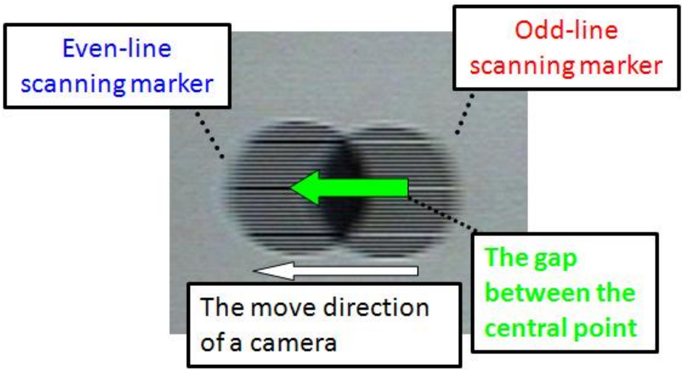


Figure 7: Blurred marker

### 2.2.3 *Migration distance estimation*

Assuming that a movement speed of camera is constant between successive frame images, our system calculates the migration distance of camera by multiplying the velocity $V$ by the scan interval as shown in Figure 8.

## 3. EVALUATION

We evaluate the accuracy of migration distance by comparing with a conventional method using non-interlace camera.

## 3.1 Experimental environment

In our experiment, we use a fixed camera and moving markers as shown in the left of Figure 9. As interlace camera, we use The CARD 7RL by RF, Inc., which has 270,000 pixels 1/4-inch color CCD. The resolution of the camera is 680×480 and a captured image is sent to PC via USB. The cylinder that markers are attached is arranged at a distance of 18cm from the camera. The right of Figure 9 shows the arrangement of markers on the surface of the cylinder. The diameter of each marker is 1.5cm, the same color, and the number of marker is 72 (3×24 lines), and the distance be-

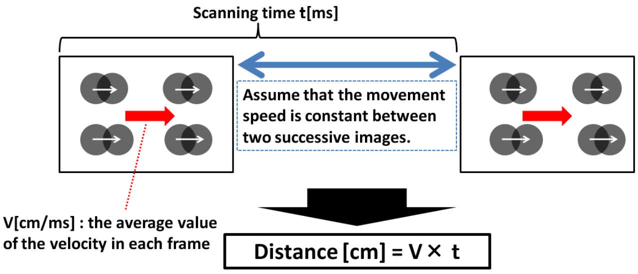


Figure 8: Migration distance estimation

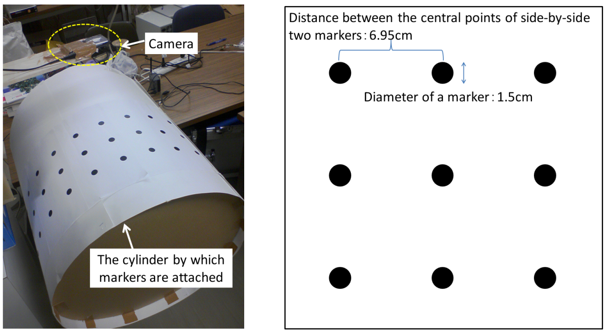


Figure 9: Experimental equipment

tween two markers is 6.95 cm. The circumference of the cylinder is 166.8cm. In this situation, the camera can see at least nine markers. The threshold value $Th$ and $R$ are set to 232 and 43, respectively, by the preliminary experiment. Note that 1 cm on the cylinder is equivalent to 30.839 pixels on a captured image. The illumination intensity of the room is about 630LUX.

## 3.2 Comparison method

As the comparison method, we use a non-interlace camera that has the same spec as the camera used in the evaluation for proposed method. It estimates migration distance by using the variation of a marker in continuous two frame images.

## 3.3 Procedure

We measure the difference of an actual movement distance of the camera and a movement distance computed by the estimation algorithm, and we evaluate the accuracy of migration distance estimation. First, we turn the cylinder, and get the relation between blur of a marker and the movement speed of a camera. Then, our system estimates the movement speed of the camera($V$) by blur of a marker. Next, we turn the cylinder 3 rounds(500.4cm). Then, our system calculates the migration distance by using movement speed $V$. Moreover, we calculate the difference of the estimated migration distance and the actual migration distance. We repeat the same operation 50 times. We tried to keep the movement speed of the cylinder on 5 cm/s, 15 cm/s, 23 cm/s, 34 cm/s, and 60 cm/s. Furthermore, for the proposed method, we employed the faster speed; 70 cm/s and 125 cm/s.

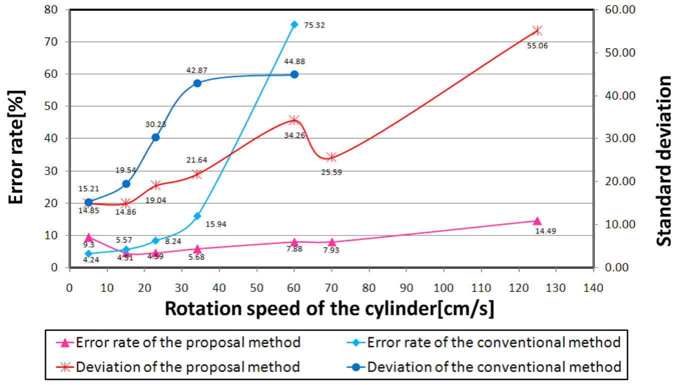


Figure 10: The summary of evaluation results

## 3.4 Result

In the evaluation, we define the error ratio as the following equation:

$error\ ratio = |D_e - D_a|/D_a$

$D_e$ means the estimated movement distance and $D_a$ means the actual movement. Figure 10 shows the average error ratio in the experiment, and Figure 11 shows the detailed distribution of estimation errors in the speed of 34cm/s. In the Figure 10, horizontal axis shows a movement speed of the cylinder[cm/s], the left side vertical axis shows the error rate and the right side vertical axis shows the deviation. The frame rate of the proposed method was 7.06fps and the frame rate of the conventional method was 4.74fps because the conventional method takes more time to get two successive images.

This result shows that the estimate error becomes large as the speed goes up in both of the proposed method and the conventional method, except for 5 cm/s in the proposed method. Moreover, it turns out that the deviation becomes also large as the speed increases in the both methods. However, these figures clearly show the advantage of the proposed method compared with the conventional method, especially in high-speed movement. For example, in 34cm/s speed, error rate of the conventional method exceeds 15%, while that of the proposed method is 5.68%. Furthermore, in the case of 60cm/s speed and faster, the conventional method cannot detect the movement properly while the proposed method keeps the accuracy under 15% even in 125cm/s speed. On the other hand, in the extremely slow situation, the proposed method does not have enough accuracy compared with the conventional method. This is because there is almost no difference between odd-line image and even-line image. It makes errors for estimating the migration distance. In future, we have to consider the selective method that changes the estimation method according to the current movement speed.

# 4. CONCLUSION

In this paper, we have proposed a new migration estimation method using interlace camera and simple visual marker without location information. The proposed method estimates migration distance using the blur of a marker between odd-line image and even-line image captured by interlace

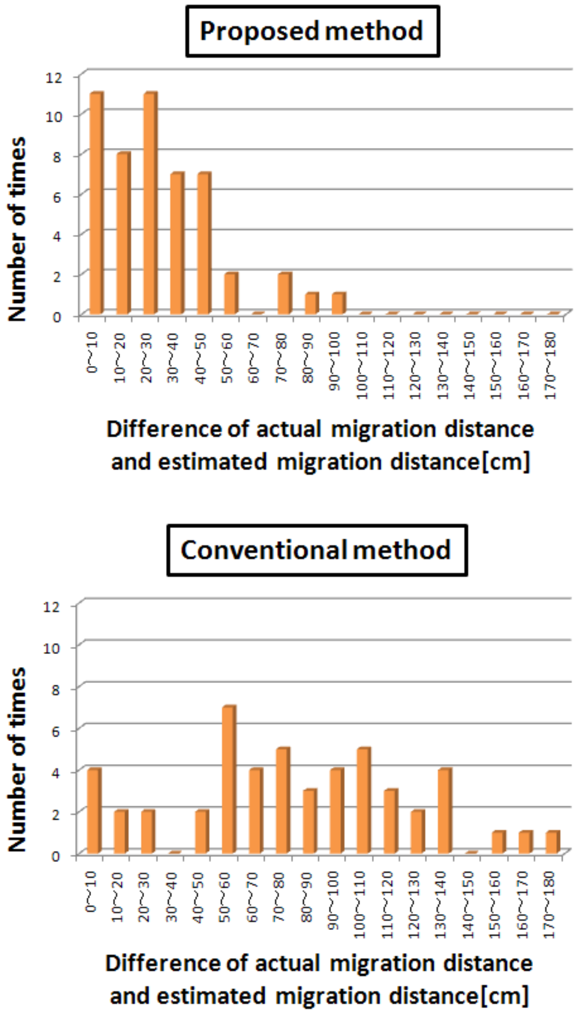


Figure 11: The detailed evaluation result in speed 34 cm/s

camera. From the result of evaluation, we confirmed that our method is accurate and can adapt to high-speed movement of objects compared with the conventional method using non-interlace camera, because our method estimates by using two successive images with short scanning interval.

In future, we will improve our method in the algorithm of calculating migration distance, and propose a method that changes the algorithm dynamically in response to the change of environmental conditions. Moreover, we will enhance the proposed method to three-dimension migration distance estimation.

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## 7. REFERENCES

[1] M. Kourogi, N. Sakata, T. Okuma, and T. Kurata: Indoor/Outdoor Pedestrian Navigation with an Embedded GPS/RFID/Self-contained Sensor System, Proc. of 16th International Conference on Artificial Reality and Telexistence (ICAT2006), pp. 1310–1321, 2006.

[2] M. Agrawal, and K. Konolige: Real-time Localization in Outdoor Environments using Stereo Vision and Inexpensive GPS, Proc. of 18th International Conference on Pattern Recognition (ICPR2006), vol. 3, pp. 1063–1068, 2006.

[3] D. Hahnel, W. Burgard, D. Fox, K. Fishkin, and M. Philipose: Mapping and Localization with RFID Technology, Proc. of IEEE International Conference on Robotics and Automation, vol. 1, pp. 1015–1020, 2004.

[4] L. Fang, W. Du, and P. Ning: A Beacon-Less Location Discovery Scheme for Wireless Sensor Networks, Proc. of 24th Annual Joint Conference of the IEEE Computer and Communications Societies, vol. 1, pp. 161–171, 2005.

[5] M. Kalkusch, T. Lidy, M. Knapp, G. Reitmayr, H. Kaufmann, and D. Schmalstieg: Structured Visual Markers for Indoors Pathfinding, Proc. of The First IEEE International Augmented Reality Toolkit Workshop(ART02), 2002.

[6] R. Tenmoku, M. Kanbara, and N. Yokoya: A Wearable Augmented Reality System Using Positioning Infrastructures And A Pedometer, Proc. of IEEE International Symposium on Wearable Computers（ISWC2003）, pp. 110–117, 2003.

[7] C. Braillon, C. Pradalier, J. L. Crowley, and C. Laugier: Real-time moving obstacle detection using optical flow models, Proc. of IEEE Intelligent Vehicles Symposium 2006, pp. 466–471, 2006.