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Human Behavior Detection Method Based on Direction Change Invariant Feature

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ABSTRACT

In this paper, we propose a human behavior detection method based on direction change invariant features. As one of the detection in human behavior, there was a method using cubic higher-order local auto-correlation (CHLAC). Conventional human behavior detection methods using CHLAC exhibit a high level of performance, but has difficulty in distinguishing between abnormal and normal movements in the case of rapidly changing the direction or the scale of human. We introduce a statistical processing of mask patterns to suppress the change in the amount of feature by using the direction of movement of human. This provides a robustness of discrimination in human movement. A computer simulation using the proposed method shows that a superior performance, when compared to the conventional method in discrimination of abnormal human behavior.

Keywords: Abnormal Movement Detection, CHLAC, Human Behavior, Image Processing, Pattern Analysis.

1. INTRODUCTION

Rapid developments in computational techniques have allowed studies of objects and human recognition from a still image or moving images (time-series images). In particular, studies of human movement detection have attracted much attention. In this paper, we consider an abnormal movement detection method for monitoring elderly people and prevention of crime [1-2].

Cubic higher-order local auto-correlation (CHLAC) was proposed by Otsu [1], and has been attracted as a useful image feature amount for quantifying characteristic movement. CHLAC converts the human movement in time-series images into a feature vector of 251 dimensions by using bi-nary mask patterns. As one example of using CHLAC feature, there has been applied to detection of abnormal movement [2]. CHLAC feature of normal human movement is calculated beforehand, and is compared to the feature amount from the target time-series images from camera. Then, an abnormality of the human movement is calculated with the degree of resemblance between two features. When an intense change in the vector describing the human movement is not observed, such as the same direction and the same scale in the time-series images, CHLAC generally provides high performance in the human behavior discrimination. However when this is, as it is, applied to the time-series images in which a scale change or a rapid direction change of the human is observed, the feature amount change largely, the detection performance in the human behavior discrimination get decreased.

To deal with this, a statistical processing for suppressing the change in the CHLAC feature amount can be considered. One of the improvements on it is multi-scale CHLAC and the image pyramid, developed by Matsunaga [6]. His method places pixel interval and temporal order intervals together to determine the change in the size of the human, and these intervals are adaptively modified. By expressing an image hierarchically, this permits to work effectively, even when the scale of the human changes. In this way, the accuracy with the discrimination of the human movement is enhanced by the improved feature amount.

We proposed a new detection method, which is different from these methods as above, of the human movement using modified CHLAC feature amount. Our proposed method adopts an adaptive mask pattern generation based on the correlation in the direction of the feature amount, and an average processing for minimizing the rapid change of the feature amount in the case of a normal human movement, even when the human movement includes a scale change or a rapid direction change. As a result, the proposed method can distinguish human the normal behavior. Computational experiments shows that the discrimination accuracy is higher than in the conventional methods for the human movement [7-9].

2. COVENTIONAL METHOD

A. Cubic Higher-order Local Auto-correlation (CHLAC)

Firstly, we review CHLAC [5] as a feature amount to determine the characteristic human movement. As for detection methods that use the CHLAC feature amount, high discrimination performance is reported in the detection of an abnormal behavior from time series-images.

Let $f(r)$ be a pixel value at the still image data f, and r the position inside the image f. The higher-order local auto-correlation function HLC, x_f^N with displacement of N a_i $(i = 1, \dots, N)$ is defined as below.

$$x_f^N(a_1, a_2, \dots, a_N) = \int f(r)f(r + a_1) \dots f(a_N)dr \tag{1}$$

When displacement N is set to at most two, and the displacement direction is limited to the 3 by 3 local domain, the combination of displacement directions a_i becomes 25 patterns except the patterns that becomes equivalent by the translation, and the HLAC is obtained as a vector of 25 dimensions (one element in zero degree, 4 elements in one degree, and twenty elements in two degree). Fig. 1 shows an example of the binary mask pattern of HLAC.

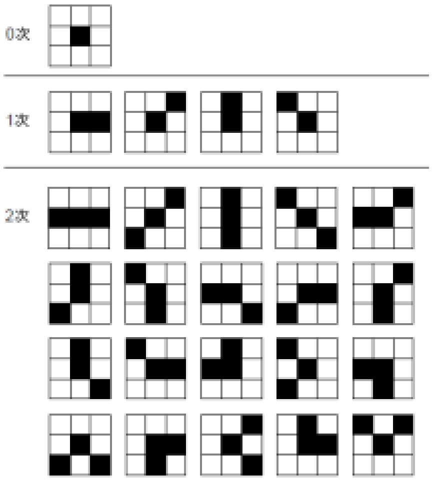

Figure.1: Mask pattern of HLAC feature

CHLAC is regarded as an extension of HLAC feature amount in temporal direction. It is calculated by integrating (1) for some interval or over the entire time series-images. As with HLC, when N is limited to two, the combination of displacement directions a_i is obtained as a 251dimensional vector by the translation. It only has to think about the binary mask pattern in the CHLAC with the lattice of a solid body(3*3*3 cubic structure) of three moving images.

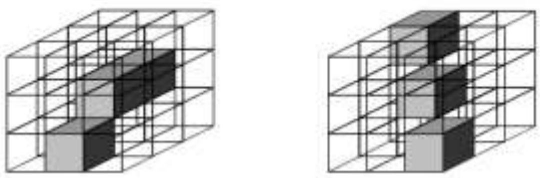

Figure 2: Example of displacement pattern of CHLAC

B. Sub-space Method

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The subspace method is adopted for an abnormal behavior detection based on the CHLAC feature amount. First, to compose a partial space based on vector obtained by the CHLAC feature amount, principal component vectors are calculated using principal component analysis (PCA), as an eigenvalue solution.

The principal component matrix $U = [u_1, u_2, \ldots, u_M]$, $u_i \in V$, is obtained from the eigenvalue problem of

$$\Sigma_x U = U\, A \tag{2}$$

In Eq. (2) Σ_x is co-variance matrix with$x$.

In the eigenvalue, a contribution rate, η_k of accumulation at the *k-the* dimension is defined below.

$$\eta_k = \frac{\sum_{i=0}^{k} \lambda_i}{\sum_{i=0}^{M} \lambda_i},\ (k \le M) \tag{3}$$

A sub-space W spanned by the principal component vectors, eigenvectors $U_{1,k} = [u_1, u_2, \ldots, u_k]$ of which the contribution rate, η_k, become more than 0.99, is regarded as the normal behavior space, and the orthogonal complement space $W_{\perp}(= V - W)$ is spanned by $U_{(k+1),M} = [u_{k+1}, u_{k+2}, \ldots, u_M]$. The space $W_{\perp}$ means the not including normal behavior space, or abnormal behavior space. The projection $P_{1,k}$ of x to the sub-space W spanned by $U_{1,k} = [u_1, u_2, \ldots, u_k]$ is shown as $U_{1,k}\ x,$ and the projection $P_{(k+1),M}$ of x to the orthogonal complement space $W_{\perp}$ is shown as $U_{(k+1).M}\ x$. The contribution, or, the distance $d_{\perp}$of the projection of x to the orthogonal complement space $W_{\perp}$ is below.

$$d_{\perp}^2 = \left\| U_{(k+1).M}\ x \right\|^2 \tag{4}$$

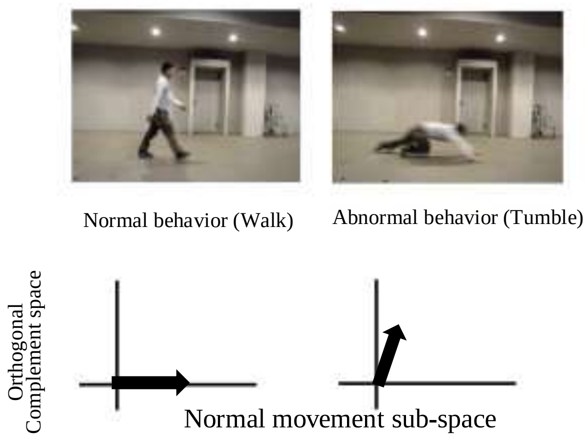


Figure.3: Subspace method

In the subspace method with the CHLAC, human behavior discrimination is judged by the projection distance $d_{\perp}$ to the orthogonal complement space $W_{\perp}$. For example, when human behavior, or movement is normal, the projection to the subspace W, which increase. Conversely, when the human behavior is not normal, that is, abnormal, the distance $d_{\perp}$ in the orthogonal complement space $W_{\perp}$ increases.

A change in the projection distance under the normal and abnormal movement is shown in Fig. 3.

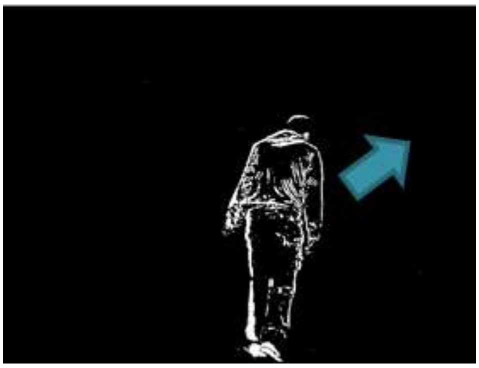
3. PRPOSED METHOD

A. Outline

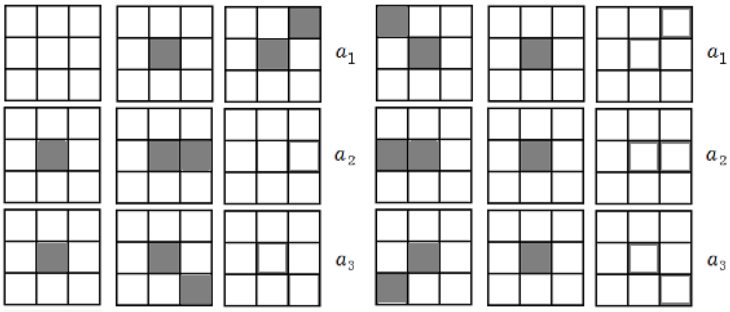
Our proposed method utilizes the CHLAC feature mount for representing a human movement, and a sub-space method for judging the human movement discrimination. Then, to decrease wrong detection of the human movement, its method adopts an adaptive mask pattern generation based on the correlation of moving direction, and an average processing for minimizing rapid change in the CHLAC feature amount with the same direction of the human movement.

B. CHLAC Feature Extraction by Correlation of Moving Direction

In the feature mask patterns used for the CHLAC shown in Fig.2, which is composed of 251 dimensional vector, some patterns with high correlation exist for a specific direction of the movement. Therefore, the feature amount for the some mask pattern depending on the type of the scene increases or decreases greatly, and the direction of the feature vector changes. Then, it may not correctly determine the human behavior.



(a) Example of binary image scene (walking movement)



(b) Example of common mask pattern

Figure 4: Example of merging mask patterns with high similarity of human direction change in instance

A new mask pattern is generated using this character in consideration of the direction of the feature amount. The specific direction of the behavior can be distinguished among the common mask patterns.

A Trend for the human movement is estimated. The mask pattern with large correlation exists with based on the direction in the CHLAC feature amount. In Fig. 4, an example of the binary image scene (walking movement) is shown with the high similarity of the human direction change. When a pattern has some common direction elements, it is judged that there is strong similarity in the mask pattern. The combinatorial total of relevant common pattern at the position in the cubic structure in Fig.2 is calculated. Then a new feature vector is composed based on this three-dimensional solid higher-order autocorrelation.

C. CHLAC Feature Extraction by Change of Moving Direction

The CHLAC feature amount in the human movement is determined based on increase and decrease of movement between successive two image frames. Because elements of the feature vector change greatly by a change in the moving speed or the size of the human inside the image frame accompanying a change in human moving direction, the discrimination of the human behavior might be difficult. Then, we consider that the human behavior can be distinguished regardless of the scale change of the human in the image frame. When a transition rate of increasing trend on the feature amount is examined, the expansion rate of the feature vector is estimated from the back to forth in frame of human movement. Then, the size of each feature amount vector is averaged along successive image frames with the expansion rate.

For this averaging processing in the feature amount, first the value of α_i , that minimizes:

$$\|\alpha_i x_i - x_{i-1}\| \quad (\alpha_1 = 1, i = 1,2 \ldots N) \tag{5}$$

, is determined using the vector obtained by the CHLAC feature amount as standard level. Here, α_i represents the expansion rate between two feature vectors along successive image frame. Each new feature vector X_i is formed from the obtained α_i with using the averaging processing. The new vector X_i , using the expansion rate α_i , is composed as below

$$X_i = \frac{(x_i + a_{i+1} x_{i+1})}{2} \qquad (i = 0,1, \ldots, N-1) \tag{6}$$

4. COMPUTER EXPERIMENTS

A. Overview

In the experimental simulation, we used a time-series image scene in which one human was walking and then fell. A difference processing between successive two image frames is conducted, and the frame difference image, that is, binary image with two values, was made based on an automatic threshold determination method by Otsu [4]. Fig.5 shows an example of binary image of human walking in the used time-series image scene. In this experiment, a normal movement to be seen frequently is defined as walking movement. Then, an abnormal movement to be slightly shown is defined as a tumbling movement. Two different time-series image scene were used. One is to include a movement with a single direction, another including a movement with two or more different directions.

Figure 5. Example of normal human movement

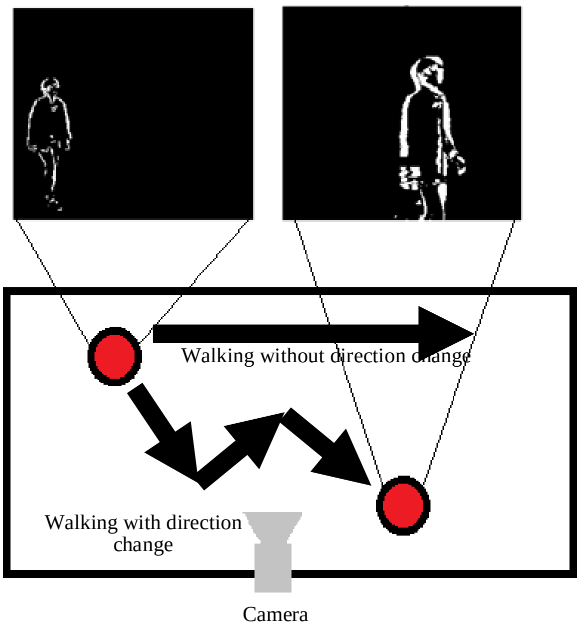


Figure 6. Example of human behavior with direction change

Fig. 6 shows an example of a direction change movement of the human including a scale change of the human. Whether a type of the movement, normal or abnormal, was correctly distinguished by the proposed method was verified for both a single direction movement and a complex movement including a direction change of movement by computer simulation.

B. Abnormal Movement Frame Detection

Time-series images including a tumbling behavior shown in Fig. 7 was used. Its experimental results showed that the discrimination between walking and tumbling was conducted correctly. The transition of the distance ($d_\perp$ value of each frame) was examined. The $d_\perp$ value retains almost the same value under the normal movement. The distance $d_\perp$ in section 2.2 was obtained as the result of the size of the projection of the CHLAC feature amount to the orthogonal complement space of the normal movement sub-space movement, and when the abnormal movement such as tumbling is observed in the time-series image scene, the $d_\perp$ value becomes very high compared to another normal image frames. Fig. 8 shows a transition of the $d_\perp$ value with each frame.

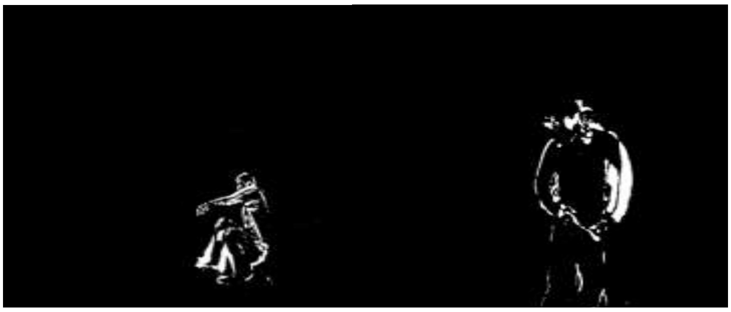


Figure 7. Example of abnormal movement (tumbling).

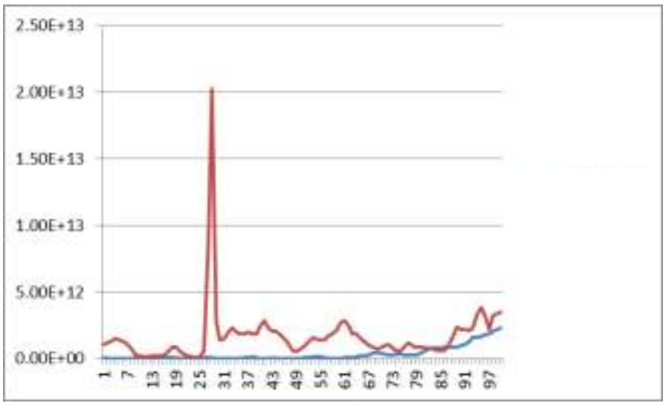


Figure 8. Value $d_\perp$ of conventional method (blue) and the proposed method (red).

C. Distinction Rate

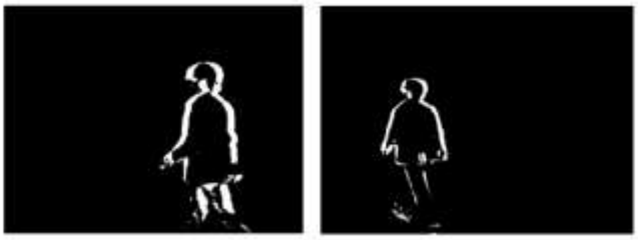
50 different types of image scenes with a moving direction change were examined. Then, we examined whether an abnormal behavior could be distinguished correctly by each image frame. Its experimental results showed that the abnormal movement was correctly distinguished when a high $d_\perp$ value was observed for the frame. Table 1 shows the discrimination rate for each method with different types of time-series image.

A computer can calculate the difference value $d_\perp$of between successive two image frames. When the $d_\perp$ value exceeds some preset threshold, it is judged that an abnormal movement have occurred. When the judgment, which include the abnormal movement, by a viewer equals to the judgment by computer simulation, the judgment is determined to be correct, that is, the computer can distinguish the abnormality of the movement.

The conventional method (the original CHALA method), as well as the hierarchal CHLAC and the multi-scale CHLAC, were compared to several kinds of the proposed methods (Method A: a feature extraction with correlation of the moving direction, Method B: a feature extraction with an averaging processing, Method C: A+B: with a mix of Method A and Method B). The discrimination results are shown in Table 1.

Table 1. Discrimination rate

Method	No Direction Change	Direction Change
Conventional	80%	52%
Hierarchal	60%	20%
Multi-scale	60%	24%
Proposed A	80%	58%
Proposed B	80%	60%
Proposed C	82%	62%



Scene 1 Scene 2

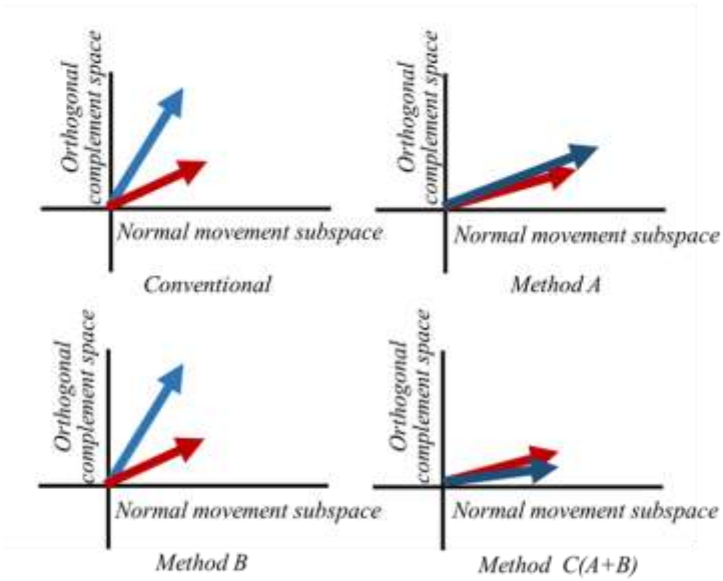


Figure 9. Comparison of Principal Component between Conventional Method and Proposed Methods for Scene 1 (Blue Arrow) and Scene 2 (Red Arrow).

Scene 1 and Scene 2 shown in Fig.2 are both a normal behavior, that is, a normal movement. However, we can see that the conventional method has greatly changed the principal component vectors in spite of the normal movement. On the other hand, for the proposed methods, especially, Method B and Method C, the principal component vectors held a few change. This is because of the effect obtained by adopting the feature extraction process with a detection of feature amount vector direction change and an averaging processing.

5. CONCLUSION

We proposed a new discrimination method of the human movement using the CHLAC feature amount. Our proposed method adopts an adaptive mask pattern generation based on correlation of the feature amount direction, and average processing for minimizing the rapid change of the feature amount in the case of the normal human movement.

As a result, we accurately categorized human movement types from image scene with a complex change in the moving direction, whereas conventional method, the original CHALA method, have struggled to distinguish such motion.

As for the problems to be solved from now on, as well as carry out the improvement of the discrimination rate, it is scheduled to proceed with the investigation in detail this proposed method.

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