A Study on Understanding Pedestrian Flow Using Intermittent Recording Images (PIRI)

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Abstract
Pedestrian flow information has been used as the basic data for urban facility planning and architecture. Pedestrian information surveys require significant time and money. Therefore, this study assesses pedestrian flow using intermittent recording images (defined as "PIRIs" in this paper).

A PIRI makes it possible to visualize the state of pedestrian flow and is developed as follows:
1) Pictures of pedestrian flow are taken from a stable viewpoint.
2) These continuous pictures are imported into an analyzing platform (some type of a PC).
3) The offset of these images caused by camera movement is adjusted to the correct position. This process can be executed automatically.

In this study, the optimal shutter interval was defined as $t = 1 \text{s}$, and the number of images processed is defined as $T_{\text{max}} = 20 \text{ [frame]}$. Using these parameters, PIRI can be applied with "time-space interfering model".

Keywords: pedestrian flow; visualization; fixed-point observation; image recognition; pedestrian

1. Introduction
1.1 Background
It is becoming more important to assess pedestrian flow today. This pedestrian flow information has been used as the basic data for congestion and comfortable space planning for urban facilities and architecture. User questionnaire surveys and origin-destination surveys are generally used to collect pedestrian flow information. However, these surveys are extremely time and money consuming. For this reason, an assessment of pedestrian flow using laser sensors and video cameras was performed; this required special equipment and significant analysis time.

1.2 Purpose of this Study
This study assesses pedestrian flow using intermittent recording images (defined as "PIRIs" in this paper). A PIRI is one image synthesized by several pictures taken continuously. A PIRI makes it possible to visualize pedestrian flow, for twenty seconds, in one image (Fig.1.). A characteristic of PIRI is that it creates data quickly; therefore, it can be used to analyze the state of pedestrian flow in real time.

2. Research Brief
2.1 Steps for Creating a PIRI
The steps to create a PIRI are as follows:
1) Pictures of pedestrian flow are intermittently taken from a stable viewpoint. These continuous pictures are the basis of data analysis. The optimal shutter interval ($\delta t$) and the number of images ($T_{\text{max}}$) used in this study are described in Chapter 3.
2) These continuous pictures are imported into an analyzing platform (some type of a PC) and synthesized. This process can be executed automatically.
3) Images that have visualized pedestrian trajectories are obtained as the PIRI (Table 1.).
2.2 Synthesis Method of PIRI

Pedestrian flow that is difficult to view using an image or movie has been visualized by the process of synthesis as follows:
1) The offset of images caused by camera movement was adjusted to the correct position (Table 1., steps 2 and 3).
2) A method to visualize pedestrian trajectories using RGB values in an analyzing platform was developed (Table 1., step 4).

3. Discussion of the Process to Visualize Pedestrian Trajectories and Characterize PIRI

3.1 Optimal Shutter Interval to Take Continuous Pictures

To define the optimal shutter interval, $\Delta t$ in this study, four PIRIs were taken at a plaza near a bus stop in front of JR Kyoto Station.

Images of pedestrian flow were taken using a hand-held camera located on the deck of the station's second floor (Fig.4.).

The PIRI shown in Fig.2. was set to $\Delta t = 1 \text{ s} \cdot T_{\text{max}} = 20 \text{ [frame]}$ and that shown in Fig.3.-i was set to $\Delta t = 0.5 \text{ s} \cdot T_{\text{max}} = 20 \text{ [frame]}$. The PIRI shown in Fig.3.-i displays pedestrian trajectories clearly. However, as the trajectory intervals of PIRI shown in Fig.3.-i are narrow when compared with those shown in Fig.2., it is difficult to discriminate each trajectory in the crossing space.

The PIRI shown in Fig.3.-ii was set to $\Delta t = 1.5 \text{ s} \cdot T_{\text{max}} = 20 \text{ [frame]}$ and that shown in Fig.3.-iii was set to $\Delta t = 1.5 \text{ s} \cdot T_{\text{max}} = 10 \text{ [frame]}$. When the trajectory intervals were wide, both PIRIs showed that assessing the state of the flow was difficult. As a result of this study, the optimal shutter interval was defined as $t = 1 \text{ s}$, and the number of images processed was defined as $T_{\text{max}} = 20 \text{ [frame]}$ (Fig.2.).

3.2 Comparing the States of Pedestrian Flow on the PIRI

A PIRI makes it possible to visualize pedestrian flow for twenty seconds in one image. A PIRI has two advantages:
1) Assessing the route of a pedestrian, and
2) Assessing the velocity change of a pedestrian.

To confirm these characteristics, the states of pedestrian flow were compared using three PIRIs (Fig.2. and Fig.5.).

The black frame in Fig.2. shows that people have lined up to get on a bus. And this line has caused congestion. In the PIRI, this congestion is visualized by the wide and narrow intervals of pedestrian trajectories.

As the line shown in Fig.5.-1 is longer than that shown in Fig.2., pedestrians have avoided the line. In the PIRIs, this state is visualized by the shape of the pedestrian trajectories.

Fig.5.-1 shows that as the line to get on a bus disappeared, there was no congestion in the white frame. At this time, pedestrians were crossing the plaza freely.
4. Verifying the Characteristics of the PIRI

4.1 Creating the Time-Space Interfering Area Model

Characteristics of the PIRI were verified using the time-space interfering area model*1 described in the research of Sano*6.

The time series pedestrian territory model*2 and the time series interfering area model*3 were created based on the pedestrian flows observed in Section 1 of Chapter 3 as follows:

1) Coordinates of the images were transformed to orthogonal coordinates.
2) Pedestrian trajectory data was created to plot the coordinates of the pedestrians in each frame.
3) The radius of the pedestrian territory was defined as 0.455 m based on a previous research*8.
4) By entering the pedestrian trajectory data into a 3D \{x, y, t\} platform, the time series pedestrian territory was created.
5) By identifying crossing objects for each of the time series pedestrian territories, the time series interfering area was created (Table 2., Section 2).

4.2 Verifying Characteristics of the PIRI with the Time-Space Interfering Area Model

To verify the characteristics of the PIRI, the shape of the time series interfering area model was classified as shown in Table 4. described in the research of the authors. Pedestrians were classified into three categories: A (moving from the north to the east), B (moving from the east to the north), and C (waiting for the bus) (Table 2., Section 2). The time series interfering area model shows that congestion type and waiting type were caused in a position of high pedestrian density as shown by PIRI (Table 3.). Therefore, PIRI makes it possible to visually assess the states of congestion.

Table 2. Creating Flow of the Time Series Interfering Area Model

<table>
<thead>
<tr>
<th>Section</th>
<th>Creation of Coordinates</th>
<th>Time Series Pedestrian Territory Model</th>
<th>Time Series Interfering Area Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Correct the Position of Coordinates</td>
<td>Time Series Pedestrian Territory Model</td>
<td>Time Series Interfering Area Model</td>
</tr>
<tr>
<td>2</td>
<td>Extraction of Pedestrian's Position Coordinate</td>
<td>Time Series Pedestrian Territory Model</td>
<td>Time Series Interfering Area Model</td>
</tr>
</tbody>
</table>

Occurrence is concentrated in the vicinity of the crowd C.
5. Conclusion

In this study, pedestrian flows were assessed using intermittent recording images. PIRI shows a pedestrian trajectory on an image and makes it possible to visually assess the states of flow. PIRI allows quick data analysis; therefore, it is able to analyze the state of pedestrian flow in real time. This characteristic makes risk management, marketing management, and the use of simple data for creating more thorough data possible. However, there is a problem with the PIRI method. Because pedestrian trajectories in different time series overlap with each other in one image, showing the position of the crossing and the direction of pedestrian movement using a PIRI is difficult. Therefore, verifying the original images is necessary. The optimal shutter interval and the number of images should be defined for each research event because a PIRI is influenced by the weather and the angle of the photograph. Therefore, an experience to create a PIRI in various locations is required.

Table 3. Analysis of PIRI with the Time Series Interfering Area Model

<table>
<thead>
<tr>
<th>Interference Load between Crowd A-C, B-C</th>
<th>Between Crowd A-B</th>
<th>Among All Crowd</th>
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<tr>
<td>t0</td>
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</table>

Table 4. Classification of Interference Load by Cross Pattern

<table>
<thead>
<tr>
<th>Avoiding Pattern of Pedestrian</th>
<th>The Time Series Interfering Area Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passing Each Other Type</td>
<td>This is the most popular passing avoiding pattern of half-length axis between A and B. Avoidance duration is relatively short. Disturbance of the walking locus of both a and b is smooth.</td>
</tr>
<tr>
<td>Wait Type</td>
<td>This is the avoiding pattern that one reduces the walking speed to wait for the passage of other when a intersects b. This is the most reasonable avoidance but walking speed other a and b is disturbed.</td>
</tr>
<tr>
<td>Congestion Type</td>
<td>This is the avoiding pattern that both of them reduce the walking speed by factors such as congestion around when a crosses b. This is the state that interfere with an area each other continues long time. Walking speed both a and b is disturbed.</td>
</tr>
</tbody>
</table>

Notes

1. The space-time interfering area diagram model is a transaction time series model describing the interference load of each pedestrian of mutual multi-directional flow crowd in time series. This allows us to grasp the variation characteristics of walking load in time series and understand the congestion change of evaluation object space in time series.

2. The authors draw the walking area \( A_t \) \( \{ A_0, A_1, A_2, \ldots \} \) in time \( t \) \( \{ t_0, t_1, t_2, \ldots \} \) on the Plane "t" in 3-dimensional space \( \{ x, y, t \} \) with "time axis = t" and "movement plane of pedestrian A = \{ x, y \}". The authors define this multi-stage cylinder as the time series pedestrian territory model.

3. The authors define a solid formed by the interference part of the pedestrian territory model.

References


