Dynamic Walking Field Estimation by Pedestrians Flow Measurement

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Abstract. This paper describes the measurement to take traffic lines of pedestrian flows outdoors and the investigation of dynamic characteristics by using the density, direction, velocity distribution and so on. These parameters become indexes of the congestion, dangerousness and passability. And, the time transition of these characteristics evaluate the field dynamically. The arrangement of structures and public facilities around the field will also be evaluated by them.

1. Introduction
To realize smooth and safe walking of people outdoors in city or town, it is necessary to know latent characteristic such as the congestion, dangerousness and passability of the walking field. The latent characteristic of the field is estimated by analyzing pedestrian flows. Pedestrian flows are affected by the formation of road and square, field conditions, the arrangement of structures(such as buildings, houses and railway stations), the position of entrances and exits of them and the public facilities(such as stairs, monuments, bus stops, crossing points and fountain). It is recognized that these are static factors. In addition, pedestrian flows are also affected by the density, walking directions and velocities of themselves. The direction, velocity and density of pedestrian flows change dynamically by time transition. It is recognized that these are dynamic factors. The dynamic state of pedestrian flows expresses the changing of congestion and the latent dangerousness of the field. To know the latent state of the field is very useful to predict frequent accidents for pedestrians and to redesign the arrangement of structures/facilities and the formation of road/field.

2. System configuration
The system configuration is shown in Fig.1. Telemetry system consist of three main systems; Onsite System (OS), Host System (HS) and Cloud System (CS).
OS is put on the building’s roof and measures pedestrian movement. The video data recorded pedestrian flow are stored in the computer temporarily. Sampling images are framed by 7 fps from the video image (Fig.2 (a)). Making differential image frame was generated by the absolute difference between neighbouring two image frames. Recognition of pedestrian movements is in white (Fig.2 (b)). White regions are enclosed with green boxes (Fig2 (c)). In order to look for the same pedestrian movement between neighbouring two differential image frames, the green box as similar size and existing near the neighbouring image frame is searched. The vector is drawn between the centers of their green boxes. Fig.3 shows a distribution of traffic lines of pedestrian flow. This place is square in Ritsumeikan University. The directions of traffic line segments are expressed with the color
distribution referred by the eight directions. After the pedestrian movement’s vector is calculated by image processing, it is sent to HS via CS.

HS estimates the dynamic characteristics in pedestrians walking field by using the data. It provides users with integrated computer display related to dynamic characteristics of the field at remote location. Pedestrians walking field is divided into small areas. The small areas is treated as a ROI (Region of Interest). Traffic lines are calculated in each ROI. Various kinds of field parameters are derived by a set of traffic lines. Three main parameters in order to estimate the congestion, dangerousness and passaility are introduced. In the distribution images, deep color areas are high level and light color areas are low level. The density distribution is constructed by counting the number of traffic line segments in each ROI. The density distribution image is shown in Fig.4. The high-density area means that many pedestrians were walking there. The velocity distribution of walking pedestrians is constructed by measuring length of traffic line segments in each ROI. The velocity distribution image is shown in Fig.5. High speed walking area seems that pedestrians wanted to go through quickly. Here is no obstacles for walking. Confusion of traffic lines is expressed with dispersion of directions which is defined by the quantification of the direction distribution and the number of directions in ROI. The number of the directions which exceeded the threshold for all directions is counted. This is the number of dispersion of directions. The image of distribution of dispersion is shown in Fig.6. This means that pedestrians were intersecting frequently at this area.

When user changes the parameter of vector’s calculation, the command file is assembled. It is sent to OS. OS reads it and execute the command listed in the file.

3. Evaluation of Congestion, Dangerousness and Passability

The congestion, dangerousness and passaility in pedestrian walking field is the dynamic characteristics. These are not constant by time. The congestion is related strongly to the density of pedestrians, the walking speed and the dispersion of walking directions. Specifically, it increases the density, slows the walking speed and is caused by dispersion of direction. Then, it is considered that congestion is mostly in proportion to the density, in inverse proportion to the walking speed and in
proportion to the dispersion of direction. By using these relations, the congestion is estimated by the model formula (1).

\[
\text{Congestion} = \frac{1}{2} \left( \sum_{m=0}^{7} \sum_{k=0}^{7} \left( \sum_{i=1}^{n_m} \frac{1}{v_i} \times W_{\theta_k} \times \sum_{l=1}^{n_k} \frac{1}{v_l} \right) \right) 
\]

where

- \( n_m \): the number of segments by every direction
- \( v_i \): the velocity of segment
- \( W_{\theta_k} \): the weight by every direction

The congestion distribution is shown in Fig.7. Green area shows low level congestion, yellow area shows middle level and red area shows high level. The areas that are surrounded in circles are the areas of high level congestion in Fig.7. These areas are that density is high, that velocity is slow and that there is much dispersion of the direction.

The dangerousness are estimated from traffic lines divided into ROI. The dangerousness is estimated by the model formula (2). The dangerousness are assumed from the collision of kinetic energy for every direction in a ROI. For instance, when the direction that faced each other in a ROI exists only, it has the biggest influence. Then the weight of collision becomes “1”. On the other hand, when the same direction in a ROI exists only, it has no influence. Then the weight of collision becomes “0”.

\[
\text{Dangerousness} = \frac{1}{2} \left( \sum_{m=0}^{7} \sum_{k=0}^{7} \left( \frac{1}{2} n_m \times V_{m}^2 \times \sin \left( \frac{\theta_k}{2} \right) \times \frac{1}{2} n_k \times V_{k}^2 \right) \right) 
\]

where

- \( V_{m} \): the average velocity by every direction
- \( \theta_k \): the angle of direction

Fig.8 shows the result that estimated the dangerousness distribution. Green area shows low level dangerousness, yellow area shows middle level and red area shows high level.

The passability is expressed with easiness to pass through the walking field. Easy area to pass through is related to the velocity difference of pedestrians and the dispersion of walking directions. Then, it is considered that passability is mostly in inverse proportion to the velocity difference and the dispersion of direction. By using these relations, the passability is estimated by the model formula (3).

\[
\text{Passability} = \exp(-V_{def}) \times \exp(-S) 
\]

where

- \( V_{def} \): the velocity difference
- \( S \): the dispersion of direction

Fig.9 shows the result that estimated the passability distribution. Red area shows low level passability, yellow shows middle level and green area shows high level.

The density, velocity and direction of pedestrian flows change dynamically by time transition. The dynamical state of pedestrian flows expresses the changing of the latent congestion, dangerousness
and passability of the field. Therefore, to know latent characteristics of the walking field, it is necessary not to evaluate by a certain time, and to evaluate by time transition. Time transition of field parameters in target area on Fig.10 (a) is observed from 8:30 to 15:30. In Fig.10 (b), the line’s color is corresponding to the direction. In Fig.10, congestion and dangerousness of target area rise quickly during lunch time and at the starting time of the class. Because the area is the doorway of schoolrooms building, many pedestrians pass each other in these time. Because of that, the area has high level congestion and dangerousness. However, the passability is low level in these time. Since many pedestrians pass each other in these time, it is difficult to go through.

4. Discussion
It is possible to estimate congestion, dangerousness and passability depending on area of the field. Latent characteristics (such as congestion, dangerousness and passability) of the field where they are walking is evaluated by pedestrian flow measurement. By measuring time transition of congestion, dangerousness and passability, we can see that these are not constant by time. When pedestrians flow is heading the same direction, the congestion is high level, but the dangerousness is low level. However, when pedestrian flows face each other, the dangerousness is high level. Therefore, there is no strong correlation between the congestion and dangerousness.

5. Conclusion
This paper has shown that the congestion, dangerousness and passability in pedestrian walking field are remotely evaluated by telemetry system. Several kinds of field characteristics are calculated by sampling of pedestrian movement. Moreover, their dynamic states are evaluated by the time transition of these parameters.

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