12th IMEKO TC1 & TC7 Joint Symposium on
Man Science & Measurement
September, 3 – 5, 2008, Annecy, France

EVALUATION OF PEDESTRIAN FLOWS BY TIME TRANSITION OF TRAFFIC LINE DISTRIBUTION

Shigeru TAKAYAMA [1], *Takahiro IWATA* [2], *Hideto NISHIKADO* [3], *Komyo KARIYA* [4]

[1] Ritsumeikan Univ.BKC, Shiga, JAPAN, s-tkym@se.ritsumei.ac.jp
[2] Ritsumeikan Univ.BKC, Shiga, JAPAN, re010048@se.ritsumei.ac.jp
[3] Ritsumeikan Univ.BKC, Shiga, JAPAN, nisikado@se.ritsumei.ac.jp
[4] Ritsumeikan Univ.BKC, Shiga, JAPAN, kariyako@pl.ritsumei.ac.jp

Abstract: This paper describes the system to take traffic lines of pedestrian flows outdoors and the investigation of dynamic characteristics by using the density, direction and velocity distribution of them. These characteristics express the congestion and latent dangerousness of field. Also the arrangement of structures and public facilities will be evaluated.

Keywords: traffic lines, pedestrians flow, congestion evaluation.

1. INTRODUCTION

To realize smooth and safe walking of people outdoors in city or town, it is necessary to know latent characteristic (congestion and dangerousness) of the field where they are walking. The latent characteristic of field is estimated by analyzing pedestrian flows.

Pedestrian flows are affected by the formation of road and square, field conditions, the arrangement of structures (buildings, houses, railway stations and so on), the position of entrances and exits of them and the public facilities (stairs, monuments, bus stops, crossing points, fountain and so on) [1-37]. It is recognized that these are static factors. Additionally, pedestrian flows are also affected by the congestion 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 dynamical state of pedestrian flows expresses the changing of congestion and the latent dangerousness of field where they are. To know the latent state of field is very useful to predict frequent accidents for pedestrians and to redesign the arrangement of structures/facilities and the formation of road/field.

This paper describes

1) the system to find the traffic lines of pedestrian flows and to construct the density, direction and velocity distribution of them in open square and street,
2) the static state (congestion) evaluated by density, direction and velocity distributions of traffic lines in a constant measurement time,
3) the dynamic state (congestion) evaluated by monitoring the time transition of density, direction and velocity distributions of traffic lines.

2. MEASUREMENT OF TRAFFIC LINES OF PEDESTRIAN FLOW

To recognize pedestrians outdoor, several kinds of research works are reported. Their targets are classified into

1) pedestrian detection [1-20],
2) counting pedestrians [21-25],
3) analyzing pedestrian behaviors [26-28],
4) pedestrian protection [29-31],
5) tracking pedestrian flow [32-37].

To recognize the pedestrian flow, this paper shows the measurement system to detect the moving track of pedestrian flow as a traffic line.

Traffic lines were generated by image processing of the pedestrian flows recorded with digital video camera. Fig.1 shows the sample of frame image of video taken the situation of pedestrians walking in morning at Student

Fig.1 Static Video Image

University Festival in autumn 2007 in morning. In Fig.1, the right-top side area (circle_1) is the entrance of restaurant building. In this area, it was found that standing students and walking students in/out the building are confusing. And the five areas shown with circle_2 are street food stalls. In these areas, the students standing in the food stall and walking slowly to see foods and goods for sale were confusing. Around these areas, the density of students is higher and the walking velocity of them is lower.

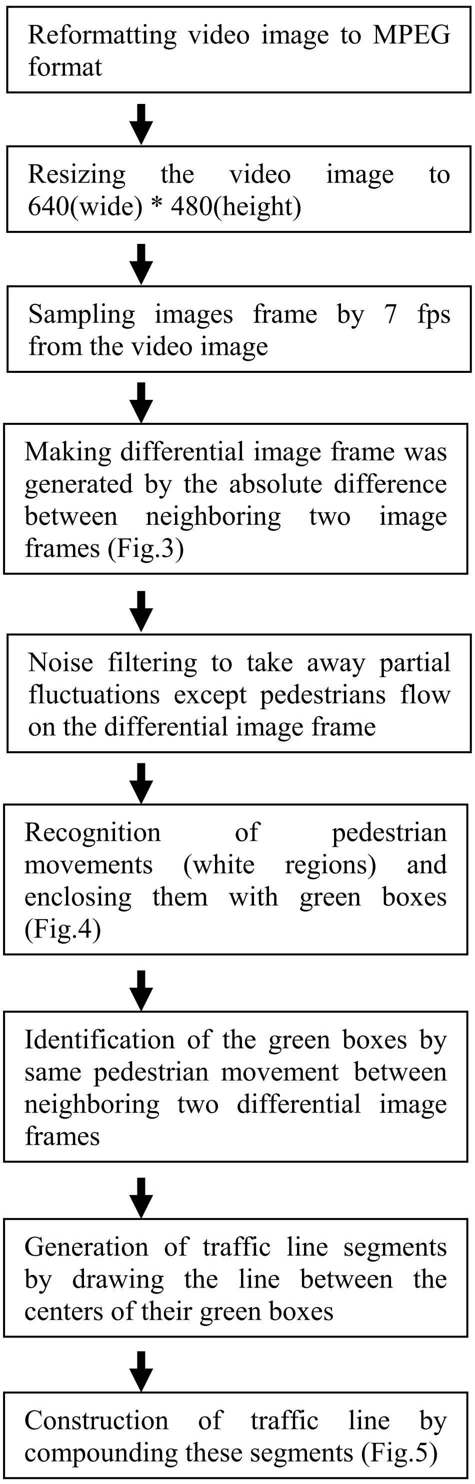


Fig.2 Image Processing to Generate Traffic Lines of Pedestrian Flow

Video camera was fixed on wall on the roof of building (21m height). The recording was continued in several hours from morning. The record was stored into several video tapes.

By the image processing as Fig.2, pedestrian movements in the video image were expressed as the connections of traffic line segments. In this experiment, the image processing was done by off-line. The image processing was done by 7Hz. The data of traffic line segments were stored to internal memory (RAM) and external database in storage (HD) each 1/7sec. At the same time, each 5min., the picture of traffic lines superimposed on static image (Fig.5) was stored as a JPEG file. By using these data, the dynamical situation of pedestrian flows and the effect of facilities/ field characteristics were evaluated in consideration on the density distribution, direction distribution and velocity distribution.

Fig.3 Differential Image Frame

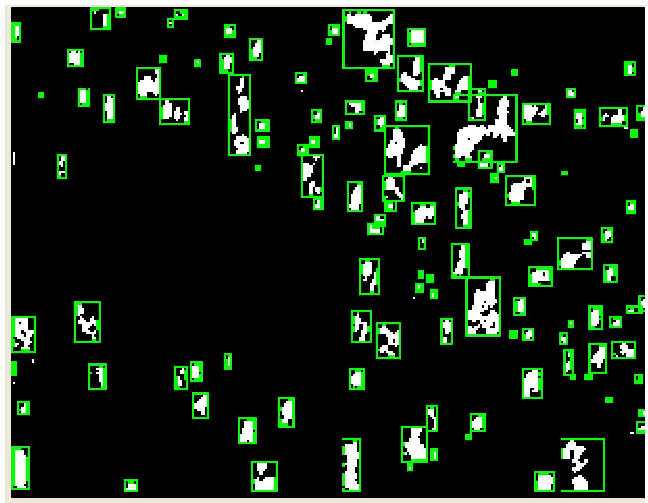


Fig.4 Recognition of Pedestrian Movement with Green Boxes

Fig.5 Traffic Lines of Pedestrians (5 min.)

3. DENSITY DISTRIBUTION OF PEDESTRAIN FLOWS

3.1 Static Density Distribution

The static congestion of pedestrian flows is evaluated with the density distribution of traffic lines. Fig.6 shows the image of absolute density distribution of traffic lines. The density distribution was constructed by counting the number of traffic line segments in each divided image block (10 dots square). Thick color areas show the state of high density of traffic lines. The density is expressed by 8bit.

It is confirmed that entrance area of restaurant building (circle_1) and the street food stalls (circle_2) was crowded. The reason of this state is by students standing and walking slowly around the entrance of restaurant building and the street food stalls. In addition to that, upper and right parts at edge (dot circle_3 and circle_4) of lawn area centered in the image are also crowded. This means that pedestrians were walking slowly at edge of lawn, especially at the corner. Their behaviors became carefully near the off limit area like lawn. Around the bottom, there is high density area formed thick straight line (dot circle_5). Here is the Main Street of campus. Many pedestrians walked through freely not affected by area and facility characteristics.

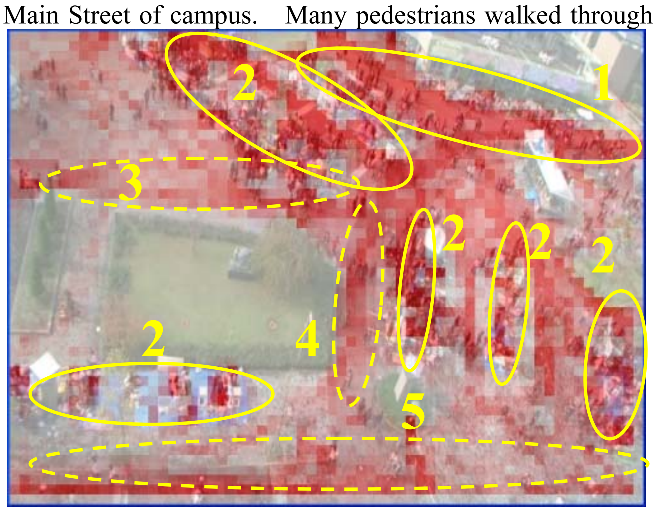


Fig.6 Density Distribution of Traffic Lines

As mentioned above, the situations of density distributions of the characteristic four areas were expressed. But these density distributions were not constant. These situations are invisible in a static image and changes according to time transition.

3.2 Dynamic Density Distribution

Fig.7 shows the time transition of the density distribution of traffic lines measured in 5 minutes. The sequence shows the dynamic change of density distribution of pedestrian flows very well. The density had become high gradually in average according to time transition (morning to afternoon). But the change of density was not uniformly. The density around entrance of restaurant building had increased from morning. After that, the density around street food stalls had increased gradually. In afternoon, the density distribution covered all area where is able to walk. In the formation of these density distributions, thick and thin red area were distinguished and emphasized gradually. That means that the distinction of high and low density areas of pedestrian flows has been obvious. In the high density (thick red) area, it is easy to congestion. In the area that the difference between high and low density was so much, there is high latent dangerousness for pedestrians.

These characteristics are recognized only by time transition of density distribution.

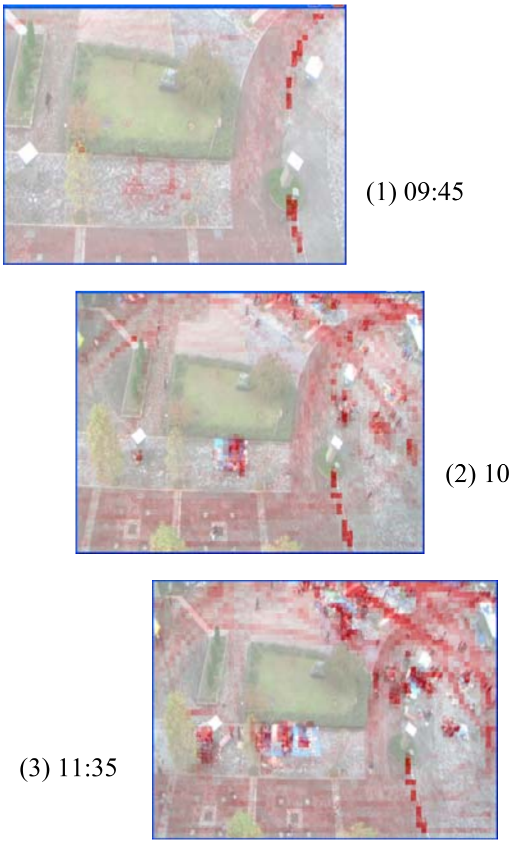
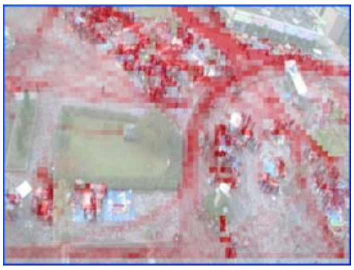


Fig.7 Time Transition of Density Distribution

(4) 12:05



(5) 12:30

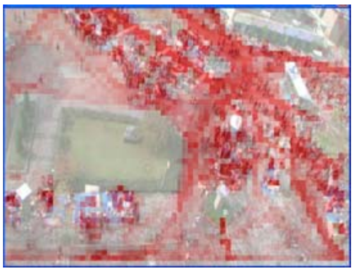


Fig.7 Time Transition of Density Distribution

4. DIRECTION DISTRIBUTION OF PEDESTRAIN FLOWS

4.1 Static Direction Distribution

Fig.8 shows the image of direction distribution of traffic line segments measured in 5 min. at 13:00. The directions of traffic line segments are expressed with the color distribution referred by Fig.9.

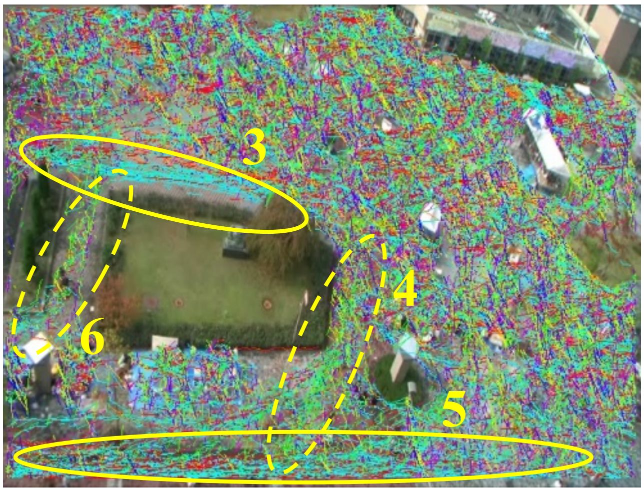


Fig.8 Direction Distribution of Colored Traffic Lines

In Fig.8, there are many traffic line segments drawn to various directions. Then, to clarify characteristics of direction distribution, the colored traffic line segments were classified into four regions as follows;

1) right side region : -45 to +45 [degree],
2) upper side region : +45 to +135 [degree],
3) left side region : +135 to +225 [degree],
4) down side region : +225 to -45 [degree].

According to this classification, Fig.8 was divided into four kinds of distinguished direction distributions (Fig.10).

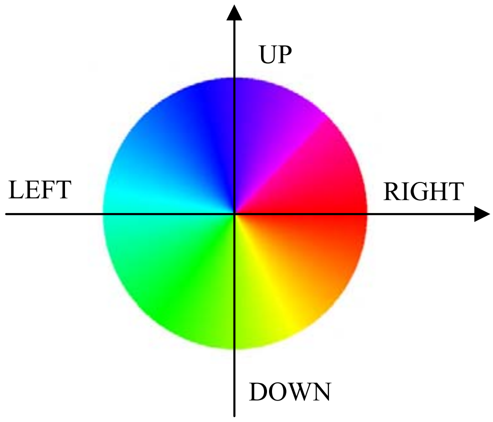


Fig.9 Matching Circle between Direction and Color

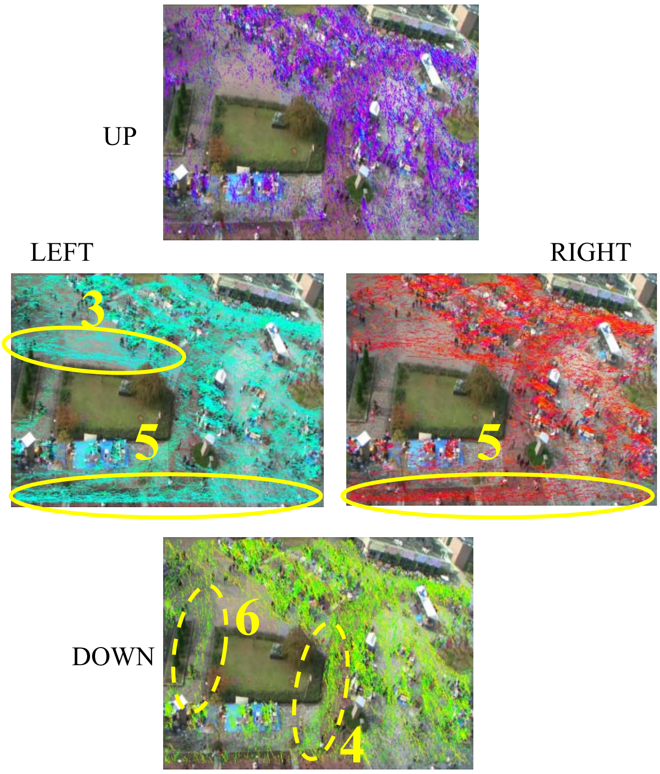


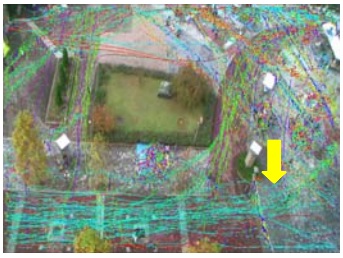
Fig.10 Direction Distributions classified into four kinds of regions (UP, DOWN, LEFT, RIGHT)

Around left and right side of lawn (dot circle_4 and 6), most of pedestrians were walking to the direction of left-down (colony of green line segments). Also, around upper side of lawn (circle_3), most of pedestrians were walking to the direction of left (colony of light blue line segments). In street at the bottom of image (circle_5), two kinds of pedestrian flows to right and left side were confused. In other regions, various kinds of directions were overlapped. That means that the pedestrians who walked to various directions were crossing.

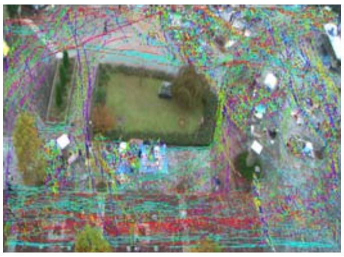
4.2 Dynamic Direction Distribution

Fig.11 shows the time transition of the direction distribution of traffic line segments measured in 5 min. at 09:45, 10:45, 11:35, 12:05 and 12:30. The sequence shows the dynamic change of direction distribution of pedestrian flows very well. In morning, pedestrian came from right-top corner, and went through to left-top and left-down area rounding a lawn (Fig.11 (1)). After one hour later, two new flows area added. One was the flows from right-middle area to left-down. Other was the flows to left middle area around left corner (Fig.11 (2)). After 11:35, pedestrian flows of various kinds of direction were confused. It became obvious that the flows of specific direction around a center lawn were concentrated (Fig.11 (4), (5)).

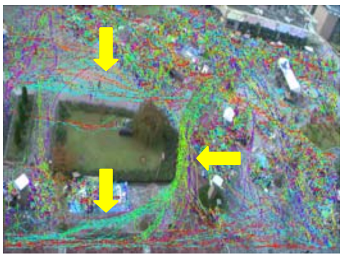
(1) 09:45



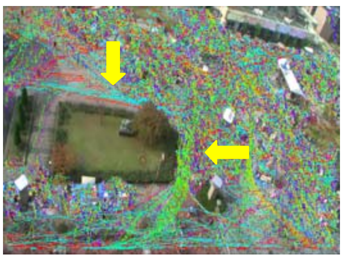
(2) 10:45



(3) 11:35



(4) 12:05



(5) 12:30

Fig.11 Time Transition of Direction Distribution

5. VELOCITY DISTRIBUTION OF PEDSTRIAN FLOWS

5.1 Static Velocity Distribution

Fig.12 shows the image of velocity distribution of pedestrian flows in 5 min. at 09:45. The velocity distribution of walking pedestrians was constructed by dividing length of traffic line segments by flame rate (1/7 sec.) in each image block (10 dots square). Thick color areas show the state that pedestrians were walking by high speed. The velocity was expressed by 8bit. In morning, as pedestrians were not so much, the density of velocity distribution was low in average. The high and low strengths of velocity were express well.

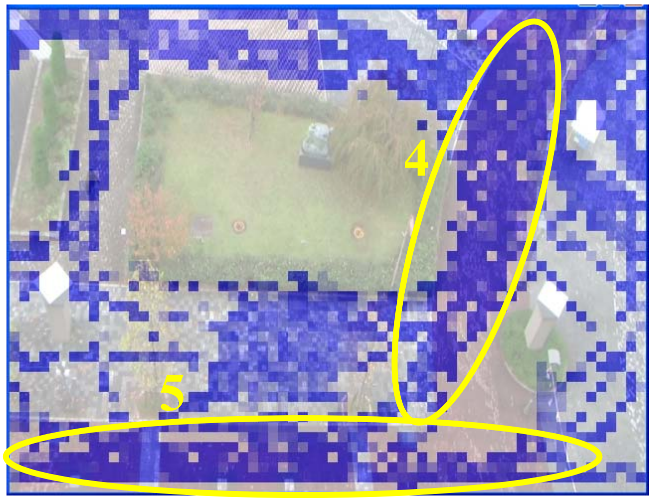
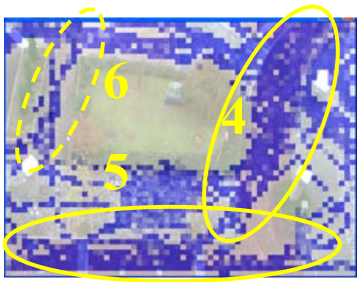


Fig.12 Velocity Distribution of Pedestrian Flows

5.2 Dynamic Velocity Distribution

Fig.13 shows the time transition of velocity distributions measured in 5 min. at 09:45, 10:45, 11:35, 12:05 and 12:30. At 09:45, around the areas (circle_4 and circle_5), the velocity of pedestrians was high (Fig.12 (1), (2)) comparing

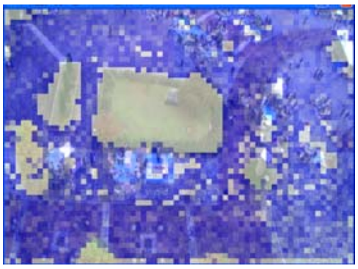


(1) 09:45

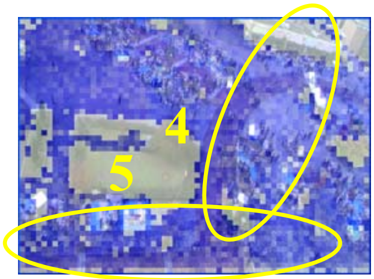
(2) 10:45

Fig.13 Time Transition of Velocity Distribution of Pedestrian Flows

(3) 11:35



(4) 12:05



(5) 12:30

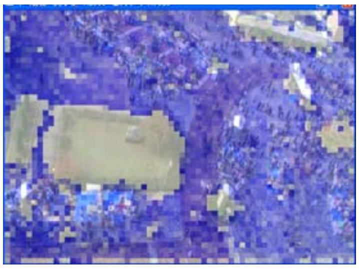


Fig.13 Time Transition of Velocity Distribution of Pedestrian Flows

to other areas. It was confirmed that these areas became main walking path for pedestrians at 9:45AM. At 10:45, the velocity distribution appeared in left-upper part (dot circles in Fig.12 (1), (2)).

After 10:45, the velocity distribution had expanded to all area except keep-off area (lawns) and buildings. According to the time transition, the velocity in two areas (circle_4, _5) was decreasing. That means that the velocity decreases in proportion to the density of pedestrians.

6. CONCLUSION

This paper describes the measurement system to detect traffic lines of pedestrian flows and evaluates the latent characteristics (dynamic states of density, direction and velocity) of field where pedestrians are walking. These characteristics are not able to recognize with video and static images. They relate to the congestion and latent dangerousness in field/area for pedestrian flows. They are not defined by only arrangement of buildings and facilities. They are dynamic estimations. They must be recognized as the dynamism of density, direction and velocity distribution of pedestrian flows.

By experiments and estimations to analyze pedestrian flow in university campus, some invisible congestions and dangerous areas were confirmed. These areas were changing corresponding with the time transition. In future, authors will reconstruct the measurement system as an on-line system, and investigate the definition of the congestion and dangerousness of field/area estimated by the dynamism of density, direction and velocity distribution of pedestrian flows.

REFERENCES

[1] O.Masoud and N.P.Papanikolopoulos, “Robust Pedestrian Tracking using A Model-Based Approach”, Proc. of the IEEE ITSC 1997, pp.338-343, 1997.

[2] G.Ma, S.B.Park, A.Loffe, S.M.Schneiders and A.Kummert, “A Real Time Object Detection Approach Applied to Reliable Pedestrian Detection”, Proc. of the 2007 IEEE Intelligent Vehicles Symposium, pp. 755-760, 2007.

[3] H.Fujiyoshi, T.Komura, I.E.Yairi, K.Kayama and H.Yoshimizu, “Object Detection Based on Temporal Differencing for Pedestrian ITS and Its Evaluation”, Trans. of IPSJ, Vol.45, No.SIG 13, pp. 11-20, 2004.

[4] T.Kinugawa and M.Ishimura, “Simple Noise-resistant Method of Motion Detection by Interframe Difference – Elimination of Randomly Fluctuating Backgrounds by Checking Space-Time Connectivity of Extracted Pixels -”, IEICE Technical Report, CS2007-54, IE2007-137, pp. 1470152, 2007.

[5] D.M.Gavrila, “Pedestrian Detection from a Moving Vehicle”, Proc. European Conf. Computer Vision, Vol.2, pp.37-49, 2000.

[6] Fang Yajun, K.Yamada, Y.Ninomiya, B.K.P.Horn, I.Masaki, “A Shape-Independent Method for Pedestrian Detection with Far-Infrared Images”, IEEE Transactions on Vehicular Technology, Vol.53, Issue 6, pp.1679-1697, 2004.

[7] O.Masoud, N.P.Papanikolopoulos, “A Novel Method for Tracking and Counting Pedestrians in Real-Time using a Single Camera”, IEEE Transactions on Vehicular Technology, Vol.50, Issue 5, pp.1267-1278, 2001.

[8] I.P.Alonso, D.F.Llorca, M.A.Sotelo, L.M.Bergasa, Pedro Revenga de Toro, J.Nuevo, M.Ocana, M.A.G.Garrido,, “Combination of Feature Extraction Methods for SVM Pedestrian Detection”, IEEE Transactions on Intelligent Transportation Systems, Vol.8, Issue 2, pp.292-307, 2007.

[9] S.J.Krotosky, M.M.,Trivedi, “On Color-, Infrared-, and Multimodal-Stereo Approaches to Pedestrian Detection”, IEEE Transactions on Intelligent Transportation Systems, Vol.8, Issue 4, pp.619-629, 2007.

[10] L.Zhao, C.E.Thorpe, “Stereo- and Neural Network-based Pedestrian Detection”, IEEE Transactions on Intelligent Transportation Systems, Vol.1, Issue 3, pp.1489-154, 2000.

[11] H.Mori, N.M.Charkari, T.Matsushita, “On-line Vehicle and Pedestrian Detections based on Sign Pattern”, IEEE Transactions on Industrial Electronics, Vol.41, Issue 4, pp.384-391, 1994.

[12] C.Curio, J.Edelbrunner, T.Kalinke, C.Tzomakas, W.von Seelen, “Walking Pedestrian Recognition”, IEEE Transactions on Intelligent Transportation Systems, Vol.1, Issue 3, pp.155-163, 2000.

[13] X.Fengliang, l.Xia, K.Fujimura, “Pedestrian Detection and Tracking with Night Vision”, IEEE Transactions on Intelligent Transportation Systems, Vol.6, Issue 1, pp.63-71, 2005.

[14] M.S.Uddin, T.Shioyama, “Detection of Pedestrian Crossing using Bipolarity Feature-An Image-Based Technique”, IEEE Transactions on Intelligent Transportation Systems, Vol.6, Issue 4, pp.439-445, 2005.

[15] T.Tsuji, H.Hattori, M.Watanabe, N.Nagaoka, “Development of Night-Vision System”, IEEE Transactions on Intelligent Transportation Systems, Vol.3, Issue 3, pp.203-209, 2002.

[16] M.Bertozzi, A.Broggi, A.Fascioli, T.Graf, M.-M.Meinecke,

"Pedestrian Detection for Driver Assistance using Multiresolution Infrared Vision", IEEE Transactions on Vehicular Technology, Vol.53, Issue 6, pp.1666-1678, 2004.
[17] l.Xia, K.Fujimura, "Pedestrian Detection using Stereo Night Vision", IEEE Transactions on Vehicular Technology, Vol.53, Issue 6, pp.1657-1665, 2004.
[18] N.D.Bird, O.Masoud, N.P.Papanikolopoulos, A.Isaacs, "Detection of Loitering Individuals in Public Transportation Areas", IEEE Transactions on Intelligent Transportation Systems, Vol.6, Issue 2, pp.167-177, 2005.
[19] Ying Wu, Ting Yu, "A Field Model for Human Detection and Tracking", IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol.28, Issue 5, pp.753-765, 2006.
[20] D.M.Gavrila, "A Bayesian, Exemplar-Based Approach to Hierarchical Shape Matching", IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol.29, Issue 8, pp.1408-1421, 2007.
[21] H.Yoshida, H.Muraki, S.Tanaka, H.Furuta, Y.Nishita and S.Fujimaki, "A Research on Traffic Calculation Using Stereo Video Camera", Trans. of IPSJ, Vol.47, No.6, pp. 1708-1716, 2006.
[22] K.Terada, D.Yoshida, S.Oe and J.Yamaguchi, "An Automatic Method of Counting Passers by Using Stereo Camera", Trans. of IEE Japan, Vol20-C, No.6, pp. 850-856, 2000.
[23] X.Zhang, G.Sexton, "Automatic Pedestrian Counting using Image Processing Techniques", Electronics Letters, Vol.31, Issue 11, pp.863-865, 1995.
[24] A.C.Davies, Jia Hong Yin, S.A.Velastin, "Crowd Monitoring using Image Processing", Jour. Electronics & Communication Engineering, Vol.7, Issue 1, pp.37-47, 1995.
[25] G.Antonini, J.P.Thiran, "Counting Pedestrians in Video Sequences Using Trajectory Clustering", IEEE Transactions on Circuits and Systems for Video Technology, Vol.16, Issue 8, pp.1008-1020, 2006.
[26] D.M. Gavrila, "The Visual Analysis of Human Movement: A Survey", Computer Vision Image Understanding, vol. 73, No. 1, pp. 82-99, 1999.
[27] P.Molnar, J.Starke, "Control of Distributed Autonomous Robotic Systems using Principles of Pattern Formation in Nature and Pedestrian Behavior", IEEE Transactions on Systems, Man, and Cybernetics, Part B, Vol.31, Issue 3, pp.433-435, 2001.
[28] E.Foxlin, "Pedestrian Tracking with Shoe-Mounted Inertial Sensors", IEEE Computer Graphics and Applications, Vol.25, Issue 6, pp.38-46, 2005.
[29] T.Gandhi, M.M.Trivedi, "Pedestrian Protection Systems: Issues, Survey, and Challenges", IEEE Transactions on Intelligent Transportation Systems, Vol.8, Issue 3, pp.413-430, 2007.
[30] G.De Nicolao, A.Ferrara, l.Giacomini, "Onboard Sensor-Based Collision Risk Assessment to Improve Pedestrians' Safety", IEEE Transactions on Vehicular Technology, Vol.56, Issue 5, pp.2405-2413, 2007.
[31] D.M.Gavrila, "Sensor-Based Pedestrian Protection", IEEE Transactions on Intelligent Systems, Vol.16, Issue 6, pp.77-81, 2001.
[32] T.Gandhi and M.M.Trivedi "Pedestrian Collision Avoidance Systems: A Survey of Computer Vision Based Recent Studies", Proc. of the IEEE ITSC 2006, pp.976-981, 2006.
[33] G.G.Lee, B.S.Kim, W.Y.Kim, "Automatic Estimation of Pedestrian Flow", ICDSC '07, First ACM/IEEE Int'l Conf., pp.291-296, 2007.
[34] Z.Huijing, R.Shibasaki, "A Novel System for Tracking Pedestrians using Multiple Single-Row Laser-Range Scanners", IEEE Transactions on Systems, Man and Cybernetics, Part A, Vol.35, Issue 2, pp.283-291, 2005.
[35] S.Munder, D.M.Gavrila, "An Experimental Study on Pedestrian Classification", IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol.28, Issue 11, pp.1863-1868, 2006.
[36] S.S.Mudaly, "Novel Computer-Based Infrared Pedestrian Data-Acquisition System", Electronics Letters, Vol.15, Issue 13, pp.371-372, 1979.
[37] S.S.Mudaly, "Improved Microprocessor-Controlled Pedestrian Data-Acquisition System", Electronics Letters, Vol.16, Issue 1, pp.3-5, 1980.