An Experiment of A Streetlamp Classifying and A Vertical Illuminance Assessing Utilizing Smartphones' Light Sensors

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***Abstract*—There is a growing demand for public managing security information such as the brightness of night sidewalks in the field of pedestrian navigation systems. Such security information is collected and visualized by some Japanese municipalities, but the coverage of the survey is not sufficient due to measurement equipment costs and labor costs. Therefore, in this study, we address these cost problems by collecting the illuminance of streetlamps utilizing the light sensors of smartphones and applying collective intelligence. However, there are differences of streetlamps' illuminance and light transition because many various streetlamps (e.g. fluorescent lights and LED lights) are installed. In this paper, we propose and evaluate the streetlamp classifying method based on the illuminance characteristics in the vertical direction of each streetlamp and light sensors for assessing safety level of night sidewalk. As a result of the evaluation, in case of setting allowable error to 2 lx, the precision ratio was 79 %, and the recall ratio was 48 %. Because the recall ratio of LED lights or inverter-type fluorescent lights (These illuminance transitions tend to become wide dispersion) became low, the precision ratio of them became low. But, the precision ratio of starter-type fluorescent lights became higher than other kind of streetlamps.**

I. Introduction

There is a growing demand for applications utilizing location information with a diffusion of smartphones installed various sensors, such as GPS, accelerometer, light sensor, and so on. In the background, public managing security information such as the brightness of night sidewalks becomes important for pedestrian navigation systems.

An example of such security information is a safety level of streetlamps installed in the road. The conventional assessment of a safety level follows the illuminance standard [1] defined by SSAJ (Japan Security Systems Association); the coverage of the survey is not sufficient due to the measurement equipment costs and labor costs. Therefore, in this study, we address these cost problems by collecting the illuminance of streetlamps with smartphone's light sensors and applying collective intelligence. For assessing a safety level, we follow the horizontal and vertical illuminance standard. However, there are characteristic differences of streetlamps' illuminance and light transition among various streetlamps such as fluorescent lights and LED lights. And, these differences affect assessment safety level. In this paper, we propose and evaluate a modeling method of illuminance transition in the vertical direction and a classifying method of streetlamps based on the characteristics of each streetlamp and each sensor.

As a result of the field study, in case of setting allowable error to 2 lx, the precision ratio was 79 %, and the recall ratio was 48 %. Because the recall ratio of LED lights or inverter-type fluorescent lights (These illuminance transitions tend to become wide dispersion) became low, the precision ratio of them became low. But, the precision ratio of starter-type fluorescent lights became higher than other kind of streetlamps.

II. Related Work

In this study, we focus on brightness of night sidewalk as indicator for implementing pedestrian navigation system which takes account of safety information. Then, we consider the assessment method of safety level of night sidewalks based on the illuminance standard [1].

Such security information is collected and visualized by Yuma K. at el in cooperation with municipalities and local organizations [2]. It describes safety assessment of night sidewalk based on streetlamps' horizontal illuminance measured with illuminometer and tabulated manually. But, in this study, the coverage of the survey was not sufficient due to the measurement equipment costs and the labor costs. Furthermore, streetlamps' owners are separated into municipalities, prefectures, block clubs, house owners and so on. In many case, not public but private owners are not managing streetlamps sufficiently. Because of needs to take account of aged deterioration of them and above-mentioned managing problem, we should survey streetlamps' illuminance periodically.

This paper describes a trial for addressing above-mentioned problems by participatory sensing and collective intelligence using smartphone's light sensors. Incidentally, a participatory sensing and a collective intelligence using mobile gadget was proposed by J.Burke et al [3]. In order to infer streetlamps' illuminance and assessing safety level of streetlamps, we need to apply the illuminance standard to both an average value of horizontal illuminance and a minimum value of vertical

TABLE I. THE ILLUMINATION STANDARDS FOR SECURITY LIGHTS

Class	A	B
Average Value of Horizontal Illuminance	over 5 lx	over 3 lx
Minimum Value of Vertical Illuminance	over 1 lx	over 0.5 lx
Illumination Effect	Recognizable the Outline of the Face	Recognizable the Posture and the Behavior

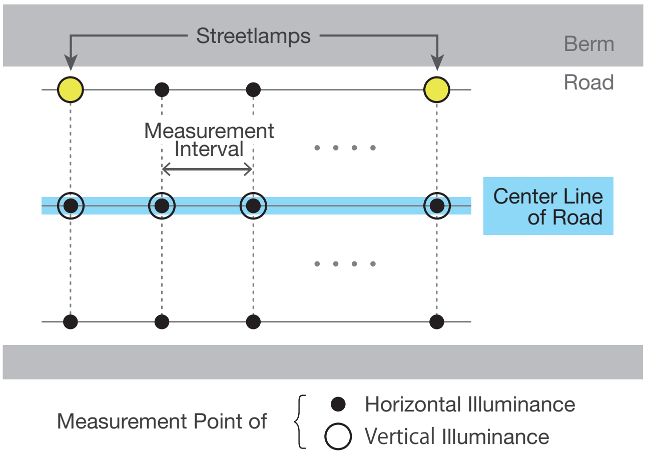


Fig. 1. A Measurement Method of Horizontal and Vertical Illuminance

illuminance according to the illuminance measurement method [4] defined by JIS (Japanese Industrial Standards). we had already done the experiments for the horizontal illuminance [5]. So, in this paper, we approach the issue of the vertical illuminance.

However, there are characteristic differences of streetlamps' illuminance and light transition among various streetlamps such as fluorescent lights and LED lights. These differences affect minimum value of vertical illuminance. Minimum value of vertical illuminance is fundamental parameter of assessment safety level. Consequently these differences will affect assessment. So, we consider streetlamp classifying method using the collective intelligence of measured data with smartphone's light sensors. In this paper, we try to classify the three type streetlamps (starter-type fluorescent lights, inverter-type fluorescent lights, LED lights) by applying the streetlamp classifying method, because these kinds of streetlamps are the majority in Japan.

III. PROPOSED METHOD BASED ON THE PRELIMINARY SURVAY

For assessing safety level of streetlamps, we need to measure an average value of horizontal illuminance, and a minimum value of vertical illuminance according to the illuminance measurement method defined by JIS (Japanese Industrial Standards). Then, we compare them according to the illuminance standard defined by JSSA (Table I). Fig. 1 shows an outline of the illuminance measurement method. The horizontal illuminance is measured by a horizontally held illuminometer against to the road surface, and the vertical illuminance is measured by a vertically held illuminometer

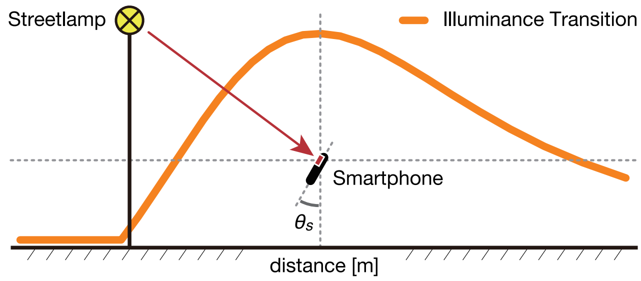


Fig. 2. A Sample of Illuminance Transition

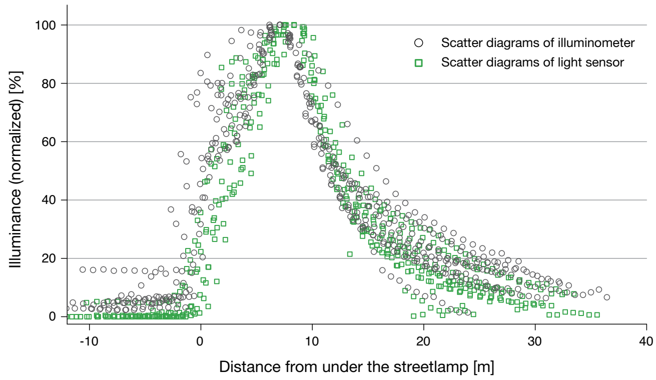


Fig. 3. Results of Vertical Illuminance Transition Research (LED Lamps)

against a road direction. Then, these illuminance transitions are classified by the kinds of streetlamps. Therefore, the quality of the classifying streetlamps by using smarphones' light sensors is important for assessing safety level of night sidewalk. In this section, we report a result of a fundamental survey about characteristics of vertical illuminance transitions and smartphone's light sensors. According to these characteristics, we propose a modeling method of vertical illuminance transitions and classifying method of streetlamps.

A. *Survey of Characteristics of Streetlights and Light Sensors*

Illuminance is the total amount of luminous flux incident per unit area, so it has an cosine-like attenuation characteristic depending on the incident angle, and has characteristic of inversely proportional to the square of the distance from the light source. According to these characteristics, illuminance is susceptible to the distance and angle from the light source.

Fig. 2 shows an illuminance transition while walking and holding smartphone at θ_s degrees. According to the characteristics described above, the illuminance transition is formed corresponding to each kind of streetlamps. In this study, we surveyed vertical illuminance transitions of three kinds of streetlamps (starter-type fluorescent lights, inverter-type fluorescent lights, and LED lights). We used the illuminometer (LX-1108) and the smartphone (Galaxy Nexus) to measure vertical illuminances. We set the angle of the illuminometer's acceptance unit to 0 degree (the vertical angle against a road direction), and set angle of the smartphone (θ_s) to 30 degrees (the angle to hold the smartphone). Then we measured illuminance of streetlamps. Fig. 3 shows the scatter diagram of vertical

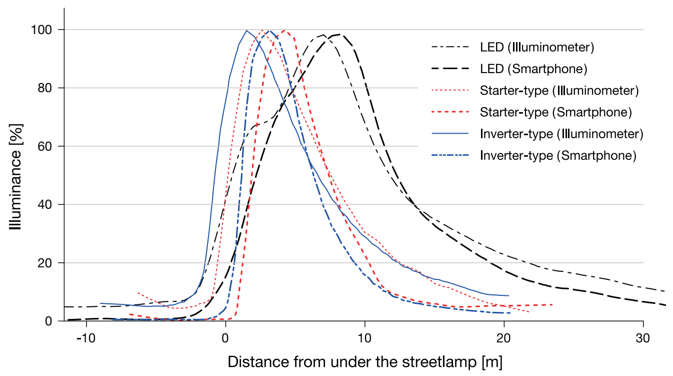


Fig. 4. Illuminance Transition Normalized Models (All Lamps)

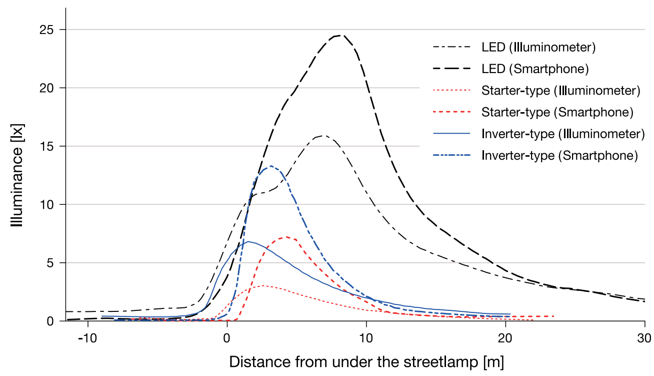


Fig. 5. Illuminance Transition Models (All Lamps)

illuminance value of LED lights normalized by [0,1] interval. Black circles mean a value measured by the illuminometer; green squares mean a value measured by the smartphone's light sensor. Also, we surveyed vertical illuminance of other kinds of streetlamps by the same way.

We assume that forms of scatter diagrams depends on kinds of streetlamps. So, we tried to model illuminance transitions of all kinds of streetlamps by using the LOWESS smoothing method which is one of the scatter plot smoothing methods. Incidentally, LOWESS smoothing method is a topically weighted scatterplot smoothing method, utilizing one order polynomial and linear least squares approximation.

Fig. 4 shows the results of the modeling of each scatter diagrams of streetlamps' illuminance transition. Each line shows the modeling results from an illuminometer and a smartphone's light sensors respectively. Because starter-type and inverter-type fluorescent lights have same characteristic in transition direction, these illuminance transitions become similar shape. And, illuminance of LED lights increases characteristically.

The maximum illuminance are difference between starter-type and inverter-type fluorescent lights despite their similar shape of illuminance transition. Fig. 5 shows the vertical illuminance transition model for each kinds of streetlamps (hereinafter referred to as the illuminance transition model). This transition model is calculated by multiplying the vertical axis (illuminance) of Fig. 4 and the the average value of each measured maximum illuminance. We confirm that the vertical illuminance of each kinds of streetlamps have large difference. So, kinds of streetlamps will affect the safety assessment.

B. Proposal of the Streetlamp Classifying Method

The illuminance transition models as shown in the last section have differences of waveform, illuminance transitions, max values of illuminance. So, we considered it is possible to classify streetlamps utilizing waveform comparison of illuminance transition model and illuminance value measured with smartphones' light sensors. The streetlamp classifying method is described as follows. At community roads, it is conceivable that an illuminance data measured with smartphones' light sensors indicate zero lx, excepting a place where is close to under streetlamps. In other words, a measured illuminance data forms like a pulse near under streetlamps. So, we can divide illuminance data of every streetlamps. Also, the illuminance data is temporal data, whereas the illuminance transition models are spatial data. So, illuminance data is converted into spatial data by using distance calculated from two points of GPS information. And, we calculate errors of mean square between the converted illuminance data and illuminance transition models, compare each errors, and select an illuminance data that has minimum error as the classifying result. But, we have to consider effects of measurement conditions such as angle of smartphones and walking speed. we select an illuminance data as the classifying result, in the case of fulfilling conditions of weighted allowable error.

IV. Evaluation of the Streetlamp Classifying Method

To evaluate proposal method, we experimented on the community roads (Fig. 6) in Uozumi-cho Akashi-city, Japan (this field has an area of one km^2). Fig. 7 shows three types of streetlamps (starter-type fluorescent lights, inverter-type fluorescent lights, LED lights) installed in the evaluation field. Incidentally, visual aspect of starter-type and inverter-type fluorescent lights are about the same. Three testers were using a smartphone (Galaxy Nexus) for a month at some nights without concerns for holding angle of smartphones and walking speed.

As a result of the experiment, we collected 4,435 samples for 261 streetlamps in the field, and used 2,288 samples those are able to convert into spatial data for the evaluation. Table II shows the result of the streetlamp classifying method. this results include precision (ratio of correct answer against streetlamps that was recognized), recall (a ratio of correct answer against all streetlamps), and F-measure value (a harmonic mean of precision and recall) for each allowable error value.

A precision is over 75% in all case of allowable error. And, if allowable error become small, a precision will increase. This result suggests that we can classify general three types of streetlamps. In this experiment, we could collect only 10 samples per a streetlamp for the evaluation. So, we couldn't realize the advantage of collective intelligence such as high noise immunity and high recall. Therefore, we should evaluate with more samples, and improve the precision of illuminance

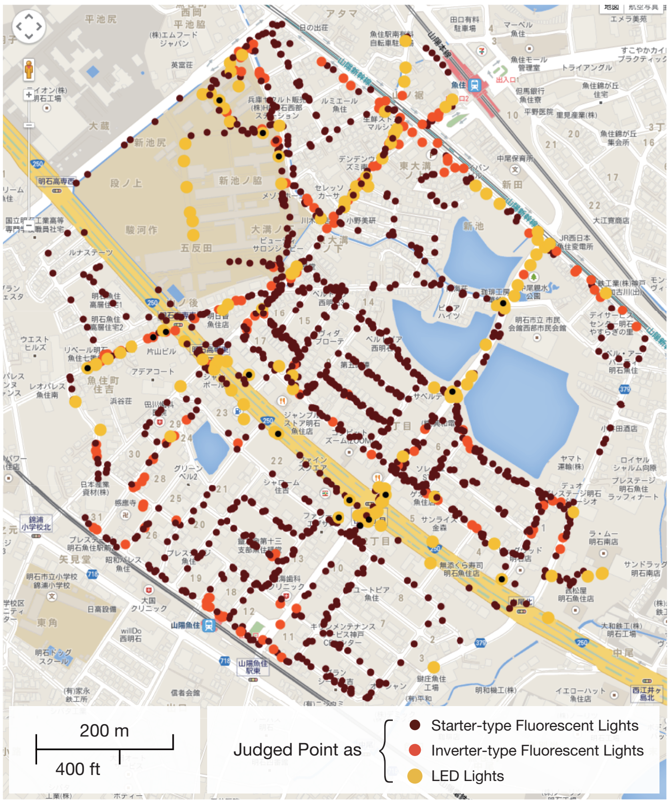
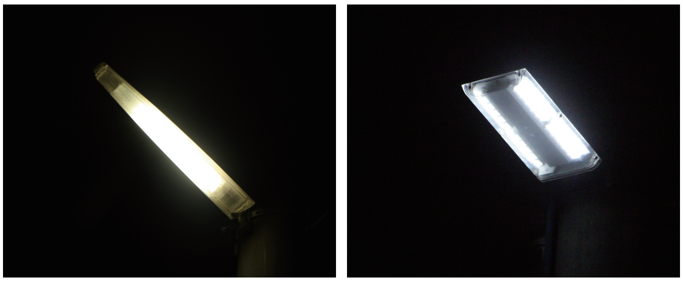


Fig. 6. The Map for Field for Evaluation



a. Fluorescent Lights (Inverter-type and Starter-type)

b. LED Lights

Fig. 7. Samples of Streetlamps

transition models. Also, we should find out the best optimum allowable error by considering a trade-off between precision and recall. Finally, we should increase a number of streetlamp samples.

Table III shows the results from the viewpoint of the kinds of streetlamps. A precision is over 85% in starter-type streetlamps, over 70% in inverter-type streetlamps. The measured illuminance value of LED lights tend to have wide dispersion, because LED lights have high illuminance and strong directivity; it is difficult to get ideal illuminance data. So, the precision and the recall decrease more than those of starter-type fluorescent lights or inverter-type fluorescent lights. From this result, it is tend to exclude excessively illuminance value by allowable error. We should consider an illuminance refinement method for reducing dispersion which

TABLE II. EVALUATION OF THE STREETLAMP CLASSIFYING METHOD

Allowable Error [lx^2]	1	2	4	9	16	25
Precision Ratio [%]	84.6	79.1	79.4	72.9	76.0	77.4
Recall Ratio [%]	4.9	23.7	48.2	67.4	73.7	76.3
F-measure	0.09	0.36	0.60	0.70	0.75	0.77

TABLE III. PRECISION AND RECALL RATIO OF EACH STREETLAMPS

Allowable Error [lx^2]		1	2	4	9	16	25
Precision Ratio	Starter-type fluorescent lights	91.7	87.7	89.1	87.8	85.6	85.1
	Inverter-type fluorescent lights	-	75.0	75.0	63.0	71.0	71.9
	LED lights	0.0	0.0	7.1	12.5	36.4	48.6
Recall Ratio	Starter-type fluorescent lights	7.1	32.5	63.6	84.4	85.1	85.1
	Inverter-type fluorescent lights	0.0	9.1	27.3	51.5	66.7	69.7
	LED lights	0.0	0.0	2.7	10.8	32.4	45.9

is independent of a kinds of streetlamps, and investigate optimal number of samples about each kinds of streetlamps. Furthermore, we should consider the classifying method using collective intelligence that reduce the rejection ratio.

V. Conclusion

In this paper, we surveyed effects that kinds of streetlamps give to assess the vertical illuminance as one of the standards to assess safety level of night sidewalks. Based on the fundamental survey, we modeled the vertical illuminance transitions for each kind of streetlamps, and proposed the streetlamp classifying method utilizing waveform comparison of illuminance transition model and illuminance measured with smartphones' light sensors.

As a result of the evaluation, we found that we should improve the recall to reduce the allowable error and improve the precision. We will consider the illuminance refinement method against LED lights or inverter-type fluorescent lights which tend to become wide dispersion, and improve the method of waveform comparison, then, propose inferring method of vertical illuminance. Additionally, we will survey similarly about the other standard. Eventually, we will consider method of assessing safety level of night sidewalk.

References

[1] Japan Security Systems Association. Standard for Levels of Illumination on Crime Prevention Lighting. *SES E 1901-3* , 2012.

[2] (All in Japanese) 神田祐磨, 高橋伸元, 三浦昌生. 農地と住宅地が共存する地区における防犯対策を目的とした住民主体の街灯照度改善活動の支援. 日本建築学会大会学術講演梗概集 (東海), 2012.

[3] J. Burke, D. Estrin, M. Hansen, A. Parker, N. Ramanathan, S. Reddy, and M. B. Srivastava. Participatory sensing. *ACM Sensys 2006*, 2006.

[4] Japanese Industrial Standards Committee. Illuminance measurements for lighting installations. JIS C 7612, 1985.

[5] Y. Matsuda and I. Arai. Safety level assessment system for sidewalk utilizing collective light sensor of smartphones. *IPSJ SIG Technical Report Vol.2013-UBI-37 No.52*, 2013.