GPS Precision Improvement System by Mobile Phone Camera Images[1]

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ABSTRACT

Some location-aware services require a sufficient precision of location information, due to emergencies, or social or environmental threats, etc. In order to realize the precision, key technical problems will be assessment of the precision, which contains certain errors depending on conditions, and how to improve it. So far, these issues have rarely been studied systematically for mobile phone functions, however.

On the other hand, mobile phones, which are the most widespread network terminals, are basically equipped with the GPS today. In this paper, we consider the assessment and improvement of the mobile phone GPS. For the improvement, we propose a method that uses pictures taken by mobile phone camera. We show some experimental results to support efficiency of the idea.

Keywords: GPS, mobile phone, camera, pattern matching

1 INTRODUCTION

A mobile phone is the most widespread network terminal and tends to be equipped with multi-functionalities so that it is eligible to be a network terminal more than just PDA. Thus the mobile phones are expected to play a major role to provide ICT solutions for personal or social service demands.

Among the functionalities, of particular importance are GPS (Global Positioning System), since location-aware service applications acquire information of relevant location from the GPS, while such service are undoubtedly increasing their significance for the sake of smart services.

On the other hand, in recent years, most of the mobile phones are equipped, in addition, with cameras. A large portion of the cameras have qualities even as high as single digital cameras. The mobile phone camera has the merit that the images taken by it have the location information from GPS as well as time information [1]. Though the location information is today very important for mobile applications as stated above, it involves certain errors.

In our previous study, we have examined that the indicated location can have large errors depending on conditions [2]. In order to make the GPS information more useful, the indicated location must be more accurate.

In this paper, we give first an assessment of the mobile phone GPS errors under several conditions. Such an assessment has not been considered so far, while it will necessarily be a key result in establishing location-aware service tech-nologies. Also, we construct a system that improves the mobile phone GPS information and evaluate the system. In order to obtain more precise location information, the system performs a pattern matching for an image taken by a mobile phone camera with corresponding images in database. We discuss its efficiency and future problems.

2 MEASUREMENT OF GPS ERROR

According to the previous experiment that examines the performance of GPS and DGPS [2], we performed our experiments by using the mobile phone with DGPS. The location measurement was done at seven places in Seikei University in Musashino City, Tokyo, for both indoor or outdoor. In the measurements, for each place, we observed the errors of GPS information every minute. Table 1 lists the observation statistics.

Table 1: Measurement statistics of location errors.

Location	①	②	③	④	⑤	⑥	⑦
Average (m)	28	19	26	84	52	51	46
Maximum Error (m)	120	80	110	500	100	130	140
Minimum Error (m)	3	5	1	20	5	15	5
Variance	756	192	477	4976	700	601	735
Standard Deviation	27	14	22	71	26	25	27

By the measurement, it turns out that synchronization losses may rarely cause severe errors and that the mobile phones with DGPS identify 90% of locations with errors less than 100[m].

3 AN IMPROVEMENT METHOD THROUGH PATTERN MATCHING

In order to make the GPS location more precise, we constructed an error reduction system that performs a pattern matching between pictures taken by a camera of mobile phone and images in database [3-4].

Let a picture be taken by the mobile phone camera at a place where an event has occurred. We call the picture the input image. Also, we call the frame images in a scenery video the database image. We will perform the pattern matching between the input images and database images.

[1] A part of this work was supported by MEXT Grant-in-Aid for Building Strategic Research Infrastructures

To obtain matched images, we evaluate similarity of two images by the correlation coefficients:

$$Correlation = \frac{\sum_{n=1}^{N}\sum_{m=1}^{M}\left(f(m,n)-\bar{f}\right)\left(g(m,n)-\bar{g}\right)}{\sqrt{\sum_{n=1}^{N}\sum_{m=1}^{M}\left(f(m,n)-\bar{f}\right)^2}\sqrt{\sum_{n=1}^{N}\sum_{m=1}^{M}\left(g(m,n)-\bar{g}\right)^2}} \qquad (1)$$

where,
N: number of pixels in vertical direction of images
M: number of pixels in horizontal direction of images
f: input image taken by mobile phone camera, and
g: database images, respectively.

We performed the pattern matching trials for every input image of 20 spots in Seikei University with corresponding 20 scenery videos in the database. The possible matching trials are thus 400 cases.

Figure 1 is the campus map of Seikei University that show 20 spots where input image and database video were taken. Figure 2 shows sample database images of 20 scenery videos in the database.

Figure 1: 20 spots in Seikei University Campus for the experiment

(a) (b)

(c) (d)

(e) (f)

(g) (h)

Figure 2: Sample images of database

The pattern matching process is as follows:

Step1: Transform the input images and database video into monochrome images

Step2: Perform edge detection on the input image and database images of a candidate video source. Calculate the sequence of correlation coefficients by Eq. (1): Firstly with the input image as it is, in order to determine frame-time intervals of video frames with high peak values of correlation coefficients. Secondly with the input image enlarged along a sequence of magnification ratios, in order to adapt the vertical height of the scene in the input image to that of database image.

Step3: Enlarge the input images in order to analyze them in detail and then perform the pattern matching.

Step4: Identify the best-matched place from the peak of the correlation coefficients.

Figure 3(a) plots, the correlation coefficients vs. frame-time of database video. It contains a portion of frame-time interval on which the correlation coefficients presents the largest peaks. By this peak detection, we judge that the input image coincides with the database video.

To find this "peak", we use Gaussian curve fitting by Eq. (2) for the sequence of correlation coefficients, which is the function of frame-time *t* as in Figure 3.

$$y = a + b \times \exp\left(\frac{-(t-c)^2}{d^2}\right) \qquad (2)$$

Figure 3(b) shows fitting result for Figure 3(a). For the curve fitting, the parameters *a*, *b*, *c* and *d* are to be calculated.

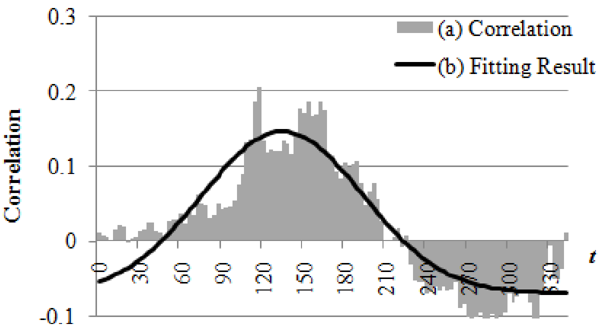

Figure 3: Correlation coefficients and fitting result.

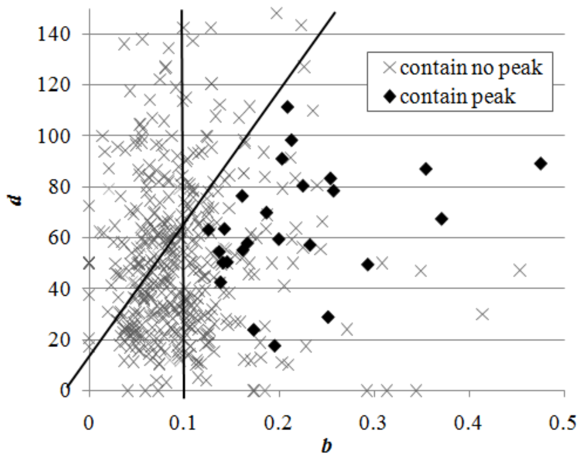

Figure 4: Relation between variables *b* and *d* in Eq. (2).

Figure 4 shows distribution of values of (*b*, *d*) calculated by Gaussian curve fitting for each correlation data. According to this relation, we determine the region of possible values of (*b*, *d*). (This restriction is shown Figure 4 as the region separated by straight lines.)

In case of data containing the peak indeed, we calculate the length of frame-time interval on which the correlation coefficients presents the peaks. To determine this length of peak interval, we use standard deviation of Gaussian curve by Eq. (3).

$$\sigma = \frac{d}{\sqrt{2}} \quad \cdots(3)$$

The length of peak interval is calculated from this standard deviation and variable *c* that show peak in interval [c-2σ, c+2σ].

We identify the location from the length of peak interval, moving speed of database video scene and magnification ratio.

4 RESULTS

Pattern matching results is as follows. Figures 5 to 10 plot, the correlation coefficients vs. frame-time.

A) The case that input image coincides with the database

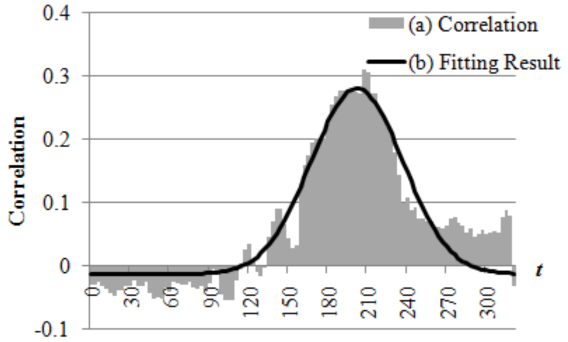

Figure 5: [Example (1)] Correlation coefficients and fitting result in case that input image coincides with Figure 2(a) database.

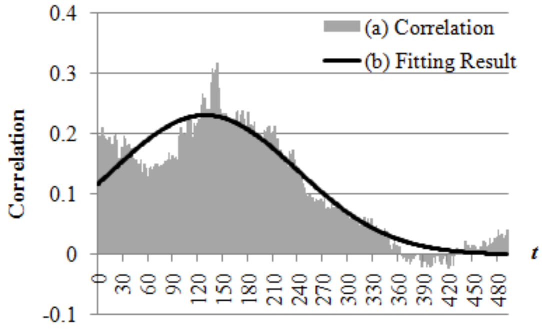

Figure 6: [Example (2)] Correlation coefficients and fitting result in case that input image coincides with Figure 2(b) database.

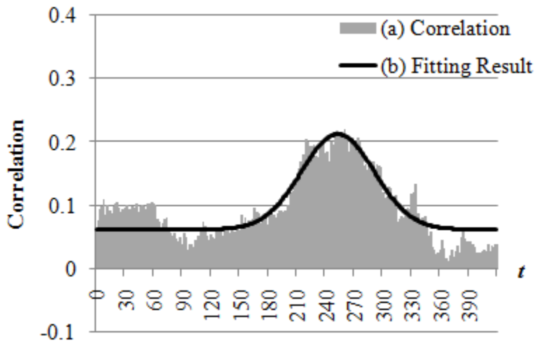

Figure 7: [Example(3)] Correlation coefficients and fitting result in case that input image coincides with Figure 2(c) database.

As Figures 5 to 7, in case that input image coincides with the database, average of correlation coefficients is high. And the plot contains a portion of frame-time interval on which the correlation coefficients presents the largest peaks.

B) The case that input image no coincides with the database

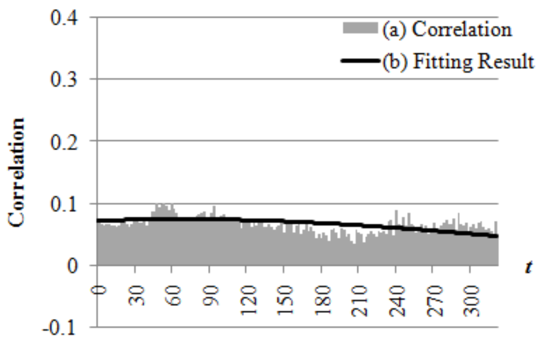

Figure 8: [Example (1)] Correlation coefficients and fitting result in case that input image no coincides with Figure 2(a) database.

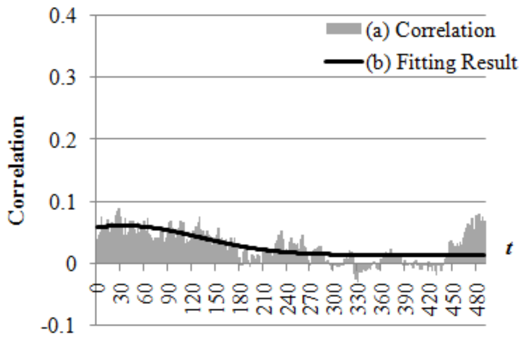

Figure 9: [Example (2)] Correlation coefficients and fitting result in case that input image no coincides with Figure 2(b) database.

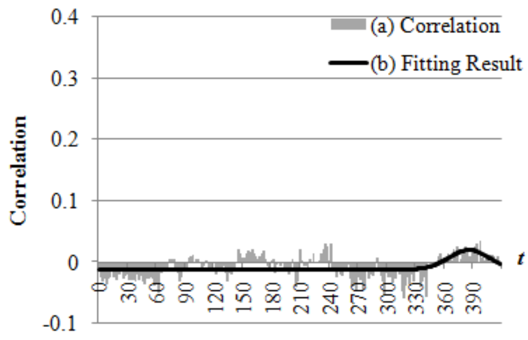

Figure 10: [Example (3)] Correlation coefficients and fitting result in case that input image no coincides with Figure 2(c) database.

As Figures 8 to 10, in case that input image does not coincides with the database video, average of correlation coefficients is low. And the plot does not a portion of frame-time interval on which the correlation coefficients presents the largest peaks.

We can summarize the results of the image processing as shown in Figure 7.

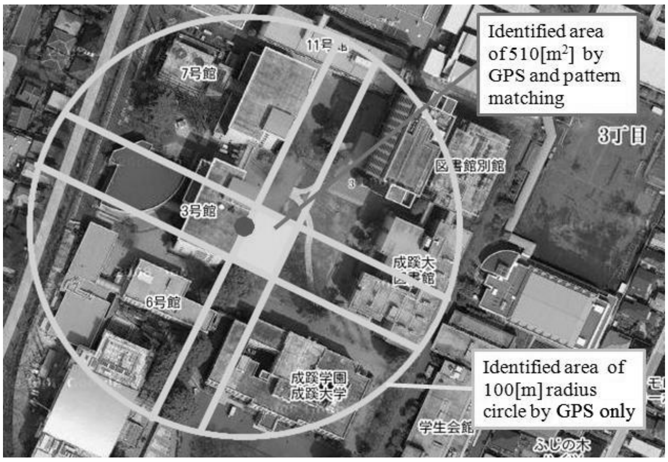

Figure 7: Comparison between identified area by GPS and pattern patching.

As a result, we were able to identify the location error range of average 86 [m^2] for 65% of the trials at 20 places (510[m^2] at worst and 10[m^2] at best.) by using the pattern matching with mobile phone camera.

5 CONCLUSION

We constructed a system that improves the mobile phone GPS information and evaluated the system. In order to obtain more precise location performance, the system performs a pattern matching for an image taken by a mobile phone camera with corresponding images in database.

Our system has gained 65% of precision for places up to the area of 86[m^2]. By the system, the precision of the location is improved in that the error is within the area of 1/360 of the one in which only GPS is used.

In addition to these concluding remarks, we will introduce additional simulation results at the conference, for the review as comments of

(1) How to evaluate similarity of two images from different angle ?
(2) How to obtain a clear photo images in night?
(3) How many images are required to improve the precision of location?
(4) How far can a user who wants to use the method get away from each of the places while the proposed method is working well?

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