When and Where Tourists are Viewing Exhibitions: Toward Sophistication of GPS-Assisted Tourist Activity Surveys

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Abstract

In recent years, many tourist activity surveys using GPS devices have been conducted, but the survey methodology needs still to be improved. One critical problem is that we can know where tourists visit and how long they stay there, but not what they actually do there. Thus, we investigated the relationship between tourists' activities recoded by a video camera and their GPS logs. The result shows that the location history of a tourist itself is not sufficient for estimating how long he/she enjoys each attraction, and his/her walking speed seems critical for this estimation.

Keywords: GPS, tourist activity survey, zoological park, logistic regression model

1 Introduction

Global Positioning System (GPS) provides accurate, continuous, worldwide, three-dimensional position and velocity information to users with appropriate receiving equipment (Kaplan, 1996). GPS expands the possibility of tourist activity surveys, because with an effective use of GPS devices we can investigate where tourists visit and how long they stay there, without recording their activities manually. As a matter of course, there are also some drawbacks; first of all, GPS receivers work properly only in outdoor environments. Measurement error and battery lifetime are another issues that need to be considered. In tourist activity surveys, however, there remains one more critical issue—GPS logs tell where tourists have been to, but not what they have been doing there.

Tourism is an activity that involves a large variety of activities. Thus, for discussing marketing strategies, renovating tourist spaces, and providing appropriate information for tourists, it is essential to clarify tourists' behaviours in conjunction with their attributes such as age and gender. For promoting tourist activity surveys to know tourists' behaviours, an intelligent technique for inferring tourist activities from their GPS logs will be highly desirable.

As a first step toward this technique, we investigated the relationship between the tourists' activities and their GPS logs, focusing on the simplest activity of tourism—

viewing something. Then, we developed a statistical model with which we can discern from a GPS log whether a tourist had been viewing exhibitions or not at each moment. This model can be applied to GPS logs in previous surveys to estimate the time spent by tourists for viewing each exhibition and eventually, to estimate the attractiveness of each exhibition.

The remainder of this paper is organized as follows: Section 2 explains the background of this research. Section 3 reports our initial GPS-assisted survey at a zoological park and points out its problems. Section 4 describes our supplementary experiment that aims at developing a new technique for estimating tourists' viewing time. Finally, Section 5 concludes with a discussion of future work.

2 Background

Recently, GPS loggers have become smaller, lighter, and less expensive. In addition, mobile communication devices equipped with a GPS sensor, such as smartphones, have become rapidly widespread all over the world. Along with this trend, activity surveys using GPS devices have been conducted in various fields (Yabe *et al*., 2010). Especially in tourism studies, location history data recorded by GPS devices are highly useful to clarify what attractions tourists have visited in what order and how long they have stayed there (Kurata *et al*., 2010). If tourists' spatio-temporal behaviours are well-understood, it would be possible to optimize transportation, operations of tourist attractions, and marketing strategies, all in line with their actual needs (Shoval and Issacson, 2007a). Of course, such information can be obtained from a questionnaire or an observation survey, but usually such surveys are costly and difficult to be conducted regularly for monitoring tourists' behaviours. On the other hand, GPS-assisted surveys impose almost no burden on tourists and are relatively inexpensive if GPS devices are used repeatedly (Kurata *et al*., 2010).

GPS-assisted activity surveys have been conducted extensively in transportation studies of motor vehicles. One of its reasons is that it is easy to install GPS devices on vehicles (Shoval and Issacson, 2007a). For example, Nagao *et al*. (2004) analyzed tourists' movement patterns in a macro scale based on the data of GPS loggers installed on rental vehicles. Some GPS-assisted tourist activity surveys targeted pedestrians to clarify their movement patterns and characteristics (Asakura and Hato, 2004; Asakura and Iryo, 2007; Shoval and Issacson, 2007b), as well as the spatial use of a city by tourists (Shoval, 2008). Some surveys attempt to extract interesting locations for tourists from their GPS logs (Zheng *et al*., 2011). However, it still remains as a research challenge to develop a technique for inferring tourists' activities from their GPS logs, while it is important to know what tourists actually do at each place in order to optimize various operations in a tourist area.

3 GPS-Assisted Survey in Tama Zoological Park

As an example of GPS-assisted tourist activity surveys, we report our survey at Tama Zoological Park (Hino, Tokyo) on 3th (Fri) and 4th (Sat) of September, 2010. There are three advantages in conducting a GPS-assisted survey in a zoological park: (i) most exhibitions are located outside, (ii) the number of its entrances and exits, where GPS loggers should be distributed and collected, are limited, and (iii) the time spent by each visitor does not exceed the battery lifetime of GPS loggers. In addition, in Tama Zoological Park, animal exhibitions are located separately and thus, we can expect clear difference between visitors' viewing and walking states. Fig. 1 shows a map of Tama Zoological Park. The plan is complicated due to its hilly location. This is why its staff has wanted to know the visitors' movement patterns in the park.

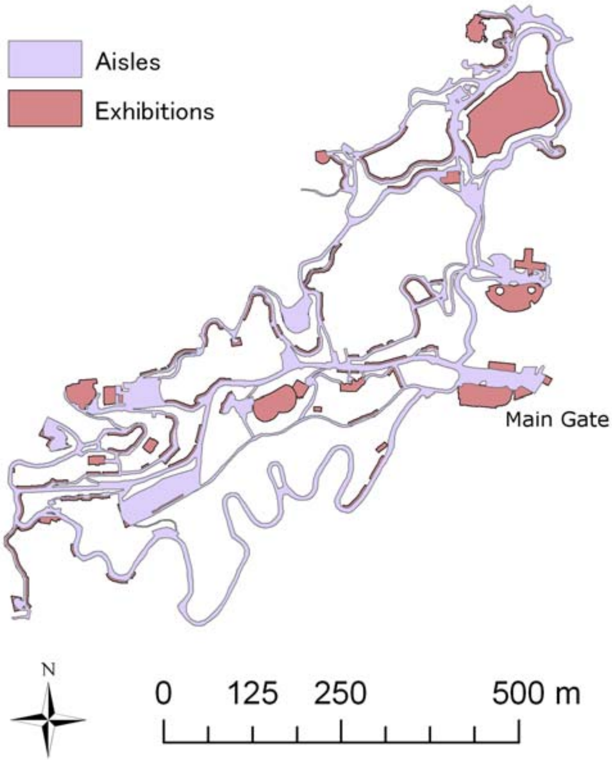

Fig. 1. A map of Tama Zoological Park

Our survey was conducted as follows: First, we stood at the main gate and distributed GPS loggers to the visitors who agreed to participate in our survey. When the visitors came back to the same place to leave the park, we collected the loggers from them and asked them to answer a questionnaire to obtain their attribute data, such as age, gender, and accompanying persons.

The GPS loggers we used were Qstarz Black Gold 1300 (Fig.2), whose weight was only 22g. We asked the visitors to put the GPS loggers on their necks, bags, baby carriages, or wherever they like. Each GPS logger was set to record the geo-coordinates of its location once in every second.

Fig. 2. A GPS logger used for our survey (Qstarz Black Gold 1300)

We obtained 190 valid sets of GPS logs and visitors' attribute data. The GPS logs were refined by removing error points. In this study 'error points' were defined as those that refer to a location more than three meters away from park aisles, because the possible horizontal error of our GPS loggers was three meters (catalogue value).

From the refined data, we first calculated each visitor's *staying time* at each animal exhibition (i.e., how long each visitor had spent there) by counting the number of points located within three meters from the boundary line between the exhibition and the aisle (Fig. 3) in ArcGIS 9.1. This is because we assumed that the visitors viewed animals just in front of each exhibition and the loggers' possible measurement error was three meters.

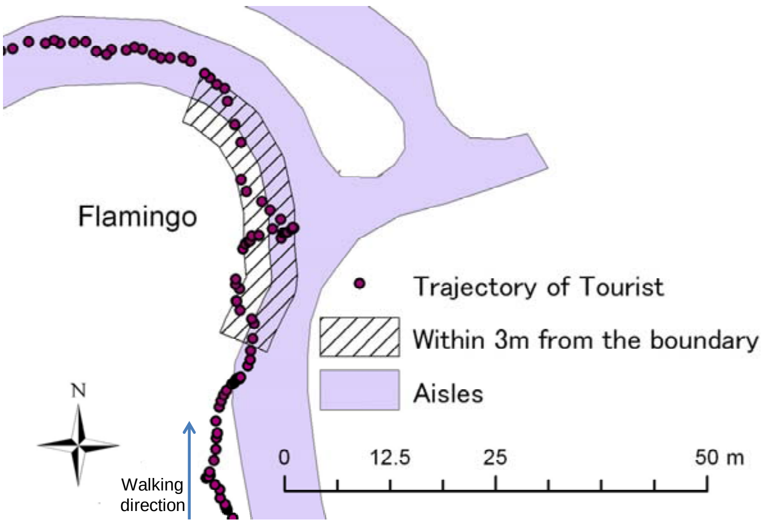

Fig. 3. A sample GPS log, together with an area within three meters from the boundary between Flamingo exhibition and an aisle

Table 1 shows ten top animal exhibitions in terms of average staying time. In addition, Table 2 shows the rankings of animal exhibitions by generations. The exhibition where all generations of people spend the longest time was Insect Museum. Children, especially boys, were caught by this exhibition (Table 2). Insect Museum has a long fixed route in it and accordingly, visitors who went into this museum naturally has spent long time there.

In general, most of Asian animals were not viewed for long time (Table 1). One of zoo staff commented that many visitors wanted to see African and Australian animals, while Asian animals were commonplace for them.

Our result shows that the animal exhibitions people visited, as well as the time they spent there, were quite different by their age, gender and accompanying persons. For instance, we found that people in their 40s spent more time in front of Japanese monkeys and Chimpanzees than those in their 20s, 30s, and 50s (Table 2). This is probably because they were typically interested in monkeys' sociality. Data about which ages of people are interested in each exhibition is suggestive for providing appropriate information through guide boards at the exhibition.

Another unique finding was that families with small children actually stayed longer time in cafeterias than in animal exhibitions.

Table 1. Ten top animal exhibitions in terms of average staying time

Rank	Animal Exhibition	Staying time
1	Insect Museum	11'23"
2	Lions	8'06"
3	Giraffes & Zebras	6'15"
4	Japanese Monkeys	4'30"
5	African Elephants	4'08"
6	Chimpanzees	3'49"
7	Walk-in Bird Cage	3'45"
8	Siberian Tigers & European Grey Wolves	3'03"
9	Orang-utans	2'30"
10	Asian Elephants	2'23"

Table 2. Ten top animal exhibitions in terms of average staying times by generations

Rank	10s	20s	30s	40s	50s
1	Insect Museum 25’49”	Insect Museum 8’45"	Insect Museum 10’16”	Insect Museum 12’21”	Insect Museum 7’23”
2	Japanese Monkeys 20’36”	Giraffes & Zebras 5’35”	Lions 8’16”	Lions 7’56”	Wolves & Tigers 7’13”
3	Giraffes & Zebras 6’20”	Lion 4’53”	Giraffes & Zebras 7’10”	Japanese Monkeys 6’03”	Giraffes & Zebras 6’54”
4	Brown Bears 5’18”	Chimpanzees 3’06”	Walk-in Bird Cage 4’56”	Giraffes & Zebras 5’49”	Lions 4’03”
5	Lions 5”11’	Walk-in Bird Cage 2”47’	Chimpanzees 4’23”	Wolves & Tigers 4’47”	Japanese Monkeys 3’53”

We also calculated the percentage of visitors who visited each animal exhibition. Here we assumed that a visitor had ‘visited’ an exhibition if he/she spent more than five seconds there. Table 3 shows the ten top highly-visited exhibitions. The result indicates that animal exhibitions along major corridors and those with large cages were visited by a larger number of people. However, we also found that higher percentage of visits did not necessarily mean longer average staying time (Table 1).

Table 3. Ten top highly-visited animal exhibitions

Rank	Animal exhibition	Percentage
1	Giraffes & Zebras	88%
2	Lions	87%
3	Oriental Storks	73%
4	African Elephants	69%
5	Great Indian Rhinoceroses	68%
6	Siberian Tigers & European Grey Wolves	66%
7	Raptors	66%
8	Orang-utans	63%
9	Parma Wallabies & Wombats	62%
10	Reindeers & Emus	62%

In this way, we successfully clarified the spatio-temporal behaviour of park visitors based on a GPS-assisted activity survey. We, however, considered only 'staying time', but not 'viewing time'. Viewing time is a direct measure for evaluating the attractiveness of each exhibition. On the other hand, staying time is easily affected by other factors. For instance, one of zoo staff pointed out the possibility that visitors had spent time resting on a bench without viewing an exhibition nearby (e.g., chimpanzees), and also the possibility that the staying time becomes inevitably longer if the exhibition has a long aisle along it (e.g., giraffes).

Our assumption that people viewed animals just in front of exhibitions was also questionable, because large animals can be viewed from more than three meters away, while small animals cannot be seen even in front of the exhibition when they are hiding. Thus, in order to judge visitors' viewing states from their GPS logs, we decided to look into additional available data in GPS logs; that is, walking speed.

4 Relationship between Tourist's State and Walking Speed

We conducted a supplementary experiment to investigate the relationship between people's activity (whether viewing or not) and his/her walking speed. This experiment was conducted from 15th of May (Sun) to 28th of June (Tue), 2011 in the same Tama Zoological Park. At this moment we employed five undergraduate and graduate students (three males and two females) as subjects. All of them are in the early 20s.

In this experiment, the subjects were asked to go around a zoological park, carrying a GPS logger. In addition, our staff followed each subject and filmed the subject's activity by a video camera. From this video we made the subject's activity log, which recorded precisely when the subject had been viewing an animal exhibition. The GPS log and activity log of each tourist were then matched. Note that the GPS logs were refined by removing the points recorded when the subject had been in a bus or an indoor exhibition.

Fig. 4 shows a sample GPS log with the subject's activity record. It seems that the subject has walked into the cage of Flamingo, but this is actually not (recall that our GPS logger has a measurement error). The figure also shows that the subject started viewing an animal exhibition even from more than three meters away when he is approaching the exhibition. Considering that the possible horizontal error of our GPS loggers is three meters, this indicates that our previous assumption that people view an animal exhibition just in front of it seems not appropriate.

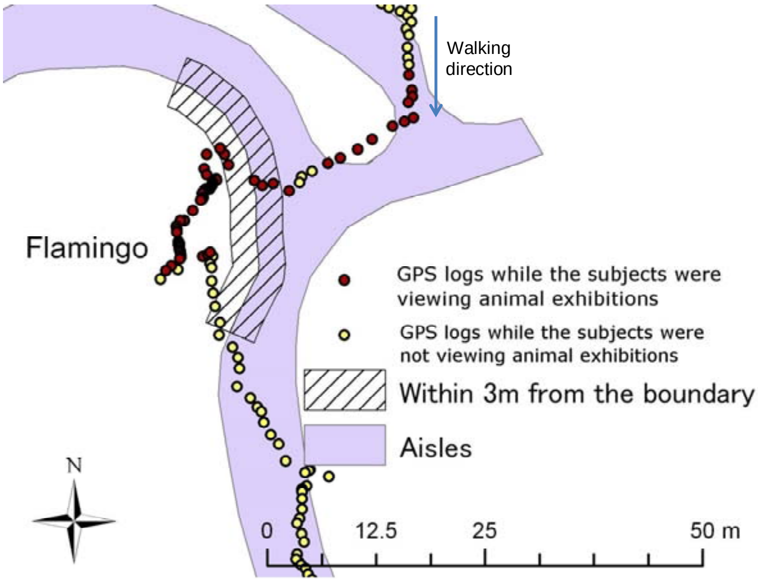

Fig. 4. A sample GPS log together with the subject's activity record

We then calculated the *probability of viewing* (i.e., the probability that people view an animal exhibition) in relation to walking speed, as the relative frequency of viewing states at each speed (every 0.1km/h). The resulting graph (Fig. 5) clearly shows a linear inverse relation between walking speed and the probability of viewing; that is, the probability of viewing increases as people walk more slowly, but even while not moving he is not always viewing an exhibition.

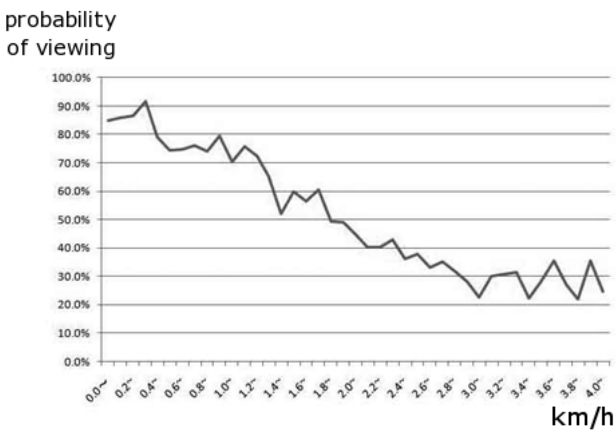

Fig. 5. A relation between probability of viewing and walking speed

From the GPS logs with the record of the subjects' activities, we built a logistic regression model in Eq. 1, with which we can estimate from walking speed whether people are viewing an exhibition or not. In Eq. 1, P_i means the probability of viewing at point i, and v_i means walking speed at point i. When applied to the GPS logs obtained in our experiment, this model correctly discerned the subjects' viewing states over 68.4 percent of the entire logs. On the other hand, if the previous rule (i.e., we regard people as viewing exhibitions if they are within three meters from the exhibition) is applied to the same GPS logs, the success rate drops down to 56.7%. From this fact, we can conclude that the time people have spent in front of an exhibition is not sufficient to estimate the time they have viewed it.

$$\mathrm{logit}(P_i) = 0.6194 - 0.3237 v_i \tag{1}$$

Estimate	**Standard deviation**	**Chi-squared**	**p-value**	**Exp(estimate)**
0.6194	0.0226	752.1810	0.0000	
-0.3237	0.0105	948.5306	0.0000	0.7235

The logistic regression model in Eq. 1 can be applied to the GPS logs recorded in our initial survey. For example, Fig. 6 shows the GPS log of a visitor in our initial survey, together with the presumption of his viewing state. In this case, he probably viewed the exhibition only first half of his stay in front of this exhibition. By counting the number of these points where he is presumed viewing an exhibition, we can estimate his viewing time on this exhibition, as each point corresponds to one second. Indeed, by repeating this process for everybody, we calculated the average of estimated viewing time for each animal.

For the calculation of average estimated viewing time, we used the GPS logs of 26 visitors who were in their 20s and accompanied by a single person, because the model in Eq. 1 was developed based on the data of subjects in their 20s followed by a staff. In addition, we assumed that each subject views the nearest animal exhibition when the subject was presumed viewing something.

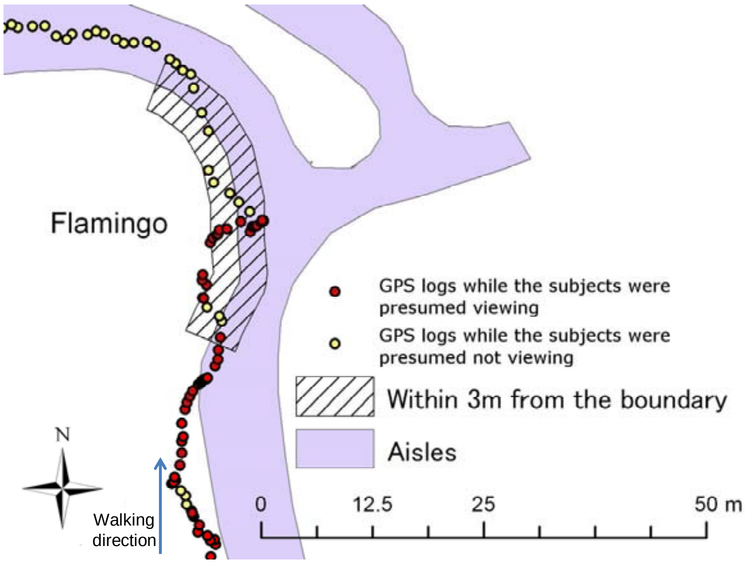

Fig. 6. A sample GPS log with the visitor's presumed viewing states at each location

Table 4 compares two rankings of animal exhibitions: the left one features average staying time, which was calculated by our previous method (i.e., counting the number of log points within three meters from the boundary between an exhibition and an aisle), while the right one features average viewing time estimated by our new method. The result shows several differences between staying time and viewing time. First, the viewing time of lions (5'08") is much shorter than its staying time (7'20"). This is because the lions' exhibition has a long aisle along it and accordingly, people have spent long time for walking the aisle often without viewing the lions. The same reason applies to Insect museum which has long fixed route in it. On the other hand, the viewing time of wolves and tigers (4'41") is estimated much longer than its staying time (2'56"). This is probably because many visitors have viewed these animals from a distance, particularly the space under trees, rather than the area near their cages.

In sum, in order to evaluate how much people are involved in each exhibition, it is better to consider not only their location, but also their moving speed. In addition, other elements such as distance and angle to each exhibition may work as additional clues for discerning whether people view it or not. Thus, we are currently working on the refinement of our logistic regression model by considering additional parameters. In addition, we are currently conducting an additional experiment with non-student subjects (e.g., families with children) to expand the target of our model.

Table 4. Two rankings of animal exhibitions in terms of average staying and viewing times, estimated from the GPS logs of 26 visitors in 20s coming with another person

Rank	Animal Exhibition	Staying Time	Rank	Animal Exhibition	Viewing Time
1	Lions	7’20”	1	Lions	5’08”
2	Insect Museum	5’43”	2	Giraffes & Zebras	4’43”
3	Giraffes & Zebras	5’14”	3	Wolves & Tigers	4’41”
4	Japanese Monkeys	4’06”	4	Insect Museum	4’34”
5	Chimpanzees	3’09”	5	Japanese Monkeys	3’40”

5 Conclusion

The result of our experiment shows that not only the location history of visitors, but also their walking speed is essential for judging their viewing states and eventually for evaluating the exhibition’s attractiveness. The information about exhibitions’ attractiveness will be important for considering how to improve exhibitions, spatial designs, and tourist information of the zoological park. For instance, animal exhibitions which small children like can be be relocated near the entrance, because children cannot walk long distance. On the other hand, animal exhibitions which attract adults rather than children may better be equipped with an adult-oriented guide board that explains the social aspect of the animal, etc.

In this work, the subjects are limited to students in their 20s. To increase generality, we are currently conducting a similar experiment where the subjects are general visitors accompanying small children, as they are the main target of zoological parks. In addition, we are refining our model by adding other parameters than location and walking speed, such as acceleration and walking angle to the exhibition.

In future work, we will refine the model, such that we can discern a larger variety of tourists’ activities. In addition, we will conduct similar surveys in other sorts of tourist facilitates, such as amusement parks and open-air museums, and examine whether our technique can be applied generally to these facilities.

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Acknowledgements

We appreciate the visitors to Tama Zoological Park who participated in our surveys, as well as its staff who kindly helped our surveys and gave valuable comments to us. This work was supported by JST RISTEX's research program on Needs-oriented Service Science, Management and Engineering (project title: "Architecting service with customer participation based on the analysis of customer experience and design processes: sophisticating tour design processes as a case study") and Tokyo Metropolitan University's internal research fund.