UbiComp/ISWC 2015 PDR Challenge Corpus

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Ubicomp/ISWC'16 Adjunct , September 12 - 16, 2016, Heidelberg, Germany

ACM 978-1-4503-4462-3/16/09...$15.00
DOI: http://dx.doi.org/10.1145/2968219.2968276

Abstract
PDR (Pedestrian Dead Reckoning) is a very promising technology for indoor positioning. We held a technical challenge, entitled the UbiComp/ISWC 2015 PDR Challenge, consisting of the following three categories: Algorithm, Evaluation, and Exhibition. In this paper, we specially focus on collected data for PDR algorithm category. UbiComp/ISWC participants equip smartphone by hand and walk around the particular floors. The pedestrian sensing data is collected. The number of our prepared route pattern is 5. Over two days, we collected the sensing data of 105 subjects. The total number of collected pedestrian sensing data was 343. After removing faulty data, this number was 241 and the number of unique subjects was 103. Sensor types are accelerometer, gyro, magnetic, and air pressure. We, PDR Challenge organizers, provide the corpus as UbiComp/ISWC 2015 PDR Challenge Corpus. The corpus contains ground truth of 3-D coordinates of the pedestrian sensing data for each second.

Author Keywords
Corpus; pedestrian sensing; pedestrian dead-reckoning

ACM Classification Keywords
H.2.8. Database Applications: Spatial databases and GIS

Introduction

Location information is important in everyday life. By using smartphones, it is possible to obtain locations using a global positioning system (GPS) from most places outdoors. However, indoors, where GPS radio waves cannot reach, it is not as easy to obtain precise locations; therefore, various approaches are under active development. It is said that 86% of urban daily life takes place indoors [1], for example, shopping at large malls and commuting via subway. In such situations, GPS is inoperable. However, even indoors we need location-based services, such as shop recommendations and transfer navigation.

Recently, various indoor positioning technologies that utilize environmental information have been developed, some of which are already in use. All of these technologies, however, have their good and bad points, so a standard technology for use in any environment does not exist. For example, smartphones, such as the iPhone and Android, are already equipped with Wi-Fi positioning technology, although the accuracy is unsatisfactory for indoor navigation in some applications. For example, if the positioning error is over 10m, the system cannot find current room correctly, so that room-to-room navigation is difficult in such case. The Bluetooth low energy (BLE)/iBeacon-based positioning is a wireless positioning technology. UWB (Ultra-Wide Band) is one type of accurate positioning technology. Otherwise, sound-based and infrared light-based positioning have been proposed. Some of this technology requires special beacons or antennae, so the establishment and running costs are concerns. Also, a magnetic fingerprint-based positioning method has been researched [2], but this method needs a preliminary survey to develop a magnetic fingerprint of the target environment and this survey cost is problematic.

PDR (Pedestrian Dead Reckoning) can be considered a promising approach to indoor location estimation [3, 4]. Using an acceleration/gyro sensor built into the mobile terminal, PDR estimates relative movement. It is not possible to pinpoint the absolute location with PDR alone; however, by combining with other location estimation methods, PDR has the potential to track the absolute location [5]. By using specialized wearable devices, various kinds of PDR-enabled products have been proposed. However, for current smartphones, high-precision PDR methods or algorithms and stability are not well known. Moreover, no evaluation method has been established for PDRs from various aspects. Of course, IMU (Inertial Measurement Unit) using an optical fiber gyro sensor can obtain PDR in centimeter order, but IMU will not be widely used because it is very expensive. Smartphones are equipped with relatively cheap sensors and smartphone use is widespread. Therefore, it is necessary to achieve accurate indoor positioning for smartphones by integrating a positioning method such as PDR and wireless positioning.

The following three points are important considerations for indoor positioning: 1: corpus development for indoor positioning; 2: evaluation measurement for indoor positioning; and 3: accuracy improvement of individual positioning technology. The corpus enables fair-minded research comparison. We developed a pedestrian sensing corpus named HASC-IPSC [6]. The corpus includes approximately 100 pedestrian sensing data, such as accelerometer, gyro, and air pressure. However, the terminal variation is unsatisfactory. For the second point, several evaluation methods for indoor positioning have been proposed [7, 8], but they are currently not standard. Additionally, the indoor positioning axis is not the only accuracy consideration. For example, latency, calculation cost, memory consumption, sensor sampling rate, power consumption, and robustness of device/user are all important. Currently, there is no evaluation method that considers this information simultaneously. For the third point, unfortunately, interest in several indoor positioning competitions has already shifted to integrated positioning technology [9, 10]. Therefore, there are few opportunities to compete in individual positioning method development such as PDR.

To create such an opportunity, we held a "PDR Challenge" at UbiComp/ISWC 2015. Three categories were prepared for the participants of this Challenge: a PDR algorithm, a PDR evaluation method, and an exhibition. The participants in the algorithm category compete in the PDR algorithm. Evaluation criteria of the proposed algorithms is not limited to position estimation accuracy, but includes latency and power conservation. The participants in the evaluation method category compete in the evaluation method of PDR. The participants in the exhibition demonstrate any type of method/product that utilizes PDR, but are not limited. Therefore, any method/product that integrates with the absolute location estimation method, "map matching," uses Wi-Fi, etc.

In this paper we focus on data collection and corpus development. Paper organization is as the following. At first, we describe UbiComp/ISWC 2015 PDR Challenge. Then, we explain statistics and data format of our developed corpus named UbiComp/ISWC 2015 PDR Challenge Corpus. On the other hand, we focus on the systems for PDR Challenge in the other paper [11].

UbiComp/ISWC 2015 PDR Challenge

We held the PDR Challenge at UbiComp/ISWC 2015. Our aim was the following three points: 1: corpus development for indoor positioning research; 2: investigation of an evaluation method of PDR; and 3: raising the level of PDR research (Fig. 1). The challenge consisted of a PDR algorithm category, PDR evaluation method category, and an exhibition.

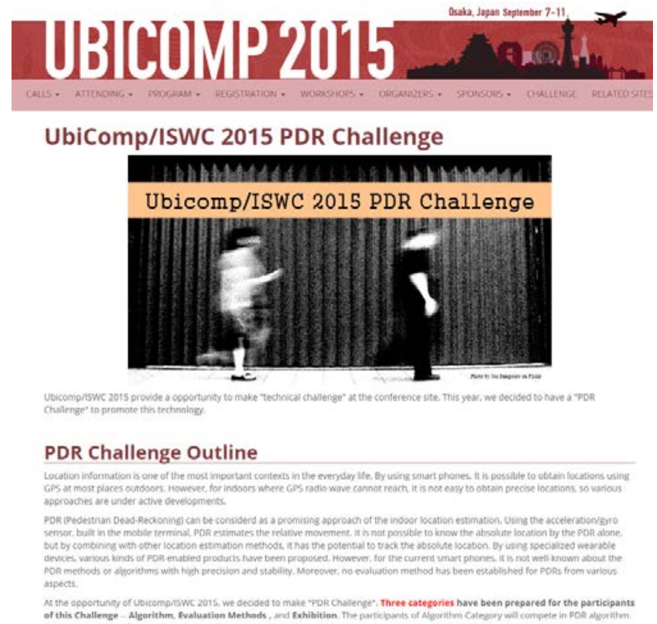

Figure 1: Webpage of UbiComp/ISWC 2015 PDR Challenge (http://ubicomp.org/ubicomp2015/challenge.html)

[PDR Algorithm Category]

In the PDR algorithm category, the challenge participants submit a PDR algorithm and compete for accuracy. The challenge environment is the Grand Front Osaka, which is the venue of UbiComp/ISWC 2015. In

PDR algorithm category, UbiComp/ISWC participants become the PDR subjects and walk around the environment with various smartphones. By using collected pedestrian sensing data, such as accelerometer, gyro, and air pressure, each PDR algorithm is evaluated.

Five teams participated in the PDR algorithm category. One team was from a business organization and they already developed commercial product based on their own PDR algorithm. The other teams are all from University. Most of them are not so familiar with activity recognition, sensor processing, and indoor positioning.

[PDR Evaluation Category]

In the PDR evaluation method, the challenge participants make a presentation about the PDR evaluation method, addressing not only accuracy, but also other novel aspects.

Two teams participated in the PDR evaluation method category, and discussed their evaluation method. One team presented PDR evaluation method according to individual function such as walking length, direction, and height change. The other presented the activity of PDR benchmark case study and standardization.

[Exhibition]

In exhibition, we allow to introduce original devices, infrastructure, and environmental knowledge to estimate detailed position such as Wi-Fi/iBeacon-based absolute positioning, and map matching.

At the exhibition, a business organization participated and demonstrated their commercial indoor positioning application based on PDR, iBeacon, and map matching. Many of the UbiComp/ISWC 2015 participants tested leading-edge indoor positioning applications.

[Detail of PDR Algorithm Category]

From here, we focus on the PDR algorithm category. We positioned the challenge as an ``Open Challenge,'' and the competition method and rules were decided via discussion with challenge organizers and participants. One reason was to promote participants from not only academic groups, but also businesses. Companies tend to have built-in limitations and constraints for participating in such kinds of challenges. Therefore, we wanted to set the challenge rules with those considerations in mind. The final rules for the PDR algorithm category were the followings.

- Android smartphone with the following sensors (a PDR skeleton was provided)
- Sensors: Accelerometer, gyro, magnetic, air pressure
- Device position: In hand
- Subjects: Participants of UbiComp/ISWC2015 and student volunteers.
- Venue: Grand Front Osaka (around the Workshop area: Tower C 8th and 7th floor)
- Calibration: Calibration data was provided for each sensing data. The calibration method was linear walking and the length was 14.4 meters.
- Ground truth: Time and coordinates were provided. The coordinates started with (0, 0, 0) and the vector was (1, 0, 0).
- Coordinate system: 3D coordinates. When a subject turns left after starting, the value of the Y-axis is plus.
- Evaluation method: Average of errors. Error is calculated for every 1 second.
- Error calculation method: Euclidean distance

For the PDR algorithm category, traditional accuracy was adopted as the evaluation method. Actually, we intended to adopt various evaluation aspects, such as latency, robustness, computational cost, and so on, but we could not prepare them. Therefore, we passed discussion of the detailed evaluation method on to the PDR evaluation method category.

Additionally, as a result of this discussion, we targeted a real-time PDR algorithm. There are several offline algorithms for pedestrian trajectory estimation, although the appealing technology of an indoor location-based service is navigation and navigation requires real-time PDR. Therefore, the PDR algorithm should estimate the current relative position by using sensing data from the start to the current time, and we do not allow the use of future sensing data for estimating current position.

All algorithms are evaluated by using same data. Through the challenge, we, the PDR Challenge organizers, collect pedestrian sensing data on the target routes. On the other hand, participants submit their PDR algorithm as JAR file before starting the challenge. The PDR algorithms are set to PDR evaluation server beforehand. PDR algorithms are emulated on the server by using all of collected pedestrian sensing data and evaluated the accuracy.

UbiComp/ISWC 2015 PDR Challenge Corpus

In this section, we describe our developed corpus named UbiComp/ISWC 2015 PDR Challenge Corpus. The data was used for the evaluation of PDR Algorithm Category. Each subject holds a smartphone prepared by an operator and walks a restricted route. To walk the correct route, the operator accompanies the subject as a guide according to need (Fig. 2).

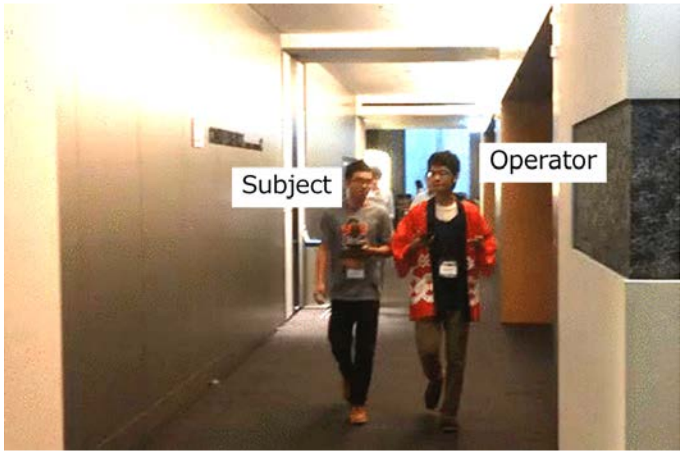

Figure 2: Scene of data collection.

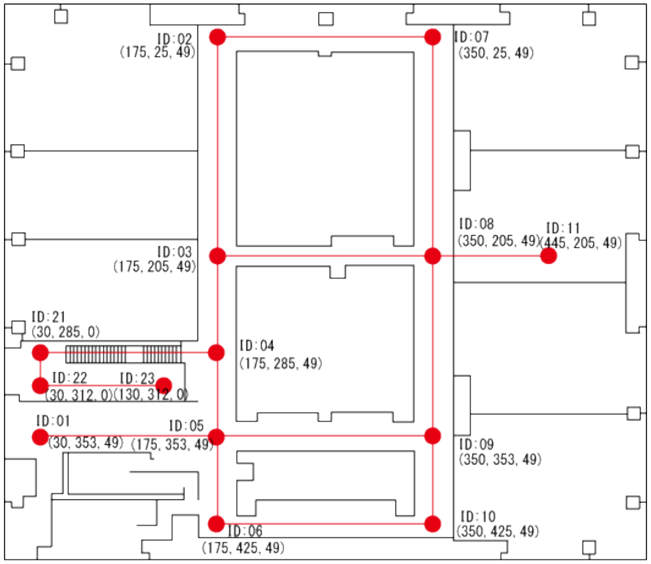

Figure 3: Floor map and pedestrian network structure of the data collection environment.

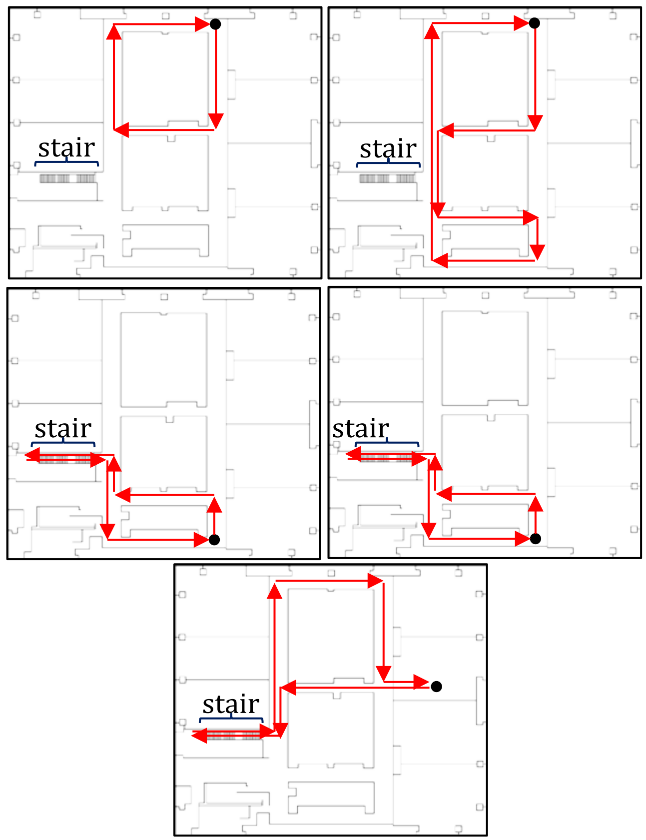

Figure 4: Five types of pedestrian route.

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11837.194427,-0.2931012717861,0.47338655042950006,0.7125413291060001
11837.198608,-0.3333942558797,0.440860911545,0.720794148049
11837.203582,-0.33436517275620004,0.41100523033900005,0.7579316395476
11837.208526,-0.2996549581532,0.4080925001037,0.8152156230930001
11837.2135,-0.24722552839900003,0.4267826219343,0.8948307049950001
11837.218505,-0.1836305800578,0.4563955305835001,0.9975049989820001
11837.224273,-0.12100653839600001,0.47945479365400007,1.091198299115
11837.228485,-0.07974264150474,0.49741669978520003,1.16013324439
11837.233428,-0.05037245442684000 5,0.5008149037544001,1.1880470918430002
11837.238342,-0.0481878950237,0.49935851314400004,1.206494461511
```

Figure 5: An example of acc.csv.

Floor Data

A floor map and pedestrian network structure is shown in Figure 3. Each node has ID such as "02". Also, there are 3-D coordinate information for each node. The floor is a relatively simple structure because it consists of straight corridors, orthogonal corners, and stairs.

Route Data

We collected five kinds of route type (Fig. 4). Two routes are one floor moving. The other three routes contain stair activity. Start position and goal position are same for each route.

Pedestrian Sensing Data

There are four kinds of sensing data. They are accelerometer, gyro, magnetic, and air pressure. Each sensor contains three axis. All sensing data is recorded as CSV file (Fig. 5). The first value is device time [sec]. Second, third, fourth values correspond to the sensor value of x-axis, y-axis and z-axis. For easy use, we prepare two types of accelerometer data. The units are [G] and [m/s^2]. Latter unit ([m/s^2]) is used as International System of Units (SI), so that the file name contains "SI" such as "***-acc-si.csv". Unit of gyro sensor is [rad/s]. Unit of magnetic meter is [μT]. Unit of air pressure is [hPa].

There is calibration data correspondent to most of all pedestrian sensing data. As the calibration, subject walk straight corridor. The length is 14.4 [m]. By using calibration data, you can estimate step length, offset of gyro sensor, air pressure of the floor, and so on.

Correct labeling data is generated by the operator who accompanies the subject. The information exists each for the pedestrian sensing data. The operator pushes the logging button as the subject starts, turns a corner, stops, and takes stairs up/down. According to the button log, we generated correct coordinates by one second (Fig. 6). First value of the CSV file is relative time. Second, third, and fourth values are 3-D coordinates (x, y, z). Note that the information is relative coordinates. First position is (0, 0, 0), and the first direction is x-axis (1, 0, 0). The unit of coordinate is meter. When the correct coordinate is generated, we assume that the subject is walking straight and at a constant speed.

```
0.0,0.0,0.0,0.0
1.0,1.2,0.0,0.0
2.0,2.39,0.0,0.0
3.0,3.59,0.0,0.0
4.0,4.79,0.0,0.0
5.0,5.98,0.0,0.0
6.0,7.18,0.0,0.0
7.0,8.38,0.0,0.0
```

Figure 6: An example of correct-1sec.csv.

Figure 7: LIDAR (left) and ATRTracker (right).

Meta Data

The subjects' personal data, device information, and route information are described in the file “***.meta”. This includes information on age, gender, height, weight, route ID, device name, device OS and so on. Each personal attribute is placed subject to common consent

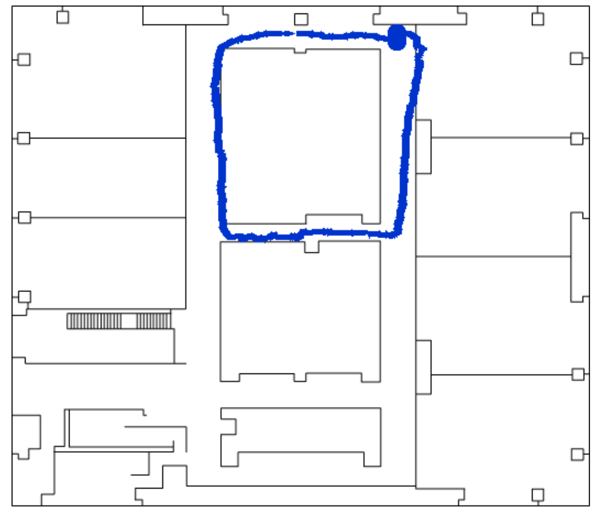

Figure 8: An example of detailed pedestrian trajectory.

LIDAR Data

On the day of the challenge, the target floors fairly bristled with UbiComp/ISWC participants. Therefore, our generated correct coordinate information is not necessarily exactly correct. To provide more accurate coordinate information, we also deployed laser range scanners (LIDAR) on the floor and attempted to track the pedestrians' positions (Fig. 7) using ATRTracker.

Figure 8 shows an example of detailed trajectory of a pedestrian. The format of LIDAR data is almost same as correct coordinate information. You can see small direction change while walking. However, tracking data could be constructed only for 1 route type, 10 pedestrian sensing data. Even using ATRTracker, most pedestrian could not continue to capture while walking. One reason of the difficulty is occlusion. There are many participants in corridor, so that pedestrian are lost while walking even using multiple LIDAR.

Statistics

Table 1 ,2, 3 shows the statics of the corpus. The number of our prepared route pattern is 5. Over two days, we collected the sensing data of 105 subjects. The total number of collected pedestrian sensing data was 343. After removing faulty data (for example, operators failed to push the button several times and sensor data was not correctly uploaded), this number was reduced to 229 and the number of unique subjects was 90. We prepared seven types of smartphones shown in Table *, all equipped with an accelerometer, gyro, magnetic, and air-pressure sensors as required by the challenge.

We prepared seven types of smartphones (Nexus (4, 5, 6), Xperia (ZL2, Z3, Tablet), and ULBANO (L01)), all equipped with an accelerometer, gyro, magnetic, and air-pressure sensors as required by the challenge. In HASC-IPSC, the number of smartphone types was only two (Nexus 4 and Galaxy S3). Consequently, we can collect pedestrian sensing data from various types of smartphones.

Routes	5
Devices	7
Subjects	93
# of pedestrian sensing data	241
# of pedestrian sensing data with calibration data	230
# of pedestrian sensing data with LIDAR data	10

Table 1: Statistics of the corpus.

Avg. of walking time [sec]	101
Avg. of moving distance [m]	115
Avg. of angular change [°]	606

Table 2: Detailed route statistics of pedestrian sensing data with calibration data.

Conclusion

This paper describes about Ubicomp/ISWC 2015 PDR Challenge Corpus that can be used as benchmark data for indoor pedestrian dead-reckoning. The data was taken from 103 people and the number of pedestrian sensing data is 241. It is used free of charge for research purposes. You can download the corpus via (http://hub.hasc.jp). We would be glad if this data could be used in basic and applied research and contribute further to advancement in the fields of indoor positioning researches.

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