Highly Accurate Location-Aware Information Delivery With PosPush

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***Abstract*—This paper proposes PosPush, a highly accurate location-based information delivery system, which utilizes the high-resolution 3D locations obtained from ultrasonic positioning devices to efficiently deliver the location based information to users. This system is designed especially for applications where a 3D space is partitioned into a set of closely neighboring small zones, and as a user moves into one of the zones, the corresponding information will be timely transferred to the user. In order to identify precise zones, PosPush defines a zone model by a set of key location points extracted by a location clustering algorithm, and the zone model is used for online zone identification based on hierarchical searching. In order to determine the appropriate delivery time, an Adaptive Window Change Detection (AWCD) method is proposed to detect the fast change along the location stream. To evaluate the system performance, a MV (Music Video) shelf demo prototype was built in which the information of commodities on the shelf can be delivered based on PosPush. We verified the feasibility and effectiveness of our proposed system from objective and subjective perspectives.**

***Keywords*-Location Based Service, Ultrasonic Positioning, Ubiquitous Computing**

I. Introduction

Location data can be contextual indexing information that a system will use to provide services to users, which is called Location Based Services (LBS)[1-6]. Location based Information Delivery System (LIDS) is one typical example of LBS, in which relevant information are predefined for different zones so that when a user enters one of these zones, the related information will be delivered automatically to the user. So far, there are already a lot of research and engineering efforts focusing on LIDS. These conventional LIDS always utilized a very coarse location data of user obtained from either Bluetooth[7,8], Wifi[9-11], RFID[12-14] or GPS[15,16] to provide proximity based information delivery service. Generally, in conventional LIDS, the location zones are relatively large (over tens of square meters). Because of the location coarseness, these zones are roughly defined and have fuzzy boundaries between each other. In addition, the delivery time in conventional LIDS only depends on the instant location of user, i.e., the location based information will be sent to user only if the user is at one of the location zones.

In this paper, we propose PosPush, a highly accurate location-based information delivery system, which utilizes the 3D locations obtained from ultrasonic positioning device [17] to efficiently deliver the location based information to users. In PosPush, a 3D space is partitioned into a set of closely neighboring small zones; a user holds a stick-style ultrasonic tag and moves it into one of zones to get more related information. PosPush can be used in many application scenarios. For example, as shown in Figure 1, in the shopping mall, the commodities on the shelf are placed so closely that the distance between two commodities may be just several tens of centimeters. The vicinity of each commodity forms a small zone. If a customer shows much interests in one specific commodity and wants to know more related information, he/she may approach the commodity and point at it with a stick-style ultrasonic tag, and then the information related to the interested commodity will be pushed to the public display near the commodity shelf. Another example is the exhibition scenario, where many exhibits are placed very closely on the booth table. Visitors can get more information related to one exhibit by moving the ultrasonic stick close to the interested exhibit. It will be a fantastic experience for users because user can get what he/she wants by just pointing a stick towards what he/she is interested in, so we call such a ultrasonic stick as ***Magic Stick***.

Figure 1. PosPush for Shopping Mall Scenario

PosPush is a novel LIDS with fine-grained location zones and highly accurate location information. Compared with the conventional LIDS, more complex mechanism is highly desirable in PosPush. Exactly, there are two unaddressed problems to the conventional LIDS:

1) Precise zone modeling and identification
   Since the zones in PosPush are small and closely neighboring, precise zone identification is extremely necessary, which poses high requirement to the offline zone modeling and online zone identification.
2) Appropriate delivery time determination
   Considering that there are many neighboring small

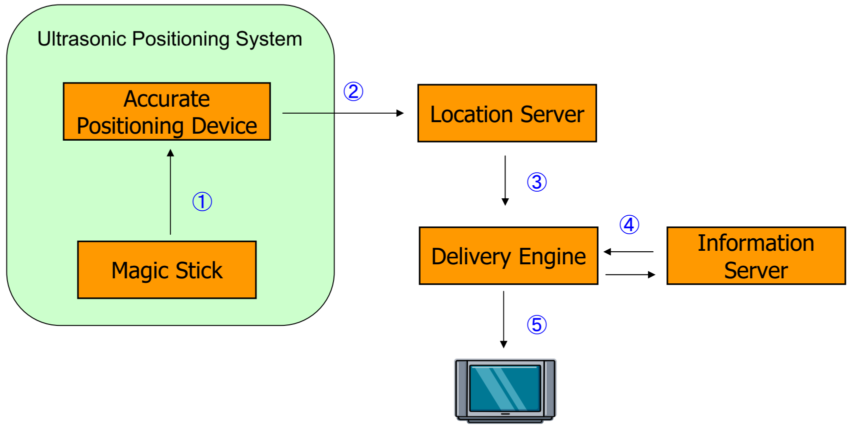


Figure 2. System Overview of PosPush

zones in PosPush, user may unconsciously pass these small zones. If information delivery is triggered whenever a user is detected within a small zone, the user will receive many unwanted information. An appropriate delivery time determination method is highly desired.

To address the above problems, two crucial mechanisms are designed in PosPush. For precise zone modeling and identification, in offline phase, we make use of a location clustering algorithm to precisely calibrate the small zone, which extracts a set of key location points from the randomly collected location trajectory inside a small zone, and in online phase, a hierarchical searching method is used to accurately and quickly determine which small zone the target is located in. To determine the appropriate delivery time, we propose Adaptive Window Change Detection (AWCD) method to tolerate the zone identification error and optimize information delivery time by monitoring the fast change along the location stream. We implement PosPush in a prototypical application for commodity information delivery in shopping mall. Based on this prototype, we carry out a number of experiments to evaluate the performance of PosPush.

The rest of this paper is organized as the follows. we present the system overview in Section 2. Zone calibration and identification algorithm, and delivery time determination algorithm are introduced in Section 3 and 4, respectively. Section 5 presents the prototype implementation and a privacy-preserving approach is also described. The performance evaluation covering not only objective evaluation but also subjective evaluation is in Section 6. Finally, Section 7 concludes the paper.

II. System Overview

The system architecture of PosPush is illustrated in Figure 2. Such architecture contains several main components:

- ***Ultrasonic Positioning System***
  In PosPush, a ultrasonic positioning system is deployed for locating the mobile targets, which is composed of Accurate Positioning Device and Magic Stick. The positioning device is named as Positioning on One Device (POD) that integrates multiple ultrasonic receivers. POD is mounted, facing downwards, in the room to be covered. Magic Stick is a ultrasonic transmitter carried by user for tracking. It works in active transmission mode and can be located by POD with the accuracy of less than 10 centimeters. For more information about the ultrasonic positioning system, please refer to our prior work [17,18].
- ***Location Server***
  The function of Location Server is to collect the accurate location of Magic Stick. In offline phase, the model for each small zone is calibrated by clustering a sequence of location data samples. In online phase, the real-time location of Magic Stick is used to determine which small zone the Magic Stick is located in by searching the location models.
- ***Delivery Engine***
  Delivery Engine aims to efficiently determine the appropriate time for information delivery. Particularly, Delivery Engine performs an AWCD based method to detect the delivery time by sequentially evaluating the location stream of Magic Stick. At the delivery time, Delivery Engine will send a query for retrieving the location based information from Information Server and then forward the information to the Public Display.
- ***Information Server***
  Information Server contains a location based information database that stores various information associated with the small zones.

Based on the system architecture, the work flow of PosPush is as follows.

① The Magic Stick carried by user emits the ranging signals to POD.

② The accurate location of Magic Stick is calculated by POD and sent to the location server.
③ Location server identifies which small zone the Magic Stick belongs to, and sends the corresponding zone index to Delivery Engine.
④ Delivery Engine determines the appropriate delivery time along the location stream and sends it as a query to Information Server to retrieve the location based information.
⑤ The location based information is delivered to the Public Display for rendering timely.

III. Zone Calibration and Identification

In PosPush, location server is an important component that performs both offline zone model calibration and online zone identification. The zone defined in PosPush refers to a small 3D space containing a specific object. For example, in shopping mall, a vicinity area around a commodity on the shelf is regarded as a zone. Qualitatively, assume the distance between two neighboring objects is d cm, such a small zone can be described as a cubic space with the edge length of d cm. Figure 3 gives an illustration.

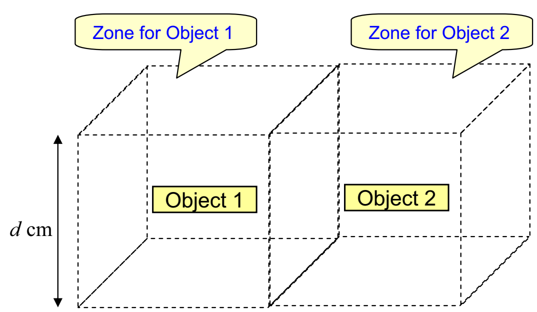


Figure 3. Cubic Space Description for Small Zone

The characteristics of these zones are small and closely neighboring. As far as the cubic space is concerned, there are two basic methods for zone calibration and identification.

1) Center based method
The coordinate of central point is recorded in offline phase, which is taken as the zone model. In online phase, the distance between the real-time location of Magic Stick and the central point of the zone is calculated. The most probable zone can be determined if such a calculated distance is less than d cm.
2) Boundary based method
In offline phase, Magic Stick is moved along the boundary of the cubic space so that the moving trajectory is recorded as the zone model. In online phase, the real-time location is compared with the zone boundary for determining if the tag is located at this zone.

However, the above methods are not so efficient because it is difficult to make a correct judgment when Magic Stick moves between the boundaries of the neighboring zones. The experiment in Section 6 also confirms it. In addition, since the Boundary based method requires user to move Magic Stick strictly along the boundary for calibration, lots of manual efforts will be needed.

To solve the problems of above methods, we propose a new method for precise zone calibration and identification.

A. *Offline Calibration*

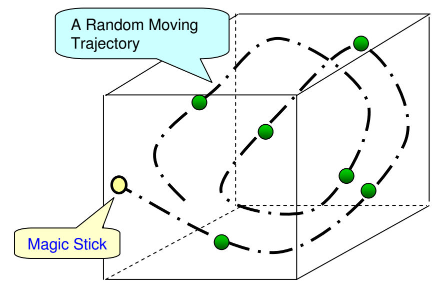


Figure 4. Random Location Collection Inside a Zone

During the offine phase, we perform location clustering method to compute the location model for each small zone. Firstly, we collect a sequence of 3D location data for a small zone by just moving Magic Stick along a random trajectory inside the small zone, which is show in Figure 4.

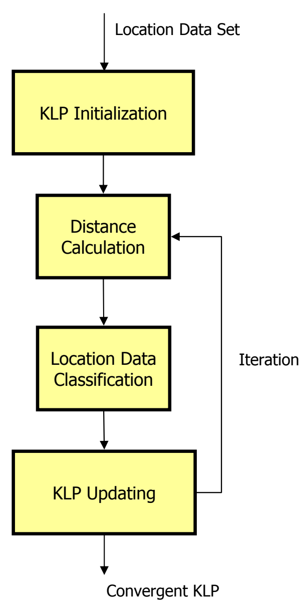


Figure 5. Block Diagram of Zone Calibration

For users, such a random collection approach is flexible and convenient. Afterwards, we apply a clustering algorithm to extract a set of key location points (KLP) form the collected location data to represent the precise model for each zone. There are a fair number of research literatures that describe various clustering algorithms [19-21]. However, we choose the classical k-means algorithm [22] to find the location model since it is a simple but efficient way to classify the collected location data set into n clusters in which each location data belongs to the cluster with the nearest distance. The whole process is shown in Figure 5. After an iterative process, n KLP are finally refined from the convergent clusters, which are taken as a location model for each small zone. It can be denoted as $P_m = (x_{mj}, y_{mj}, z_{mj}), j = 1, 2, ..., n, m = 1, 2, ..., M$, where n is the number of KLP in one model and M is the total number of the zones. It should be noted that at the case of $n = 1$, i.e., the number of KLP is 1, the proposed clustering based method will be reduced into the above mentioned Center based method.

B. Online Identification

During the online phase, a hierarchical searching method is used to quickly find the most probable small zone where the Magic Stick is located in. In this method, there are two search stages, which are shown in Figure 6.

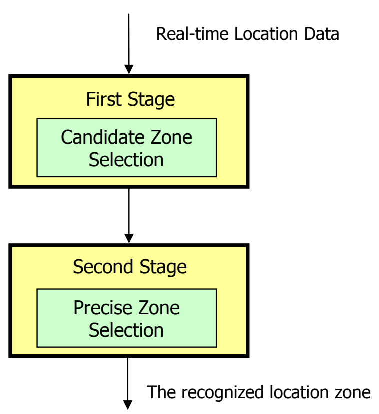


Figure 6. Block Diagram of Zone Identification

The first stage is Candidate Zone Selection, in which for each small zone, only one of KLP is randomly selected for distance calculation to the real-time location data. The distance data are filtered by comparison with a predefined threshold so that only M_c zones from all M zones with minimum distance to the real-time location data are selected as the candidates for next stage processing, especially, $M_c << M$. The second stage is Precise Zone Selection. For each candidate small zone, the average distance between location model of m^{th} zone from M_c candidates and the real-time location data $X_t = (x_t, y_t, z_t)$ is calculated according to the following equation.

$$Dist_m = \sqrt{\frac{\sum_{j=1}^{n}[(x_t-x_{mj})^2+(y_t-y_{mj})^2+(z_t-z_{mj})^2]}{n}} \quad (m = 1, ..., M_c) \qquad (1)$$

Finally, the index of the most probable zone will be obtained using minimum criteria among the M_c distances, which is depicted as

$$Loc_t = \arg\min_m Dist_m \qquad (2)$$

Through the online zone identification to the real-time location data of Magic Stick, the location stream of Magic Stick can be mapped into the matched zone index stream.

IV. Delivery Time Determination

For purpose of providing friendly user experience, it is important to find the appropriate and reasonable time for information delivery. This is especially true for PosPush where the small zones are close neighboring so that user may unconsciously pass through some of the small zones. If we apply the conventional instant-location based delivery method, many unnecessary information delivery will be triggered, which would be rather annoying to the users. So we define the time for starting and stopping information delivery:

Information Delivery Time (IDT): the moment when the location based information should be delivered to user client as user is close or inside one of location zones.

Information Stop Time (IST): the moment when the location based information delivery should be terminated as user is leaving the location zone.

IDT and IST are detected by sequentially evaluating the newest location data in the location stream to find an adaptive window whose accumulate departing significance is compared against a IDT-threshold and a IST-threshold respectively. The IDT, IST determination problem is illustrated in Figure 7. The upper stream is the location stream and the lower stream is the corresponding zone index stream.

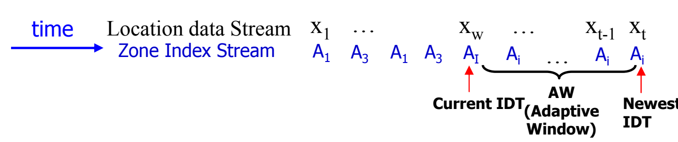


Figure 7. IDT Determination from Streaming Data

The total M small zones can be denoted as $\{A_i, i = 1, 2, ..., I, ..., M\}$. Suppose the time when the location data is X_w, which located at zone A_I is the current IDT. At this IDT, A_I related information is delivered to user. Our objective is to find a IST to stop the information delivery to $A(I)$, as the magic stick leaves A_I. After the information delivery stops at IST, we need to find the next IDT to

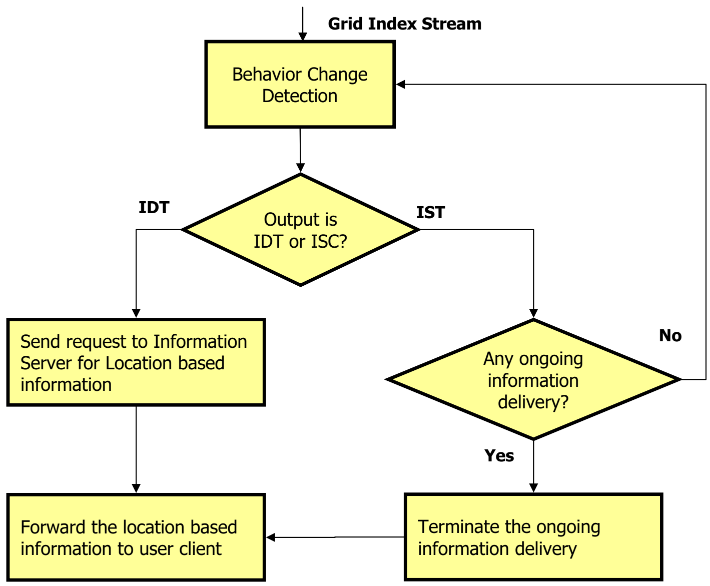


Figure 8. The Block Diagram of IDT and IST Detection

start new information delivery process as the magic stick enters another zone. Particularly, we focus on detecting the moving trend within a time window that is started at X_w and ended at the newly-received X_t. Since the window size is always adaptive to newly-received location data, we call the proposed ISC and IDT determination method Adaptive Window Change Detection (AWCD).

The key idea of AWCD is that we calculate Accumulate Departing Significance (ADS) in the adaptive window, which is used as a measurement to online check the trend of Magic Stick departing from the current IDT zone A_I. Since we have known the last location at IDT, which is A_I, AWCD algorithm tolerates noises by following schemes:

1) if the following location data in the stream departs from A_I only a little, we predict that the location of Magic Stick has not changed.
2) If the trend that the data in adaptive window departs from A_I is larger than a user defined IST-threshold, an IST event is detected and the location based information delivery should be stopped.
3) If the trend that the data in adaptive window departs from A_I is larger than a user defined IDT-threshold, A new IDT is detected to inform the new information delivery.

In details, the AWCD algorithm includes the following steps.

1) Reset Step

At the time of the current IDT (that is, X_w located at A_I as shown in Figure 7), the ADS to all of zones except A_I are reset to zero.

$$ADS(A_i, X_w) = 0, \forall A_i, (i = 1, ..., M, i \neq I) \quad (3)$$

2) Update Step

Each time the new location data X_t is received, the ADS to all of zones except A_I are calculated in the adaptive window from X_w to X_t by a recursive approach.

$$\begin{aligned} ADS(A_i, X_t) = ADS(A_i, X_{t-1}) + DS(A_i|A_I, X_t) \\ \forall A_i, (i = 1, ..., M, i \neq I) \end{aligned} \quad (4)$$

where $DS(A_i|A_I, X_t)$ is Departing Significance that is defined as

$$DS(A_i|A_I, X_t) = \begin{cases} -\alpha, & \text{if } X_t \in A_I & (a) \\ \beta, & \text{if } X_t \in A_i & (b) \\ 0, & X_t \notin A_i \text{ and } X_t \notin A_I & (c) \end{cases} \quad (5)$$

where α and β are positive values. From the above equations, we can find that if X_t is located at A_I, all ADS will be decreased by α, but if X_t is located at one zone A_i, the ADS of A_i will be increase by β and all other ADS will keep unchanged.

3) Maximum Step

As the real-time location data is received continuously, we can obtain the spatial-temporal distribution of ADS, which is shown in the following equation.

$$\begin{array}{cccc} ADS(A_1, X_w) & ADS(A_1, X_{w+1}) & & ADS(A_1, X_t) \\ ADS(A_2, X_w) & ADS(A_2, X_{w+1}) & & ADS(A_2, X_t) \\ . & . & \ldots\ldots & . \\ . & . & & . \\ ADS(A_M, X_w) & ADS(A_M, X_{w+1}) & & ADS(A_M, X_t) \end{array} \quad (6)$$

Each line represents a temporal trajectory of the ADS of one zone; and each column represents the ADS distribution for all zones at one time. According to the update step, the ADS to A_i will be monotonically increasing if Magic Stick has an apparent trend of leaving A_I and entering A_i; On the other hand, all ADS will be relatively small if the location steam of Magic Stick concentrate on the vicinity of A_I. So, for each time, the maximum value of ADS should be picked out.

$$M(X_t) = \max_z(ADS(A_z, X_t)) \quad (7)$$

4) Judgment Step

Finally, the maximum value of ADS is checked against the predefined thresholds for IST and IDT. The threshold of IST is predefined as T_{IST}. It means that when the accumulate departure trend is larger than T_{IST}, the current information delivery should be stopped. The threshold of IDT is predefined as T_{IDT}, which means that when the accumulate departure trend to another grid is large enough, a new information delivery process should begin. Generally T_{IST} is smaller than T_{IDT}.

Figure 8 shows the block diagram of the IDT&IST detection. If $M(X_t)$ is larger than the IST threshold (i.e., T_{IST}), an IST is detected, the current information delivery stops.

If $M(X_t)$ is larger than the IDC threshold (i.e., T_{IDT}), an IDT is detected, and

the new IDT zone will be found accordingly.

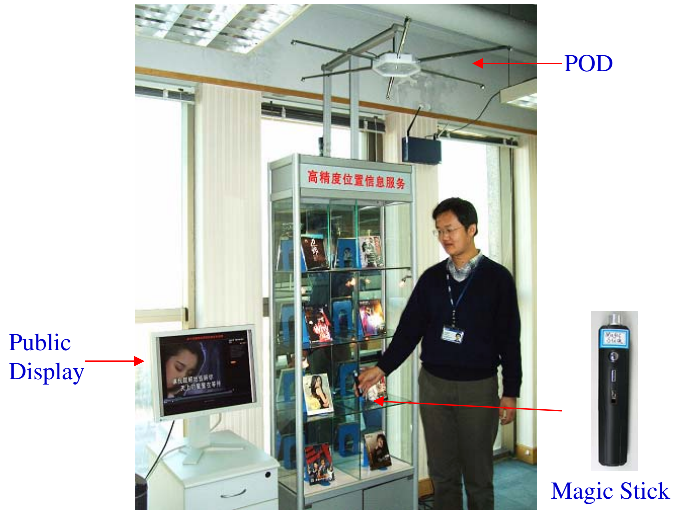
$$A_z = \arg\max_z(ADS(A_z, X_t)) \quad (8)$$

V. Prototype Implementation - Information Delivery of Music Video Disc

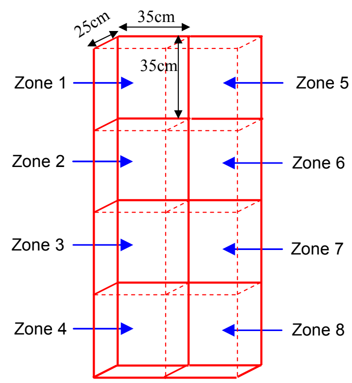
Based on PosPush, we implemented a prototypical application of commodity information delivery in shopping mall scenario. Particularly, considering that Music Video (MV) is popular to most people, we choose MV disc as the commodity in our prototype, in which if customer is interested in a MV disc, he/she will move the Magic Stick close to it and soon a video clip from this MV disc will be rendered on the Public Display. Figure 9(a) illustrates our prototype.

Basically, the prototype mainly includes:

- **Commodity Shelf and MV Disc:** In the prototype, a commodity shelf with eight grids is used. Each grid contains one MV disc so totally eight discs are placed on the shelf. It should be noted that the MV discs we used are from the popular singers nowadays for attracting the attentions of the visitors. The grids on the shelf are closely neighboring and each grid has a size of 35cm height and 35cm width. Since ultrasonic signal may be obstructed by the grid board, we define a vicinity area outside the shelf but close to a MV disc as the small zone for information delivery. Exactly, the zone size is $35cm \times 35cm \times 25cm$, as shown in Figure 9(b). The zone index is also given.
- **POD and Magic Stick:** A POD is fixed on the top of the commodity shelf to cover all zones of eight MV discs. It has a hexagon shape containing six surrounding ultrasonic receivers. A stick-style ultrasonic tag is used as Magic Stick to be held by user. As the user moves the Magic Stick to the interested MV disc, POD can calculate the accurate 3D location of Magic Stick and sent the location data to a server computer. It should be pointed out here is that the updating rate of Magic



(a) Demonstration



(b) Zone Definition

Figure 9. PosPush Prototype

Stick's location is 5Hz, i.e., the transmission interval of Magic Stick is 200ms.

- **Server Computer:** On server computer side, the video clips of all MV discs are stored at an information database, and a Java-based PosPush software is developed to perform both precise zone calibration&identification and IDT determination. PosPush software also provides a user-friendly GUI for ease of use. In offline phase, PosPush aggregates a sequence of location data in the vicinity area of a MV disc and extracts a set of KLP as the zone model. Then, the location model is associated with the corresponding video clip of the MV disc. In online phase, PosPush obtains the appropriate IDT from the location stream of Magic Stick. At the IDT, the video clip is retrieved from information database and is played on the Public Display.

A. *User Privacy*

A potential problem to Magic Stick mode is user privacy issue. Considering that public display is used to render the video clips and there are always many people in shopping mall, it is unavoidable that the video clip of a user interest will be seen by others, which leads an uncomfortable experience. Another problem is that only one public display is placed in a shelf so that more than two users can not view the interested information simultaneously. To solve this problem, we further designed a small USB-style ultrasonic transmitter, which can be easily plugged into user's personal mobile device, such as PDA or mobile phone. As user want to know more information to the interested commodity, he/she just move the personal mobile device close to such a commodity and soon, more information will be delivered to user's personal mobile device via wireless connection, e.g., Wifi, Bluetooth, etc. Figure 10 gives an illustration to this scenario.

Figure 10. Prototype for User Privacy Preservation

VI. Performance Evaluation

Based on the prototype, a number of experiments are carried out to evaluate the PosPush performance. In addition, we showed the MV demo in a formal exhibition to visitors for subjective evaluation.

A. *Evaluation of Zone Calibration&Identification*

In PosPush, zone models are offline calibrated by applying k-means clustering to a randomly collected location sequence with length L, so that n KLP can be extracted as the zone model. The selection of parameters L and n will affect the complexity of zone calibration and the accuracy of the zone identification. On one hand, larger value of L and n can create a more precise zone model. On the other hand, larger L means more time consumed for location collection processing. Thus we expect to find an optimal combination of parameter L and n so as to obtain a precise location model while minimizing the calibration efforts as much as possible.

In our experiment, the length L of collected location sequence during offline calibration phase varies from 30, to 60 and 90. Considering that the update frequency of Magic Stick is 5Hz, the corresponding collection time is 6s, 12s and 18s respectively. The number of KLP (n) ranges from 1 to 20. For each pair of parameter L and n, zone models are built for all the eight zones of the prototype. In online phase, we collect a set of real-time location as the test data. Particularly, most of the test data are collected near the boundary of zones. The ground truth of zone index stream is manually labeled. We use the error rate of zone identification for performance evaluation. The results are shown in Figure 11. From this figure, we can see that, firstly, the length of collected location sequence has little effect on the zone identification accuracy. Especially, when $n > 10$, although the length of the location sequence is different, the identification accuracy are almost identical. Secondly, the identification accuracy is improved with the increase of the number of KLP, but the accuracy will increase very slightly when $n > 10$.

Therefore, according to the experiment results, we select $L = 30$ and $n = 11$ as the optimal parameters. With this parameter setting, a precise zone model can be built for online identification through moving Magic Stick in a specific zone for just about 6s.

Next, we perform experiment to compare the error rate between our proposed clustering based method and the two baseline methods mentioned in Section 3. In online identification phase, we use the same test data with the above experiment to evaluate the performance of the three methods. Figure 12 shows the comparison result. From this figure, it is obvious that our proposed method can achieve the best accuracy compared to the other two methods. We also find that the error rate of Center based method is very close to

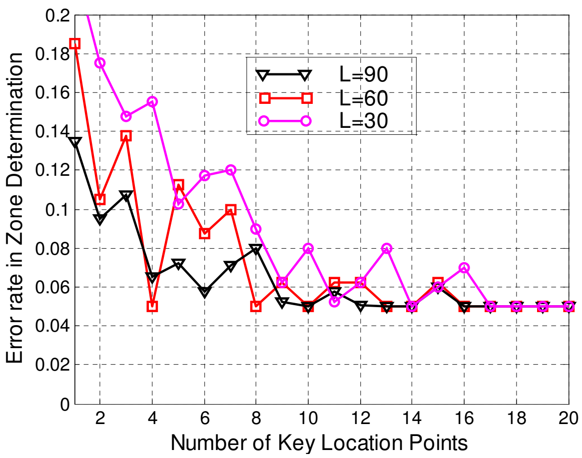


Figure 11. Effect of L and n to the Zone Determination Accuracy

the case of $n = 1$ in the clustering based method as shown in Figure 11.

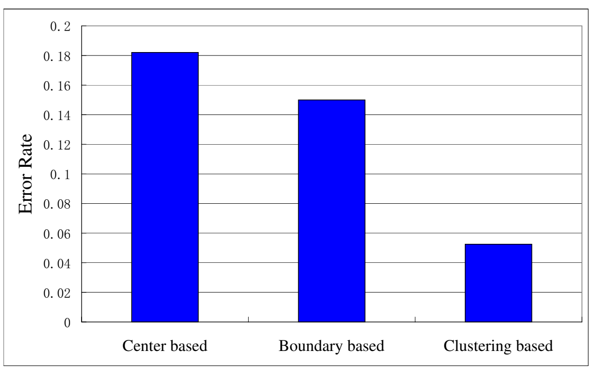


Figure 12. Comparison between Different Methods

B. Evaluation of AWCD

To evaluate the performance of the proposed AWCD method, we need a metric to check if there is a good match between the IDT determined by AWCD and the user's true interest. We propose Matching Rate between the user's true interest and the actually delivered information as the evaluation metric. At each time instance, user's true interest is manually labeled. If the delivered information is the same with the user's true interest, a "match" is counted; otherwise, a "mismatch" is counted. After the user has used the PosPush system for a period, a sequence of "match" and "mismatch" will be recorded. Matching Rate is defined as the percentage of the whole sequence occupied by the "match" number. For convenience of evaluation, we index all zones. The four zones on the left column are indexed as Zone 1 to Zone 4 from top to bottom, and the four zones on the right column are indexed as Zone 5 to Zone 8 from top to bottom.

The experiment result of one test is shown in Figure 13. The Y-Axis is the zone index, and the X-Axis is time. A user moves the Magic Stick in the shelf area. His true interest is the commodities placed in the Zones 1, Zone 6, Zone 3 and Zone 8. The green dotted line shows the zone determination results. We can see the trace starts from Zone 1 for a while, then passes Zone 5 and stays in Zone 6 for a while; next fast passes Zone 7 and stays in Zone 3 for a while; finally fast passes Zone 4 and ends in Zone 8. The true interest is labeled by the user himself and is shown in the dotted black curve. According to the zone determination result, the Magic Stick traveled all of zones considering that there are fast-pass zone result and error determination result. If the delivery time is just dependent on the instant location like the conventional LIDS, the information related to all zones will be pushed to user. It will bring uncomfortable experience to users. For comparison, the delivered result generated by our proposed AWCD is plotted in the solid purple curve. It can be found that the information delivered by AWCD well matches the user's true interest and AWCD can tolerant the zone identification error and fast-pass zone result. Exactly, the Matching Rate of AWCD based method is as high as 96.5%.

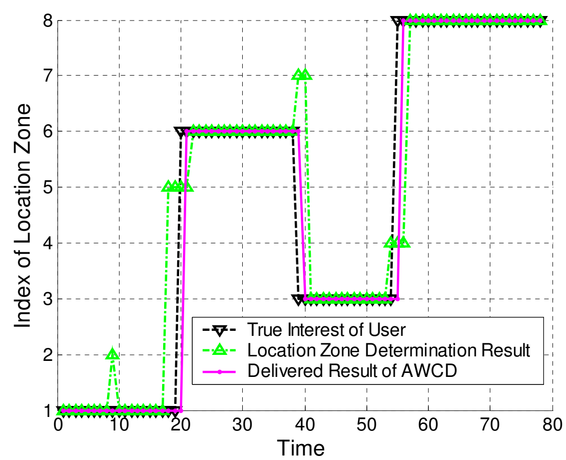


Figure 13. Experiment of AWCD based Delivery

We carry out 50 times of above test to compare the Matching Rate between AWCD and the conventional instant-location based method. The average Matching Rate are summarized in Table I. We can see AWCD-based method can improve Matching Rate over 10% compared with the conventional method.

Table I
MATCHING RATE COMPARISON

	Instant-Location based Method	AWCD based Method
Matching Rate	86.1%	96.7%

C. Subjective Evaluation

To better understand user's subjective affection to PosPush, we showed our MV shelf prototype at NEC Solution Fair 2008 (as shown in Figure 14).

During this exhibition, we presented the MV information delivery demo to many visitors who had never seen PosPush before. It is worth noting that almost all of the visitors were from information technology domain, which means they may have a stronger willing to experience new applications. Firstly, we introduced the visitors to PosPush and then explained MV shelf demo to them. Such a live demonstration attracted the attention of visitors immediately. Most of the visitors took the Magic Stick or PDA in their hands and experienced PosPush system by themselves. After the visitors had experienced the functionalities of PosPush, they gave us their feedback. One hand, we got some praising words, such as

1) *"It is really the first time for me to see such a technology."*
2) *"It is an interesting experience for me."*
3) *"It is definitely high accurate locating system."*

On the other hand, we also got some advice, such as

1) *"If I use Barcode reader to scan the goods ID and send it to server via wireless, I can also get the more information of my interested goods."*
2) *"PosPush may just be applied for MV shop, but it is more common in shopping store that the commodities (such as shampoo, cookie) are placed very close, so it is difficult to realize PosPush in such real scenario. "*

VII. Conclusion

In this paper, we designed, implemented and evaluated PosPush - a highly accurate location based information delivery system, which utilizes the 3D locations obtained from ultrasonic positioning device to efficiently deliver the location based information to users. To meet the requirement of practical application, we proposed two key mechanisms. 1) Precise zone modeling and identification 2) AWCD based delivery time determination. Based on PosPush, we implemented a prototypical application of commodity information delivery in shopping mall scenario. It verified the feasibility and effectiveness of our proposed system. In the future, there are several directions to pursue in order to further improve PosPush. Firstly, we investigated the PosPush system into the zone with the size of tens of centimeters in this paper. But it is common in current supermarket that the commodities (such as cookie, shampoo etc.) are placed one by one so that the zone has a smaller size of less than $10cm$. So we plan to apply PosPush system to such smaller zones for performance evaluation. Secondly, the current PosPush is based on the ultrasonic positioning system. We will investigate the use of other 3D positioning system [23-25] for PosPush in near future.

VIII. Acknowledgement

The authors would like to thank Wang Yanzhe for his effort and assistance in the testing experiments and in helpful discussions regarding system development. The authors would also like to thank Toshikazu Fukushima and Zhang Hongming for their valuable support.

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Figure 14. User Experience in Exhibition

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