複合技術を用いた展示会参加者情報のデータマイニング

Heterogeneous Information Mining in Expo

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要　旨

中国の展示会市場では，来訪者の現場での興味の度合いについてのデータ収集・解析サービスに強い需要がある．従来のアンケートによる調査方法では来訪者の会場での嗜好性を取得することが難しい．我々の手法では各ブースに無線センサーを配置することによって，展示品を中心にデータ収集エリアを限定することができる．来訪者がある展示品の限定エリアに入ると，その人の滞在時間や振舞いをリアルタイムで収集でき，それによって，来訪者の展示品への興味の度合いを判断することができる．無線センサーのほか，会場に配置した体感型インタラクティブシステムで来訪者の外見の特徴，振舞い，音声情報を収集する．これにより来訪者の会場での興味の度合いを判断するための補助的手段となる．来訪者の滞在時間やインタラクティブなやりとり，会話などの情報によって，アンケートより信頼性のある方法を構成できる．さらに，来訪者の会場での興味の度合いを分析することによって，客観的な統計データを得ることができるだけでなく，より深くデータを解析することができる．例えば，協調フィルタリングを通じて来訪者の嗜好を推測し，より適切な参観経路を推奨することができる．

ABSTRACT

The Chinese exhibition market has rigid demands for "visitors' on-site interest collection and mining". The traditional questionnaires could not accurately collect a visitor's "real" on-site interest. Our solution deploys a wireless sensor for each exhibit, which forms a restricted area. When a visitor enters an exhibit's restricted area, our solution records his/her stop time and interactive behaviors, which is used to estimate his/her interest in the exhibit. In addition, our solution also utilizes a somatosensory interaction system to estimate a visitor's interest by iteratively analyzing his/her gender, various gestures, and verbal information. Compared with questionnaires, our method of utilizing the heterogeneous information including the stop time, interactive behaviors, and verbal information to estimate a visitor's interest is more reliable. Furthermore, by analyzing the visitors' on-site interest, we could not only get more objective statistical data but also conduct further data mining, such as predicting a visitor's exhibit-of-interest with collaborative filtering and recommending an optimal visiting route.

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1. Background and Target

In an expo (such as Auto China 2014, one of the three top level automotive expos in China), the visitors' on-site interest is among the most valuable data that could be collected and analyzed. Currently, the questionnaire is still the common way to collect the visitors' on-site interest through either face-to-face service or the social network. However, the questionnaire could not reflect a visitor's "***real***" interest, like "really interested" as shown by a long stop at an exhibit, staring at it, and having a rich interaction with it. Therefore, we present a more straightforward solution to perform the ***visitors' on-site interest collection and mining***.

Fig. 1 Visitors' on-site interest collection through either face-to-face service or social network (left); visitors' on-site interest collection through behaviors analysis (right).

2. Solution Overview

When a visitor arrives at an expo, the solution encourages the visitor to install the "***Smart MICE***" mobile application, which could obtain the visitor's International Mobile Subscriber Identity as the visitor's unique identity and start to collect the visitor's on-site behaviors through both the ***Wireless Sensor*** and the ***Somatosensory Interaction System***.

By analyzing the visitor's on-site behaviors, the solution calculates his/her interest in the exhibits he/she has visited, which is used to predict his/her interest in the exhibits he/she has not yet visited, and recommends the ***exhibit-of-interest candidates*** and the ***optimal visiting route***.

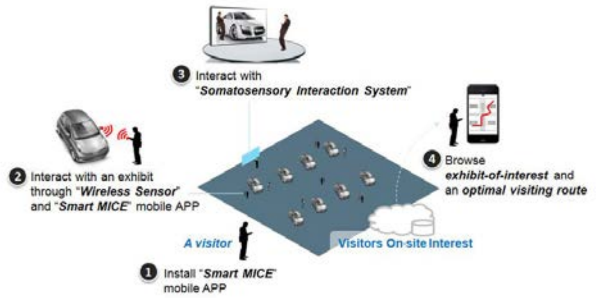

Fig. 2 Solution overview from visitor's point of view.

3. Behaviors Collection

The solution collects a visitor's on-site behaviors for an exhibit, including ***Objective Behaviors***, such as stop time, taking photos, and browsing information, and ***Subjective Behaviors***, such as giving comments and voting. The solution collects such behaviors through both the Wireless Sensor and the Somatosensory Interaction System.

3-1 By Wireless Sensor

3-1-1 Overview

A wireless sensor is deployed for each exhibit, which defines a circular restricted area. When the visitor's mobile phone (on which the "Smart MICE" mobile application has already been installed) enters the sensor's circular restricted area, the mobile application determines the visitor's current position and starts to record his/her objective and subjective behaviors for this exhibit, which are the input for further interest mining.

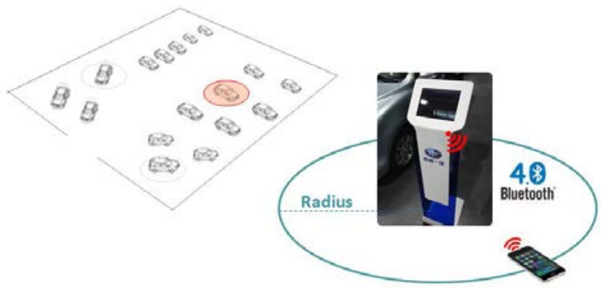

Fig. 3 Visitor's current position and behaviors collection through wireless sensor and mobile phone.

3-1-2 Current Position

Although an accurate position is always expected, the feasibility and cost must be considered. In addition, in the expo scenarios, both the organizers and exhibitors are concerned about which visitor shows how much interest in which exhibit, and the visitor wants to know which exhibit he/she is looking at or is close to. Therefore, an exhibit-unit position instead of an accurate position is more valuable and feasible in expo scenarios.

In the current expos, almost every exhibit has a mobile device close by, such as an iPad. The solution reuses the Bluetooth Low Energy (BLE) module embedded in the iPad or a separate BLE dongle to keep broadcasting the exhibit's identification.

The visitor's mobile application receives and ranks the broadcasted signals based on Radio Signal Strength Indicator (RSSI) and calculates the distance to the nearest BLE module or dongle with Equation 1.

$$d = 10^{\frac{ABS(RSSI) - ABS(A)}{10n}} \qquad (1)$$

where A is RSSI at 1 meter, and n is the path loss index.

If the distance is within the range of the nearest BLE module or dongle's predefined circular area, the solution determines the visitor's current position, and informs the visitor which exhibit he/she is looking at or is close to, and starts to record his/her behaviors for this exhibit.

Fig. 4 "Smart MICE" mobile application automatically displays nearest exhibit's information (a BLE dongle is deployed for each exhibit).

3-1-3 Behaviors

The solution records when the visitor's mobile phone enters the BLE module or dongle's circular restricted area, and calculates the ***stop time*** in this area. In addition, the solution records both the visitor's objective and subjective behaviors in this exhibit through the mobile application, including ***taking photos***, ***browsing information***, ***giving comments***, and ***voting***.

3-2 By Somatosensory Interaction System

3-2-1 Overview

Since a visitor may have no chance to interact with an exhibit closely because of a crowded hall and limited visiting time, we present a non-intrusive way to predict the visitor's on-site interest.

A somatosensory interaction system is deployed on-site, which enables the visitor to browse and interact with the exhibits by using gestures and verbal comments, together with the visitor's gender, the somatosensory interaction system provides the constant input for further interest mining.

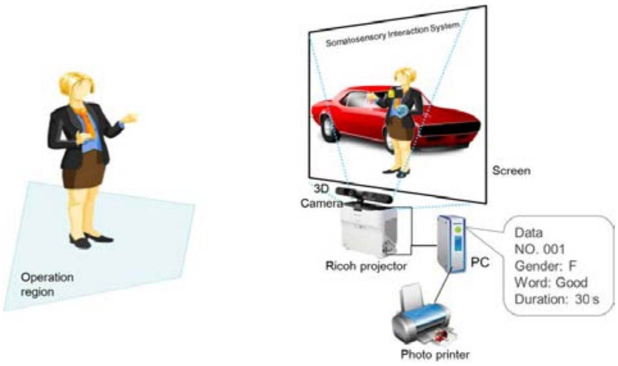

Fig. 5 Visitor's behaviors collection through the somatosensory interaction system.

As shown in Fig. 5, the somatosensory interaction system includes a 3D camera that sits on a projector and is connected to a PC. A photo printer connected to the PC is used to print out a composite photo for the visitor as a souvenir. The system responds to the visitor in the operation region, which is set based on the camera's position. The system translates the visitor's gestures into commands by analyzing the captured color and depth information of the scene.

The user interface of the system contains three layers, which are the background, foreground, and operation tips from bottom to top. The background shows an exhibit's image with its information. The foreground shows the visitor's image, which is extracted from the real scene image. This type of visualization provides a fun and immersive experience for the visitor. The system counts the number of total visitors and analyzes visitors' behaviors, including gait, verbal comments and gestures.

3-2-2 Gender

The system detects and tracks a visitor when he/she enters the operation region, which is set based on the camera position. Then, the system recognizes the visitor's ***gender*** based on his/her gait. The human gait refers to the locomotion achieved through the movement of human limbs. Using gait is non-intrusive and anonymous compared to the other biometric features, such as face and iris. The gender recognizing unit of our system uses the view-adjusted 3D motion feature, which has a superior tolerance to covariate condition changes to describe the gait. It extracts features from the gait cycle of the person walking into the operation region of our system, sends them to a trained classifier, and gets the gender classification result. The gender information is then used to initialize the background image. Once the system analyzes that there is a woman coming, it sets the background pointedly as an image of female-targeted exhibit.

3-2-3 Behaviors

The system extracts the visitor's image by analyzing the color and depth information of the scene and shows it on the screen with various exhibit images as the background.

The visitor can use a swiping gesture to switch exhibit images, and the system records his/her ***stop time*** at each exhibit, which is useful for interest mining. Generally speaking, the longer the stop time, the more interested the visitor is.

Meanwhile, some functional icons, such as the camera shutter icon, are shown dynamically based on the visitor's position. That way, the visitor can trigger ***photo taking*** by naturally moving his/her hand into the functional icon region, like touching the icon.

The visitor can also use a push gesture to check the exhibit's ***detailed information***, thumb up gesture to give a positive ***vote***, palm open/close gesture to drag the exhibit image, and two hands spread/squeeze gesture to zoom in and out of the exhibit image.

In addition, the visitor may give ***verbal comments*** to the exhibit during browsing, such as "cool", "expensive", etc. The speech recognition function of the system can recognize such exhibit related terms and record them for further interest mining. For example, the system will update the background into an image of a cheaper car if the visitor says "expensive".

3-2-4 Privacy Protection

The system values and thoroughly respects visitor privacy by detecting but not recognizing the visitor. It does not record personally identifiable information. It utilizes anonymous pattern detection algorithms to determine the gender; more specifically, it is based on machine learning and uses features extracted from the visitor's walking pattern. The system provides the function of printing a composite photo for the visitor with the pattern of discarding captured image on the fly. It does not record any images or personal information of the visitor. Similarly, it counts the number of times a product related word such as "expensive" or "cool" is used, but does not record the visitor's actual statement.

4. Interest Mining

One of the solution's targets is to predict a visitor's interest in the exhibits he/she has not yet visited based on his/her historic interest, and then recommend the exhibit-of-interest candidates and the optimal visiting route.

To do so, the solution first calculates a visitor's interest in an exhibit based on his/her objective and subjective behaviors for this exhibit.

4-1 Interest Calculation

As described in Chapter 3, the solution records a visitor's objective behaviors, such as stop time, taking photos, and browsing information, and subjective behaviors, such as giving comments (either text or verbal), and voting, and also the visitor's gender. Based on those inputs, the solution calculates the visitor u_i's ***interest*** in the exhibit e_j with Equation 2.

$$interest(u_i, e_j) = \frac{I(u_i,e_j)}{\sum_{j=1}^{n}(u_i,e_j)} \qquad (2)$$

$$I(u_i, e_j) = \frac{d(u_i, e_j)}{\sum_{j=1}^{n} d(u_i, e_j)} B_{obj}(u_i, e_j) + B_{sub}(u_i, e_j)$$

$$B_{obj}(u_i,e_j) = \begin{cases} 0, \text{no objective behaviors happened} \\ 1, \text{objective behaviors happened, i.e. photo captured, information browsed} \end{cases}$$

$$B_{sub}(u_i,e_j) = \begin{cases} 0, \text{no or negative subjective behaviors happened, i.e. negative comment, negative vote} \\ 1, \text{positive subjective behaviors happened, i.e. positive comment, positive vote} \end{cases}$$

where $d(u_i, e_j)$ is the visitor u_i's stop time at the exhibit e_j, and n is the total number of exhibits.

Before the expo, the solution initializes an ***Exhibit-of-Interest Matrix M*** shown in Fig. 6, with all the matrix item default values as $isited(u_i, e_j) = 0$, $interest(u_i, e_j) = 0$, where $visited(u_i, e_j)$ is whether the visitor u_i's stop time at the exhibit e_j is over a predefined threshold, and $interest(u_i, e_j)$ is the visitor u_i's interest in the exhibit e_j. Then, during the expo, the solution keeps updating the *Exhibit-of-Interest Matrix M* whenever a visitor has behaviors for an exhibit.

	e_1	e_2	...	e_n
u_1	{1, 0.6}	{1, 0.2}	...	{0,0}
u_2	{1, 0.2}	{1, 0}	...	{0,0}
...	...	...	...	...
u_m	{0,0}	{0,0}	...	{0,0}

Fig. 6 *Exhibit-of-Interest Matrix M* updated during expo whenever visitor has behaviors for an exhibit.

4-2 Exhibit-of-Interest Candidates Recommendation

Since the number of on-site exhibits is limited, and the recommendation is more personalized, the solution utilizes the Item Collaborative Filtering method to recommend the exhibit-of-interest candidates for a visitor.

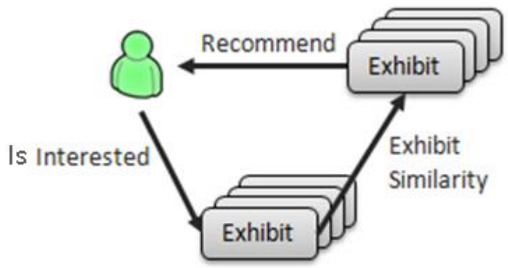

Fig. 7 Item Collaborative Filtering method.

Firstly, the solution calculates the ***similarity of any two exhibits*** with Equation 3 based on the *Exhibit-of-Interest Matrix M*.

$$similarity(e_i, e_j) = \frac{|N(e_i) \cap N(e_j)|}{\sqrt{|N(e_i)||N(e_j)|}} \qquad (3)$$

where $|N(e_j)|$ is the number of visitors who are interested in the exhibit e_j (that is, $intersest(u_i, e_j)$ is over a predefined threshold), and $|N(e_i) \cap N(e_j)|$ is the number of visitors who are interested in both e_i and e_j.

After calculating the similarity of any two exhibits, the solution maintains an ***Exhibits Similarity Matrix S***, and keeps updating the *Exhibits Similarity Matrix S* periodically.

	e_1	e_2	...	e_n
e_1		0.34	...	0.78
e_2	0.00		...	0.65
...	...	...		...
e_n	0.10	0.31	...	

Fig. 8 *Exhibits Similarity Matrix S* updated during expo periodically.

Secondly, the solution obtains the visitor u_i's ***unvisited exhibits set*** $\boldsymbol{E(u_i)}$ based on the *Exhibit-of-Interest Matrix M*, where $e_j \in E$ and $visited(u_i, e_j) = 0$.

Thirdly, the solution predicts the visitor u_i's **interest** in $e_j \in E$ with Equation 4.

$$interest\_predict(u_i, e_j) = \sum_{e_k \in N(u_i) \cap S(e_j, K)} similarity(e_j, e_k) interest(u_i, e_k) \quad (4)$$

where $N(u_i)$ is the exhibits the visitor u_i is interested in, and $S(e_j, K)$ is the most similar *K* exhibits to exhibit e_j, and $similarity(e_j, e_k)$ is the similarity between the exhibit e_j and e_k, and $interest(u_i, e_k)$ is the visitor u_i's historic interest in the exhibit e_k.

Finally, the solution ranks and recommends ***TopN exhibit-of-interest candidates set*** $\boldsymbol{C(u_i)}$ for the visitor u_i.

In addition, to cold start the recommendation (if the visitor has no on-site behaviors), the solution could utilize the visitor's gender to recommend the exhibit-of-interest candidates based on the exhibits features and classification.

4-3 Optimal Visiting Route Recommendation

As described in Chapter 3, the solution locates the visitor u_i's current position, and as described in Chapter 4-2, the solution recommends TopN exhibit-of-interest candidates set $C(u_i)$ for the visitor u_i, then, the solution recommends an optimal visiting route passing by all the exhibits in $C(u_i)$, which could be formulated as a Traveling Salesman Problem (TSP) as shown in Fig. 9.

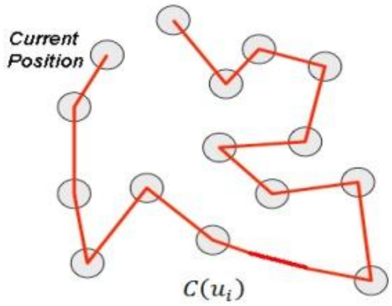

Fig. 9 *Exhibits Similarity Matrix S* is updated during the expo periodically.

Specifically, the solution initially sorts $C(u_i)$ by:

- Calculating the distance between the visitor u_i's current position and each exhibit in $C(u_i)$, obtaining the nearest exhibit e_i, and ranking e_i in the first place of $C(u_i)$;
- Calculating the distance between the exhibit e_i and the remaining exhibits in $C(u_i)$, obtaining the nearest exhibit e_j, and ranking e_j in the second place of $C(u_i)$. Perform such step recursively until all the exhibits in $C(u_i)$ are sorted.

Finally, the solution links all the exhibits in sorted $C(u_i)$ as the optimal visiting route.

5. Conclusion

Targeting the expo scenarios, we have presented an integrated solution to collect a visitor's on-site behaviors, which are heterogeneous information collected through different methods; calculate his/her interest in the exhibits he/she has visited; predict his/her interest in the exhibits he/she has not visited; and recommend the exhibit-of-interest candidates and the optimal visiting route.

As one method to collect the visitors' on-site behaviors, the somatosensory interaction system has been test run in Auto China 2014, which was held this April. And the complete solution will test run in Chinese auto expos step by step, which have rigid demands but few competent solutions until now.

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