RFID Tags as Technology for Value Sensing in Real Space Market

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1. Introduction

Following the literature, let us define a *chance* as an event which plays a significant role in the decision making of human [1]. For example, suppose there is a cheese which seems good to eat, in a supermarket. This cheese, however, costs 2000 JPY (ca 20 US dollars). Customers walking around the store may pick out the cheese, but mostly give up buying when they look at the price label.
Suppose a certain customer (called Mr. A) often comes to this supermarket and mostly buys liquor. The manager of this supermarket likes Mr. A to buy things to eat also, but an established lifestyle is hard to change. One day, Mr. A finds a very nice looking cheese close to the liquor shelf from which he usually takes and buys wine. The cheese looks good to eat with wine, but he picks up the cheese and returns it back to the shelf because it is as expensive as 20$. However, he does not go home immediately. He walks to the shelf of cheese and snacks, because he is now interested in something to eat like cheese. Thus, Mr. A learns to buy food with liquor. Although the 20$ cheese was not bought, it led this customer to a new decision of purchase to be continued in his future manner of buying.
See Fig.1 for the conceptual sketch of this scenario. The cheese of 20$ here is apparently a chance, because the event of Mr. A's picking the cheese made a strong influence on the future decision of Mr. A. As well, the supermarket manager may decide to keep the expensive cheese on the same shelf rather than to move it elsewhere only because it is not a frequently sold item. Changing the lifestyle of a customer makes more benefit than having the customer just buy an expensive item.
An important point of Mr. A's case for sales promotion is that the man's real desire cannot be understood if we pay attention only to his decision of purchase. The data at the point of sales (POS) show he finally came to buy cheap cheese, but does not even imply he was tentatively interested in the outstandingly good cheese and seeked good sidefood for wine. If the manager understands this real desire, he/she will keep the expensive cheese in the shelf as an attractor for wine lovers rather than discard it, or attract them by showing a little cheaper sidefood on the same shelf. In other words, marketing decision maker can catch customers' latent interests from the data collected before they come to the register to buy.
Thus such a map as in Fig.1, which we call a *scenario map*, is useful for creating a scenario of marketing. Here, a scenario is a series of actions and events which occur under a coherent

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context. As in [2,3,4], a scenario map is useful for aiding chance discovery i.e., to detect an event significant for decision making as the picking of 20$ cheese. This effect works more finely, if the customer's behavior to pick an item out of a shelf can be taken in the data. We introduced RFID tags for obtaining really useful scenario maps.

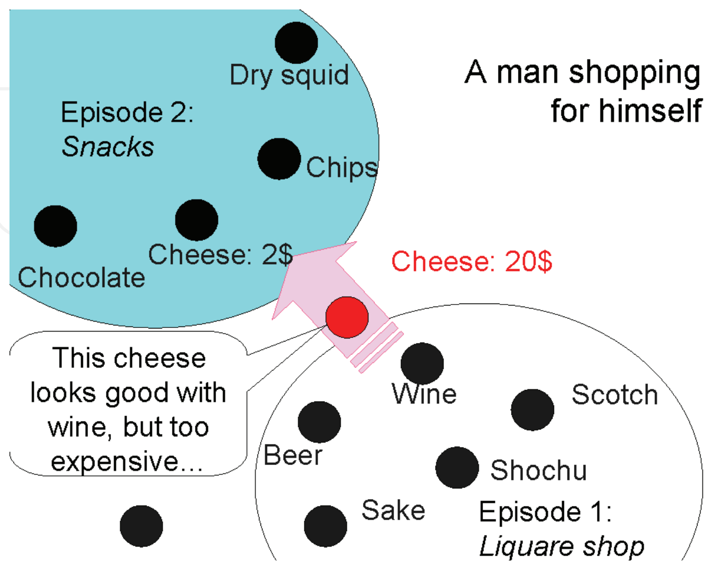


Fig. 1. Chance discovery in a supermarket: The expensive cheese plays a role.

2. Our system of middle-ranged frequency RFID tags

The customer in the of Fig.1 took the cheese from the shelf, and may have smelled the cheese, felt the weight and the softness. He estimated how good the product is, and finally decided not to buy it. Thinking about this scene, we find the customer's co-existence in the same space of the store as the 20$ cheese was essential for his decision. We can also point out another effect of the real space to the customer. Let us define a community as a group of people who do verbal or non-verbal communications. A verbal communication means communication by talking in a common language, and a non-verbal communication means to understand the behavior of each other without talking. Suppose each member of the community embraces a scenario planned in the mind. A member Ms. B who hears or interprets the scenario in the mind of Mr. A may like to import it into her future action if she feels empathy with Mr. A. Thus, the scenarios underlying the behaviors of customers may be combined in a way as in genetic crossover and create new behaviors of purchase and consumption.

From this view point, we take a hypothesis that the scenario map as in Fig. 1 can represent not only an individual customer's behavior but also the behaviors of people in a community. That is, if Mr. A and Ms. B behave like a community, with interacting with exhibited items in the real space, we can expect Ms. B may also come to be interested in the cheese of 20$ in the extension of her recent purchase history. For example, the sequence of Mr. A's and Ms. B's behaviors can be:

On February 2, Ms. B touched the set {beer, wine},
On February 2, Ms. B bought the set {beer, wine},
On February 3, Mr. A touched the set {beer, wine, cheese 20$},
On February 3, Mr. A bought the set {chips, cheese 2$},

On February 3, Mr. A bought the set {wine, cheese 2$, chips},
On February 3, Ms. B touched the set {beer, wine, whisky, cheese 20$},
On February 3, Ms. B touched the set {cheese cake, chips}.
On February 3, Ms. B bought the set {wine, cheese cake, chips}.

Here, Ms. B has been interested in liquor (beer and wine) until February 2nd. However, on February 3rd she looked at someone (Mr. A) acting similarly to herself, except that the man touched the cheese of 20$ but did not buy it. Then, Ms. B notices this cheese might be good also for her taste and picks it to see the price label. As a result, she takes a similar choice to Mr. A – goes to a different shelf. She moves to the shelf of cakes to buy a cheese cake that is a mixture of cheese and sweet for her. The behavior of Mr. A thus infects to Ms. B, and makes a new behavior which is a combination of Ms.B's and Mr. A's past behaviors.

An important point here is that the cheese of 20$ hardly appears in the sales data, i.e. in the POS (position of sales) data. As far as we have only POS data, we cannot understand the role of this expensive item and the sales manager may stop showing it on the shelf of the supermarket. However, if we can record the behaviors of customers to touch items, the data can include useful information, e.g., some customers picked the cheese but did not buy it. Introducing the RFID tags, we may be able to tell it is meaningful to discount the price of this cheese.

Market researchers' interest in RFID tags is growing rapidly. The ability to record the pick-out behaviors of customers in a retail store, before they decide to buy or not to buy, enables to understand their latent interests more deeply than the data on the position of sales (POS). That is, the information that a customer's interest in an item was strong enough to pick it but not enough to buy it has not been dealt with as far as we deal only with POS data. In this sense, we expect to enable chance discovery more finely by introducing RFID tags to visualize the data of customers' touching sold items in the way similar to the map in figure 1.

The reason why we apply RFID tags in face of the existence of fascinated video camera systems [5], infrared-ray[6,7]/sonar sensing systems, and other up-to-date sensing systems [8,9] is that RFID tags have the suitable feature that it can be attached to items on shelves, and the shelves can also become high-resolution sensor if we finely design the antenna embedded in the shelves. In contrast, the video camera system, if installed up at the ceiling of a retail store (a supermarket, an apparel shop, etc) can detect the position of the item a customer touches, to the resolution of 10cm (see SiteView for example [5]). This resolution is good enough for telling the shelf to which the customer's hand entered. However, more than one kind of items may be exhibited on the same shelf, one over (or very close to) the others. Sumi et al designed a video-camera array, where cameras are located at the top (*m* cameras in a horizontal line) and the side of a shelf (*n* cameras in the vertical line) to distinguish *mn* areas in one shelf, in order to improve the sensing resolution [10]. Even though, an error due to the mis-location of items is not ignorable at all, because popular items tend to be moved from/to areas within a shelf. In the case of infrared ray, the ray emitted from a the body of a customer is detected by sensors. For example, if a customer passes in a region in the store, the movement shall be detected finely if infrared-red sensors are aligned periodically and finely. This system can detect a rough location of the customer, but the resolution is not high enough to detect touched items on shelves. In comparison to these different kind of sensors, we can say RFID tags are low-cost and suitable-resolution pick-out sensors.

Motivated with the merit of RFID tags, the data from RFID tags came to be dealt with from the aspect of data-based marketing [11,12,13]. Applying the methods of data mining and data visualization, we are able to acquire deeper level knowledge about customers from RFID data than from POS data, because the customer's thought and vacillation before buying are reflected to the pre-purchase behaviors taken by RFID tags. Reader may compare this to the prevalent experience that shoppers' browsing log data in a shopping web site enabled to analyze the latent interest of people than by seeing just the purchase records in the same site [14]. However, the human's behavior in the real space is more informative than in the cyber space, in that the length of time one takes an item in hand reflects one's interest, whereas the length of opening a Web page may mean the user is just away for coffee, tea, or for restroom.

Reader may relate this article to previous work on the studies to trace customer's movements in the real space [13,15] with active RFID tags (having power sourse and omitting customer's ID numbers) attached to customer bodies. That comparison is reasonable in that we also deal with real-space action of customers. However, the difference is two-fold. First, customer IDs, i.e., the information for identifying each customer tends to be missed in a retail store, for the reason of privacy security [16]. This has been regarded as an obstacle in predicting customer's preference of each item. In this acticle, we consider the circumstance where customer-ID-less RFID tags are used, and regard this as the setting for collecting the behaviors of a group of customers in the real space. Second, the granularities of information dealt with are different, between our approach and active tags attached to customers. If we trace the movement of a customer's body, the intension of the customer i.e., whether he likes to take a red necktie or a green one beside the red tie, is hard to understand in spite of its important meaning. Our aim can be expressed as in-store chance discovery, to discover an event of customer's taking a significant item for marketer's (and, in turn, customer's) decision making. From this viewpoint, we experimentally show that the data on the group behavior of customers in the real space can be recorded with ID-less RFID tags and the visualization of the data, aids the discovery of new values in the market. This expectation is validated in a apparel shop and a book library.

3. Value sensing from the real space customers' choices: in apparel store

Let us show the experiment we conducted in a real apparel shop, laying RFID tags, antenna, and controller as in Fig.2. In this experiment, we collected both data on RFID tags and POS, in the following manner.

a. The data from RFID tags: The data collected 14 days have been taken, and each set of three items picked sequentially by customers is taken as one basket. The number of baskets was 18212 for all the time of experiment. See Fig.2 to find the way we attached RFID tags to items and we put those items on the shelves. For example, suppose items were picked by customers as in the listed order in the left columns of Fig.3. In the second and the third columns, two lines and three lines are inserted respectively at the top, in order to make each line containing three items represent three items picked sequentially. Thus, the data are to be obtained as the set of baskets, where a basket is given by one line in Fig.3.
b. The data at the Position of Sales (POS): The data collected for the same period of days as of the RFID tags above, for all purchase of items to which RFID tags were attached.

Here, one basket is taken as the set of items bought by one customer at one time. 473 baskets have been collected as a result.

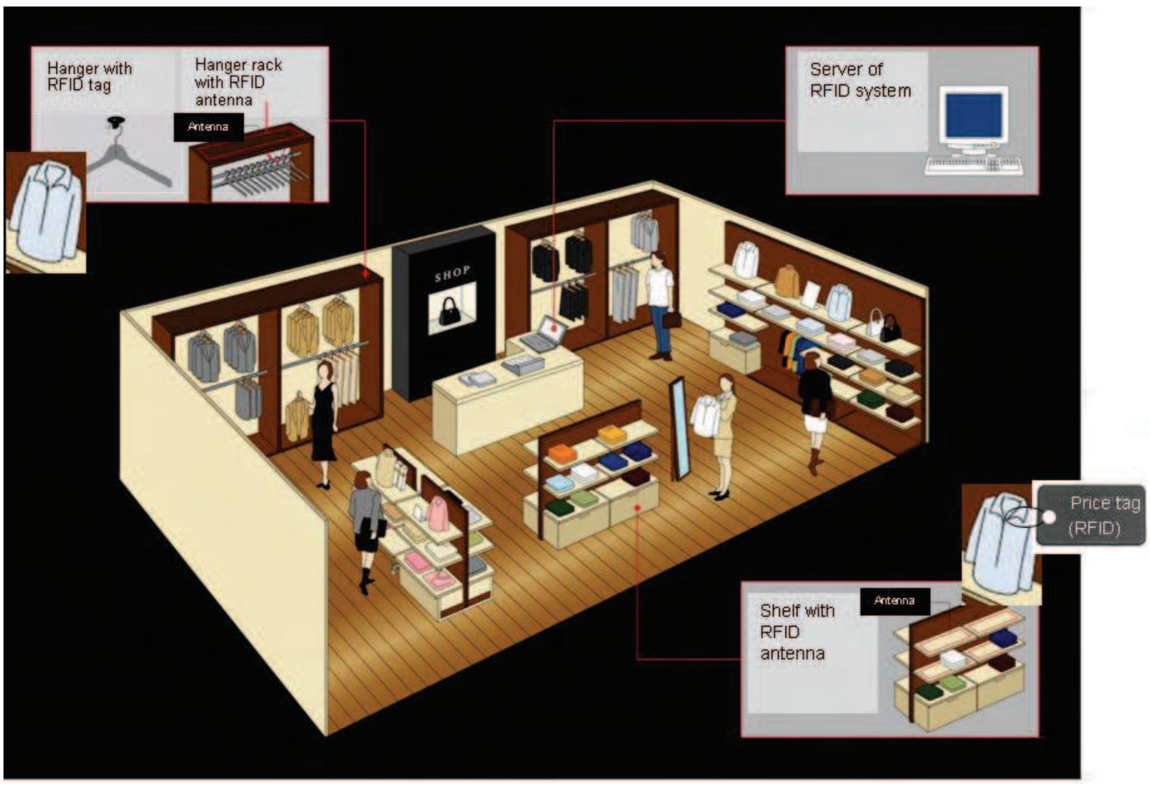


Fig. 2. The apparel store engaged in the experiment

time	Item (product)	color	item	color	item	color
	58147002	4				
	30057011	19	58147002	4		
basket 1	30057033	98	30057011	19	58147002	4
basket 2	58116526	70	30057033	98	30057011	19
•	58116526	86	58116526	70	30057033	98
•	58117007	28	58116526	86	58116526	70
•	58117006	50	58117007	28	58116526	86
•	58116506	52	58117006	50	58117007	28

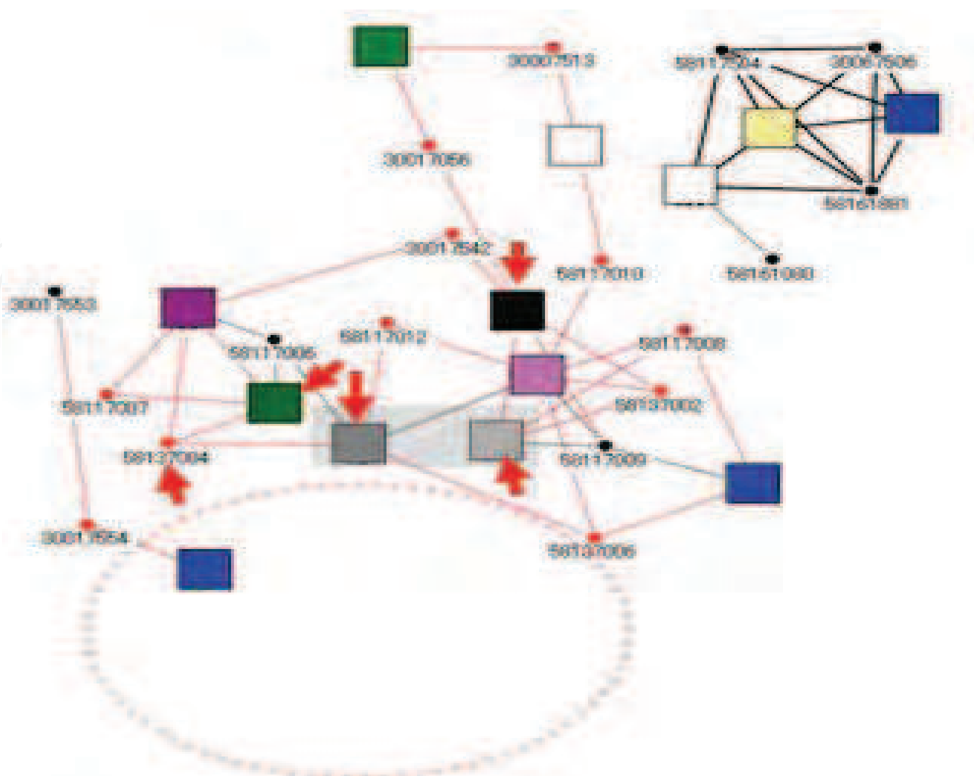
Fig. 3. The data of RFID tags for the experimental (but real) apparel store

These two sets of obtained data were visualized as in Fig.4 (a) and (b). In these results of KeyGraph visualizing the co-occurrence of items in the touching (RFID) and buyng (POS) data, the shadow of the first figure (a) is shown weakly in the second figure (b), so that we can intuitively understand the difference between customers' picking-out shown by RFID tags and buying of items shown by POS data. From the two figures, find features suggesting the trigger of customers' awareness of new values in other items than those they touched. For comparing the two figures, reader is advised to first look at the shadow in the center of figure (a) and in figure (b), because these two shadows represent the same item set in the two different figures. A feature of KeyGraph is that the black nodes and black links show frequent items and their frequent co-occurrences (occurring in the same baskets in the RFID data and in the POS data), whereas the red nodes and red links show rare items and their co-occurrences with frequent-item clusters depicted by black nodes and links. For example:

1. The white colored clothes, surrounding the white square in the cluster at the upper right of figure (a), are picked (appear in figure (a)) but not bought (do not appear in figure (b)). After touching these items, customers tend to move to the items in the cluster at the center of figure (b). Seeing that these items are linked from the previous upper right cluster in figure (a), we can guess customers who were touching the upper-right items could not decide to buy anything in the cluster, and the white color item in this island finally effected as a trigger to move the customers to the densely colored items in the center of figure (b). The author asked consumers who are women, about their interests in this white cloth. A common opinion according to them was that a white cloth may be generally attractive but one shall not buy it as far as the design does not exactly match one's interest.
2. Item 58137004 pointed by an arrow in figure (b) is linked to a newly appearing cluster of items in the bottom of figure (b), whereas 58137004 has been only linked to the purple, green and gray colored items in (a). These previous links in (a) remains also in (b), but the new links from 58137004 to such item as 58117016 can be interpreted by the analogy on the basis of Fig.1, where an event may trigger human's attention to a new group of events. That is, in the case of figure 4, selling staffs (two ladies working in the store), looking at the two figures, mentioned that item 58137004 was an outstanding new cloth and set at the height of customers' eyes. Customers tend not to buy such a cloth, but come close to its exhibition and buy items nearby. The emergence of the right-hand side cluster in figure (b), via the strengthening of item 58117077, has been explained similarly, although 58117077 itself was bought frequently.
3. The item 58117016 in the core of the new cluster at the bottom of figure (b) has been know as a popular item according to the sales staffs. However, they thought its blue colored item was sold the most frequently. In reality, the most frequently bought color of item 58117016 was the yellow, as appearing in the right-hand side of the same cluster. The staffs also remarked this awareness is useful, because they should exhibit yellow ones in a more outstanding shelf.

The hypothetical interpretations above came to be supported by our interview to other women, who were 5 consumers (women) having experience to buy in the real store we made the experiment. We cannot say these are "novel" ideas, because such knowledge should have already existed in the deep level of the memory of subjects from before they looked at the graph. However, this provides real decision makers in marketing with helpful information because they tend to accept scnarios fitting their feelings acquired from daily experience. New information provided automatically by machine might be useful, but not always necessary.

a. Results for data from RFID



b. Results for data from POS

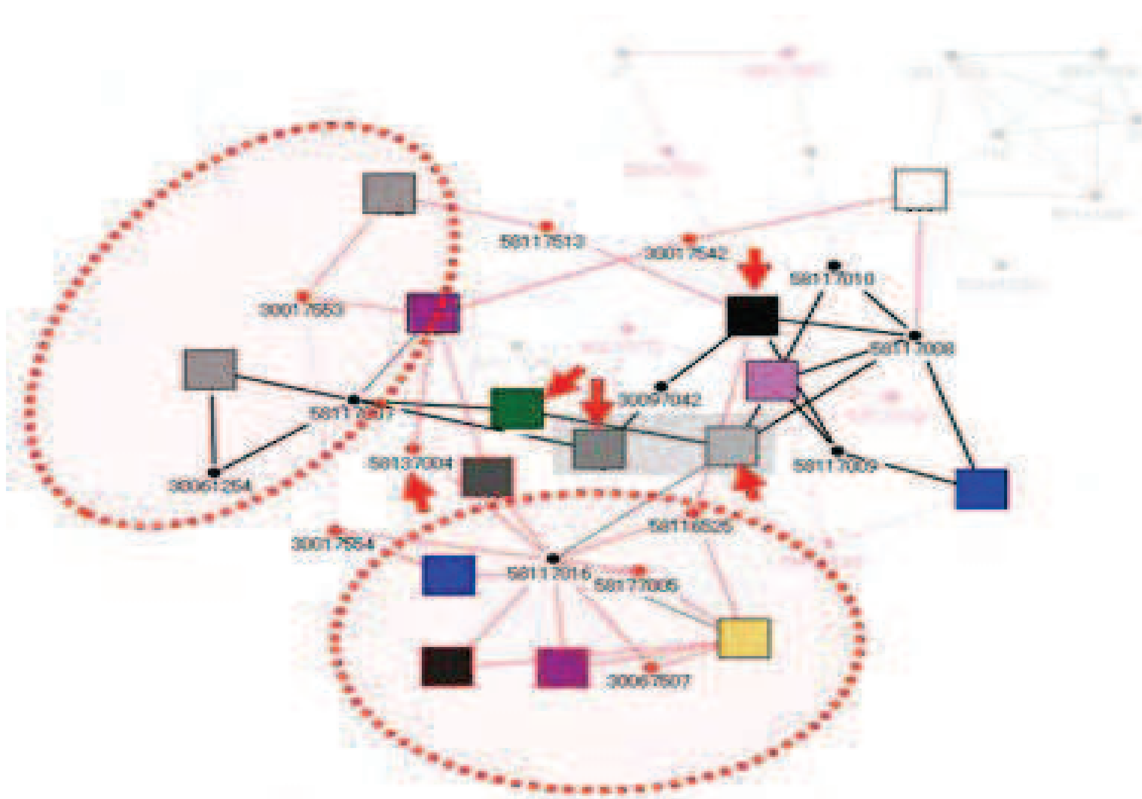


Fig. 4. Graphs presented by Pictorial KeyGraph for the data on RFID tags and POS, for two weeks experiments in an apparel store.

4. Analysis of browser's intentions in library by using RFID sensors

4.1 The effect of *tachiyomi* in the real space of books

Next let us show the application case of RFID tags to the behaviors of browsing customers of a book library. This domain of application has been studied in [17]. On the other hand, we especially focus on the "tachiyomi" (a Japanese word) behavior of customers, which means the customer stay at the book shelf to open a book to read it. In Japanese book shops, a trend is to allow customers to do tachiyomi, because tachiyomi is expected to have customers stay long in the shop space, walking around to find books worth to buy, even though the customer does not buy the book he reads on the way of tachiyomi. This expectation may be extended to other kinds of shops such as apparels: By allowing customers to do test wearing of clothes, customers may not only check the comfort of each cloth but also stay long and touch various clothes and may finally buy some.

Tachiyomi in a library is different from tachiyomi in a book shop in that it is usually not a manner to be punished in a library. However, we find the merit of tachiyomi is common to both a bookshop and a library, buy regarding purchase as just one way for reaching satisfaction. That is, tachiyomi may let customers walk around to pick and open books to reach satisfactory books, although he/she knows only a very small part of the whole collection. From this aspect, we should investigate more of the wander behaviors (customers' walking around to pick and open books) in order to see how tachiyomi is meaningful for stimulating customers into a desirable direction, and what kind of books really trigger wander behaviors.

In this section, let us show the experiment we conducted, to record the data on customer's behaviors to pick out books, to analyze the relation between the value of a picked book for the customer and the following wander behaviors. Here, we regard the pick-and-return behaviors observable by RFID tags as the essence of wandering, because just walking around with seeing the titles do not mean interest strong enough to raise the book to a candidate of the read-worthy.

4.2 A preliminary experiment

We constructed an experimental book library as in figure 5, in which all books are attached with RFID tags. 23 subjects were segmented to two groups and each group stayed in the library for one hour. This setting was introduced because we aimed to set a condition where the group effect (like Mr. A and Ms.B in section 1) works as in a usual book library. In total, 275 books were picked and returned sequentially. As in the case of apparel, we took each set of three books sequentially taken by the same customer as one basket, and applied KeyGraph to the data. Although the RFID tag system in this library did not have the effect to tell the customer corresponding to each picking event, we compensated for the customer information by having each customer insert his/her ID card to the same shelf area the book was picked from, until returning the book to the shelf.

As a result, figure 6 has been obtained. The left hand table shows the location of areas of the shelf, and the right hand shows KeyGraph representing the co-occurrence of book-picking events at different shelves. Simply put, close areas tend to appear closely in KeyGraph and form clusters, i.e., {5-A, 5-B} at the top, {6-A, 6-B, 6-C}, etc. These parts of KeyGraph are easy to interpret, because it is natural that customers move around close areas at close times. And, some exceptional parts like the links between 6-A and 4-C, between 6-C and 2-C, etc exist in KeyGraph. According to the data on the relation between the shelf areas and book categories, 6-A had books about company management, and 2-C and 4-C had books about leaderships and service management respectively. Considering the contextual relevance among these categories, we can regard these co-occurrence of remote areas, in that customers wandered from/to shelf areas due to the effect of books read in the course of tachiyomi in the real space affected the customers' awareness of their own interest.

Fig. 5. The book library we applied the RFID tag system to

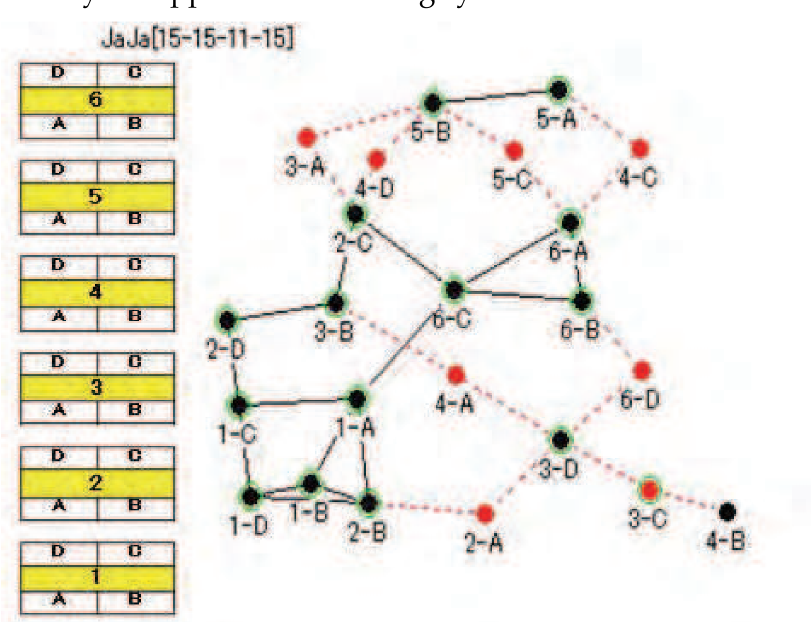


Fig. 6. The location of shelves (left), and the KeyGraph representing the co-occurrence of book-picking events at different shelves (right)

Based on the findings from the preliminary experiment, we pay attention to the customers' real space interactions in their wandering behaviors. We classified the customer's behaviors just after picking one book into four groups (1) stay at the same area (e.g., 5-A -> 5-A) (2) stay at the same shelf (e.g., 5-A -> 5-B) (3) move to the next shelf (5-A -> 4-B), (4) move over two or more shelves (e.g., 5-A > 3-B). We regard (4) as the most drastic wandering effect, and investigated the factors causing drastic wander. More specifically, we hypothesized that encountering an unexpectedly interesting book in wandering re-enforces oneself to wander more drastically.

4.3 The effect of "unexpected interestingness" of an encountered book

We hired new 27 subjects. Each subject was instructed to stay one hour in the library to brows, as in the preliminary experiment. Each time one picks a book, he had two missions: Evaluate the book just after picking (i.e. before reading) and just after returning (i.e., after reading or being tired of the book), and then report the evaluation score ranging between 1 (poor) and 5 (interesting). Denoting the score of the book before reading by *E* (Expectation) and after reading by *P* (Preference), we quantified the "unexpected interestingness" of a book by *P*- *E*.

As a result, we obtained the result as in Figure 7. Accordingly, we can conclude the unexpected interestingness of a book one picks and looks in to read stimulates the customer's wander behavior. On the other hand, if the unexpected interestingness is low, one tends to stay in the same area.

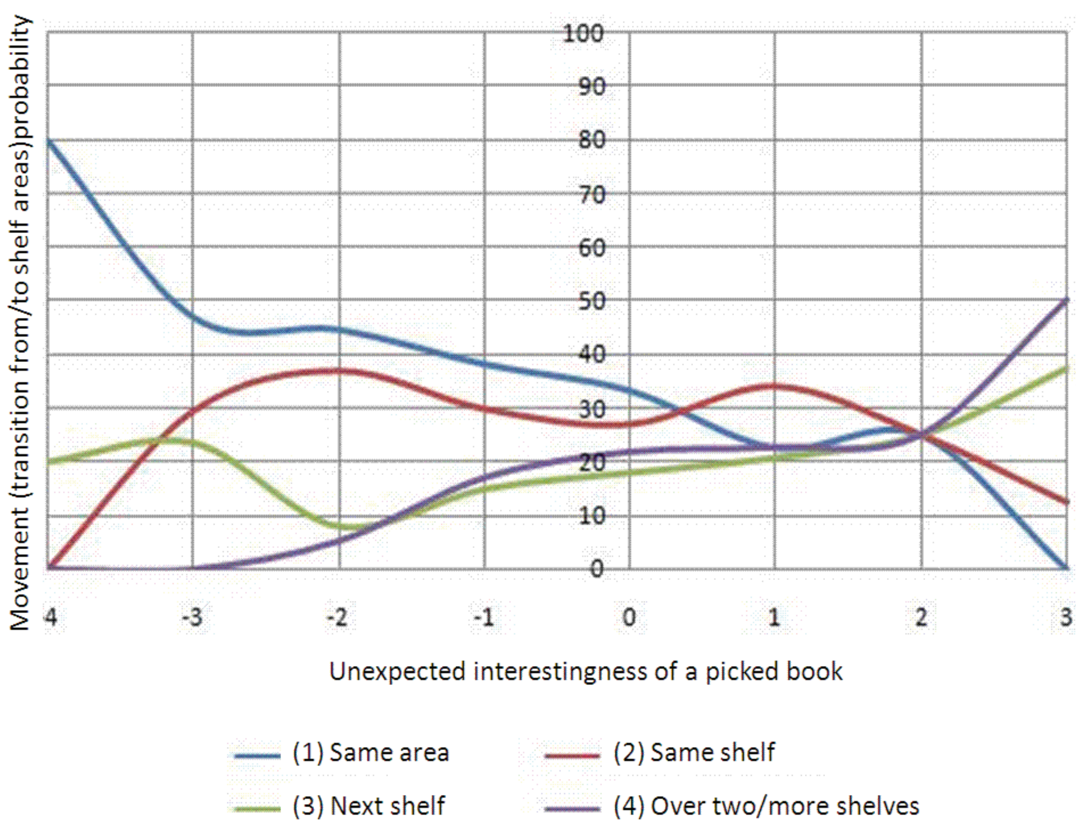


Fig. 7. The relation between unexpected interestingness of a picked book and the customer's following wander behavior

5. Conclusions and future work

An expectation of RFID tags applied to marketing has been to detect items that are touched but not bought, which may correspond to customers' latent interest which did not appear in sales data. On the other hand, we aimed in this paper to realize chance discovery by introducing the visualization method KeyGraph to the data. This here means to detect items which are touched and influence the near-future behavior of customers. The experimental results in this paper show our successful progress in confirming that our aim comes true by RFID tags applied to libraries and apparel stores.

We may address our next challenge to the discovery of purely novel knowledge, by deepening the level of tacitness of experience-based knowledge obtained via the process of knowledge/chance discovery [18]. Although we may not be allowed to distinguish customers considering their will to protect privacy [16], the experiment here under artificial setting, where each customer is taken for just anonymous someone (in the apparel experiment) or identified on a new devise such as a customer's ID card (in the book library), encourages us to introduce RFID tags to real spaces such as apparel stores and supermarket.

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The book generously covers a wide range of aspects and issues related to RFID systems, namely the design of RFID antennas, RFID readers and the variety of tags (e.g. UHF tags for sensing applications, surface acoustic wave RFID tags, smart RFID tags), complex RFID systems, security and privacy issues in RFID applications, as well as the selection of encryption algorithms. The book offers new insights, solutions and ideas for the design of efficient RFID architectures and applications. While not pretending to be comprehensive, its wide coverage may be appropriate not only for RFID novices but also for experienced technical professionals and RFID aficionados.

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