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Recommendation Method with Rough Sets in Restaurant Point of Sales System

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Abstract—**In recent years, a point of sales (POS) systems with a restaurant order function are developed. Since expensive apparatus and system for exclusive use are required for a point of sales system, the introduction is restricted to the large-scale chain store etc. In this research, we consider the point-of-sale management which cooperated with the automatic order function by using a personal digital device aiming at the safety of the menu in a restaurant, pursuit of service, and operational efficiency improvements further, such as foods management, accounting treatment, and ordering work. In the traditional POS system, information recommendation technology was not taken into consideration. We realize recommendation of the menu according to the user's preference using rough sets, and menu planning based on stock status by applying information recommendation technology. Therefore, it is thought that offer in consideration of freshness of foods, allergy, people with diabetes, etc. can use this system in comfort. Furthermore, it becomes possible even if it is reduction of the personnel expenses by an operational efficiency improvement, and a small-scale store.**

Keywords: Point of sales system, Rough sets, Recommendation

1 Introduction

Many kind of POS system having a restaurant-oriented automatic order function is developed by many companies until now. The system is introduced in the conveyor-belt sushi restaurant and broiled meat restaurant of a major company, Japanese-style bar, etc in Japan. The functions of the system are showing menu, detail of menu, PR of dish, calorie of dish, and allergy. However, we think it important to recommend a user knowledge acquired by analyzing the information which a user searches for inevitably or potentially. Recommendation of the menu according to the user's preference leads to the improvement in a degree of satisfaction of a user in a restaurant. Thus, we think it important to grasp a user's decision rule and trend and to carry out a user's decision support. The user's decision rule are using rough sets theory [1].

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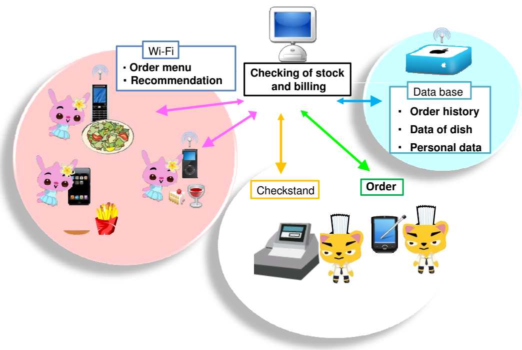

Figure 1: Image of POS system with menu planning system

The actual implementation in a restaurant can be considered by modifying the menu system with a point of sales (POS) system functionality. Restaurant POS systems assist businesses to track transactions in real time and a system adopting the recommendation function could take a user's food preference into consideration. A possible scenario could be as follows. A user can browse through the available menus at a restaurant on a touch-sensitive tablet PC with wireless connection to the store's database. He can then receive a custom-made menu recommendation according to his preferences and directly place his order online. Furthermore, the system could be linked with inventory control at the restaurant to not only perform order automation, but also assure freshness of the food in stock or consider seasonal availabilities of menu components. Additionally, it is possible to also integrate the system into the whole supply chain management, not only into the POS function (Fig. 1).

1.1 Restaurant POS

Restaurant POS refers to point of sale (POS) software that runs on computers, usually touchscreen terminals or wireless handheld devices. Restaurant POS systems assist businesses to track transactions in real time. Typical restaurant POS software is able to print guest checks, print orders to kitchens and bars for preparation, process credit cards and other payment cards, and run reports. In the fast food industry, registers may be at the front counter, or configured for drive through or walk through

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cashiering and order taking. POS systems are often designed for a variety of clients, and can be programmed by the end users to suit their needs. Some large clients write their own specifications for vendors to implement. In some cases, POS systems are sold and supported by third party distributors, while in other cases they are sold and supported directly by the vendor.

The staff of restaurant can make reduction, and also since the opportunity loss of the order by the time of rush hours is lost, the rise of sales is expectable. Moreover, since an order mistake is also lost, a claim also decreases, and it has effect also to improvement in service. Actually, the sushi boats and Japanese-style bar of the major company were able to increase the sales volume by having introduced this system. In this way, the merit of POS system has been known. Although there are few stores which have introduced this system. Because of possible cause of payment of hefty utility fee of devices and system for registration are required by system company. Therefore, the present condition is that the restaurant and the small-scale store which are carrying out 24-hour to sale are in the state where it cannot decide on introduction, and introduction of system is restricted to the major company chain store. But it becomes realizable to use our POS system by using handheld devices. Reality becomes possible even if it considers the most important cost. This system is also taking into consideration user's preference which was not taken into consideration about the function until now.

1.2 Example of cost

When introducing a POS system at a retail store, the case where lease is used is common. Although cost changes with a leasing company or systems, the basic monthly charge for the system is about 29,800 yen. And initial cost of construction of the introduction of the new system is 500,000 yen. The software of the POS system which takes over a POS system main part (personal computer), a scanner (bar code reading portion), cash desk, a receipt printer, a fee indicator machine, merchandise management, etc. unify consolidate the management, and these servise as the general contents of a set. On the other hand, in our system, it becomes possible to realize low prices. Because, our system is used automatic order system using a personal digital device like ipod touch. And the order system is not need waiter at all. So Self order POS system by iPodtouch's cost are 296,800yen in one year.

1. **Ten waiter of employee** Hourly wage of 1,000yen, 8hours / one day, 20days / one month. The wages paid to ten employees are <u>19,200,000yen</u> in one year.
   (a) **One day** 1,000yen × 8hours = 8,000yen
   (b) **One month** 8,000yen × 20days = 160,000yen
   (c) **One year** 160,000yen × 12months = 1,920,000yen
2. **Three waiter of employee, and handheld POS device for waiter** Monthly wage of 29,000yen, Initial cost is 500,000 yen. The wages paid to three waiter of employee, and handheld POS device for waiter are Total costs are <u>6,608,000yen</u> in one year.
   (a) **One month** 29,000yen
   (b) **One year** 29,000yen × 12months = 348,000yen
   (c) **Initial cost** 500,000yen
   (d) **Total cost of POS system**848,000yen
3. **Self order POS system by iPodtouch for customer** Total cost are <u>296,800yen</u> in one year.
   (a) **Initial cost (iPodtouch)** 19,800yen × 10 = 198,00yen
   (b) **Initial cost (Macbook)** 98,800yen
   (c) **Total cost of POS system by iPodtouch** 296,800yen

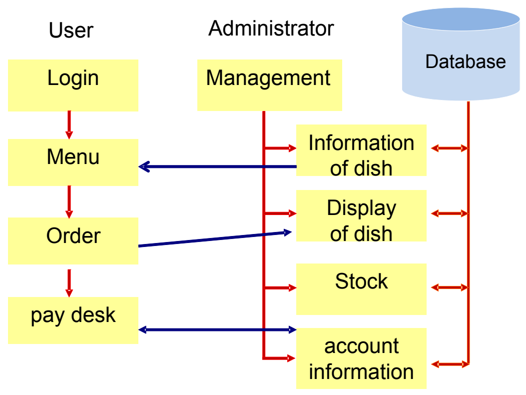

Figure 2: System structure of self order POS system by iPodtouch

1.3 System structure

The self order POS system consists of two part (Fig. 2). User can look at menu of dish, can order menu, and can check payment. Administrator can do management of dishes in database, can get user's order data and the dish's stuff of stock information, and can account of user's pay information.

2 Decision Rule using Rough Sets Theory

2.1 Background on Rough Set Theory

Rough set theory, as a mathematical approach for analyzing data, was developed by Pawlak in the 1980's [1]. As

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a new data analysis approach, rough set theory can effectively deal with all kinds of inaccurate, inconsistent, and incomplete data. It is well suited to extract useful information and rules in information systems. Compared with other classic data classification approaches, rough sets have several advantages by easily handling fuzzy data. In the recent past, rough sets have been flourishing in mathematical theory, algorithms, and applications.

The current state on rough sets is that most of the research is focusing on the mathematical theory and algorithms. Theoretical research includes studies on the structure of the rough arithmetic operators, the relationship between rough sets and topological spaces, the measures of rough set theory, the extension of the rough set theory and so on. The research on the algorithmic side includes algorithms for the reduction in the rough set rules, algorithms for extracting the decision rules, algorithms for rule-matching, etc.

Rough set theory, as proposed by Pawlak, has recently also been used to analyze data sets for the purpose of classification. This theory is an extension of the classical set theory for studying insufficient or incomplete information and has been demonstrated to be useful in fields of applications such as pattern recognition, machine learning, or automated knowledge acquisition.

2.2 Rough Sets Definition and Rules

The database regarding the experts ’ knowledge is generally given in the form of an *information system.* The definition of a traditional information system given by Pawlak is as follows.

Definition 1 (Information System *IS*). *An* information system *(IS) is an ordered quadruple* $IS = (U, Q, V, \rho)$ *where* U *is the universe (a non-empty finite set of objects* x*),* Q *is a finite set of attributes* q*,* $V = \bigcup_{q \in Q} V_q$ *is the domain of attribute* q*, and* ρ *is a mapping function such that* $\rho(x, q) \in V_q$*,* $\forall q \in Q$ *and* $x \in U$*.*

The set Q is composed of two parts: a set of *condition attributes* C and *decision attributes* D, i.e., $Q = C \cup D$. Function ρ also is called *decision function.* If we introduce the function $\rho_x : Q \to V$ such that $\rho_x(q) = \rho(x, q)$ for every $q \in Q$ and $x \in U$, ρ_x is called *decision rule* in *IS*, and x is called a *label* of the decision rule ρ_x.

Let $IS = (U, Q, V, \rho)$ be an information system and let $q \in Q$, and $x, y \in U$. If $\rho_x(q) = \rho_y(q)$, then we say x and y are *indistinguishable* (in symbols xR_qy) where R_q is an equivalence relation. Also, objects $x, y \in U$ are indistinguishable with respect to $P \subset Q$ in *IS* (in symbols xR_Py), if xR_py for every $p \in P$. In particular, if $P = Q$, x and y are indistinguishable in *IS*, i.e., we have xRy instead of xR_Qy. Therefore, each information system *IS* uniquely defines an approximation space $\mathcal{A} = (U, R)$, where R is an equivalence relation generated by the information system *IS*. The equivalence relation R partitions U into a family of disjoint subsets, which are called Q-*elementary sets.* Likewise, R_C leads to C-elementary sets, and R_D leads to D-elementary sets. Given an arbitrary set $X \subseteq U$, it may not be in general possible to describe X precisely in $\mathcal{A}$. Thus, one may characterize X by a pair of lower and upper approximations.

Definition 2 (Rough set)**.** *Let* R *be an equivalence relation on a universe* U*. For any set* $X \subseteq U$*, the* lower approximation $\underline{apr}(X)$ *and the* upper approximation $\overline{apr}(X)$ *are defined by as follows:*

$$\underline{apr}(X) = \{x \in U \mid [x]R \subseteq X\} \tag{1}$$

$$\overline{apr}(X) = \{x \in U \mid [x]R \cap X = \emptyset\} \tag{2}$$

where $xR = \{y \mid xRy\}$ *is an equivalence class containing* x*.*

The lower approximation $\underline{apr}(X)$ is the union of elementary sets which are subsets of X, and the upper approximation $\overline{apr}(X)$ is the union of elementary sets which have a non-empty intersection with X. The set $bnd(X) = \underline{apr}(X) - \overline{apr}(X)$ is called *boundary* of X in $\mathcal{A}$. If $bnd(X)$ is empty, then subset X is exactly definable. Note that a rough set is a pair of both, lower and upper approximation. An accuracy measure of set X in the approximation space $\mathcal{A} = (U, R)$ is defined as

$$\alpha(X) = \frac{\mid \underline{apr}(X) \mid}{\mid \overline{apr}(X) \mid}$$

where $\mid \cdot \mid$ denotes the cardinality of a set. Clearly, it is true that $0 \leq \alpha(x) \leq 1$. Besides, X is called *definable* in $\mathcal{A}$ if $\alpha(X) = 1$, and X is called *undefinable* in $\mathcal{A}$ if $\alpha(X) < 1$.

Now, let us consider the issue of rule extraction from an information system. A natural way to extract rules or to represent an expert's knowledge is to construct a set of conditional productions, each of them having the form

if { set of conditions } **then** { set of decisions}

Such a form can be easily induced by taking the advantage of rough sets. In an approximation space $\mathcal{A} = (U, R)$, regarding a subset X of U, the whole universe U is partitioned into three regions which corresponds to certain decision rules. The *positive region* $posS(X) = \underline{apr}(X)$ corresponds to positive (certain) decision rules, whereas the *negative region* $negS(X) = U - \overline{apr}(X)$ corresponds to the negative decision rules. Finally, the boundary region $bnd(X) = \overline{apr}(X) - \underline{apr}(X)$ represents the possible decision rules.

3 Decisions Based on User Preferences

Suppose that there is an information system $IS = (U, Q, V, \rho)$, which is a database about menu recipes as

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Table 1: Example of menu data

U	Q				
	C				D
	c_1	c_2	c_3	c_4	d
x_1	2	0	0	0	1
x_2	1	1	0	1	1
x_3	1	0	1	1	0
x_4	0	1	1	0	1
x_5	2	0	0	0	0
x_6	0	1	1	1	0
x_7	1	1	0	0	0
x_8	1	1	1	1	1

shown in Table 1. In this information system, $U = \{x_1, x_2, ..., x_8\}$ in which each object (element) expresses a dish; $Q = C \cup D = \{c_1, c_2, c_3, c_4, d\}$ in which c_i denotes the attribute of dish i and d is the user's decision value. For instance, if c_1 represents the type of cuisine, its domain set is $V_{c_1} = \{0, 1, 2, 3\}$ in which the numbers represent "Japanese", "Chinese", "German", or "other" food, respectively. The other attributes c_2, c_3, c_4 could be binary values representing other dish characteristics with $V_{c_i} = V_d = \{0, 1\}$, for $i = 2, 3, 4$ in which 0 expresses "no" and 1 "yes". Furthermore, the mapping function ρ for Table 1 is given as $\rho(x_1, c_1) = 2$, $\rho(x_2, c_1) = 1$.

Clearly, *IS* yields the following elementary sets with respect to the condition attributes $C = \{c_1, c_2, c_3, c_4\}$:

$$\begin{aligned}
E_1 &= \{x : c_1 = 2, c_2 = 0, c_3 = 0, c_4 = 0\} = \{x_1, x_5\} \\
E_2 &= \{x : c_1 = 1, c_2 = 1, c_3 = 0, c_4 = 1\} = \{x_2\} \\
E_3 &= \{x : c_1 = 1, c_2 = 0, c_3 = 1, c_4 = 1\} = \{x_3\} \\
E_4 &= \{x : c_1 = 0, c_2 = 1, c_3 = 1, c_4 = 0\} = \{x_4\} \\
E_5 &= \{x : c_1 = 0, c_2 = 1, c_3 = 1, c_4 = 1\} = \{x_6\} \\
E_6 &= \{x : c_1 = 1, c_2 = 1, c_3 = 0, c_4 = 0\} = \{x_7\} \\
E_7 &= \{x : c_1 = 1, c_1 = 1, c_3 = 1, c_4 = 1\} = \{x_8\}
\end{aligned} \tag{3}$$

Thus, the C-elementary sets are $\{E_1, E_2, ..., E_7\}$.

Now, let us consider to approximate a subset $X = \{x_1, x_2, x_4, x_8\}$, which is a set of dish which a user likes. Based on the concepts defined above, we now have the sets:

$$\begin{aligned}
&\underline{apr}(X) = \{x_2, x_4, x_8\} \qquad \overline{apr}(X) = \{x_1, x_5, x_2, x_4, x_8\} \\
&posS(X) = \{x_2, x_4, x_8\} \quad negS(X) = \{x_3, x_6, x_7\} \\
&bnd(X) = \{x_1, x_5\}
\end{aligned}$$

Therefore, the *certain* rules follow from $posS(X)$ as given below:

1. **if** $c_1 = 1 \wedge c_2 = 1 \wedge c_3 = 0 \wedge c_4 = 1$ **then** $d = 1$

Figure 3: Screenshot of web-based menu planning system on handheld device

2. **if** $c_1 = 0 \wedge c_2 = 1 \wedge c_3 = 1 \wedge c_4 = 0$ **then** $d = 1$
3. **if** $c_1 = 1 \wedge c_2 = 1 \wedge c_3 = 1 \wedge c_4 = 1$ **then** $d = 1$

Furthermore, the *possible* rules follow from $bnd(X)$ as:

4. **if** $c_1 = 2 \wedge c_2 = 0 \wedge c_3 = 0 \wedge c_4 = 0$ **then** $d = 1$
5. **if** $c_1 = 2 \wedge c_2 = 0 \wedge c_3 = 0 \wedge c_4 = 0$ **then** $d = 0$

where we can see that in rules (4) and (5), although they have the same condition in the **if** part, their decisions are different in the **then** part. It means in such a case that the user may probably like a dish. The *negative* decision rules are obtained by describing $negS(X)$ as follows:

6. **if** $c_1 = 1 \wedge c_2 = 0 \wedge c_3 = 1 \wedge c_4 = 1$ **then** $d = 0$
7. **if** $c_1 = 0 \wedge c_2 = 1 \wedge c_3 = 1 \wedge c_4 = 1$ **then** $d = 0$
8. **if** $c_1 = 1 \wedge c_2 = 1 \wedge c_3 = 0 \wedge c_4 = 0$ **then** $d = 0$.

The total approximation accuracy is $\alpha(X) = \frac{3}{5} = 0.6$.

3.1 Design of Menu Planning System

In developing an implementation of the menu planning system, we use a Web server running Apache, MySQL, PHP, and a database management system as Web application. The reason for using this environment is because they are all multi-platform software, freely available under the Open Source License. For example, the system abbreviated as "WAMP (Windows, Apache, MySQL, PHP)" is a very popular combination. Since a large amount of documentation and programming interfaces are provided, the system is easily portable for access from handheld devices, see Fig. 3. The database that we use in this study stores the data of approximately 300 dishes consisting of several ingredients. The data for these dishes is taken from the book "Foods Supporter" [2].

Decision support is realized in the following procedures and aims at recommending the user a favorite menu.

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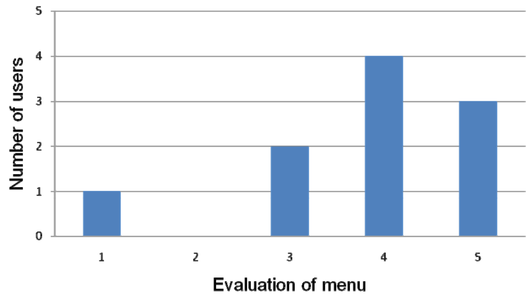

Figure 4: Result of test installation

1. The system presents a menu of 10 arbitrary dishes. Then, the user replies to a questionnaire and evaluates the menu. Evaluation is done by entering “like” or “dislike”.
2. The result in response to the questionnaire is then stored in a database.
3. A preference rule is extracted from this information.
4. The user is then presented the information of a menu suitable for his preference. The menu also provides nutrition information, which can be used to optimize the menu selection in terms of calorie intake and nutrition balance [3].

3.2 Implementation and Evaluation

The operation of the system developed in this research was evaluated in [4]. First, ten users tested the system and its performance was investigated. It was verified how much the recommended menu conforms to a user’s preferences as compared with the subject’s taste. Each user estimated the performance of the system in five steps. The total result of this evaluation is shown in Fig. 4. Here, the vertical axis expresses the number of users and the horizontal axis expresses their evaluation of the system on a scale of 1–5. Three users gave evaluation 5, four users gave evaluation 4, and two users gave evaluation 3. However, one user was not satisfied with the result. Although the number of test candidates were only ten people, this figure shows that the majority of users are satisfied with the menus suggested by our system.

We got the user to evaluate to all the dishes, and analyzed the menu chosen by the menu recommendation system. You can see this Fig. 5 result shows that many high evaluation dishes of a user are recommended.

Figure 6 shows the average of the experimental results in [4]. First, the users evaluated all of the dishes in the database. Each dish is given points ranging from 0 to 100. The blue bars in Fig. 6 represent the average ratio of entries in the database according to the liking or disliking from the user. As a result of analyzing the dish selected by the system, the white bars show that the dish

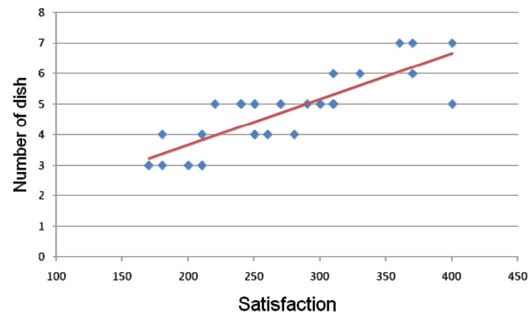

Figure 5: The relation between satisfaction and items

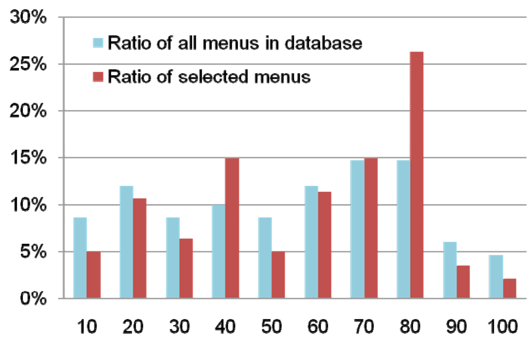

Figure 6: The change ration sof dish’s evaluation

which has 80 points increases over the ratio of all entries. On the other hand, the ratio decreases for the menus with high evaluation score of 90 or 100 points because the evaluation of junk food, which has a bad nutritional balance, is high for some users. Such a result is expected when there are constraints that are inversely proportional to a user’s degree of satisfaction. Therefore, many dishes of 80 points which can both fulfill nutritional balance and user’s preference are recommended.

Recommendation of a menu shows several kinds of menus at the same time. By analyzing the recommended dish showed that there were two features. One of the features is to have characteristics in common (Fig. 7). For example, the recommendation of a menu has some decision rules “Staple food”, “Side dish”, and “Easy to arrange cooking”. The menu shows some dishes cooked by vegetables, the dishes are non-fatty in common. Other of the features is to have Chain structure (Fig. 8).

This survey showed the basic performance of a decision support system using rough sets. Preference support of a food menu has been offered by the example of a concrete application. The user’s potential criteria for selection are shown by his evaluations, i.e., liking or disliking ten kinds of menus chosen at random. Moreover, only the menu that a user desires is selected out of the large quantity of information stored in the database. Information presentation to a user was realized in an experimental system. In order to validate this system, experiments have been performed on ten test users and a high degree of match in

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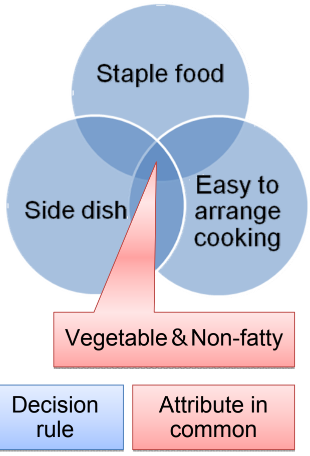

Figure 7: Structure feature having characteristics in common

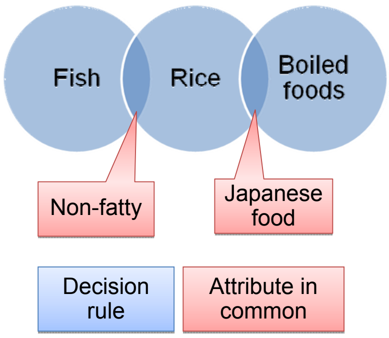

Figure 8: Chain structure feature having characteristics in common

the users' taste and the recommended menus is obtained.

4 Conclusions and Future Work

In this paper, we considered about make an arrangement of automatic order, and POS system using handheld device. The result is that the system could use as the effective management support technique for raising the service and the customer satisfaction to the restaurant of a private management scale. We think that useless reduction of foods and healthy support of the customer by a nutrition labeling are the effective functions for attaining a competitor and differentiation.

A part of the menu planning system was designed in this work since it is very intuitive in explaining and interpreting the essential properties of rough sets. However, decision making is an important field in a vast area of applications. One future challenge is applying the concept of rough sets with fuzzy weights to research areas such as information networking, especially in the context-aware scenarios of future ambient information environments. For example, the menu planning system could respond to the activities that take place in the kitchen of restaurant. An "Ambient Kitchen" [5] can sense which ingredients the user has available, presents the nutrition value of the recipe they can choose, as well as step-by-step preparation instructions. Such a system will make our life more comfortable and healthy.

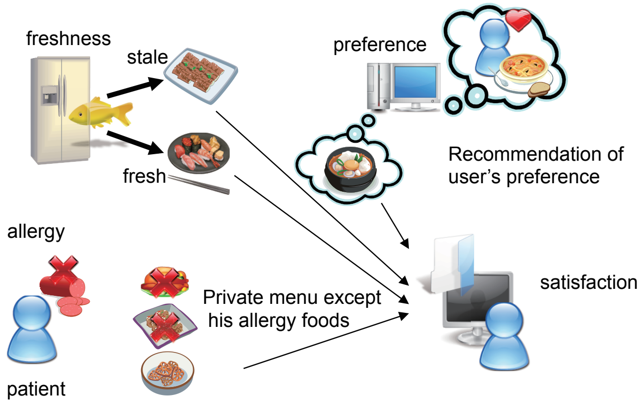

Figure 9: Menu recommendation in consideration of the best-before date of stock

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References

[1] Z. Pawlak, "Rough sets," *International Journal of Computer and Information Sciences*, vol. 11, no. 5, pp. 341–356, 1982.

[2] "Foods supporter - nutrient calculation software." Hitotsu bashi-shuppan (In Japanese), 2007.

[3] T. Kashima, S. Matsumoto, and H. Ishii, "Development of web-based menu planning support system and its solution using genetic algorithm," in *IAENG Transactions on Engineering Technologies* (S. long Ao, A. H.-S. Chan, H. Katagiri, and L. Xu, eds.), vol. 3, pp. 56–68, America Institute of Physics, 2009.

[4] T. Kashima, S. Matsumoto, and H. Ishii, "A web-based menu recommendation system with interactive interface using rough sets," in *Proceedings of International Symposium on Management Engineering (ISME 2009)*, (Dalian, China), August 2009.

[5] P. Olivier, A. Monk, J. Hoey, and G. Xu, "Ambient kitchen: Designing situated services using a high fidelity prototyping environment," *Workshop on Affect & Behaviour Related Assistance in the Support of the Elderly*, pp. PETRA–09, 2009.