# Personalized Smart Suggestions for Context-aware Human-activity Support by Ubiquitous Computing Networks

*Hiroshi Sakai*†*, Yoshiko Sueda, Koji Murakami, and Takeshi Nakatsuru*

**Abstract**

This paper describes a method for making personalized smart suggestions, in which context-adjusted and personalized activity-support information is provided. This method provides functions for evaluating how the current contextual information affects the user's activity and determining the best time for providing activity-support information to each user. We propose a general measure "motivation-indicator" for user-oriented context evaluation (e.g., level of burden, profit, and familiarity). We also discuss a self-tuning mechanism for personalization rules by analyzing how the behavioral response to the changing contextual information changes over time. The motivation-indicator provides a framework for analyzing whether or not activity-support information should be provided to a user in a specific context, which dispenses with the annoying procedure of pre-defining information-provision rules for each user. Thus our proposal has a beneficial effect on sharing context-based activity-support information among users without losing the personalization policy of each user. We have confirmed the feasibility of our method with a prototype.

## 1. Introduction

With the progress of broadband wireless networks, it has become possible to use broadband services distributed in various networks (e.g., the Internet, office networks, and home networks) from anywhere at anytime. Moreover, various kinds of appliances such as portable computers, cellular phones, and PDAs (personal digital assistants) are now available, enabling us to utilize services using the most suitable appliance. The network environment that offers flexible access to rich services is thus called the "ubiquitous computing network".

With some recent sensing technologies including RFID (radio frequency identification) tags reaching the level of practical use, various kinds of contextual information in the real world can now be imported into the cyber world. By utilizing advanced sensing technologies, a ubiquitous computing network can not only simply provide a variety of services in response to a user's request, but also autonomously provide various awareness and relief information to help us in our personal daily activities.

Human activities are greatly influenced by user context, which includes location, schedule, and preferences, and by the environmental context, such as the weather, temperature, and traffic congestion.

Therefore, the ability to collect and analyze these types of contextual information and provide context-adjusted support information is required. For this purpose, context-awareness [1] is a key technique.

To bring awareness to users, some activity-support information should be pushed to them. However, to ensure this does not become a nuisance, it is especially important to provide the context-awareness with a powerful personalization mechanism, which selects the minimum set of truly required information and provides it in a timely manner.

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The remainder of this paper is organized as follows. Section 2 briefly mentions related work. Section 3 describes the concept of "context-aware human-activity support" in ubiquitous computing networks and clarifies its requirements. Section 4 proposes a personalized smart suggestion method and discusses some key issues including a user-oriented context analysis based on the context-evaluation measure "motivation-indicator", a best information-provision timing analysis, and a self-tuning*1 mechanism for personalization rules. Finally, section 5 discusses the configuration of a prototype system.

## 2. Related work

Much of the work on personalization in the context-awareness field is concerned with providing frameworks that analyze user preferences, which are manually configured by users or automatically obtained from the history of their activities [2]-[4]. Jack-in-the-net [4] has a genetic-algorithm-based self-tuning mechanism that evaluates the strength of the relationship between users and services and replaces old-fashioned services with more attractive new ones. Preference-based personalization is effective at screening out information that the user is not interested in; however, it is inadequate for selecting the truly required information and determining the best time to provide it. Finkelstein et al. [5] proposed a personalization framework based on a variety of contextual information, in which the ECA (event, condition, action) mechanism is applied for personalization rules. By pre-defining "context-changes" or "profile-changes" in the Event part, context-oriented information screening can be achieved. Williams et al. [6] introduced a user-modeling concept, in which a user's profile or history is linked to a specific context and gives a user-oriented meaning to it. Both proposals apply the concept of user-oriented context analysis, which empowers the context-awareness system by providing a powerful personalization factor "information-provision timing". However, they still have room for improvement, as follows:

- The ECA rules have to be pre-defined for each user, which makes it difficult to share context-based activity-support information among users without losing the personalization policy of each user, because it is impractical for a user to prepare ECA rules whenever new activity-support information is registered by others.
- Personalization rules need to be tuned by users themselves, which might be a nuisance for non-experts.

Our goal is to introduce a general measure of how much the context affects a user's activity, which enables the system to analyze whether or not the activity-support information should be provided to a user in a specific context without ECA rules. We also aim to achieve self-tuning of the personalization rules.

## 3. Requirements for context-aware human activity support

Context-aware human activity support aims to autonomously provide various awareness and relief information that helps human activities in every stage of a task cycle. **Figure 1** shows an overview of the

*1 Self-tuning means that the system autonomously tunes configuration parameters instead of the user doing so manually.

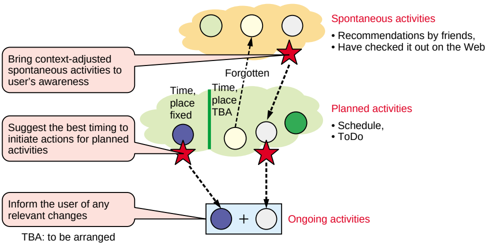


Fig. 1. Context-aware human-activity support.

concept, which includes capabilities to:

- make the user aware of spontaneous activities (e.g., activities recommended by the user's community and activities which are of interest to the user but have been forgotten or overlooked) that best suit the context,
- suggest the best timing to initiate actions for planned activities,
- monitor the contexts related to ongoing activities and inform the user of any relevant changes (especially negative changes).

Examples of human-activity support information are shown in **Fig. 2**. All the support information is generated by analyzing both user and environmental contextual information and is displayed on the user's mobile appliances. **Figure 3** describes requirements for the context-aware human-activity support, which include functions for:

(1) extracting the contextual information sets that are relevant to activity-support information; in the example shown in Fig. 3, the contexts related to the activity-support information "rainy-day-only dessert is a special only for couples" are weather (rainy), companions (couple), and information source (Mr. A),

(2) evaluating how the extracted contextual information affects a user's motivation, such as the companion context "couple" greatly increases user's motivation in the example in Fig. 3,

(3) analyzing the best time for providing information to each user, and

(4) self-tuning individual context-evaluation rules in

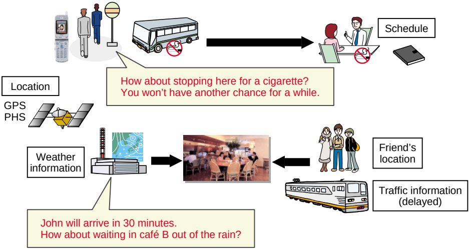


Fig. 2. Example of human-activity support information.

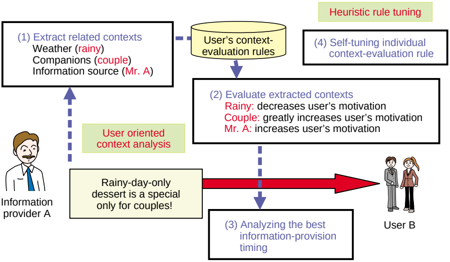


Fig. 3. Requirements for context-aware human-activity support.

response to the user's behavior.

In the next section, we propose a 'personalized smart suggestion' method for achieving these functions. For function (2), we discuss several measures of how much the given context-set affects a user's activity in section 4.1, and by using these measures we describe a solution to providing functions (3) and (4) in sections 4.2 and 4.3, respectively.

## 4. Personalized smart suggestion method

### 4.1 User-oriented context analysis based on the context-evaluation measure

In this section, we propose a general measure "motivation-indicator" for context evaluation and a user-oriented context analysis method based on it. The motivation-indicator shows the human motivation level for an activity based on the user and environmental contexts. It consists of both positive features (e.g., the level of profit and familiarity) and negative features (e.g., the level of burden), as shown in **Table 1**, and varies in response to the changing contextual information. For instance, the weather-context "rainy" affects the motivation-indicator "level of burden" of users who dislike walking in the rain, and also affects the "level of profit" when a limited-period sale is held only on rainy days.

We define several activity-categories such as "playing sports", "eating", and "waiting". When users register activity-support information, they select the appropriate category. The motivation-indicator for the specific activity-support information can be calculated by

$$\mathrm{MI}(\mathrm{A},\mathrm{C}) = \sum_{j} \delta_j \times \mathrm{F}(\mathrm{A},\mathrm{S}(\mathrm{C}_j)), \qquad (1)$$

where $C = \{C_0, ..., C_j, ..., C_n\}$ represents a context-set that is relevant to the activity-support information and A is an activity-category to which the activity-support information is attached. In the example shown in Fig. 3, the context-set for activity-support information "Rainy-day-only dessert is served only for couples" is $C = \{C_{weather}, C_{companions}, C_{information\text{-}source}\}$, and the activity-category could be "eating". $S(C_j)$ is the current status of the context $C_j$. For instance, $S(C_{weather})$ has a status such as fine, cloudy, or rainy. $F(A, S(C_j))$ analyzes whether or not the context status $S(C_j)$ affects the user's motivation for the activity-category A, and returns 1, –1, or 0 if the motivation-indicator increases, decreases, or is unaffected, respectively. $\delta_j$ is a weight parameter for each affected context.

When a couple near a cafe serving a special dessert performs an online search for activity-support information about a rainy day, the motivation-indicator for that cafe is evaluated by adding the values of i) F(eating, rainy) $\times\ \delta_{weather}$, ii) F(eating, couple) $\times\ \delta_{companion}$, and iii) F(eating, friend) $\times\ \delta_{information\text{-}source}$ of user A. When the motivation-indicator exceeds the minimum threshold, the cafe information is displayed on the user's appliance.

Thus the motivation-indicator dispenses with the annoying procedure of pre-defining information-provision rules such as ECA for each user, which makes it possible to smoothly share context-based activity-support information among users without losing the personalization policy of each user.

### 4.2 Analysis of best time to provide information

The best time to provide activity-support information can theoretically be obtained by seeking the context-set that maximizes the positive features of motivation-indicator or minimizes its negative features. However, such ideal timing does not necessarily appear in the real world. One possible solution is to give another threshold. This approach is reasonable for analyzing the best timing to initiate actions for a user's planned activities. However, considering suggestions for the user's spontaneous activities, the threshold approach, which tends to propose the same activity repeatedly, is inadequate.

Table 1. Features of motivation-indicator.

| Features of motivation-indicator | Example contexts which affect the feature |
|---|---|
| Familiarity | Have previous experience of visiting, have checked it out on the Web |
| Interest | Recommended by friends, never been there |
| Preference | Frequently eat this food |
| Burden | Congestion, bad weather, long distance |
| Profit | Have a discount card, limited-period sale |
| Urgency | Deadline is near, limited time event |
| Danger | Alone, in a group, accompanied by experts |

We assume that a suggestion made when the motivation-indicator changes drastically or after a long interval could appeal to the user's psychology effectively even if the absolute value of the motivation-indicator does not exceed the threshold. For example, if the motivation-indicator burden-level for eating is greatly influenced by how far the target restaurant is from the user's current location, the motivation-indicator for the activity-support information for restaurant X near the user's home might increase every day; however, informing the user about restaurant X every day does not make sense. On the other hand, if the user visits a certain place after six months, it is effective to provide activity-support information for restaurants in and around that place based on an analysis that the motivation-indicator has increased after a long interval.

Thus our method can trace behavioral response to changes in the motivation-indicator over time and evaluate the variation of the motivation-indicator

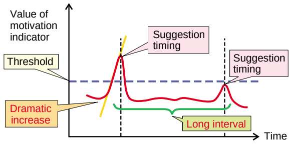


Fig. 4. Temporal response of the motivation-indicator and suggestion timing.

within a specific period. **Figure 4** shows the temporal response of a motivation-indicator and indicates suggestion timing.

This tracing is also used to monitor contexts related to ongoing activity (especially ones whose changes might have a negative influence on the user's activity), which enables our method to suggest alternative activities when the traced contexts become worse.

### 4.3 Self-tuning mechanism for personalization rules

The biggest hurdle to personalization is to predefine individual personalization rules and their modification, which is a nuisance for users. Thus, a self-tuning mechanism is mandatory to make our personalization method practical. In this paper, we propose a heuristic tuning mechanism for personalization rules. More precisely, the return value of F(A, S($C_j$)) and the value of $\delta_j$ in formula (1) are automatically tuned by analyzing the user's response to the suggestion.

**Figure 5** shows an overview of our self-tuning method. The first step looks up an activity-support information influenced by tuning target contexts by checking the return value of F(A, S($C_j$)), which must be 1 or –1 because activity-category A, to which the activity-support information is attached, is influenced by context $C_j$.

The next step verifies the tuning history of each target context (e.g., number of tunings, last tuning date, and user's behavioral responses) and selects a few of them. An example of a context selection-rule is given below:

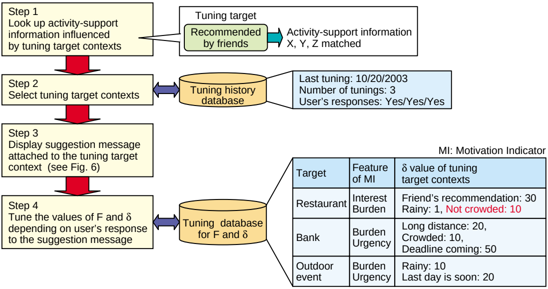


Fig. 5. Overview of self-tuning method for personalization rule.

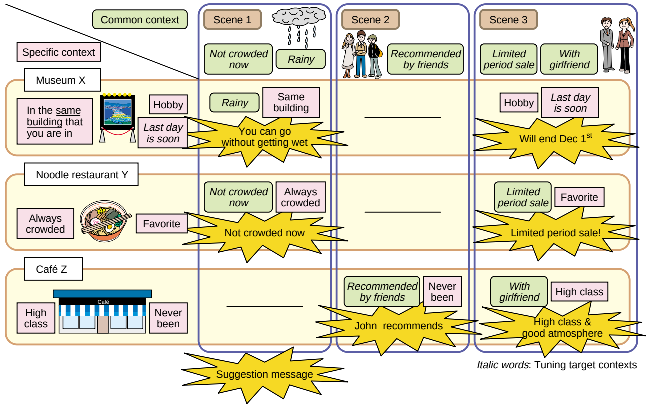


Fig. 6. Example of suggestion message for tuning target context.

1) select a context that often produced a positive response from the user,
2) select a context that has never been tuned,
3) select a context that has not been tuned for a long period.

The third step displays a suggestion message attached to the tuning target context, which could be defined by activity-support information providers or generated automatically based on the rules prepared for each context. **Figure 6** shows examples of suggestion messages for the tuning target contexts.

The final step automatically tunes F(A, S($C_j$)) and $\delta_j$ depending on the user's response to the suggestion message. For instance, considering that the context $C_{congestion\text{-}level}$ affects the motivation-indicator "burden-level" and F(A, S($C_{congestion\text{-}level}$)) and $\delta_{congestion\text{-}level}$ have the following default values:

- F(A, crowded) = 1,
- F(A, not crowded) = 0,
- $\delta_{congestion\text{-}level} = 10$.

If the user always responds positively to a suggestion message such as "This popular restaurant is not crowded now", the tuning mechanism modifies the return value of F(A, not crowded) from 0 to –1, which decreases the negative motivation-indicator "burden-level," thus increasing the user's motivation-level. The tuning mechanism also raises $\delta_{congestion\ level}$ to 20 if necessary.

## 5. Configuration of prototype system

To verify the feasibility, effectiveness, and scalability of our proposal, we developed a prototype system (**Fig. 7**). We considered the user's location, schedule, and preferences as user context. The user's location can be gathered from multiple devices including a cellular phone, GPS (global positioning system), and RFID (radio frequency identification) tag reader. Environmental context, including weather, temperature, mass transit delay information, and shop crowding levels is gathered by the context management server, which supports http and simple [7] as context gathering protocols. The application server contains the personalized smart suggestion engine and provides activity-support information that is not only context-adjusted but also personalized to the user's mobile appliances through the wireless network.

We developed software for registering context-based activity-support information from mobile appliances. **Figure 8** shows a screenshot of a cellular

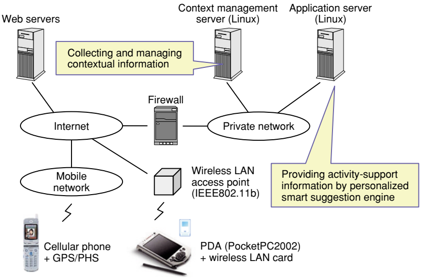


Fig. 7. System configuration of prototype system.

phone. The left side shows the information registration page. The contextual information at that time including the user's location, companions and the weather is automatically gathered and attached to the registered information. It is also possible for information providers to explicitly specify the attached contextual information. The right side is a screenshot of the result page for an information search. **Figure 9** shows a screenshot of a PDA. The upper part mainly informs the user of the best timing to initiate actions for planned activities. Suggestions for user's spontaneous activities are listed in the lower part with the suggestion message. The results to date with the prototype confirm the feasibility of our method. The effectiveness and scalability will be examined in the ongoing field trials.

(a) Registration (b) Search result

Fig. 8. Screenshot of cellular phone (only Japanese version available).

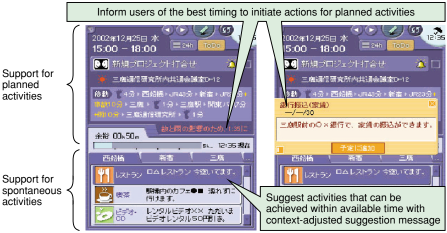


Fig. 9. Screenshot of PDA (only Japanese version available).

## 6. Conclusion and further work

This paper described a personalized smart suggestion method that provides activity-support information that is not only context-adjusted and personalized but also timely. Our method is based on a general measure "motivation-indicator" for context evaluation, which indicates the human motivation level for an activity based on the user and environmental contexts. We also propose a heuristic tuning mechanism for personalization rules by analyzing the user's response to the suggestion.

The motivation-indicator provides a framework for analyzing whether or not activity-support information should be provided to a user in a specific context, which dispenses with the annoying procedure for predefining information-provision rules and achieves smooth sharing of context-based activity-support information among users.

We have confirmed the feasibility of our proposal and are currently examining its effectiveness and scalability through a field test. We plan to study privacy issues and an effective context-structuring method. A context-awareness system handles a variety of private information, which requires a privacy protection mechanism especially when the private contextual information is shared in a community. Context-structuring aims to derive a meta-context such as a user's activity from a set of sensed contexts, which not only makes context-aware applications simple but reduces the size of contextual information stored as the user's history.

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