Context aware service control based on personal history

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Abstract

We have developed a home service control platform, “Home Service Harmony (HSH)” that structures services by combining various information appliances and devices via a home network. It then automatically controls the services depending on each situation. In this paper we propose a service control method for HSH that enables the client/user to control many home services at one time in response to the situation by sharing contexts across different services. This means that the proposed control method has high context scalability. Moreover the main feature of the proposed control method is to select the controls for each service in a given situation by applying Bayes’s rule, based on the personal history accumulated when the user actually controls the services autonomously. Therefore, it is adaptable to many situations and enhances user friendliness.

Keywords: context aware service; home network; information appliance; personal history; Bayes’s rule

Ⅰ Introduction

Various networked devices, such as PCs, mobile phones, PDAs, and broadband networks (optical fiber, ADSL, etc.) have become increasingly popular. Recently, home devices, such as audio/visual (AV) equipment and white goods, known as “information appliances”, have progressed to the stage where they can be connected via networks and structured home networks, as illustrated in Fig. 1. By connecting these appliances to home networks, it is possible to provide remote services to remotely control them (e.g., turning an air conditioner on and off) and monitor the home surroundings, such as home security and pets.

In next-generation home network services, however, we anticipate not only remote services but also higher value-added services. One of the services is a flexible service that is structured by combining appliance functions taking the information collected over home networks into account to automatically control or restructure the service depending on individual situations and users. Moreover, the scope of the flexible service will spread beyond localized combinations of information appliances to services or functions over the Internet to enrich peoples’ lives by making them more convenient and comfortable [1, 2, 3].

Owing to information appliances and home networks, it has become easier to provide services, such as remote control of individual devices and communications between two or more predetermined devices or functions. However, it has been impossible to provide services using a combination of devices or to control services adapted to each situation and user. Furthermore, as the number of device functions and the amount of information available over home networks increases, it will become even more complicated to combine them and still structure services effectively to automatically control services adapted to information based on individual situations or user preferences. Of course, it is possible to pattern appliance combinations, control conditions, and user preferences in advance, but it is not very realistic. In addition, it is impossible to deal with emergency situations or unplanned events in which the user’s schedule changes suddenly.

We have developed a home service control platform, “Home Service Harmony (HSH)” to resolve these problems and realize higher value-added (situation- and user-oriented) home services [4, 5].

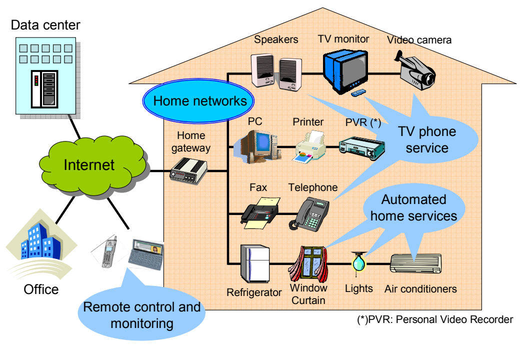

Fig. 1 Home networks and next-generation home services

The remainder of this paper is outlined as follows. Section Ⅱ describes HSH and its architecture and focuses on the HSH service manager. Section Ⅲ describes the proposed service control method for the service manager.

Section Ⅳ discusses an experimental system and describes some scenarios realized by the system. Related works are described in Section Ⅴ. Finally, we end with a conclusion and discuss the future directions of our research in Section Ⅵ.

Ⅱ Home Service Harmony

Home Service Harmony (HSH) is a home service control platform that can provide higher value-added home services, structured by combining various information appliances and devices over home networks that can automatically control or restructure the services depending on individual situations or users. Therefore, it requires a lot of home network information, which is collected by directly talking to the user or implicitly monitoring the user's environment and service requirements.

Information about users includes personal preferences, existing location, and schedule, etc. Information about services includes device states, network usage bandwidth, and information obtained using services (telephone caller, video genres, etc.), Environmental information includes time and sensor data, such as room or outside temperatures, humidity, lighting intensity, and so on. This information, is generally referred to as "context" [6, 7], and services controlled using contexts or context changes, are known as "context aware services". These areas have been the subject of intensive research recently [8, 9, 10, 11].

Logically, HSH consists of four components: service manager, service, resource manager, and resources, as illustrated in Fig. 2.

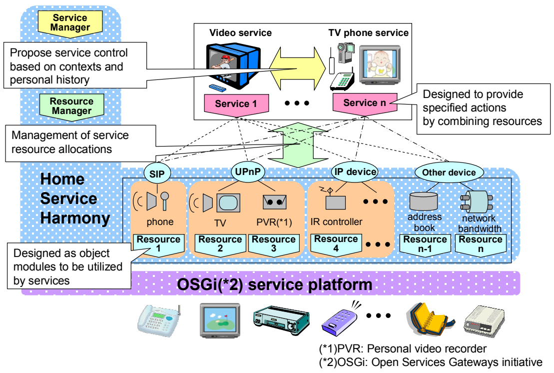

Fig. 2 Home Service Harmony architecture

Service manager

The service manager provides strategies about structures and controls each service using various contexts and the personal usage history to automatically control or restructure multiple services simultaneously, depending on each situation and user.

Service

A "service" is structured by combining information appliances and devices and it performs specified actions, such as video services, TV phone services, light services, and so on. Moreover the service notifies the service manager of existing contexts or contexts detected by the sensors, and receives control instructions from the service manager.

Resource manager

The resource manager has a resource database and centrally manages the resource states and allocations for each service, based on instructions from the service manager.

Resources

All entities are designed as object modules to be used by services, including home equipment (information appliances/devices/sensor), applications, network bandwidths, and personal data, such as the user's schedule and address book.

These modules are implemented in compliance with the OSGi Alliance specifications [12]. OSGi is the standard for open service platforms for home networks, and it enables the dynamic addition/deletion/updating of program modules during system operations. Therefore, we can dynamically add/enhance services and resources to achieve a high level of maintenance performance/operability.

We focus on the HSH service manager and propose a service control method for the service manager. Therefore, we refer to other functional components at the end of this paper [4, 5].

A. Service manager

The HSH service manager plays a vital role as a mediator or a coordinator for home network services.

We believe that users today require a variety of home services, rather than only one or two. Sometimes users request several services at the same time. For example, perhaps they are monitoring a baby or a pet on a PC monitor while watching TV on the same monitor. Regardless of the user's intent, unplanned events can occur that require several services to be used at once. For example, while the user is watching TV, they receive a telephone call or a TV phone service, which is structured by combining a telephone and a TV monitor.

For these unexpected events, the user usually needs to take some action, without interrupting any of the other services. Because all the services cannot be displayed on the monitor at the same time, the user has to decide which the most important service is and how to control each service. If the user decides to keep watching TV, they must switch the TV phone's image to another monitor or speak after turning off the TV phone's image. On the other hand, if the user is not really interested in the TV program, they can let the TV phone image take over the screen, and record the TV program on a VCR for later viewing. Even if the external event is not a TV phone service, but a phone service and there is no conflict, the user needs to take some action, such as turning off or turning down the TV volume, or switching the phone to an answering machine.

Traditional service control systems that use contexts or user preferences have been developed to cover a fixed independent service, so they cannot handle or coordinate the individual services to resolve previously mentioned problems. Moreover, the service's control conditions cannot be changed easily, and new contexts cannot be added to control services because the controls and contexts are uniform and fixed in advance. However, the control conditions required by individual users vary, depending on each situation. In short, traditional context aware systems are not entirely satisfactory, and they are still far from being situation- or user-oriented.

The service manager had to be developed to realize the above requirements and automatically coordinate the many independent services at the same time, based on each situation or user's preference. The service parameters for priorities or emergencies, used to compare multiple services in the traditional service manager, are calculated using only contexts related to the service, and users must manually set some simple configurations in advance. Hence, it lacks in scalability for new contexts or new service control and user friendliness. The number contexts will increase home networks in the near future, and users will be required to set more configurations. The service manager should be able to control multiple services, taking the situation and user requirements into consideration in detail, and then set functions to enhance user friendliness and stability. We propose a service control method in which a variety of different contexts that do not require the control conditions to be set in advance can be used by the system, which will allow them to be changed by receiving feedback about user behaviors to enable the user to spontaneously control the services.

Ⅲ Context aware service control based on personal history

We propose a service control method for the HSH service manager in which a variety of contexts are available to control services, regardless of whether or not the services are relevant to the contexts. The proposed control method enables the user to control multiple home services at the same time, in response to context changes. In addition, complicated configurations do not need to be set in advance and service control conditions can easily be added or changed using the user's personal history. For this purpose, our service manager uses Bayes' rule to realize control, based on various contexts and the user's personal history.

A. Bayes' rule

Bayes' rule is a succinct, graphical representation of a joint probability distribution algorithm to extract probability values from distribution. It enables us to infer future events based on the conditional probability of past events or history. Decision-making using Bayes' rule is widely used for document classification methods, spam filtering, and as a reorganization method for situations or human activities [13, 14, 15]. The following is the decision-making key of Bayes' rule.

- Create rules based on user behaviors
- Customize by modeling past behavior patterns
- Obtain a high precision and performance easy to use algorithm.

B. Service control using Bayes' rule

If control types in which services can be applied are designed as $\{type_i;\ type_1, type_2, \cdots, type_p\}$, and situations where the user needs to control the service are designed as $\{scene_j;\ scene_1, scene_2, \cdots, scene_q\}$, then $\{type_i\}$, which the user needs to control types for the service in $\{scene_j\}$ is a $type^*$, which is represented as $type_i$ of the highest posterior probability $P(type_i|scene_j)$ as

$$type^* = \arg\max P\left(type_i \middle| scene_j\right) \quad \cdots(1)$$

When contexts collected by the system in a $\{scene_j\}$ are $\{context_k;\ context_1, context_2, \cdots, context_k\}$, (1) is changed by Bayes's rule to

$$type^* = \arg\max P\left(type_i\right)\prod_{k=1}^{r} P\left(context_k \middle| type_i\right) \quad \cdots(2)$$

This means that the service control type that the user needs in a situation can be inferred using a conditional probability calculation, based on the frequency of each context in a personal history.

C. Discrete context

In the proposed control method, all contexts should be designed to be discrete, based on a defined interval or contexts in order to apply them to (2), which uses the frequency of each context in a personal history. Therefore the integrated contexts are defined as "discrete contexts" in this paper. Moreover, some situations can be designed as a set of discrete contexts. The following are examples of discrete contexts and sets of discrete contexts in a given situation.

- Example of context: {Example of discrete context}
  - Time : {early morning, morning, noon, afternoon, night, midnight,…}
  - Outdoor lighting : {bright, normal, dark,…}
  - Temperature : {cold, cool, comfortable, hot,…}
  - Weather : {sunny, cloudy, rainy,…}
  - Location : {living room, kitchen, bedroom,…}
  - Number of people in the room : {none, one, multiple, …}
  - Video genre : {movie, cartoons, sports, comedy,…}
  - Telephone caller : {family, friend, unknown,…}
- Example situation: {discrete context set}
  - Takuya is watching *cartoons* on TV *with his father in the living room at noon*. It is *sunny*, 25 degrees outside and *bright* outside. : {noon, sunny, comfortable, bright, living room, multiple, cartoons}
  - Junko is talking to *her friend* on the phone. She is *alone in her room* at 11:00 o'clock *(at night)*. It is *rainy*, 15 degrees and *dark* outside. : {night, rainy, cool, dark, her room, one, friend}

D. Control type

Our control method controls a service based on the control type selected by (2) from the various feasible $type_i$s. Therefore the service controls should also be designed to be discrete. The service controls can be designed by combining various control elements, and are defined as "control types" in this paper. The following are examples of control elements in a video service, and the control type image is shown in Fig. 3.

- Example of video service control elements
- Run: decision to "play" or "stop".
- Mode: selection of both moving image and sound, only moving image, only sound, still image and sound, and so on.
- Device: selection of an appliance or a device, such as a TV monitor, a PC monitor, a projector, TV speakers, ceiling speakers, phone speakers, and so on.
- Link: selection of a communication link, for example, wired LAN, wireless LAN, power lines, phone wires, IEEE1394, and so on.
- Quality: selection of a moving image's quality, for example, codec, bit rate, frame rate, and so on.

If the video service has the above control elements, the control type is represented as the following.

Control type =

$$\{Run_i\}*\{Mode_j\}*\{Device_k\}*\{Link_l\}*\{Quality_m\}$$

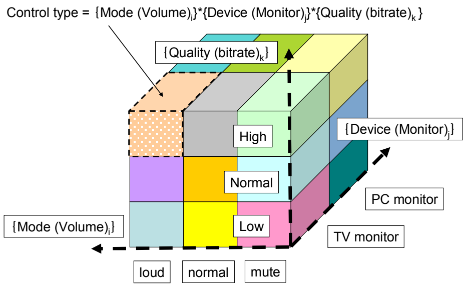

Fig. 3 Control type model for a video service

E. Personal history

To establish user preferences, a personal usage history is accumulated by relating the contexts collected in situations to the control types in which the user actually controls the service. The contexts are designed as a set of discrete contexts, referred to as *C*.; the user's controls are changed to control types, referred to as *D*.; and the number of times each discrete context for each control type is increased accumulates as the personal history.

The system can establish user patterns when the user controls a service spontaneously, rejects automatic system controls, or selects a control type from the various control types listed when it is unable to infer the control type from the system. This is because the system can estimate, and not infer the control type when the probability of $type^*$ calculated by (2) is lower than the set probability threshold value when the learning time is short. Because the personal history is accumulated this way, the inferred control type is different, depending on each user in the same situation. Hence, the proposed control method is highly adaptable to users and enhances user friendliness.

F. Scalability for context and control types

All contexts do not need to be defined and quantified because they are used only to accumulate the times of the discrete contexts using the proposed control method. Therefore, when a new context is added to the system, the context should be designed as a discrete context and the accumulated occurrences of the discrete context per situation should be added, relative to the control type the user autonomously controls. Furthermore, a new control type can only be inferred by adding the discrete context occurrences for the new control type, designed in the same way as when contexts are added to the system. Hence, the proposed method is scalable for contexts and control types.

G. Multiple service controls

As mentioned previously, the proposed control method selects the likely control type from a variety of feasible control types using Bayes' rule and a set of discrete contexts in situations and the accumulated personal history.

In this paper the proposed control method applies to the HSH service manager that controls many services at the same time, depending on each situation. In short, we selected each control type for all services according to Bayes' rule using the discrete contexts collected from all services, or by sharing contexts across different services. Hence, all services could be automatically controlled by the various contexts over home networks, regardless of whether or not the service is relevant.

Here the features of the proposed service control method are summarized, and an image of the process of automatically controlling multiple services and the process of establishing the user's pattern are illustrated in Fig. 4.

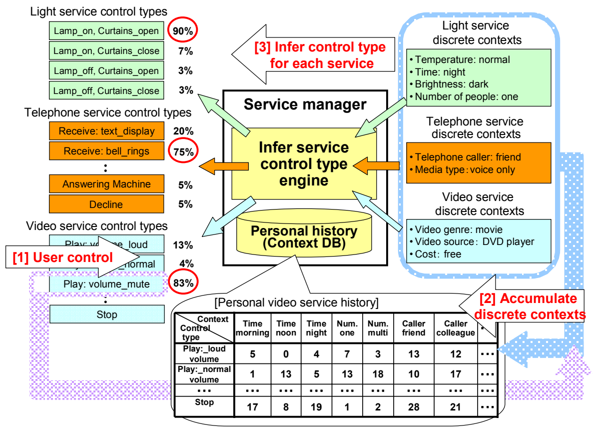

Fig. 4 Infer each service control and establish user's behavior pattern

- The control method enables the creation of control conditions for all services, based on user behaviors.
- The control method enables the selection of a control type adapted to each situation and each user.
- Various contexts are available to control services.
- The control method is not needed for changing the decision algorithms to control service when a new context and a new control type have been added to the system.
- The control method enables us to infer a likely control type in encountering situations based on

personal histories.
- The control method has a high performance and precision, owing to Bayes' rule.

Ⅳ Implementation and Experiments

A photograph of the experimental system is shown in Fig. 5. In the experimental system, sample services with the following control types were implemented using Java (J2SE1.4) on OSGi, and each service obtained, stored, the following discrete contexts and notified the service manager of them. The system was feasible for automatically controlling multiple services simultaneously, depending on each situation and based on each personal history.

- Service control types:
  - Light service: {lamp1_on, lamp1_off}*{lamp2_on, lamp2_off}*{curtain_open, curtain_close}
  - Video service: {play, pause, stop}*{volume_loud, volume_normal, volume_mute}
  - TV phone service: {image_display, image_non}*{text_display, text_non}*{bell_ring, bell_non}
- Discrete contexts collected from each service or sensors by the service manager:
  - Time: {morning, noon, night}
  - Outdoor lighting: {bright, normal, dark}
  - Number of people in the room: {none, one, multiple}
  - Video genre: {movie, cartoon, sports, comedy}
  - Telephone caller: {family, friend, unknown}

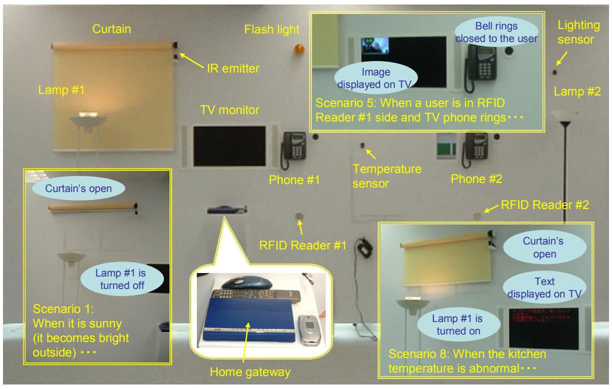

Fig. 5 Experimental system using Home Service Harmony

A. Results

The personal history was accumulated when a user spontaneously controlled services, based on the following seven scenarios prepared in advance. After establishing the user's behavior patterns, we confirmed that the system was feasible for controlling each service described in these scenarios. For example, the light service was structured by combining two lamps and one curtain, and could be automatically controlled considering the video content without changing the light service. Additionally, the video service could be automatically muted or reduced the volume depending on the caller identity, without disrupting the video service. It should be noted that these scenarios weren't achieved by setting the control conditions for the contexts in advance. Therefore the system can be used in a variety of similar scenarios.

The user needed a few sessions to control and complete each scenario and still maintains a high degree accuracy in inferring the controls, depending on individual circumstances. In addition, it took less than one second for the service manager to infer the control type of each service and simultaneously control them. Therefore, the user does not feel uncomfortable during these operations.

Hence, establishing and inferring functions of the service manager was both effective and useful. Furthermore, the system enabled us to enhance user friendliness, because the user could individually customize the system without taking time to set the control conditions.

- Scenario 1: When it is bright outside during the day, all lamps are turned off and a curtain is opened.
- Scenario 2: When it becomes dark, one lamp is turned on and a curtain is closed.
- Scenario 3: At night, many lamps are normally turned on and the curtains are closed
- Scenario 4: Then, the user begins to watch a movie and the lamps change to theater-mode. If the TV program is a cartoon, the lighting is increased to watch the program in a well-lit room.
- Scenario 5: If the TV phone rings, the image is displayed on the screen closest to the user.
- Scenario 6: If a family member calls the TV phone while the user is watching a movie, the video volume is reduced and a ringing sound is heard and both the image and the "Family caller!" text are displayed for the user.
- Scenario 7: If the caller is unknown, the volume isn't reduced and there is no ring tone –just a text message saying "Unknown caller!" is displayed, and the movie is not interrupted.

Because personal histories are compiled based on the number of discrete context times for each control type for each service, the system can easily handle a new context to control services without changing control conditions or the decision algorithm setting, when the system obtains the new context from services or home networks. Adding to these scenarios, if the system's temperature sensor detects an "abnormal temperature" near the stove in the kitchen, Scenario 8 is realized.

Through these experiments, we found that the system has high context scalability and adaptability to many situations, because new contexts or service control types are easily added to the system.

- New discrete context
  - Temperature near the small kitchen range: {normal, abnormal}
- Scenario 8: When the temperature in the kitchen increases because the user forgot to put a pan on, the light service automatically turns on all the

lamps and opens the curtain to create an escape route. Then, "Kitchen, abnormal temperature!" text appears on TV to warn the user of danger.

Ⅴ Related works

HSH and the service manager are related to context aware services, adaptive networking services, and user modeling. While there has been a lot of research on these services, HSH differs from previous applications or services on many points.

Most context aware services are based on location and time contexts [1, 9, 10], and some work has recently reported the extraction of more complex contexts, such as user activities and environmental conditions [11, 14]. But they basically cover a fixed independent service, so they cannot handle multiple services depending on situations or share contexts across different services. There is some research on systems that enable the coordination of two or more predetermined services [16, 17], but they restrict combinations of services, or require users to set a priority for each service. Therefore, they lack scalability, adaptability, and user friendliness. Further, traditional adaptive networking services can be structured and controlled, depending on the situation [3, 10, 11], but cannot easily be customized to the individual, such as adding new contexts and changing control conditions, because they are structured based on service templates prepared in advance and controlled based on predetermined control conditions for a given situations. Finally, previous user modeling research, based on data mining approaches, such as Neural networks or Bayesian networks, can achieve highly precise reorganization of human activities or situations [13, 14, 15], but they are used only to identify user states or activities and as simple schedules for the user's upcoming activities. Therefore, they cannot be effectively applied to structure network services or control services.

Ⅵ Conclusions and future work

In this paper we proposed a service control method for the HSH service manager that applies Bayes' rule to control service decisions, and described an experimental system and some scenarios realized by the system. The system enables the provision of situation- and user-oriented home services by controlling many services at the same time, based on various contexts collected over home networks and a personal history. Moreover the system has context scalability and enhances user friendliness because it can be spontaneously customized and new contexts and control types can easily be added to the system without changing the decision algorithm and setting complicated configurations for control conditions.

In the future, we will evaluate precision and user modeling when the number of situations is increased. In other words, we will raise the number of contexts collected in the system and create a wider variety of service control types. We will also consider how to design and represent contexts to more effectively establish the user's behavior patterns.

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