

Object Negotiation Mechanism for an Intelligent Environment Using Event Agents

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Abstract—With advancements in science and technology, the concept of the Internet of Things (IoT) has gradually developed. The development of the intelligent environment adds intelligence to objects in the living space by using the IoT. In the smart environment, when multiple users share the living space, if different service requirements from different users arise, then the context-aware system will have conflicting situations for making decisions about providing services. Therefore, the purpose of establishing a communication and negotiation mechanism among objects in the intelligent environment is to resolve those service conflicts among users. This study proposes developing a decision-making methodology that uses “Event Agents” as its core. When the sensor system receives information, it evaluates a user’s current events and conditions; analyses object, location, time, and environmental information; calculates the priority of the object; and provides the user services based on the event. Moreover, when the event is not single but overlaps with another, conflicts arise. This study adopts the “Multiple Events Correlation Matrix” in order to calculate the degree values of incidents and support values for each object. The matrix uses these values as the basis for making inferences for system service, and to further determine appropriate services when there is a conflict.

Keywords—Internet of things, intelligent object, event agents, negotiation mechanism, degree of similarity.

I. RESEARCH OBJECTIVES AND BACKGROUND

SMART Living is receiving attention from the general public gradually. IoT was begun mainly out of a very primitive idea of providing the benefits of ubiquitousness and convenience by applying Smart Tag and Sensor Network ubiquitously and by presenting massive real-time data in IoT, thus leading to the emergence of a new form of interactive context. With these purposes in mind, the major factors of consideration are therefore creating various service contexts based upon the needs of the user and providing the services that the user expects by leveraging the feature of ubiquitousness of IoT. In a sensor environment, context-oriented method is the most economical way of building information capture platform of IoT in a Cloud Computing environment and of developing the service program to access User Portfolio in the Cloud for recording and managing data from various sensors, such as RFID, ZigBee Sensor, GPS, and temperature, humidity, and ambient light sensors. Data from various sensors, as well as ambient information are automatically collected through deployment, management and control of various kinds of sensor, and are stored in the IoT Repository, and are finally stored in the Cloud database by employing a Context Agent which integrates the data into a Contextual Portfolio file with

semantic illustration.

The development of the Intelligent Environment has made habitable space and becomes even smarter thanks to the application of IoT. The occupant of the space then interacts with various kinds of smart objects in the environment, including mainly smart appliance and equipment. The interactive environment records the behaviors and activities through sensors while computer computes in real time and generates event information and dynamic message, and eventually makes judgments for the response and provides feedback to the space. The smart behaviors of the objects are therefore achieved through personal feedback model, including controlling the temperature of dining room, turning off the light in the living room, and turning on the stereo system in the bed room. Once made smart, the objects then possess the ability of receiving, transmitting, and processing information; therefore, how smart objects in the space sense and transmit information, and how objects communicate with each other in order to service the user are the subjects worth of discussion.

In conclusion, this study believes that the material, the forming of space atmosphere by using lamp, and the functional satisfaction are not the only factors that an environment designer should consider in designing a habitable space; he/she needs to further consider the dynamic relationship in the communication among objects. Furthermore, conflicts may arise when the context-sensing system makes decisions with respect to the provision of service if multiple users are sharing the same space and are generating different service needs; therefore, the purpose of creating a communication mechanism among objects in an intelligent environment is resolving the issue of conflict in providing services. With this in perspective, this study proposes a decision-making method based on an “event model.” An event model is defined on the basis of a location (such as living room), listing the events that may happen in each location. Smart Object, Location, Time, Environment Information and User Information are the five major dimensions in the study. The on-going event of the user is evaluated after the sensor system receives information; smart object, location, time, and environment information are analyzed according to the status of the user; and the weight of use is calculated; finally, the user service is provided in response to such an event. If there are multiple and overlapping events, the issue of conflict may happen. This study creates a relation matrix for multiple events and calculates the degree of the event that happens and the levels of support provided by each smart object, as the basis in determining suitable service, provided by the context system in a conflict. A set of procedures used to assist the designer in planning a needed

context model is therefore offered through creating the method and standard of an event model.

II. RELEVANT THEORIES AND TECHNICAL DISCUSSIONS

Important studies relevant to this subject are further discussed and explained in terms of the objective of this study as follows:

A. Communication among Objects in an Intelligent Environment

Human physiological perception includes physiological changes such as body movement, body temperature, heartbeat, blood pressure, and so on. They can be analyzed by computer and developed into a dynamic information model. As an extension to the subject of intelligent environment, the studies of Bosse et al. [5] point out that an intelligent environment must satisfy three requirements in order to provide people-oriented service, making it consistent with ubiquitous and intelligent computing:

(1) Internal network: all digital appliances in an intelligent environment should be able to interlink with each other, forming an internal network. (2) Smart control: smart object and service in an intelligent environment can be centrally controlled via remote control, whether the control is requested indoors or outdoors, while control interface can be a computer screen or a smart phone. (3) Automation: an application for indoor housework automation. In view of this it is understood that as the number of technicians required by the sensor group deployed in an environment increases, a set of smart application of a smart agent model is required to coordinate and handle the issue arising from any conflict sensed between the environment and human. This way the environment can function as a real intelligent environment. The attributes that coordinate smart objects can be divided into five categories while smart objects under the categories of Passive and Reaction are mostly used in a family context. These two categories alone do not constitute a smart agent. Proaction, Interaction, and Communication are three categories of behavioral model; they are smart object constructions which are mainly smart agent-based. In summary, the major difference between smart objects under the categories of Passive and Reaction lies in the perception mode of sensor. Smart object of Passive category must receive user message before it can react while those under Reaction category detects external information and then reacts. The smart object under Proaction category is equipped with a computational judgment mechanism and it can make adjustment with respect to user identity and the service needed in order to choose the optimum solution. Smart object under Interaction category must be equipped with human-machine interface as a dialog mechanism for user and is capable of coordinating should a conflicting event arises. Smart objects under Communication category must possess a generic communication protocol, such as Bluetooth, Wi-Fi, ZigBee, and Cloud database.

B. Important Literature on Criteria Dimension of Context-Aware Model

Table I illustrates interested features of this study in constructing a context-aware model, i.e., the center of this study, including Proaction, Reason, Human-oriented, and Communication. This study considers that these four features are four important indexes in constructing a context-aware model. Communication is the most important feature of the four. If the system has the capability of reasoning, it will help in the determination of the changes of human behavior and environmental status; then the system is enabled to provide service voluntarily with human-oriented features. If different needs arise among different users, a conflict will happen in determining the service to provide; therefore, the context-aware communication mechanism is more important. Based upon the consideration above, this study will consider the feature of Communication as the core feature.

TABLE I
THE FEATURE OF SPECIAL INTEREST OF THIS STUDY IN CONSTRUCTING A
CONTEXT-AWARE MODE

Feature	Remark
Proaction	Context-aware system voluntarily provides the most suitable service and information based on human behavior or environment information.
Reason	Procedures and methods of applying awareness information.
Human-orientation	Since human is the major object of service in a context-aware system, the development of context-aware system thus puts emphasis on user equipment.
Communication	Context-aware system is about information sharing and providing better and more suitable service.

The smart perception living space, called Inphase, was proposed jointly by Hitomi et al. [8]; it expands the connections between people and family environment object and emphasizes a more natural human interaction. The on-going event that the other family members are involved is communicated through prompts given indoors, allowing interlink of activities that happen in different spaces. Similar case studies include Spatial Context-aware Building Data Model proposed by Lertlakkhanakul et al. [14]. In such a study, the spatial context-aware data model consists of five major elements - User, Activity, Context, Space and Object, which are an integral part in designing the interaction among themselves. When a constructing element of a real space is embedded into each object of the sensing device, each object then includes the sensor module that is carried. When user is engaged in his/her daily activity in the real space, the user event is then recorded by the sensing device embedded in the objects used in daily life, such as floor, partition wall, furniture, and home appliance. The information will be recorded continually; the dynamic information, computed by computer, is compared and made judgment for using the analysis method of the system against the rules defined in the behavior database; the dynamic information is then fed to the object which is capable of providing feedback. Such is a cycle of the dynamic information. As a result, in addition to the most important feature, communication, among the four indexes above, this

study focuses more on spatial "communication mechanism among objects" in constructing a context-aware model. Communication mechanism among objects will be further explored and analyzed in this study.

C. Event-Based Context Information

The context-aware model indicated in this study receives various context information on the basis of "event" and all context information is categorized into groups. The event is defined by quoting the viewpoint of Tan et al. [18] and is categorized into two groups: Primitive Events and Composite Events. Primitive Events are those at the lowest level; they all are the information received by the sensor, such as current time and temperature. On the other hand, Composite Events are the new events which are generated from handling and merging the Primitive Events, such as the events: "the user is surfing the Internet" or "the user is sleeping." A Composite Event combines multiple pieces of information and it is the type of the event that is defined in this study. All possible events that may happen in each space are listed on the basis of location while the content of such an event is based on five pieces of information that such an event must use - Object, Location, Time, Environment, and User [7], [6]. The tree structure of the five pieces of information vs. event is shown in Fig. 1, indicating each information that the event receives. The content of the five pieces of information is illustrated as below:

- 1) User information: a description about a particular user which defines his/her basic information and the event that he/she may involve, and records the information about the event that he/she may involve
- 2) Environment information: a very important role in the process of the reasoning by a system due to the user's continual interaction with the equipment in the environment. With the environment information received

by the sensor, the information needed in the analysis of the event and required for the event of reading a book in the study room may be listed, such as temperature, illumination, and etc.

- 3) Time information: a list of times when an event may happen; the time is defined in three kinds: (1) a precise time, e.g. 9 A.M.; (2) a duration of time, e.g., from 1:00 to 3:00 P.M.; (3) an abstract time, e.g. noon or morning.
- 4) Location information: a description of the location where the event may happen; all possible and qualified locations must be listed since there may be multiple locations
- 5) Object information: the object(s) the user may use in case an event happens; with the recording of the objects being used by the user, the user's activity, such as watching TV in the living room or sleeping in the bedroom, may be concluded from reasoning

Human has a different behavior in a different environment as illustrated in the relationship between human behavior and environment. An intelligent environment must be capable of providing service to the user voluntarily and such a capability relies on the reasoning of context-aware system which chooses, among multiple services, the one that is most suitable to meet the current need of the user, based on information obtained. The accuracy of reasoning depends on the information obtained. If the information received is more complete and accurate, it will help better the suitability of the service chosen in the process of reasoning. Therefore, the analysis of the event that the user currently involves requires the analysis of the object(s) because the service is provided by the object. The event-based context-aware model proposed in this study takes control of the object(s) in the environment; in other words, it can distinguish events.

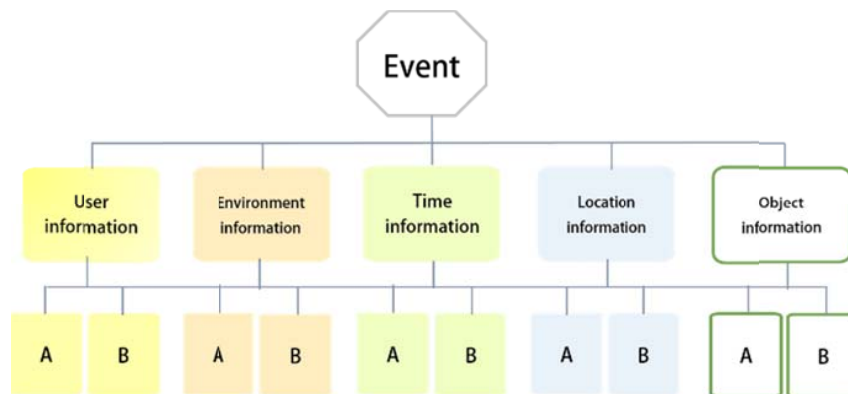


Fig. 1 Event-based Context Information

D. Conflict Coordination Mechanism in an Intelligent Environment

Intelligent environment aims to provide the user a comfortable and convenient environment for living while service device determines the suitable service based on the user's preference for needs. In the realization of the goal of smart home, it is inevitable that conflicts will arise in meeting

service needs of multiple users. A conflict happens mainly due to sharing of a common space by multiple users. In such a scenario, the system must provide services simultaneously to all environment users who have their own preference and habits; therefore, it is essential to resolve the conflict that originates from multiple users [12]. In the study of conflict coordination mechanism, Shin et al. [16] have proposed the

User-oriented Conflict Management Mechanism which resolves a conflict by using context knowledge and personal action partner. Context knowledge includes User Information, User Preference, User Service Document, Service Device Code and Service-required Information. Personal action partner assists the user in controlling preferred service device. Through the process of conflict detection all conflicts generated by all users who access the same service are displayed in the screen of the personal action partner. With the process of service suggestion, a suggested service list is displayed and a re-sorted service list by personal preference is provided. As a result, how other users choose the service may be revealed and the conflict may be resolved. Shin et al. [17] further divide the Conflict Resolution Mechanism in an intelligent environment into two sub mechanisms - Auto Conflict Resolution Mechanism and Coordinated Resolution Technique Mechanism. In the past, Auto Conflict Resolution Mechanism failed to generate optimum solution because user's intent and need may change dynamically while coordinated technique can provide the user multiple kinds of conflict resolution information, provided that the user actively participates the process of resolution. Mises [15] mentioned that human behavior is intentional because all human decisions are made on the basis of sorting. A behavior consists of many behaviors and happens for some purposes. This study applies such a viewpoint in determining the human behavior while many studies also adopt similar approach, such as Anagnostopoulos, et al. [1], [2] who used this approach to build their ontological arguments to display the knowledge of all circumstances and to find the probable circumstance in the now through fuzzy match.

The literature above tells us that the design method of multiple-user conflict resolution mechanism has already been proposed in relevant studies of intelligent environment. Although the study of Shin et al. [16], [17] determines the service provided, based on calculated weight of the user's service, the user's need changes with time and environment as an intelligent environment is changeable. A user need-oriented coordination mechanism design is therefore required. In order to address the constraints coming with two methods above, this study suggests to employ user priority, context attribute, and preference for reasoning the event that involves the user, and apply them in conflict resolution. The coordination technique system is used to list candidate solutions which is then provided to multiple users for discussion and choosing. The event-based context information categorization method defined in Sections II and III is used to form five concepts - People, Time, Location, Object, and Environment; the Degree of Similarity (DOS) is used to calculate the degree of similarity between the event, and individual user's information, time, location, object and environment information; and such a degree value is the value of the Similarity function whose concept comes from the Similarity function suggested by Anagnostopoulos, et al. [1]. DOS will be matched by following the algorithm if a certain circumstance happens and the match result can help the system identify the circumstance which the user is in.

E. Spatial Event-Based Object Coordination Mechanism in an Intelligent Environment

Based on the theoretical base and the literature above, four perspectives are discussed: communication among objects in an intelligent environment; framework and criteria dimensions of context-aware model; event-based context information; and conflict coordination mechanism in an intelligent environment. The theoretical model of this study is then proposed. With sensor technology as the base and the script of life for user's resident space as the center, the user(s) is engaged in various activities and behaviors in the living space. The condition with single user and the condition where multiple users share the space may generate different events and the way the service is generated is also different. Therefore, the user's behavior must be recorded through the objects in the space; and the information collected is converted by the event agent to the data which are transmitted to coordination agent system for storage. The main purpose is to determine whether the service needs suggested by the event agent creates any conflict. Once a conflict occurs, coordination mechanism can be initiated while the computed coordination result is provided to the service agent. There are also feedbacks among four perspectives, as shown in Fig. 2. The figure shows that the main functions of the event agent are: issuing a service request to the coordination agent in behalf of the intelligent environment while the number of event agents depends on the number of users; interacting with coordination agent; and the coordination agent's coordinating the service need and service provision of the event agent. In the other words, once any conflict in service need arises among event agents, it will definitely cause difficulty in providing service. Although one user's need may be met, consequently the other users' needs may not be satisfied. The role of the coordination event has become even important. Finally, after the coordination agent walks through conflict resolution mechanism, the service agent will provide to each object the message indicating completion of coordination, so as to achieve the purpose of providing suitable service in a multi-user environment.

III. CONTENT OF STUDY

Based upon the literature above and the objective of this study, the content under discussion in the study are: (1) creating an environment information model and analyzing the radial hierarchy chart of event construction based on floor plan; (2) how to reason to determine on-going event of the user upon receipt of context information and how to apply the calculation of DOS to reason and determine the event that is most likely happening; (3) the calculation of DOS; (4) analysis of script of life - after user event is reasoned and determined with the calculation of DOS, suitable service is provided to the user by applying the concept of personal "event package." The details of how each content is implemented are described as below.

A. Creating an Environment Information Model and Analyzing the Radial Hierarchy Chart of Event Construction Based on Floor Plan

This study uses a nuclear family as an example in its case

study. There are four members in this family – Mr. Smith, Mrs. Smith and their son and daughter. Mr. Smith, over 40 years old, is the owner of a medium size business. His hobbies are reading and travel. His friends often visit him at home. He likes to have coffee and chat with friends and spend most of his time in front of his computer. Occasionally he goes hiking in the mountain. Mrs. Smith stays home most of the time. She is a very good cooker. Occasionally she would invite friends over for a meal. She likes coffee, arts, and crafts. She often goes for a walk in the country side and travels overseas. The building site is located on Taiwan Boulevard, Taichung City with a total area of 165 square meters. In the floor plan (as shown in Fig. 3), the public space consists of a living room, a study room, a dining room and a kitchen while the private space includes master bedrooms, the son's and the daughter's bedrooms.

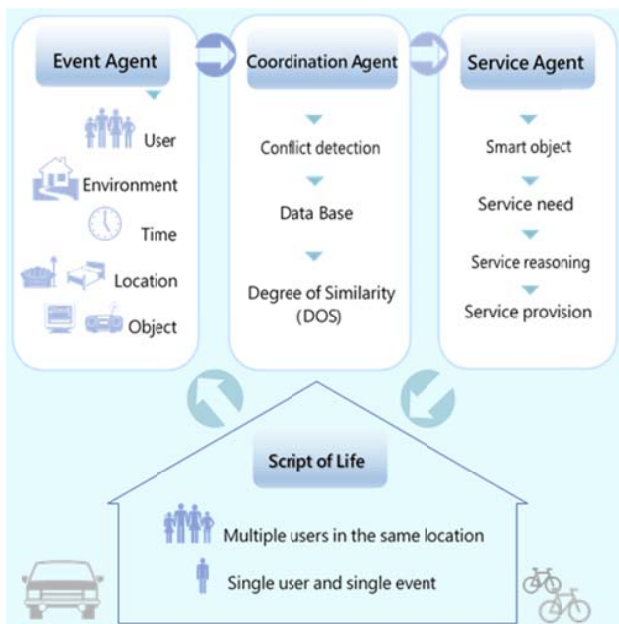


Fig. 2 Spatial Event-based Object Coordination Mechanism in an Intelligent Environment

Tree structure is considered as a more reasonable and complete approach as seen in several studies on the subject of environment information of an intelligent environment [3], [4], [9]-[11], [13]. The environment models used in these studies are all tree structure-based. However, as far as the Cloud computing environment of IoT nowadays is concerned, the drawback of a tree structure is its focus on vertical context and its lack of horizontal relationship in the network communication. Although the environment model of this study cites the fundamental principles as adopted by the scholars mentioned above, it is somewhat different from their tree structure. An alternative approach has been adopted to transform the floor plan to an environment model of "radial hierarchy," as shown in Fig. 4. The whole environment model is divided into three levels while the innermost level is "Environment Level" which marks the starting point of the environment model with a purpose of distinguishing a public

space from a private one. The second level is "Location Level" which is the spatial distribution of a smart home, consisting of a living room, a study room, a dining room, and bedrooms. The third level, also the most important one, is "Object Level." After the spatial distribution of a smart home is determined, the system must be aware of the service(s) or the user information equipment each space may provide. Object Level will record the information of the object equipment that each space possesses. Through the radial hierarchy chart analysis, the environment information relationship of a smart home is presented. The elements in each hierarchy in the radial hierarchy chart interlink, indicating the relationship among elements. The Object Level is distinguished with Location Level, indicating the equipment in various rooms; the information of the equipment existing in each space will be recorded. Therefore, only the equipment in the same room may have communication with each other. The relationship among elements in each level is presented with radial hierarchy relationship approach; various events are further distinguished in terms of space. The complexity of event occurrence analysis may be reduced with this approach.

B. Apply the Calculation of DOS to Reason and Determine the Event

Environment changes over time. It takes reasoning to know the event that may happen. Above section mentions that various kinds of context information are received in the basis of "event" in this study, and DOS calculation is used to determine the DOS of event with respect to individual user's information, time, location, object and environment information, i.e., the value of Similarity function. Similarity(*si*) function is used to calculate the DOS of event with respect to time, location, object and environment information and user information. When a conflict happens, DOS will be compared with the values from calculation. The result may help system identify the situation the user is in, and the likelihood of an event is shown with the index of DOS which is the calculated result of Similarity(*si*) function for event occurrence. The formula of DOS is shown as follows:

$$DOS = \left[\sum_{i=1}^s \frac{\text{Similarity}(si)}{s} \right] * 100\%, i = 1 \sim 5$$

where *s*1 is time, *s*2 is location, *s*3 is object, *s*4 is environment information, and *s*5 is user information. This is how calculation is done:

IF (*i* = 1 and consistent with the time defined for the event) OR (*i* = 2 and consistent with the location defined for the event) OR (*i* = 5 and consistent with identity of the user and consistent with the event that the user may involve)

IF (*i* = 1 and inconsistent with the time defined for the event) OR (*i* = 2 and inconsistent with the location defined for the event) OR (*i* = 5 and inconsistent with identity of the user OR (*i* = 5 and inconsistent with the event that the user may involve)

IF *i* = 3 [number of objects being used/total number of relevant objects]

IF *i* = 4 [number of environment information being received/total

number of relevant environment information]

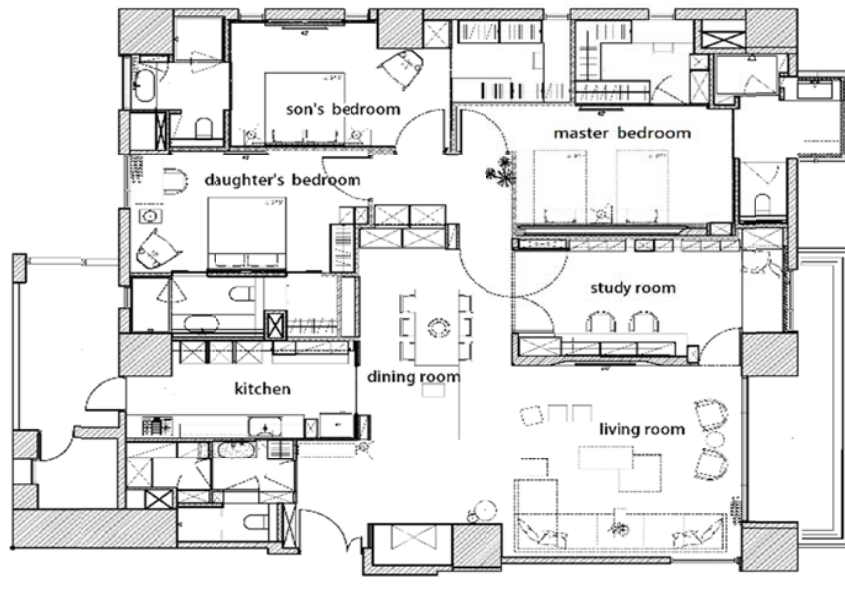


Fig. 3 Floor plan of the Smith's House

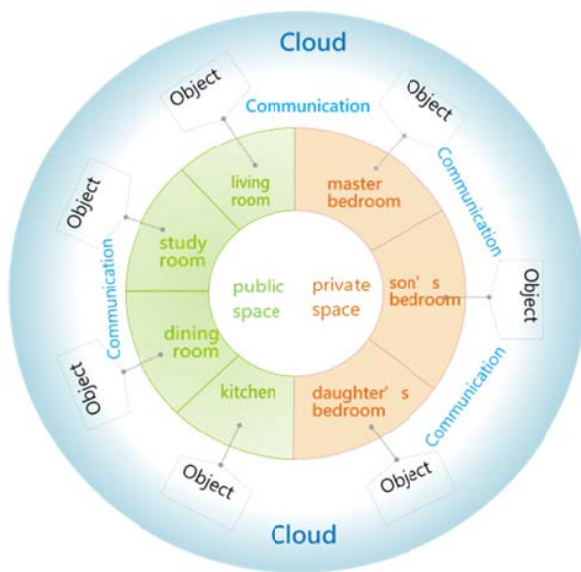


Fig. 4 Radial hierarchy chart of spatial event structure

Among the five kinds of information used above, there are three kinds of "time": (1) abstract time, such as morning and evening; (2) precise time, such as 10:00 A.M.; (3) a duration of time, such as 10:00 A.M. to 12:00 P.M.. As far as "time" is concerned, there several kinds of time when an event may happen: having meal may happen in the morning, noon or evening, for example. Let's assume that an unknown event happens at one of the time settings; we can then determine, to some degree, whether such an unknown event is Event A. However, there can only be one time for occurrence of an event, i.e., the time of event occurrence, so it is specified that only one

event time is possible among morning, noon and evening.

As far as "location" is concerned, there are several possible locations for an event to happen (such as living room or bedroom). Let us assume that an unknown event happens at one of the location settings; we can then determine, to some degrees, whether such an unknown event is Event A. However, there can only be one location for occurrence of an event, i.e., the location of event occurrence (such as living room), so it is specified that only one event location is possible among these settings.

As far as "object" is concerned, the objects being used at the time of event may be more than one object and several objects may be used simultaneously. Therefore, how the object is calculated may be different from how time and location are calculated. In this study the objects used by the event are divided into two kinds: object which is being used and object which is related to the event.

As for "environment information," environment information relevant to the location and received at the time of event is calculated in the same way as the object information is calculated. Since various kinds of environment information may be received, the environment information is divided into two kinds: the environment information of the event and the environment information which is being received.

As for "user information," the user information received at the time of the event can be divided into two kinds: the basic user profile information (salutation or name), such as Mr. Smith in the case study under this study; special information of the user, such as the complete list of all events that the user has involved and the events that happened at each time and each location yesterday, as recorded in the historical information.

C. The Calculation of DOS

1) Calculation of DOS of Time and Location vs. Event

"Mr. Smith was doing architectural drawing in the study room in the afternoon:"

Similarity (Time) = 1 (Morning, Noon, Afternoon, either one of the three, then "1")

Similarity (Location) = 1 (Living room, Study room, either one of the two, then "1")

$$\text{DOS (Degree of Similarity)} = [(1+1)/(1+1)] * 100\% = 100\%$$

How Similarity(si) is calculated: an event may be involved with several kinds of objects simultaneously as opposed to single choice with time and location; therefore, the calculation of Similarity(si) of object should be modified as below by employing, in calculation, the ratio of objects involved to the total number of relevant objects: $\text{Similarity}(si) = 1 * [(\text{number of objects being used}) / (\text{total number of relevant objects})]$, where si refers to object.

2) Calculation of DOS of Object vs. Event

Involved objects in the event are worktable, light, and electrical fan, three pieces in total;

Objects which are being used are worktable and light, two pieces in total:

$$\text{Similarity}(si) = 1 * [(1+1)/3] = 2/3$$

$$\text{DOS} = [(12)/(13)] * 100\% = 66.7\%$$

Combined with "Time," "Location," and "Object," the DOS of the "Drawing" event is as follows:

In the event of "Mr. Smith is in his study room at noon and the objects, worktable and light, are being used," it is thus:

- Location relation function Similarity (1)= 1
- Time relation function Similarity (2)= 1
- Object relation function Similarity (3)= $1 * (2/3)$
- DOS of Drawing event = $[(1+1)/(+1+1)] * 100\% = 89\%$

D. Analysis of Script of Life

This section explains how an event conflict arising from single or multiple users is reasoned through calculation and how to provide the most suitable item to service agent with computed coordination model of the event agent.

1) Single User and Single Event Model

The system can provide service(s) to the user when it determines the event with which the user is currently involved. The relationship among events, after the event agent group receives the five pieces of information of such an event, is shown in Fig. 5. Table II shows that the possibility of occurrence of "digital drawing" is 91.6%; the service content for such an event is thus determined and provided to the user. When the system determines that the current event is "digital drawing," the event agent group searches for facts about such an event and loads relevant rules with respect to both the event and the fact; a notification is passed to the service agent which lists items of each service, such as adjusting the temperature and fan speed of air conditioner or turning the light to the brightest illumination.

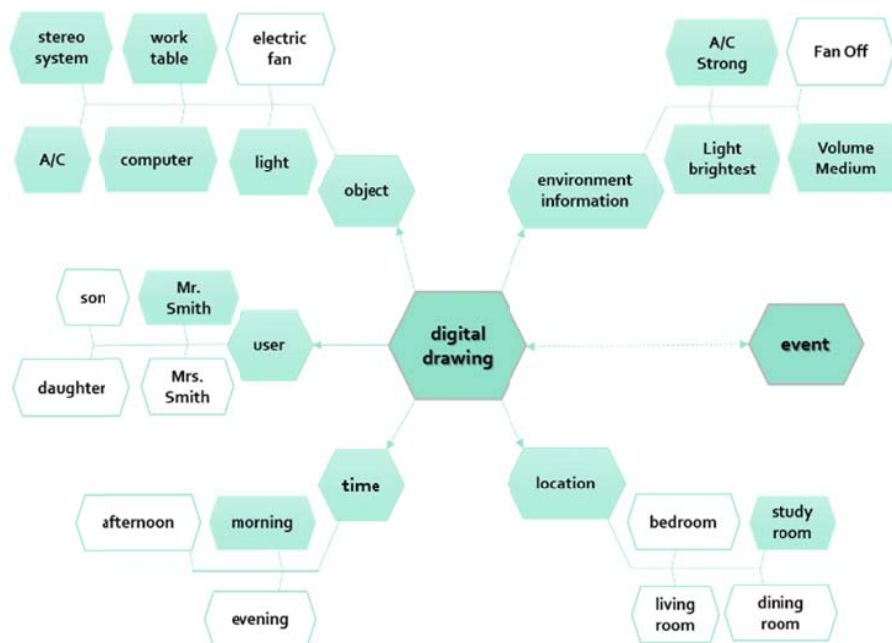


Fig. 5 The digital drawing event agent group receives the five pieces of information

2) Single User and Multiple Event Coordination Model

The issue with DOS of event may arise from the event(s) that involve single user. The rules of multiple events may conflict with each other; therefore, the system must resolve such a conflict in accordance with the event priority determined by the coordination agent and load the most suitable rules as the basis in reasoning. Take the calculation of two events - digital drawing and reading - for example, the DOS of event "reading" is shown in Fig. 6. Table III lists likelihood of the occurrence of digital drawing as 91.6% which is more than that of reading event, 80%. Such a message is passed to the service agent to provide the user the most suitable service item.

The main purpose of the operation mechanism process is for system to conclude that the user is working in the study room from the first reasoning result and, in the meanwhile, to detect the devices available for providing service(s), such as a stereo system, an air conditioner, and six light bulbs; the service agent then can provide chosen service(s) based upon computed result by the event agent and coordination agent, thus concluding that the current event is "digital drawing." The record of the event agent shows that music service, temperature service and lighting service were provided to the user before. Among

different genre of music (such as pop and classical music), the user prefers classical music; therefore, the system activates the device radio that is coded as Classical Music. In the case of Temperature Service, since the user prefers the temperature of 23 °C and a fan speed of Medium, such preference information is made known through event agent, and temperature and fan speed are adjusted to 23 °C and Medium, respectively. In the matter of Lighting Service, as the user's preference is turning on all six light bulbs, the system thus activates all lighting devices.

TABLE II
DOS CALCULATION TABLE FOR SINGLE EVENT

Event name	Digital drawing
User information relation function	
Relate (user information)	1
Environment information relation function	
Relate (environment information)	3/4
Time relation function	
Relate (time)	1
Location relation function	
Relate (location)	1
Object relation function	
Relate (object)	5/6
DOS	$[(1+3/4+1+1+5/6)/(1+1+1+1+1)]*100\%=91.6\%$

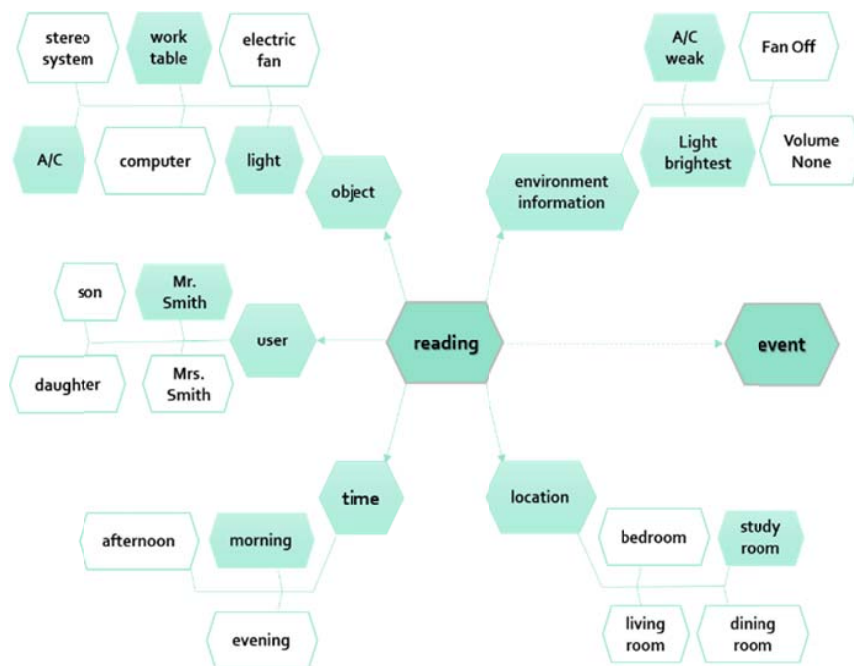


Fig. 6 The reading event agent group receives the five pieces of information

3) Multiple Users in the Same Location

The multiple-user context may happen in a space where a conflict in the conditions of temperature and lighting arises from two users in the same space. Take temperature for instance, if Mr. Smith (User A) feels comfortable in the temperature range of 22 °C - 24 °C while the comfortable zone of Mrs. Smith is 23 °C - 25 °C, we can manage to provide the control model of various degrees by using maximization and maximization of the fuzzy logic. This study uses the logic

operand AND to obtain the value of a "minimized" and user-oriented membership function. As a result, the overlapped temperature range is 23 °C-24 °C in which the optimum temperature may be obtained and both users may be satisfied. The comfortable range can be obtained by tracing and learning from the user's behavior model. If there is no overlapped range between users' comfortable ranges, then the users can enter updated information and store it in the agent group (e.g., user A and user B = agent group AB); the value of comfortable range is

hence generated, which is called the Value of Common Understanding under this study.

Generally speaking, an event may be made known from the first reasoning; however, such an approach may cause the following issue: a new rule must be added to determine the kind of service the system should provide when the services provided to two events by the system have any conflict. For instance, Mr. Smith watches TV while eating, the system does not know if it should turn on or turn off the music service. Therefore, a new rule must be added to resolve such a conflict. However, the conflict increases with the complexity of the environment, leading to more and complicated rules, as shown in Fig. 7. Therefore, this study adopts the concept of personal "event agent" to wrap up the services in packages provided by the system and to distinguish the packages by events. Each event agent group is an independent unit. Therefore, the complicated rules can be coordinated into a simple package, as shown in Fig. 8. Event package contains the demands of all services, and the event services of various events can be adjusted through setting up. Each event has the record of DOS calculations; therefore, suitable service may be determined through calculation and comparison of events when there is any conflict between the services offered.

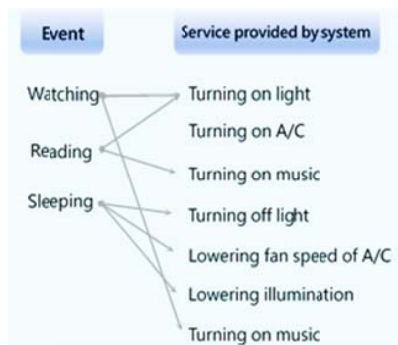


Fig. 7 Complicated Rules



Fig. 8 Simple Event Package

IV. CONCLUSION AND SUBSEQUENT STUDIES

The environment information model of the case study under this study is completed on the basis of the result obtained so far. The Event Radial Hierarchy Chart is obtained by transforming the floor plan, leading to the development of the "Event Agent" model and coordination mechanism for the situation where a

conflict exists among multiple users in case multiple events occur simultaneously. The script of life of the family members (users) in the case study of the house is verified by the event agent; and a set of solution is provided for the building and interior designer to evaluate the needs of the smart home logically.

TABLE III
DOS CALCULATION TABLE FOR MULTIPLE EVENT

Event name	Digital drawing	Reading
User information relation function Relate (user information)	1	1
Environment information relation function Relate (environment information)	3/4	2/4
Time relation function Relate (time)	1	1
Location relation function Relate (location)	1	1
Object relation function Relate (object)	5/6	3/6
DOS	$\frac{[(1+3/4+1+1+5/6)/(1+1+1+1+1)]*100\%}{91.6\%}$	$\frac{[(1+2/4+1+1+3/6)/(1+1+1+1+1)]*100\%}{80\%}$

In an actual environment, it is difficult for an independent agent to complete the task alone; agents in the agent group must coordinate and collaborate to resolve the problem faced. The independent agent may not be able to address the problem with the factor of "weight" alone, given the complexity existing in the actual environment. When the agent faces the dilemma in conflict, it takes agent group to take action to resolve the problem. The event agent under this study is applied in the area of smart home service. The system seeks the service device available based on user location. The user can make favorite settings to the device and such settings will be stored in the event agent group to help the system make service decision. For instance, the system detects that the user is eating in the dining room and there are devices in the dining room, such as a stereo system, lights, and an air conditioner. The services that the service agent can provide include temperature, light, and music services, and so on. The system detects from first reasoning result that the user is eating in the dining room, and, in the meanwhile, detects the devices available for providing service(s), such as a stereo system, an air conditioner, and four light bulbs; the service agent can then provide chosen service(s) based upon computed result by event agent and coordination agent. If no event agent is created, the system may help the user find many services. Since the system does not know the user's preference, the user then is required to verify the services one by one. If the system has the event agent which stores the record of user events, then it can determine itself and satisfy the needs of the user based on his/her habits and preference.

Communication and coordination is a natural and efficient way of decision making because the information is exchanged to find the optimum balance point. In view of this, this study employs the decision making approach of "event priority" with which user's priority assigned to the events are compared and the decision in a conflicting situation can be made automatically. For instance, the priority of "digital drawing" is higher than that of "reading." When the user is doing digital

drawing and listening to music simultaneously, the system would only consider the services needed for "digital drawing" while the service for "reading" would be ignored. Moreover, it is also found that there is a difference in the degree of involvement with respect to Time, Object, and Location in an event, such as the case in which the event is influenced by time more than by location. The calculation mechanism offered by this study cannot solve this problem at the moment; therefore, it will be the subject of an extended study under this study. Objects of communication model and the multiple factors that establish the trigger sequence in linking objects will be created continually in addition to the use of mere weight in making decision.

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