Construct a Commonsense Knowledge Model of Activities in Urban Leisure Space with the Spreading Activation Theory

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ABSTRACT

This paper presents a semantic network of commonsense knowledge that is useful in capturing human experience in ambient intelligence environments. Human behavior is composed of a series of behavior patterns. And a behavior pattern contains behavioral features, such as the objects touched by users, time, and location information, within a period of time. Consequently, in this paper, the algorithm of the spreading activation model is adopted. Each behavior node is inferred based on the possibility of what behavior may happen next and on their mutual relationships. In the spreading activation model, various weights are put into certain nodes and checked to see if some behavior nodes are enabled under such a circumstance.

Keywords: commonsense knowledge modeling, spreading activation, smart city.
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1 RESEARCH PROBLEMS AND PURPOSES

With the coming of ubiquitous computing era, and at the time when an intelligence platform integrated by electronic communication industry and living space is gradually being formed, researches on the issues related with smart living space, future office, smart city and so forth, have been the main priority in most advanced academic researches and industrial development in all nations in the world. In famous studies of the past few years, including “MIT Project Oxygen” [1] of the Massachusetts Institute of Technology, “Aware Home” [2] [3] of the Georgia Institute of Technology, “The EasyLiving Project” [4] of Microsoft Research, and “Vision of Ambient Intelligence” of Koninklijke Philips Electronics N.V. (Royal Philips Electronics Inc.), a concept of the operational mechanism and intelligence that are hidden behind the space and that can instantaneously respond to user needs is particularly emphasized. Also included are three important innovative connotations; that is micro-operation, the usage of interface design, and the omnipresent communication network.

However, academic researches and industries put more efforts in the development of the sensor structure, to create a digital environment which can sense, adapt, and react to the activities of human beings with the sensor being put into the ambient intelligence. Usually the adopted strategies are to develop the smart sensor, which is embedded into the space, to construct a programmable space and to develop an interactive system to actively respond to user needs at the same time. The motivation behind these perceptual characteristics is to amplify the human capacity and to influence people’s experiences along with cognition so that the field of human-machine interaction can be re-defined. But in most of the research results, the ability of sensors is emphasized and less attention is paid to the construction of logical structure regarding people's everyday life experiences [5]. In order to solve the problem we propose a commonsense model. The commonsense includes various facets of life concerning the relationships among the space, human experiences, social communication, psychology, time sequence and so on [6].

Based on what is mentioned above, "urban leisure activity" is set to be the theme in this paper. By collecting various activities and events of human beings in urban plazas, dependencies are further analyzed. The interactive data based on users' cumulative usage are explored. By means of capturing human experiences, a set of rules is researched and developed to regularly record the activities and events and to construct a rule for general use. In this research, the commonsense knowledge model of activities in urban leisure space is called "SmartCypin". Its theoretical structure is as shown in Fig. 1. The purposes for construction of the model are; (1) exploring the interactive behavior between pedestrians and urban leisure space; (2) the activity-based recognition; (3) the commonsense knowledge-based reasoning; (4) the spreading activation theory. In the future development of smart urban space, "smart" can be woven into the "life style" of the nature, allowing mutual relationships to form an information network.

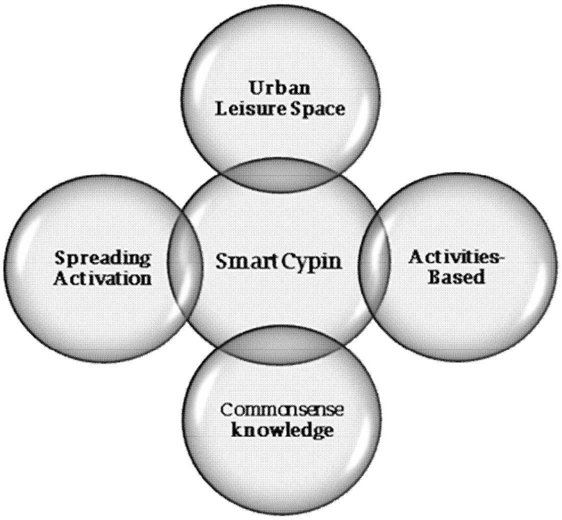

Fig. 1: Commonsense knowledge model of activities in urban leisure space.

2 EXPLORATION OF RELEVANT THEORIES

The research range involved in this paper includes spreading activation theory, commonsense knowledge-based reasoning, and activity recognition, all of which are analyzed and commented, respectively as follows.

2.1 Spreading Activation Theory

Collins and Loftus [7] proposed the spreading activation model in 1975. The theory of the spreading activation model claims that the memory organization is a complex network and that the specific memory will spread by following the links among relevant concepts. The strength of connection represents the length of links. The longer the link is, the more remote the connection is. The shorter the link is, the closer the connection is. This model tells us that we can be activated by associated words or the prime if we would like to think of a certain concept. The closer the connection is, the faster the activation is. Therefore, to improve the memory, more clues for retrieval should be established. In the spreading activation model, the knowledge structure is compared to the circuit board, and the activation connecting the nodes is regarded as a kind of electrical energy or chemical activity. The activation among channels is regarded as a kind of scalar quantity. The numerical value of this index is between 0 and 1. Therefore, there are different degrees of strength in the activation among channels, and the connection speed among nodes is also different.

Human behavior is composed of a series of behavior patterns. And a behavior pattern contains behavioral features, such as the objects touched by users, time, and location information, within a period of time. These behavioral features reveal both the status of human behavior and the differences between different behaviors. We can identify various behaviors by means of these features. Consequently, in this paper, the algorithm of the spreading activation model is adopted. Each behavior node is inferred based on the possibility of what behavior may happen next and on their mutual relationships. In the spreading activation model, various weights are put into certain nodes and checked to see if some behavior nodes are enabled under such a circumstance.

2.2 Commonsense Knowledge-Based Reasoning

The research results based on the inference of commonsense knowledge are mainly from what is done in the MIT Computer Science and Artificial Intelligence Laboratory (also CSAIL) led by Marvin Minsky of MIT. They have developed the knowledge models and inference mechanism such as Common Sense Computing Initiative [8], ConceptNet [9], LifeNet [10], and EventNet [11]. The relationships of events are by default and fixed. The system is the event relationship defined in advance. Its inference mechanism uses the inference engine of the event network. In other words, every sensor can be regarded as a term which describes an event network model. For instance, a lady sits on the sofa beside which there is a telephone. Hence, the chance for her to sit on other sofas to make a phone call is very low. Therefore, when the data input based on user behavior is received, the connotative inference on these input data will be conducted according to the common sense or the built-in professional knowledge. Humanity of “human-machine interface” can be increased without making users feel disturbed or unnatural in the process of interaction [12].

2.3 Activity Recognition

Owing that various uncertain factors are hidden in the environment and the targets, it is a crucial challenge for the research on activity recognition to infer the collected fragments of information into concrete and accurate activity behavior. The main considerations include the time to continue an activity and variability, frequency of occurrence, sequential occurrence of activities, cultural differences and so forth. It is especially more challenging under a circumstance of multi-user activity recognition, and is also a key research issue in this field.

A representative case of activity recognition is the research done by Tapia [13] in the MIT Media Lab in 2004. The activity set to be recognized in this case is a simpler and lower-level one. For example, to detect someone to enter the restroom, to sit on the toilet, or to stand on the floor. It is easier to detect such behavior through simple sensors and get the precise results. Hence, only when the activity is put to an end can this system recognize what kind of simple activity it is. It can neither predict what behavior will be the next nor provide its relationship with other behaviors.

Based on what is mentioned above, the commonsense knowledge model and the inference mechanism of LifeNet and EventNet proposed by the research team led by Marvin Minsky, a computer scientist in MIT, are adopted as the concepts in this paper. What is different is that the user information about activity sequence in each of space area in the plaza to be transformed into the commonsense knowledge of nodes of semantic network and to be applied to “ambient intelligence” of smart urban space in the future is observed in this research. The nodes of semantic network are the input ports (sensors) surrounding the intelligent environment. Through the spreading activation model, a theoretical foundation of knowledge structure is composed [14] and can be used to infer the next behavior node in which users are interested.

2.4 Case Studies

We use the following examples to compare the three types of systems: (1) Tapia’s System [13], (2) PROACT [15], and (3) Kitchen Sense [16], as shown in Tab. 1.

	Tapia's System	PROACT	KitchenSense
inference mechanism	Single-Layer Bayesian Network Algorithm	Monte-Carlo Algorithm	Spreading-Activation Algorithm
able to predict the next behavior		○	○
able to identify the higher-order behavior		○	○
the inference mechanism is open-ended		○	○
the inference mechanism can infer multiple behaviors			○
the inference mechanism can deal with different variables		○	
the inference mechanism is adaptable	○		
the inference model is scalable		○	○
The accuracy rate of inference is high	○		○

Tab. 1: Comparison of Three Types of Systems.

3 RESEARCH PROCESS

The routine activity in the urban system refers to an intangibly spatial system which is formed during the process when residents conduct a variety of routine activities (such as leisure, and shopping). It is a spatial form and structure system which is formed by the individual's habitual and continuous behavior. In other words, human behavior is composed of a series of behavior patterns. And a behavior pattern contains behavioral features, such as the objects touched by users, time, and location information, within a period of time. These behavioral features reveal both the status of human behavior and the differences between different behaviors. We can identify various behaviors by means of these features. The space for residents' routine activity and the routine activity in the urban system, both of which are important contents in the researches on human spatial behavior, directly reflect the formation mechanism of behavior space as well as the mutual relationships of physical space [17]. The activity space is the space where the individuals conduct most of routine activities. It can be viewed as the subset of behavior space. The activity space represents the individual's direct contact with the environment. And such contact generates the effects which cannot be neglected for people to form and delimit the range of their own behavior space. The activity space also represents an important process for people to acquire the information and to connect the information with their living environment.

In this research, Mitsukoshi Plaza located in Taichung City, Taiwan, is the area for observation and analysis of activity behavior. Video recorders are used to record the fragments of life. Then, some continuous behaviors and behavior patterns are induced from the recordings. Meanwhile, the events are corresponded to the space in order to understand the relationships between behavior and space. Then, what is the smallest unit, "Entity", of the activity and what are the features of entity are identified to be the foundation of system development. The research contents include:

- the observation and recording of activities, and corresponding the activities to the space,
- the induction of active spatial points and behavior,
- the construction rule of activity library; and,
- the establishment of commonsense knowledge model of events.

3.1 The Observation and Recording of Activities

Through the records and observation of activities, the user information about activity sequence in each of space area in the plaza is recorded and the information is corresponded to the space. For instance, "a boy and his mother walk from the Flower area (E) toward the Fountain area (F) as shown in Fig. 2. They splash water to each other and have fun. The boy's father sits on the flower stand beside the Fountain area, smoking." Then, these behaviors are transformed into the description in plain text to be the semantic network. Each event is induced to be a behavior node. The connection among behavior nodes is the connection of events; that is, the sequence, or the cause-and-effect relationship. These semantic network of activities in urban plaza leisure space can be accumulated and constitute a commonsense knowledge model base. They can provide the information on the smart sensing environment of the area in the future.

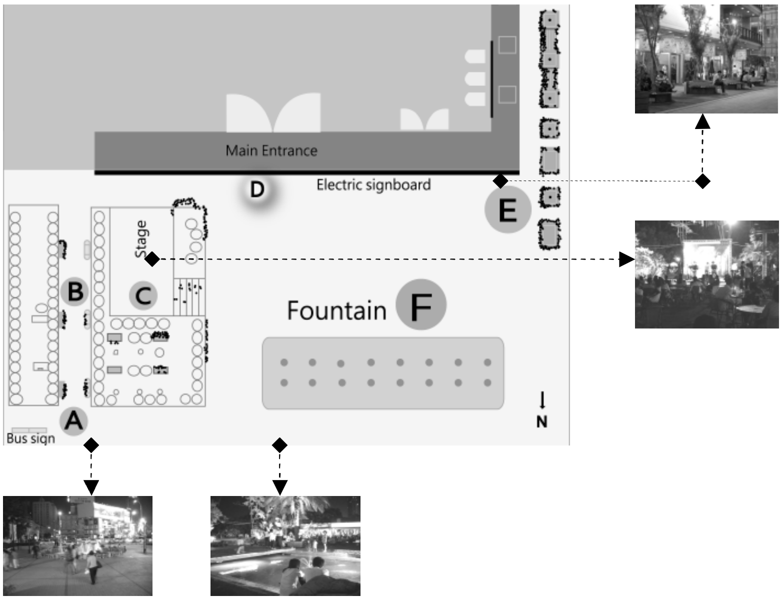

Fig. 2: Layout of the location of user at Mitsukoshi Plaza.

Use the video to record the information regarding people's sequence of activities in a space, as shown in Fig. 3. Then some continuous behaviors and behavior patterns are induced to understand the relationships between the behavior and the spatial environment. Then the sequence of these behaviors is written into plain text, in a way similar to describe the script. And then, the description of the plain text is converted into the semantic network. Each event that occurred is induced into a mobile action. The links among mobile nodes are the ones of the event occurrences (sequence, causal relationship). The semantic network constituted by these different subsets constitutes the fundamental element of the event commonsense model.

(a) a family of three people

(b) a couple

(c) a group of young people

(d) three generations

Fig. 3: Observation chart: screenshots of behavior sequence.

3.2 The Induction of Active Spatial Points and Behavior

The most active spatial regions (A, B, C, D, E, F) where activities occur; that is, Entity in each area, are as shown in Tab.2. These spatial points are the centered range of important message. The overlap of time can constitute the patterns of activities. After the accumulation for some time, some important behavior qualities can be induced from different spatial points and overlapping relationships of users in various activities and events in the plaza, as shown in Tab. 3.

Region	Rest Entity	Environmental Entity
A	6 metal benches	Bus stop
B	6 metal benches, 2 wooden benches	Plants
C	1 metal benches, 4 wooden benches, green decks, stairs, stage	Plants, lights
D	6 pillars	Electronic billboards, lights
E	2 wooden benches, green decks	Plants, television wall
F	16 fountains	lights

Tab. 2: Categories of entity in each region.

No	Ongoing User Activities
1	watching the activities at plazas
2	watching the fountain
3	playing with children
4	watching the people in the plaza
5	eating and drinking
6	waiting for activity held by plazas
7	having a conversation
8	waiting for movie
9	waiting for the partners
10	resting
11	watching TV screen or electronic billboards
12	talking on the telephone
13	smoking
14	watching people
15	waiting for bus or their car

Tab. 3: Categories of user activities at Mitsukoshi Plaza.

3.3 The Construction Rule of Activity Library

The basic viewpoints of the spatial activity commonsense knowledge model which is researched and developed in this study are that people's activities in a spatial environment are basically a constant search process. When people constantly move in a spatial environment, their attention and perception keep receiving the messages issued by the environment. After the messages are processed by the brain, a kind of human need or yearning is indirectly conveyed simultaneously via the body movements. Thus, human beings are contributors of ideas who assign meanings to behaviors. They are incorporated to make sentence for a word, or find a work to fill in the bank. This research proposes a solution to this problem-contextualization-a concept from linguistic field. This approach is much like the concept of Open Innovation. The commonsense Knowledge model can be turned into a pattern language for behavioral interaction in diverse context of daily life.

The construction rule and the application method of activity library in urban leisure space are that the next possibly enabled behavior node can be inferred through the used behavior nodes, the cause of events, and mutual relationships. Through the recording and observation of activities, the activity called "a family of three people play water in the Fountain area" is taken as an example to illustrate the structure of constituent elements in an activity as shown in Fig. 4.

```
// Activity Representation

Activity Description;
                    {2010/08/08 15:00} at {Mitsukoshi Plaza};
                       { a family of three people };
                          { play water in the Fountain area };

Events:{ play water in the Fountain area }; {talking}{sitting}{playing};

Location : { Mitsukoshi Plaza};

Time : {2010/08/08 15:10};

User : {a family of three people};

Object
    Set : { Fountain area };
      Entity : {wooden benches}{green decks}{plants};
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Fig. 4: The structure of constituent elements in an activity.

3.4 The Establishment of Commonsense Knowledge Model of Events

Behavior can detect the location of human beings by means of sensors, inferring from the inference engine what behavior is happening and then further infer the next possible attempt. In the event knowledge model, different weight values and the graphs showing the direction are adopted to reproduce the relationships of behavior. Each node is a behavior. The connections represent mutual relationships. What an arrowhead points to is the child node, and the other end of the arrow is the father node. The weight value refers to the probability of generating the behavior of the father node when the child node is activated. The weight value is between 1 and 0. The algorithm of spreading activation is utilized for the algorithm logic to predict next behavior. The energy is put into the activated node, and spreads to adjacent nodes. The energy spreading to adjacent nodes is the weight which is the energy of the previous node multiplied by interlinks. This way, the height-related nodes can be located. In other words, the closer nodes do not always mean the higher relations of the nodes. The expression method is shown in Fig. 5.

The behavior model is defined as the sequential logic for the occurrence of the behavior pattern. When Behavior A is activated, the possible sequence of occurrence is Behaviors C, D, and F, according to the behavior which is occurring. When Behavior E is activated, the probability of the behavior which is occurring is Behaviors B and F. Such a recursion theory can be as an inference for a user's currently possible behavior and for the next point in which a user is interested, according to the activated behavior. The equation is as follows:

$$Ni = \sum_{j = links(Ni)} energy(Nj) * weight(Ni, Nj)$$

In this equation, *Ni* represents the node. *weight(Ni, Nj)* represents the weight of links between the node *i* and the node *j*. *energy(Nj)* represents the energy of the node *i*. *j = links(Ni)* represents the variable of the setting for adjacent nodes of the node *i* to *j*.

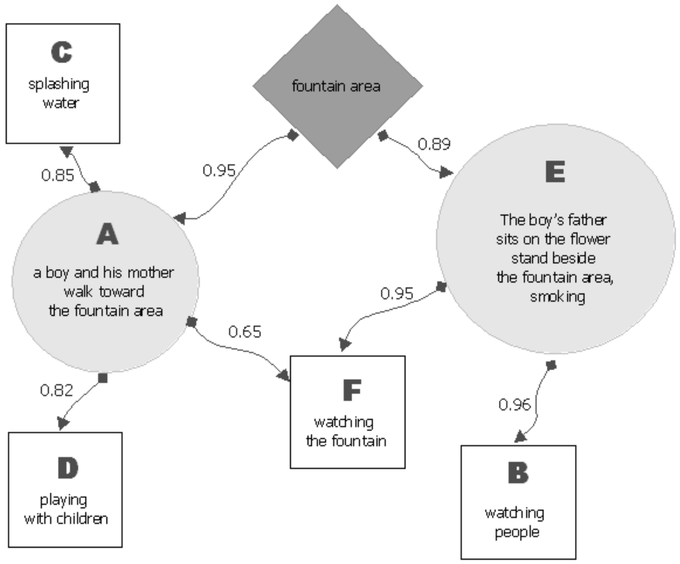

Fig. 5: The expression method of the activity model in the commonsense knowledge model. The circle represents the sensor node. The behavior detected by a set of sensors is corresponded to a sensor node. The rectangle represents the behavior node, the behavior inferred by the sensor node and the location node. The rhombus represents the location node. The location detected by a set of sensors is corresponded to a location node. The connective arrowhead represents the relationships between the nodes. The direction to which the arrowhead point is the child node, and the other end of the arrow is the father node.

4 DISCUSSIONS

The more behavior details are observed, the more what users are doing can be guessed to more accurately make judgments about requirement for the next step. Likewise, the artificial intelligence system should also contain such logic. The more users trigger sensors, the more what they are doing can be guessed. The activities with more procedures will trigger more sensors. Hence, the guess will be more accurate and more precise assistance can be offered. In other words, the more user habits are understood, the more what users are doing can be guessed from a small amount of information. Therefore, when more user habits are recorded with the artificial intelligence system, the system can adapt more to user habits. The weight of the commonsense model of the system can be closer to the user behavior pattern, and the next behavior of users can be further inferred with more accuracy from a small amount of information.

To place the common sense into the computer has long been a dream in the development of artificial intelligence. The fact, however, has proved that it is very difficult to implement the process. Yet, there has been considerable progress recently, because the open architecture of the internet and the participation of the public have accumulated large quantities of the commonsense knowledge base to which there are better strategies to apply than before. Based on this, we need to develop a mechanism which can still solve the new interface design problem even though the knowledge of the system is insufficient. By using the common sense as a basis of the applied system, commonsense knowledge along with the interaction between people and computer are used to solve problems. Technical prototype of the system should be implemented and iterated. The smart interface is expected not only to exact meanings of movements, but also predict the action of next moment by comparing the input data to prior knowledge. It requires a from-known-to-new learning model with a template, which is adaptable to newly acquired information and capable to guess it with preexisting knowledge and experience.

Currently, the commonsense model constructed in this study is a recurrence behavior model in a simplified condition. What needs to be complemented contains how the state is described and how necessary behaviors and undefined behaviors are described. Some behaviors do not vary from person to person, and can be established into behavior modules. However, behavior effectiveness is more complicated in a multi-user environment. How to detect the behavior which is generated by a user and which is also effective to another user is indeed a complex problem. Consequently, the behavior commonsense model of various levels must be more deeply researched and developed.

In our research, the model emerges from researchers' observation, and interpretation of behaviors in a context. Another approach is to employ knowledge and intuitions of real users, rather than have researchers established the entire system. Given that meanings are extracted from commonsense Knowledge which is due to the matching of behavior, activity, and context. It requires building the database of behavioral Library, Context, and Commonsense Knowledge, which are critical to the extraction of meanings in the future.

5 SUBSEQUENT STUDIES

The main purpose of sensor technology is to sense and detect the activities and behaviors of human beings. People have similar or the same habits in their behaviors. Such a habit will naturally be accumulated in the space and become the patterns of activities. For the establishment of the rule of activities in future smart urban space, main contribution made by this research at this stage is to develop a set of simple and formalized approach, to construct the commonsense knowledge model of activities in urban leisure space by recording the behavior patterns of human beings, and to provide a reference for digitized support and service in the future.

At the next stage, the urban leisure space will be used as an experimental site. Sensors will be built in these spatial points to detect the behaviors and activities of human beings. ActionScript3.0, a software program, will be utilized to write for the commonsense knowledge base and the sensing device both of which connect activities in urban leisure space. The commonsense knowledge data of SmartCypin will be imported. In addition, each spatial point will be set with its own database system. It can offer relevant environmental information on the area, connect serially the sensing device of human-machine interface in the surroundings, speculate the intentions of human beings, track the activities of human beings, further infer the next behavior node in which people may be interested, and evaluate the feasibility to connect the commonsense knowledge base and the software programming interface of the sensing device.

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