Designing an Indoor Situation-aware Ubiquitous Platform Using Rule-based Reasoning Method*

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Abstract *-In recent years, with the development of computing technology, it becomes realizable to use embedded micro-processors in order to provide a variety of services. For example, some systems have been proposed to provide context-aware services such as protecting children from dangers, taking care of patients and so on, by getting the user's surrounding information using mobile computing technology and sensor networks. However, these systems can not describe the information gotten from sensor network as situations explicitly and uniformly, and also can not recognize the specified situations defined by the users. Therefore, we design this ubiquitous platform which can accomplish the above functions. We get the indoor objects position information from U-tile sensor network. And we design a language named SDML which is based on the situation theory to describe situations explicitly and uniformly. We also design an easy-to-understand interface to let users sketch the specified situations and support actions on those situations, which can be transformed into situations by SDML and then into rules. Finally we use the rules to recognize the specified situations by comparison the information grasped by the U-tile sensors with the user-defined situations, and provide the corresponding support services.*

Keywords: Ubiquitous Computing, Situation Description, Situation Recognition, U-tiles Indoor Positioning System

1. Introduction

Recently, with the development of computer technology, an environment consisting of dozens of embedded micro-processors, various sensors, and RFID technology has come into researchers' horizon. Therefore, we can provide many context-aware services based on the user's actions, the user's situations and the user's intention. For example, some systems have been proposed to provide outdoor learning services [1] by getting the user's surrounding information using mobile computing technology, and sensor networks. And there are also some projects [2, 6] for protecting children from dangers, setting up a smart living environment for elderly people, taking care of patients, and so on.

Even though these systems have been proposed successfully, there are also some problems to be solved after getting the surrounding information. The problems are how to describe the surrounding information as situations and how to recognize the specified situations. To solve these problems, we think that a kind of platforms which can describe the information gotten from a sensor network as situations, specify situations and support for them, recognize the happening of the specified situations, and provide the corresponding context-aware services are needed.

For getting indoor environment information, there are some previous researches, like the Aware Home [2] and the Ubiquitous Home [3]. The Aware Home project is noteworthy and successful and can provide several services to its residents to enhance their quality of life. And then the Ubiquitous Home has been built for home context-aware service experiments in 2004 by the National Institute of Information and Communications Technologies (NICT), Japan. It simulates a two-bedroom house, equipped with 17 cameras, 25 microphones and several other sensors which acquire data continuously. And then Silva [4] presented a system for retrieval and summarization of continuously archived multimedia data from a home-like ubiquitous environment. They use pressure-based floor sensors to analyze data for indexing video and audio from a large number of sources. Even though these systems have been developed successfully and can get the indoor environment information. However, these systems can not describe the information around the users as situations explicitly and uniformly and recognize the specified situations.

There are also some previous researches about recognize specified situations. A system for elder people using Visual Cues can be found in [5]. It uses two types of position detector systems - an ultrasonic position detector (Furukawa Industrial Machinery System Co., Ltd.) and

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active RFID (Radio Frequency Identification) system (RF Code Co., Ltd.) - to trace persons and objects in real time. This system judges whether or not an elderly person will be in danger based on the state of the person and objects sensed in the situation recognition unit and information on the person and objects stored in a risk information database. However, it will be better if this system describe the both information gotten by sensors and stored in a risk database as situations. And it also will be better if it can grasp all position information in the house but not just for some sensed object around users, and then the system can recognize the dangerous situations around the user much more really and truly. Takata [6] developed a space-oriented system for kid's safety care in an outdoor environment, which can get outdoor location and surrounding information using GPS module and RFID technology. They use Space oriented Model (SoM) concept to group all our living spaces into two types called Accident space and Safety Zone space. Then they recognize dangerous situations based on these two spaces. However, it is too simple to judge a kind of situation just based on these two spaces because the real life situations are very complex.

To this end, we designed this ubiquitous platform. We grasp all the situations in the house using a U-tile [7] based sensor network and embedded computing technology designed by our laboratory. And we proposed a language named SDML (Situation Description Markup Language), to describe the information gotten from U-tile and specified by a user as situations. This xml-like language is based on the Situation Theory [8]. It describes a situation using four basic elements, and manages the situations using three combinations of the four elements. Therefore, we can describe a situation in a uniform way, and the situation can be recognized easily. And then this system compares the real situations around the user with this specified situations sketched by the users using Rule-Based reasoning. Finally the system provides the corresponding services depending on the situations.

The rest part of this paper is organized as follows. In section 2, the model of this system is presented. In section 3, the detail design of this system is presented. A case study is presented in section 4. Finally, conclusion is presented in section 5.

2. Model

2.1 U-tile

Fig. 1 shows the structure of U-tiles. It includes a sensor network and management device. The sensor network can get all position information of this house, and send the information to computer center through management device.

The sensor network is built on a real floor. From Fig. 1, we can see that the U-tiles consist of several tiles and each tile has a tile ID like 'A' or 'C'. This figure is an example of U-tiles, so the ID is just from A to I. In real device, there are more pieces. On the back of each tile, there are pressure sensors and an RFID antenna for getting the object information on each piece, assuming every object is attached by a related RFID tag.

Management device consists of a switch, an RFID reader, an MCU, a tile interface and a computer interface. All pieces of tiles are connected to management device through the tile interface, and the switch is used to connect to different pieces of tiles. If an object is on one piece of tile, then pressure signal of that piece will be produced and sent to the management device, then the management device controls the RFID reader to read information

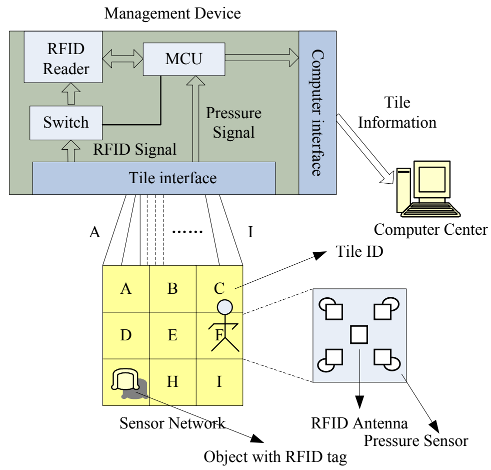

Fig. 1 **Structure of U-tiles**

corresponding to tile.

In this figure, a user is on the piece of F, and then the pressure signal of the piece of F is produced and sent to the MCU in the management device. So it can know there is an object on the piece of F. Then it lets the RFID reader read information from RFID tag attached to the object (the user) on the piece of F. With this information, computer center can know there is a person on the piece of F by searching a DB with the RF-ID read as a key, and similarly, it also can know there is a sofa on the piece of G. Finally, management device sends this information to computer center using computer interface. So with the help of this device, we can grasp which object is on which tile, in other words, we grasp all position information of objects and persons in this house.

2.2 Model

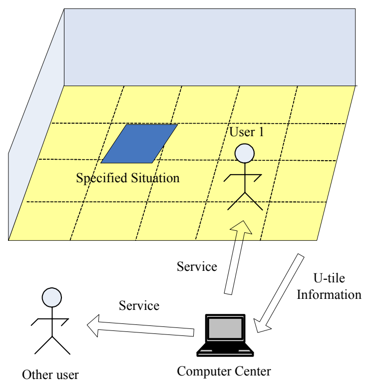

Fig. 2 **Model of the system**

Fig. 2 shows a scheme for the model of this system. The model consists of U-tile, computer center and specified situations. It supports multi-user model. For example in the Fig.2, one of the users (User 1) is on the floor which is built using U-tiles, and then this system can get the position and surrounding information of user 1 using U-tiles. But the user 1 is someone who should be taken care of, such as children, elderly people, and so on. So it also gives the services to other users when user 1 meets the specified situation. The specified situation is defined by the users. It is a kind of situations we should recognize, such as a dangerous situation for the children or the elderly people, or an impermissible situation for the patients. The computer center includes the function of defining specified situations by users, getting the objects position information from U-tile, recognizing the specified situation, finally give services to the users.

2.3 The Main Problems to be solved

(1) Situation Description

We can get the surrounding information around the user 1 from U-tile sensor network, but it is just a kind of information or signal from various sensors, how to describe this information as a kind of situation is what we should solve firstly. On the other hand, the users should define specified situations in the user interface. Similarly, we should describe this information as a kind of situation.

(2) Recognizing Specified Situations

After getting the surrounding situations from the user 1, coupled with the defined specified situations by the users, we should match these two situations to recognize the specified situations. How to design the reasoning engine and rules to recognize the specified situations is another problem we should solve.

3. Design of the System

We need to compare the information gathered by the U-tile and the situation sketched/specified by the user to recognize the specified situation. But the information gathered by U-tile is the physical signal from the sensor network, and the information sketched by the user is a kind of unstructured data. Therefore, we need to find a method to describe and compare these two kinds of information. So, we design a language named SDML (Situation Description Markup Language) which is based on the situation theory [8] to describe the physical information gotten from U-tile and the specified information sketched by the user as situations.

The basic parts of the system include: Signal translation, Situation recognition, and Support.

- ✧ Signal translation is for decoding the physical signal, describing this information as a snap shot and finally describing as a situation using SDML.
- ✧ Situation recognition is for recognize the specified situations, sketched/specified by the users. We also use SDML to describe the sketched/specified information as a situation, and then translate it into rules and store in a rule DB for recognition.
- ✧ Support is for providing some supports based on the recognition result. In other words, the support is provided based on the situations, which are specified by the user, and happen in the real world.

Fig. 3 is the structure of our system. Besides the basic three parts, there is a U-tile sensor network for getting the physical information, e.g. RF-ID and their positions, a user interface for setting the specified situation, and the users to whom we should provide the corresponding supports to. In the signal translation part, we compare the physical signal with the content in an objects (or users) DB to get the objects/users information, using the detected RFIDs as searching keys. In the situation recognition phase, we use Rule-Based reasoning to recognize the specified situations. In the support part, we provide support to the users based on the result of the recognition.

3.1 Signal Translation

In this part, system gets the physical signal from U-tile, and represents this information as a snapshot and finally as a situation in SDML.

3.1.1 Processing of the physical signal. To get the indoor objects position information, we basically need to get the two kinds of information: object information and its position information. Therefore, the physical signal mainly consists of RFID tag information and tile ID information. With the tile ID information, we can get the object position information because the floor is built on the U-tile which has been referred before. And this system will compare the RFID tag information with the content in the object DB to get the object information such as the name, the property, and so on. It stores this information into the signal DB, and then we can produce a snapshot of the environment in that room based on the objects information and position information.

3.1.2 Situation description. We design a language named SDML to describe the information as situations. This language is based on the situation theory which was first formulated in detail by John Barwise and Jon Perry on natural language processing field 1983 [8]. It is an attempt

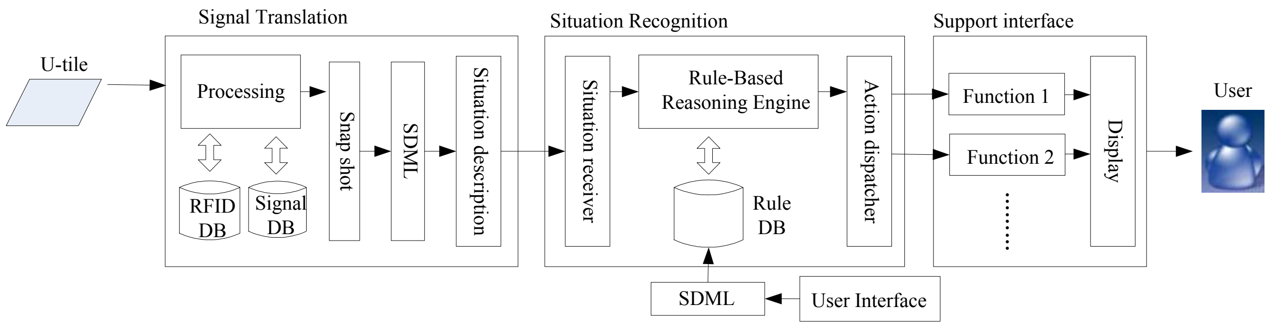

Fig. 3 **Structure of the system**

to develop a mathematical theory of meaning which can clarify and resolve some tough problems in the study of language, information, logic, philosophy, and the mind [9]. Individuals, properties, relations, and spatial-temporal locations are basic elements of situation. The world is viewed as a collection of objects, sets of objects, properties and relations [10]. They also designed some combinations to manage the situations. The combinations are the type of situation, state of affair, and courses of event. But they have not used a very structured computer language to express the situations. Then we design this xml-like language to represent the situations, since the xml language is very structured and easily be processed as web-based applications. Fig. 4 is the structure of SDML.

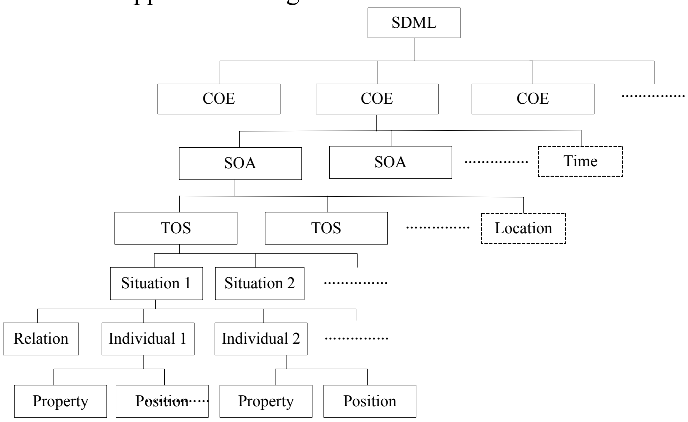

Fig. 4 **Structure of the SDML**

TOS is the short for “Type of Situation”. Situations have many types. We classify the situations by the different types, and save the same type situations in the same TOS. For examples, a type is “ChildWithSth.” which means a child is with something now, and the other is “ChildNearbySth.” which means a child is nearby something now.

TOS includes many situations with the same type. Each situation has its actors, and we use “individuals” to describe them. Then we use “relation” to show the relation among the individuals, and it is also the character of the situation. And each individual has his/her/its property and position. As shown in Fig. 5, in the situation 001, there are two individuals John and chair. John has his property of “Child” and position of Tile C, and chair has its property of “undamaged thing” and position of Tile C. And the relation is “With”. We name the TOS using the property of individual and the relation with others.

SOA is the short for “State of Affairs”. It is the combination of a kind of TOS and the location information as shown in the Fig. 4. It includes the situations happen in the same places. In the example of Fig. 5, we save the situations happen in the same place of “bedroom1” in the SOA of “bedroom1” and save the situations in the same place of “bedroom2” in the SOA of “bedroom2”.

COE is the short for “Course of Events”. It describes a series of events happen in the different place or different time. In this paper, we explain that in a narrow way that a series of events happen in the different time for describe situations conveniently. It is a subset of COE. As shown in Fig. 4, it is the combination of the SOA and temporal information, which assembles the situations happen in the different time. As shown in Fig. 5, we save the situations happen at 3 o'clock PM, Jul. 10th, 2008 in the COE of "2008/7/10 15:00", and save the situations happen at 4 o'clock PM, Jul. 10th, 2008 in the COE of "2008/7/10 16:00".

```
<?xml version="1.0" encoding="Shift_JIS" ?>
<SDML>
  <COE name = "2008/7/10 15:00">
     <SOA name = "Bedroom1">
      <TOS name = "ChildWithSth.">
        <Situation id = 001>
          <Individual name = "John"
            Property = "child"
            Position = "Tile C"
              />
          <Individual name = "chair"
            Property = "undamaged thing"
            Position = "Tile C"
              />
          <Relation name = "With"
              />
        </Situation>
        <Situation id = 002>
          ……………
        </Situation>
      </TOS>
      <TOS name = " ChildNearbySth.">
        <Situation id = 003>
           <Individual name = "Dan"
            Property = "child"
            Position = "Tile A"
              />
           <Individual name = "Heater"
            Property = "danger"
            Position = "Tile B"
              />
           <Relation name = "Nearby"
              />
        </Situation>
      </TOS>
      <TOS name = "ElderlyPeopleWithSth.">
      </TOS>
      <TOS name = "ElderlyPeopleNearbySth.">
      </TOS>
     </SOA>
    <SOA name = "Bedroom2">
    ……………
    </SOA>
  </COE >
  <COE name = "2008/7/10 16:00">
    < SOA name = "Bedroom1">
      <TOS> …………. </TOS>
    </SOA>
  </COE >
</SDML>
```

Fig. 5 **Example of the SDML**

3.2 Situation Recognition

In the signal recognition part, users input some information about the situations. We use SDML to describe the information as situations and Fig. 6 shows an example of describing the defined situation using SDML. There is a little different with the SDML for describing the information gotten from U-tile. It adds an item of actions for providing the support functions to the users. Then this system translate this situation and the actions into a rule and store that in rule DB. And then the system receives the real time situation gotten from U-tile and compare with the user specified situation using Rules in DB. Finally the system provides the corresponding support actions through support interface.

```
<?xml version="1.0" encoding="Shift_JIS" ?>
<SDML>
  <COE name = "2008/7/10 17:00" to "2008/7/10 18:00">
     <SOA name = "studyroom">
      <TOS name = "ChildWithSth.">
        <Situation id = 001>
          <Individual name = "Tom"
            Property = "child""
              />
          <Individual name = "book"
            Property = "mathematic"
              />
          <Relation name = "With"
              />
          <Action name = "A reminding message for him to
          know tomorrow's lecture time "
                 ID = "Action01"
              />
        </Situation>
      </TOS>
     </SOA>
  </COE >
</SDML>
```

Fig. 6 **Example of describing specified situation**

3.2.1 Rule-Based engine. The rule-based system itself uses a simple technique: It consists of a rule-base, which contains all of the appropriate knowledge about the specified situations encoded into If-Then rules, and a working memory, which may or may not initially contain any data, assertions or initially known information. It includes facts, rules and actions, and compares the facts and rules to get the corresponding actions. There are two broad kinds of rule system: *forward chaining systems*, and *backward chaining systems*. In this paper, we use forward chaining systems because it starts with the initial facts gotten from U-tiles and using the rules to take certain actions based on given facts. It will be easy to recognize a situation.

3.2.2 Rule generation. Fig. 7 is an example of rules for detecting a situation that the learning state of a student after school, and it also shows the process of Rule-Based reasoning. An ellipse represents a fact, and a rectangle represents a rule.

Then we use this example to explain the generation of rule. Firstly, we translate the defined information by the users into situations using SDML. And then we build a rule by extract the SDML items as shown in Fig.7. We extract the COE name, the SOA name, the TOS name, the individual name, the relation name as a condition and extract the action name and action ID as an action. And then for recognizing the specified situation step by step, we decompose this rule into four sub-rules. They are rule B, rule E, rule H, and rule K just as shown in Fig. 7. We extract the COE name to built the rule B for recognizing the time of situation, extract the SOA name to built the rule E for recognizing the location of situation, extract the TOS name to built the rule H for recognizing the type of situation, and finally extract the individual and relation to built the rule K for recognizing the detail of the situation. If all of the four sub-rules are matched, it will provide the corresponding supports.

```
RULE rule_for_TomStudy:
DESCRIPTION: To know the Tom's learning state after school
CONDITION:
        "*/*/* 17:00" < COE name < "*/*/* 18:00"
        SOA name = Studyroom
        TOS name = ChildrenWithSth.
        Individual name = Tom
        Individual name = Book
        Relation = With
ACTION:
        Action 01 (a reminding message for Tom to know
  tomorrow's lecture time)
END_RULE
```

Fig. 8 **Example of the Rule**

Fig. 8 is an example of the rule. It consists of rule name, description, condition, and support action. The condition is a kind of situation which should be recognized. As in this example, we detect Tom is learning with a book in the study room from 17:00 to 18:00. The action expresses a support based on this condition. For example, it gives a reminding message for Tom to know tomorrow's lecture time as shown in Fig. 8.

3.3 Support interface

The last is support interface. It can provide the corresponding support to the user based on the action. We provide the support to the user who is in the specified situation, and can also provide the support functions to his family to let them take care of him.

4. Case Study

In the case study, we use the proposed method to detect the dangerous situations around a child, and give alert messages to him and his parents, when he meets the dangerous situations, and let him know basic safety knowledge necessary for such situation at the same time. Firstly, parents sketch the dangerous situations using the user interface and this system describes this information as a rule and stores it into Rule DB. Fig. 9 is the screen

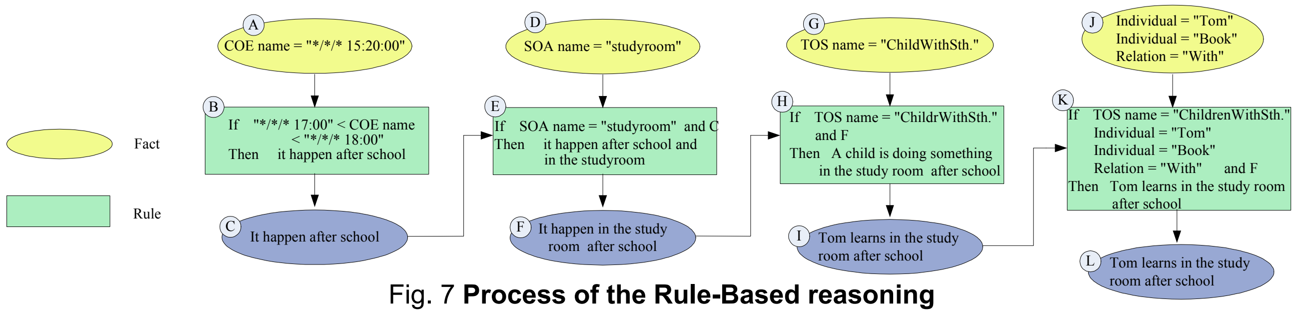

Fig. 7 **Process of the Rule-Based reasoning**

capture when the users define the dangerous situations. The users just need to select the time of situation, location of situation, type of situation, individual, relation of situation and actions, and do not need to consider how to describe a situation formally based on the situation theory. So it adapts to the general users who do not have so much computer/technology knowledge. In this case, we define a situation that a child is very close to a heater as a dangerous situation as shown in the Fig. 9. We define the time of situation, and choose the location of situation is bedroom1, and then choose the type of situation is ChildVeryCloseToSth., and finally choose the individual and relation among the individuals.

Fig.10 is the experiment environment of this system. It consists of the U-tile, Management Device and Computer Center. In this case, we attach an RFID tag to a heater. Fig. 11 is an image showing the interface to give alert messages to the child and let him know basic safety knowledge at the same time.

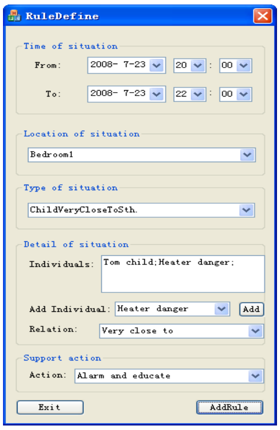

Fig. 9 **Screen capture of user interface**

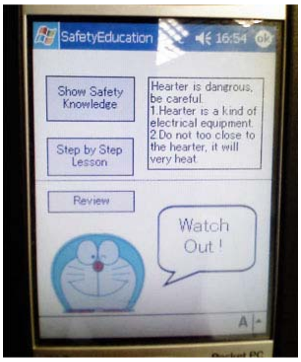

Fig. 11 **Image of support application**

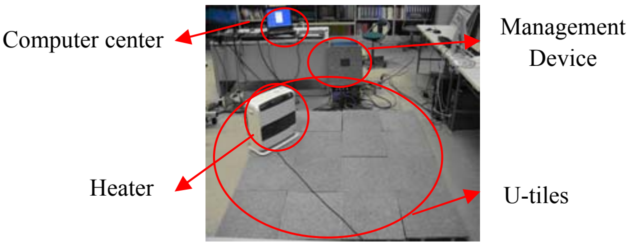

Fig. 10 **Experiment environment**

At present stage, this system has not been finished completely. We are working on implementation of the system.

5. Conclusion

For providing context-aware services to users such as protecting children, taking care of patients and elderly people, we need to know what the situations are around them. At present, there are some systems which have been proposed to get the user's information from sensor network. However, these systems can not describe the information as situations, and can not recognize the specified situation sketched by the users. Therefore, we proposed the SDML language which is based on the situation theory to describe the situations. This xml-like language describes the situation using four elements of a situation, and manages the situations using three combinations of the four elements. Therefore, situations can be described in a uniform way, and the situations can be recognized easily. We design a U-tile sensor network to get the user information in the indoor environment, and describe the information as situations using SDML. We also design an easy-to-understand interface to let a user easily sketch the specified situations. And then we recognize the specified situation using Rule-Based reasoning, and finally provide the corresponding services to users. We perform a case study about protecting a child in the indoor environment using this platform. We let his parents sketch dangerous situations in the user interface, and then this system recognizes these dangerous situations and avoids accident, finally gives an education service to the child.

6. References

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