Modeling and Verification of Hospital Intelligent Diagnosis and Treatment Service Based on Timed Automata in Internet of Things

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***Abstract*—Intelligent diagnosis and treatment service is the core content of hospital Internet of Things. Due to the complexity of the hospital environment, the disregard of the system design leads to the uncertainty of data and the instability of system. Timed automata provides an effective method for formal modeling of Internet of Things systems. Therefore, based on the theory of timed automata, introducing the related concepts such as environmental entities, the interaction between Internet of Things services and external environment and the time attribute of services are fully considered, and a method for modeling and verifying hospital intelligent diagnosis and treatment services under the Internet of Things environment is proposed to improve the stability and reliability of system to ensure its correctness. Firstly, on the basis of discussing common scenes of intelligent diagnosis and treatment in hospitals, the application composition is analyzed, and an intelligent diagnosis and treatment service providing framework based on environment interaction is built. Secondly, based on the formal description of two types of environmental entities, the three atomic services, that is, perception type, control type and processing type are modeled respectively. On this basis, the modeling of composite services is completed based on the timed automata network, so as to build a hospital intelligent diagnosis and treatment service model based on timed automata. Finally, taking the application scenario of hospital intelligent diagnosis room as an example, the effectiveness and feasibility of the above-mentioned modeling method are analyzed, and its timeliness correctness is verified by UPPAAL model detection tool. Practice shows that the method can accurately analyze the model during system design, avoid design errors, reduce design defects, and provide effective support for the implementation of hospital intelligent diagnosis and treatment services in the Internet of Things.**

Keywords-Hospital Internet of Things; Internet of things service; Intelligent diagnosis and treatment; Timed automata; Service modeling; UPPAAL

I. INTRODUCTION

The ultimate value of the Internet of Things (IoT) lies in services and applications [1-3]. The modeling, analysis and verification of the Internet of Things system are important issues for the application of the Internet of Things technology using service-oriented methods. The Internet of Things system is a typical complex system, and in order to ensure its correctness and reliability, it is very necessary to conduct sufficient testing and inspection before the system is deployed. This has become a critical problem that the Internet of Things project needs to solve urgently. Formalization method [4] is an effective method to verify the system. Due to its low cost and short cycle, it provides better support for the pre-deployment inspection of the Internet of Things system.

Service modeling is the core content of Internet of Things system in its formal research. For example, by extending the physical objects and service contents of the Internet of Things service, reference [5] proposes a meta model of the Internet of Things service description based on the traditional Web service description (WSDL) model, and selects OWL-DL as the formal description language of the model. Reference [6] models the Internet of Things service as the relationship with equipment, entities and resources, and describes it by OWL-S. Reference [7] uses the Communication Sequential Process (CSP) method in process algebra to model Internet of Things services. Reference [8] uses the dynamic logic method of quantitative differentiation to build the Internet of Things service model and its verification framework based on the theory of hybrid system.

The modeling of the Internet of Things service described above uses WSDL model, CSP, differential dynamic logic and other methods to describe the Internet of Things service from the aspects of service object, service content, service function, service resources, service order and so on, and does not involve the interaction between the service and the external environment. However, in the Internet of Things service, some related equipment directly operating in the physical environment is inevitable to interact with the surrounding environment, and the Internet of Things service must make reasonable response according to the dynamic changes of the surrounding environment to meet the requirements of its security, reliability and real-time. Therefore, the construction of the Internet of Things service model needs to pay special attention to the interaction with the external environment.

In addition, the above modeling methods does not consider the time attribute of the service. The Internet of Things service belongs to the application layer and needs to complete real-time acquisition of state information and

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real-time monitoring of behavior information of various entities in the physical world through various types of sensors, and the sensors sense and collect relevant information of the surrounding environment at certain time intervals. Therefore, the time attribute of the service needs to be considered in building the Internet of Things service model.

Based on the above ideas, reference [9-12] proposes a modeling method for the Internet of Things service and the physical environment in which it operates based on the theory of timed automata. However, there is no literature that specifically focuses on modeling hospital-related application services in the medical field under the Internet of Things environment from the aspects of interaction with external environment and time attribute. In addition, as a classical formal description tool, timed automata [13] can effectively model and verify the Internet of Things system. It has been widely used in railway [14-16], mine [17-18], traffic [19], agriculture [20], industry (equipment control) [21], robot [22-23] and other fields, but it is not involved in the modeling of Internet of Things application services in the medical field.

From the above, it can be seen that the research on formal modeling of Internet of Things services in the existing literature mostly focuses on the general modeling of Internet of Things services, which used WSDL model, CSP, differential dynamic logic and other methods to describe Internet of Things services from the aspects of service objects, service contents, service functions and so on. The interaction between services and external environment is not involved, and the time attribute of services is not considered. Moreover, the modeling of Internet of Things services for a specific field is rare, which is only limited to railway, mine, transportation, agriculture, robots and other fields, and there is no modeling research specifically for Internet of Things application services in the medical field.

As far as the medical field is concerned, the hospital is an important application place of Internet of Things technology. Intelligent diagnosis and treatment service is the core service content of the hospital Internet of Things and an effective means to realize hospital informatization. Due to the environmental characteristics of the hospital, there are higher requirements for the diagnosis and treatment services of real time (patients' tolerance of waiting time for diagnosis and treatment services is limited), reliability (diagnosis and treatment services cannot have any errors, such as power failure during surgery), and timely responsiveness (such as real-time monitoring of critically ill patients, and immediate notification of the doctors and nurses on duty in case of any abnormality in physiological indexes). Therefore, compared with other application fields, the application modeling of hospital diagnosis and treatment services under the Internet of Things environment needs to pay more attention to the interaction with the external environment and the time attribute.

Therefore, based on the theory of timed automata and introducing some related concepts such as environmental entities, fully considering the interaction between Internet of Things services and external environment and the time attribute of services, this paper proposes a modeling method for hospital intelligent diagnosis and treatment services under the Internet of Things environment, and verifies its correctness through UPPAAL model testing tool, which provides a method for testing the stability and security of hospital Internet of Things intelligent diagnosis and treatment application system.

The rest of this article is organized as follows: Section II analyzes the application scenarios of hospital intelligent diagnosis and treatment under the Internet of Things environment and builds its service providing framework. Section III builds a hospital intelligent diagnosis and treatment service model based on timed automata under the Internet of Things environment on the basis of modeling the three atomic services, that is, perception type, control type and processing type. Section IV discusses the verification method of the above model by using the model detection tool UPPAAL. Section V analyzes the effectiveness and feasibility of the above-mentioned modeling method by taking the application scenario of hospital intelligent clinic under the Internet of Things environment as an example, and verifies its correctness through UPPAAL tool. Section VI summarizes the research work of the whole paper and points out the focus of the next research.

II. Providing Framework of Hospital Intelligent Diagnosis and Treatment Service under Internet of Things Environment

This section first analyzes the typical application scenarios of hospital intelligent diagnosis and treatment under the Internet of Things environment, then studies the components of hospital intelligent diagnosis and treatment application system under the Internet of Things environment and their mutual relations, and finally builds the providing framework of hospital intelligent diagnosis and treatment service under the Internet of Things environment.

A. Application Scenarios of Hospital Intelligent Diagnosis and Treatment under Internet of Things Environment

Intelligent diagnosis and treatment service is the core service content of hospital Internet of Things, and its application requirements mainly include the following aspects:

1) Intelligent clinic system

The Internet of Things application system in intelligent clinic is the most direct application of Internet of Things system in hospital outpatient service. It is assumed that the intelligent clinic of the hospital is equipped with air conditioner, fluorescent lamp, entrance guard system, light box for observing X-ray film, CT film, magnetic resonance film and other films, and screen for protecting the privacy of patients when they need in-depth examination. The specific description is as follows:

The temperature sensor is used to collect the air temperature in the diagnosis room in real time, and the indoor temperature is adjusted by the air conditioner.

The illumination sensor is used to obtain the illumination intensity of ambient light in the diagnosis room in real time, and the intensity of indoor light is adjusted by fluorescent lamps.

The infrared sensor is used to sense whether there are X-ray films, CT films, magnetic resonance films and other films in the viewing area of the light box, and if so, the light box is automatically turned on; otherwise, the light box will be automatically turned off.

The infrared sensor is used to sense whether the patient enters the examination area, which is separated from the examination room by a partition curtain (screen) and is provided with a bed and a stool, thus being suitable for privacy examination. When the patient enters this area and needs to be examined, the screen is lowered to the bottom, and when the patient leaves this area and the examination is finished, the screen is raised to the top.

An RFID reader is installed on the door, and the door is sensed and controlled through an RFID medical card to implement entrance guard management. After registering, the patient should also check in the medical guide desk in front of the clinic by swiping his card. The calling system takes account of the registration order and the check-in order to make calls when the patient swipes the card at the door, the entrance guard system automatically detects whether the ID number of the currently called patient is consistent with the ID number of the patient swiped with the RFID card. If yes, the door will open, otherwise, you will be prompted "Please wait patiently before you go to see a doctor". If no patient swipes his card to enter within 1 minute, it will directly enter the call with the next serial number. If a patient needs to go to the clinic again after testing, examination and taking medicine, he will check in again and be treated according to VIP, which will be treated immediately after the current patient is finished.

2) Intelligent ward system

Through physiological sensors such as a body temperature sensor, a blood pressure sensor, a pulse sensor, a heart rate sensor and so on, various physiological indexes are collected and monitored in real time and the abnormal physiological indexes are fed back to a doctor on duty in time. By wearing RFID wristbands to patients and installing entrance guard systems at all entrances and exits of the hospital, patients are monitored and positioned in real time in the hospital.

3) Intelligent guidance

According to the diagnosis and treatment plan and the real-time perception of the number of patients waiting in each link, the patient is guided intelligently to maximize the efficiency of treatment and reduce the contradiction between doctors and patients.

4) Telemedicine

The first three scenarios refer to the internal application scenario of the hospital, and also refer to the application scenario of intelligent diagnosis and treatment under the hospital Internet of Things environment in a narrow sense. With the arrival of 5G era, the hospital Internet of Things will break the limitation of space and make telemedicine a reality, including tele-consultation, tele-ultrasound, tele-surgery, emergency rescue (seamless connection between pre-hospital first aid and hospital treatment), tele-monitoring, etc. Telemedicine is an external application of hospital intelligent diagnosis and treatment, and is also an application scenario of intelligent diagnosis and treatment under the hospital Internet of Things environment in a broad sense.

In order to facilitate the subsequent elaboration, the intelligent diagnosis room system in the hospital is selected as the application scene for detailed analysis. Fig. 1 is a description of an application scenario of an intelligent clinic in a hospital under the internet of things environment. As can be seen from the Fig. 1, the entire outpatient intelligent clinic application scenario consists of two major parts: the clinic external environment and the clinic Internet of Things application system. The specific analysis is as follows:

1) External environment of clinic

It is the physical environment in which the whole intelligent clinic is located involves air conditioning, fluorescent lamps, curtains, light boxes, entrance guards, people (doctors, patients) and other objects.

2) Internet of Things application system in clinic

The Internet of Things system of intelligent clinic consists of the following three parts: a sensing network composed of temperature sensors, illumination sensors, infrared sensors, RFID readers, etc., which can sense and acquire various environmental information in the consulting room in real time, the controllers of various physical equipment such as air conditioners, fluorescent lamps, curtains, light boxes, entrance guards, etc., which can control all physical equipment in the clinic in real time. The background processor, which sends instructions to each device controller according to relevant rules based on the sensed environmental information in the clinic.

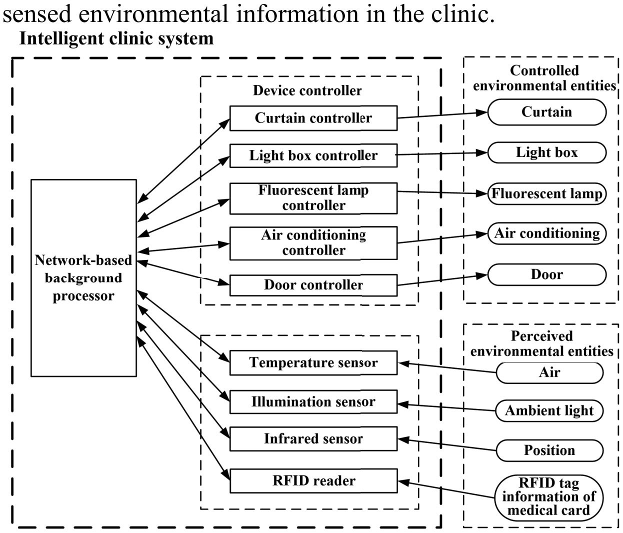


Figure 1. Application scenario of intelligent clinic in hospital internet of things environment

B. Environmental Entity

As can be seen from Fig. 1, hospital intelligent diagnosis and treatment service under the internet of things environment interacts closely and frequently with its surrounding environment. The surrounding environment is composed of several related environmental entities, which can be divided into two categories, as follows:

1) Perceived environmental entity: indoor air, light, patients involved in the intelligent diagnosis room system, and various physiological parameter information such as patient body temperature, blood pressure, pulse, heart rate collected in the intelligent ward system all belong to perceived environmental entities, and their state values are obtained by service in a perceptual manner.

2) Controlled environmental entity: fluorescent lamps, air conditioners, light boxes, curtains in the intelligent diagnosis room all belong to controlled environmental entities, the state of which can be changed according to predefined instructions sent by the service, and the most common one is various embedded equipment.

C. Internet of Things Service

The Internet of Things service refers to software modules provided by various Internet of Things devices, which show the functions of the devices and can be called by each other, including atomic services and composite services [24].

1) Atomic Service

Atomic service refers to service that is indivisible and cannot be decomposed into finer-grained services during execution. Atomic service includes three categories:

a) Perception service: in the scene of the intelligent clinic, the temperature sensing service obtains the temperature information in the clinic in real time, the illumination sensing service obtains the light information in the clinic in real time, and the position sensing service obtains the patient position information (whether it is in the examination area of the clinic) and the film position information (whether the films such as X-ray films, CT films, magnetic resonance films are on the viewing area of the light box). In the scene of an intelligent ward, physiological index information of patients is collected and monitored in real time by the sensing services of physiological index such as body temperature, blood pressure, pulse, heart rate and so on. This kind of service perceives its relevant state information through interaction with external environment entities and transmits it to other services.

b) Control service: in the scene of the intelligent clinic, all the physical equipment involved correspond to relevant control services, such as air conditioning control service, curtain control service, light box control service, fluorescent lamp control service, entrance guard control service, etc. This kind of service can be used to control the state and behavior changes of relevant environmental entities.

c) Processing service: in the scene of the intelligent clinic, the patient's current position information is sensed in real time according to the patient's position sensing service. When the examination area of the patient in the clinic is monitored, a Down command is issued to the curtain control service, otherwise, an Up command is issued, the process of which is completed by the curtain processing service. Similarly, according to the current position information of X-ray films, CT films, magnetic resonance films and other films sensed by the film position sensing service in real time, when the viewing area of the light box is monitored, an On command is issued to the light box control service, otherwise, an Off command is issued, and the entire process is completed by the light box processing service. The characteristic of this kind of service is that it does not directly interact with environmental entities, but converts the information obtained from the perception service into control instructions according to specific rules and transmits them to relevant execution devices, thus controlling their behavior operations [9].

2) Composite Service

Composite service, as its name implies, is a new and more complex Internet of Things service formed by the aggregation of multiple atomic services according to specific business processes.

In an intelligent clinic system, information such as air temperature, illumination, location, RFID diagnosis card and so on are acquired through relevant sensing services, and then the information is transmitted to a processing service, and the processing service comprehensively processes the information and then transmits the result to control services of relevant environmental entities such as air conditioners, fluorescent lamps, curtains, light boxes, entrance guards and so on. Then the control services issue corresponding control commands to the environmental entities according to the received information and execute corresponding operations, thus forming an intelligent clinic diagnosis and treatment combined service in the whole process.

D. Providing Framework of Hospital Intelligent Diagnosis and Treatment Service under Internet of Things Environment

On the basis of the existing Internet of Things service modeling, combining the actual characteristics of hospital diagnosis and treatment, the hospital intelligent diagnosis and treatment service providing framework under the Internet of Things environment is built. In particular, this refers to intelligent diagnosis and treatment in the narrow sense of the hospital Internet of Things environment, and does not consider out-of-hospital application scenarios. Overall, the framework consists of four parts, namely, the hospital intelligent diagnosis and treatment service set module, the diagnosis and treatment environment knowledge set module, the diagnosis and treatment service model construction and verification module, and the diagnosis and treatment service selection and combination strategy module under the hospital internet of things environment, as shown in Fig. 2.

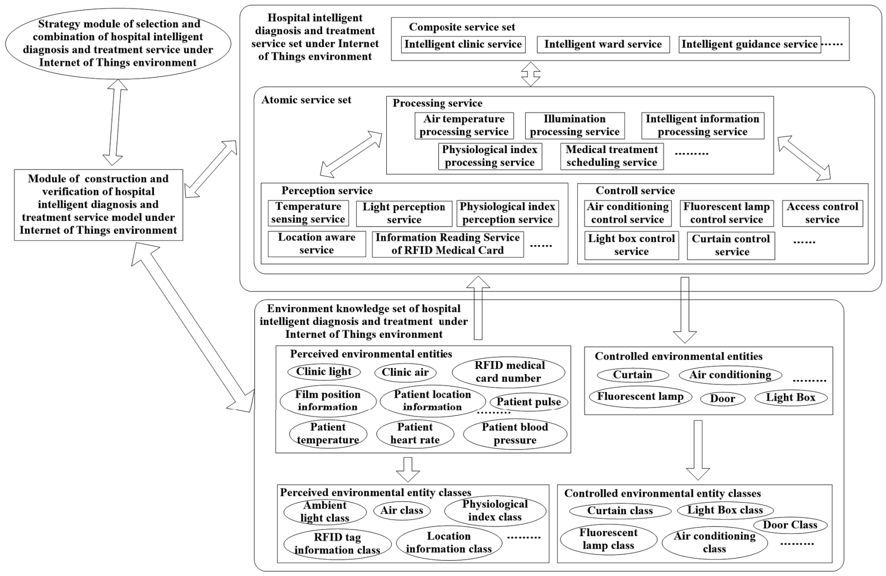


Figure 2. Providing framework of hospital intelligent diagnosis and treatment service under the internet of things environment

The hospital intelligent diagnosis and treatment environment knowledge set under the Internet of Things environment contains various environmental entity classes and environmental entities under the diagnosis and treatment environment, including two categories of the perceived and the controlled. The former mainly includes the entity classes of ambient light, air, physiological index, location information and RFID tag information, etc.; the latter mainly includes the entity classes of air conditioners, fluorescent lamps, screens, light boxes, entrance guards, etc.

Hospital intelligent diagnosis and treatment service set under the Internet of Things environment includes two parts, one is atomic service set and the other is composite service set. The atomic service set includes three types, namely, perception service, control service and processing service. The perception services mainly include environmental information such as room temperature and light, location information such as patient location and film location, physiological indexes such as patient temperature, blood pressure, pulse and heart rate, and RFID card information reading service. The control services mainly include curtain control service, lamp box control service, fluorescent lamp control service, air conditioning control service and entrance guard control service. The processing services include temperature processing services, light processing services, physiological index processing services, intelligent information processing services and medical treatment scheduling services. The composite service set is composed of atomic services of the hospital intelligent diagnosis and treatment system according to certain rules to meet the application requirements of the hospital intelligent diagnosis and treatment under the Internet of Things environment, specifically including the intelligent diagnosis and treatment room system, the intelligent ward system, the intelligent diagnosis and treatment guide system, etc.

The constructing and verification module of hospital intelligent diagnosis and treatment service model under the Internet of Things environment mainly carries out formal modeling and relevant correctness verification on various diagnosis and treatment services under the hospital Internet of Things environment. There are many methods of formal modeling and verification, which need to use related tools, such as UPPAAL [25-26], KRONOS [27] for timed automata, PAT [28-29] for concurrent real-time systems, etc.

The hospital intelligent diagnosis and treatment service selection and combination strategy module under the Internet of Things environment stores the relevant strategies of intelligent diagnosis and treatment service selection, matching, combination and recommendation to meet the diagnosis and treatment application needs of patients and their families. For example, when patients choose outpatient service, they always hope that the closer the clinic site is, the better, the shorter waiting time is, the better, the cheaper the cost is, the better, and the higher the credibility of the doctor is, the better, which is the recommendation and combination strategy of outpatient service.

III. MODELING OF HOSPITAL INTELLIGENT DIAGNOSIS AND TREATMENT SERVICE BASED ON TIMED AUTOMATA IN INTERNET OF THINGS ENVIRONMENT

A. *Extension of Timed Automata*

Timed automata is a classical formal description model, which usually needs to be defined from the aspects of initial state, state set, character set, clock set, transformation relation and so on [13]. In this paper, the timed automata is defined as seven tuples, as follows:

Definition 1: The timed automaton is a seven-tuple $TA=(L,L_0,\Sigma,C,V,I,E)$. L is a finite state set; L_0 is the initial state; Σ is an action set, and

$\Sigma = \{\alpha? \mid \alpha \in chan\} \bigcup \{\alpha! \mid \alpha \in chan\} \bigcup \{\tau\}$ indicates that the action set consists of three parts, namely the input action, output action and internal action, where τ refers to the internal action; C is the set of all clock variables; V is the set of finite variables involved; I refers to the mapping $L \to \Phi(C)$, where $\Phi(C)$ refers to the clock constraint set; E refers to the set of all transformation relations, that is, the set of all directed edges.

Definition 2: Suppose there are n timed automatons TA_1, TA_2 .... TA_n, where for $\forall i \in \mathrm{N}, 1 \le i \le n$, $TA_i = (L_i, L_{0i}, \Sigma_i, C_i, V_i, I_i, E_i)$, and the timed automaton network composed of these n timed automatons is denoted as $NTA = TA_1 || TA_2 || TA_3 .... || TA_n$. These different timed automatas can realize synchronous communication by sharing clock variables and data variables.

B. Modeling of Environmental Entities

Firstly, based on the concept of class in the object-oriented idea, the environmental entity class is defined as follows:

Definition 3: An environment entity class can be represented by the quad $ET =< ETid, Pro, Act, Fun >$. $ETid$ is an identifier identifying the environmental entity class; Pro is the collection of all attributes of the environment entity class; Act is the set of all operations allowed by the environment entity class; $Fun : Pro \to DataType$ is the mapping from attribute set to data type, where $DataType$ can be basic data types such as integer, floating point, Boolean, or other user-defined types.

Use EET as a collection of all environmental entity classes. From the foregoing, it can be seen that the environmental entity class includes two types: the perceived environmental entity class and the controlled environmental entity class. In the following, the specific environmental entity class will be described by taking the patient class $Patient$ (perceived environmental entity class) and the curtain class $Curtain$ (controlled environmental entity class) as examples respectively.

$Patient =< Patient, \{ploc\}, showploc, fun_p >$, where $Patient$ is the identifier of entity class $Patient$, and $ploc$, the attribute of the class $Patient$, indicates the location area where the patient is located. Here, it is assumed that there are two values $True$ and $False$, which indicates whether the patient is in the sensed examination area, so the range type is $Bool$. $showploc$ indicates the action of class $Patient$ to inform the outside of the patient position information, and fun_p is defined as $fun_p(ploc) = Bool$.

$Curtain =< Curtain, \varnothing, \{cup, cdown\}, fun_c >$, where $Curtain$ is the identifier of entity class $Curtain$. The entity class $Curtain$ has no attributes, so the attribute set is empty. cup and $cdown$ are the two operations of entity class $Curtain$, where cup indicates that the curtain rises and no patients is being examined in the examination area, and $cdown$ indicates that the curtain is lowered and there are patients being examined in the examination area. There is no definition of fun_c because the attribute set of entity class $Curtain$ is empty.

After the above definition of the environmental entity class is completed, the following defines the specific environmental entity to which it belongs.

Definition 4: An environmental entity can be represented by the triplets $E =< Eid, ET, ETA >$. Eid is an identifier identifying the environmental entity; $ET \in EET$ is an environmental entity class to which the environmental entity belongs; $ETA = (L, L_0, \Sigma, C, V, I, E)$ is a timed automata according to definition 1, and its main function is to describe the dynamic behavior of the environment entity.

In the following, specific environmental entities will be described by taking the perceived environmental entity $patient$ and the controlled environmental entity $curtain$ as examples.

The environmental entity $patient$ belonging to the class of perceived environmental entities $Patient$ is represented as $patient =< patient, Patient, ETA_p >$. $patient$ is the unique identifier of the environmental entity $patient$, which belongs to the environmental entities class $Patient$, and its behavior description ETA_p is shown in Fig. 3. The location of the patient is represented by the variable $ploc$, which is a logical variable to indicate whether it is in the sensed examination area, and output via the channel $ShowPatientloc$.

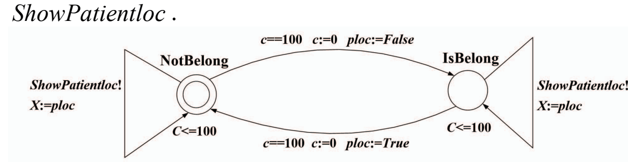


Figure 3. Description of patient entity automata

The environmental entity $curtain$ belonging to the class of controlled environmental entities $Curtain$ is represented as $curtain =< curtain, Curtain, ETA_c >$. $curtain$ is the unique identifier of the environmental entity $curtain$, which belongs to the class of controlled environmental entities $Curtain$, and its behavior description ETA_c is shown in Fig. 4. The curtain receives the Up and Down commands from and the two channels Cup and $Cdown$, respectively.

Based on the above description of environmental entity classes and environmental entities, the following is a modeling of Internet of Things services.

C. Modeling of Internet of Things Services

1) Modeling of Atomic Service

In order to realize the function of Internet of Things service, it is inevitable to interact with the surrounding environment. Therefore, when modeling it, it is necessary to describe the environment entity classes with which interact. First of all, the Internet of Things atomic service is defined as follows:

Definition 5: Internet atomic services for something can be represented by the triplets $<Sid,SE,STA>$. Sid is an identifier identifying the service; $SE \subseteq EET$ is a collection of environmental entity classes to which all environmental entities interacting with the service belong; STA is a timed automaton to describe the dynamic behavior of the service.

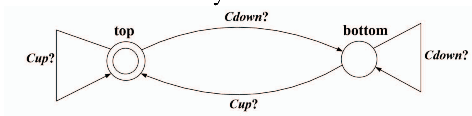


Figure 4. Description of screen entity automata

In the following, combined with the intelligent diagnosis and treatment of hospitals under the Internet of Things environment, we give examples of the three types of atomic services.

a) Perception service

For example, $<S,\{Patient\},SA>$ represents a patient perception service, and its behavior description SA is shown in Fig. 5. The service acquires the location of the patient through the channel $ShowPatientloc$ every 5 time units and stores it in the variable p_loc. Then according to whether the location is within the examination area, it communicates with other services through the channels $IsBelong$ and $NotBelong$, respectively.

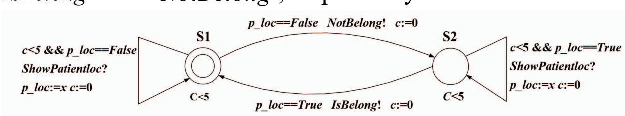


Figure 5. Timed automata description of patient perception service

b) Control service

For example, $<C,\{Curtain\},CA>$ denotes the curtain control service, and its behavior description CA is shown in Fig. 6. The service sends the Up and Down commands to the curtain through the channels Cup and $Cdown$, respectively, and maintains communication with other services through the channels $RiseCurtain$ and $DescendCurtain$.

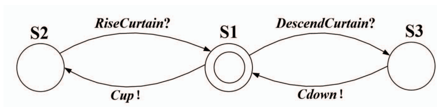


Figure 6. Description of the time automaton of the curtain control service

c) Processing service

This type of service does not directly interact with any environmental entity, so its $Eset$ is empty.

For example, the curtain position adjustment service $<P,\varnothing,PA>$, where PA is described as shown in Fig. 7.

It is assumed that the service obtains the location information of the patient from the patient location sensing service at regular intervals. If the service obtains the location information of the patient from the channel $IsBelong$ when the patient enters the examination area, the service sends a Down command to the curtain through the channel $DescendCurtain$ until the curtain reaches the bottom. If the service obtains the location information of the patient from the channel $NotBelong$ when the patient leaves the examination area, an Up command is issued to the curtain through the channel $RiseCurtain$ until the curtain reaches the top.

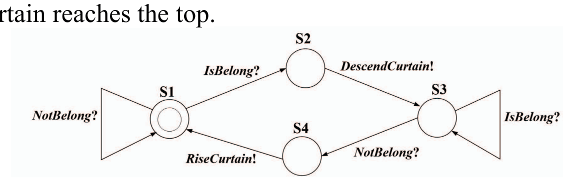


Figure 7. Description of the time automaton of the curtain position adjustment service

2) Modeling of Composite Service

The composite service of Internet of Things composed of several atomic services can be modeled on the basis of the atomic service model through the timed automata network [9-10]. The relationship between the composite service of internet of things based on timed automata and timed automata network is shown in Fig. 8.

The definition of composite service is given below, as follows:

Definition 6: If there are n the Internet of Things atomic services $S_1, S_2, S_3, ...S_n$, where $S_i =< Sid_i,SE_i,STA_i > \quad (1 \le i \le n)$, the new Internet of Things service composed of these n atomic services can be expressed as $S =< Sid, \bigcup_{i=1}^{n} SE_i, STA_1 \| STA_2 \| STA_3 \| ......STA_i >$, and $S_1, S_2, S_3, ...S_n$ are called the member services of this new service S. Sid is an identifier for identifying the new service; $\bigcup_{i=1}^{n} SE_i$ indicates that all environmental entities of the new service, which is the union of the respective environmental entities of all member services; $STA_1 \| STA_2 \| STA_3 \| ......STA_i$ denotes a timed automaton network of the new service, in which $STA_1, STA_2, STA_3,......STA_i$ can concurrently execute the respective actions and can also realize the interaction between member services $S_1, S_2, S_3, ...S_n$ on a shared channel.

For example, the patient perception service $<S,\{Patient\},SA>$, the curtain control service $<C,\{Curtain\},CA>$, and the curtain position adjustment service $<P,\varnothing,PA>$ mentioned above are combined into a new Internet of Things service $<CompS,\{Patient,Curtain\},SA \| CA \| PA>$. The patient perception service SA perceives the position information of the patient in real time, and transmits the information to the curtain position adjustment service PA. Then PA analyzes and comprehensively processes the information according to the set rules, and transmits the control information to the curtain control service CA, which controls the rise and fall of the curtain to adjust the final position (top or bottom) of the curtain.

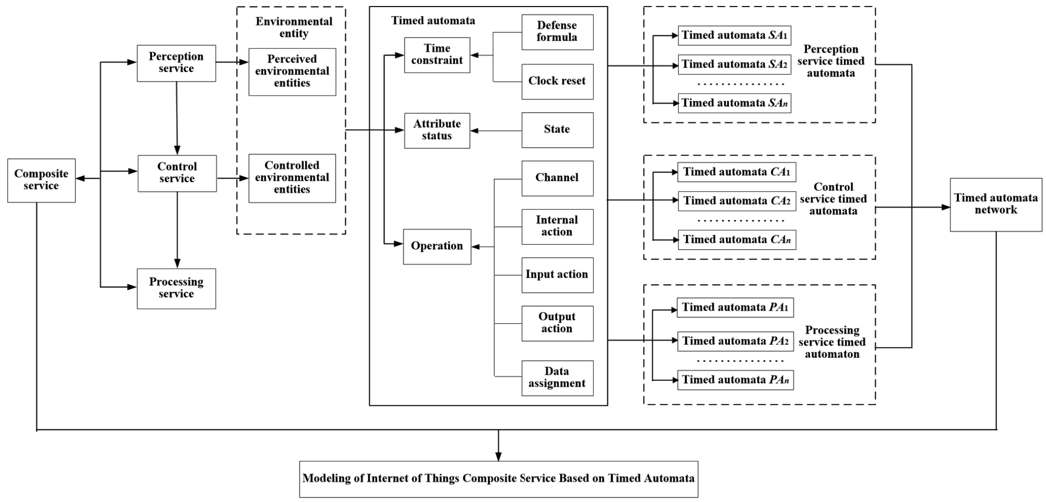


Figure 8. Modeling of composite service of internet of things based on timed automata

IV. VERIFICATION OF INTERNET OF THINGS SERVICES

From the foregoing discussion, we can see that the capability of Internet of Things services is manifested through interaction with the environment, so its correctness lies not only in its own behavior, but also in adapting to changes in the environment [10]. Next, the timeliness correctness of Internet of Things services will be discussed, and UPPAAL, a model detection tool, will be selected as the verification tool. Verification is carried out from four aspects of accessibility, security, system activity and time constraint of Internet of Things services, and description is uniformly carried out by using the sequential logic formula in UPPAAL, as follows:

1) Security: it is to verify that the service can always be in a running state under the condition of abnormal stop of operation, and that unexpected events will never occur. The typical representation of security is the deadlock-free nature of services. For example, if you want the whole hospital intelligent clinic system to operate without deadlock, it is expressed as: $\forall not\ deadlock$

2) Accessibility: it is to verify that the final desired target state of the service can be achieved. For example, if it is hoped that the falling state of the curtain of diagnosis room is reachable, it is expressed as: $\exists <> curtain.descend$

3) Activity: it is to verify that the events the service hopes to occur can occur. For example, when it is monitored that the patient to be treated is located in the examination area of the examination room, the curtain will be lowered, which is expressed as: $patientarea.IsBelong \rightarrow curtain.descend$

4) Time constraint: Some service behaviors have time constraints, which are reflected by time constraint variables in the nature description. For example, when it is monitored that the patient is located in the examination area of the examination room, the curtain will fall to the bottom within 5 seconds, which is expressed as $patient.IsBelong \rightarrow curtain.bottom \wedge curtain.c < 5$, where $curtain.c$ is a time constraint variable that will automatically clear when the curtain falls to the bottom.

V. SPECIFIC EXAMPLES

Next, taking the application scenario of intelligent clinic in hospital intelligent diagnosis and treatment service under the Internet of Things environment as an example, the Internet of Things service is modeled by using timed automata, and UPPAAL is used as a tool for correctness verification.

The working principle of the Internet of Things application system in the intelligent clinic has already been introduced. The intelligent diagnosis room is equipped with air conditioner, fluorescent lamp, light box, curtain, entrance guard system, etc. According to the above methods and ideas, the Internet of Things application system in hospital intelligent clinic is modeled. Due to space constraints, the common functions of general rooms such as temperature control (automatic control of air conditioner), light adjustment (automatic control of fluorescent lamp) and so on will not be described in detail. Here, the modeling is focused on the special functions of the hospital clinic. The specific process is as follows:

A. Creation of Environmental Entity Classes

1) Perceived environmental entity classes

a) Class of patients

$Patient =< Patient, \{ploc\}, showploc, fun_p >$, which has been explained in detail in the example of definition 3.

b) Class of films such as X-ray films, CT films, magnetic resonance films, etc.

$Film =< Film, \{floc\}, showfloc, fun_f >$, where $floc$ indicates the location area of x-ray films, CT films, magnetic resonance films and other films. It is assumed here that it has two values $True$ and $False$, which indicate whether it is on the viewing area of the light box, so the type of value range is $Bool$, and it is defined as $fun_f(floc) = Bool$.

c) Class of tag readers

$Reader =< Reader, \{cardID\}, read, fun_r >$, where $cardID$ indicates the ID of the medical card. Here it is assumed that it has two values of $True$ and $False$, indicating whether it is consistent with the ID of the next patient sorted by the system. Therefore, the type of value range is $Bool$ and it is defined as $fun_r(cardID) = Bool$.

2) Controlled environmental entity classes

a) Class of curtains

$Curtain =< Curtain, \varnothing, \{cup, cdown\}, fun_c >$, which has been explained in detail in the example of definition 3.

b) Class of light boxes

$Lamp =< Lamp, \varnothing, \{lon, loff\}, fur_l >$, where lon and $loff$ are the two operations of the light box, which are turning on and off the light box, respectively. Because the attribute set of entity class $Lamp$ is empty, fur_l has no definition.

c) Class of entrance guards

$Door =< Door, \varnothing, \{dopen, dalarm\}, fur_d >$, where $dopen$ and $dalarm$ are the two operations of entrance guard, namely, opening the door and giving an alarm. Access control is normally closed and will only be opened after receiving the opening instruction. Because the attribute set of entity class $Door$ is empty, fur_d has no definition.

B. Creation of Environmental Entities

1) $patient =< patient, Patient, ETA_p >$

It indicates the patient entity, which has been explained in detail in the example of definition 4.

2) $film =< film, Film, ETA_f >$

It indicates an entity in the area where films such as x-ray, CT and magnetic resonance are located, and its behavior description ETA_f is shown in Fig. 9(a). Film position is expressed by the variable $filmloc$, which is a logical variable to indicate whether it is in the viewing area of the light box, and output through the channel $ShowFilmloc$.

3) $reader = < reader, Reader, ETA_r >$

It represents a reader entity, and its behavior description ETA_r is shown in Fig. 9(b). Here it is assumed that patients swipe their cards at regular interval. Use the variable $cardID$ to record the card number of the patient swiped read by the reader, and output it through the channel $ShowCardID$, that is, whether the current swiped patient ID is the next patient in the system sequence.

4) $curtain =< curtain, Curtain, ETA_c >$

It indicates a curtain entity, which has been explained in detail in the example of definition 4.

5) $lamp =< lamp, Lamp, ETA_l >$

It indicates the light box entity, and its behavior description ETA_l is shown in Fig. 9(c). It is assumed here that the light box receives instructions to turn on the light box and turn off the light box from the two channels Lon and $Loff$, respectively.

6) $door = < door, Door, ETA_d >$

It indicates the entrance guard entity, and its behavior description ETA_d is shown in Fig. 9(d). Assuming that the entrance guard receives an opening command from the channel $Dopen$ (the entrance guard is normally closed and will only be opened when receiving the opening command), it receives an alarm prompt command from the channel $Dalarm$.

C. Modeling of Internet of Things Services

1) $< s_1, \{Patient\}, SA_1 >$

It indicates the patient perception service, which has been explained in detail in the example of definition 5.

2) $< s_2, \{Film\}, SA_2 >$

It indicates the sensing services of film such as X-ray, CT, magnetic resonance, etc., and the behavior description SA_2 is shown in Fig. 9(e). The perceived film position is acquired by the service through the channel $ShowFilmloc$ at regular intervals and stored in the variable f_loc . According to whether the film position is in the viewing area of the light box, the service communicates with other services through the channels $IsBelong$ and $NotBelong$, respectively.

3) $< s_3, \{Reader\}, SA_3 >$

It indicates the RFID tag service for reading the RFID card swiped by the patient, that is, to sense the tag number of the RFID card swiped by the patient, and its behavior description SA_3 is shown in Fig. 9(f). The service acquires the card number of the RFID treatment card swiped by the patient through the channel $ShowCardID$ at certain time intervals and stores it in the variable r_id . According to whether the number of treatment card currently swiped is consistent with the system sequence, it communicates with other services through the channels $Consistent$ and $InConsistent$, respectively.

4) $< c_1, \{Curtain\}, CA_1 >$

It indicates the curtain control service, which has been explained in detail in the example of definition 5.

5) $< c_2, \{Lamp\}, CA_2 >$

It indicates the control service of light box, and its behavior description CA_2 is shown in Fig. 9(g). The service sends out On and Off commands to the light box through the channels Lon and $Loff$, respectively, and maintains communication with other services through the channels $TurnonLamp$ and $TurnoffLamp$.

6) $< c_3, \{Door\}, CA_3 >$

It indicates the access control service, which behavior description CA_3 as shown in Fig. 9(h). The service sends out On and Alarm commands to the entrance guard through the channels $Dopen$ and $Dalarm$, respectively, and maintains communication with other services through the channels *OpenDoor* and *AlarmDoor*.

7) $< p_1, \varnothing, PA_1 >$

It indicates the location adjustment service of the curtain, which has been explained in detail in the example of definition 5.

8) $< p_2, \varnothing, PA_2 >$

It indicates the processing service for turning on and off the light box, and its behavior description PA_2 is shown in Fig. 9(i):

a) when the service obtains the location information of x-ray films, CT films, magnetic resonance films and other films from the channel *IsBelong*, it sends signals to the lamp box through the channel *TurnonLamb*;

b) when the service obtains the location information of X-ray films, CT films, magnetic resonance films and other films from the channel *NotBelong*, it will send signals to the light box through the channel *TurnoffLamb*.

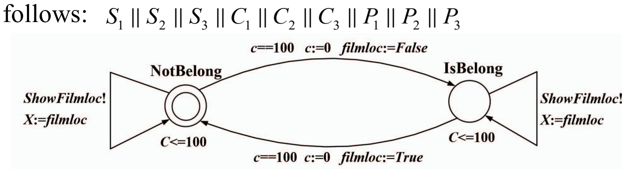
9) $< p_3, \varnothing, PA_3 >$

It indicates the processing service for opening and closing the entrance guard, which behavior description PA_3 as shown in Fig. 9(j):

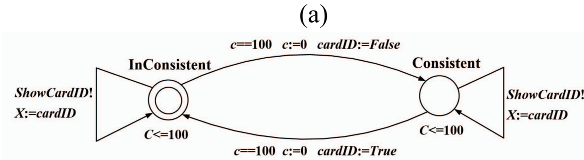
a) when the service obtains the information from the channel *Consistent*, it sends a signal to the entrance guard through the channel *OpenDoor*;

b) when the service obtains the information from the channel *InConsistent*, it sends a signal to the entrance guard through the channel *AlarmDoor*.

All the above services are combined to form an intelligent clinic service of the hospital internet of things, which is described by the timed automata network as follows: $S_1 \| S_2 \| S_3 \| C_1 \| C_2 \| C_3 \| P_1 \| P_2 \| P_3$



(a)



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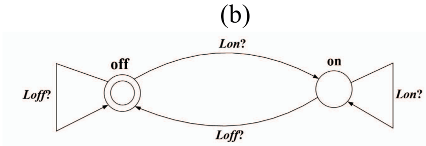

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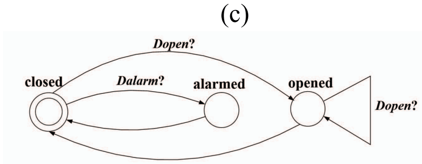

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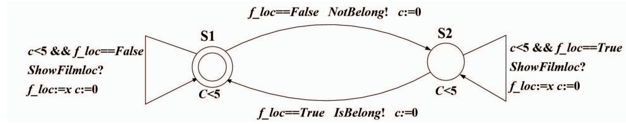

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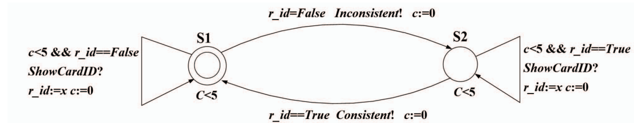
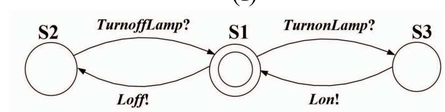
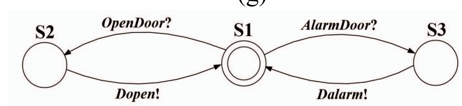


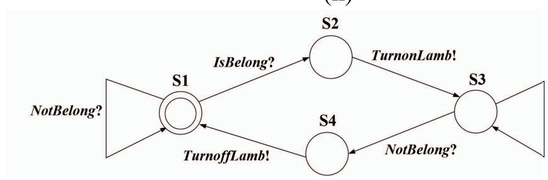
(f)



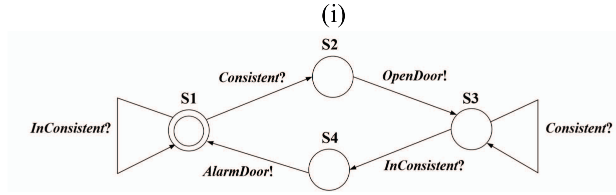
(g)



(h)



(i)



(j)

Figure 9. Hospital intelligent clinic timed automata network under internet of things environment

D. Verification of Internet of Things Services

In order to verify the Internet of Things service, the external environment in which it interacts must be considered. Next, the combined intelligent clinic service in hospital Internet of Things and interactive related environmental entities will form an overall system: $S_1 \| S_2 \| S_3 \| C_1 \| C_2 \| C_3 \| P_1 \| P_2 \| P_3 \| patient \| film \| reader \| curtain \| lamp \| door$

The validity of the prescription is verified from the following four aspects:

1) System security:

Input the statement $\forall not\ deadlock$ into UPPAAL validator for detection. The green button of the validator lights up, indicating that deadlock will not occur. The intelligent clinic service described by the above model can proceed normally.

2) System accessibility:

Input a statement $\exists <> curtain.descend$ into the validator for detection. The statement indicates that the partition curtain can enter a descending state, and the detection result is that the property is satisfied.

Input the sentence $\exists <> lamp.on$ into the validator for detection. The sentence indicates that the light box can enter the open state, and the detection result is that the property is satisfied.

Input the statement $\exists <> door.open$ into the validator for detection. The statement indicates that the entrance guard can enter the open state, and the detection result is that the property is satisfied.

3) System activity:

Input the sentence $film.IsBelong \rightarrow lamp.on$ into the validator for detection, indicating that the light box is turned on when the positions of films such as X-ray, CT and magnetic resonance are in the viewing area of the light box. The detection results show that this property is satisfied.

Input the statement $patient.IsBelong \rightarrow curtain.descend$ into the validator for detection, indicating the curtain will fall down when the position of the patient is in the examination area of the examination room. The detection results show that this property is satisfied.

Input the statement $reader.Consistent \rightarrow door.open$ into the validator for detection, indicating that the entrance guard is opened when the ID of the RFID medical card swiped by the patient is consistent with the ID of the patient currently called by the system. The detection results show that this property is satisfied.

4) System time constraint:

Input the statement $patient.IsBelong \rightarrow curtain.bottom \wedge curtain.c < 5$ into the validator for detection, indicating that when the patient is detected to be located in the examination area of the examination room, the curtain drops to the bottom within 5 seconds. The detection results show that this property is satisfied.

Input the statement $patient.c <= 5 \rightarrow infrasensor.work$ into the validator for detection, indicating that the infrared sensor installed in the examination area of the clinic runs every 5 seconds to sense the location of the area where the patient is being treated. The detection results show that this property is satisfied.

Input the sentence $film.c <= 3 \rightarrow infrasensor.work$ into the validator for detection, indicating that the infrared sensor installed on the light box runs every 3 seconds to sense the location of the area where films such as X-ray, CT, magnetic resonance, etc. are located. The detection results show that this property is satisfied.

Input the statement $reader.c <= 1 \rightarrow reader.work$ into the validator for detection, indicating that the RFID reader installed on the entrance guard runs every 1 second to sense the ID number of the RFID card brushed by the patient. The detection results show that this property is satisfied.

VI. CONCLUSIONS

In order to provide a method for testing the stability, reliability and correctness of the hospital Internet of Things system, avoid system design errors, reduce design defects and avoid design risks, a modeling and verification method for intelligent diagnosis and treatment service of the hospital Internet of Things is proposed by taking timed automata as a modeling tool and fully considering the interaction between the Internet of Things service and the external environment and the time attribute of the service. Furthermore, taking the application scene of the intelligent diagnosis room of the hospital outpatient service as an example, the whole process of modeling and verification is given.

The main work done in this paper is as follows:

1) Through the actual analysis of the hospital diagnosis and treatment service scene, the Internet of Things technology is combined with the actual application of the hospital to build the hospital intelligent diagnosis and treatment service providing framework under the Internet of Things environment.

2) Based on the theory of timed automata, the traditional model of timed automata is expanded. On the basis of modeling the three atomic services, that is, perception type, control type and processing type respectively, the timed automata network is established, and the hospital intelligent diagnosis and treatment service model based on timed automata under the Internet of Things environment is constructed.

3) Using the timed automata modeling and verification tool UPPAAL, taking the application scenario of intelligent clinic in hospital outpatient service as an example, the correctness of the formal model has been verified to avoid design errors, reduce design defects, improve system stability and reliability, providing a feasible method for hospital intelligent diagnosis and treatment service modeling design under the Internet of Things environment.

On the basis of the above work, the next step will be further research from the following two aspects:

1) The hospital diagnosis and treatment services under the Internet of Things environment mentioned in this paper cannot be dynamically combined by atomic services according to patient needs, and the basic combination mode of diagnosis and treatment service is only sequential combination, and other complicated combination modes have not been considered. In the next step, it is necessary to construct a dynamic combination method of diagnosis and treatment services on demand under the hospital Internet of Things environment and other combination methods of services suitable for diagnosis and treatment scenes, so as to further improve the analysis and verification of the hospital Internet of Things system.

2) When describing the hospital diagnosis and treatment service under the Internet of Things environment, we should not only pay attention to the functional behaviors of the hospital diagnosis and treatment service, but also pay attention to the service quality attributes attached to the functions, such as the consumption of consumables, expenses and other resources in the implementation of the diagnosis and treatment service described by using cost functions. In addition, we should also describe the patient's service requirements in a simple, understandable and analytical way. This paper has described the functional

behavior of hospital diagnosis and treatment services under the Internet of Things environment as a finite automaton. Next, it is proposed to model the diagnosis and treatment services with the attributes of service quality as a time automaton network with cost, and describe the patient needs as a time series logic formula, laying a solid foundation for the analysis and verification of the nature of hospital diagnosis and treatment services under the Internet of Things environment.

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REFERENCES

[1] Chen Haiming, Shi Hailong, Li Qin, etal. Challenges and Research Progress of Internet of Things Service Middleware [J]. Chinese Journal of Computers, 2017, 40 (8): 1725-1749.

[2] Chen Zhao, Zeng Fanping, Chen Guozhu, etal. Overview of Internet of Things Security Assessment Technology [J]. Journal of Information Security, 2019, 4(3): 1-16.

[3] Chen Haiming, Cui Li. Service-oriented Internet of Things Software Architecture Design and Model Testing [J]. Chinese Journal of Computers, 2016, 39(5): 853-871.

[4] Wang Ji, Zhan Naijun, Feng Xinyu, etal. Overview of formal methods [J]. Journal of Software, 2019, 30(1): 33-61.

[5] Yu Lei, Lu Yang, Zhu Xiao-Juan, Qiu Shu-Wei. A Web Services Description Language-Based Description Model of Internet of Things Services [J]. Sensor Letters, 2014, 12(2): 448-455.

[6] De S, Barnaghi P, Bauer M, etal. Service modeling for the Internet of Things. In: Proceedings of Federated Conference on Computer Science and Information Systems. Szczecin: COMPUT SCI INF SYST, 2011, 949-955.

[7] Ma Li, Li Weikang, Chen Liang, etal. Formal Modeling and Verification of Resource-Oriented Internet of Things System [J]. Miniature Microcomputer System, 2018, 39(1): 140-145.

[8] Ye Lin, Tang Bao, Guo Lipeng, etal. Modeling and Verification of Internet of Things Service Based on Hybrid System [J]. Minicomputer System, 2013, 34(12): 2663-2668.

[9] Li Lixing. Internet of Things Service Description and Performance Analysis Based on Environmental Modeling [D]. Beijing: Chinese Academy of Sciences University, 2013.

[10] Li Lixing, Jin Zhi, Li Ge. Modeling and Verification of Internet of Things Service Based on Timed Automata [J]. Chinese Journal of Computers, 2011, 34(8): 1365-1377.

[11] Li Ge, Wei Qiang, Li Lixing, etal. Internet of Things Service Modeling: A Method Based on Environmental Modeling [J]. Chinese Science: Information Science, 2013, 43(10): 1198-1218.

[12] Wang Guoqing, Zhuang Lei, Wang Ruimin, etal. Modeling and verification of Internet of Things gateway security system based on timed automata [J]. Journal of Communications, 2018, 39(3): 63-75.

[13] Zhu Kai, Guan Guoqing, Wu Lihua, etal. Computational Complexity of Some Problems Concerning Timed Automata Reset [J]. Journal of Software, 2019, 30(7): 2033-2051.

[14] Chen Yonggang, Yang Lu, Dong Wang. Research on Modeling of Train Tracking Module Based on UML Sequence Diagram and UPPAAL [J]. Journal of Measurement Science and Instrumentation, 2019, (10): 157-167.

[15] Lu Jidong, Zhu Xiaolin, Wang Haifeng, etal. Research on Uncertain Time Delay Consistency Test of High Speed Railway Train Control System Based on UPPAAL-TRON [J]. Journal of Railways, 2016, 38(1): 54-64.

[16] Han Xiao, Tao Tang, Lu Jidong, etal. Failure Cause Analysis of CTCS-3 Train Control Vehicle Subsystem Based on Failure Logs Caused by Wrong Demand [J]. Journal of Railways, 2017, 39(3): 59-70.

[17] Bao Yu, Zhao Liang, Chen Shuzhao, etal. Usability Test of WSNs for Roadway Gas Monitoring Based on Entity Interaction Model [J]. Journal of Coal Industry, 2019-05-23: 1-10 (First Online, Unpublished Paper)

[18] Zhao Lei, Wei Xing, Zhang Jianjun, etal. Modeling and Verification of Autonomous Driving Process of Mine Locomotive [J]. Journal of Hefei University of Technology (Natural Science Edition), 2018, 41(10): 1362-1367.

[19] Shang Guanwei, Zhang Fengjiao, Cai Bogen, etal. Optimization of CVIS Test Sequence Based on Firefly-Immune Algorithm [J]. China Journal of Highway and Transport, 2017, 30(11): 129-137, 155.

[20] Deng Xuefeng, Sun Ruizhi, Nie Juan, etal. Modeling of Internet of Things System for Greenhouse Environment Monitoring Based on Timed Automata [J]. Journal of Agricultural Machinery, 2016, 47(7): 301-308.

[21] Sun Cheng, Xing Jianchun, Yang Qiliang, etal. Modeling and verification of hierarchical timed automata for automatic inspection control logic of equipment [J]. Computer Science, 2017, 44(14): 66-78.

[22] Meng Yao, Li Xiaojuan, Guan Yong, etal. Modeling and Verification of Robot Joint Communication Bus System [J]. Journal of Software, 2018, 29(6): 1699-1715.

[23] Gong Weiwei, Wang Rui, Li Xiaojuan, etal. Modeling and Verification of Control Behavior of Cognitive Robot Based on UPPAAL [J]. Minicomputer System, 2016, 37(6): 1279-1283.

[24] Guinard D, Trifa V, Karnouskos S, etal. Interacting with the SOA-based Internet of Things: discovery, query, selection, and on-demand provisioning of web services. IEEE Trans SERV COMPUT, 2010, (3): 223-235.

[25] Larsen K, Pettersson P, Wang Y. UPPAAL in a nutshell [J]. International Journal on Software Tools for Technology Transfer, 1997, 1(1-2): 134-152.

[26] David A, Larsen KG, Legay A, etal. Uppaal, SMC tutorial [J]. International Journal on Software Tools for Technology Transfer, 2015, 17(4): 397-415.

[27] Yovine S. KRONOS: A verification tool for real-time systems [J]. Internal Journal on Software Tools for Technology Transfer, 1997, 1(1-2): 123-133.

[28] Yan Pei. Formal Analysis and Verification of Intelligent Home Care System [D]. Taiyuan: Taiyuan University of Technology, 2016.

[29] Liu Yang. User Manual [EB/OL]. http://pat.sce.ntu.edu.sg/wp-source/resources/OnlineHelp/htm/index.htm. 2013-05-27.