A Smart Health Service Model For Elders Based On ECA-S Rules

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***Abstract*—Health services delivery relating to chronic diseases in elders are becoming a hot spot with the progressively severity in population aging in China. To provide a better service system for the elders, researchers have used active rule based techniques including Event-Condition-Active (ECA). In this paper, we enhanced ECA to ECA-Sequence (ECA-S) rules to detect abnormal condition in physiological indices. Our method extracts accurate health information from historical sequence data. The ECA-S is used to differentiate burst variations in physiological indices from morbid cases. Our further experiment in giving early warning for diabetic patients shows that ECA-S can deal with the burst abnormal physiological index problem. Finally, an evaluation is made among existing ECA based solutions including prime ECA, ECA-Parameters, ECA-Post-condition and proved that our proposed ECA-S method performs better in health diagnosis quality as compared to others.**

Keywords—Smart Health; Active services; ECA-S rules; burst abnormal physiological index

I. INTRODUCTION

Population aging is the general trend in the world with respect to the increase in the scientific progress and economic development. For the treatment of chronic diseases on the elders, China is facing sundry problems such as unreasonable medical resource allocation, medical ethics problem etc. These problems change the psychology of humans in fact patients in a way that they now avoid to go to hospital for medical treatment, and even afraid to go to the hospital. However, smart health is helpful for the treatment in senile chronic diseases significantly.

The governments attain smart health mostly through the hospital, such as the electronic medical record (EMR), electronic payment. But it does not work without hospital and obviously can't improve medical ethics problem, particularly in senile chronic diseases (e.g. diabetes, hypertension, etc.). In most situations, patients don't have to go to hospital for routine body inspections, because the doctor would usually tell the patient that everything is normal, and just suggest to take the medicine on time. Smart health services proposed in this paper will help patients to keep a good health and go to hospital as less as possible. Sometimes patients could make a simple diagnosis remotely.

Aiming at senile chronic diseases' rehabilitation and healthcare, this paper pro-posed a smart health service model based on ECA-S rules mainly solves the following problems:

1) Patients could acknowledge about their own health situation at any time. Most old patients with chronic disease can't understand their healthy status. They don't want to go to hospital when they feel a little discomfort. This leads to the gradual deterioration of the physical situation. This model uses specific active rules to provide accurate health information for patients.

2) The problem of burst abnormal physiological indices. In view of the actual situation, we need to solve the problem that the key physiological index (e.g. blood pressure) changed suddenly by special events (e.g. scare). In this paper, we provide accurate health information and early warning to patients using ECA-S rules and graded warning.

3) Utilization of ECA-S rules. In order to improve the quality of services, the smart health model should improve the matching rate of ECA-S rules.

II. RELATED WORK

A. Smart Health Service

Smart health service has quite a few successful cases, such as health services based on mobile phones. These kinds of services are the most common. There is real-time monitoring health service, and it works with some wearable devices, such as insulin monitoring [1]. In addition, image processing and analysis are also used to provide health services. This case includes sequential pattern profiling based bio-detection for smart health service [2], which provides health instruction to the chronic disease patients through abnormal image analysis. Other similar services like the smart home services [3], context-aware services [4]. So there are a large number of solutions to achieve the smart health services.

Now there is still a need in enterprises and the governments in China concentrating on the development of smart health. For instance, the smart bracelet gradually appeared a few years ago.

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These smart bracelets only cover some simple functions. So it has great limitations in health detection and service providing.

B. Relevant Rules

At present, the ECA rules mainly embodies in active way (distributed active database [5], adaptive distributed systems [6], web service composition [7], and UML modeling language [8]). There are two popular extend class of ECA rule: ECAP and ECA-P.

Event-Condition-Action-Parameters (ECAP) [8] is a kind of rule which combines event trigger with object-oriented and event-driven environment.

$$r=\{E:\{e_n\}C:\{c_1,c_2,...c_m\}A:\{a_1,a_2,...a_u\}P:\{p_1,p_2,\ldots p_k$$

To finish the separation of data and knowledge, the management and process policies are abstracted as rules. In this case, there are numerous factors to participate in the calculation, while a single rule does not need all the factors, thus the Parameters part can help selecting appropriate factors.

Event-Condition-Action-Post-condition (ECA-P) [9] is also the extension of ECA rules.

$$r=\{E:\{e_n\}C:\{c_1,c_2,...c_m\}A:\{a_1,a_2,...a_u\}P:\{post-condition\}\}$$

This rule is used to solve those different users and administrators may have conflicting policies for managing the massively distributed system. In ubiquitous computing environment, there are a large number of policy rules and conflicts. For example, rule R1 may state, “If a person enters the active space, start authorization application” and rule R2 may state, “If a person enters the active space, suspend applications”. Suspending applications stops all applications running in the space including the authorization application. This leads to a conflict between the two rules. It is easy to find out on the description of the natural language. But these two rules will not be able to coexist if there are no restrictions. So in this environment, ECA requires a restriction (Post-condition) to control these conflicts.

Smart health service model neither needs ECAP nor ECA-P. It is better to use the ECA rules. Because before using the ECA rules, all kinds of data from patients are easy to translate into ECA rules. For example, in a period of time, the blood pressure is greater than 160, it’s judged to be hypertension. Patient is most likely to appear dizziness for a period under this blood pressure. Once all the conditions are met, it will immediately send out warning information to patients. There aren’t many factors or complicated environment. Using the simplest ECA rules will enough to accomplish active service. But using ECA rules directly will face the critical problem: How to deal with burst abnormal physiological index? In order to solve this problem, this paper proposed an ECA-S rule.

III. Smart Health Service Model and Optimized Rule

A. Dataset

Healthy data can be divided into two parts by data source (As shown in figure 1): the first part of the data is collected through patients. In other words, data are produced by patients, which requires patient to input or acquire from the wearable or portable devices actively. The data are about patient's personal information or physical signs, such as the medical history of the patients, allergic history, age, sex, blood glucose. This type of data is usually collected by patients and patients' family. In addition to these non-real-time data, smart health service also needs to obtain real-time data, such as heart rate, breathing rate, body temperature.

The second part of the data is crawled from Internet. Then extract the feature information according to demands, and save data in database. But there is a series of unexpected data like incomplete data, inconsistent data and noise data, so it is necessary to clean the data to save complete, correct and consistent information. Data fusion integrates multiple data and knowledge represents the same real-world object into a consistent, accurate, and useful representation. After data fusion, we need to reduce the data volume. After acquiring the knowledge from the data, smart health service model has been established. Finally, we could provide patients with corresponding and appropriate services on the basis of these data.

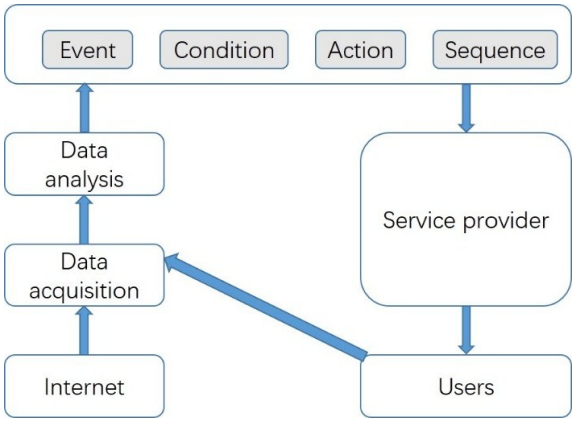

Fig. 1: Smart health service model

B. ECA-S Rule

If the main service is driven by ECA rules, it will produce a wrong information service in the case of burst abnormal physical index. There are 2 situation：1. When the patient is measuring his blood pressure, the blood pressure will get high due to the tension or scare. 2. A patient with diabetes had slightly higher sugar content before measuring blood glucose, but he was not aware of it. The ECA rules will trigger a warning to remind the patient that the blood pressure/blood glucose is too high directly. But in fact we know that this is not due to the illness. This way it

can't provide accurate health information of the patient if we still use ECA rules.

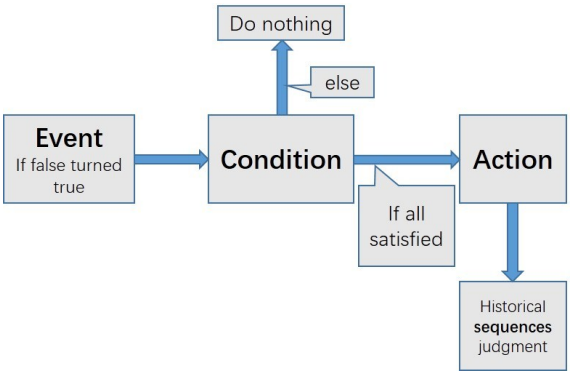

Fig.2: The semantic of ECA-S rules

Therefore, we proposed the ECA-S rule (As shown in figure 2). We add the historical sequence determination after the original rule. If the patient has an abnormal sign, it will not only trigger the rule matching, but also compare with the historical sequence (results of previous detection). According to the historical sequence and classification warning (Yellow warning, blood glucose gets high!), we can effectively deal with burst abnormal physiological index problem, and provide patients with accurate health information.

The optimized ECA-S rule can be expressed as a vector r:

$$r = \{E:\{e_1, e_2, ...e_n\}\, C:\{c_1, c_2, ...c_n\}\, A:\{a_1, a_2, ...a_n\}\, S:\{sequence\}\}$$

To explain ECA-S rule more concretely, we define Event, Condition, Action, Sequence, burst abnormal physiological index as follows:

- The event is a set of sub situations.
- The condition is a Boolean expression to fire smart health services.
- The action is a function that calls the health information service and the historical sequence determination.
- The sequence is a length of inspection data before one checkpoint.
- The burst abnormal physiological index is the situation that the physiological index becomes strange suddenly.

Different diseases will appear different symptoms. When an Event (diabetes) comes to "true", it will match corresponding conditions (blood glucose value>11, polydipsia=="true", polyphagia=="true") of the rule. When conditions $\{c_1, c_2... c_m\}$ are met, the Action will call the corresponding information service module and checking historical sequence model. Finally, it will send the appropriate health information to patients depend on the length of historical sequence.

C. A Half-Active Application of Active Rules

The rule can't be too simple considering the precision of the service. At the time of patients require services, the corresponding rules could not be triggered due to lacking patient's information. The case will greatly reduce the quality of smart health services.

For instance, a patient needs a daily exercise health recommendation. We should provide different advice according to each patient's specific situation. After all, different disease severity ought to take different measures. For this reason, different patient's advices are different. As for patients, it is extremely hard to send the complete and right data, and it will not able to obtain the complete and accurate data even through the mobile terminal. In order to solve this problem, this paper proposed a half-active application way of ECA-S rules.

This kind of application needs to interact with patients. Sometimes the information is shared by patient in application incomplete. In this situation, the information which patient doesn't give a feedback could be supplemented through interactions. This will effectively improve the trigger rate of ECA-S rules and service quality.

D. Health information Service

There are 3 types of smart health services: daily reminding service, early warning service, message pushing service. A lot of elderly chronic disease needs to take medicine regularly, but many people may not take medicine on time or reduce the dosage of medicine privately. For instance, hypertension patients have to take medicine regularly to control blood pressure. Hence it is necessary for these patients to provide daily reminding health care services. Patients need only once guidance from doctor if they want to set the reminding on their own.

In addition, early warning service is of great importance in all services. When the patient's data are analyzed and met requirements of early warning analysis, smart health services will send out corresponding early warning information. For example, when the terminal device found that the patient's blood pressure is higher than normal (140mmhg/90mmhg), and has been rising. The phenomenon shows that blood pressure isn't under control obviously. The service will remind patients taking medicine or taking other measures. Chronic diseases, which break out usually need a process, and this process is accompanied by some gradually abnormal physical index. So the warning can also be classified as different levels (e.g. yellow level, orange level, red level, etc.). Classified warning can avoid the problem of warning not in time. Once data exceptions occurred, and met all the conditions for a rule as well, the warning will be sent by invoking a web service to patients.

Message pushing service is the embodiment of the personalized recommendation. For patients suffering from chronic diseases, if they can do some physical therapies independently, this will be beneficial to their rehabilitation. For example, patients are recommended to walk for half an hour after

a meal, breathe fresh air outside, keep a good mood, and etc. Though it is seemingly trivial daily habits, if patients can hang on these habits, which will be very helpful in keeping health.

IV. THE EXPERIMENT AND EVALUATION

A. Experiment

Here, we design a process of the early warning for diabetic patients. It shows the smart health service model and how to solve the burst abnormal physiological index problem and provide accurate health information.

Before the patient gets the service, they need to login. We identify a specific patient through the account and password, the account also includes the basic information of patients. Meanwhile the account + password + alias mechanism could protect personal privacy. We use a table to store the basic information of the patient (as shown in table1), if the problems of patient physical condition occurred, such as hunger, fatigue, high blood glucose and etc. (Event). Once these symptoms appear, the corresponding rule will immediately match the conditions (Condition), in other words, the system will compare these conditions with the standard signs which stored in table2 and table3. Once the warning conditions are met, the system will call the early warning module (Action). Then it will show the corresponding warning information to patient after checking the historical sequence. Besides, the smart health services are provided in many other ways. It will also trigger the rules when we obtain, update, check and analyze the patients' information. So many kinds of health information about the patients will be shown, and it is beneficial to the patient's rehabilitation and daily health care.

TABLE I. THE BASIC INFORMATION OF THE PATIENTS

Attributes	Data Type	Primary Key	Remarks
Account	Char	key	
Password	Char		
Sex	Char		
Name	Char		nickname
Age	Int		
Blood_pressure	Double		
Temperature	Double		
Pulse	Int		
Breath_rate	Int		

TABLE II. WARNING MATCH

Attributes	Data Type	Primary Key	Remarks
Name	Char	Key r t1 Name	nickname
Disease	Char	Key r t 3 Disease	Name of disease
P_symptoms	Char		Patients' symptoms
Key	Int		Standard symptom
Warning_info	Char		Warning information

TABLE III. STANDARD INFORMATION

Attributes	Data Type	Primary Key	Remarks
Disease	Char	Key	Name of disease
Symptoms	Char		
Prediction	Char		
Susceptible	Char		

Since the adopted rule model is the optimized ECA-S rule model. It is more in line with the application environment. And ECA-S rule works better in dealing with the burst abnormal physical index when it combines with warning classification. As shown in Figure 3, when the abnormal index appeared first, (record 23) we have to make a minimum level of early warning (yellow alert), because the historical record (as shown in Figure 4 line 21, 22 records) shows that the results are in the normal range.

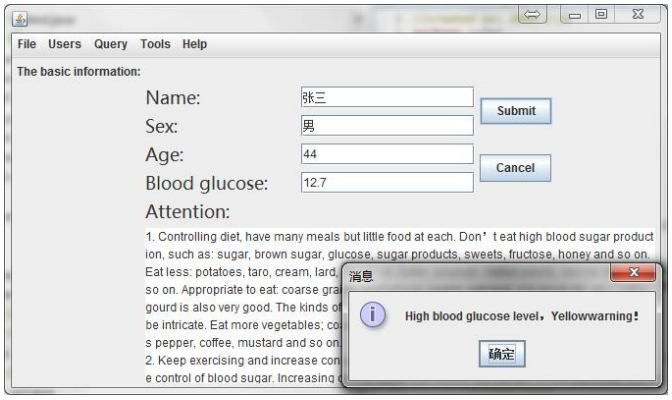

Fig. 3: Processing of burst abnormal physical indexes

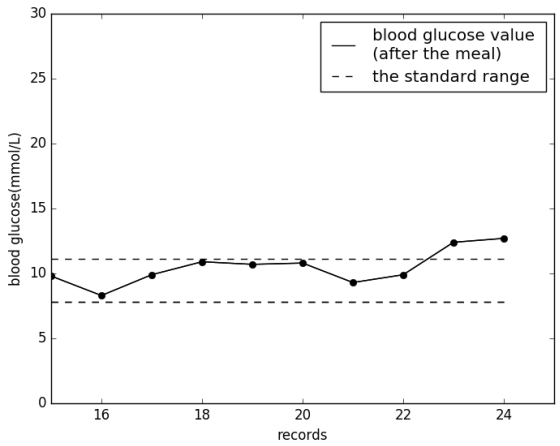

Fig.4: Patient physical indexes records

The values of historical sequence are beyond the normal range (as shown in Figure 5). When the blood glucose value is too high after the records 23 and 24, the higher level warning (orange alert) is issued.

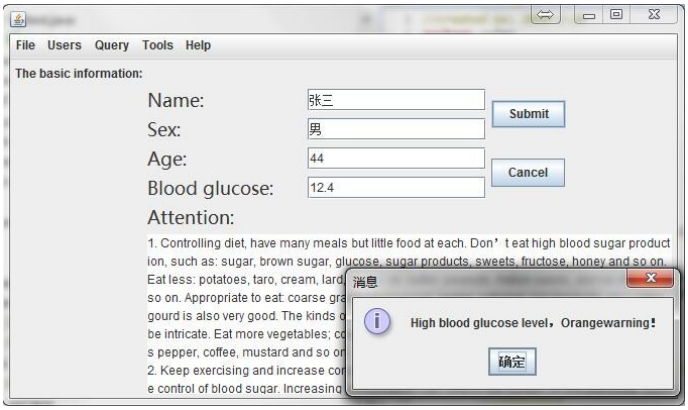

Fig. 5: Increasing the warning level

B. Evaluation

Under the elderly smart health application environment, we evaluate the performance of ECA-S rules and other rules in following aspects: Initiative, easy maintenance, expansibility, burst abnormal physical index processing ability (BAPPA).

TABLE IV. EVALUATION OF ECA-S

Rule	Initiative	Easy maintenance	Expansibility	BAPPA
ECA	√	√	√	—
ECAP	√	—	—	—
ECA-P	√	—	—	—
ECA-S	√	√	√	√

It is shown by table 4, under the elderly smart health environment, only ECA-S rule can efficiently solve the burst abnormal physical index problem. Meanwhile in other aspects, it performs better than other optimized rules.

CONCLUSION

Let's review the whole smart health service model. There are many layers of data transmission, and it seems to affect the whole system time efficiency, but getting the data and analyzing data from the internet are finished before the service requirement. The "finished" refers to that rules set reached a certain scale to provide services for users. Meanwhile, the server of the health service iterates this process continually, and constantly optimizes rules. Most of the data is not obtained when patients need services. Thus this process will not affect services' time efficiency.

The future development tendency of our smart health services will combine with the mobile terminal development. There will be more accurate and timely warning to chronic diseases. In server end, the rules are defined by people. But we expect that rules could be defined by the system. Services mainly reflect in providing patients with a certain self-rescue measure. As for a heart attack, patients can quickly cough in time to save their lives. This kind of service requires an extremely short time to detect symptom and send the warning information. We are going to put the part of the relevant data in mobile terminal. It is one of the solutions to the problem of real-time services. The system may save the life as long as it can detect out the abnormal data and send warning information in advance. This type of services is extremely valuable.

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