Design Petri Net to Simulate the Processes of Tele-Healthcare

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Abstract: - Because of the health care is getting important to people and the Internet services are getting reliable and stable, the tele-healthcare services built on the Internet can be good supports of the traditional home healthcare and hospital medical services. Hence, how to save the medical resource such like the manpower of health professionals and medicinal resources which are the limit of institutional beds; and, the unnecessary medical examinations. Hence, this research uses Petri nets to analyze and build the operating flow of the tele-healthcare. The petri nets make the resource transfer process among different states very clear, and the states and the token-based flow which can help the care providers, e.g. care organizations and caregivers, ensuring the right care actions are given at right time and decreasing the possible mistakes may caused by caregivers accidentally.

Key-Words: - Petri net, Healthcare, Homecare, Telemedicine

1 Motivation and Contributions

Recently, life conditions and medical techniques are getting better and people's average lives have longer than before. Besides, most developed countries have accepted the age of 65 or older as being "elderly" [14]. According to the report by Director-General of Budget, Accounting and Statistic (DGBAS) in Taiwan, life expectancy was 71.8 for men and 77.2 for women in 1992. In 2006, life expectancy has risen to 74.6 for men and 80.8 for women. The percentage of the population in Taiwan in 1993 was 7.1% at elderly. In 2007, the percentage of the population was elderly has gone from 7.1% to 10.21% of the total population [3]. This situation also happens in Canada. In 1920, life expectancy was 59 for men and 61 for women. Life expectancy has risen to 75 for men and 81 for women in 1990. The percentage of the population that is elderly has gone from 6.68% to 12.87% of the total population in Canada [2].

Hence, more and more questions about an aging society such like the elder can not obtain suitable care action with their family, the shortage of health professionals such like doctor and caregiver, and waste of medical resources such like institutional beds. In order to deal with those questions, the care organizations are hoping to investigate the way to solve the care requests progressively. The care request for instance, cared people ask doctors or caregivers to examine their

health conditions and/or explain their health conditions for them in either hospitals or their homes..

Recently, the Internet services are getting reliable and stable. There are many medical organizations which are using computers and Internet technologies to deal with care requests. We call the system as a tele-healthcare system. Using tele-healthcare system is easier for the care organizations to reduce the medical costs caused by the shortage of health professionals and caregivers, because of the caregivers and doctors can monitor the health conditions of the cared people via the tele-healthcare system remotely [1][5][7]. The tele-healthcare system let the caregivers get the cared people's health conditions with measurement instruments at home and take suitable care actions at right time [6][9][12].

Hence, using the tele-healthcare services can have many advantages for doctors, caregivers, and cared people, for instances, doctors can realize the health conditions of cared people who have chronic diseases; caregivers can avoid doing unnecessary care actions; and, cared people do not need to go to the hospitals very often.

In order to develop the ideal tele-healthcare services, there are at least three issues needed to take into considerations. The first issue is how to reduce time costs by defining the care action timing and manpower [1]. The second issue is how to get the cared person's health conditions. There are two kinds of medical examination instruments: non-invasive and invasive instrument. This research uses non-invasive instrument to get cared people's health conditions. The non-invasive instruments are usually using in measuring physiology signals, for examples, blood pressure, electrocardiogram, and breath frequency. The third issue is how to ensure the cared people received appropriate care actions given by caregivers.

This research does a thing to deal with the performance of tele-healthcare. We use Petri nets to design a tele-healthcare processes which has three modules. The processes clearly and simply show the health conditions of a cared person to his/her caregiver and delivers the care requests to the caregivers.

Section 2 introduces the researches of Petri nets. Section 3 defines alarm state levels and describes the detailed processes of three modules in Petri-net-based tele-healthcare. At the end, this paper will use a complete example to show the process of using the tele-healthcare system Section 5 makes a simple conclusion.

2 Related Works in Healthcare System

There are some researchers who find the cared people has chronic diseases in the hospital who need time for traveling and medical resources for monitoring and healthcare [4][8]. Many healthcare designers build healthcare information management processes for the cared people. Such application indeed improves the cared people's life and healthcare conditions, also provides them a better medical environment [1].

Emanuel proposed four care service for the cared people: nursing care, transportation, homemaking services, and personal care [4]. In order to deliver the cared people the care services and save the manpower and medical costs, this research makes the caregivers have ability to do appropriate care actions by defining the care actions with Petri nets.

2.1 Using Petri Nets to Control the System Flows

A Petri net is one of mathematical representations of discrete distributed systems. It was invented by Carl Adam Petri in 1962. Petri net has been used in many different domains such like Performance Evaluation, Communication Protocols, Fault-tolerant systems, Programmable logic, VLSI arrays, discrete event systems, Decision models, and Office-information systems.

There are some elements in Petri nets which have state nodes s_i, transition nodes t_j, and directed arcs connecting states and transitions [11]. States may contain any numbers of tokens. When the condition of the transition nodes is satisfied, the token will transfer from one state to another.

Fig 1 shows a Petri-net example in which there are four states: s_1, s_2, s_3, s_4, and three transitions: t_5, t_6, t_7. The token starts at the state s_1 and should transfer to other states through the transition t_5. After t_5 is triggering, the token would be transfer to states either s_2 or s_4.

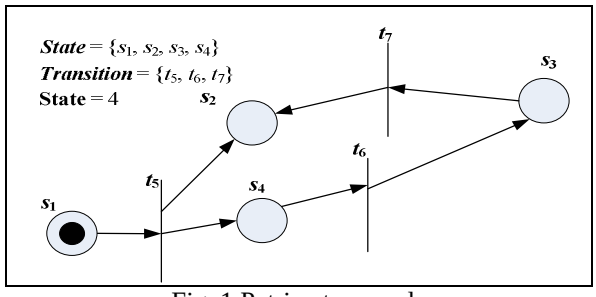

Fig. 1 Petri net example

This research uses Petri nets to represent how the care actions will be changed if the health conditions of the cared people changed. The detailed descriptions will be introduced in Section 3.3.

3 Petri Net in Healthcare

In order to reduce both of resource and time costs, there are some tele-healthcare system solutions. Maglaveras thought that the tele-healthcare system should have four functions [10]:
(1). Measurement: cared people can upload their health conditions by using tele-healthcare instrument at home. Medical personnel can take the appropriate care actions after analyzed the cared people's healthcare conditions.
(2). Communicative: cared people can use the internet and cared platform to communicate with medical personnel and/or doctors. By using this way, cared people can get appropriate medical services and responses.
(3). Interactive: cared people can use healthcare system to discuss the electrocardiogram data and realizes their health conditions with professionals, also, cared people can get right medical care action at right time.
(4). Educational: cared people can use the internet and/or short message service (SMS)/multimedia messaging service (MMS) to get the information or education materials such like blood sugar control plan and program to improve the cared people's health conditions.

3.1 Petri Nets modules in Tele-Healthcare System

3.1.1 Measurement Module

Fig 2 shows the process that the cared people use the measurement module to do physical examination and get reminders from the system when they forgot doing the examinations. There are two elements in this Petri net include states and transitions. Initially, the system is halt at state s_1. The transition t_1 would be triggered and make the system go to state s_2 after the cared person registered and filled the personalized information. At state s_2, the cared person should do the physical examination by himself/herself at home.

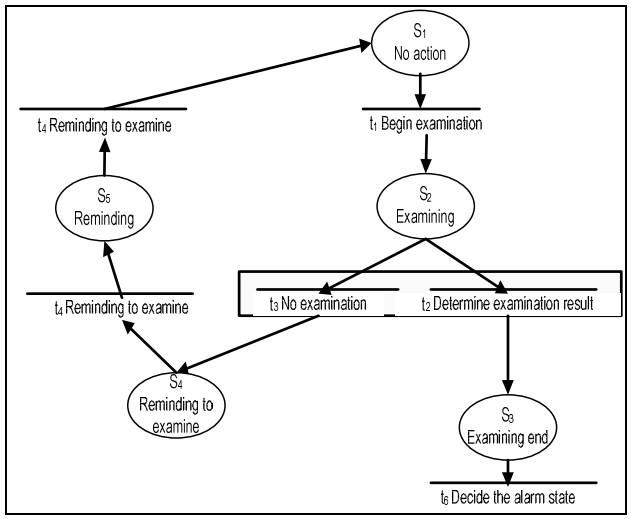

Fig. 2 Measurement module in Petri net

Cared person at state s_2 in Fig 2, there are two situations might be happened. First, the cared person does the physical examination and the transition t_2 will be triggered to make the system go to state s_3. In this case, the cared person finishes his/her physical examination and the transition t_6 will be triggered to decide the alarm level.

Another case, the cared person does not do the physical examination and the transition t_3 will be triggered to make the system go to state s_4 to remind the cared person to do physical examination. If the cared person does not do physical examination over a week, the transition t_4 will be triggered and make the system go to state s_5. The tele-healthcare system will send message to the cared person to remind again and the transition t_5 will be triggered and make the system go to state s_1 again to repeat the physical examination process.

After the cared person got alarm level about his/her health conditions, his/her caregiver will take appropriate care actions according to the alarm level. The detailed research descriptions about the arrangement of care actions are in [13].

3.1.2 Care Action Arrangement Module

Care action arrangement module is showed in Fig 3. When tele-healthcare system receives the cared people's measurement results, system will decide the alarm state of the cared persons which state was examined by themselves at present. According to this measurement results, caregivers realize the cared people who have health status. Alarm states have four levels: A, B, C, and D. The level "A" means cared people do not need to be cared by their caregiver.

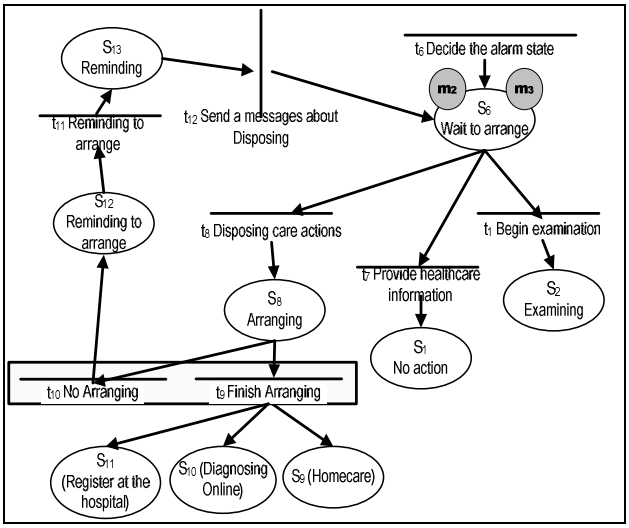

Fig.3 Care action arrangement module in Petri net

There are two tokens, m_2 and m_3, in this module. The token m_2 is the alarm level of the cared person. The token m_3 represents whether the caregiver has done care actions for the cared person already or not.

In Fig 3, after the transition t_6 triggered, the system goes to state s_6 to decide the cared person's alarm level and waits for care action arrangement. There are two situations in Care action arrangement module. First, caregivers arrange the appropriate care actions for the cared people according to their alarm levels. Second, the caregivers do not take any care action for cared people.

In the first situation, when the cared people's alarm level are "A", the caregivers may ask cared people to do another physical examination. The transition t_1 will be triggered and the system will go to state s_2 again. Also, the caregivers may provide related healthcare information about the cared people's health conditions. The transition t_7 then will be triggered and the system will go to state s_1.

If the cared people's alarm level is "B", the caregivers may arrange the suitable care actions. The transition t_8 will be triggered and the system will go to state s_8. Caregiver will arrange the home care service for cared people who have alarm level is "B". The transition t_9 would be triggered and the system will go to state s_9.

If the care people's alarm level is "C", caregiver will arrange the diagnoses online with doctors. The transition t_9 will be triggered and system will go to state s_{10}.

If the care people's alarm level is "D", caregiver will arrange the care action is registering at a hospital. The transition t_9 will be triggered and the system will go to state s_{11}.

Another case, when the caregiver does not arrange any care actions. The transition t_{10} will be triggered and the system will go to state s_{12}. Also, the caregiver does not arrange care actions for cared people over two days. The transition node t_{11} will be triggered and the system will go to state s_{13}. And the system will automatically send a message to ask the caregiver to arrange a care action immediately for cared people. The transition t_{12} will be triggered and the system will go to state s_6.

3.1.3 Action Module

Action module is showed in Fig 4. There are two tokens, m_4 and m_5, in this module. The token m_4 is the alarm level of a cared person. The token m_5 represents whether the caregiver have finished the care actions or not.

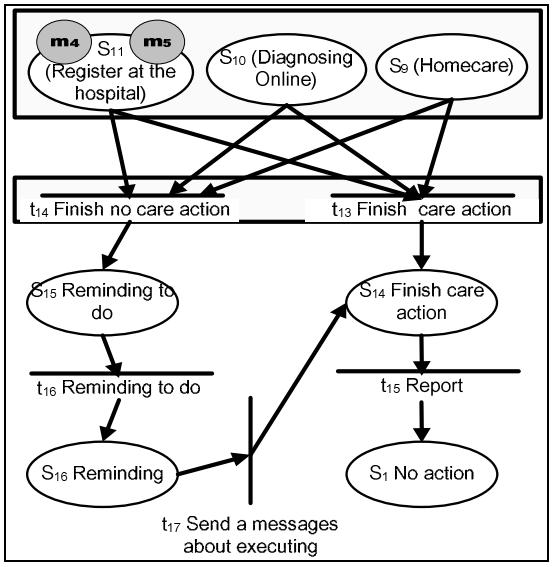

Fig. 4 Action module in Petri nets

There are two situations in action module: (1) the caregiver has done the care actions and (2) the caregiver didn't finish the care actions. If caregivers finished care actions for the cared people, the transition t_{13} will be triggered and make the system go to state s_{14}. The caregivers are asked to upload the care reports back to the tele-care system and the transition t_{15} will be triggered to make the system go to state s_1.

If caregivers did not finish the care actions for the cared people, the transition t_{14} will be triggered and make the system go to state s_{15} to remind the caregiver to do care actions. If the caregivers did not finish care actions in three days, the transition t_{16} will be triggered and the system will go to state s_{16} from state s_{15}. The system will send the message to caregivers and request them to finish the care actions immediately. The transition t_{17} then is triggered and makes the system go to state s_{14} again.

4 Complete Example in System and Experiment

In this example, there are cared person, caregiver, and doctor. Stis is the cared person, Alex is the caregiver, and Maiga is the doctor. Some parameters involved in Petri-net are defined, for example, the token m_1 in Fig 6 represents if Stis needs to take an examination in a week or not.

After Stis did the physical examination and stored the examination data in database via the Internet, Stis gets information about his health conditions. If Stis did not take any physical examination for a while, the system will send message to Stis and ask him to do some examination at home by himself as Fig 6 shows.

The message looks like: "Hello, [Stis]: it's a reminder. The records show that you did not use the tele-physical examination system for a while. [Alex] hopes that you could use the tele-physical examination system. This reminder is sent on [2007/07/19] ".

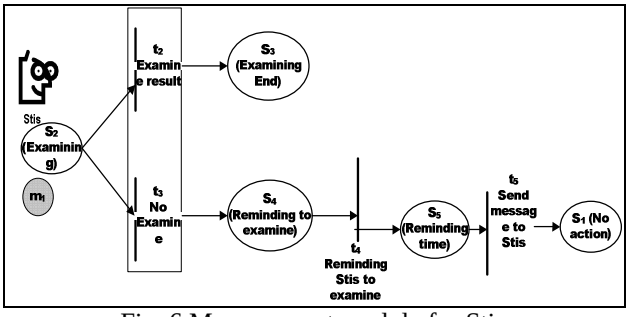

Fig. 6 Measurement module for Stis

After Stis takes the examination, the data will be sending to the system. Alex will know Stis' health condition. If Stis' health condition is classified at the alarm level "C", then Alex should arrange suitable care actions for him. Based on Table 4, Alex arranges Stis doing online diagnosis with Dr. Maiga. If Alex does not arrange the care action for Stis, the system will send a message to Alex.

The message looks like: "Hello, [Alex]: it's an alarm message about your cared person, [Stis], whose liver function is at the alarm state [C]. Please take the suitable care actions for him/her. This message is sent on [2007/07/19]." The process of care action arrangement described above is shown in Fig 7.

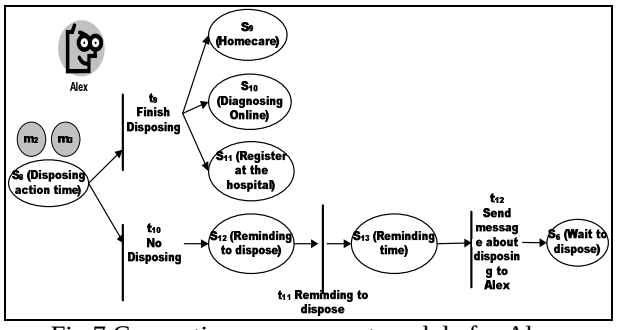

Fig.7 Care action arrangement module for Alex

After arranged the care actions for Stis, Alex will take do the care actions for Stis. Because of Stis' alarm level is 'C', Alex will cooperate with Dr. Maiga to conduct a diagnosis report. If Alex does not do the care actions for Stis in expected time period, the system will send a message to ask Alex to finish the care action as soon as possible.

The message looks like: "Hello, [Alex]: it's a message about your cared person, [Stis], whose liver function is at alarm state [C]. The care action was arranged on [2007/07/19]. If you did not take any care actions for him/her yet, you must take appropriate care action immediately. If you completed the care actions already, please upload the care report form immediately. This message is sent on [2007/07/20]." The process of action module described above is shown as Fig 8.

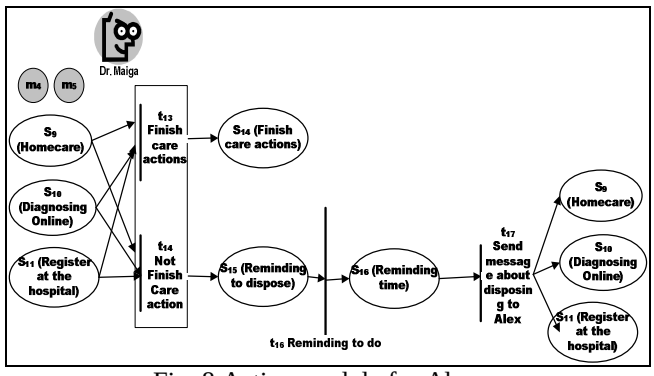

Fig. 8 Action module for Alex

6 Conclusions

It is important to develop a tele-healthcare for care organizations. People can monitor and realize their health conditions with the system easily. Utilizing Petri nets to analyze the tele-healthcare processes which we proposed in this research can clearly and simply show the relations between the cared person's health conditions and the caregivers' care actions. In addition, the system can also remind the caregivers choose appropriate care actions and monitor the care action activities.

The tele-healthcare in homecare not only saves the high-cost of medical manpower and resources, but also discovers the unusual situations happened on the cared person according to long-term examination data. In the future, the tele-healthcare services should be able to help the caregivers and medical professionals in preventative healthcare and health delivery service.

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