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Development of the Structure of the Knowledgebase for Countermeasures in the Knowledge Acquisition Process for Trouble Prediction in Healthcare Processes

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***Abstract*—**Healthcare safety has been perceived important. It is essential to prevent troubles in healthcare processes for healthcare safety. Trouble prevention is based on trouble prediction using accumulated knowledge on processes, troubles, and countermeasures. However, information on troubles has not been accumulated in hospitals in the appropriate structure, and it has not been utilized effectively to prevent troubles. In the previous study, however a detailed knowledge acquisition process for trouble prediction was proposed, the knowledgebase for countermeasures was not involved. In this paper, we aim to propose the structure of the knowledgebase for countermeasures, in the knowledge acquisition process for trouble prediction in healthcare process. We first design the structure of countermeasures and propose the knowledge representation form on countermeasures. Then, we evaluate the validity of the proposal, by applying it into an actual hospital.

***Keywords*—**Trouble prevention, knowledge structure, structured knowledge, reusable knowledge.

I. Introduction

In recent times, more attention has been focused on the quality and safety in healthcare services, particularly on the prevention of medical accidents. An incident reporting system has been widely implemented as a tool or method for accumulating information about medical malpractice in hospitals. In addition, there are some trials [1] to utilize the accumulated information to address the potential troubles. However, the sufficient effects have not been achieved. Before undertaking any preventive action, we must be able to predict the potential troubles. Knowledge regarding past troubles is essential toward this end. However, applying the accumulated knowledge to practical use presents some impediments. In addition, it is challenging to retrieve the required knowledge from enormous information in each situation. Consequently, despite the accumulation of extensive information about medical malpractices it has not been possible to achieve efficient prevention of medical malpractice yet. It is necessary to design a structured knowledgebase to acquire and accumulate reusable knowledge from the records or experiments of past troubles.

Trials have been executed to analyze the past records on troubles and summarize the perceptions for trouble prevention. For instance, [2] analyzed around 11,000 incidents and proposed an “Error Map.” The error map is a metric that expresses the types of errors that tend to occur in each type of process for each operational domain such as injection, internal use, and sample examination. However, it is difficult to abstract appropriate knowledge for concrete consideration objects, because the processes are classified roughly. In addition, it is difficult to utilize this method to specify improvements in existing operation process and process design because only the direct factors are addressed as occurrence factors of the error. Further, it is challenging to identify the part in the process that has problems.

Another example of a trial towards prevention of medical malpractice is presented here. Nakajo et al. [3] proposed a method for applying error proofing principles and proven healthcare solutions for systematically generating workable solutions to reduce human error. They focused on a method for planning countermeasures after identifying the parts of the process that had problems; however, it did not identify the occurrence mechanism of errors and troubles.

Healthcare processes are performed by humans; thus, they are susceptible to human error. Moreover, healthcare work is extremely complex. Besides, the conditions of patients vary hourly and various occupations are intricately related to each other. These complexities lead to human error. It is difficult to represent the mechanism of human error, and an appropriate representation method for troubles in healthcare is needed. Besides, it is difficult to prevent human error only by encouraging workers to work attentively. Therefore, it is necessary to render the work process tolerant to human error, or to avoid situations that lower human attentiveness. Trouble knowledge could be used to improve processes or avoid undesirable situations that lower human attentiveness.

II. Related Studies

Tamura [4] proposed the structure of trouble prediction thinking (as shown in Fig. 1). Possible troubles on an object are predicted through two steps in trouble prediction. First, attributes responsible for troubles concerned with the object are extracted from the accumulated knowledge on object. Then, possible troubles on the object are predicted by being extracted from the accumulated knowledge on trouble, by using those attributes as retrieval keys.

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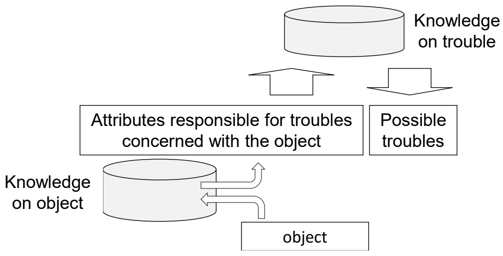

Fig. 1 Structure of trouble prediction thinking [4]

Based on the structure in Fig. 1, [5] proposed the total structure of trouble prediction process for preventing medical malpractice (as shown in Fig. 2). It consists of two processes, the "knowledge acquisition process," and the "knowledge application process." In this case, objects are processes in healthcare services. And through these processes, the knowledge on trouble occurred on healthcare processes is accumulated, and possible troubles for the target process would be predicted, by searching knowledgebase, using the features of the process as retrieval key. Kato et al. [5] also proposed the details of knowledge acquisition process for trouble prediction including the knowledgebase on process and trouble (as shown in Fig. 3).

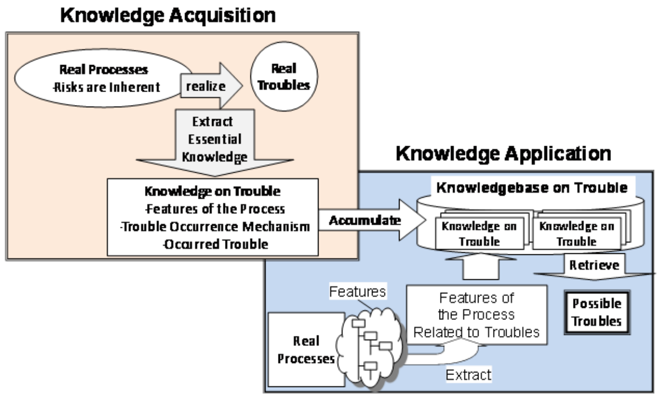

Fig. 2 Total structure of the trouble prediction process for preventing medical malpractice [5]

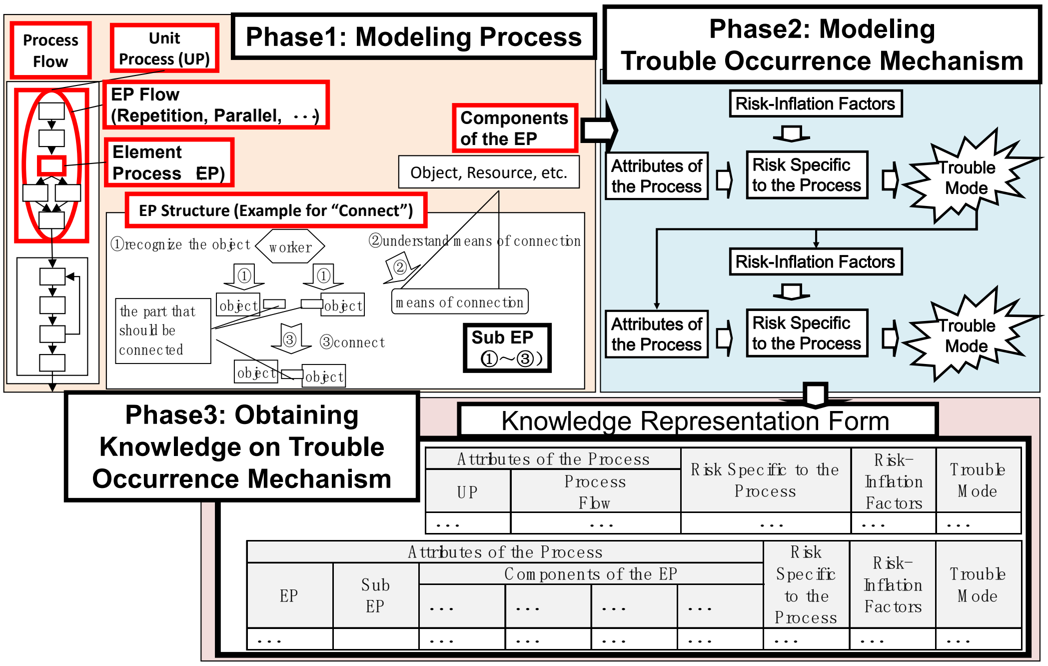

Fig. 3 Detailed knowledge acquisition process [5]

Through verification at actual hospitals, some validity of the model was confirmed, and some issues have emerged as suggestions for future study. The detailed design for knowledge application process was also needed, including a method for appropriately abstracting attributes of the process. It was also required to extend the framework of the proposal to adopt the types of troubles where medical staff gets unconcerned action done. In addition, the knowledgebase on countermeasures, which would be effective for each trouble occurrence mechanism, was needed in both the knowledge acquisition process and knowledge application process, to take appropriate countermeasures for the potential troubles.

III. Purpose of This Study

Among above further issues described in the previous section, we aim to propose the structure of the knowledgebase for countermeasures, which would be used in both the knowledge acquisition process and the knowledge application process, in this study. To achieve this purpose, we first design the structure of the knowledgebase for countermeasures and propose the knowledge representation form on countermeasures. Then, we evaluate the validity of the proposal, by applying it into an actual hospital.

IV. Designing the Structure of the Knowledgebase for Countermeasures

A. Structure of Countermeasures

Kato et al. [6] proposed a risk structure model for patient falls (as shown in Fig. 4), which expresses the time-series process of the accident occurrence, patient factors concerned to the accident, and effective types of countermeasures for each phase in the time-series process. In the risk structure model, patient factors were critical because patient fall is caused by mainly patient actions. The effective type of countermeasures depends on the types of patient factors.

Though we focus on accidents caused by mistake of medical staff in the process for service provision, patient factors would be eliminated, and we could simplify the model.

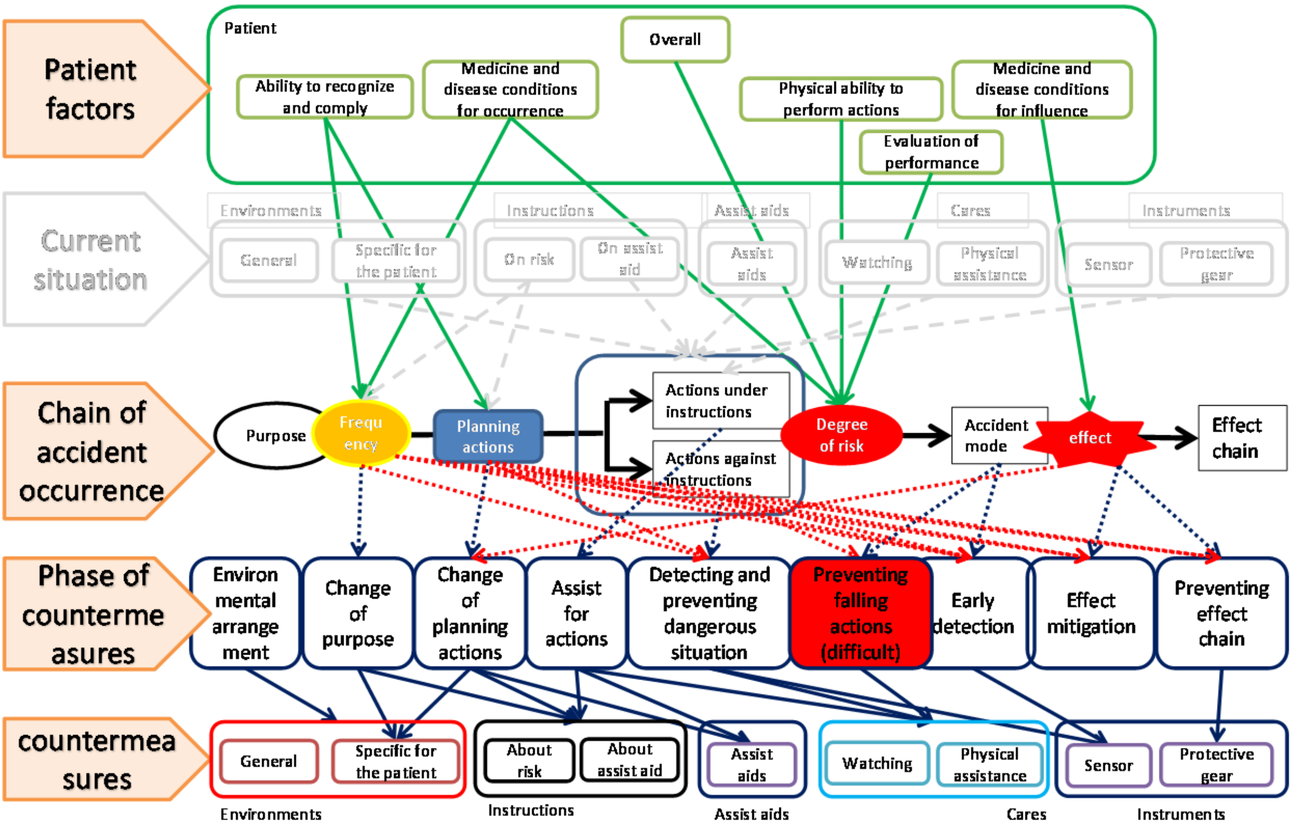

Fig. 4 Risk Structure Model for Patient Falls [6]

Kato et al. [5] proposed the structure of trouble occurrence mechanism as shown in Fig. 5. The process has various features. The features related to trouble are referred to as “attributes of the process,” which generates “risk specific to the process.” Factors that inflate the risk specific to the process are referred to as “risk-inflation factors.” Risk-inflation factors are the conditions of the workers, their surroundings, or any other such factors that connected with the execution of a process. Risk-inflation factors and risk specific to the process combine to generate the “trouble mode.” Trouble mode represents the essence of an undesirable situation or action. The trouble mode sometimes generates other risk-inflation factors. Consequently, a trouble chain occurs. Generally, as above, the occurrence of trouble in service provision processes has some causes. One trouble mode is caused by not only risk specific to the process, but also cause-and-effect chains. There are also various types of countermeasures to prevent one trouble. Not only direct intervention in the causes of trouble occurrence, but also immediate detection and response to the occurring trouble would be effective. To express the appropriate countermeasures belong with the trouble occurrence mechanism, it is necessary to represent the phase, method, and variety of countermeasures systematically.

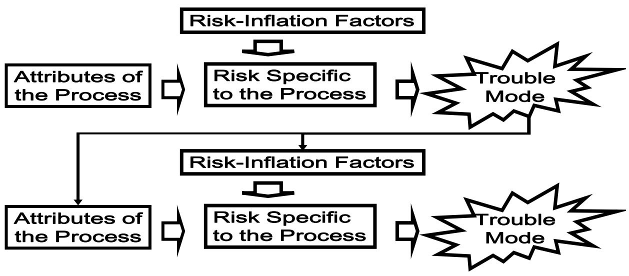

Fig. 5 Structure of Trouble Occurrence Mechanism [5]

We defined the phases in the trouble occurrence and the types of countermeasures (Table I). The relationship between phases and types of countermeasures are shown in Fig. 6.

TABLE I
TYPES OF COUNTERMEASURES

Types of Countermeasures	Definition
Trouble prevention by reducing the opportunity to implement high-risk Element Processes (EPs)	remove high-risk EPs from the plan for process implementation or substitute low-risk EPs for high-risk EPs in the phase of process planning
Trouble prevention through risk reduction	remove the potential risk by changing or confirming components of the high-risk EPs
Detection of the actualized risk	detect that the potential risk is actualized in the preparation phase
Effect mitigation	mitigate the influence of troubles at the moment when the trouble occurred in EPs
Immediate detection of the trouble occurrence	detect that the trouble has occurred as soon as possible in the phase of EP performance
Immediate response	give medical treatment or correct error soon after detection of the occurrence of the trouble
Prevention of cause-and-effect chain	break the cause-and-effect chains built between the occurrence of troubles in the present process and the risk in the next processes

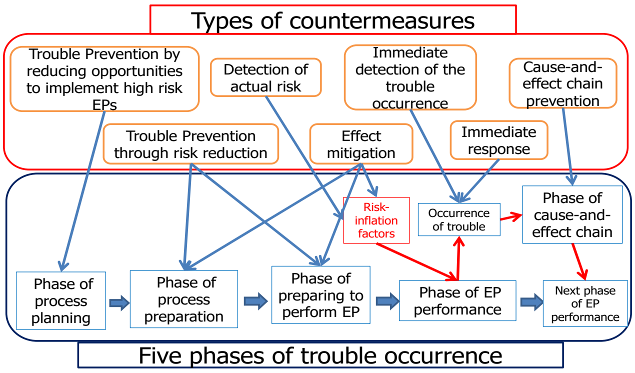

Fig. 6 Structure of Countermeasures

As shown in Fig. 6, five phases are included: the phase of process planning, the phase of process preparation, the phase of preparing to perform EP, the phase of EP performance, the phase of cause-and-effect chain. And, each type of countermeasures is associated with each phase.

B. Knowledge Representation Form on Countermeasures

The whole work process can be divided into several unit processes (UPs). UPs can further be divided into smaller element processes (EPs). In this manner, the work process can be divided into various sizes. Therefore, we must consider the appropriate size to represent knowledge regarding trouble. In this paper, we adopted the work elements framework suggested by [7].

Based on the structure of countermeasures, we designed knowledge representation form on countermeasures as shown in Table II. Then, we actually developed the knowledgebase on countermeasures, which includes 106 Element Processes (EPs), for which knowledge on trouble was obtained in the previous study [5]. These EPs were newly obtained from five real cases of medical accidents in the operation room at Iizuka Hospital, which is an acute stage hospital with 1,000 beds located in Fukuoka Prefecture, via use of the method of trouble acquisition.

Trouble prevention by reducing the implementation of high-risk EPs cannot be described easily at the EP level because it was considered at the Unit Process (UP) level in the phase of process planning. Therefore, six countermeasures (except for trouble prevention by reducing implementation of high-risk EPs) are described in the form of knowledge representation form.

TABLE II
PARTS OF THE KNOWLEDGEBASE ON COUNTERMEASURES

Attributes of Processes				Countermeasure					
EP	Sub-EP	Risk-Infration factors	Trouble mode	Prevention of trouble through risk reduction	Detection of actual risk	Effect mitigation	Immediate detection of the occurrence of trouble	Immediate response	Cause-and -effect chain prevention
· · ·	· · ·	· · ·	· · ·	· · ·	· · ·	· · ·	· · ·	· · ·	· · ·

V. EVALUATION OF THE KNOWLEDGEBASE FOR COUNTERMEASURES

A. Method for Evaluation

In order to validate the knowledgebase for countermeasures, we applied the knowledgebase into some actual cases. We focused on the cases in the operation room, and examined three important cases extracted from incident reports filed in 2007–2009 at Iizuka Hospital.

We applied the method of knowledge acquisition including the knowledgebase for countermeasures designed in chapter 4. Then, we derived countermeasures for possible troubles in the processes concerned with these three cases.

If we could derive countermeasures toward not only the direct causes of the occurred trouble, but also other potential troubles, it would be a guidepost regarding the validity of the designed structure of the knowledgebase for countermeasures.

B. Results of Evaluation

In this section, the example of the results of evaluation, which is for the case "during the operation, a nurse failed to write down the contents of a medical message sheet for the operation" is described as an instance. The standard process for this case was, "nurse writes 'positive reaction against hepatitis B antigen' on the message sheet for the operation." However, the nurse actually wrote "negative reaction against hepatitis B antigen." Actually, the following three elements of trouble occurred:

(1) It was an emergency process, so the nurse forgot to confirm the contents of the medical sheet.
(2) The nurse misunderstood that the patient showed a "negative reaction against hepatitis B antigen" because she did not confirm the contents of the medical sheet. One percent of patients show a positive reaction against the hepatitis B antigen in Japan.

(3) Therefore, the nurse filled in the message sheet with "negative reaction against hepatitis B antigen." It was revealed as a mistaken entry via later reference to the medical sheet.

We described EP flow by paying attention to these main causes and parts of "recognize" and "write." We represented interventions against the causes of trouble and the trouble itself as knowledge of countermeasures in EP form in Fig. 7. In this way, we visualized countermeasures that should be performed in each phase. Moreover, we described widespread countermeasures against other potential troubles, such as "fail to write," "unclear writing," and "mistaken contents of writing." For other cases, we could derive not only countermeasures for direct causes of the occurred troubles, but also various countermeasures for potential troubles.

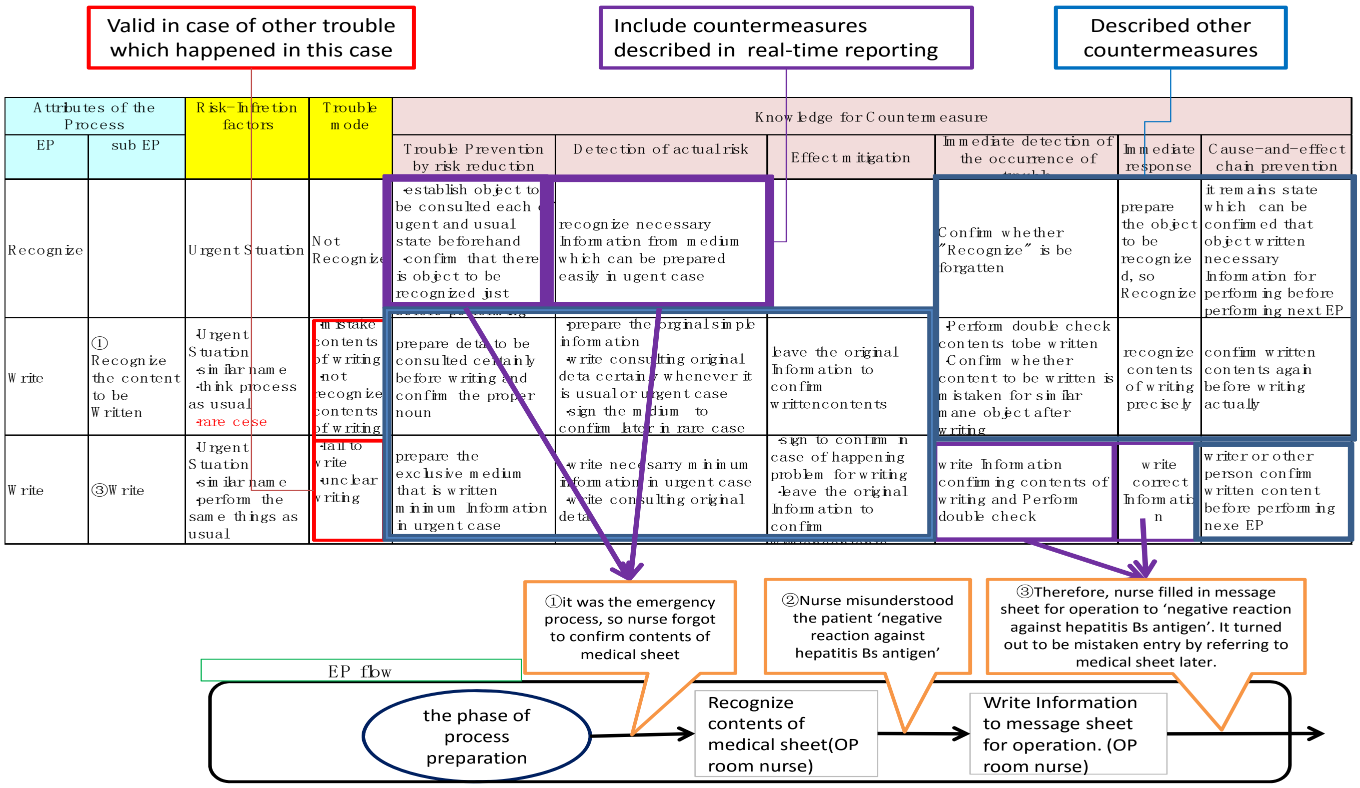

Fig. 7 Example of the Results of Application

VI. Discussion

A. Results of Verification

In two other real cases, one being, "mistakes in sterilization methods," the authors extracted 15 EPs and 40 elements of knowledge of countermeasures including 10 countermeasures described in real-time reporting documents. Similarly, in a case of "discrepancies in the order and size of objects to take," the authors extracted 10 EPs and 25 elements of knowledge of countermeasures including 8 countermeasures described in real-time reporting documents. Therefore, we considered that the model for knowledge of countermeasures to be appropriately widespread. As above, using the proposed method, we could largely predict the possible troubles for processes in operation room at Iizuka Hospital, and some validity of the proposal was confirmed.

B. Future Issues

In this study, we designed the structure of a knowledgebase for countermeasures. The whole model for trouble prevention was designed by acquiring knowledge of processes, trouble, and countermeasures and by reusing obtained knowledge. However, in its present form, the knowledgebase is not yet designed to cover a wide variety of topics; it is too complicated to implement in real processes. Therefore, it is necessary to obtain knowledge continuously in order to increase the amount of knowledge and to visualize unclear points and points for improvement. Evaluations clearly revealed a need to acquire more models for EPs. In addition, we consider that detailed design for knowledge application process is needed, including a method for appropriately abstracting attributes of the process. Further, it is required to extend the framework of the proposal to adopt the types of troubles where medical staff gets unconcerned action done.

VII. Conclusion

We proposed the structure of the knowledgebase for countermeasures, in the knowledge acquisition process for trouble prediction in healthcare service provision processes. The structure of countermeasures along with the time-series process of trouble occurrence, and the knowledge representation form were proposed. As the results of verification, the adequacy of the structure of the knowledgebase for countermeasures were confirmed, while it was also mentioned that we need more contents of such knowledgebase both to predict potential troubles and to derive effective countermeasures widely.

In the future, we will aim to acquire and accumulate more and more knowledge on processes, troubles, and countermeasures, and to develop the standard models of them for each healthcare process. In addition, we will aim to design the detailed knowledge application process, to predict possible troubles and to discuss appropriate countermeasures in the phase of process design and process improvement.

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