ACQUISITION OF SERVICE PRACTICAL KNOWLEDGE BASED ON ONTOLOGIZED MEDICAL WORKFLOW

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Abstract: It is ideal to provide medical services as patient-oriented. The medical staff share the final goals to recover patients. Toward the goals, each staff has practical knowledge to achieve patient-oriented medical services. But each medical staff has his/her own priorities and sense of value, that derive from their expertness. And the results (decisions or actions) from practical knowledge sometimes conflict. The aim of this research is to develop an intelligent system to support externalizing practical wisdoms, and sharing them among medical experts. In this article, the author propose a method to model each medical staffs' sense of value as his/her way of task-understanding in medical service workflow, and to obtain the practical knowledge using the models. The method was experimented by developing a knowledge-sharing system base on the method and running it in the Miyazaki University Hospital.

1 INTRODUCTION

Service science is an attempt to seek a scientific/engineering framework, in order to sophisticate continuously that service, by defining it as the actions and activities through which one person serves another (Yoshikawa, 2008). This paper proposes that information and knowledge for the design and evaluation of such services be shared not only among service providers, but also among service recipients (which we call an intelligence cycle). This study uses a scientific framework to understand the phenomenon that service values vary depending on the subjectivity of the stakeholder. Knowledge engineering is widely expected to serve as a basic technology to support the intelligence cycle and value creation, but there are enormous variations in targets—such as knowledge and problems. Therefore, this study seeks to establish a new system to support the sharing of practical knowledge to convey medical information and knowledge in consideration of individual patient conditions when medical professionals provide medical services (hereafter "practical knowledge"), as an application of knowledge engineering for medical services.

A system of knowledge engineering has been investigated wherein knowledge can be shared and reused in the medical field from an early stage of development, and through which medical knowledge can be obtained and used to help solve problems such as computer-aided diagnosis (glaucoma CASNET (Weiss and et al., 1977), internal disease Caduceus (Myers and et al., 1982), and infection Neomycin (Clancey, 1983)). In addition, an ontology for sharing medical knowledge has been studied in line with the development of knowledge sharing via the Internet. For example, the EON project (Tu and Musen, 2001)(Musen and et al., 2006) has studied a patient-oriented clinical decision support system by modeling clinical guidelines. Likewise, the SAGE project (Tu and et al., 2007) has investigated a methodology for modeling guidelines in the light of the GLIF3 studies (Boxwala and et al., 2004), and PROforma (Sutton and Fox, 2003), which demonstrate a modeling method to create a medical workflow to appropriately explain the context of medical practice. (Hurley and Abidi, 2007) is a study of the construction of a clinical path (discussed later), which is one of the transcriptions of a medical workflow, and Abidi attempts to unify a clinical path and knowledge from the guidelines based upon the Hurley study (Abidi, 2009).

These studies on medical knowledge support the sharing of the knowledge that medical services can

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provide. In comparison, our study focuses on the acquisition and sharing of knowledge (practical knowledge) on how to provide a service after that service is established from the standpoint of patients. In particular, this paper proposes a method to structure knowledge-acquisition interviews in which experts (medical professionals who provide medical services in this study) are asked about their practical knowledge.

Previous studies on knowledge acquisition classified the knowledge of experts into the references used, the knowledge content, and the implementation of the modeling (KADS methodology (Schreiber and et al., 2000)), the defined nature of problems, and a problem-solving method as task knowledge to enhance the reusability of the knowledge, and used them in knowledge-acquisition interviews (SIS (Kawaguchi et al., 1989), Protégé (Gennari et al., 2003), and others). In these cases, knowledge about tasks pertaining to the problems was used to acquire knowledge in order to solve problems. A method to conduct interviews with respect to the conceptual structure of tasks whose type is specified (ROGET (Bennett, 1985)), generic tasks that are defined by concepts with a high general versatility (Chandrasekaran, 1986), and a system for knowledge-acquisition interviews (MULTIS (Tijerino and et al., 1993)) based on modeling by task ontology that was developed based on the above-mentioned items (Mizoguchi and et al., 1995) have been proposed. These studies selected targets and conducted in-depth analyses of the nature of the tasks, which enables computers to help decide the "what to provide" of "what to and how to provide" by medical services. The authors focus on the fact that knowledge about "what to provide" plays a role in the preparation phase of an interview (some practical knowledge is needed for "what" to do) when conducting a practical knowledge-acquisition interview to inquire "how to provide." This study proposes a modeling method for logical medical tasks. The modeling of medical tasks aims to help medical professionals understand their own values and purposes (called an "understanding of services" by medical professionals), which demonstrates the recognition level of the tasks of medical professionals. Medical-service providers such as doctors and nurses share the same final goal—that patients regain healthy and comfortable physical and mental conditions—but they have different expertise. Therefore, they sometimes find their own values and purposes for a task, which may influence their practical knowledge. To be more specific, the value of medical service tasks, which is a subjective and vague factor, is modeled, and a method is studied to conduct modeling at an appropriate level to share information. The modeling focuses on a knowledge medium of a clinical path (hereafter "Path"). Path is defined as a standard workflow for typical cases (Coffey, 2005) and guarantees a minimal medical care quality (Tachikawa and Abe, 2005). This concept has been spreading rapidly. A path is made by integrating the opinions of experienced medical professionals. It is considered that the modeling of the contents of a Path from the above-mentioned viewpoints may enable a differentiated understanding of medical services provided by medical professionals, and that the result may clarify the acquisition of practical knowledge.

This paper proposes a method to differentiate the understanding of medical services by medical professionals by Path-modeling based upon an ontology (see Section 3), and demonstrates a technique to use the model for a practical knowledge-acquisition interview (use as a handle to acquire knowledge) (Section 4.2). The technique was included in the system (Section 4), and verified in the University of Miyazaki Hospital (the Hospital), (Section 5).

2 CONCEPT FOR A SUPPORT SYSTEM FOR SHARING PRACTICAL KNOWLEDGE ON MEDICAL SERVICES

Medical professionals are required to provide patient-oriented medical services. They obtain the knowledge they need about patients by means of trial and error when providing medical services, as shown in Fig. 1. Such acquisition may be supported by advice and the experience of other medical professionals such as seniors and colleagues. This study terms such advice and experience "practical knowledge" (in a broad sense). This practical knowledge is quite diversified, and varies depending upon the conditions of the patients, the extent to which medical services are provided, and the sense of values of the providers. In sharing support of practical knowledge, medical professionals should consider how to access practical knowledge after the necessary information has been obtained, for example, in which phase patients are—the acute phase, the recovery phase, or the maintenance phase, and who is responsible for making decision (whether the patient can decide for themselves or whether medical professionals need to make the decisions because of the extreme urgency of a situation). This study focuses on practical knowledge during the recovery phase (during a hospital stay). Observations

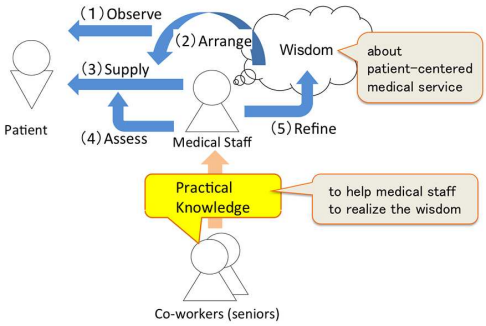


Figure 1: Practical knowledge to support patient-oriented medical treatment.

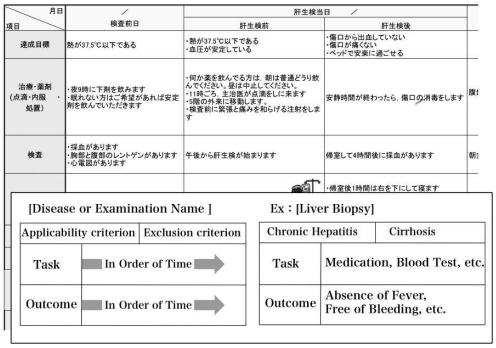


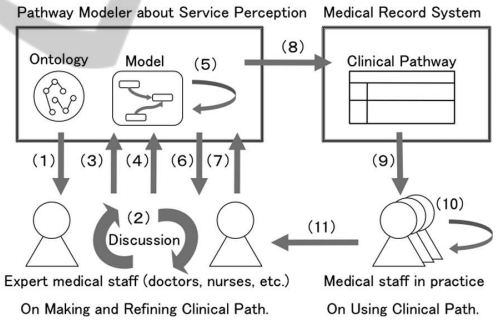
Figure 2: Clinical pathway.

made during the provision of medical services during hospitalization reveal that there is some typicality in the conditions of patients and this has been standardized by the clinical path and other factors. This study seeks to create a model for computer processing such as typicality in patients' conditions and a standardized service in order to establish a system of provision based upon practical knowledge that simultaneously enables the conducting of practical knowledge-acquisition interviews by computer and the use of an electronic health record system.

Recently, standard medical treatment has been scheduled for typical cases in clinical settings in an attempt to secure a minimal quality of medical services. A clinical path is a knowledge medium to define such medical services (Fig. 2). A Path contains inclusion/exclusion criteria, medical tasks, outcomes, and other factors. Each hospital formulates and uses its own Path by trial and error. The Hospital, which conducted this study, introduced an electronic health record system based on a Path in 2006, and uses 150 or more clinical paths. The Hospital reports that the introduction of the system has reduced the number of instructions and orders required to carry out routine work, and that it has rationalized medical treatment. In contrast, another survey on the use of a clinical path (Kato and et al., 2005) reported that there was concern that the "use of a clinical path interferes with thinking in clinical settings." In addition, a guide for the introduction of a clinical path ((Fukushima, 2004) and others) emphasized that "a Path is not a schedule. It is tool for thinking about good medical practice." Concerns about the use of a Path can be summarized as follows.

- The use of Path decreases communication among medical staff and decreases opportunities for sharing knowledge, and
- Medical staff feel comfortable in implementing medical practice according to Path and cease to think for themselves.

This study aims to establish a system to promote practical knowledge sharing by using an electronic health record system based on Path in order to eliminate concerns about a lack of communication among medical staff. The targeted practical knowledge includes strategies after a decision has been made as to which medical tasks are to be provided, for example, strategies to offer safer treatment and higher satisfaction for patients, as well as guidelines to implement the strategies, and the contents of communications among medical professionals and between medical professionals and patients.



(1) to provide Medical Service Ontology (M.S.O)
(2) to present and discuss Service Perception
(3) to model Service Perception into unified vision
(4) to add new M.S.O found in modeling
(5) to validate the model
(6) to interview expert medical staff about P.K.
(7) to obtain P.K.
(8) to export P.K.
(9) to hand down P.K. in the service context
(10) to improve service
(11) to participate in Path-making Meeting

Figure 3: Support system for sharing practical medical knowledge.

In order to integrate practical knowledge sharing into the use of Path, the most important thing is that an understanding of the services provided by medical professionals is clearly specified (how they think about their patients and what they are trying to provide to their patients). In general, medical professionals share the goal of returning patients to health, but

their sense of values varies depending on their specialty and personality (Yoshitake and others point out this conflict, which is part of the difficulty in reaching agreements in clinical settings (Yoshitake, 2007)), which may influence the conditions of patients, an understanding of their feelings, and the priority of the projected outcomes. That is, medical professionalsf understanding of service defines the significance of practical knowledge.

Figure 3 shows the concept of the support system used in this study. The system for the preparation of Path (1 to 5 in the figure) shows that the framework for an understanding of the services provided by medical professionals is modeled based upon an ontology (Section 3). Our method is to use the model as a handle to obtain knowledge from medical professionals (hereafter "the knowledge handle") at the time of the interview to acquire the practical knowledge (6 to 7 in the figure), and this is presented in Section 4.

3 MEDICAL WORKFLOW MODELING BASED UPON MEDICAL SERVICE ONTOLOGY

3.1 Modeling the Understanding of Services by Medical Professionals

As mentioned, this study models medical workflow to clearly specify the understanding of services provided by medical professionals. This model aims to express the intention of the design of Path, and is intended to be used as a step prior to interviewing medical professionals about their practical knowledge (how they recall their medical practice). Specifically, this modeling aims to identify the purpose that medical professionals find in the medical practices (tasks) that constitute workflow, and how they correlate their purpose with other medical practices, and to what level and extent.

3.2 Guideline for Construction of an Ontology

The construction of an ontology for the modeling of an understanding of service has two entangled problems.

- There are no agreed common words to express difference in ways of thinking
- Difference in ways of thinking arises when a concrete Path is reviewed.

At the time of designing a Path, medical professionals have repeated discussion held to share their understanding of "service." This study seeks a method to prepare a vocabulary (ontology) to facilitate communication. It is desirable that an ontology be prepared prior to communication, but it is communication that causes difference in the understanding of service. Thus, there is a dilemma as to which one should (or can) acquire first—the content or the means to express the content.

In light of these problems, a method of constructing an ontology is prepared by dividing the task into the early phase and continuous phase.

- Early phase: By focusing on the understanding of service, extract the necessary concepts for the modeling of medical practice in order to prepare the ontology ("early ontology")
- Continuous phase: Model the understanding of service according to the early ontology at the time of the design and revision of a Path. If there are no necessary concepts for the modeling (no match with the modeling) in it, it should be added to the ontology (or the ontology should be revised).

Knowledge engineers interview medical professionals during the early phase. Medical professionals take the lead in constructing the continuous phase after a system utilizing the early ontology is completed (the result is reviewed by a knowledge engineer). The following two points were the focal points of the construction of the method.

- Accept ambiguities and errors when adding to the ontology and using the ontology
- Receive the benefits of the ontology immediately

3.3 Medical Service Ontology

As mentioned, the modeling of medical services is aimed at clarifying the understanding of services provided by medical professionals. This section summarizes the ontology so as to make it easier to understand the purpose of this modeling. The early ontology was prepared by analyzing the Path in a liver biopsy under the condition that the clinical paths used in the Hospital have been used for a long time and are simple. The selection of a Path whose contents have been accepted by all medical professionals can avoid unnecessary discussions about medical practice and allow for a focus on the ontology used. As an environment for ontology construction, Semantic Editor (Hasida, 2007) was used. A method to express differences in ways of thinking by medical professionals is summarized as follows.

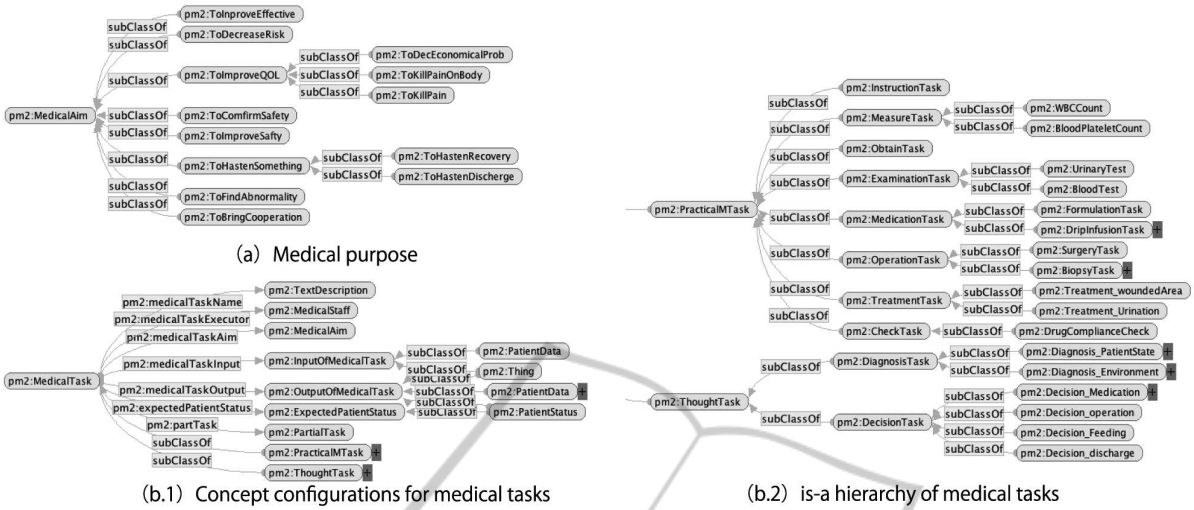


Figure 4: Medical service ontology.

- What medical goals do you find in each medical task?
- How do you structuralize medical tasks to accomplish these medical goals?

Fig. 4(a) shows medical ontology. For medical purposes, highly abstract goals, such as the enhancement of therapeutic effect, risk reduction, and enhancement of a patient's Quality of Life (QOL), are given priority. The enhancement of a patient's QOL includes a reduction of physical and mental burdens.

Medical purpose is a term used to express how much the goal of accomplishing each medical task of their medical services means to medical professionals (which may vary depending on specialty and the role played by each medical professional).

Fig. 4 (b.1, 2) show concept configurations for medical tasks. Medical tasks consist of a "performer" who deals with the tasks; "input", which are items handled in the task, such as patients and samples collected from patients; and "output" which is goods, information, and knowledge obtained when the task is conducted; and "part tasks," which are parts of a task (the opposite term is "whole task"). The task includes one or more medical purposes. Each task has the purpose of the task itself and a purpose from higher tasks. Medical tasks are classified into tasks to do (actions that influence the real world, such as treatment to patients) and tasks to think about (actions that do not influence the real world, such as diagnosis and decision making) in order from the highest medical tasks downward.

By clarifying that medical tasks for a medical purpose and that the relationship between the medical tasks and medical purpose have been clarified, the modeling for the understanding of a service by medical professionals is achieved. A Path as used in clinical settings never includes tasks to think about , because a Path is used only for progress management of medical practices, and because the method of conducting medical practices and the decision on what to do are left in the hands of individual medical staff. The modeling reveals not only tasks to do, but also tasks to do in the mind (diagnostic tasks). The understanding of service by medical professionals is expressed by how much and how they are correlated with the treatment provided.

3.4 Examples of Modeling of Understanding of Service

This section explains how an understanding of service by medical professionals is expressed as a model. Figure 5 shows a model of one of the medical tasks set in a Path, which includes a medical procedure, "walking patients to the toilet."

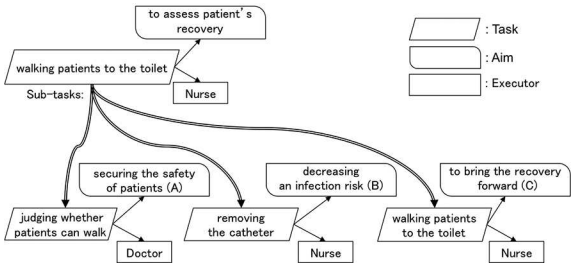


Figure 5: Model of the medical task "walk patients to the toile".

This medical task evaluates patient recovery (for medical purposes). A prerequisite of the medical task is urination via a catheter, and the requirement for the

medical task is the removal of the catheter. In addition, the task has the purpose of decreasing an infection risk (B) by removing the catheter as soon as possible, because once inserted a catheter may become contaminated and cause an infection. The removal of the catheter enables the provision of better mobility to patients and encourages patients to move about in order to accelerate their recovery (C). In consideration of these purposes, a catheter should be removed as soon as possible, which sets the timing of the medical task "walking patients to the toilet." At the same time, there is a secondary medical task of "judging whether patients can walk," which is aimed at securing the safety of patients (A). In this case, it is not always necessary to accelerate the timing for when patients can walk to the toilet.

Such modeling of medical tasks helps find multiple purposes. In the above-mentioned purposes, A and B "focus on risk reduction" as the purpose of the medical practice, while C places a "focus on the rapid recovery of health," which may be set according to the specialty of the medical professional in question. Therefore, the timing and method of a series of medical practices may vary depending on purpose, which suggests that acquisition of the practical knowledge may need clarification for each purpose. However, it is difficult to comprehensively systematize in advance that each medical task has a medical purpose. It is more practical that systematization be gradually arranged throughout the continuous phase of the construction of the ontology.

4 SUPPORT SYSTEM FOR SHARING PRACTICAL KNOWLEDGE ON MEDICAL SERVICES

As mentioned in Section 2, a support system for sharing practical knowledge on medical services has been established by: expressing as a model the understanding of medical services by medical professionals; acquiring practical knowledge by an interview function based upon the model; and providing practical knowledge acquired in clinical settings via an electronic health record system. This section explains "Path modeler," which is a tool that has the functions to model the understanding of services by medical professionals and interviews about practical knowledge, and which can provide practical knowledge (and is equipped with the electronic Path (medical record) system used in the Hospital).

4.1 Path Modeler

Path modeler is a tool through which medical professionals can discuss the design intent of Path, which has a framework and vocabulary through which to express the ideas of medical professionals on medical service (understanding of service). The framework is based on an ontology, as described in Section 3, and it has a mechanism through which it can be gradually developed by modeling an ontology to be used in meetings on the design of and revision to Path. Representatives of medical professions attend the meetings to discuss the contents of Path. Health information managers, who are considered the end-users of the tool because basic ontology literacy is required to use Path modeler, also participate in meetings and deal with issues of computerizing the content of Path (entry into an electronic Path system).

Path modeler is implemented as a JAVA application. Figure 6 shows the configuration of the system, which includes a repository for the ontology, and a support system for the modeling of medical services and practical knowledge interviews. Semantic Authoring Server (Hasida, 2007) handles the ontology repository as well as ontology editing and sharing from multiple clients.

Modeling procedures using Path modeler for the understanding of services by medical professionals is explained here. Figure 7 shows the user interface.

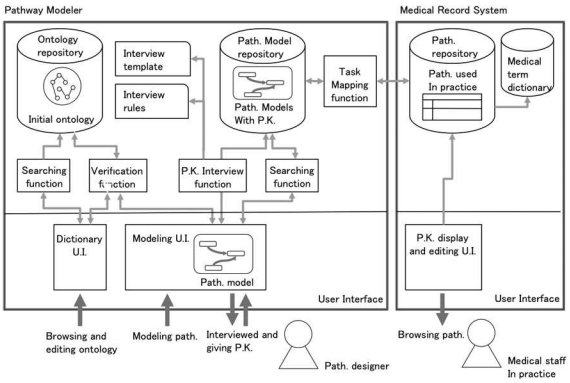


Figure 6: Structure of functions of Path modeler.

A task for discussion on design intent is displayed on the main viewer (a in Fig. 7). As the tasks necessary to explain the design intent of the task are added, the relation with these tasks is described as a link. At the same time, the ontology panel (b in Fig. 7) is used as a dictionary (adding the necessary ontology if it is not defined). Detailed information, such as "who uses the task and for what purpose," is registered in the detailed information panel (c in Fig. 7) (modeling is described in detail in Section 4). While the purpose

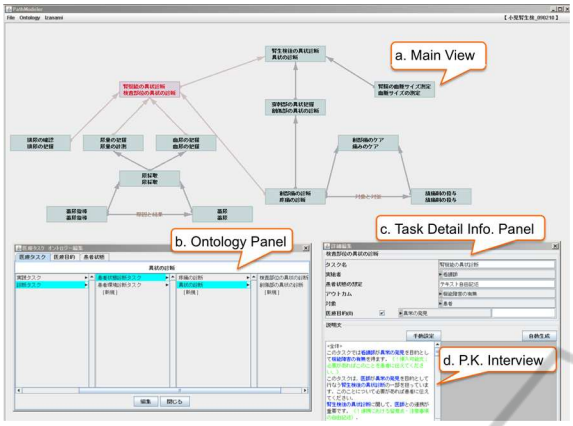


Figure 7: Interface of Path modeler.

and value of medical tasks by medical professionals are expressed by modeling, any relation with tasks for realization is expressed as a model. The interview panel (d in Fig. 7) obtains the practical knowledge acquired through interviews using the knowledge handle, and performs a practical knowledge-acquisition interview using the resulting model, based upon the relation between the targeted medical task and other medical tasks. The details of this are described in the next section.

4.2 Practical Knowledge Acquisition using a Model and the Knowledge Handle

The interview functions are set to ask questions of Path designer about practical knowledge in light of the relation between the purpose of the task and other tasks. The interaction between Path designer and the system is as follows.

1. Path designer selects a task that he/she pays attention to or wants to accomplish.
2. The system checks the applicability of the knowledge to the task selected by the Path designer and decides upon the type of practical knowledge to be utilized in the task.
3. The system explains the understanding of the service based upon the relation between the selected task and related tasks, and asks questions about the practical knowledge needed.
4. Practical knowledge is acquired from the answers provided by Path designer.

Table 1 shows a sample interview created from the model. The words in black in the table explain the way of thinking of Path designer about medical services (what level the tasks are and how they are related), while the words in blue ask questions based upon them. Table 2 shows answers to the questions. Table 4 shows that the knowledge handle defines the type of interview to the model (a handle to obtain knowledge). The knowledge handle consists of practical knowledge patterns (Table 3), rules, and templates. The knowledge handle is created in accordance with the following procedures.

1. Make a model using Path modeler.
2. The knowledge engineer explains the content of the model to medical professionals who cooperate in creating the knowledge handle, and asks them to evaluate the appropriateness of the content.
3. Samples of practical knowledge are collected from the medical professionals.
4. The practical knowledge samples are analyzed by the knowledge engineer and the medical professionals, and the features of the practical knowledge pattern are abstracted and described as “type of practical knowledge.”

Table 1: Example interview.

Task of generating explanations: "Understanding signs of abnormal renal functions" in Path for "pediatric renal biopsy"	Question No
For medical staff: (1) This task encourages < a nurse > to ascertain < the presence or absence of renal dysfunctions > in order to < detect any renal abnormalities >. (2) This task shares the role of the task < diagnosis of renal dysfunctions > so that < a doctor > can < secure safety >. This task requires collaboration with < a doctor >. (3) This task includes < check of urination after the test >, < detection of urine volume >, and < detection of gross hematuria >. This task should compile the above-mentioned data.	
> < to detect gross hematuria > helps accomplish the purpose to < detect any renal abnormalities >. What are the points to remember and the precautions to take to accomplish the (5) The part task, < detection of gross hematuria >, is involved in a patient's anxiety.	(Question.1)
Focus on care and explanation when checking for a gross hematuria. How will you perform the task? Please specify. [Message to patient (a)]	(Question.2)
For patients : (a) (!The part task,< to detect gross hematuria >, is involved in a patient's anxiety. How do you explain things to your patients to ease their anxiety?	(Question.3)

Table 2: Example answer.

Question	Answer
Question.1	・In the case of bed excretion after an examination, a nurse must check the first urination. If there is gross hematuria, consult a doctor.
	・If urethral balloon is in place, a nurse should check the color of the urine when a patient ’s vital signs are taken. If there is gross hematuria, consult a doctor.
Question.2	・Even after a patient can walk to a toilet, the patient or a guardian should continue to check for the presence or absence of gross hematuria during hospitalization.
Question.3	・Gross hematuria may occasionally develop after a renal biopsy, however, such a case will usually improve by resting.
	・If gross hematuria persists, it should be reported to the doctor in charge, and the patient should be sent for ultrasonography and a blood test to ascertain the severity of bleeding.

Table 3: Pattern of practical knowledge.

Intention of practical knowledge
Overview of practical knowledge
Encouragement of practice--possibly generated from a model (obtain detailed information through interviews)
A. Encourages medical staff to communicate with patients to make them comfortable and obtain their consent, as this will make patients willing to undergo their treatments voluntarily.
A.1 Encourage medical staff to explain to a patient the purpose of a treatment in order to have the patient undergo treatment voluntarily.
A.1.1 Encourage medical staff to explain to a parent the purpose of a task as the purpose of a treatment if necessary.
A.1.2 If there is a task to be integrated, encourage medical staff to explain to the patient the purpose of a task at the granularity level as the purpose of a treatment if necessary.
A.1.3 When explaining a part task to a patient, encourage medical staff to explain the purpose of the entire task as the purpose of a treatment if necessary.
A.2 Encourage medical staff to perform a task in consideration of a patient 's pain and anxiety.
A.2.1 Extract a task to obtain information about a patient's pain, and call attention to the interview method.
A.2.2 Encourage medical staff to take care of a patient, assuming a patient's pain and anxiety from the task itself and those before and after the task.
A.3 Encourage medical staff to tell a patient about the strategies and measures being taken on the patient's behalf.
A.3.1 Encourage medical staff to link the task of understanding a patient's condition —including symptoms —to the task of dealing with the condition (Subject-Measures Link), and to explain the relationship between the two to the patient.
B. Encourage medical staff to secure the quality of medical care (appropriateness and safety).
B.1 Encourage medical staff to understand the relationship among tasks.
B.1.1 Explain the contents of comprehensive tasks and part tasks.
B.2 Encourage medical staff to facilitate appropriate collaboration among themselves.
B.2.1 Specify areas where comprehensive tasks and part tasks need different performers, in order to encourage collaboration.
B.3 Encourage medical staff to acquire appropriate outcomes.
B.1 Encourage medical staff to acquire rational outcomes for the purpose of tasks. Give them the know-how (criteria and strategies) to achieve the goal.
B.1-1 When a task is aimed at obtaining data on a patient's condition, and when the resulting data are data that need to be interpreted, the task goal may be not appropriately conveyed. Point out to the medical staff that there is a possible risk that interpretation may vary depending on the sense of purpose of the medical staff.
B.1-2 Specify the tasks that can be acquired by making a comparison with the criteria, in order to indicate explicit criteria.
B.1-3 Specify the tasks based on an interview with a patient (ambiguity due to the subjective ideas of a patient), and point out that the patient's ability to explain things and their nature should be taken into consideration. In addition, explain the strategy to obtain such information.
b.2 Specify that one task is included in multiple whole tasks, and explain that two or more outcomes should be obtained by the purpose.
B.4 Encourage medical staff to appropriately perform the tasks to be integrated for the outcomes of the subtasks (e.g. evaluation).
B4.1 Specify the tasks that are classified into the overall task group with several purposes, and instruct medical staff how to acquire outcomes by the purpose integration of the overall tasks.
B4.2 When dealing with a part task which has its own goal, encourage medical staff to perform the task in consideration of the goal of the whole task to which the part task belongs.

5. An effective aspect of the type of practical knowledge is encoded as a rule, based upon the practical knowledge described in the step 4.
6. Templates are prepared for descriptions and questions for the tasks so as to obtain practical knowledge from samples.

Table 3 shows types of practical knowledge. The largest category was defined as "Intention" to acquire practical knowledge, and the second-largest category was defined as "Summary" of achievement of the intention, which was further divided into concrete "Method." For example, practical knowledge with Intention "A. Provide a sense of safety and understanding to patients to encourage them to undergo treatment" includes "A.2. Medical staff conduct the task in consideration of the pain and anxiety of patients," and as the concrete method, there is "Method 2. Administer treatment to patients by estimating their pain and anxiety from the task itself and the previous or next task."

Table 4: Knowledge handle.

Example of Intreview	Overview
	Rule
	Template
Ex.1	Search a task that deals with status of patient's pain, and get P.K. about how to ask amount of pain.
	<task.sub-task>.num≧1,<task.sub-task.output>⊆ pain_status
	The sub-tasks {<task.sub-task n>, 1..n} are assessment task, and may make patient nervous. In assessment, you give some mental care and some explanation. Please answer its detail.
Ex.2	Search tasks that have part-of relation and each task executer is different, and then get P.K. about how to collaborate.
	<task.included-task>.num≧1,< task.included-task.executor >≠<task.executor >
	Toward <task.included-task>, <task.executor> needs some collaboration with <task.included-task.executor>, what are the points to remember?
Ex.3	Search a task that is included more then 2 tasks, each of them has different medical aim. And get P.K to execute the task to trade off or to unify the aims.
	<task.included-task>.num≧2, enumerate(<task.included-task.medicalAim>).num≧2
	This task is included multi tasks {"<task.included-task>.n", 1..n} and they have different aims {"enumerate(<task.included-task.medicalAim>).n", 1..n}, To execute this task, what is the key points to trade off or to unify the aims?

This rule is used to decide which type of practical knowledge should be asked in which task in the model. The rule is described using task and/or purpose. Table 4 shows some of the knowledge handles. For example, concepts about pain (the concept of pain as a subclass and the concept of bearing pain as a part) are specified in the output in order to find medical tasks that induce pain, when asking a method to treat patients for their pain (The practical knowledge pattern, A.2.1). As mentioned above, the knowledge handle consists of practical knowledge patterns that medical professionals conduct, the aspect in which the type of practical knowledge interview is effective (Rule), and descriptions to interview them about their practical knowledge. These patterns look like a generalized empirical rule so that the completeness cannot be guaranteed, but they are positively effective, which suggests that an accumulation of patterns could gradually improve the completeness.

4.3 Provision of Practical Knowledge Via Electronic Health Record

The practical knowledge acquired is provided for the

clinical settings via an electronic health record system. The Hospital, the venue for this study, uses an electronic medical record system based upon Path (electronic Path). This electronic Path system originally had a function to explain each Path. In this study, a function to indicate practical knowledge was added. Accordingly, the Path system matches the Path items that are defined in Path with the medical tasks in the Path modeler, which enables practical knowledge to be indicated when items are performed (Fig. 8). The aim of this is to ensure compatibility with electronic health records, which vary from hospital to hospital, and to place less of a demand on a critical system for the electronic health records, by making the Path modeler independent from electronic health records.

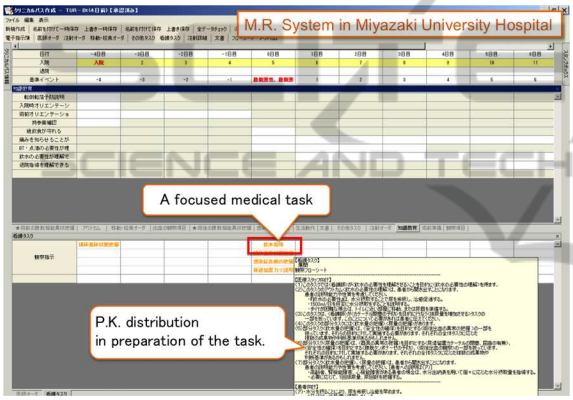


Figure 8: Interface of Path modeler.

5 OPERATION OF SYSTEM

This section shows the result of the acquisition of practical knowledge using the Path modeler and the provision of the acquired knowledge to the clinical settings, verifies whether the function works as intended, and discusses the rationale of the function.

5.1 Practical Knowledge Acquisition using Path Modeler and a Discussion on Acquired Knowledge

5.1.1 Operation Procedures for Path Modeler

The understanding of service by medical professionals was modeled and practical knowledge was acquired in the five clinical departments of the Hospital. Table 5 shows the targeted Path and medical tasks. The clinical paths were selected in consideration of experience of long-term use and content that did not need to be modified in order not to adjust the service

Table 5: Path and medical tasks used in operation.

Specialty	Path Name	Medical tasks focused on
Urology	TUR-BT	Instructions on water intake, detection of bladder anomalies before surgery, detection of postoperative bladder anomalies, detection of any signs of infectious diseases, explanation of necessity of urethral catheter placement
Radiology	Oral administration of iodine	Understanding of patient's condition before (and after) treatment, detection of any adverse reactions caused by treatment, check patient's level of understanding
Surgery II	TAI	Detection of any abnormalities in the puncture area, detection of any signs of hepatic failure, detection of any signs of hepatic abscess, pain care
Pediatrics	Pediatric renal biopsy	Detection of any signs of renal dysfunction, instructions for urine collection, detection of any abnormalities in the site to be examined, pain care
Obstetrics and gynecology	Cesarean section	Instructions for walking to toilet, evaluation of ability to walk to toilet, detection of any dysfunctions of organs, detection of any abnormalities of the operative site, pain care

content but to understand a service whose content had been agreed upon medical experts. The procedure is as follows.

1. Modeling of medical tasks in which the understanding of service may vary according to occupation (extract the task from the results of interviews with medical professionals in the clinical settings, and modeling by knowledge engineers and doctors in the medical information department.
2. Obtain problems and questions related to the descriptions (and questions) of the task that is produced by the interview functions (the report should be corrected by doctors and nurses in the clinical setting).
3. Acquire practical knowledge from the answers to the practical knowledge interview (performed by doctors and nurses in the clinical settings).
4. Discuss the results of (2) and (3) (performed by knowledge engineers and doctors in the medical information department)

5.1.2 Discussion about Modifications of Descriptions

As mentioned, the descriptions produced by the interview functions help explain the understanding of service as a model by natural language, and illustrate the state of the service that is asked of respondents (medical professionals). When medical professionals correct the descriptions, they will understand the modeling errors and the difference in the understanding of the service modeled and their understanding of the service. This section discusses the necessity of the understanding of service by medical professionals at the time of acquiring practical knowledge in light of the results.

It was pointed out that there was one modeling error. There was a task “measurement of hematoma size” after a kidney biopsy on a child, which was at first defined as a part task, “wound treatment,” for

Table 6: Sample answers.

Purpose	e.g. Additional task	Question	Answer
For medical staff			
If the task result is obtained through an interview with a patient, such as "fully aware of the meaning of the test" and "pain," take their ability to explain things and their nature into consideration. Explain your strategy to obtain such information.	Pediatric renal biopsy "Instructions for urine collection"	The outcome of this task < understanding of urine collection > is obtained through am interview with a patient. Take their ability to explain things and their nature into consideration. What is your strategy to obtain such information?	・Check appropriate urine collection in an urinal with a nurse. (No test to check their understanding is performed)
When this task is a part of a larger task, instruct both task performers to collaborate with each other.	Cesarean section "Detection of any abnormalities in the operative site"	It is important to collaborate with < a doctor> when making < diagnosis of postoperative abnormalities >. What are the points to remember and the precautions to be taken during the collaboration?	・Report immediately the presence or absence of lochia and wound bleeding, drain volume and abnormal pain to a doctor.
When performing a part task of this task, encourage medical staff to perform to achieve the purpose.	TAI "Detection of abnormalities in the puncture area"	< Severity of pain > in < detection of severity of pain > should be appropriately evaluated in accordance with the purpose < detection of any abnormalities >. What is your strategy for the evaluation?	・Assess severity of pain using face scale, specify the onset location and classify the pain into sensitivity to tapping, indirect pain, spontaneous pain, colic, knot feeling, radiating pain, and referred pain.
If the part task of this task is related to judgment, tell the criteria to medical staff.	Cesarean section "Detection of organ dysfunction"	< Urine volume > of a patient should be obtained by the part task < detection of urine volume > and examined by the criteria of < detection of any abnormalities >. What is the criteria?	・Urine volume and swelling are compared with those before surgery, but there is no strict criteria.
If the part task of this task is involved in patient anxiety (when treatment and interview are performed), perform the task to relieve the anxiety.	TUR-BT "Detection of bladder anomalies before surgery"	The part tasks, < detection of micturition pain > and < detection of pain >, are involved with a patient's anxiety. Take care of the patient and explain to the patient about the task in the interview. What is your strategy?	・Explain the pain scale (face scale, VAS) according to the patient. ・Tell the patient that an analgesic drug can be administered if a doctor so decides.
If the task result is obtained through an interview with a patient, such as "fully aware of the meaning of the test" and "pain," take their ability to explain things and their nature into consideration. Explain the measures when such information is obtained.	Cesarean section "Detection of organ dysfunctions"	The part task < detection of urine volume > is obtained through an interview with a patient. Take their ability to explain things and their nature into consideration. What is your strategy to obtain such information?	・Urine volume is checked during the placement of a balloon catheter, but ask a patient to check whether spontaneous urination occurred, the frequency of urination (frequent or infrequent urination compared with before the surgery), the presence or absence of edema, and less urine volume each time, after removal of the catheter
For patients			
Information to be given to a patient before the start of the interview	Pediatric renal biopsy "Instructions for urine collection"	< Understanding of urine collection > is obtained through an interview with the patient. What should the patient be told in advance?	・Urine collection is to obtain information on your urine volume for 24 hours and your urine protein level, and to determine serum cretonne and urine creatinine for an assessment of your renal function. ・If the urine volume is decreased, bodily symptoms such as renal dysfunction or hypoproteinemia can be checked.
Information to be given to a patient about the part task that is involved in their anxiety	TUR-BT "Detection of bladder anomalies before surgery"	< Detection of micturition pain > and < detection of pain > are involved in a patient's anxiety. What should the patient be told to relieve anxiety?	・If you have micturition pain and incomplete voiding an analgesic drug can be prescribed.
Information to be given to a patient about the part task that requires an interview	Cesarean section "Detection of any organ dysfunctions"	The part task < detection of urine volume > is obtained through an interview with the patient. What should the patient be told in advance?	Please tell us if you urinate after the tube is removed, and also tell us whether urination frequency and urine volume are increased or decreased compared with those before the surgery. Please tell us if you have swelling in your legs or other areas.

nurses. However, medical professionals in the clinical settings pointed out that the description of "wound treatment" was not appropriate, saying "the size of this kind of hematoma in a kidney is measured by a doctor using an ultrasonic echo so that it should not be included in wound treatment." Therefore, it was classified into a part task of the task "diagnosis of kidney abnormalities" by doctors. This was the only modeling error, and it was reviewed on a model basis and confirmed in "Trial use of practical knowledge in clinical settings" (Section 5.2). Thus, the model is reviewed and modified by a correction of the descriptions in consideration of the ontology literacy of the system users, which functions as we expected.

Next, when an understanding was reached that the service was different from the model, an instruction was issued to adjust the medical tasks and purposes to match those of the actual work. For example, concerning the task of "measurement of urine volume" in the Path for TURBT (transurethral resection of a bladder tumor), the entire task of "understanding of bladder dysfunction" was changed to "understanding of urination abnormalities," and "risk reduction of infection" for the purpose of "instruction for water drinking" was changed to "prevention of catheter obstruction." These instructions expressed the degree to how much medical professionals understood the medical knowledge of "bladder dysfunction by knowing the urinary volume (whether it significantly decreases) and the fact that a low infection risk can be maintained by predicting the chance of catheter occlusion (catheter occlusion increases infection risk)."

The correction instructions were studied by the person in charge of the modeling and the person in charge of correcting the descriptions. According to the results, it was found to be ideal that these instructions be explained both before and after the corrections. The task of "understanding of bladder dysfunction" was evaluated by doctors as a final stage, but the part task of "measurement of urination volume" was conducted by nurses. The nurses in charge of this task understood the task of "measurement of urination volume" as "understanding of bladder dysfunction" for the medical purpose, and "urination abnormalities" for operational purposes. Nurses in charge of the task of "instruction for water drinking" were also responsible for the task of "checking catheter abnormalities." For nurses, "prevention of catheter obstruction" may more appropriately express the purpose of "instruction for drinking water" rather than "risk reduction of infection" and their actual medical tasks. However, the description before modification may be more rea-

sonable if the medical purpose is emphasized. Thus, the descriptions should convey the understanding of a service containing medical logic, and the understanding of a service that underscores an important point in promoting work flow in clinical settings. In other words, it suggests that at least these two types of descriptions are necessary to describe the status of a service when interviewing medical professionals about their practical knowledge.

5.1.3 Discussion about Answers to Questions about Practical Knowledge

Table 6 shows sample answers to the questions used to acquire practical knowledge. The total number of questions was 97 for 23 medical tasks, which were contained in five clinical paths, of which 88 questions were answered. Of the nine unanswered questions, three were invalid due to instructions for modifying the model structure; four were not necessary because the content overlapped; and two were excluded for unknown reasons. Such a high response rate demonstrated that the function to conduct interviews on the practical knowledge of medical services in light of the understanding of service by medical professionals was as successful as intended.

This study provided examples wherein the acquisition of practical knowledge required an understanding of the tasks. For example, the Path for cesarean section contained the task of "understanding of the severity of pain," which was modeled to be included in the task of "understanding of organ dysfunction" and a task of "detection of abnormalities in the operative site." However, there was an instruction to excluding the task of "understanding of organ dysfunction." According to the reason, the pain described in the task "understanding of the severity of pain" indicated wound pain and was not related to the organs. When asked more specifically, the answer obtained was: "the result of the detection of abnormalities in the surgical wound site has been described as wound pain in the medical record. Based upon the result, it is decided whether or not an analgesic is prescribed. Therefore, the description has been corrected to describe the task flow, and the task of 'understanding of organ dysfunction' has not been included in the task flow." In addition, there was another answer, "we observe them thinking about two such possibilities in detection of abnormalities in the surgical wound site."

Here, we have to focus on the medical task that is performed while thinking about the two possibilities in "detection of abnormalities in the surgical wound site." However, when questioned about practical knowledge as a task of "understanding of organ dysfunction," the respondents stated it was different from their understanding of the medical service, and did not talk about their practical knowledge. On the other hand, when questioned about practical knowledge as a task of "detection of abnormalities in the surgical wound site," the respondents talked about their practical knowledge. This phenomenon suggests that medical professionals relate their practical knowledge to their understanding of service, and that their understanding of service should be taken into consideration when acquiring practical knowledge on a service.

5.2 Trial Use of Practical Knowledge

A trial use of practical knowledge was conducted to determine whether there was any inadequacy or underlying problems in the practical knowledge acquired in terms of descriptions and questions about the understanding of service during an operation.

5.2.1 Trial Method

- Venue: Five clinical departments (obstetrics and gynecology, urology, radiology, second department of surgery, and pediatrics
- Path: Cesarean section, transurethral resection of a bladder tumor (TUR-BT), intake of iodine, hepatic arterial infusion chemotherapy, renal biopsy in a child
- Trial period: November 10, 2008 - January 15, 2009 (*the knowledge has been continuously used)
- Date of interview: Latter part of January 2009

5.2.2 Impressions and Findings after the Trial

We received replies from medical professionals that there were no inadequacies in the descriptions on the relation between medical tasks and the understanding of service and the content of practical knowledge. Their impressions after the trial included: "I could explain to patients showing them evidence," "it is easy to give instructions and explain things to patients using a uniform presentation," and "newly hired staff and shift workers also understand the intentions of the tasks," which were generally positive impressions. After the trial, the practical knowledge has been continuously used in the hospital. However, there were some negative opinions about the template of the descriptions, such as "the descriptions are complicated and unnatural," and a request that medical professionals needed individual presentation according to their experience.

5.3 Future Subjects

The practical knowledge on medical services acquired through the operation was generally accepted, which suggested that it might have some usefulness. Furthermore, as described in 5.13, attention should be paid first to the understanding of service by medical professionals for the acquisition of practical knowledge. However, in order to realize this, we note that the understanding of service should be modeled from different points of medical logic and actual medical practice, as mentioned in 5.12. This suggests a direction of greater functionality of the modeling, but the implementation may make the modeling more complicated. Greater functionality should be advanced according to the level of ontology literacy of the users.

Medical service ontology as used in this paper is a form of ontology to express the understanding of medical service as a model depending on the structure of medical tasks and their medical purpose, and an ontology constructed in the early phase is the framework. Basically, medical professionals add their concepts to the early ontology, which can then be applied to other medical institutions. Currently, however, only five Paths, that were tested in the system used at the Hospital, have been used. We intend to conduct a future study in which we will classify the ontology established by the modeling into one with a strong field dependency, and one with high general-purpose properties and degree of reusability, and arrange them as guidelines for the construction of an ontology to ensure interoperability with a model beyond the relation among the clinical departments in a hospital and among hospitals. In medical ontologies, the concepts of the medical tasks included in Path can be comprehensively arranged to some extent based upon medical dictionaries, while the concepts of tasks that are not included in Path need to be reviewed in more detail and in consultation with the results of studies such as the field of medical diagnosis. The vision at the root of this study is that individuality by clinical settings should be respected, and that a special methodology to construct and use a medical ontology is needed. In view of such a theory for the construction of an ontology, there are some quite interesting points of views, for example, what the level of medical purposes is: to what degree is actual medical service—not medical logic—recognized; and how much does this recognition differ by occupation or hospital. We will collect as many modeling cases as possible in order to obtain sufficient findings.

6 CONCLUSIONS

This paper introduced a method of using an ontology-based information support system for the acquisition and sharing of information in a clinical setting (practical knowledge) when a patient-oriented service is performed. It is difficult to comprehensively systematize ontology based upon service modeling to express medical professionalsf understanding of service in terms of the operation of the system, and it was confirmed that the practical knowledge of medical professionals and the understanding of service were closely related—according to the results of interviews conducted to acquire practical knowledge. We consider that the results of this study show that the acquisition of practical knowledge should be ontologized, as well as expressing the understanding of service by medical professionals (what do they think and what values do they provide to patients through the medical tasks) support the contention of this study.

A future study will focus on such challenges as devising a method to systematize an ontology, a method to eliminate intra-sender conflict during the process of compilation, and a function to support the elimination of conflict by promoting usage of the system. The system described in this paper provides a framework to express the understanding of service by medical professionals. In addition to the framework, a function to guide procedures for expressions and a supporting function to check whether there is any imperfection in the model are required. To implement these functions, not only was a modeling of the understanding of service as the result of thinking investigated, but also an approximate modeling technique of the thinking process, such as assumption of patients to be treated and problems in the assumption, have been investigated. Also, a close relation with the electronic health record needs to be achieved by obtaining access to medical dictionaries. We will study a method of connecting to the to ontology in light of a discussion about the concept level of disease and pathology (Mizoguchi and et al., 2009) (Ohe, 2010).

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