ONTOLOGY-DRIVEN DECISION SUPPORT SYSTEMS FOR MANAGEMENT SYSTEM AUDIT

Syohei Ishizu, Andreas Gehrmann, Junya Minegishi, and Yoshimitsu Nagai
Aoyama Gakuin University, 5-10-1 Fuchinobe, Sagamihara, 229-8558, Japan

ABSTRACT

Many types of management system audit are widely spread in the companies, e.g., quality management system audit, etc. The management system audit can be regarded as management decision-making. But there are very few decision support systems for the management system audit, since management system audits are different from usual management decision-making. For management system audit management standard is developed, and auditors must verify that an individual management system of a company consistent to the requirements of management system standards. Ontology is information structure, which helps to acquire knowledge, share it, and check consistency within the knowledge. One of our main aims of this paper is to present a methodology of ontology-driven decision support systems for management system audit. Firstly, we characterize the management system audit as a new decision-making. Next, we introduce a concept of ontology formally, and develop generic management system ontology, and company quality management system ontology. Finally we present a methodology of ontology-driven decision support system for management system audit, and show the characteristics of the decision support system

Keywords: Management system standard, decision support system, ontology, audit

INTRODUCTION

Decision-making is one of the main research themes of systems science, and decision support systems (DSS) were developed in many area; e.g., management decision-making, group decision-making, etc. DSS helps the decision-maker to gather information, generate alternatives, estimate the values of alternatives, and to make choice. Power (2007) classified DSS as model-driven DSS, data-driven DSS, communications-drived DSS, document-driven DSS, knowledge-driven DSS, web-based DSS. In the most of DSS, decision-making may be regarded as a choice between alternatives based on the estimation of the values of the alternatives. Now many types of management system audit are widely spread in the companies, e.g., quality assurance management system audit, environmental management system audit, information security management system audit, etc. These management system audits can be regarded as management decision-making. But there are very few DSS for the management system audit, since management system audits are different from usual management decision-making. For management system audit management standard is developed, and auditor must verify that an individual management system of a company consistent to the requirements of management system

1

standards. In usual decision-making, to generate alternatives, to estimate the values of alternatives, and to make choice are important. And DSS want to support these activities. But in management system audit, to gather management information, translate the information to the generic management system standard, and to check the consistency of the management system to the generic management system standard. Gehrmann et al (2005, 2008) introduced the concept of ontology in order to support management system audit. Where ontology is information structure, which helps to acquire knowledge, share it, and check consistency within knowledge. One of our main aims of this paper is to present a methodology of ontology-driven decision support systems for management system audit, and to clarify the characteristics of the ontology-driven decision support system. Firstly, we characterize the management system audit as a new decision-making. Next, we introduce a concept of ontology formally, and develop generic management system ontology, and company quality management system ontology. Finally we present a methodology of ontology-driven decision support system for management system audit, and show the characteristics of the decision support system

CHARACTERISTICS OF MANAGEMENT SYSTEM AUDIT

In this paper, we focus on the quality management system audit as a typical sample of management system audit. ISO 9000 family is a set of standards for the quality management system audit, and consists of IOS 9000, 9001, and 19011. ISO 9001 is a main standard in ISO 9000 family, and is a standard for the requirement of the quality management system. ISO 9000 is a standard for the terminology for quality management system, and is used for the definitions of the requirements of quality management system. ISO 19011 is guidance for the audit. The main focus of the management system audit is to determine if the management system has been developed, is effectively implemented, and is being maintained. Management system audit should be on verifying conformity. An organization becomes registered/certified on the basis that it has effectively implemented a management system that conforms to the requirements of ISO 9001. The characteristics and difficulties of management system audit may be summarized as follows.

Characteristics of management system audit

1. Management system audit is performed by the form of document audit and on-site audit. Auditor acquires the company knowledge which related to the management system standards.
2. Auditor acquires many types of partial knowledge from the audit activities of on-site audit, and auditor need to synthesis the knowledge according to the management system standards.
3. Auditor has generic management system standard, and auditor must verify that an individual management system of a company conform the requirements of management system standard.

4. Auditor need to communicate with auditee in order for auditee to accept the result of the audit decision easily.

Difficulties of management system audit

1. Audit knowledge is acquired by document audit and on-site audit, and the form of the audit knowledge is very flexible. Knowledge acquisition of audit is not easy.
2. Audit knowledge has to be translated to the terms of generic management system standards in order to understand the situation of the company's management system. It is not easy to translate the audit knowledge about management system into generic management system standards.
3. Audit knowledge is partial knowledge about management system. We need to synthesize the partial audit knowledge according to the management system standards. But it is difficult to address the partial knowledge and synthesize them.
4. Auditor must judge whether the management system is conform to generic management system standards or not. This decision is not easy, and this decision is usually dependent on the personal ability of the auditor.
5. The collaboration with auditors and auditees in not easy. We need some communication tool among auditors and auditees.

CONCEPTS OF ONTOLOTY AND MANAGEMENT SYSTEMS ONTOLOGY

Concept of ontology

In this section we introduce a formal concept of ontology and propose management system ontology. Ontology is an information structure, which helps to acquire knowledge, share it, and check consistency within knowledge. Gruber (2007) proposed a formal definition of ontology as a 5-tuple (N, R, D, F, T) where each element is defined as follows:

$-$ N, a set of nodes.

$-R \subset N$, s a set of relationTypes.

$-$ D, a set of description logic sentences. Each sentence can use the elements in N and 2 variables *subject* and *object*. Indicating respectively the first en third element in 5-tuple in T.

$-$ F, a function that maps each element in R maps onto one element in D.

$-$ T, is a set of relations which is defined as a set of 3-tuples where for each element consists of (s, r, o) where:

$-$ s is the subject, an element of N

$-$ r is the relation, an element of R

$-$ o is the object, an element of N

In ontology (N, R, D, F, T), knowledge is mainly represented by D and T. D is a set logical descriptions of knowledge and may be regarded as deductive knowledge. T is a set of relationships among nodes, and may be regarded as inductive knowledge. An invalid relation is an element $t=(s,r,o)$ in T, where the description logic sentence $d=F(r)$ in which

the variables are substituted with *s* and *o* returns false. The invalid relation means the inconsistency among deductive knowledge and inductive knowledge. This is a mechanism for the consistency check within the ontology. Next we introduce the ontology of management system standard.

Ontology of generic quality management system

ISO 9000 family is a set of standards for the quality management system audit, and consists of a standard for the requirement of the quality management system, a standard for the terminology for quality management system, and a guidance for the audit. Ontology derived by ISO 9000 family is defined by the next form.

ISO 9000 Ontology: $O_0=(N_0, R_0, D_0, F_0, T_0)$
− N_0, a set of nodes. N_0 consists of the terms and requirement of quality management standard, procedure of audit, and the following relationTypes.
− $R_0 \subset N_0$, s a set of relationTypes. is-a relation is a typical relation type in ontology. Is-a relation shows the class hierarchy of the terminology of quality management system standard. Verbs in the sentence of system requirement may also be regarded as relationTypes.
− D_0, a set of description logic sentences. Some of the definitions of the terms and the conditions of the requirements are defined by description logic.
− F_0, a function that maps each element in R maps onto one element in D_0.
− T_0, is a set of 3-tuples. (*s, r, o*) shows that node *s* related by the relationType *r* to node *o*. T_0 is a set of inductive and factual knowledge within the standard.

Ontology of company and ontology of company quality management system

Company may have its own ontology. It may be unclear and ambiguous for the auditor. We assume company ontology as follows: $O_C=(N_C, R_C, D_C, F_C, T_C)$

− N_C, a set of nodes. N_C consists of the terms and rules in the company.
− $R_C \subset N_C$, s a set of relationTypes. Names of the rules in the company may be regarded as the relationTypes.
− D_C, a set of description logic sentences. D_C is a set of deductive knowledge and the rules in the company may be defined as D_C.
− F_C, a function that maps each element in R maps onto one element in D_C.
− T_C, is a set of 3-tuples. T_C is a set of inductive and factual knowledge within the company.

Through the audit activities, auditor acquires the factual knowledge of the company which is related to quality management system standard. The audit knowledge is a company knowledge which is acquired by audit activities: (N_A, T_A)

− N_A, $N_A \subset N_C$, a set of company terms or rules which are acquired by audit activities.

− T_A, $T_A \subset T_C$, a set of factual knowledge of the company which is acquired by audit activities.
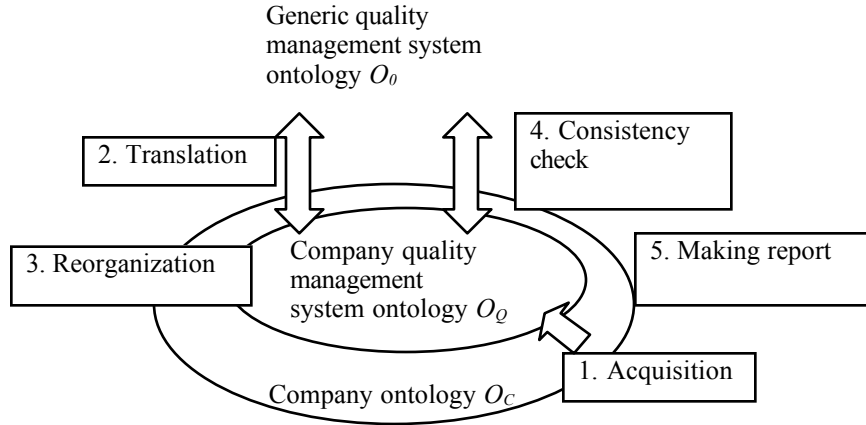
Figure 1. Conceptual Figure of Company Quality Management System

Ontology of the company quality management system consists of the ontology of generic quality management system and the acquired knowledge by audit activities. Ontology of the company quality management system is defined as follows: $O_Q=(N_Q, R_Q, D_Q, F_Q, T_Q)$.
− N_Q, $N_Q = N_C \cup N_0$.
− $R_Q = R_0$, $D_Q = D_0$, $F_Q = F_0$.
− T_Q, $T_Q = T_C \cup T_0$.

Figure 1 shows the relationships among generic management system ontology, company quality management system ontology, and the company ontology. Figure 1 also shows the following methodology of ontology-driven decision support system.

METHODOLOGY OF ONTOLOGY-DRIVEN DECISION SUPPORT SYSTEM FOR MANAGEMENT SYSTEM AUDIT

Based on the definitions of management system ontology, we present a methodology of ontology-driven decision support system for management system audit. According to the methodology, we show the interface of the ontology editor Protege.

Methodology of ontology-driven decision support system

0. Development of generic quality management system ontology $O_0=(N_0, R_0, D_0, F_0, T_0)$

    Within the ontology O_0, terms of quality management system N_0 is represented by the hierarchical manner as shown in Figure 2 based on is-a relationType. This hierarchy of the terms is usually called taxonomy. It helps us to understand the structure of the terms.

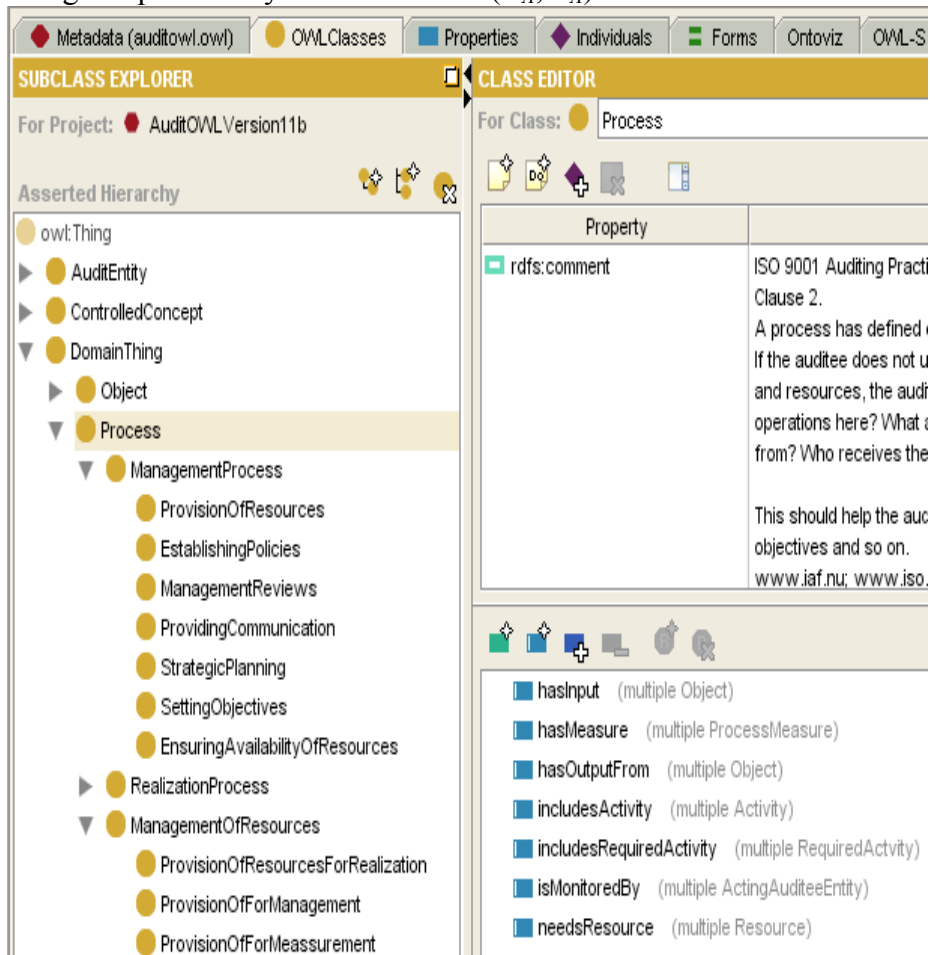1. Knowledge acquisition by audit activities (N_A, T_A)

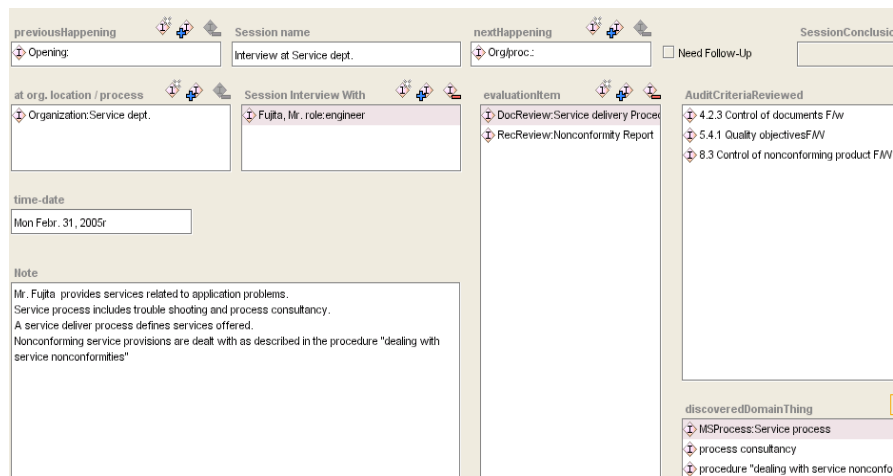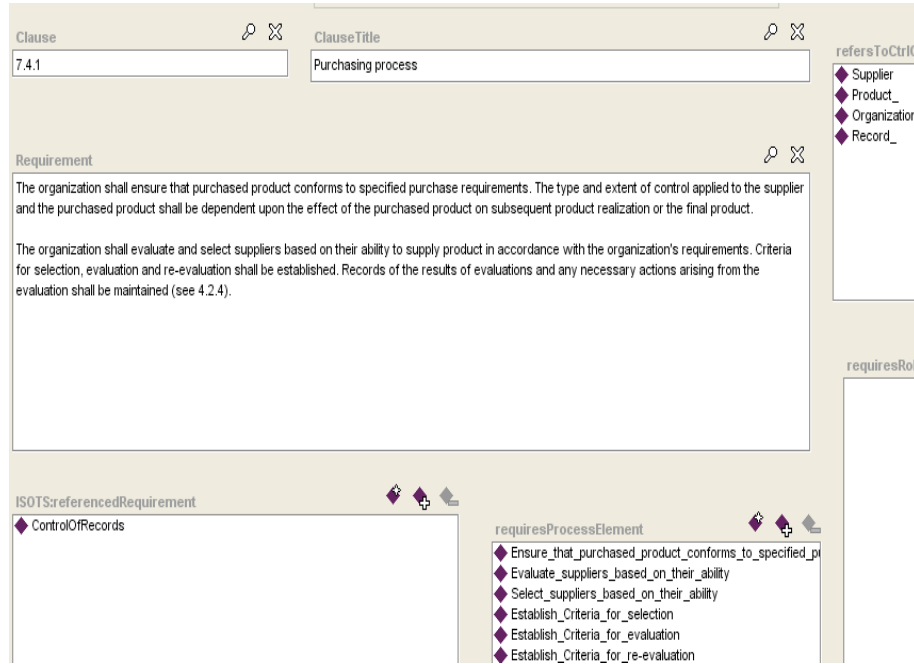**Figure 2. Taxonomy of Generic Quality Management System Ontology**

Figure 3. Knowledge Acquisition by Audit Activities

Figure 4. Definition and Real Company's Activities of the Requirement

Through the audit activities, auditor acquires the factual knowledge of the company (N_A, T_A) which is acquired by the audit activities. For any o in N_A, $\{s \mid (o,r,s) \in T_A\}$ will be
change with flexible manner. $\{s \mid (o,r,s) \in T_A\}$ can be regarded as the flexible check list for audit activities. Protege provides the forms as shown in Figure 3. The forms works as flexible check list and helps us to reduce the effort of input of the acquired knowledge.
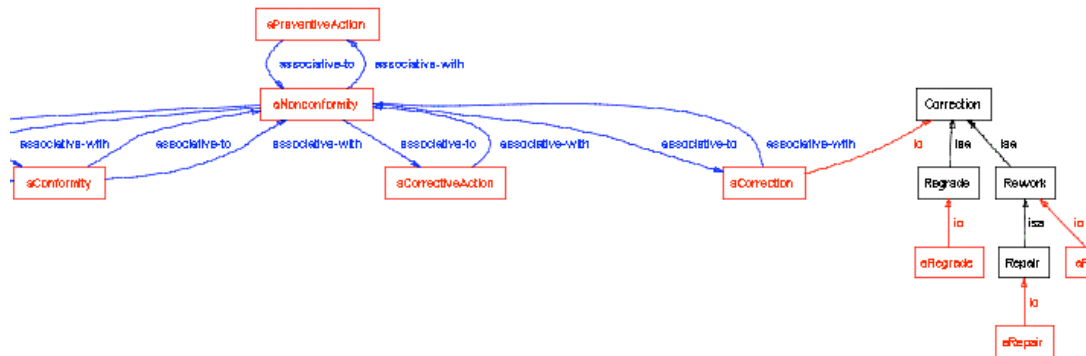
2. Translation of acquired knowledge to generic quality management system ontology
    Node o in acquired knowledge N_A is translated to s, if (o, is-a, s) in T_Q. If o is translated to s, then the definition of s is also applicable to o. Figure 4 shows the definition and real company's activities of the "Purchasing process" requirement.

3. Synthesis of the acquired knowledge (N_A, T_A) in the context of generic management system standard ontology $O_0 = (N_0, R_0, D_0, F_0, T_0)$
    As a synthesized ontology, we can get company quality management system ontology $O_Q = (N_Q, R_Q, D_Q, F_Q, T_Q)$ as defined in the previous section. Figure 5shows the Synthesis of the acquired knowledge in generic quality management system ontology.

4. Consistency check of the acquired knowledge
    If for any $t = (s,r,o)$ in T, the description logic sentence $F_Q(r)$ in which the variables are substituted with s and o returns true, then the knowledge acquired by audit (N_A, T_A) is consistent with generic quality management system standard. In short, if for any

(o,r,s) in T_A is not invalid relation, then the knowledge acquired by audit (N_A, T_A) is consistent

Figure 5. Synthesis of the Acquired Knowledge in Generic Quality Management System Ontology
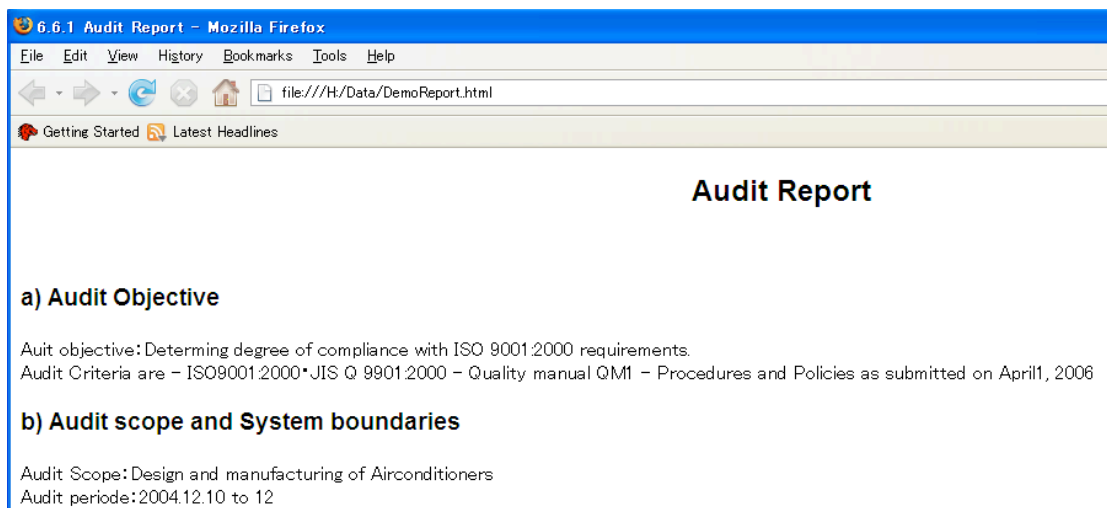
Figure 6. Generation of Audit Report

with generic quality management system standard. Then part means that the company quality management system ontology O_Q=(N_Q, R_Q, D_Q, F_Q, T_Q) is consistent.

5. Making audit report.

As a result of audit activities, auditor must make audit report. Audit report generator supports auditor to select relevant factual knowledge and organize items according to the format of audit report, and publish the report. Figure 6 shows the audit report generated by ontology-driven decision support system.

CONCLUSION

As a new type of decision-making, we introduce a decision-making for management system audit. We characterize decision-making for management system audit, and show the difficulties within the management system audit. In order to support management system audit decision-making, we introduce the ontology-driven decision support system. We define generic quality management system ontology, acquired knowledge by the audit activities, and company quality management system ontology. Based on the definition, we present a methodology of ontology-driven decision support system for management system audit. If we have conceptual models or standards, and our decision-making is close related to the consistency check among conceptual models and real systems, then ontology-driven decision support system will be useful for us.

REFERENCES

Gehrmann A. and Ishizu S. (2008). "Improving management system audits by knowledge sharing with ontologies," *JASMIN*, Vol.16, No. 4, pp.51-65, 2008.

Gehrmann A. and Ishizu S. (2005). "Ontology based auditing in complex organizations," *ICQ '05*.

Gruber, T. (2007). What is an Ontology? http://www-ksl.stanford.edu/kst/what-is-an-ontology.html.

Ishizu, S., Gehrmann, A., Nagai, Y., and Inukai, Y. (2007). Rough set: extension of Ontologies by rough sets, *Methods, Techniques and Tools in Information Design*, 456-462, Springer-Verlag.

Ishizu S and H. Osada (2005). "Methodology and application of self-diagnosis for sustainable management innovation," *ICQ '05 Tokyo*.

McGuinness, D.L., and van Harmelen, F. (2007). OWL Web Ontology Language Overview, *http://www.w3.org/TR/owl-features/*.

Power, D.J. A (2007). "Brief History of Decision Support Systems." *DSSResources.COM, World Wide Web, http://DSSResources.COM/history/dsshistory.html*