

A Proposal of Quality Assessment for System Model

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Abstract : Recently, the increased complexity of systems has made systems engineering necessary. It is very useful for system designers to understand the whole context of the concerned system based on systems engineering. A system model can be used to describe the outcome of a system design. A system model describes the system from the viewpoint of the stakeholder's needs using the mutually exclusive and collectively exhaustive principle. A system model can be used to smoothly design a large and complicated system based on the systems engineering development process. Many companies and countries are attempting to apply model-based systems engineering, and the significance of the system model quality is increasing as system models are referenced during system development. In this paper, we propose a quality assessment method for ontology which is one of system models by focusing on the system development process. First, in this process, a system developer should explicitly show the relationship between viewpoints. Then, the system developer should select dependent rather than independent viewpoints. With dependent viewpoints, each viewpoint used to describe the system has some logical relationship. The set of viewpoints makes it possible to show, not only tangible and physical system parts, but also conceptual system parts. In this paper, we develop an ontological system model of a Japanese weather observation system. By comparing some ontological system models, we verify the effectiveness of explicitly describing the relationships between viewpoints and select dependent viewpoints.

Key Words : System model, Ontology, Model-based systems engineering, Weather observation satellite

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1. Introduction

In recent years, technical progress has increased the complexity of the products that have been developed. This has made it more difficult to understand the whole system compared to the previous simple systems. Currently, many kinds of research on methodologies for efficiently developing system are being conducted. One answer to this problem is the application of model-based systems engineering (MBSE). The advantage of applying MBSE to the system development process is the ability to quickly design a high-quality, low-cost system [1]. MBSE also makes appropriate communication possible using valid notations and rules, which makes it easier to obtain insight from the system model.

Even if the system model exists, however, its quality is very important. If the quality is inappropriate, the model developer will not be able to appropriately explain the concept of the model, and the model viewer will misunderstand this concept. In this paper, we consider a system model from an ontology perspective. The ontology identifies and defines the concepts and terms. Furthermore, it systematically shows the entities and relationships. Hence, the ontology is the basis of the system model, and building a high-quality ontology is necessary to build a high-quality system model. We propose a quality assessment method that defines a dependent viewpoint as the basis of the ontology. As a case study, we verified this quality assessment method by applying it to a weather observation system ontology.

In the first section, we give an overview of the system model and ontology. The second

section discusses the previous studies on ontology quality assessment. The third section shows several ontologies for earth observation systems, along with the necessary conditions for constructing a high-quality system model. The conclusion is given in the fourth section. Finally, the references for this paper are shown.

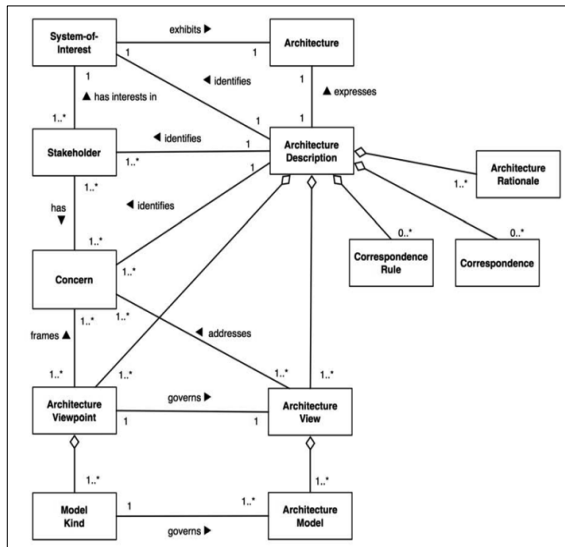
2. OVERVIEW

2.1 System Model

The needs of systems engineering are increasing to deal with complex problems. Systems engineering requires structural, behavioral, physical, and simulation-based models that represent technical designs that can evolve throughout the life cycle, and support trade studies, design verification, and system verification and validation. Model-based systems engineering (MBSE) was developed to support these activities.

MBSE is the formalized application of modeling to support system requirements, design, analysis, verification, and validation activities beginning in the conceptual design phase and continuing throughout development and later life cycle phases [2].

First, what is a “model”? A model is a representation of one or more concepts that may be realized in the physical world [3]. A model describes the structure and behavior of an integrated system according to the concerns of the stakeholders rather than as a collection of subsystems [4]. These two definitions indicate that a model should consider appropriate viewpoints because the system has numerous characteristics, properties, and relationships. These relationships are clearly visualized in ISO 42010 (figure 1) [5].



[Figure 1] ISO 42010 architecture description

The motivation for utilizing a system model is to allow model viewers to easily understand the system by controlling the level of abstraction for the object and situation.

There are some advantages to applying a system model [3] [4]. First, a system model is a convenient way to quickly understand the object as a system. Compared to document-based management, system-modeling management is easy to understand and has flexible dynamics because a system model can describe the real world system visually. Therefore, everyone can quickly understand the entire scope of the system. Second, the traceability is explicitly described. As a system becomes larger and more complex, it is more difficult to comprehend the relationship between the top-level requirement and the bottom-level specification, along with the impact due to some modifications. One of the most important points of system modeling is the ability to understand not only the elements but also their relationships.

2.2 Ontology

2.2.1 Definition

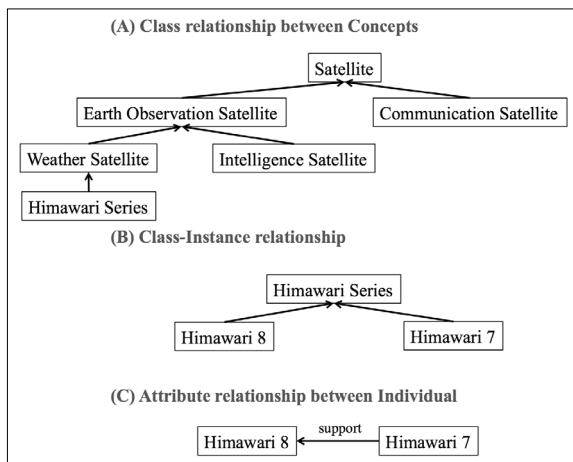
An ontology identifies and defines the concepts and terms [6]. It also provides descriptions of the concepts and defines their relationships [7]. An ontology provides better definitions for the usage than a dictionary or taxonomy [1], which means an ontology is not just a classification method. From these perspectives, an ontology is based on the same concept as a system model. Hence, we will treat the system model as an ontology.

2.2.2 Advantage

An ontology has two advantages. First, it provides viewers with a consensus. When numerous parties are involved in a project, it is very difficult to obtain a consensus because there may be many different interpretations of a concept. Having the same dictionary with definitions at a very deep conceptual level can prevent misunderstandings between the parties. Having such a common dictionary makes it possible to explicitly express their tacit knowledge. The second advantage is the ability for the viewer to reuse and share knowledge. It becomes possible to identify the basic concepts that constitute such knowledge by considering the object world in relation to the original knowledge to be an object entity. Then, by considering the hierarchy according to the abstraction level of the knowledge, the viewer can consider the origins of the knowledge from the basics, and will be able to find shared and reusable knowledge.

1.2.3 Ontology Type

The ontology has three main types of re-



[Figure 2] Basic relationships of ontology

relationships, as shown in figure 2.

(A) Class relationship between concepts

Satellites can be classified using several categories, including earth observation satellites and communication satellites. Earth observation satellites can also be divided into categories such as weather satellites and intelligence satellites. The Himawari series consists of geostationary weather satellites operated by the Japan Meteorological Agency (JMA). These support weather forecasting, tropical cyclone tracking, and meteorology research.

(B) Class-Instance relationship

The Himawari series includes eight satellites (Himawari 1 to Himawari 8). In this case, Himawari is the class and Himawari 7,8 are the instance.

(C) Attribute relationship between individuals

Currently, Himawari 8 is in operation, and Himawari 7 supports Himawari 8 as its backup. In the ontology, we can describe this relationship as “Himawari 7 supports Himawari 8.”

3. PREVIOUS STUDIES

Many discussions have been conducted in the past on the quality of an ontology. Tartir et al. proposed a method to analyze ontology schemas and their populations and describe them using a well-defined set of metrics [8]. One of the metrics that they proposed was a schema metric. These metrics indicate the richness, width, depth, and inheritance of an ontology schema. In addition to their research, Sathya et al. suggested a semantic metric to assess the quality of an ontology [9]. They focused on the deviation in the relationships of the ontology. In order to evaluate the ontology, they utilized a relationship deviation metric (RDM), which is the ratio between the number of relationships at each concept level (left-right) and the number of relationships in a hierarchical manner (top-down). RDM provides an easy way to measure the concept reusability and consistency.

Significantly, the previous ontology quality research used schematic and semantic approaches. Several metrics were proposed using the schema approach [10] [8], and an ontology transformation approach was also proposed [11] [12]. In another semantic approach, quality criteria were defined, as listed in table 1.

This paper proposes a method for assessing the quality of an ontology from the ontology development process, especially focusing on how to select the viewpoint.

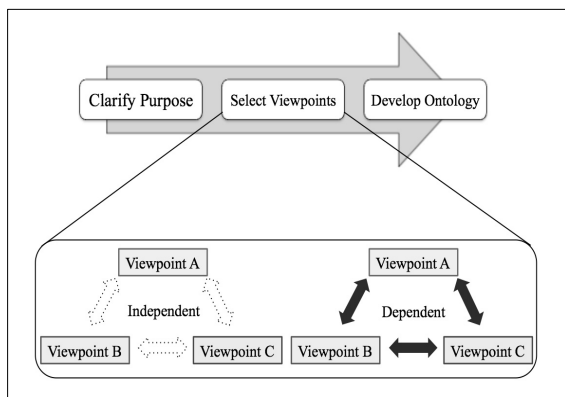
4. QUALITY ASSESSMENT

4.1 Quality Assessment

We outline the process of developing an

<Table 1> Example of ontology quality criteria [11][12]

Criteria	Note
Homogeneity	Class in ontology should have similar instances.
Explicitness	The clarity of the definitions for the classes, properties, relationships, and other constructs.
Size	The number of ontology object types and attributes. Increasing the size of a schema can be beneficial in certain situations.
Query Simplicity	The simplicity of queries that access the ontology and instance.
Stability	How stable the ontology is if a change occurs.
Uniformity of Properties	Properties (either data-type or object properties) need to be single-valued and total.



[Figure 3] Ontology development process

ontology in figure 3. First, it is necessary to clarify the purpose for developing the ontology. For example, it is difficult to clearly picture the entire weather observation system during a typhoon. Therefore, we began to develop an ontology to understand this system. The next step is selecting the viewpoints. It is easy to write down the numerous entities and relationships that comprise a system. However, simply selecting entities and relationships at random will not provide model viewers with an understanding of the whole system. Dependent

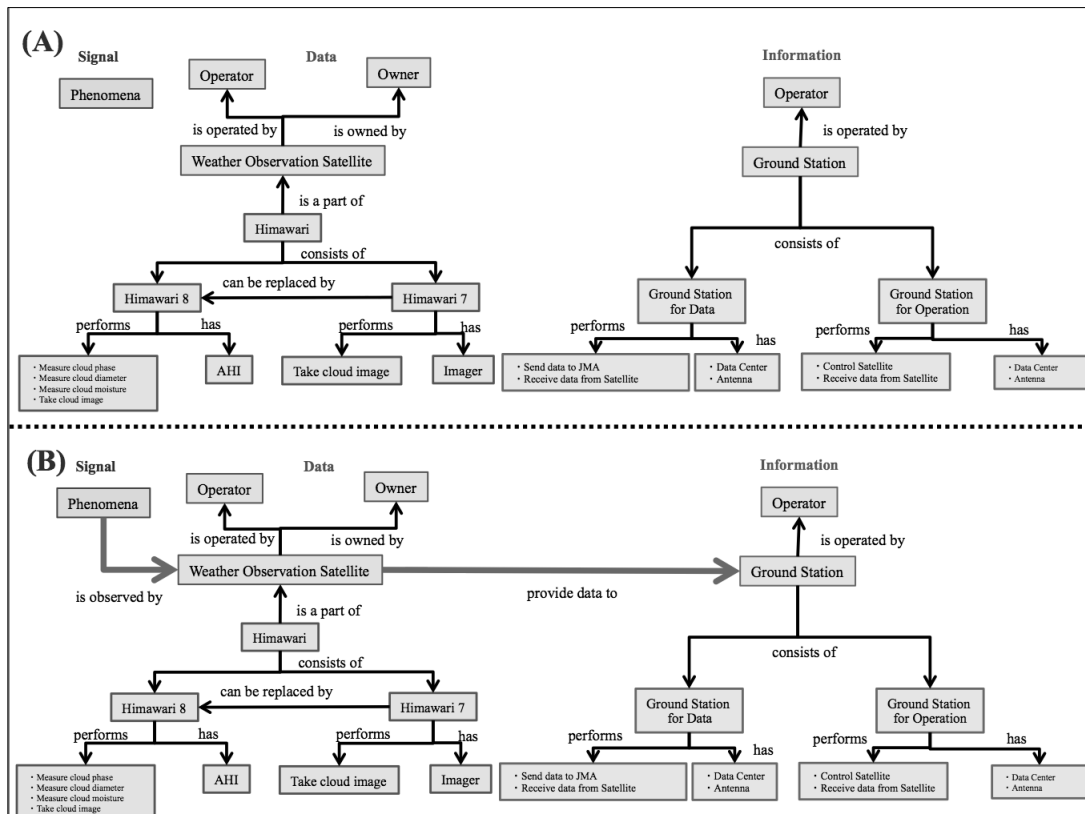
viewpoints address this issue. These dependent viewpoints can cover the entire structure of the system maintaining the relationships between entities. In this case, the dependent viewpoints indicate that there are some logical relationships between viewpoints. In addition, the dependent viewpoints provide the potential to add values that describe the conceptual parts of the system, in addition to the tangible parts. After selecting the viewpoints, we begin to develop the ontology. During the entire ontology development process, the quality of the ontology is mainly determined by how the dependent viewpoints are selected. In addition, the viewpoints have the efficient “enabler relationship” [13]. This relationship is discussed in section 3.2.2.

4.2 Result

In this section, we show two kinds of ontologies. The purpose of developing the ontology is to understand the entire weather observation system. This is common to both ontologies. The difference between the two ontologies is the viewpoint. The first ontology is developed by selecting independent viewpoints, and the other is developed by selecting dependent viewpoints in the ontology development process.

4.2.1 Independent Viewpoint Ontology

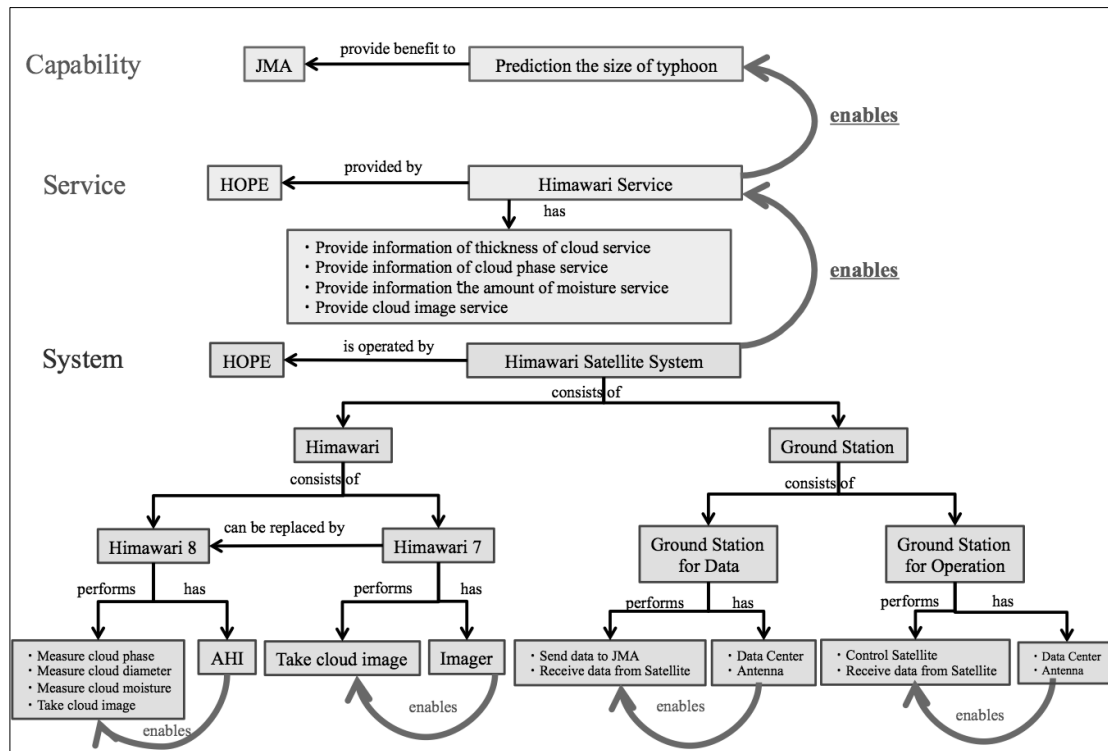
The viewpoints of the ontology are “signal, data, and information” from the data information knowledge wisdom (DIKW) hierarchy [14] [15]. The signal, data, and information are part of the hierarchy and do not have any logical relationships. Hence, the viewpoints are independent. The weather observation system with independent viewpoints is shown in figure 4. In figure 4 (A), the signal, data, and information are shown



[Figure 4] Weather observation system ontology with independent viewpoints

separately. Of course, a model viewer can understand this system from each viewpoint (signal, data, and information), but the relationships between them are unclear. Model viewers have to consider the relationships themselves. In figure 4 (B), we add descriptions of the relationships between the viewpoints. By visualizing these relationship, model viewers easily understand the system. Of course, the satellite is owned and operated by another organization. The system consists of the Himawari satellites and ground station. The Himawari series consists of Himawari 8 and Himawari 7, and Himawari 8 can be replaced by Himawari 7. Therefore, we define their relationship as “can be replaced by.” There is a large performance difference between these two satellites.

Himawari 8 has an imager called the advanced Himawari imager (AHI), which has more functions than that of Himawari 7. These functions include measuring the phase, cloud diameter, and moisture of clouds, as well as taking images of them. The ground station consists of two units. The first is the ground station used for data. It has a data center and an antenna as physical components. It sends data to JMA and receives data from the satellite. The second is the ground station used for operation. It has the same physical components as the ground station used for data, but it has different functions such as those for controlling the satellite. Of course, the ground station is operated by an operator.



[Figure 5] Weather observation system ontology with dependent viewpoints

4.2.2 Dependent Viewpoint Ontology

We next present an ontology with dependent viewpoints. As dependent viewpoints, we select “capability, service, and system.” The Department of Defense Architecture Framework 2.0 (DODAF 2.0) [16] suggests these viewpoints for describing a system. The capability, service, and system viewpoints have enabler relationships. In other words, one viewpoint is enabled by another viewpoint to realize the viewpoint. This relationship can be applied to the DODAF 2.0 viewpoints. The capability is enabled by the service, and the service is enabled by the system. also In addition, this relationship can be applied to the function and physical viewpoints. For example, in figure 5, AHI (physical viewpoint) makes it possible to measure the cloud phase (functional viewpoint). This relationship can be

applied between physical entities and function entities.

The Himawari system has the capability of predicting the damage from a typhoon. This information is beneficial to JMA. This capability is enabled by the Himawari services. These services provide information about the cloud thickness, phase, and amount of moisture, as well as a cloud image. The Himawari operation enterprise corporation (HOPE) provides these services, which are enabled by the Himawari satellite system. This system is shown in figure 4 (B).

4.3 Discussion

We developed ontologies from different view- points. The ontologies shown in figure 4 and figure 5 clearly have different quality schemas.

Figure 4 shows only the visible elements such as the satellite, ground station, and phenomena. On the other hand, figure 5 represents not only visible elements but also invisible elements used by the system to realize its objectives. The purpose of developing this ontology is to understand the entire weather observation system. Of course, the system has several visible elements such as hardware, but it includes more than just visible elements. For example, the system context, purpose for using the system, and process are included. Again, the purpose for developing the ontology in this paper is to understand the whole system. From this perspective, figure 5 is better (more purposive) than figure 4. The difference stems largely from selecting dependent viewpoints in the process of developing the ontology. In addition, the relationships between the system viewpoint and service and capability viewpoints help model viewers to understand the whole system. Each function described from the system viewpoint connects to a service, and each service connects to a capability. The model viewer clearly understands how each system realizes its service and capability. These “capability, service, and system” viewpoints maintain consistency in the system model because they are dependent viewpoints.

A comparison of figure 4 (A) and figure 4 (B) shows that clearly visualizing the relationships between viewpoints helps model viewers to understand the whole system model.

5. CONCLUSIONS

After we showed the similarity between a system model and an ontology from a certain

perspective, we stated that the quality assessment criterion for a system model was the selection of dependent viewpoints to develop the system model. The effectiveness of the quality assessment was empirically verified based on its application to a weather observation ontology. Dependent viewpoints added value to the system model. In addition, for the quality of the system model to be purposive, it was necessary to select dependent viewpoints as a very first step to develop the system model. We also saw the effectiveness of visualizing the relationships between viewpoints by comparing two ontologies.

6. FUTURE WORKS

The ontology should be evaluated from both the quality and quantity perspectives. Thus, the next step is to develop a quantitative evaluation method for the system model. Absolute assessment criteria should also be defined in order to assess the quality of system model.

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