Role Explication of Simulation in Intelligent Training Systems by Training Task Ontology

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1 Introduction

With the advancement in technology, computers have been used for training novice operators, for it is more cost-effective than the real system, and with the recent development of Multi-Media technology, a simulator environment can be realized in computer just like a real-time control system. But on the other hand, the more complex and the more advanced the technology is, the more difficult to make a teaching material for computer. That is to say, it will take a lot of time for an author to make a good teaching material including simulations so that the learner can master it easily. Because there is a large gap between the concepts of authors and the concepts for computer, it feels difficult to save more time for the author.

In order to solve such a problem, we think the ontology technology is needed, and it is now widely accepted among the researchers.

The system which we call SmartTrainer is a CBT (Computer Based Training) system including a set of simulators for facility of electric power systems. The development of SmartTrainer is partly motivated by the need for a powerful authoring system of Intelligent CBT systems. Of course, here we do not just want to discuss how to make an authoring system itself which can be used easily only, we also emphasize on what the simulation is from the view of training task.

In this paper, as a preliminary step, we will mention the intelligent training system itself, and then explain what is ontology which is used as a base for making our Intelligent Training System. At last, we will briefly discuss the designing of authoring environment based on ontology in Smart Trainer.

2 Intelligent Training System

General, Intelligent Training System is composed of student module, teaching materials module, teaching module and simulation module. Many AI-oriented researchers have the ambitious and visionary goal to supplant experienced human instructors by aiming for stand alone training systems(Steamer and Sherlock systems). The training system developed by LeiLa and Richard envisage serves instead as training support tools, tools that assist human instructors to perform their task more effectively[Leila, 1996]. In this paper, we also try to make an environment that assist the author make the simulation-based teaching material easily based on ontology.

As the characteristics of our training system, Practice->knowledge->Practice is an important one. For the first practice, a learner can do simulation by himself/herself to solve a problem, if he/she made a mistake, system will teach him/her the principle behind the operating to overcome the error, and the last practice can check the learning effect of the learner. As a simulation-based training system, for the system, when to start a simulation; for the teaching material author, how to set the simulation conveniently are the subjects which we will discuss here.

Because our authoring environment for Intelligent Training System is based on ontology, in next session, we will explain what ontology is? Who use or write ontology? and what the role of ontology for building an Intelligent Training System is.

3 Ontology

3.1 What is an ontology?

Three simple definitions are given below.

(1) Ontology is a term in philosophy and its meaning is "Theory of existence".

(2) In AI, ontology is defined as "An explicit representation of conceptualization" [Gruber, 1992].

(3) In KB community, ontology is defined as "a system of primitive vocabulary/concepts used for building artificial systems"[Mizoguchi, 1993]. Although these are compact, it is not sufficient for in-depth understanding what an ontology is. A more comprehensive definition is given in the next subsection.

3.2 Kinds of ontology

In the world of ontology, there are several kinds of ontology from different views. Task ontology and domain ontology are the main two. Task ontology is a system/theory of vocabulary for describing inherent problem solving structure of all the existing tasks domain-independently, and domain ontology is a system/theory of vocabulary for describing the domain. Recently, we defined the CBT(Computer Based Training) ontology which organizes a set of concepts specific to training system under task ontology and use task ontology as its core. We will introduce the task ontology in detail in section 3.4.

3.3 Users of ontology

We divide people into four kinds from building a training system to using it.

(1) The user of a training system(End user).

(2) The author who creates the training system(End author).

(3) The author who creates the domain ontology(Domain ontology author).

(4) The author who creates CBT ontology(Task ontology author).

As an example of such a method of division, we give you an example in authoring of SmartTrainer which is a Computer Based Training System including a set of simulators in the area of Electric Power System.

(1) End user: the newcomer as a trainer.

(2) End author: the instructor in the Electric Power System.

(3) Domain ontology author: the department of development in the Electric Power System.

(4) Task ontology author: the general author who creates the tools of training system.

As the purpose of our research, we want to provide convenient tools with kindness and reusability to all these authors and users, and as the final purpose of our research, we want to create an environment for authoring which can support the people from (1) to (4).

3.4 Task ontology

3.4.1 What is a task ontology?

Task ontology is a system/theory of vocabulary for describing inherent problem solving structure of all the existing tasks domain-independently. It is obtained by analyzing task structures of real world problems. Design of task ontology is done in order to overcome the shortcomings of generic tasks[Chandra, 86] while preserving their basic philosophies. It does not cover the control structure but do components or primitives of unit inferences taking place during performing tasks. The ultimate goal of task ontology research includes to provide theory of all the vocabulary necessary for building a model of human problem solving process.

When we view a problem solving process based on search as a sentence of natural language, task ontology is a system of semantic vocabulary for representing meaning of the sentence. The determination of the abstraction level of task ontology requires a close consideration on granularity and generality. Representations of the two sentences of the same meaning in terms of task ontology should be the same.

3.4.2 Roles of task ontology in authoring environment

The authoring environment based on the task ontology has characteristics as below:

(1) Provide friendly interfaces: because the ontology define the concepts which are very familiar to human beings, the interface of authoring environment based on it has high level of kindness. To express the model which provides interface, the author can select concepts which have the construct of different lays created by graphics and trees simply.

(2) Verify the coordination of model: because the guideline has been made clear as an axiom of ontology.

(a) Hint a suitable selecting ways to the author.

(b) Give some warnings and explanations to the author when he made some unsuitable selections in a created model.

(3) Make the system be reusable: because all the interfaces are defined by ontology, you just need to change the definitions of ontology to suit the different systems. As we said before, ontology is familiar to human being, it is very easy for people to redefine it and make the system be reusable.

Based on such kind of task ontology, we will discuss designing of an authoring environment.

4 Designing authoring environment based on ontology

4.1 What is the problem?

As we mentioned before, there are two problems which we are trying to solve now, the first is when an Intelligent System should start a simulation? we try to solve this problem by the method of selecting a suitable simulation according to the intention of a question and the situation of the student's learning for the knowledge in this question; the second is how to initial the simulation more easily for the teaching material author? We try to solve this problem by supplying an authoring environment which makes the relationship between ontology and model clear. Next we will introduce you an Intelligent Training System --- Smart Trainer, and then discuss the designing of the Smart Trainer's authoring environment based on task ontology to solve these problems.

4.2 SmartTrainer

SmartTrainer is a Computer Based Training System including a set of simulators in the area of Electric Power System.

The target task of SmartTrainer is mainly to recover the accidents of substations in the electric power system. When an accident happens, the electric power transmission will be interrupted, and the operators should recover it as quickly as possible. The operators should find the spot of the accident, continue to supply the electric power to some special places such as hospital, police station at once by borrowing some power from the other substations, find the causes of the accident and recover it within the limited time.

The goal of the training oriented by SmartTrainer is to improve capability of not only skill-based or rule-based reasoning but also knowledge-based reasoning[Rasmussen, 1983]. The set of the scenarios incorporated into SmartTrainer has been designed by the experienced trainers.

In order to let the trainee master the principled knowledge, SmartTrainer let them do practice first and then teach them the first principle behind it adaptively to their mistakes, and finally, check their learning result by practice(training) again. With the cycle of practice->knowledge->practice, teaching process is going forward. This is a form of “learning by doing”.

Here we want to emphasize that the training we give to the trainee has the time-limitation just like in real accidents. Multi-media technique has been widely used in SmartTrainer to attain high fidelity, including the sound processor to create mock buzzer when an accident happens, the movie display to show the accident scene when the repairing man needs, the picture processor to create the static graphics of the various equipment, and so on.

SmartTrainer is composed of five parts, those are human interface, authoring, training model based on the training ontology, teaching materials model based on the teaching materials ontology and simulator. Here we will discuss the designing of authoring environment based on task ontology in SmartTrainer mainly.

4.3 The organization of Teaching Materials

Because simulation is included in teaching materials, before discuss the environment of authoring, we want to discuss the organization of teaching materials of SmartTrainer first. Teaching materials of SmartTrainer is organized by the method of backbone stream and rib stream. A backbone stream which starts from an accident and ends to a suitable goal as a sequence of questions along with a scenario representing a sequence of operations, and it includes an accident case which should be experienced by the learners. A rib stream consists a series of teaching behaviors for transferring the knowledge of the learning items included in a backbone stream to learners. The original knowledge in the background of operation and its teaching behaviors are written in the rib stream. Rib stream conducts the learning process to associate principles behind each operation with a situation during the accident recovery procedure. Inside the backbone stream, there are lots of questions with intentions behind each of them, and according to these intention and the situation of the students' learning, an suitable simulation will be selected. System renew the student model according to the learner's error and the intention behind the question, and select a suitable new rib stream to solve the problem due to renewed student model. Of course, "Do simulation" is selected as one of the teaching strategy including in a rib stream.

4.4 "Do simulation" according to the intention behind question

As we wrote in last section, "Do simulation" is selected as one kind of the teaching strategies included in a rib stream according to the intention of a question in a backbone stream and situation of the student's learning. So what is the intention of a question? Here we define it by ontology.

The intention of a question is a thinking process when the expert makes the teaching materials. There are three parts including in it, those are "question", "thinking process" and "hypothetical pattern".

Inside the "question", there are types of questions, contents of the question and the answer. We make it clear so that the author can write the question easily due to its order.

In "thinking process", there is a cycle of recognition, we create this recognition cycle with four processes defined by task ontology, those are recognition of situation, establishment of assumption, distinguishment of assumption and decision of resolution. Recognition of situation receives the learner's learning information, explain it and return the conclusion. Establishment of assumption receives the conclusion from recognition of situation, and assume what has happened. Distinguishment of assumption verify truth of the assumed phenomenon by asking question, giving a test, letting him/her do simulation and so on. Decision of resolution make the decision(teaching strategy) and execute it.

We can also decide when to let the learner do simulation by his/her learning situation. We realize it through the "hypothetical pattern". In the "hypothetical pattern", there are error types and learning items which is an unit of knowledge or principle. The learning situation of a trainer includes how many operating errors he/her has made, how many times he/she made the same operating error. If he/she just made an operating error which is not very important once, we think it maybe just a operating miss, so we will restart the same simulation , and let him/her try again; otherwise we don't think he/her know the operating order and the principle behind the operating, so the system will teach him/her the principle behind the operating. If he/she makes the same error operating, we will show him the right operating by simulation.

4.5 Authoring Environment

4.5.1 Tasks in creating teaching materials of training systems

An authoring environment is to support to create the teaching materials, and when we create the basic teaching materials in training systems, we should think about three tasks as below:

(1) Simulation in target task

(2) The knowledge in target task

(3) The training scenario

and we classified the training goals into three kinds.

(A) To master the operating ability of regular forms(skills, rules mainly).

(B) To master the knowledge of principles behind the operations.

(C) To create the thinking ability and operating ability based on the knowledge of principles(knowledge mainly).

The author should combine these three tasks by different orders and different contents in order to suit for different students with different levels and different training goals. For example, in order to make a work flow(see section4.5.2) for a newcomer of training(an end user), the instructor in the Electric Power System(the end author) should select some suitable level of knowledge to make a training scenario including some simulations. In our research we define some abstract nouns and verbs to express the knowledge in the electric power system, and organize the training scenario by backbone stream and rib stream as we discussed before. Inside backbone stream and rib stream, there are some different questions with different forms and axioms defined by task ontology for different purposes.

Every expert has his/her own way which is a easy way for him/her to create the teaching materials, and we analyze those ways, select the best one and make it clear (including order and contents) by training task ontology according to the experts' thinking and the Intelligent Training System's needs. This job is done by task ontology author. When the experts (the teaching materials author) write the teaching materials, the authoring environment applies ontology environment to help them create model, and applies created models to help them create new model, so for the experts, creating teaching materials become easy.

Next we will discuss the relationship between ontology and model which our authoring environment supports.

4.5.2 Ontology and model

Fig.1 shows the order to edit ontology, to make model, and the relationship between ontology and model, model and model.

There are lots of equipment, device, cables in an Electric Power System, we organize them by define system ontology. System ontology includes equipment ontology, device ontology and so on, because it is the base for editing other ontology, the ontology author should edit it first.

Target task is very complicated, changing it into teaching materials directly is very difficult for the author, so we present a work flow edit tool for the author to write a work flow first which can be used as a reference for the author to write backbone streams --- the real teaching materials. Work flow is a sequence of recognition, judgment and practice for recovering an accident in the electric power system. Initial state expresses the situation when the accident happened and goal state expresses the status when the accident has been covered. Of course lots of equipment will be used when write the work flow, because it has been prepared in system ontology, so what the author should do is just to open an ontology blowzier, select the equipment which he/her want to use.

Refer to the work flow, the author can edit the backbone stream and its related rib streams, and system will check all the paths in work flow so that no routine will be forgotten by the author.

After the ontology author has prepared the ontology, the teaching material author can make the model refer to it. As showing in Fig. 1, the expert can use system ontology when he/she makes system model(Mark 1); use task ontology, system ontology and system model(Mark 2) to make task model; use question ontology and work flow ontology and model(Mark 7) to write question; use thinking process ontology and system model(Mark 10) to write think process model; use hypothetical pattern ontology(Mark 12) to write hypothetical pattern model in backbone streams; use thinking process model, hypothetical pattern model, system model and teaching strategy ontology(Mark 8) to write teaching strategy model, and use system model, learning item ontology(Mark 11) to write learning item.

4.5.3 Create task ontology in authoring environment

As we discussed before, SmartTrainer is composed of five parts. Except those five parts, there is an ontology server to support the system including the authoring tools. Ontology library is separated into two parts, those are task ontology and domain ontology (Fig. 2).

Task ontology is composed of five parts, those are "The Goals of training", "Learner's state", "System's functionality", Interaction between the system and the learner" and "Teaching material knowledge". Here we just discuss the "Interaction between the system and the learner" which supports the authoring tool. What we need is definitions of some axioms which can be used to make a model.

Using the authoring tool, author can input questions, define the possible errors related to a

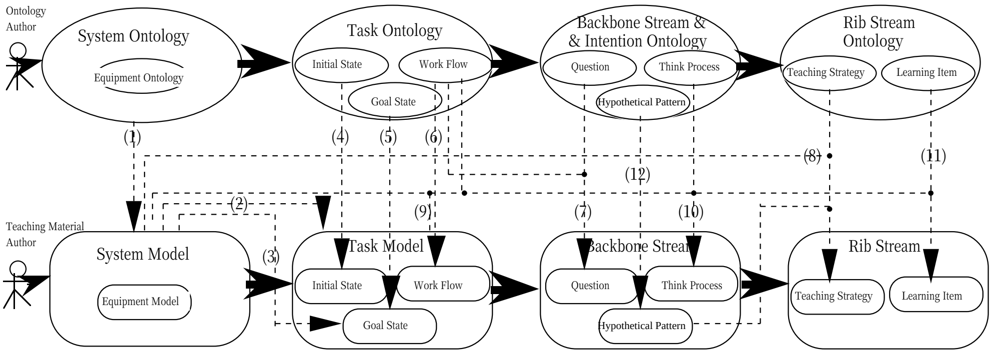

Fig. 1 Relationship between ontology and model

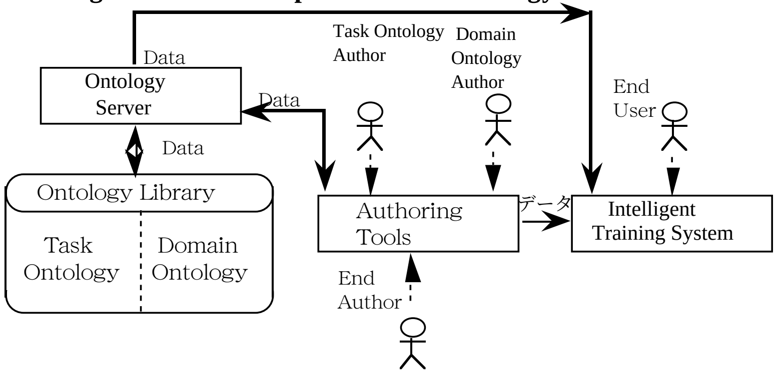

Fig. 2 Ontology server

question, input the method to recognize those errors and edit the teaching strategies including simulations to solve those errors. Here we give you an example of defining the question types, error types and behavior related to these errors.

Six types of questions have been defined in our system, those are account, correction, proof, calculation, selecting one out of N alternatives, filling blank and ordering. The error types related to the question types are defined by "is-a" which is one of the expression method of ontology, we list the errors of Ordering question and the behaviors related to the errors as below:

Example:

The error type of "Ordering" "is-a" "Reversing", "Deletion", "Insertion", "No Answer".

The axiom between "Reversing" and it's behavior is:

"Reversing": Explain the reason, Show the result by error order.

When the learner reverse the answer especially the ordering of the operating, it means danger in the real system. In order to help him/her remember the right order, we think it is better to show him/her what will happen due to his/her mistake by simulation.

Ontology specifies the concepts, related behaviors like these by describing axioms among them. We want to use such a task ontology to supply an easy authoring environment.

Inside the ontology server, we define some functions which can be used to express the task ontology above for computer as below:

(defmacro make-ontology-server ()) ;initialize the server

(defun def-concept (concept-name super-concept documentation slots-def axiom-def pict-movie) ;define an concept

(defun add-instances-of-concept (concept-name instance-name slots) ;add instances

(defun def-relation (relation-name super-relation relation documentation) ;define axiom

(defun instanciate-relation (relation-name instance-name relation) ;instanciate axiom

(defun check-relation (relation-name author-relation) ;check axiom

5 Prototype

We have discussed the authoring environment based on ontology in the sections before. In Smart Trainer, how the authoring environment works, next we will introduce you it by showing some images in prototype of SmartTrainer .

Fig.3 shows the image of creating a work flow. In window(1), the author writes the sequence for recovering an accident. From the initial state which is a state when an accident happened to the goal state, there are lots of paths, window(2) shows the author set one of those paths as a reference to make a backbone stream, and window(3) shows the system checks whether all the paths has been selected or not. Of course, the author can ignore the warning due to the checking results from the system if he/she thinks it is an unnecessary routine. What we want to emphasize here is that current work flow has its resemblance according to the initial state and so on, the backbone streams which will be edit later based on current work flow will have the similar simulation parameters like those in that resemblance. That is to say, the author does not need to set all the simulator from zero, and this will make the author's life easier.

After making a work flow, the author will edit the backbone stream in them one by one. Backbone stream is composed of some questions and the intention behind those question. Fig. 4 shows an edit window to write questions. When the end author starts to edit the questions in a backbone stream, the system creates a selecting window with several types of questions' buttons based on the ontology defined by task ontology author. window(1) shows the end author selected a ordering question, and the system applied him an ordering question window with the

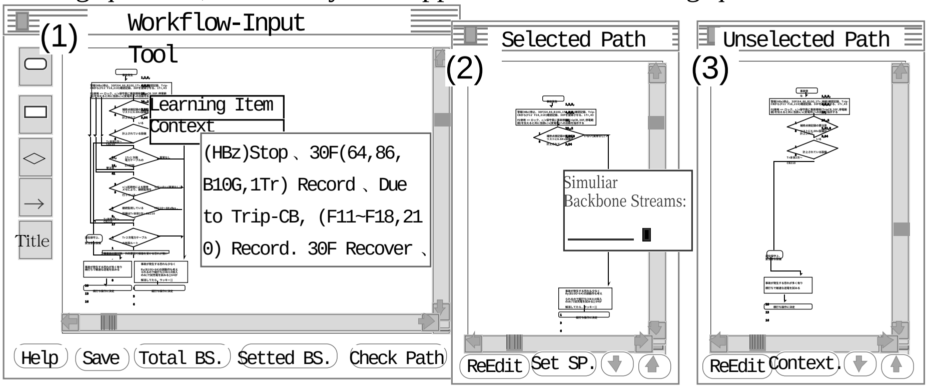

Fig. 3 Workflow input tool

form of one question line, seven selecting item lines, one correct answer line and some buttons, this form is also predefined by the task ontology author. Window(2) the end author edit the error and it's teaching strategies of this question after inputted the question. For example, when the end user has an error of "Reversing" of items 1 and 2, the teaching strategies selected from the "Treatment" window(5) are "Do Simulation" and "Give Explanation". In this time, the system will compare the strategies defined by the end author as showing in window(4) with the strategies predefined by the ontology author which is regarded as an axiom, if there is a difference, the system will give the end authoring some suggestions which is a axiom in ontology library. In window(6), the system suggest the end author that it is better to let the learner explain reason directly because that subtopic's contents are factual knowledge. On the otherwise, if it is better to let the learner do simulation, the author will set simulation.

Fig.5 shows the authoring environment to set the simulator. When "Do Simulation" has been selected from the treatment window(1) as a suitable teaching strategy, the "set simulator" window will be opened. There are lots of initial status of objects should be set such as cable, device, substation and so on, and it is a hard work to an author, because he/she should set all the objects from zero. But in Smart Trainer, the author can use the ontology and model which has been created before to create a new model. That is to say, if the current accident case is a resemblance accident case which has been set before, it is unnecessary to reset all the simulator again. System will search the similar accident cases according to the task model, for example, an accident with the same initial state, and use their simulation establishment as a base to set the current one. Window(2) shows what does not need to set again, what should reset, and what the system is not sure and the author should judge it by himself/herself in current simulation. Window(4) shows how to reset a transformer, author select device name from the ontology window(3) and fill it in device window(4). In this example, the device ontology is a transformer and the model is the No.1 transformer in SanDa substation. Detail parameters of that transformer will be set in window(5), and then the model which has been set will be expressed in the system board, for example, 1Tr is flashing in window(6). After all the initial state has been set, the current simulation model is made and you can see it on system board.

Fig. 5 shows the relationship between ontology and model, and it provides the author an convenient authoring environment to set the simulation. "The littler the author should do, the better the environment is" is our goal.

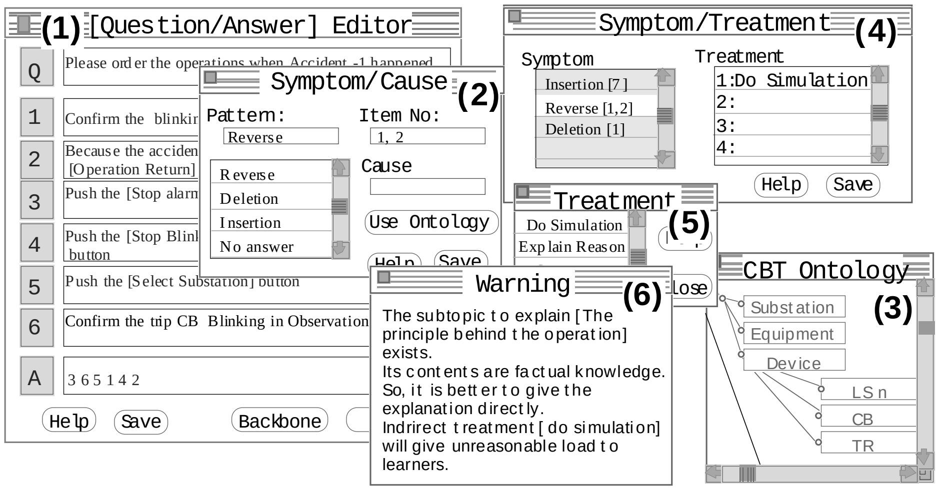

Fig. 4 Question and teaching strategy

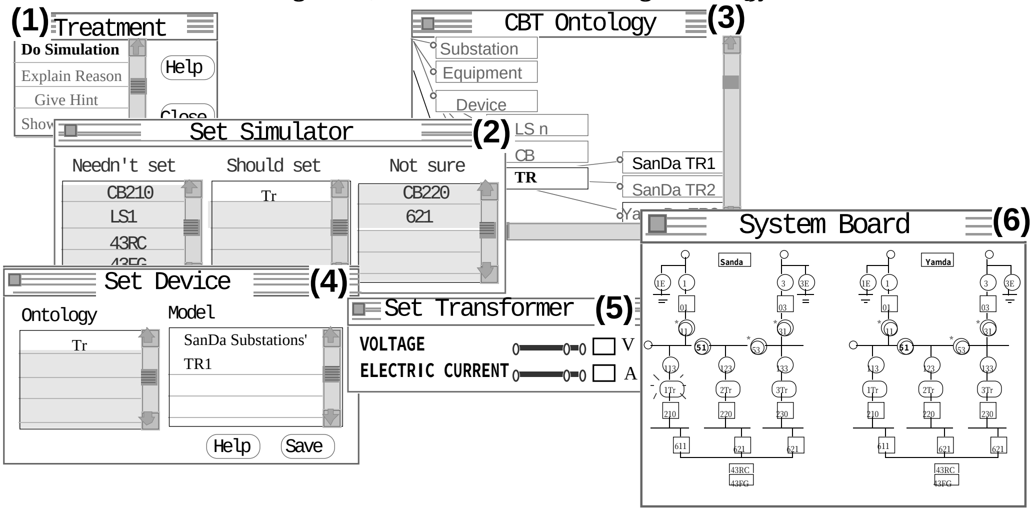

Fig. 5 Simulation set tool

6 Concluding Remarks

The characteristics of authoring tools based on ontology is that it can fill up the large gap between the concept of the author and the concept for developing a system. We try to make the system's components reusable by such a method so that it can be not only used in one substation but also in the others, not only in the domain of electric power system, but also in the other systems.

We have made a prototype which is an authoring environment including some tools based on ontology, and currently, we are formulating ontology and initiate to rebuild SmartTrainer based on it. The most important part of ontology is a training task ontology to represent how to train the learners and an authoring task ontology to represent how to write teaching material conveniently. At the workshop, we will present them in more detail.

Acknowledgments

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