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KNOWLEDGE REPRESENTATION AND KNOWLEDGE MANAGEMENT FOR VARIOUS PHASES IN SYSTEMS ANALYSIS AND DESIGN

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"...Today, complexity is a word that is much in fashion. We have learned very well that many of the systems that we are trying to deal with in our contemporary science and engineering are very complex indeed. They are so complex that it is not obvious that the powerful tricks and procedures that served us for four centuries or more in the development of modern science and engineering will enable us to understand and deal with them. We are learning that we need a science of complex systems, and we are beginning to construct it..."

Nobel Laureate Herbert A. Simon
Keynote Speech, 2000 IDPT Conference

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Abstract

In the course of systems development, several kinds of documents such as specifications, chart representations etc. are described to analyze the target system. These documents are not described from scratch but, rather, are described by reusing knowledge which is included in documents described in the past analysis of other similar systems. The reuse is performed manually based on analyst's experience. The reusing process is performed manually. In order to reuse the knowledge efficiently, it is desirable to be able to manage the knowledge systematically. The authors classify the knowledge into three types of knowledge primitives such as topological knowledge primitives, geometrical knowledge primitives and operational knowledge primitives. These are represented by using Knowledge Representation for Systems Analysis (KRSA).

Keywords

Knowledge Representation, Knowledge Management, System Design

1 Introduction

In order to develop systems rapidly, the system is analyzed by reusing several kinds of results such as specifications, documents, drawings, etc. acquired in the past similar system development. In system development, systems are developed not only from scratch but also by reusing a part of or all of the existing systems. It is expected to perform the effective analysis in a short time compared to development of a new system.

In systems analysis, the system is analyzed from various viewpoints such as static, dynamic, time, dependency, components, relationships, attributes, state-transition, process, procedure, method, etc. These are represented by various kinds of chart representations. In the course of systems analysis, the analysts describe several kinds of documents such as the chart representations for grasping the target system. In this process, a lot of knowledge about the target system is acquired and is described in the documents. New documents are described by reusing knowledge which is acquired in the past analysis (see Figure 1). Actually, the reusing is performed manually based on analyst's experience.

In order to perform the systems development efficiently, the knowledge management for systems analysis is effective. In order to manage knowledge systematically, it is necessary to organize knowledge described in the document. For effective knowledge management, the authors classify the knowledge into three kinds of knowledge primitives such as topological knowledge primitives, geometrical knowledge primitives and operational knowledge primitives. KRSA was developed to describe the knowledge primitives. By using KRSA, the knowledge included in

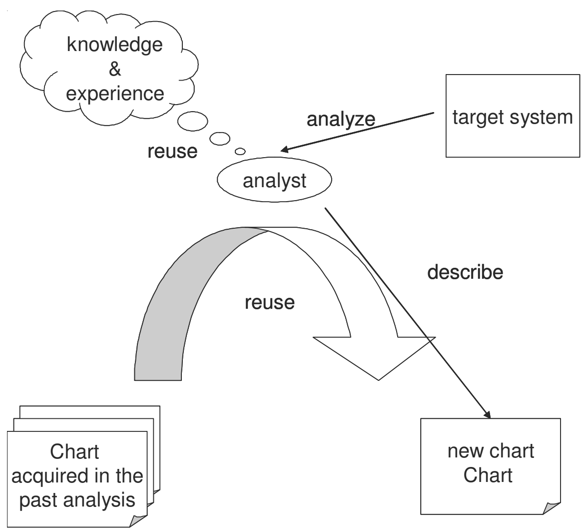

Fig.1 System analysis by reusing chart.

the document can be represented in a unified format. It facilitates the reuse of the knowledge to describe chart representation. In this paper, the authors focus on the chart representations used in the systems analysis and define the KRSA for these chart representations.

2 Chart Representations in Analysis

In the systems analysis, many kinds of chart representations are used for describing the domain model of the target system. The chart representations are useful for grasping the entire system, dynamic aspect and static aspect of system, and so on. The information described in the chart representations are as follows.

- components
    - attributes
    - name
    - ID
    - performance
    - size
- relationships
    - connection
    - position

    - layer
    - client and server
    - master and slave
- states of components
- procedure
- process
- time
- timing

3 Knowledge Management for Systems Analysis

The chart representations are described in the systems analysis. In many cases, they are not described from scratch, but are described by reusing other chart representations. The chart representations are acquired in the analysis or in the other analysis of the similar system. The chart representations are reused by modification such as adding information, renaming of labels, changing relationships and so on.

In most cases, the chart is described by combination of several kinds of nodes and arcs which are represented by several kinds of shapes and arrows. The labels for nodes and arcs are described with terms used in the system. The differences between chart representations are the terms, the type of node, the type of relationships, relationships between nodes, etc. The analysts see the chart representation and obtain the knowledge described in the chart representation. The process is manually and empirically performed. It is desirable to be able to manage knowledge systematically.

In order to manage knowledge systematically, it is necessary to organize knowledge and describe the knowledge in a format for ease of use. The authors classify the knowledge into three kinds of knowledge primitives below.

1. Topological knowledge primitives
2. Geometrical knowledge primitives
3. Operational knowledge primitives

In the following sections, it is stated about these primitives.

3.1 Topological Knowledge Primitives

These knowledge primitives are related to the relationships. The relationships represent the connections between nodes on the chart representation. In many cases, this is represented by an arc on the chart representation. This represents the qualitative proximity. The connected two nodes are near in terms of quality, property, characteristics etc. When the node represents the term, the connected two terms have relationships such as synonym or antonym.

3.2 Geometrical Knowledge Primitives

These knowledge primitives are related to the space. On the chart representation the nodes are placed on, they have x, y coordinates. The geometrical knowledge primitives represents these coordinates or position. On the chart representation, the node is represented by some shapes and arcs represented by some arrows. The geometrical knowledge includes the type of shape and arrow.

The distance between nodes is defined by using the coordinates. The distance represents the quantitative proximity. When nodes represent terms and arcs represent relationships such as synonym and antonym, the distance between nodes represents the distance of the relationship. When there are nodes, which represent the terms, connected by arc, the distance between nodes represents the difference in terms of meaning.

3.3 Operational Knowledge Primitives

These knowledge primitives are related to the operation. This knowledge primitive represents the operational properties of components. The operational properties include number of components, performance, load to be processed, service time, queue length, utilization, etc.

4 KRSA

The description method of knowledge is essential to manage the knowledge. The authors developed the representation for describing the knowledge primitives which is called KRSA (Knowledge Representation for Systems Analysis). KRSA is in the form of prolog. Most chart representations consist of nodes and arcs. Predicates correspond to each node and arc. The first parameter of predicate is ID of node or arc. The second and subsequent parameters are attribute value and information of node or arc. The BNF notations of general KRSA are as follows.

[predicate of chart] := [predicate of node] | [predicate of arc]

[predicate of node] := [type of node] ([ID of node] { , [attribute value of node] $\}_0$ { , [information of arc to be connected] $\}_0$)

[predicate of arc] := [type of arc] ({ [ID of arc] $\}_0$ { , [attribute value of arc] $\}_0$ {, [information of node] $\}_0$)

In this method, one component is described by the three viewpoints such as relation, space and operation. The different type of primitive knowledge can be referred by name of component. It is easy to convert between different kinds of chart representations. Some components in a system are the same in different chart representations. The knowledge primitives for the new chart can be converted by changing the type of shape and coordinates of node described by the geometrical knowledge primitives and the connection between nodes described by the topological knowledge primitives. All types of chart representations can be described by these knowledge primitives.

KRSA is used to describe the knowledge primitives. The format of KRSA is unified. The unified description facilitates the development of editors for chart representations. In most chart editors, the user describes the nodes and connects the nodes by arc. The nodes and arcs have attributes. The essential program of editor is to describe the node, arc and attributes and loading/saving the chart representation as file. Some of the programs of editor can be reused. The primary differences are the type of shape representing nodes and the arcs representing relationships.

5 KRSA for Several Kinds of Chart Representations

The authors define KRSA for the following eight kinds of chart representations.

1. Well-disciplined IDEF0
2. MCM
3. CLM
4. Petri Net
5. E-R Diagram
6. SFC
7. STD Triad
8. Semantic Network

5.1 Well-Disciplined IDEF0

IDEF0 (Marca et al., 1988) is a standardized modeling technique. The process of the task is recognized as sets of activity in IDEF0. The information and material, etc. of the target task are classified into ICOM (input, control, output, and mechanism). Well-disciplined IDEF0 (Kawabata et al., 2001) for collaboration task analysis/design is described by introducing the discipline based on the collaboration interface model. By introducing the concept of the collaboration interface model, the meaning of the arrow is distinguished; thus, ambiguity in IDEF0 can be removed.

5.1.1 Topological Knowledge Primitives for Well-Disciplined IDEF0

Definitions of components and relationships between components of IDEF0 are described by topological knowledge primitives. IDEF0 consists of components such as activity, input, output, control and mechanism (see Figure 2). Activities are connected with input, output and control. Activities are performed by using the

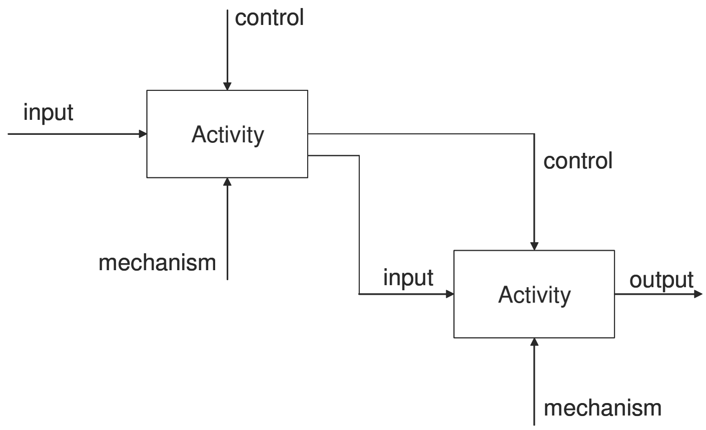

Fig. 2 IDEF0.

mechanism. These are represented by topological knowledge primitives. The BNF notations of KRSA for IDEF0 are as follows.

[type of node] := { activity }
[type of arc] := { input | output | control | mechanism }

The name of activity is described as the attribute of node. The name of arc and source activity and destination activity are described as the attributes of arc.

5.1.2 Geometrical Knowledge Primitives for IDEF0

In IDEF0, the activities have coordinates. These are represented by geometrical knowledge primitives. The coordinates are described as follows.

coordinate (activity name, x coordinate, y coordinate).

5.2 MCM

Multi-Context map (MCM) (Kumagai et al., 1998) is a description method according to the collaboration interface model. The collaboration task can be analyzed and designed in terms of function. Collaboration interface model is a well-disciplined model for analysis of the collaboration task. By focusing on the personnel and the organization with various views and the positions in various tasks, the process of the task are recognized as sets of contexts of the collaboration task in which various collaborators work together. The context facilitates clarifying the position (perspective) of each collaborator of the task and the organization, the fact (token) recognized between them, the material, and information.

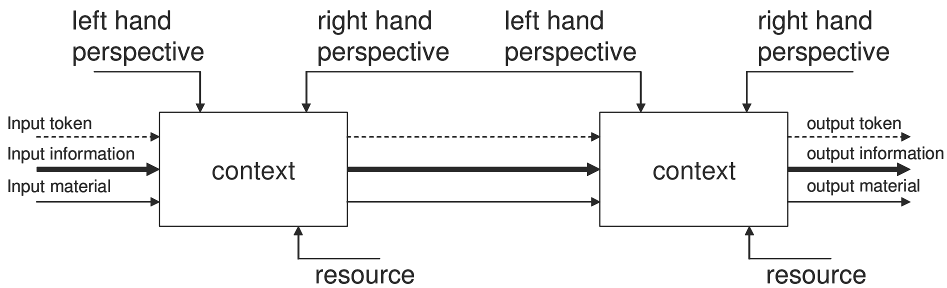

Fig. 3 MCM.

The process of the task can be described with MCM by combining context maps (CM) and the junctions by which the divergence and the join are shown with the flow of token, material and information. MCM clearly recognizes the difference of perspective depending on various collaborators and the difference between essential information, which is necessary to transmit, and physical material. Figure 3 shows the MCM.

5.2.1 Topological Knowledge Primitives for MCM

MCM consists of components such as context, perspective, token, information, material and resource. These components have relationships. At a context, perspectives start an activity with information, material and resource after receiving a token. After finishing the activity, the token, information and material are output. These relationships are represented by topological knowledge primitives. The BNF notation of KRSA for MCM is as follows.

[type of node] := { context | junction}
[type of arc] := { input token | output token| input information | output information | input material | output material | left hand perspective | right hand perspective | resource }

The name of context is described as attributes of the node. The names of arc and source context, destination context and junction type are described as attribute of arc. The component and relationship have names, which are different depending on the system but the meanings are same. These are represented by KRSA for the case of thesaurus.

thesaurus (term A, term B).
This shows term B is a thesaurus of term B.

5.2.2 Geometrical Knowledge Primitives for MCM

In MCM, context has coordinates. Coordinates of other components can be decided by the coordinates of contexts. The coordinates of context are represented by geometrical knowledge primitives. The KRSA is below.

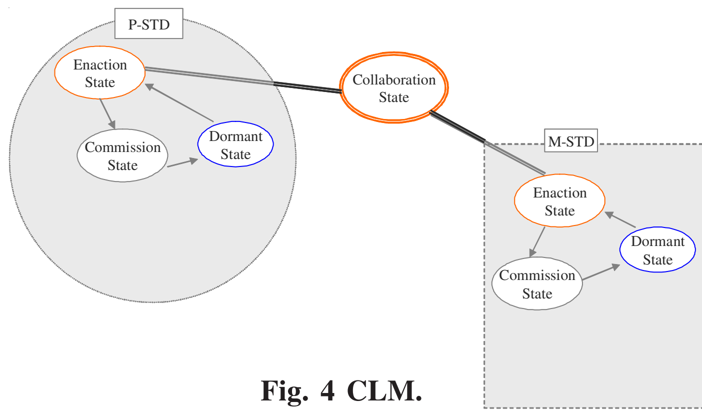

Fig. 4 CLM.

coordinates (context name, x coordinate, y coordinate).

5.2.3 Operational Knowledge Primitives for MCM

MCM describes the flow of tokens, materials and information in a system. MCM also has performance parameters such as processing time, arrival rate, etc. These parameters are used for simulation of the system. It facilitates to resolve bottlenecks. These performance parameters are represented by operational knowledge primitives.

[type of operation] := {arrival rate of token| arrival rate of information | arrival rate of material | probability of branch | average service time at context | utilization of context | utilization of perspective | queuing time of token | queuing time of information | queuing time of material | queue length of token | queue length of information | queue length of material }

The node name or arc name and parameters of the operation are described as attribute.

5.3 CLM

CLM (Hasegawa et al., 2000) unites three kinds of maps called Personnel-State Transition Diagram (P-STD), Material-STD (M-STD), and Collaboration-STD (C-STD), and specifies the state transitions of transmitted information in the process and information of resource. The states of collaborators and material are described by three kinds of state such as Enaction-State that the state of performing essential activity, Commission-State that the activity is requested and succeeded, and Dormant-State that the collaborator performs activities unrelated to the task. Figure 4 shows CLM.

5.3.1 Topological Knowledge Primitives for CLM

CLM consists of states such as personnel-state, material-state, etc. The BNF notation of KRSA for CLM is as follows.

[type of node] := {P-STD | M-STD | PP-Collaboration State | MM-Collaboration State | PM-Collaboration State | personnel-state | material-state | mm-collaboration | enaction state | commission state | dormant state }

[type of arc] := {arc between states}

The name of the state is described as an attribute of the node. The names of arc and source state and destination state are described as attribute of arc.

5.3.2 Geometrical knowledge primitives for CLM

P-STD, M-STD, PP-Collaboration State, MM-Collaboration State, PM-Collaboration State, Enaction State, Commission State, Dormant State have coordinates. The KRSA which represents the coordinates is below.

coordinates {node name, x coordinate, y coordinate}.

5.4 Petri Net

Petri Net is used for describing the system flow which includes synchronization and competition. In the Petri Net, the system is described by connecting two kinds of nodes such as the place and the transition with the arc. The element which flows in the system is represented by the token. What the token signifies in a certain place represents that the system is in a state. Transition with input from two or more places shows the synchronization. The tokens merge as one token. Moreover, when there is an output from the transition to two or more places, the number of outputs is generated and the tokens are input to the following places.

The authors define the knowledge primitives for a well-disciplined Petri Net. A well-disciplined Petri Net has a discipline for describing collaboration tasks. The Petri Net is described by identifying the personnel and the work flow of the personnel. The place of the Petri Net is distinguishing the place of the queue before the task and the place which represents the personnel. Figure 5 shows the well-disciplined Petri Net (Senuma et al., 2003). In this figure, two transitions and two places in the left shows the work flow. The place in the right shows the personnel who perform the work.

5.4.1 Topological Knowledge Primitives for Petri Net

The BNF notation of KRSA for well-disciplined Petri Net is as follows.

[type of node] := [place | transition]

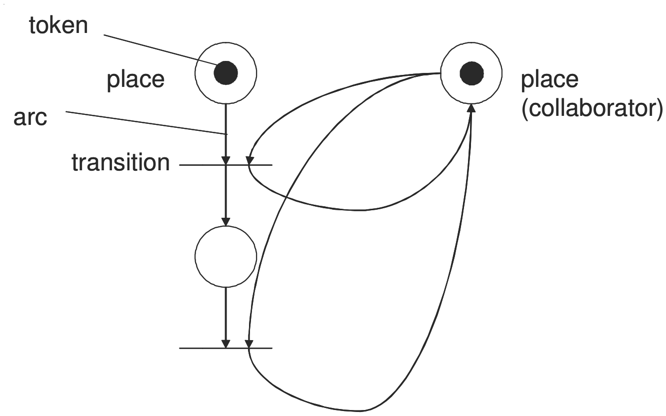

Fig. 5 Well-disciplined Petri Net.

[type of arc] := [arc between place and transition]

The place name, the number of tokens, the collaborator name, and the transition name are described as attributes of the node. The name of source/destination place and source/destination transition is described as attributes of the arc.

5.4.2 Geometrical Knowledge Primitives for Petri Net

The place and transition have coordinates. The KRSA which represents coordinates is below.

coordinate (node type, node name, x coordinate, y coordinate).

5.4.3 Operational Knowledge Primitives for Petri Net

By adding the parameters related to time, it is possible to simulate the Petri Net. The parameters given for simulation and the resulting parameters of simulation are described by operational knowledge primitives. The BNF notation of KRSA for simulation parameter of Petri Net is as follows.

[type of operation] := { service time at transitions | the number of tokens | probability of branch | priority of branch | staying time at place | number of staying token at place | number of staying token at transition | occupied time of transition }

5.5 E-R Diagram

In general, an E-R diagram is used for analyzing and designing RDB. E-R

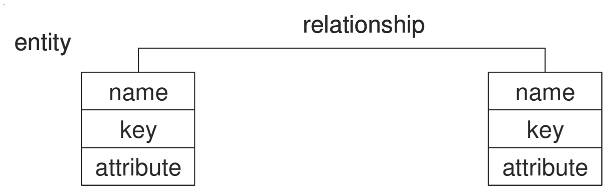

Fig. 6 E-R Diagram.

diagram consists of entities and relationships. Entity has attributes. Figure 6 shows E-R diagram.

5.5.1 Topological Knowledge Primitives for E-R Diagram

The BNF notation of KRSA for E-R Diagram is as follows.

[type of node] := { entity }
[type of arc] := { key | attribute | relationships }

5.5.2 Geometrical Knowledge Primitives for E-R Diagram

The entity of E-R diagram has coordinates. The KRSA which represents the coordinates of entity is below.

coordinates (entity name, x coordinate, y coordinate).

5.6 SFC

Sequential Function Chart (SFC) is a chart representation for describing sequence control. In this paper, the chart is applied to describe the target system from the viewpoint of collaboration which two or more personnel share information and do work in cooperation. Usual SFC represents the one sequential flow. In the SFC for collaboration task (Senuma et al., 2003), the work flow of one personnel corresponds to the one sequential function chart. The collaboration between collaborators is described by connecting two or more SFC with the node which represents exchange. Figure 7 shows the SFC.

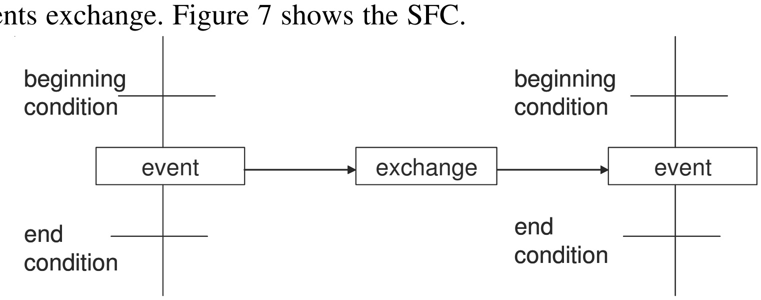

Fig. 7 SFC.

5.6.1 Topological Knowledge Primitives for SFC

SFC consists of event, beginning condition, end condition, exchange and arc. The BNF notation for SFC is as follows.

[type of node] := { beginning/end condition of event | event | exchange }
[type of arc] := { arc between condition and event | arc for exchange }

5.6.2 Geometrical Knowledge Primitives for SFC

The node of SFC such as beginning condition, end condition etc has coordinates. The KRSA which represents the coordinates is below.

coordinates (node type, node name, x coordinate, y coordinate).

The attribute of node type is beginning condition, end condition, event or exchange. Node name is the name of conditions, event, or exchange.

5.7 STD Triad

STD Triad (Itoh et al., 1994) is used for describing the state transition in the reactive system. STD Triad is a domain model for requirement analysis of the reactive system. STD Triad is described by grasping the reactive system with three kinds of state groups such as a State Group by Heuristic Thresholds, a State Group by Nature Dynamics, and a State Group by Artificial Enforcements. Figure 8 shows STD Triad.

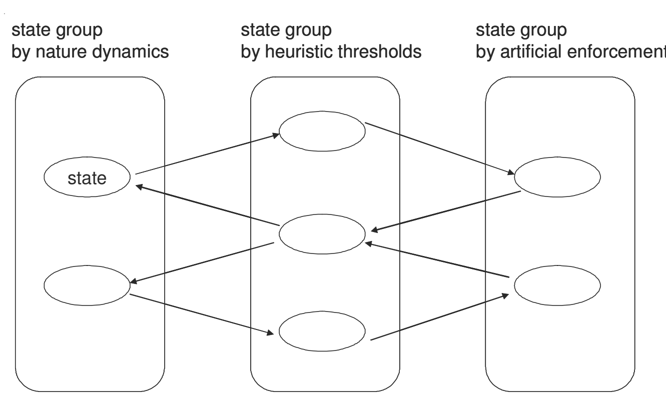

Fig. 8 STD Triad.

5.7.1 Topological Knowledge Primitives for STD Triad

STD Triad consists of three types of state and arc. The BNF notation of KRSA for STD Triad is as follows.

[type of node] := { state group by nature dynamics | state group by heuristic thresholds | state group by artificial enforcement }

[type of arc] := { arc between states }

5.7.2 Geometrical Knowledge Primitives for STD Triad

States have coordinates. The KRSA for coordinate is below.

coordinate (state name, x coordinate, y coordinate).

5.8 Semantic Network

The authors define the Semantic Network for reactive system domain. In order to describe the semantic network, the authors define the relationship and thesaurus. These are the topological knowledge primitives. Figure 9 shows Semantic Network.

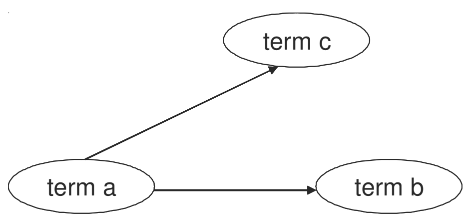

Fig. 9 Semantic Network.

5.8.1 Topological Knowledge Primitives for Semantic Network

In the semantic network, the terms are described as nodes. The relationships between terms are described as arcs.

[type of nodes] := { term }
[type of arc] := { arc between terms}

The name of node is the attribute of node. The relationship between terms and type of relationship are described as the attribute of arc.

6 The Tools Using KRSA.

In this paper, editor and converter which use KRSA are developed. By using these tools, the chart representations are processed in KRSA (see Figure 10). By the KRSA editor, the KRSA of chart representation is described. KRSA converter converts KRSA of chart representation into KRSA of other chart representation.

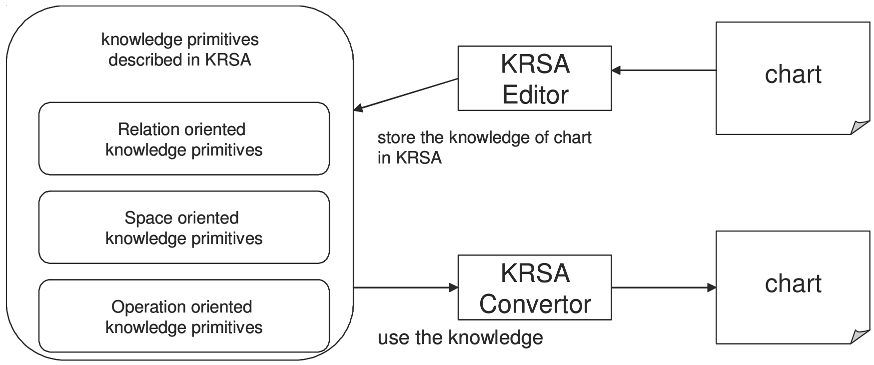

Fig. 10 Knowledge primitives and KRSA tools.

6.1 KRSA Editor

KRSA editors for some chart representations are developed. This editor supports to describe KRSA. The editor is included in the chart editor. The user draws the chart representation by the editor. Then the editor outputs the KRSA for chart representation. The KRSA editors for MCM, CLM, Petri Net, E-R Diagram, SFC and STD Triad are developed. Figure 11 shows the screenshot of MCM editor. Figure 12 shows a part of KRSA for MCM.

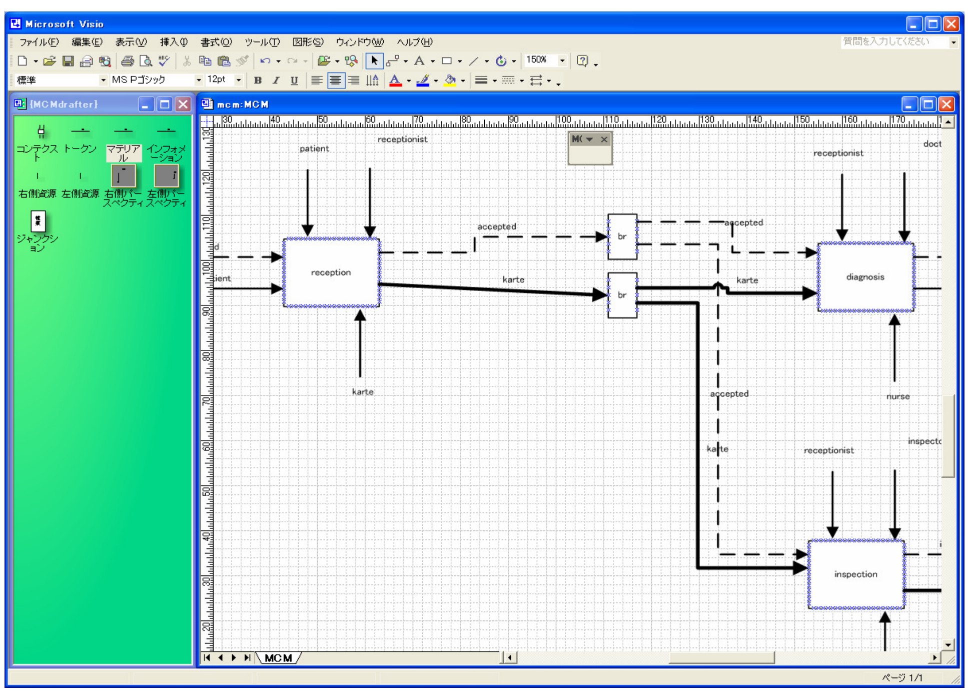

Fig. 11 MCM Editor.

```
context(reception).
context(diagnosis).
context(inspection).
inputtoken(arraived,reception,_,_,_).
inputtoken(accepted,diagnosis,reception,accepted,br).
inputtoken(accepted,inspection,reception,accepted,br).
inputmaterial(patient,reception,_,_,_).
inputinformation(karte,diagnosis,reception,karte,br).
inputinformation(karte,inspection,reception,karte,br).
resource(karte,reception).
resource(nurse,diagnosis).
resource(nurse,inspection).
righthandperspective(receptionist,reception).
righthandperspective(doctor,diagnosis).
righthandperspective(inspector,inspection).
lefthandperspective(patient,reception).
lefthandperspective(receptionist,diagnosis).
lefthandperspective(receptionist,inspection).
```

Fig. 12 KRSA for MCM.

6.2 KRSA Converter

KRSA converters between some chart representations are developed. This tool supports to describe new chart representation from a chart representation which is already described. When new chart representation is described, the knowledge described in other chart representation is reused. This is achieved by converting knowledge primitives. There are two cases involved in the process of converting knowledge primitives. In the first case, knowledge primitives are converted into the same kinds of knowledge primitives. In the second case, knowledge primitives are converted into different kinds of knowledge primitives.

The converter cannot convert all the knowledge primitives. Since some components are not common between two chart representations, several knowledge primitives are lost in new chart representation. Several new knowledge primitives are added manually in the new chart representation.

6.2.1 Conversion Between the Same kinds of Knowledge Primitives

The three types of knowledge primitives can be defined about the same components. When a chart representation is converted into another chart representation, conversion between several components is represented by conversion between the same kinds of knowledge primitives.

(a) topological knowledge primitives

The change of node type, arc type and connection is done by changing the parameters in the topological knowledge primitives.

(b) geometrical knowledge primitives

When a chart is converted into a new chart, the shapes of the node and arc is changed. This is done by changing the geometrical knowledge primitives. Geometrical knowledge primitives represents.

(c) operational knowledge primitives

The change of operational parameters is done by changing the parameters described in the operational knowledge primitives.

After conversion of chart representation, nodes and arcs newly added on the chart representation are represented by adding the knowledge primitives.

6.2.2 Conversion Between Different Kinds of Knowledge Primitives

This kind of conversion occurred when new information is added on the chart representation based on the information in the chart representation to be converted. For example, when the simulation model is described, the components, connections and flows are converted by changing topological knowledge primitives. The performance parameters are newly added as operational knowledge primitives based on topological knowledge primitives and geometrical knowledge primitives.

6.2.3 The Conversion of KRSA

The authors develop converters between several chart representations. The converter converts the chart representation in the knowledge primitive level. Editors for each chart representation can read the knowledge primitives and draw the chart representations.

(a) Conversion between well-disciplined IDEF0, MCM, CLM and Simulation Model

Figure 13 shows conversion between well-disciplined IDEF0, MCM, CLM and Simulation Model. Well-disciplined IDEF0 can be converted into MCM by adding information of the junction to IDEF0. By this conversion process, conversion of topological knowledge primitives and conversion of geometrical knowledge primitives are performed. In the conversion of topological knowledge primitives, the components of well-disciplined IDEF0 are converted components of MCM. MCM can be converted into CLM and simulation model. In converting from MCM to CLM, the conversion of topological knowledge primitives and geometrical knowledge primitives occurs. In converting from MCM to the simulation model, operational knowledge primitives, which represent the performance parameters are added.

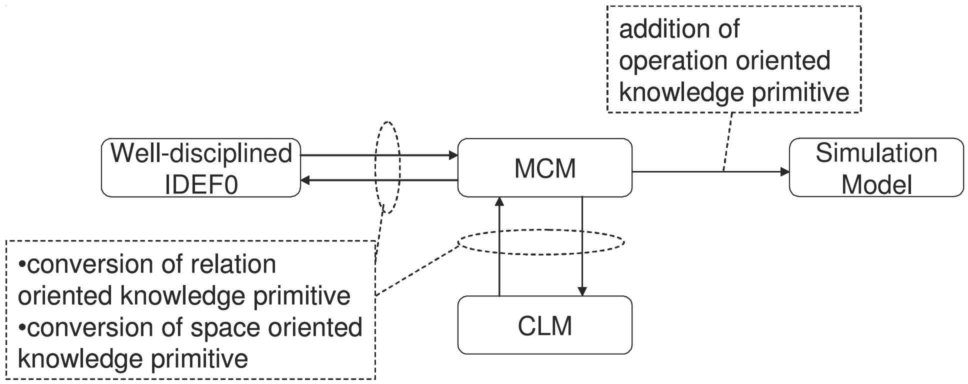

Fig. 13 Conversions Between Well-disciplined IDEF0, MCM, CLM and Simulation Model.

(b) Conversion between Petri Net, E-R Diagram and SFC

Figure 14 shows conversion between Petri Net, E-R Diagram and SFC. E-R diagram can be converted from Petri Net. SFC can be converted from E-R diagram and Petri Net. Several Entities and relationships of E-R diagram can be extracted from Petri Net. The knowledge of entity is derived from knowledge of place. The knowledge of relationship is derived from knowledge of arc. These are done by changing topological knowledge primitives. The shape of E-R diagram is derived by changing the geometrical knowledge primitives. Addition of entity and attributes are done by adding topological knowledge primitives and geometrical knowledge primitives.

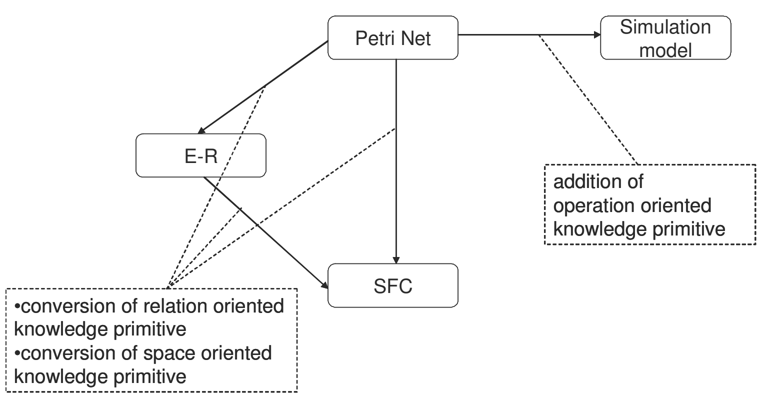

Fig. 14 Conversion between Petri Net, E-R diagram, SFC and Simulation Model.

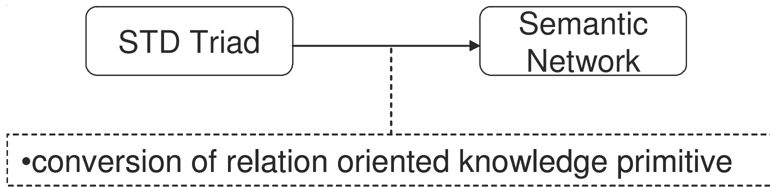

Fig. 15 Conversion Between STD Triad and Semantic Network.

(c) Conversion between STD Triad and Semantic Network

Figure 15 shows conversion between STD Triad and Semantic Network. In the STD Triad, the components and relationships between components are described. The terms in the reactive system are described. The terms and relationships between terms can be acquired from STD Triad. The authors develop the converter between STD Triad and Semantic Network. This converter converts topological knowledge primitives, which shows the components and relationships between components in reactive system.

In this conversion, topological knowledge primitives, which represent the states in the STD and relationships between states, are converted to the topological knowledge primitives, which terms and relationships between terms in semantic network.

7 Related Works

To manage the knowledge, there are several tools and platforms using xml, ontology etc. Ontology is used in the case of e-business, e-learning, semantic Web, etc. In (Aldea et al., 2001), an ontology based knowledge management system was stated. An ontology editor is available to the user to describe the knowledge. In (Sànchez-Marrèa, M.), Knowledge is discovered from the database by filtering, analyzing, and using case based techniques. This paper focuses on the knowledge in the systems analysis. In the systems analysis, the knowledge is included in the documents such as specifications, chart representations, etc.

XML is often used to represent the knowledge. XML is used to describe the ontology also. In (Fensel, D.), the knowledge is described by XML and Resource Description Framework (RDF). In this paper, the knowledge is represented by KRSA which is prolog formed description. It facilitates to describe and manage the knowledge because KRSA is a unified format and easy to process by prolog environment. KRSA is represented by a combination of predicate and attributes. KRSA can be converted easily to XML. The name of predicate and attributes can correspond to a tag of XML.

8 Concluding Remarks

In the systems analysis, several kinds of chart representations are used to describe the target system. In order to shorten the development period, the knowledge described in the chart representations is reused. The authors classify the knowledge into three types of knowledge primitives and develop KRSA which is the description method for knowledge. The chart representation described in the systems analysis is described in KRSA. The previously known chart representations such as E-R diagram can be used to acquire the knowledge. KRSA is the description of knowledge in systems analysis. The chart representations can be described by reusing the KRSA.

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