Development of an Information Flow Mechanism for Commissioning

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ABSTRACT

The present paper proposes a new information flow mechanism for commissioning and develops tools to make the proposed information flow mechanism feasible. Although many technical tools have been developed in order to reduce the amount of labor necessary for commissioning, the information needed for the application of the tools to a real building is not rationally organized. It is necessary to manage and organize the necessary information rationally for the promotion of the usage of the tools.

In order to resolve the issues of the present information flow, the present paper proposes a new information flow mechanism, which is constructed using a CAD data file, for example, IFC, SXF, or gbXML, a database, for example RDBMS of HDF5, and a process modeling method IDEF0. If the information about the building is organized rationally according to the proposed mechanism, the technical tools for commissioning can be applied easily and effectively, and the human error in the commissioning process can be reduced.

INTRODUCTION

It is important to verify the performance of HVAC systems and optimize the operation method of the system in order to save energy. Since verification and optimization requires significant time, cost, and professional knowledge about the equipment in HVAC systems, many technical support tools have been developed in order to reduce the labor required for commissioning [1]. However, these tools are not frequently used in the actual commissioning process. This is partly because the information needed when the tools are applied to an actual building, for example design drawings, performance curves of the building equipment, and operation data measured by sensors in the building, is not rationally organized and it is difficult to obtain the information. For the promotion of the usage of these tools, it is important to develop a method by which to manage and organize the information rationally through the building life cycle.

The present paper proposes a new information flow mechanism for commissioning using several existing information processing techniques, which can resolve the issues of the present information flow. The proposed information flow mechanism can be applied to not only new buildings but also to existing buildings. The present paper develops several tools that are helpful in building the new information flow mechanism.

ISSUES WITH RESPECT TO THE PRESENT INFORMATION FLOW

This chapter analyzes the present information flow and identifies issues with the information flow. The present information flow is shown in Figure 1.

Issue 1

Information about the performance of the building equipment and the configuration of the system, which are needed when a technical tool is applied during the commissioning process, is generally described not in digital data files of fixed form but rather in printed documents. Reading the information manually from the large amount of printed documents is inefficient. There are no rationally designed databases to store the information, and the information is not organized as a single document, but rather is described in various documents.

Issue 2

The operation data used for the tools are retrieved from BEMS (Building Energy Management System) commonly as a form of a CSV data file. However an important capability of BEMS is to store and retrieve the

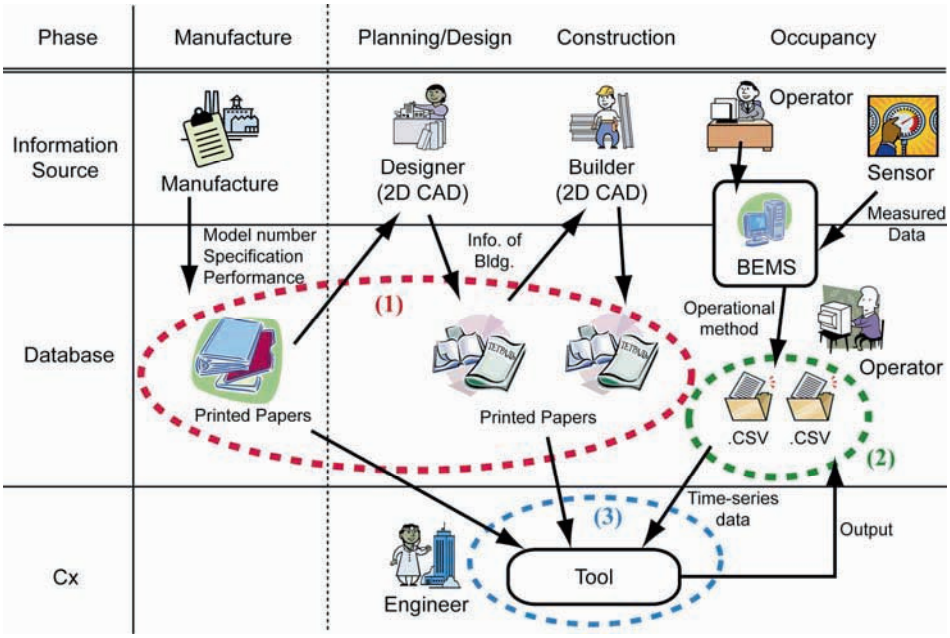

Figure 1 Present information flow

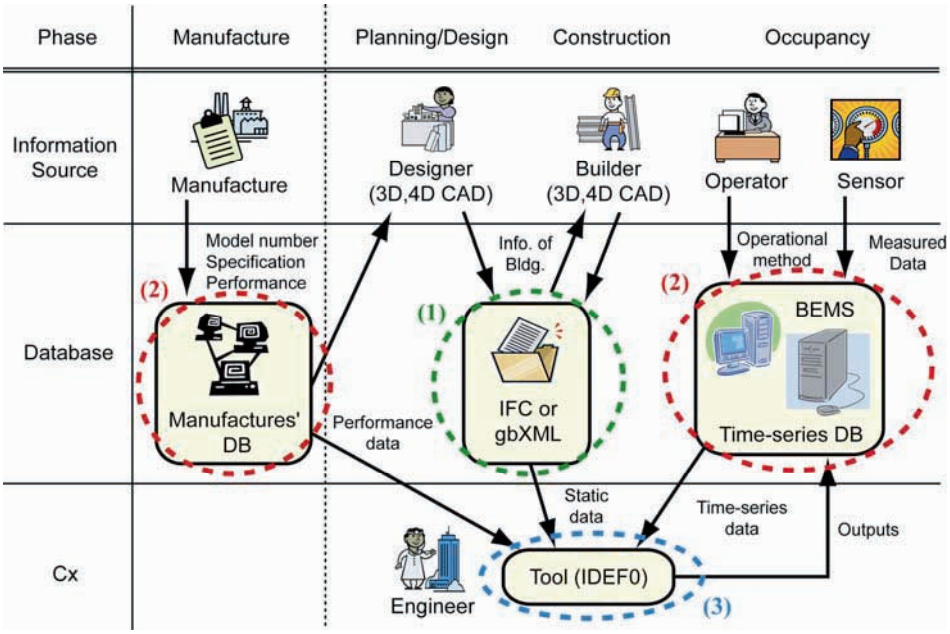

Figure 2 Proposed information flow mechanism

operation data electronically transferring the stored data by a CSV data file has the following issues:

1) If a building has a number of measurement points, it is inefficient and requires a great deal of time to handle the data file because the size of the file is large.

2) Since the format of the CSV file is generally different from each building, the program that reads the necessary data from the file must be modified in each project.

3) It is troublesome and time consuming to select the necessary items from a large text file. This may result in human errors because the file is generally edited manually.

Although the recent BEMS has a database facility, the database is not used effectively. There is no method for transferring the operational data directly between tools and the database, and there are few BEMS that can retrieve the necessary data hierarchically and efficiently from the database, which stores a large amount of data.

Issue 3

It is unclear that what type of information is needed when the tool is applied to an actual system. The reason for this is partly because there is no standard method to describe the necessary information, and only developers of the tool know the necessary information. Since the algorithm and the information flow in the tool are not clear, it is difficult to modify the tool, enhance its functions.

DEVELOPMENT OF NEW INFORMATION FLOW MECHANISM

This chapter proposes the new information flow mechanism. An outline of the mechanism is shown in Figure 2. The mechanism can resolve the issues of the present information flow.

Utilization of an Electronic CAD File

In order to resolve Issue 1, the proposed information

```
<gbXML>
-     <Campus id="Cmps-001">
-       <Building id="Bldg-001" buildingType="Office">
-         <Area Unit="SquareMeters">1640</Area>
      </Building>
    </Campus>
-     <HydronicLoop, id="Loop-001", fluidType="Water"
-                 loopType = "PrimaryChilledWater">
      <Name>Storage Operation</Name>
      <Description>Loop for Storage</Description>
-     <HydronicLoopEquipment id="Equip-001"
-                         equipmentType ="Pump">
        <Name>PC-1</Name>
        <Manufacture>XXX</Manufacture>
        <Model>YYYY</Model>
        <RatedFlow unit="CubicMPerHr">90</RatedFlow>
        <DeltaP unit="kPa">294</DeltaP>
        <Power unit="Kilowatt" powertype="Electricity"
              meterIdRef="Sensor-e001">15</Power>
      </HydronicLoopEquipment>
</gbXML>
```

Figure 3 Example of a gbXML file

flow mechanism stores all of the information about the configuration of the building in an electronic CAD file ((1) in Figure 2). If the designers and the builders use different CAD applications, the CAD data can be shared using a file format that facilitates interoperability in the building industry, for example Industry Foundation Classes (IFC)[2], Seadec data eXchange Format (SXF)[3], or Green Building XML (gbXML)[4]. These applications are used in the field of architectural planning and structural design, but are not currently used in the field of building equipment design. Although these files cannot import all building equipment data from the CAD application at present, the translatability will be improved in the future.

The information of the location, size, and configuration of the system is mainly stored in the IFC, SXF, and gbXML files. For example, Figure 3 shows a sample of a gbXML file. This file shows the information of the specifications of a pump in an actual system. In this mechanism, these files are used as the database of the CAD data. It is not difficult to retrieve the necessary data from these files.

In order to achieve this mechanism, it is necessary to develop a tool that can retrieve the necessary information from the CAD data file, and transfer the data to the tools.

Application of Database System

In order to resolve Issue 2, the present paper proposes the usage of the database. In the proposed information flow mechanism, the information about the specifications of the building equipment from manufactures and the operational data measured by sensors are stored in databases. As a database for the building operational data, the Relational DataBase Management System (RDBMS) and the Hierarchical Data Format version 5 (HDF5), which enable the efficient management of extremely large and complex data collections and can store and retrieve the data efficiently, can be used.

The following two types of database are needed for commissioning:

a) Database for the information of the specifications of the building equipment

This database stores the information about the performance of the equipment, for example, the rated performance and specification curve. This database is not specific to individual buildings and should be made public.

b) Database for the time series data measured by sensors

This database stores the time series data measured by sensors in a building. This database is specific to individual buildings and should be kept private.

In order to achieve this mechanism using the databases, it is necessary to develop the following tools:

1) A tool that can retrieve the necessary data from the database visually

2) A sub-tool that can export the operational data stored in CSV files to the database. This tool is necessary for existing buildings that have no database.

Application of IDEF0

In order to resolve the Issue 3, authors propose to adopt IDEF0 which systematically and hierarchically describes the internal information flow and the calculation algorithm of a tool. IDEF0 (Integrated DEFinition method 0) is a widely used function modeling method designed to model the decisions, actions, and activities of a system aiming at analyzing and communicating the functional perspective of the system[5]. As shown in Figure 4 an IDEF0 diagram

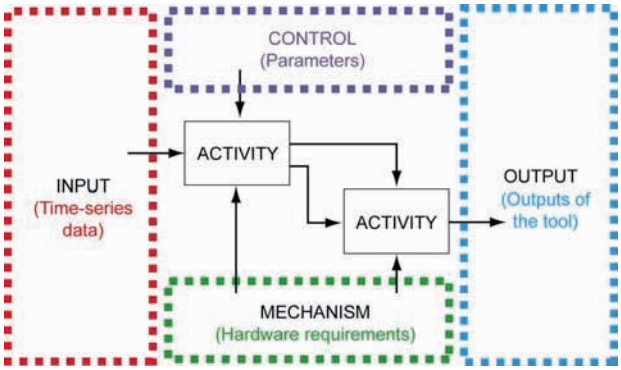

Figure 4 Description Method of IDEF0

consists of a simple box and arrow graphics. The meaning of an arrow is fixed by the side of the box where the arrow is connected (left side: INPUT, top side: CONTROL, right side: OUTPUT, bottom side: MECHANISM). IDEF0 is useful for the following reasons in order to fulfill our purpose.

1) Adopting a standardized modeling method in developing commissioning tools is very important because it greatly reduces the time or cost of future modification work. IDEF0 is one of the best methods for standardization because of its wide use.

2) Compared to other modeling methods the simplicity of the IDEF0 structure helps tool users to easily understand what the functions and needed information of a tool is even if they have little knowledge about IDEF0.

The present paper proposes a method to describe the tool clearly using IDEF0. In the proposed method, the operational data that is variable with time is described as INPUT. The information about the CAD data and the specifications of equipment, which do not vary with time, are described as CONTROL. The hardware requirement of the tool is described as MECHANISM. The outcome of the tool is described as OUTPUT. The description of the tool using IDEF0 makes the algorithm of the tool and the necessary information clear and facilitates the maintenance of the tool.

Advantage of the Proposed Information Flow Mechanism

This chapter shows that the new information flow mechanism can be built using the CAD data files, for example IFC, SXF and gbXML, the databases, for example, RDBMS and HDF5, and the process modeling method IDEF0. If all of the information about the building is organized according to the proposed information flow mechanism, it is possible to rationally manage the information needed for commissioning and to apply the tools easily.

DEVELOPMENT OF TOOLS THAT MAKE THE MECHANISM FEASIBLE

The present paper develops several tools and methods to make the proposed information flow mechanism feasible. Figure 5 shows the elements developed in the present paper.

Tool to build a mathematical model of a component using a visual digitizer on screen from the specification curves

In order to verify the performance of the equipment, the measured operational data must be compared with the value on the specification curve. In most cases the value on the curve must be read from the printed specification curve. Reading the value and comparing

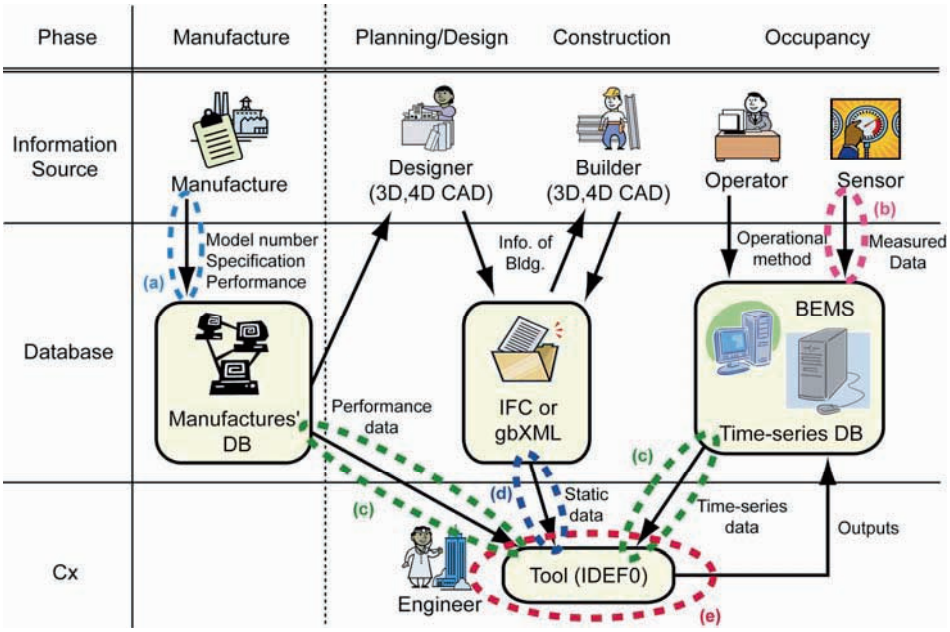

Figure 5 Tools developed in the present study

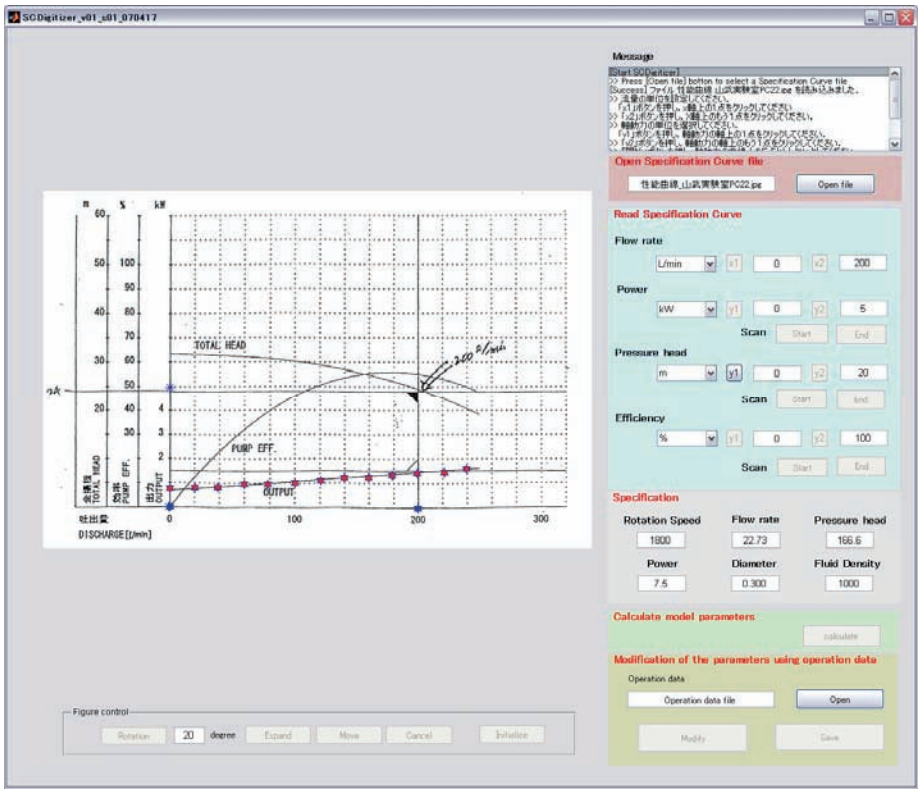

Figure 6 Visual digitizer for the specification curve

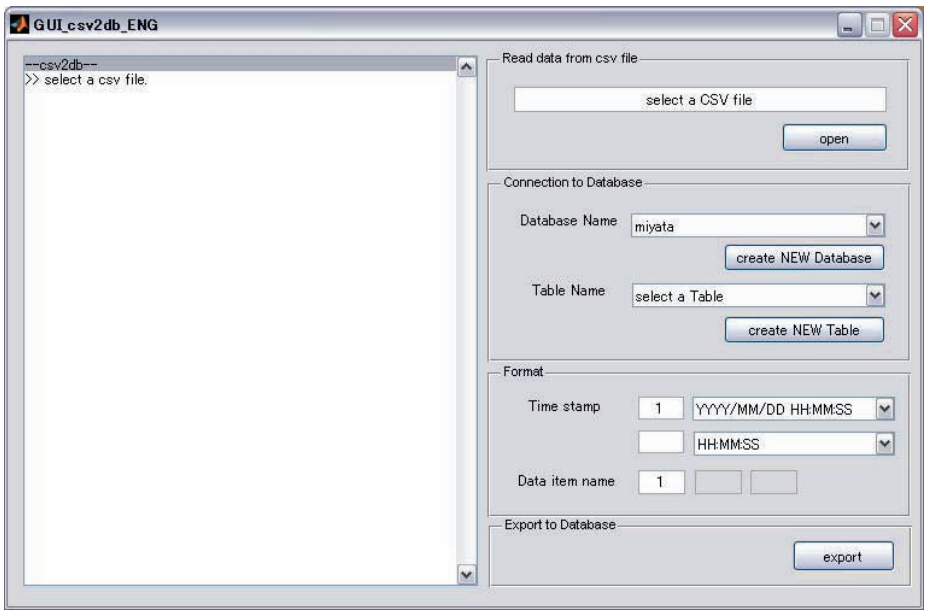

Figure 7 Tool to transfer CSV data to the database

the value with the measured value manually is troublesome. Therefore, the authors develop a technical tool using the model of the equipment based on the specification curve to automate the verification process[6]. Although we researched how to develop the model and how to apply the tool to a real building, we did not discuss how to determine the parameters of the model using the specification curve. Since it is inefficient to read the printed specification curve, we herein develop a tool to build a mathematical model of a component from the specification curve using a visual digitizer. This tool has the following three functions:

1) a function to display the specification curve on the screen,
2) a function to digitize the specification curve by clicking on the screen, and
3) a function to calculate model parameters automatically.

Figure 6 shows the interface of the developed tool. This tool makes it possible to determine the parameter of the model when there is insufficient knowledge about the mathematical model.

Tool to transfer CSV data accumulated by an existing BEMS to a SQL database

A tool to transfer the operational data of a building that has no database and the data measured by the temporary sensor to a SQL database is developed. When a CSV file name, a name of database and table in an SQL database, and a format of the time stamp in the CSV file are input, the data in the CSV file is transferred. This tool has a function to interpolate the missing value. Figure 7 shows the visual interface of the tool.

Tool to retrieve stored data arbitrarily from a SQL databases via a user-friendly window

A tool to retrieve stored data from the SQL database is developed. Figure 8 shows the interface of the tool. This tool can display the stored data hierarchically and can retrieve the necessary data graphically via a user-friendly window.

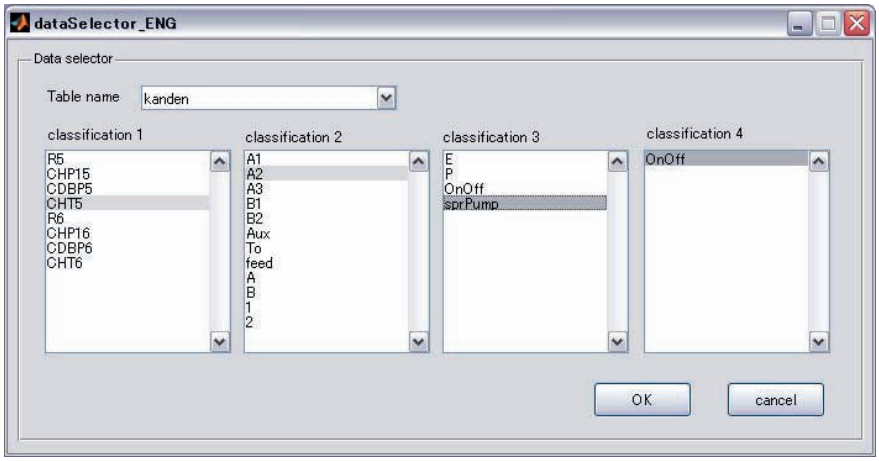

Figure 8 Tool to retrieve needed data from the DB

Table 1 Results of a survey on the database (Type A: Records include one time stamp and one value)

Bldg.	Database	Record													
		time	Name	Value	Invalid data flag	Key	Info. of the value	Valid or invalid	Group	Point ID	Record INDEX	Min.	Max.	Ave.	Sum.
A1	Oracle	■	■	■						■					
A2	Microsoft SQL Server	■	■	■	■										
A3	SIGMAT-HS DB	■		■		■									
A4	Microsoft Access	■		■											
A5	Microsoft SQL Server	■		■											
A6	Proprietary database	■		■	■		■	■							
A7	Proprietary database	■		■					■	■					

Table 2 Results of a survey on the database (Type B: Records include one time stamp and several values)

Bldg.	Database	Record													
		time	Name	Value (Value 1,…,N)	Invalid data flag	Key	Info. of the value	Valid or invalid	Group	Point ID	Record INDEX	Min.	Max.	Ave.	Sum.
B1	Microsoft SQL Server	■		■						■	■	■	■		■
B2	PowerGres	■		■						■	■	■	■		■
B3	Microsoft Access	■		■								■	■	■	■
B4	Oracle	■		■								■	■	■	■

Tables 1 and 2 show the results of the survey on the database structure of the Japanese BEMS. The purpose of this survey is to clarify the database structure and develop tools that can store and retrieve the necessary operational data for commissioning to and from a database. Record types could be categorized into two types: Type A and Type B. The Type A record has a single value with a time stamp, and the Type B record has multiple values with a time stamp. Based on the survey results, this tool provides a function to access both Type A and Type B databases.

Method to describe a tool using IDEF0 in order to clarify what type of data are needed when a tool is applied to a real building

The information flow of a technical tool developed for the performance verification of an HVAC system with a ground thermal storage system is described using IDEF0 as an example[6]. Figure 9 shows the IDEF0 diagram of the tool. Figures 9(2), 9(3), and 9(4) are the expanded diagrams of Activities C2, C3, and C4, respectively, in Figure 9(1).

The upper area of these diagrams shows the necessary information of the building design and the performance of the equipment. The left side of these

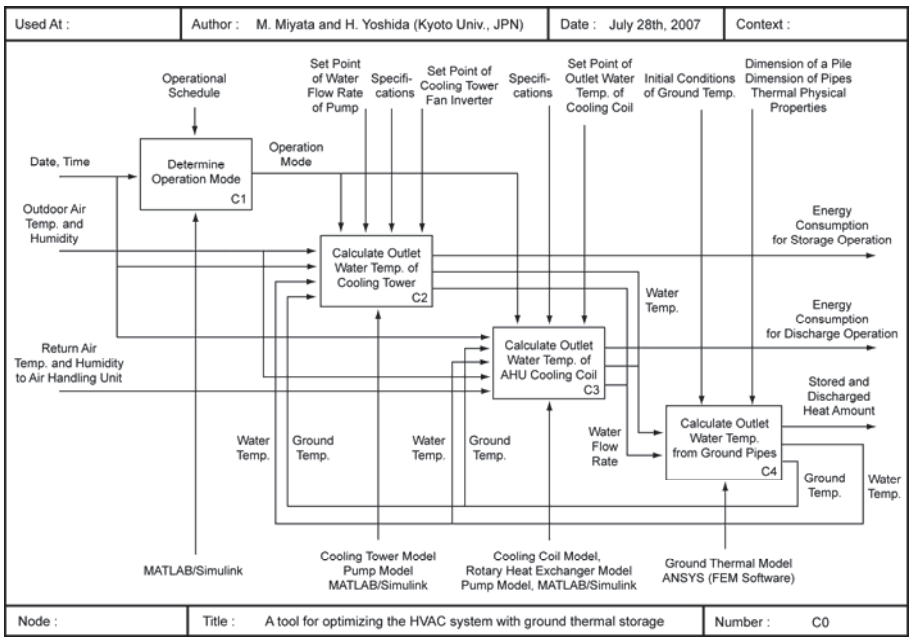

Figure 9(1) Example of IDEF0 model (Root)

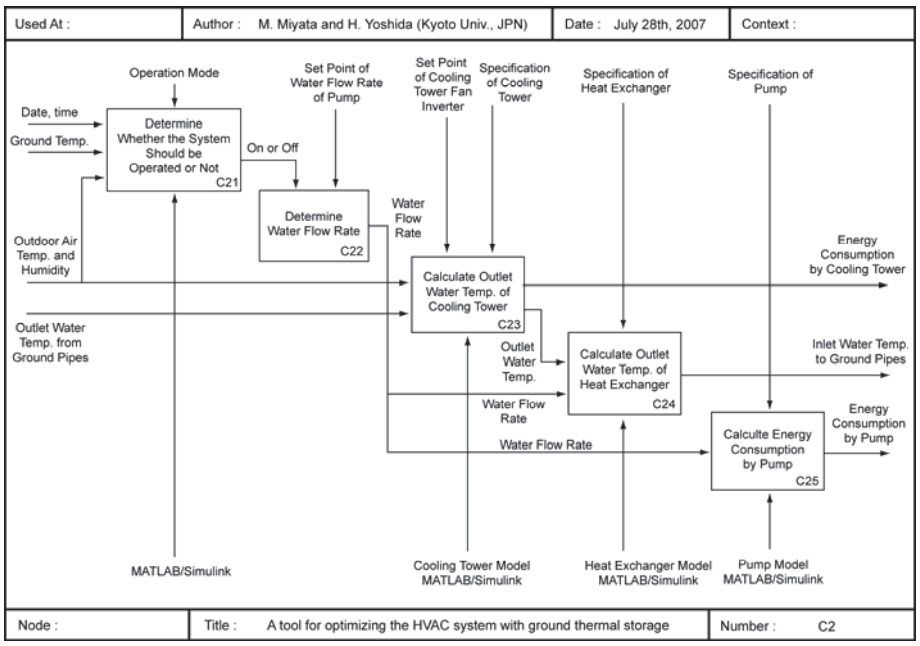

Figure 9(2) Example of IDEF0 model (C2)

diagrams shows the time series data, which is used as the input data of the tool. The bottom area of these diagrams shows the models used in the tool. The right side of these diagrams shows the output of the tool. Information about the design is retrieved from the CAD files, time series data is retrieve from the database in the BEMS.

The description of the tool using IDEF0 provides the following advantages:

1) Since the algorithm of the tool is clear, it is possible to write a readable and simple program.

2) The developers can share information about the algorithm of the tool and can co-develop the tool easily.

3) Since the necessary information for the application of the tool is clear, even individuals who were not involved in the development of the tool can use the tool easily.

DISCUSSION

Based on the results of applying the tools developed in the previous chapter to a real building and the proposed information flow mechanism, the mechanism provided the following benefits:

1) Since there are tools that can store and retrieve the necessary data for the application of the tool arbitrarily to and from the database, the simulation tool can be used easily.

2) The human error can be avoided in the commissioning process because of the reduction of manual handling of troublesome tasks.

SUMMARY

The present paper proposes a new information flow mechanism for commissioning and develops several tools to make the proposed information flow mechanism feasible. If the information about the buildings is organized rationally according to the proposed mechanism, the technical tools for commissioning can be applied easily and effectively and human error in commissioning process can be reduced.

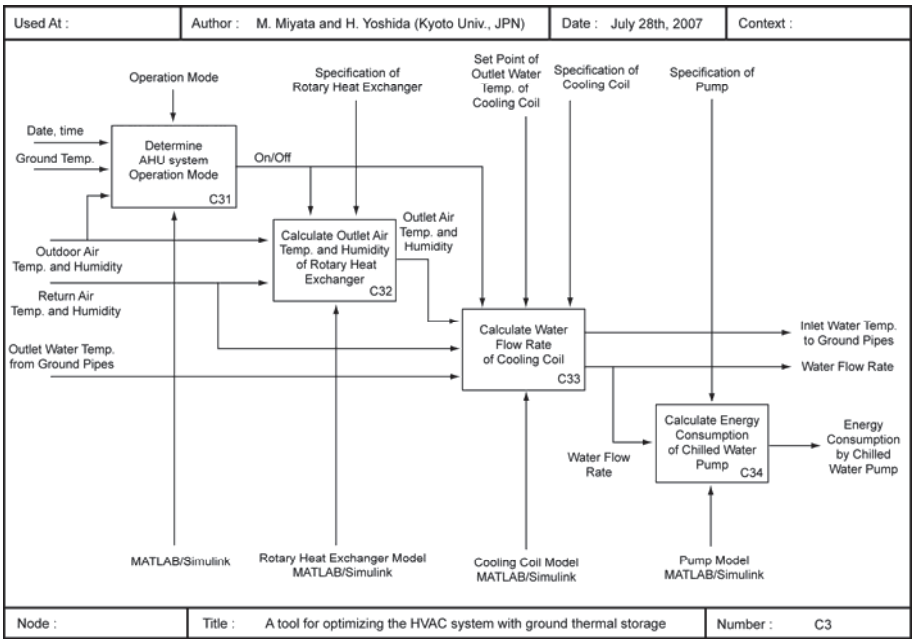

Figure 9(3) Example of IDEF0 model (C3)

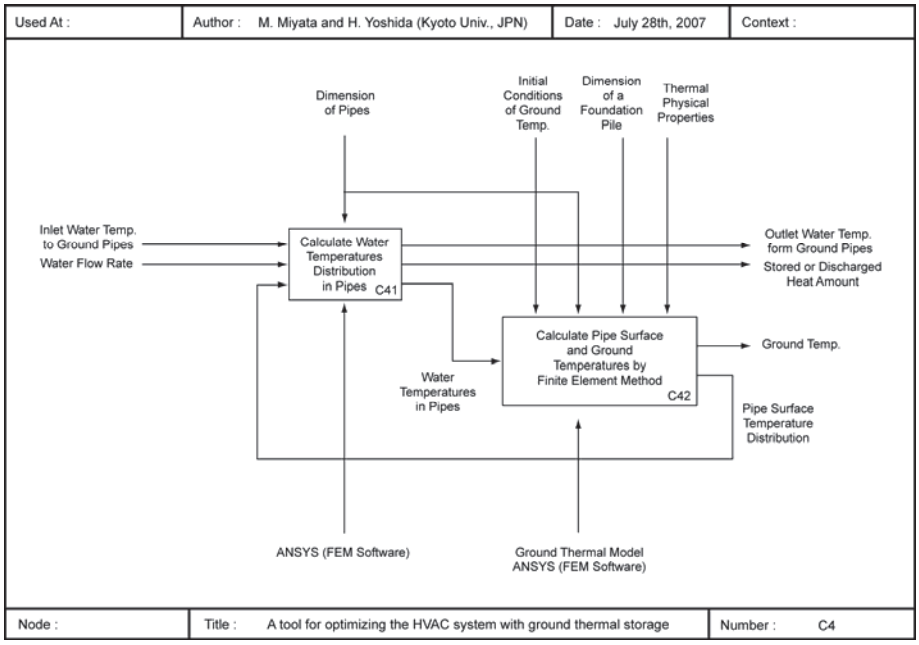

Figure 9(4) Example of IDEF0 model (C4)

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