Simulation Structure of Model Predictive Control of HVAC System

Y. Utsumi[1*], K. Hatakeyama[2], Y. Esaki[3] and R. Kimura[1]

[1] Sendai National College of Technology,
Natori, Miyagi, Japan
[2] Imagic Design Co., Ltd.,
Sendai, Miyagi, Japan
[3] BIT Co., Ltd ,
Yokohama, Kanagawa, Japan

ABSTRACT

It is necessary for Japanese public welfare section to reduce CO_2 emission rate with severe constraints on the power supply after great east Japan earthquake. One of the most effective methods to reduce energy consumption in buildings is to install the advanced HVAC control system that responds to weather condition, the influence of thermal property of the building envelope, occupants' schedule, heat generation from the OA apparatus, etc. Also Model Predictive Control, MPC, with predictive simulation and related control systems is often mentioned as the future of the building simulation in the smart grid, smart community, etc.

This paper describes MPC as the optimum HVAC control system. The simulation is executed using BEMS data, the weather forecasting, etc. The concerned targets are to reduce CO_2 generation, energy consumption and cost with insuring thermal comfort for occupants. For MPC to achieve the targets, the role of simulation is very important and it may be pursued by the embedded system including BEMS. The brief simulation structure and whole system is explained. The accumulation of expertise of the construction, the tuning of the simulation model, the operation in many usages of buildings may offer the simplified systems.

Especially, the function of communication with user-friendly interface between complicated control program and a user who may be a building manager, etc. is necessary. Also the data transferring in the MPC system is discussed in the form of "Adaptor-Bridge" that consists of two functions "Adaptor" and "Bridge".

The former function can modify the unit or the range of input data in advance and delivers the data to simulation engine, etc. The latter function can transfer input and/or output data between "Adaptor" and each module in simulation engine, and adds new "Adaptor" functions accordingly. Simulation result as an output from each module is transferred under the control of "Bridge", "Adaptor" and user interface, UI.

* Corresponding author email: utsumi@sendai-nct.ac.jp

KEYWORDS
MPC, Simulation, HVAC system, User Interface, Meta Data

INTRODUCTION

It is necessary for Japanese public welfare section to reduce CO2 emission rate. The energy consumption in buildings is one thirds of the total energy in Japan, therefore, it is important to reconsider the energy use for the air conditioning that holds a most part of the total energy in buildings. One of the most effective methods to reduce energy consumption in buildings is to install the advanced HVAC equipments and to control them properly, that is variable by influence of thermal property of the building envelope, occupants' schedule, heat generation from the OA apparatus, etc.
To achieve the target, the role of simulation is very important and it may be pursued by the embedded system including BEMS. Though there are many issues concerning to the building simulation (Malkawa 2004), the model predictive simulation and related control system may be the issues as often mentioned in the future.

THE OUTLINE OF MPC FOR HVAC SYSTEM

The brief structure of the developed MPC, Model Predictive Control, for HVAC system (Utsumi 2006) is shown in figure 1. The system is composed from measuring equipments of the indoor environment such as temperature and humidity, the operation situation, the use of energy consumption of the devices, software and PC for building simulation of heat load, new and existing control systems, those interface and communication network, etc.
The real time control is possible with concurrent simulation, while the system functions as the cycle, "measurement -> calculation -> control -> measurement ->...(clockwise)", are repeated. The result from the optimum control should be considered in terms of CO_2 reduction, energy consumption, cost and comfort. It is important to take the balance by varying factors daily, because of the achievement all of the index are difficult.
The system can apply for various devices such as BEMS (Building Energy Management System), DDC (Direct Digital Control) and energy saving, etc. The communication protocol is "BAC-net" standardized by ASHRAE and other protocols are merged by customized relay control system. The system can be installed with low

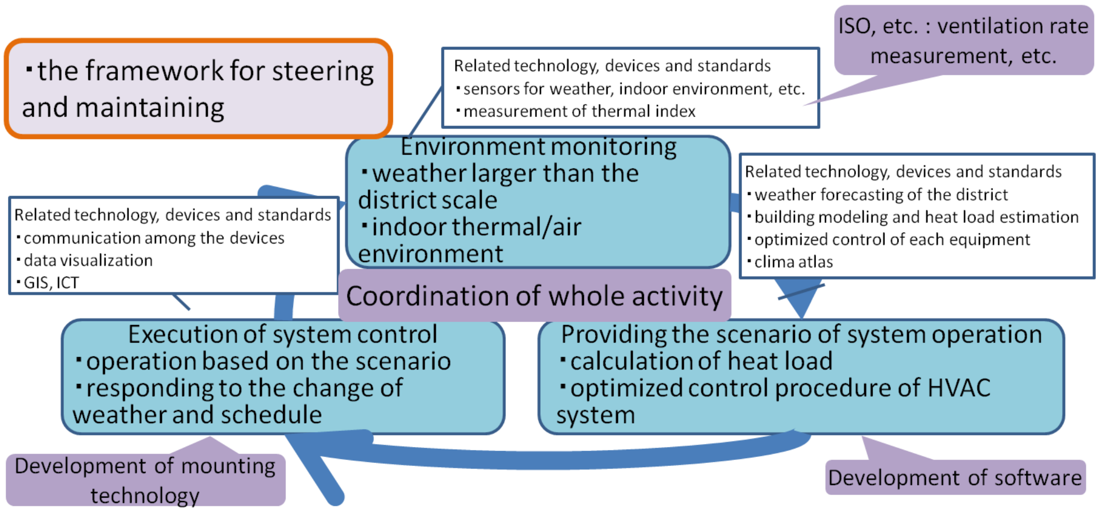

Figure 1. *Concept of MPC for HVAC system*

cost because of using the open network protocol BAC-net (ASHRAE 2010) that can connect various measurement equipments or control devices via internet. An example using BAC-net system is indicated in figure 2.

Also the system can predict the effect of the application of energy saving technologies such as new air conditioning system, new lighting bulbs, etc. The system suggests many scenarios that describe the energy saving actions to the occupants, e.g. the recommendation of another wears.

THE ADOPTER-BRIDGE FOR DATA AND USER INTERFACE

The various data to be used in the simulation can be allocated according to the each simulation tool with specific physical phenomena including heat, airflow, acoustic, etc. The idea of meta data, that is, a category of higher level of abstraction based on concrete and actual data can be applied to deal with the data in the scope.

The characteristics are; an element, a set of data, can be easily specified and the actual data in the element can be referred easily. Also for the combination of elements, the data can represent the actual phenomena, and the structure of the meta data is not changed when applied to another phenomena. To ensure these issues, the tree structure of meta data and actual data, and the layers with some rules may be useful.

In the simulation activity, human often has the mixture data and it is necessary to make the data in the classified form in order to help understanding both for human and simulation engine. The manager process should take the role of data transformation, transferring. It does not store the data but indicate the classification and the rules of transformation, etc. to user interface, UI, see Figure 3.

The data structure of UI is independent from the simulation tool and is common to different software. The manager process has the adopter to prepare the data for each simulation tool based on this shared structure. The flow of operation is described in figure 4.

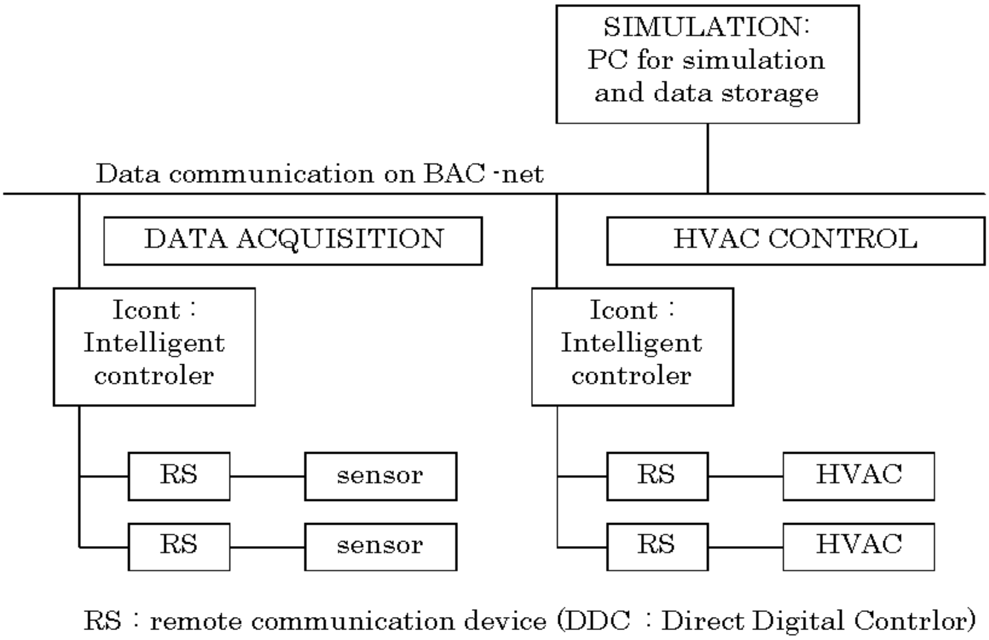

Figure 2. *An example of MPC on the network*

The adopter receives the data from user, libraries, etc. and provides the transformed data to simulation engine via the bridge. The manager receives the inquiry of a data set from user, and indicates and provides the specific data set to the engine. Then the engine starts the calculation.

To provide and share the data to all related users, such as occupants, managers, building owner, local bodies, etc., the mutual communication through UI is necessary. The database may have four layer structures as shown in figure 5.

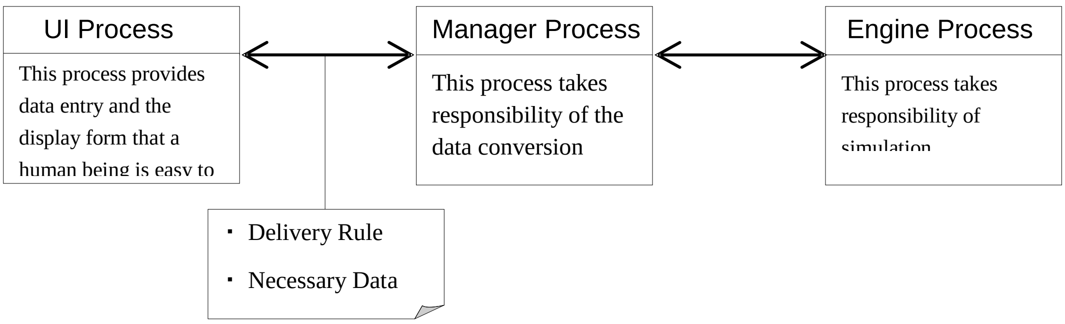

Figure 3*. Constraint conditions of user interface*

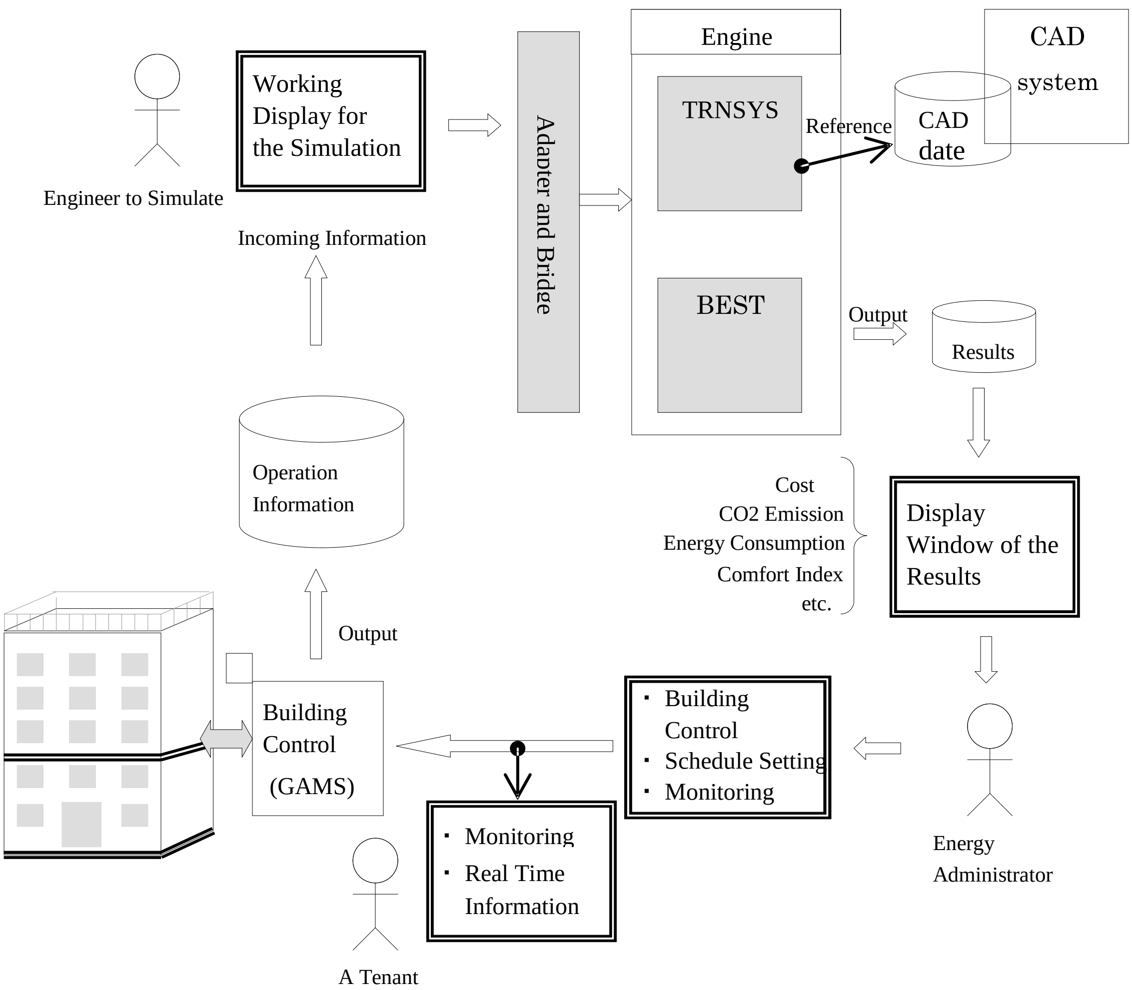

Figure 4. *Flow of system operation and the related data*

AN EXAMPLE OF THE ADOPTER-BRIDGE

A brief data structure of the actually developed for MPC of HVAC system is shown in figure 6. The outline of the whole configuration of an energy simulation tool viewed from UI is shown in figure 7.

The input data by user with the default data passes through UI and adopter-bridge. The data has the links between HVAC components, weather data. The delivered data is stored at the module corresponding to HVAC components.

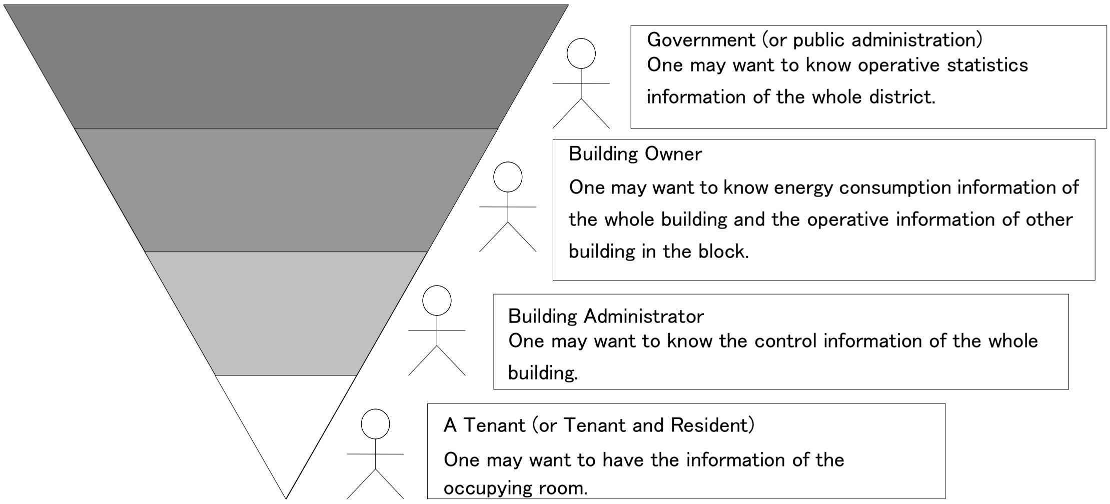

Figure 5. *Example of the information access layers*

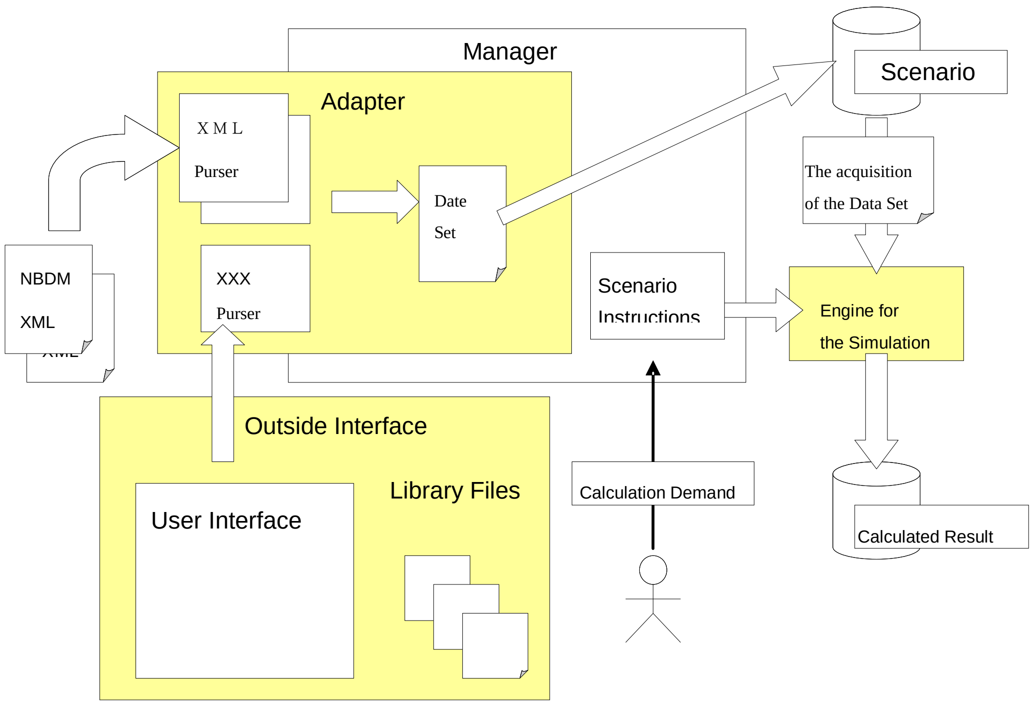

Figure 6. *A brief data structure of the actually developed for MPC of HVAC system*

The adopter checks the input data range, units, etc. and passes them to the engine through the bridge. The bridge is between the adopter and the modules as in the figure.

When the new module is added, the module is connected to the bridge and then a new adopter function is accompanied.

CONCLUSION

According to MPC for HVAC system, the data structure and UI of the building energy simulation are discussed. Because the introduced structure of adopter-bridge and user interface, UI, are based on the actually developed MPC system, it would be evolved to general system with utilising the idea of meta model. Also if the specification is opened and is clearly described, the third party can develop its UI.

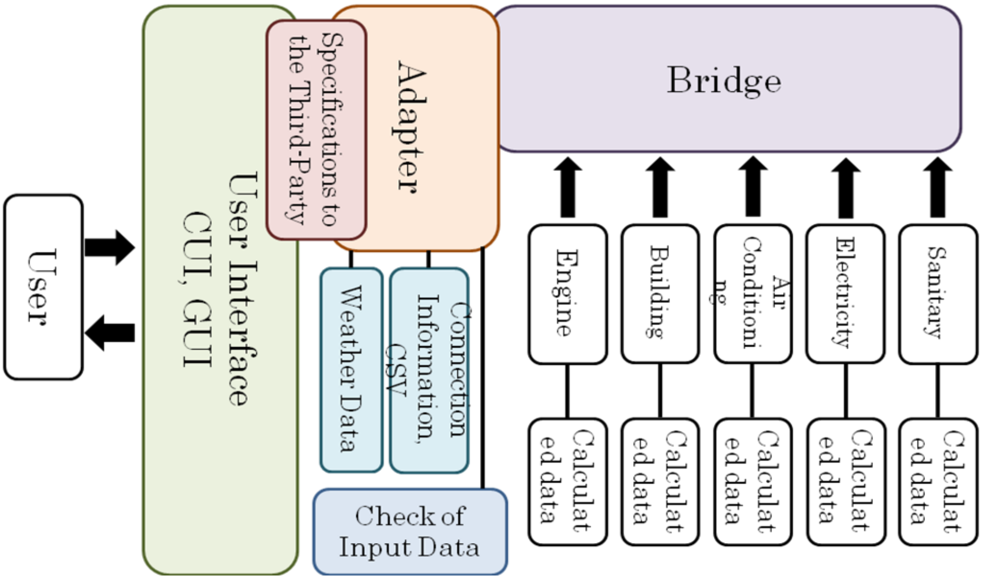

Figure 7. *The outline of the whole configuration of an energy simulation tool viewed from UI*

ACKNOWLEDGEMENTS

The paper is partly based on the results of the project, 'Technology development of auto-control system of HVAC and lightings in buildings', the project leader Dr. Yasumi FUJINUMA during 2004 and 2007, and is also supported by Kajima Josei Zaidan during 2009 and 2011.

REFERENCES

ASHRAE, 2010. ANSI/ASHRAE Standard 135-2010, BACnet – A Data Communication Protocol for Building Automation and Control Networks.

Malkawa, A. et al. 2004. Advanced Building Simulation. Spon Press, 2004, pp.4-24.

Utsumi, Y. et al. 2006. Development of the HVAC Control System by the Concurrent Simulation, 2006EPIC AIVC2006, 013#179, pp.1-6.