DEVELOPMENT OF VENTILATION DESIGN TOOL UTILIZING EXPERT SYSTEM

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ABSTARCT

This study is aimed to spread the intelligent design tool of ventilation in buildings and to improve indoor air quality (IAQ) in rooms. This paper describes two prototypes for diagnosing IAQ and ventilation calculation in rooms, by utilizing the technology of artificial intelligence, such as ES (Expert System), in which the data concerning ventilation design are summarized and the knowledge is presented in the form of production rule. Diagnosis system calculates up to eleven rooms of typical residential house in Japan and shows the capability of predicting the IAQ level of house with given ventilation rate and various using patterns. Also the ventilation calculation system gives an example of calculated minimum required ventilation rate with given pollutant generation rate and allowed pollutant concentration.

KEYWORDS

Artificial Intelligence, Expert System, Ventilation Design, IAQ, Diagnosis, Residential House, Pollutant Concentration, Ventilation Rate, Design Tool

INTRODUCTION

Air-tightened houses may have the problem of IAQ, e.g. CO, CO_2, NOx, VOC, etc. The practical method of ventilation design is needed to avoid it, while most of existing design tool, such as, multizone air flow model (e.g. COMIS), CFD, is not user-friendly for users who are not familiar with building physics, coding, etc.

This research is aimed to improve a ventilation design tool that authors had developed for three rooms, Iwasa et al (1996), where people in the scope is house builder, designer, building constructor, etc. This paper describes a newly developed system diagnosing up to eleven rooms and shows an example with standard house of AIJ (Architectural Institute of Japan). Also ventilation rate design tool is introduced with an example.

OVERVIEW OF DESIGN TOOL

Ventilation Design

There is a relationship between pollutant concentration required by code, pollutant generation rate and ventilation rate, i.e. supplied outdoor air and air flow from adjacent rooms, as shown in Figure 1. Diagnosis compares the standard concentration with value calculated by pollutant generation rate and supplied outdoor air. In ventilation design, ventilation rate is derived from allowed pollutant concentration and pollutant generation rate.

The ES applied here consists of 4 parts, that is;
1) knowledge base : necessary knowledge for ventilation calculation is stored as subroutines in the form of production rule. They are pollutant generation rate of human according its metabolic rate, gas burner and kerosene heater, and diagnosis table for pollutant concentration, SHASE (1987).
2) inference engine : Diagnosis of IAQ is one way inference and it is coded by macro of spread sheet in the graphical format.
3) user interface : the interface enables input of conditions in rooms and ventilation rates.
4) interface for knowledge acquisition : it has graphically displayed and is easily modified afterwards.

Generally ES is developed with particular shell for coding, however, it is not common that the shell is suitable especially for ventilation design. In order to offer a user-friendly design tool, the system has been coded with common spread sheet and its macro.

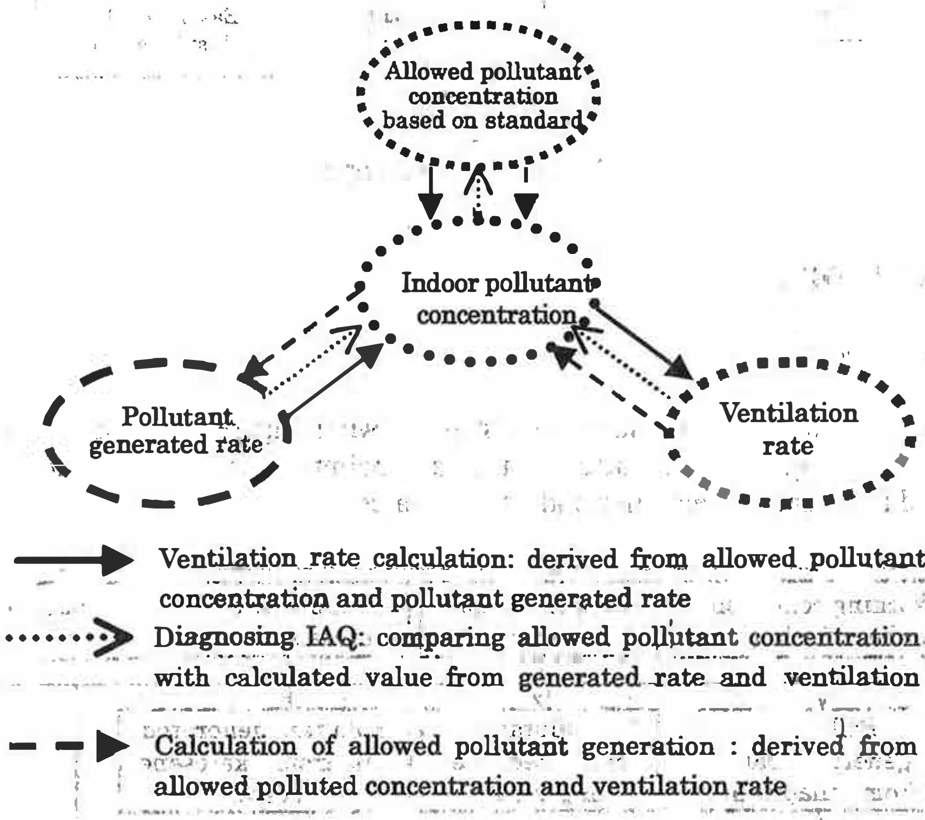

FIGURE 1
The relationship of ventilation design

Model of House

The house to be used is the standard house of AIJ, IBEC (1996), as shown in Figure 2. The house is two story and has eleven rooms. The height of story and ceiling is 2.7m and 2.4m each, and the floor area is 125m^2. Ventilation system is natural supply and mechanical exhaust of 0.5ach. Possible pollutant sources in the house are gas burner, kerosene heater and human (same working condition in each room).

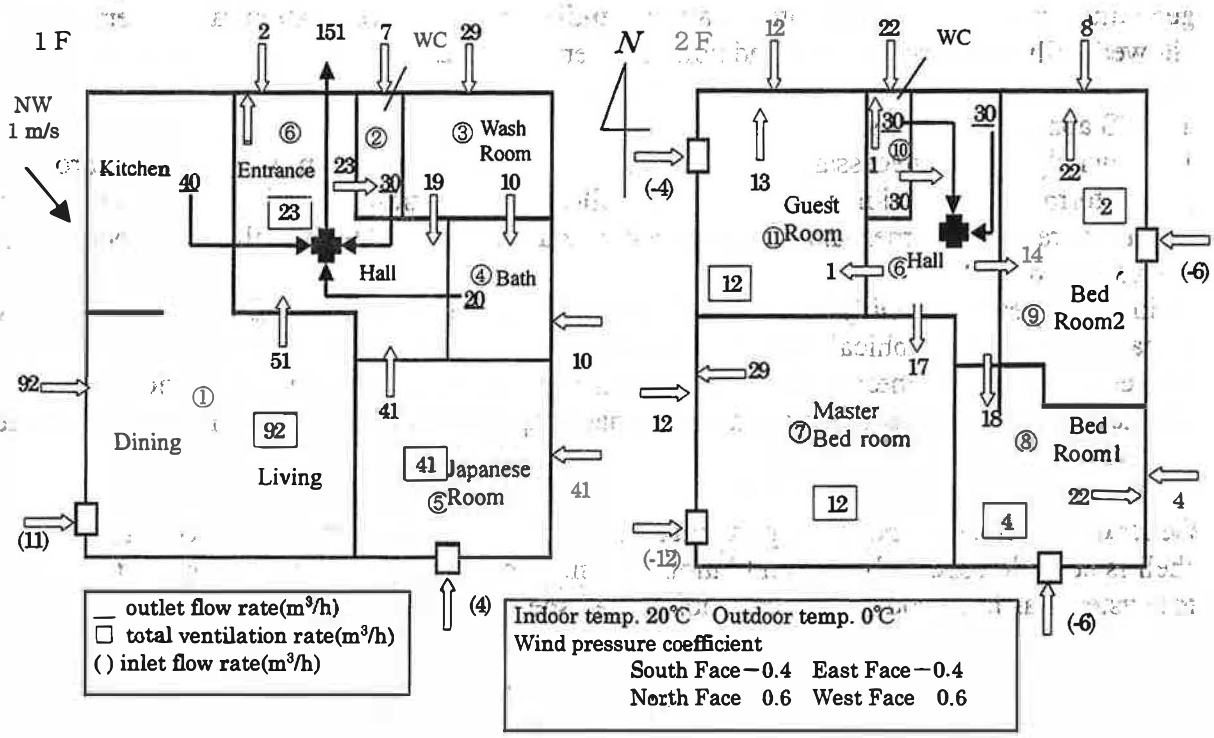

FIGURE 2
Model house and input data

DIAGNOSIS OF IAQ

Diagnosis Procedure

The diagnosis procedure consists of three steps shown in Figure 3. The steps are 1) data input, 2) calculation of generated pollutant volume and pollutant concentration, and 3) comparison of resulted pollutant concentration and allowed value.

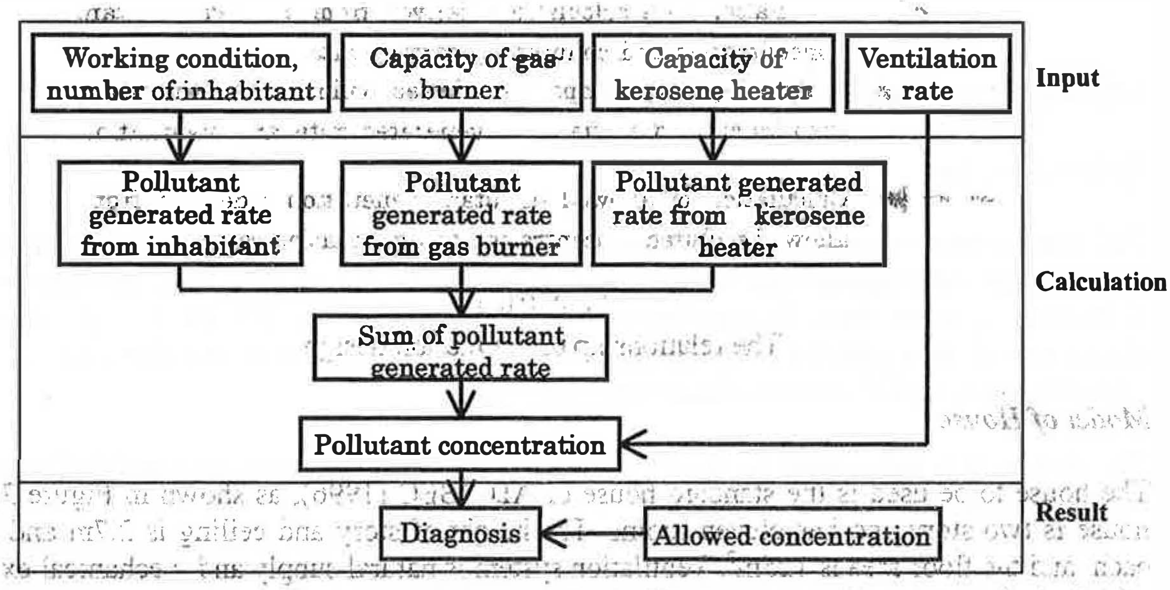

FIGURE 3
Diagnosis procedure

The input is ventilation rate, pollutant generation rate, here CO_2 for example, and allowed concentration. Uniform dis ibution of pollutant is assumed in each room. Generated volume of CO_2 is sum of these from human, gas burner and kerosene heater, and the concentration in rooms are calculated with supplied outdoor air and air from adjacent rooms. Input of an example is shown in Figure 2. Finally the concentration is judged with reference value stored in knowledge base.

Result of diagnosis of CO_2 concentration

An example is shown in Figure 4. In this case CO_2 concentration in kitchen with contaminant source is beyond 6000ppm, and five rooms, entrance hall, toilet, bedroom 1&2 and guest room, where air of kitchen flows into, are over 1000ppm, where 1000ppm is one of the allowed levels in Japan. The situation in rooms is easily understood by graphical expression.

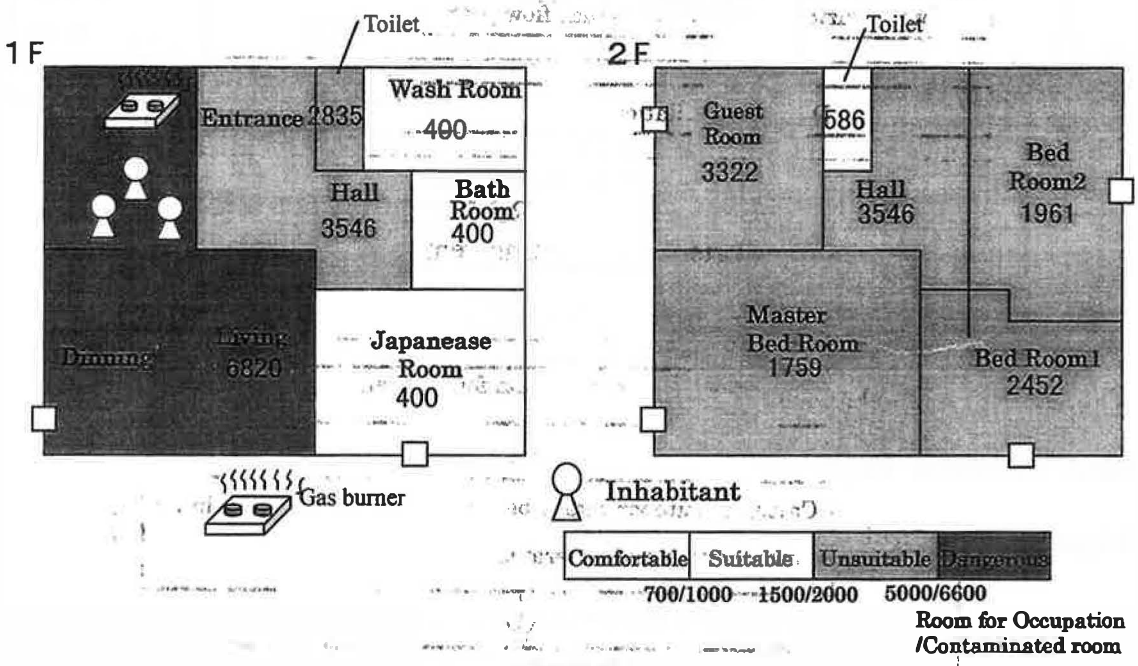

FIGURE 4
An example of diagnosis (CO_2 concentration unit : ppm)

VENTILATION RATE CALCULATION

System Structure

Pollutant generation rate, a possible flow path between rooms and allowed concentration are needed to provide required outdoor supply rate. As shown in Figure 5, there are three steps as following; 1) input data, 2) calculation of required outdoor supply air in each room and decision of air flow path between rooms, and 3) accumulation of flow rate along the flow path and calculation of designed ventilation rate in rooms.

The flow path is determined to satisfy the adequate IAQ. The rooms are classified into three types, such as;
1) room for occupation : living room, dining room, bedroom, etc. for long time occupation.
2) room for transportation : entrance, corridor, hall, etc. for human transportation and short time occupation.
3) contaminated room : kitchen, toilet, bath, etc. with possible contaminant generation.

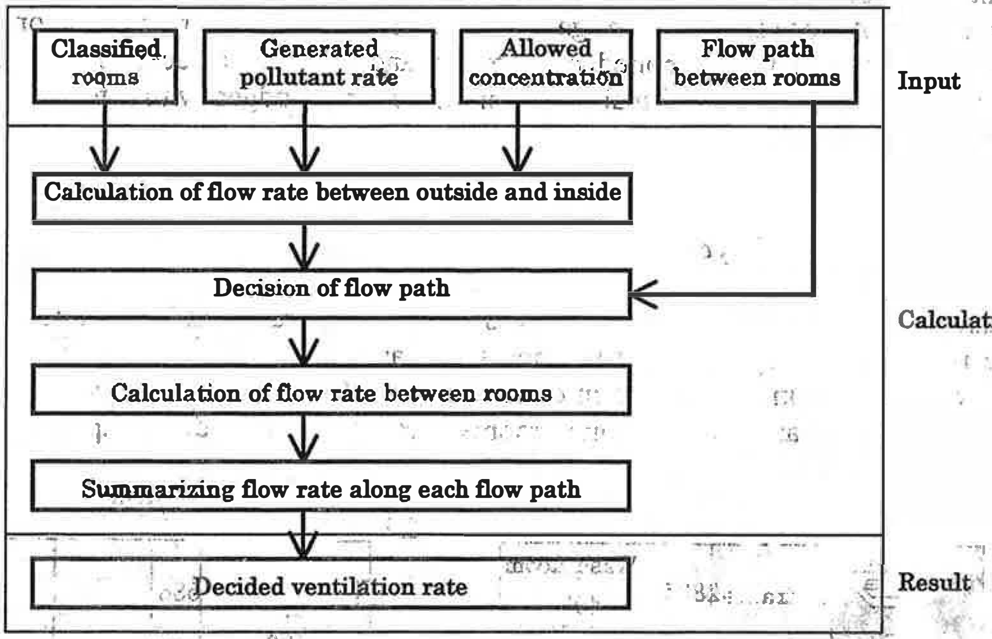

FIGURE 5
The step of calculating ventilation rate

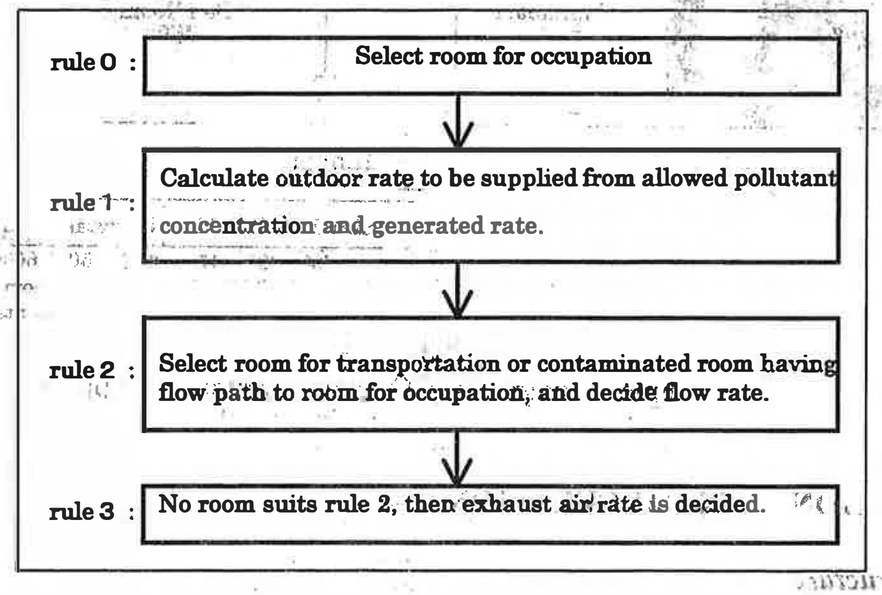

FIGURE 6
An example of production rule to decide a flow path

For example the production rule of the room for occupation is indicated in Figure 6. The rules are used in two phases for flow path decision, that is;

1) to ensu e allowed concent ation level in rooms for occupation : this phase starts from rooms for occupation and ends at contaminated ooms.

2) to ensure allowed concentration level in contaminated rooms : this phase starts from contaminated rooms and ends at ooms for occupation.

Finally all flow rate are summarized along each flow path.

Result of ventilation rate calculation

For instance ventilation rate of house shown in Figure 4 are calculated under the same condition of living pattern and the result is indicated in Figure 7. The flow path and flow rate is only for CO_2 concentration, therefore, other contaminants, CO, odor, moisture, etc. should be treated respectively.

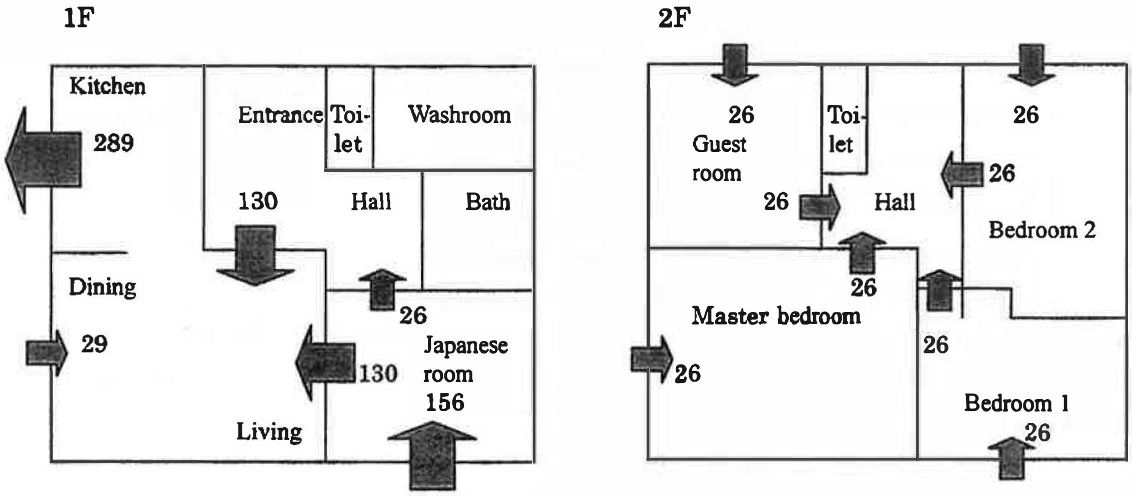

FIGURE 7
An example of derived flow path and ventilation rate (m^3/h) for CO_2 concentration

CONCLUSION

Diagnosis system of IAQ in rooms and the system for design of ventilation rate are developed. They have user-friendly user interface and some example calculations are performed. Former system reveals enough capability for house and latter system gives a solution of outdoor air distribution. Further development with actual building is a future task.

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