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Technical Note

A Smart Green Building: An Environmental Health Control Design

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Abstract: This study proposes the establishment of an environmental health information management platform providing residential users with a comfortable, healthy indoor environment. Taking the S House as an example, the study: (1) assigned environmental health performance indicators, (2) established constraints to maintain environmental conditions, and (3) provided optimized management control mechanisms and methods. The environmental health information management platform provides an optimized control and solution pathway ensuring the quality of the indoor health environment and equipment energy conservation.

Keywords: indoor healthy environment; energy conservation; optimal control design

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1. Motivation and Goal

In view of the energy conservation and carbon emissions reduction trends, this study proposes the establishment of an environmental health information management platform enabling optimal control of both the quality of the indoor health environment and equipment energy conservation. Modern people spend more than 90% of their time in indoor environments, and indoor environmental quality can directly influence residents' health. In addition, because contemporary buildings do not have equipment integration or communications platforms linking different equipment items, the independent operation of equipment may cause redundant burdens on and waste of resources and energy, reducing the equipment's operating efficiency. Taking the S House as an example, this study proposes a practical environmental health information management platform, analyzes the necessity and feasibility of such a platform, and examines directions for future development.

2. Literature Review

2.1. Environmental Health Age Issues

Health is a fundamental human right. According to the World Health Organization (WHO), health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity [1]. In this time of strenuous energy conservation and carbon reduction efforts, how to optimize control and management of residential equipment in order to preserve residential users' health and comfort, while maintaining the sustainability of the ecological environment, has become an important contemporary issue (see Table 1).

2.2. Optimized Control Theory and Selected Conditions

Generally speaking, there are two approaches to optimized control: use of mathematical algorithms and adoption of logic control. In the field of automatic control, optimized control must possess the following three elements: (1) establishment of system performance indicators, (2) establishment of constraints, and (3) provision of optimized management control mechanisms and methods. Because residents' activities in their living environment are typically sporadic, dynamic, discrete, and nonlinear, they cannot be easily expressed using a small number of mathematical equations. As a consequence, this study advocates the use of logic control to drive the responses and actions of equipment and architectural elements on the basis of environmental and living situations in order to establish and maintain an optimal environment. According to Bryson [2], optimize refers to the most suitable control scheme or best possible control rule, which will enable a system to best reach its desired objective. In addition, Chen [3] suggests that optimized design requires the establishment of an appropriate physical model for an engineering design problem, the construction of mathematical equations on the basis of that model, and finally use of the appropriate model to derive an optimal design. In the field of automatic control, Landau [4] proposes that optimized control must possess three key elements: (1) setting of system performance indicators, (2) establishment of constraints, and (3) provision of optimized control mechanisms and methods. Here performance indicators are also known as target functions, and quantify a system's ability to adapt to various usage conditions and achieve maximal operating efficiency. Constraints are defined as rules for a system's permissible control logic values, and may be the limiting values of control effects or engineering parameters, or the subordination of engineering parameters. Constraints are standard mechanisms for constraining the integrity of a system's control logic. During use, constraints take precedence over event-driven models, rules, and default values. As a consequence, optimized control mechanisms and methods refer to the determination of appropriate control rules under given constraints, ensuring that a certain performance indicator in the optimized control process achieves the maximum or minimum value.

Table 1. Review of literature on environmental health.

Goal	Organization, literature, year	Themes discussed	Theory and methods	Specific solution	Trend research
Cities of health	Vancouver Declaration On Human Settlements [5].	(1) Insufficient quantity of dwellings; (2) Poor residential quality; (3) Coexistence of new and old building types.	Health encompasses physical, mental, environmental, and social aspects.	The cities of health concept emphasizes that the living environment must possess functionality, comfort, and safety planning.	The cities of health concept emphasizes that health is inseparably linked to the living environment.
Healthy communities	Declaration of Alma-Ata [6].	(1) Reflection on the large-scale development of energy; (2) Avoidance of ecological destruction; (3) Reduction in use of synthetic chemical substances.	Communities should implement primary-level health care in order to achieve the goal of health for all.	Healthy communities rely on public participation strategies to achieve sustainable environmental health.	Healthy communities perform the important tasks of promoting health and disease prevention for all, and maintaining public health.
Health promotion	Ottawa Charter for Health Promotion [7].	(1) Increasing consciousness of housing quality; (2) Increasing competitive pressure in society; (3) Wastage of environmental resources.	Health promotion is the process of encouraging people to strengthen control and promotion of physical health.	Health promotion seeks to create healthy supportive environments via public health policy, interdepartmental cooperation, and community participation.	Environments supporting health include: (1) the physical environment; (2) the social environment, and also encompass other relevant environmental developmental technologies.
A healthy indoor environment	Study on the Comprehensive Indicators of Indoor Environment Assessment for Occupants' Health in Taiwan [8].	Immediate or potential effects of an unhealthy indoor environment on the human body.	To maintain sustainability of the living environment, proposal of health assessment systems and indicators in view of residents' basic health needs.	Drafting of indoor environmental health and control assessment indicators.	Indoor physical environmental quality factors must possess (1) objectivity; (2) scientific basis; (3) measurability; and (4) comparability.

Table 1. *Cont.*

Goal	Organization, literature, year	Themes discussed	Theory and methods	Specific solution	Trend research
Healthy housing	Technical Essentials for Healthy Housing Construction [9].	(1) Insufficient social welfare as demographic aging approaches; (2) Problems such as soil and water quality, severe air pollution, and the greenhouse effect.	The healthy housing concept reflects the relationship between health factors and three aspects: basic elements; (2) the living environment, and (3) sustainable development.	Three major systems involved in the establishment of healthy housing: (1) assessment system; (2) technical system, and (3) architectural system.	Proposal of a housing improvement strategy based on architectural quality standards for the purpose of enhancing residential quality, health factors, and health preservation.
Smart environments	Insights of Smart Environments [10].	"Smart environments" are places designed to be user-friendly, employing intelligent solutions (including smart materials and information & communications technology), and which are able to interact with the environment.	The basic principles of a smart environment include: (1) a human-centered design; (2) context-awareness; (3) a high touch architectural plan, and (4) interdisciplinary integration.	(1) Establishment of a responsive building that can meet changing needs, and (2) linkage of virtual space with the real environment.	While fusing information/ communications with living applications, a smart environment achieves optimal linkage between design and technology, and takes key issues such as environmental health and sustainability into consideration.
Green and intelligent buildings	How do smart buildings make building green? [11].	(1) Smart green buildings embody sustainable management of environmental health and environmental protection/energy conservation/carbon emissions reduction features; (2) Smart green buildings emphasize quality of life, individualization, and customization.	Smart green buildings incorporate sustainable environmental protection and smart technologies within the building, creating an architectural space capable of active sensing and meeting users' needs.	Based on a green building, a smart green building incorporates smart high-tech technologies, materials, and product applications, making the building safer, healthier, more convenient, and more comfortable, while conserving energy and reducing carbon emissions.	Combination of information design, electromechanical design, industrial design, and architectural design in response to the need for (1) safety; (2) health; (3) comfort; (4) energy conservation, while creating a human-centered living space.

3. Optimized Control of Environmental Health

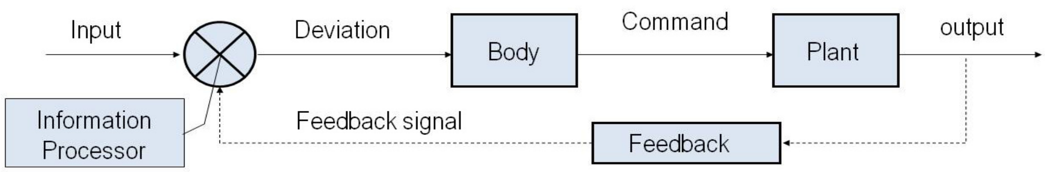
According to the foregoing literature, this study proposes the establishment of an environmental health information management platform performing optimized control of the quality of the indoor health environment and equipment energy conservation. Optimized control of environmental health can be achieved using a control model ensuring that equipment operation can simultaneously maximize environmental health and achieve minimum equipment energy consumption.

This study proposes that an environmental health control system should be designed using a closed-loop control approach. Control systems may employ open-loop control or closed-loop control approaches. Open-loop control is the simplest control approach, and involves a system comprising (1) the body and (2) the plant. In an open-loop control system, the plant does not initiate any reaction to the body, and there is no feedback circuit achieving a controlling affect (see Figure 1).

Figure 1. Open-loop control process flowchart.

In contrast, closed-loop control employs feedback generated by the controlled entity to achieve correction. A closed-loop control system comprises: (1) the body, (2) the plant, (3) feedback, and (4) an information processor. After measuring the deviation between the plant's actual and planned state, the system corrects the body in accordance with the information processor's preset indicators (see Figure 2). Most of the information processor's target settings are determined on the basis of single thresholds or if-then relationships. The key to reaching the set performance indicators lies in the use of the information processor and employment of appropriate control mechanisms or methods to achieve optimized design [12].

Figure 2. Closed-loop control process flowchart.



4. Use of the S House as an Example

Based on the foregoing research, and relying on the use of thermal air conditioning and monitoring of the air environment, the S House uses sensing, computing, and communications technology to establish (1) a building environmental control system and (2) an environmental health information management platform. The S House can provide residents with superior living conditions, while simultaneously achieving an optimal relationship between the quality of the indoor health environment and the functioning of equipment in the building's environmental control system. According to the needs of residential users, the S House can (1) set health and comfort indicators, (2) establish equipment operating constraints, and (3) provide optimized control mechanisms and methods. The house's environmental health information management platform handles and responds to state conditions, transmits action commands to the plant, and thereby regulates and controls the residential environment. Under the system's continuous closed-loop control mechanisms, the environmental control system's sensing, information processing, and actuation processes continue ceaselessly.

4.1. Overview of Site Conditions and Design Concept

The S House is located among the foothills of Alishan, in Taiwan's Chiayi County, and is very near the Tropic of Cancer (N23.27°). The site is situated on a mountainside; the house faces the southwest, with its back to the mountainside in the northeast. It is a four-story private villa with a two level foundation. The S House realizes the "smart plus green building" concept proposed by Taiwan's Architecture and Building Institute, Ministry of the Interior, and its design features span the aspects of: (1) architectural plan, (2) environmental health control, (3) landscaping, (4) seismic isolation system, and (5) sustainability. As shown in Table 2, the house seeks to achieve the objectives of (1) safety & peace of mind, (2) health maintenance, (3) convenience & comfort, and sustainability & energy conservation.

Table 2. The S House's design, technological applications, and living objectives.

Dimension	**Smart green building technological applications [13]**	**Living objectives**			
		Safety & peace of mind	**Health maintenance**	**Convenience & comfort**	**Sustainability & energy conservation**
Architectural plan	Analysis of regional climate and seasonality				*
	Mountain slope water and soil conservation	*			*
	Disaster prediction and control	*			
	Regional ecological survey and impact assessment		*		*
	Demographic change analysis				
	Open architecture			*	*
	Modular design			*	*
	Fair-faced concrete pre-cast construction	*	*		
	Adaptive spatial design for lifelong house	*	*	*	
	General purpose architecture and interior planning	*	*	*	
	Dry compartment wall construction	*	*	*	
	Flat slab construction	*	*	*	
	Lofted lower floor ceiling and anti-pest design	*	*	*	
	Security and alarm system	*			

Table 2. *Cont.*

Dimension	**Smart green building technological applications [13]**	**Living objectives**			
		Safety & peace of mind	**Health maintenance**	**Convenience & comfort**	**Sustainability & energy conservation**
Environmental health control	Air quality survey	*	*		*
	Noise control		*		
	Water quality survey	*	*		*
	Microclimate monitoring system (weather station)	*	*	*	*
	Healthy air quality monitoring system	*	*	*	*
	Thermal buoyancy ventilation staircase and automatic control Ventilation tower	*	*	*	*
	Solar water heater	*	*	*	*
	Natural ventilation plan	*	*	*	*
	Natural insulation, sun protection, natural lighting facade design	*	*	*	*
	Indoor situational control system		*	*	
Landscaping	Optimized visual landscaping façade	*	*	*	*
	Rainwater recycling, gray water irrigation system	*	*	*	*
	Vegetation suitable for the local climate	*	*	*	*
	Atrium landscaping bridge reducing ecological impact and balcony design	*	*	*	*
Seismic isolation system	Main structure seismic isolation system	*	*	*	*
	Isolator	*	*	*	*
	Hollow floor slabs	*		*	*
	Earthquakes sensor	*		*	*
Sustainability	Property management system	*		*	*
	Hotel-style management team				
	Building life cycle management	*	*	*	*

4.2. Compliance with Passive Design Principles

In order to achieve environmental sustainability, the S House complies with passive architectural design principles. With regard to regional climate and seasonality, the S House is located in the subtropical zone near the Tropic of Cancer (see Figure 3), and the climate is warm and humid, with an average annual temperature of 23.7 °C and an average annual relative humidity of 80.3%. The levels of pollutants (such as SO_2, NO_2, and CO) in the air are all below the standard values, and the air quality is very good. The house possesses excellent natural ventilation conditions, with a sea breeze blowing up the mountains from the lowlands in the daytime, and a land breeze blowing down from the mountains at night. Because of this, the floor containing the building's main entrance (3F, used as a parking area) is lofted to enhance natural convection (see explanation of natural ventilation in Figure 4), and there is an opening facing the southwest in the lowest floor (B1F, equipment level) to catch the cool breeze from the lowlands. The glass staircase serves as a thermal buoyancy ventilation tower, and hot air from inside the house is vented from air shutters at the top of the stair tower.

Figure 3. The S House is near the Tropic of Cancer.

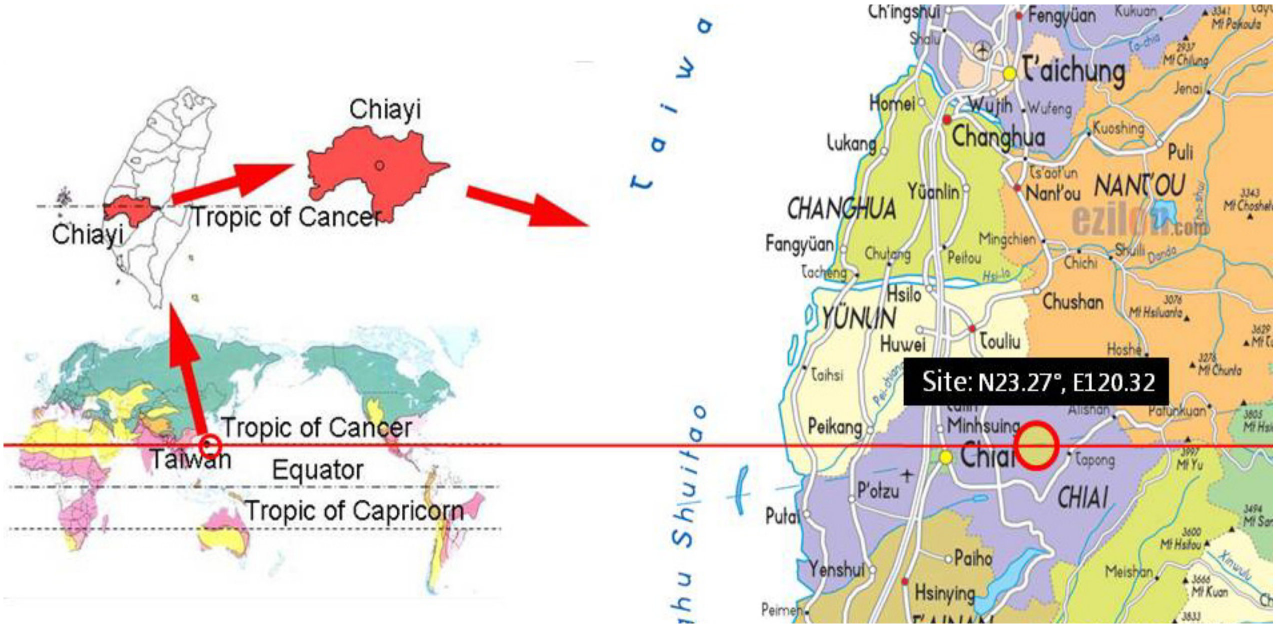


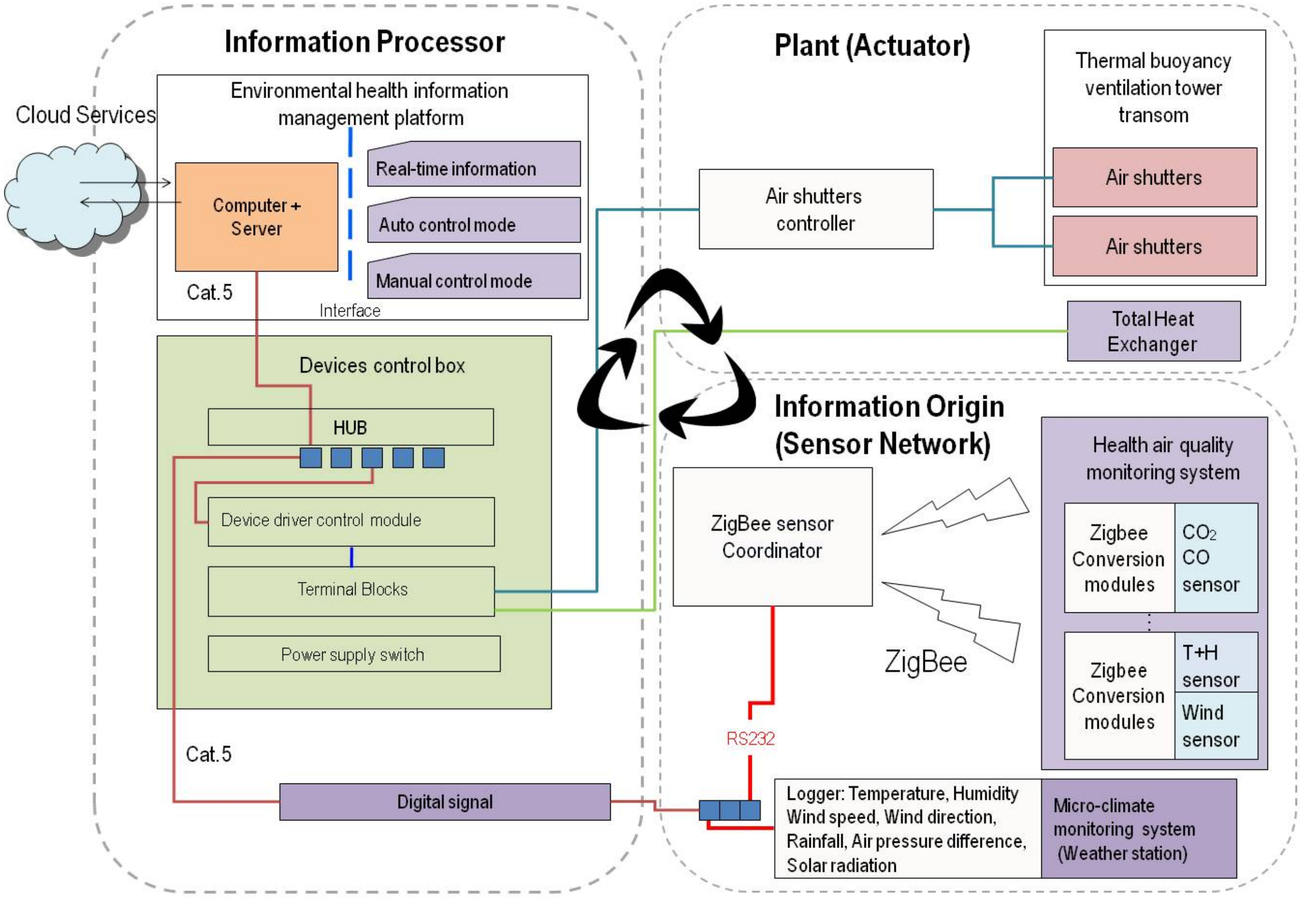
Figure 4. The S House's natural ventilation conditions.

4.3. Selection of Intelligent Conditions

Houses constitute the containers of life and the machinery of living. Nevertheless, passive design has many deficiencies under real conditions, and often cannot adequately meet users' comfort needs. Intelligent design is consequently needed to resolve the shortcomings, and even mutual contradictions, of passive design. Ideally, passive design will not require any electromechanical systems or devices, and can take advantage of the natural climate to maintain a comfortable environment [14]. However, when the built-configuration is incorrect, electromechanical facilities and systems must be employed to correct the errors of passive design [15]. Taking natural lighting and ventilation as examples, when building apertures are similar, the amount of sunlight will depend on the building's latitude, position of the sun at different times, and the sun's path in sky throughout the year; weather conditions and cloud layers may cause the strength, length, and distribution of sunlight to change. Ventilation similarly depends on local climate conditions, nearby buildings, landforms, and the topography, which may all cause changes in wind direction and wind speed. Passive design operating models clearly can account for only conditions with relatively large probabilities, but have difficulty coping with complex, highly variable environmental conditions and exceptions. Another issue is illustrated by the scenario of opening a window in a school classroom to provide ventilation. Suppose a classroom is full of students on a hot, muggy day. It is very hot in the classroom, but a construction project is underway outside, and it is also very noisy. Should they open the window or not? Opening the window would let in loud noise, but not opening it would leave the classroom unbearably hot. In this kind of situation, passive design alone cannot satisfy users' need to avoid both heat and noise.

After first satisfying the building's need for passive natural ventilation, intelligent facilities and equipment can be used to implement a context-driven operating model, providing an optimal solution to the need to achieve both environmental protection/energy conservation and health & comfort. A building environmental control system primarily encompassing thermal air conditioning (temperature T + humidity H + Wind) and the air environment (CO, CO_2) has been established for the S House through the use of sensing, computing, and communications technology, and an environmental health information management platform has been installed. As shown in Figure 5, the S House contains smart, interconnected facilities and equipment. The environmental control system employs wired or wireless signals to integrate the microclimate monitoring system (the weather station), healthy air quality monitoring system, thermal buoyancy ventilation staircase, and automatically controlled ventilation tower air shutters. The environmental health information management platform is able to respond to real-time environmental information, adjust environmental parameters and thresholds to actively control facilities and equipment, and use the Internet to obtain the services of remote experts and technicians via the cloud in the event of environmental monitoring situations, parameter revisions, and malfunction troubleshooting. The system's continuous closed-loop control mechanisms enable the environmental control system's sensing, information processing, and actuation processes to continue ceaselessly as the system maintains the house's environmental health quality.

Figure 5. Flowchart of the S House's building environmental control system.



4.4. Optimized Control

To deal with sporadic, dynamic, discrete, and nonlinear changes in the physical environment and user needs, this study recommends the adoption of logic control as part of an optimized control actuation model. As described above, the S House has a building environmental control system primarily encompassing thermal air conditioning (temperature T + humidity H + Wind) and the air environment (CO, CO_2), and is equipped with an environmental health information management platform. As shown in Figure 6, the designers of the building's environmental control system had to: (1) set health and comfort indicators, (2) establish equipment operation constraints, and (3) provide optimized control mechanisms and methods in accordance with the physical environment and user needs. The environmental health information management platform is therefore able to respond to changes in circumstances in accordance with the if-then conditions established by the logic control, and can transmit actuation commands to the plant, regulating and controlling the residential environment.

Taking the design of the thermal buoyancy ventilation tower as an example, the tower can effectively maintain the health and comfort of the indoor thermal air conditioning (temperature T + humidity H + Wind) and the air environment (CO, CO_2). The S House employs a staircase as a thermal buoyancy ventilation tower. Under ideal circumstances, due to the effect of thermal buoyancy, hot indoor air can enter the ventilation tower via the staircase, and then escape through the air shutters at the top. Nevertheless, under certain conditions, when the air shutters on the side of the tower facing the wind are open, the external wind pressure may exceed the indoor air pressure resulting from thermal buoyancy ventilation, and the air flow may reverse, preventing air from escaping (Figure 7). After receiving wind direction and wind speed information from the weather station, the environmental health information management platform can control the opening of the tower-top air shutters; if the air shutters on the ventilation tower are facing the wind, in order to maintain the positive pressure of air flowing from the tower relative to the external air, the air shutters facing the wind are shut, and the shutters facing other directions are opened.

Figure 6. Building environmental control system.

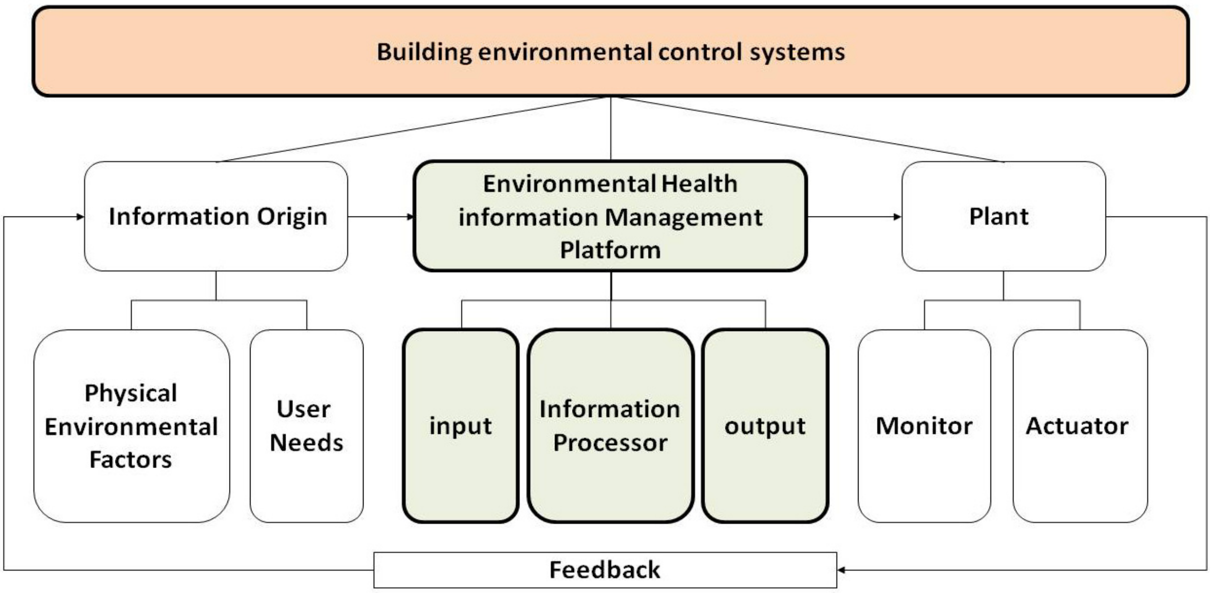
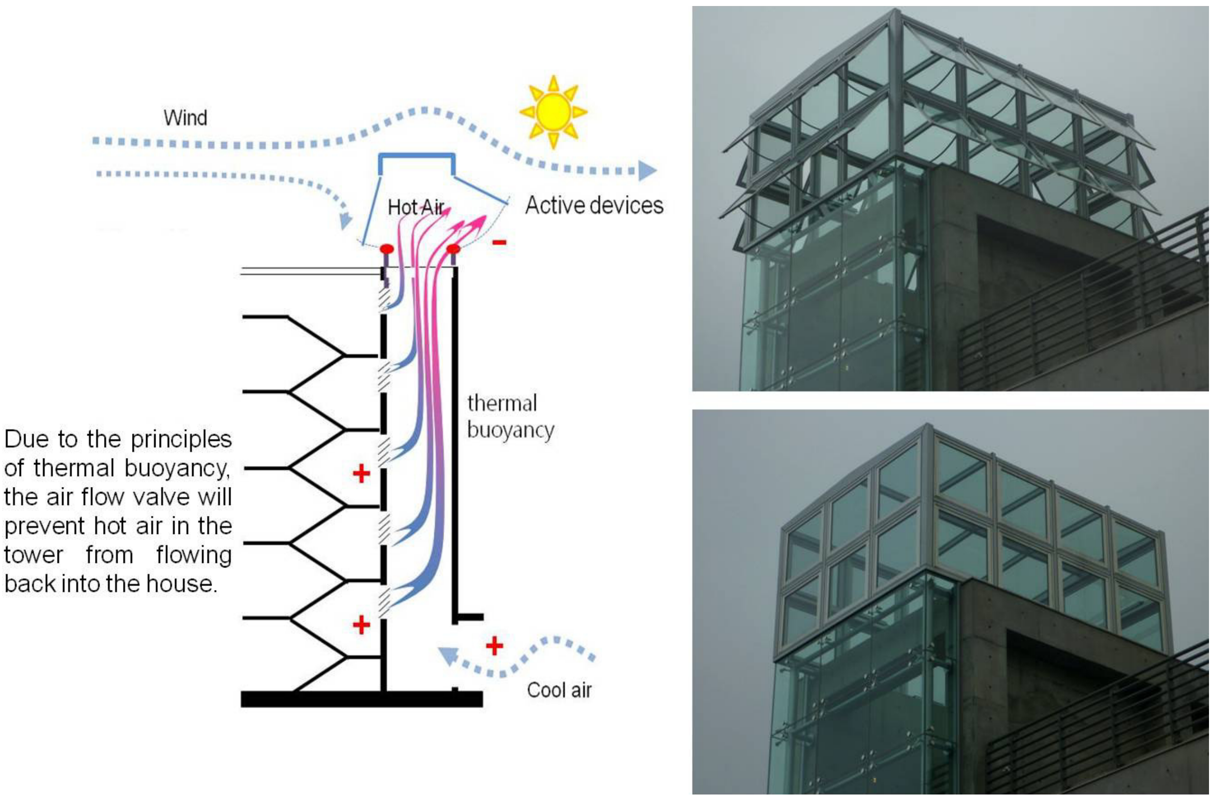
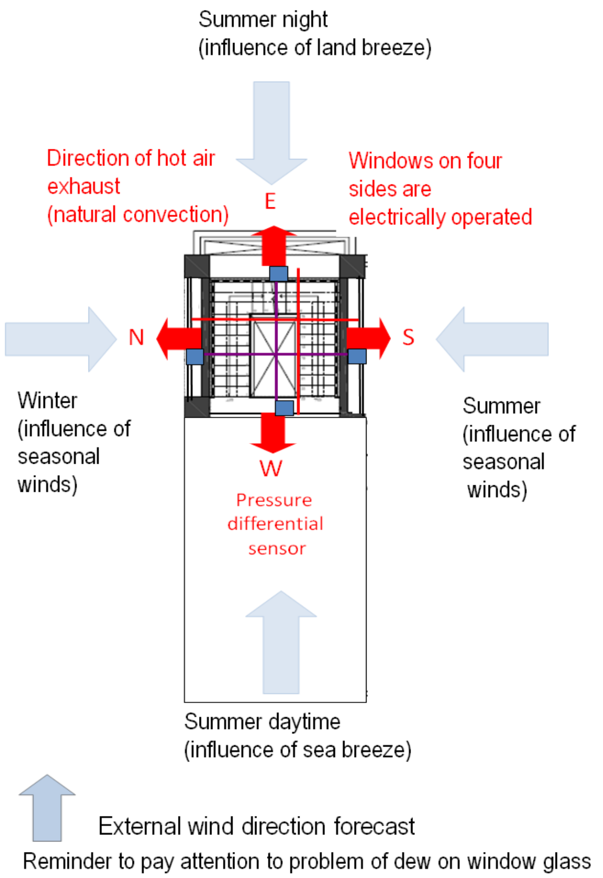


Figure 7. Operating principle of the thermal buoyancy ventilation tower and control of air shutters.



This approach can ensure that hot air can escape freely from the thermal buoyancy ventilation tower. In addition, users are often perplexed by the question of whether to open the thermal buoyancy ventilation tower air shutters under certain atypical conditions. For instance, under the ordinary model, when the system senses that the air shutters facing the wind are open, but it is raining, the system will conclude that the air shutters should be shut. Under the special model, when the external air is too cold or too hot, causing the system to conclude that the air shutters should be shut, if the indoor CO or CO_2 concentration becomes excessively high, at which point it may even threaten users' lives and safety, the system will be forced to open the shutters. When these abnormal conditions occur simultaneously, the system will face a conflict deciding whether to open the air shutters; how should the logic controller make its decision (see Figure 8)?

Figure 8. Ventilation tower air shutter opening and shutting constraints.



• Regular times: window open (monitor indoor/outdoor pressure differential, inside must maintain positive pressure)
• Indoor negative pressure: The windows will automatically close when there is continued negative pressure inside the house (after pressure differential disappears due to unstable fluctuations in the wind).
• Rain: The windows will automatically close when the rain detector detects rain.
• End of rain: The windows will automatically open when the rain detector no longer detects rain.
• Indoor air conditioning turns on: In order to conserve energy, doors or separating blinds, etc. should be used to control air conditioning. It is not necessary to control the vent at the top of the tower. If necessary, the windows can be set to automatically close when the air conditioning comes on and automatically open when the air conditioning turns off.

Possible indoor/outdoor pressure differentials (+: open, -: closed) (for reference only, control should be performed on the basis of measured pressure differential values from all four sides of the building)

Season	Summer			Winter
Wind direction	W	S	E	N
N-side windows	+/-	+	+/-	-
E-side windows	+	+/-	-	-
W-side windows	-	+/-	+	-
S-side windows	+/-	-	+/-	-

P.S. In order to enhance gravity air exchange, it is recommended that all windows be opened when there is no clear wind direction in summer. It is recommended that all windows be closed when there is suspicion of sinking air in the winter.

Figure 9 shows a feasible solution to this situation: when the CO or CO_2 concentration is too high, apart from opening the shutters, the system can also turn on a total heat exchanger to actively acquire fresh air from outside, improving the quality of the indoor air. Because of this, the air shutters are controlled employing both an ordinary model and a special model. The control logic specifies that the special model takes precedence over the ordinary model, and the order of priority in the special model is: "CO, CO_2" > strong wind > rain > "too hot or too cold". Nevertheless, optimization of an environmental health information management platform will depend on building users, and the platform must set and adjust the equipment's operating constraints on the basis of health and comfort indicators (temperature, humidity, pollutant concentrations) set by users in view of their usage habits, as well as on the basis of the experience values for the climate. For instance, the red values shown in Figure 9 can be revised or adjusted by system designers or residential users to achieve the goal of customization.

Figure 9. The logic control model includes health and comfort indicators and equipment actuation constraint settings.

Total Heat Exchanger Control Logic

Mode	Event Rules/ Device operation mode	Event terminate conditions / Device operation mode	Operating frequencies
Total Heat Exchanger Control Logic	(CO> 20 ppm) or(CO_2 > 800 ppm) Act: Turn on the Total Heat Exchanger	(CO< 15 ppm) or(CO_2 < 600 ppm) Act: Turn off the Total Heat Exchanger	Startup the Determine cycle Of The every time: 1 min Relieve the Determine cycle Of The every time: 15 min

Air shutters Control Logic

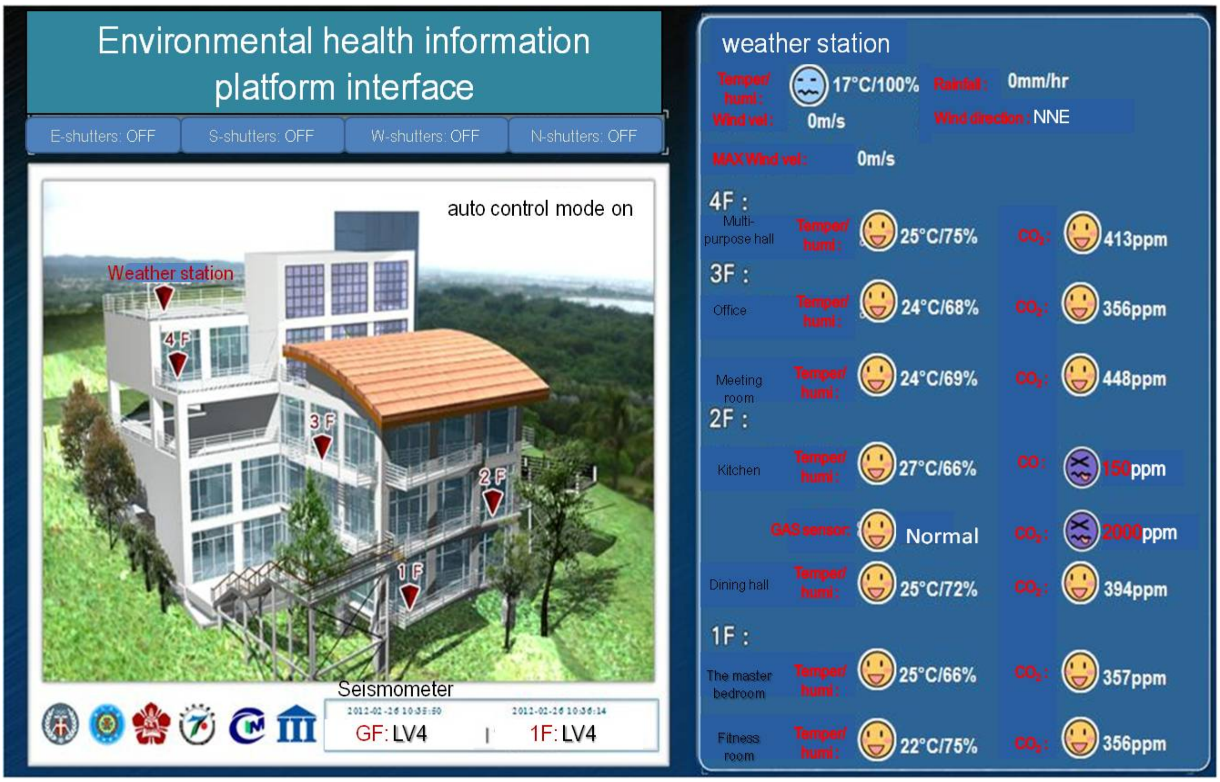
Event priority /Mode	Event Rules/ Device operation mode	Event terminate conditions / Device operation mode	Operating frequencies
1ST Abnormal event mode (Strong wind / rain / abnormal temperature)	(Outdoor wind speed > 18 m/s) or (Rainfall >0 ㎜) or (Outdoor Temper < 18 ℃) or (Outdoor Temper > 32 ℃) Act: Turn off all air shutters	(Outdoor wind speed > 17 m/s) and (Rainfall =0 ㎜) and (Outdoor Temper > 18 ℃) and (Outdoor Temper < 32 ℃) Act: Switch to the Wind Ventilation mode	Startup the Determine cycle Of The every time: 1 min Relieve the Determine cycle Of The every time: 15 min
2nd Wind Ventilation mode	See wind direction table below Act: Open the air shutters by corresponding wind direction position	N/A	Detection cycle Of The every time: 30 min

Wind direction	E	S	W	N
N	□	■	□	□
NNE	□	■	□	□
EN	□	■	■	□
ENE	□	□	■	□
E	□	□	■	□
ESE	□	□	■	□
ES	□	□	■	■
SSE	□	□	□	■
S	□	□	□	■
SSW	□	□	□	■
WS	■	□	□	■
WSW	■	□	□	□
W	■	□	□	□
WNW	■	□	□	□
WN	■	■	□	□
NNW	□	■	□	□

4.5. The Environmental Health Information Management Platform Interface

The environmental health information management platform provides an appropriate environmental information interface, which enables residential users to control the interior environment via two types of interface: The type shown in Figure 9 requires authorization, and is used to adjust the range of health and comfort indicators and equipment operating constraints. The interface shown in Figure 10 is used more often, and displays current environmental information acquired by sensors. Here the right field displays the outdoor temperature, humidity, wind speed, and wind direction, and the indoor temperature, humidity, and pollutant concentration (CO, CO_2). The upper left part of the interface shows the open/shut status of the air shutters on the four sides of the ventilation tower, and the lower left part displays the magnitude of the most recent earthquake. The interface will display a warning when any of these values exceed the safe indicator values. For instance, in Figure 10, the CO_2 concentration has reached 2000 ppm and the CO concentration has reached 150 ppm, both of which exceed the normal tolerable limits for humans. As a result, users must respond to the warning by eliminating the problem. In addition, because the interfaces shown in Figure 9 and Figure 10 are both linked to the Internet, as long as users obtain formal authorization, they can obtain the services of remote experts and technicians via the cloud in the event of environmental monitoring situations, parameter revisions, or need for malfunction troubleshooting.

Figure 10. Environmental health information platform interface [16].



5. Recommendations and Discussion

From design to formal occupation, the process of developing the S House took more than eight years (4/2004–8/2011). Although high expectations have been placed in the S House, operation has thus far been very successful. As shown in Table 2, the S House embodies many innovative "smart green building" concepts. Although the house can be examined from many angles, this paper only looks at the aspect of optimized control of environmental health, which is discussed as follows:

(1) Pursuit of maximum health quality and minimum equipment energy consumption: Home users always seek a healthy and comfortable residential environment. When considering sustainability, including energy conservation and carbon emissions reduction, a passive design should receive first consideration. However, smart situation control can be used to drive adaptive architectural elements and thereby make up for the deficiencies of the passive design. Furthermore, only when a passive design is inadequate to maintain environmental health, such as during the occurrence of special conditions, will the system use active equipment (such as air conditioning and total heat exchangers) to maintain a comfortable environment.

(2) Sensor installation and active actuation device installation conditions: inappropriately or insufficiently intelligent facilities and equipment may disturb residential users' normal lives. For instance, when all windows are actively actuated, the noise from the window operation is frequently a cause of complaints by the users. Nevertheless, the use of necessary equipment can improve health conditions and prevent hazards. For instance, because people are generally unable to detect high concentrations of harmful pollutants such as CO and CO_2, the installation of CO sensors in kitchens and CO_2 sensors on the ceilings of rooms often containing many persons, such as living rooms, is clearly very appropriate. In addition, the installation of actively actuated air shutters in staircases, which seldom attract much attention or contain people for very long, and especially in relatively inaccessible ventilation towers, is obviously very thoughtful.

(3) Restrictions on logic control: In keeping with the sporadic, dynamic, discrete, and nonlinear nature of changes in the physical environment and user needs, this study recommends the adoption of logic control in an optimized control actuation model. Nevertheless, although commonly-used binary rule-type control methods employing specific threshold values are indeed simple, they easily give rise to conflicts. For instance, although the literature states that people will feel discomfort when the CO_2 concentration is greater than 800 ppm, the personnel participating in design of the S House felt very comfortable on an occasion when the CO_2 concentration of a full conference room exceeded 1,200 ppm. Because the human body's feeling of comfort is a subset consisting of values within a certain scope and contrasting with other factors, if-then logical conditions should be multi-value versus multi-element. The widely-used binary rule control approach uses specific threshold values, and is extremely simple. Its only limitation is the use of priority to resolve conflicts, and it can only be used for the actuation of equipment with open and shut actions.

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