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Complexity and Contradiction in Intelligent Green Architecture
—The S-House as an example

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ABSTRACT

The development of Taiwan's information and communications industries, and the application of information and communications technology to civil applications, has made the achievement "intelligent green architecture" a worthy goal. Nevertheless, how should we define "intelligent green architecture"? Furthermore, the question of how to resolve the complexity and contradiction between the natures of intelligence and green in architecture has become an important contemporary research issue. This study advocates the use of intelligence in intelligent green architecture to coordinate and manage the complex and contradictory needs among occupants and building environment or environmental factors, and thereby achieve the goal of "greenness." Taking the S-house project as an example, an intelligent design employing air pressure difference switch sensors, computing and communications technology, and thermal buoyancy ventilation towers, was able to actively correct the ventilation performance exceptions of passive thermal buoyancy ventilation towers. Practical operation has verified the theoretical and practical feasibility of the intelligent green architecture proposed in this study, as well as its differentiation and future prospects.

Keywords: intelligent building, green architecture, passive design.
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1 BACKGROUND AND GOALS

The development of intelligent green architecture is currently seen as an in important task in the field of architecture. But how should we define "intelligent green architecture"? And how can we resolve the complex and contradictory relationship between the attributes of "intelligence" and "greenness"? According to the 3173rd [6] and 3174th [7] conferences of the Executive Yuan, on December 3, 2009 and December 10, 2009 respectively, the government should accelerate the promotion of cloud computing, intelligent electric vehicles, the industrialization of invention patents, and intelligent green architecture as the "four major intelligent industries." Furthermore, the 38th Architecture Festival on December 12, 2009 made a forceful appeal for increased intelligent green architecture R&D, promotion of reform in the industry, and the improvement of human life [5]. Nevertheless, we must ask how "intelligent green architecture" should be defined. What is the goal of

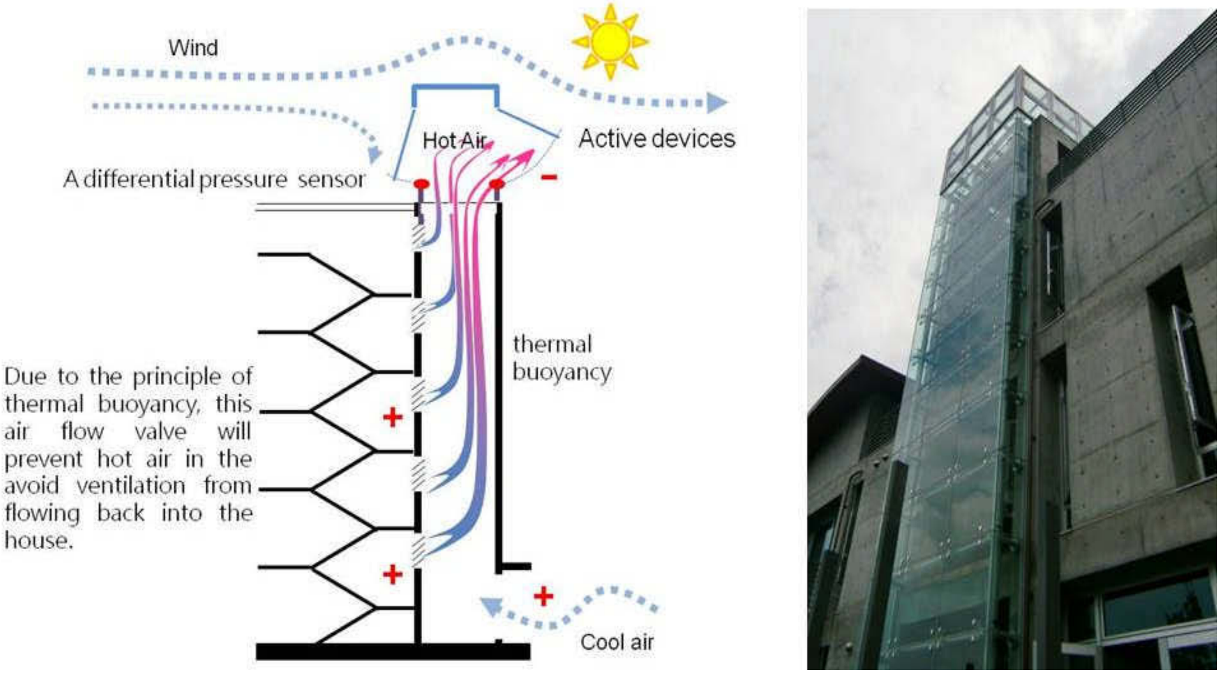


Fig. 1: Intelligent design of thermal buoyancy ventilation tower.

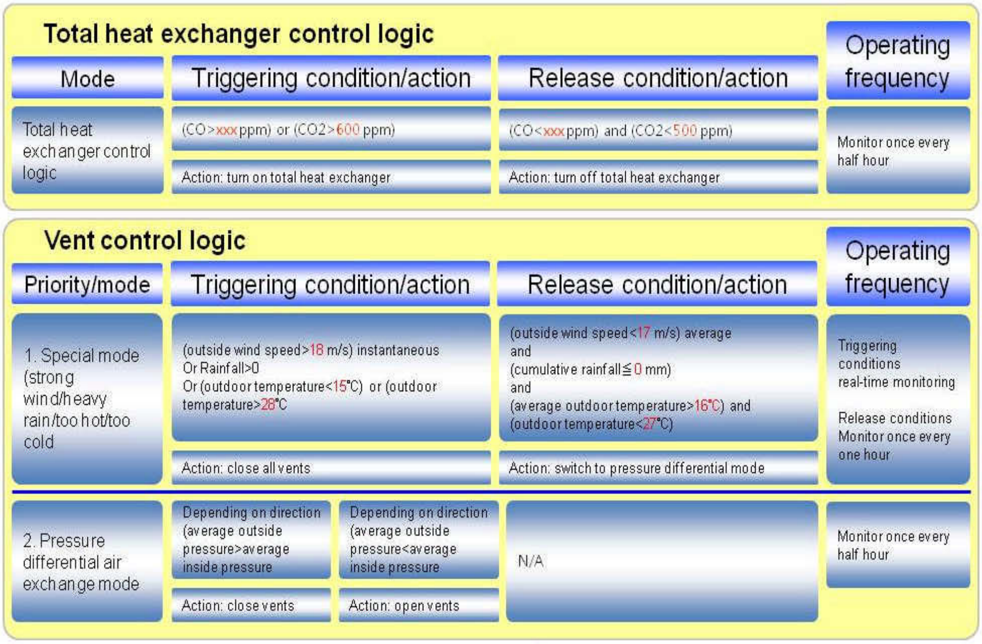
Fig. 2: DPS series air pressure differential switching sensor –Honeywell.

employing intelligent green architecture? What methods can be used to achieve these goals? There has been a universal belief in architectural education that an intelligent building should be automatically controlled, and should apply active equipment to achieve a comfortable living environment; as a consequence, an intelligent building is energy consuming. In contrast, green architecture emphasizes positive design, pursues the goal of environmentally sustainable development, and conserves energy and reduces carbon emissions.

2 THEORY AND METHOD

This study advocates the use of intelligence in intelligent green architecture to coordinate and manage the complex and contradictory needs among occupants and building environment or environmental factors, and thereby achieve the goal of "greenness." In other words, this study sees intelligence as a method, and greenness—environmental sustainable development—as a goal.

Traditional green architecture involves the use of passive design to achieve the goals of energy conservation and reduced carbon emissions. But while this is the ideal, a building is a container for living, and is the machinery of dwelling; there are many aspects of passive design that are impractical in the real world, or that cannot easily satisfy users' need for comfort. As a consequence, intelligence is needed to remedy the deficiencies of passive design, and we can even consider intelligent and passive design models to be contradictory. In architecture, "passive design" implies that a building can maintain a comfortable environment by taking advantage of favorable natural climatic conditions without the use of any electronic or mechanical systems or devices [9]. From another angle, buildings must employ passive methods (including built-configuration, use of architectural elements, and selection of materials) in order to achieve low energy consumption. However, when the built-configuration is incorrect, electronic and mechanical facilities and systems must be used to compensate for errors in the passive design [3]. Moreover, experts and scholars are still pondering the question of how a passive building can adapt to complex environmental changes while maintaining environmental comfort. For example, when natural lighting and ventilation depend on the same architectural opening conditions, lighting will be affected by the building's latitude and longitude, the sun's position at different times, and the changes in the sun's trajectory due to the seasons; in addition, the weather and degree of cloudiness will also affect intensity, depth, and distribution of sunlight. For its part, ventilation will also depend on factors affecting the wind direction and wind speed, such as the area's climatic conditions and other buildings and landforms around the site. It is obvious that passive design provides an operating model that can only account for the most likely events and changes, but hart to respond to other environmental changes and exceptions. Taking the command of "open the window" in a classroom as an example, on a sweltering day, in a hot classroom containing many students, should we still open the window if a noisy construction area lies outside? It will be extremely noisy if we open the window, but so hot that no one can stand it if we don't open the window. In these circumstances, passive design is wholly inadequate to deal with the contradictory needs to avoid heat and noise. In contrast, an intelligent window would be able to judge the situation, and in the face of this kind of contradiction could perhaps activate the air conditioning system, and then close the window; or could arrange for the construction unit to avoid class hours, and then open the window to maintain natural ventilation [1].



Total heat exchanger control logic

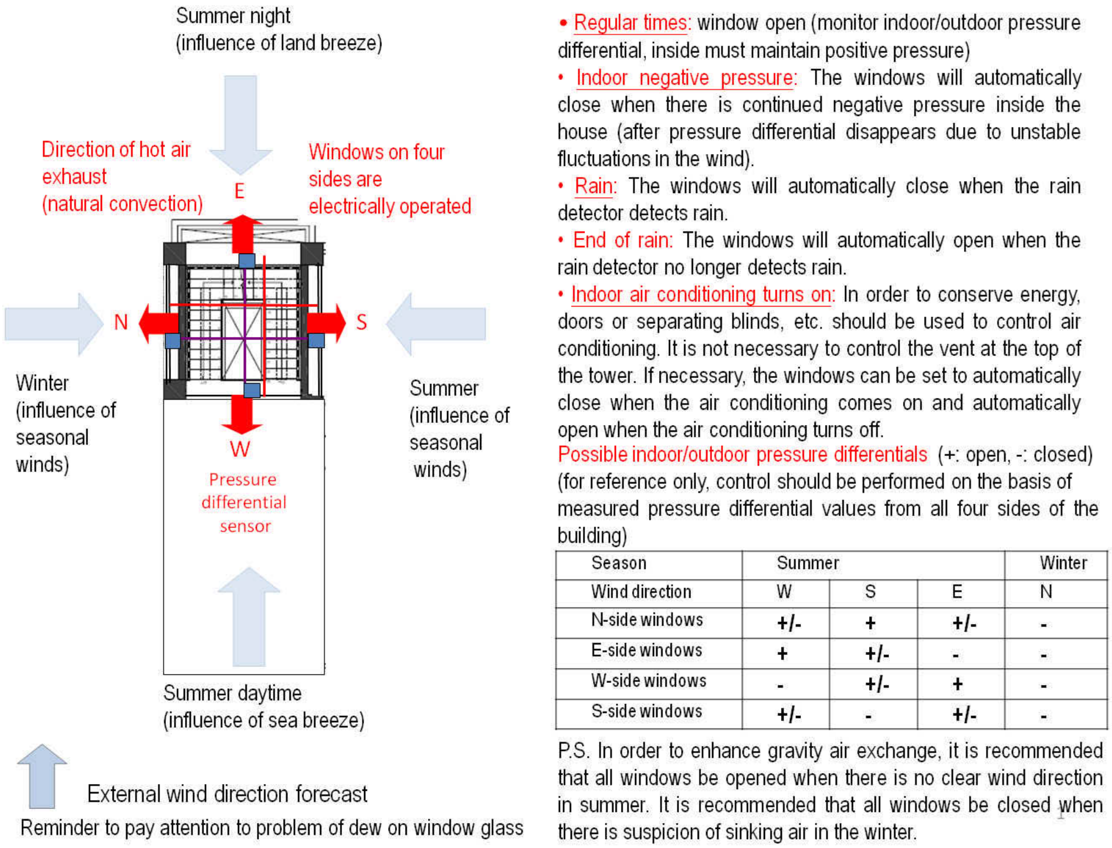
Mode	Triggering condition/action	Release condition/action	Operating frequency
Total heat exchanger control logic	(CO>xxx ppm) or (CO2>600 ppm) Action: turn on total heat exchanger	(CO<xxx ppm) and (CO2<500 ppm) Action: turn off total heat exchanger	Monitor once every half hour

Vent control logic

Priority/mode	Triggering condition/action	Release condition/action	Operating frequency
1. Special mode (strong wind/heavy rain/too hot/too cold	(outside wind speed>18 m/s) instantaneous Or Rainfall>0 Or (outdoor temperature<15°C) or (outdoor temperature>28°C Action: close all vents	(outside wind speed<17 m/s) average and (cumulative rainfall≦0 mm) and (average outdoor temperature>16°C) and (outdoor temperature<27°C) Action: switch to pressure differential mode	Triggering conditions real-time monitoring Release conditions Monitor once every one hour
2. Pressure differential air exchange mode	Depending on direction (average outside pressure>average inside pressure Action: close vents Depending on direction (average outside pressure<average inside pressure Action: open vents	N/A	Monitor once every half hour

Red items indicate adjustable parameters.

Tab. 1: Control logic for thermal buoyancy ventilation tower vents (Networks and Multimedia Institute, Institute for Information Industry).



- 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.

Fig. 3: Explanation of ventilation tower vent control method.

With regard to the development of "intelligent buildings," the evolution of sensing, computing, and communication technology has caused changes in the development of intelligent buildings and the intelligent building concept. According to the Taiwan Architecture & Building Center, an intelligent building refers to the installation of a building automation system (BAS) in a building and on its site, where the BAS integrates ergonomic, physical environmental, operating format, and management format in conjunction with architectural space and building elements, and thereby automates operation, maintenance, and management of electrical, telecommunications, water supply and drainage, air conditioning, fire prevention, theft prevention, and transportation equipment systems and spatial utilization. This can improve building functionality in quality, achieving the goals of architectural safety, health, energy conservation, convenience, and comfort. The basic constituent elements of a smart building include (1) building automation system equipment, (2) building use space, (3) and the building operating management system [8]. Nevertheless, the government's 1990 building automation policy [8] primarily favors automation of large buildings and facilities; this paradigm involves large central processing and control systems and various types of active electronic mechanical facilities. To date, the implementation of "smart living spaces" emphasizing the application of personal mobile equipment employing computer networks and pervasive computing is evolving into a focus on "intelligent green buildings" promoting energy conservation and low carbon emissions; intelligent green buildings emphasize the application of environmental sensing and monitoring technology in order to enhance green design performance.

The following section uses the example of the intelligent design of thermal buoyancy ventilation towers to explain how intelligent green architecture can use a building's intelligence to coordinate the complex and contradictory needs of the manager and environment or environmental factors, and thereby achieve the goal of "greenness."

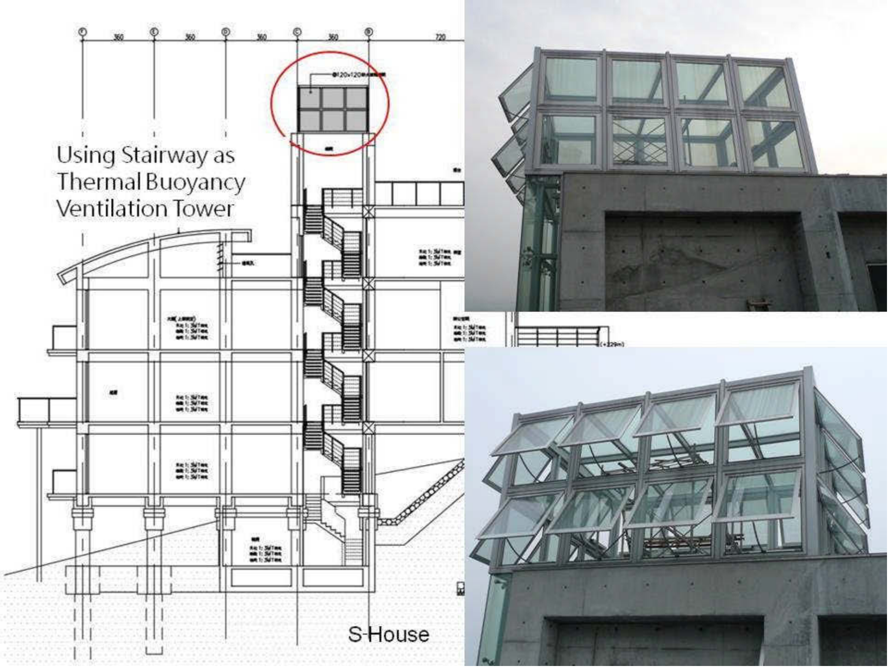


Fig. 4: Actual view of the S-House (Chen Cheng-hsiung Architectural Office).

3 PRACTICAL IMPLEMENT: EXAMPLE OF INTELLIGENT DESIGN EMPLOYING THERMAL BUOYANCY VENTILATION TOWERS

Conforming to the principle of passive design, the practical S House project uses staircases as thermal buoyancy ventilation towers (Fig. 1). Under ideal circumstances, due to thermal buoyancy, hot air from inside the house enters the ventilation towers via the staircases, and escapes through vents at the top of the towers. However, in real world situations, the outdoor wind pressure may be greater than the indoor air flow pressure, causing air flow to reverse, and preventing air from escaping. The application of air pressure difference sensors (Fig. 2) and computing technology can enable the ventilation towers to control the vents at the top of the towers. Accordingly, when the ventilation towers have negative pressure compared with the outside air, the system can open or close vents pointing in different directions (Fig. 3), ensuring that the air flow in the towers maintains positive pressure and outside air has negative pressure, enabling hot air inside the house to easily escape. The intelligent design of thermal buoyancy ventilation towers employing sensors and computing technology allows the system to actively correct "exceptions" in the ventilation action of the passive thermal buoyancy ventilation towers [2]. Apart from this, the question of whether to open the vents of the thermal buoyancy ventilation towers often perplexes users. For instance, when the pressure difference is normal (i.e., there is positive pressure inside the towers), the vents should be opened, and if it is raining hard outside, or if there is an abnormal pressure differential (i.e., there is negative pressure in the towers) the vents should be closed; but if there is an excessively high, or even life-threatening, CO2 concentration inside the house, the vents must certainly open. When more than one of these types of abnormal conditions occur at the same time, the decision to open or close the vents may be difficult. In these circumstances, how should logic controller respond? Table 1 displays feasible solutions when the foregoing contradictory situations occur. When the CO2 concentration is excessively high, apart from opening the vents, the system should also activate a total heat exchanger, which will actively bring in fresh air from outside to improve indoor air quality. The control of the vents includes special mode and ordinary mode (pressure differential ventilation mode), and the control logic specifies that the special mode has greater priority than the ordinary mode. In the special mode, the order of priority is high wind > heavy rain > too cold/too hot. Apart from control based on window opening or closing conditions, release conditions, and changes in frequency parameter settings, the system can also accommodate home users' habits, and can make adjustments based on climate change experience values. Fig. 4 displays the implementation results for the practical S House case and actual records.

4 DISCUSSION AND RECOMMENDATIONS

The intelligent green architecture advocated in this study can coordinate the complex and contradictory needs of the manager and environment or environmental factors, and thereby achieve the goal of "greenness." The following practical guidelines are recommended:

(1) Intelligent green architecture is based on passive architectural design, and employs supplementary intelligent functions. Greenness is the goal, and intelligence is the method. Intelligent functions are employed in a supplementary role to make up for deficiencies in a building's passive design.

(2) Future outlook: Motivated by the need to enhance the competitive advantage of Taiwan's existing ICT industry and in response global environmental trends, the Taiwan Power Co. plans to deploy intelligent meters, establish the Advance Meter Institute (AMI), and ultimately create an intelligent grid during the period of 2016-2021 [4]. With an intelligent grid and intelligent meters as a basic infrastructure, building/residential energy management system (EMS) can be employed to properly manage energy and achieve the goals of energy conservation and carbon emissions reduction. This is a feasible pathway by which information and communications technology can be used to achieve the intelligent green architecture defined above.

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5 REFERENCES

[1] Chen Shang-yuan, 2007. The study of applying agent-based theory to adaptive architectural environments－Smart skin as an example, Paper identification no. etd-0823107-160830, National Cheng Kung University doctoral dissertation, 179 pages.

[2] Chen, N.T., C. M. Chiang, C. H. Chen, Y Hsieh, C. Y. Kao, S.Y. Chen, W. J. Wang, 2005/ 0927-0929, The Case Study of Sustainable Healthy Housing Fitting in with Subtropical Taiwan's Climate and Geography, The 2005 World Sustainable Building Conference in Tokyo, Proceeding of SB-05 Tokyo, CD-ROM, No. 06-030, pp 2280-2287

[3] Ken Yeang, 2004, The skyscraper bioclimatically consideration: A design primer, ISBN: 986-7897-99-4, Walkers Culture, pp8, 155, 204

[4] Su Yu-lin (ed.), (8/2009), The bright future of network communications; finding new opportunities for growth, Topology Research Institute, pp83-92

[5] Executive Yuan, 12/12/2009/, Premier Wu: Strengthening research and development of an intelligent green construction industry, promotion of industrial reform and improvement of living, http://www.ey.gov.tw/ct.asp?xItem=65001&ctNode=1435&mp=1

[6] Executive Yuan 3173rd conference，2009/12/03，http://www.ey.gov.tw/ct.asp?xItem=65023&ctNode=1230

[7] Executive Yuan 3164th conference，2009/12/10，http://www.ey.gov.tw/ct.asp?xItem=65207&ctNode=1230

[8] Taiwan architecture & building center, 2011, http://iblogo.tabc.org.tw/ibsm/p-1.aspx

[9] The Australian Government and the design and construction industries, Passive Design, Your Home Technical Manual, http://www.yourhome.gov.au/technical/fs41.html