International Journal of Advances in Computer Science & Its Applications– IJCSIA
Volume 5: Issue 1 [ISSN : 2250-3765]
Publication Date : 30 April, 2015

A Composition of Monitoring System for Environmental Comfort Performance of Korean Traditional Residence

[Tae-Ryong Kim, Kyoung-Hee Kim, Seulki Kim and Seung-Hoon Han]

***Abstract*—The purpose of this study is to suggest a composition of the sensor network and smart device for evaluation system for integrative comfort performance. For this study, the degree of integrative comfort was analyzed and comfort performance has been classified. Comfort performance was divided into two large comfort performance categories: physical and psychological. For this research, survey data from residents were collected for evaluating psychological comfort, while it is necessary to acquire both survey data and environmental data measured by sensors to evaluate physical comfort. This study has proposed a monitoring system that can measure the indoor environmental condition and survey from residents as well. As a result, it is turned that the proposed system would have a pretty good applicability to the field.**

***Keywords*— Comfort Performance, Evaluation System, Degree of Integrative Comfort, Sensor network**

I. Introduction

Currently, Post-Occupancy Evaluation (POE) is one of common research methods to investigate the degree of satisfaction for environmental factors from residents. However, POE can be performed at specific time when residents are staying in the room. Therefore, the long-term analysis is hardly available for simultaneous situation. Commonly, residential time is vary various, and some people spend their time in their settlement for short time while other don't. So thinking of new method for long-term analysis of the residential comfort is essential. Established indoor circumstance monitoring system is almost physical value based sensors so far. But fundamental comfort is made of combination of physical and psychological comforts. Therefore, various factors are needed to measure integrative environmental comfort performance.

This study proposed an Integrative Environmental Monitoring System (IEMS). The IEMS can help the process of POE and also makes possible to perform occupancy evaluation through building performance analysis. To build the suggested system, it is necessary to set the test module as a Korean traditional residence which is built as Hanok in Korea.

Tae-Ryong Kim[1], Kyoung-Hee Kim[2], Seulki Kim[1] and Seung-Hoon Han[1]*
[1] School of Architecture, Chonnam National University, Korea
[2] School of Architecture, University of North Carolina at Charlotte, USA

II. Scope and Method of Research

A. *Scope of Research*

This study has set the test unit as a Korean traditional house located at Myoungji University, in Youngin, Korea. The size of the target has been planned as a two-story house. In the house, there are three rooms and two bathrooms and first foor is $81m^2$ and second floor is $45m^2$. In addition, actual residents are living for providing survey answers.

Figure 1. Test Module of Evaluation System for Investigating Environmental Performance (Yongin, Gyeonggi-do, Korea)

With setting test module as a Korean traditional house, special psychological comfort factors have been indexed. Most factors have been induced from previous cases and researches. Those factors will be collected by each device and the estimated information of them will used for evaluation of integrative environmental comfort performance.

B. *Research Methods*

The purpose of this study is to investigate the varies factors for environmental comfort performance such as individual characteristics and lifestyle, social elements and so on, just as the post occupancy evaluation. Hanok style shown from Korean traditional residence has differences from the western housing for structure, space organization, and design as well. But, previous studies seemed only efforts to improve structural efficiency or to suggest design application for modern buildings. Those mostly handle alternative materials on the finishing and openings to cover disadvantages of the original

Hanok component[1], but still tend to be lack of approaches in the integrated improvement and/or eco-friendly effectiveness.

This paper proposes a monitoring system for determining environmental comfort performance indicators including rating systems by residents' responses for thermal comfort that is known as predicated mean vote of Hanok residence. For this study, a spatial environmental network measuring the thermal condition in the living space has been utilized to collect various information such as indoor temperature, relative humidity, airflow velocity and mean radiant temperature in combination with human metabolic status and clothing insulation. These data have simultaneously been gathered from different channels assigned from mobile devices own by the residents.

The physical comfort factor has various data type. So we should classified the comfort factor into two parts for convenience of experiment. The first one is smart sensors and data from those sensors were used to analyze the predicted mean vote values. The second one is eco-sensors and data from eco-sensors can evaluate the degree of eco-friendly indoor environment. These two sensors were not enough to analyze the above values. Figure 2 shows the requirement of sensing thermal comfort values, and network server was to be built to obtain clothing status and metabolic status.

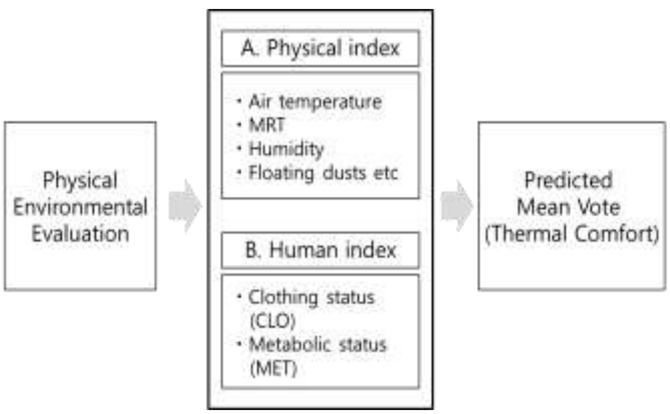

Figure 2. Evaluation for Environmental Comfort

This research has tried to combine resident monitoring for more concrete comfort performance analysis. By this way, residents can send sensuous responses acquired from the interior space psychologically and select the answers survey questionnaires about psychological comfort value of Hanok residence in order to calculate comprehensive qualitative comfort indexes as shown on Figure 3. The survey is constructed to gather the information and opinions about the psychological comfort values that affects residents from the indoor environment. Its forms are also provided with Web pages and smart phone applications to help residents respond in real-time in case the event occurs.

[1] Ahn, E. and Kim J., Computational Analysis of Air Flows Inside Korean Traditional House, Multimedia Institution, 2012.

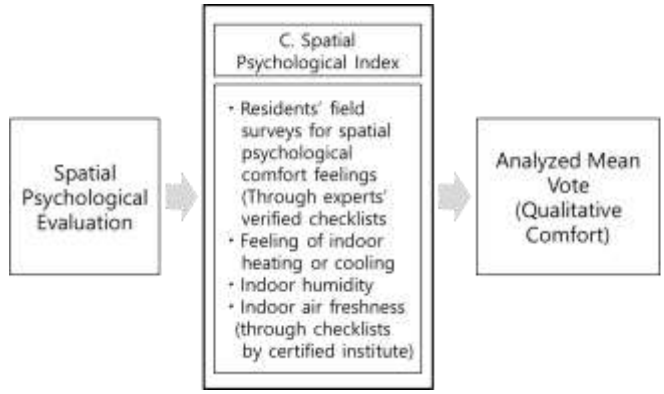

Figure 3. Evaluation for Spatial Psychological Comfort

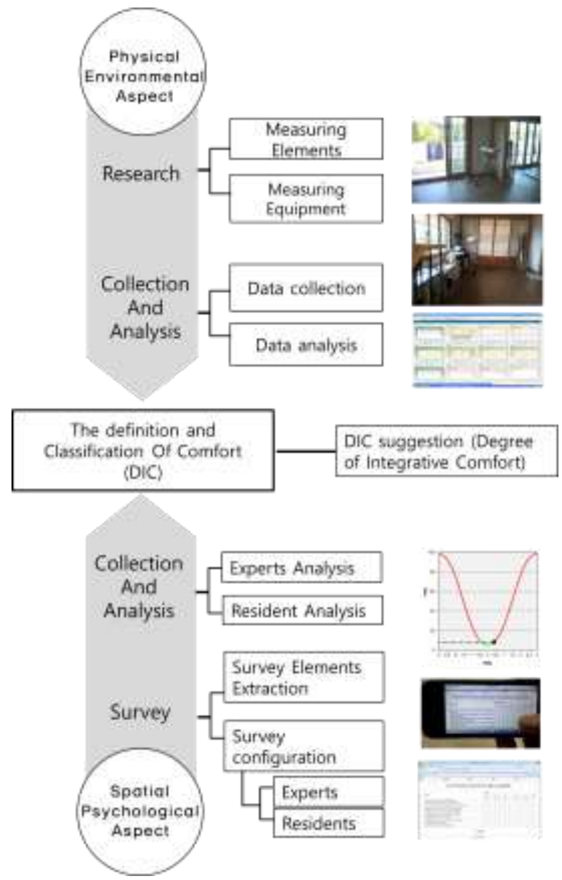

Figure 4. Process of Integrative Comfort Analysis

Environmental factors such as temperature, humidity, airflow, and mean radiant temperature were measured monthly and compared per season. Integrated environmental data was applied with range and score for the predicted mean vote, it shows monthly predicted mean vote measured in traditional residence and modernized residence. In order to calculate psychological comfort value of Hanok residence, psychological factors were classified according to itemized standard and survey result based on standard was calculated the average and accumulated percent. The relative importance was accord to each articles.

International Journal of Advances in Computer Science & Its Applications– IJCSIA
Volume 5: Issue 1 [ISSN : 2250-3765]
Publication Date : 30 April, 2015

III. Deployment of Monitoring System for Environmental Comfort

A. Sensor Network For the Evaluation of physical Comfort

Each sensor measuring one of IAQ factors sends the database server the collected information through a relay node too. This relay node doesn't have a function for gathering information, but is capable of measuring output information in the TCP/IP and/or UART channels similar to the above PMV case. All sensor nodes are assembled in a set of the single module for the convenience of installation and management in purpose. A relay node included in the module synthesizes information from all different sensors and sends the information to database server.

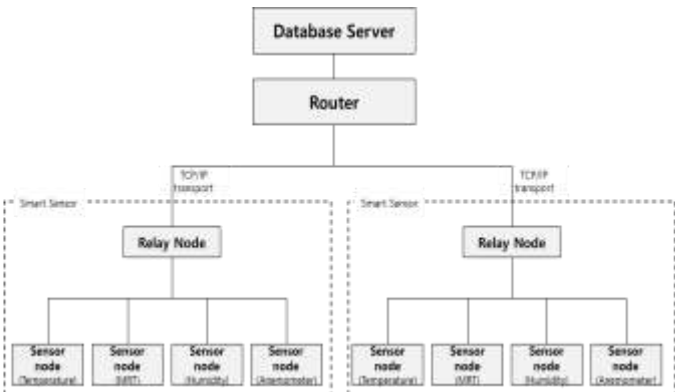

Figure 5. Composition of Smart Sensors

Figure 6. Position of the Smart and Eco Sensors

Indoor temperature, relative humidity, air flow rate sensors and relay node that can transfer information to analyzable data are became a one module placed in each room for indoor-generated data. Other eco-sensors became another module that each sensor was modularized by collected data type. Modularized sensor are also placed in the rooms. Figure 6 show position of the modularized sensors.

TABLE I. SPECIFICATION OF SENSORS

Sensor			Specification
Smart Sensor	Temperature		Range : -40℃ ~ 120%℃(max) Accuracy : ± 0.3℃ Response time : <4 Sec Power Consumption : 30μW
	Mean Radiant Temperature (MRT)		Range : -55℃ ~ 125%℃ Accuracy : ± 0.5℃ Response time : 750ms(Max) Supply Voltage : 3 ~ 5.5V
	Relative Humidity		Range : 0 ~ 100% RH Accuracy : ± 1.8% RH Reproducibility : ± 0.1% RH Response time : <4 Sec Power Consumption : 30μW
	Anemometer		Range : 0 ~ 30m/s, 0~50℃, 0~10,000m^3/h Resolution : 0.01m/s Unit : m/s, fpm, ℃, °F, m^3/h, L/s, cfm Output : 2×4-20mA, 2×0-10V Omni-directional Flow Measurement
Eco Sensor	CO		Analog sensor Range : 0 ~ 500ppm Supply Voltage : DC 12V ~ 30V Output Voltage : 4mA(zero gas) 20mA(Full scale) Digital Supply Voltage : DC5V Output Voltage : TTL (3V Level)
	CO_2		Range : 400 ~ 2000ppm Accuracy : 500ppm = ± 35ppm 800ppm = ± 60ppm 1000ppm = ± 75ppm 1200ppm = ± 90ppm Response time : < 2 min(Start-up) < 10 min Supply Voltage : 5VDC(±5%) Non-Dispersive InfraRed
	Dust		Range(Density) : 0 ~ 2.0mg/m3 Range(Particle Size) : 1μm more Detection method: Optical detection Supply Voltage : DC 5V Output type : Negative Logic Pulse Operation Rage : 10 ~ 45%, 95%RH less
	VOCs		Range : Toluene 0 ~ 75(max) Formaldehyde 0 ~ 75(max) Accuracy : ±7% Detection of the target : Formaldehyde, Toluene, Benzene, Xylene, ect. Supply Voltage : DC 5V(±1%)
	NOx		Range : 200ppm(max) Accuracy : ±10% Supply Voltage : DC 5V(±1%) Output Voltage : 0.5 ~ 5.0V

B. *Evaluation for Integrative Environmental Comfort Performance*

The measuring method limited to the physical thermal environment might make a serious omission of spatial psychological factors which are considered as the advantages and the positive values of the Hanok residence in aspect of comfort performance evaluation. For this reason, this research has tried to combine resident monitoring for more concrete comfort performance analysis. By this way, residents can send sensuous responses acquired from the interior space psychologically and select the answers survey questionnaires about psychological comfort value of Hanok residence in order to calculate comprehensive qualitative comfort indexes.

The temperature sensor can measure -40℃ to 120℃ and its tolerance is ± 0.3℃. This sensor can respond within four seconds and the power consumption is only 30μW. Mean Radiant Temperature (MRT) sensor can estimate -55 ℃ to 120℃ and its tolerance is ± 0.5℃, and the response time is 750ms. And, relative humidity sensor can measure between 0% and 100% RH and its tolerance is ± 1.8RH. The measuring range of the anemometer sensor s is 0 to 30m/s and it is omni-direction sensor. These sensors are components of Smart Sensor Module (SSM) and measured values from them are used for PMV analysis. Data from the questionnaires are also applied for the PMV analysis as well. The highest PMV score is -0.5 to 0.5 and detailed information is shown in table II.

TABLE II. EVALUATION STANDARD OF PMV VALUES

PMV Range	-0.5~0.5	-1.0~1.0	-1.5~1.5	-2.0~2.0	Under/ Excess 2.0
Measure Score	10	8	6	4	2
PPD (Predicted percentage of dissatisfied)	Under 10%	Under 25%	Under 50%	Under 75%	Under 100%

Otherwise, additional data are measured and collected by Eco-Sensor Module (ESM) and saved in a database server. Those can be monitored simultaneously with data from SSM, and evaluated for integrative comfort analyses. CO sensor can measure 0 to 500ppm and its recommended optimal standard is 10 to 20ppm. CO2 sensor can measure 400 to 2000ppm and its tolerance is 35ppm to 90ppm. 1000ppm or less falls into the comfort range in aspects of CO2. I addition, dust sensor can measure 0 to 2.0mg/m3 and 1 μm or greater matches within the standard. This sensor uses optical detection as its critical algorithm and the output type normally shows negative logic pulse. The comfort range of dust should be under 150 μg/m3. Measurement range of NOx sensor is 0 to 200ppm and its accuracy has to be within ±10%, and the recommended range is 0.05 to 0.3ppm. VOCs sensor can measure inclusion ration of Toluene, Formaldehyde, Benzene, Xylene and so on, and its tolerance is ±7%. The specification of evaluation standard is shown in table III. VOCs evaluation criteria for Hanok follows the New Apartment House Indoor Air Quality Guideline published by Korea Government and other factors refers Multiuse Facility Indoor Air Quality Based Maintenance.

TABLE III. EVALUATION STANDARD OF SENSORS

Measure Element	CO	CO_2	Dust	NOx	VOCs				
					Benzene	Toluene	Methyl Benzene	Xylene	Styrene
Quality Guideline of Concentration	10 ~ 20 ppm	1000 ppm	150 μg/m³	0.05 ~0.3 ppm	30 μg/m³	1000 μg/m³	360 μg/m³	700 μg/m³	300 μg/m³
Relative Standard	Multi-use Facility Indoor Air Quality Based Maintenance				New Apartment House Indoor Air Quality Guideline				

The comfort factor for a residential performance would be able to be easily identified everywhere by the IEMS. Predicated mean vote are calculated by collected environmental data for thermal comfort analysis and qualitative factors from the residents could also be examined by AHP (Analytic Hierarchy Process) analysis simultaneously. The AHP analysis is normally used with unequal sample sizes, and its critical value is the degrees of freedom for a variety of opinions that can be different badly each other among residents with possibly modifiable answers for environmental comfort in the same condition by the same routine.

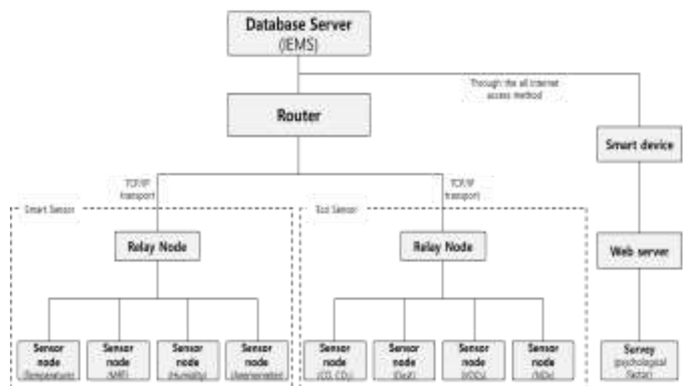

Figure 7. Composittion of Environmental Comfort Monitoring System

IV. Conclusion

The purpose of this study is to suggest a composition of the sensor network and smart device for evaluation system for integrative comfort performance. For this study, the degree of integrative comfort was analyzed and comfort performance has been classified. Nine Sensors modularized and placed in the test module as shown on Figure 7 and survey was actually proceeded. The measured values were saved in a database server. The database server evaluates each comfort factor and combines the comfort values, and the values finally can be monitored in real-time.

In particular, IEMS could be implemented to synthesize sensor data and send them to database server for gathering information to evaluate physical environmental comfort performance. This way can be adaptable in and extensible to more various types of housing step by step. In addition, the data gathered through network-based applications are more accurate and effective than previous data acquired from the stand-alone sensing devices, especially for the spatial environment, because both residents and examiners can connect all required information including questionnaires and completed responses anytime by using mobile devices in real-time.

As a result, it is turned that the proposed system would have a pretty good applicability to the field. And the integrate comfort values can be calculated with tolerances for 66.7% physical comfort and 33.3% psychological comfort. However, additional yearly data will be required to be settled as a meaningful evaluation data. Nevertheless, the suggested monitoring system will have high values in terms of utilization as a post- occupancy evaluation.

Acknowledgment

This research was supported by a grant (G01201406010105) from Standardization Research Program (Development of Korean Standard Technology) funded by Korean Agency for Technology and Standards under Ministry of Trade, Industry and Energy of Korean government.

References

[1] S. Han, O. Im, M. Lee and D. Cheon, "A Study on the Establishment of an Evaluation System for Integrative Comfort Performance of Korean Traditional Residence," Journal of the Korean Housing Association, vol. 24, no.3, pp. 27-35, June, 2013.

[2] G. Cho, "Decision-Making by Analytic Hierarchy Process for Leaders," Euijeongbu, Donghyun Publication Co., 2003.

[3] S. Cho and N. Kang, "A Study on the Evaluation Indicators of Healthy Housing Quality of Multi-Family Housing," Journal of Korean Housing Association, vol. 22, no. 1, pp.43-55, 2011.

[4] S. Jung and J. Seo, "A Study on the Visual Characteristics of New Material for Emotional Housing Space Design," Journal of Korean Housing Association, vol. 23, no. 3, pp. 71-78, March 2012.

[5] Y. Kwon, "A Consumer Research for NEO-Hanok Maeul, Korean Traditional Style Village," Journal of Architectural Institute of Korea, vol. 26, no. 11, pp. 97-106, 2010.

[6] Y. Kwon, W. Um and H. Kim, "A Design Guidelines for NEO-Hanok Maeul, Korean Traditional Style Village," Journal of Architectural Institute of Korea, vol. 27, no. 3, pp. 39-50, 2011.

[7] S. Min, K. Byun and T. Kim, "A Study on the Attractive Items of Hanok in Urban Area - Focused on Preceding Studies," Proceedings of Architectural Institute of Korea, vol. 32(1), pp. 91-92, 2012.

[8] S. Min and T. Kim, A Study on the Attractive Items of Hanok in Urban Area focused on Preceding Studies, Journal of Korean Institute of Rural Architecture, vol. 14, no. 3, pp. 61-68, September 2012.

[9] S. Kim, Y. Chang, J. Kang and S. Han, "Implementation of the Wireless Smart Sensor Network for Spatial Comfort Performance of Hanok Residence," Proceeding of the 7th International Conference on Anti-counterfeiting, Security, and Identification (ASID 2013), pp. 44-47, Shanghai, China, 2013.

[10] E. Ahn and J. Kim, "Computational Analysis of Air Flows Inside Korean Traditional House," Multimedia Institution, 15(3), 2012.

About Author (s):

Tae-Ryong Kim
- Master's Program, School of Architecture, Chonnam National University in Korea.
- Research Interests: Architectural Design, Integrative Design, Architectural Energies and Performance Engineering

Kyoung-Hee Kim
- Professor, School of Architecture, University of North Carolina Charlotte, USA.
- Research Interests: Architectural Planning, Integrative Design, Building Sustainability and Performance Engineering

Seulki Kim
- Master's Program, School of Architecture, Chonnam National University in Korea.
- Research Interests: Architectural Planning, Integrative Design, Exhibition Planning and Performance Engineering

Seung-Hoon Han
- Professor, School of Architecture, Chonnam National University in Korea.
- Research Interests: Architectural Design, Urban Planning, Building Information Modeling and Performance Engineering