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Description Method of Outdoor Climate Characteristics Considering the Comprehensive Effect on Indoor Climate

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ABSTRACT
What human and buildings perceived the environmental information is comprehensive information. However, existing indoor environment design methods are often simplified to single parameters for indoor and outdoor environmental prediction and indoor environment design. In order to describe the indoor climate characteristics of the comprehensive impact of outdoor climate, this study uses the ensemble empirical mode decomposition (EEMD) method to establish a multi-parameter integrated outdoor comprehensive environmental information description method based on the information-response theory. The outdoor climate feature description method is applied to the analysis of the amplitude and frequency characteristics of outdoor comprehensive information, which provides a research basis for further exploring the indoor and outdoor environmental response under the multi-parameters interaction.

KEYWORDS
Feature extraction; natural information; information-response; comprehensive parameters.

INTRODUCTION
Indoor and outdoor environmental status points are formed under the influence of multiple parameters. Due to the limitations of the test instrument, we can only test a single parameter, but can't acquire a comprehensive environmental parameter. Under this condition, the information transfer process between the indoor and outdoor environments is described by constructing the heat and mass transfer equations. However, it is difficult to simulate building information response combined heat, air, moisture and pollutant simulation environment for whole-building performance analysis (Tariku F et al. 2010). This paper put forward building environment information analysis method transformation from single parameter to comprehensive parameters. In order to build a comprehensive parameter, this paper attempted to combine multi-parameters by EEMD for feature extraction.

BUILDING ENVIRONMENT INFORMATION ANALYSIS METHOD TRANSFORMATION
All of the orderly linear transfer laws of heat, mass, and fluid can be described using Fourier's law. Based on the above rules, the heat conduction equation, mass diffusion equation, etc. can be derived. However, these linear conduction laws are only correct when the mass and energy transfer processes are not strong. When the transfer process is very strong, it is necessary to consider the interaction between mass and heat transfer. However, the building mass and heat transfer process is actually a strong transfer process. When the steady-state solution equation is used to solve the mass and heat transfer process of a building, it often brings about a large error in simulation calculation. Onsager (1931) put forward the fluxes as linear combinations of the forces, in analogy to Stokes law where the velocity of a body pulled in a viscous fluid is proportional to the drag force. According to Onsager, a thermodynamic system can then be described by a set of linear equations, as shown in Eq. (1).

$$
\begin{aligned}
I_1 &= L_{11}X_1 + L_{12}X_2 + L_{13}X_3 + L_{14}X_4 \\
I_2 &= L_{21}X_1 + L_{22}X_2 + L_{23}X_3 + L_{24}X_4 \\
I_3 &= L_{31}X_1 + L_{32}X_2 + L_{33}X_3 + L_{34}X_4 \\
I_4 &= L_{41}X_1 + L_{42}X_2 + L_{43}X_3 + L_{44}X_4
\end{aligned}
\tag{1}
$$

where I_i is the conjugated thermodynamic fluxes, L_{ij} is symmetric matrix, X_i is the different force.

The above equation has showed that the state point of the outdoor environment was formed by the coupling of multiple factors. The same process exists in human thermal comfort and free-running building. Because of the complexity of solving the above equation, we generally use the theory of reductionism to decompose the overall information transfer process of the building into a single parameter response process. Under such a theoretical system, we have established a series of prediction model for the building thermal transfer, moisture migration, pollutant diffusion and so on. However, some researchers (Hens 2015; Zhang et al. 2017) found that the single parameter transfer process was influenced by other parameters. Therefore, researchers began to try to establish a coupled prediction model with two or three parameters (Kumaran et al. 2008). Due to the influence of factors such as multi-parameter interactions, personnel behaviour, cultural background, and architectural control methods during the actual operation of the building, it is difficult to couple multiple parameters to solve the problem (Zhang & Qin 2011). Therefore, this study proposed that if the outdoor multiple parameters could be converted into a single comprehensive information, the information transmission process of the building can be simulated, as shown in Figure 1.
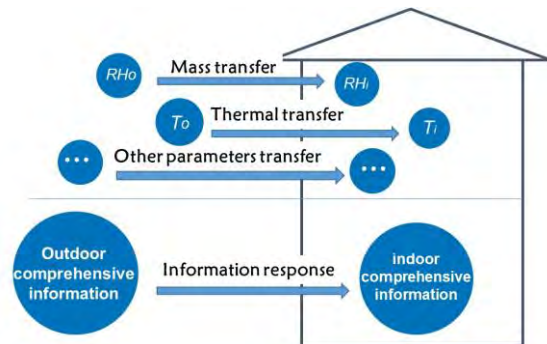

Figure 1. A schematic diagram of the information response of a building.

INFORMATION FEATURE EXTRACTION METHOD

The outdoor comprehensive information contains multiple parameters such as temperature, relative humidity, solar radiation, wind speed, dew point temperature, vapour pressure, etc. The existing integrated information theory description model mainly establishes the integration of several parameters, such as the PMV index and Universal Thermal Climate Index (UTCI) (Fiala et al. 2012). In addition to the theoretical model, there are some relational models in Chinese traditional culture to analysis the outdoor environment and human health, such as Jiugong Bafeng (Xinying Fan et al. 2017). However, it is difficult to establish a comprehensive information description method for the above model. Chinese people have always believed that there are certain differences in outdoor comprehensive information at different times. The 24 Solar Terms have been formed under the special climatic conditions in China, which is reflected in the basic necessities of life. It means the small-scale climate directly affects people's feelings. Meehl et al. (2001) proposed a conceptual model of multi-time scale coupling of outdoor climate, which means outdoor weather data could be decomposed into different time-scale information for analysis. It provided a certain theoretical

basis for the Chinese to experience climate change on a small time scale. Due to the different time scale characteristics of the outdoor environment parameters, it is very important to choose an appropriate feature extraction method. Norden E. Huang et al. systematically compared several common information decomposition methods, as shown in Table 1.

Table 1. Comparison between Fourier, Wavelet, and EEMD analysis

Characteristic	Fourier	Wavelet	EEMD
Basis	a priori	a priori	a posteriori adaptive
Nonlinearity	×	×	√
Non stationarity	×	√	√
Feature extraction	×	discrete, no; continuous, yes	√
Theoretical base	complete mathematical theory	complete mathematical theory	empirical

Compared with wavelet and Fourier analysis method, EEMD can not only analyze nonlinear problems, but also extract the features of information, such as climate data. Due to the advantages of EEMD in the feature extraction of outdoor meteorological parameters, it was used to analysis the feature of outdoor meteorological information in this study. The original single using the EEMD method can be decomposed into the sum from the high frequency to the low frequency components and the residual sequence. The residual sequence represents the trend of the original sequence, as shown in Eq. (2).

$$x(t) = \sum_{i=1}^{n} IMF_i(t) + r_n(t) \tag{2}$$

where $x(t)$ is the original single; $IMF_i(t)$ is the different frequency components; $r_n(t)$ is residual sequence (RES).

SINGAL ENVIRONMENT PARAMETER DESCRIPTION

The feature description process of a single meteorological parameter information mainly consists of three steps. This article takes the outdoor temperature in Zhengzhou, China, from 2014 to 2016 as an example.

(1) First, the outdoor air temperature in Zhengzhou was decomposed using the EEMD method to obtain 12 IMF and one residual sequence. Accumulation of IMF 1~IMF 5 below the time scale of the year gives the high-frequency component of outdoor temperature, ie, high-frequency (HF); Accumulation of IMF 6~IMF 12 at the time scale and above can produce the low frequency component of the outdoor temperature, ie, the periodic change sequence (PCS); summing the PCS and RES to obtain the annual low-frequency cycle (ALC), as shown in Figure 2.

(2) Second, by calculating the same day average of the ALC of meteorological parameters for the period 2014-2016, a 365-day smooth annual average cycle sequence ALC_{avg} is formed.

(3) Then, by fitting the annual average cycle sequence ALC_{avg}, Zhengzhou outdoor temperature information feature description model can be obtained, as shown in Eq. (3).

$$y = 13.694 + 14.05 * \sin(\frac{\pi(n - 96.131)}{199.234}) \tag{3}$$

where y is the temperature, °C; n is the number of the day starting from January 1 (e.g. for the 1st January, n = 1 and for the 31st December, n = 365); 13.694 was average temperature of Zhengzhou , °C; 14.05 is the amplitude of temperature, °C.
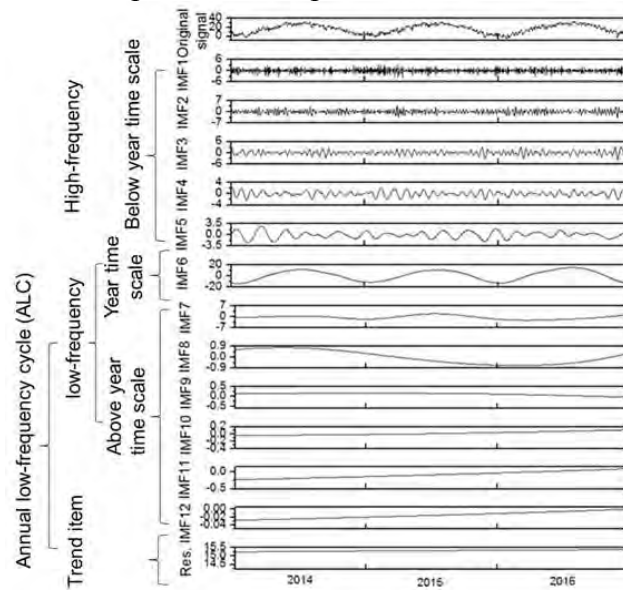

Figure 2. Feature extraction of outdoor temperature in Zhengzhou.

In addition to temperature, any other outdoor weather parameters can also be described as the above model. Through literature research, it is difficult to find the expression of outdoor climate parameters that represent a region. In order to obtain solar radiation mathematical formulas for use in computer software, several mathematical models are given below. Bulut (2007) presented a simple model using sine wave equation (SW) below to predict global solar radiation, as shown in Eq. (4). Kaplanis (2007) suggested the following cosine wave (CW) relationship, as shown in Eq. (5). Some researchers (Zang et al. 2012) presented a daily global solar radiation model in connection with a sine and cosine wave (SCW) correlation which is developed to simulate the long-term measured data as shown in Eq. (6). In the present study, we get solar radiation model by EEMD method in Zhengzhou, as shown in Eq. (7).

$$I = a + b \left| \sin(\frac{\pi}{365}(n+5)) \right|^{1.5} \tag{4}$$

$$I = a + b \cdot \cos(\frac{2\pi}{364} \cdot n + c) \tag{5}$$

$$I = a + b \cdot \sin(\frac{2\pi c}{365} \cdot n) + d \cdot \cos(\frac{2\pi e}{365} \cdot n) \tag{6}$$

$$I = 12.71 + 5.59 * \sin(\frac{\pi(n - 72.48)}{187.97}) \tag{7}$$

where I is the daily global solar radiation; n is the number of the day starting from January 1 (e.g. for the 1st January, n = 1 and for the 31st December, n = 365); a, b, c, d and e are regression coefficients of Zhengzhou, as shown in Table 2.

Table 2. The regression coefficients of different solar model in Zhengzhou

Model	a	b	c	d	e
SW	6.4235	11.678			
CW	12.9363	-5.7068	0.2944		
SCW	12.0955	4.1152	0.9500	-5.8501	0.8580

In this study, the Pearson correlation coefficient was used to analysis the relationship between predicted solar radiation and original data, as shown in Figure 3. The result showed that the EEMD model almost same as other models. However, the EEMD method could be used to other environmental parameters ie, outdoor temperature. Therefore, this study selected the indoor and outdoor temperature of a tested building in Zhengzhou to analyze the frequency characteristics. The testing time is February 12-19, 2015. Figure 4 shows that the building filters outdoor high frequency information (IMF1-IMF5). Low-frequency information (IMF6-IMF9) has a certain influence on the indoor environment. It means the building envelope filter many outdoor environment information which may be benefit for people.
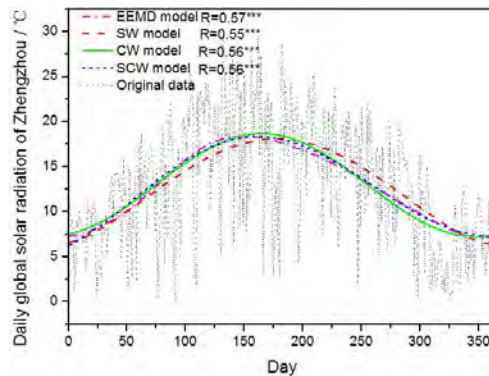

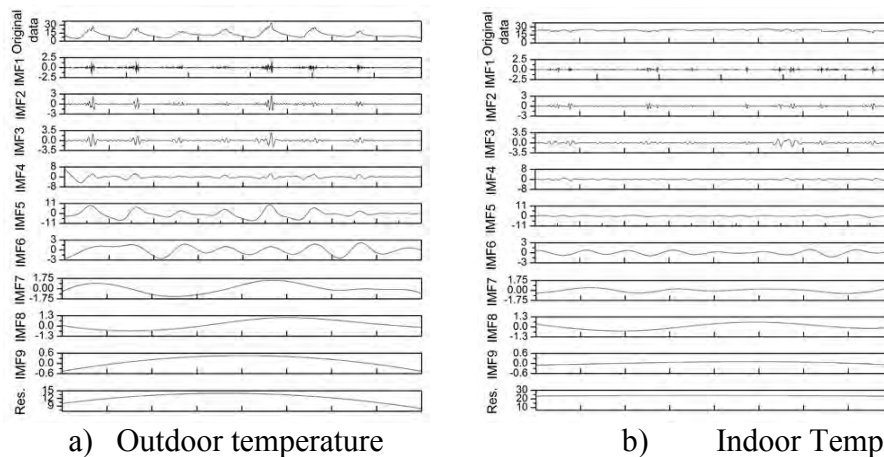Figure 3. Comparison of several solar radiation models of Zhengzhou.

a) Outdoor temperature   b)   Indoor Temperature

Figure 4. Comparison of indoor environmental information differences about temperature.

OUTDOOR ENVIRONMENT COMPRESIVE INFORMATION DESCRIPTION

The existing outdoor environment comprehensive parameters are generally described by establishing an equivalent temperature for people and buildings as objects. The environmental parameters considered are often limited. For example, the UTCI index takes into account four outdoor environmental parameters, and the outdoor integrated air temperature takes into account three outdoor environmental parameters. However, the outdoor environment parameters has more than four parameters. In order to describe the comprehensive parameters, this paper build a simple described formula by EEMD method, as shown in Figure 5. The weighting factors of the comprehensive environmental parameters refer to the weights of the meteorological factors during the typical meteorological year of TMY3. This formula expressed the frequency characteristics of the comprehensive ibformation of the outdoor environment. This study uses the EEMD method to attempt to describe the comprehensive information of the outdoor environment. It also needs further discussion. This study provides the basis for further research on environmental comprehensive information - response.
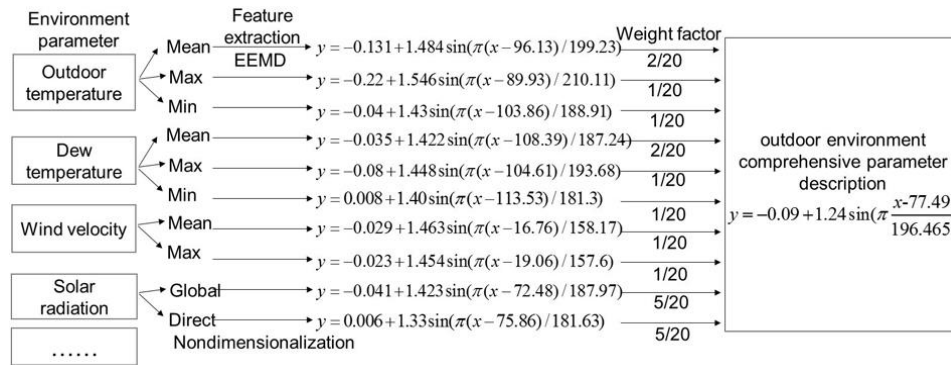
Figure 5. The outdoor environment comprehensive parameters formed process with EEMD.

CONCLUSIONS

This study proposed analysis method transformation of building environment information from single parameter to comprehensive parameters. Based on the conceptual model of multi-time scale, the described method of single outdoor meteorological parameter was put forward. This study has attempted to obtain the description method of outdoor comprehensive parameters considered weight factor in Zhengzhou region by EEMD.

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REFERENCES

Bulut, Hüsamettin, and Orhan Büyükalaca. 2007. Simple model for the generation of daily global solar-radiation data in Turkey. *Applied Energy*, 84(5):477-491.

Fiala D, Havenith G, Bröde P, et al. 2012. UTCI-Fiala multi-node model of human heat transfer and temperature regulation. *International Journal of Biometeorology*, 56(3):429-441.

Hens, Hugo L. S. C. 2015. Combined heat, air, moisture modelling: A look back, how, of help? *Building & Environment*, 91(9):138-151.

Kaplanis, S., and E. Kaplani. 2007. A model to predict expected mean and stochastic hourly global solar radiation values. *Renewable Energy*, 32(8):1414-1425.

Meehl, G. A., R. Lukas, G. N. Kiladis, et al. 2001. A conceptual framework for time and space scale interactions in the climate system. *Climate Dynamics*, 17(10):753-775.

Norden E. Huang and Zhaohua Wu. A review on Hilbert-Huang transform: Method and its applications to geophysical studies[C]// Rev. Geophys. 2008.

Onsager, Lars. 1931. Reciprocal Relations in Irreversible Processes. I. *Physical Review*, 38(37):405-426.

Tariku F, Kumaran K, Fazio P. 2010. Integrated analysis of whole building heat, air and moisture transfer. *International Journal of Heat & Mass Transfer*, 53(15):3111-3120.

Xinying Fan, Bin Chen, Yu Chen et al. 2017. Relationship between seasonal variation and occupant health based on nine-palaces and eight-winds theory. *Healthy Buildings 2017 Europe*, Lublin, Vol. 3, pp. 63-68.

Zang, Haixiang, Qingshan Xu, and Haihong Bian. 2012. Generation of typical solar radiation data for different climates of China. *Energy*, 38(1):236-248.

Zhang J J, Qin M. 2011. Combined heat, air moisture and pollutant simulations (CHAMPS) for buildings. *Building Simulation*, 4(4):279-282.

Zhang M, Qin M, Rode C, et al. 2017. Moisture buffering phenomenon and its impact on building energy consumption. *Applied Thermal Engineering*, 124(9):337-345.