Exergy House for well-being, development, and healthy longevity in a smart community

Shun Nakamura

Tokyo University of Agriculture & Technology, CorLab Inc.

Abstract: We stay more than 80% of our life time in building environment. However, most of the buildings in megacities are designed as thermally closed systems, where the room temperature is regulated at a constant level. This situation has raised high energy demand and health issues like cooling-syndrome after staying long time in the air-conditioned room in summer time. We developed an exergy meter that can visualize exergy consumption. We integrated information captured by a body-environment sensor network system and implemented an algorithm to evaluate exergy consumption, well-being, and health (Bouquet method). This exergy meter linked to AI_IoT may support not only well-being, but also child development and healthy longevity in a future smart community.

Key-Words: *Built Environment, Exergy, Health, Multi-sensor Network, Bouquet Analysis*

1. Introduction

The issue on Energy and Global Environment has raised the fundamental concern about future development of built-environment by advancement of both active and passive system technologies. Human body has evolved to find a balance of the active (central nervous-voluntary muscular) and passive (autonomic nervous-involuntary muscular) system with low exergy consumption (the ability of energy to disperse into environment) [1]. Here, we have developed an exergy-meter to visualize and regulate built environment in terms of exergy consumption.

2. Method

2.1 Sensor network system

A sensor network consists of a time-synchronized thermocamera and visual camera developed in house with low price, an environment sensor unit (air-pressure, air temperature, radiation temperature, humidity, color temperature) developed also in house, and a microwave sensor (Mio-Corporation, Sagamihara, Kanagawa). All the sensor information was transported to a miniPC (Intel NUC 5250U) either through USB (in house thermo-visual camera), 920MHz (ARIB STD-T108/IEEE802.1, in house environment sensor unit), or Bluetooth version 2.1(Mio-Corporation).

2.2 On line computation

The sensor information was further processed, used for computing Exergy parameter according to Annex49 [2] and multivariate correlation (principal component analysis, PCA) [3] using in house software (C#).

3. Result

3.1 Comparison of exergy consumption in two built environments

We collaborated with Chiba University to understand built environment from exergy viewpoint. A student team of Chiba University participated the Energy-management house competition (Enemane2014) in January 2014 at Tokyo Big site and the Solar Decathlon Europe 2014 (Renai House) during June-July at Versailles, Paris. We monitored both house

Received: 5, 12, 2016, Accepted: 23, 12, 2016

*Corresponding author: Shun Nakamura

Email: nakashn@cc.tuat.ac.jp

environments by our sensor network system for two days, computed the exergy consumption, and correlated with environmental parameters by PCA. The change of environmental parameters in Enemane2014 showed that the pressure and out-door temperature went down over two days and out-door humidity increased at the second day. In contrast, indoor air temperature and radiant temperature increased during each night. The change of exergy clearly showed that PPD (predicted percentage of discomfort) raised parallel with indoor air- and radiant temperature and exergy for exhalation (sweat) and heat dispersion through convection (out_conv) (②,④ in Figure 1). On the while, the indoor environment in Ranei House was quite constant, but two peaks of PPD appeared parallel with the exergy flow from body to environment through radiation (out_radiant) and convection during very early morning and late evening (③,⑤ in Figure.2). The analysis by PCA showed the difference of regulation of built environment and human body adjustment against not comfortable environment (high PPD and high exergy consumption) in two houses (data not shown).

Figure 1 Change of exergy in Enemane_House 2014 during January 28-29

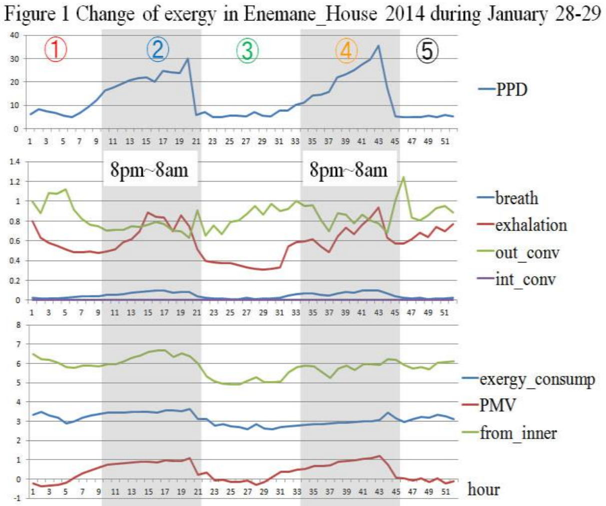
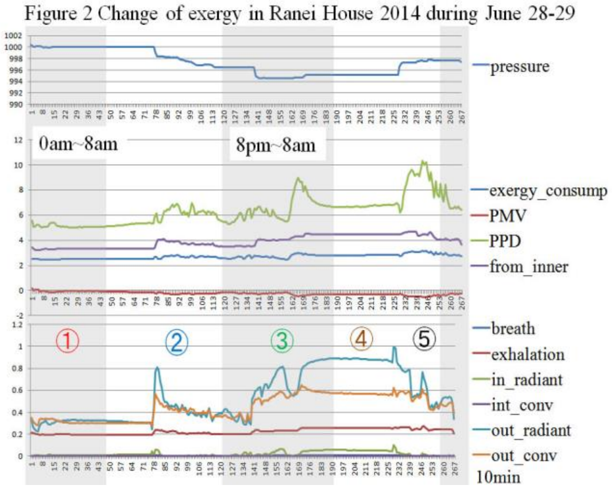


Figure 2 Change of exergy in Ranei House 2014 during June 28-29



3.2 Real time visualization of exergy consumption

Based on these observations, we started to develop an exergy-meter which can visualize the correlation of exergy consumption with environmental and physiological parameters. As described in Method section, we developed a sensor network system that can visualize the analyzed data on line. The network system can work in house/office via intra-network and be easily extended to internet environment.

4. Conclusion

Exergy concept is crucial to design the low energy-demand building and at the same time the well-being and health in built environment. We may act adjust environment to be comfortable, which may not lead to be long-term health. Thus, self-awareness of exergy-flow between body and built environment would be helpful to realize the accumulated thermal and environmental stress on the well-being and health. This concern is important for child development since the child adjusts a body sensor network to environment for life-long during a sensitive period [3]. Elderly (e.g. heat stroke) and patient with sever burning may require special care in terms of exergy consumption [4]. Our exergy meter may be useful in these cases. (Thank EMBOSS Inc. and Kaneka Corp., Japan for their technical and financial supports).

Reference

[1] Masanori Shukuya: Exergy, Theory and applications in the built environment, Springer (2013)

[2] The Annex49 Project. http://www.annex49.info/background.html

[3] Koshiba M, et al., A cross-species socio-emotional behaviour development revealed by a multivariate analysis. Sci Rep. 3:2630, 2013;

[4] Dovjak M, et al., Integral control of health hazards in hospital environment, Indoor Built Environ, 22776-795, 2013.