

Potential Roles of Awareness Computing Technology for Energy Management

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Energy management aims to financial and ecological success by optimizing the energy consuming sources such as sensors, computers and appliances. Hence, acquiring energy-related data from the sources in an automated manner is the starting point of managing energy. Recently, awareness computing has been emerging in system and cybernetics area. Awareness is the most fundamental ability for any living things to survive, and also the first step to make systems intelligent with the help of artificial intelligence. Even though the potential reciprocal benefits between energy management and awareness computing, frameworks which show how awareness computing contributes to manage energy-related strategy have been very few. Hence, this paper aims to introduce the awareness computing issues to improve energy management. In particular, we focus on satisfaction awareness computing which potentially realize the balance of energy savings and user's utility.

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1. Introduction

Currently, the world is dramatically moving toward the energy economy. Along with the social justification on providing clean or renewable energy is diffusing, the expectation of the market gets more. Greening business practices such as supply chain becomes a new way of making com-

petitive advantage. Diffusion of successful business practice that consumes less energy is also noticeably appearing phenomena in the energy economy. On the other side, eco-friendly habit improvement of users in everyday life is crucial for energy conservation. This results in the adoption of energy efficient technology including information technology. Information technology en-

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ables more efficient operation and utilization of hardware devices, as well as its proper disposal (Vykoukal et al., 2009).

However, since energy conservation may result in dissatisfaction of the energy consumers, optimizing energy consumption considering utility value from saving energy cost and satisfaction from consuming energy, rather than just coercive energy conservation, is needed. It is important that the balance between a saving viewpoint and a using satisfaction view is important in the energy management. Accordingly, instead of measuring only how much the energy was less consumed, it should be measured to what extent people feel satisfaction through consuming and saving energy. However, research which attempts to establish a rational energy policy by considering economic feasibility and at the same time user satisfaction is under progress (Moriarty and Honnery, 2010). Some researchers have built relationships between comfort and cost (Mozer, 1998; Bernard and Kuntze, 2001; Kolokotsa et al., 2002). However, correctness and validity of these relationships need confirmation by actual data from the real world.

To cope with this concern, measuring energy consumer's comfort level through sensor network is undergoing (Wul and Noy, 2010). However, they still did not consider psychological and subjective factors of human beings in measuring the comfort level. Actually, psychological and subjective factors are latent and high-level abstract data that are not directly acquired from physical sensors. Hence, context reasoning

to estimate the high-level situation can be an interesting challenge for ubiquitous computing, especially awareness computing area. Indeed, ubiquitous computing or awareness computing may have potential roles for energy management.

Hence, the purpose of this present paper is to envision how awareness computing field potentially contributes to improve energy management system. Especially, we will propose some research issues on optimizing energy consumption and their implications to energy management. On the contrary, energy saving issues in executing awareness computing services and applications are discussed, too.

2. Energy Management Issues in Ubiquitous Computing

One of the crucial issues on the construction and operation of ubiquitous computing system is how to successfully deal with energy-quality tradeoffs. Energy-quality tradeoff refers to the fact that energy savings and quality of service is negatively related to each other. For example, if a ubiquitous computing system intends to acquire sensor data very frequently for timely response, then installing more sensors or stronger sensory network should be needed. These improving capabilities generally require more power and hence result in more energy consumption. Energy-packet delay tradeoff for data collection in sensor networks is an instance of energy-quality tradeoffs (Wu et al., 2010). The energy saving issue becomes more severe

and hence one of the obstacles in ubiquitous computing, too. Developing energy-saving devices, network design optimization, and algorithmic sensing power reduction are the selective issues to build energy- or eco-efficient systems.

2.1 Development of Energy Saving Devices

The traditional approach to cope with saving energy is to invent hardware which consumes less energy. First, the minimalist approach aims to minimize the size or number of devices to decrease energy leakage of battery and maximize its sustainable life. Even if this method is helpful in energy saving, however, the method consumes more operation costs due to lack of flexibility of the devices. As a typical trial to overcome this concern, the approach to migrate an application code between remote devices has been suggested in the Bluegrid project, NTT Japan (NTT, 2003). Secondly, the embedding approach embeds memory and applications into a device as built-in modules to reduce energy consumption which is occurred when transmitting and receiving data and applications on a network. The approach can decrease service reaction time, while let the embedded devices have self-processing capacity. However, since this approach requires the operation of always-on devices installed in ubiquitous service domain, it is not energy efficient

Hence, power-aware approach is worthwhile to acquire power usage amount as context data and finding out optimal status by consider-

ing tradeoffs between energy consumption and task complexity (Kim et al., 2002). Recently, embedding modules which electronically controls energy consumption into hardware is considered (Kim et al., 2009). Reconsidering traffic patterns on current power management protocols needs another effort to save energy consumed while data traffic control.

2.2 Optimization of Network Design

Design of relevant communication protocol can contribute to resolve energy-delay tradeoff problem. The communication method consists of pull and push method. Pull method waits until a user's request for service occurs as an event. When it comes to push method, it sends signal or data only if a set of pre-defined conditions are fulfilled on the network, which runs all the time. In general, push method is superior to pull method. In special, push method is relevant for executing pay-per-use services in smart space, which is an integrated set of sensors and applications.

Energy-delay tradeoff issues can be taken care of by network design aspect. As long as software is concerned, middleware controls the energy-delay tradeoff: Middleware can save energy by making applications minimize the communication volume carried between networks, because typical ubiquitous computing applications depend on context acquired through sensory networks. Conventional approach has used CORBA and JINI. However, since they perform

pull based approach-searching for relevant services or service devices by itself, the conventional approach is not cost effect considering that service discovery is a main activity that causes energy consumption of mobile devices such as sensors and end-user devices. Hence, to cope with these shortcoming, a variety of efforts have been proposed (Benini et al., 2000; Hwang and Wu, 2002; Yau and Karim, 2003). New ways of service discovery which optimize frequent and energy costly tasks are needed (Schiele et al., 2004; Munir et al., 2009).

Meanwhile, using the networking resources, accessing remote memory can be more energy-efficient way of ubiquitous devices operations (Fryman et al., 2003). Energy-aware routing is another effort to realize lower energy consuming sensor networks. To do so, volume of energy consumption at each node and link is calculated for making real-time routing change (Raul and Rabaey, 2002).

2.3 Sensing Power Reduction through Context Prediction

One of the promising methods to avoid energy consumption while preserving context data accuracy is to build up a context prediction method rather than sensing context directly in the computing environment all the time. With this context prediction, estimated context data can be partially inserted to actually sensed context data. This method would be called hybrid context sensing, comparing with physical context sens-

ing, which is conventionally used in the context-aware applications. As a result, accurate context prediction reduces the interval of physical sensing and hence enables context-aware system which is more efficient in terms of energy savings.

By the way, the energy-delay tradeoff problem puts its interest of the meanwhile on reducing energy consumption, although the electric power can be always used sufficiently. It is important that the optimized utilization of energy can be achieved by considering two utility values: value of saving energy saving and that of user satisfaction from energy consumption.

3. Awareness Computing Issues in Energy Management

In general, using mobility and embeddedness, which are the key capabilities of ubiquitous computing technology, people can remotely communicate and co-work with each other anytime and anywhere supported by more intelligent communication services. These capabilities can support teamwork and conferences with globally distributed employees. This results in reducing transportation cost, any transaction cost caused by miscommunication, and saving energy.

3.1 Power Awareness Computing

Awareness computing technology can contribute to enable the energy saving business practices. First, energy-aware technology, which is a kind of awareness computing, acquires the

energy consuming context from the smart space and then provides the applications with context data for making reasonable decision in energy management. For example, in smart home applications, always-on connectivity is essential to establish home networks, which induces more energy consumption. To save energy, energy usage patterns of the information appliances in a space can be used to home energy management (Mok et al., 2007).

In power awareness technology, smart power grid clearly contributes to energy management. The smart power grid promotes efficiency of energy use by sharing real-time information related to power generation and distribution through utilizing information technology. Accordingly, when viewed in the utilization stage of home appliance, the real-time demand management on the electric power and online power request are possible.

The smart power grid potentially utilizes information technology in monitoring the current status and, if necessary, solving unbalance between power demand and supply. To do this, smart power grid encompasses control system for guaranteeing power quality, real-time power measurement and power trade, etc. Also, the awareness computing technology being expressed as situational recognition, and autonomy and intelligence can largely contribute to smart power grid.

3.2 Activity Awareness Computing

Activity awareness computing, supported by automatic recognition of users' life logs or e-

memories, identifies an individual or group's activities of everyday life (Tentori and Favela, 2008). By referencing energy consumption data and some environmental data such as temperature and humidity, activity-awareness computing applications can make the user or group reasonable in consuming energy. Moreover, risk activities can also be monitored. This will result in better providing information to encourage the energy user's green choices. For example, SEER (Selective Perception Architecture for Activity Recognition) system applied a hidden Markov model to analyze and predict activities with a higher level of abstraction (Oliver et al., 2004).

The individual difference of user's satisfaction is revealed according to individual activity. The satisfaction on energy use or dissatisfaction on its insufficiency can get bigger as the action of the person has bigger influence on the quality of life (Sundarama et al., 2009). In other words, user's activity is an indicator of the user's satisfaction on energy usage and/or availability. In addition, the action of the person can play a role of an adjusting variable between the quality of life and energy use. If we can automatically and unobtrusively identify the user's activity somehow, then we can make energy management more adoptable to the energy users.

3.3 Energy Awareness Computing

Energy awareness computing is a technology that identifies the potential source and quantity of energy at a certain location. One of the

goals of energy awareness computing is to support the generation and distribution of renewable energy. To do so, geographic data are main source of energy aware process. The geographic data include tide, altitude, volume of water reservoir, wind, ground heat and solar. Along with the geographic data, socio-economic data such as population, income and ages can be used to estimate the energy from trashes or nature. Besides this, the technology of energy acquisition from the nature needs a knowledge base linked together with geographical information. The knowledge base is the potential source for energy resources and generation method.

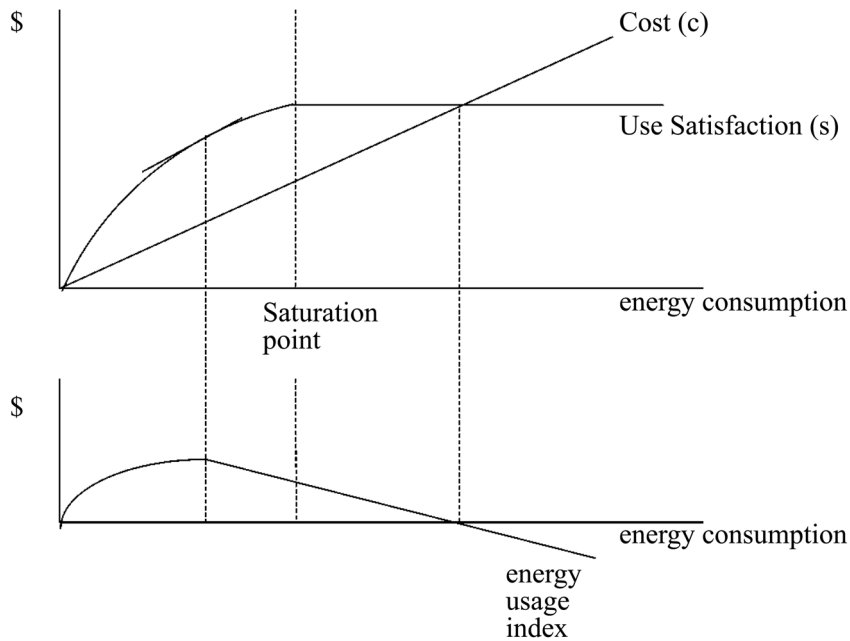
Energy awareness computing can track environmental information such as amount of energy used. For example, James et al. (2008) made an artificial agent which manages a wind power generator and a battery storage being installed at each home. The artificial agent technology makes the present decentralized generation condition become the centralized generation condition. This is helpful to the individual user in selling electricity in the open energy market. Ueno (2006) developed the on-line interactive energy consumption information system (ECOIS II) for energy saving and efficiency at residual buildings. This system periodically measures overall power use at entire space and appliances, the amount of city gas consumptions, and room temperature. The measured information is displayed to the users, so that the user is able to see several methods capable of saving energy by clicking a button of the screen. Thus, ECOIS II is a

decision tool to support energy policy by providing the user with current status, candidate policies and user dialogue.

However, since energy awareness per se consumes energy, we have to carefully consider the trade-off between sense and movement: the benefits by gathering energy information might be offset by sensing costs occurred by information gathering.

3.4 Context Awareness Computing

Even though context awareness is not new in context-aware computing, applying context-aware technology to energy management is just in its earlier age. Context data acquired from sensory network are main resources to make decisions in a timely manner. Kwon et al. (2005) proposed a ubiquitous decision support system (UbiDSS) by adding context subsystem into conventional decision support system framework. In UbiDSS, from the acquired context data, context subsystem conducts events acquisition, context inference, and action request for making decisions. These functionalities can be applied to diverse decision making tasks around energy management, and eventually improves quality of decision making by executives by highlighting sustainability issues. Meanwhile, the context-aware functionality in Context-Aware Infomobility Systems monitors geo-referenced information used to annotate maps and routes such as additional weather information and amount of carbon dioxide emitted (Stojanovic, 2009).



<Figure 1> Analysis Model of Energy Utilization Optimization Timing

4. Satisfaction : Combinatorial Awareness Computing

The concept called satisfaction among internal psychological situations of human beings is the most typical factor that explains human action or evaluation on a target. However, because the satisfaction on energy supply in an individual or group level like this may be not expressed outside, it is difficult to grasp with a physical sensor, etc. If the satisfaction is viewed as situational information, the technology estimating a psychological situational factor called satisfaction based on observable situational information would be valuable in assessment and optimization on energy use to support more

qualified life. Hence, satisfaction awareness needs the combination of several awareness computing methods introduced in section 3.

<Figure 1> shows how the users optimize energy consumption. If the function in <Figure 1> is known accurately, we could more accurately estimate the optimal level of energy consumption which will maximize the energy usage index. The electricity usage index is a function of user satisfaction and cost of energy consumption. However, several factors must be considered for optimization on power utilization; Individual difference of a satisfaction on energy consumption as follows:

- Estimating degree of satisfaction about the amount of energy supply

- Individual difference of a satisfaction on energy consumption
- Recognition of a saturation point of energy use
- Activity and energy consumption
- Cost structure and energy consumption

First, the degree of satisfaction would generally increase as the power consumption increases <Figure 1>. Since energy would be consumed from a big part having marginal utility under the human rationality, the derivative of satisfaction level would be diminished. Finally, after arriving at a certain saturation point, increase of energy consumption actually didn't positively affect the degree of satisfaction.

Second, individual difference of a satisfaction on energy consumption results in the variations of the energy consumer's satisfaction function. One can be frustrated if power or energy is not sufficiently provided any time he or she needs, whilst another person may feel better with the same amount. This must be reflected in the satisfaction function: the user's energy usage index curve adopts individual differences such as personality, demographics and value structure on consumption. The individual data can be obtained by user profile and personal sensors embedded in everyday computing devices subjects to the clearance of privacy concern.

Third, there will be the individual differences of saturation point on energy usage. For example, when reading a book in the evening, one may need brighter environment for better readability, while another person sufficiently satis-

fies about the same strength of illumination and does not have any additional satisfaction about more energy consumption. It is important that many people surprisingly consume energy even at a point of time that doesn't need more energy. What is worse, one example shows a result that much more energy is consumed in a situation that doesn't need at that much energy (Masoso and Groblera, 2010). This means that even when the energy consumption level surpasses the saturation point, continued energy consumption is often observed as an example of undesirable life habit. Moreover, self-control after the saturation point is necessary. To support this functionality, saturation point needs to be measured and estimated somehow with awareness computing technology.

Next, relationship between the nature of activity and user satisfaction on energy use must be considered for satisfaction awareness. Recently, activity sensor becomes more available as wireless network and artificial intelligence techniques are improving. For example, we can extract user's action by combining vision sensor and lifelog. SenseCam periodically captures what the user is seeing and based on it intelligent method can support making storytelling as a well-formed activity context in everyday life (Lindley et al., 2011). Meanwhile, relationship between the nature of activity and user satisfaction on energy use is highly related to the saturation point of power usage. For example, people have different saturation point about eating, reading, watching movies and sleeping at

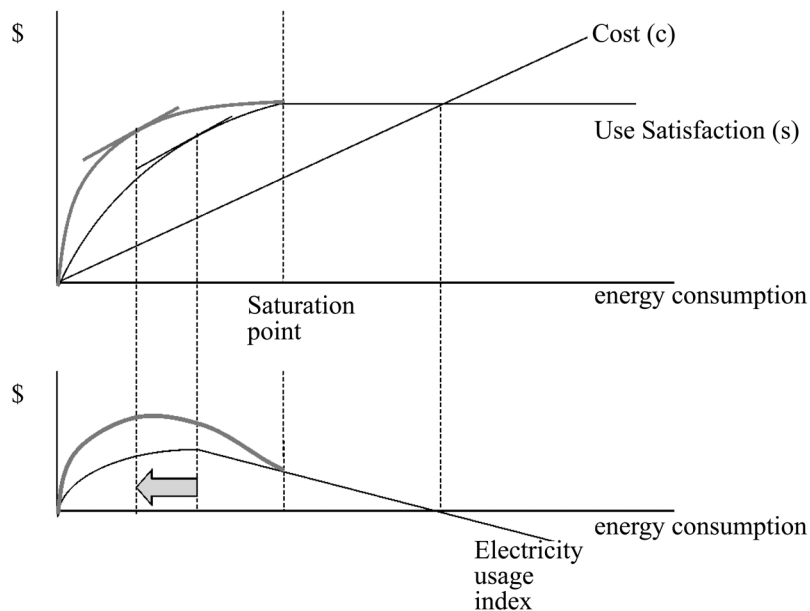
home. Hence, the user satisfaction curve needs to be more accurately drawn by sensing power consumption behavior.

Last, the user satisfaction curve depends on the cost policy or structure. One of the most salient values affecting energy consuming behavior is utility and sensitivity on financial and environmental costs. In response of the request about distribution policies, the cost policy should consider leverage of green energy, service-level agreement and energy consumption level (Le et al., 2010). Moreover, with the help of simulation and real experiments, various scenarios of energy policy need to be generated and compared for identifying optimal policy of energy management.

These five considerations for accurately

identifying energy usage index and then estimating an optimal energy utilization method are parts that can potentially be supported by awareness computing technology. How the energy usage index is individualized is described in <Figure 2>. In the figure, first of all, if the attitude of users is improved in power consumption of a specific portion, this curve will be bent upwardly. Then the point that the marginal satisfaction on consumption becomes the same as the slope of a cost function moves to the left: the user will try to consume less power usage at a certain living or working space. That is, the user will feel optimal satisfaction with less power usage.

Moreover, individual socio-economic and psychological characteristics affect the user sat-



<Figure 2> Individual Difference in Energy Use Satisfaction

isfaction curve. For example, satisfaction on temperature is associated with age and gender. When it comes to income level, users of low-income group tend to accept more extreme temperature (Indraganti and Rao, 2010). It is also known that the level of comfort in terms of temperature shows big difference according to the location, activity and social context (Wul and Noy, 2010). On the other hand, the visual comfort is mostly related to satisfaction on the intensity of radiation. The visual comfort depends on what the user is seeing, orientation of the place, color, and even fixtures inside space like furniture, etc. Besides, the schedule or personal preference of the user will have influence on the visual comfort. These data can be sensed by awareness computing technology.

The acoustic comfort varies according to user activities. While working, the level of acoustic comfort will be raised. On the other hand, the case that is rather noisy a little at time for social meeting or pleasure would be more helpful. The above factors are related to situational information (Fanger, 1972). What this is summarized is in <Table 1>.

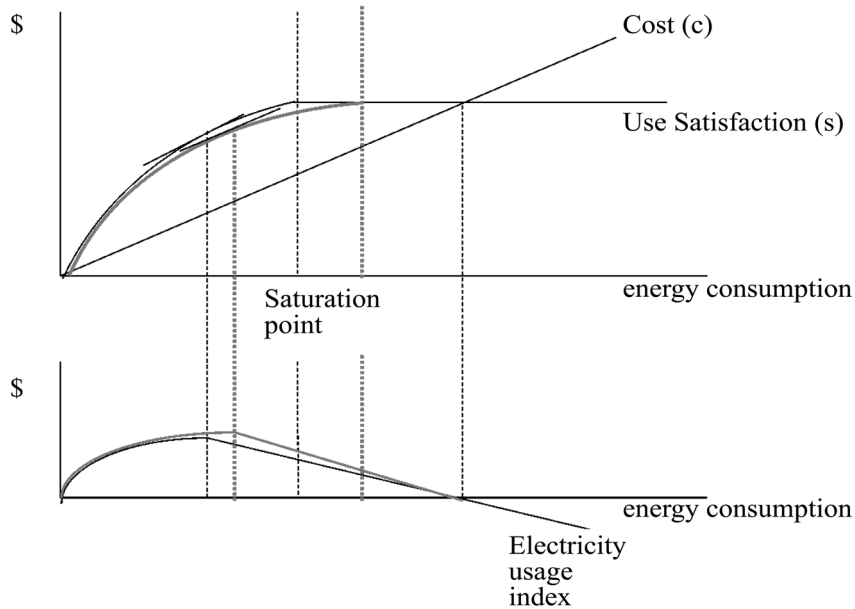
Accordingly, there is a part that the situa-

tional recognition technology can contribute to the accurate estimation of user satisfaction level. For example, Malkawi and Srinivasan (2005) used wireless sensor data to build up a model that can visualize and interact with buildings and their thermal environments. However, a significant part of this situational information is a subjective and psychological. For example, it was regarded as impossible to measure satisfaction level on view and relative humidity with the existing sensor network technology. Moreover, there is an individual difference in comfort level related to user satisfaction. For example, although the temperature of 20~24°C, humidity of 30~70%, CO₂ concentration of 1000 pm and mean brightness of 500~2000 lux, etc. are suggested as conditions of general comfort (Ashrae, 1992). However, this suggestion does not the individual difference. If there is a technology that can accurately estimate subjective situational information from objective situational information like sensor data or user's profiles comparatively, then user satisfaction function could be sought more accurately and timely.

Meanwhile, if the saturation point moves, the consumption satisfaction curve can be changed

<Table 1> Factors Having Influence on User Satisfaction

Psychological Factor	Situational information	Type of user satisfaction
Thermal comfort	air velocity, mean radiant temperature, people's activity, absolute humidity	relative humidity, clothing parameter, perceived comfort level on temperature
Visual comfort	light levels, color rendering	spatial distribution, glare, view, perceived comfort level on light levels
Air comfort	air pollution, dioxide concentration	perceived comfort level on air pollution
Acoustic comfort	noise level, personal activity	perceived acoustic level on acoustic comfort



<Figure 3> Effect of Movement of a Saturation Point on Optimal Energy Consumption

together as shown in <Figure 3>. For example, if the user satisfaction function becomes lower and hence saturation point goes rightward, then the optimal energy consumption or the quantity supplied tends to increase assuming that there is no change in energy supply costs due to the reduction of marginal satisfaction.

Consequently, automatically estimating user satisfaction level with awareness technology can be a key ingredient of realizing personal energy management system. Satisfaction awareness needs interdisciplinary effort because we have to combine technical, psychological and even economical aspect. Moreover, identification of user satisfaction needs environmental context data from primitive (e.g. temperature) to very compound (e.g. current activity).

5. Conclusion

While legacy context-aware computing technology stresses more on context reasoning, research community of awareness computing newly issued by IEEE SMC society is interested in acquiring situational data as much as possible. Increasing the kinds of objects to be automatically acquired by computing technology has promising practical area which seldom assisted or even considered by context-aware computing. Among those, energy management applications are focused in this paper, just because more sustainable economy inevitably requests the individual's habitual or life change. However, due to complexity and obtrusiveness, individual level energy management was not technically via-

ble: obtaining individual context is very hard to be implemented. Even worse, psychological context such as user satisfaction level is far more difficult to have in a manual manner.

In this paper, we aim to propose how awareness computing can support the energy management managers and practitioners in developing energy management system. Power, energy and miscellaneous context are investigated first. Then high abstract and compound context such as satisfaction level is introduced with fundamental idea and issues to acquire the level in an automated manner. Currently, we are implementing satisfaction aware system to show the feasibility of the idea and vision proposed in this paper.

References

- Benini, L., A. Boglio and G. Michelli, "A survey of design techniques for system-level dynamic power management", *IEEE Transactions on VLSI Systems*, Vol.8, No.3(2000), 299~316.
- Bernard, T. and H. B. Kuntze, *Sensor-Based Management of Energy and Thermal Comfort*, In O. Gassmann and H. Meixner (eds), *Sensors in Intelligent Buildings*, Weinheim, Germany, Wiley-VCH. 2001.
- Kim, D., J. J. Garcia-Luna-Aceves, K. Obraczka, J. Cano and Manzoni, P. "Power-aware routing based on the energy drain rate for mobile ad hoc networks", *Proceedings of the 11th Int'l Conf. Computer Comm. and Networks (ICCCN 2002)*, (2002), 565~569.
- Fanger, P. O., *Thermal Comfort*, New York, McGraw-Hill.
- Fryman, J. B., C. M. Huneycutt, H. S. Lee, K. M. Mackenzie and D. E. Schimmel, "Energy-efficient network memory for ubiquitous devices", *IEEE Micro*, Vol.23, No.5(2003), 60~70.
- Gamou, S., R. Yokoyama and K. Ito, "Optimal unit size of cogeneration systems in consideration of uncertain energy demands as continuous random variables", *Energy Conversion Management*, Vol.43(2002), 1349~1361.
- Hwang, C. H. and A. C. H. Wu, "A predictive system shutdown method for energy saving of event-driven computation", *ACM Transactions on Design Automation and Electronic Systems*, Vol.5, No.2(2002), 226~241.
- Indraganti, M. and K. D. Rao, "Effect of age, gender, economic group and tenure on thermal comfort : A field study in residential buildings in hot and dry climate with seasonal variations", *Energy and Buildings*, Vol.42, No.3(2010), 273~281.
- James, G., W. Peng and K. Deng, "Managing household wind-energy generation", *IEEE Intelligent Systems*, Vol.23, No.5(2008), 9~12.
- Kim, H. S., S. K. Kang, K. J. Park, C. W. Baek and J. S. Park, "Power management circuit for wireless ubiquitous sensor nodes powered by scavenged energy", *Electronics Letters*, Vol.45, No.7(2009), 373~374.
- Kolokotsa, D., G. S. Stavrakakis, K. Kalaitzakis and Agoris, D. "Genetic algorithms optimized fuzzy controller for the indoor environmental management in buildings implemented using plc and local operating networks", *Engineering Applications of Artificial Intelligence*, Vol.15, No.5(2002), 417~428.
- Kwon, O., K. Yoo and E. Suh, "UbiDSS : a proactive intelligent decision support system as an expert system deploying ubiquitous com-

- puting technologies”, *Expert Systems with Applications*, Vol.28(2005), 149~161.
- Le, K., O. Bilgir, R. Bianchini, M. Martonosi and T. D. Nguyen, “Managing the cost, energy consumption, and carbon footprint of internet services”, *SIGMETRICS’10*, (2010), 357~358.
- Lindley, S. E., M. Glancy, R. Harper, D. Randall and N. Smyth, “Oh and how things just don’t change, the more they stay the same : Reflections on SenseCam images 18 months after capture”, *International Journal of Human-Computer Studies*, Vol.69, No.5(2011), 311~323.
- Masoso, O. T. and L. J. Groblera, “The dark side of occupant’s behaviour on building energy use”, *Energy and Buildings*, Vol.42, No.2 (2010), 173~177.
- Mavrotas, G., K. Florios and D. Vlachou, “Energy planning of a hospital using mathematical programming and Monte Carlo simulation for dealing with uncertainty in the economic parameters”, *Energy Conversion and Management*, Vol.51(2010), 722~731.
- Min, X., W. Shi, C. Jiang and Z. Ying, “Energy efficient clustering algorithm for maximizing lifetime of wireless sensor networks”, *AEU : International Journal of Electronics and Communications*, Vol.64, No.4(2010), 289~298.
- Mok, H., S. Son, J. H. Hong and S. Kim, “An approach for energy-aware management in ubiquitous home network environment”, *Lecture Notes in Computer Science*, Vol.4761 (2007), 293~300.
- Moriarty, P. and D. Honnery, “A human needs approach to reducing atmospheric carbon”, *Energy Policy*, Vol. 38(2010), 695~700.
- Mozer, M. C., “The neural network house : an environment that adapts to its inhabitants”, *Proceedings of the American Association for Artificial Intelligence Spring Symposium on Intelligent Environments*, Menlo Park, CA, (1998), 110~114.
- Munir, S. A., X. Dongliang, C. Canfeng and J. Ma, “Service discovery in wireless sensor networks: protocols and classifications”, *Proceedings of the 11th international conference on Advanced Communication Technology*, (2009), 1007~1011.
- NTT Japan. *Bluebird Project*, <http://www.ntts.co.jp/java/bluegrid/en/>, 2003.
- Oliver, J. Y., R. Amirtharajah, V. Akella, R. Geyer and F. T. Chong, “Life cycle awareness computing : reusing silicon technology”, *Computer*, Vol.40, No.12(2007), 56~61.
- Oliver, N., A. Garg and E. Horvitz, “Layered representations for learning and inferring office activity from multiple sensory channels”, *Computer Vision and Image Understanding*, Vol.96, No.2(2004), 163~180.
- Rahul, C. and J. Rabaey, “Energy aware routing for low energy ad hoc sensor networks”, *IEEE Wireless Communications and Networking Conference (WCNC)*, Orlando, FL, (2002), 350~355.
- Schiele, G., C. Becker and K. Rothermel, “Energy-efficient cluster-based service discovery for Ubiquitous Computing”, *Proceedings of the 11th workshop on ACM SIGOPS European workshop : beyond the PC*, Leuven, Belgium. 2004.
- Stojanovic, D., *Context-Aware Mobile and Ubiquitous Computing for Enhanced Usability*, Premier Reference Source, 2009.
- Sundarama, M., M. J. Smitha, D. A. Revickib, B. Elswickc and L. Millerd, “Rasch analysis informed the development of a classification system for a diabetes specific preference-based measure of health”, *Journal of Clinical Epidemiology*, Vol.62, No.8(2009), 845~856.

- Tentori, M. and J. Favela, "Activity-awareness computing for healthcare", *IEEE Pervasive Computing*, (2008), 51~57.
- Ueno, T., R. Inada, O. Saeki and K. Tsuji, "Effectiveness of an energy-consumption information system for residential buildings", *Applied Energy*, Vol.83(2006), 868~883.
- Vykoukal, J., M. Wolf and R. Beck, "Does green IT matter? Analysis of the relationship between green IT and grid technology from a resource-based view perspective", *Proceedings of the PACIS 2009*, (2009), 51.
- Wu, S. and P. Noy, "A conceptual design of a wireless sensor actuator system for optimizing energy and well-being in buildings", *Intelligent Buildings International*, Vol.2(2010), 41~56.
- Wu, Y., X. Li, Y. Liu and W. Lou, "Energy-efficient wake-up scheduling for data collection and aggregation", *IEEE Transactions on Parallel and Distributed Systems*, Vol.21, No.2 (2010), 275~287.
- Yau, S. S. and F. Karim, "An energy-efficient object discovery protocol for context-sensitive middleware for ubiquitous computing", *IEEE Transactions on Parallel and Distributed Systems*, Vol.14, No.11(2003), 1074~1085.

Abstract

에너지 관리를 위한 인식 컴퓨팅의 잠재적 역할 연구

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에너지 관리는 센서, 컴퓨터나 가전기기와 같은 원천들의 에너지 소비를 최적화함으로써 재정적 생태적 성공을 달성하는 것이 목적이다. 따라서 각 원천들로부터 에너지 측정과 관련된 자료들을 획득하는 것이 에너지 관리의 출발점이다. 최근 상황인식 컴퓨팅을 아우르는 다른 인식컴퓨팅이라는 분야가 정보기술 영역에서 새롭게 부각되고 있다. 인식이란 생물체들의 생존을 위한 가장 기본적인 능력임과 동시에 인공지능의 도움으로 정보 시스템을 지능화하는 시발점이 될 수 있다. 이렇게 에너지 관리와 인식 컴퓨팅 연구가 상호 호혜적인 이익을 획득할 것임에도 불구하고 인식 컴퓨팅이 어떻게 에너지 관련 전략에 기여할 것인지에 대한 연구는 거의 존재하지 않는다. 따라서 본 논문의 목적은 에너지 관리 개선을 위한 인식 컴퓨팅 연구 이슈에 대해서 소개하는 것이다. 특히 인식 컴퓨팅이 에너지 절감과 사용자의 효용 간의 균형을 실현하는 역할에 대해 집중하였다.

Keywords : 에너지 관리, 인식 컴퓨팅, 유비쿼터스 컴퓨팅, 만족감 인식 컴퓨팅

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