유비쿼터스 센서네트워크를 위한 퍼지시스템 기반 적응형 센싱

Adaptive Sensing based on Fuzzy System for Ubiquitous Sensor Networks

마테오 로미오* 이 재 완**
Romeo Mark A. Mateo Jaewan Lee

요 약

무선 센서네트워크는 효율적인 자료처리 및 유비쿼터스 시스템 구현을 위해 여러 응용에서 사용되고 있다. 그러나 무선 센서네트워크에 기반 한 최근 주차관리시스템 연구에서는 적응형 센싱이나 효율적인 자료처리 기법은 거의 고려되지 않고 있다. 주차관리응용에서의 성능은 이러한 분산된 컴퓨팅장비들의 효율적인 구현에 연향을 받는다. 이 논문은 주차관리 유비쿼터스 네트워크 시스템을 위해 퍼지 무선센서를 이용한 적응형 센싱기법을 제시한다. 효율적인 주차탐색을 위해 퍼지추론시스템이 센서에 탑재된다. 또한 자동차 주차공간의 환경변화에 적응을 위해 새로운 값을 각 센서에 무선으로 전송하는 규칙기반 적응형 모듈을 제시한다. 실험결과 제안한 퍼지기반 무선센서가 일반적인 무선센서에 의해 수집하는 방법에 비해 우수한 처리율과 적은 지연시간을 보였다.

Abstract

Wireless sensor networks are used by various application areas to implement smart data processing and ubiquitous system. In the recent research of parking management system based on wireless sensor networks, adaptive sensing and efficient data processing are not considered. The effectiveness of implementing these distributed computing devices affects the performance of the applications in parking management. This paper proposes an adaptive sensing using fuzzy wireless sensor for the ubiquitous networks of parking management system. The fuzzy inferencesystem is encoded in the sensor for efficient car presence detection. Moreover, a rule base adaptive module is proposed which wirelessly transmit the new values to each sensor for adapting the environment of car park area. The result of experiments shows that the fuzzy wireless sensor provides more throughputs and less time delays compared to a normal method of data gathering by wireless sensors.

☞ keyword : Fuzzy system, wireless sensor networks, ubiquitous system

1. Introduction

Wireless sensor systems have been popularly researched on the field of healthcare, military, environmental monitoring and others[1]. These wireless sensor networks (WSN) are characterized by its low-cost, limited-power, small sized, specific or multiple functional devices and wireless communication that smartly processes data and provide ease information. Wireless sensor networks provide a multi-disciplinary area of research where concepts and techniques are used to solve the problems on diversity in various applications. Some important performance issues of WSN rely on the

* 정 회 원 : 군산대학교 전자정보공학부 박사과정
rmmateo@kunsan.ac.kr
** 종신회원 : 군산대학교 전자정보공학부 교수
jwlee@kunsan.ac.kr
[2007/11/15 투고 - 2007/11/26 심사 - 2008/02/12 심사완료]
1) This research was financially supported by the Ministry of Education, Science Technology (MEST) and Korea Industrial Technology Foundation (KOTEF) through the Human Resource Training Project for Regional Innovation

protocols and architecture [2]. Communication protocols of WSN are crucial on providing reliable information from the source to the destination. Efficiency in energy consumption is considered by most researchers. Power-aware methods by removing redundant functions from the WSN are studied to provide the wireless sensors a longer time operations. It is also important to consider adaptation of the sensor reading based on changes in the environment. Extreme conditions like having different weather in an area where the sensors are deployed can affect the accuracy of the sensor readings.

This paper proposes an adaptive sensing using the proposed fuzzy wireless sensor for the ubiquitous networks of parking management system. The architecture of the ubiquitous parking management system is consisted of three separate layers of hardware and software components. This paper focuses on the efficiency of ubiquitous network by using fuzzy wireless sensors. The proposed fuzzy wireless sensor is designed to process the raw data of the sensor in the fuzzy inference system for efficient car presence detection. Moreover, a rule base adaptive module is proposed which wirelessly transmit the new values to each sensor for adapting the changes in the environment of parking area. The fuzzy wireless sensor is implemented in the parking system simulator. The result of experiments shows that the fuzzy wireless sensor provides more throughputs and less time delays compared to a normal method of data gathering.

2. Background and Related Works

Parking management system using WSN are popular studies of researches [3,4,5,6,7,8]. This method implements WSN to sense the presence of the car and monitors the location of cars. Relevant services in car parking system rely on this method like car locator system, car parking negotiator and other ubiquitous application in car parking system management. However, efficient data processing and adaptive methods must be designed. The following subsections are related works basis on designing the adaptive system of the fuzzy wireless sensor.

2.1 Parking Management System using WSN

Current studies in smart parking management system are efficient implementation of WSN to sense the car arrivals and determine the specific slot where the car parked. In [3] wireless sensor networks are used for automatic vehicle car parking where wireless sensors and infrareds are used for the positioning to enhance the accuracy of positioning. The positioning and error correction procedures are calculated by the vehicles, and forwarded to the server by WSN. A parking monitoring system using WSN is proposed in [4]. Low-cost wireless sensors are deployed into a car park field which detects and monitors the occupation of the parking lot. The status of the parking field detected by sensor nodes is reported periodically to a database via the deployed wireless sensor network and its gateway. The database can be accessed by the upper layer management system to perform various management functions, such as finding vacant parking lots, auto-toll, security management, and statistic report. In [5], Miura et. al., describe results of a simulation where reports from wireless sensor nodes are passed from car-to-car in order to achieve scalable dissemination of information regarding parking spaces. An analysis of link characteristics in the car-park scenario is

studied [6]. The experiments shows unexpected reliability patterns which have a strong influence on MAC and routing protocol design. It concludes that the presence of the cars being sensed can cause significant interference and degradation in communication performance and link quality has a high temporal correlation but a low spatial correlation. A comparison of data from different sensors for improvements to WSN in car parking system is presented [7]. An RFID-based parking management system is proposed which presented the design of a hybrid middleware [8]. The design of the previous researches does not include efficient data processing. Processing a large amount of data from the WSN in a single sink node can cause delay time because of the overlapped processes. Also, adaptive design where variables from the environment are considered for adapting new configuration in the sensor to read the inputs correctly is not considered.

2.2 Fuzzy Inference System

Fuzzy inference system is based on the concept of fuzzy logic and fuzzy sets, which was conceived by Lotfi Zadeh [9]. It is presented as a way of processing data by allowing partial set membership rather than crisp set membership or non-membership.

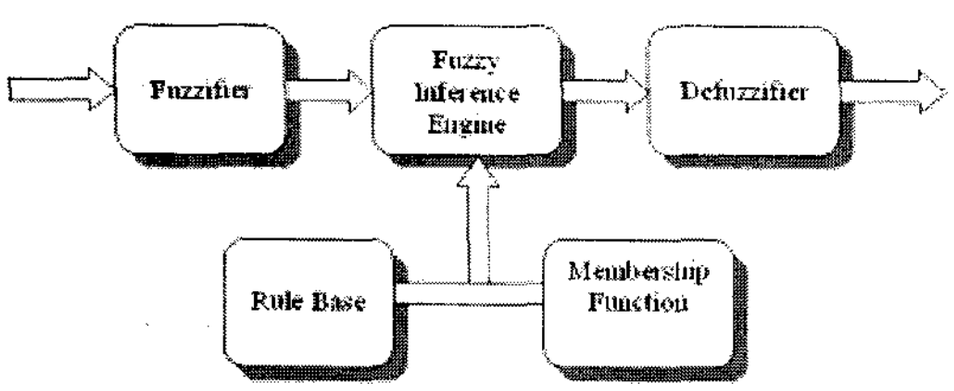


Fig. 1. The component and procedure of fuzzy inference system

Fuzzy logic is one of the earliest fuzzy systems using fuzzy sets where most fuzzy controllers benefit this technique because of the it's smooth transition to transfer the another fuzzy set and the way it handles its imprecise values [10]. Figure 1 shows an example of a fuzzy inference system. A fuzzifier is an interface for the input where maps the numeric input to a fuzzy set and it maps the premises of the fuzzy rules from the rule base. The fuzzy inference engine applies the inference mechanism to the set of rules using the membership function. Lastly, the crisp value is determined by the deffuzifier. The fuzzy inference system in Figure 1 is efficient in processing data in fuzzy concept.

3. Fuzzy Wireless Sensor for Ubiquitous Parking Mgnt. System

The architecture of the ubiquitous parking management system using WSN is shown in Figure 2. The architecture consists of three layers: ubiquitous network, middleware and application services layers. In the ubiquitous network, represents the physical networks of different sensors and computers communicating in the wireless environment. The components in the middleware layer are transparently executing for the efficiency on managing data from the ubiquitous network layer. Interaction of clients and application services are also handled by the middleware layer. Users and administrators do not need to know the configuration on how to find, where to find and how to manage the resources but transparently executes the services. The application service layer is consisted of services for car park system. This paper proposes the fuzzy wireless sensor and adaptive module for the ubiquitous network layers

of the parking management system. The subsection discussed the fuzzy wireless sensor and adaptive module for efficient data gathering.

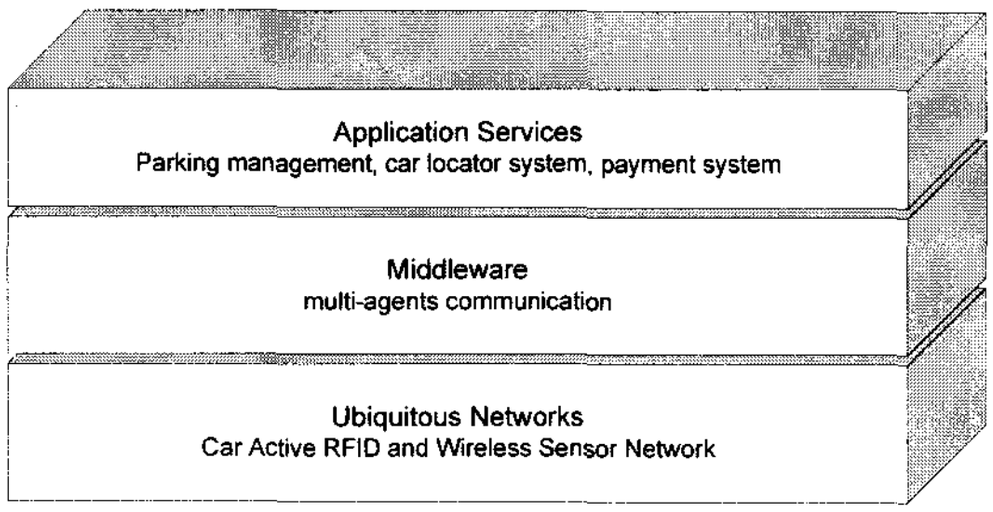


Fig. 2. Architecture of the ubiquitous parking management system

3.1 Fuzzy Wireless Sensors with Adaptive Module

Wireless sensors are used for the car detection. A sensor module is consists of several sensor like light, temperature and humidity to process in the fuzzy inference system (FIS). The FIS consist of fuzzifier, fuzzy rules and defuzzifier. Fuzzifier is an interface for the input where maps the numeric input to the fuzzy sets and fuzzy rules. FIS applies the inference mechanism to the set of rules using the membership function. Lastly, the crisp value is determined by the defuzzifier. This paper proposes the fuzzy sensor where the FIS is embedded in the module of the wireless sensors shown in Figure 3. The sensor inputs of a single sensor module are processed by the FIS and send the output value to the sink node. The FIS of the proposed fuzzy wireless sensor adapts the rules from the adaptive module from the sink node. The rules are configured by expert based on the environment of the parking area. Other sensors are provided for inputs of the rule base on the sink node.

Procedure of the FIS. This research uses the

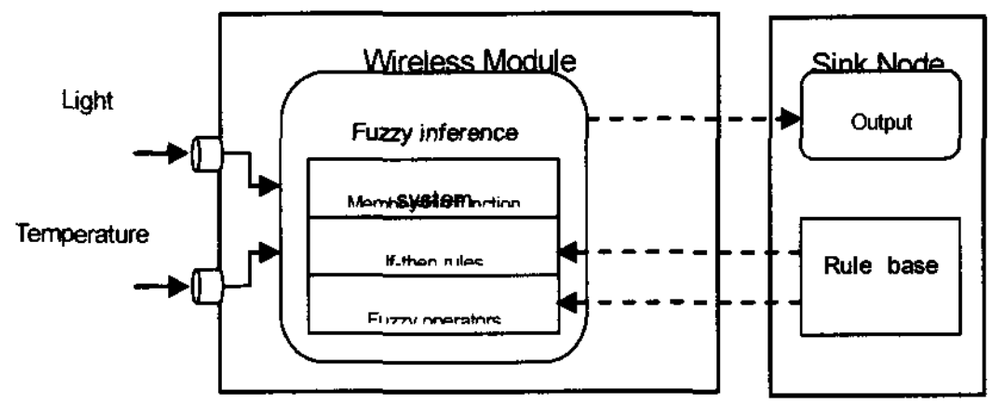


Fig. 3. The proposed fuzzy wireless sensor consists of fuzzy inference module

sensor inputs (S_i) in a single module to process in the FIS. The S_i, refers to sensor input value, where i is the index of the input. The values gathered at the same time, t_n={ S_1, S_2,$\cdots$, S_{ij}, and processed in the FIS to determine the presence of the car represents as c. Two input parameters are defined for the fuzzy rules of the FIS shown in Table 1.

Table 1. Fuzzy rules used in the proposed fuzzy sensor

Rule	Temperature (S_1)	Luminance (S_2)	*Car Presence (C)*
1	Low	Dark	*Not present*
2	Medium	Dark	*Not present*
3	Low	Medium-bright	*Not present*
4	Medium	Medium-bright	*Present*
5	High	Medium-bright	*Present*
6	Medium	Bright	*Present*
7	*High*	Bright	*Present*

The S_1 and S_2 both have three linguistic values while the candidate has two linguistic values. The presence of the car is determined by processing the S_1 and S_2 in the FIS and then the value of the center of gravity, c_i, is determined to decide the state of the car presence, The car presence function, *CarPresence*(c_i), is consist of input variables, input(c_i), state(present, absent), boundary(0.5), and returns the state. Equation 1 shows the conjunction of two variables process in minimum function used

for mapping the rules in Table 1. Equation 2 calculates the deffuzzified value of a rule and Equation 3 presents the boundary condition to decide the state.

$$\mu_j = \mu_{A \wedge B}(x) = \min\{\mu_A(x), \mu_B(x)\} \quad (1)$$

$$c_i = \frac{\sum_{j=1}^{r} \mu_j \cdot s_j}{\sum_{j}^{r} \mu_j} \quad (2)$$

$$f(c_i) = \begin{cases} present & if\ c_i < boundary, \\ absent & if\ c_i > boundary \end{cases} \quad (3)$$

Adaptation of FIS. Extreme conditions in the car parking area could vary the values of the sensor readings. In this paper, an adaptive module for the proposed fuzzy sensors is implemented to adjust the values in the FIS. Fuzzy values are reconfigured based on the rules from the adaptive module of the sink node shown in Figure 3. The new configuration of the FIS correctly processes the inputs. Rules are defined by expert based on the conditions of the car parking where R={R_1, R_2, ⋯; R_{kl}.

$$R_k = IF\ S_1\ is\ A_1\ AND_2 ..., AND S_k\ is\ A_k\ then \Sigma_k \quad (4)$$

$$B_x = \sigma_x;$$

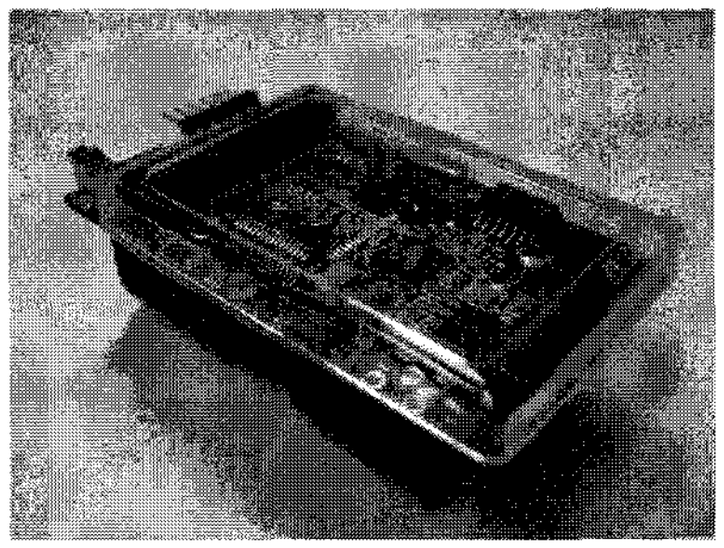
$$A_x = \begin{cases} C_{\min} & if\ x = 1, \\ \sigma_{x-1} & else \end{cases};$$

$$C_x = \begin{cases} C_{\max} & if\ x = last\ index, \\ \sigma_{x+1} & else \end{cases}; \quad (5)$$

The outcome of the rule in Equation 4 () is consist of fuzzy sets center value ($_l$) *and expressed by* ={$_1$, $_2$, ⋯; $_{ll}$. *These values are sent in wireless transmission method. Each center value is used to calculate the fuzzy sets shown in Equation 5. The x is the index and, A, B, C are the minimum, center and maximum values of fuzzy set x, respectively. The procedure of Equation 5 is done in the proposed fuzzy wireless sensor.*

4. Implementation and Evaluation

Our design of the car parking system simulator used wireless sensor motes which is a 2.4 GHz IEEE 802.15.4 compliant RF transceiver. The wireless sensor mote in Figure 4a is consisted of temperature, light and humidity readings. Temperature and light sensors were used to detect the presence of the car. The active RFID is put on the top of the car model shown in Figure 4b. Every time the wireless sensor detects the presence of the car, it sends a message to the active RFID of the car model.



(a)

(b)

Fig. 4. The wireless sensor mote (a) for the car presence detection and the active RFID (b) on the top of the car model used in the car parking system simulator

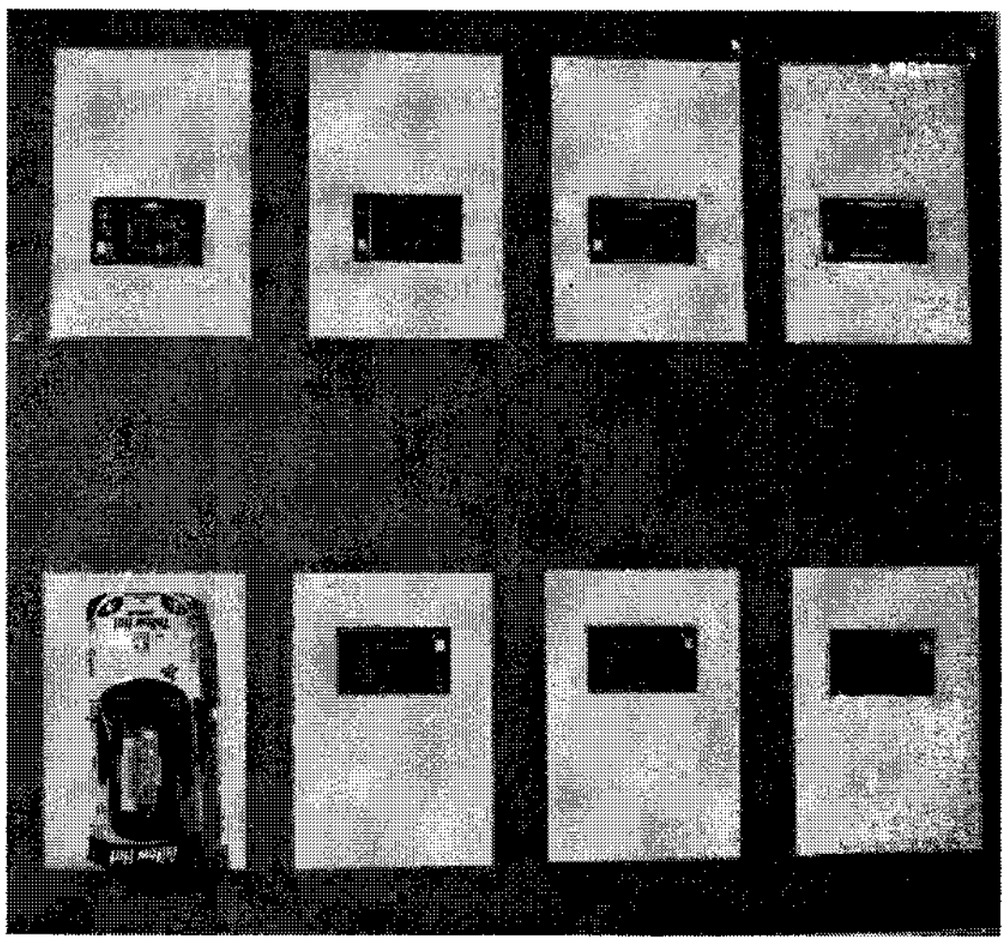


Fig. 5. The parking system simulator with 8 wireless sensors embedded over the platform performs the car presence detection

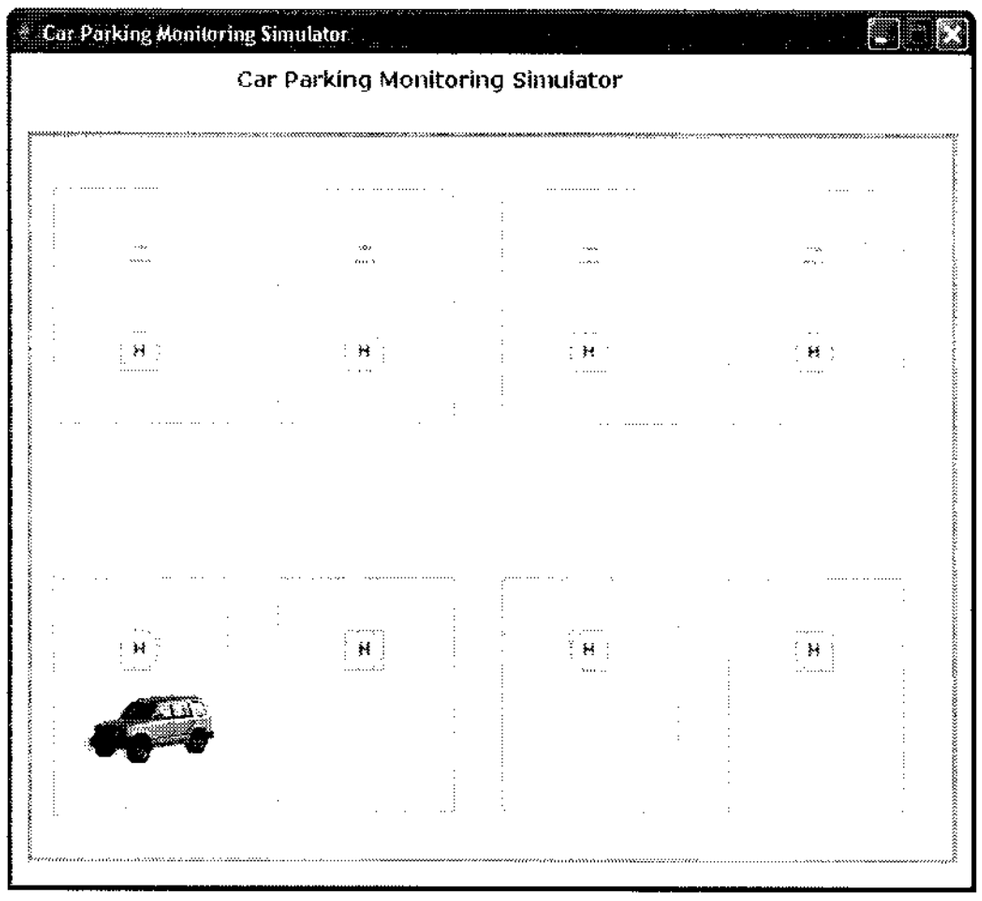


Fig. 6. The parking monitoring program displays the output from the car parking system simulator

The proposed fuzzy wireless sensor and rule based adaptive module is implemented in the car parking system simulator. The FIS of the fuzzy wireless sensor is coded and designed in nesC, which is a programming language for wireless sensors, and the rule-base adaptive module is programmed in Java. The ID is encoded in a wireless sensor mote to simulate the active RFID where the active RFID sends message to all sensors in the parking system simulator. Figure 5 shows the car parking system simulator.

The interaction of the parking simulator platform is presented in Figure 5. In Figure 5, a car parked in a slot and is detected by the wireless sensor mote. The values from sensor reading are processed in the FIS of the proposed fuzzy wireless sensor. The car parking platform is consisted of 8 slots embedded with wireless sensors. A sink node is used in communicating with the wireless sensors and gathering of the data from sensor readings. In Figure 6 is an output display from the parking simulator platform. The output value from fuzzy wireless sensor is sent directly to the sink node. The output display is updated every second and the values are stored in the database. Also, the rule-base adaptive module is executing at the same.

4.1 Performance Evaluation

The approach of using the proposed techniques was evaluated by determining the throughput and delay time of the fuzzy wireless sensor to process the sensor readings. In measuring the throughput, the completed work is determined after the message has been sent by the sensor to the sink node. The sink node processes one task at a time and has to queue other incoming process. Because of the delay from other processes in the sink node, classical method of gathering wireless sensor data cannot optimize the throughput of the system.

In Figure 7, shows using the fuzzy wireless sensor improved the completed work or throughput compared to the normal sensors as the time

increases. Because the fuzzy wireless sensor is designed to processes the task within the module, it eliminates the delay time caused by sending and processing the data in the sink node. The sink node only reads the output value and stores it on the database.

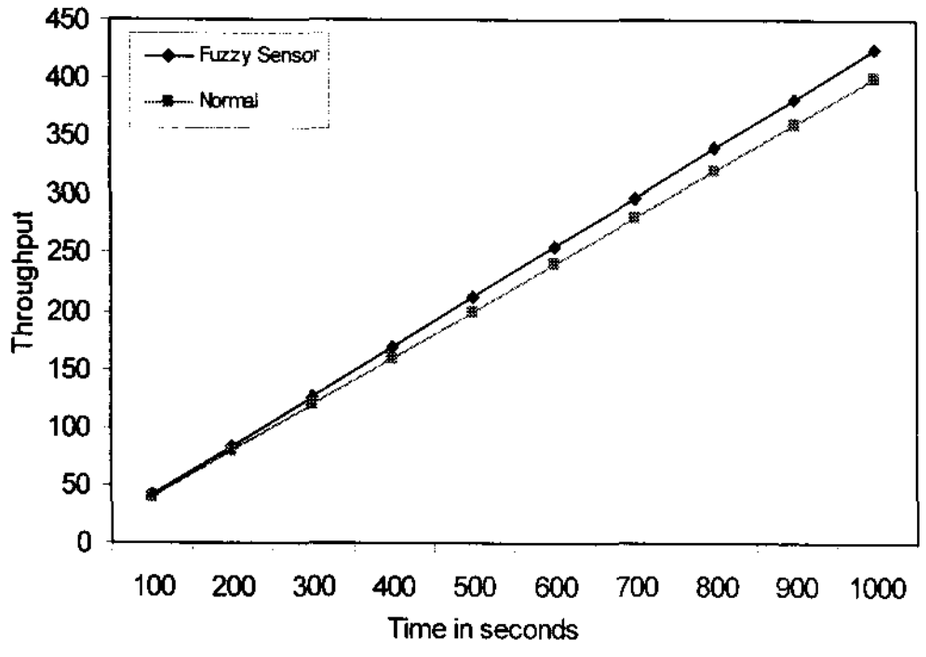


Fig. 7. Throughput comparison of fuzzy sensor and normal sensor based on time

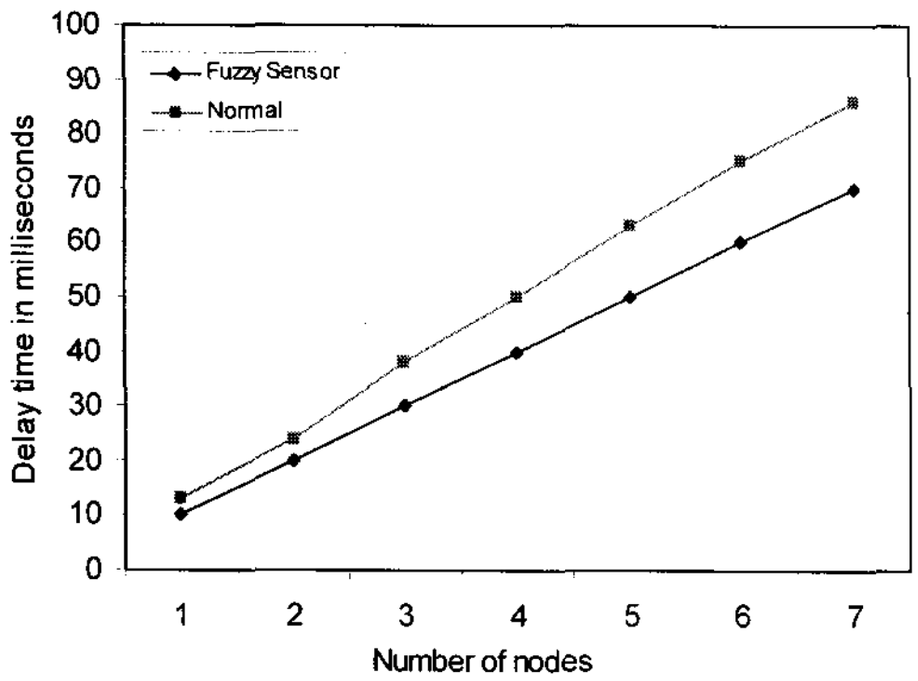


Fig. 8. Delay time comparison of fuzzy sensor and normal sensor based on increasing the number of nodes

The average delay time is calculated. In Figure 8 shows that the fuzzy wireless sensor optimizes the process in the sink node by minimizing the delay time. It is observed that using normal method on wireless sensor has increased the delay time as the number of nodes increases. Adding an additional nodes in using the fuzzy wireless sensor resulted to 25% time efficient than the normal method. Also, the proposed fuzzy wireless sensors do not constrain the network because of the short bits it sends compared to the normal method.

5. Conclusion and Future works

This paper proposes the adaptive sensing using fuzzy wireless sensor to implement the efficient ubiquitous networks in the parking management system. The architecture of the ubiquitous parking management system is consisted of three separate layers of hardware and software components. The proposed fuzzy wireless sensor is designed to process the raw data of the sensor by using fuzzy inference system for efficient car detection. Moreover, an adaptive module is presented to adapt on new rules set by an expert. The proposed fuzzy wireless sensor is implemented in the parking system simulator. The result of experiments shows that the fuzzy wireless sensor provides more throughputs and less time delays.

The future work will be the functions of application services and middleware of the parking management system based on the proposed architecture from this paper. Also, additional ubiquitous devices needed to be implemented are the next topic.

References

[1] Arampatzis, T., Lygeros, J., and Manesis, S.: A Survey of Applications of Wireless Sensors and Wireless Sensor Networks. Proc. of the 2005 IEEE International Symposium on Intelligent Control (2005) 719-724

[2] Karl, H. and Willig, A.: Protocols and Architectures for Wireless Sensor Networks, John Wiley & Sons Ltd. (2005) 231-288.

[3] Chou, L., Sheu, D. C. C., and Chen, H. W.: Design and Prototype Implementation of a Novel Automatic Vehicle Parking System. International Journal of Smart Home, Vol. 1, No. 1 (2007) 11-16

[4] Tang, V. W. S., Zheng, Y., and Cao, J.: An Intelligent Car Park Management System based on Wireless Sensor Networks. Proc. of the 1st International Symposium on Pervasive Computing and Applications, 65-70

[5] Miura, S., Zhan, Y., Kuroda, T.: Evaluation of Parking Search using Sensor Network. Proc. of the 1st International Symposium on Wireless Pervasive Computing. (2006) p. 6

[6] Benson, J. P., O'Donovan, T., O'Sullivan, P., Roedig, U., Sreenan, C.: Car Park Management using Wireless Sensors

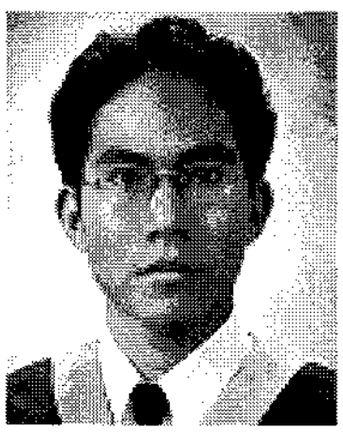
[7] Kumar, R., Chilamkurti, N. K.,and Soh, B.: A Comparative Study of Different Sensors foe Smart Car Park Management. Proc. of International Conference on Intelligent Pervasive Computing, (2007) 499-502

[8] Cervantes, L. F., Lee, Y. S., Yang, H. and Lee, J.: A Hybrid Middleware for RFID-based Parking Management System using Group Communication in Overlay Networks. Proc. of the International Conference on Intelligent Pervasive Computing (2007) 521-526

[9] Zadeh, L. A.: Fuzzy Sets, Information and Control (1965) 338-353.

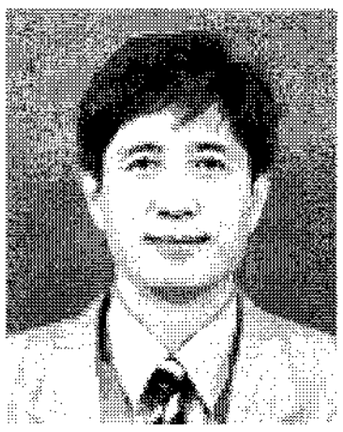
[10] Zilouchian, A., and Jamshidi, M.: Intelligent Control System using Soft Computing Methodologies, Wiley, (2001) 187-210

◐ 저 자 소 개 ◑



마테오 로미오(Romeo Mark A. Mateo)

2004 West Visayas State University, Philippines
BS in Information Technology
2007 Kunsan National University, South Korea
Master of Engineering major in Information and Telecommunications
2007 ~ current Kunsan National University, South Korea
Graduate student in Ph.D course
Research interest : Distributed systems, data mining, fuzzy systems, multi-agents, mobile computing
E-mail : rmmateo@kunsan.ac.kr



이 재 완(Jae-wan Lee)

1984년 중앙대학교 이학사-전자계산학
1987년 중앙대학교 이학석사-전자계산학
1992년 중앙대학교 공학박사-컴퓨터공학
1996년 3월~ 1998년 1월 한국학술진흥재단 전문위원
1992 ~ 현재 군산대학교 전자정보공학부 교수
관심분야 : 분산 시스템, 운영체제, 실시간 시스템, 컴퓨터 네트워크, 멀티미디어 등
E-mail : jwlee@kunsan.ac.kr