Hindawi Publishing Corporation
International Journal of Distributed Sensor Networks
Volume 2012, Article ID 421259, 8 pages
doi:10.1155/2012/421259

Research Article

For the Pet Care Appliance of Location Aware Infrastructure on Cyber Physical System

Chung-Ming Own

Department of Computer and Communication Engineering, St. John's University, Taipei 62107, Taiwan

Correspondence should be addressed to Chung-Ming Own, cmown@mail.sju.edu.tw

Received 24 February 2012; Accepted 12 April 2012

Academic Editor: Chih-Yung Chang

"Technology stems from humanity." This sentence is a good description of modern life. The interaction between humans and physical devices and objects in the real world is gaining more attention and requires a natural and intuitive methodology to employ. Cyber physical systems refer to a new generation of systems that integrate computational and physical capabilities and are capable of interacting with humans through many new modalities. Thus, this study examines the ability of computation, communication, and control technologies to improve human interaction with pets. This study proposes a mobility-aware algorithm to enable digital home technology for pets and implements the proposed system to prove that it meets the needs of pet owners.

1. Introduction

Over the years, system and control researchers have pioneered the development of powerful system science and engineering methods and tools, such as time and frequency-domain methods, state space analysis, system identification, filtering, prediction, optimization, and stochastic control. Simultaneously, scientific researchers have made major breakthroughs in many innovative approaches to ensure computer system reliability, security, and efficiency. Cyber physical systems (CPSs) have attracted the attention of many researchers. These systems aim to develop new science and supporting technology by integrating knowledge and engineering principles across computational and engineering disciplines [1, 2].

Unlike traditional systems [3], CPS is highly heterogeneous because it interconnects many heterogeneous cyber and physical devices into an application module, including computers, various types of sensors, and actuators. Thus, the technology for communicating between the physical world and computers is becoming increasingly important.

Wireless sensor networks (WSNs) consist of a large number of unattended, self-organized microsensors scattered in an area for a specific application. Each microsensor can sense environmental data, perform simple computations, and transmit data over a wireless medium to a command center, either directly or through a cluster gateway. Although WSNs are similar to networks, they differ from traditional networks primarily because of their strict energy constraints, greater sensor node density, lower cost, and precision design for information gathering [4].

Recent localization research involving location-aware applications has concentrated on improving the accuracy of target locating [5]. Energy efficiency and target tracking are essential for WSN deployment. The contradicting goals of energy saving and communicating activities make it difficult to determine the rate of triggering the localization system. This study shows that the energy consumption of a mobile unit is related to the sampling rate of the location information.

Because of the low birth rate in Taiwan, researchers should focus more on the rapid changes in lifestyle. Some studies indicate that when people go to a park on the weekend, more of them are walking dogs than carrying babies. According to a June 2006 report from Pet Care Services in the United States, America's pet care service generated approximately 363 million dollars in revenue in 2005. The annual growth rate of this service should reach 6% in the future [6]. In addition, Eastern Europe and Asia will become potential markets for pet services [7]. Meadows and Flint indicated that a low birth rate and weakening links between family members have increased the importance of pets [8], leading to a corresponding rise in pet services.

This study attempts to improve pet appliances with the ability of location-awareness and to help pet owners raise their pets easily. The proposed system integrates the concepts of CPS and WSN communication. The mobility of pets can be influenced by the location. That is, the mobile units in a WSN are classified as live, normal, or slow depending on their location. The parameters of velocity, moving distance, and stationary time vary greatly. This study presents a fuzzy logic system based on this concept. The contribution of this study is twofold. First, this study proposes a location-based mobility-aware sampling mechanism based on status classification. Second, this study applies a fuzzy logic system for decision making. Simulation results show that the proposed scheme can extend network lifetime.

This paper is organized as follows: Section 2 provides a brief review of pet products and WSN modules; Section 3 presents the proposed system model; Section 4 provides a discussion on the implementations; and, finally, Section 5 offers a conclusion.

2. Preliminaries

2.1. Pet Raising Solution. As Taiwanese society continues to have a low birth rate and an aging population, increasingly more people regard their pets as family members. This trend is reflected in pet-related products and market activities. For example, some pet owners have started bringing their pets with them while traveling. A report from the 2010 Asia Pacific Pet Economic Conference [6] mentioned that the pet industry has grown considerably in recent years. They forecasted that the market would double in the following two years. According to previous research [7], families in Taiwan raised 1,630,000 dogs in 1999. However, this figure decreased to 1,320,000 in 2007. The family average has 1.55% dogs. Conversely, only 195,000 cats were in families in 2001, and the total increased to 281,000 in 2006. This is an increase of 4.4% per family. Based on these figures, the average family has 1.6% cats. According to a report of the council for economic planning and development, more than 166,000 babies were born in Taiwan in 2009, representing a drop of more than 20,000 from the previous year. Thus, Taiwan's birthrate has dropped to the world's lowest at 8.29%, with only under one baby born per woman over a lifetime. The average family has more pets than children. This means that the demand for pet products will grow quickly, and household spending on pets will exceed that for children. The pet industry and pet owners have gradually begun to realize the need for automated raising devices.

Pet doors are one of the most common products in the market, and various types of pet doors are available for cats and dogs. Pet doors can be fitted in a lower portion of a wall or an existing full-sized door. A pet door may consist simply of a flap hung from a horizontal axis. This flap swings open, against the force of gravity, when pushed by an animal. A simple latch may hold the door in a closed position to prevent the movement of the door in either direction. The problem with this simple construction is that any animal small enough to fit through the opening may gain entry or egress, depending on the position of the latch. To prevent passage of unwanted stray animals, electronic pet doors have been designed with magnetically operable latches. In this type of design, any magnetic tag of adequate field strength can unlock the latch.

Pets face many of the same problems as humans, such as obesity, diabetes, and stomach problems. Automated feeding machines can provide for the care of such pets. Several automated pet feeders on the market are capable of dispensing kibbles, and some are capable of feeding canned food. Feeding kibbles do not cause food spoilage, whereas feeding canned food does. Canned food cannot be left in a device for prolonged periods because it spoils.

Pets also tend to be restless when owners are not at home, and they become hyperactive when owners return. Thus, a feeding device can help reinforce the behavior of playing when owners are not at home. It is occasionally necessary for pet owners to reinforce pet behavior by providing food for certain behaviors they may want the pet to perform.

There are many automatic pet feeders for feeding pets at predetermined times during an owner's absence. This type of pet feeder comprises a base, a feeding bowl with pie-shaped divisions, a timer module, a bowl cover, handle to bowl cover, and a locking mechanism to hold the entire unit in place. The timer provides programmed feeding schedules that determine the time the bowl cover closes or opens. This programming can be achieved through the timer interface or RF and IR remotes.

2.2. WSN Module. A typical WSN consists of sensors containing nodes with varying capabilities that collaborate with each other. Current WSNs include several advanced research modules with variable sensor sizes, power consumption, operating systems, and basic sensing abilities. The Mica family of sensors is one of the most common sensing modules in use [9, 10]. These sensors are supported by numerous operating system and sensing modules, including TinyOS, Mantis OS, and Contiki. The Mica family includes the MicaZ, Mica2, and Mica2Dot series of sensors.

The Telos family of sensors consists of TelosA and TelosB motes [11]. The Telos sensors represent a newer generation of motes when compared to the Mica family, because they have a USB interface for data collection and programming. The Tmote sky sensors contain a USB port to facilitate programming and are an exact replica of the TelosB suit of sensors. These features make them well-suited to experiments involving wireless sensor networks.

The Crossbow Imote2 is a sensor module in the Intel PXA271 Xscale processor with a built-in 2.4 GHz antenna [12]. It is a powerful module that supports computationally intensive tasks such as digital image processing. This is because of the scaling capabilities of its processor, which range from 13 up to 416 MHz. The 256 KB of on-chip SRAM, 32 MB of SDRAM, and 32 MB of FLASH memory in this module provide several orders of magnitude more resources for memory-intensive applications than other modules. Power consumption is extremely low, making this module ideally suited for demanding but battery-powered applications.

SHIMMER is a sensor module for health-related technologies with intelligence, modularity, mobility, and experimental reusability [13]. This module supports wearable applications such as capturing real-time kinematic motion and physiological sensing. SHIMMER motes are driven by TinyOS and support up to 2 GB of data storage for offline data capture. Some applications of this module include sleep studies, cognitive awareness, vital signs monitoring, and chronic disease management.

The proposed system is based on the Octopus family [14]. Octopus-I includes an 802.15.4 compliant RF transceiver and works around the ISM band (from 2.4 to 2.48 GHz) with a direct sequence spread spectrum. Octopus-I is also programmed using TinyOS, and the sensor node design is based on the Atmel ATmega128L. The programming board provides a serial interface and an onboard microcontroller for extended monitor control. The other module is Octopus-II, which is a reliable low-power WSN module for extremely low power, high data rate, sensor network applications. This module has 10 Kb of on-chip RAM, is compatible with the IEEE 802.15.4 protocol, and has an integrated on-board antenna. Octopus-X is a new WSN module in this family, the MCU is CCC2431, and the external crystal is up to 32 MHz.

2.3. Fuzzy Logic System. Fuzzy logic systems (FLSs) are knowledge-based or rule-based systems. The heart of a fuzzy system is a knowledge base consisting of the so-called fuzzy IF-THEN rules. A fuzzy IF-THEN rule is an IF-THEN statement in which some words are characterized by membership functions. The basic configuration of a pure fuzzy system is shown in Figure 1. The fuzzy rule base represents the collection of fuzzy IF-THEN rules. When an input is applied to a system, data from a real-value point is mapping to a fuzzy set in [0, 1], and the inference engine computes the output set corresponding to each fuzzy rule. The defuzzifier then computes a crisp output from these rule output sets.

Consider a p-inputs 1-output FLS, using singleton fuzzification, center-of-sets defuzzification and "IF-THEN" rules of the form

$$\begin{aligned} R_l: &\text{IF } x_1 \text{ is } F_1^l \text{ and } x_2 \text{ is } F_2^l \text{ and} \ldots \text{and } x_p \text{ is } F_p^l, \\ &\text{THEN } y \text{ is } G^l. \end{aligned} \quad (1)$$

Assuming single fuzzification, when an input $x' = \{x_1', \ldots, x_p'\}$ is implemented, the degree of firing corresponding to lth rule is defined as

$$\mu_{F_1^l}(x_1') * \mu_{F_2^l}(x_2') * \cdots * \mu_{F_p^l}(x_p') = \prod_{i=1}^{p} \mu_{F_i^l}(x_i'), \quad (2)$$

where $*$ and Π both indicate the t-norm [15], $\mu_{F_i^l}(\cdot)$ is represented as the membership function of the ith item in the l fuzzy rules. Accordingly, the center-of-sets defuzzifier is used to generate the output of FLS by computing the centroid, c_{G^l}, of every consequent set G^l, and then computing a weighted average of these centroids. The weight corresponding to the lth rule consequent centroid is the degree of firing of the lth rule, $\Pi_{i=1}^{p} \mu_{F_i^l}(x_i')$, that is, the general inference system is defined as

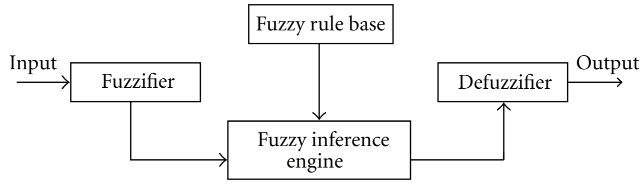


Figure 1: The structure of a fuzzy logic system.

$$y_{\cos}(x') = \frac{\sum_{l=1}^{M} c_{G^l} \Pi_{i=1}^{p} \mu_{F_i^l}(x_i')}{\sum_{l=1}^{M} \Pi_{i=1}^{p} \mu_{F_i^l}(x_i')}, \quad (3)$$

where M is the number of rules in the FLS. $y_{\cos}(\cdot)$ is used to derive the output of the center-of-sets defuzzifier, which value is indicated as the importance of inference results [15]. This equation is represented as our fuzzy inference engine in this study.

Accordingly, in our real world, knowledge about exceptions may be incomplete, so representing the set of exceptions exclusively by using a default rule is impossible. Therefore, reasoning systems should be modified to accommodate such partially true knowledge. In our study, the authors use fuzzy rules of the following type for the rule weight specification

$$\begin{aligned} R_l': &\text{IF } x_1 \text{ is } F_1^l \text{ and } x_2 \text{ is } F_2^l \text{ and } \ldots \text{and } x_p \text{ is } F_p^l, \\ &\text{THEN } y \text{ is } G^l \text{ with } CF_l, \end{aligned} \quad (4)$$

where CF_l is a certainty grade (i.e., rule weight). Thus, the weighted inference equation is derived by the previous equation (3):

$$y_{\cos}(x') = \frac{\sum_{l=1}^{M} c_{G^l} \Pi_{i=1}^{p} \mu_{F_i^l}(x_i') \cdot CF_l}{\sum_{l=1}^{M} \Pi_{i=1}^{p} \mu_{F_i^l}(x_i')}. \quad (5)$$

3. System Design

Although numerous automatic pet monitoring systems exist, such as automatic pet doors and pet feeders, these systems cannot meet the needs of pet owners. For example, most pet care systems are based on infrared detector/recognition, which can be used to spot pets at the door, register their movements, and alert owners when pets enter areas where they are not allowed. This type of design has some disadvantages because infrared detectors can be influenced easily by unknown reasons. The detection cannot go through. The proposed system focuses on the implementation of a pet care system with a location-aware algorithm.

3.1. Intelligent Pet Door. Many families install a pet door for family pets. Pet doors are adapted to be fitted in the lower portion of a wall or existing full-sized door. Pet doors allow family pets to pass the door easily. Figure 2 shows the system flowchart of the pet door. The pet wears a sensing tag on its collar, and the collar broadcasts the pet ID continuously. Figure 3(a) shows the collar design. The pet door detects the pet's location and periodically requests the pet schedule from the server. The proposed system is based on the following ideas.

(1) An animal detector can detect an animal seeking passage through the pet door.

(2) A controller enables selective passage.

(3) A selective latch is disabled to allow passage past the pet door.

(4) A clock allows the pet owner to manage the time schedule or set up predefined pass-through condition for pets.

(5) A detecting tag is programmed by the WSN module, not infrared detection or magnetic detection.

(6) An LED light can inform the pet owner where the pet is located.

The development process is listed as follows. First, we installed several WSN modules as the outdoor sensing platform. These modules provide the pet owner with outdoor temperature/humidity data, allowing them to can change the pet scheduling permission according to the weather change. For example, no pets are allowed to go outside on a rainy day.

Second, we installed a light motion sensor on the top panel of the pet door to detect flap switching. By identifying the flap switching direction, the system can determine whether the pet is trying to enter or exit, illuminating differently colored lights to indicate the pet's location. The pet owner can quickly identify the pet location by reading the indicator.

Finally, according to the system diagram shown in Figure 2, a pet wears a sensing tag on its collar and broadcasts the pet id message to the pet door for every 20 seconds. This tag functions as a tracking node in Figure 3. In the meantime, the environment center also broadcasts the microtemperature message of the outdoor for 30 minutes. Finally, the control center functions as a data center collecting all the system messages from the above devices. Besides, Figure 3 is the prototype of pet tag we will load the system with the box for the function of waterproof in the actual operation.

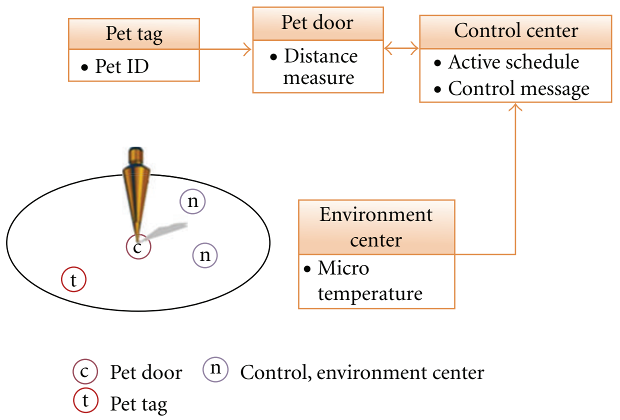


Figure 2: The system diagram of pet door.

(a)

(b)

Figure 3: (a) Sensing tag on the cat neck, (b) sensing tag on the collar.

3.2. Intelligent Pet Feeder. Most pets eat dry food. Pet owners cannot leave out wet food because it spoils in the time the pet must eat it. Dry food feeders can keep dry food fresh longer and allow the owner to feed a pet automatically, even when outside the home. These feeders are nearly always placed on the floor next to an external wall where they are accessible to crawling insects, such as ants, which have a propensity to seek a supply of food. These insects not only contaminate the pet food, but are often intolerable to the pet owner.

Numerous attempts have been made to design a pet feeder that resolves the problem of crawling insects. Most of these efforts have produced feeders with a multiplicity of discrete components. These feeders must be disassembled for cleaning and then reassembled before further use. The pet feeder of a trading company has the general appearance of a conventional feeder, but has a moat-forming cavity surrounding the food bowl [16]. This pet feeder can keep the pet food and water clean until the pet is ready to eat. This pet feeder also has a bowl cover that opens and closes automatically. The bowl cover is actuated by an infrared proximity sensor and battery-operated electric motor. The sensor detects the presence of the pet and then opens the cover, enabling only the pet to have access to the food. When the pet is out of sensor range, the bowl cover closes automatically. This keeps dust, flies, and bugs from reaching the food and keeps the food fresh.

The intelligent pet feeder system in this study is based on the following ideas.

(1) An animal detector can detect an animal trying to access the food.

(2) A controller allows a permitted pet to access the food.

(3) A clock allows a pet owner to create a time schedule or establish predefined eating conditions for pets.

(4) A detecting tag is programmed by WSN module, and not infrared detection or magnetic detection.

(5) A pet owner can schedule eating time remotely.

The system process is listed as follows. First, a pet owner can use a web page to remotely modify the pet eating schedule, including the number of meals, beginning/ending time of meals, and which bowl to open immediately. Hence, when it is meal time, the feeder plays alert music to call the pet within the WSN sensing range to obtain food. A controller requests permission from the server node to open the cover. During meal time, the feeder opens the cover whenever the pet is within sensing range.

Second, if the owner forgets to feed the pet, the owner can use remote access to open the bowl on demand.

Finally, Figure 4 shows the system diagram of the pet feeder. A pet wears the sensing tag on the collar as the description in Figure 2, and this tag broadcasts the pet ID every 20 seconds to identify the pet's location. The control center functions as a data center, collects all the system messages from the above devices, and includes the eating schedule and the control messages.

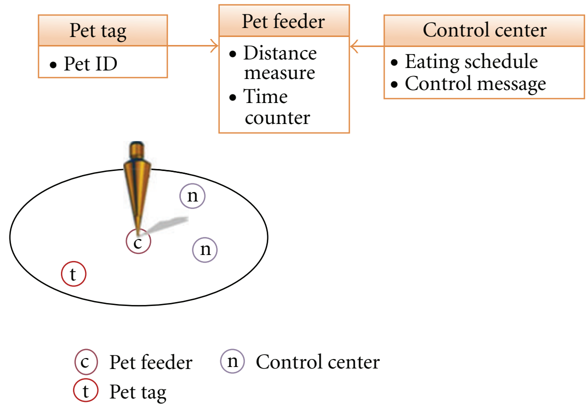


Figure 4: The system diagram of pet feeder.

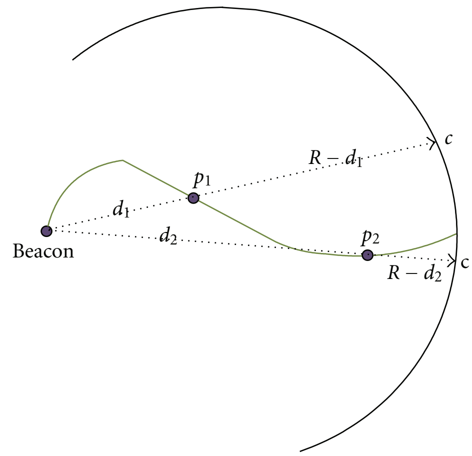


Figure 5: The node illustration in WSN environment.

3.3. Location Aware Algorithm. This algorithm helps the system detect the exact time the pet reaches the critical point. Because of the high speed of home pets, the system must detect the pet's location rapidly to react to the pet's activity.

The critical point is where the line of movement intersects with the critical region. To simplify the sampling mechanism, Figure 5 shows a WSN environment for a one-dimensional space. Figure 5 shows two recent sample points p_1 and p_2. As the mobile unit reaches position p_2, the proposed system computes the next sample time by calculating the time for the mobile unit to move from the current position p_2 to the critical point c in velocity V_{p_2}, which is estimated by dividing the rate of movement from p_1 to p_2. The critical region is set as the distance away more from than R distance to the beacon node in WSN, and the critical points all fall on a circle, the center of which is the beacon node. Assuming that the mechanism of deriving the distance between the mobile unit and beacon node is clear and precise, the proposed system focuses on reducing the amount of distance estimation messages. During the message exchange stage, the beacon node sends probing messages to the mobile unit and waits for reply messages from the mobile unit. Both nodes can derive the relative distance by using the distance estimation method (e.g., d_1 and d_2 in Figure 5).

Accordingly, after obtaining the outgoing velocity, distance between the pet and the critical point, stationary time, and stationed location, we listed the relationships with the sampling rate (frequency) in Table 1. After calculating the velocity of a mobile unit, the sampling rate (probing frequency) increases in conjunction with the velocity because the system regards the target as active and ready to leave. When the pet approaches the critical point, the critical distance decreases and the sampling rate increases to catch the target motivation (e.g., $|R - d_1|$ in Figure 5), and vice versa. Similarly, with longer stationary time of the mobile unit and the role matching degree of the stationed location, the higher value means that the sampling rate is set low for lower activities.

The proposed inference algorithm sets up fuzzy rules for tracking the target node based on the following descriptors:

(1) distance between the mobile unit and critical point,

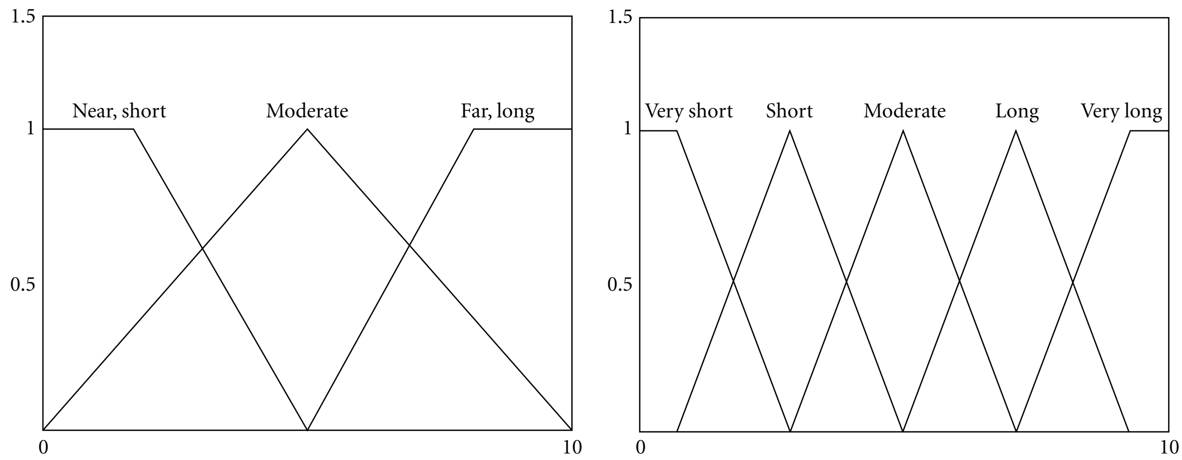
(2) its stationary time,

(3) its relative velocity.

This study uses three linguistic variables to represent the distance between a target node and the destination: *near*, *moderate*, and *far*. The terms representing its stationary time and relative velocity are *short*, *moderate*, and *long*, and *slow*, *moderate*, and *fast*. The consequent (i.e., the estimated time before the node reaches the critical point) is divided into

TABLE 1: Sampling rate with the parameters of system.

	Relative velocity	Critical distance	Stationary time	Stationed location
Sampling rate↑	Fast	Near	Short	Unfitted
Sampling rate↓	Slow	Far	Long	Fitted



(a) (b)

FIGURE 6: The MFs used to represent the linguistic labels. (a) MFs for antecedents, and (b) MFs for consequent.

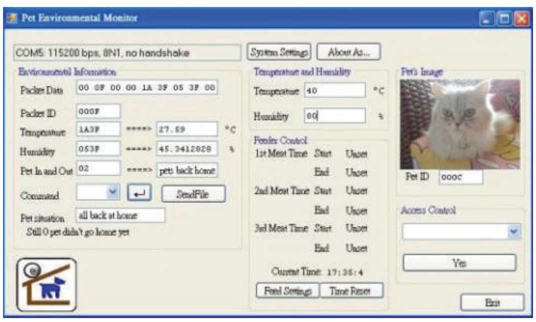


FIGURE 7: The control interface on the web server (C# code).

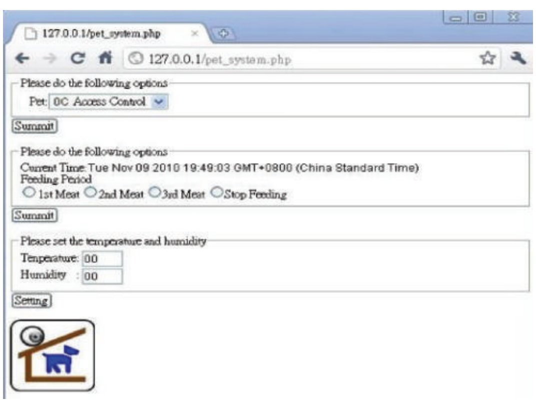


FIGURE 8: The control interface of the web server (php code).

five levels: *very long*, *long*, *moderate*, *short*, and *very short*. Accordingly, the proposed FLS has 27 rules.

Conversely, the value of stationed location is defined as the rule weight of the FLS. This value varies with the WSN environment. Therefore, this study uses trapezoidal membership functions (MFs) to represent near, short, slow, far, long, and fast. Triangular MFs represent moderate in Figure 6(a), and Figure 6(b) shows the MFs for consequent MFs. For every input (x_1, x_2, x_3), the output can be computed as (5):

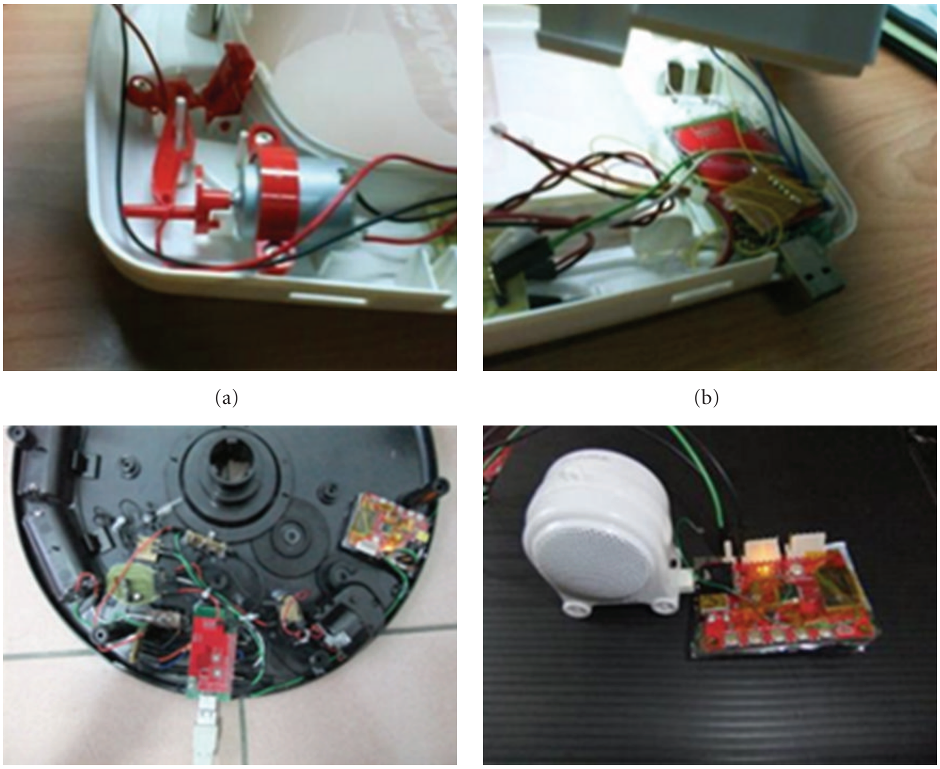
$$y' = \frac{\sum_{l=1}^{27} c_{G^l}\mu_{F_i^l}(x_1)\mu_{F_i^l}(x_2)\mu_{F_i^l}(x_3)\cdot CF_l}{\sum_{l=1}^{27}\mu_{F_i^l}(x_1)\mu_{F_i^l}(x_2)\mu_{F_i^l}(x_3)}, \tag{6}$$

where c_{G^l} is the centroid of the consequent set, and CF_l is the rule weight. The system output y' represents the possibility that the mobile unit moves across the critical point. Thus, the expect time elapsed for the mobile unit is defined as

$$T = \frac{|(R - d_b)|}{|V| \cdot y'}, \tag{7}$$

where d_b is the distance between the beacon node and mobile unit, and the absolute value on $R - d_b$ is computed as the critical distance. The variable y' is the moving possibility of a mobile unit, and the expected time increases as this possibility decreases.

After identifying the relative parameters and deriving the system output, the system obtains the time interval T to send the next probing message, and then returns this message to the beacon node, along with the reply message. The beacon node then schedules the next probing message. Both sides can then immediately suspend radio communication to conserve energy.



(a) (b) (c) (d)

Figure 9: (a) and (b) are the disassemble pictures of pet door, (c) and (d) are the disassemble pictures of pet feeder.

4. The System Implementation

Figures 7 and 8 show the proposed control software in the control/web server. The proposed design uses a C# program for the native client user (Figure 7), and a PHP program can be remotely executed on a smart phone as the pet owner wishes (Figure 8). According to the software design, the pet owner can monitor environmental data (i.e., obtain the weather report), the managed pet ID, and the pet location (inside/outside). The pet owner can also set the eating time schedule and command the bowl cover to open remotely.

Figure 9 shows a disassembled pet door. Figure 9(a) shows that we directly connected the motor to the IO interface of the WSN module, and Figure 9(b) shows that we installed the Octopus-II as the coordinator node into the system design. This node also codes the location-aware algorithm. Figure 9(c) shows the interior of the pet feeder. The Octopus-II node controls the gears to rotate the bowl and open or close the cover. Figure 9(d) shows the music module. At each set eating time, the server sends data packets to the WSN module, causing the music module to play music when it is eating time.

5. Conclusion

The interaction between humans and physical devices and objects is attracting increasing attention. Many studies have attempted to provide a natural and intuitive approach to request services. The current trend of combining pet control and CPS technology offers exciting future developments. This study presents an intelligent pet care system based on the concept of the Internet of things. The proposed system is based on smart-home technology, including an intelligent pet door and pet feeder. The implementation reported here shows that the system can overcome the disadvantage of traditional products and meet the needs of pet owners.

Acknowledgment

The author thank the National Science Council of the Republic of China, Taiwan, for partially supporting this research under Contract no. NSC 100-2218-E-129-001.

References

[1] E. Lee, “Cyber-physical systems—arecomputing foundations adequate?” *Workshop On Cyber-Physical Systems*. In press.

[2] L. Sha, S. Gopalakrishnan, X. Liu, and Q. Wang, “Cyber-physical systems: a new frontier,” *Machine Learning in Cyber Trust*, pp. 3–13, 2009.

[3] Y. Tan, G. Goddard, and C. P. Lance, “A Prototype architecture for cyber-physical systems,” *ACM SIGBED Review*, vol. 5, no. 1, 2008.

[4] K. R. Bhakare, R. K. Krishna, and S. Bhakare, “An energy-efficient grid based clustering topology for a wireless sensor network,” *International Journal of Computer Application*, vol. 14, pp. 24–29, 2012.

[5] T.-C. Chiang, J.-L. Chang, and S.-W. Lin, "A distributred multicast protocol with location-awae for mobile Ad-Hoc networks," *Advances in Intelligent and Soft Computing*, vol. 129, pp. 691–697, 2012.
[6] Packaged Facts, *Pet Care Services in the U.S*, 2nd edition, 2006.
[7] APPEC, "Asia pacific pet economic conerence," http://www.apec.org/.
[8] G. Meadows and E. Flint, *The Cat Owners'Handbook*, 2006.
[9] B. Buchli, F. Sutton, and J. Beutel, "GPS-equipped wirelesssensor network node for high-accuracy positioning applications," *Lecture Notes in Computer Science*, pp. 179–195, 2012.
[10] C. Townsend and S. Arms, "Wireless Sensor Netowrks, Priciples and Applications," Principles and Applications, Sensor Technology Handbook Newness Publication, 2005.
[11] D. Wen and Y. Ma, "The Application of wireless sensor in aquaculture watrer quality monitoring," *IFIP Advances in Information and Communication Technology*, vol. 370, pp. 502–507, 2012.
[12] Crossbow Imote2, http://www.xbow.com/.
[13] Shimmer, "Wearable Wireless Sensor Module," http://www.shimmer-research.com/.
[14] Octopus Series Family, http://www.wsnc.ntu.edu.tw/.
[15] J. M. Mendel, *Uncertain Rule-Based Fuzzy Logic Systems: Introduction and New Direction*, Prentice Hall, New Jersey, NJ, USA, 2001.
[16] The Pet Feeder, http://gadgets.softpedia.com/gadgetsImage/Automatic-Pet-Feeder-1-22503.html.