Cat@Log: Sensing Device Attachable to Pet Cats for Supporting Human-Pet Interaction

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ABSTRACT

In spite of the development of technologies that support human-computer or human-human interaction, few studies have been conducted for improving interactions between humans and pets, pets and computers, or between two pets. We propose a new area of research on entertainment using computers, called "human-pet interaction." As an initial step in this research, we have developed a series of sensing devices that can be attached to pet cats, called Cat@Log (cat-a-log). These devices comprise various sensing units such as a camera, a GPS, an accelerometer, and a Bluetooth module. Here, we attempted to determine an optimum design of the devices such that they can be attached to a pet without causing discomfort to it; for determining this design, we considered parameters such as the device's form factor and way of attachment. These developed devices can recognize the experiences and activities of cats; information sensed by the devices is transmitted in real time by using the Bluetooth wireless module. We used this platform and developed a software system that automatically recognizes a pet's high-level behavior and posts it to Twitter.

Categories and Subject Descriptors

H.5.2 [**User Interfaces**]; I.3.6 [**Methodology and Techniques**]: Interaction techniques

Keywords

User Interface, Human-Pet Interaction, Life Log, Wearable Computing, Activity Recognition

1. INTRODUCTION: HUMAN-PET INTERACTION

Since ancient times, animals have been closely associated with people, in the form of pets that act as partners and companions. Around 63% of all U.S. households have pets.

Figure 1: Cat wearing Cat@Log sensing device.

Almost all owners wish to gain a better understanding of the moods, feelings, and behavior of their pets. Unfortunately, it is difficult to communicate with pets, because human and pets do not speak a common language. Recently, various digital technologies have been developed for supporting human-to-human communication, such as emails, blogs, chat rooms, and social networking sites (SNSs). However, these systems are limited to humans. If we could support interactions between human and pets, our lives and those of our pets could be enriched. In spite of the development of human-human communication technologies, few studies have been conducted to improve communication between humans and pets. Thus, our goal is to establish such communication media; we term this research area "human-pet interaction."

The design space for pet interaction is shown in Figure

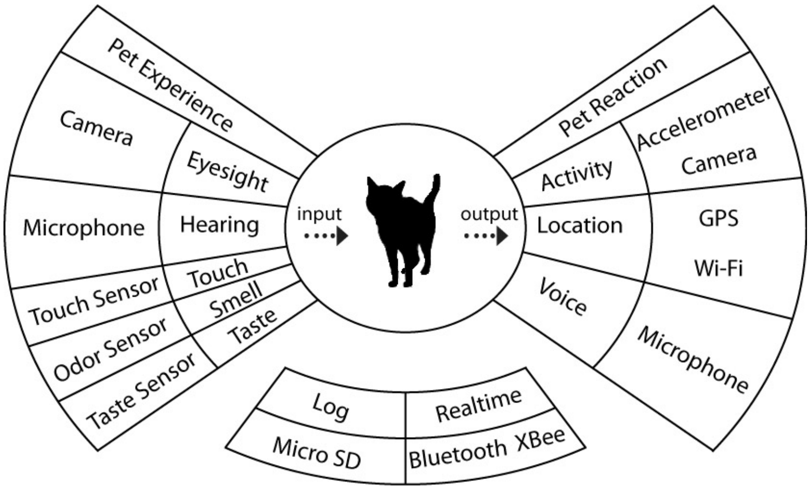

Figure 3: Pet input and output. (Pet experience (pet input) is shown on the left. Here, each sensor corresponds to one of the five senses. Pet reaction (pet output) is shown on the right. Here, the sensors correspond to a cat's reaction. The logging function is shown at the bottom.)

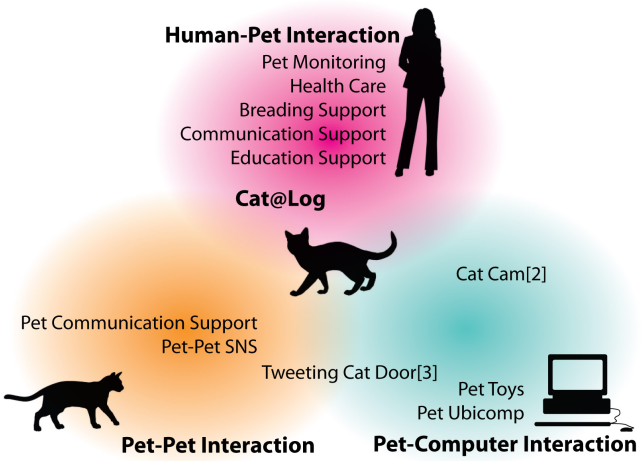

Figure 2: Design space for pet interaction.

2. Currently, various *pet-computer* interaction tools for cats, that is, cat-friendly systems, are available on the market. Examples include electronic toys and automatic feeding plates. Some researchers have developed ubiquitous computing systems for application to their pets. For example, a cat door that opens with an RFID tag attached to a cat's collar has been developed[12]. This system ensures that cats apart from the owner's pet cat do not enter the house; thus, the food of the pet cat is protected. Further, a system called Cat Cam[13] has been developed, which is a camera that enables a cat to take photos outside of home.

We further thought of improving communication among pets. An SNS service could be developed for investigating the interaction among pets. A Nintendo DS game called "Nintendogs" is available on the market, in which a player owes a pet dog. With the help of the "Surechigai" crossing mode available by an ad hoc Wi-Fi connection, even players who do not know each other can exchange messages. Though this system is virtual, it indicates the possibility of a *pet-pet* interaction.

In this study, we focused on the *human-pet* interaction. Here, the interaction between humans and pets is supported by a computer. For this scenario, we could think of many applications, as shown in Figure 2. By means of such an interaction, humans can monitor the activities of their pet even when the pet is not around. Thus, by using a personified interface, owners can understand their pets better.

Owners feel the need to know what their pets are seeing, hearing, doing, etc. Such pet experiences and reactions are shown in Figure 3, indicated as *Pet Experience* and *Pet Reaction*, respectively. These two categories can also be classified as *input* and *output*, respectively. On the *input* side, data on the five senses, that is, sight, hearing, touch, smell, and taste, can be collected. On the *output* side, data on the activities, location, and voice can be collected. The sensors for collecting such data are also shown in Figure 3.

2. CAT@LOG PROJECT

To achieve the abovementioned goals, we have developed a software system and a series of sensor devices that can be worn by cats. The sensor device has multiple sensors (e.g., accelerometers, cameras, global positioning systems (GPSs), etc.) and a storage unit in order to record activities of pets continuously. A wireless communication system may also be required to collect these data in real time. We must select these sensor devices carefully because they would be used to collect different information from the outside world than that collected by humans (for example, the audible frequency ranges of cats and humans are different).

2.1 Pet Selection

We conducted this study with a female house cat as a pet. It is known that cats are the most popular pets worldwide. In addition to this reason, we selected a house cat in this study because as reported by Driscoll[8], cats contribute virtually nothing in the way of sustenance or work to human endeavor, whereas other once-wild animals were domesticated for their milk, meat, wool or servile labor. Though cats do not serve any such purpose, around 600 million cats are currently living among humans. Humans adopted cats as pets because their features elicit nurturing from humans.

It is said that understanding the feelings of cats is more difficult than understanding those of other pets such as dogs. Dogs usually live in a pack with their relatives and form their own society. Therefore, dogs are used to having a leader (leader of the pack); as a result, they quickly adjust to humans as their leaders. In contrast, cats almost always live in isolation and do not like external interference in their lives. This is why many humans feel that cats are difficult pets. For these reasons, we focused on developing an interaction system for pet cats.

2.2 Possible Ways of Attaching Sensor Devices

Because of the inability of cats to converse with humans, they cannot communicate even when the device attached to them causes them discomfort. Therefore, the device must be designed with extra care. In the conceptual phase, we looked at several possible ways of attaching the device, as shown in Figure 4.

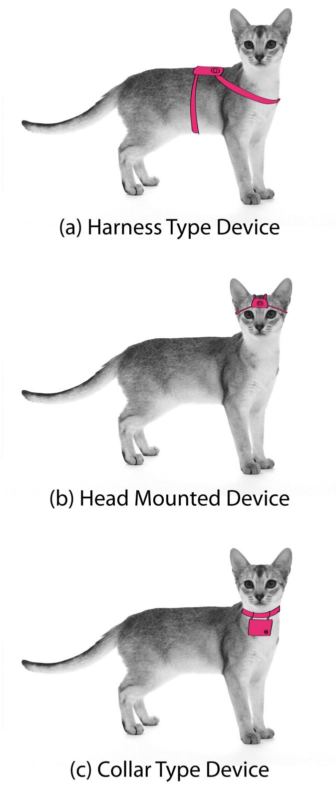

Figure 4: Possible ways of attaching sensor devices to cats.

In the case of a *harness-type device* (Figure 4(a)), the load of the device would be distributed, and the comfort level by this way of attachment would be higher than that in the case of other ways of attachment. Dogs, for example, wear harnesses often when they are taken out for a walk. Filets wear harnesses as well. However, this harness-type device could be an obstacle when a cat wants to lick its body and groom itself. Moreover, it is impossible to collect optical data from the viewpoint of the cat's sight because the front side of the device is occluded by the cat's head.

Data on the cat's sight can be collected most accurately by the use of a *head-mounted device* (HMD) (Figure 4(b)). This type of device offers another advantage: receiving information from GPS satellites would be easy because the device is attached to the upper part of the cat's head. If this device were to be attached to a human candidate's head, the candidate would be instructed not to move his/head vigorously in order for the device to remain stable; further, a human candidate would also bear with the uncomfortable feeling of having a device mounted on a body part. However, it would be extremely difficult to attach an *HMD* to a cat's head. Cats are highly temperamental, and they would dislike having any external object mounted on them, particularly on their head. It is not difficult to imagine that they would shake their heads vigorously in an attempt to get rid of the device.

As a result, a *collar-type device* (Figure 4(c)) appears to be most suitable for being attached to cats. Many pet cats wear collars, and some collars even have charms on them. The feeling of equipment attached to a collar may be quite familiar to cats. If a camera is attached below the neck, it provides a pseudo-view of the cat's sight. By this way of attachment, most of the sensors would be located under the cat's chin. This could cause difficulty in collection of data from GPS satellites. Our solution for overcoming this difficulty is to attach an extending cable so that the GPS antenna may be attached to the other side of the collar, as is shown in Figure 5. This will provide easy access to GPS satellites. Though the GPS-related problem is solved, it would still be difficult to accurately detect the cat's line of sight.

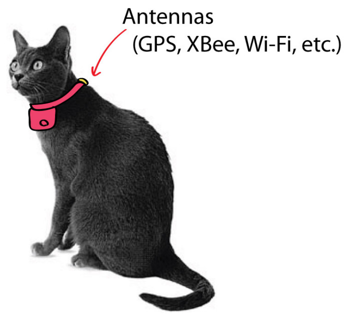

Figure 5: Antennas attached to back side of collar-type device.

2.3 Sensor Selection

From the viewpoint of animal ethics, devices attached to an animal must be less than 4 to 5% of the animal's weight[16]. The average weight of an adult cat varies, but it is usually between 2 and 7 kg. The weight of the participant cat in this study is 3 kg, but we think that the developed systems should be compatible with cats of different weights. From these considerations, we set the maximum weight of the device to 60 g, which is 3% of a cat weight of 2 kg.

To satisfy this weight condition, we must carefully select the sensors to be loaded onto the device. For this, we focused on the point that sensors could be broadly divided into two categories on the basis of the input and output Figure 3 of the cat, that is, information collection and cat's reaction, respectively. Since cats are dependent mostly on the sense of *sight*, an optical camera would be appropriate for collecting the same information that cats collect from the outer world. Since a cat's eye collects more light than human eyes do, a highly sensitive camera may reproduce the cat's view with accuracy, but due to the weight limitation, it might be difficult to mount such a camera.

Cats are also dependent on their sense of *hearing*; thus, we performed an experiment in which noise from a microphone was collected. However, cameras were more effective for collecting surrounding data. As mentioned earlier, the audible frequency range of a cat differs from that of a human; thus, the collected data may be quite different from the data actually being received by the cat. Loading a microphone onto the device would require power, and in consideration of the battery endurance, we decided not to load a microphone onto the device. However, we are considering the possibility of loading a microphone in a future study.

Another necessary sensor is an accelerometer. Data from an accelerometer could be analyzed to determine the activity of the cat. It is true that a cat's activities can possibly be monitored by a camera, but cats are small and sensitive, so the device must be small and light so as not to be a burden to the cat. A high-performance camera is required for analyzing and classifying cat's activities, but it is difficult to mount such a camera because of the abovementioned weight limitation.

A location platform would also be a useful tool for determining the cat's reaction. For cats living in urban areas, a Wi-Fi-based location platform would yield accurate location information, but the problems with using such a platform are its size and weight. A GPS is smaller and lighter, and thus, we decided to use a GPS module as a location platform.

A memory device is required to store the collected data. A micro SD card is a popular memory device that can be read in many personal computers (PCs); therefore, we mounted micro SD card slots on our devices.

To acquire real-time information on the cat, a wireless communication system is required. We selected a class 1 Bluetooth device to transmit information to the computer. An XBee module was another candidate for this purpose because of its small size; however, its power consumption is greater than that of Bluetooth modules, and a receiver must be attached to the computer if the XBee module is to be used. For these reasons, computers containing Bluetooth modules are becoming increasingly common.

2.4 Output

Since the subject of this study was nonhuman, we did not have to be concerned about privacy. However, since cats and humans cannot communicate via a common language, it is difficult for one to determine the other's thoughts and emotions. To solve this problem, it is important to know one's pet's lifestyle; e.g., one should know when, where, and what one's pet is doing. Checking the cat's life log would help the owner understand the cat. The owner would then be able to reward the cat for some difficult task performed successfully or to adjust the amount of food given to the cat in order to control its diet. An area of research, called "life log," has been developed in the past. For example, Clarkson [6] extracted his life patterns from wearable sensor data for human. Application of a similar life log technology can enable humans to determine a cat's life log using a device made especially for cats.

In order for owners to be able to feel more empathy for their pet cats, the output of the system should be a personified representation. Blogs, SNSs, emails, and chat rooms are some of the possible outputs of the system. We now are considering blogs and Twitter (a mini-blog) as output media for our Cat@Log project.

3. SYSTEM IMPLEMENTATION

3.1 Evolution of Cat@Log Devices

We have developed three kinds of devices as a part of our Cat@Log project. Figure 6 shows the evolution of these devices. The latest device contains a camera module, an accelerometer, a GPS module, a micro SD card logger, a Bluetooth module, and a Li-Po Battery. Figure 1 shows the cat wearing the latest collar-type device.

3.2 Camera (and Microphone)

3.2.1 Video of Cat's View and Stabilization of Video

Photos and videos will replace the cat's vision. By attaching a camera near the cat's face, we can collect information that cannot be obtained using an external camera. However, there are some problems associated with mounting a camera on a collar. Cats cannot hold the camera still, but they do not generally move their heads while walking or running. Therefore, applying video stabilization would yield accurate data on the cat's view. Then, we selected Takahashi's real-time video stabilization method[15], since this method can be used to stabilize jerky or blurred videos after they have been recorded. Figure 8 shows the result of video stabilization.

3.2.2 Module for Detection of Cat's Face

We prepared a database for detecting the cat's face, by using data collected by the camera. We used rapid object detection with a cascade of boosted classifiers based on Haar-like features supported in OpenCV. This program can be used to detect desired objects by changing the database. We can use a face detection algorithm to detect cats' faces, as shown in Figure 9. By detecting the face of a cat, we can know the relationship of the cat both inside and outside home.

3.3 Accelerometer

3.3.1 Activity recognition

We could recognize the cat's activity from daily logging data obtained from the acceleration sensors. The possibility of human activity recognition was verified by Clarkson[5]. We applied this technique to cats for monitoring some of their activities. We collected acceleration data by using a tri-axis analog accelerometer. Results of a previous study on activity

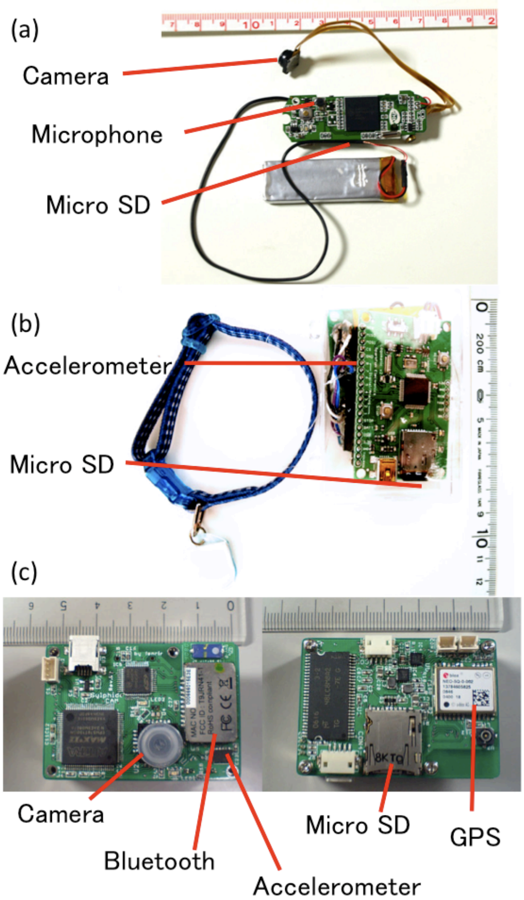

Figure 6: Evolution of Cat@Log devices: (a) With camera and microphone, (b) with accelerometer, and (c) with camera, accelerometer, GPS, and Bluetooth.

Figure 7: Videos recorded by camera attached to collar.

Figure 8: Video stabilization. (Left: raw image captured by mounted camera; right: image stabilized by video stabilization)

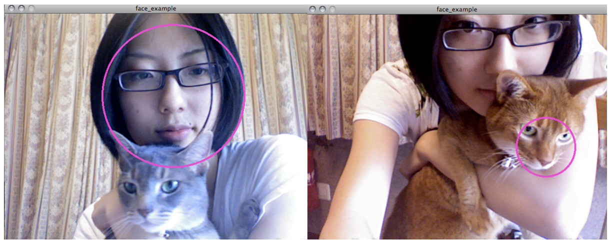

Figure 9: Normal human face detection (left) and cat face detection (right).

recognition using ±2G acceleration data have been found to be promising[7]. Data obtained from the accelerometer have the following attributes: time, acceleration along the x axis, along the y axis, and along the z axis. The accelerometer was worn by the author's cat, named Ann.

Data on nine activities were collected: sleeping, walking, running, being brushed, eating, climbing up stairs, climbing down stairs, jumping up, jumping down, and scratching. These activities were performed and data on them were collected over several days. Figure 10 shows some examples of the collected data.

Features were computed on 64 sample windows of acceleration data with a 20% overlap between consecutive windows. The sampling frequency was 50 Hz; thus, the size of each sampling window was 1.28 s. In a previous study on human activity recognition [3], desired outcomes were obtained with a window size of 6.7 s with 50% overlap. However, since cats move more quickly and are more restless than humans, we decided to narrow down the window size to 1.28 s. It has been proved that for faster movements, it is preferable to reduce the sampling window size and the overlap[14]. From each window, we computed the mean, variance, correlation between each axis, DC component, and AC component. We used the fast Fourier transform algorithm to compute the last two features.

Many methods are available for classifying the activity data. In a previous study, it was found that the recognition accuracy was highest for C4.5 decision tree classifiers[2, 3]. C4.5 builds decision trees from a set of training data that has already been classified, by using the concept of information entropy. At each node of the tree, C4.5 selects one attribute of the data that most effectively splits its set of samples into subsets enriched in one class or the other. Its criterion is

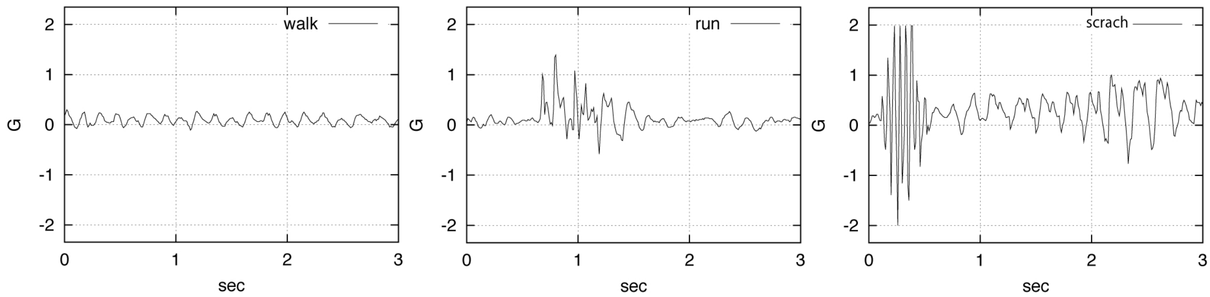

Figure 10: X-axis readings for various activities.

the normalized information gain that results from selection of an attribute for splitting the data. The attribute with the highest normalized information gain is selected for making the decision. The C4.5 algorithm then recurses on smaller sublists. Here, we used the Weka Machine Learning Algorithms Toolkit[17] to preform the feature.

As an example, we can estimate the amount of exercise performed by the cat by recognizing and logging the activity data. We can quickly know if the cat is low on energy, by observing the blog of her life log. Further, if the cat is observed to suddenly start scratching herself vigorously, it could be possible to detect fleas in early stages.

3.3.2 Relationship Prediction

By recognizing activities of multiple cats, we can predict the relationship among them. Figure 11 shows acceleration data recorded when two cats were playing together. We can predict the relationship between them by combining location data with a higher activity recognition method[4].

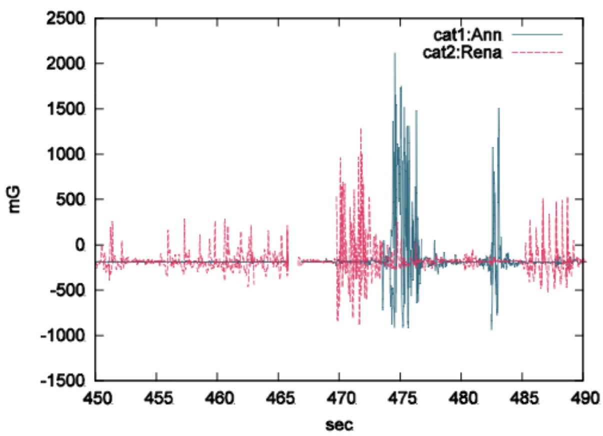

Figure 11: Acceleration data on two cats playing together.

3.4 GPS

3.4.1 Territory Map of Cat

Cats often go outdoors, but owners are mostly never aware of the cat's whereabouts. However, owners would certainly like to know the whereabouts. To achieve this, owners could send location data from the GPS satellite via the wireless communication module. Then, if the location data are logged, it is possible to construct a territory map of the cat.

4. INTERFACE

The abovementioned automatic event detection technologies enable the creation of an automatic blog-posting module by means of which cats can transmit their activity information automatically. When information is automatically posted to a personified interface like blogs, it would appear as if the cat itself is writing the post.

4.1 Twitter Module

After the acceleration data are collected, they are sent to a PC in real time. After the raw accelerometer data are sent, the features are computed and classified into one of the nine activities. The activities are posted in Twitter as shown in Figure 12.

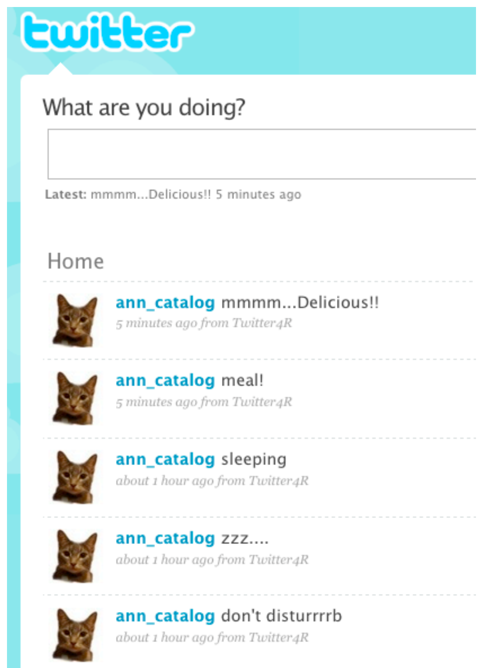

Figure 12: Cat tweets on Twitter.

4.2 Blog Module

The blog is shown in Figure 13. The cat's activity is posted in the form of an article on the blog. The cat's current lo-

Figure 13: Blog written by a cat using territory map widget. (The territory of the cat is indicated by yellow markers and its present location is indicated by blue markers.)

cation and estimated territory are shown on a Google-map-type blog widget. For privacy, a static map is used. As compared to normal Google maps, in static maps, one cannot zoom in and out or move areas. This will protect the privacy of the map's author. The amount of exercise performed by the cat is shown on another blog widget. RSS is transmitted to the blog's audience. Photos and videos are posted as an article on the blog. They are sharpened and stabilized by Takahashi's method[15].

5. DISCUSSIONS

5.1 Related Work

Various digital technologies have been developed for supporting human-to-human communication, such as emails, blogs, chat rooms, and SNSs. However, these systems are limited to communication among humans. Some researchers have developed one-way communication systems for pets. For example, "CatCam[13]" is a device that collects images from a cat's point of view by means of a camera mounted on a cat's collar. "ZooGraph[11]" is a system for extrapolating pets' activity from an acceleration sensor. Both these systems do not have features to determine what pets want and to help owners decide what actions to take with respect to their pets. In order to make progress in our proposed research area of human-pet interaction, two-way communication channels should be enhanced by means of various ubicomp technologies.

A research area that has recently gained popularity is called "lifelog computing." The main purpose of this research is the archiving of entire lives of humans and activity recognition on the basis of the archives. A "MyLifeBits[9]" database is built using a tiny camera that periodically captures a user's viewpoint. Clarkson[5] has used an accelerometer to recognize human activities from sensors. The methodology of lifelog research can be applied to human-pet interaction for understanding pet activities. However, the difference in sensing objects usable with humans and pets should be borne in mind. In the present study, we applied veterinary and observational knowledge for determining the optimum design of sensor devices for cats.

Currently, many blogs about the life of pets are active, as typified by "BloggingCat.com[10]." In these blogs, the owner and not the pet writes the pet's diary. It is not written from the pet's viewpoint, and thus, it is difficult to get an accurate overview of the pet's actual life. In the service "BlogPet[1]," which is a blog widget, the pet itself can write a post. This kind of personified representation is effective for enabling owners to communicate with their pets. However, in this case, the pet is just a virtual persona that is not linked to the real world.

A service called "PigeonBlog[6]" provides an alternative way to collect data on environmental air pollution by means of sensors placed around a pigeon's neck. This service appears similar to Cat@Log at first; however, the biggest difference between them is that the PigeonBlog project is not actually for the benefit of pigeons but for improving the quality of human life (e.g., for an air pollution survey). As explained earlier in the paper, cats are ideal animals for investigating possible ways of human-pet interaction by various communication methods; this is because the living environment of cats is rather similar to that of humans.

5.2 Future Work

One of the main purposes of developing the Cat@Log system was entertainment. However, if the interaction between humans and pets is to be fruitful, pets should also benefit from the developed system. With this in mind, we are now planning to develop a healthcare module for pets. This module can be used to log the change in the amount of exercise; thus, it would be possible to detect diseases in pets in early stages.

We also intend to develop a platform for enhancing pet-pet interaction. By this platform, pets can record their meetings by ad hoc communication and exchange letters from their owners. This may give rise to a new type of interaction between pet owners.

6. CONCLUSION

In this paper, we have proposed a new research area termed "human-pet interaction" and developed a device that is wearable by pet cats. Pet owners can use this system to monitor the life and feelings of their pets; in addition, owners can understand, empathize with, and love their pets better. This device is useful even in the case that the cat and its owner are positioned remotely. We extracted a cat's interaction data from a video recorded from the cat's viewpoint, activity pattern from the acceleration data, and explored the possibility of determining relationships between cats.

7. ACKNOWLEDGMENTS

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