Chapter 5
Poultry Internet

5.1 Introduction

In days gone by, most people lived on the land, or were hunters/gatherers, or nomads. People would spend many hours with their animal friends and helpers. For example, cowboys and their dogs in the prairies, aborigines hunting with dingoes in Australia, and Asian villagers keeping chickens in their homes. However, in our modern, global, city age, people are too busy to spend time with their pets. This is part of the phenomenon of modern life, where people are getting farther from each other and from nature as well. Society's uncontrolled development results in modern humans feeling isolated and lonely and lacking a sense of value [39]. Nowadays, one of the few things that bring warmth to our hearts and home are pets. They are the symbol of nature with absolutely non-machinery behaviors. We can express our kindness feelings by fondling them. Thus in our modern lives, we need a mechanism to feel a presence with our pets, no matter where we are, at work or on business.

Unfortunately, we are not allowed to bring pets in our offices and releasing them alone in the backyard makes us always worry about them. The basic solution for this problem is to use 2D video monitoring (or surveillance) systems using one (or more) cameras. But these systems bring only little sense of presence with no tangible or tactile interaction.

In this chapter, we present a novel type of physical interaction and symbiosis between human and pet with computer and the Internet as a new form of media. Our system is a human–computer–pet interaction system that transfers the human physical touch through the Internet to the pet and at the same time transfers the pet motion in real time with a physical doll movement on our low cost X–Y positioning table. Figure 5.1 depicts the general schematic view of the system. As can be seen in this figure, our system consists of two physical entities. We define the *Office System* as the space and setup at the owner's office premise; it is here where the owner touches the doll and sees its physical movement that follows the pet motion. This, in fact, can be anywhere and not just in an office. We also define the *Backyard System* as the space and setup where the real pet is situated. The Office System and the Backyard System are remotely separated and are both connected to the Internet.

A.D. Cheok, *Art and Technology of Entertainment Computing and Communication*,
DOI 10.1007/978-1-84996-137-0_5, © Springer-Verlag London Limited 2010

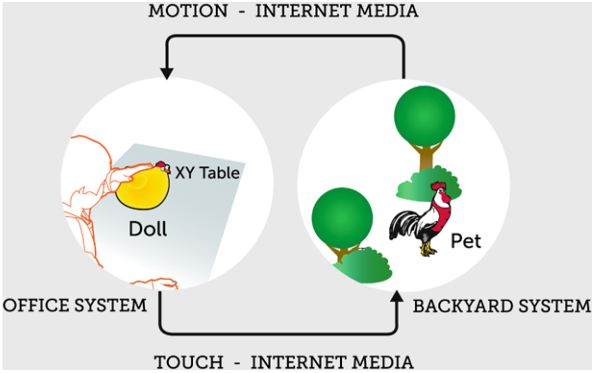

Fig. 5.1 The general schematic of our system

The pet wears a special light weight haptic dress embedded with vibrating actuators and whenever the doll is touched, the action is transmitted through the Internet to the pet dress, the vibrators are activated, and the pet feels the sense of touch.

In our system, we focus on poultry as our pets. This is because poultry are one of the worst treated animals in modern society, being mainly used for meat and egg production in tiny cages and quite terrible conditions. However, it has been scientifically proven that poultry have high levels of both cognition and feelings. Therefore, there has been a recent trend of promoting poultry welfare and also of keeping poultry as pets [8]. Poultry should have the same status as other pets such as cats and dogs because of their similar level of cognition and feelings. It has been shown that chicken are easily capable of observational learning [29]. They also have intelligent goal seeking and declarative mental images (when looking for a goal object they have a definite mental image of the object rather than following a set of rules to reach it) [16].

As they are cognitive and intelligent animals, we should be concerned about their welfare. In animal welfare, it is not necessary to know exactly what an animal is feeling, but the important thing is to know whether the animal feels bad or feels good [12]. A good amount of study has been done on investigating the major states of suffering in poultry (such as fear, frustration, pain, and discomfort) [15]. However, until recently there has been little work on positive subjective feelings in poultry and other animals. However, more and more researchers are becoming interested in a systematic investigation of pleasure in animals and poultry. In the Gordon Memorial Lecture of the World's Poultry Science Association in 2001, it was stated that "There will always be things that have to be done to poultry 'for their own good' that will reduce their welfare. It may be possible to counter-balance unavoidable negative feelings by understanding and promoting positive feelings." It has been shown that poultry are animals that experience pleasure [13]. Thus it is important to develop systems that also promote poultry pleasure. We hope similar research can also be extended to all maltreated domestic animals.

Table 5.1 Modes of interaction between a human and a pet

Mode of interaction	Description
Physical presence	Pet movement on an X–Y positioning table
Haptic sense	Touching real doll as an avatar for the pet
Remote touching	Transmitting human touch information to the pet
Physical stimulation	When the pet moves, the user feels it by physical stimulation on her feet

Thus our motivations for this research are summarized as follows: Poultry are important animals with feelings which are treated poorly by society, and thus it is of value to treat them as our companion pets, as well as promote their pleasure. However, in modern cities and societies, it is difficult to keep poultry as pets, particularly in working and office conditions. Therefore, the motivation of this work is to use mobile and Internet technology to improve the welfare of poultry by creating positive feelings towards them, and to allow humans to feel connected to poultry even if they cannot be physically present with them.

The interaction between a human and a chicken is through a mobile wearable computer system on the chicken and a tangible interactive system for the human. The system uses multiple modes of interaction which are summarized in Table 5.1.

We understand the perceived eccentricity of developing a system for humans to remotely interact with poultry. Most interaction-oriented research focuses on human–human interaction rather than human–poultry interaction that has been focused on in this research. However, we would like to emphasize that this work has much wider significance and applications, as it paves the way for humans and animals to work together in a collaborative way based on equal partnership, as well as provides important points for multimodal human–human interaction.

We think that human–animal interaction is unique in a sense that animals do not respond to human linguistic (or verbal) expressions in a straightforward manner, so there is one less dimension as far as multimodal interaction is concerned. This poses a big challenge in developing a system that allows effective human–animal interaction. Hence, this is an area of research worth exploring, yet it has received limited attention thus far. Furthermore, there are applications where remote human–animal interaction is a crucial kind of work, such as that in a rescue operation where trained pets (dogs) gain access to confined places such as dangerous, narrow caved-in tunnels. Using the ideas from this research, we can "see what the animal sees" with a tiny wireless camera connected to the pet mobile wearable computer when it moves around in places which are impossible (or not safe) for a human to go into, and then we can guide and control the trained pet movements by remotely touching different parts of the virtual animal. The ideas can be used for the people who have allergy to touching animals. Using our system, they can see the reaction of the animal to their remote touch. It can even be used in the same way in zoos to have feeling of touch and stroking live, wild animals which cannot be done in normal conditions due to the danger.

This chapter has been organized as follows: In Sect. 5.2, the psychological pleasurable effects of touch interaction between human and animal on both sides are shortly described. In Sect. 5.3, we review the related works on remote tele-haptic systems and also the previous works on human–pet interaction. We give a brief relation of this system to a cybernetics system in Sect. 5.4. Section 5.5 explains the technical parts of our system. In Sect. 5.6, we describe the experiences with our system. Section 5.7 looks at the possibilities of extending our work to non-pet applications, and in Sect. 5.8 we provide conclusion and future works.

5.2 Motivation for Human–Pet Touch Interaction

In the past few years, there has been an increase in interest in relationships between humans and animals and in particular with the animals that we keep as companions. In this section, we discuss the benefits of pet ownership both to the owner and to the animal.

5.2.1 Why Do We Keep Animals as Companions?

Pets have been cited as providing social support which has some advantages compared to the social support given by humans. Pets can make people feel unconditionally accepted, whereas fellow humans will judge and may criticize. Sanders [37] stated that social support by other humans can cause anxiety and worry.

Pets satisfy human's need to nurture. There is evidence that self esteem is an important aspect of social-emotional development of children. Bergesen [3] found that children self-esteem scores increased significantly over a 9-month period of keeping pets in their school classroom. Many parents admit that pets can be valuable tools which can be used to educate children about life events [27].

Beginning in the 1980s, professionals who used animals in therapeutic settings began to make a distinction between animal assisted activities (AAA) and animal assisted therapy (AAT) [6]. AAA provides opportunities for motivational, educational, recreational, and therapeutic benefits to enhance the quality of life, and is delivered in a variety of therapeutic environments by a specially trained professional in association with animals. AAT is a goal directed intervention in which an animal is used as an integral part of the treatment process. A successful prison-based AAT which involved cats, goats, birds and small farm animals [5] demonstrated that inmates who had pets to care for were less violent, had increased appropriate social interaction, had fewer infractions, and needed less medication than those inmates without pets. Animals can be used in therapy setting to teach new skills or to reduce maladaptive behaviors [6].

5.2.2 *The Effect of Touching and Caressing on Poultry and Other Animals*

Many homes have pets as companion animals, and people enjoy stroking them. Animals often respond by closing their eyes and showing pleasure. Touch is very important to both animals and human beings. In a study by Jones [24], it was shown that poultry farmers could have more productive hens if they installed video screens showing chickens being stroked. It was found that hens that are deprived of human contact are likely to be more anxious and prone to poor egg-laying. However, it is not feasible for the farmer to handle every chicken in today's huge commercial flocks, and further tests showed that for a chicken to watch another one being stroked had almost the same effect.

In another study [36], it was shown that stroking suppresses stress-induced elevation of ACTH (secretion due to maternal deprivation) in animals. The above shows that the touch and stroking are very essential for humans and animals. There might be a situation in which touching them is not possible, for instance, when we are in the office, traveling or in a hospital; therefore, virtual stroking would be helpful when our real presence is not practical.

Thus the above research results provide motivation for exploring a new form of media, emphasizing touch and stroking between humans and animals, where the emotional attachment and sense of presence can be felt even if the human is separated from her pet, while also providing pleasurable feeling of touch in the poultry. Hence, the system described here, provides a new form in interactive and symbiotic media between animals and humans.

5.3 Review of Related Works

In the real world, touch and physical manipulation play a key role in understanding and affecting our environment. As has been proven in academic works, touch is a key advantage for human being to interact, understand, and feel affected by the real environment [23]. The use of the Internet as a medium for transferring human touch could be the next big wave in interaction technology, as it provides haptic sensation of touch for distant users.

In this section, firstly, we briefly review the previous works on remote touch or tele-haptic systems, and after that the previous works on human–pet interaction are discussed.

5.3.1 *Previous Tele-haptic Systems*

There have been a number of projects that explored haptic interpersonal communication (or tele-haptic communication). Brave [4] presented the InTouch system for remote collaborative communication by bringing a greater sense of touch and physicality to distributed multi-user interactions. This was developed as an enhancement of tangible user interface (TUI) proposed by Ishii in [21]. In that paper, some previous works on tele-haptic field have been cited, such as Telephonic Arm Wrestling [43] that provides a basic mechanism to simulate the feeling of arm wresting over a telephone line or Dents Dentata [18], an elementary "hand holding" device that communicates one bit of information over the phone line to activate a mechanism that can squeeze a user's hand. Also in [30] a system called Walkii (wide area locomotion and kinesthetic interaction interface) is proposed as a multi-modal haptic interface which frees the operator from being bound to a stationary kinesthetic work station.

In [21], PSybench was developed with the intention to provide a generic shared physical workspace across distance. The goal was to allow distributed users to cooperate in an environment which is heavily based around physical objects. It is actually constructed from two connected motorized chessboards. The positions of the objects on the chessboard have magnetic bases so that they can be moved using electromagnets placed on a 2-axis positioning mechanism under the board. It employs sensors and actuators to synchronize the physical states of the objects, or "Telemanipulation" as Ishii called it. This interface provides some degree of visual, yet physical feedback to the user, but it still lacks two things: the mechanism for synchronizing the orientation of the objects, and the tactile sensation feedback.

A multitouch 3D touch-sensitive tablet [26] is based on the technique of capacitance measurement between a finger tip and a metal plate. This is one of the earliest researches into the application of capacitive sensing in HCI. In order to handle multiple inputs at one time, the design of the hardware is based on the requirements of the fast scanning algorithm and on tradeoffs between software and hardware.

SmartSkin [35] introduces a new sensor architecture for making interactive surfaces that are sensitive to human hand. This sensor recognizes multiple hand positions and shapes and calculates the distance between the hand and the surface by using capacitive sensing and a mesh-shaped antenna. On the basis of this sensor technology, two applications of HCI were built. Firstly, it was an interactive table that can track multiple hand positions, which emulates a mouse-like interface. The user could manipulate 2D graphical objects using their bare hands. Secondly, a gesture-recognition pad was developed, which is a more intelligent interactive system as compared to the previous one.

In contrast with all these interpersonal communication work, our system is a telehaptic system between humans and pets, and probably the first system that communicates with a pet over the Internet.

5.3.2 Previous Human–Pet Interaction Systems

Very little research has, until now, been done in the field of human–computer–pet interaction. Most of the work in this field is in robot pets. For instance, Sony has introduced a reconfigurable robot [17] called AIBO based on OPENR, a standard for robot entertainment systems with 4 legs and a head such that each leg has 3 degrees of freedom and it can be reconfigured to a wheel based mobile robot. The AIBO entertainment robot dog can be programmed using OPENR. AIBO has built-in artificial intelligence and has been used in many applications such as robot-assisted therapy in Japan [25]. To some scientists, robots are the answer to caring for aging societies in Japan and other nations where the young are destined to be overwhelmed by an increasing elderly population. These advocates see robots serving not just as helpers (e.g., carrying out simple chores and reminding patients to take their medication) but also as companions, even if the machines can carry on only a semblance of a real dialog.

Then there is the Tamagotchi, a once very popular virtual pet which is currently making a comeback. It was marketed as "the original virtual reality pet". It can be described briefly as a tiny hand-held LCD video game that comes attached to a key chain or bracelet. The objective of the game is to simulate the proper care and maintenance of a "virtual chicken", which is accomplished through performing the digital analog of certain "parental" responsibilities, including feeding, playing games, scolding, medicating, and cleaning up after it. If good care is provided, it will slowly grow bigger, healthier, and more beautiful every day. But if it is neglected, the little creature may grow up to be mean or ugly.

Druin et al. [11] also proposed a robot animal that tells stories for the children. Sekiguchi [38] presented a teddy bear robot as a robot user interface (RUI) for interpersonal communication.

All the above-related work did not use real animals, and instead they used robot or virtual pets. It is easier to make such systems which interact with virtual pets, rather the real animals. However, as will be shown in the next section, there are definite differences and advantages in using interactive research technology with real living animals, rather than robotic or virtual animals. Furthermore, as mentioned above, this research work can have wider impact where humans and real animals work together in partnership, such as in remote rescue operations.

The growing importance of human-to-pet communication can also be seen in recent related company products. Recently, an entertainment toy company [40] has produced a Bowlingual dog language translator device. It displays some words on its LCD panel when the dog barks. As an another example, cellular giant NTT DoCoMo Inc launched pet-tracking location based services for I-mode subscribers in Japan, connecting pets wirelessly to their owners [22]. This is a one way position information interface (non-interactive). However, our system is the first system to allow real time remote interaction with free moving live pets in a tangible manner.

5.3.3 Why Not Just Interact with Virtual or Robotic Pet?

We have looked at several human–robotic–virtual pet interactions. There are advantages of such systems in providing companionship, communication, and interactions between humans and virtual or robotic pets. However, there are also some disadvantages in such robotic–virtual pet systems, and lacking features in the interaction with humans, which have been found in research studies. Behrens [1] criticizes the fact that Tamagotches never die (in fact, they do, but they are born again and again as long as batteries are fresh), unlike a real pet. Therefore, people, especially children, can become confused about the reality of the relationship. Children will no longer treasure the companionship with their pets because even if the pet dies, it can be brought back to life by changing the battery. The lack of such moral responsibility will cultivate a negative psychology which eventually will do harm to the society. After few times children will lose their interest in such a repetitive game; however, a real pet will show new and different behaviors everyday based on its owners actions. This makes the real pet more engaging in the long term than a virtual, or robotic, pet.

Another related psychological study was done using Furby (a realistic, interactive animatronic plush pet that interacts with the environment through sight, touch, hearing, and physical orientation). Turkle and Audley [19] studied a group of young children who owned Furby. Some children panicked when the toys broke, a sign to their small owners that the Furbies had died untimely deaths. They told of midnight calls from frantic parents whose children were beside themselves because their Furbies had suddenly gone on the blink; and then they would rush over to the house with a new Furby, and every single time, the child showed no interest in the new one. The children felt betrayed, taken in, and fooled. It had revealed its nature as a machine, and they felt embarrassed and angry. They were totally unwilling to invest that kind of emotional relationship in an object again.

While we do not deny the fact that robotic dog such as AIBO could provide the elderly with some of the physiological, cognitive and emotional benefits, and while people talk about the advantage of a robotic pet as having a perfect imaginary friend, there is a kind of psychology of connection, but not necessary of a real companionship that grows between a human and a real pet [32]. As for the children, it is not the issue of whether they will love their robotic dogs more than the real pets, but rather what it means to love a creature and to feel you have a relationship with a creature that really *does not* know that you are there. According to Turkle [32], simulated thinking might be thinking but simulated feeling could never be feeling, simulated love could never be love, and it is important to always keep it mind that no matter how convincing and compelling this creature in front of us, this is still just simulation. Hence it can be seen that if the interaction between a human and an animal is replaced with an equivalent system with a human and a virtual or robotic animal, there are definite disadvantages and differences in the emotional response and feeling of companionship. It is thus proposed that it is critical to develop a remote interactive system between humans and biological living animals to promote the human response of true companionship with the animal. Furthermore, as is detailed in the experimental results below, this work is equally aimed at promoting positive feelings of enjoyment in the animal, which cannot be done if only virtual/robot animals are used.

5.4 Poultry Internet as a Cybernetics System

The term cybernetics was originally proposed by Wiener [42] as "the control and communication in the animal and the machine". This emphasized the concept of feedback control as a construct of value in the study of neural and physiological relations in the biological and physical sciences. Wiener's research included observations of how human and machine interact when engaged in purposeful action. He was researching pilot (human)– jet fighter (machine) interaction during World War II. It was clear to him that feedback was involved in the sensory and motor activities that constitute any purposeful action. Also he studied pilot's behavior under different conditions of stress, such as changes in blood pressure under flight conditions, in order to obtain a better understanding of pilot behavior, and ultimately, to be able to design an efficient radar–antiaircraft system. From then on, communication engineering and neurophysiology joined forces in the study of human–machine interaction.

In our system, we use this philosophy to construct a biological–computer feedback system where the pet is part of the cybernetic loop through touch, motion and sound. The human is also in the same cybernetic loop through touch and visual feedback. The computer is part of the system by feeding back and transmitting human and animal feeling and senses. As a newer definition [34], cybernetics uses epistemology (the limits to how we know what we know) to understand the constraints of any medium (technological, biological, or social) and considers powerful descriptions as the most important result. Cybernetics has evolved from a "constructivist" view of the world [41] where objectivity derives from shared agreement about meaning, and where information (or intelligence for that matter) is an attribute of an interaction rather than a commodity stored in a computer [44] (see [34] for more information about cybernetics perspective).

Thus, using the same philosophical viewpoint, we construct a biological–social cybernetics system where the data is not simply a commodity but it is an attribute of interaction. Concretely, digital bits take on a meaning. The bits are carriers of human touch to living pets, and the bits take on a meaning of human warmth and emotion.

5.5 Technical Details of the Multi-modal Interaction System

In this section, we describe our mobile wearable computer chicken jacket along with two major parts of our system, the *Backyard System* and *Office System*, as shown in Fig. 5.1. These two sub-systems communicate with each other over the Internet.

5.5.1 Overall System

The Backyard System is where the real pet chicken is kept (Fig. 5.2, left). It consists of a computer with a web camera attached to it. The web camera monitors a chicken

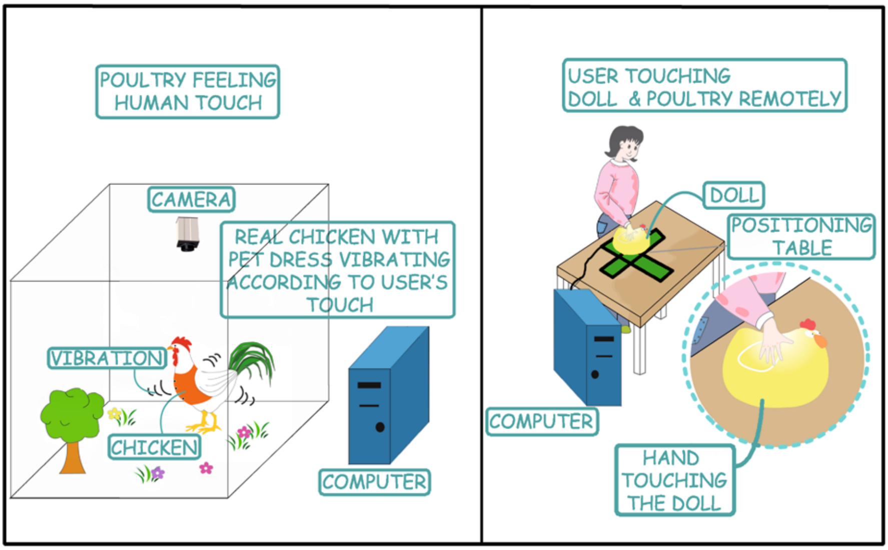

Fig. 5.2 The pet owner touches the doll with embedded touch sensors, and the pet in the backyard feels the touch

house where the chicken lives and moves about. The movement of the chicken is tracked by the camera, and data is then sent to the Backyard computer. Also, the chicken wears a special pet jacket with embedded wireless transceiver and vibrator motors. This jacket receives touch data from the computer wirelessly. Whenever the user touches the pet doll on the Office System, the pet jacket reproduces the touch by activating the vibration motors corresponding to the spot it is being touched.

The Office System is at a remote location from the real pet (Fig. 5.2, right). The Office System consists of a computer with a pet doll sitting on a mechanical positioning system. This mechanical positioning system moves the pet doll in the X, Y and rotational axes. It receives movement tracking data from the Backyard System in real time, and moves the pet doll accordingly. Therefore, users are able to see the doll move in a similar manner to the real pet.

5.5.2 Remote Physical Touch

In order to enable physical remote touch, we use a physical doll as an avatar for the pet. The doll movements are controlled by the computer, and it follows the pet motion in the garden. Here the user has physical interaction with the avatar.

Also the audio-visual information of the pet from the Backyard is received through the Internet. These are displayed to the user on an LCD screen and speakers.

Figure 5.3 shows the Office System. As can be seen in this figure, the user is touching the doll and at the same time she can see the pet in the LCD screen. The doll

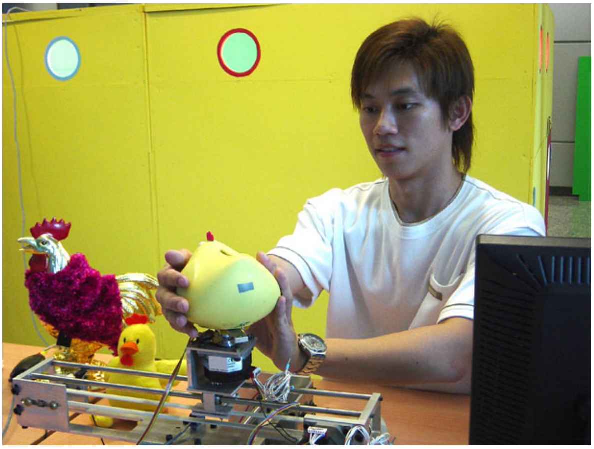

Fig. 5.3 The pet owner touches the chicken pet via the pet doll avatar

follows the real pet motion in 2D by moving on a mechanical positioning system. When she touches the doll, data is transferred to the pet dress and vibrates one of the vibrotactile actuators on the pet jacket according to the part of the doll which is being touched.

The physical touch mode contains two major parts which are described here: the doll which detects the user's touch and transfers it to the PC, and the mechanical positioning system which controls the doll movements based on the pet motion in the backyard.

5.5.2.1 Mechanical Positioning Table

To move the pet on the table, we designed and implemented a mechanical positioning system using two stepper motors for movements in the X and Y directions and also one stepper motor for the rotation of the doll. These position data are calculated based on the real pet motion in the backyard by a computer vision tracking algorithm, and then the tracking results which are X, Y and rotation information are sent through the Internet to the office.

Figure 5.4 depicts the hardware system of the mechanical positioning table. It consists of the X and Y axis structures, each driven by a stepping motor. A third stepping motor is mounted on the carrier of the structure, with the axis of rotation perpendicular to the table. The doll is not directly coupled to the rotation motor (the third one) for aesthetic reasons. We have hidden the mechanism by covering it with a sheet of plastic on the table. By attaching magnets on both the doll and the third motor, the doll follows the motor 2D movement as well as rotation, without direct coupling, as depicted in Fig. 5.4.

Compared to PSybench [21], which gives only 2D position information, our system gives the owner a sense of both pet's position and orientation.

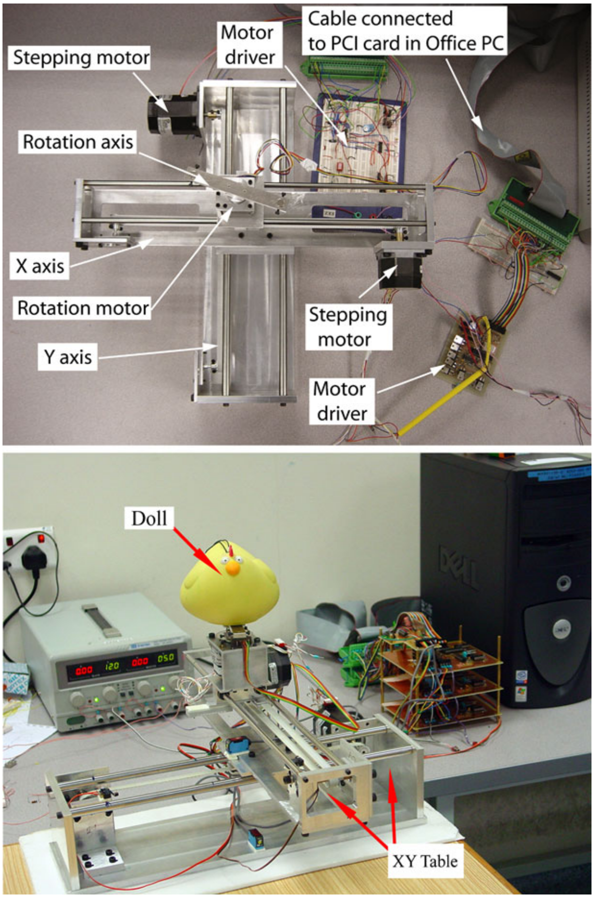

Fig. 5.4 Hardware mechanism of the mechanical positioning table

5.5.2.2 Doll

In the office system, the pet is represented by a real object, a doll. The doll consists of a touch-sensing board, a RF transmitter, a microcontroller, and the doll itself with a hollow body. The aim of this device is to detect the user's touch on different parts of the body of the doll and to send this data (touch event and touch position) to the pet dress for activating the related vibrators on the dress, and thus cause the real pet to feel the touch in the same place as the human touching the doll.

The touch-sensing board mainly consists of the five capacitive touch sensors and a sensor chip QT161 from Quantum Research Group [33]. The microcontroller and an RF transmitter are soldered to the touch-sensing board as well. All five of the capacitive touch sensors are connected to the QT161 sensor chip. The sense field of each sensor pad was tuned by changing the capacitance on the board, so that it would only respond to a massive dielectric object such as the human hand in our context.

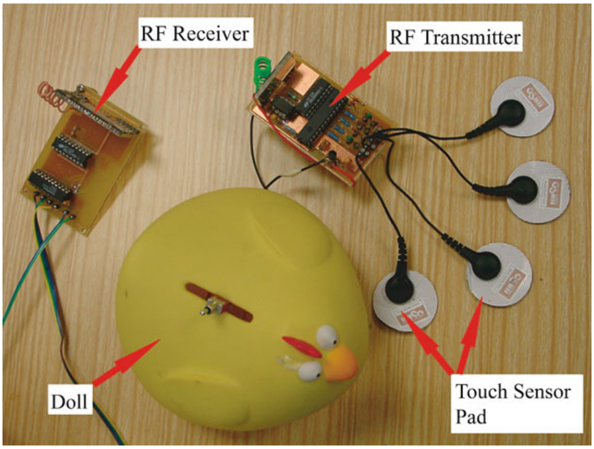

Fig. 5.5 The doll and its electronic devices: touch-sensing board with battery and capacitive sensing-pads

Note that the capacitive touch sensors are operated by placing them inside the doll; thus they are not noticeable to the user. The microcontroller sends a 5-bit (each bit corresponds to a sensor output) information to the RF transmitter. There is also an RF receiver board, which is connected to the Office PC's serial port, that receives the information and sends it to the PC. The PC then transmits the information through the Internet, which then will control the vibrating devices on the pet.

The doll and the touch-sensing board are shown in Fig. 5.5. The inside body of the doll is hollow and we concealed the touch-sensing board and the sensor pads inside. The capacitive touch sensor pads are distributed on various parts of the doll.

5.5.2.3 Mobile Wearable Computer Pet Jacket

We have also provided a special pet dress for transferring the user's touch to the pet. Therefore, the pet can feel whenever its owner touches its avatar at the office.

The main reason of designing a dress for the pet is to make a system that receives touch information from the Office System through the Internet and then transfers it to the pet so that the pet feels the human touch.

There are several ways of conveying the touch sensation, such as vibration, pneumatic and hydraulic. All these tactile display devices stimulate the skin to generate these sensations of contact. In our system, we used high-frequency vibration motors (or vibrotactile actuators; we use the two terms interchangeably) because vibration can relay information about phenomena like surface texture, slip, impact, and puncture. In many situations, vibrations are experienced as diffused and unlocalized.

Here we designed and implemented a jacket with a wearable computer for the pet with vibration motors to simulate a stroking sensation. These vibrotactile sensors give the pet a distributed touch sensation. Also, note that multiple motors could be

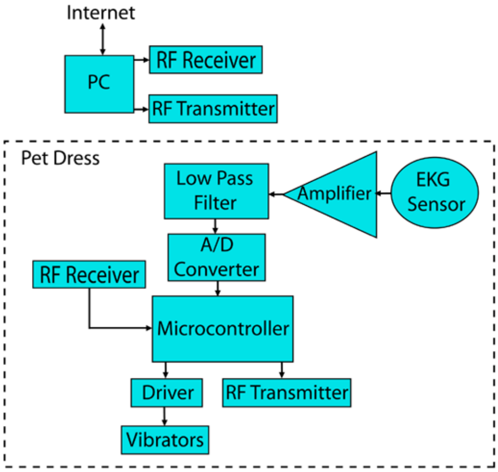

Fig. 5.6 The block diagram of the pet dress

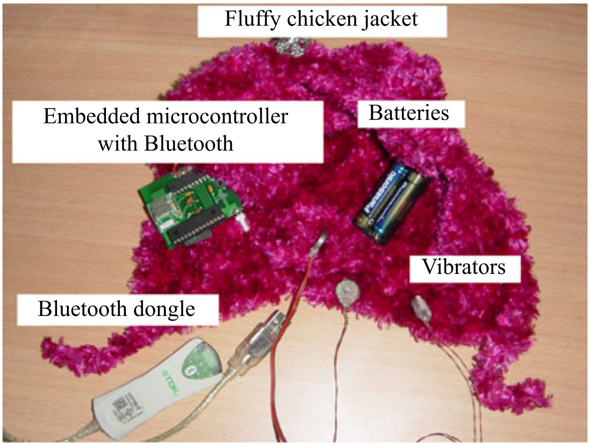

Fig. 5.7 The pet jacket with micro-controller, electrodes and vibrotactile actuators

activated at one time, just like the multipoint sensing of the capacitive touch sensors on the pet doll which is located remotely on the user's side in the office system. The schematic block diagram of the hardware is shown in Fig. 5.6. As can be seen in this figure, the pet jacket contains an RF receiver to receive touch information from the Office System.

The mobile wearable hardware dress consists of an RF receiver to receive data from the Backyard System, a microcontroller to control the vibration motors, and current drivers to supply the necessary current to the vibrators. A consumer 9 V battery is used to provide power for the whole system. Figure 5.7 shows the hardware system and the pet dress. Here we put five vibration motors on the neck, back, left, right and breast of the pet. The total weight of our dress with hardware and battery is just 127 g. Figure 5.8 depicts our pet (a chicken in this application) wearing the

Fig. 5.8 The chicken wearing the mobile computer pet jacket

dress. Many tests on our pet chicken showed that it did not make any problem or discomfort for the pet to wear it (as will be detailed below).

5.5.3 Computer Vision Pet Tracking

We perform the tracking of the pet in two dimensions to understand its location and its orientation in the backyard. It is done by computer vision-based tracking methods. We assume that there is no other moving object in the room except our pet. Hence, we applied a background subtraction algorithm to detect the movement of the pet in the backyard. The input image for detection comes from the tracking camera mounted on the ceiling which captures the whole backyard area. After background subtraction, we calculated hue similarity between background pixels and new captured image pixels to remove shadowed regions. The result is filtered to remove the small regions in the output image. We also modified the background in regions of the image which do not have large RGB disparity to have a robust detection mechanism. As a result the background is also updated in our algorithm for every frame.

The result of the background subtraction algorithm is the position of the centroid of the pet in pixel coordinates. The centroid provides us with the two dimensional coordinate. We also need to obtain the direction the pet is facing, i.e., its orientation. Figure 5.9 shows how we derive the orientation from centroid data. An important assumption made is that the pet is facing where it is moving to.

Using the tracking data obtained in pixel coordinates, we map the position from image frame to the corresponding position on the mechanical positioning table. The image frame size is 640 pixels for the X axis and 480 pixels for the Y axis. The positioning table has a range of 1,000 steps for both the X and Y axes. In order not

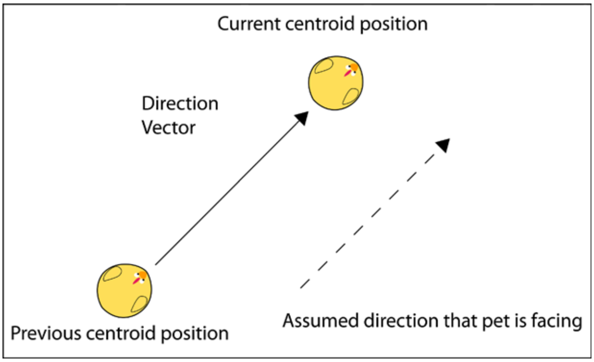

Fig. 5.9 Obtaining orientation from centroid

to distort the overall frame, we keep the ratio of Y to X axis of 0.75 in the image frame. Therefore, to match, we make use of 750 steps on the Y axis and 1,000 steps for the X axis on positioning table. The following equations perform this mapping in software:

$$CurXS = \frac{CurX \times 1{,}000}{640}, \tag{5.1}$$

$$CurYS = \frac{(CurY + 80) \times 1{,}000}{640}. \tag{5.2}$$

CurX and *CurY* represent the image pixel coordinates of the centroid of the pet, while *CurXS* and *CurYS* represent the mechanical positioning table coordinates of the same centroid of the pet. *CurXS* and *CurYS* are in step coordinates while *CurX* and *CurY* are in pixel coordinates for the X and Y axis, respectively.

In determining the amount each motor needs to rotate, we obtain the difference between the current and previous coordinate. After obtaining the results from (5.1), we perform the following:

$$StepX = CurXS - PreXS, \tag{5.3}$$

$$StepY = CurYS - PreYS, \tag{5.4}$$

where *PreXS* and *PreYS* are used to store the previous coordinate values, while *StepX* and *StepY* are the number of steps motor X and motor Y needs to rotate, respectively.

The calculation of orientation makes use of the values of *StepX* and *StepY*, as shown below:

$$\theta_r = \arctan(StepX,\ StepY),$$

$$\theta_s = \frac{\theta_r}{\pi} \times 100.$$

θ_r represents the angular orientation of the pet in radians calculated from the image pixel coordinates, while θ_s represents the same orientation in terms of rotation steps on the mechanical positioning table. θ_r is the angle in radians, and θ_s is the angle in steps.

As the rotational axis has 200 steps for one revolution, π corresponds to 100 steps. This completes the integration of tracking data with the motor control module.

5.6 Experiences and User Studies

People who have participated in and tried out our system experienced the human–animal interactive symbiosis supplied by the system. They saw that the doll moved in real time according to the chicken movement. Furthermore, through the touch interface, the participant stroked the doll and saw in real time that the touch was transmitted to the chicken.

As will be detailed below, the experiments on our pet showed that it was not irritated by wearing the jacket and it acted naturally with the jacket. In response to remote touch with our system, it did not act as a linear constant coefficient system, but we found that it was very sensitive to the vibrotactile actuator mounted on its neck. Most of the time when we tele-touched it from the neck, it moved down its head in the direction of the vibration.

We have done a user study for our system. The interviewees were 31 students (18 male and 13 female) between 20 and 30 years old. They completed our questionnaire after having some experiences with our system. The users were asked to firstly interact with the chicken in the present conventional remote method interaction with pets, a live webcam and monitor. Then the users were asked to interact with the poultry using the physical doll. The users were not given any time limit of interacting with the system. The results of the user study have been summarized in Table 5.2.

The results of Question 1 from Table 5.2 show that most of the interviewed (84%) admitted that our system is better than current telecommunication systems for pets.

As can be seen from the results of Question 2, 84% of the interviewed had a feeling of presence for the remote pet with our system.

The survey shows that almost all interviewees liked being able to touch and stroke their pets when they were out of home and their pets were alone (see the results of Question 4); and as can be seen from Question 3, it was important for them to do that.

Although the results of Question 5 indicate that 48% of interviewees did not like their pets wearing a dress with electronic devices, the results of Question 6 show that most of them (68%) believe the pet had a pleasurable feeling, and they liked the remote touch using our system. Although these results seem contradictory, users stated that due to the novelty of the pet dress it would make them feel “odd” or “unconventional” to put it on their pet, even though most thought it would provide a pleasurable feeling to the poultry. Thus, it seems that there are some contradictory feelings among the users due to the novelty of the system.

Also the user study results show that for most of the interviewed touching was more important to them than the other kind of interaction, i.e., watching their pets

Table 5.2 User study results for our system

1) How do you compare this system with other remote communication methods with a pet such as webcam and phone?	Percentage
Much more better	32.26
Better	51.61
Almost the same	12.90
Worse	3.23
2) How acceptable is the representation of the pet by a doll for you?	**Percentage**
Exactly like the pet being here	3.23
Almost gives the same feeling as a real pet	32.26
Gives a little feeling of the presence of the pet	48.39
I can't feel the presence of the pet at all	16.12
3) How do you rate the importance of having a kind of interaction with your pet when you are in the office or at school, or on holiday, and it is alone back at home?	**Percentage**
More than 75%	22.58
50–75%	51.61
25–50%	22.58
Less than 25%	3.22
4) Do you like to touch your pet when you are in the office and it is alone in the backyard of your house?	**Percentage**
Yes. I really want to do it	25.81
Yes. I want but it is not a necessity	38.71
Yes. It is fine but not so important to me	35.48
No. I do not like it	0
5) Do you mind if your pet wears a dress containing electronic sensors and devices?	**Percentage**
Yes. I like it	9.68
Yes. I don't mind	41.94
No. Prefer not	45.16
No. I won't allow	3.22
6) Do you think your pet will have better feeling when you remotely touch it?	**Percentage**
Yes. It clearly enhances its mood	12.90
Yes. I think it likes it	54.84
No. I think it dislike it	29.03
No. It feels violence	3.23

Table 5.2 (continued)

7) If you are able to interact with your pet, what kind of interaction is more important for you?	Out of 4
Touching	3.29
Watching it in 2D like web cam	2.97
Hearing it	2.06
See the movement of the doll in backyard as displayed on the X–Y table	1.68

through a monitor (Question 7). Our system allowed the users to compare using the proposed system and a normal webcam system, as they could experience viewing the pet using a web cam and monitor only. Then they could directly compare the use of both methods of interaction.

The data analysis showed that females compared to males preferred their pets wearing such a jacket by more than 10%. At this stage, we had not realized the reason for the sex differences, and plan to study this deeper at a later stage.

It was also important to us to test the feeling of the chicken in a scientific manner. It has been shown that in animal welfare it is not necessary to know exactly what an animal is feeling, but the important thing is to know whether the animal feels bad or good [12]. Previously, a significant amount of study has been done on investigating the major states of suffering in poultry [15], but until recently there has been little work on positive subjective feelings in poultry and other animals.

However, there are established scientific tests to prove chicken motivation (to pleasure) and avoidance of bad feelings. Avoidance of bad feelings can be tested when the animal is allowed to choose between certain aspects of its environment and by assuming it will choose in its best interests and welfare. This is the preference testing method pioneered by Hughes and Black who worked with poultry [20]. Hughes has used this method to test poultry preferences for cage floor types, inside or outside environment, cage size, and social conditions.

In order to test poultry motivation for pleasure, we must take an extra step. This is to measure the strength of preference of the poultry. In poultry, there are various methods to do this, for example, by obstruction methods [9]. However, we use the method of Duncan [14] which is to have a weighted push door. This has the purpose of being related to nature, similar to the push of a chicken through undergrowth to reach a goal.

As shown in Fig. 5.10, we created two 3×3 m cages and one small 3×1 m cage interlinked with a push door one colored red and one blue. Each cage contained the same food and water. This test can be described by the sequence of pictures in Fig. 5.11. In the beginning of every experiment, the chicken is placed in a common corridor (I) with a blue door and a red door leading to two separate rooms, respectively. In both rooms, there is food and water (II). If the chicken enters through the red door, it will be left untouched. If the chicken enters through the blue door, the human user will remotely touch it through the pet doll interface (IV). The chicken wearing the haptic pet jacket will feel its owner's touch (III).

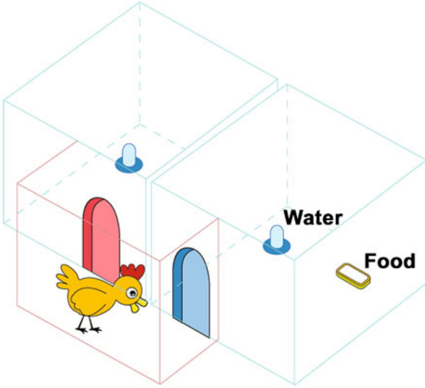

Fig. 5.10 Schematic diagram of our test system for experimenting chicken preference (using the method of Duncan)

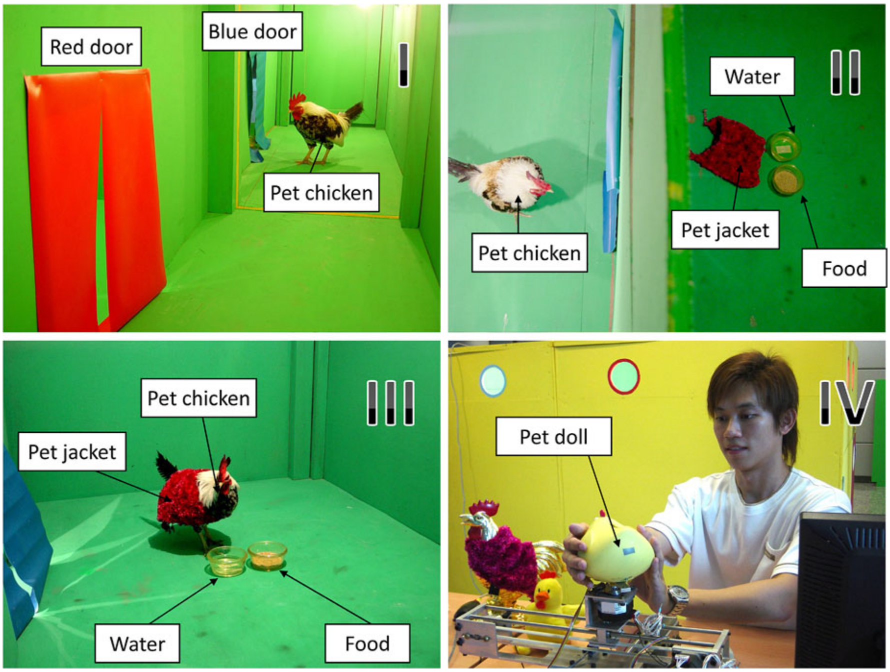

Fig. 5.11 Test for poultry motivation (Sequence I to IV is described in the text)

Over a period of 28 days (testing on two chickens separately) we placed the chicken in the small cage. If it entered through the red door it would be picked up and we put the dress on it and used the system for 10 minutes. If it entered through the blue door, there was no picking up or putting on and testing the dress. This was repeated 200 times (100 times per chicken) over 28 days and it was found that 73% of the time the chicken would choose the red door and 25% of the time the chicken would choose the blue door, and 2% of the time not enter any door after 10 minutes.

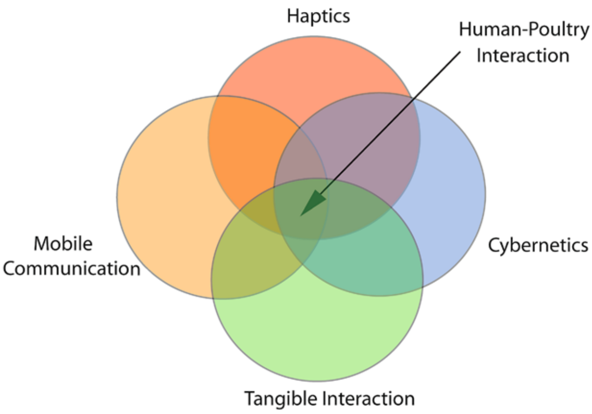

Fig. 5.12 Our system is the intersection of mobile communication, haptics, tangible interaction, and cybernetics

Thus we can conclude that at least there is no negative or bad feeling of the chicken by using the vibrating dress for many periods.

In order to test for positive feeling and pleasure in the poultry, we conducted the same test with a heavier red door (500 g extra weight). The same test as above found that 70% of the time the chicken would choose the red door and 27% of the time the chicken would choose the blue door, and 3% of the time not enter any door after 10 minutes. Although it is a small decrease from the above results without the weight, we can safely say that the poultry positively chose the red door, even though it contained the weight, and found the system pleasurable (which confirms the results previously given in [24] that the poultry positively reacts to touch).

5.7 Wider Applications

This research project is built on the platform of remote multimodal interaction using mobile wearable computer. In general, the proposed system is an integration of mobile communication, haptics, tangible interaction, and cybernetics as shown in Fig. 5.12. Though the application is to human–pet interaction, we need to emphasize that the multimodality is generic, and it can be extended to human–human without loss of genuineness and novelties. We hereby discuss several human-centered applications that fit into the theme of this project.

5.7.1 Multiplexing Existing Communication Channels

Human communicate and interact among each other in rich and complex ways. When co-located we adeptly trade off between a wide range of cues, both verbal and nonverbal [31]. However, when we examine the technological mediated communication tools we use when not co-located, we quickly see our information channels restricted to primarily verbal channels such as text and speech. There is a need to explore nonverbal interfaces between non-co-located people. In places where remote communication already takes place, touch devices could allow people to increase their communication by multiplexing information and emotional communication channels [7]. To enable such ubiquitous and pervasive interfaces, we propose multiplexing of touch and voice information (multimodal) based on the system that we build. The wearable computer dress, when worn on the body, could function as a haptic communication tool. Loved ones, when separated, often want to communicate without interrupting the flow of each other's work by active conversation. For example, when one partner is in a meeting, the other one might want to express support by touching him – that's multiplexing touch and voice. Remote dance synchronization can be seen as another example to this. In this application, both dancers listen to the same music, while the foot strikes of the first dancer are transmitted to the second one to synchronize dance steps.

5.7.2 Intimacy Through Ubiquitous Computing

The extension of multiplexing voice and touch leads us to explore the relationship between intimacy and ubiquitous computing. Ubiquitous computing has long been associated with intimacy [2]. The term "intimate computing" refers to technologies that enhance or make possible forms of intimacy between remote people that would normally only be possible if they were proximate; it is a technology that can express of our intentions, actions and feelings toward others. Very little work has been done in this area. In [10], a working interactive environment is designed using the familiar and intimate space of a bed. This bed environment applies the philosophies of ambient environments for the presentation of background information in order to help humanize inter-personal communication. Similarly, our system could be developed further to suit the subtle philosophies of intimate computing in the following way: both non-co-located persons wear the wearable computer dress with Peltier junction heating device and tiny vibration motors. Also on each dress there is a ECG sensor to detect individual's pulse. Peltier junction is a low power thermocouple device that when electrical current is applied to it, one side of the thermocouple becomes hotter than the other. The feeling of presence of the person can thus be represented through both the body warmth and heartbeat, as realized by Peltier junction and vibration motors, respectively. This provides access to a personal "life signal" of another person. We have just added "body warmth" and "heartbeat" to the multimodalities of human–human remote interaction. For instance, people can feel remote hugging using our system.

5.7.3 Spying/Rescuing Pet

Last but not least, we would like to extend the application of our work to dogs. Police use dogs in sniffing traces of criminal fugitives in bushes; anti-narcotic officers use them to sniff out drugs; rescue personnel rely on them in rescue operation to access narrow caved-in rubble. However, with the advances in technology, the kind of help that dogs render does not really change much over time. Our proposed system can improve the interaction between the human and the animal work as an equal partnership, especially when they are not co-located and the rescuer's command has to reach the dog and be executed faithfully, and, at the same time, the dog's feedback to rescuer has to be timely. Especially in the military and rescue operations, where the dogs carry out surveillance/spying duty in the battlefield or deep in the enemy territory. Using a dog, rather than a robot, to penetrate enemy territory is a major advantage because no robot to this day and in the near future has the agility and intelligence of a dog.

For such an application, we can use our wearable computer dress with an extra camera attached to the dog's head. The light-weight dress, when worn on the dog, will have the dog's body and neck area covered evenly. While the dog is out in the battlefield and if it is remotely tickled, say, on the left side of its body, the dog changes its walking direction to the left as it is trained to respond this way. The wireless camera attached to the head of the dog captures the surrounding view and the video images are compressed by the wearable computer dress. It is then sent through wireless link (Internet) back to the human commander. The commander thus is able to see what the dog sees in real time. As he remotely tickles the neck of the dog, the dog turns its head and sees different views from the camera.

5.8 Conclusion and Future Works

In this chapter, we introduced a novel multi-modal interaction system with mobile devices for human–poultry tangible remote tactile communication. We can summarize our novel points of our system as follows:

- Remote tele-haptic tangible body fondling sensation
- Human–poultry and poultry–human interaction
- Pet–computer control mechanism
- Physical representation of pet in office
- Mobile light weight wearable computer pet dress

The system benefits both the human and the poultry in an equal partnership. As shown in the user study, people like to be able to touch their pets when they are out of home and their pets are alone, and they had a feeling of presence for the remote pet with our system. As for the pet, the experimental results confirmed that the proposed system is pleasurable for the pet, too. The system is specifically designed for sentient beings.

Our experimental results show that for a human having a tactile sensation with her remote pet is more important than watching it through a webcam.

This system can also be used for people who love animals but cannot touch, hug and stroke any pets because of their sensitive skin or allergy. With this system, they will not worry anymore about this and can have enjoyable time with their pets. Even with this system, people can feel a new kind of touching not only with pets but also with wild animals. For example, it would be nice for children and adults to go to a zoo and be able to enjoy stroking the lion mane.

Our cybernetics interaction system is able to connect not only people and animals but also people and people together in a new symbiotic manner. This is an example of new technologies for families. With this technology you can remotely touch and stroke the one that you love.

Although the mechanical positioning table for displaying the 2D movement of the pet is bulky and takes some space of the table in an office environment, the reader should note that it is an prototype system, and it can be improved and made smaller in order to be used as a commercial product.

We now propose possible improvements that can be made to our present work.

We can use a robot doll with more degrees of freedom instead of mounting a simple fluffy doll on a mechanical positioning table in the office. Then the robot doll in the office will follow the movements of our pet in the backyard, which will give us more realistic representation of our pet. Also it would be more handy to carry around.

Also in future work, we will better measure the strength of human touch on the doll, instead of just sensing it as a high (‘1’) or low (‘0’). In this way, the frequency and amplitude of the vibration is adjusted according to the strength of touch, giving us a high fidelity tele-haptic sensation. In psychophysical experiments, correlated variations in the frequency and amplitude of the stimulators extended the user’s perceptual response compared to varying amplitude or frequency alone [28].

We can use our system in a rescuing application with a trained dog pet moving in an unsafe area for human. When the pet feels a touch on the left or the right, it will move left or right. We will “see what the pet sees” with a tiny wireless camera connected to the pet wearable computer. Or a small trained pet can help to check small areas such as when checking pipes in a power planet.

In conclusion, we must say that interacting with a living being is more pleasurable and important for humans than interacting with a toy. Nowadays, one of the few things that brings warmth to our hearts and homes are pets. They are the symbol of nature with absolutely non-mechanistic behaviors. We can express our kindness feelings by stroking them. Thus, in our modern lives, we need a mechanism to feel a presence with our pets, no matter where we are, either at work or on business. The proposed system is one of the solutions to bring this togetherness to us, no matter how far we are from our poultry companions.

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