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Master's Thesis
Academic Year 2017

It-Pet: Interactive Therapeutic Pet Device for
Remote Replication of an Animal

Graduate School of Media Design,
Keio University

Pafan Julsakrisakul

A Master's Thesis
submitted to Graduate School of Media Design, Keio University
in partial fulfillment of the requirements for the degree of
MASTER of Media Design

Pafan Julsaksrisakul

Thesis Committee:

Associate Professor Kazunori Sugiura	(Supervisor)
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Abstract of Master's Thesis of Academic Year 2017

It-Pet: Interactive Therapeutic Pet Device for Remote Replication of an Animal

Category: Design

Summary

In the past decades, it has become widely accepted that pet ownership and pet therapy may have beneficial effects on humans, which leads to several studies on positive effect of Human-Animal Interaction(HAI) [15] [7]. However, there are risks and limitation to pet therapy, involving safety, sanitation and difficulties in management etc.; as a result, animals are not permitted in certain areas such as hospitals or senior homes etc. Thus, it-Pet, an Interactive Therapeutic device that transmits real-time simulations of a pet through visual, sound, temperature and vibration, is introduced in this research. It-Pet is a set of device that enables a user to see a pet through a real-time camera, hear the sound, sense the temperature and feel the movement of a real pet through vibration instantaneously. In this study, the psychological effects of it-Pet that has on humans is explored. This approach is demonstrated by applying it to the usability testing of the four simulations of the device to evaluate if there is a mental effect on users. The evaluation shows a positive result as it provides a calming and relaxing effect to the users and potentially reduces stress and loneliness to a certain extent. The result aims to open a new perspective for remote pet therapy and HAI.

Keywords:

Human-Animal Interaction; Interactive Pet Sensing; Haptics; Telepresence

Graduate School of Media Design, Keio University

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Chapter 1

Introduction

1.1. Background

Animals and humans have had long history together for thousands of years. Even though in the beginning, animals were mainly used for utilitarian purposes such as food, clothes and laboring; as time past, humans started to domesticate them which led to the popularity of household pets in this modern era. Pets, such as dogs and cats, thus, have become a part modern family and companion for humans.

As time progresses, numerous studies and researches on benefits of companion pets on humans and HAI have been developed, employing as strong brief that relationship with animals benefits well-being of humans in various ways. there is an increasing awareness that besides entertainment aspects, scientifically, pets have positive effects in physical, mental and social wellness of human health [15] [7] [2]. This, thus, leads to more studies on the Human-Animal Interaction or HAI.

Having animals around as a pet can help reduce stress, anxiety, and depression [2] [3]. It can also increase self-esteem and improve social skills [5]. This results in Animal-Assisted Therapy (AAT) and Animal-Assisted Activities (AAA) being introduced hospitals and senior homes where people have tendency to experience mental and social health issues.

1.2. Motivation

Motivation:

Back in 2013, my aunt was diagnosed with Lymphoma cancer, which later weakened her body and turned her into a bedridden. Since then, most of her activities lied on the bed, either at home or a hospital. Without being able to move around much, she had to stay in her room for most of her time and did not have an actual interaction with other people. Every time, I went home to visit her, she lit up and became very talkative. Interaction is what she needed.

At my house, we had dogs and cats. I knew that my aunt was an animal lover, so every time I visited her, I would carry one of the pets for her to see. She loved talking about them. Unfortunately, due to her physical condition, she could not directly interact with them due to the sanitation issue.

I, then, notice that there are people with limitations and restrictions due to their own physical health. Moreover, a certain places such as hospitals and senior homes prohibit animals to be in the areas due to safety, sanitation and management issues.

There are many people like her in the world where they have to live apart from their pets, whether it is because of health condition or some other restrictions, it can have a direct and indirect effect on mental health, such as depression, stress and dementia, that will potentially deteriorate ones health condition.

I, as a foreign student in a foreign country, understand how it is to have to separate from my own pets and live alone. Therefore, I would like to do a research on this topic in order to help out people like my aunt.

1.3. Problem

Every animal lover knows how pets can be a source of positive energy . However, there are many people who experience difficulties in interacting with pets due to their physical conditions as well as logistical limitations.

Moreover, even though the effectiveness of pet therapy on people's mental health has been more accepted, there are still a number of hospitals and senior homes that do not permit animals to enter due to safety, sanitation and difficulties

in management and logistic.

1.4. Research Objective

The objective of this research is to understand if remote one-way human-pet interaction through a device could have any positive effects on emotional and mental health of humans, and possibly be a solution to remote animal-assisted therapy and animal-assisted activities in the future.

1.5. Expectation and Hypotheses

Regarding the use and impact of it-Pet, a few expectations and hypotheses were set beforehand as follows:

- The concept of interactive therapeutic device for a remote pet therapy will be positively received.
- By implementing 'attachment' factor by using a real pet will differentiate the proposed it-Pet from other related works and will give a pleasant result.
- People who consider themselves a pet lover or own a pet at home are more likely to receive a better effect.
- A longer time in interaction with it-Pet, a better and more sustainable result.
- Positive emotional effect are likely to be evaluated better using the evaluation method of interviewing and observation.

1.6. Contribution

To the best of my knowledge, the result aims to open a new perspective and possible solution for remote pet therapy-related areas such as animal-assisted therapy (AAT), animal-assisted activities (AAA) and Human-Animal Interaction (HAI).

1.7. Thesis Structure

This thesis is divided into 5 chapters. Following this introductory chapter, Literature Reviews and Related Works will be discussed . It will touch on the topics of Human-Animal Interaction (HAI) and pet therapy, as they are the heart of this research. Related works are included in this chapter as well. Chapter 3 then explains about the design process, including design concept, pre-research study, design scheme , concept drawing and the limitations in this design. Chapter 4 talks the process of making a prototype and address the evaluation methods, as well as its results and corresponding discussions. Finally, Chapter 5 shows a conclusion with a proof of concept, limitations and the possibility of the future works.

Chapter 2

Literature Review and Related Work

2.1. Human-Animal Interaction (HAI)

Starting in the eighties, the field of study known as Human-Animal Interaction has become known to the world when scientific societies were established and international conferences were organized [14]. This field of study cover a wide range of scope, including all interactions between man and animal. In the beginning, the focal part is highlighted in in the use of animals in therapeutic events of disabled person. Later on the scope has been expanded into people in needs, including elderlies and children. In the present, the so-called Healthy and active people can also be benefited from HAI.

However, it has to be noted that not everyone will benefit from HAI and companion animals. For example, those who have practical limitations in keeping or interacting with animals, people who are allergic to animal dander and/or simply people who hate animals (even though this is a rare case).

2.1.1 Concept of HAI

In the field of Interaction, Human-Human Interaction has gained more attention as it is closer to people. However, as stated, people have become more aware of Human-Animal Interaction and its benefits and utility. It can be an alternative

to human-human interaction. One significant advantage of the use of animals in HAI is that animals are non-judgmental and easily to gain trust. It is a simple fact but will make a big difference in medical field of pet therapy which will be explained in the later part.

Furthermore, theoretically, positive typical interaction between human and human can also be replaced by human-animal interaction ¹ as shown in Fig. 2.1

HAI has capability to promote a positive physical, mental (and emotional) and social health of a person and acts as an alternative, if not a better solution, to human-human interaction.

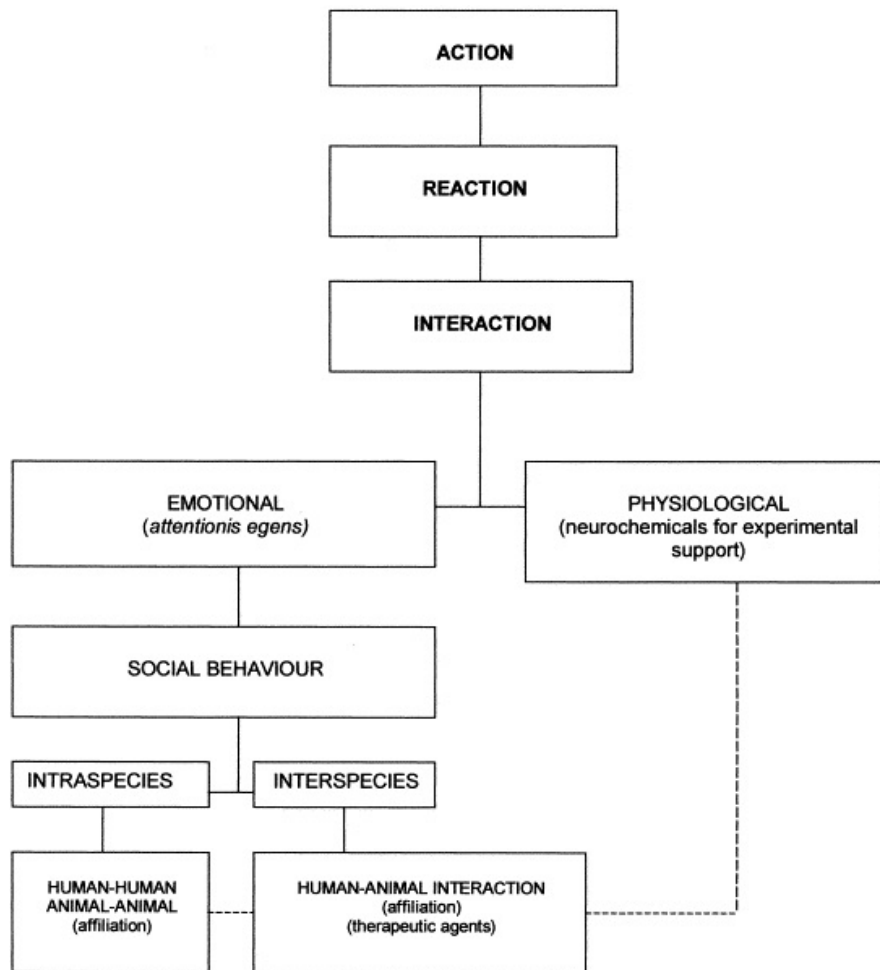


Figure 2.1: Humananimal interactions in humanhuman contact

2.1.2 The Conceptualization of Human-Animal Bond

Many studies show that animal bond is important to humans and community health. This animal-human bond and relationship is significant for human health and well-being, as it fulfills a certain need in humans as shown in Fig.2.2

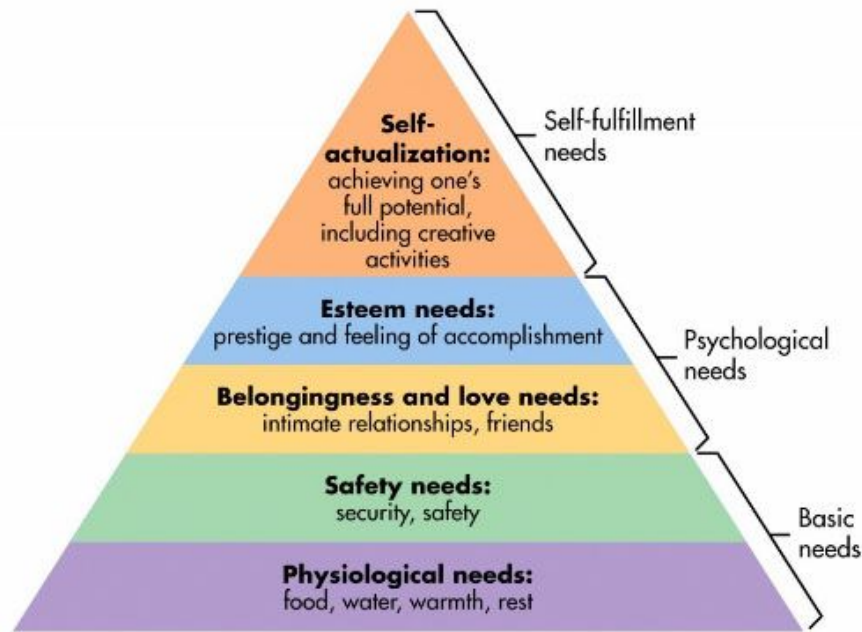


Figure 2.2: Maslow's Hierarchy of Needs

In Maslow's Hierarchy of Needs ², people are motivated to achieve certain needs and that some needs take precedence over others. Under the Psychological needs of the 5-stage model, it shows a need of belongingness and love. All in all, friendship, intimacy, trust and acceptance, receiving and giving affection and love, affiliating and being part of a group are all under this category. This psychological need then attributes to need for companionship. The absence of need of companionship can result in depression and feelings of loneliness [9]. There are many alternatives to fulfill this need and one of them is through relationship and bond between humans and animals.

One might argue that the better alternative is bond in humans. However, bond between human-human is more complicated to form, compared to human-animal

bond. Since animals are non-judgmental, it is less likely that one will experience fear of being judged and rejection from animals [11]. Since companionship in animals is unconditional, trust and bond between human and animal are much easier to create.

Taken together, this leads to a study of utility of pet animals which is beneficial in today's health care. As a result, healing power of pets have become more accepted, and thus using animals in pet therapy has become more popular as time progresses.

2.2. Pet Therapy

Pet Therapy builds on a pre-existing human-animal bond. Interacting with friendly pets can facilitate human's physical, mental and social health and well-being. It can help reduce blood pressure and improve overall cardiovascular health. It can also release endorphins that produce a calming effect. This can help alleviate pain, reduce stress, and improve your overall psychological state.

Pet Therapy is a general term of Animal-Assisted Intervention which includes Animal-Assisted Therapy (AAT) and Animal-Assisted Activities (AAA). It is a goal-directed intervention, designed to improve emotional and/or cognitive functioning of the person(s).³

It is beneficial to a certain group of people that encounter mental issues, ranging from a severe mental disorder to depression in normal people. Even though it is often used with people with special needs such as patients in hospital and health care facilities and elderly facing social and mental issues, it is also beneficial with normal people. Nowadays, stress is no stranger to normal people, and negative emotional downfalls such as stress, depression and feeling of loneliness can easily occur with anyone. Pet therapy can be one of the solution to tackle this problem.

2.2.1 Animal-Assisted Therapy

Animal-Assisted Therapy is a growing field of medical treatment that includes animals in a patient's treatment process. It helps patients better cope with health problems, such as heart disease, cancer and mental health disorders etc. It can assist therapist to overcome significant therapeutic challenges as well.

For AAT, the goal is pre-determined for a specific result. AAT increases relaxation and can provide a wonderful calming effect [12]. It is more a more structured intervention in which an animal is incorporated as an integral part of the treatment process. Comfort level can be increased and animal therapy programs can lower blood pressure, heart rate and stress level [10].

AAT's sessions usually have a fixed length and are documented and evaluated within an individualized treatment plan. It is handled by a professional health provider whose expertise in the area of AAT.

2.2.2 Animal-Assisted Activities

Animal-Assisted Activities, on the other hand, is the use of animal for motivation, education, or recreation to enhance quality of life. It is less goal-directed than AAT as a specific objective might not be planned. Compared to AAT, AAA is more flexible and easier to handle. It usually starts with someone who has a pet that they think would be suitable, whereas AAT usually starts from the patient's perspective, identifying the patient's needs and finding a suitable animal.

Sessions of AAA can be carried in a variety of environments by either professional or volunteer in association with animals that meet specific criteria. Each visit is spontaneous and does not need to be documented. It can be a short meet-and-greet session or a longer session, depending on the need of the patient.

AAA is open to groups or individuals and suitable for everyone, whether it is children, young people or adults. There is no specific treatment goal for individuals, and just by interacting with animals through animal-related activities can improve emotional and physical health, emotional wellbeing and quality of life ⁴.

2.2.3 Limitations in AAA and AAT

Indeed, AAA and AAT have proven their benefits and advantages in the medical field. However, there are a number of places that animals are prohibited due to safety and sanitation issues. In addition, management and logistical difficulties also contribute to the limitation in promoting and implementing AAA and AAT programs in hospitals, senior homes and extended care facilities. With such limitation, other possible solutions are being introduced such as traditional animal

dolls and more advanced technologies such as interactive pet devices and robots.

2.3. Related Works

2.3.1 Interactive Virtual Pet for Entertainment Purpose

For decades, there were attempts to create virtual pets (also known as digital pet, artificial pet or pet-rising simulation) as an artificial human companion for a purpose of entertainment, as a substitute for a real pet [18]. It can provide a sense of security and self-confidence. This can pose to be especially true in those who have difficulties in communicating and interacting with other people in real life. Some examples of Interactive Virtual pets are as follows:

1. Tamagotchi

Tamagotchi⁵, a hand-held digital pet created in Japan, was a big hit toy of the 1990s throughout the world. [6]. Most Tamagotchi are in a shape of a small egg-shaped computer. The objective of the game is to pet a small alien through several stages of growth, and its development depends on the care of the player provides. It is similar to taking care of a dog or a cat in a real life scenario.

Tamagotchi is a proving phenomenon that interactive virtual pets could have a big impact on people's emotional state as well as people's imagination could turn an object into a living thing.



Figure 2.3: Tamagotchi Connection V1 by Bandai

2. Aibo Aibos⁶ . are a serie of dog-like robotic pets, first introduced to the market in 1999. All AIBOs are programmed with AIBOLife software that gives the robot a personality, the ability to walk and see its environment via camera and recognize spoken commands. Even though AIBOs were marketed for domestic use as "Entertainment Robots", they were frequently used and tested for educational purposes and researches on HAI.



Figure 2.4: An Aibo.

3. Cat@Log Cat@Log⁷ (cat-at-log) is a device used in this research on enter-

tainment using computers in an area of "human-pet interaction" [19]. It is a sensing device attached to a pet, comprising various sensing units such as a camera, a GPS, an accelerometer, and a Bluetooth module. The research aims to determine an optimum design of the devices such that they can be attached to a pet without causing discomfort to it. The device can recognize a real-time activities and high-level behaviors of a cat, and post the information to Twitter.



Figure 2.5: Cat@Log: A Human-Pet Interaction Platform

2.3.2 Interactive Therapeutic Pet for Medical Use

1. Paro Paro⁸ is an advanced interactive robot in a form of baby white seal, developed by AIST⁹, a leading Japanese industrial automation pioneer. It is a medical device, used as an alternative for therapeutic animals in environments such as hospitals and extended care facilities where live animals present treatment or logistical difficulties [17].

The robot has five types of sensors - tactile, light, audition, temperature, and posture sensors - in order to detect the environment and respond back

to patients. It is developed in the way to recognize and learn to behave according to what a user prefers and to respond to its new name. For example, if you stroke it after a certain action, Paro will remember and try to repeat that action. The same goes to hitting, if you hit Paro, it will learn that the previous action is 'bad' and will try not to repeat the action again. This ability makes patients feel as if Paro is less of a robot, and more of a living animal.



Figure 2.6: Paro Robot Seal Healing Pet

2. Ollie Ollie¹⁰ is a therapeutic robot, developed by a team of students at MIT, to help with anxiety and depression in dementia patients. It is designed, based on studies showing that animals can have a significant positive impact on people with dementia, which includes one out of every three seniors. Ollie has a touch sensor, allowing it to understand how a user interacts with it and be able respond back in pleasant, soothing ways with sound and movement and purring.



Figure 2.7: Ollie the baby otter

2.4. How Individual Conceptualize Living and Non-living Things

As stated previously, a difference between non-living and living animals [13]

The effect is the level of attachment formed between man and animal. A real pet can provide certain components of attachment that contribute to emotional and social well-being of human. Also, due to this attachment, the feeling of comfort is supplied while loneliness and stress level is likely to decrease [16].

2.4.1 Contribution of This Research

As discussed in this chapter, HAI has shown high potential implicitly and explicitly as a way to assist people to cope with physical, mental, emotional and social health problems. This leads to more studies on AAT and AAA and it has shown a pleasant results as far as the studies go. However, a certain limitation that hinders a proper implementation of AAT and AAA for people in needs does exist. Several alternatives toward solving the stated limitations have been introduced and implemented. However, these alternatives cannot replace a real pet and even though the result using non-living pet agent is positive, relatively living animals still shows better results [1] [13]. Real relationship, bond and attachment formed between human and animal is what marks the difference between today's

alternatives to AAA and AAT from a living animal.

This research, thus, poses as a contribution on multiple fronts. It can pave the way for a new possible solution to remote animal-assisted therapy and other animal-assisted activities in therapeutic scenarios. Also, with additional studies, it can give a new perspective for remote HAI. This will benefit not only the target subjects such as disabled person and people in needs, but also healthy and active people that experience an emotional and mental issues such as stress and depression etc.

Chapter 3

Design

In this chapter, I will discuss the pre-research, framework, design concept and design elements that were used in this research, as well as explaining the rationale behind the design of the device. This chapter is, thus, divided into four sections as below:

1. Pre-Research Study
2. Design Concept
3. Design Elements
4. Limitation in Design

The first section will talk briefly about the field trip for the pre-research purpose. The second section introduces the overall concept used in designing it-Pet. The third section explains about the important elements in the design. Lastly, the last section is the limitation and challenges encountered for this design.

3.1. Pre-Research Study

3.1.1 Background

The pre-research's field trip is carried at Ban Bang Khae ??, the first residential care institution for older persons in Thailand on the 9th and 12th of January 2017.

Ban Bang Khae Social Welfare Development Center for Older Persons, or formerly know as Bang Khae Home for Older Persons, was the first residential care institution for older persons in Thailand. There are six sub-centers i.e. data center, a training center, a learning center, an institutional care center f, a community-based social welfare service center for older persons and a counseling center. As of September 2017, there are six residential buildings with 240 elderly residents in total (74 males and 172 females).

The objective of the pre-research is to observe how people in senior home deal with mental issues such as stress, depression and loneliness, and what could be a solution for their problems. The senior home is selected in this pre-research because one of the most beneficial group for pet therapy is elderlies who live by themselves. They are prone to psychological effect.

In Ban Bang Khae, there are two big groups of elderlies - healthy and bedridden elderlies. For healthy group of old people, when they feel stressed or emotionally declined, they have several activities to help themselves such as taking a stroll, talking to staff, other residential friends or feeding stray animals. However, for bedridden old people, due to their condition, they cannot move around and there are not many people that they could interact and communicate to. Due to the lack of interaction with humans or any living things, their mental and emotional condition has a tendency to decline.



Figure 3.1: Ban Bang Khae Residential Care Institution

3.1.2 Pre-research's Find Outs

1. People who used to own a pet are more likely to have a positive impact on interacting with animals

During the observation, it is obvious that animals of any kind are prohibited in and around the residential care institution. Majorities of elderlies do not like animals to be around them, while there are some groups of elderlies that used to have their own pets and would like to have one. The group that loves animals sneakily feed stray cats (even though stray cats are not allowed to be in the area). They always bring cat food with them and whenever they find stray cats, they will try to feed them without letting staff know. This shows that for a group of old people who love animals, animals such as cats and dogs have a positive emotional effect on them.

2. Old people prefer to talk to humans; however, due to several limitations, there are not enough chance for them to interact with other people.

When further interview the staff, they said animal therapy or visitation has not been used in Thailand. They felt that having pets as a way to heal people physically or emotionally is still unnecessary.



Figure 3.2: Elderly at Baan Bang Khae

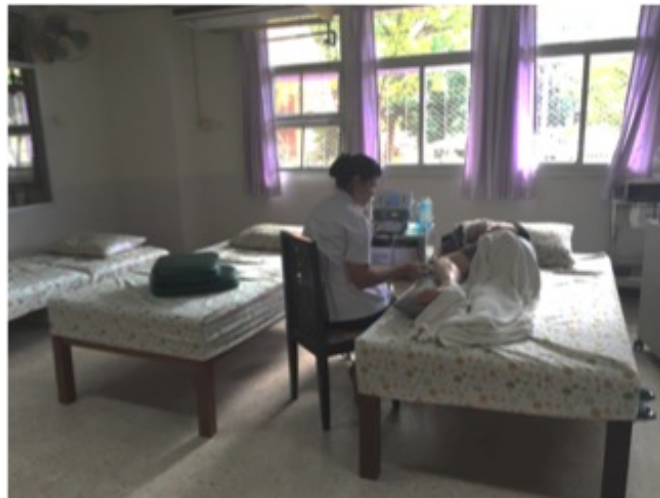


Figure 3.3: Bedridden elderly in a special care facility

3.1.3 Originality of the Concept Idea

It-pet was originally called 'Nene' which is a short form for 'sleeping cat' in Japanese. The idea was from a behavior of cats that like to sleep or sit on people's body. Sleeping or sitting on people's body is a sign that a pet trusts and attaches to the person he/she is sleeping on. It is a special interaction that shows a mutual bonds between human and animal.



Figure 3.4: A cat sleeps on a human's body

It is an interesting observation as when people talk about HAI, most people will relate the concept with an active interactions such as playing with animals. However, interaction does not need to be active , passive interaction can provide calming and relaxing effect to humans as well.

According to the pre-research study, some group of people in needs such as elderlies and patients have physical limitation to move around actively. Some are bedridden, while some are on wheelchair. Taken together, passive interaction is a better design solution.

Moreover, unlike typical robots, it-Pet exists for the purpose of providing human beings with happiness and peace of mind. For this purpose, it is important that This design emphasizes on the receiving end, i.e. human.

Therefore, with a model of passive interaction, a 'sleeping pet' was chosen for this design concept, emphasizing on human agent's side.

3.2. Design Concept

3.2.1 Incorporating the Components of Individuality Recognition

One of the factors contributing to people's attachment toward a particular animal is 'Individuality Recognition' [4]. This is similar when a pet owner forms a bond with his or her pet. A pet owner can recognize the individual characteristic and personality of their pet, which make it unique to the owner. A recognition of an individual animal's uniqueness through observation and physical contact can form an attachment and bond between two living creatures. A unique 'personality' and 'characteristic' of any individual is what differentiate a living from non-living being, or in other words, a real pet from an interactive pet robot.

Recognize a pet's individuality can be done through interaction of the five senses of human - sight, touch, hear, taste, smell, and also through communication. In this design, however, I will focus on the first three senses (sight, touch and hear), together with oral communication for a remote interaction between human and animal agents.

3.2.2 Design Scheme

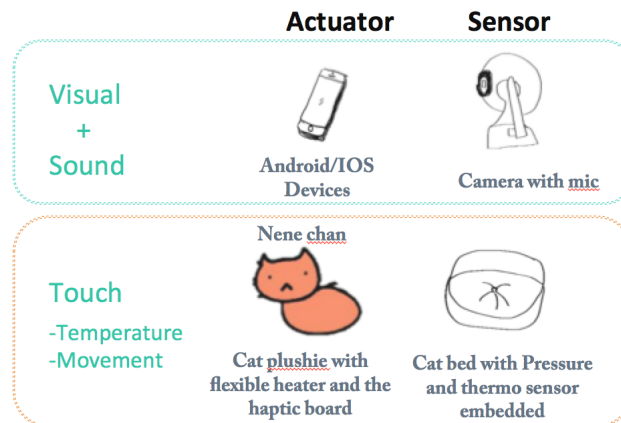


Figure 3.5: Design Scheme

3.2.3 Concept Drawing

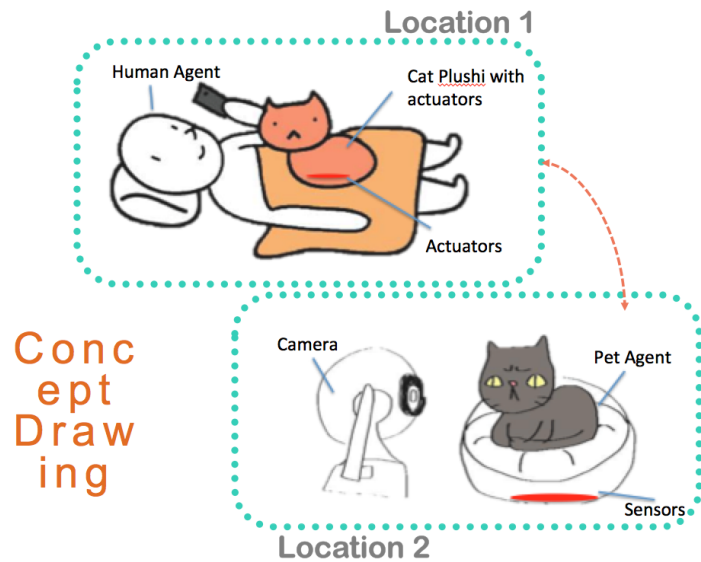


Figure 3.6: Concept Drawing

3.3. UX and UI

The design concept is from the combination of AAT-AAA and interactive pet robots. The design concept's core idea lies on the belief that robots cannot replace a real interaction between human and living-animals.

There are three important factors contributing to the user experience (UX):

1. Real-Time Factor
2. Simulations
3. Communication

First is the real-time factor, the device has to be real-time in order for a user to be able to interact with his or her pet remotely.

The second factor is simulations. In order to make a user feels as if his or her own pet is being with them, a proper set of simulations is needed. As stated above, the focus is on the first three senses - sight, touch and hear.

The third factor is the communication. This is the most tricky part. In today's technologies, there has not been any research proving that human and animals could communicate remotely, and a pet in a remote area could recognize an owner's voice. However, the focus in the design is not about making human-pet communication but on a user's feeling. Therefore, a user's voice will be transmitted to a pet in another location through an application.

3.3.1 UX Elements

It-pet is an interactive cat-shaped device to create a real-time interaction by recording, streaming and reproducing the 'feeling of interacting with a pet' in real time.

When a pet sleeps or sits on a person's body, what they will feel is the warmth of the pet's body and the breathing movement when a stomach inflates and deflates.

On the pet's side, the device is equipped with auditory, vibration, temperature sensors that are able to recognize and comprehend a pet agent's action and environment.

The four elements of it-Pet include:

1. Video Streaming: A real-time CCTV is linked with a mobile application. A user is able to see his or her own pet anytime anywhere via a mobile phone. Video Display is helpful to create awareness of the remote presence of friends, family or even animals [8].
2. Audio simulation: it-Pet is able to transmit real-time pet's sound. In addition, the device allows the user to communicate with their pet by transmitting the owner's voice back.
3. Temperature: by using an infrared contactless temperature sensor, the real temperature of a pet can be transferred to Nene and as a result, the user can feel his or her pet's actual body warmth.
4. Breathing vibration of their pet: We use the DRV2605EVM-CT module to transform the sound into vibration.

3.3.2 User Interface

Each and every pet has its own uniqueness on appearance, characteristic and personality. However, for the prototype, the form of cat was chosen for the experiment as it is one of the most popular domesticated animals people own. The appearance, sound, size and personality of different breeds of cats are not hugely different from one another, compared to those of dogs.

It-pet is in a form of a white cat. It wears a cat costume with a total weight of 0.6 kg, when all the actuators are assembled inside.



Figure 3.7: It-Pet's Interface as a white cat doll

3.4. Limitation in Design

This study aims to design a device that can provide remote interaction and communication between human and pets. However, it is difficult to know if pets can detect and recognize their owners' presence such as physical appearance, voice or gesture through remote communication medium such as mobile phone and

computer. In this study, the design, thus, focuses mainly on the experience of a human agent. It opts out the interaction on the pet's side, and aims toward one-way interaction on the human side.

Chapter 4

User Test and Evaluation

In the Prototyping process, three prototypes were made. The first prototype was a paper prototype, demonstrating expected user interface, user experience, design concept, design scheme and use case of it-Pet. Following the paper prototype, the second prototype was made based on the first paper prototype. With several limitations in design encountered during the process of the second prototyping, the final prototype was designed. The details of each prototyping and its evaluation process are explained in this chapter.

4.1. First Prototype: Paper Prototype

The first prototype and the use case of it-Pet are as shown in Fig.4.1 respectively. Note that in the first prototype process, it-Pet was still named as 'Nene'. The prototype is in a cat-shaped plushie as cat is one of the most popular domesticated pets (besides dogs), and unlike dogs, there is no major difference in size, shape and overall appearance of each cat regardless of its breed.

The prototype shows the scenario of how the device works.

In Location 1, a real pet (in this case, a cat) is resting on its cat bed, which is embedded with a touch sensor. On the collar, a mic and audio transmitter are attached to transmit a pet's sound such as purring to another location in real-time. A camera is set in Location 1 as well and it is linked with a mobile phone in Location 2. Location 1 is where all of the sensing units are.

In Location 2 where a human agent is, mobile phone is used to demonstrate

a real-time video streaming of a pet in Location 1 via an application. A sound simulation that is linked with the Location 1's mic and voice transmitter in order to transmit real-time pet's sound to the user. The touch actuators will be placed in the cat plushie (later known as it-Pet), to produce a haptic feeling of the pet in Location 1.

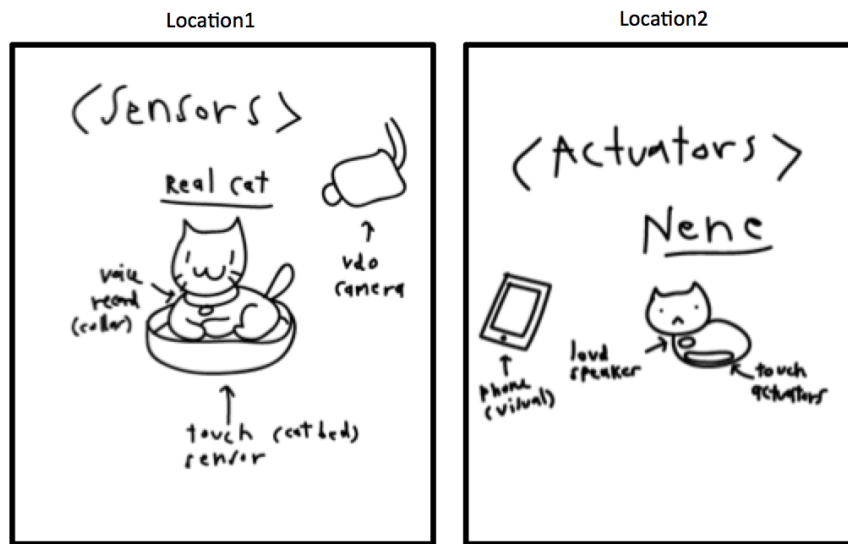


Figure 4.1: Paper Prototype of it-Pet

In Fig.4.2, it shows a prototype's use-case. To be able to produce a real-time simulations, two sets of Arduino¹ are needed to link sensors and actuators together via a cloud server. On the Sensor side, there are pressure sensor, temperature sensor, Camera and audio transmitter (and a mic). On the Actuator side, an application on the mobile phone is used for a user to see a pet on the Location1. Loud speaker is to receive transmitted sound and PS3 is used as an vibration actuator for the touch aspect.

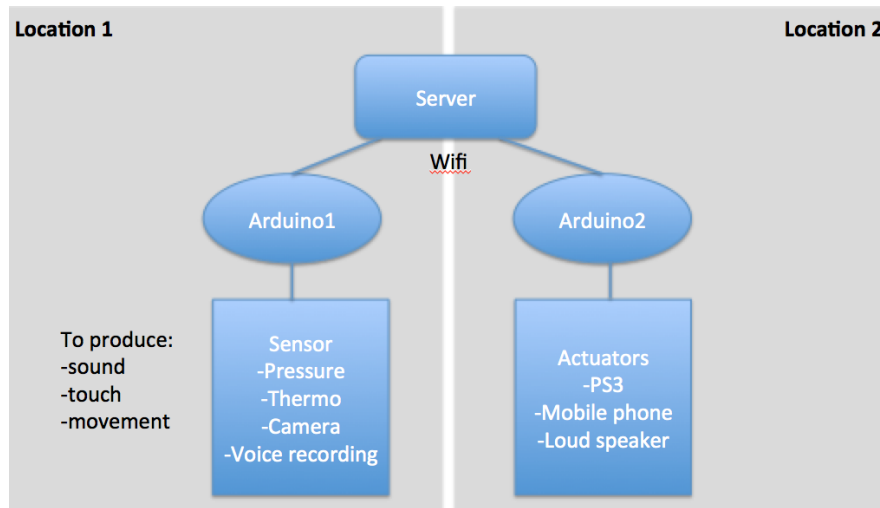


Figure 4.2: First draft of a prototype's use-case

4.1.1 Testing

This concept is tested with a group of 8 people (4 females, 4 male), 25-60 year-old from different ethical background. Five people are Japanese seniors over 60 years old from Meguro International Friendship Association². The method of the test is through presentation and one-on-one interview. The rest are either a student or faculty member of Graduate School of Media Design, Keio University³.

4.1.2 Feedbacks

10 out of 10 people were interested in the concept, and answered 'I am interested in this device' and deemed to understand the utility and benefit of it-Pet. One issue is the user interface of a cat as those who do not like cats show were less interested in the device, compared to those who love or own a cat. 3 out of 10 suggested to add the temperature element to the device.

4.2. Second Prototype

The sensors and actuators are paired up as shown in the table below:

Sense	Sensor	Actuator
Temperature	Temperature Sensor	Flexible Heater
Vibration	Vibration Sensor	Haptic Board
Visual	CCTV	Mobile Phone
Sound	CCTV	Mic

In this prototype, we used 2 sets of Arduino Xbee Shield (Fig.4.3) as the settings are in different locations. The location with a pet is in Thailand, whereas the location to test the device is in Japan.



Figure 4.3: Arduino+XBee Shield

For UI, three different skins were being chosen - an unrealistic cartoon-like plushie, a white cat and a grey cat (4.4)



Figure 4.4: Skin selection for UI

The skin selected is the white cat as it looks like a pet but not too realistic. And the white colour is a common colour in animals and it gives a pleasant feeling to users.



Figure 4.5: Selected Device Skin and a Cat Bed for UI

For the video Streaming, a real-time CCTV is linked with a mobile application. The CCTV used in the demonstration is called 'True CCTV' from True

Information Technology Company Limited Communication. The True CCTV mobile application works in a relation with the True IOT 4G CCTV, which uses 4G/3G signal. The CCTV is able to pan 355 degree horizontally and 120 degree vertically, and also equipped with smart detection program and can detect movement in the surrounding.

Moreover, a mic is attached at the base of the camera, enable the 2-way communication between people in two different locations. For example, if a pet is in Location 1 with the CCTV, while a user is in Location 2, with his phone linking the application to the CCTV. The user in the location 2 is able to see and hear his pet in Location 1. In addition, he can talk to his pet via the mobile application. The pet in Location 1 is able to hear its owner's voice through the CCTV.

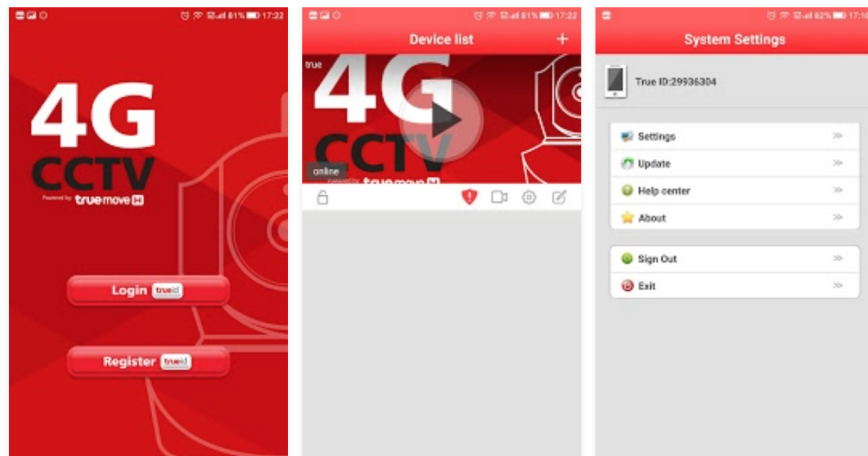


Figure 4.6: True CCTV mobile application's interface



Figure 4.7: True IOT 4G CCTV



Figure 4.8: Example of the Video Stream

For temperature sensor, and TMP006 are used together in this experiment.

DS18B204.9 is 1-Wire digital temperature sensor from Maxim IC. Reports degrees in Celsius with 9 to 12-bit precision, from -55 to 125 (+/-0.5). Each sensor has a unique 64-Bit Serial number etched into it - allows for a huge number of sensors to be used on one data bus. It is attached to the flexible heater in order to measure and control temperature' range produced by the heater.

For TMP006, it is an infrared contact-less temperature sensor. The actual temperature of a pet can be transferred to it-Pet and as a result, the user can feel

his or her pet's actual body warmth. It can measure temperature from 55C to +125C (0.5C) with accuracy from 10C to +85C.

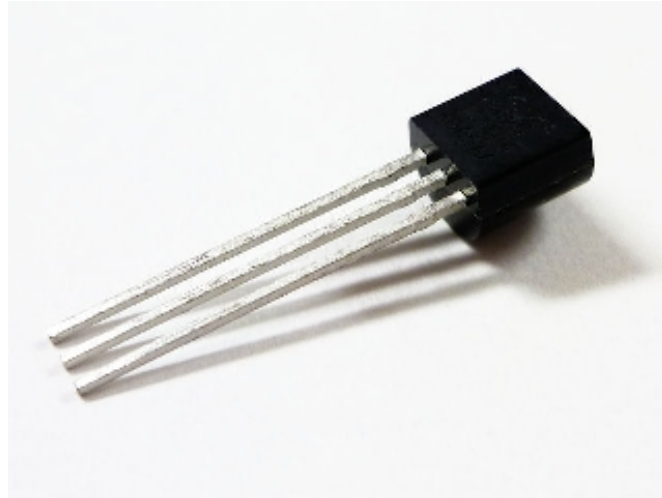


Figure 4.9: Maxim Integrated Board Mount Temperature Sensors :

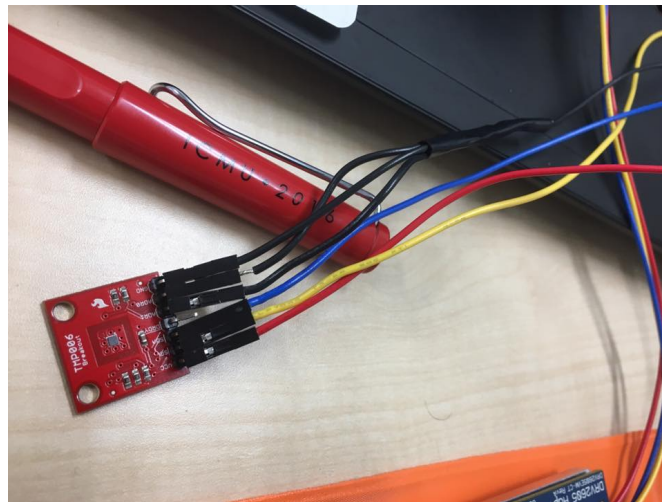


Figure 4.10: TMP006

The Schematics diagram⁴ is connected as shown below:

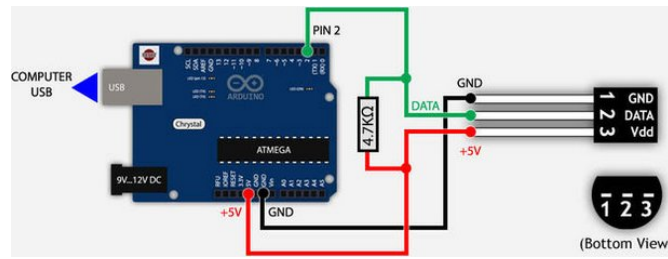


Figure 4.11: Schematic Diagram of Temperature Measurement

Flexible Heater (M-08908) was used as an actuator. It can be heated up to 60 degree Celsius, which is sufficient for this experiment as a cat's average body temperatures is 38.6 degrees Celsius, and a dog's average body temperature ranges from 38.3 to 39.2 degrees Celsius. The size of the flexible heater is 100(W) x 255(L) mm, with 2 mm thickness. Hence it's size is suitable and match the size of the cat's skin.



Figure 4.12: Flexible Heater Sheet: M-08908

After building the circuit by following the schematic, the temperature is measured and showed in the Serial monitor at the IDE4.13 (see Appendix.1 for the Code)

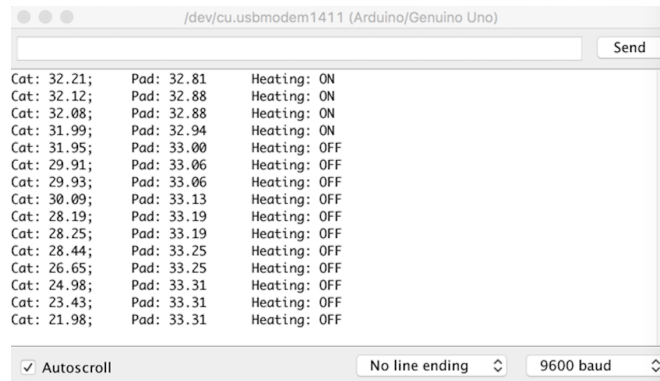


Figure 4.13: the Serial monitor at the IDE

Note that the temperature is limited in a range of 39 to 40 degree Celsius.

Lastly, for the haptic simulation, I decided to imitate a pet's breathing movement through vibration motor.



Figure 4.14: Vibration Motor

4.2.1 Testing

The four simulations - visual, sound, temperature and vibration - are being tested upon. The method of testing is to compare the experience using the prototype with an actual perception of a user when interacting with a real pet. For

this test, it is carried in a lab; therefore, there are 2 participants participating in the test.

4.2.2 Findings

1. The level of the vibration was relatively stronger than an actual breathing movement of a pet.
2. There are too many wires which make it inconvenient and messy to use the prototype.
3. The temperature is an essential factor for 'feeling calm'.

4.3. Final Prototype

Most parts of the final prototype did not change significantly from the second prototype. The only parts that requires to adjust are temperature and vibration.

For temperature, I used a cotton wrapping up the temperature sensor that is attached on the flexible heater as shown in Fig.4.15 in order for the sensor to measure only the temperature of the flexible heater, and not of the surrounding.

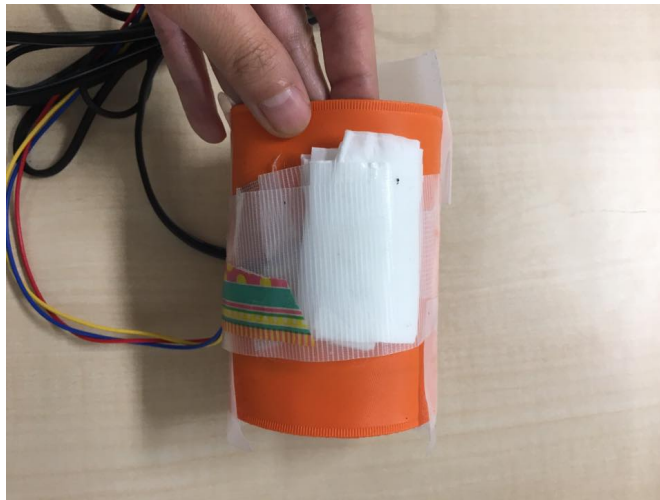


Figure 4.15: Flexible heater with cotton wrapped around the temperature sensor.

Since vibration motor is 'too strong', it will be substituted by the haptic board, the DRV2605EVM-CT module. This haptic board transforms the sound into vibration.

The cat purring noise is a pre-recorded noise from a website⁵ that can produce a relaxing experience. Even though it is pre-recorded and not real-time, it is much easier to control. It is used when a pet is not in the range of CCTV and when a pet's sound cannot be detected.

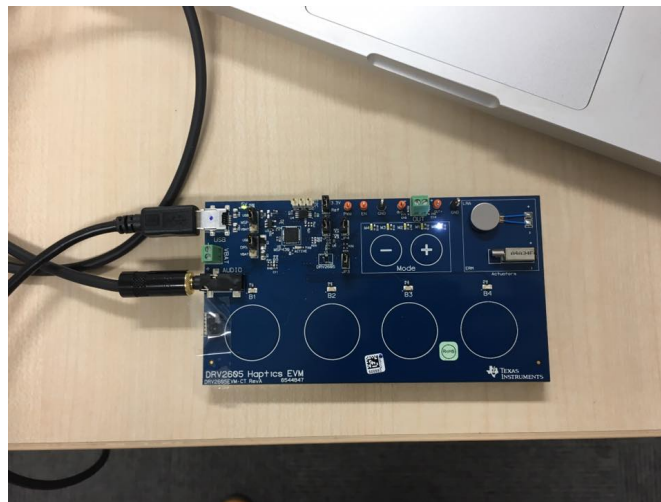


Figure 4.16: Haptic Board: DRV2605EVM-CT

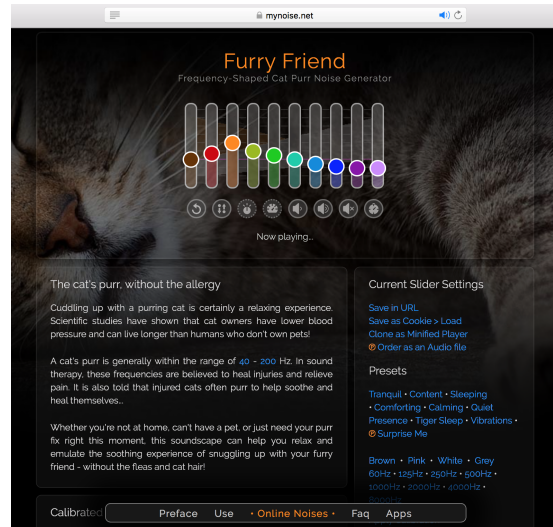


Figure 4.17: Cat purring simulation from mynoise.com

The user-end setup overview of the final prototype is shown as below:

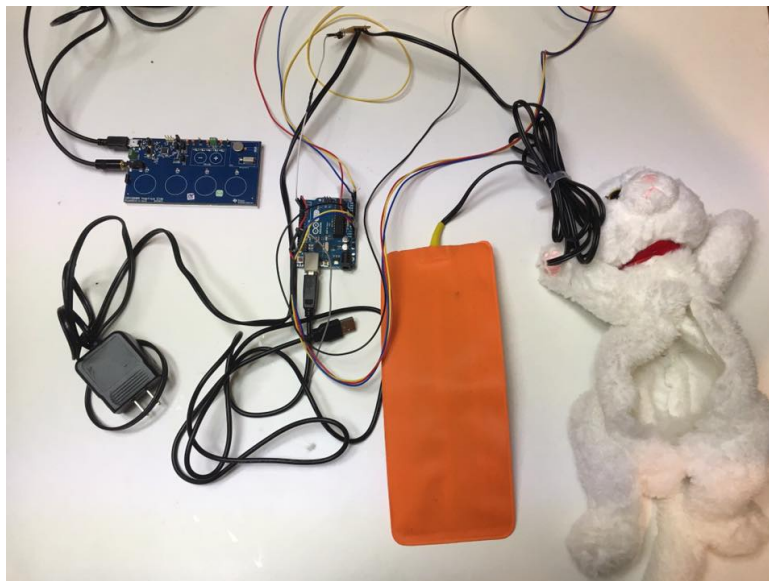


Figure 4.18: The user-end setup overview

4.4. Evaluation

4.4.1 Methodology

To assess the viability of our approach, we conducted a 2 week long user study with 5 adult subjects (4 females, 1 male), 21 to 33 years old, from different ethical backgrounds, who live abroad and either have or used to have a dog or a cat in their home countries. Each participant tested the demo for 10 minutes for each of the 5 sessions and each session was conducted on a different day within a two week period. The basic idea of the study is to test the effects for different combinations of simulation modalities and compare them with a normal emotional state of the participants without exposure to the prototype (as a baseline).

In every session, each participant's blood pressure and heart rate were recorded. In addition, participants were asked to complete two loneliness tests (Campaign to end loneliness measurement tool and UCLA 3-item loneliness scale) before and after each demonstration. The test was conducted using a Latin Square⁶ experimental design which looks as on Fig.4.19.

	D1	D2	D3	D4	D5
U1	Baseline	H	HS	HST	HSTV
U2	H	HS	HST	HSTV	Baseline
U3	HS	HST	HSTV	Baseline	H
U4	HST	HSTV	Baseline	H	HS
U5	HSTV	Baseline	H	HS	HST

Figure 4.19: H: Haptic Simulation S: Sound Simulation T: Temperature V: Visual Simulation

Note that the reason I chose Loneliness Scale over other scales as one of the evaluation methods is that since the experiment's focal point is on the emotional impact of the user which is related back to the concept of 'Individuality Recognition', the important factor is 'living animals are different from non-living animals' which contribute to attachment factor. This attachment formed the during the experiment will contribute to the 'Loneliness' level of the subject.

In the last session, there we added a post-test survey consisting of open-ended and Likert Scale⁷ questions, together with an in-depth interview on usability

and user experience, and observation of each user's reaction to assess the overall experience.



Figure 4.20: A user testing the prototype

4.4.2 Consideration and Limitations of Evaluation Method

For the Quantitative Approach of measuring blood pressure and heart-rate, the number of subjects are too small. Moreover, I hypothesize that the 10 minute exposure period may be not enough to cause any significant quantitative changes.

4.4.3 Quantitative Approach Findings

The baseline condition showed a slight heart rate increase of 4.4 beats per minute, however, all other conditions showed no significant change in the heart rate. The blood pressure changes did not show significant results as well.

The two loneliness scales gave some positive results. The first loneliness measurement tool shows that without the prototype, the participant's loneliness level increases by 0.75 points. But there was a noticeable decrease of loneliness when the participants interact with the prototype. The second scale also shows similar results. The loneliness level decreased by 0.25 points for the baseline condition, while 3 out of 4 days of using the prototype, show much higher decrease by 0.4

points of loneliness level. However the number of participants is not enough to claim any statistical significance, we still consider this to be a very promising result for the preliminary study.

	Baseline	H	HS	HST	HSTV
BP(H):	-4.6	-1.4	-1	1.6	-5.6
BP(L):	-1.8	0	14	-3	-1.8
HR:	4.4	0.2	0	0	0.4
LC1:	0.75	-0.4	-0.4	-0.4	-0.2
LC2:	-0.25	-0.4	-0.2	-0.4	-0.4

Figure 4.21: Summary of Result from BP, HR and Loneliness Scales measurement

Moreover, 3 out of 5 participants show a decreasing trend in their loneliness levels over a course of 2 weeks.

4.4.4 Qualitative Approach Findings

The Qualitative Approach consists of in-dept interview and observation. All of the participants have a positive experience for the test as everyone mentioned the word 'calming' and 'relaxing' when asked to elaborate their experience in the test. 3 out of 5 people say that the 'temperature' factor of the device gives them 'relaxing' experience.

	No. smile count	No. time pushing the 'talk' button and talk with the cat	No. of time that say the word 'cat', or 'pet' or 'dog'	Time length, looking at the camera
U1	7	8	3	15 min
U2	5	5	4	8 min
U3	4	7	3	12 min
U4	4	4	2	15 min
U5	1	0	0	3 min

Figure 4.22: Result from observations

4.5. Discussion

According to the experiment, interaction alone is not enough to replicate the feeling of a 'real pet'. Interaction between the two parties is needed. In all four

simulations, the video streaming which allows a user to see, hear and talk to a cat is the most effective to make people feel calm. Hence, this experiment is successful in providing calmness to a user using a device that replicate essential simulations of a pet.

However, what is needed to test more is that if the idea of using this device is better than the existing technology that aims to solve the same problem e.g. pet robots.

It is also necessary to test with a target group in a real setting such as hospitals or senior homes for the purpose of a future implementation.

However, taken together, it can still imply that the prototype provides a calming and relaxing effect to the users which potentially reduces stress and loneliness level, as well as can possibly be used as an easy alternative for Animal Assisted Therapy and Animal Assisted Activities.

Notes

- 1 <https://www.arduino.cc/en/Guide/Introduction>
- 2 <http://www.mifa.jp>
- 3 <http://www.kmd.keio.ac.jp>
- 4 <https://create.arduino.cc/projecthub/TheGadgetBoy/ds18b20-digital-temperature-sensor-and-arduino-9cc806>
- 5 <https://mynoise.net/NoiseMachines/catPurrNoiseGenerator.php>
- 6 <http://www.tfrec.wsu.edu/ANOVA/Latin.html>
- 7 <https://www.simplypsychology.org/likert-scale.html>

Chapter 5

Conclusion

5.1. Proof of Concept

Based on the result of the usability test from both quantitative and qualitative approach, it-Pet has a potential to provide positive emotion-related result. Even though the result of blood pressure and heart rate is still debatable due to the sufficient time period, number of participants and other environmental factors, the overall result shows that there is an upward trend in emotional improvement when the experiment is carried in a longer period of time.

Nonetheless, more research needs to be done to explore benefits and advantages of this concept over the existing technology.

5.2. Future Work

Our experiments show very interesting possible application scenarios for it-Pet. For example, it-Pet can be used in therapeutic scenarios for cases of depression and mental disorders, and can be an alternative solution to remote animal-assisted therapy and other animal-assisted activities. Also, with additional studies, it can give a new perspective for remote HAI for pet owners.

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This has been a long journey with ups and downs. When I first started this project, it seemed impossible to achieve as design is not my forte. let alone technology. However, I will never be able to surpassed all of the obstacles and impossibility without support from these people:

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Appendix

A. Arduino Code for Temperature Measurement

```
// An example to get started with the TMP006 temperature sensor
// Modified by SparkFun Electronics.
// We release this code under ([Beerware license](http://en.wikipedia.org/wiki/Beerware)).

// Original Code license:
/*
 *-----
 * This is a library for the TMP006 Temp Sensor
 *
 * Designed specifically to work with the Adafruit TMP006 Breakout
 * ----> https://www.adafruit.com/products/1296
 *
 * These displays use I2C to communicate, 2 pins are required to
 * interface
 * Adafruit invests time and resources providing this open source code,
 * please support Adafruit and open-source hardware by purchasing
 * products from Adafruit!
 *
 * Written by Limor Fried/Ladyada for Adafruit Industries.
 * BSD license, all text above must be included in any redistribution
 *-----
 */

// Only things needed to configure are the sensor address and
// samples per reading, however the defaults work fine if using
// just one TMP006 sensor. Check out the hook up guide tutorial
// if you want a better explanation of the hardware and code.

#include <stdint.h>
#include <math.h>
#include <Wire.h>
#include "I2C_16.h"
#include "TMP006.h"

#include <OneWire.h>
#include <DallasTemperature.h>

// Data wire is plugged into pin 2 on the Arduino
#define ONE_WIRE_BUS 2
// Setup a oneWire instance to communicate with any OneWire devices (not just Maxim/Dallas temperature
// ICs)
OneWire oneWire(ONE_WIRE_BUS);
// Pass our oneWire reference to Dallas Temperature.
DallasTemperature sensors(&oneWire);

uint8_t sensor1 = 0x40; // I2C address of TMP006, can be 0x40-0x47
uint16_t samples = TMP006_CFG_BSAMPLE; // # of samples per reading, can be 1/2/4/8/16

uint8_t heaterPin = 3;

float cat_temp;
float pad_temp;

float cat_temp_filtered;

int numberOfSamples = 5;
float precision = .7f;
float tau = 0.35662494268; //ln(1/precision);
float filter_alpha = 0.93115922687; // exp(-tau / numberOfSamples);
```

Figure 5.1: Arduino Code (Page 1 out of 2)

```

float filter_beta = 1 - filter_alpha;

void setup()
{
  Serial.begin(9600);
  Serial.println("Cat Surrogate Heater Ver 0.1a. Loading.....");

  pinMode(heaterPin, OUTPUT);
  config_TMP006(sensor1, samples);
  sensors.begin();

  delay(500);
  cat_temp_filtered = readObjTempC(sensor1);

  Serial.println("Done!");
}

uint8_t isHeatingON = false;

void loop()
{

  sensors.requestTemperatures();

  cat_temp = readObjTempC(sensor1);
  pad_temp = sensors.getTempCByIndex(0);

  cat_temp_filtered = filter_alpha*cat_temp_filtered + filter_beta*cat_temp;

  Serial.print("Cat: ");
  Serial.print(cat_temp_filtered);
  Serial.print("\tPad: ");
  Serial.print(pad_temp);

  if( cat_temp_filtered > pad_temp +1){
    digitalWrite(heaterPin, HIGH);
    isHeatingON = true;
  }

  if( cat_temp_filtered +1 < pad_temp ){
    digitalWrite(heaterPin, LOW);
    isHeatingON = false;
  }

  if(isHeatingON){
    Serial.print("\tHeating: ON");
  } else {
    Serial.print("\tHeating: OFF");
  }

  Serial.println();

  delay(500); // delay 1 second for every 4 samples per reading
}

```

Figure 5.2: Arduino Code (Page 2 out of 2)

B. Pre-Test Questionnaire

THANK YOU for participating in this experiment.
Before we start the experiment, I would like you to answer questions below.

DEMOGRAPHICS

1. Name : _____

2. Gender:

Male

Female

3. Age Range:

Under 18

18-24

25-34

35-44

45-54

55-64

65-74

Over 75

4. Marital Status:

Single

Married

Widowed

Divorced/Separated

5. Occupation:

Student

Employed full time

Employed part time

Housewife

Self-employed

Retired

Other _____

6. Nationality : _____

Figure 5.3: Pre-Test (Page 1 out of 3)

7. Do you have pets?
 Yes. What is it? _____
 I used to have one/ones. What is it? _____
 No

8. Do you live with your pet now?
 Yes
 No

9. Would you describe yourself as an animal lover?
 Yes
 No

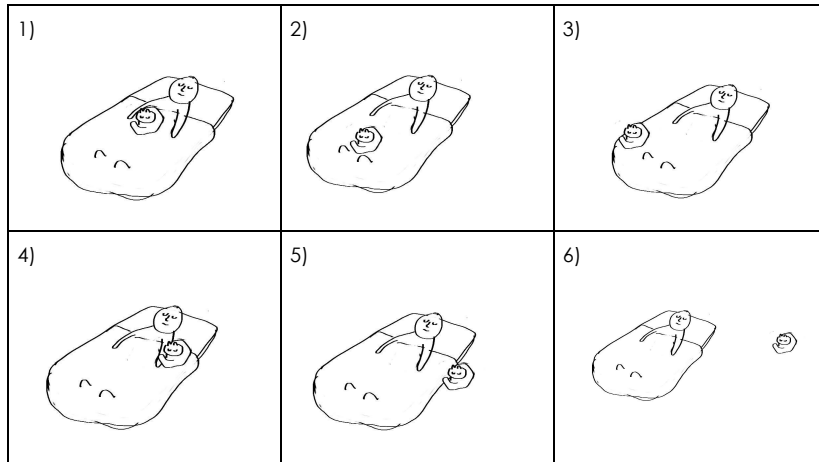
10. Do you sleep with your pet?
 Yes
 No
 Sometimes

11. Do you prefer to sleep with your pet?
 Yes, Why? _____
 No, Why? _____

12. Does your pet sit on your lap or next to you?
 On the lap
 Next to me

13. Do you prefer pet to sit on you or next to you?
 On the lap
 Next to me

14. Please select how you normally sleep with your pet.



15. Please select how you like to sleep with your pet

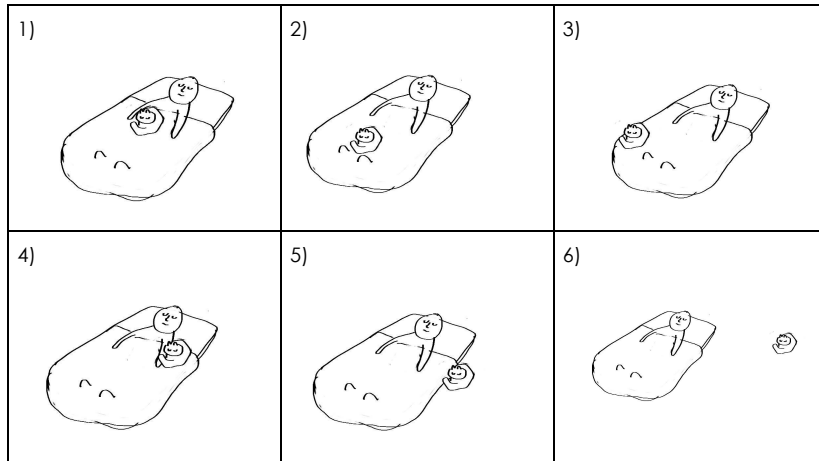


Figure 5.5: Pre-Test 4 (Page 3 out of 3)

C. Post-Test Questionnaire

THANK YOU for participating in this experiment.

As a follow up, please let me know about your thoughts about the prototype, experiment and overall experience.

**The post-test survey will focus on 2 main parts: device usability and user experience

USABILITY

1. Please rank the simulations you like the most to the least (5 = the most favourable simulation and 1 = the least favourable simulation)

Visual Sound (Hearing) Sound (Talking) Temperature Movement

2. Do you like the placement or setup of the sensors?

Yes No

3. Please rank the most realistic and favorable of the simulations (5 = the most realistic/favorable simulation and 1 = the least realistic/favorable simulation)

	Realistic	Favorable/Preferable
Visual		
Sound		
Sound (Talking)		
Haptic (Temperature)		
Haptic (Vibration)		

4. Do you want other simulations but the ones we represent in the experiment?

Figure 5.6: Post-Test (Page 1 out of 2)

USER EXPERIENCE

	Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
I like the overall concept of it-Pet					
I felt comfortable to use the device					
It was enjoyable to me that I can feel body temperature from it-Pet					
It was enjoyable to me that I can feel it-Pet moving					
I think it-Pet is an adequate to a real pet					
I think it-Pet is different from robots					
I experienced a positive emotional change after using it-Pet					
I think it-Pet will help me fight loneliness as I feel that my pet is with me					
I feel that it-Pet can represent my own pet at home					
I will want to it-Pet to animate other senses as well					

Any comments?

Figure 5.7: Post-Test (Page 2 out of 2)

D. Loneliness Scale Questionnaire

Four Scales Loneliness Measurement Guidance Out of the four scales, The Campaign To End Loneliness Measurement Tool and the UCLA Loneliness Scale are being used.

Please answer the questions below by marking an X

User: _____

Date: _____ (Day _____)

- Pre-questionnaire
 Post-questionnaire

Q. Set1:

1) I am content with my friendships and relationships

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

2) I have enough people I feel comfortable asking for help at any time

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

3) My relationships are as satisfying as I would want them to be

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

Q. Set2:

1) How often do you feel that you lack companionship?

Hardly ever	Some of the time	Often

2) How often do you feel left out?

Hardly ever	Some of the time	Often

3) How often do you feel isolated from others?

Hardly ever	Some of the time	Often

Figure 5.8: Loneliness Scales)

E. Loneliness Measurement Tool Guidance



Figure 5.9: Loneliness Measurement Tool Guidance) Loneliness Measurement Tool Guidance