DESIGNING PET CARE

AN IOT APPROACH FOR INTEGRATED AND EMPOWERED PET CARE AT A DISTANCE

by ROSSA KIM
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A thesis submitted to the School of Design, Carnegie Mellon University, for the degree of Master of Design in Interaction Design

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I would like to thank my advisor professor, Mark Baskinger for your guidance and constant encouragement through this thesis journey. I couldn’t have done it without your help.

Thanks to my friends, for going through this journey together with. I am so thankful to have you all in my life.

Thanks to my parents, for your love, support and unwavering trust in me.
ABSTRACT

Many people have pets that they consider to be family. Often, owners find themselves experiencing difficulties in coordinating health care for their pets because of the time investment, required knowledge, and responsibilities. There is a major gap in understanding between an owner and their pet(s), which only gets wider when the owners are away from their pets. This thesis project explores opportunities for an Internet of Things (IoT) approach to close this gap. It aims to create an ecology of digital tools for integrated and informed pet care over physical distance. Based on identified design opportunities, this project proposes the concept of SnapPet, a smart care system consisting of integrated tools in support of remote care activities for their pets.
01 / INTRODUCTION
01 / INTRODUCTION

According to the National Pet Owners Survey from APPA, 85 million of all households in the US own a pet.\(^1\) In the past decade, pet care products have rapidly grown into an $18 billion industry, which is evidence that pet owners care greatly about their pets.\(^2\) The relationship between humans and pets has a long history. Since the emergence of domestic pets, people have perceived pets as their friends, family members, or even as an extension of themselves.\(^3\) But the reality is that there is a gap between humans and pets due to biological differences, different needs, and different communication. Because of this gap, many challenges or breakdowns can happen during pet ownership, especially when owners don’t have adequate means to fully understand their pet’s needs.\(^4\)

Among the challenges, pet owners are having the most difficulty in coordinating healthcare because of the time investment and require a diverse set of knowledge and responsibilities. When providing healthcare, there is a major gap in understanding between an owner and their pet.\(^5\) Owners cannot necessarily read the signs of a pet’s state of health and may miss critical behaviors and symptoms that can signal a developing condition.

The gap in understanding gets even wider when the owners are away from their pet. When they are away, it becomes more difficult to understand their pet and provide quality care due to the physical distance and lack of direct presence. Often, pet owners miss signs of health and behavioral issues simply because they are just “not around” enough.

Given the above needs, researchers in the design and Human-Computer Interaction (HCI) communities have attempted to close this gap by exploring how “Internet of Things” (IoT) technologies can support remote care activities through monitoring and tracking the pet’s behavior and conditions. To support understanding the nature of
the pet, research has been conducted on how computer vision and machine learning technologies can support recognizing and categorizing the physical and emotional state of the pet. In rapidly growing pet industries, companies have released a plethora of products that allow pet owners to monitor and interact with their pet remotely. Despite the diversity in products, the gap in understanding when owners are not present persists. Furthermore, these products promote passive (and lazy) care and do not account for multiple dimensions of pet care. Finally, the majority of these products only offer fragmented data points and not fully connected as a service, thereby leaving the pet owner to make sense of individual dimensions of a pet’s health and behavior. 6

This thesis project explores opportunities for Internet of Things (IoT) technologies to close this gap in understanding for owners through more directly engaged, integrated and informed health care for pets across physical distance. To delve into this space, a number of in-depth interviews and survey with dog owners and experts were conducted to define the opportunity space for an IoT approach. Based on the opportunity space and key findings, various concepts were generated to validate the dog owner’s needs. The most prominent concept, an integrated concept of mobile platform was further prototyped and iterated based on the rounds of user testing. The qualitative findings on dog owners and their pain points have unfolded four main opportunities in which IoT takes an important role to enable engaged, integrated and informed care over distance:

1. Interpret and provide knowledge of critical moments in a pet’s development.
2. Remind owners of pet’s need and have information accessible to accomplish them.
3. Expand the care network across the multiple dimensions of pet care to include expert guidance.
4. Monitor and intervene at the right time with a compelling suggestion.

Based on identified design opportunities, the concept of SnapPet, a smart care system consisting of integrated tools in support of remote
care activities for their pets is proposed. The connected system of SnapPet empowers pet owners to make informed decisions through high fidelity monitoring and data collection, behavior pattern recognition, and insights and resources to positively impact on quality of pet's health care.
02 / RELATED WORK
COMMUNICATION TECHNOLOGY

Design and HCI research regarding animal(pet) - human interaction and technology developed for pet care recently received much attention. Research mainly concentrated on remote interaction and monitoring and tracking the welfare and activities of pet. Both strive to improve the quality of life of pets by constantly providing stimuli or to help interpret the nature of the pet. A master’s student from MIT, Resner explored a remote care system in his thesis that allow owners to toss treats or trains with clicker across physical distance. [FIG 1-2] Yonezawa et al. created sensing devices that can track the cat’s experience and activities and posts it to Twitter. Paasovaara et al. explored monitoring using an collar that is equipped with location tracking and audio sensing feature. Ladha et al. also explored the smart collar platform that monitors and records the dog’s behavior. [FIG 1-1] Mancini et al. proposed the smart kennel environments that allow owners to monitor, interact with information management. This thesis project aims to create a network of care by utilizing both two main concentrated area of studies- monitoring and tracking to support integrated and informed pet’s health care over physical distance.

[FIG 1-1] Ladha et al’s collar based sensor platform used for activity recognition.
PET CARE

This thesis project explores opportunities for IoT in pet care. Pet care has been defined in this project as: the provision of what is necessary for the health, welfare, maintenance, and protection of a domestic or tamed animal kept for companionship or pleasure. In the field of HCI, the pet care is defined as “healthy” and “fulfilling pet’s needs.” In order to meet basic needs, the owner’s attitudes and behavior is important when raising a pet. However, owners often experience difficulties, challenges and breakdowns that lead to problems in pet care. Research in the field of HCI explored ways to support pet care using technology and guidelines for designing pet care has been provided. The lack of consideration of pets such as ergonomic issues or aversive stimuli in such designs was raised as an issue. Foremost, the importance of not placing the owners was a recurring guideline.
ANIMAL BEHAVIOR RECOGNITION

Behavior indicators have been widely used to access animals welfare, especially for dogs. However, interpreting body language or biological parameters requires professional knowledge and handling. (e.g., Saliva, blood sampling, et.)

As computer vision and machine learning technology advances, taking a computational approach to recognize animal behavior has recently received much attention. The studies mainly developed a better way of detecting and classifying the animal’s body parts using pictures or videos or recognizing the pattern of behavior to predict the future action using automatic monitoring system.

Pistocchi et al. proposed a system that detect dog’s body parts using 3D sensors. Similarly, Bernard et al. prototyped a 3D system that detects and analyzes dog’s body parts and some behaviors. Ehsani et al. created a model that learns from video in dog’s perspective and makes a prediction of future movements. [FIG 1-5] The concept for SnapPet, the design project of this thesis, is based on current computational approaches, YOLO (You only look once), a real-time object recognition system and utilized its approach as technical validation of the final concept.

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[FIG 1-4] Barnard et al. body part detection results. The line colors correlates with different parts of the body.

Top [FIG 1-5] Ehsani et al. prediction result using 5 frames of video. (Green: ground truth; Blue:Prediction)

03 / DESIGN PROCESS
3-1. EXPLORATORY RESEARCH

SCOPING

During the initial research, the main research question was: How can a holistic approach to pet health, enabled by IoT technologies, empower pet owners to provide better care and quality of life for their pets?

With this question, I reviewed a range of journals, articles, and veterinary forums to understand the different types of pet ownership and the current state of pet care. From the United States Pet Population and Ownership Trends report 2017, I learned that dogs and cats comprise the largest proportion pets in the United States.

From numerous survey and articles on the pet ownership, pet care, especially dogs care, related to health is the largest challenge that requires time and knowledge, as well as considerable financial expense.

To delve deeper into design for pet care, I decided to focus mainly on supporting owners to care for their dog as a household pet and to build a model of pet care that can be expanded to other types of pets. Compared to other types of non-canine or non-feline pets like birds or fish, dogs exhibit a distinct, dynamic behavior which allows owners to elicit the intention and condition of their health in every scenario. Cats also have distinct behaviors, but the way they communicate their condition of health is less distinct than dogs. Moreover, dogs go through very dynamic periods of change compare to other pets, which requires close attention and wide scope of knowledge to provide appropriate care.

This narrowed project scope was helpful to conduct surveys and interviews with specific stakeholders during the exploratory research.
PRELIMINARY RESEARCH

As a starting point for the exploratory phase, the primary domains of pet care that are required for raising a dog were investigated to gain an overview of care. I reviewed a range of research articles from animal science and veterinarian communities on the fundamental domains of pet care. The Five Freedoms, a basic requirements for animal welfare from the Farm Animal Welfare Committee (FAWC) mainly informed the categorization I used for structuring the research. One of the important findings was that dogs go through very dynamic changes and have a different needs in care, especially during the puppy stage. In order to understand the dynamics of needs, the care intensity map was created [FIG 3-1]. Based on the findings, five types of care domains were clustered for to guide the next phase of the research:

- **EMOTIONAL CARE**
  Providing emotional support to avoid fear or distress and to express normal behavior

- **PHYSICAL CARE**
  Providing support for physical health and hygiene

- **NUTRITIONAL CARE**
  Providing healthy foods and fresh water to maintain full health

- **SAFETY CARE**
  Providing sufficient space and an appropriate environment

- **MEDICAL CARE**
  Providing prevention or rapid diagnosis and treatment

[FIG 3-1] Five types of care domains informed by the Farm Animal Welfare Committee

COMPETITIVE ANALYSIS

Pet care has rapidly grown into an $18 billion industry in the past decade. A competitive analysis was conducted to gauge the current state of pet products and services that support care activities based on the diversity of characteristic and popularity. Numerous products were investigated, and an affinity diagram was used to find an opportunity space [FIG 3-2]. In the affinity diagram below, passive care
refers to products that allow owners to provide static care such as just staring at the pet through pet cam or only affords set of activity data. Active care refers to products that allow owners to provide effective care such as fling a treat through a pet cam to train dog remotely or give feedback on the activity data and suggests ways to better care for their pets. The products are categorized, and the number of products is counted to find an under-explored area at the intersection of “active” and “remote” care.

From researching the product market, the key finding was that current products and services tend to offer passive care and do not account for multiple dimensions of a pet’s health profile [FIG 3-3]. For example, pet cameras like Sectec only allow owners to watch their pet remotely, which is reassuring for owners but does not provide direct care for their pets. [FIG 3-4] A two-way interactive camera like
Petchatz allows owners to interact with their pets using their voice or a type of video chat, but some research argues that interacting with their pets remotely using voice can confuse and distress pets [FIG 3-5].

Furthermore, the tracking devices often gives fragmented data points and are not fully connected as a service, which is burdensome for owners to make sense of the data and provide appropriate care. For example, an activity tracker such as Fitbark tracks and presents activity and sleep patterns, but it does not provide any insights from the data to provide appropriate care [FIG 3-6]. One can make assumptions from the data, but it requires same speculative and interpretation to respond with appropriate care.

![Competitive landscape shows how each of these popular products provides pet care based on the five types of care domains.](image)

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As Taylor et al. and Ladha et al. pointed out in the research, active care that is directly relevant to the dog’s state seems needed. Ladha et al. also specifically mentioned that little work had been done to provide “depth analysis of specific, assessment relevant behavior traits that go beyond monitoring the general physical activities of dogs.” They pointed out existing approaches are not applicable for looking at detailed evaluation and tracking of specific behaviors.

Overall, remote care has been a recent trend in pet care, which is evident in the range of commercial remote monitoring products for pets. Pet cams, such as Petcube or Furbo, can provide awareness to owners when they are not present at home and can entertain pets by tossing a treat [FIG 3-6]. Smart toys, such as PlayDate allow monitoring while playing, [FIG 3-8] and a dog walking service like Wag shares the care-taking role with owners [FIG 3-9].
The infinity digram, it revealed an opportunity area where remote care takes place [FIG 3-2]. Since it is an under-investigated area that requires a approach, it's clear that exploring the way to provide active care in a remote situation would make a meaningful contribution.

LITERATURE REVIEW
To establish an understanding of the dog-human relationship, a literature review was conducted in various fields, such as animal science, anthrozoology, and business.

One of the major findings in pet-human relationships is how humans consider pets as their friends or family even though they are not human. In his research, Belk claims that pets are extension of themselves. Compared to other animals, dogs are more intrinsically affectionate and more supportive, which leads to a greater feeling of attachment. Sometimes, dogs are even considered to be closer than other family members and rank higher in the social hierarchy of the family dynamic. Compared to other animals, Hart suggests that dogs provide displays more of affection, loyalty, devotion, and playfulness and engage in more interactions that involve body contact, which is important aspects for owners in terms of interacting and communicating with their dogs. Acknowledging the characteristics of dogs in a dog-human relationship is an important aspect to consider when designing specifically for dogs. This review established ground knowledge regarding pet-human relationship and further informed the survey questions that asked participants to describe their relationship with their dogs [FIG 3-9].

Additionally, a diverse range of academic research, from the fields of design, HCI, and computer science, that explores the technology for pet care was reviewed to gain meaningful insights. The literature review involved diverse related works, such as communication technology, animal welfare and behavior, animal-computer interaction, and ubiquitous computing.
FIELDWORK

The goal of the fieldwork was to understand and identify the specific pain points in pet ownership when providing various types of care, especially in a remote context. To learn from various stakeholders, surveys were conducted with thirty-four dog owners and in-depth interviews were conducted with five dog owners and five experts.

The main aim of the survey was to get qualitative responses directly from the pet owners. The questions cover current pet care experience, in particular focusing on pain points that they faced throughout the ownership journey [FIG 3-10]. The survey responders were recruited via email and social network, and follow-up interviews were conducted via video chat. Also, an expert interview with an animal scientist, a pet shop, and an animal shelter were conducted to learn more about the
challenges and breakdowns in pet ownership from an expert’s angle of the strategies to address these issues. Based on the fieldwork, a better understanding of the current state of pet care and pain points of dog owners was achieved. In addition, the journey map of dog owners [FIG 3-12] was created for comparison with the care intensity map [FIG 3-11].

SYNTHESIS
The understanding from the exploratory research phase has been synthesized by creating affinity diagrams and journey maps. The insights collected from each phase have turned into succinct findings, as follows.

KEY FINDINGS

(1) Owners face challenges in understanding their pet’s signal.

Dogs continuously have different care needs related to health during the critical periods throughout their lifetimes. During the puppy stage (approximately from week 7 to 1 year) shown in care intensity map [FIG 3-12], they exhibit very dynamic, rapidly changing behavior, and this is the period in which they need the most extensive care. An adopted dog often shows high anxiety from the moment they move in because of the adjustment period which owners need to provide

“There’s definitely a gap between us and them, but we must learn their way of expression.”
- P1, expert from pet shelter

“People misunderstand their pets more than pet understand them.”
- P3, expert in Animal science

“Owners have to read the warning signal.”
- p5, veterinarian

[FIG 3-11] Care intensity map of dog from the puppy stage and when they get adopted
various care like house training, provide treats and toys, let the dog initiate interaction and exercise patience for about six to eight weeks.

According to one interviewee, an expert in animal science, the breakdowns in care during this critical period can bring a lifelong stigma to dogs. Therefore, understanding and providing appropriate care during these stages is crucial. However, breakdowns in care often happen due to the gap in understanding between owners and their pets. The summary and interviews have revealed that owners experience difficulties in understanding a pet's various signals, because the pet has different needs and a different way of communication than humans. It gets even tougher in a remote situation because the physical distance creates a blind spot in pet care.

For example, one of the dog owners from the follow-up interview said she couldn't understand why her dog continued mounting even though he was neutered. Also, through her security camera, she learned that he was not mounting when she was not around. It turns out that mounting was not a sexual act or a sign of dominance but simply a behavior intended to grab her attention. Because she always grabbed him and put him next to her when he exhibited mounting behavior, he thought that mounting would bring her attention.

(2) Pet ownership requires remembering and maintaining the daily routine care for the lifetime of the animal.

Many people consider raising a pet to be similar to raising a baby. However, one of the experts pointed out the fact that a baby grows into a more autonomous child, while dogs need to be taken care of for their entire lifetime. As shown in the owner's journey map that synthesized findings from the survey [FIG 3-12], once you bring your dog into the house, they begin the period of adjustment. It is a tough process to properly help the dog adjust to the new environment, orient the, and routinize new behaviors. First time owners are especially likely to be overwhelmed by the responsibilities and amount of care due to the gaps in understanding due to not having cared for a dog before. As a
pet parent, they have to adjust their lifestyle and integrate their new role with their established work and life routines. Foremost, the findings from survey revealed that they were most challenged to maintain and remember the daily routine of care needed to keep their pet healthy.

(3) Owners lack qualified information with actionable steps they can take to better care for their pets.

Pet ownership requires a wide scope of knowledge to stay informed and to address multiple dimensions of a pet's health care. However, owners often experience difficulties in providing appropriate care due to the lack of knowledge on specific care activities and lack of qualified information on how to properly accomplish them. A competitive analysis also shows how current products are lack of providing active care in both remote and in-home care situation. [FIG 3-2] Owners often take actions based on their dog's reaction and body language, but a gap in understanding may still exist. Asking veterinarians are a proper way to get appropriate information, yet the cost is the huge barrier to do so. Another huge pitfall is that a lot of owners make misinformed steps in a first place because they tend to receive guidance from

*People continue to make misinformed choices at every stage of their pet ownership journey, and consequently pet welfare is being compromised*

- p4 veterinarian

*I thought I was well prepared...*

- P6 Dog owners

“They get information from Dr.google.”

- p5 veterinarian
unreliable sources, web searches and online forums but also from their friends or family members, who are not always reliable.

**(4) Taking steps early on minimize the potential breakdown in pet's health care.**

Cost of care is one of the challenges that dog owners are facing. Because pet care requires multiple dimensions of care, owners need to deal with physical care, such as food and grooming, and medical care, such as visiting the vet, which can be expensive. As a strategy, the vet suggests that the owner should read the signs of the pet's state of health and take steps as early as possible. In this way, both pet and owners can benefit by preventing the potential breakdowns before it advances to the point that medical treatment is necessary. This strategy also applies not only to health care but also to behavior issues such as biting or barking. Yet, it is important to notice that the signal can happen at any point. For instance, when a pet owner is absent, what they miss could be an energetic puppy chewing up the furniture or an ailing older dog in pain.

**SUMMARY**

Through exploratory research, a range of research methods were conducted to better understand the problem space and the needs of pet owners, focusing on dogs within a home environment. The initial research from the literature review and market analysis informed considerations when designing for dogs and identified the primary domains of pet care, which helped analyze how current products and services that provides pet care fall under each domain. As a result, remote care was identified as an opportunity space for making a meaningful contribution in the design of better pet care. The key findings from the fieldwork revealed the gap in understanding as a reason for pain points and breakdowns between owner and pet. The findings also clarified the importance of focusing on remote care, where the gap only gets wider and various challenges are amplified.
DESIGN OPPORTUNITIES
As a design direction, the findings revealed the role of an IoT (Internet of Things) approach in providing more directly engaged and integrated pet care across physical distance by creating a connected system of computational communication devices. This approach can support owners in providing more informed pet care over distance, thus closing a gap in understanding between owners and their pets. With this direction, four design opportunities were identified, in which IoT could support a connected care system for more integrated and empowered pet care:

1. Interpret and provide knowledge of critical moments in a pet’s development.
2. Remind owners of pet’s need and have information accessible to accomplish them.
3. Expand the care network across the multiple dimensions of pet care to include expert guidance.
4. Monitor and intervening at the right time with a compelling suggestion.

3-2. GENERATIVE RESEARCH
VALIDATION
The exploratory research phase revealed that a gap in understanding between owners and pets results in challenges and breakdowns in pet care, and the gap only gets wider when owners are not present. Remote care was identified as an opportunity space, which revealed the role of an IoT approach could provide more directly engaged and integrated pet care across physical distance by creating a connected system. To support this argument, I reviewed academic research from design and HCI for validation.

As Paldanius et al. validated, pet owners have a desire to "know about their pets' well being while they were away from home and wanted ways to comfort them remotely." They found owners are interested in monitoring the dog’s wellbeing the most. Neustaedter et al. explored
the potential of monitoring and interacting with their pet using video-mediated communication system and validated the needs by conducting a large amount of user survey. Most of the respondents valued remote interaction with their pet such as taking, watching or providing play or exercise.⁴⁵

Mancini et al. also claimed that "pervasive monitoring" is the best way to support the dog’s wellbeing. ⁴⁶

Also, a number of research products realized the gap in understanding between the pet and owners. Even though people consider pets as their friends and family members, many researchers stated that dogs are not a “furry human” but genetically different creatures that cannot communicate the same way as a human does. ⁴⁷ ⁴⁸ ⁴⁹ ⁵⁰ Kujala realized the gap in understanding dogs’ emotions, whereas Quinn et al. point out the dogs’ emotion are visible in the whole body, unlike humans. ⁵¹ For providing health care, Fontain et al. pointed out that owners are poorly informed about the health risks when they have a pet. ⁵²

Through the validation phase, the needs of remote care were identified through research mentioned above. In addition, many studies explored the IoT approach for pet care; in particular, monitoring dogs was a recurring approach.

[FIG 3-13] Neustaedter et al. used radio-frequency collars for tracking to test on participants in the study. They were asked to track their dog using a Garmin receiver.
IDEATION & ITERATION

Based on the identified design opportunities, early concepts were generated and refined through brainstorming and sketching with my advisor, who currently owns a dog. As a result, six concepts that support the needs of the dog owners and address the challenges were finalized. The concepts mainly explored the different challenges and breakdowns via a new approach that uses IoT technologies to provide integrated and informed care over physical distance.

In order to validate the concepts, a speed dating method with dog owners and an expert was conducted in person or through video chat. The goal of the speed dating was to elicit a reaction from them as well as where and when they value IoT technology. Each scenario was explained and followed by the sequences of the storyboards and some scenarios were described with persona. For remote cases, the series of storyboards were placed in an online presentation tool for participants at, and the questions and answers were completed via video chat.

3-3. EVALUATIVE RESEARCH

During the evaluation phase, the most prominent concept was developed from wireframe to hi-fidelity prototype based on the key scenarios. The final prototype was tested and iterated using the think-aloud protocol with ten dog owners. The user testing helped me figuring out the specific features that they value, as well as the types of scenarios in which they appreciate this technology the most.

![Concept sketches for remote care](image-url)
TECH VALIDATION

The final design proposes an integrated ecosystem that is still speculative, yet it is grounded in current computer vision and machine learning technology. I’ve validated YOLO, a real-time object recognition system that is based on a recurrent neural network (RNN). The goal was to gauge the level of the current state of detection as well as how the final design can be implemented in the near future. YOLO was also used during the live demo to demonstrate the real-time detection with a webcam, utilizing CUDA, a NVIDIA parallel computing platform and Open Source Computer Vision Library (OpenCV).
04 / FINAL PROTOTYPE

SnapPet: A smart care system for remote pet
4-1 CONCEPT OVERVIEW

SnapPet is a smart care system consisting of collective tools that help pet parents to holistically care for their pets when they are away from their home. It provides a new method of remote care through a network that connects a camera, smart socket, smart collar and a mobile application for integrated and informed pet care. The system aims to prevent potential challenges and breakdowns caused by a gap in understanding a pet due to the physical distance.
4-2. MAIN FEATURES

SnapPet has three main features that stem from identified design opportunities:

**MONITORING**
The system monitors the pet to detect and interpret behaviors and conditions, and then it predicts whether there is a need for urgent care. It aims to assist owners in assuring their pet’s well-being while they are away from home and provide ways to care for them remotely. The system intervenes at the right time to prevent potential challenges and breakdowns such as when there are signs of a developing condition or emergency situation, including heavy breathing or an unusual heartbeat.

**INFORMING**
The system provides holistic information by storing a snapshot of important events, activity data, and relevant information in a digital archive. It helps owners to better understand their pets by minimizing the blind spot while they are away and have access to expert guidance on unfamiliar care activities in order to ensure quality care.

**CONNECTING**
The system supports remote care activities by creating a network of care. The connected ecosystem allows owners to check their pets in real-time and provide appropriate care based on the pet’s condition. It is designed to deliver rich information to improve care-related decision making and to reduce anxiety for both owners and their pets.
4-3. SYSTEM MAP

MAIN COMPONENTS
SnapPet consists of a camera, smart collar, smart socket and a mobile application. In order to better explain how the ecosystem works, images of existing products (a camera, a collar, and a smart socket) were used to show how each component within the network senses, monitors, and interprets the data of a dog at home.

THE BASIC PREMISES OF THE ECOSYSTEM
SnapPet’s mobile application, smart collar, smart socket, and the camera connect via Wi-Fi and Bluetooth.

SnapPet recognizes the pet’s behavior and distinguishes whether there is a need for urgent care by leveraging computer vision and machine learning technology.
SnapPet learns from previous patterns of pet behavior and owner care coordination, including exercise history, personal schedule, and time they spend together to predict their needs in care.

SnapPet can connect the primary owner to veterinarians or a trusted person depending on the urgency of the situation.

SnapPet can store the data for three months, with exception of the early development stage of the pet, which requires close attention to the pet's behavior.

SnapPet has a cloud service that stores behavior in a data base. It also accesses the public database that provides reliable breed-specific information.

4-4. SYSTEM MECHANISM

The SnapPet ecosystem empowers owners to understand their dog's behavior through the following three steps: detect, Interpret, and Predict.

![Step-by-step diagram of SnapPet understanding dog's behavior.](image)

[FIG 4-4] A step by step diagram on how the SnapPet understands dogs behavior.
First, the camera detects the objects and actions to analyze the pet's behavior based on the behavior training model.

Based on the detection, SnapPet identifies the behavior along with the pet's age, breed, and health information. The activity data gets sensed in real-time from the collar, supporting the behavior identification. If the identified behavior needs attention, the system takes a snapshot of the scene and stores it as a live photo in the digital archive so that the owners can determine when, where, how, and why a behavior occurs. If the same behavior occurs overtime, SnapPet will only record the duration and frequency.

Once the behavior is identified whether it is teething or heavy breathing, then the system predicts whether there is a need of urgent care. When an emergency occurs, the system alerts the owner via a push notification and allows them to check on their pet in real-time and call for help if needed.

4-5. PERSONA AND KEY SCENARIO

Olivia recently moved to Pittsburgh right after completing her masters degree. She is a first-time pet owner who owns a three-month-old German shepherd named Jumbo. She lives alone and works from 9 to 5, so Jumbo has to stay home alone. She usually keeps him in the living room with food and water. She tries to come home right away to

Name: Olivia
Age: 27
Marital Status: Single
Occupation: UX designer in design agency
Pet: A three-month-old dog
walk him and spend time with him as much as possible, but still worries about him being left alone for a long time. Recently, Jumbo started to chew everything he sees and makes a mess while she is gone, and she does not know how to deal with it and is concerned about him being stressed out. She tries to see if there is any product or service that can monitor and relieves the anxiety of for her dog remotely and foremost, and help her to understand the behavior of her dog.

ON-BOARDING
Olivia bought SnapPet so she could care for Jumbo even she is away. First, she downloads the mobile application to activate the camera and collar. She plugs in the TV and the air conditioner using smart socket. She also downloads some music that is designed to soothe dogs. Lastly, she puts in detailed information about Jumbo, emergency contacts, her regular schedule, and syncs this with her calendar for reminders and updates.
LEAVING FOR WORK

Olivia always struggles when she has to leave Jumbo because he tends to get anxious and barks loudly. She plans to turn on his favorite TV channel or play a song to soothe Jumbo after she leaves via the mobile application. After she leaves home, she checks on Jumbo, using the camera connected to her mobile application, to see if he is doing well.

WHILE AT WORK - EMERGENCY

Olivia receives a notification that SnapPet detected heavy breathing. She quickly connects to the camera via the mobile application to see if he is okay. She understands that he is okay based on the key information provided on the screen, but she calls her sister to check on Jumbo until she can get home.
HIGH TEMPERATURE

During the hot summertime, Olivia receives a notification that Jumbo is feeling warm. She quickly goes to the mobile application and turns on the air conditioner for Jumbo. Once the care is on, the smart socket turns on and off automatically until the collar senses the right temperature for Jumbo.

AFTER WORK

When Olivia gets off work, she checks on her mobile application to see how Jumbo was doing today. She immediately gets a sense of how he is doing and what kinds of behaviors need attention and receives a summary of relevant information.

The live photos of Jumbo are organized in chronological order and tagged according to the behaviors. She can also sort the live photos by behaviors to get a better sense of specific behavior as well as any cues for behavior. Looking at the time stamp also helps her to understand how critical certain signs and behaviors are.
She clicks learn more to learn more about why Jumbo is tearing up everything he sees. It provides a summary of why he does what he does and specific steps she can implement right away when she gets home.

DESIGN DETAILS

CONSIDERATIONS

To design an integrated system, I chose to focus on a mobile experience to close the gap between owners and their pet. Due to its fast, portable and readily available capabilities, mobile usage exceeds that of the desktop—making it a natural choice for the ecosystem of SnapPet. Since SnapPet shows a live photo to delivers the summary of the behavior more live, the simplicity of the overall interface is crucial. The color palette was used to strategically inform the different...
status of the pets, such as bright pink for emergency attention and blue for the normal and natural behavior. To keep the focus on the image of the dogs, the information is scaffolded in a way to best delivers the current state of the pets. The overall tone of the design is friendly, but not too light, as to effectively provide critical information for users to better care for their pet.

MOBILE APPLICATION

HOME
As discussed in the key scenario, the main page provides highlights of the day. The key behaviors and tips or guidelines to appropriately handle that behaviors are presented upfront. The notification provides an overview of when the behavior occurs as well as issues that need to be considered. When an emergency occurs, the tone changes in order to alert the owners. As discussed in the key scenario, the main page provides highlights of the day. In terms of hierarchy, the connect button was one of the most important features, which is placed in the header. The dog character gets visualized based on breed to deliver more approachable feeling. The date function lets owners to keep track of the highlight behavior, as well as the key information. Key behaviors
that need an owner’s attention was designed in a carrousel style, in a way to more inform users without clicking. When an emergency occurs, the tone gets changed to alert the owners. The icon of the ambulance creates a strong visual cue. The information section at the bottom alerts users with the same color palette to further informs users with the condition. The notification gives an overview of when the behavior occurs as well as issues that need to be considered using a different color palette for different hierarchy of attention.

**HEALTH**

The health feature is designed to provide a dashboard of for the day’s activity data, gathered by the smart collar. Owners can see the current state based on the color (blue represents normal, while yellow is a call for attention) as well as the activity pattern at a glance. Detailed analysis has been created for owners to better understand each

![Dashboard view](left), today’s activity view (middle), Prediction for the current week (right)
category of health. In detail pages, owners can understand the quality of their pet’s activity with a dynamic color palette according to the level of the activity, along with the numerical quality of the activity to holistically understand the pet’s behavior. Owners can also view the activity data by date, and this information is especially valuable for the veterinarians. In the prediction page, the key aspect is where owners can get a sense of how much exercise needs to be done based on the standard activity rate. It also learns the owner’s behavior patterns and is aware of owner’s schedule from the external calendar in order to predict the future activity rate. The gray bars represent the predicted activity rate based on the owner and pet’s behavior and owners can get a sense of how well they are doing in order to keep the standard activity rate, which is represented as light grey line behinds the bars. The prediction page is valuable, especially because it provides feedback to owners on how well they are doing.
CARE

The care feature is one of the core parts of the ecosystem. When the camera and collar sense a high anxiety level or continuous bark, owner can provide appropriate care to relax or distract the pet's attention. The SnapPet ecosystem allows owners to engage in three research-driven care activities: turning on a dog-specific TV program, turning on music designed to soothe dogs, and controlling the air conditioner based on the room temperature.

Owners can also provide the care when they are remotely connected to camera to check on their pet. If the pet seems board or anxious, owners can provides the appropriate care in a second. The care also support owners to see if it helped dogs to be more relaxed and entertained by providing a live photo right after the care has been applied. It relieves owner’s stress, as well as their pets. Owners can also set a care plan ahead of time. When owners turn on one of the care, the color of the box changes accordingly. The color scheme gets shifted from the main color pallet to help owners to understand the meaning of the key color, blue and bright pink and what each color relates to: blue for normal whereas pink represents the attention and urgency.

![Care, TV, Song & AC]

[FIG 4-13] Default view (left), turning on tv (middle), playing a song and control the air conditioner (right)
ARCHIVES
The archives consist of live photos taken from the camera. The live photos are organized in chronological order and can be searched and sorted by keywords or dates. During the user testing, many owners expressed interest in saving cute moments separately from the behaviors. The saved section functions in a manner similar to the use of “favorites” in a photo application.

[FIG 4-14] Overall live photo collections view (left), sorting the photos by tags (middle), saved view which contains specific photo that owners have chosen (right)
CONNECTED VIEW

The camera allows owners to provide remote care activities while monitoring. The owner can check on their pet and provide care, such as turning on the TV, if needed.

When an emergency occurs, SnapPet informs the owner with the appropriate information and advice. The call button in the middle allows the owner to directly call a veterinarian or a trusted person for help.

[FIG 4-15] Default view when connected to camera (left), remote care view when connected to camera (right)

[FIG 4-16] Providing key information to inform owners during the emergency (left), emergency call view (right)
LIVE DEMO
During the final presentation, a live demo was set up for audiences to better understand how SnapPet works. [FIG 4-17] I used a photograph of a dog in on a tabloid size to simulate how the shape of the dog gets detected. It is important to prove how the current technology is viable and feasible to fully deliver the SnapPet’s ecosystem. YOLO, the real-time object recognition system, was used to set up a demo based on NVIDIA GTX 950. During the demo, the objects were detected in 9.5 fps with a 96% accuracy level in the live detection of the dog.
MULTIPLE DIMENSIONS OF PET CARE

While care needs differ from dog to dog (and are also influenced by environmental factors), every pet has basic care domains: emotional, physical, nutritional, safety and medical care. Each domain is interrelated and interconnected, so none can be ignored. In addition, the domains that support daily routines influence the latter in the long term [FIG 5-1].

Dogs especially go through very dynamic changes compared to other types of pets, so they require close attention and a diverse set of care activities. However, current products or services often support only a single dimension of pet care and are not connected each other as a service to address the entire spectrum of care needs. Therefore, it is crucial to create a holistic system that has the expansiveness to provide responsible and quality pet care.

PET-HUMAN RELATIONSHIP

Throughout the thesis project, it was evident that owners deeply care for their pets and consider them to be friends or family members. Companionship was shown to be an integral part of the pet-human relationship. Because “a tired dog is a happy dog,” as one of the dog owners said, spending time together and have a face-to-face interaction is an important aspect of pet care. During the evaluative phase, some concerns were raised about how such an advanced, connected system might further increase the time spent alone by pets.
However, it is important to recognize that people do want to spend as much time as possible with their pets and care for them, so considering how technology may best serve to support and deepen the emotional and social bonds between animals and humans is crucial. Furthermore, the technology should not replace the role of the owner but should deepen the relationship by opening the pet’s world to the human.56

LIMITATIONS AND FUTURE WORK
As discussed earlier, pet ownership requires multiple dimensions of care, which involves extensive activities. SnapPet proposes a spectrum of dimensions of care, but it remains limited to certain dimensions. Especially, emotional care is hard to address as well as to be measured, since there is a gap between humans and the pets. On the other hand, the investigation and exploration focused on dogs, and the owners, which considers the largest proportion of pets (in the United States) but does not represent all pets. Moreover, the fact that most of the feedback on dogs is gained via their owners needs to be taken into account. The physical aspects, such as activity level or food intake, are easily detected and observed, however emotional aspect related to mental states is extremely challenging to assess. Therefore, further research should investigate how to provide emotional care, considering multiple types of pets.

Also, the concept of SnapPet considers only a single dog in a single household, so a more extensive system would be required for multiple breeds of dogs (or pets) in a family context. As mentioned, the system functions holistically to acknowledge the multiple dimensions of pet care, so a diverse set of interactive tools can be connected to provide a wider scope of care. With a more extensive system, the detection aspect of SnapPet can be utilized beyond the home environment and expanded to shelters or zoos for more engaged and informed pet care.
This thesis project explored the opportunity for IoT technologies to provide more engaged, integrated, and informed pet care across a physical distance, thus closing the gaps in understanding between the owner and a pet. The key findings from the exploratory research were four design opportunities in which IoT could play an important role in empowering pet parents in their care-taking activities:

1. Interpret and provide knowledge of critical moments in a pet’s development.
2. Remind owners of pet’s need and have information accessible to accomplish them.
3. Expand the care network across the multiple dimensions of pet care to include expert guidance.
4. Monitor and intervening at the right time with a compelling suggestion.

Based on the identified design opportunities, the concept of SnapPet, a smart care system consisting of integrated tools in support of remote care activities for their pets, is proposed. The connected system of SnapPet empowers pet owners to make informed decisions in every stage of pet ownership through high fidelity monitoring and data collection, behavior pattern recognition, and insights and resources. This system can be applied to other types of pets that exhibit distinct behaviors such as birds, and it can be expanded to multi-animal contexts, such as shelters and zoos. The ecosystem of SnapPet can positively impact on quality of pet’s health care through engaged, integrated, and informed pet care across physical distance.
THE PRODUCTS UNDER EACH GROUPS:

REMOTE CARE THAT ARE PASSIVE:
Petnet: JEMPET, PetSafe, Arf, Feed and GoisYoung, Petdiary, Wopet, Westlink
Seatec: YI Home Camera, TOOGOE, Mi Home Security Cam, Takihoo, EZVIZ, Arkmiido, Zmodo, ANNKE, itTiot

REMOTE CARE THAT ARE ACTIVE:
Petcube: Pawbo, furbo, Petzi
WAG: Rover, Fetch!, DogVacay
PHYSICAL CARE THAT ARE PASSIVE:
Fitbark: whistle, Findster: duolink Poof, jawbone, nuband, wonder woof, petkit, Garmin, starwalk, Black+Decker pod tracker
iCalmDog: Pet acoustics

PHYSICAL CARE THAT ARE ACTIVE:
Playdate: GoBone, pebbly
Obe: Petnet, Petkit, Petkit-water fountain, Meal Tracker
Petrics: dog parker
iFetch: Play ball, PetSafe

APPENDIX 2
[FIG 3-14] Concept sketches for remote care (first one: an automatic delivery service for foods and toys during the critical periods. second top: RFID tracking for daily routines of care such as walking or feeding with mobile service to better manage the schedule in a family context; third top: Sharing the care activities with neighbors enabled by a system that is similar to Amazon lock, to let your neighbors come into your house and care for your pets. bottom: a connective system that let you play the song for your dog, and track where your dog has been and reacted to bark to turn on the music for relaxing their anxiety level.
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FIG 3-4: SECTEC: https://www.pinterest.co.uk/offsite/?token=847-606&url=https%3A%2F%2Fwww.pricearchive.org%2Falirexpress.com%2Fitem%2F3282656492&pin=644155552925980775&client_tracking_params=CwABAAAADDk2NDc1MDYxNTE3NgA~0
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Speaker: Xiaomi MIJIA Dome Home Camera WIFI Wireless 1080P HD Smart IP Camera 100.2° 360 Wide Angle Infrared Night Vision Webcam-White

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