The Intersection of Computer Science and the Animal World

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Introduction

Computer Science is a field of study with a very wide impact on the technological advancements in the world today. However, when one thinks of the term "Computer Science," animals are definitely not the first thing that pops into your head. One traditionally imagines an individual either designing programs, analyzing data, or doing web/mobile app development for a human centered company. This paper aims to focus on a largely underrepresented subject and user of Computer Science contributions, the animal, and how these contributions and principles of Computer Science can be used in a highly beneficial way for the animal world. First, I will explore the topic of Human Computer Interaction. Through examining Human Computer Interaction (HCI), I will be show that animals gain to benefit from Animal Computer Interaction (ACI) and how this has been accomplished so far, as well as limitations of ACI. Next, I will explain how using animal technology, veterinarians can better treat their animal patients and study diseases or illnesses, just as technology has done for human doctors. Next, I will describe how the domestic pet can be transformed through robotic technologies, as well as explain its impact on the human-pet bond but also the advantages of a robotic pet in certain environments.

Finally, I will introduce a unique contribution in the form of a suggested technology integrating already existing research and technologies. A lot of research and technologies in these fields relate or refer specifically to the canine species, as this is often a species studied due to their relationship with humans as pets and the fact that they can be easily trained. As humans, it is easy to overlook how our work can benefit another species, as we tend to think of ourselves before others. This paper aims to show that the animal world stands to benefit from the human world in the area of Computer Science and its related applications, as well as how the human world can benefit from applications designed for or from the animal world.

Human Computer Interaction (HCI)

Human computer interaction (HCI) is defined as “an interdisciplinary field that focuses on the study, design, implementation and evaluation of the interactions between human users and computer systems” (Ritvo and Allison, 2017). HCI encompasses the study of all communication between a human and a computer interface, including playing a game on your phone, using Facebook, or even wearing a Fitbit to track fitness levels. In the modern world, computer interfaces are essentially in most things we do or use, including everyday office work or even ordering food through an online menu. However, HCI is not only the literal interaction we have with interfaces, but also includes the study of the interaction and the design process of these interfaces and technologies that continues to improve them.

HCI focuses on user-centered design in order to make technologies like a phone game accessible, compelling, or beneficial for the user. As Ritvo and Allison explain, “HCI attempts to understand the way human users interact with computer technologies so as to design systems that fluently satisfy users’ needs.” As we interact with systems, HCI researchers seek to gain knowledge from our interactions and continually improve user interface design. HCI continues to build upon recorded and observed human computer interaction to continue to refine the interfaces through which the computer and the human interact. The field of HCI ensures that the design of HCI interfaces and technologies continue to put the user first.

HCI is important because of its ability to improve the user's life using user-centered design, as well as provide meaningful advances on matters like health, education, and safety. In the current pandemic, HCI interfaces have enabled people to avoid in-person interaction and thus reduce the spread of coronavirus through advancements such as telemedicine appointments, temperature scanning, virtual learning via a platform like Zoom or Microsoft Teams, and much more. Due to the fact that HCI researchers continue to improve on existing designs, one can expect these systems mentioned above to only continue to be improved on behalf of the user.

An example of an HCI interface that many may be familiar with is 3D printing. Many 3D printing interfaces currently use a digital editor to create designs. Mueller (2017) suggests that perhaps the use of interactive fabrication, where users could work with physical design pieces that are then uploaded to a program, would be more beneficial for the user in the design process. MixFab, a mixed-reality environment for personal fabrication, currently utilizes this approach, and has done so to try to make 3D printing more accessible and increase usability of the product design process (Weichel, 2014). Mueller's suggestion is a product of her HCI knowledge, where the user comes first in design. The study of the 3D printing interface and creation process has been able to provide users with advantages such an easier creation process and increasing the speed with which objects can be created and printed. HCI researchers continue to evaluate the design of 3D printing interfaces to try to enhance and better the user experience.

The principles of user-centered design and the study and improvement of the interaction between humans and computer interfaces that encompasses HCI are transferable to the interactions between animals and computer interfaces as well. The goals of HCI have therefore been used as a foundation to create another discipline that stems from HCI, which is animal computer interaction (ACI). ACI looks to gain similar beneficial impact on animals that HCI has had on humans.

Animal Computer Interaction (ACI)

The field of ACI is the prioritization of user-centered interface design and the study of interactions between animals and computer interfaces in order to continue to improve the design of interfaces to put the user first and focus on ethical treatment of animals. ACI and its associated technologies have the ability to provide both domesticized animals and captive animals a better quality of life and overall wellbeing, just like HCI does with humans. According to Ritvo and Allison, “ACI systems could be employed for environmental enrichment, entertainment, behavioural training, physical examination, veterinary procedures, therapy, cognitive testing, communication, protection and safety, husbandry, etc.” (Ritvo and Allison, 2017). ACI can also create an environment where humans and animals can form a special bond together.

One such example of ACI improving animals’ lives is explored in a preliminary study by Wallis et al. (2017) involving aging dogs. The study was designed to investigate the potential for dog computer interaction (DCI) to provide mental/cognitive stimulation that leads to a more positive attitude and overall greater wellbeing in aging dogs. The study proposes that cognitive enrichment through DCI can have positive effects on an older dog’s wellbeing, including slowing the aging process in dogs which can cause their mobility and mental cognition to reduce at a slower rate as well. Well-being is defined as, “not just the absence of pain or fear, but is predominately the presence of positive affects” (Wallis et al., 2017). The study aims to show that aged dogs using DCI for cognitive enrichment have an increased positive affect. Supporting this statement, Wallis et al. write that,

> Positive affect is difficult to measure in animals, [sic] however evidence from recent studies show that animals living in enriched environments can benefit from the creation of situations where there is the anticipation of positive rewards, by promoting play, and opportunities to collect information, such as in problem solving tasks, which results in positive physiological and behavioral reactions. When these positive emotional experiences are sustained or repeated, a global state of 'well-being' may ensue, which could help to improve health, and give the animal a better quality of life.

They note that other studies have proven that continued training in dogs can help preserve cognitive levels in dogs and that they believe cognitive enrichment through a touchscreen interface could do the same, as well as increasing the dog's well-being.

While dogs can gain positive affect from play periods, many humans reduce the amount of play they give to their older dogs or aren't as motivated to play with them. The touchscreen is a way to stimulate an older dog without requiring the dog to do too much physical exertion, which can be especially helpful for aging dogs already showing motor issues and eliminates the unpredictability of human initiated enrichment. The device proposed in this study is a computer monitor sitting behind a touchframe which can also either be hooked up to an automatic feeding device or have a trainer remote operate a feeder device with a remote, which provides the dogs positive reward for undergoing the cognitive enrichment. Positive reinforcement through a reward is something we all enjoy, like getting ice cream each time you win a soccer game or taking a nap after 5 hours of working, and dogs enjoy this too. That is how we train dogs to do commands like sit or lay down, through the reinforcement of treats.

The program on the touchscreen itself consists of generating two images paired next two each other, one whose touch would generate a positive reward and one whose touch generates no reward. In order to complete training, the dogs needed to correctly touch the positive image around twenty out of thirty times. It was observed that, "the positive association to the touchscreen is so strong that on several occasions when the dog was alone, and the feeder failed, the dogs continued to work to the touchscreen with no reward until the end of the session" (Wallis et al., 2017). It can be inferred from this that the dogs actually enjoyed the cognitive enrichment through DCI due to their continuation through the interface even without positive reinforcement.

In some ways, the older dogs who participated in this study developed a stronger bond with their human in that once their owner saw the results, they realized that their dog would enjoy more play time or other stimulation. Many older dogs have reduced relationships with their owner as their owner does not feel the need to spend time with their dog once they have aged and have less energy to do things like play or go on walks. Wallis et al. write that many of the owners hung up the certificates the dogs received upon completion of the training. By strengthening the owner dog bond, humans also stand to benefit from their dogs undergoing cognitive enrichment through DCI. Wallis et al. conclude however saying that more research needs to be done, "to determine the effects of long-term touchscreen use on dog personality, activity levels, and measures of well-being, as well as any influence on the dog-human bond," but that the proposed method seems promising and should be developed further.

An ACI design which has been quite interactive between both humans and animals is a mixed-reality game called Metazoa Ludens designed by Cheok et al. (2011) for humans and their hamsters. The game was designed to create more remote quality time between humans and their small pets due to the fact that people tend to leave pets home alone for a long time during the day. Cheok et al. describe the importance in the design that the hamster is allowed to choose when to play, thereby actually benefitting the hamster and not just the owner, by having a separate space not in their main cage where the game is played. The mixed-reality game involves a floor that the hamster stands on whose shape mimics the virtual gaming surface that the human user sees in the virtual environment, where a hamster avatar chases a bait that is controlled by the human user. The chosen bait is a tunnel, as hamsters love burrowing and do not chase their food (which rules out food as a bait), and the human user controls the bait in real life in the hamster's cage through a robotic arm holding the tunnel, but in their virtual environment they are controlling a human avatar (Cheok et al., 2011) whose movements dictate the movements of the robotic arm. The game allows not only allows interactive play between owner and hamster remotely, thus strengthening the relationship between owner and pet, but it also encourages healthy exercise for the hamster.

Extensive studies were done to evaluate whether the Metazoa Ludens ACI was actually beneficial to the hamster and also wanted by the hamster. Cheok et al. conducted these studies over the course of 6 and 4 weeks respectively to evaluate the results of these studies, thereby giving a significant amount of time to try to reduce any researcher bias based on outcomes. It is important to note that the cage which housed the Metazoa Ludens ACI was significantly large, which allowed for hamsters in the control group to get a significant amount of exercise if they wanted to as well. Cheok et al. found that both the hamsters who played the ACI and the control group had a healthier Body Condition Score (BCS), the animal version of a BMI, but that the BCS of the hamsters that were not in the control group was in a healthier range than those in the control group. To evaluate whether Metazoa Ludens was actually wanted by the hamster, Cheok et al. conducted a second 4-week study which allowed the hamsters the opportunity to play the game or leave the cage. The results were that the control group hamsters stayed in the cage at an increase of 30% from the first to last week, whereas the hamsters allowed to play the game stayed in the cage at an increase of 60% from the first to last week. These results indicated to the researchers that the ACI they developed is enjoyable for the animal user, not just the human user, thereby fulfilling one of the main goals of ACI development and design.

Challenges in the ACI Field

Although ACI has become a popular field of research and implementation, it does have some limitations and challenges. One of the challenges that ACI faces is that ACI technologies must be species specific designed in most cases, as animals have a wide range of varying intelligence and physiology. Usually, the technology chosen for ACI is a touch screen tablet or wearable device due to the simplicity offered by these devices. A touch screen is easy for an animal to learn to use because animals typically "engage with their environment through unmediated direct contact and manipulation", which means using a touch screen plays on their natural sense to use touch as a means of interaction (Ritvo and Allison, 2017). Though these two devices are usually the technology of preference, there are other biological, mental, and environmental factors that must be taken into consideration.

An essential factor is to the field of ACI is that ACI interfaces need to be designed to benefit the animal. Therefore, the specific species targeted by an ACI technology should be studied in depth by the designers in order to gain accurate insight into what the ACI needs to include/not-include or target. The ACI should incorporate the animal's already natural tendencies, actions, and preferences in order to make sure the ACI is actually benefiting and not unnecessarily confusing or encouraging unnatural behavior in the animal. For example, in the aging dog study, in order for the study to cater best to the dogs using their noses to touch the screen (their natural choice to touch unknown objects), "an infrared touchframe was chosen as the best option for use with dogs, since it allowed for a level of moisture, and saliva from the nose presses of dogs, whilst still functioning" (Wallis et al., 2017). Also used were movable doors on either side of the screen in order to keep the dog from becoming distracted while undergoing the cognitive enrichment and keeping the dog in the correct position to best interact with the touchscreen and to avoid what Wallis et al. describe as side bias.

Another challenge in ACI is that it is considerably harder to get feedback from an animal about whether a certain interface or device is beneficial as they cannot directly communicate this. One possible solution is to allow the animal the opportunity to choose to continue ACI after trying it out a few times. In the aging dog study, the dogs participated voluntarily and their increase in positive affect was "reflected in dogs' motivation to continue participating" (Wallis et al., 2017). Perhaps an even stronger example of choice is Lee et al.'s (2006) ACI testing, which is noted by Ritvo and Allison, where a chicken has the choice between two cages each day, where in one of which the chicken is given a wearable jacket that simulates being stroked through vibrations. If the chicken chose to go into the wearable jacket cage, then the conclusion was that the chicken did enjoy the wearable jacket ACI.

The problem with humans designing anything for animals is also part of the communication issue. Mancini et al. (2017) question whether "such technology can ever truly represent the animals' interests," as when we design for the animals, even using preference studies to determine overall enjoyment of an ACI, they tend to be for issues we as humans believe need to be solved in the animal world or for our combined entertainment in play time with animals. Mancini et al. (2017) also note that "it is hard to see how humans' interpretation of animals' interests would be free from biases deriving from humans' own world views and value systems, which are not necessarily shared with other animals." When evaluating animal user satisfaction and what would benefit animals, we tend to think first of what we would want should we be in the same position, but Mancini et al. (2017) are suggesting that this is not the way to approach the issue. They are suggesting, rather, that animals' interests are not necessarily aligned with our own, which is another thing we must try to consider when developing technologies for animal use.

We must try to see the experience and the world from animals' points of view, rather than conforming their needs to our point of view. This is why it is extremely important for the animal user to be involved in the design process and trials. And when evaluating the animal's satisfaction through methods like preference studies or measuring behavioral responses, extra caution needs to be taken to "reduce the arbitrariness of or biases in choices made by researchers during the design process" (Mancini et al., 2017). For example, Ritvo and Allison write that "inferring mental states from spontaneous animal behavior (e.g., facial expressions) is subject to confounding misinterpretation and anthropocentric bias." Researchers should not make quick assumptions based on what they believe to be animal enjoyment or well-being, but rather should make educated decisions based on long term observed data from all factors, like changes in behavior or mood after some specified period of time.

In this way, human bias can be greatly reduced, and researchers ensure an experience more centered towards the animals' wants and needs. Several trials may be needed to come to an ACI *for* the animal's welfare instead of for our own interests and some of the trials may go against some of the principles of ACI, but that is how we as humans learn and come to a better solution, through trial and error. The important thing is that from each new technology that comes out, we learn something to better the next wave of ACI technology, to better the lives of animals not just for our benefit, but for theirs as well.

Through the challenges faced in ACI and the solutions that have sprung up to answer these challenges, advances in HCI can also be made. An animal is considered an exceptional user, which is categorized as anyone with a disability, because they cannot perform in the same manner as an able-bodied human. In discussing the benefits of adaptation over redesign of computer interaction technologies for the exceptional user, it is noted that when a user such as an animal is observed in interacting with an interface, they can more easily get frustrated when systems aren't as efficient as possible, such as a lag between touching the screen and the response (Ritvo and Allison, 2017). In this way, Ritvo and Allison explain that, "These exceptional users can be employed to detect deficient interface design that able-bodied humans would tolerate." What this suggests is that if interface designers take the exceptional user into account when designing their interfaces (even if the interface is for the average human), their product can have significant increases in overall quality. For those who value the efficacy and efficiency of their products, the exceptional user becomes a highly valued user, no longer neglected in mainstream technology, whose interaction with the computer can be the most crucial. Thus, the animal world and research in ACI can therefore directly benefit the human world and human users.

Animal Technology

ACI is a subset within the larger category of animal technology. As defined by Mancini (2013), animal technology is "any technology intended for animals." Mancini (2013) also points out that the design of animal technology does not have always have "user-centered design principles" in mind like there is in ACI. The difference between ACI and animal technology is that ACI directly interacts with its user in some way, as highlighted above, whereas animal technology does not require interaction on behalf of the animal user. While animal technology is lacking in direct interaction, it can still provide great benefits for their users, including making sure they remain healthy. Veterinarians can use information provided by domestic and captive animals' technologic devices to monitor their health more easily and even try to catch illnesses earlier on.

A consumer-based animal technology for dogs, which is referenced by Wallis et al. in their study of aging dogs, is the FitBark, a health tracker for dogs with an option that includes a GPS tracker, much like the Fitbit or Apple watch for humans. The FitBark technology is based on a 3-axis accelerometer to measure the acceleration levels in your dog, which helps to track their daily activity ("FitBark 2 Dog Activity Monitor: FitBark Store US", FitBark). The FitBark can be linked to the owner's health tracking device like the Apple Watch or Fitbit. The device has an associated app that the owner downloads in order for the owner to be able to see updates about their dog's health and optionally their location as well. Owners can also set activity goals for their dogs based on their age, weight, and breed, helping the dogs to maintain a healthier lifestyle ("How It Works", FitBark). The FitBark not only helps to increase overall dog health with activity and sleep trackers which improves dog welfare, but with its connectivity to a human interface, FitBark makes it easy for humans to further their bond with their dog by keeping them updated and involved in their dog's daily activities.

A dog owner can choose to share their dog's health and sleep information with their local veterinarian so that the veterinarian can look for any sign of illness using either the sleep tracker or the mobility chart ("How It Works", FitBark). The website notes that through observing your dog's sleep score, it is possible to notice skin conditions developing. The company has a web dashboard designed for both veterinarians and animal researchers to keep track of groups of dogs and monitor their health progress. For researchers, the FitBark can be used as an objective activity monitor, helping them gain insight into their subjects' health through noninvasive analysis. ("FitBark Dog Activity Monitor for Research", FitBark). Through this analysis of the anonymous data sent from each dog's FitBark to researchers in collaboration with FitBark, FitBark has created graphs of health data, including sleep levels of different breeds, activity levels of male vs. female dogs, and much more which has can be viewed on the FitBark website ("Explore: Digital Map of Dog Health & Wellness", FitBark).

Another animal technology which uses motion as a health indicator is explored by Haladjian et. al. (2017) in their research on motion sensors to help detect early signs of lameness in dairy cows. They define lameness as "the clinical manifestation of painful disorders that result in an impaired movement or derivation from normal gait or posture. In dairy cattle, the main causes of lameness are lesions in the claws which cause bacterial infections and swelling" (Haladjian et al., 2017). Lameness affects nearly 72% of cows per dairy farm (Van Nuffel et al., 2015), which is why the solution presented by Haladjian et al. is imperative for the betterment of animal welfare. Helping to detect lameness early on can be crucial for the animal's health and pain and can even prolong their lives. Normally, lameness is detected by the herd farmers through visual inspection, but because of the increasing numbers of cattle being introduced into dairy farms to meet demand, this is a long and tedious process that requires a lot of time taken away from the farmers' other duties and is also prone to subjective opinion on behalf of the herdsmen or their tolerance of what they believe to be minor cases (Leach et al, 2010; Leach et al., 2013, Van Nuffel et al., 2015). With the help of automatic detection devices, farmers can help their cows with lameness issues while still being able to spend time helping to maintain and produce milk for the rest of the farm.

Haladjian et al. researched and found that the “first observable symptom of lameness is a change in a cow’s usual walking pattern (i.e., gait).” They therefore propose a system to detect gait anomalies using a motion senser worn on a cow’s left hind leg. Haladjian et al. write that, “assuming the cow is healthy and walks normally at the time the sensor is attached to it, our approach create a model of the usual walking pattern for each individual cow during the first minutes of use and detects deviations from that pattern later on.” The reason why Haladjian et al.’s approach is so valuable is that it creates a pattern from the cow’s own motion through its initial use instead of basing off what is to be expected through data obtained from other cows. By basing off of each individual cow’s gait, a more specialized approach can be taken for each cow and can greatly reduce the efficiency of detecting lameness in cows.

Haladjian et al. detail the steps taken for each cow to create an individualized automated anomaly tracker. It starts with a training phase, “which builds a model of the usual gait of a single cow,” using data preprocessing, step segmentation, feature extraction, and model training. During the data preprocessing, the acceleration measurements of movement laterally, vertically, and parallel to the cow are sent to a program which divides these measurements into windows (units), which Haladjian et al. chose to be 3000 samples (30 second intervals) noting that larger samples/intervals lead to better anomaly detection accuracy, in order to determine whether the window contains normal or abnormal measurements (Haladjian et al., 2017). During step segmentation, an algorithm is used to break down the window into the various steps estimated to have taken place during the window based on the peaks produced from the motion sensor data. During feature extraction, the peaks of each step are evaluated based on peak height and duration and statistical features are used to gain insight from the data to determine various features of the cow’s gait. During model training, a Support Vector Machine classifier “finds a boundary around observation of the *normal* class and classifies new observations based on their distance to this boundary. The classifier is trained automatically based on the gait of a cow acquired during the first minutes of use" (Haladjian et al., 2017). Using the boundary for normal gait, new gait observations are then classified within the context of the established normal boundary.

To test the efficacy of their proposal without causing harm to the test animals, Haladjian et al. conformed to the principles of ACI and made a user centered design. In order to simulate lameness to test the efficacy of their proposal without physically hurting the animals, a plastic block was attached in separate instances to each of the hind hooves for a very short period of time. This was to ensure that the cows' daily lives were not interrupted for too long and to prevent any harm to the cows through over-walking with the block and causing discomfort. Veterinarians were involved along the process to ensure that the simulation did not cause pain to the animals.

Haladjian et al. found that that the system they devised with the motion sensor and gait tracking information "classified gait instances with an average accuracy of 91.1% among all the cows… [and] when cows do indeed walk abnormally, our approach classifies 74.2% of their gait observations as abnormal." They also argue that because the block attached to the hoof does not actually cause the animal pain and causes a less severe change in gait, actual lameness detection accuracy could be even greater. Based on these results, the motion sensor-based gait tracker seems like a reasonable way to enhance dairy cows' welfare through early lameness detection. Dairy farmers can increase the automation of lameness detection using Haladjian et al.'s program, thereby increasing the likelihood and decreasing the time of lameness detection.

This motion sensor device and subsequent algorithmic calculations to classify gait as normal or abnormal proposed by Haladjian et al. could also be used by veterinarians to monitor cow health and detect whether the cow was experiencing any of the painful disorders that lead to lameness. Haladjian et al. write that, “veterinarians might decide to examine a cow if the number of detected *lame* gait observations has exceeded considerably for that particular cow.” Just like FitBark, the gait anomaly detector allows veterinarians access to a more technologically advanced healthcare system for animals, providing better animal welfare as a result. Also related is the indirect benefit to the owner of the animal. Through FitBark, owners can keep track and help their dogs maintain fitness, which can help strengthen the dog-owner bond and could even motivate the owner to be more active by helping their dog remain active. Through the gait anomaly detection system, dairy farmers can provide their cows with better healthcare, leading to greater milk production and benefit on their part, but also benefitting their cows in helping them receive better medical treatment.

While the overall category of animal technology is not the same as ACI technology, it is important that those developing technology for the use of animals, but not necessarily for interaction, should still abide by the principles of designing in ACI research. Anyone developing products for use of or for animals should be designing with the animal user’s needs and welfare in mind. The two examples brought above were presented because they do take these issues into account. The FitBark is designed to be compact enough so as not to hinder any of the dog’s usual activities and not weigh down the dog’s collar. The gait anomaly motion sensor for cows was designed through a process that put the animals’ needs first and researchers made sure to consult with veterinarians to ensure overall health throughout the design and trial process. Both products also focus on improving the health of the users of their products.

Robotic Animals

Somewhat related to animal technology is a category of technology that looks to learn from animal behavior and produce companions for those unable to have a living companion, i.e., the field of robotic animals used as pets or for animal assisted therapy (AAT). At the 2020 Consumer Electronics Show (CES), a convention that brings together the tech world, which was held remotely this year due to COVID-19, a review was written of new up and coming personal technologies, in which two robotic pets were featured among the list. Due to the rise of the development of robotic pets, it is important to consider how they are actually viewed in comparison to a live dog and in what situations they would be preferable for use. In those situations, we should determine how a robotic pet could benefit both those seeking companionship and animals who would be placed in bad home situations.

In order to discover how a robotic dog is treated compared to a living dog, Melson et al. (2009) gathered information from three different studies with a robotic dog developed by Sony called AIBO. What is interesting about AIBO is that it learns different behaviors based on its interactions, somewhat mimicking live dogs in this sense. Last year, Sony released a software update that "allows owners to create original movements and tricks for aibo" (Sony Group, 2019). According to Melson et al., "there is an increasing interest in examining AIBO's potential as a social companion and adjunct to therapy, especially for vulnerable populations." Some are not so ready to jump to robotic conclusions, and caution replacing live animals with robotic animals, as they argue the effects are not the same.

This is why it is important to note that many, including myself after conducting this research, only recommend the use of robotic animals as social companions in cases where a live animal is not suitable or not a possibility, like in the case of elderly people who simply are past the point of being able to care for a live animal but wish for company in their homes. This could also be the case for those suffering mental or physical health issues and cannot handle the responsibility of caring for a live animal. But in a regular home situation, I, along with Melson et al. and Preub and Friederike (2017), argue that living animals as pets should not be substituted with robotic animals, as the benefits of a live animal are significantly higher than a robotic animal. As a society, we should also be trying to nurture our bond with nature and introducing widespread robotics in place of natural beings would only be ruining our bond with nature.

In their research, Melson et al. question whether "robotic pets, compared to biological pets, provide children and adults with similar outcomes related to social companionship or improved quality of life?" They also wonder how the treatment of the "animal" differs between a live and robotic dog. To answer these questions, they reviewed three studies utilizing AIBO with all different age groups. They decided on a basis for their evaluation as whether people viewed AIBO as alive or incapable of being alive, having a mental state where it can make decisions and have thoughts, and whether it was social, i.e., "We may enjoy their company, feel less lonely in their presence, and be their friends" (Melson et al., 2009). Based on the answers to these questions, Melson et al. determine the impact of robotic animals both to humans and on the relationship between humans and animals.

Melson et al. found that younger children were more likely to believe AIBO was alive than older children, but surprisingly in a discussion forum for AIBO owners, almost half of them had written a post about AIBO being like a living being. Melson et al. note the possibility, "that when people interact with AIBO 'as if' it were alive, the nature of the interaction can go beyond mere metaphor, imagination, or pretence, evoking some feelings and judgements about AIBO's aliveness even while recognizing it as a technology." Even when older adults know AIBO is a technology, when acting towards AIBO in the imagination of it being a real dog, they begin to feel that AIBO is more “alive”. In accordance with their second and third question, Melson et al. found that “most participants viewed AIBO as having a mental life that included thoughts and feelings,” and also “endorsed AIBO as a social companion.” These answers provide insight onto the capabilities of a robotic dog to provide companionship.

While owners do not necessarily see AIBO as being fully alive in a biological sense, they do associate thoughts, behaviors and feelings of social companionship to AIBO. Melson et al. also sought to determine whether people felt AIBO had any moral standing, i.e., whether it should be treated in a moral way. The results to this question were harder to interpret, and Melson et al. discuss that there are many outside factors that can influence the results. Overall, the conclusion about moral standing was that more research needs to be conducted in this specific area of personified robotic technology.

The findings of Melson et al. suggests the ability of using a robotic animal as a social companion, but it is cautioned against fully integrating robotic animals into households that don’t require the sophistication of robotic technology. While AIBO was viewed as capable of being a social companion, children who were given the opportunity to compare a live dog against AIBO rated the live dog significantly higher, at almost 100%, in all areas of social companionship, while AIBO was only rated on an average at 80%. Melson et al. note that, “Children viewed the robotic dog as a much more restrictive interactive partner,” and showed five time more affection to a live dog than AIBO. Thus, a live dog is significantly more beneficial in terms of social companionship than AIBO and highly suggested over AIBO by Melson et al. in regular situations. In a situation where a live dog is not a possibility, AIBO could be a suitable replacement but would not match the capabilities of social companionship in a live dog.

Even though with greater technological advancements it is possible AIBO could get closer to matching the capabilities of a live dog, I would also caution on the use of AIBO when not necessary as the human-live animal bond is crucial for issues of animal welfare and treatment. Replacing nature with technology would only ruin the human relationship with the biological world and distance us more from our humanity. Through our relationship with other living things, we develop a greater sense of caring for others, especially those who cannot care for themselves, like plants and animals. If we replace living things with technology, the level of care for the natural world will decrease.

If we replace animals, who's to say human-human interaction won't be next? We, as humans, need live interaction, as many have found out this year due to the coronavirus pandemic. That is why I strongly agree with Melson et al. and Preub and Friederike in that we should only be replacing live animal interaction in cases where an animal's welfare may actually be in danger. If someone cannot properly care for a live animal, a robotic animal can be a suitable replacement, but should not be used in situations where a live animal could be properly cared for.

Based on the fact that live animals offer benefits that robotic animals cannot mimic, live animals are preferred in animal assisted therapy (AAT) for elderly adults if possible. Sometimes AAT with a live animal is not possible due to animal welfare concerns, animal aggression, or other limiting factors, which is when a robotic animal in AAT could be considered. Live AAT and robotic AAT have both shown positive affect in patients' lives. Preub and Friederike mention that robotic pets have been successfully implemented in nursing homes and hospitals and are a good option due to the different needs of patients in the home/hospital or the location's pet policy. Still, discussion with the patient and their family and evaluation of the specific patient's situation should occur to ensure the patient's needs are met.

An example of an appropriate use of robotic animals is the study conducted by Gustafsson et al. (2015). In the study, a robotic cat, JustoCat, was introduced into a dementia patient's life for AAT. Dementia patients can often have increased aggression and confusion, which can cause stress in live animals. This is why Gustafsson et al. explore the possibility of robotic AAT for dementia patients. The study was conducted with the aim to try to help "to improve the well-being" of the individual's life. The JustoCat is less advanced than the previously mentioned robotic dog AIBO in that it does not walk or have a programmable interface, rather it is designed to be a stationary "animal". The JustoCat is made to resemble a real cat in that it has fake fur and is the same size and weight as a real cat. One advanced feature of the JustoCat is that it responds to touch by purring.

The patients in the study were individually assessed to make sure that the study would be suitable for them. In order to avoid ethical issues about tricking patients, the cat was introduced specifically as a robotic cat and not a living animal to ensure the dignity of the patients. Caregivers helped the patient to initially adjust to the robotic cat and learn how to interact with it. According the to the caregivers, they felt the robotic cat opened up new channels of communication with the patients, and even led one patient to start speaking again. The robotic cat gave patients, caregivers, and family members a new shared topic of interest. Patients "expressed pride, joy, and mutual well-being in the pleasure of using it in their daily lives and care" (Gustafsson et al., 2015). The robotic cat generated "increased well-being, reduced loneliness, having something/someone to touch, and dedicated and tolerant love were expressed as benefits of using the robotic cat. Another import aspect was a sense of stability" (Gustafsson et al., 2015). Caregivers also noted that the robotic cat helped to soothe patients in times of anxiety. JustoCat even "stimulated participants to participate in other activities and increased their activity levels" (Gustafsson et al., 2015).

Overall, there was high positive affect in using the robotic cat in AAT. Brecher (2020) noticed a similar result in his case study using a robotic cat to treat terminal restlessness in a dementia patient. There were some concerns about over attachment and increased agitation among other things, which is why more research should be done in the field to see how the negative impacts can be reduced. Perhaps smaller AAT time periods could help with some of the issues. In general, Gustafsson et al.'s pilot study can be seen as a positive use of robotic animals in a situation where live animals could be at risk.

Robotic Animals for the Elderly

Following the caution of Melson et al. in replacing a live animal with a robotic one when not necessary, Preub and Friederike (2017) discuss the robotic pet in ambient assisted living for the elderly. Ambient assisted living is defined as the technologies in a person's home that make it possible for them to continue living independently and that also help prolong their life through inobtrusive measures. This can include smart home systems, medical sensors, fall detection, and more. Recently, more studies have been conducted on the use of robotic pets with elderly patients in the hospital suffering cognitive disabilities like dementia, and the results "demonstrates overall positive effects of pet robots on the older residents… especially in comparison with control groups without living animals" (Preub and Friederike, 2017). Just as Melson et al. pointed out, Preub and Friederike note that robotic animals could be used as a replacement for live animals with the elderly. However, Preub and Friederike argue that a live animal should be kept in the house as long as possible and that the ambient assisted living can even be designed to help the elderly's animal companions stay in the home longer as well.

Preub and Friederike point out the benefits of the elderly to have a social companion, especially that of a live animal. They write,

> "The human-animal relationship benefits especially the elderly, for example those with cognitive disabilities. It is reported that animals offer their elderly owners changes in daily routines; they are communication partners and in some cases better able to establish a relationship with an individual than other people. They frequently offer the only opportunity for bodily contact to a living creature. Social contact is facilitated through animals…Animals are a symbol of one's independence, they help keep a person active and give content to life. Domestic pets reduce fear, aggression, agitation, pain, and feelings of depression. They have an effect on the body's endogenous stress system, fostering relaxation and regeneration."

The benefits to a live animal companion, as noted by Melson et al., cannot directly compare to a robotic companion, who is viewed as lesser on the social interaction and affection scale. Preub and Friederike note, however, that in some cases of the elderly, having a living animal is not a good choice, either due to allergies, inability to maintain the pet's needs and mental health, or even the fact that the death of the animal would cause the owner extreme stress. Animal ethics concerns also include the impact of the owner's death on the animal's mental health, the ability of the elderly owner to provide sufficient physical care, and the owner's ability to notice medical issues.

Robotic animals, however, do not require the same level of care because they are not biologically alive, and are therefore looked at as a reasonable substitute for a live animal in the homes of the elderly who can no longer give the care needed to a live animal. Preub and Friederike express that robotic animals can help in similar ways to live animals, that "they reduce feelings of loneliness and stress reactions, improve quality of life, and extend and preserve abilities." Another aspect of robotic pets that is not present in live pets but can be beneficial towards elderly owners is the ability of a robotic animal to be repaired or replaced with a replica, with no worry of the pet dying. Robotic pets can also be health monitors for their owners, something a live animal can only achieve with extensive training, and can help ambient assisted living systems to assess the homeowner's health.

Even though robotic pets can be seen in theory as a good substitute for a live animal, Preub and Friederike argue that some see the relationship between the owner and the robotic pet as further disconnecting the elderly from the outside world or even "a deception that could appear questionable and affect the dignity of elderly people." Sometimes a living pet is the elderly owner's last contact with nature and living animals, and when it is replaced with a robotic animal, the owner is effectively severed from the natural world, a relationship I argued above in agreement with Melson et al. that is so crucial to protect. Preub and Friederike therefore argue that introducing a robotic pet into ambient assisted living as a replacement companion for live pets of the elderly must be assessed on a case-by-case basis of the person's needs, thoughts, and disabilities. They emphasize that a live pet should be the first course of action if possible and should remain in the home until the situation requires action on the animal's behalf and an assessment of a robotic pet could take place.

In order to prolong the amount of time that a live animal can remain in the care of elderly owners, Preub and Friederike argue that ambient assisted living technology should not focus only integrating robotic pets into their system, but rather include developing the ambient assisted living systems to integrate live animal companions. Preub and Friederike point out that the ambient assisted living systems "already have the equipment that makes feasible the upkeep of pets and their proper treatment. The AAL system could not only detect changes in human residents, but also in the animals or in their treatment." The animal's illnesses and treatment could be monitored and even reported to a family member or caretaker.

In this manner, the AAL system could elongate the amount of time a living animal can be kept in the home. Preub and Friederike point out that while “No 1000% safety for the animal can be guaranteed… it must be possible to introduce a check-up for behavior and health… Examples might include regular weight monitoring, recording food and water consumption, motion detectors directly on the animal (collars),” as well as motion sensors already present in the AAL system for the human that could be used for the animal. Using artificial intelligence, a full health and behavior evaluation of the animal’s condition could be assessed and given to a veterinarian who could help notice negative changes earlier on to prevent future harm to the animal. Whether appropriate changes can be made by both the elderly owner and the AAL system to help the animal continue to live in the home after non-optimal care is noticed on the animal’s assessment must be decided by both the owner and the family or caretake or the owner. Preub and Friederike argue that more ethical discussion is necessary on the topic of when the animal must leave the home, at what point we no longer allow sub-optimal treatment.

Proposed System

For my original contribution to the intersection of Computer Science and the animal world, I propose combining existing animal emotion recognition capabilities through artificial intelligence with home security systems in order to help monitor your pet’s mental health. In recent research by Franzoni et al. (2019), it was shown that it is possible for machine learning systems to recognize animals’ emotions in images. If a smart home security system could include machine learning capabilities, then it could use the images captured in its video feeds to determine the emotions of pet animals in the home. While Franzoni et al.’s research data set only included a subset of emotions, the system I propose would ideally include a large dataset of images with which to compare images taken from the home security system to. If possible, I would also propose the system to monitor the behavior of the animals in the home, though this would require a dataset of normal and abnormal behaviors and more advanced research to implement.

Using Franzoni et al.'s research as a foundation, the creation of a home security system with machine learning capabilities for dog emotion recognition seems possible. In line with Preub and Friederike's argument, the system could be combined with AAL for the elderly to help report on the conditions of animal(s) in their care. This would thereby help to prolong the animal's ability to be in the home by giving feedback to caretakers of family members about the treatment of the animal. The system could potentially qualify as an animal technology since it is intended for animals. In the same manner as the animal technologies I mentioned before could help improve the health of animals, this system could help veterinarians give better care and improve overall animal health as well. If a detailed health report was sent to the veterinarian each month based on the home emotion (and behavior) analyzations, a more accurate assessment could be made about the animal's mental health. It could even help the veterinarian notice signs of mental illness like depression or anxiety earlier on.

The system I propose could also be paired with a mobile and web application. The applications could provide the summarized mental health information in hourly, daily, monthly, or yearly form. The mobile application could send the owner or caregiver specialized notifications based on the current state of the animal. For example, if you had a pet dog named Spike and the system recognizes that he is happy, the owner could get a notification saying, "Spike is happy! Keep doing what you're doing." In order to not overload app users, they could set a preference to be notified on specific behaviors and how many times a day. The security aspect of the system, which is not my focus, could give updates based on movements inside certain rooms, outside the house, and about alarms being triggered. I believe that a system like this could be the next step towards bettering the animal world through Computer Science.

Conclusion

Computer Science is helping create beneficial change in the animal world. The field of ACI aims to improve on technologies that interact with animals by designing for and with the animal user. By taking a user-centered design approach, ACI ensures that the technologies being created benefit the animal's needs and health while accounting for their natural environment and tendencies. Certain animal technologies, including those I mentioned earlier and the one I propose, can help improve animal health by providing real time information. The crossing of technology and veterinary practice has made diagnosing illnesses and analyzing animal patient information much easier for the veterinary world. Robotic animals have made situations where there are issues of animal welfare easier to avoid. Though robotic animals don't come without their own set of ethical challenges, introducing a robotic pet into a necessary situation can alleviate the stress sometimes experienced from and by a live animal. The fields of ACI, animal technology, and robotic animals should continue to be developed and researched so as to continue enhancing the lives of animals. You may have considered the intersection of computer science and the animal world a non-existent or minimally important topic before, but together, Computer Science and the animal world have and continue to make significant change for the betterment of animals and their treatment.

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