Animal-Robot Interaction for Pet Caring

Jong-Hwan Kim, Seung-Hwan Choi, Duckhwan Kim, Joonwoo Kim and Minjoo Cho

Abstract— **Pet has been serving as an emotional companion to people. However, nowadays it is common that people are too busy to take care of their pet due to everyday work. This research is to see the possibility that robot can replace the role of taking care of pets on behalf of their owner and the conventional Human-Robot Interaction (HRI) can be extended to the interaction of robots and animals. In this paper, the concept of Animal-Robot Interaction (ARI) and its characteristics are presented along with basic experiments. The experiments are carried out with a cat and mobile robots. It clearly shows the possibility of implementation of ARI.**

I. INTRODUCTION

Human beings are social animal because human pursue their ordinary job with a stable relationship with colleagues in their life living in a society. However, the society has been urbanized with high growth of economy and it demands to change traditional family structure to nuclear family which seems to be more effective than large family. Therefore the number of nuclear family has increased and single life has become common in these days. Even if the change gives us material prosperity but it does not provide psychological comfort. Many people try various ways to get over their loneness in this modern society. Raising a pet is quite popular life style for the people who feel lonely. Nowadays, many people think their pet as a member of their family.

The business for the pet is founded on food or toy for the pet in the early days. Nowadays, there are various kinds of toys or tools for pet to play with such as chews, balls, squeaky toys, etc. In addition, many hospitals and clinic centers which specialize in pets are established and also there are various dental and health care products for them. Moreover caf?s are also created, where people can take their pet and share information about raising and training their pet. Of course, the cafe provides the pet with foods and toys to feel comfortable and enjoy its staying. The area of the business for the pet has been extended such that the market size of the pet business increases 6% rate in every year and Americans spend $41 billion a year on their pets in 2007 [1].

Although the number of pets has increased, most people have not enough time to take care of their pet all day long due to their daily life. The pet loses its peace of mind by isolation when the people go out and their pet is left alone. For example, the puppy which is the most popular pet has a strong sociality. Therefore, when it is left alone, it feels lonely and shows various separation anxiety syndromes such as barking, agitation, excretion, etc. [2]. This is a significant problem for the pet and also for the family because it has a possibility to make a trouble with neighbors [3][4].

There are already some products which care the pets to prevent the syndromes. One product is 'The litter bot,' which cleans the excretion for the cat using timer. The robot is made up of two cylinders and the cat can live in the cylinder. One of them is rotating in counter clockwise and cleans inside of the cylinder. Another product looks like microwave oven. User puts the cat in the robot and makes the robot clean the cat by spouting water. However, it does not consider pet's emotion. Therefore, pet is scared about the water and be nervous when it is working. These products just do predefined services and do not consider the feeling or emotion of pet at all. They can help users by doing some chores for the pet but cannot solve the fundamental problem for the pet.

This paper proposes the concept of animal-robot interaction (ARI). ARI starts with the idea that on behalf of human robot can provide a proper service to pet. It is based on the idea of human-robot interaction (HRI). HRI deals with relationship between human and robot, however, ARI between animal and robot. Even though ARI is motivated from HRI, the required properties of ARI are different from those of HRI. The robot based on ARI, called pet care robot (PCR), should have the function to interact with the animal. And also the interaction should be under the control of the user. For example, the creature, which has low intelligence, such as pet cannot do the role as user of robot. In HRI, human can request the robot to do a service such as cleaning the room. However, pet cannot request a service to the robot directly. They just bark or go back and forth disquietingly when they are hungry. Robot should figure out the pet is hungry from their behavior. Thus, designer should consider pet ethology when they design the robot. To show the possibility of implementing the proposed concept of ARI, real experiments carried out with a cat and mobile robots.

This paper is organized as follows: Section II proposes the definition of the ARI and its characteristics compared to HRI. Section III introduces the PCR based on the concept of the ARI and its functions are classified. Section IV describes the implementation of PCR and the realized functions. Section V verifies that interaction between animal and pet is possible by experiments. The concluding remarks follow in Section VI.

This work was supported (National Robotics Research Center for Robot Intelligence Technology, KAIST) by Ministry of Knowledge Economy under Human Resources Development Program for Convergence Robot Specialists.

Authors are with Department of Electrical Engineering, KAIST, Guseongdong, Yuseong-gu, Daejeon, 305-701, Republic of Korea {johkim, shchoi}@rit.kaist.ac.kr, {kimduckhwan, joonwoo, mins03}@kaist.ac.kr

II. CONCEPT OF ANIMAL ROBOT INTERACTION

ARI means the interaction between robot and animal without direct human intervention. Although there are robots which provide the service to the pet, they just do their works based on the order from the user not from the interaction with the pet. Therefore these robots do their service regardless of the current state of animal, which is not the real interaction. The interaction used in this research is not the just unilateral service from the robot to animal, but the bilateral one because it receives animal's feedback when it provides the service and it applies the feedback to its service later.

A. Characteristics of ARI

ARI is an extended idea of HRI which is based on the concept that robot is a sociable partner. As the robot takes a role as a sociable partner in human society, it should have easier and simpler user interface for HRI [5][6]. On the other hand, the robot for ARI should be able to perceive animal's behaviors and emotions from which it should be able to reason what the animal needs at that moment. Also it should be able to provide the feedback as a response to the animal. The development of ARI has the following characteristics [7][8][9][10][11]:

1. The developer should have a full knowledge of animal's behaviors and emotions to make robot understand animal's needs well for natural interaction with the animal.
2. The robot should know the state of animal and provide the service to animal by itself, as most of animals do not know how to request a service to robot.
3. The animal may have a fear of the robot because the robot is a noisy creature which has never been seen before. The shape and texture of robot need to be familiar with animal to reduce the fear.
4. The smell of the robot should be also considered because most of animals are sensitive to the smell.
5. The noise of the robot may astonish animal and it would be a great difficulty for the robot to be familiar with animal.
6. As the sudden movement of robot may also scare pet, robot behaviors should be well designed considering the animal ethology.

B. Cases of Providing Service in ARI

There are two cases when the robot serves the animal. One is 'user oriented service' which robot provides according to the commands from user's decision. The other is 'robot oriented service' which robot provides by figuring out the current state of pet and making a decision by itself. It will serve the pet with the proper service based on the cognitive intelligence.

For 'user oriented service,' user figures out the needs of the animal by himself/herself instead of the robot. The robot only provides the service following the user's command. As shown in Fig. 1, the robot just gets the order from the user. User perceives the state of animal and orders the robot to do service for the animal. The robot does not sense or monitor the pet by itself. After the robot provides the service, a user confirms the feedback from the animal about the service.

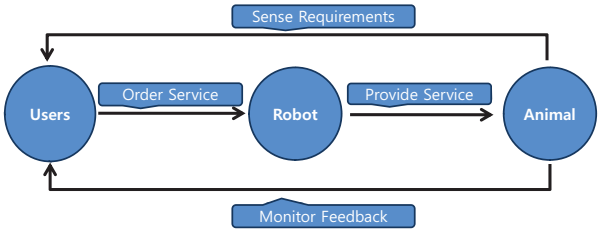


Fig. 1. User oriented service providing.

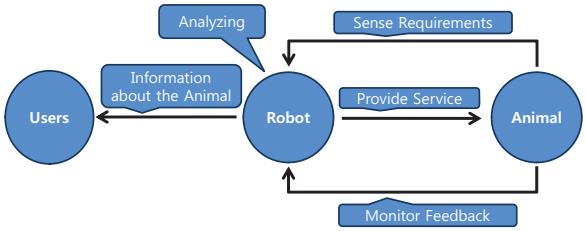


Fig. 2. Robot oriented service.

For example, when the user detects that the pet is hungry, user gives an order to robot to feed it. Analyzing the animal's needs is done by the user not the robot. The robot just follows the user's command.

For 'robot oriented service,' the robot monitors the animal and analyzes the need of the animal by itself. After analyzing animal's needs and requirements, it decides the service and serves the animal (Fig. 2). It monitors the feedback from the animal about the service. Also the robot can send the information about the animal to the user based on the monitoring. For example, when the animal is in a hungry state, the robot analyzes the animal's behaviors and decides to feed the animal. It provides the animal with the food and observes the animal's behaviors. The robot also checks the feedback about the service from the animal.

The robot should consider both the first case and the second one at the same time. When the order from the user and animal's request are in conflict, the robot should decide a priority and provide the service based on it.

Fig. 3 shows the overview of ARI. The interaction between user and robot is dealt with in HRI. The robot senses and monitors the animal's states. After analyzing its behavior, robot decides the service based on the states of the animal and the order from the user. The robot should monitor the feedback from the animal about the service.

III. PET CARE ROBOT(PCR)

In this section, basic functions of pet care robot are described considering ARI.

A. Commercial Product for Pet

There are several products to provide the service for the pet. These products only provide the service to the pet in the unilateral way which means they do not sense or monitor the state of pet. There are two major types of products. One of them cleans the pet instead of user. The problem is that the

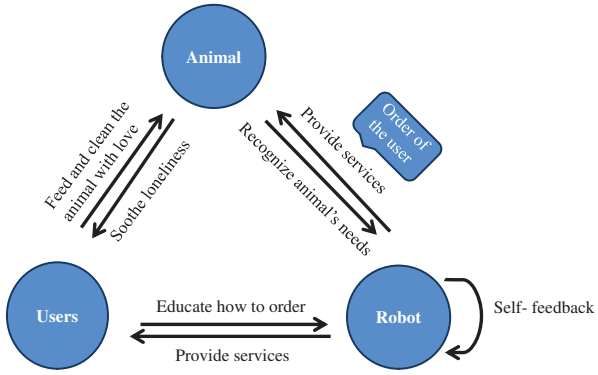


Fig. 3. The overview of animal robot interaction.

pet may be very anxious when it is inside the product. When the water is spouted, the pet inside bumps into and becomes very nervous. Although the product is efficient in cleaning the pet, it doesn't consider the emotion of the pet and it doesn't interact with animal at all. The other product is the house for the cat. It is composed of two cylinders which have the same axis and there is a weighting sensor inside of the cylinders. When the weighting sensor senses that the cat is not in the house, it cleans the inside by rotating the inner cylinder. Since the house of the cat is cleaned when it is not in the house, the product does not fear the cat. It only senses the animal's location with no interaction with the pet. These robotic products do not have the function to feedback to the response from the animal when they provide the service. This research focused on the interaction between robot and animal which has not been realized before.

B. Functions of PCR based on ARI

There are three functions of PCR based on ARI. 'Remote control' is the lowest level of the function and robot follows user's command to take care of the pet. 'Playing function' takes a role as a partner of the pet and interacts with the pet emotionally. 'Caring function' is the highest level of the function and the robot takes care of the pet by itself.

'Remote control' is for the function to carry out the user's command for 'user oriented service.' The robot is delegated by the user to take care of the pet under the user's monitor. The main role of the robot is to provide the pet with service instead of interaction with it. Most of robotic products are designed with this function. Therefore they just provide the services which are programmed by user regardless of animal's reaction. The examples are the products for feeding the pet and cleaning the house of the pet.

'Playing function' is for the function to provide 'robot oriented service' to pet. Robot can interact with pet autonomously and it can be a friend to the pet without user's intervention. In this function, robot is no longer a tool to help the pet owner but is one of the members in the family enough to play with the pet. It will be a friend of the pet and will be helpful for the pet to keep its health and to prevent the mental disorder.

'Caring function' is for the function that robot takes care of the pet left alone at home and it monitors the pet's reaction and provides the service based on the needs of the pet. Robot is to do some works for the pet during the absence of the owner. This function is mainly for providing 'robot oriented service' to the pet. It can be also designed for monitoring the pet and alarming to user about the pet's health according to the database about pet's medical information.

IV. DESIGN CONCEPT OF PCR

Conceptual design of PCR is presented in this section along with some characteristics of cat. To localize the cat and PCR a global vision system is employed in the design.

A. Functions of PCR

'User oriented service' is provided by following the user's order. 'Robot oriented service' is the one that robot provides the pet with a service based on the pet's needs and states which are monitored. The main target of the research is 'Robot oriented service.' This paper focuses on how to make the pet exercise more, as nowadays the pet living in the house may not be able to suffice the amount of exercise to be healthy. The pet has lots of curiosity about the moving object instinctively and a lot of toys for the pet have been designed using this characteristic. To use this characteristic, PCR should be developed to make the pet move around. To get cat's attention a laser pointer can be used. The laser pointer beam is safe enough because pets move continuously so the eyes are not exposed to the laser long time. Two servo motors control the pointing of the laser pointer beam. The scenario for exercising the cat with the laser pointer beam is described in the following:

i) Find the location of pet
ii) Turn on the laser pointer beam pointed around the pet
iii) Check if or not the pet notices laser pointer beam
iv) Move the laser pointer beam to lead the pet
v) Check if or not the pet traces the point of the laser pointer beam

B. Specification of PCR

The global vision system uses a UNIQ vision UC-685CL digital camera which further utilizes a PANTAX 6.5mm C-mount lens. The X-bot of Yujin Robotics Co., which is a robot platform for education, is used for body of PCR [12]. It has bumper sensors and infrared sensors to detect the barrier around. The communication module and the laser pointer controller are developed by using ATMEGA128. PC is used for the total system made up of these parts and data transfer among those parts is done by serial network. For the robot's mobility, some of serial network is replaced by Bluetooth network.

Fig. 4 shows the design concept of overall system for PCR. The global vision gets the image of X-bot and the cat. PC calculates their location from the image based on their own color. The implemented system uses the normalized RGB plane for image processing. The system is able to figure out each object based on its own color [13][14]. The patch which

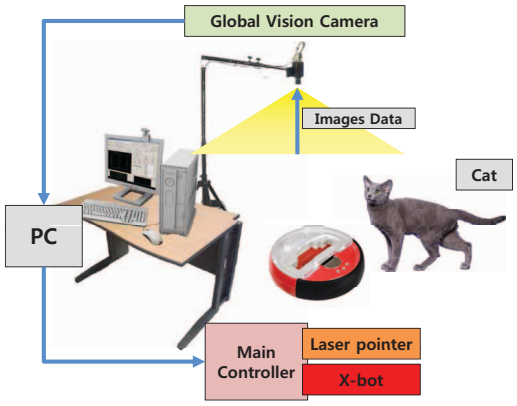
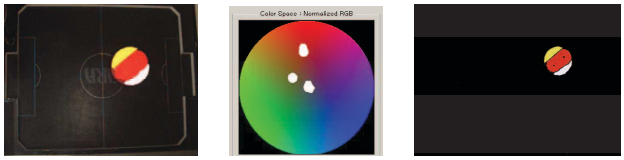


Fig. 4. Conceptual design of pet care robot system.



(a) (b) (c)

Fig. 5. Localization of the robot.

is designed with red, yellow and white color is used for the X-bot. The system is able to find the direction and position of the X-bot using the color patch. Color patch is not needed to locate the cat of which color is dark gray. The location of the cat is obtained in the same way as that of the X-bot.

The localization result of the robot is shown in Fig. 5. Fig. 5(a) shows the image of the X-bot on the floor. On top of the X-bot, there is a color patch composed of three colors: red, yellow and white. As Fig. 5(a) shows, each of the three colors is marked in the normalized RGB plane. The white circular areas denotes the three colors marked in the normalized RGB plane (Fig. 5(b)). With the marking of the colors in the plane, the X-bot can be detected by the camera. Fig. 5(c) shows the image of the detected X-bot. The moving direction of the X-bot can be also calculated using the different colors on the side of the patch on top of the X-bot.

Fig. 6 shows the localization result of the cat. Fig. 6(a) shows the image of the cat on the floor. In Fig. 6(b), the white circular area denotes the cat's color marked in the color space. Fig. 6(c) shows the image of the detected cat.

The commands for the robot and its laser pointer are generated by PC using their location information. The commands are sent to the main controller. The main controller controls both X-bot and servo motors for the movement of the laser pointer beam pointing. The laser pointer beam is used to engender the curiosity of cat. The cat shows great interest in the beam following and tries to catch it up, which naturally leads the cat to do exercise.

(a) (b) (c)

Fig. 6. Localization of the cat.

V. EXPERIMENT

Experiment was carried out with the cat, Russian Blue, which was a female with dark gray color and three month old. It did not have stripes or spots on the body. Initially, the experiment was tried in the lab. The cat was placed near the PCR and it showed anxiety and took a long time to be used to the experiment. Thus, to reduce the anxiety, the experiment was performed in the house in which the cat had lived. The cat seemed to be comfortable and showed curiosity and interest in the PCR.

A. Characteristics of Pets

PCR is to take care of a cat in this research because it is one of the most popular pets these days. The characteristics of cat are studied before developing PCR for real experiment. The important characteristics of cat are described for realizing PCR as follows:

1. The standard weight and height are checked according to the species and age of a cat. Weight and height can be used to check the fatness of the pet.

2. Cats can figure out the objects, such as robots, from 2-month-old. However, as they have a lot of wariness, they require long time to be familiar with the robot when they are more than 8 9-month old.

3. Cats use visual sense rather than auditory and tactile sense. Therefore cat has a lot of interest on the moving object.

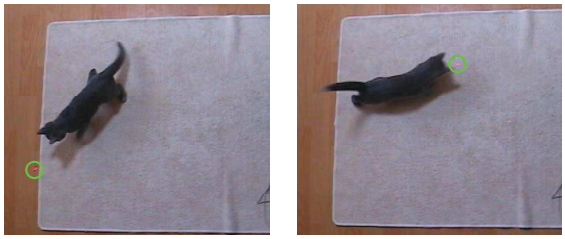
B. Experiment Result in the House

The cat showed totally different response to the robot in the house in which it had lived, compared to the result of the experiment in the lab. The cat looked like comfortable and showed some curiosity and interest to other objects. For that reason the followed experiments proceeded in the house.

1) Interaction with the laser pointer

When the robot started to control the laser pointer, the cat showed the interests on the movement of laser pointer because the sound was generated from the motors. However the cat showed more interests on the red mark of the laser pointer because the cat is more sensitive to sight compared to sound (Fig. 7). It did not consider other things once it had an interest in playing with the red point of the laser beam.

Repetitive experiments were carried out to check whether or not the cat lost the interest in the moving laser beam point. Each experiment tested three times with one hour interval and each time the robot controlled the laser pointer about two hours. The cat traced the red point of the laser



(a) (b)

Fig. 7. Interaction with the laser pointer. The green circle shows the position of the laser pointer.

(a) (b)

Fig. 8. Interaction with two types of robots.

beam all the time for the three experiments and it means that the cat was very much interested in the moving point of the laser beam controlled by PCR.

2) Interaction with two types of robots

The shape of robot is an important issue for pet caring because animals are usually afraid of big objects. For example, cat likes to play with the small objects such as balls. However, it is scared of the ball having the size bigger than itself. In the experiments, two types of robots were used to have an interaction with the pet. One is the X-bot which is bigger than the pet and the other is much smaller one which looks like a box. When the X-bot started to move, the cat observed it carefully. However the cat stepped back from the robot with fear when the robot came closer to the cat (Fig. 8(a)). In contrast, the cat approached to the box-type robot easily (Fig. 8(b)).

3) Interaction with the robot which has a feather

The laser pointer already showed its usefulness for the interaction with pet. However, this was an interaction between the cat and the system. Even if the robot controlled the laser pointer, the cat did not have any attention to the robot. Therefore, the features of robot should be changed to familiar shape such as a toy. Since a feather is the most popular toy for cats, it was easily attached on the robot. Fig. 9 showed the interaction between the robot with the feather and the cat. The cat showed interests to the robot with curiosity rather than fear. Moreover the cat sometimes began to have an interaction with the robot.

There are several conditions required for the natural interaction between the robot and the pet. First of all, the pet should be familiar with the environment. Second, a user needs to stay with the pet until it is used to the robot. Third, the shape and size of the robot should not be gigantic such

(a) (b)

Fig. 9. Interaction with the robot which has a feather.

that it would not scare the pet. Fourth, the robot should hold a device such as laser pointer to have proper interface and attract to the pet.

VI. CONCLUSION

This paper proposed a novel concept of ARI and design concept of PCR. ARI was to provide the service to the pet, which was implemented in two ways. One of them was to provide the service based on user's decision when the user figured out the needs of the pet. The other was to provide the service based on that robot's decision when it found the needs of the pet based on its cognitive logic. To figure out the needs of the pet, the robot should be able to monitor the animal's state directly and feedback from the animal about the service to realize ARI because animal cannot request service to robot by itself. The function of PCR based on the ARI could be classified in three levels; the lowest level was to support the user or pet owner to take care of the pet, the middle level is to play and interact with the pet as its friend, and the highest level is to care the pet by itself. The basic experiments showed that cat could interact with the robot by using a proper device such as a laser pointer. The shape of robot was spherical for safety and the cat liked it to play with. For monitoring the pet, other methods can be used such as infrared camera, microphone, indoor GPS, motion capture devices, etc. because most of the pet shows their request by barking, wagging the tail or specific behaviors using their body.

VII. ACKNOWLEDGMENTS

This work was supported (National Robotics Research Center for Robot Intelligence Technology, KAIST) by Ministry of Knowledge Economy under Human Resources Development Program for Convergence Robot Specialists.

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