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Emotional Robot for Intelligent System
- Artificial Emotional Creature Project -

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Abstract

Recent advances in robotics have been applied to automation in industrial manufacturing, with the primary purpose of optimizing practical systems in terms of such objective measures as accuracy, speed, and cost. This paper introduces the Artificial Emotional Creature project that seeks to explore a different direction that is not so rigidly dependent on such objective measures. The goal of this project is to explore a new area in robotics, with an emphasis on human-robot interaction. There is a large body of evidence that shows the importance of the interaction between humans and animals such as pets. We have been building a pet robot, as an implementation of an artificial emotional creature, with the subjective appearance of "behaviors" that are dependent on internal states, or "emotions," as well as external stimuli from both the physical environment and human beings. Human-robot interaction plays a large role, with mutual benefits. The pet robot has visual, audio, and tactile sensors. Olfactory sensors will also be available. The paper will describe an algorithm implementing a focus of attention through the integration of those sensors. In particular, simple sound localization will be developed by the robot through the integration of vision and audition, using the interaction of a human being with the robot as the training reference.

1. Introduction

When we think of machines, we design them as convenient tools and evaluate them in terms of objective measures, such as time, accuracy and energy. We may search for the best solution. This is a rational way and quite reasonable in engineering. We may be able to obtain the best solution in the static problem which include few uncertainties.

When we think of ourselves, we are not always able to find the best solutions of any problems because our society is dynamic and includes uncertainties. Nevertheless the human society is almost coordinated. Each person behaves intelligently while considering interaction with others and his environment in a subjective manner. How does he decide his behavior? What is the motivation of his behavior?

On the other hand, we would have attachment to objects if we used them for a long time. We may have stronger attachment to animals than static objects because of physical interaction. Therefore, interaction is important for human mind. In psychology, the emotions are put into two categories: the basic emotions and the sophisticated emotions. The former is innate emotion and the later is acquired one through learning with social interactions [1]. The machines do not have emotions so far. If the machines behaved the same thing repeatedly as "machine" while interacting with human, they would seem not to be intelligent though they could be convenient tools for us. Can machines be intelligent?

This paper introduces the Artificial Emotional Creature project to try to answer the questions while thinking of emotions. Human beings are not the machines. We have "mind" [2]. The emotions have been considered to be important. As a hypothesis in this project, the emotions play not only biasing roles in decision making but also a role for generating motivation of the behavior. Therefore, this project is building pet robots such as dogs and cats. If we interacted with the pet robots and they behave emotionally, they might stimulate our affection and we might have positive emotions such as happiness and love or negative emotions such as anger, sadness and fear. Then, we may have attachment to them while thinking of them as intelligent or stupid by our subjective measures.

The chapter 2 describes relationship between human and animals to explain important points of

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interaction. The chapter 3 describes some current research on human computer interaction. The chapter 4 describes the current status of the artificial emotional creature project. The chapter 5 describes auditory and visual sensory systems for human robot interaction. The chapter 6 concludes and describes perspectives.

2. Interaction between Human and Animals

In our project, we are building a pet robot as an artificial emotional creature. The robot will be personal robots for the human being like real pets such as dogs and cats. We are now trying to create the robots in an attempt to make a personal robot to realize a human-robot environment. Then, is it just a waste of time for us to conduct research on a pet robot?

Caring for pet is something we all experience when young or at least have touched an animal. In 1992, the United States' statistics calculated that at 58% of the entire American household had at least one or more pets [3]. The top is the cat population of 60 million, dogs with 52 million, birds with 12 million and horses came in forth at 5 million. A total of 130 million pets in all. In addition, 8% feed their fishes, 4% have ferrets, gerbils, rabbits, and reptiles such as snakes and lizards. The pet owners also spend billions of dollars on pet food, accessories, and veterinary care.

There is much research being conducted between the relationships between humans and animals. We can basically categorize them into two. One is to investigate the learning mechanisms of an animal through interaction with human beings. The other is how the human being is affected psychologically by an animal. A famous example of the former is Pavlov's conditional reflex. But research on the latter has just begun and feel that it is not widely known to the public. Thus, further insight on the latter will be discussed.

In 1972, Dr. Boris Levinson [4], a clinical psychologist wrote, "A pet can provide a boundless measure of love, adoration, and unqualified approval. Many elderly and lonely individuals have discovered that pets satisfy their needs and enable them to hold on to the world of reality, of care, of human toil and sacrifice, and of intense emotional relationship. Their self-concept as worthwhile individuals is restored and even enhanced when they find that the pet they have been caring for loves them in return."

At that time, people were either uninterested or laughed. But in 1975, Drs. Corson sent carefully selected dogs to a large nursing center in Ohio [5]. Here they studied how dogs could psychologically influence a patient. One example was a patient who had fallen from a tower and from this fall, was thought to have hearing and speech impairment. This patient had been in this center for 26 years without speaking a word but was so pleased by the sight of the dog, spoke "you brought that dog." Since then, he took loving care of the dog, spoke to the staff about the dog, and most of all, the dog had helped a patient, who had for many years, a speech impairment, recover from this disability.

From then on, many have come to approve that animals have great health benefits on the mental and physical aspects on human beings. And in 1979, a program called "The People-Pet Partnership Program (PPP)" was officially recognized at the Washington State University to mark a beginning on the research related to how animals can help human beings. In 1981, the International Conference on the Human-Companion Animal Bond in Philadelphia was held. In the same year, an organization intended for the studies and education of the relationship between man and animals called the Delta Society was formed. To date, many research results have been given and of them the following relationship can be said to be one of the most important:

Service Dogs

Dogs that are given special training to assist people who are blind and or with other disabilities [6]. These dogs provide services by guiding to people who are visually impaired, warn those with hearing disabilities, or pull wheel chairs. In Japan, the Mechanical Engineering Laboratory, Ministry of International Trade and Industry has created a service robot called "The MEL Dog" with this purpose in mind.

Animal and Senior Citizens

A companion for a elderly without any dependents, to find happiness in taking care of someone, or with a group of neighbors are some of the interactive effective opportunities that animals can provide [7]. A notable case was proven when California passed a state law allowing senior citizens to live-in with their pets at the state's public housing complex.

Health Benefits of Animals

An animal's positive psychological effects given to the human being has been widely reported. Daily stress can be relieved by owning a pet. Siegel discovered that out of 938 mentally healthy people, those who did not own a pet had a higher ratio of going to a physician, than those who did [8]. As previously mentioned, ever more aggressive Animal Assisted Therapy is being applied to

heal psychological problems [9]. When man pets their dog, or hugs them, the dog will respond by wagging its tail or lick the owner's hands and/or face. Through this physical interaction, the human being then feels not only happiness but also a senses that he/she is needed and self-respect. There are many cases where an AIDS patient have been given mental comfort by the presence of a pet [10].

Animals and Children

They are many psychological effects that a man can receive by interacting with animals [11, 12]. The following six areas are most often debated between the relationship between pets and human beings, especially that concerning children:

1) Love, attachment and comfort
2) sensor-motor and nonverbal learning.
3) responsibility, nurturing and sense of competence
4) learning about life, death and grief
5) therapeutic benefits to psychological and physical health
6) nurturing humanness, ecological awareness and ethical responsibility

The above interactions show that they are indispensable for the growth process of children.

What we have listed so far are just a few of the relationship between human and animals and not to forget there are more merits not mentioned here. When a human being talks to an animal, pets, or cuddles it not only does he/she cares for the animal but in return, the animal provides the human being with peacefulness, happiness or enjoyment and even sadness through this interactive process. In other words, through this interaction it enriches the psychological aspects.

Is owning a pet a total merit?

Here, we will discuss some of the demerits such as allergies, bite, and infections [3]. Approximately 1.5% of the (American) population are allergic to some sort. Of them 25% are sensitive to cats and dogs. Much needs to be yet improved on hygienic care and this is one of the reasons why pet-lovers can not afford to have one around. With the case of animal bites, approximately 1% of patients with medical emergency are related to animal bites and of them 80% are minor injuries but all carry the danger of infections such are rabies. Special attention must be paid to animals that are around AIDS patients.

3. Interaction between Human and Computer

A room called the Human Computer Interaction (HCI) Room is now the subject of research at MIT Artificial Intelligence Laboratory. A method that can automatically execute the user's demand is being sought inside this room by placing attaching several sensors throughout the room. Such room should function quite well as a conference room (when unwanted interruptions should be avoided). In reality, televised meetings are already being used. The style of future meetings (that are held at two or more different sites) will gradually slide into a phase where one can actually observe the behavior and feelings of others by not having to be dependent on audio-oriented tele-communication information because visual perceptible information will become available. If the phone lines are vast capacity enabled lines such as the B-ISDN, communication can be sent to each other by adding excessive information through the computer.

Televised meetings may help cut down on travel expenses, time, and have great access to unlimited visual information. There is still a gap hole. That is, a matter of whether or not you have understood the intra-personal aspects of others can make a big difference. So, actually attending a meeting and having one over a visual screen may not have the same results. Moreover, even if a room is equipped with sensors, which is indispensable to catch human behavior, people inside this room will more or less be attacked by the 'Big-brother-is-watching-you' effect– an uneasy feeling and deprived freedom that one gets when under constant watch by someone or something.

Televised meetings only connect simulated space visually and not to be mistaken as heart-to-heart connection. In addition, to have an intelligent room or space, an object that appeals to the user's taste must be available. Especially, this is an important factor if this is intended for daily use. Then what must be done? This is the most difficult and vital theme for this research. What is the most important factor for a pet robot that appeals to the tastes of the human beings? The way to attract people is to create a robot or machine that seems to have a heart and a temperament.

Artificial pets have been studied. At MIT's Media Laboratory their ALive Project concerns interaction between the gestures from human beings and pets in Cyber Space are conducted by using computer graphics [13]. But when the information is processed and fed back to the user (human being), it is merely visual information. The gesture patterns are given in advance; the pets are given the emotional models before hand and only the

programmed behaviors will appear. Already on the market is a software that displays an aquarium of tropical fishes but these does not have physical interaction with human. In other words, current artificial creature available inside the computer is incapable of physical human interaction. Thus, does not give the user a feeling of owning a pet because the pet responds indirectly.

In the artificial emotional creature project, we also handle cyber space pets but in order to study the human and pet interaction within the real world, the study focuses on a physical robot. What is a physical robot?

When we consider how human beings and robots can coexist, one direction would be to focus on robots that support human beings as one of the tools and the other would be exactly visa-versa. In such case, robots have advanced to a point where it can be categorized as an equal; a biologically live creature that is very much the same as us, human beings. Needless to say, industrial robots require enormous task planning procedures thus require a lot attention. In recent years the criterion of the effectiveness of a robot has been measured objectively by how fast and how meticulous a robot performed a given task. Industrial robots may require such evaluation methods, but when a robot is intended for a more daily application to suit the needs of most people, such objective evaluation method may not be necessary. Parents say that the more the child requires attention, the more the parents feel attached to the child.

Therefore, the artificial creature with emotions is not evaluated by the objective evaluation. In other words, the robot is not intended as a tool. In this sense, a robot with life-like characteristics can be created. Through interaction between human beings and/or the environment, the robot tries to behave in a way that is best for survival and decides the best behavioral evaluation that will enable the robot to behave through this acquired process.

4. Building Artificial Emotional Creature for Intelligent System

Brooks had studied an insect-type robot with a bottom up system; that can generate behaviors through interaction with the environment instead from a prior given pattern that is usually implanted inside the robo [14]t. His groupe is now trying to express a bottom-up pattern for the intellectual behavior of human beings through the COG humanoid robot project [15].

The artificial emotional creature does not aim simple reflex-related behavior such as the insect robot nor are we interested in the multi-functional capabilities like human joints. We use a sensor system that works as perceptions; visual, auditory, and tactile sensors. For mobility and simple gestures, the robot has several actuators. We are striving to create a robot that will adapt to the environment through human-robot and robot to robot interaction learning through experience. Such robots, when observed, may seem to express emotion. Such behavioral evaluation will be only be subjective, and evaluated by the individual it interacts with. As mentioned, in order for robots to survive, the robot itself abides to a learning pattern it makes through interactive method by creating an evaluation of its own. The emotional structures, often discussed in psychology, is not implanted before hand as a top-down model in a form of a specific function. The robot's behavior is based only from the values the robot has been able to define on its own.

5. Human-Robot Interaction Based Training of Sound Localization

A typical engineering solution to a particular problem is to analyze the problem, construct a model (often simplifying the situation), and implement a fixed system to produce the desired result within a pre-defined specification. Some disadvantages of such a rigid and static approach in real-world situations is the lack of adaptability to changing stimuli and the difficulty in scaling or extending the solution to slightly different problems. Biological systems, and the artificial ones that are inspired by them, seek to address such shortcomings by adding a learning component, with the environment itself often used as a training reference to improve performance.

Artificial creatures such as the pet robot described in this paper will at first have only crude sensor-motor primitives with poor performance; with human-robot interaction the creature may learn to improve its performance and combine primitives to form more complex perceptual tasks. A simple example of interaction-based improvement of a perceptual task is described below.

Sound localization is the auditory perceptual task that deals with identifying the location of a sound source, usually based solely on auditory cues. This task is naturally very useful in animals, in tracking prey or determining the location of predators. Audition provides a complementary source of information to a creature, with respect to vision.

There is, however, a very strong interaction between the two modalities; there is biological evidence

that vision plays a major role in the development of sound localization in animals as well has human infants, and it is this biological basis that provides the inspiration of much of the following [16]. For example, investigations with owls have determined that owls that have had one ear occluded since infancy could not, after reaching maturity and having the ear plugs removed, correct their auditory localization errors without visual input. With the plugs removed and vision fully restores, the owls could relearn how to localize sounds correctly. If, however, vision was restored but subjected to a constant error using prisms, the owls would adjust their localization such that localization errors match the induced visual error. Vision therefore provides the spatial reference for fine-tuning auditory localization [17].

There are two acoustic cues used generally to determine the location of sounds; interaural time differences (ITDs) and interaural intensity differences (IIDs). Sound localization in a realistic sound environment is not a static task that can be completely solved with a fixed solution. The effects of reflections and nonlinearities in the room acoustics must be taken into consideration, and often not all of the cues are valid simultaneously.

We have implemented a neural network that learns how to integrate the various cues to produce correct localization on the horizontal plane, using visual cues, such as the motion of a person clapping his or her hands, as a teacher, or training reference. The assumption being made here is that visual motion is often associated with sound production, and visual localization is used to train the auditory localization map. This is consistent with the results of biological experiments such as those described above. A block diagram of the system is given in Figure 1.

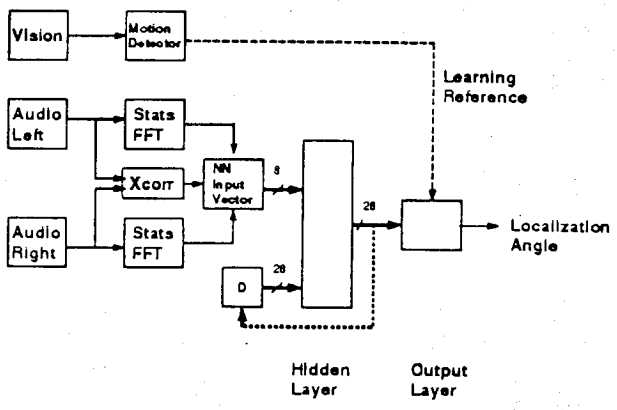

Figure 1: Human-Robot Interaction Based Training of Sound Localization

Very simple audio signal processing primitives are hard coded to extract IID and ITD cues from the two audio streams. Another primitive extracts motion information and visually locates the azimuth (ie. on the horizontal plane) of the assumed sound source. The recurrent neural network is trained using a modified backpropagation algorithm, with the visual information used to generate an error signal. Once training has taken place, visual input is not necessary to perform sound localization.

At present, the localization angle that is the output of this system is still only a rough approximation of the actual location of the sound source. However, we have shown that it is at least feasible to train a robot to perform a difficult task by using the interaction of human beings with the robot.

Other tasks, such as multiple audio stream segmentation, are currently being explored using this method.

6. Conclusions

This paper introduced the artificial emotional creature project. The paper described the purposes, back ground, and current status of the project. A pet robot has been built which has vision, auditory, and tactile sensors. The project will investigate psychological effect to human through human-robot interaction.

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