Bio-Inspired Therapeutic Pet Robots: Review and Future Direction

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***Abstract*—This paper presents an extensive review of "bio-inspired therapeutic pet robots", an emerging class of social robots deployed for therapeutic scenarios with a wide range of human stakeholders from elderly to autistic children. We begin by covering prominent literature that studies the roles and benefits of biological pets in therapeutic situations. We then present an overview on biologically inspired therapeutic pet robots. Finally, we discuss the needs and future potential for a parrot inspired robot and related research challenges.**

Keywords-Bio-inspired robots; autism therapy; parrot therapy; therapeutic pet robots; parrot-inspired robot

I. INTRODUCTION

Growing popularity and increasing viable application domains has contributed to greater presence of robots in the commercial marketplace especially in industrial and service space. Robots are now dominating the manufacturing industry, performing repetitive manual tasks that are hazardous to humans. A new class of service robots are also gaining wide spread popularity that are designed to tackle a radically different kind of tasks such as interacting and entertaining humans, performing daily chores including healthcare in a home environment [1]. Recent studies show that robotic systems can be of great help in treating patients who suffered from long-term illness where therapy oversight, coach and mental motivation can be provided with minimal or no human intervention [2] [3]. Especially, robots that mimic biological pets are gaining pervasive research attention over the last decade due to their ability to bring the benefits of real pets while overcoming negative issues related to allergy, safety, manpower resources and maintenance. Numerous research works has been undertaken that studies diverse aspects of the development and deployment issues associated with these bio-inspired therapeutic pet robots. This paper is dedicated to the review of this particular class of robots that inspired from bio-inspired pets and deployed for therapeutic applications. This paper is organized as follows: In Section 2, we present significant research work from literature that presents the benefits of animal pet assisted therapies across a range of pets from dogs to cats. In Section 3, we share our findings from robotics related literature that covers development, deployment and human robot interaction related research issues centered at bio-inspired therapeutic pet robots. We then discuss the future potential for a parrot inspired therapeutic pet robot and associated research challenges in Section 4. In Section 5, we present concluding remarks and future work.

II. ANIMAL PETS ASSISTED THERAPY – A REVIEW

Robots inspired by everyday pets are gaining significant attention due to their proven merits reported in medical literature. Interaction with animals has long been known to be emotionally beneficial to people. Aubrey in [4] details the benefits of incorporating animal assisted therapy into their practice, how to design and implement animal assisted interventions, and the efficacy of animal assisted therapy with different disorders and patient populations. Marcus et al in [5] evaluates the effects of therapy dog visits to an outpatient pain management facility compared with time spent in a waiting room. Participants were able to spend clinic waiting time with a certified therapy dog. When the therapy dog was not available, individuals remained in the waiting area. Therapy dog visits in an outpatient setting is able to provide significant reduction in pain and emotional distress for chronic pain patients. They can also significantly improve emotional distress and feelings of well-being in family and friends accompanying patients to appointments and clinic staff. Zilcha-Mano, Mikulincer, and Shaver [6] propose a model of Animal-Assisted Therapy (AAT) based on attachment theory and on the unique characteristics of human–pet relationships. The model includes clients' unmet attachment needs, individual differences in attachment insecurity, coping, and responsiveness to therapy. It also suggests ways to foster the development of more adaptive patterns of attachment and healthier modes of relating to others.

Nurenberg et al in [7] conducted a controlled random study where equine and canine forms of AAT were compared with standard treatments for hospitalized psychiatric patients to determine AAT effects on violent behavior and related measures. The study included 90 patients with recent in-hospital violent behavior or highly regressed behavior. Results indicated that AAT is an effective therapeutic modality for long-term psychiatric patients at risk of violence. Pedersen, Ihlebaek, and Kirkevold in [8] presents a study to obtain participants' own experience of a farm animal-assisted intervention, and what they perceived as important elements in relation to their mental health. A qualitative study, inspired by a phenomenological-hermeneutical perspective was conducted. Eight persons with clinical depression who had completed a 12-week farm animal-assisted intervention at a dairy farm

participated in thematic interviews. The intervention was regarded as a positive experience for the participants. The analyses revealed that central elements in the intervention were the possibility to experience an ordinary work life, but also the importance of a distraction to their illness.

McNicholas and Collis [9] interviewed family members of three individuals with autism and found that although they demonstrated aggression and difficult behaviour towards humans, they were affectionate and attached to the family pets. This preference for animals over humans has also been demonstrated in an experimental setting, in which children with autism tended to prefer interacting with dogs over humans and other objects in preliminary research in a naturalistic setting [10]. Kršková, Talarovičová, and Olexová, [11] demonstrated that children with autism consistently preferred interacting with an unfamiliar animal (guinea pig) to an unfamiliar person; they also engaged in increased social interactions with their peers in the presence of the guinea pig. These findings have led to the speculation that social aversion in autism may be human-specific and does not extend to interaction with animals [12].

The effects of animals on humans have been applied to medical treatment. Animal-assisted therapy and Animal Assisted activities (AAT & AAA) are widely used in hospitals and nursing homes. AAT has clear goals set out in therapy programs designed by doctors, nurses or social workers, in cooperation with volunteers. In contrast, AAA refers to patients interacting with animals without particular therapeutic goals, and depends on volunteers. AAT and AAA are expected to have 3 effects:

- Psychological effect (e.g. relaxation, motivation)
- Physiological effect (e.g. improvement of vital signs)
- Social effect (e.g. stimulation of communication among inpatients and caregivers)

However, most therapeutic centers in the developed world are increasingly hesitant to accept animals, even though they admit the advantages of AAT. They are afraid of negative effects of animals on human beings, such as diseases, animal and subject's safety, and allergies. When involving animals in a nursing home, subject with allergies could suffer due to the animal dander. Even though frequent bathing and application of certain lotion helps to some extend but it adds to the already constrained manpower resources in these institutions.

One of the critical concerns with the animal assisted therapy is the possible spread of zoonotic diseases which are common in pets. Prevention measures such as frequent hand washing, veterinary check-ups and cleaning of facility, use of throwaway pads for pets, and limiting physical contacts could help in minimizing the spread of diseases. But, these preventive measures results in increased cost, manpower resources and time. Given the possibilities of animal biting, scratching, and/or kicking an elderly, another serious concern with AAT is the safety of the subject involved.

Also, aggravated subject, mishandling and over-scheduled therapies possess a serious concern to animal safety in AAT. Again preventive measure does exist with additional manpower and cost in the form of staff-student training, frequent veterinary check-ups, and monitoring stress level in animals.

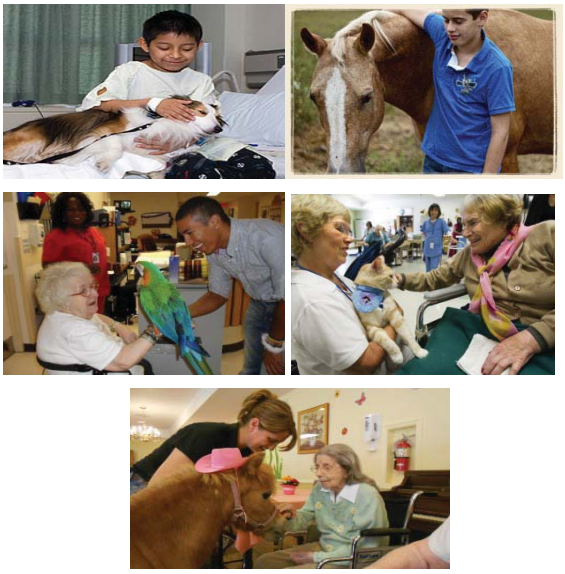

Figure 1: Animal Pet Assisted Therapeutic Scenarios [33 - 36]

These reasons have been a driving force behind increased research interest into robotic pet robots that brings the benefits of animal assisted therapy while nullifying the negative issues associated with living pets.

III. Bio-Inspired Therapeutic Pet Robots: A Review

The development and deployment of bio-inspired therapeutic pet robots are undertaken all across the world targeting a number of contexts from elderly care to special needs children. Several studies have proven the medical benefits of pet robots and their abilities to not only mimic the behavior of their biological counterparts but also retain the essence of interactions with humans. This section summarizes a number of such significant studies involving bio-inspired therapeutic pet robots. Kanamori et al., in [13] examine the usefulness of a dog like pet robots using AIBO (Artificial Intelligence Bot) platform among elderly patients or handicaps in nursing home or at home by biochemical marker, self-assessment, or some health-related QOL (quality of life) questionnaires. The activities with pet-type robots were regularly carried out for 7 weeks to enhance quality of life (QOL) for Japanese elderly people. In activity evaluation, the scores of the items of "Utterance", "Demonstrative Language" and "Satisfaction" obtained at the last activity significantly increased compared with those at the initial activity.

Tamura et al., in [14] also use AIBO, a dog-like robot in occupational therapy instead of animal-assisted therapy to avoid any danger or injury to the patient and maintain cleanliness. This study compared the effectiveness of a robot animal, AIBO, with a toy. The paper demonstrated AIBO to severely demented elderly people living in a geriatric home and observed their reactions. Another work with significant results is presented by Fernaeus et al., in [15] where they present an exploratory study of how dinosaurs inspired robot, Pleo was interacted with and reflected upon in the homes of six families during 2 to 10 months. Their analysis emphasizes a discrepancy between the participants' initial desires to borrow a

Pleo and what they reported later on about their actual experiences. Further, their data suggests an apparent tension between participants expecting the robot to work as a 'toy' while making consistent comparisons with real pet animals. Sharkey and Sharkey in [16] raise and discuss six main ethical concerns associated with the pet robots in the context of NeCoRo, a cat like pet robot: (1) the potential reduction in the amount of human contact (2) an increase in the feelings of objectification and loss of control (3) loss of privacy (4) loss of personal liberty (5) deception and infantilization (6) circumstances in which elderly people should be allowed to control robots.

Wada and Shibata in [17] present the investigation of psychological and social effects of PARO, a seal like pet robot. Each subject was interviewed, and their social network was analyzed. Their results indicate that interaction with the seal robot increased their social interaction. Furthermore, the urinary tests conducted in their experiment showed that the reactions of the subjects' vital organs to stress improved after the introduction of the robot. Sheba, Mohan, and García in [18] put forward a metric that measures easiness of acceptance using the length of time to initiate interaction, total interaction time, time needed to identify perception-reaction phenomenon, its occurrence, number of violations and affective interaction factor. This measure is expected to be useful as a parameter to compare different target groups, robots, and different nature of interaction. Experiments were conducted to validate the proposed metric in an eldercare nursing home using a therapeutic pet robot ERIC (Elderly Rehabilitation Interactive Companion), a dog-like robot.

Banks, Willoughby, and Banks in [19] compared the ability of a living dog (Dog) and a robotic dog (AIBO) to treat loneliness in elderly patients living in Long Term Care Facility. In comparison with a control group not receiving AAT, both the Dog and AIBO groups had statistically significant improvements in their levels of loneliness. As measured by a Modified Lexington Attachment to Pets Scale (MLAPS), residents showed high levels of attachment to both the dog and robot. Maeda in [20] addresses a bear like pet-type welfare robot system for aged people. The robot offers interactivity, which can communicate autonomously and communicate with others, using Internet-connectivity for being a partner. Tan et al., in [21] report the development of an interactive pet companion, CuDDler, with the capability to recognize verbal and non-verbal communication acts that are tied to the emotional state of a person. Their experiment indicated high ratings of the Godspeed attribute in “likeability” and “perceived safety”. Shinozaki, Tsuda, and Nakatsu in [22] propose a new type of robot called the "Centaur Robot" by merging the concepts of these two types of robots for therapeutic scenarios. This robot has a human-like upper body and a four-legged animal-like lower body. Due to this basic architecture, the robot has several merits, including human-like behaviors and stable walking even on non-smooth ground.

Dautenhahn et al., in [23] address different possible social relationships between robots and humans, drawing on animal-human relationships. This work argues that humans have been living in (generally peaceful) co-existence with a number of potentially dangerous species, such as some canines. Interestingly dogs are not born ‘pet dogs ’; it’s not completely ‘predefined’ in their genes whether they will become friendly or dangerous. A critical period in a puppy’s early life significantly shapes its socialization and behavioral conformation. This work suggest that such a developmental model of socialization could be an interesting viewpoint on the design of future generations of robots that need to co-exist with humans, and that humans like to live with. This work proposes the challenge of developing ‘personalized robot companions’, machines that can serve us for life-long companionship. The work also argues that such individualized robots are necessary due to human nature. people have individual needs, likes and dislikes, preferences and personalities that a companion would have to adapt to. One and the same robot will not fit all people. Cognitive robot companions need to be socialized and personalized in order to meet the social, emotional and cognitive needs of people they are living with.

Robins et al., in [24] performed a longitudinal study with four children with autism, who were exposed to a humanoid robot over a period of several months. The longitudinal approach allowed the children time to explore the space of robot–human, as well as human–human interaction. Based on the video material documenting the interactions, a quantitative and qualitative analysis was conducted. Tapus and Matarić in [25] conduct a hands-off therapist robot that monitors, assists, encourages, and socially interacts with post-stroke users engaged in rehabilitation exercises. They investigated the role of the robot’s personality in the hands-off therapy process, focusing on the relationship between the level of extroversion-introversion of the robot and the user. The experiments map the extroversion-introversion personality dimension and the spectrum of therapy styles that range from challenging to nurturing.

Figure 2: Bio-inspired Therapeutic Pet Robot Precedents [37 – 41]

IV. Parrot-Inspired Therapeutic Pet Robot: Needs, Future Potential, and Research Challenges

Several pet inspired companion robots have been researched within therapeutic setting where the robots mimic the form, behavior and multimodal human pet interactions. Previous work covers studies involving a number of pets ranging from dog, cat, seal, and bear. With this, platforms have been developed and evaluated in the context of therapeutic scenarios [1]-[21]. Vast majority of such studies as presented in the literature above, points to successful improvement in physiological, psychological and social aspects within a therapeutic setting. Among several animals adopted for pet therapy, one very relevant species that has received little attention is parrot. With an estimated 11 million birds living as pets within the United States, parrots are now thought to be the fourth most common household animal after dogs, cats, and fish [26]. Parrots can be very rewarding pets to the right owners, due to their intelligence and desire to interact with people. Many parrots are very affectionate, even cuddly with trusted people, and require a lot of attention from their owners. Some species have a tendency to bond to one or two people, and dislike strangers, unless they are regularly and consistently handled by different people. Properly socialized parrots can be friendly, outgoing and confident companions. Most pet parrots take readily to trick training [27].

Parrots have been successfully able to help those with mental or physical disorders. Parrots help overcome these conditions and are specifically used for a case study involving patient suffering from bipolar disorder with psychotic tendencies [28]. Another popular case involved in parrots assisted therapy is for treating post-traumatic stress disorder among war veterans in United States [29]. Haw, in [30] present her experiences in adopting parrots for therapy with psychiatric patients. Grandgeorge and Hausberger [31] present evidence that parrot presence at home may induce wellbeing in people and the development of social skills in children. Experimental data obtained on parrot models suggests that this is indeed a promising line. Pepperberg and her team [32] study the large-brained, highly social parrots and their abilities to mastering complex cognitive concepts and the rudiments of referential speech. This work presents the details of their investigation and the bird at its center—Grey parrot named Alex—have since become almost as well-known as their primate equivalents and no less a subject of fierce debate in the field of animal cognition. This book represents the long-awaited synthesis of the studies constituting one of the landmark experiments in modern comparative psychology.

With such promising experiences with parrot assisted therapy, there still prevails the same set of constraints as with any other animal assisted therapies including allergy, maintenance, safety, and manpower issues which opens up the possibility for a robotic pet for therapeutic purposes. Additionally, unlike dogs and cats, parrots do not carry any religious or cultural preconceptions. However, there has been no precedence for research into a parrot inspired robotic platform that mimics parrot behaviors within a therapeutic setting.

A bio-inspired robotic platform that mimics parrot behavior within a therapeutic setting opens up numerous research opportunities and challenges. Given the research potential and significant academic impact, design of a parrot inspired therapeutic robot would form the core of our ongoing research project at Auckland University of Technology especially targeting user studies with elderly and autistic children. Realizing a robotic platform that mimics physical behavior of parrot at scale within a therapeutic setting is highly challenging in terms of design mechanism, actuation framework, and motion control. Such a robotic platform would involve numerous components both passive and active, requiring an effective strategy for system integration and design trade-off studies. A number of parrot behaviors have been found to be useful within therapeutic setting, reproducing these behaviors autonomously in artificial robots requires highly sophisticated behavioral algorithms that handles data from multiple sensors and reacts to events at real time. Studies involving parrot assisted therapy clearly depicts the involvement of multiple modalities for human parrot interaction such as tactile, acoustic and visual. Parrots are highly sensitive creatures with powerful sensing capabilities that directly relates to their abilities to interact with humans. Bringing these niche abilities in-to their artificial counterpart is highly critical to retain the therapeutic benefits of human parrot interaction. Enabling parrot inspired robots with such sensing capabilities require putting together a wide range of sensors, addressing associated software-hardware integration issues, developing sensor fusion algorithms that ensures vital perception behaviors. A parrot inspired pet robot within a therapeutic framework opens up a number of research questions as well associated with human robot interaction as in the case of other pet robots. Extensive user studies that covers a wide set of usage scenarios over short and long term would be needed to validate the efficacy of the developed platform.

V. Conclusion

Trends in animal pet assisted therapy were reviewed in detail. Key research and developmental works on bio-inspired therapeutic pet robot assisted therapies were discussed. Several robotic platforms have been developed both within commercial and academic settings and their numbers are expected grow even rapidly in the future. However, there is still several research, developmental, deployment and economic issues associated with therapeutic pet robots yet to be solved. Based on the literature review, this paper put forward the needs, future potential and research challenges associated with a parrot inspired approach to therapeutic pet robots.

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