Recent Developments on Social Robots and Imitation Learning for Robotic Therapy

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Abstract. The development of social robots has been notably increasing and gaining popularity in recent times. These are also being integrated into healthcare systems, as a means to accompany patients, provide mental health therapy, and entertainment in place of direct human intervention. This paper discusses the recent developments on imitation learning for robot therapy in the field of social robotics to gain knowledge about the importance of this approach as an alternative solution to mental health therapy. The integration of robots to the mental healthcare system is known as robot therapy, which is used as a substitute for animal assisted therapy. Therapy that makes use of animals has been proven to be effective in dealing with mental disorders. However, there are risks such as allergic reactions, bites, and scratches that come with animal assisted therapy, but not robot therapy. The goal for developing robots for this is to make them seem almost life-like--has a way of thinking and emotions. For this to happen, humanoids are being programmed to appear human-like. A solution for this is imitation learning, which is a way for machines to learn, not only tasks, but responses in certain situations, only by observing and imitating humans in an environment.

1. Introduction
Robotic applications in general have expanded to social uses instead of limiting to industrial uses. There is a shortage in healthcare personnel, as well as an increasing number of vulnerable populations such as the elderly and the disabled. Due to these reasons, the use of social robots in healthcare is becoming more widespread [1]. As a result, social robots are deployed in healthcare to provide health education and entertainment to hospital patients, as well as assist the sick and elderly. Companion robots are traditionally designed to provide company, boost immunity, as well as reduce stress in order to improve the health and psychological well-being of the sick and the aged. Hence, companion robots mitigate helplessness, boredom, isolation, depression, and loneliness [2]. Robots that make use of human-robot interactions are rapidly spreading. These robots provide services that stimulate minds by interacting with humans for psychological enrichment. These do not only entertain but also provide therapy, assistance, and guidance, as well as entertainment and education. Robot therapy uses robots as substitutes to animals in animal-assisted therapy and activities. This is considered a new application for robotics which is attracting the attention of researchers and psychologists [3].

Robots, despite significantly improving on a variety of motor skills, still lack human-interactive capabilities. Most robots are unable to counter or react accordingly to a human partner which raises the
need for adaptive algorithms that ensure responsive robot behaviour [4]. An example for the said algorithms would be a robot extracting an interaction model that specifies the movements and responses of involved parties simply by observing how two human subjects interact in a specific situation, like lifting an object, using machine learning algorithms. With this, the robot would then be able to assist a human partner in a similar activity. This approach is known as an extension of imitation learning, wherein the behaviour and interaction between two agents is imitated. In this paper, the different technologies developed for robot therapy, their functions, and the advantages of integrating imitation learning in said developments will be reviewed.

2. Robot Therapy

Mental disorders including depression and dementia that cause behavioural and psychiatric disturbances are considerably common among elders, especially those in nursing homes. Said disturbances caused by these disorders may include aggression, wandering, and even hallucinations. Connecting with these patients is considered challenging for the caregivers. Caregivers conduct several recreational activities, such as arts and crafts and singing songs to try communicating with the elderly people. However, some people are not comfortable singing songs or experience difficulty in trying to draw due to their illness [3].

2.1. Animal Assisted Therapy

Interaction with animals has long been known to be emotionally beneficial to people. A study conducted by Garrity et al. [6] found that among the elderly people who have been socially isolated or lost a loved one, those who had no pets had a higher intensity of depression compared to those who did. Friedmann et al. [7] observed the survival rate of those who were released from coronary care throughout a year. As the findings claim, those who had kept pets had a higher survival rate than those who did not. It was reported by Baun et al. [8] that the blood pressure of patients dropped when they pet their dogs. While a study about the social influences of animals on people by Hart et al. [9] found that those with dogs experience more friendly encounters with strangers compared to those without. Although the positive effects of animal assisted therapy and activities are understood, animals are not allowed in most hospitals and nursing homes due to fear of any negative impacts such as allergic reactions, infections, bites, and scratches [3].

This is where robotics can be integrated, as the applications for robotics have been expanding towards social uses [1]. This then enables the robot to have more natural interactions with humans and become socially fit for the human environment. With previously stated reasons for finding such solutions necessary, there is an extensive deployment of social robots in the healthcare system [1]. For instance, researches have shown that those suffering from Autism Spectrum Disorders responded more to treatments involving robotic technology than treatments from human therapists [10].

2.2. Human-interactive Robots

There are different types of social robots meant for purposes such as physical enrichment: performance robots, tele-operated performance robots, operation, building, programming, and control robots, and interactive autonomous robots [3]. Among the different types, the interactive autonomous robots have mostly personal interactions with humans. The dog robot AIBO by Sony falls under this category as it was meant for entertainment purposes, and having a mechanical appearance and using nonverbal communications, people are more drawn to it and peak their interests [11]. The communication robot, if a bot, makes use of facial expressions as a means to communicate, together with many prepared conversation scenes.

In the area of welfare and mental health therapy, a study by Shibata et al. [12–26] led to the development of a mental commitment robot meant to be a personal robot, designed to enable mental effects such as pleasure and relaxation. Robot therapy is also proposed, which basically uses robots as substitutes for animals in Animal Assisted Therapy and Activities. The target patients of robot therapy
are those in medical and welfare institutions wherein animals are prohibited. The robot designed to look like a seal, namely Paro, was developed specifically for robot therapy and was used in hospitals and facilities for elderly people in several countries. Robot therapy has been revealed to have the same effects on people as animal therapy by recent studies. Additionally, robot therapy is being recognized as a new method of mental healthcare [27]. Previously mentioned AIBO has also been used as a companion robot in nursing homes. A study conducted by Banks et al. [28] showed that AIBO not only reduces stress hormones, but also improves brain functioning of patients.

![Figure 1. (left) Sony’s AIBO [11], and (right) Paro Therapeutic Robot [3]](image)

2.3. Required Functions
An important factor in robot therapy is the ability to stimulate the knowledge of people and experiences with animals through interaction with robots, in order to enable them to bring out similar feelings as when they are interacting with animals. As a result, touch sensations, autonomous actions, and animal-like responses are all needed. Those expected to interact with the robot are mostly people who experienced a loss in strength and healing capabilities which were caused by possible sickness and aging, hence the said robot is required to have features and functions that seem harmless, hygienic, and can easily be accepted by people [3]. Mental commitment robots are not designed to provide services involving physical work [12-27]. These have one intended function which is to trigger positive mental effects in their role as personal robots. These robots, like living organisms, function independently with an intent and motivations when obtaining stimuli from the environment. The behaviour of robots during encounters with humans can be perceived as if they had hearts and feelings. Through physical interaction, mental commitment robots will activate various senses of humans. Hence, nonverbal communication is the asset and main characteristic of such robots [3].

3. Imitation Learning
A new approach to robot learning was presented by Amor, et al [2] which provides the ability to learn a library of interaction skills for humanoids and anthropomorphic robots only with demonstration. The asset of this approach is the idea that by simply observing human interaction and collaboration, the robot will gain information regarding how and when to interact with a human partner in a particular situation. The behaviour and interaction between two subjects can be imitated, and in turn, learned, making this approach an extension of imitation learning [29].

In robotics, finding easy and natural ways to define robot control programs is a major focus. Imitation learning, which is also known as “programming by demonstration”, has been proposed as a possible solution to this problem [30]. A robot creates an autonomous control program based on human-provided demonstrations of a particular skill, allowing it to generalize the said skill to certain situations. Most imitation learning approaches obtain a control policy, which encodes the user’s demonstrated behaviour.

The Gaussian Process Dynamics Model was presented by Wang et al. [31] in their study as a way to make out the intention behind the movements of a human in playing a table-tennis game. With analysing
the movements of the players, the robot can then determine in which direction and position the ball can be returned. Even before the human player can hit the ball, the robot can already initiate the returning movement with the use of such predictive abilities. In another study by Ikemoto et al. [32], adapting to the timing for close-contact interaction scenarios between a humanoid and a human partner was made possible by making use of such Gaussian Models. The study used binary evaluation data gathered from the human subject to modify the parameters of the model. Although the method allowed for human-inclusive learning and adaptation, no imitation of observed interactions was included.

Figure 2. Overview of the interaction learning approach [29]

First, motion capture technology is used to monitor the actions of a pair of people performing a competitive (or cooperative) activity. Following that, the collected data is used to build an interaction model. The mutual effects during task execution are captured by the interaction model. The interaction model, in turn, allows us to predict one human’s state (skeletal configuration) based on the observed states of the other. Finally, a robot employs the learned model in a similar relationship with a human partner. The tasks included boxing, martial arts, high five, and handing over. A robot needs to be able to respond immediately and accordingly to the behaviour of the human in interactive scenarios. With such requirements, the computational demands of the algorithms, as well as the runtimes for processing an appropriate response were analysed [2].

Figure 3. Captured human movement (top), joint angle configurations generated (2nd row), log-likelihoods for the different behaviours (3rd row), pictures of the interaction between the human and the robot (bottom). [2]

A robot partner must not only know what a human teammate is doing to have the right kind of assistance at the right moment by observing the actions of the human, but also comprehend the intention behind them. This kind of cooperation between a human and a robot encourages the improvement and
development of robots capable of understanding the intent and mental state behind an interaction. In humans, social interactions are defined by particular features, such as how shared control is expected in human interactions [5]. People execute and rely on certain social mechanisms such as shared attention and taking turns in order to share said control. Consequently, there is a mutual regulation within these human interactions, as each reaction and behaviour would adapt to the interacting partner’s [5].

Imitation learning has already been integrated in other robot therapy research. A robot-mediated imitation skill training system, called RISTA, was studied and used with young children with Autism Spectrum Disorder (ASD) [33]. The robot would imitate the upper limb movements of the participants, which was deemed as not only entertainment, but companionship. The children noticeably paid more attention to the robot than the human administrator, and demonstrated enhanced performance in response to robotic prompts than those delivered by human counterparts [33]. Another study by Cabibihan et al. [34] reviewed the use of socially interactive robots to assist in the therapy of children with autism. In their paper, they studied the use of both anthropomorphic and non-anthropomorphic robots in autism therapy. They made use of imitation for children to learn social skills and environment. Imitation activities help develop cross-modal mapping mechanisms in children [34].

4. Discussion and Conclusion

Robot therapy targets those who need companions, and those with mental health disorders such as autism, depression, and anxiety. It has been observed that patients with disorders such as anxiety prefer interacting with non-human companions, as they would not feel embarrassed. It has been reported that they feel more comfortable as they would not feel judgement, unlike when interacting with humans. This is where animal assisted therapy and activities come to view as a solution. However, as there are known disadvantages to AAT such as allergic reactions, bites, and scratches, robot therapy is to be considered as its substitute. Hence, more information that can be integrated with the development of technology for robot therapy is necessary.

In robot therapy, it is ideal for machines to imitate animals, and humanoids imitate humans. Researchers have been continuously studying how to achieve such human-like interactions and experiences with robots. The goal is to make them appear almost life-like but assure the audience they are not simply machines being controlled by humans. It is also ideal for robot therapy as it can feel more like a companion with understanding, with the exclusion of judgement. Having a human-like interaction would also allow, for example, young children with autism, to learn valuable social skills and maintain joint attention with another person. A solution that is suggested in order to achieve this is the use of imitation learning.

The previously mentioned study that makes use of RISTA is an example of how imitation learning brings positive effects and advantages in dealing with mental health. It suggests that robotic systems capable of triggering positive effects in non-social attention preference can be used to enhance skills related to core symptoms of ASD. In other existing studies, it has been observed that knowledge is transferred from an external source to a child through activities related to imitation. Numerous positive effects have also been reported to stem from imitating peers in social situations, such as hand-eye coordination and people recognition.

In conclusion, imitation learning is a method to be considered in developing technology for robot therapy. Imitation learning allows machines to learn not only new tasks, but also how to respond and interact with other beings in a given situation. The way machines can learn new tasks by simply observing and imitating can lead to numerous implementations, including robot therapy.
References

[1] Oloronke I, Oluwaseun O and Rhoda, I 2017 State of the art: A study of human-robot interaction in healthcare. *International Journal of Information Engineering and Electronic Business*, 9(3), 43–55.

[2] Robinson H, MacDonald BA, Kerse N and Broadbent E 2013 Suitability of healthcare robots for a Dementia unit and suggested improvements. *Journal of the American Medical Directors Association*, 14(1), 34–40.

[3] Shibata T and Wada K 2011 Robot therapy: A new approach for mental healthcare of the elderly a mini-review. *Gerontology*, 57(4), 378–386.

[4] Ben Amor H, Vogt D, Ewerton M, Berger E, Jung B and Peters J 2013 Learning responsive robot behavior by imitation. *IEEE/RSJ International Conference on Intelligent Robots and Systems*, 3257-3264.

[5] Billard A, Calinon S, Dillmann R and Schaal S 2008 Robot Programming by Demonstration. *Springer handbook of Robotics. Springer Berlin Heidelberg*, 1371-1394.

[6] Garrity TF, Stallones LF, Marx MB and Johnson TP 1989 Pet ownership and attachment as supportive factors in the health of the elderly. *Anthrozoös*, 3(1), 35–44.

[7] Friedmann E, Katcher AH, Lynch JJ and Thomas SA 1980 Animal companions and one-year survival of patients after discharge from a coronary care unit. *Public Health Reports Washington, D.C.*, 95(4), 307–312.

[8] Baun M, Bergstrom N, Langston N F and Thoma L 1984 Physiological effects of human/companion animal bonding. *Nursing Research*, 33(3).

[9] Hart L.A, Hart BL and Bergin BL 1987 Socializing effects of service dogs for people with disabilities. *Anthrozoös*, 1(1), 41–44.

[10] Diehl JJ, Crowell CR, Villano M, Wier K, Tang K and Riek L D 2014 Clinical applications of robots in autism spectrum disorder diagnosis and treatment. *Comprehensive Guide to Autism*, 411–422.

[11] Fujita M 2004 On activating human communications with pet-type robot aibo. *Proceedings of the IEEE*, 92(11), 1804–1813.

[12] Osborne J 2018 Sony Aibo is AN Adorable, artificially INTELLIGENT puppy for everyone. *TechRadar*.

[13] Shibata T, Inoue K and Irie R 1996 Emotional robot for intelligent system-artificial emotional creature project. *Proceedings 5th IEEE International Workshop on Robot and Human Communication*, RO-MAN’96 TSUKUBA, 466-471.

[14] Shibata T and Irie R 1997 Artificial emotional creature for human-robot interaction-a new direction for intelligent systems. *Proceedings of IEEE/ASME International Conference on Advanced Intelligent Mechatronics* p 47.

[15] Shibata T, Tashima T and Tanie K 1999 Subjective interpretation of emotional behavior through physical interaction between human and robot. *IEEE SMC’99 Conference Proceedings, 1999 IEEE International Conference on Systems, Man, and Cybernetics*. Vol. 2, pp. 1024-1029.

[16] Shibata T and Tanie K 2000 Influence of a priori knowledge in subjective interpretation and evaluation by short-term interaction with mental commit robot. *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS 2000)*, 1, 169–174.

[17] Shibata T, Mitsui T, Wada K, Touda A, Kumasaka T, Tagami K and Tanie K 2001 Mental commit robot and its application to therapy of children. *IEEE/ASME International Conference on Advanced Intelligent Mechatronics*, 1053–1058.

[18] Wada K, Shibata T, Saito T and Tanie K 2002 Robot assisted activity for elderly people and nurses at a day service center. *IEEE International Conference on Robotics and Automation* Vol. 2, pp. 1416-1421.

[19] Saito T, Shibata T, Wada K and Tanie K 2003 Relationship between interaction with the mental commit robot and change of stress reaction of the elderly. *IEEE International Symposium on*
Computational Intelligence in Robotics and Automation. Computational Intelligence in Robotics and Automation for the New Millennium, 1, 316–319.

[20] Shibata T, Wada K and Tanie K 2002 Tabulation and analysis of questionnaire results of subjective evaluation of seal robot at Science Museum in London. 11th IEEE International Workshop on Robot and Human Interactive Communication, 14, 13–19.

[21] Wada K, Shibata T, Saito T and Tanie K 2004 Psychological and social effects in long-term experiment of robot assisted activity to elderly people at a health service facility for the aged. IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS) Vol. 3, pp. 3068-3073.

[22] Wada K, Shibata T, Saito T and Tanie K 2004 Effects of robot-assisted activity for elderly people and nurses at a day service center. IEEE 92(11), 1780–1788.

[23] Wada K, Shibata T, Saito T, Sakamoto K and Tanie K 2005 Psychological and social effects of one year robot assisted activity on elderly people at a health service facility for the aged. IEEE International Conference on Robotics and Automation, 2796–2801.

[24] Marti P, Bacigalupo M, Giusti L, Mennecozzi C and Shibata, T 2006 Socially assistive robotics in the treatment of behavioural and psychological symptoms of dementia. The First IEEE/RAS-EMBS International Conference on Biomedical Robotics and Biomechatronics, BioRob 2006, 483–488.

[25] Wada K and Shibata T 2007 Living with seal robots—its sociopsychological and physiological influences on the elderly at a care house. IEEE Transactions on Robotics, 23(5), 972–980.

[26] Wada K, Shibata T, Musha T and Kimura S 2008 Robot therapy for elders affected by dementia. IEEE Engineering in Medicine and Biology Magazine, 27(4), 53–60.

[27] Inoue K, Wada K and Uehara R 2011 How effective is Robot THERAPY?: Paro and people with dementia. IFMBE Proceedings, 37, 784–787.

[28] Banks MR, Willoughby LM and Banks WA 2008 Animal-assisted therapy and loneliness in nursing homes: Use of robotic versus living dogs. Journal of the American Medical Directors Association, 9(3), 173–177.

[29] Schaal, S. 1999. Is imitation learning the route to humanoid robots? Trends in Cognitive Sciences, 3(6), 233–242.

[30] Wang Z, Deisenroth M, Ben AH, Vogt D, Scholkopf B and Peters J 2012 Probabilistic modeling of Human movements for Intention Inference. Robotics: Science and Systems VIII.

[31] Ikemoto S, Amor H, Minato T, Jung B and Ishiguro H 2012 Physical human-robot INTERACTION: Mutual learning and adaptation. IEEE Robotics & Automation Magazine, 19(4), 24–35.

[32] Breazeal C, Buchsbaum D, Gray J, Gatenby D and Blumberg B 2005 Learning from and about others: Towards using imitation to bootstrap the social understanding of others by robots. Artificial Life, 11(1-2), 31–62.

[33] Zheng Z, Young E M, Swanson A, Weitlauf A, Warren Z and Sarkar N 2015 Robot-mediated mixed gesture imitation skill training for young children with asd. International Conference on Advanced Robotics (ICAR) pp. 72-77.

[34] Cabibihan J, Javed HA and Aljunied SM 2013 Why robots? A survey on the roles and benefits of social robots in the therapy of children with autism. International Journal of Social Robotics, 5(4), 593-618.