A companion dog robot inspired by AIBO: Alleviating loneliness

Toshimitsu Ota (s5251464)

Bachelor of Intelligent Digital Technologies
Griffith University, Queensland Australia

11 June 2021

Abstract— **Loneliness has become an increasingly important social issue. There are reports to support that dog robots can reduce loneliness at the same level as real dogs. Alleviating loneliness by developing a companion robot which would expand the existing attributes of AIBO, by being equipped with more advanced interaction skills is a possibility. Technologies such as face recognition, emotion recognition and user interaction inspired by canine behaviors could improve the human-robot interaction and meet the greater needs of companionship.**

1 INTRODUCTION

The human population has been increasing rapidly and our style of living is changing. Density living in cities is more common and a sense of community has been disappearing from these cities. While the sense of belongingness made humans evolve to reach this level of civilisation, more people are suffering from a lack of belonging and feelings of loneliness and isolation. Loneliness has become an evident social issue in developed countries such as Australia, U.K. and Japan. This report will explore the possibilities of helping the social issue of loneliness by developing a companion dog robot inspired by Sony AIBO. It will discuss how technologies such as face recognition, emotion recognition and user interaction can improve the human-robot interaction (HRI) aspect of companion robots with findings from the literature.

1.1 Social Issue Loneliness

As the world rapidly moves towards high density living, loneliness is becoming more prevalent. U.K. created the world's first minister of loneliness to deal with the growing social issue in 2018 [21], funding £11.5 million to tackle the issue. In Australia, 51% of people feel lonely at least one day a week [4] and loneliness has been identified as a cause of poor mental and physical health and even earlier mortality [4]. Japan has been suffering from deaths related to loneliness, called kodokushi, for decades and the COVID-19 pandemic pushed it to a new level [18]. Building quality relationships and pet ownership are considered effective ways to reduce loneliness [4].

1.2 Robotic Dogs

Animal therapies are used for many mental health issues which is also effective for loneliness. Banks *et al.* [14] compared the effectiveness for reducing loneliness between a live dog and a robotic dog (AIBO) which were both equally effective, suggesting that robotic dogs may be an option for people who cannot have a living animal. Another study [2] reported that 44% of participants preferred a dog like robot for their domestic robot over a humanoid or a machine-like robot. They also listed empathy as one of the advantages of dogs over robots which indicated that robots need empathy to become more like a pet dog for users. Empathising empathy may be important to make social robots more emotionally intelligent which would improve effectiveness in therapy, healthcare, and rehabilitation [12].

1.3 Learning from Aibo

Sony's AIBO has often been used as a tool in experiments to represent a dog robot. With its long history of serving as a dog in domestic homes in real life, there are some valuable studies [8], [6] which share opinions from long time owners of the popular dog robot. The study of Kertész *et al*. [7] reported that the most requested improvement was better interaction skills with humans. Richer personality came third and good face and object recognition was eighth in the list. 20% of the participants owned AIBO for more than 10 years and 51% of them owned AIBO between 2 and 10 years. Sony AIBO's success came from the likeness of a dog which resulted in owners' expectation of less intelligence than a humanoid robot [20].

2 FINDINGS

A companion robot with better interaction skills than AIBO to become more like a dog would be advantageous in the mission to help people with loneliness. This section presents findings from the current literature to explore the possibilities in three areas of technology: face recognition, emotion recognition and user interaction.

2.1 Face Detection and Recognition

Face detection and recognition are necessary processes for a companion robot to recognise emotions on human faces. Emotion recognition often includes this process as a part in pre-processing. The study conducted by Ghiţă *et al*. [16] implemented YOLO to detect objects and FaceNet to recognise faces for a social robot. The experiments resulted with high accuracy for both face recognition and people detection and detected people in many positions including from behind. The face recognition achieved close to 100% accuracy even from a distance of four meters, although it showed its weakness in strong back lit conditions to recognise faces. Both face recognition and object detection were processed in an external server using RGB and depth images provided by the robot.

2.2 Emotion Recognition

While there are a wide variety of studies about methods for machines to recognise humans' emotions from various sources such as image [3], [5], audio-visual [9] or speech [13], [17], this report focuses on studies which used image as a source for use in social robots. Ruiz-Garcia *et al*. [1] developed an emotion recognition model for a companion robot to recognise seven emotions in real time. They experimented with several combinations of classifiers and filters to find the best architecture. The best model architecture was a hybrid of a convolutional neural network (CNN) and a support vector machine (SVM) as classifier which had a simplified configuration with less parameters. It required less amounts of data to train by utilising batch normalisation for a faster connection. It achieved state of art accuracy when tested with both the KDEF dataset and the CK+ dataset. After the successful results, they conducted another experiment to test the model in unconstrained environments closer to a situation in which a companion robot would be used. In the test the accuracy rate fell significantly. It showed the challenges which social robots would face when it comes to reading emotions in uncontrolled situations. The model would need further training with lager datasets including images that are taken in various environments to reflect real life scenarios in order to recognise emotions more accurately.

Companion robots confront challenges which are not limited to environments they are in but also limitations of computational power and responsiveness in order to respond to users without a noticeable delay. Muhammad *et al*. [12] developed a low latency emotion recognition system with exploiting edge computing and deep learning technologies to compliment an IoT device, in this case, a smartphone. As depicted in figure 1, the system used a smartphone as an end device to pre-process images by face detecting, cropping, enhancing contrast and resizing before the rest of emotion recognition processing was carried out in the GPU equipped edge. In off times, the edge server can download the global deep model which was trained in the cloud to be executed when the end device sends face images. Thanks to edge computing and the light CNN model which they developed for the system, it achieved 96% accuracy with a fast-processing speed of 100 milliseconds.

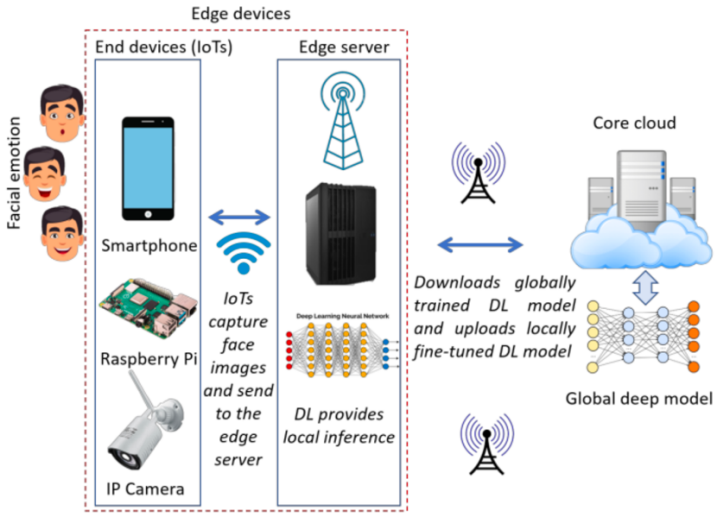

Figure 1Framework of edge computing [12]

2.3 User Interaction

A companion robot requires the ability to react to human emotions effectively, to express emotions, be interactive, and emotionally intelligent. HRI can be delivered through text, speech, gestures, and other forms. This report focuses on HRI through gestures mimicking canine behaviours.

Lakatos [10] found that robots with social behaviours inspired by dogs were effective in HRIs. By implementing human-dog interaction, social robot behaviours can be less complex which mitigates technical difficulties relating to implementations of complex human behaviours. In addition, people were forgiving towards a dog robot, laughing when it did not respond as intended [19]. Most of them had positive attitudes towards the robot and instead tried different approaches to interact with the robot.

In the study by Ghafurian *et al.* [11], they measured the recognition rates of eleven affective expressions delivered through the dog-like robot Miro. Those expressions were designed mainly based on canine behaviours. As depicted in figure 2, five expressions; happy, excited, sad, surprised, and tired were recognised correctly by majority of participants, while most of other expressions were recognised by some participants. Complex expressions such as annoyed and disgusted struggled being recognised. The author suggested that ratings could change if Miro had eyebrows and a mouth for better expressions and each expression was in line with social cues.

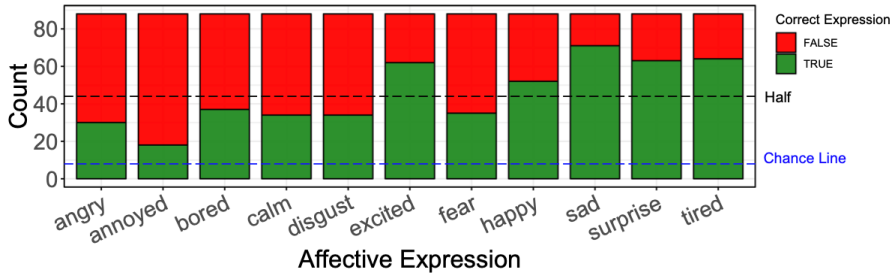

Figure 2Evaluation of the 11 affective expressions for Miro. [11]

3 DISCUSSION

The findings for face and object recognition indicated that it can be delivered accurately in challenging conditions in real life environments, although it showed a weakness against a strong back lit condition. The first example of emotion recognition presented a hybrid of CNN and SVM with a state of art accuracy rate. Although, when it was tested in an uncontrolled environment close to real life, the accuracy rate fell significantly. This indicated that there are many challenges to overcome for a

companion robot to be able to detect human emotions in a wide variety of situations. The other example of emotion recognition, using edge computing, demonstrated a great solution to deliver a fast recognition. While a companion dog robot would require a small computational unit to fit in a small body similar to AIBO (see figure 3), the proposed system using edge computing could solve the processing power limitation of the small unit by bypassing the heavy tasks to the edge server. The possible challenges for the system would have security issues relating to edge computing and the reliance on low latency network such as 5G mobile network. Both face and object recognition, and emotion recognition require high computational power to deliver accurate and fast results to support the real time interactions. In the future, if some technology advancement enables a small powerful computational unit to be fitted in the body of dog robot, the robot itself can process all recognition tasks and eliminate the need of an external server or edge computing.

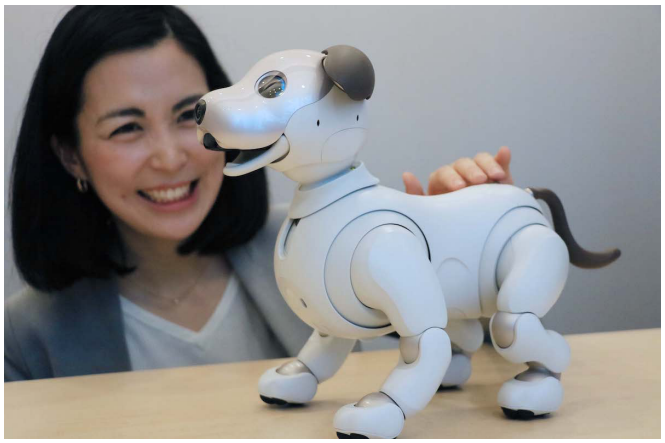

Figure 3Small body of Sony's AIBO (Photo by Ken Kobayashi, Source: https://asia.nikkei.com/Life-Arts/Life/Sony-gives-a-sneak-peek-of-aibo-its-new-robotic-dog)

The findings in section 2.3 highlighted the benefits of modelling the human-dog interaction for HRI. By mimicking canine behaviours, robots can express emotions without complex human behaviours enabling users to easily understand basic expressions. Implementing dog appearance and canine behaviours also bring great acceptance and positive attitudes from users.

When a companion robot achieves a greater level of interaction skills to help users with loneliness, a possible advancement for it could be to have the ability to walk outside and communicate with other dog robots which will encourage users to go outside and find an opportunity to socialise with other owners too. That would potentially help solve the loneliness issue even further.

4 Conclusion

The findings in this report presented how a companion dog robot can deliver accurate emotion recognition in real time to understand users' emotions which would enable a robot to interact with affective expressions through canine behaviours. There are some limitations of computational power and abilities in some environments, however it is possible to develop a companion dog robot that overcomes AIBO's limited interaction skills. By utilising edge computing and external servers via a low latency network, the robot would be emotionally intelligent with sufficient interaction skills to satisfy users and help alleviate loneliness. With more technical advancements in the future, the robot could deliver even more advanced assistance for loneliness to encourage users to walk outside and socialise with other owners. The robot may not replace real dogs, however, it will be a great option for people who cannot have a live animal.

5 REFERENCES

[1] A. Altahhan, A. Ruiz-Garcia, M. Elshaw, V. Palade, "A hybrid deep learning neural approach for emotion recognition from facial expressions for socially assistive robots," *Neural Computing & Applications*, vol. 29, (7), pp. 359-373, 2018.

[2] A. Miklósi, B. Korcsok, M. Gácsi, V. Konok, "Should we love robots? – The most liked qualities of companion dogs and how they can be implemented in social robots," *Computers in Human Behavior*, vol. 80, pp. 132-142, 2018.

[3] A. S. Alphonse and D. Dharma, "Novel directional patterns and a Generalized Supervised Dimension Reduction System (GSDRS) for facial emotion recognition," *Multimedia Tools and Applications*, vol. 77, (8), pp. 9455-9488, 2018.

[4] Australian Government. "Social isolation and loneliness." Australian Institute of Health and Welfare. https://www.aihw.gov.au/reports/australias-welfare/social-isolation-and-loneliness (accessed Jun. 9, 2021).

[5] B. Li *et al*., "SCEP-A New Image Dimensional Emotion Recognition Model Based on Spatial and Channel-Wise Attention Mechanisms," *IEEE Access*, vol. 9, pp. 25278-25290, 2021.

[6] C. Kertész and M. Turunen, "Exploratory analysis of Sony AIBO users," *AI & Society*, vol. 34, (3), pp. 625-638, 2019.

[7] C. Kertész and M. Turunen, "What can we learn from the long-term users of a social robot?" in *Social Robotics 9th International Conference.*, 2017, pp. 657-665.

[8] F. Krueger, G. Deshpande, J. Katz, K. Mitchell, "Human-dog relationships as a working framework for exploring human-robot attachment: a multidisciplinary review," *Animal Cognition*, vol. 24, (2), pp. 371-385, 2021.

[9] F. Noroozi et al, "Audio-Visual Emotion Recognition in Video Clips," *IEEE Transactions on Affective Computing*, vol. 10, (1), pp. 60-75, 2019.

[10] G. Lakatos, "Dogs as Behavior Models for Companion Robots: How Can Human-Dog Interactions Assist Social Robotics*?" IEEE Transactions on Cognitive and Developmental Systems*, vol. 9, (3), pp. 234-240, 2017.

[11] G. Lakatos, K. Dautenhahn, M. Ghafurian, Z. Tao, "Design and evaluation of affective expressions of a zoomorphic robot," in *Social Robotics 12th International Conference.,* 2020, pp. 1-12.

[12] G. Muhammad and M. S. Hossain, "Emotion Recognition for Cognitive Edge Computing Using Deep Learning," *IEEE Internet of Things Journal*, pp. 1-1, 2021.

[13] L. Jiang *et al*., "Speech emotion recognition using emotion perception spectral feature," *Concurrency and Computation*, vol. 33, (11), pp. n/a, 2021;2019;.

[14] M. R. Banks, L. M. Willoughby and W. A. Banks, "Animal-Assisted Therapy and Loneliness in Nursing Homes: Use of Robotic versus Living Dogs," *Journal of the American Medical Directors Association*, vol. 9, (3), pp. 173-177, 2008.

[15] N. Hajarolasvadi and H. Demirel, "Deep emotion recognition based on audio–visual correlation," *IET Computer Vision*, vol. 14, (7), pp. 517-527, 2020.

[16] Ş. A. Ghiţă *et al*., "User detection, tracking and recognition in robot assistive care scenarios," in *Towards Autonomous Robotic Systems 19th Annual Conference.,* 2018, pp. 271-283.

[17] S. Cunningham et al, "Supervised machine learning for audio emotion recognition Enhancing film sound design using audio features, regression models and artificial neural networks," *Personal and Ubiquitous Computing*, 2020.

[18] S. Kodama. "Japan appoints 'minister of loneliness' to help people home alone." Nikkei Asia. https://asia.nikkei.com/Spotlight/Coronavirus/Japan-appoints-minister-of-loneliness-to-help-people-home-alone (accessed Jun. 9, 2021).

[19] T. W. Leong and B. Johnston, "Co-design and robots: A case study of a robot dog for aging people," in *Social Robotics 8th International Conference*., 2016, pp. 702-711.

[20] R. Gockley *et al*., "Designing robots for long-term social interaction," in *2005 IEEE/RSJ International Conference on Intelligent Robots and Systems.*, 2005, pp. 1338-1343, doi: 10.1109/IROS.2005.1545303.

[21] United Kingdom. "Loneliness Minister: Write letters to people isolating at home." GOV.UK. https://www.gov.uk/government/news/loneliness-minister-write-letters-to-people-isolating-at-home (accessed Jun. 9, 2021).