MIRO: A Versatile Biomimetic Edutainment Robot

Emily C. Collins[1], **Tony J. Prescott**[1], **Ben Mitchinson**[1]
[1]Sheffield Robotics
The University Of Sheffield, Sheffield, U.K.
{e.c.collins, t.j.prescott, b.mitchinson}@sheffield.ac.uk

Sebastian Conran[2]
[2]Sebastian Conran Associates
Kensington, London, U.K.
sconran@sebastianconran.com

ABSTRACT

Here we present MIRO, a companion robot designed to engage users in science and robotics via edutainment. MIRO is a robot that is biomimetic in aesthetics, morphology, behaviour, and control architecture. In this paper, we review how these design choices affect its suitability for a companionship role. In particular, we consider how MIRO's emulation of familiar mammalian body language as one component of a broader biomimetic expressive system provides effective communication of emotional state and intent. We go on to discuss how these features contribute to MIRO's potential in other domains such as healthcare, education, and research.

Author Keywords

Companion robot; biomimetics; edutainment; healthcare.

ACM Classification Keywords

I.2.9 [Artificial Intelligence]: Robotics, Commercial robots and applications.

INTRODUCTION

Companion robots require the ability to be effectively social. But what is an effectively social companion robot? Why is it effective? And what role could such robots have beyond offering us novel playthings? Robots defined as 'social' are designed to interact and communicate with humans – usually, in a naturalistic way by using biological communication channels (e.g., body language or vocalisation rather than a keypad). Some examples of companion robots that have been made commercially available include Sony's AIBO, and Omron's NeCoRo. What marks them out as companion robots is that they not only communicate, but play a role in their user's emotional life through these interactions. Recently success has been achieved with 'simple' companion robots such as AIST's PARO in healthcare scenarios, as tools for conducting therapy. Robot therapy borrows from the Animal-Assisted Therapy (AAT) branch of healthcare by creating robots with the capacity to act as pet surrogates for those who do not have access to animals. The large existing body of AAT research points to its benefits for lowering stress, elevating mood, and social facilitation [5]; benefits demonstrated as achievable with companion robot therapy too [11].

One possible design feature underpinning these early successes may be the biomimetic nature of these robots. Biomimetics is the imitation of the models, systems, and elements of nature for the purpose of solving a problem. The relevance of biomimetics to human-robot interactions, in general, is widely attested. Robots that are biomimetic in their morphology, in the way they move, and that have expressive faces are immediately and intuitively engaging, owing to our familiarity with mammalian channels for conveying emotion and intent [2]. Biomimetic companion robots are therefore effectively social because they emulate these familiar communication channels. Naïve 'users', for example, choose to interact to a greater degree with robots that include naturalistic body language in their interactions [3], and robots can emit powerful social signals simply by following rules long-established by animals [8].

In this paper, we introduce a new robot platform, 'MIRO' (see Figure 1), which follows biomimetic design principles aesthetically, morphologically, and behaviourally, as well as with respect to control architecture.

Figure 1. Concept art for MIRO attending to its user.

MIRO is a companion robot designed to engage an audience in science and robotics via edutainment. However, we go on to discuss below the potential of this platform in other domains where its biomimetic nature could play an important role.

ACE '15, November 16-19, 2015, Iskandar, Malaysia
ACM 978-1-4503-3852-3/15/11.
http://dx.doi.org/10.1145/2832932.2832978

MIRO: AN EDUTAINMENT ROBOT

The MIRO robot was commissioned as a commercial pedagogical and leisure product, targeted particularly at the domestic and school markets. It achieves its edutainment goal through the encouragement of exploration of its construction and operation (the flagship configuration has ‘build-it-yourself’ form and is accompanied by an extensive series of magazines). MIRO is also intended as an artefact to drive public engagement with science, robotics in particular, and biomimetic robotics most of all (this agenda being reflected also in the magazine).

Aesthetics and morphology

MIRO’s initial design brief focussed on the personality, behaviour and performance of what would eventually become a programmable companion robot platform. In response to this MIRO’s aesthetics and morphology were chosen to be engaging through evocation of a mammalian identity. Animal morphology was chosen over humanoid in a bid to lower user expectation of behaviour and performance; indeed a puppy that can obey twenty voice commands is more impressive than an equivalent humanoid which evokes greater perceived intelligence.

The personality aesthetics were required to capture the essence of the Japanese word ‘kawaii’ (‘cute’), whilst not being too toy-like. Although design choices explicitly avoided targeting a particular mammal, visual and behavioural cues were taken from puppies, kittens and rabbits and morphed into a single pet-like, ‘generic mammalian’ form.

The platform is equipped with some of the same expressive appendages available to many mammals allowing mammal-like direct signalling of emotional state and responses to stimuli, for example blinking eyes, articulating neck, wagging tail and ears that move in a distinctly animal-like manner. MIRO also possesses a coloured lighting communication channel on its body and head that has no mammalian correlate. This channel also displays emotional responses to human interaction such as: happiness, enthusiasm, and sulking.

Platform

The MIRO platform is built around a core of a differential drive (plus caster) base and a three-DOF (lift, pitch, yaw) neck. Additional DOFs include two for each ear (curl, rotate), two for the tail (droop, wag), one for the caster (raise/lower), and one for the eyelids (open/close). Whilst these latter DOFs target only communication, the movements of the neck and body that serve locomotion and active sensing play a significant role in communication as well. Finally, the platform produces simulated mammal-like vocal utterances through an on-board speaker.

All DOFs are equipped with proprioceptive sensors (potentiometers for absolute positions and optical shaft encoders for wheel speed). Four light level sensors are placed at each corner of the base, two task-specific ‘cliff sensors’ point down from its front face, and four capacitive sensors are arrayed along the inside of the body shell providing sensing of direct human contact. In the head, stereo microphones (in the base of the ears) and stereo cameras (in the eyes) are complemented by a sonar ranger in the nose and an additional four capacitive sensors over the top and back of the head (behind the ears). Taken altogether, then, MIRO offers a rich and varied sensor/actuator suite.

Control architecture and gross behaviour

MIRO’s control system is a brain model with a layered architecture (see Figure 2) [10]. That is, its most fundamental organising feature is the presence of sensorimotor loops layered on top of one another, so that lower loops function without the help of higher loops, but higher loops can modulate the behaviour of those lower down. Low-level loops implement reflex-like behaviours, immediate responses to sensory information that make use of neither memory nor signal analysis and can be implemented simply (for instance, soft threshold units respond to cliff sensor signals to inhibit forward wheel motion). Mid-level loops make use of short-term memory and within- and cross-modal signal relationships to implement ‘hard-wired’ behaviours that require co-ordination across motor systems (a major centre is a model of superior colliculus that represents recent salient events in a multi-modal map of egocentric space and responds to specific ‘innate’ stimuli with directed action).

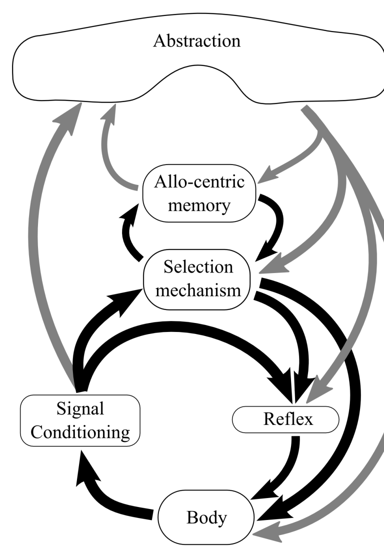

Figure 2. MIRO’s brain-based layered control system. Loops at the lowest level are the least abstract, computing behaviours directly in the signal spaces of sensors and actuators. Abstraction, depth of memory, and complexity of computation all increase in progressively higher loops. Mid-level loops are focused on action selection (including selection of spatial targets). Even the highest loops can modulate directly the behaviour of the lowest, as required.

High-level loops use arbitrarily deep memory and inter-signal relationships to implement cognitive competences (reinforcement learning provides the ability to 'train' MIRO to perform simple stimulus-response tasks, for example).

Whilst this three-level breakdown is simplified, it conveys well the architectural principle of layers of increasingly sophisticated processing, with each layer making an important contribution to overall behaviour rather than being obsoleted by higher processing. In order to arbitrate between behavioural sub-systems at mid and high levels we implement a model of the basal ganglia in an abstract form as used in several previous robots. Thus, MIRO's gross behaviour emerges from the competition between various sub-systems to explore locations with high sensory salience, escape from stimuli that are perceived as threatening, seek out goals (such as a charging station), have social exchanges with an interacting human, and so on.

Modelling and expressing affect

MIRO represents affective state using the circumplex model [9]. This model represents emotions (as well as, on the longer term, moods and temperaments) as points in a space having dimensions of valence and arousal. These dimensions are purported to have neural correlates whilst terms used to describe emotions (such as 'excited') are cast as locations in this space. This stands in contrast to 'basic emotions' theory which considers individual emotions (such as 'excitement') to correspond to discrete neural systems. These models are remarkable for their clarity and accessibility for the non-psychologist, as well as for their light computational weight, and have, accordingly, received some attention from roboticists (including at ACE, [7]).

Figure 3. (Top) MIRO is equipped with six LEDs under its body shell through which it can display arbitrary light patterns in a bid to communicate affect. Here shown in blue, neutral mode. (Bottom) Prototype artwork showing original conception of signaling LEDs.

MIRO displays affective state through its behaviour. Affect is fundamental to MIRO's functional behaviour because gross behaviours (such as approach, or flight) have unambiguous emotional correspondences and are, correspondingly, facilitated or suppressed by affective state. Affect is also communicated directly and explicitly through its encoding in MIRO's non-locomotory movements. MIRO has mobile ears, eyelids, and tail expressly for the communication of affect, but body configuration movements are also driven by emotions. Consistent interpretation of the body language of animals by humans has been demonstrated [12]. Moreover, the use of human-like body language in humanoid robots is effective for communication of emotion to naïve humans [1]. An example of MIRO's behaviour motivated by this is the robot's expression of positive and negative affect via the wagging or drooping of its tail respectively, a component of the robot's behaviour inspired by that of dogs.

In addition, MIRO is equipped with six RGB LEDs (three on each side) under its body shell that can be controlled dynamically (at up to 50Hz). Through these, MIRO can display arbitrary light patterns that change in parameters, such as colour and rate, in a bid to communicate affect (see Figure 3).

MIRO: MORE THAN EDUTAINING

MIRO was conceived as a commercial product accessible to the general public, and has excellent affordability: the current configuration can be manufactured for around USD250. Whilst a MIRO-like platform would need some development for, for example, the healthcare market, maintaining affordability will make companion robots accessible in very considerable volumes, with a consequent impact on their relevance not only as a healthcare tool, but as a useful platform in other domains as well.

Healthcare

MIRO's biomimetic design provides it with an ability to attend to, and communicate with its user in an effective social manner. This indicates its potential as a social healthcare robot akin to PARO. PARO is one of the most active commercial examples of a companion robot used as a therapeutic tool. It is sold on the premise that it will interact with human beings guiding their emotional attachment to it. It does this by engaging its user with basic capabilities such as sensing touch, expressing utterances and small movements. The relationship that develops between a user and PARO is built upon the limited reactions the robot makes to the user's spoken and physical actions [6]. PARO is designed for, amongst other things, use in therapy attended by individuals suffering from conditions of cognitive decline. MIRO's considerably richer emulation of mammalian behaviour (and richer representation of emotional and functional state) has the potential to offer even more effective emotional engagement than has been achieved using tools such as PARO.

Education

As an edutainment robot MIRO is marketed for domestic use. However, its rich sensor/motor suite and accessibility to user modification (primarily through user programming) is expected to allow a more general role as a pedagogical tool for the schools market. Built as a long-term project, in a structured educational environment, MIRO can be used to supplement existing curriculum components which target teaching students about robotics, biomimetics and biology.

Research

Finally, MIRO's accessible architecture and biomimetic morphology make it an attractive platform for researchers in fields such as biomimetic robotics, and robotics more generally.

Indeed, MIRO is beginning to be used for research already. For example, whilst coloured light displays offer rich expression and low cost, changing patterns of lights – in contrast to body language – do not have a direct biological analogue (though see cephalopods). Can such patterns of lights serve to communicate mood? Certainly, cultural associations exist for parameters such as colour – red/green for traffic lights is an almost universal contemporary code, for example – but a clear picture on universal responses to colour has not emerged. Moreover, it is not clear in what way colour associations would translate to perception of the affective state of a robot, nor whether these perceptions would be reliable in a naïve user. In a recent pilot study [4], MIRO has been used to begin to investigate these questions directly.

MIRO will also be made available as a development platform to research laboratories worldwide, facilitating contributions to the development of MIRO's functionality.

DISCUSSION

The MIRO robot is a low cost, attractive, edutainment product, with an extensive suite of sensory and motor peripherals. However, these same features render MIRO an attractive platform for research, education, and clinical use in healthcare. MIRO is an example of a new class of robots, designed with the end-user in mind, that are now finding their way out of the labs and into the commercial world.

ACKNOWLEDGEMENTS

The MIRO project is funded by Eaglemoss Publishing, and developed by a partnership with Eaglemoss, Sheffield Robotics, Sebastian Conran Associates, Gadgetlab and Buzzamo. Emily C. Collins is supported by an ESPRC Doctoral Training Award and a JSPS Fellowship. Tony Prescott is part-sponsored by the European Union Framework 7 projects Convergent Science Network (FP7-ICT-601167) and EASEL (FP7-ICT-611971).

REFERENCES

[1] Beck, A., Hiolle, A., Mazel, A., and Cañamero, L. 2010. Interpretation of emotional body language displayed by robots. In *Proceedings of the 3rd international workshop on Affective interaction in natural environments*, pp. 37-42.

[2] Breazeal, C., and Scassellati, B. 1999. How to build robots that make friends and influence people. In *Intelligent Robots and Systems, IROS'99 Proceedings*, pp. 858-863.

[3] Bruce, A., Nourbakhsh, I., and Simmons, R. The role of expressiveness and attention in human-robot interaction. 2002. In *Proceedings of ICRA'02 IEEE International Conference on Robotics and Automation*, vol. 4, pp. 4138-4142.

[4] Collins, E. C., Prescott, T. J., and Mitchinson, B. 2015. Saying it with light: A pilot study of affective communication using the MIRO robot. In *Biomimetic and Biohybrid Systems*, p. In Press.

[5] Collis, G. and McNicholas, J. 1998. A theoretical basis for health benefits of pet ownership: Attachment versus psychological support. In *Companion animals in human health*, C. Wilson and D Turner, Eds.: Sage Publications, pp. 105-122.

[6] Kidd, C., Taggart, W., and Turkle, S. 2006. A sociable robot to encourage social interaction among the elderly. In *Proceedings 2006 IEEE International Conference on Robotics and Automation*, pp. 3972-3976.

[7] Martínez, J. I. 2014. "emoPuppet: low-cost interactive digital-physical puppets with emotional expression. In *Proceedings of the 11th Conference on Advances in Computer Entertainment Technology*.

[8] Mutlu, B., Shiwa, T., Kanda, T., Ishiguro, H., and Hagita, N. 2009. Footing in human-robot conversations: how robots might shape participant roles using gaze cues. In *Proceedings of the 4th ACM/IEEE international conference on Human robot interaction*, pp. 61-68.

[9] Posner, J., Russell, J., and Peterson, B. 2005. The circumplex model of affect: An integrative approach to affective neuroscience, cognitive development, and psychopathologyy- chopathology. *Development and psychopathology*, vol. 17, no. 03, pp. 715-734.

[10] Prescott, T. J., Redgrave, P., and Gurney, K. 1999. Layered control architectures in robots and vertebrates. *Adaptive Behavior*, vol. 7, no. 1, pp. 99-127.

[11] Robinson, H., MacDonald, B., Kerse, N., and Broadbent, E. 2013. The psychosocial effects of a companion robot: a randomized controlled trial. *Journal of the American Medical Directors Association*, vol. 14, no. 9, pp. 661-661.

[12] Wemelsfelder, F., Hunter, A., Paul, E., and Lawrence, A. 2012. Assessing pig body language: Agreement and consistency between pig farmers, veterinarians, and animal activists. *Journal of animal science*, vol. 90, no. 10, pp. 3652-3665.