Towards a Performative Body Mapping Approach

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Abstract. This paper presents a proposal for a creative robotics approach to human-robot interaction. The 'Performative Body Mapping' method exploits the expertise of artists and performers to imagining novel robot morphologies and movements. The proposed approach describes a mapping method between human and robot bodies, which supports the learning of socially meaningful interactions through imitation.

1 INTRODUCTION

This paper proposes a Creative Robotics approach to human-robot interaction that explores non-humanlike morphologies for robots and their capacity to move and behave in ways that are socially meaningful to humans.

Creative Robotics is an emerging research area in experimental arts that brings together methods from a range of fields including robotic art, sculpture, interactive art, robotics and artificial intelligence. Embedded within a critical discourse, Creative Robotics looks at human-robot interaction from a broad cultural perspective and develops new artistic practices for producing and probing meaningful relationships. As such, Creative Robotics is in direct dialogue with the field of Human-Robot Interaction.

Artists have innovated in robotics to create 'living' sculptures and machine environments since decades. Important examples include Ihnatowicz's pioneering work *The Senster* (1970) that moved in response to movements and sounds in its environment. Using an approach that came to dominate robotics research from the late 1980s onwards, *The Senster* implemented a small set of simple behaviours that combined to produce seemingly more complex ones. With *Petit Mal*, Simon Penny aimed to produce a robotic artwork, "which was neither anthropomorphic nor zoomorphic, but which was unique to its physical and electronic nature" [7]. Mari Velonaki's *Fish-Bird*, comprising two robot wheelchairs developed in association with the Australian Centre for Field Robotics, demonstrated that irrespective of the robots' form their behaviours could convey a social capacity [14]. Both authors have collaborated on *Accomplice*, a large-scale robotic installation that turns the walls of a gallery into a playground for a colony of artificially curious machines (see Figure 1) [6]. One could argue that over the past 50 years, robotic art has demonstrated that movement, more so than appearance, is key to human recognition of a robot's responsive and social qualities.

The motivation for developing this Creative Robotics study is to empirically test the hypothesis that movement is fundamental to a robot's capacity to carry social agency. Currently, much research in human–robot interaction is based on the assumption that robots that appear human- or pet-like are easier for people to relate to and communicate with [5]. In contrast, we seek to imagine robot morphologies and movement abilities that don't mirror humanlike or animal-like bodies and behaviours. The challenge then is to understand how this 'strange' robot body can move and express itself in ways that humans can relate to and feel comfortable with. Thus, the objective of this study is to explore how to efficiently teach a non-humanlike robot to move according to its own machine embodiment, whilst imbuing it with a sensitivity for the shapes, rhythms and textures of human movements and gestures.

The following section will introduce a human-robot interaction methodology, currently being developed by the authors, that focuses on a non-humanlike robot's capacities of movement, in order to open up a much wider range of potential social robot morphologies. The authors would like to share these ideas to gain feedback from the Human-Robot Interaction community in the early stages of the research development.

Figure 1. *Accomplice*, detail.

2 PERFORMATIVE BODY MAPPING

The 'Performative Body Mapping' (PBM) methodology addresses two core open questions that have emerged from research in Human-Robot Interaction (HRI): how should a social robot behave, and, directly related, how does a social robot look like? In addressing these open questions, this research will attempt to tackle two fundamental assumptions in HRI, as identified by Dautenhahn [5]: the robot's ability to interact 'naturally' and the need for a social robot to appear humanlike.

A robot's embodiment and with it, its capacity to perceive and act, significantly differs from the human, independently of how humanlike it may appear. This capacity determines the

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perceptual world in which the robot acts—its *umwelt* [13], thus human and robot are each embedded in their own distinct *umwelt* [17]. The PBM methodology proposed here aims to open up the possibility for both human and robot to bodily negotiate their two *umwelts*. Complementing expert knowledge and methods from human-robot interaction with expert knowledge and methods from interactive art, performance, choreography and dramaturgy, the research will foreground meaning making through movement and aesthetics of experience in human-robot interaction.

The following describes our proposed PBM approach to the design and development of sociable, non-humanlike robots, comprising three phases and learning cycles.

Phase 1: Design, Build—Learning Cycle 1

The first phase focuses on the design of the robot morphology. The underlying concept draws upon the 'body sculptures' of renowned artist Rebecca Horn, in particular the 'Mechanical Body Fan' (1974), a soft radial fan, stretched by metal ribs, measuring three meters in diameter. The 'Mechanical Body Fan' was attached to a performer, whose movements reconfigured the body fan, creating constellations of planes that seemingly mark intersections between her body and space. The notion of 'body sculptures' allows for the imagining of a body that is different to the human in shape, structure, and ability to move, but whose movements can still be negotiated by a human body (see diagram of 'Mechanical Body Fan' illustrating a model for possible non-humanlike robot morphologies in Figure 2). This dramaturgical strategy was pioneered by Bauhaus artist and theatre designer Oskar Schlemmer, who used geometric costumes of substantial volume to transform dancers' bodies and constrain their movements (Figure 3). The costumes for the 'Bauhaustänze' opened-up "a range of possibilities to change bodily relationships to the exterior space" and required the dancers to "develop particular haptic sensibilities" [3].

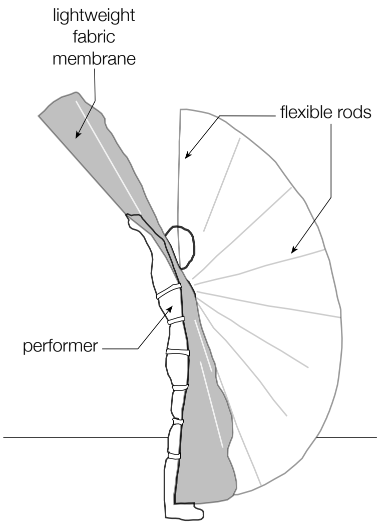

Figure 2. Diagram of *Mechanical Body Fan* as a model for possible non-humanlike robot morphologies

The design process begins with conceiving a non-humanlike 'body sculpture' that fits around, along or in relationship with a human body. This is both a 'sculptural costume' for the performer to inhabit and activate, and a prototype of the robot's eventual body. Criteria for the non-human morphology imagined at this stage are: no obvious front and back; no head or face; no limb-like structures. The objective is to experiment with a geometric and relatively simple/abstract form or frame consisting of articulate planes that effectively constrain and redirect usual human modes of movement. Inhabiting or performing the 'body sculpture' will allow a performer to enact the robot's body and to get a bodily sense for what it can do.

The contours and movement capacity of both this high fidelity prototype ('performed' by human) and the robot's stand-alone body will be virtually the same. For the robot body to become an autonomous agent, the sculpture will be extended with a sensorimotor system that will enable the robot to move its articulated planes in a highly controlled fashion. The sensori-motor system will also include distance sensors to avoid collisions with people and the environment, and wide-angle cameras for detecting faces. These cameras will be hidden to ensure that they will not be interpreted as eyes.

Figure 3. *Triadic Ballet* by Oskar Schlemmer

Following the prototyping and development of the robot morphology, in the first learning cycle the robot will learn how to develop a map of its body and how it can move in relation to the environment through self-exploration. This initial self-exploratory learning will ground the robot's later imitation learning in its specific embodiment. At this stage, we imagine to use 'active motor babbling' [11], a technique from developmental robotics. The robot will learn a sensorimotor mapping between its motor movements, proprioceptive sensors and an external view provided by three 3-D depth cameras (overhead and both sides) that produce a high-density point-cloud representation of the robot and its environment in real-time. This combined feed of external visual information will permit the robot to learn an inverse mapping from body shape to movement, providing a foundation for imitation learning [2].

Concluding this phase will be a workshop study with a performer inhabiting and performing the high-fidelity prototype/model of the robot body design. Here we will explore and record a set of expressive movements and gestures that re-enact everyday social encounters and interactions, as constrained by the robot's body contours. The workshop setting will use the identical 3-D depth camera configuration used in the robot's self-exploratory learning to record the performer's movements.

Phase 2: Imitation Learning, Curious Exploration—Cycle 2

In the second learning cycle, the robot will learn to imitate the recorded movements from the performer, using the high-density point-cloud representation recorded in the first workshop as its video input, but with the performer's human body digitally erased. A significant aspect of the PBM method is that the input for the robot's learning is video of the performer inhabiting the model of the robot body, at which times the robot will learn by copying a moving body that looks like its own body. It is thus expected that footage of the performer can be used to drive and expedite the imitation learning. The sculpture approach, by providing training data for the robot, becomes a liminal resource for 'bootstrapping' the robot's learning.

Once the robot has learned to imitate the given set of movements and gestures from the workshop study in Cycle 1, it will learn to extend and modify them based on what its different, robotic embodiment affords it to do. Methods from computational creativity—in particular the computational modelling of curiosity, in which the motivation for an agent's open-ended learning is the learning itself rather than an externally defined goal [12]—will provide the robot with the motivation to explore combinations of and variations on its movements. This self-motivated adaption of learned movements will allow the robot to expand its repertoire of behaviours.

As part of this learning process, the robot will rehearse its movements in a series of workshops involving the performer. In a feedback loop indicative of social learning in wider society, this process will be repeated as required. We expect the performer to also learn from the robot in these workshops, and each time the robot will again learn to imitate the recorded movements by performer. The performer will also be asked at each stage of the development process to provide feedback on the morphology's potential for expression and its ability to successfully imitate the expressive qualities of the recorded movements. If specific problems are identified, this may result in alterations to the robot's morphology, which in turn would be reflected in the model performed by the performer.

Phase 3: Turn-taking, Social Interaction—Learning Cycle 3

The final phase introduces social interactions. The robot will learn to move in direct response to a person's movements and to elicit response from a person in real-time, based on *robot–human interaction kinesics* [9]. In a further series of workshops, the performer will again inhabit the robot model (original 'sculpture'), this time enacting the robot in improvising social scenarios with another person (not in 'costume').

To facilitate the learning for the robot, these social scenarios will be limited to turn-taking interactions [9], again captured by the three 3-D depth cameras as a high-density data-cloud, and again with the performer's human body digitally erased. This 3-D external view will provide the robot with the same 'pedagogical' set-up as in the previous cycles, with the addition of an interlocutor with whom it needs to learn to correlate its mappings. The next workshop will then involve the robot in *direct* social interaction with a non-costumed human, attempting its first *socially interactive*, turn-taking gestural conversations. Turn-taking will permit the robot to put into practice its repertoire of behaviours in engaging an interlocutor socially. The robot will learn simple cue and response pattern and attending to different rhythms and timings in its corporeal interaction, which humans are sensitively attuned to in human-human interaction.

Another new skill that the robot will need to acquire in this learning cycle is the ability to recognise simple gestures using a Markov model [1] and respond appropriately based on its learned repertoire of turn-taking interactions.

To further facilitate a more situated interaction between human and robot, this phase will also include an expansion of the robot's reflexes, based on which it will be able to track movements and attend to sounds in the environment [8]. While these are simple automated responses, they provide the necessary social scaffolding for the interaction.

Cycle 3 will conclude with a workshop with a group of performers that serves as rehearsal for an open experiment study, where the robot and its expressive movements and interaction capabilities will be tested in a museum or gallery setting. During the rehearsal workshop, a group of performers will engage with the robot-sculpture to test how it can cope. This will provide useful data to better understand the constraints needed for the open experiment study.

Evaluation in Public Space

The efficacy of the methodology will be evaluated through two studies based on the open experimentation method in creative robotics [14] and the authors' experience in tracking the movements of audience members in interactive art exhibitions. The objective for the public study is to involve non-expert participants in an interaction scenario with the robot, without them being prepared or instructed. The museum or gallery setting is not only chosen for gaining access to a large number of unprepared participants, but also for providing a 'natural' social framing for the study. Studies on social interaction in museum spaces have demonstrated that "social interaction forms a pivotal and a virtually unavoidable part of people's experience of museums" [15].

In the museum, the robot will be presented as a kinetic sculpture, not a social robot, to avoid audience members encountering the robot with already–formed expectations. Visitors, who approach the 'sculpture', will be surprised to be attended to and greeted. One goal of this study is to observe whether the robot will be able to sustain interaction with individual members of the audience and to proactively elicit responses from the audience. Is the 'sculpture' experienced as a social agent? A more typical interaction scenario in the museum context would be for the audience member to engage with the robot to find out 'how it works' or to probe how it can be controlled [4].

Quantitative video analysis will be deployed along multiple dimensions, e.g. proximity and spatial alignment of audience members, duration of engagement [16]. In addition, qualitative results will be gathered using a questionnaire with a series of open-ended questions related to the visitor's social experience.

3 PROTOTYPING SOCIAL ROBOTS

The 'Performative Body Mapping' methodology builds on and extends the Theatrical Robot methodology [10]. In the Theatrical Robot method, an actor or mime artist is disguised as a robot, "behaving according to a specific and pre-scripted robotic behaviour repertoire" [5]. It is used to embody a live-sized robot to simulate humanlike movements and cognition. The following will describe how the methodology, presented here, expands on the Theatrical Robot.

The PBM method involves performers in the early prototyping of both the morphology and the robot's behavioural envelope through the use of low and high fidelity prototype 'body sculptures' worn by the performers. The performers provide expert feedback on the expressive potential of the robot morphology, which is not restricted to humanoid forms but instead can take on any form that can be inhabited by or attached to the performer, e.g., using of props/prosthetics. The performer is not restricted to pre-scripted behaviours but instead is required to improvise movements while taking on the character of a non-humanlike robot. While the 'body sculpture' may impose constraints on the performer, much of the value in the study comes from the embodied knowledge that the performers provide through improvisation.

The interactions in the performative body mapping may also be staged, i.e., with another performer, such that a range of responses to social situations may be recorded in controlled conditions. Similar to the Theatrical Robot, this provides a way of thinking through movement scenarios in an embodied way by allowing experts within the domain, i.e., performers, to communicate their embodied knowledge. Finally, by providing training data for the robot, the 'body sculpture' is not a stand-in for a robot that has not yet been built, but rather a resource for 'bootstrapping' the learning of a non-humanlike robot with socially meaningful movements and interactions.

It is our hope that the morphological mapping between human and robot bodies established within the PBM simplifies the so-called correspondence problem [2] as the robot learns to imitate a human disguised and performing as that particular robot; thus the human teacher 'meets the robot half way'.

REFERENCES

[1] F. Bevilacqua and R. Muller. A Gesture Follower For Performing Arts. In: S. Gibet, N. Courty and J-F. Kamp (eds.) *Proceedings of the 6th International Gesture Workshop* (2005).

[2] A. Billard, S. Calinon, R. Dillmann, S. Schaal. Robot programming by demonstration. In: *Springer Handbook of Robotics*, Springer Berlin Heidelberg, pp. 1371-1394 (2008).

[3] J. Birringer. Bauhaus, Constructivism, Performance. In: PAJ. A Journal of Performance and Art 35:2, 39-52 (2013).

[4] O. Bown, P. Gemeinboeck, R. Saunders. The Machine as Autonomous Performer. In: L. Candy, S. Ferguson (eds.) *Interactive Experience in the Digital Age. Evaluating New Art Practice.* Springer, 75-90 (2014).

[5] K. Dautenhahn. Human-Robot Interaction. In: Soegaard, Mads and Dam, Rikke Friis (eds.) *The Encyclopedia of Human-Computer Interaction*, 2nd Ed. Aarhus, Denmark: The Interaction Design Foundation, http://www.interaction-design.org/encyclopedia/human-robot_interaction.html (2013).

[6] P. Gemeinboeck and R. Saunders. Creative Machine Performance: Computational Creativity and Robotic Art. In: Maher, M.L., Veale, T., Saunders, R. and Bown, O. (eds.) *Proceedings of the Fourth International Conference on Computational Creativity*, University of Sydney, Australia, 215–219 (2013).

[7] S. Penny. Embodied Cultural Agents: At the Intersection of Art, Robotics, and Cognitive Science. In: *Socially Intelligent Agents: Papers from the AAAI Fall Symposium*, AAAI Press (1997).

[8] R. Pfeifer and J. Bongard. *How the body shapes the way we think — a new view of intelligence*. MIT Press (2007).

[9] B. Robins, K. Dautenhahn, C.L. Nehaniv, N.A. Mirza, D. Francois and L. Olsson. Sustaining interaction dynamics and engagement in dyadic child-robot interaction kinesics: Lessons learnt from an exploratory study. In: *Procs of the 14th IEEE Int. Workshop on Robot & Human Interactice Communication (RO-MAN 2005)*, 716-722 (2005).

[10] B. Robins, K. Dautenhahn and J. Dubowski. Investigating Autistic children's attitudes towards strangers with the theatrical robot-A new experimental paradigm in human-robot interaction studies. In: *Procs of the 13th IEEE International Workshop on Robot and Human Interactive Communication (RO-MAN 2004),* 557-562 (2004).

[11] R. Saegusa, G. Metta, G. Sandini and S. Sakka. Active motor babbling for sensorimotor learning. In: *Procs of the IEEE International Conference on Robotics and Biomimetics* (ROBIO 2008), 794-799 (2008).

[12] R. Saunders. Towards Autonomous Creative Systems: A Computational Approach. In: *Cognitive Computation*, Special Issue on Computational Creativity, Intelligence and Autonomy, 4:3, 216–225 (2012).

[13] J.v. Uexküll. A Stroll Through the Worlds of Animals and Men: A Picture Book of Invisible Worlds. In: Claire H. Schiller (ed. and trans.) *Instinctive Behavior: The Development of a Modern Concept*. New York: International Universities Press, Inc., 5–80 (1957).

[14] M. Velonaki. Multi-Objective Evaluation Of Cross-Disciplinary Experimental Research. In: *Studies in Material Thinking 8,* AUT University, http://www.materialthinking.org (2012).

[15] D. vom Lehn, C. Heath and J. Hindmarsh. Re-thinking Interactivity. In: *Rethinking Technologies in Museums*. Limerick, Ireland, 29 June 2005.

[16] M. L. Walters, K. Dautenhahn, S. N. Woods, K. L. Koay, R. Te Boekhorst, and D. Lee. Exploratory studies on social spaces between humans and a mechanical-looking robot. In: *Connection Science*, *18*:4, 429-439 (2006).

[17] T. Ziemke, N. Sharkey. A stroll through the worlds of robots and animals: Applying Jakob von Uexküll's theory of meaning to adaptive robots and artificial life. In: *Semiotica*, 134:1-4, 701-746 (2001).