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Grounding emotions in robots – An introduction to the special issue

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Abstract

Robots inhabiting human environments need to act in relation to their own experience and embodiment as well as to social and emotional aspects. Robots that learn, act upon and incorporate their own experience and perception of others' emotions into their responses make not only more productive artificial agents but also agents with whom humans can appropriately interact. This special issue seeks to address the significance of grounding of emotions in robots in relation to aspects of physical and homeostatic interaction in the world at an individual and social level. Specific questions concern: How can emotion and social interaction be grounded in the behavioral activity of the robotic system? Is a robot able to have intrinsic emotions? How can emotions, grounded in the embodiment of the robot, facilitate individually and socially adaptive behavior to the robot? This opening chapter provides an introduction to the articles that comprise this special issue and briefly discusses their relationship to grounding emotions in robots.

Keywords

Emotions, grounding, social interaction, intrinsic processes

1 Introduction

This special issue seeks to address the significance of grounding of emotions in robots in relation to aspects of individual and social embodied interaction. The notion of 'grounding emotions' here most simply refers to *laying the foundations for* levels of emotional complexity that serve adaptive behaviour. It also refers to providing robots and controller systems with processes that through dynamic interaction with the environment (and other processes intrinsic to the controllers) permits more flexible and naturalistic behaviour. Grounding emotions in robots is especially challenging when we consider that morphologically and structurally they are not the products of an evolutionary or self-organized process. It is for this reason, however, that the endeavour to imbue in robots emotional processes that enable, and emerge from, interactive processes is so important to adaptive behaviour.

Different emphases on the relevance of grounding emotions have been posited. Ziemke and Lowe (2009), Lowe, Sandamirskaya, and Billing (2014) and Vernon, Lowe, Thill, and Ziemke (2015) have offered perspectives on grounding affective and emotional processes in cognitive robotic architectures where self-organized dynamics are suggested to promote autonomous behaviour. Cañamero (2001) and Cañamero and Avila-García (2011) have imbued robots with controller systems abstractly simulating physiological drives and hormones to thereby ground affective, and adaptive, interactions in the environment. Grounding emotions in reinforcement learning signals has also been an approach of interest in recent years (Balkenius, Morèn, & Winberg, 2009; Broekens, Jacobs, & Jonker, 2015; Lowe et al., 2014) where different reinforcement contingencies, e.g. reward, punishment and omission thereof, can be associated with different 'corrective' behaviours. Finally, grounding emotions and affective states in interactions of a social nature (human-robot interaction) has also been the focus of much emotions research (e.g. Barakova & Lourens, 2010).

The selected articles, briefly introduced below, relate to the above themes on grounding emotions in robots according to issues of embodiment and social and non-social environmental interaction. Such grounding is found to promote adaptive behaviour in robots in

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relation to foraging, exploration, morality, emotion expression and recognition and joint (inter-)action.

2 The selected articles

The articles in this special issue concern how emotions can be grounded and spontaneously emerge out of behavioural interaction with the environment. In this case the 'environment' can be both social and physical (non-social).

In the article of Lewis and Cañamero, the theme of grounding the affective state of pleasure, specifically 'liking', in homeostatic processes is addressed. The authors claim this process is grounded in (survival-related) physiological needs but also hedonic states that are not directly related to need satisfaction. In their work, the authors test a hormonal modulation model of pleasure within an action selection architecture on a minimalist decision-making problem – the so-called two-resource problem. They utilize this hormonal model in different conditions that test the homeostatic versus hedonic adaptive use of such signals. This mechanism, when tied to homeostatic states, bears some similarities to the use of arousal as a behavioural compensatory mechanism (Kiryazov, Lowe, Becker-Asano, & Randazzo, 2013) albeit here the hormonal mechanism is used in a perceptual context. The use of the pleasure modulating hormone for either need satisfaction or hedonic signalling was most adaptive depending on the type of environment (resource accessibility difficulty and abundance of resource types) that the robot imbued with the mechanism faced.

The embedding of emotion features/variables into reinforcement learning algorithms also features in this special issue. Gao and Edelman, in their article, utilize a reinforcement learning approach in emotional grounding, testing their algorithm on a set of related foraging tasks. Their focus, similar to Lewis and Cañamero, is on intrinsic value states, here imbuing 'dynamic states of well-being' (happiness). Happiness here consists of hedonic (short-term) and eudaimonic (longer-term) reward not directly tied to fitness measures. Such fitness measures for the authors concern *exploration* and foraging at different challenge levels. The authors find that a 'happiness' reward function combining hedonic and eudaimonic aspects outperforms other reward functions in the different environments. Embedding emotion-like variables within a reinforcement learning process thereby improved adaptive behaviour. The article of Balkenius et al. focuses instead on providing principles for grounding an intrinsic morality into robotic agents emphasizing the use of reinforcement learning signals. The authors here look at emotions and affective states emanating from experienced rewards and punishers (and omission thereof), taking from the modelling approach of Rolls (1990). Learning of reinforcer contingencies helps to physiologically ground internal values that provide a root for social values once similar states are detected in others and the causal effects of such states are apprehended. The minimalist approach proffered to imbuing robots with morality provides the scope for robots to learn about moral and social values according to experience and their own individual concerns, something not feasible if such morality is imposed upon them (hard-coded) by a designer.

The articles of Vallverdù and Bonarini posit frameworks for imbuing robots with emotion perceptual and emotion expressive properties grounded in embodied interactions in the environment. Vallverdù provides a taxonomy of emotional affordances that can emerge from particular (e.g. culture-differentiated) interactions between humans and be used thereby in robots for facilitating human-robot interaction (HRI). For the author, emotional affordances are taxonomized according to *Bodily* (e.g. haptic, visual, auditory), *Social* and *Other*. The last includes includes non-conscious and non-deliberative processes that influence interaction (e.g. may signal some affective state in the human). The purpose of such a taxonomy is to guide roboticists into appropriately designing their robots such that emotional activity adaptively emerges out of interactions with humans. Bonarini's article, on the other hand, discusses principles for grounding emotion expression through embodied processes, specifically movement. Components of movement such as acceleration, rhythm, speed and other bodily dimensions provide constituents of this emotion expression grounding. The framework is described with the use of examples showing how different robots with particular properties of movement, e.g. rotation and speed, imbue actions characteristic of different primary emotions. Such grounding helps robots (and robot designers) avoid the 'uncanny valley' effect so common when robots (especially humanoid robots) reach a particular level of behavioural and morphological complexity. Indeed, the articles of both Vallverdù and Bonarini stress the need for grounded approaches to emotional activity so as to increase the believability of robots that interact with humans.

The work of Silva et al. and Barros and Wermter focus on robotic algorithms for emotion detection in humans grounded in interactive processes both within the robot control architectures and through exploiting the interactive dynamics of the environment. Silva et al.'s article focuses on the role of emotions in the specific (human-robot) interactive domain of Joint Action (cf. Sebanz, Knoblich, & Prinz, 2005), i.e. tasks that require two or more inter-actors for resolution. The use of neural fields for the different components of the robot control architecture permits emergent interactive dynamics between human and robot. Emotion state representations are influenced by perceptions of errors in the joint task and provide output to action units concerned with both decision making and emotion expression. This implements a feature hypothesized to play an important role for emotions in joint action (Michael, 2011). Perception of different human emotion states allows the robot to adjust its behaviour in a manner that facilitates the joint action. The interaction of the different components, including the field for representing emotional state detection, permits a further level of grounding of emotional interaction adding to the flexible and adaptive nature of the (joint) action. Silva et al.'s architecture uses a FACS (facial action coding system)-based approach to recognize emotions, addressing a challenge of using such a face recognition system in a robot which operates in a dynamic and noisy physical environment. Barros and Wermter, on the other hand, provide an account of a deep learning based architecture (using convolutional neural networks) that is able to spontaneously learn the emotional states of human inter-actors based on visual and auditory information. Rather than using a FACS-emotion decoding approach, which requires much data, their algorithm specializes in learning emotion states on-the-fly. This may be particularly useful in robotic systems that act in the real world and are required to be particularly flexible regarding the context and potentially noisy emotional sensory inputs that are perceptible. Furthermore, the use of self-organized maps and classification of states thereafter allows for the mimicking of a sort of developmental approach that could be used to ground recognition of emotional states in robots.

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References

Balkenius, C., Morèn, J., & Winberg, S. (2009). Interactions between motivation, emotion and attention: From biology to robotics. In L. Cañamero, P.-Y. Oudeyer, & C. Balkenius (Eds.), *Proceedings of the Ninth International Conference on Epigenetic Robotics: Modeling Cognitive Development in Robotic Systems. Lund University Cognitive Studies, 146*. Lund: LUCS.

Barakova, E. I., & Lourens, T. (2010). Expressing and interpreting emotional movements in social games with robots. *Personal and Ubiquitous Computing*, *14*, 457–467.

Broekens, J., Jacobs, E., & Jonker, C. M. (2015). A reinforcement learning model of joy, distress, hope and fear. *Connection Science*, *27*(3), 215–233.

Cañamero, L. (2001). Emotions and adaptation in autonomous agents: A design perspective. *Cybernetics & Systems*, *32*(5), 507–529.

Cañamero, L., & Avila-Garcìa, O. (2011). A bottom-up investigation of emotional modulation in competitive scenarios. In *Emotion-oriented systems* (pp. 427–440). Berlin Heidelberg: Springer.

Kiryazov, K., Lowe, R., Becker-Asano, C., & Randazzo, M. (2013). The role of arousal in two-resource problem tasks for humanoid service robots. In *2013 IEEE RO-MAN* (pp. 62-69). IEEE.

Lowe, R., & Kiryazov, K. (2014). Utilizing emotions in autonomous robots: An enactive approach. In *Emotion modeling* (pp. 76–98). Springer International Publishing.

Lowe, R., Sandamirskaya, Y., & Billing, E. (2014). A neural dynamic model of associative two-process theory: The differential outcomes effect and infant development. In *4th international conference on development and learning and on epigenetic robotics* (pp. 440-447). IEEE.

Michael, J. (2011). Shared emotions and joint action. *Review of Philosophy and Psychology*, *2*(2), 355–373.

Rolls, E. T. (1990). A theory of emotion, and its application to understanding the neural basis of emotion. *Cognition & Emotion*, *4*(3), 161–190.

Sebanz, N., Knoblich, G., & Prinz, W. (2005), How two share a task: Corepresenting stimulus-response mappings. *Journal of Experimental Psychology: Human Perception and Performance*, *31*, 1234–1246.

Vernon, D., Lowe, R., Thill, S., & Ziemke, T. (2015). Embodied cognition and circular causality: On the role of constitutive autonomy in the reciprocal coupling of perception and action. *Frontiers in Psychology*, *6*. DOI:10.3389/fpsyg.2015.01660

Ziemke, T., & Lowe, R. (2009). On the role of emotion in embodied cognitive architectures: From organisms to robots. *Cognitive Computation*, *1*(1), 104–117.

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