The Role of Emotions in Inter-Action Selection

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Keywords: human-robot interaction; artificial emotions; social behaviour

Faragó et al (hereafter FMS&G) draw attention to an important issue for researchers of human-robot interaction (HRI): can we conceive a scheme for making social robot behaviour both comprehensible and appropriate in human social settings? We agree with the authors concerning the potential utility of drawing on the example of domestic animals — particularly dogs, the species with which we have the longest history of co-evolution as social interactors. Here we seek to extend from the authors emphasis on the detail of species-specific interaction to a general blueprint for robot action selection. We particularly emphasise the integral role of emotions in facilitating social inter-action selection as social signals of internal agent states that are relevant to joint action.

Our research questions concern the general abilities of artificial agents, particularly robots, to express their current, transient internal states in ways that people find comprehensible and acceptable. This requires that researchers consider not only the potential communicative value of a social signal but also the validity or utility of the internal state which it describes. Were it the case that the role of the human was to correctly identify a signal, as a passive observer of the robot, it would be a simple matter to construct a repertoire of discriminable social actions. However, this leads us to an important issue in HRI research not emphasised by FMS&G : the nature of interaction itself as a concept that requires simultaneous consideration of the actors and the acted-upon. Dynamic selection decisions for emotional signalling must depend on considerations that span human and robot: a question of emotional inter-action selection.

1 Interaction must support the construction and refinement of human mental models

Interaction differs from individual action in that it requires consideration of at least two entities: the actor and the acted-upon. An action can be described uniquely (if rather unsatisfactorily) in terms of the behaviour of a particular actor in isolation. An attempt to describe interaction in such a way is meaningless. Since the Norman [16] Theory of Action, human-computer interactions are typically understood as a cycle of: goal-directed plan formulation based on an internal model of the effects of a particular action on an object or system, execution of the plans, observation of the result, and reformulation. Reformulation may include updating the agents internal model, alteration of the plan, or alteration of the internal model, and may be conducted on-the-fly to compensate for low-level execution errors [15]. In the human case, the internal model is typically referred to as a 'mental model' of a system with which a person interacts — a model that encapsulates a person's own understanding of that system and their capabilities with respect to it. As humans automatically ascribe agency to robots, any robot's signalling mechanism will naturally be treated as indicative of its internal functioning, and human 'mental models' of the robot will be constructed accordingly. As a result, a signalling system that is intended only to improve the superficial acceptability of a robot will almost certainly not succeed. It is necessary to consider how one might engineer a meaningful relationship between any robots internal state and the social signals it produces.

As FMS&G correctly state, social communication is typically identified with affective states. It is less clear that the authors recognise that many emotional states are not simply broadcast but are often directed at other agents in particular. Social communication may be exclusively about interpersonal affective attitudes (John smiles at Jane →John likes Jane) or combined with other social significance (Jane smiles at and motions John towards a café →Jane likes John and proposes that they eat together). In the case of social robots, we can expect mental model generation to be facilitated by the human tendency to anthropomorphize any system with uninspectable internal states. McCarthy [12] famously argued that more humanly manageable interactions result from the ascription of mental qualities to machines, especially beliefs, knowledge, intentions, and wants. It is quite simply easier for people to understand machines in these terms than in terms of their underlying architecture or functionality. Consequently, people routinely attribute affective states to machines as part of a "social actor" strategy for informally modelling hidden processes [19]. Moreover, people anticipate that such objects or agents will respond to them in emotional ways [4].

2 The Value of Emotions in Social Human-Robot Interaction

Emotions are not only key to reducing dithering and stabilising individual action selection [3], but also joint inter-action selection. As such, they are an important part of the embodiment necessary for social interaction [5]. For the purpose of this commentary, we refer to emotional action selection as action selection based on temporary but durative state triggered by response to observed events combined with internal motivation. To demonstrate the value of emotions in social HRI we turn to the list of social skills highlighted by FMS&G: cooperating, communicating in different modalities (e.g. visual and acoustic), and showing individuality. We analyse these from a constructivist perspective [6] taking particular account of the role of emotions.

2.1 Emotions in Cooperation

Cooperation is an important social skill, well developed in dogs and certainly useful to implement in social robots. However, it would be difficult to associate cooperation with specific behavioural patterns. Rather than looking for a specific personal behaviour which accompanies human-robot cooperation, it could be more useful to focus on general facilitators of and influences on cooperation.

The persuasion approach to cooperation indicates that cooperation increases after the presentation of persuasive messages [22]. Persuasion here is understood as a form of social influence [1], a way to influence people through communication without using force. In order to persuade it is necessary, among other things, to induce or evoke affective states (whether moods, sentiments or emotions). Although effective non-emotional verbal persuasion techniques certainly exist, non-verbal messages are of the greatest importance in persuasion [13], and the emotional component, in at least some conditions, has been shown to have priority over the informational one [14].

The topic of affective persuasion is addressed in many disciplines, including marketing, law, and politics, as well as in daily life. However, little work is currently done on the role of emotions in influencing human behaviour in the area of HRI [7].

2.2 Emotions in Communicating Personality and Individuality across Modalities

FMS&G claim that a behaviour of a dog wagging its tail can be considered as a part of a greeting behaviour, "probably signalling the excitement". The authors also suggest using a general visual signal as "a functional analogue of a tail, with similar dynamics but different appearance and position". The authors do not explain clearly what is considered to be a primary function of a dogs tail wagging and how different its implementation should be in a robot. Researchers explain a functionality of tail movements both in dogs and in other animals in many different ways, e.g. female goats stimulate sexual interest from a male by wagging a tail [8], a cat's tail plays an important role in balance during locomotion[25]. Even in dogs, much is communicated by the height and stiffness of the tail as well as the rate and enthusiasm of its wagging [11], and even the direction of its wagging [24]. One very important function of tail wagging and many other gestures in dogs is expression of dominance status. To humans they often express subordinate status, a fact that may be critical to the health benefits of canine companions. This important aspect of the relationship between humans and dogs may also explain some of the dogs' responses to unusual anti-social behaviour by their owners.

Obviously (and as the authors imply) robots have very different appearances, and it is unlikely that a direct simulation of dogs' tail-wagging behavior can help every robots signal excitement (or subordinance) in all the situations. On the other hand, it should be possible to express internal state of a robot in an understandable way using a variety of modalities at once — facial expressions (where a face is present) [23], gestures [20], sounds [18], language [10], colour, brightness, and even the overall shape of a robot [9]. It is also possible that it is worth adding effectors for communicating emotion, as has been highly successful with the ears of Kismet [2]. Such a multi-modal approach helps to make robots both more acceptable and more understandable for people, and to make them appear more individual and independent, thus increasing their life-likeness through emerging of a robots ‘personality’.

In consideration of the results FMS&G present, it is also worth remembering first that dogs and owners all have individual personality, and not every dog/owner coupling will be equally well suited. This will also be a consideration for robotics: some owners will want more or less proactive, confident, open or attentive robots. Second, dogs are cognitive systems. Some of their orientation behaviour will not be merely communicative but also triggered by uncertainty in an unusual situation and the need to gather more information. But in closely-coupled agents, every action is also an interaction, so it is not surprising that these functional gestures are perceived as, and therefore serve as, communicative acts as well.

3 Implications for Research on Affective Interactive Robots

We have argued that emotional state and expression are critical to cooperation, including that between person and machine. Our current work approaches this problem by modelling artificial emotions as internal states that factor into a dynamic action selection process. This process couples the synthetic-emotional state with external cues for communicating discrete emotional states to a human before and during the execution of those actions [17]. Artificial emotions can be connected with the goals of the robot and thus can also be triggered by a list of conditions [2]: e.g. the presence of an undesired stimulus, presence of a desired stimulus, a sudden stimulus, or delay in achieving goal. We are currently experimenting with robots’ internal emotional state represented in two dimensions, following a simple valence and arousal model of human affect [23], though we have also explored discrete representations [3]. There are many possible ways to construct such internal state, given a range of sensor input, goal structure and action feedback; our current approach is to change the state dynamically such that it feeds back into the computation of subsequent levels of intensity, treating robot emotion as a latched process that is tied in to its external expression [21]. The key idea following on from the commentary above is that for robot emotion to function effectively in human interactions, it is necessary to consider the internal relevance of the emotional state for the robots operation so that intelligible mappings can be made to a set of signals for the robots human partner. Without this step, the *social* epithet not only has little meaning but emotion is also unlikely to serve interactions well.

4 Conclusions

For robot behaviour to be understandable to people, it must be designed to facilitate the progressive construction of human mental models. All human mental models are constructed through personal interactions with systems, reflecting the characteristics of those systems and beliefs about the utility and dangers that might arise through their use. Human mental models for social interaction inevitably include social components, especially those that support inferences about internal affective state and external signals and actions. The personal history of an individual with a robot means that each mental model is likely to be unique. Affective states, such as transient emotions, are part-and-parcel of social signalling. An effective design strategy for human-robot interactions depends on an architectural commitment to maintaining robot states that are material to interactions with humans, and that may then be communicated to their human users. The social acceptability of a robot certainly depends on the ability of a person to infer a usable understanding of the robot from its behaviour and signals. However, social acceptability also relates to a broader meaning of social interaction that embeds the rights and responsibilities of social agents towards one another. If signals give rise to unrealistic mental models, they are likely to result in rejection or worse.

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Joanna J. Bryson conducts research in two areas: the development of intelligent systems, and the understanding of natural intelligence through scientific simulation. She holds degrees in behavioural science, psychology and artificial intelligence from Chicago (BA), Edinburgh (MSc and MPhil), and MIT (PhD). She is currently a Reader (Associate Professor) at the University of Bath where she leads the Intelligent Systems research group, and a visiting research fellow at the Mannheim Centre for European Social Science Research. She also heads Artificial Models of Natural Intelligence, where she and her colleagues publish in cognitive science, anthropology, behavioural ecology, philosophy, and systems AI.