Animal–Inspired Peripheral Interaction

Evaluating a Dog-Tail Interface for Communicating Robotic States

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Abstract. Animals use emotions for communicating how they feel, e.g., cats arch their back and dogs show their teeth when angry. We believe that allowing robots to communicate using animal-inspired interfaces (e.g., wagging a tail) will help people understand robots' states in terms of affect (e.g., happy, sad, etc.), serving as a clear peripheral awareness channel. This understanding can help people decide when and how to interact with a robot. For example, by appearing scared, a robot can suggest that it needs help. As an investigation of our work, we built a robotic dog-tail prototype and conducted a user study to explore how various parameters of tail movement (e.g., speed) influence people's perception of affect. The results from this study indicated that people interpret tail motions in consistent terms of valence and arousal. We formed an initial set of design guidelines from the results, and further conducted a design workshop by inviting people working as interaction-designers to design tail motions for various states of robots working in different scenarios (e.g., search and rescue), using our design guidelines. Finally, in this paper, we briefly discuss the user study we conducted, present our initial set of guidelines, discuss the steps we took for testing them, and how we improved them so that they can be readily used by Human-Robot Interaction (HRI) designers to convey affective states of their robots.

Keywords: human-robot interaction, animal-inspired interfaces, affective computing.

1 Introduction

In this rapidly advancing field of HRI, many robotic interfaces, designs and prototypes are built to help people in their day-to-day lives (e.g., the iRobot Roomba vacuum cleaner robot cleans the floor while moving). Interaction with robots might be challenging if people are not aware of the present state of the robot, such as low-battery, etc. In addition, it is also important for robots not to bother people too intrusively by giving them status updates, but maintain a peripheral presence to let people know how and when to interact with them. For example, a dishwasher gives an indicator light to show it is working and you can hear the sound it makes while cleaning – it provides peripheral awareness.

Part of the affective computing tradition in human-computer interaction is to incorporate human or animal-like affect and emotion directly into interfaces [6, 8]. For

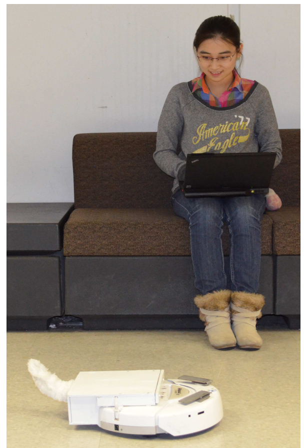

Fig. 1. A person notices the ambient tail state of a cleaning robot

example, a picture frame which uses an ambient color display to communicate emotion between people when they are apart [2]. There is a well-established application of ideas from affective computing to human-robot interaction, where impressions of robotic affect can be used to help users gain high-level state information without requiring them to read complex sensory information [9].

One way of communicating robotic affect is to use animal-inspired interfaces (e.g., dog ears and tails). Zoological research tells us that dogs can convey a broad range of states through their tails, for example, suggesting a happy state by wagging, high arousal or self-confidence by raising, or fear by lowering their tail [1, 3]. In addition, we believe that people understand basic dog tail language such as wagging and high vs. low tail posture. This can be leveraged to understand the present affective state of the robot. For example, when a robot is wagging its tail, it could be considered as being happy (doing its task and does not need attention).

To investigate this, we built a robotic tail prototype to enable an iRobot Create (a disc-shaped robot that resembles a Roomba except that it does not a have a vacuum) to communicate its states (Fig. 1). In addition, we conducted a formal exploratory user study (20 participants) to investigate how people perceived the affect of three tail behaviors: wags - tail moving in horizontal, vertical and circular patterns, static - tail keeps a pose, and discrete gestures such as raising and lowering the tail, which happened at timed points. Movement parameters were systematically varied, e.g., high, medium and low speeds and wag sizes, height and offset of wag, and so forth, to result in 26 distinct tail motions. Participants rated each motion in terms of valence and arousal using Self-Assessment Manikin (SAM), a psychological instrument for rating affective states on Russell's circumplex model of affect [4, 5]: this classifies affect on an arousal dimension (level of energy) and valence dimension (positive versus negative). We found significant results via within-subjects repeated-measures Analysis of Variance (ANOVAs). One such result is Speed by Wag type (as shown in Fig. 2). The results from this study (published in full detail [7]) were used to form a set of prelimi-

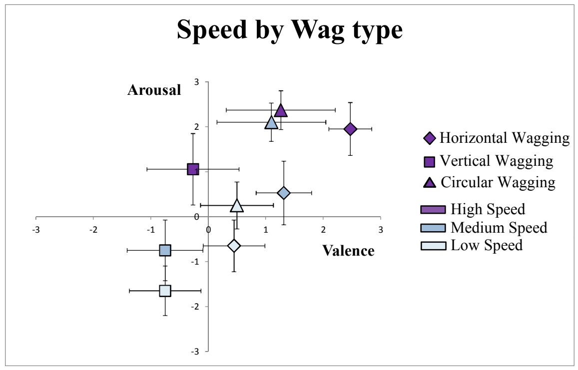

Fig. 2. Average responses (error bars are 95% confidence interval) for low-high speed of horizontal, vertical, and circular wagging. Significant effects (p<.05) were found of: a) speed on both valence and arousal, and b) wag type on both valence and arousal. In addition, for valence, vertical wagging was rated significantly lower than horizontal and circular (no significant results were found between horizontal and circular wags). For arousal, all wag types were rated significantly different (for full statistical details see [7]).

nary design guidelines to help HRI designers in conveying the affective states via a dog-tail interface.

Although, we developed our design guidelines, we did not yet know if these could be readily used by the HRI designers and if they can be further improved to be easy to read and use. To investigate this, we conducted a design workshop where we invited people working as interaction-designers and asked them to design tail behaviors for a set of possible states of robots' working in different scenarios (e.g., healthcare robot taking care of people at a hospital)

In this paper, we briefly describe: our preliminary design guidelines, a design workshop we conducted to evaluate our approach, and the results of this workshop. We believe that this is an initial step in exploring how animal-inspired interfaces can be used by robots to communicate affective states to help people decide when and how to interact with them, for peripheral awareness.

2 Preliminary Design Guidelines

We found that the tail was able to convey a broad range of affective states and that people reliably interpreted the tail motions in a consistent fashion. Through informal pilots, we summarized our results into design guidelines for HRI designers for communicating affective robotic states via dog-tail interfaces. Our design guidelines comprised of having each tail behavior in terms of: motion type - parameter (e.g., horizontal wagging - high speed), level of happiness (valence) and energy (arousal) and a descriptive keyword (emotional adjective) conveyed by that particular tail behavior (Fig. 1). Some of the tail characteristics that emerge from our guidelines are:

- A higher tail projects a more positive valence (e.g., happier), and lower tail a more negative valence (e.g., sadder).

- A smaller wag-size projects more arousal (e.g., energetic) and a larger wag-size projects less arousal (e.g., lazier).
- A higher speed projects a higher valence and arousal (e.g., elated) and a lower speed projects a lower valence and a lower arousal (e.g., uninterested).

3 Informal Design Workshop

To investigate whether our design guidelines are easy-to-understand, easy-to-use or need any further improvements, we conducted an informal design workshop where interaction-designers used our guidelines to communicate the states of various robots that might work in different scenarios (e.g., search and rescue.). Through this workshop, we verified that our design guidelines can actually be used for designing the robotic states and asked participants to point out the unclear or confusing parts which might need further improvement.

Our design workshop was conducted with 6 participants (5 males, 1 female) in this way: they were first brought into our experiment space, and we briefly explained the purpose of the workshop and their involvement. Next, we presented 6 robotic scenarios using cue-cards that contained details of robots working in a particular scenario (e.g., domestic environment), and some of the states these robot can communicate (e.g., looking for dirt in case of a utility robot). We used 6 different cue-cards (one for each participant): search and rescue, robot player, robot learner, robotic teacher, security guard robot, domestic robots. We explained our design guidelines to the participants (using a simplified version and a video) and gave them sheets having some prelisted robotic states such as robot looking for a victim (in search and rescue environment). Next, we asked them to write more states which according to them can possibly be communicated in the given scenario, and asked them to design tail behaviors for all the listed states. In the end, participants proceeded to fill in a post-study questionnaire where we asked them to describe their overall experience, some positive and negative points about our guidelines and suggestions for improving them.

Results. Participants stated that our guidelines as: "very useful," "thorough," "easy to follow," and "helpful." Most of the participants were able to design the tail behaviors for the listed states; however, only one participant wanted the use of sound and LEDs for one state (a robotic teacher being harassed) and one participant suggested the use of other tail motions not in our vocabulary, such as tail moving in cross-motion and "wobbling" in horizontal wagging. One participant noted that "action gestures [discrete tail actions at given times] should be used for events and not states, since they are not continuous or static like wagging or postures."

In addition, for improving our guidelines, one participant suggested to use a "reverse-index" to avoid the complexity which might arise as the descriptive keywords were listed according to the categorized tail behaviors. We added an index (lookup index, Table 2a) to our guidelines by assigning a number to each row in Table 1 and made Table 2b) by sorting the descriptive keywords alphabetically and placing the appropriate index value next to them. This improvement is aimed at making the process of designing a tail behavior for a specific affective state quicker and easy to use.

Table 1. Preliminary design guidelines

				results		
category	sub-type	parameter	attributes	happiness	energy	descriptive keywords
continuous wagging	horizontal	speed	low	medium	medium	modest
			medium	s. more*	s. more*	wondering
			high	more	more	joyful or elated
		wag-size	small	–	more	strong, mighty or powerful
			large	–	less	interested
		height	low	less	–	contempt
			parallel to floor	medium	–	awed
			high	more	–	wonder
	vertical	speed	low	lesser	lesser	solemn
			medium	lesser	medium	shy or disdainful
			high	lesser	more	aggressive
		wag-size	small	–	more	aggressive
			large	–	less	selfish or quietly indignant
	circular	speed	low	medium	medium	reverent
			medium	s. more*	more	aggressive or astonished
			high	more	e. more*	overwhelmed
action gestures	raising	speed	low, medium and high	–	–	shy, selfish, disdainful or weary
		height	low and high	–	–	shy, selfish, disdainful, weary timid or fatigued
	lowering	speed	low, medium and high	–	–	shy, selfish, disdainful or weary
		height	low and high	–	–	shy, selfish, disdainful, weary timid or fatigued
static postures		height	low	very less	very less	lonely
			parallel to floor	less	less	fatigued
			high	medium	s. less*	concentrating

*s. more = slightly more, s. less = slightly less, and e. more = even more

4 Future Work

Although we have learnt about how various tail parameters are perceived by people, and how they can be used to communicate affective robotic states, there still remains a question as to how these parameters can be combined with one another. For example, how a tail behavior having large wag size and high speed will be perceived differently from one with a small wag size and low speed. In the short term, we will conduct a formal user study by combining the tail parameters (e.g., speed and wag-size by wag type) to investigate how people perceive the resultant robotic states. Next, we aim at conducting studies to investigate how tail usage relates to type of robot (e.g., humanoid robots like Nao), etc.

Ultimately, this tail exploration is part of a larger program of exploring how other animal-inspired interfaces (e.g., cats ears to suggest aggressive and relaxed behavior, dog-like pawing to exhibit playfulness, etc.) can be used by robots for communicating their states.

Table 2. Reverse-index tables suggested by participants: a) part that attaches to Table 1, and b) part that can be referred by HRI designers to find the tail motion for a specific affective state.

descriptive keywords	lookup index
modest	1
wondering	2
joyful or elated	3
strong, mighty or powerful	4
interested	5
contempt	6
awed	7
wonder	8
solemn	9
shy or disdainful	10
aggressive	11
aggressive	12
selfish or quietly indignant	13
reverent	14
aggressive or astonished	15
overwhelmed	16
shy, selfish, disdainful or weary	17
shy, selfish, disdainful, weary timid or fatigue	17
shy, selfish, disdainful or weary	17
shy, selfish, disdainful, weary timid or fatigue	17
lonely	18
fatigued	19
concentrating	20

a)

descriptive keywords	lookup Index
aggressive or astonished	11,12,15
awed	7
concentrating	20
contempt	6
fatigued	17,19
interested	5
joyful or elated	3
lonely	18
modest	1
overwhelmed	16
reverent	14
selfish or quietly indignant	13
shy or disdainful	10,17
shy, selfish, disdainful or weary	10,17
shy, selfish, disdainful or weary	10,17
shy, selfish, disdainful, weary timid or fatigued	10,17
shy, selfish, disdainful, weary timid or fatigued	10,17
solemn	9
strong, mighty or powerful	4
wonder or wondering	8,2

b)

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