Affective Expression in Appearance-Constrained Robots

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1. INTRODUCTION

The use of affective expression and social interaction is an emerging area of importance in robotics, with the focus historically on facial expressions and/or animal mimicry [5], [10]. However, a large number of mobile robots currently in use for applications such as law enforcement, military, and search and rescue are not anthropomorphic, do not have any method of projecting facial expressions, and cannot be re-engineered explicitly to support affective expression. This poses significant challenges in how these appearance-constrained robots will support naturalistic human-robot interaction. Fincannon *et al.* provides an example of how rescue workers conducting breaching expected a small tank-like robot to follow social conventions despite the robots non-anthropomorphic appearance [9]. Work by Murphy *et al.* [13] in using man-packable robots to act as a surrogate presence for doctors tending to trapped victims, identifies how the robot will interact with the victim as one of the four major open research issues. They noted that the robots operating within 3 meters of the simulated victims were perceived as "creepy" and not reassuring. In each of these cases, the robots were operating in highly confined spaces and the additions of faces or other devices might interfere with the critical attribute of mobility.

Our work focuses on affective expression in non-anthropomorphic and appearance- constrained robots for human-robot interactions occurring within three meters of each other. Appearance-constrained robots are not engineered to be anthropomorphic and do not have the ability to exhibit facial expressions. Application limitations include mobility, power, platform size, and size of operational envelope. In terms of economics, in many cases manufacturers and organizations have already developed and invested large amounts of money into their robot designs and it would not be practical to alter the robots physical appearance to produce a more naturalistic social interaction.

While facial displays have been the most common mechanism for expressing affect, some roboticists have used body movement [3], [4], [5], [12], [16], orientation [3], [4], [5], [6], color [18], and sound [3], [4], [6], as either the primary method of expression or to provide affective expression redundancy. These approaches were developed mostly for educational and/or entertainment purposes. Although facial expression has been shown to be quite effective in the expression of affect, some researchers feel that body movement and posture may reveal underlying emotions that might be hidden otherwise [1], [4], [7], [15].

Although non-anthropomorphic affect features are being used by roboticists, the choice of feature for a particular application is ad hoc. This work synthesizes the cognitive literature on affective expression and the lessons learned from the robot implementations to date to generate a prescriptive mapping of which expressions are appropriate for what applications. This mapping allows a roboticist to add appropriate affective expression simply through software control, without physically changing the robot.

2. FACTORS IN AFFECT EXPRESSION

There are two main factors related to affective expression identified in the psychology literature and supported by observations from computer science and robotics: (A) presentation methods for affect expression, and (B) the importance of the relative distance between agents or proxemics in social interactions. In general, researchers in the fields of psychology, computer science, and robotics have focused most of their attention on facial expression as the main method for expressing affect and have neglected other important methods of presentation such as body movement, posture, orientation, color, and sound [1], [7].

Non-facial and non-verbal presentation methods of affect can be broken down into five different cues: body movements, posture, orientation, color, and sound. Researchers such as Bull, Spiegel, and Machotka have the opinion that body movements and posture can reveal more about the actual affective state of an individual than the facial expression or even verbal communication [7], [17]. Argyle [1] describes some affect expressions using body movements: depression - slow and hesitating movements, and elation - fast, expan-

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sive, and emphatic movements. Robot orientation toward a person it is interacting with is indicative of its attentiveness and caring for that person [2], [6], [9], [10]. Argyle [1] discusses the use of color to produce an affective response such as: blue elicits pleasant, calm, secure, and tender responses; yellow elicits cheerful, joyful, and jovial responses; and red elicits anger, affection, and love. Norman [14] discusses that vocal patterns and tone can express affect even if the literal meaning is not understood.

Proxemics, the study of spatial distance between individuals, can have a significant impact on the quality and comfort level of interactions between humans and robots [2], [4], [6], [8], [9]. From a psychology point of view, Argyle's classification of proxemics [1] based on the original work of Hall [11] is the most commonly utilized. Argyle's classification consists of four main proximity zones: intimate (0.15 - 0.46 m), personal (0.46 - 1.22 m), social (1.22 - 3.66 m), and public (3.66 m or greater). This poster focuses on the intimate, personal, and social proximity zones.

3. ROBOT IMPLEMENTATIONS

The focus of this poster is on implementations that rely soley or heavily on non-facial/non-verbal affect expression. Of the four implementations discussed, three of them display affective expression using non-anthropomorphic mobile robots. Sugano and Ogata [18] display affect on their WAMOEBA-1R robot using red (anger), yellow (expectation/pleasure), and blue (fear) colored lamps which reflect the internal state of the robot while operating in the personal and social proximity zones. Maeda [12] implements affective expression using orientation, direction, body vibration, and speed of movement on a miniature Khepera robot operating in the intimate, personal, and social zones. Smoothness of motion, velocity, and direction are used for affect expression, in the social zone, on a radio-controlled tank designed by Shimokawa and Sawaragi [16]. Bruce *et al.* [6] developed Vikia, the museum robot that is an avatar appearing on a monitor attached to a fixed robotic base that is capable of turning to orient toward museum visitors. Results indicate that using tracking (orientation) only was more effective than using a face alone or no face/no tracking for attracting visitor interactions and indicating attentiveness [6] when used in the personal and social zones.

4. GUIDELINES FOR USE OF NON-FACIAL AND NON-VERBAL EXPRESSIONS

The psychology, computer science, and robotics literature support the use of non- facial/non-verbal expressions; however the literature does not explicitly address when to use which affective presentation method. We propose a set of prescriptive mappings designed to guide the selection of one or more of the particular methods based on the relative distance between agents. Table 1 captures our mappings and is a synthesis of psychology literature and robotic experience.

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Table 1: Effectiveness of non-verbal and non-facial Affect Expressions by Proximity Zones

Affect Expression non-verbal and non-facial	Proximity Zones		
	Intimate	Personal	Social
Body Movement	No	Yes	Yes
Posture	No	Yes	Yes
Orientation	Yes	Yes	Yes
Color	Maybe	Yes	Yes
Sound	Yes	Maybe	Maybe

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