Perceptions of Affective Expression in a Minimalist Robotic Face

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***Abstract*— This study explores deriving minimal features for a robotic face to convey information (via facial expressions) that people can perceive/understand. Recent research in computer vision has shown that a small number of moving points/lines can be used to capture the majority of information (~95%) in human facial expressions. Here, we apply such findings to a minimalist robot face; recognition rates were similar to more complex robots. The project aims to answer a number of fundamental questions about robotic face design, as well as to develop inexpensive/replicable robotic faces for experimental purposes.**

Keywords*— *Human-Robot Interaction; Facial Expression; Emotion; Minimalist Design; Robot Design

I. Introduction

This study is an intersection between three fields – computer vision, psychology, and social robotics. Recent research in computer vision has shown that a small number of moving points/lines could be used to capture the majority of information in human facial expressions. This insight has been leveraged to develop automated techniques allowing computers to classify human facial expressions with high degrees of accuracy (~95%) for the six basic Ekman emotions: Happy, Sad, Angry, Fear/Worry, Surprise, and Disgust. The principle idea in this study is to "flip" that insight to answer questions about human perception and robot design – can a small number of moving lines be used to communicate robotic facial expressions to humans in an understandable way?

This work has implications for the development of interactive robots – such as those used for therapeutic or assistive purposes – that need not only detect human facial expressions but also express them. In contrast to more complex robots designed to capture facial aspects of nonverbal communication such as Kismet [1] or Eddie [2], simpler facial representations focused on two linear features (upper and lower) and their critical points may be able to convey most of the same information. Other aspects of the face could perhaps be omitted or left as purely aesthetic (and/or economic) choices. This minimalist approach could reduce the complexity of constructing affective robots, or other artificial entities such as digital avatars, allowing for greater flexibility in robot design by freeing up constraints associated with mimicking non-critical aspects of human anatomy. It also raises interesting cognitive research questions about people's ability to make inferences using incomplete information during social interaction.

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Here we describe initial results from ongoing research with such a minimalist robotic face – Minimalist Robot for Affective Expressions (MiRAE) – a robot platform we developed capable of performing an array of facial expressions and neck motions (Fig. 1). MiRAE was designed to cost under $150-175 USD and require less than a day of construction time (~6 hours), using easily accessible components (e.g. Arduino). The project aims to answer a number of fundamental questions about robotic face design, as well as to develop inexpensive and replicable robotic faces for experimental purposes. Our design also addresses challenges with previous research projects in this area, e.g. the inclusion of unnecessary confounding variables (e.g. adding ears) or use of custom-made components that limit experimental replicability.

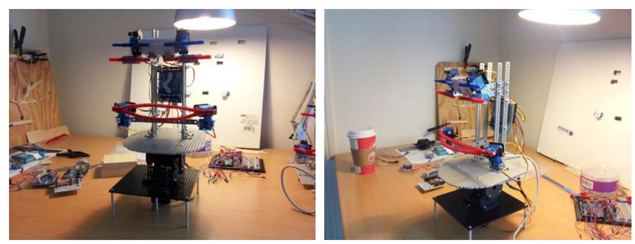

Figure 1: MiRAE

II. Methods

A. *Robotic Face Design*

The robotic face design was taken from recent research in computer vision on human facial expressions and rooted in Ekman's theories of emotion and the Facial Action Coding System (FACS) [3]. Feature selection techniques from machine learning have indicated critical features (Action Units, AUs) in facial expressions. These were translated into the schematic representation shown in Fig. 2, comprising two principle linear feature sets: upper (eye/brow) and lower (mouth).

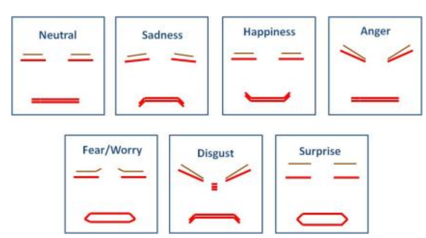

Figure 2: Schematic Facial Expressions

Although many other researchers have utilized similar approaches in the design of robotic faces [1,2,4] our approach differs in its strict adherence to the minimal features (Action Units) without addition of extraneous (and potentially confounding) attributes, e.g. ears or aesthetic properties.

B. *Experimental Design*

We are conducting a series of experiments to evaluate human abilities to perceive and understand robotic non-verbal affective cues while varying factors related to robot and study design. The first two experiments have been completed to-date: 1) a comparison of the embodied robotic face with a near-replica digital avatar version and, 2) a study of the effect of additional neck motion on facial expression identification.

We recruited 30 subjects for the first experiment and 15 more for the second (in total, n=45). All subjects were college undergraduates from various disciplines (e.g. computer science, psychology) and of varying gender. Subjects observed the robotic face (and/or digital avatar) making a randomized pre-set series of facial expressions (the six Ekman emotions, less disgust) and were asked to identify the expression and rate the strength of expression. We used the same 7-option forced-choice design for the questionnaire as was used as in studies with Kismet, Eddie, etc. for comparability purposes [1,2]. Subjects were also allowed to select any "other" expressions they think the robot might be showing, as well as administered the NARS [5] and Godspeed scales [6] (data not shown).

III. RESULTS

Table I shows the identification results between the embodied robotic face and the digital avatar version, including the main identified emotion and the accuracy including "other" identified emotions. In general, the results are comparable, with the digital avatar version slightly higher. This made some intuitive sense, in that it was easier to maintain better fidelity to the FACS in the digital version. Also of note, the perceived strength of expression significantly correlated with the identification accuracy (r^2=.896 for the embodied version).

Table I: Main Results of Expression Recognition

	Expression	Main Accuracy	Other Accuracy	Strength Rating
Embodied	Happy	96.7%	96.7%	7.31
	Sad	100.0%	100.0%	8.30
	Anger	86.7%	93.3%	7.25
	Fear	43.3%	63.3%	6.25
	Surprise	96.7%	100.0%	7.96
Digital	Happy	100.0%	100.0%	6.93
	Sad	100.0%	100.0%	8.09
	Anger	100.0%	100.0%	7.98
	Fear	53.3%	66.7%	6.38
	Surprise	86.7%	100.0%	7.22

Table II shows the comparison between MiRAE and several other recent robotic faces: Kismet [1], Eddie [2], Feelix [7], and BERT [8]. Generally, MiRAE produced higher, or at least comparable, identification accuracy rates for all expressions, despite its minimalist design, low cost, and ease/brevity of construction. Across all faces, similar patterns can be observed (e.g. fear). Note that many robotic faces from the last decade are not included because similar rigorous experimental evaluation was never performed/reported.

Table II: Robot Face Comparison

Expression	MiRAE (n=30)	Eddie (n=24)	Kismet (n=17)	Feelix (n=86)	BERT (n=10)
Happy	97%	58%	82%	60%	99%
Sad	100%	58%	82%	70%	100%
Anger	87%	54%	76%	40%	64%
Fear	43%	42%	47%	16%	44%
Surprise	97%	75%	82%	37%	93%
Disgust	-	58%	71%	-	18%

Table III shows the results from the added neck motion, which pushed identification accuracy for all expressions to 100%, except for fear.

Table III: Added Neck Motion

	Expression	Main Accuracy	Other Accuracy	Strength Rating
Embodied	Happy	100.0%	100.0%	9.07
	Sad	100.0%	100.0%	8.80
	Anger	100.0%	100.0%	8.00
	Fear	40.0%	86.7%	8.60
	Surprise	100.0%	100.0%	7.80

IV. CONCLUSION/FUTURE WORK

In this ongoing project, we have shown that a minimalist robotic face using a small number of critical features can convey most of the information needed for humans to perceive/understand robotic facial expressions. We did so using a robotic design that cost $150-175 USD and can be built in under a day using easily accessible components. Ongoing experiments will systematically test the effect of other factors, such as the strength of expression; a series of cross-cultural experiments between Japan-U.S. set for spring 2013 will explore cultural variability in robotic facial cues during non-verbal communication.

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