Recognizing Nonverbal Affective Behavior in Humanoid Robots

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Abstract. This paper describes the addition of nonverbal affective behaviors to a humanoid robot, as well as recognition of these behaviors based on an online survey. The expressive behaviors were implemented in the context of a framework for affective robot behavior (TAME) and span across three types of affective phenomena: traits, moods and emotions.

Keywords. Humanoid Robotics, Interactive Systems, Human-Robot Interaction, Robot Affect, Nonverbal Behavior

Introduction

Nonverbal behavior plays a large role in interpersonal communication. Not only does it augment speech, emphasizing, disambiguating, or even substituting it in some cases, but it also provides information often omitted in spoken words, such as a person's friendliness or nervousness, likes and dislikes, or their affective state – emotions and moods they are currently experiencing. People are very capable of reading such nonverbal displays; they can recognize the traits of extraversion and conscientiousness, and negative affective state from such short exposure as 5 seconds, and positive affect, neuroticism, openness and agreeableness in 20 seconds of exposure to video clips displaying interpersonal interaction [1]. Granted, most humanoid robots at present, especially those without changeable facial features, lack the wealth of human expressive capabilities – for example, shrugging shoulders, wringing hands, or fidgeting with a pencil or clothes. However, given the findings in the context of *Computers As Social Actors* framework [2], suggesting that people are sensitive to even minimal social cues displayed by computers, we believe that even the current imperfect state of humanoid robots would enable recognition of robot personality and affective state through nonverbal behavior.

With the goal of facilitating human-robot interaction, we have implemented a number of nonverbal affective behaviors for a humanoid robot Nao (Aldebaran Robotics) in the context of the *TAME* (Traits, Attitudes, Moods, Emotions) framework [3] and *MissionLab*, a robotics software toolkit [4]. In order to determine whether these behaviors were representative of the affective states they were designed to portray, we conducted an online survey, in which the participants were asked to judge 6 short video clips as to the manner the robot behaved in them. This paper describes the design and implementation of the affective behaviors, as well as the survey and its results.

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To the best of our knowledge, there has been no explicit research that addresses nonverbal behavior for humanoids across multiple affective constructs. The most relevant work in this area is, perhaps, that on behavioral overlays for nonverbal expression for a humanoid robot Qrio [5]; it provides a thorough overview of nonverbal behavior in general, and a specific method on integrating such behavior on a humanoid. Please see [6] for a review of nonverbal affect for appearance-constrained robots.

1. Framework Overview

Nonverbal affective behaviors for a Nao robot were designed and implemented within an integrative time-varying framework for affective robotic behavior, *TAME*, described in detail elsewhere [3, 7-8]. The framework consists of four affective phenomena, namely personality Traits, affective Attitudes, Moods and Emotions which interact together to create complex variations of affective states and dispositions. The Trait component is based on Five-Factor Model of Personality [9], and is comprised of 5 dimensions: Openness, Conscientiousness, Extraversion, Agreeableness and Neuroticism. Traits are more or less time-invariant, and specify a person's/robot's disposition to behave in a certain way. Attitudes express likes or dislikes towards a certain object or situation, and are enduring. Moods are represented along the dimensions of Positive and Negative affect [10], are diffused, non-object-specific, relatively short in duration and sensitive to general environmental and internal conditions (e.g., level of light and battery level). Finally, Emotion component contains 6 basic emotions: Joy and Interest (positive), and Fear, Anger, Disgust, and Sadness (negative). Emotions serve as an adaptation mechanism to environmental contingencies, are short in duration, and capable of hijacking currently active behaviors in favor of a quick response to an arising need. From the point of view of human-robot interaction, these phenomena serve a predictive function by communicating the internal state of the robot and its assessment of the current situation (e.g., fear communicates possible danger; and negative mood may indicate low sensor reliability due to environmental conditions), thus facilitating an understanding of present and future robot actions.

1.1. Software Architecture

The architecture itself is fairly straightforward, and consists of: *TAME Manager* (the main module of the system), *TAME Communication Manager* (receives sensor data and passes the updated affective values to the robot), a module for each of the affective components, and *Stimuli Interpreter*. Configuration files contain initial default values for each component and dependency specifications, thus providing flexibility in tailoring the affective system to specific needs or preferences.

TAME Manager runs as a threaded process and manages all the affective components in the *TAME Module*. It is responsible for supplying to each component relevant stimuli data or necessary values from other affective components. The affective variables in the *TAME Module*, such as the *Joy* variable in the *Emotion* component or the *Extroversion* variable in the *Trait* component, are comprehensively referred as the TAME variables. After appropriate calculations, each affective component sends the updated TAME variable values to *TAME Manager*. *TAME Communications Manager* is a separate thread that is responsible for receiving raw sensor data from the robot. It sends the data to *Stimuli Interpreter* to processing into meaningful stimuli information, and it relays this information to *TAME Manager* to be used by each affective component. Then, it retrieves most up-to-date TAME variable values and communicates them back to the robot.

1.2. Integration with MissionLab and Nao Humanoid

MissionLab is a robotic software toolset which allows the user to create and configure multi-robot missions with ease using a graphical user interface [4, 12][2]. The *TAME Module* has been integrated with *MissionLab* and tested using Aldebaran Robotics' Nao humanoid robot (Figure 1 Left).

In *MissionLab*, the user specifies missions through *Configuration Editor* (*cfgEdit*) using a graphical representation called an FSA. The mission is translated into C++ code and compiled to make the *Robot Executable*, which can be deployed in simulation or real robot platforms, and the user can monitor the mission execution in real-time using the *mlab* GUI display. *HServer* is a control interface to various robotic hardware.

HServer acts as a bridge to the Nao robot to communicate between the *Robot Executable* (which contains the actual control code for the robot's current mission) and the *TAME Module*. Upon receiving perceptual data from the robot, *HServer* relays the information to both *Robot Executable* (needed for performing certain behaviors and especially for determining when to make transitions in different states) and the *TAME Module*. When the *Robot Executable* is executing a certain behavioral state, *HServer* receives the generated motor commands to actually control the Nao robot at the hardware level. A mirror database of the TAME variables is created in the *Robot Executable*, and their values are updated at three hertz by the *TAME Module*. The mirrored TAME variables maintained in the *Robot Executable* in turn influence the robot's behavior by changing its appropriate behavioral parameters. Figure 1 (Right) presents a graphical view of the integration.

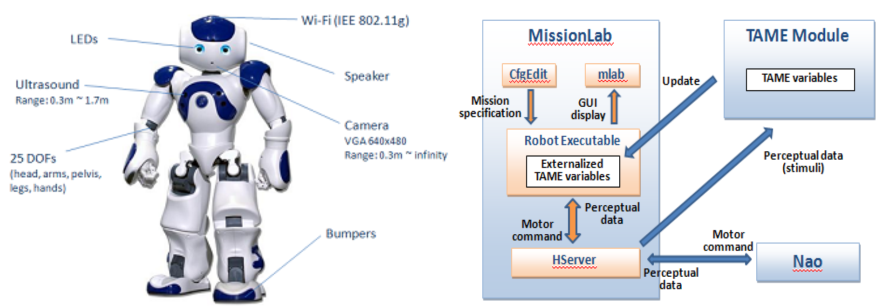

Figure 1. (Left) Nao humanoid robot (Source: Aldebaran Robotics). (Right) Architectural view of the *TAME Module* integrated with *MissionLab* and *Nao* humanoid robot.

2. Design and Implementation of Nonverbal Affective Behaviors

Until now, the research on *TAME* has focused on the generation of individual affective states and dispositions, and modeling the complex interactions between them. We now

[2] *MissionLab* is freely available for research and development and can be found at http://www.cc.gatech.edu/ai/robot-lab/research/MissionLab/

expand upon this interaction model to express these phenomena nonverbally to make human-robot interaction easier, more enjoyable, and, consequently, more productive. In designing nonverbal affective behaviors we employ:

- Kinesics – movement of the body either as a whole or in part; this includes general walking behavior, gestures, posture shifts, etc.
- Static Postures – certain posture attributes are indicative of affective state, and are recognizable even without movement
- Proxemics – the distance maintained between interaction partners
- Paralinguistic cues – voice qualities, such as pitch, pitch variation, speech rate and volume

Although color does possess affective potential, there is currently no consensus on which colors express what emotions (i.e., they can be culturally dependent); in fact, a color can be indicative of multiple affective states – such as, red can be viewed as a sign of either anger or love and affection. Besides, the most prominent display of color in Nao robot is through LEDs in its eyes, and an informal evaluation showed that the use of eye color produced an unwanted result, making the robot look somewhat unnatural and strange to the observer. Finally, facial expressions were not used, because Nao humanoid lacks actuators in the face to produce variable expressions.

The nonverbal displays for the following affective phenomena were implemented for this work:

- **Personality Traits:** dimension of Extraversion, with individuals on one end of the scale characterized as outgoing, sociable, lively, assertive, and those on the opposite end as quiet, shy, withdrawn, passive and introverted.
- **Emotions:** Fear and Joy.
- **Moods:** Positive (high level), and Negative (high level).

These robotic behaviors were videotaped as short scenarios for use in the online survey described below.

2.1. Nonverbal personality display

The dimension of Extraversion was chosen for this work for two reasons: 1) it's an interpersonal dimension of personality, and, as such, important for human-robot interaction 2) it has been successfully implemented in both computer-generated speech [13], and on a robotic dog Aibo [14], giving a precedent and a source of useful ideas.

For the survey purposes, we implemented a short sequence of actions, which were the same for a highly extraverted and a highly introverted robot (at the opposite ends of the Extraversion scale): the robot walked up to a person, stopped some distance away, and engaged in a scripted dialogue with the person. To show distinction between an introverted and extraverted robot, we differentiated: kinesics (walking style and gestures), proxemics, and paralinguistic cues.

From a kinesics point of view, extraverts use larger, faster and more frequent body movements than introverts [15, 16]. Additionally, extraverts are characterized by boldness, friendliness and a positive disposition. Therefore, we programmed the extraverted Nao to have a more erect posture, raised head, swinging arms during walking, and more frequent and expansive gestures during the conversation. In particular, extraverted Nao uses an above-the-head waving gesture in greeting, raises both arms shoulder length while praising the weather, and makes an open hand gesture at the end, whereas its introverted counterpart only raises its arm chest-high in greeting, keeps its head down during introduction, and its arms along the body at the end.

In terms of paralinguistic cues, [13] found that manipulating pitch, pitch range, speech rate and volume via a TTS engine (CSLU toolkit [17]) allowed them to successfully produce recognizable introverted and extraverted synthetic voices, where extraverted speech was louder, higher and more varied in pitch, and faster. We used the same toolkit to produce introverted and extraverted speech according to the suggested variations. In addition, being talkative is a defining characteristic of an extravert, therefore in the script Extraverted Nao produced more phrases than Introverted Nao (5 vs. 3).

Finally, as introverts are described as aloof and reserved, the introverted Nao stops father away from its interaction partner than does the extraverted Nao.

Figure 2 displays the ending poses for extraverted (left) and introverted (right) Nao. Although static poses are not sufficient to recognize the level of Extraversion, they are indicative of the general trend we followed; in particular, please note the difference in the head level, arm position, and distance from the camera.

Figure 2. (Left) Ending pose for extraverted Nao. (Right) Ending pose for Introverted Nao.

2.2. Nonverbal emotion display

Emotions of Joy and Fear were selected due to the importance of the functions they perform for interpersonal communication. Joy's affiliative function strengthens mutual bonds and attachment, making interaction more pleasant, and fear communicates potential danger and serves as a warning signal.

Several researchers from fields of Psychology, Communication and Computer Animation identified certain characteristic aspects for expression of these emotions. Our design for body language for fear and joy was guided by the following findings:

- According to [18], expression of fear almost always involves moving away from the contact point, contracting or cowering movements, often including raised hands, especially in front of the face. [19] suggests that fear is manifested nonverbally by an individual's crouching down, shrinking, with arms violently protruding as if to push away and head sinking between shoulders.

- Happy expressions often include raising the arms, accompanied by shaking of the fists [18], jumping and dancing for joy, clapping hands, performing various purposeless movements, and holding body erect and head upright [19]. Also, [20] provides a picture of a static posture for joy, displaying a stick figure standing upright, with straight arms raised up and to the side overhead.

As these manifestations of emotions are rather prototypical, only a short sequence of movements was required to encode them on Nao. For joy, when presented with a desirable object, Nao opened its palms, lifted its head up, raised arms overhead and to the side, and emphasized the latter movement by bending the arms at the elbows and straightening them again, as if shaking them. For fear, when a loud sound was heard, Nao crouched low to the ground, lowered its head down, and placed one hand in front of the face, as if covering it. Figure 3 presents the static poses for Fear and Joy.

Figure 3. (Left) Static pose for Joy. (Right) Static pose for Fear.

The expression of mood in Nao was mainly achieved through gestures and posture while walking. To show highly positive mood, the robot walked with body erect, head up, arms rhythmically swinging; after a few seconds, the robot stopped and enthusiastically waved with its hand, with an upraised arm overhead. To show highly negative mood (nervous, scared), the robot walked with its head lower down, periodically turning the head left and right as if looking for threats, with fists opening/closing, and wrists turning; for the video clip, the robot started out a neutral walk, then, as the lights were dimmed, it stopped to scan the environment first, and then continued its "anxious" walk, as described earlier. Unfortunately, still photographs are not sufficient to show the mood display, therefore they are not included.

2.3. Nonverbal mood display

Only limited information could be found on nonverbal display of moods. According to [21], distress can be characterized by an increase in percentage of walking and object manipulation, and greater arm position asymmetry; anxiety is expressed through fidgeting or hiding movements [22]. The design of positive mood expression was guided by descriptive adjectives taken from PANAS-T (positive/negative emotionality measure, or "mood") questionnaire [23], such as 'happy', 'excited', 'attentive', 'enthusiastic', and others.

3. Survey Design and Results

3.1. Design

In order to test the recognition of the nonverbal affective behaviors, we designed an online survey in which participants were asked to judge 6 short video clips according to the manner the robot behaved in them. The survey objective was to determine whether participants without significant robotics experience can correctly recognize the affective state or trait presented in each clip via nonverbal behavior. The video clips were organized according to the affective phenomena they represented, into 3 sets (traits, moods, emotions), with 2 clips per set (Extraverted/Introverted personality, Positive/Negative mood, Joy/Fear). The sets and the clips within the sets were counterbalanced to avoid presentation order bias. The survey was IRB-approved, and hosted by SurveyGizmo, an online survey company.

After each clip was presented, the participants were asked to describe the manner in which the robot behaved in the video in their own words, and only on the next page they were given a list of adjectives/nouns for rating.

In particular, for Extraversion/Introversion set, the Extraversion subset of the brief version of Goldberg's Unipolar Big-Five Markers [24] (personality questionnaire) was used. The participants were asked to rate the robot behavior in the clip using a 9-point Likert scale (ranging from "Extremely Inaccurate" to "Extremely Accurate") according to the following traits: 'extraverted', 'talkative', 'bold', 'energetic', 'quiet', 'bashful', 'withdrawn', 'shy'. The first four traits describe extraverts, and the latter four introverts.

To rate the recognition on the Positive/Negative mood set, a shortened version of the PANAS-T [23] (positive/negative emotionality measure, or "mood") questionnaire was used. The participants were asked to rate the feelings the robot was experiencing in the clip on a 5-point Likert scale (ranging from "Very Slightly or Not at All" to "Extremely") according to the following adjectives: 'happy', 'active', 'excited', 'interested', 'enthusiastic', 'determined', 'depressed', 'irritable', 'distressed', 'afraid', 'upset', 'nervous'. The first five adjective indicative of experiencing positive affect, and the last five negative.

For the Joy/Fear set, the participants were asked to select the emotion most likely expressed by the robot in the clip (from the list containing 'joy', 'fear', 'anger', 'disgust', 'interest', 'sadness', 'none', and other); if an emotion (other than none) was selected, they were asked to rate the extent to which it was expressed on a 4-point Likert scale (ranging from 'a little' to 'extremely').

At the end of the survey the users were asked a few demographics questions, such as their gender, age, education level, and technology and robotics experience.

3.2. Results and Discussion

A total of 26 people participated in the survey. Demographically, they were distributed as follows: 38% female, between 18 and 40 years old (69% in their twenties), and well-educated (88% had a Bachelor's degree or higher). Only 4 participants claimed to have prior robotics experience. Due to missing data, one response was excluded in the analysis of personality display and 3 responses in the analysis of mood display.

2-tailed paired T-tests were conducted to compare recognition of Extraversion and Introversion, and Negative and Positive moods. Overall, the results of the survey suggest that all of the affective constructs were successfully recognized.

For judgment of personality, a single Extraversion score was calculated for each response, ranging from 1 (the least extraverted/highly introverted) to 9 (extremely extraverted). The average scores for Nao displaying extraverted/introverted behaviors were 7.1 and 3.6, respectively, and these scores were significantly different ($p<0.001$, see Table 1 for Mean and Standard Deviation and Fig. 4 for Mean/SE plot). This demonstrates that the affective behaviors added to even a limited robotic platform were sufficient to differentiate between expression of extraversion and introversion. The portrayal of this trait would be useful for different tasks – e.g., a museum guide could display friendly and engaging extraverted behavior, and a robot engaged in a human-robot task requiring concentration would serve better as an introvert.

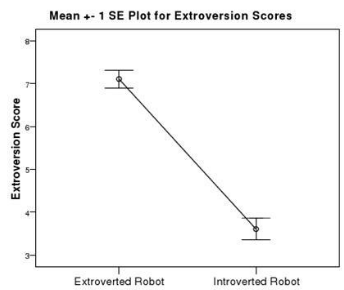

Figure 4. Plot of Extraversion scores: extraverted robot was rated much higher on Extraversion dimension.

For judgment of mood, a cumulative score was calculated for Negative and Positive Affect separately [23]; the lowest possible score was 6, and the highest possible 30. Each of the mood clips was scored for both Negative and Positive Affect. The robot displaying positive mood was rated low on Negative and high on Positive Affect; the robot displaying negative mood was rated medium on Negative and low-medium on Positive Affect (Table 1). For the positive robot mood, Positive Affect score was significantly higher than that for the negative robot mood (21 vs. 12.3, $p<0.001$, Fig. 5 Left), and vice versa, its Negative Affect score was significantly lower than that of negative robot mood (8.6 vs. 12.3, $p<0.001$, Fig. 5 Right). The medium, rather than high, level of Negative Affect in the negative mood clip can be explained by some participants' interpreting 'looking around' gestures as indicative of curiosity and interest, and movements of fingers and wrists as a sign of being active and determined, as indicated by some open-ended responses; this finding should be taken into consideration while developing further nonverbal mood expressions.

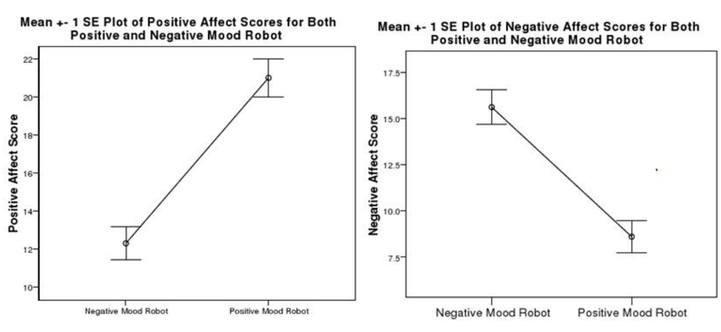

Figure 5. (Left) Plot of Positive Affect for both videos: the robot displaying positive mood was rated higher on Positive Affect. (Right) Plot of Negative Affect for both videos: the opposite effect is observed.

Table 1. Mean Scores and Standard Deviations for Personality and Mood

	Extraverted Robot	Introverted Robot	Negative Affect/ Negative Mood Clip	Positive Affect/ Negative Mood Clip	Negative Affect/ Positive Mood Clip	Positive Affect/ Positive Mood Clip
Mean	7.1	3.6	15.6	12.3	8.6	21
SD	1.1	1.2	4.5	4.1	4.1	4.8

Finally, the recognition rates for emotions of joy and fear were high – 85% and 81%, respectively. These rates are comparable to those obtained in judgments of joy and fear portrayals by human actors in movie clips (facial features obscured), which were 87% and 91%, respectively [18]. Figure 6 shows the distribution of recognition rates for fear (left) and joy (right). In those responses where joy and fear were correctly recognized, they were deemed to be expressed "quite a bit", with mean scores of 3.2 and 2.9, respectively. Display of these emotions by robots, especially given the high recognition rates, serves as a step towards more natural, enjoyable and productive human-robot interaction.

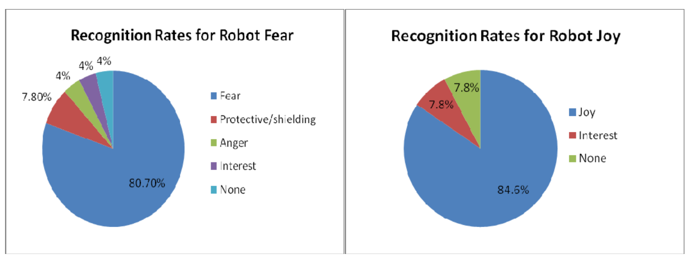

Figure 6. (Left) Recognition rates for fear. (Right) Recognition Rates for joy.

These findings show that it is, indeed, possible to successfully encode a variety of affective expressions on a humanoid robot lacking variable facial features. These behaviors will be used in HRI studies to test the effectiveness of use of robotic affect in facilitating interaction with humans.

4. Conclusion

This paper described design and implementation of nonverbal affective behaviors on a humanoid robot. According to our online survey, people could correctly identify when the robot behaved in an introverted or extraverted manner, was displaying fear or joy, or expressed positive or negative mood. In the future, we are planning to expand the repertoire of nonverbal affective behaviors, to include a richer set of personality dimensions and emotions, as well as augment the existing displays. We will also use the results of this survey to inform the design and implementation of further human-robot interaction studies to test the usefulness of using robotic affect.

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