Exploring Emotive Actuation and Its Role in Human-Robot Interaction

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***Abstract*— In this paper, we present our research efforts in exploring the role of motion and actuation in human-robot interaction. We define *Emotive Actuation*, and briefly discuss its function and importance in social robotic interaction. We propose a suggested methodology for exploring *Emotive Actuation* in HRI, and present a robotic testbed we designed for this purpose. We conclude with informal results of a preliminary design critique we performed using our testbed.**

Key Words: emotive actuation; social human-robot interaction

I. Introduction

We believe motion is a fundamental aspect of the design of human-robot interfaces. Robots essentially are physical, spatially dynamic computerized entities which can move and deform in ways that are meaningful to their task and to their users. Arguably, meaningful physicality and meaningful motion are all that set robots apart from computers. Furthermore, we see emotionally expressive motion as being crucial to the design of acceptable and meaningful *social* robotic interfaces.

In this paper we discuss our concept of *Emotive Actuation*: the ability to actuate a robot in an emotionally meaningful manner. We begin by discussing why further exploration of the role of *emotive actuation* and its use in HRI design is important; we then outline a research methodology that can help foster this exploration; we conclude with our preliminary design of the "*Stem*", an *emotive actuation* robotic testbed, and the results of a preliminary design critique we performed with it.

II. Motivation

In a seminal 1944 paper, Heider and Simmel [1] explored the personification of abstract shapes and motion. They demonstrated that, when shown an animated video of simple two-dimensional (2D) geometric shapes engaged in various motions relative to each other and a static background, the majority of observers interpreted those motions in surprisingly consistent ways; often attributing genders as well as strong emotional descriptions such as "fearful", "aggressive", and "jealous" to the animated triangles and circles. This same phenomena has been demonstrated repeatedly in classic Disney films, where non-living objects such as candlesticks and straw brooms "come to life" through the skill of the film's animators. More recently, and most directly related to HRI research, Pixar Animation Studios 2008 film "Wall-E" demonstrated how a relatively simple robot could endear itself to millions of people through motion and simple sounds; even without a full set of facial features or speech.

Together, Heider's experiment and decades of traditional animated work highlight the impact that motion has on our emotional interpretation of living and non-living entities. These observations transition directly into the emerging research of human-robot interaction; robotic entities are now "leaping off the screen" and into our daily lives, and our social connection to them is likely to be even more strongly impacted by how they move and behave, compared to the aforementioned 2D animated characters.

An important parallel between visual appearance and emotional familiarity, which has dramatic impact on the HRI domain, has been theorized by Masahiro Mori in his 1970 paper "The Uncanny Valley" [2]. Modern android science is still struggling with the jarring and disturbing effects of Mori's theory: while the visual appearance of most modern androids are strikingly similar to live humans in photographs, observers are often quickly struck by eerie feelings of discomfort as soon as these androids begin to move. The importance of believable motion is further highlighted by claims from leaders in the computer graphics industry that computer generated characters, free of the mechanical constraints of physical systems, are already beginning to exit the uncanny valley and approach true photo-realism thanks to increasingly powerful computer processing and advanced, motion capture capabilities [3].

Given how important believable motion can be to emotional engagement, especially in the unique context of social robotic interaction, we feel there is a need to investigate the role of *emotive actuation* and the potential of generating a related set of design heuristics for how motion maps to emotion in social robotic entities.

III. Methodology

In order to explore the concept of *emotive actuation*, we propose a fundamentalist approach: designing a set of robotic platforms that strip away the visual and situational context of recognizable entities and enable focus on individual, fundamental motions; analyzing these fundamental "atomic" motions and their emotional interpretations by human observers; and then using this taxonomy of emotive actuations to build up more complex robotic entities and unique behaviors, binding the fundamental *emotive actuations* back to higher level context. Our current methodology will explore three sets of *emotive actuations*, mapping emotions to varying levels of meanings of contextual motion in three robotic interfaces we are designing: the *Scorpion*, *Teeter*, and the *Stem*.

The *Scorpion* is a robotic interface that attempts to capture the fundamental threatening motion of a scorpion. Our basic *emotive actuation* goal in this project is to ask what about the scorpion elicits fear in human observers and can part of that fear be attributed only to the animal's motion (regardless of its form and context)? Is the quick, unpredictable striking motion of the scorpion tail enough to scare a human observer away? Is it the coordinated motion of the scorpion's many legs that invokes a feeling of strangeness (much like other many-legged insects do)? From these basic questions alone, two robotic *emotive actuation* implementations will be designed in an attempt to explore these individual aspects in isolation and in combination; a quick, unpredictable robotic tail and an abstract "body" with many legs moving in different combinations.

Teeter is an attempt to elicit concern through *emotive actuation*. Consider viewing a walking toddler that seems to be about to fall over. *Teeter* will be design to emulate this random, swaying style of locomotion and could be contrasted with a parallel robotic interface, similar in form, that employs a more straightforward and balanced style of travel (e.g. rolling or rigid walking). Through *Teeter*'s emotive actuation we hope to explore how the swaying robot may elicit emotions of concern in its observers.

The *Stem* is a robotic interface that explores even more abstract motions. The *Stem* is a simple stick that sways back and forth in varying patterns, amplitudes, speeds, and frequencies. Through the *Stem*'s *emotive actuations* we hope to investigate whether rapid frequencies are generally interpreted as more threatening or more productive. We are wondering whether it even possible for such an abstract robot, absent of almost all context and apparent purpose, to convey emotional intent or social behavior?

Finally, the environmental and situational context in which these *emotive actuated* robots are situated plays a critical role in how they are interpreted. Controlling these contexts becomes yet another variable during our explorations of *emotive actuation*. If a fast moving robotic arm is physically larger or much closer to the observer than a smaller or more distant arm, its motions are likely to be interpreted more intensely. Temporal context is also critical: a quick twist of a robotic "head" could be interpreted as "surprise" if the observer has just entered the room or as a prompt for conversation if the observer has been sitting next to the robot for a longer period of time.

IV. Implementation

We have designed and implemented a very abstract "*Stem*" robotic interface. Our robotic *Stem* consists of a 1 meter wooden stick mounted to a series of three servo motors which are in turn anchored to a large base platform. The stick is able to simultaneously pitch and roll about its fixed end in 180 degree arcs and can continuously twist about its length.

We performed a preliminary design critique of our *Stem* robot. The *Stem* was placed under a spotlight in an empty room and participants, all part of our research team, were seated 2 meters from it. We asked participants to meditate and reflect on the *Stem*'s actions as it performed a series of simple, abstract motions such as swaying front to back or side to side repeatedly. The participants were asked to provide their interpretation of the robot's motions and to suggest a possible intent that might have been motivating the robot for each pattern.

Based on this very preliminary design critique, we were encouraged to find that the interpretations of each motion were generally consistent. For example, faster motions were considered more threatening and more sweeping motions were interpreted as "searching" across the majority of participants. Even under these informal circumstances, more advanced patterns of emotional engagement began to emerge: although the more rapid motions were initially interpreted as more threatening, the fact that the robotic entity was performing them in a very predictable, repeating pattern gave rise to a sense of trust for the participants. Eventually, the initial sense of aggression was often replaced with an interpretation that the robotic entity was "working hard" and being productive.

V. Future Work

The early results uncovered by the "*Stem*" design critique have already prompted further avenues of investigation into the specifics of emotive actuation. For example, the trust that participants developed in the entity's repetitive motions, even the more rapid and aggressive gestures, could be offset by the introduction of random variability; prompting the question "How predictable must the motion be before most observers come to trust in the robot?" Further, does the fact that a robot, typically a very precise machine, is performing a supposedly "random" motion introduce a juxtaposition of mental models that will affect participants' interpretations of the motion?

Additionally, the fundamental approach to these investigations provide ample opportunity for experimentation: for our preliminary design critique, the "S*tem*" platform pointed upwards towards the ceiling in a manner similar to a standing human torso, head, or upraised arm. By rotating the entire platform onto its side, it is possible that the same motions could be interpreted in the context of a "tail" or "leg", entirely altering the interpretation of the same abstract motion patterns.

Finally, these further examples focus only on the current "*Stem*" platform and its very abstract motion. As further research is performed into the unique contextual forms of *emotive actuation* and with more varied robotic platforms, we hope to gain a better understanding of how motion can affect emotion in social human-robot interaction. Ultimately, we hope to develop a taxonomy of *emotive actuation*, and to provide a set of design heuristics so that future social robotic entities can leverage on these concepts and provide an improved social and emotional impact.

References

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