Using Affect to Increase Empathy in Near-Living Architecture

Ali-Akbar Samadani, Dana Kulić & Rob Gorbet

The psychology literature reports on the human tendency to ascribe human-like social and affective attributes to non-anthropomorphic structures. In some cases, researchers report that observers even consider these structures to be engaging in social interactions with each other[1]. Our experience with the *Hylozoic Series* of sculptures supports this observation: visitors are both emotionally impacted by their visit, and ascribe definite emotional states to the environments, which they often anthropomorphize. At the Venice Biennale installation of *Hylozoic Ground* in 2010, visitors were overheard saying, "Look, it's happy!" or "It's angry", and ascribing many other emotions to the sculpture. In some cases, visitors interacted with the sculpture as if it was human, talking to it, observing it with sidelong glances, and wagging their fingers at it admonishingly.

If we are to realize the full potential of Near-Living Architecture, along with a host of other interactive machines, such as service and companion robots and interactive games, it is important to equip them with affective communication capabilities in order to enable an engaging, entertaining and empathic human-machine interaction. The capability to automatically recognize occupants' expressions and generate actuated affective responses improves the life-like attributes of the sculptures and enhances the hylozoic[2] perception, the perception that the environment is living, by their occupants.

To pave the path toward fully interactive kinetic mechanisms capable of affective communication with their occupants, it is important to first develop a sufficient understanding of how humans perceive and express affect through bodily movements, and the postural and motion cues most salient for affective expressions.

To this end, we have been conducting experiments on different affective human movement corpora to identify salient movement features for affective

[1] F. Heider and M. Simmel, "An experimental study of apparent behavior," *American Journal of Psychology,* vol. 57, no. 2, pp. 243–259, 1944.

[2] Hylozoism is the ancient belief that all matter has life.

facing page
3 Radiant Soil, Paris 2013

expressions, employing these features in developing computational models for affective movement recognition and generation. Human movement data consists of the time-series values describing the motion of many different body joints, resulting in large-scale datasets. We employ stochastic modeling approaches to derive a more concise representation of the movements that isolate movement cues relevant to affective expressions and enable efficient and accurate affective movement, recognition and generation. In particular, our research focuses on:

1. Understanding which features of movement convey affective expressions;
2. The automatic recognition of affective expressions encoded in movements; and
3. Adapting pre-defined motion paths in order to "overlay" affective content and generate affective expressions with kinetic mechanisms.

When generating affective expression with a kinetic mechanism, several additional considerations are introduced. The mechanism kinematics and dynamics may be different from a human demonstrator and may impose constraints on the range of motion. Furthermore, the structure and physical appearance of a mover might influence the human perception of its affective expressions. For example, if a mechanism doesn't have a human appearance, we have found it may be more difficult for a viewer to ascribe the full range of human emotions to it[4]. As part of our research, we have been conducting perceptual user studies to investigate the impact of the mechanism's structure and physical appearance on the perception of its movements. This article reviews the ongoing research and current results on the computational analysis of affective movements.

1 AFFECTIVE MOVEMENT PERCEPTION

Body movements are important observable manifestations of underlying affective states, and humans are adept at recognizing affective expressions encoded in body movements[5]. In order to develop reliable computational models for automatic affective movement recognition and generation for interactive machines and near-living architecture, it is important to understand how humans perceive affect from movements. In our work[6], we focus on the movement of human hands as the hand is an important medium for communicative gestures, and closely resembles the motion style and structure of the moving components of the Hyzoloic sculptures.

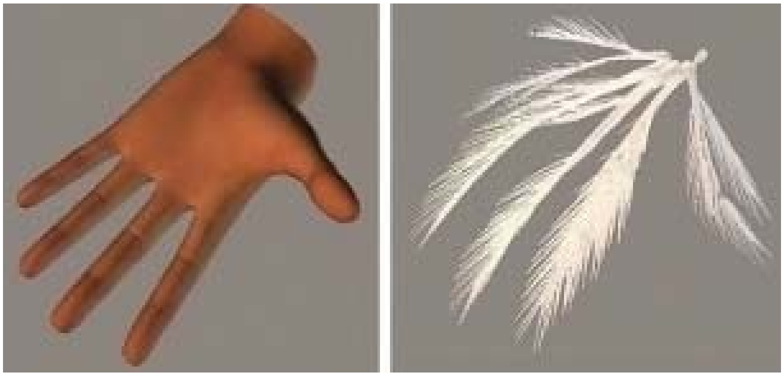
---

[4] A. Samadani, E. Kubica, R. Gorbet and D. Kulić, Perception and Generation of Affective Hand Movements, *International Journal of Social Robotics,* Vol. 5, No. 1, pp. 35 - 51, 2013.

[5] M. Karg, A. Samadani, R. Gorbet, K. Kuhnlenz, J. Hoey, and D. Kulic, "Body movements for affective expression: A survey of automatic recognition and generation," *IEEE Transactions on Affective Computing*, vol. 4, no. 4, pp. 341-359, Oct. 2013.

[6] A. Samadani, E. Kubica, R. Gorbet and D. Kulić, Perception and Generation of Affective Hand Movements, *International Journal of Social Robotics,* Vol. 5, No. 1, pp. 35 - 51, 2013.

[7] M. Karg, A. Samadani, R. Gorbet, K. Kuhnlenz, J. Hoey, and D. Kulic, "Body movements for affective expression: A survey of automatic recognition and generation," *IEEE Transactions on Affective Computing*, vol. 4, no. 4, pp. 341-359, Oct. 2013.

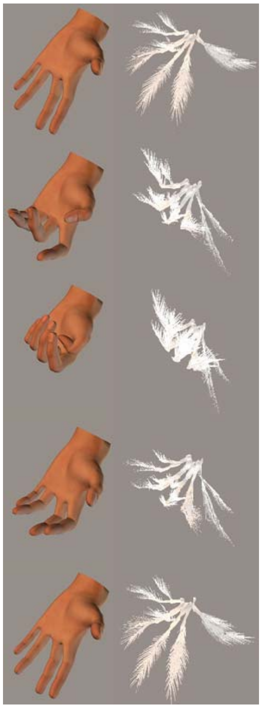


8 Structures used to display the affective hand movements in the user study. Anthropomorphic hand model (left), non-anthropomorphic frond like hand model.

We have tested the perception of hand movements intended to convey happiness, anger and sadness in a user study[7]. The hand movements were animated on a human-like hand model and frond-like hand model[8], and the impact of physical appearance of the mover on the perception of the movements was also studied. The frond-like structure was selected to resemble the appearance of the moving parts of the *Hylozoic Series* of near-living architectural environments.

Participants were able to perceive, above chance level, that there was some affective content in the movements from both the human-like and frond-like models. However, the accuracy of perception of the affective expressions varied between the structures. Participants perceived the expressions encoded in the hand movements as intended when the movements were displayed on the human-like model[9]. On the other hand, the sad movements displayed on the frond-like structure were perceived as happy movements. Furthermore, the frond-like structure displaying sad movements was frequently described as pleasant, friendly, and gentle, which also indicates the influence of the display structure on the perception of affective movements.

We have also conducted an experiment to investigate the potential role of the gender of the observer in the perception of affective movements displayed on different structures. To the best of our knowledge, there has been no previous research reporting on the role of gender and display structure on the perception of affective movements.



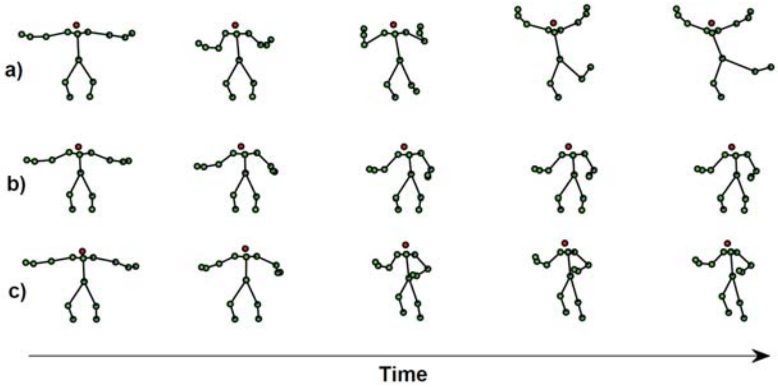
9 Sequence of frames displaying a movement on a human-like and frond-like hand models.

We found that the observer's gender significantly influenced their perception of affective movements and that the impact of the display structure and intended emotion on the perception of the affective movements differs between male and female observers[10]. For instance, male observers correctly recognized angry movements regardless of the display structure, whereas female observers associated less arousal and less-negative valence[11] to the frond-like structure displaying angry movements.

2. AFFECTIVE MOVEMENT RECOGNITION

The qualitative nature of affective movement perception, along with the subconscious and individual nature of affective movement expression, pose several challenges for computational analysis of affective expressions and, particularly, for automatic recognition. Furthermore, affective movements can be highly variable in terms of intensity, timing and the flexibility of the body, even when the same demonstrator repeats a single movement multiple times (viz., stochastic variabilities).

In addition to the interpersonal and stochastic differences, an affective expression can be communicated through a number of kinematically different movements. There also exist kinematically similar movements that convey distinct affective expressions[12]. Ideally, an automatic affective movement recognition model should be able to recognize the affective movements independent of kinematic, interpersonal and stochastic variabilities.



12 Movement exemplars from an affective human movement corpus[13]: (a) and (b) are two happy movements, which are kinematically different, whereas the happy movement in (b) is similar to the fearful movement in (c).

---

[10] A. Samadani, R. Gorbet and D. Kulić, Gender differences in the Perception of Affective Movements, International *Workshop on Human Behavior Understanding*, LNCS vol. 7559, pp. 65 - 76, 2012.

[11] In psychology, affective expressions are often represented using *categorical (discrete)* or *dimensional* models3. The most popular categorical description of affect is the *Ekman* model, which proposes anger, happiness, sadness, surprise, disgust, and fear as the six basic and universally recognized emotions. In dimensional models, affective expressions are described as points in a continuum of a low-dimensional space. For instance, the *Circumplex* model represents affective expressions in a two dimensional space defined by *arousal* and *valence*. The arousal dimension represents the level of activation, mental alertness, and physical activity, whereas the valence dimension ranges from negative (unpleasant) to positive (pleasant).

[13] A. Kleinsmith, P. De Silva, and N. Bianchi-Berthouze, "Cross-cultural differences in recognizing affect from body posture," *Interacting with Computers*, vol. 18, no. 6, pp. 1371–1389, 2006. pp. 65 - 76, 2012.

We have developed computational models that identify an abstract encoding of affective movements on which we built recognition models for distinguishing between different affective expressions[14, 15]. The abstract encoding of the movements is a dimensionally reduced movement representation in terms of a minimal set of movement features most salient for affective expressions.

In our recent work[16] we have presented an affective movement recognition approach based on stochastic dynamic models robust to temporal variabilities in the movements, capable of encoding kinematically dissimilar movements conveying the same affective expression in a single model. We have demonstrated the accuracy of the model using different affective human movement corpora with various bodily expressions of affect displayed by different demonstrators. Promising interpersonal recognition rates of 77% and 97% were achieved for full-body affective human movements (conveying anger, fear, happiness, and sadness) and hand-arm affective human movements (conveying anger, disgust, fear, happiness, sadness, and surprise), respectively. The achieved recognition performance surpasses previously reported recognition accuracy on the same movement sets. The recognition performance of the developed models could be further improved given a richer training dataset of affective movements that covers a wide range of expressions with kinematic, stochastic, and interpersonal variability.

In near-living architecture, the recognition model could help the environment to correctly perceive occupants' expressions and use these perceived expressions as a control input to mechanical actuation modules in order to generate an appropriate actuated response.

2.1 SALIENT AFFECTIVE MOVEMENT FEATURES

We have found that both postural and dynamic movement features are important for accurate affective movement recognition. Figure 12 demonstrates a set of salient movement features identified in our work as contributing to conveying different affective expressions. We have found that the upper body plays a key role in affective expression in full-body human movements. Our findings also indicate the important role of the human hand postures and motion for discriminating between different affective expressions.

---

[14] A. Samadani, A. Ghodsi, and D. Kulić, Discriminative functional analysis of human movements, *Pattern Recognition Letters*, vol. 34, no. 15, pp. 1829 – 1839, 2013

[15] A. Samadani, R. Gorbet and D. Kulić, Affective Movement Recognition based on Generative and Discriminative Stochastic Dynamic Models, IEEE *Transactions on Human-Machine Systems*, 2014, Accepted for Publication.

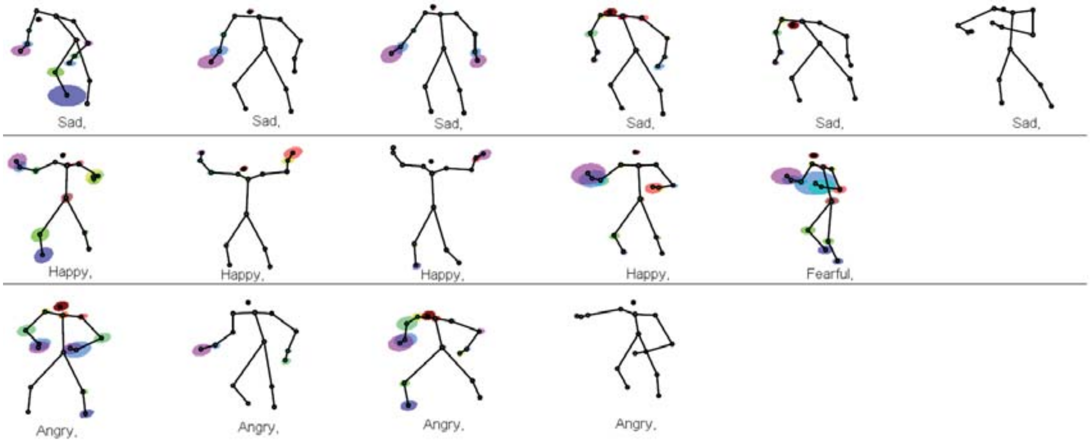
[16] A. Samadani, A. Ghodsi, and D. Kulić, Discriminative functional analysis of human movements, *Pattern Recognition Letters*, vol. 34, no. 15, pp. 1829 – 1839, 2013

As can be seen in Figure 17[17], there are characteristic postures salient to different affective expressions:

- Sad movements are generally characterized by a drooped head and shoulders, an overall slumped posture and a protective crouch posture;
- Happy movements are characterized by open and expansive postures, upward hand and arm movements, and advancing movements;
- Angry movements are characterized by arms akimbo postures, angled forward postures and clenching fists; and
- Fearful postures seem to show alert, retreating and cowering movements.

With regard to the speed of movements, we found that sad movements are slow and are characterized by lingering in time, and happy and angry movements are characterized by fast motions. Fearful movements are long in duration and are characterized by frequent jitteriness and freezing postures.

Knowledge of the salient affective movement features gained from our experiments can inform the design of physical elements for the Hylozoic sculptures for a more affective interaction with their occupants, which in turn will improve our ability to enhance the occupant experience. Nevertheless, the efficacy of the identified salient features for generating affective movements displayed on Hylozoic sculptures needs to be verified through user studies.



17 The full-body postures corresponding to the salient features for different affective expressions. The colored spheres around the body joints show the importance of the movements of these joints (high velocity and jittery movements).

3. AFFECTIVE MOVEMENT GENERATION

In order to give near-living environments and interactive mechanisms in general a more affective motion language and encourage increased empathy in communication, we are developing a framework for synthetically generating movement trajectories with recognizable affective content. The research question we are interested in is: How can we modulate a specific motion trajectory to overlay a desired affective expression? It is important to exploit an abstract movement representation in the computational analysis of movements that captures both kinematic and dynamic specificities as well as expressive qualities. Such an abstract representation also enables a more computationally efficient analysis of the movements.

Our approach to affective movement generation makes use of abstract movement representations in terms of a set of high-level descriptors. For a given trajectory, this generates a novel motion trajectory that conveys a desired expression while closely resembling the given trajectory. In a previous work[18], these descriptors represented the main modes of variation in a collection of affective movements identified using a statistical feature extraction technique. We observed that movements conveying different affective expressions form distinct clusters in a low-dimensional space spanned by the identified modes of variation. The centroid of each cluster was used as the prototypical representation for the corresponding affective expression and high-dimensional movement trajectories were generated for the prototype movements using an inverse transformation defined in terms of the main modes of variation.

We verify the expressivity of the synthetically generated affective movements both objectively and subjectively. For objective verification, we test how well the generated movements are recognized using our automatic recognition models (discussed in Section 2). The expressivity of the generated movements is subjectively verified via user studies, in which participants rate the perceived expressions from animations of the generated movements. In our previous study[19], synthetically generated affective movements were recognized correctly by the recognition model, and were also perceived as intended by observers in a user study.

Another set of high-level descriptors exploited in our ongoing generation work comes from movement notation systems. Movement notation systems from psychology and the dance community provide a rich tool for an abstract and informative representation of the movements as compared to high-dimensional body joint trajectories commonly used in computational movement analysis.

[18] M. Karg, A. Samadani, R. Gorbet, K. Kuhnlenz, J. Hoey, and D. Kulic, "Body movements for affective expression: A survey of automatic recognition and generation," *IEEE Transactions on Affective Computing*, vol. 4, no. 4, pp. 341-359, Oct. 2013.

[19] A. Samadani, E. Kubica, R. Gorbet and D. Kulić, Perception and Generation of Affective Hand Movements, *International Journal of Social Robotics,* Vol. 5, No. 1, pp. 35 - 51, 2013.

The Laban system is a prominent movement notation system that was developed for writing and analyzing dance choreography[20]. Laban encodes both the structural characteristics and the expressive qualities of a movement using a set of semantic descriptors. The Laban system has four major descriptors: Body, Effort, Shape and Space. Body and Space describe the structural characteristics of the movement, whereas Effort and Shape are primarily concerned with the qualitative aspects of the movement. Effort encodes the use of energy along four bipolar dimensions of Weight, Time, Space and Flow with their extremes being Light/Strong, Sustained/Sudden, Indirect/ Direct and Free/Bound, respectively. Bartenieff emphasizes that emotions and their intensity can be precisely observed through the Effort components[21].

In collaboration with a certified motion analyst (CMA), we have proposed a set of formulas for quantifying Laban descriptors and verified the efficacy of the quantification in comparison with annotations provided by the CMA for a hand-and-arm affective movement dataset. The dataset consists of different affective expressions communicated through a set of predefined hand and arm movements by a professional actor[22]. In an ongoing project, the quantified Laban descriptors are used to obtain an abstract encoding of affective movements and form the basis for a new affective movement generation approach.

With respect to near-living architecture and interactive machines, the generation models can be used to modulate actuated responses of the sculptures to manifest more empathic, life-like and affective expressions. When integrating generative models into the sculptures, the affective motion parameters should be attenuated to meet the kinematic and dynamic capabilities of the actuators (range of motion and maximum velocity and/or acceleration).

4. CONCLUSIONS

We have learned from the analysis of affective movements that it is feasible to perceive and express affect via movements of non-anthropomorphic mechanisms. However, there are limitations in creating such affect-aware mechanisms. These limitations stem from appearance, kinematic and dynamic differences between the mechanisms and humans. Kinematic and dynamic differences constrain the range of motion executable by a mechanism, which along with a mechanism's physical appearance may limit the range of expressions conveyable or in some cases may alter the perception of intended affective movements displayed by the mechanism.

There are also several reports on perceptual differences, which arise depending on whether the affective expressions are conveyed directly from a physical

[20] R. Laban and L. Ullmann, The mastery of movement. Plays, Boston, 1971.

[21] I. Bartenieff, Effort-Shape analysis of movement: The unity of expression and function. Albert Einstein College of Medicine, Yeshiva University, 1965.

[22] A. Samadani, S. Burton, R. Gorbet, and D. Kulić, "Laban effort and shape analysis of affective hand and arm movements," *International Conference on Affective Computing and Intelligent Interaction,* 2013, pp. 343 – 348.

structure (e.g., kinetic sculpture), a video or an animation[23]. Therefore, the physical structure and presentation (physical versus virtual) of display mechanism may influence the human interaction with them and merits further exploration.

We have also observed gender-specific differences in the perception of affective movements displayed on different structures, which emphasize the importance of considering the user's gender in designing affect-aware mechanisms and call for validating displayed affective movements by interactive mechanisms with both male and female users. Furthermore, research should be conducted to identify if there exist physical structures and appearances that might limit (or modulate) the communication of affective expression with male or female observers.

The occupants' culture and the context within which the sculptures are presented might also influence occupant experience. Therefore, it is important to investigate the impact of culture and context during human-machine interaction and consider them in developing interactive sculptures capable of affective expressions; expressions that best match the expectation of their occupants. Other modalities such as sound and light can be also combined with the actuated responses of the sculptures to express a wider range of expressions, which in turn help in creating a more empathic and hylozoic experience for the occupants.

On the recognition side, in order to develop recognition models that closely emulate the human perception of affective movements, the affective movement perception from differing human observers should be incorporated in developing automatic recognition models.

For the generation side, as part of our ongoing research, generation approaches are being designed that are capable of generating a wide range of movements with various affective expressions. These approaches are either example-based or model-based. Example-based approaches are data-driven and their success depends on the dense sampling of affective movements available for training the generation algorithm. Model-based approaches make use of our findings on the salient features for affective expressions to constrain a target motion trajectory with a set of motion and postural features specific to a desired expression.

By understanding what aspects of movement connote different affective states, and developing algorithms for generating corresponding motion paths, this research gives the environment the ability to communicate affective state to its occupants. This is a critical step in furthering our broad goal of imbuing near-living architecture with the ability to engage in more empathic relationships with occupants.

---

[23] A. Samadani, E. Kubica, R. Gorbet and D. Kulić, Perception and Generation of Affective Hand Movements, *International Journal of Social Robotics,* Vol. 5, No. 1, pp. 35 - 51, 2013.