A Shape Grammar of Emotional Postures

An approach towards encoding the analogue qualities of bodily expressions of emotions

Nasim Motalebi[1], José Pinto Duarte[2]
[1,2]Pennsylvania State University
[1,2]{nfm5140|jxp400}@psu.edu

This paper is concerned with the translation of analogue qualities of human emotions into digital readings. Human body postures are considered as one of the main behavioral conduits for non-verbal communication and emotional expressions (Shan et.al., 2007). This research is the first step towards identifying and detecting emotions through posture analysis of users moving through space; leading towards generating real time responses in the form of spatial configurations to users' emotions. Such spatial configurations would then help inhabitants reach certain emotional states that would enhance their life quality. In order to achieve this goal, we propose a methodology for developing a comprehensive shape grammar algorithm that could evaluate and predict bodily expressions of emotions. The importance of this study lies under the embodied interactions (Streech et.al., 2011) in space. As the circumfixed space impacts the embodied mind, the body impacts its surrounding including the architectural space.

Keywords: *Shape Grammar, Computation, Emotion, Posture, Interactive Architecture*

BACKGROUND

In their paper Abreu et. al. (2009) discuss architecture as a composer for melodic behavior; an arranged sequence of movements and feelings called a gesture. "The subject-person is induced to a sort of slow dance movement by the melody architecture plays [...]. A place produces a complex of motions and emotions in the subject" (Abreu and Esteves, 2009). Abreu calls this complex of motions and emotions "gesture". A gesture caused by architecture could be comprehended for its meaning- emotions. Gestures then become a universal and shared basis for further interpretation: not only to understand the meaning of a work of architecture, but architecture's impact on human psychology and emotions.

In an empirical study by Abreu (Abreu, 2017) the impact of architecture, specifically a church, on the gestures of its visitors has been experimented. Focused on a sequence of walking and gazing, they use multiple strategies such as eye-tracking glasses, heart beat trackers, and semi-manual GPS trackers to trace the visitor's gestural response as they face the church's environment. However, their work does not exceed beyond the understanding of shared patterns among visitors and individual expressions have not been studied beyond walking patterns in space. In this case, bodily expressions of individual visitors could have been studied through postural behavior in order to evaluate emotional responses of each individual, subject to experiencing space. In other words, postures are representations of certain emotions that if studied, they could have been implemented in the evaluation of each inhabitant's perception of space.

Figure 1
The Ephemeral Dreamspace: (Re)Activating an Evocative Architecture through Computational Devices and Bodily Interaction. Master's Thesis by Nasim Motalebi. Advisor Marcus Shaffer. On the bottom, the bladders have been inflated.

In another work, Heinrich et al., propose a methodology in order to measure people's responses to the qualities of certain buildings (Heinrich and Wurzer, 2016). This method however, is limited to surveys and indirect evaluation of architectural qualities. The direct interpretation of bodily expressions in the architectural space and the evaluation of postural behavior could be a method that would complete, or rather, validate their measurement of the perceived architectural quality.

Stepping beyond architectural evaluation, bodily expressions of emotions can help architects to design spaces that would change their properties in accord to the psychological needs of the individual inhabitant. In the work done by Motalebi (Motalebi, 2017), a computationally actuated sitting area has been designed that changes shape in response to the gestural behaviors of those sitting on it (Figure 1). At this point however, this design has yet to appropriate its actuation based on the variety of postures and the psychology of gestural behavior of the inhabitants. Today on one hand, the technology exists to design and manufacture actuated environments, while on the other hand, the gestural behaviors of the inhabitants have been merely studied and implemented in defining such actuations. There still remains space to apply the psychology of gestural behavior into the design of actuated environments in order to achieve what is known as "interactive architecture" (Fox and Kemp, 2009).

As the first step to fill this gap, we propose the use of shape grammars as a tool that goes beyond the design of architectural elements towards incorporating behavioral factors into the design process. Shape grammars can help us identify the characteristics of the bodily postures and expressions that compose the properties of the architectural space. As architecture shapes movements, and movements shape architecture, the postural understating of human behavior could lead to appropriating the architectural space for those behaviors.

Postural studies relate to the semiotics of human behavior (Eco, 1976), (Radford, 2003). Thus meanings cannot be generalized to postures across cultures. However, there are certain postural habits that have been studied and identified as universal (Hewes, 1955). The postural behavior of each person in different architectural contexts, while it can be based on personal and contextual preferences, could indicate an emotional behavior (Wallbott, 1998). A vast number of researches have used worked on using computational devices for postural analysis and emotion evaluation such as (Clavel et al., 2009), (Coulson, 2004) providing proof to this claim. However not many have integrated design and design processes into their technology for emotion detection. Knowing such technology exists, it is time to integrate user behavioral analysis with the design of architectural spaces that could adjust their qualities to users' emotional state. Next section is dedicated to presenting a methodology for incorporating bodily expressions of emotions with a descriptive shape grammar that could be used as a computational tool for the design of architectural spaces.

METHODOLOGY

Today machine learning algorithms are developed towards image recognition and visual search (Pannaman, 2016). There are techniques that would train the computer on the user's emotional gestures and behavior with a 98 percent accuracy (Behoora and Tucker, 2015). In their paper, Behoora et. al (2015) use skeletal joint data inferred from the user's body language to read live time emotions. However, these techniques are mostly limited to a high level representation of raw data from the user's body postures. Predicting, simulating, and generating responses to the collected data are usually condoned. This research proposes shape grammars for their high level visual analytic and generative power as a tool to incorporate behavioral analysis of the users with architectural design as a creative process. As to demonstrate this power, this paper uses shape grammars to generate variations of bodily expressions; to not only detect emotions from body postures, but to simulate certain emotional postures and define descriptive responses for the analogue qualities carried by those emotions.

By generating a shape grammar of emotional postures, we can exceed beyond a quantified detection of emotions to a descriptive qualification of postural behavior. In the context of description grammars (Garcia, 2016) we will integrate posture recognition with a descriptive labeling system (Stiney, 1980) in order to simulate, predict, and generate emotional responses to the user's emotions. In other words, we argue for implementing empathetic behavior in computer systems with such methodology. Followed by the implications of postural detection of emotions, the shape grammar of bodily expressions of emotions are presented and discussed.

Shape Grammars, as a visual calculating system are based on shapes and shape rules. Rules are repeatedly applied on any given shape to generate new forms and shapes based on specific transformations. Shape Grammars work closely to the eye and the visual qualities of any 3D shape (Stiney, 1980), suggesting that they can be used to calculate body movements, postures, or in other words motions and hence emotions. However, the use of shape grammars has been mostly limited to shape generation for arts, design, architecture, and so on. Shape grammars allow symbolic calculation of shapes, where shapes are infused with ambiguity (Stiney, 2006). Even though calculation is inherently in oppose to ambiguity, shape grammars leave the space for calculating qualities that were not originally thought of.

For this, shape grammars seem to be the appropriate tool for calculating the analogue qualities of human behavior; to not only analyze human behavior based on visual postures, but to predict, generate, and simulate the behavior of an embodied mind. The importance of such system lies in its integration with design where shape grammars have already proven to be useful. As soon as the analogue qualities of human behavior is translatable into digital readings, it will be possible to train digital systems that would directly interact with their human subjects in different scenarios. In the case of this paper, we focus on embodied emotions and the shape grammar of emotional postures. In order to design systems that interact with the emotional behavior of their users, we needed to start from understanding such behaviors using the shape grammar tool. Next, we will demonstrate how shape grammars were used to specify some emotions based on postural studies.

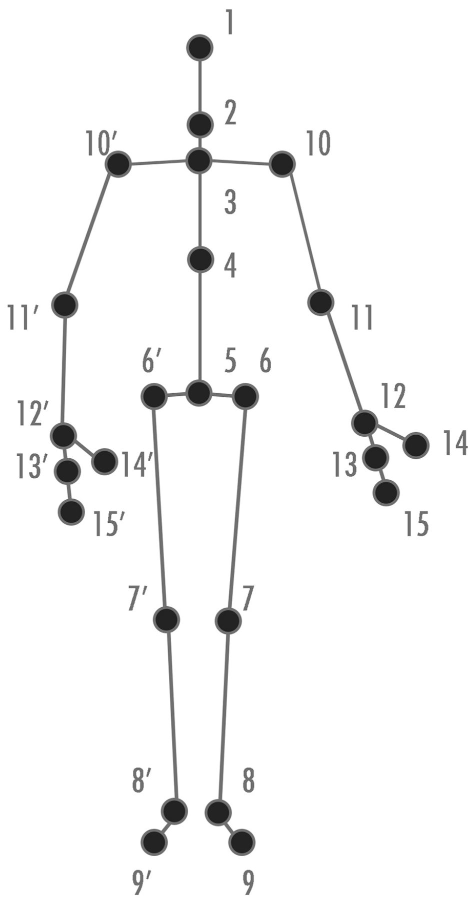


Figure 2
The initial shape shows the numbering of the joints based on the Microsoft Kinect Skeleton Library. The shape grammar library was then written based on these numbers.

The Shape Grammar of Emotional Postures

In this paper, a shape grammar of emotional postures is proposed in which emotions are assigned to different layers of bodily movements based on a psychological study by Wallbott (1998). The grammar itself functions similarly to a human movement simulation tool previously investigated by Maria Piedade Ferreira (2011). Adding emotional qualities to certain postures, the rules and parameters that define the grammar are more confined. The initial shape represents the standing position of a human body. Based on the skeleton data, the body joints are numbered for the description and application of the rules of the grammar (Figure 2).

The rules extracted from Wallbott's study are then developed to generate series of variations for different emotional postures and behaviors. Every stage of the grammar represents a set of emotions. By applying more rules to the outcome of each stage, the emotions become more specific. Figure 3 demonstrates the grammar for simulating Elated Joy in three different views in the Cartesian system- Frontal, side, and plan view. The applied rules and the description of each stage follows a specific structure. For instance, to achieve a position for Elated Joy, rules 1 to 4 must be applied as below:

- R1: Upper Body Erect / Possible Emotions: Cold Anger, Hot Anger, Elated Joy, Interest, Pride
- R2: Shoulders Up Center in 3: Rotate until joints make an angle between 0 and 90 with the X axis: 10,10' / Possible Emotions: Hot Anger, Elated Joy
- R3: Head Backward Center in 2: Rotate until joints make an angle between 0 and 90 with the Y axis: 1 / Possible Emotions: Elated Joy
- R4: Arms Outward Center in 10: Rotate until joints make an angle between 90 and 180 with their drop down position with the X axis: 11,11',12,12',13,13',14,14',15,15'
- If: R1->R2->R3->R4 Then: Elated Joy

In this description, first the joint number as the center of rotation is identified. Consequently, the action is specified following the joint numbers which the rule will apply to them.

Figure 3 is part of a more complex system of posture generation and emotional evaluation. This grammar is capable of describing any number of preidentified postures. Figure 4 demonstrates a bigger scale of posture generation that narrows down cer-

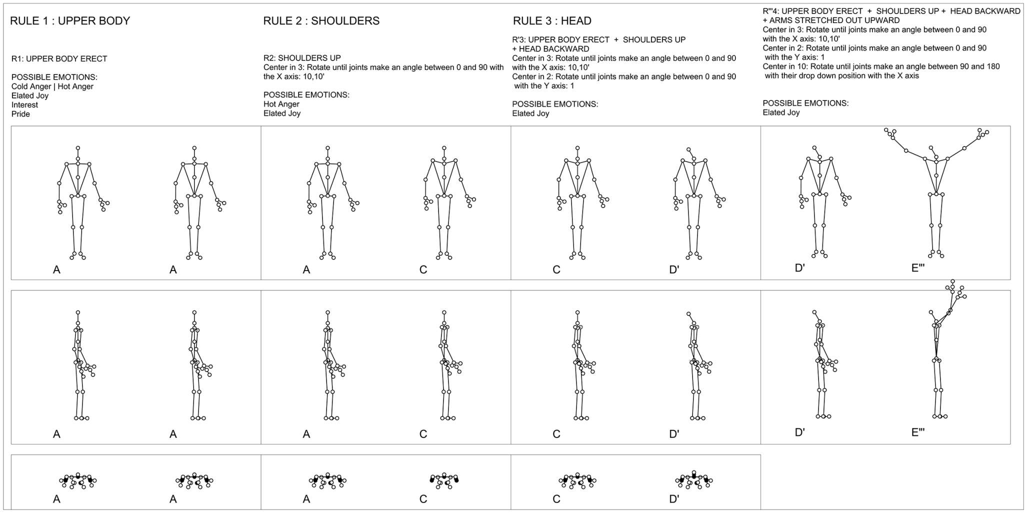


Figure 3
The postural grammar for "Elated Joy". By applying four rules to the initial shape, we can achieve the posture that represents this emotions.

tain emotions. In this example, elated joy, sadness, cold anger, hot anger, interest, pride, disgust, contempt, despair, fear, terror, shame, and boredom are the identified emotions. The rules can differ for different parts of the body which as a result concludes to specific emotions.

By focusing on the body joints, we have defined a clear representation of body movements which are understandable and can be used as high level representations to be implemented in visual search APIs and machine learning algorithms. As a first step towards achieving this goal, the code above has been used in a Processing code for Kinect using the built-in Skeleton Library (Figure 5). The same visual algorithm can be further developed for designing simulations of postural emotions and to be used for interactive systems. A very good example is the use of such visual algorithms for designing human-robot interactions. Nonetheless, architecture can use the same algorithms in different contexts for the design of actuated and interactive environments; capable of responding to human emotions based on their postural movements in space.

Developing such environments necessitates taking the first step towards translating analogue qualities of human behavior into digital readings. Posture recognition as a more convenient method for emotion analysis could then be integrated with other sensorial data inputs such as galvanic responses (Kurniawan et al., 2013), EEG readings (Soleymani et al., 2016), facial expression recognition, and so on for more accurate behavioral data. However, posture recognition has the advantage to allow the inhabitant to move freely in space, as the first medium for spatial perception. It is for the future steps to build up the way towards developing environments capable of understanding their inhabitants more accurately and adapting to their needs accordingly. One example of such developments is expanding the design for "The Ephemeral Dreamspace: (Re) Activating an Evocative Architecture through Computational Devices and Bodily Interaction" (Motalebi 2017) to not only react to positions, but adapt itself to detailed postural behaviors.

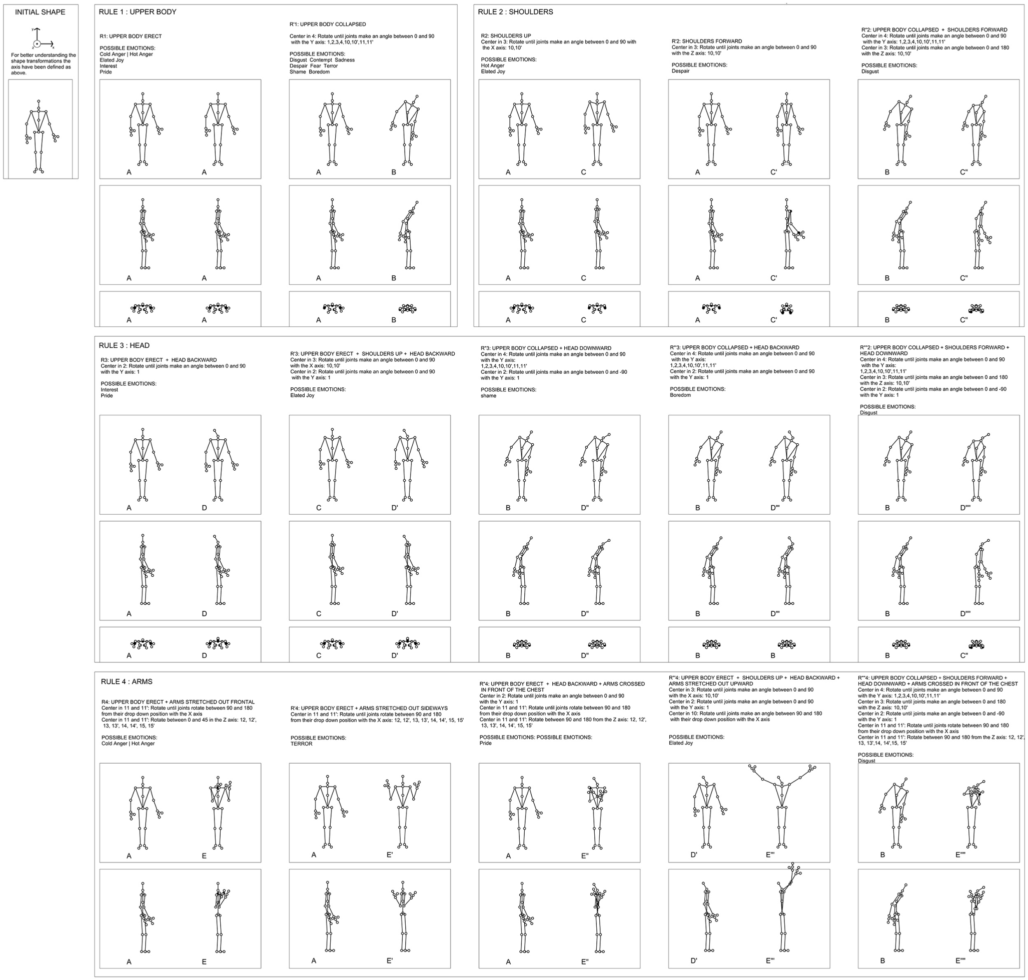
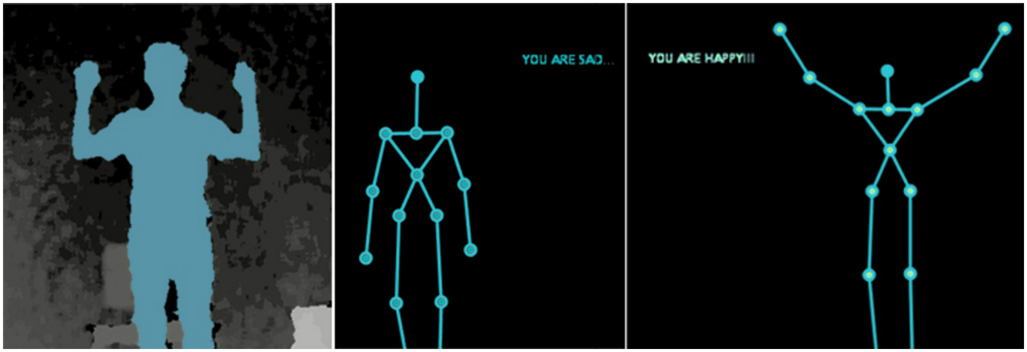


Figure 4
The Shape Grammar of Emotional Postures

Figure 5
Postural Emotion Detection: Implementation of code in processing using the Open NI Library for skeleton data. Sad and happy postures have been implemented in the code and the represented through simple text



CONCLUSIONS

A shape grammar of bodily expressions of emotions has been developed to be used as a high level representational tool for evaluating, predicting, and simulating different emotional states. Implementing the logic of shape grammars in visual search algorithms helps training systems that can not only detect emotions from gestures, but will help the system to simulate the emotional behavior and define appropriate responses for such emotions. The importance of this approach lies in developing technologies that would consider human psychological responses in different situations. These technologies can vary from robotics, web interfaces, and architectural spaces that detect and interact with their user's emotional behavior. Today researchers are trying to study empathetic behavior and ways in which spaces can empathize with human emotions in order to help the inhabitants in overcoming emotional difficulties in times of stress, anger, and so on. We hope that this research can be further developed and implemented in the design of interactive environments in which physically actuated environments change their properties based on the emotional and psychological need of their inhabitants.

CONTRIBUTIONS

The generative abilities of shape grammars would help designers to not only predict, but to generate responses in accord to the inhabitant's emotions. The implementation of shape grammars in computational algorithms can be used as a tool for architects and designers for implementing human emotions in their designs for interactive environments. In addition, shape grammars can be used for the study of human behavior and implementing them into the design process and education. Shape grammars can exceed beyond shape generation towards incorporating behavior analysis of the users of space and how it affects the design outcome.

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