Using verticality to classify motion: analysis of two Indian classical dance styles

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Abstract. The Indian classical dance styles of Bharatanatyam and Kathak have many similarities in movements and hand gestures, but their execution varies greatly. Analysis of similar movements from two styles results in observed differences in position and tension. Limitations in a previously developed motion capture metric (verticality) are discussed. Other movement measures are introduced that may be more appropriate to highlight differences in the two styles. Potential applications include robots that need different measures to appropriately sense human motion in different cultures.

1 Introduction

The Sanskrit text Natya Shastra (500BCE to 500CE) delves into the ancient Indian performing arts [2]. The dance section describes hand/feet positions and conveying emotions through movement and expression. The Indian National Academy for Music, Dance, and Drama recognizes eight styles of Indian classical dance - Kathak, Bharatanatyam, Kuchipudi, Kathakali, Manipuri, Odissi, Sattriya, and Mohiniyattam.

Bharatanatyam and Kathak, from southern and northern India respectively, diverged significantly from their common ancient dance ancestor due to historical, cultural and regional differences. Sharpness, tension, and straight lines in arms and legs characterize Bharatanatyam movements. In contrast, Kathak movements are softer with less tension in elbows and wrists.

Qualitative features of these dance styles have not been quantified and pose challenges to typical capture processes. How do we quantify small differences observed in similar movements from these two styles? Similar research has compared other pairs of dance styles, such as Kathak and Flamenco [7].

Working with a trained ballet dancer, our research has previously used motion capture to compute reduced DOF models recording human motion. Using motion capture of two interacting individuals observed by a Certified Movement Analyst, we correlated their movement using a single DOF measure, called verticality. Verticality measures leaning of the spine during a movement [4] (Figure 1). We also presented motion segments for which a low DOF simulated robot motion based on verticality imitated the human motion capture skeleton better than a robot following a pseudo-random signal [3].

Since Western dance primarily motivated our previous research in verticality, this measure may not directly apply to other dance forms. In this extended abstract, we will further examine qualitative differences between two Indian dance styles (Section 2). We will then consider how verticality would represent those differences and suggest improved measures based on our observations (Section 3).

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Figure 1. Verticality vector (green) with respect to positive z-axis of the mover (black). **Left:** Motion capture skeleton with angle from z-axis to verticality vector θ labelled. Figure from [4]. **Right:** A Kathak (left) and Bharatanatyam (right) dancer performing similar movements. The verticality vector does not capture differing hand gestures or tension in limbs. Screenshot from [5]

2 Kathak and Bharatanatyam movement comparison

We will observe similarities and differences in an analogous position and in hand gestures performed in both dance styles. These observations were performed by the first author who has trained in both the Lucknow school of Kathak and Kalakshetra school of Bharatanatyam.

2.1 A similar movement in two styles

Figure 2 shows a movement performed in both styles (left:Kathak, right:Bharatanatyam). Both dancers extend their left arm to the upper-back-left corner and point their right foot towards the bottom-front-right corner. Their right hands point inward at chest level with head turned looking at their left hand. Their bodies are angled, pointing towards the front-left. However, the Bharatanatyam dancer extends her left elbow while lunging, right knee unbent. The Kathak dancer bends her left elbow and has a more balanced stance. We therefore conclude that these dancers are performing similar movements in different styles.

The positions in Figure 2 also differ in hand gestures, named using [1]. The Bharatanatyam dancer's left hand is in *alapadma* (fingers splayed), and her right hand is in *katakaamukha* (first two fingers touching thumb with other two fingers splayed). The Kathak dancer's left hand is in *pataaka* (fingers outstretched and together with thumb slightly tucked inward), while her right hand is in *araala* (index finger touching thumb with other fingers outstretched and together).

Figure 2. A Kathak (left) and Bharatanatyam (right) dancer performing similar movements with left arm pointing up and right foot extended out. Weight shift, tension in the limbs, and hand gestures differentiate the two positions. Screenshot from [6]

2.2 Hand Gesture Comparison

The same hand gesture still exhibits subtle differences when performed in these two styles. Figure 3 illustrates the differences in two hand gestures (*pataaka* and *araala*) performed in Kathak and Bharatanatyam. The purple circles highlight differences in thumb positioning. The Kathak gesture has lower tension in the thumb, lightly touching the side of the hand, while the Bharatanatyam gesture has higher tension in the thumb, held forcefully into the hand.

The green circles emphasize differences in muscular tension in the entire hand. In Bharatanatyam, this tension is created by arching the tightly squeezed fingers and can be observed through veins standing out prominently in the wrist. The Kathak gesture has fingers placed flatter, not pressed together as tightly, and lower tension in the wrist. These subtle differences in hand gestures exemplify the stylistic differences between Bharatanatyam and Kathak.
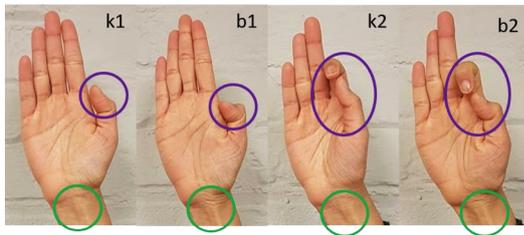

Figure 3. The Kathak(k) and Bharatanatyam(b) hand gestures *pataaka*(1) and *araala*(2) compared. The purple circles call attention to the thumb's positioning, and the green circles emphasize the increased tension in the wrist, spreading to the entire hand.

3 Verticality and other possible measures

After observing the similarities and differences in the two dance styles, we will now attempt to apply verticality, developed in prior work, to quantify these differences. We will also discuss the arising limitations and introduce a few preliminary measures that could address those limitations.

3.1 Verticality and its limitations

We will apply verticality developed in prior research to differentiate Kathak and Bharatanatyam movements. Figure 1 (right) illustrates a Kathak and Bharatanatyam dancer in a similar position (mirrored). The verticality vector (green), connecting the lower neck and pelvis, indicates the spine leaning away from the z-axis (dotted black). The roughly corresponding angles formed by the two verticality vectors demonstrates the movements' similarity. However, nuances in hand gestures, limb positions, and tension are not captured by this metric.

3.2 Proposed other measures

We will propose a variety of measures to detect differences in the two dance styles not evident through verticality. For example, we can extend the mathematical process used to compute verticality to construct other vectors on the motion capture skeleton. A measure of angles made by arms and legs with the vertical may yield a richer representation of motion. Evaluating such measures is the subject of our current research.

An alternative method may look at specific angles in the data set. These could include the angles between the hand and wrist, forearm and upper arm, and lower and upper leg. For example, in Figure 1, the elbow angle varies in the two positions because Kathak dancers tend to keep a greater bend in the elbow, to preserve the softness of the movement.

Tracking differences in tension, especially in hand gestures, may be difficult to measure. A hand motion capture system, integrated with a full body motion capture system, may be capable of tracking small differences in the hand positions between styles. However, these differences in tension may not be distinguishable through motion capture alone, requiring the use of other types of sensors.

4 Conclusions

We have presented a set of observations comparing similar movements executed with different movement features (e.g. hand gestures and muscular tension) in two Indian classical dance styles. We have described limitations in a previously developed motion capture metric, verticality, to discriminate between the two styles. We have also discussed other potential measures to quantify differences in similar movements for this comparison.

Examining static positions in the two dance styles yields useful information. However, analyzing motion data sets from both dance styles where dancers perform similar movements will provide a richer quantitative comparison of Bharatanatyam and Kathak. This comparative framework can generate better motion representations valuable in a variety of applications. The previously developed measure of verticality was useful within the context of Western dance but can break down when differentiating between two Indian dance styles. Similarly, in-home robots may need additional metrics for sensing motion in users of different cultures or environments.

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