1) Introduction

There have been many ways of Communication like oral communication, written communication, visual communication or Sign Language communication etc. The written communication seems very attractive when it is about symbolizing human motion in textual form.

This work is focused on generating a grammar or script for typical Indian Classical Dance i.e. Bharatnatyam from its video recording. Bharata Natyam is known for its grace, purity, tenderness, and sculpturesque poses.

2) Background

The work done in [1] can extract features of *static* skeleton frames from Depth data of Kinect recordings of Indian Classical Dance. It tracks left, right hand and left, right leg postures. This work extends [1] by incorporating automatic selection of skeleton frames relevant for feature extraction. This work adds dynamism and automation to [1].

3) Motivation

There is very less or no known work to provide a textual and diagrammatical form to Dance movements. If dance movements could be recorded in this way, then it would overwhelmingly bring down the circulation and distribution costs and overheads of Dance recordings. This work is inspired by the idea of having a music script for a pianist.





Figure 1: Duality with a piano script



Figure 2: Symbolization of Dance movements

Anyone who can read the script can play music on the piano. Similarly, we envision that anyone who is familiar with a precise notation of Dance movements can read and interpret the given script describing various dance postures and could assimilate the postures without use of any video recordings. This vision can also revolutionize the way of dance tutoring and dance classes.

4) Outline

In this work, I proposed various methodologies and algorithms for graceful and accurate selection of skeleton frames from Kinect video recordings of Indian Classical Dance. Then for each selected skeleton frame, angles between various bones are used to form feature vectors. These feature vectors are then used to classify the body postures by supervised methods like SVM and ANN. The data collection and classification is already carried out by [1]. I simply integrated my frame selection algorithms with the work done by [1].

5) Summary

This work begins with overview of Kinect and how Kinect's Depth data is a potential resource for classifying dance postures. It then

highlights about Labanotation. It then broadly discusses about the algorithms proposed for selection of frames relevant for important dance postures. It then discusses about the integration with already done work [1].

6) Literature Survey

Zella Wolofsky[3] has worked on Computer Interpretation of selected Labanotation commands. L. Loke[4] et al. worked on Labanotation for Design of Movement-Based Interaction. Alexiadis et al.[5], has worked on performance evaluation of dancer based on kinect skeleton.

7) Objectives

- To symbolize dance movements of Indian Classical dance using Labanotation
- To leverage elegance of Labanotation in generating a pictorial script and providing a grammatical and diagrammatical representation to Indian Classical Dance
- To select frames which cover major postures of the movement
- To avoid lose of important frames at turning points of movement
- To skip similar skeletal frames
- To integrate my work with work done in [1]



8) Overview of Kinect

In 2010, Microsoft released Kinect – a motion sensing input device for the Xbox 360 gaming console and Windows PCs. Besides being a gesture-controlled console for gaming, Kinect for the first time, offered inexpensive depth sensing that enables direct interaction between human and computer; between the physical and the virtual world. The device features an RGB camera, depth sensor and multi-array microphone running proprietary software, which provide

1. <u>Raw sensor streams</u>: Access to low-level streams from the depth sensor, colour camera sensor, and four-element microphone array.

2. <u>Skeletal tracking</u>: The capability to track the 20 joints skeleton image of one or two people moving within the Kinect field of view for gesture-driven applications.

3. <u>Advanced audio capabilities</u>: Audio processing capabilities include sophisticated acoustic noise suppression and echo

cancellation, beam formation to identify the current sound source, and integration with the Windows speech recognition API.

In different human body postures, as the angular information of different limbs plays a crucial role to suggest symbols of a standard notation (discussed in following section) and so in this work the main focus will be the skeleton data taken out from Kinect. The data feed generated by the Kinect will have multiple output screen to enable user for viewing the feed of RGB data, Depth data and Skeletal data. When kinect runs live on some human figure the feeds would look like as shown in figure above:



Figure 4: Depth, Skeleton and RGB data from Kinect

9) Methodology



Figure 5: Flow Chart of work done

9.1) Familiarity with Labanotation

Labanotation is a system of analysing and recording of human Movement. The original inventor is the (Austrian-) Hungarian Rudolf von Laban (1879-1958) an important figure in European modern dance.

In Labanotation, it is possible to record every kind of human motion. Labanotation is not connected to a singular, specific style of dance (unlike other dance notations e.g. Benesh Notation is based on English classical ballet). The basis is natural human motion, and every change from this natural human motion (e.g. turned-out legs) has to be specifically written down in the notation. Labanotation is way of writing which tries to record every aspect of motion as precisely as possible.

9.1.1) Staff

Similar to music notation Labanotation uses a staff. It consists of nine columns and runs vertically. The sequence of movements is read from the bottom to the top of the page (instead of left to right like in music notation).



Figure 6: The Staff

Anything that happens on the left side of the body could be written on left side of the staff and anything that happens on the right side of the body could be written on the right side of the staff .Left part has 4 columns namely left support, left leg, left torso and left arm. Similarly for right side of body we have 5 columns namely right support, right leg, right torso, right arm and head. So for each column as the name suggest we annotate body parts movement in that column only. For example left leg related movement is described in left leg column only.

9.1.2) Direction and levels

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Labanotation has two integral parts which makes it different from others namely direction and level. The easy to annotate or understand these notations are that make these highly valuable. Direction shows directional movement of a body limb and level shows the degree of movement.

Direction has 11 symbols namely Place, Forward, Backward, Left Side, Right Side Diagonally Left Backward, Diagonally Right Backward, Diagonally Left forward and Diagonally Right Forward.





Figure 8: Levels

Level has 3 symbols namely high, medium and low as shown in figure 8. Low level is represented by full shaded part and medium is represented by small black dot in middle of the corresponding symbol and high is represented by multiple tilted lines corresponding symbol.

9.1.3) Examples



Figure 9: Examples of Labanotation

To make it easy to understand we will follow few examples shown in the figure 9:

In first example (from top left corner) a man is placing his hand downwards this is represented by place (rectangular) box with full black shades i.e. low level. In second, the man is putting his hand right side so right side triangle shape is used with full black shaded part i.e.; low level. In fourth one, hand position is high in right side so a triangle facing right side and with tilted lines is shown ie; right side high. In similar fashion other pictures can be understood.

There are different symbols assigned for different body parts as shown in figure 10. The movement of left foot and right hand is shown as an example in the figure 11.



Figure 10: Symbols for body parts





Figure 11: Movement of left foot and right hand

9.2) Proposed algorithms for Selection of skeletal frames:

9.2.1) Random k frames



- Randomly choose k frames
- Skip every w frame where w=N/k, N being total no. of frames

Problem:



Figure 12: Plot of random selected tracked x,y coordinates of right hand

Can loose frames with important postures

9.2.2) Statistical approach (Variance)



Figure 13: Plot of min and max variance selected x,y coordinates of right hand

Algorithm

Along x axis:

Let (x_i,y_i) be depth coordinates of a joint in i-th Skeletal frame

- Compute $\mu_x = (\sum x_i) / N$
- Let $var_i = Abs(\mu_x x_i)$
- Sort var[]
- Choose k/2 frames from upper end and lower end of var[] with a skip of w frames

Along y axis:

Let (x_i, y_i) be depth coordinates of a joint in i-th Skeletal frame

- Compute $\mu_y = (\sum y_i) / N$
- Let var_i= Abs(µ_y y_i)
- Sort var[]
- Choose k/2 frames from upper end and lower end of var[] with a skip of w frames

Problems:

- We got frames clustered around extreme ends due to high variance and clustered around mean due to low variance.
- Need for a better Approach

9.2.3) Cubic polynomial Curve Fitting



- · Fit a polynomial to the dataset
- · Compute derivative say deri at i-th point
- Sort der[]
- Choose k/2 frames from upper end and lower end of der[] with a skip of w frames

Problems:

- Need for Smoothing s.t. Jittering and noise is avoided
- Cannot rely on cubic curves. Highly unstable for complex movements



Figure 14: Plot of min and max derivative selected x,y coordinates of right hand

9.2.4) Smoothing:

Applied : single exponential double exponential moving average median filter savitzky golay filter

Observation: Savitzky golay filter and Moving average performed best



Figure 16: Savitzky Golay filter



Figure 17: Moving filter



Figure 18: Cubic Bezier Curve

 $B(t)=(1-t)^{3}P_{0} + 3(1-t)^{2}tP_{1} + 3(1-t)t^{2}P_{2} + t^{3}P_{3}$, where t lies in [0,1] Here, P_{0} and P_{3} are called end points and corresponds to t=0 and t=1. P_{1} and P_{2} are called control points.

9.2.5.1) Derivative Computation

- To compute derivative at a point P
 - Find t corresponding to P
 - Find B_x(t) and B_y(t)
 - The magnitude of derivative= $\sqrt{B_x^2 + B_y^2}$
 - The direction of derivative = $tan^{-1}(B_y/B_x)$

9.2.5.2) Bezier curve fitting

- Input: n points P_0, P_1, \dots, P_{n-1}
- Output: 2(n-1) Control points
- 1) Let $B_0, B_1, \dots B_{n-2}$ be bezier curves s.t. B₀ passes through P_0, P_1
 - B_1 passes through P_1, P_2 and so on ...
- 2) Find two control points corresponding to B_0 s.t.

$$B_0'(1)=B_1'(0)$$

$$B_0"(1)=B_1"(0)$$

3) Do step 2) for all the n-1 bezier curves



Figure 19: Polynomial Vs Cubic Bezier Curve frame selection

9.2.5.3) Frame selection by Magnitude

Algorithm

- 1) Now we know $B_0, B_1, B_2, \dots, B_{n-2}$ from 2.5.2)
- 2) Find derivative at $P_0=B_0'(0)$, $P_1=B_1'(0)$,... $P_{n-2}=B_{n-2}'(0)$ and $P_{n-1}=B_{n-2}'(1)$
- 3) Form der[] considering sign of derivative at each point

4) Sort der[] and select k/2 frames with min. derivative and k/2 frames with max. derivative

Problem:

Frames with neither high or low derivative magnitude can have important postures

9.2.5.4) Frame selection by Angle of Tangent

Algorithm

1)Compute angle of tangent at each point, say stored in der_dir[] 2)curr=0

3) for i=1 to n-1 do

if Ider_dir[i]-der_dir[curr]l >= thresh

select frame i

curr=i

9.2.6) Technical Details

Libraries used: Matlab, MathNet.Numerics, LibSVM, ANN.

- · Captured frames in dcl file
- Saved joint coordinates of right hand with corresponding frame no. of skeleton frame on disk
- · Smoothed the points using Savitsky Golay Filter
- Applied Bezier Curve(Angle of Tangent) algorithm to select frames
- Extracted features for selected frames
- Tested their Labels

9.2.7) Experimental Results:

- I experimented with thresh=1.5, 2.0 and 3.0 radians
- Converted all angles in range [0,2∏] in counter clockwise direction wrt positive x-axis
- I tried for circle, dumb-bell curve and bharatnatyam postures

Current derivative	Next derivative
0.124363394384219	5.90291021017183
2.35329269822637	0.124363394384219
5.89965430146964	2.35329269822637

Table	1:	Circle	with	thresho	ld=1.5
101010		0.1.0.0			

Current derivative	Next derivative
2.43695695284697	4.44817085318594
4.44260840561619	2.43695695284697
1.6008777392528	4.44260840561619

Current derivative	Next derivative
3.699113422965	5.83590549701552
6.09369941975927	3.699113422965
3.64792838576819	6.09369941975927

Table 3: Dumbell with threshold=1.5

Current derivative	Next derivative
5.8657718986449	2.71296676160922
0.0946545930459858	5.8657718986449
3.17224386123625	0.0946545930459858

Table 4 : Bharatnatyam with threshold=3.0



Figure 21: Smoothed x,y coordinates of right hand for circle



Figure 22: Selected frames by Bezier Curve (Angle of Tangent) for circle



Figure 23: Tracked x,y coordinates of right hand for dumbell



Figure 24: Smoothed x,y coordinates of right hand for dumbell





Figure 25: Selected frames by Bezier Curve (Angle of Tangent) for Dumbell



Figure 26: Tracked x,y coordinates for Bharatnatyam



Figure 27: Smoothed x,y coordinates for Bharatnatyam













Figure 28: Selected frames by Bezier Curve (Angle of Tangent) for Bharatnatyam

9.3) Integrated my work with work [1] for static frames





Figure 29: Feature Extraction and classification

The selected frames are then used to get angular features from joint coordinates of selected skeleton frame. Then its limb postures is labelled using SVM and ANN classifiers as shown in figure 29.

10) Future Work

- To take into account other joints of body
- · To detect the speed and direction of motion

11) References:

[1] Automated Encoding of Human Postures in Labanotation from Kinect Depth Data by Vivek Nautiyal, IIT Kharagpur

[2] Ann Hutchinson Guest "Labanotation The System of Analyzing and Recording Movement"4th Edition, Publishing Year 2005, Publisher Routledge

[3] Zella Wolofsky "Computer Interpretation of Selected Labanotation Commands ", M. Sc. thesis, Year 1974

[4] Lian Loke , Astrid T. Larssen, Toni Robertson "Labanotation for Design of Movement-Based Interaction" Proceeding IE '05 Proceedings of the second Australasian conference on Interactive entertainment, Pages 113-120, 23-11-2005

[5] Alexiadis et al., Evaluating a dancer's performance using kinect-based skeleton tracking in Proc. 29th ACM Int'l Conf. Multimedia, New York, NY, 2011.

[6] "Kinect for windows features", http://www.microsoft.com/en us/ kinectforwindows/discover/ accessed on date 21-10-13 [7] "LIBSVM -- A Library for Support Vector Machines" http:// www.csie.ntu.edu.tw/~cjlin/libsvm/ accessed on date 30-04-14

[8] "Kinect Technology" http://en.wikipedia.org/wiki/Kinect, accessed on date 10-04-14