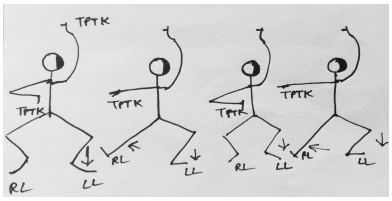

Figure 1: A Hand-drawn Stick figure.

1 Dance Pose Representation

In this chapter we have discussed the method of representing our data. It demanded a detailed study of the ancient dance scriptures *Natyashastra* and *AbhinayaDarpana*. We also involved several dance experts from Goa and other states for the need to understand and represent the major limbs of the human body, so as to generate various combinations permissible within the dance framework. The following subsections explain as to why we didn't choose Labanotation (a notation system for recording and analyzing human movement that was derived from the work of Rudolf Laban in 1928 ([Wikipedia, 2016b]) or video capture methods for the same and how we arrived at our method of modeling the body.

2 Labanotation

ICD especially BN does not follow any notation system and usually its learnt from the teacher to the student under the *guru-shishya parampara* i.e. teacher-student traditional learning system through regular practice. Students use non-standardized stick figures notation to depict and remember the sequence of choreography as shown in Figure 1. The obvious dis-advantage to this system are many which was found through our experiments in ([Jadhav et al., 2014]). For example the projection of 3D poses onto 2D always created a loss of dimension. The intricate and finer hand movements of BN called as *mudras* were lost. The finer expressions of eyes or lips could not be captured through stick figures and hence the same dance could be interpreted in different ways by different dance teachers.

3 Labanotation Symbols

3.1 Basics of Labanotation

Western dances like Classical Ballet, Ballroom (Tango, Cha-Cha and Two-step) and Folk Dances (Cherkessia, Israeli Dance) follow Labanotation, see Figure 2 for a basic cha-cha movement. It is difficult to notate a dance movement through this notation until and unless one has gone through rigorous training as can be seen in the notation system from the Figures 3, 4, 5. The technical standards and education for Labanotation are provided by several organizations. For example, the International Council of

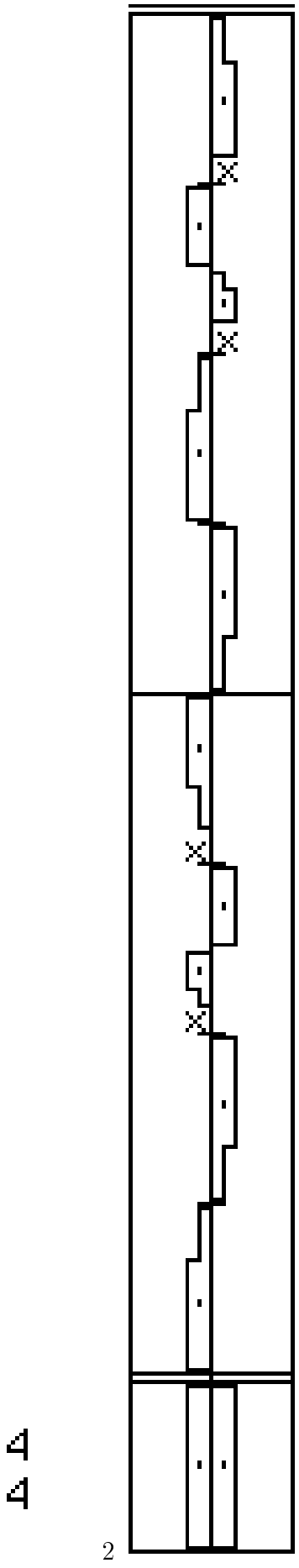

Figure 2: A Basic Cha-cha movement.

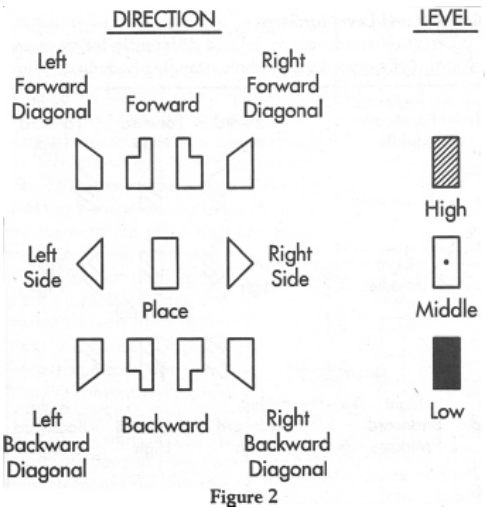

Figure 3: Direction symbols.

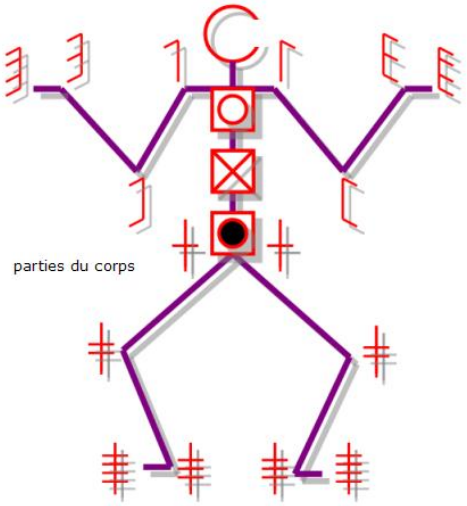

Figure 4: Parts of the body.

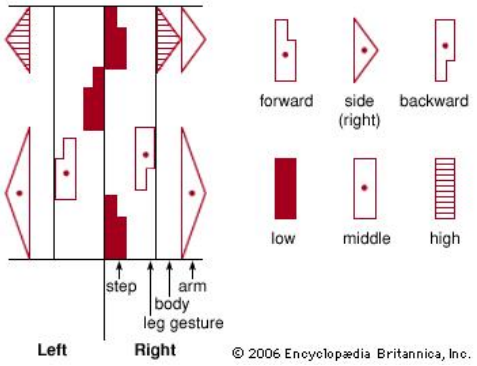

Figure 5: Staff symbols.

Kinetography Laban / Labanotation promotes standards and development for Labanotation ([Wikipedia, 2016b]). Also the Department of Dance, Ohio State University has designed a website to teach the basics of Labanotation ([Department of Dance, 2014]). Several websites are dedicated to teach Labanotation.

This is a Dance Notation system derived from the work of (Austrian-Hungarian) Rudolf von Laban (1879-1958) and further developed by noted dance notation historian, Ann Hutchinson Guest and others. It is a system of analyzing and recording of human movement ([Wikipedia, 2016b]). Labanotation uses abstract symbols to define the:

- Direction and level of the movement
- Part of the body doing the movement
- Duration of the movement
- Dynamic quality of the movement

3.2 Data Representation, Editing and Animation

When Labanotation was designed, there was no intention of computerization. Several researchers have worked towards representation, editing and animation of Labanotation. One of the oldest papers date back to 1978 ([Smoliar, 1978]) where Stephen W. Smoliar from the University of Pennsylvania developed a program to compile the Labanotation movements into graphic simulation of human movement. He has used ordered pair to represent Direction (DIRECTION, direction-indication) and Level- indication (HIGH, MIDDLE or LOW). The data structure was represented in a page as variable number of staves and floor plans. Each staff was associated with 17 columns of objects.

Life Forms (1996), the animation program was developed by Dr. Tom Calvert ([Calvert and Mah, 199 from the Simon Fraser University stemming from an earlier work in 1977. It had begun as a visualization tool for generating choreographic ideas in 1993. LabanWriter was developed by the Department of Dance at Ohio State University by Dr. Tom Calvert ([Calvert et al., 1991]). This system was only supported on a Macintosh platform and suitable for preparing Labanotation scores and recording them in digital form. LabanDancer ([Wilke et al., 1932]) was a tool for animating the inputs from LabanWriter. Today Life Forms is being commercially marketed by Credo Interactive, a Vancouver- based animation company. The dance figures can be manipulated through key framing techniques and also uses motion capture inputs.

Some researchers from Japan, Kojima et al. in 2002 ([Kojima et al., 2002]) and Nakamura et al. ([Nakamura and Hachimura, 2002]) have developed LabanEditor which helped to input / edit the Labanotation scores and display character animation. Choensawat et al. in 2010 ([Choensawat et al., 2010]) had introduced a dynamic template technique for notating Japanese traditional performing arts called as *Noh* by using fundamentals of Labanotation. Later they have generated a tool called as GenLaban in 2015 ([Choensawat et al., 2015]) for automation of Labanotation scores from Motion Capture data. They claim that their work is more comprehensive than others due to use of whole

body posture analysis for generating the Labanotation scores. However they clearly stated that the Labanotation symbols are being continually introduced and hence will be incorporated in the tool as time permits, indicating that the entire symbols have not been coded yet. In the year 2005 Chinese researchers X. Shen et al. ([Shen et al., 2005]) removed few problems with LabanEditor about the quantization of front direction in an animation sequence and introduced new ideas. Thus in 2006 ([Nakamura and Hachimura, 2006]), Nakamura and Hachimura introduced LabanXML which was an XML representation of the Labanotation.

3.3 Use of Labanotation for BharataNatyam

Annemette P. Karpen, a BN dancer of Russian origin has attempted in her paper at the 11th European Conference of South Asian Studies ([Annemette P. Karpen, 1990]) to use Labanotation, for BN. She concluded that the finer hand gestures couldn't be captured successfully with the same. So she devised her own method of notation for BN. Ami Pandya, from the Department of Dance, Maharaja Sayajirao University of Baroda, in her Doctoral Thesis ([Pandya, 2016]) has also used Labanotation for BN. She has added several columns on to the original Staff of Labanotation and successfully notated with this system for Nritta Choreography especially *Adavus* to the minutest detail. She adopted the Laban fundamentals to suit BN movements for e.g the high, medium, low symbols were used for standing, half-sitting and sitting movement of BN. Divya Venkatesh ([Venkatesh, 2016]) has presented a graphic design project in her experimental work on BN notations through comparing and contrasting on three different notation systems: Benesh System, Beauchamp-Feuillet and Labanotation.

Since Labanotation was extensively used by several researchers earlier, we ruled out modeling the body with Labanotation .

4 Capture Data through videos or Kinect Camera

Few researchers have worked in the area of capturing BN dance through Kinect camera. Sharma ([Sharma, 2013]) has used an action classifier for *adavus* using SVM. Kale et al. ([Kale and Patil, 2015]) have used the kinect camera to recognize 5 *adavus* of BN which would help in recognizing the meaning of dance and display it to the audience. We couldn't use any of the above existing methods mainly due to one main reason. We didn't want to use any of the existing choreography but generate altogether new steps and suggest the same to the choreographer. This generation of steps also had to follow BN norms and be consistent enough to be accepted by dancers. Thus capturing dance which was already existing would not add any novelty to our research at all. We also wanted various techniques of pruning the unwanted data and displaying those poses that were feasible and totally innovative. Thus capturing or recording existing sequences would not help us in our innovative technique.

5 Modeling the Human Body for Pose Notation

We have attempted to model the human body for Indian Classical Dance in a totally different way. There are **two assumptions** which we followed. These are as follows:

1. Movement of the limbs are represented with respect to the dancer.
2. Movement of the dancer is taken with respect to facing the audience which is the default position of the dancer.

After an extensive literature review of ancient dance books like NS, AbhinayaDarpana (AD), CDs/ DVDs, several discussions with dance experts from all over India and abroad and the author's personal experience of BN; we noted down all the position of major limbs. These included the head orientation, the hand movements along with the dance *mudras* for *Nritta*, the waist position and the leg positions.

5.1 The initial stages of codification

This involved the use of codes from NS ([Bharata, 1996]) and AD ([Ghosh, 2002], [Ghosh, 1975]) which were in Sanskrit along with their orientations in English. For example following are the codes for *Shiro Bheda* (SB) (head movements) written in brackets. The pictures can be seen in Appendix **??**.

Shiro Bheda (**SB**) total - 9 movements.

```
Samam(sm)          :straight
Udhvaahitham(ud)   :head with eyes facing up
aalolitham (al)    :rotating the head
adhomukham(ad)     :face is cast down
dhutam (d)         :shake head from side to side
kampitham(kam)     :shaking head up and down
paraavritham(prv)  :looking to one side
utkshiptham (ut)   :semi circle movement
parivaahitham(pvh):shaking from one side to the other.
```

Similarly the Neck called as *GreevaBheda*(**GB**) and Eye movements called as *DrishtiBheda*(DB) were also constituting of 4 and 8 movements respectively. The Hand movements are divided into Double hand Gestures called as (*Samyukta Hasta*) (**SH**) and Single hand Gestures called as (*Asamyukta Hasta*) (**AH**) or *mudras* .The AH has 28 *mudras* and SH has 23 *mudras*. The Leg movements *Pada Bheda* (**PB**) has total 39 movements in all.

Thus initially, we used the following Table 1 for codifying the Body movements. Head (2 attributes), Neck(3 attributes), Hands(Double hand Gesture (*Samyukta Hasta*) and (6 attributes) each for Right and Left Hand) and Legs ((6 attributes) each for Right and Left Leg along with Strike and Jump).

SB	Ori	**GB**	Hori	Verti	**SH**	**AH**-R	
Hori-R	Verti-R	El-O-R	P-twist-R	P-bend-R	**AH**-L	Hori-L	
Verti-L	EL-O-L	P-twist-L	P-bend-L	**PB**-R	Hori-R	Verti-R	
PB-L	Hori-L	Verti-L	Str	Jump			

Table 1: Initial Codes Designed

Ori/O: Orientation, *Hori*: Horizontal (if orientation is in front or back of the body),*Verti*: Vertical (if orientation is along the body i.e. not in front and back), *R*:Right, *L*:Left , *El*:Elbow, *P*:Palm, *Str*:Striking or tapping Leg.

These were 26 attributes in all and later we realized that a mixed data type of string and numeric will not give good results with (Waikato Environment for Knowledge Analysis) WEKA, the Machine Learning tool. The results of WEKA couldn't be interpreted and also the combinations generated with these attributes were very large. Although it was easier for us to decipher the positions but the system wasn't able to handle these mixed data, due to the specific techniques used by WEKA. Thus we finally agreed on numeric data types for all the codes. Also the intricate Hand Gestures of BN, SH and AH were combined into Single Hand Gesture representation only. Most of the SH convey meaning (like *shankha, chakra, shivlinga*, etc.) however few of these gestures while being used for *Nritta* can be easily depicted with the help of AH and hence they are not shown explicitly. For example *Anjali Hasta*(the *namaskar* position) which is a SH can be shown with the help of *Pataka Hasta* (which is a AH) of both hands at the chest level. Also our Dance Position Vector representation has each hand (right and left) modeled separately.

5.2 Modeling

We chose to fuse the Neck and Eye movements with the Head since these three work in unison and are related to each other always. The Head and Neck movements are detailed in the Appendix **??**. Only the circled ones are used by us and rest are discarded since we wanted movements for *Nritta* only. Eye movements are not considered since they are very fine movements used to express feelings like anger, happiness, etc. For *Nritta* we use the eye movements as per the *shloka* in *Natyasastra* ([Bharata, 1996]) as follows:

"*yato hasta tato drishti; yato drishti tato manah; yato manah tato bhava; yato bhava tato rasa*" ||

Meaning: Where the hand is, eyes should follow there, where the eyes are, the mind should be there, where the mind is, there goes the expression, and where there is expression, there arises sentiments/emotions.

Thus the above *shloka* explains that the eye movements will automatically follow with the hands and we need not specify them separately. Moving the head in a particular direction automatically will require the movement from the neck and the eyes need not show the finer expressions since Nritta does'nt use expressions other than keeping a pleasant smiling face which is radiated through the eyes as well. Thus our proposed model can

easily capture the required pose needed for the purpose of creative choreography and the finer details are left to the interpretation of the choreographer. Also it has to be noted that we have developed a system to assist the choreographer and not give entire details. Thus only one SB would solve the purpose instead of adding Neck and Eye movements also. This also helped us in reducing the number of permutations and combinations for each body part.

Table 2: The dance movement details

Sr. No.	Body Part	*No.	**Codes
1	SB	9	ad, sm, prv, ut
2	GB	4	Not Considered
3	DB	8	Not Considered
4	AH	23	pat, tri, karm, ardc, kap, katm, suc, ala, shi, dol
5	SH	28	considered with help of AH
6	PB	39	sm,anc,kun,suc
	TOTAL	111	18

Number of Legitimate and Documented Movements

*Positions of the Limbs and their codes used in for research purpose(in Sanskrit)

Shiro Bheda-SB (head movements): *Adhomukha (ad), sama (sm), parivartita (prv), utkshipta (ut).*
Greeva Bheda-GB (neck movements).
Dhrishti Bheda-DB (eye movements). (Refer Appendix **??**)

Hasta Bheda (hand movements)

Asamyukta Hasta- AH (Single Hand Gesture): *Pataka (pat), Tripataka (tri), Kartarimukha (karm), Ardhachandra (ardc), Kappitha (kap), Katakamukha (katm), Suchi (suc), Alapadma (ala), Shikhara (shi), Dola (dol).* (Refer Appendix **??**)

Samyukta Hasta – SH (Double Hand Gesture) (Refer Appendix **??**)

Pada Bheda- PB (leg movements) : *Sama (sm), Anchita (anc), Kunchita (kun), Suchi (suc).* (Refer Appendix **??**)

Table 2 shows the exact number of legitimate dance steps that are documented in NS but the Codes represent those chosen by us for *Nritta*. *Tripataka* and *Ardhachandra* have the same code as can be seen in Appendix **??** since *Ardhachandra* is not used at all for *Nritta Hasta* but used while doing an *adavu* which does not use any hand gesture explicitly. The hand is kept on the waist turned backwards with this *Ardhachandra* gesture. Sometimes its done with both hands or one hand is kept on waist and the other hand depicts some *Nritta Hasta*. It is to be noted that the Hand gestures are numbered (from 0 to 8) (Refer Appendix **??**) on the basis of ease of transition from one *mudra* to another and the same sequence is followed in NS too!

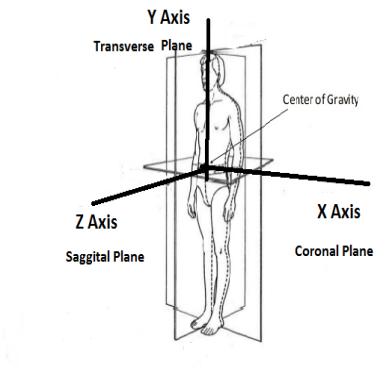

Figure 6: The three Body Planes showing the Orientation of Hand and Leg in X,Y and Z axis .

5.2.1 Bartenieff Fundamentals

Bartenieff Fundamentals (BF) are a set of principles for corrective body movement developed by Irmgard Bartenieff, who studied with Rudolph Laban and colleagues in Germany (1925) ([Wikipedia, 2016a]). BF are additional development to Laban's research and use **anatomical body planes** for movement. As can be seen in Figure 6 saggital, coronal and transverse are the three body planes. The **sagittal** or lateral plane divides the body into left and right halves and is an x-z plane. The **coronal** or frontal planes divide the body into front and back (also called dorsal and ventral or posterior and anterior) sections and are x-y planes.The **transverse** planes, also known as the axial or horizontal planes, are parallel to the ground and divide the body into top and bottom parts. They are the x-z planes.

We have used these body planes for modeling the human body pose notations. Use of Genetic Algorithm and Bartnieff fundamentals for Computer aided choreography has been efficiently carried out in ([Carlson and Pasquier, 2011]). In the next two Chapters **??** and **??**, we have explained the use of Genetic Algorithm for Single Beat and Multi Beat choreography.

The codification went through several revisions over time to finalize the model to be designed for the human body as per BN norms, as can be seen in Table 3 (which is used in all the database tables) and 4 (is an easier way to understand the same code through index numbers and Right and Left orientations).

SB	ORI	HAR	HRX	HRY	HRZ	HRE	HRW	HRP	HRJ	
HAL	HLX	HLY	HLZ	HLE	HLW	HLP	HLJ	WT	WB	
AR	KR	LRX	LRY	LRZ	AL	KL	LLX	LLY	LLZ	

Table 3: Final Codes

The final result was a thirty attribute dance position (DP) vector which could represent the end of a static pose through the major limbs used in BN dance (head, right

hand, left hand, waist, right leg and left leg position). These six major limbs of the body were identified and they were further given orientations as per BN norms. For example the head position was further divided into front facing, right and left position. Although the head can move up, down, back and in circles too, we eliminated these orientations since they were used for representation purposes as follows. A circling head indicates a drunken movement which is not used for *Nritta* purpose. Likewise all other major limbs of the body were given angles and orientations as per the possible availability in BN dance. They were codified with numbers to ease the process. Detailed paper presented in the following ([Jadhav et al., 2012]).

1 Sb_M	2 Sb_O	3 R_Fg	4 R_HX	5 R_HY	6 R_HZ	7 R_El	8 R_WR	9 R_Pm	10 R_Sj	
11 L_Fg	12 L_HX	13 L_HY	14 L_HZ	15 L_El	16 L_WR	17 L_Pm	18 L_Sj	19 W_tw	20 W_be	
21 R_An	22 R_Kn	23 R_LX	24 R_LY	25 R_LZ	26 L_An	27 L_Kn	28 L_LX	29 L_LY	30 L_LZ	

Table 4: Final Codes with Index position of Vector

With the help of the Index positions of the Vectors, the codes can be explained as follows:

Position of Head : 1 and 2,
Position of Right Hand : 3 to 10,
Position of Left Hand : 11 to 18,
Waist position : 19 and 20,
Right Leg position : 21 to 25,
Left Leg position : 26 to 30.

5.3 Orientation

The details of each of these major limbs are specified in detail as follows:

5.3.1 Head Orientation

The Head has 2 attributes as can be seen in the Table 5 which are given a nomenclature as **Mudra** (Sb_M) and **Orientation** (Sb_O). The head can move in several directions in different ways like right, left, sideways, looking straight, turned sideways and rotational movement. However for *Nritta*, we have kept only 3 orientations namely right/ left, tilt and looking straight. Since the other orientations will depict a meaning to the pose, they are not kept. For example NS specifies *dhutam* : shake head from side to side which denotes saying no. Thus any such depictions carrying a meaning to the gesture are not considered and only the ones used for *Nritta* are specified.

Table 5: Head Orientation

Attributes	**Orientation**			
Sb_M	Adho: -1	Sama: 0	Prv: 1	Utt: 2
Sb_O	Right: 1	Straight: 0	Left: -1	

Sb_M: ShiroBheda Mudra, **Sb_O** : ShiroBheda Orientation .
Adho: Adhomukha, **Prv**: Parivartita, **utt**: Utkshipta .

Table 6: Waist Orientation

Attributes	**Orientation in Degrees** (°)					
	-90°	-45°	-30°	0	45°	90°
W_tw	NA	-1	NA	0	1	2
W_be	NA	-1	0	NA	1	2

W_tw : Waist Twist, W_be : Waist Bent.

5.3.2 Waist Orientation

Waist also has 2 attributes **twist** (W_tw) and **bend** (W_be). These attributes have Orientation in 0, 45 and 90 degrees on the same side (right side has positive degrees on right and vice versa) and -30 and -45 on the other side (right side will have negative degrees on the left and vice versa). 0 indicates no twist or bend happening while a 45 degree twist on the right side has half of the movement of the waist and 90 shall have a complete waist twist. These are the dancer's capabilities depending on their fitness and flexibility but it needs to be recorded in this manner so that the degree of twist can be understood clearly. Also a negative twist happens when for example the dancer sways from right to left side. It is to be noted that only -45 degree is specified here because -30 and -90 degree twists are not done in BN. Since we have not specified the left or right side of the waist, this can be understood with the help of the left or right hand being used for that pose notation. So if a left hand is being used and a positive degree is used for waist attribute it shall mean the movement is towards the left side and vice versa.

5.3.3 Hands Orientation

The Hand Orientation is divided into 8 attributes namely: L_HX, L_HY, L_HZ, L_El, L_Fg, L_Wr, L_Pm, L_Sj. These indicate the following: Left Hand **X-axis, Y-Axis and Z-Axis** co-ordinates, Left **Elbow**, Left **finger** which denotes the Hand Gesture or (*HastaMudra*), Left Wrist, Left Palm positions and whether there is a Left Shoulder Jerk or no. Here also for representation purpose we have chosen to explain the Left hand attributes but similar 8 attributes exist for the Right hand also. The X,Y and Z axis positions of the hand can be seen in the Figure 6.

The **X axis** is the Coronal Plane (Right and Left Side); as shown in Table 7; which can take values from -60 to 90 degrees. Here the right hand in the right direction will have positive values and vice versa. Similarly the right hand going towards the left shall have

Table 7: Hand Orientation

Hand-parts	**Att.**	**Orientation in Degrees (°)**								
		90	60	45	30	0	-30	-45	-60	-90
Shoulder	L_HX	4	3	2	1	0	-1	-2	-3	NA
	L_HY	4	3	2	1	0	-1	-2	-3	-4
	L_HZ	Frnt: 1		N: 0		Bk : -1				
Elbow	L_El	2	NA	1	NA	0	135= 3			
Hastas	L_Fg	Pat:	Tri	Krtm:	Kutm	Shi:	Suc:			
		0	&	2	3	4	5			
			Ardc:	Kap:	Ala:	Dol:				
			1	6	7	8				
Wrist	L_Wr	Fup: -1				0	Fdn: 1			
Palm	L_Pm	B fr: 1				0	Opp: -1			
Shou.Jerk	L_Sj	P in: 1				0	Pout: -1			

Att.(Attributes): L_HX, L_HY, L_HZ: Left Hand X-axis, Y-Axis and Z-Axis;
L_El: Left Elbow; L_Fg: Left Finger(*HastaMudra*); L_Wr: Left Wrist,
L_Pm: Left Palm,L_Sj/ Shou.Jerk: Left Shoulder Jerk.

Frnt: Front, N: None, NA: Not Applicable, Pat: Pataka, Tri: Tripataka,
krtm: Kartarimukha, Kutm: Kutukamukha, shi: shikhara, suc: suchi,
Ardc: Ardhachandra, Kap: Kapittha, ala:Alapadma, dol: Dola.

Fup: Facing up, Fdn: Facing down, B fr: bent towards finger,opp: opposite,
P in: Pulling in, Pout: Pushing Out

negative values and vice versa. A negative 90 degrees for the X axis is not possible since it's not aesthetically pleasing to see your hand doing a *mudra* in the opposite direction at 90 degrees for a dance performance.

Y axis is the Transverse Plane (Up and Down) which can take values from -90 to 90 degrees depending on the degrees of freedom allowed for a BN performer while moving hands in the Y direction..

Z Axis is the Saggital Plane (Front and Back) which indicates whether the hand is in front (positive value) or back (negative value). The method of moving the hand from front to back is done on BN principles which every student or teacher is already familiar with and hence not explicitly mentioned. (Refer the last Section, before the Conclusion of this Chapter, for more details on hand movement in the Z axis).

The **elbow** bends for BN are restricted to only 45, 90 and 135 degrees. The reason is 30 degrees and 180 degrees of elbow bends are not aesthetically pleasing and not done in a BN sequence.

The most intricate part of BN are the ***Hasta Mudras*** which have Sanskrit names and also convey specific meaning. When a BN performer uses a *Mudra* for an action, she conveys a meaning to the dance sequence. However some of the *Mudras* are used to perform *Nritta* and do not convey any meaning. We have chosen only these *mudras* for our *Nritta* choreography. They are numbered from 0 to 8 depending on the sequence of transition of the fingers.

The downward movement of the **wrist** (while keeping hands straight in X axis) is very easy and a default position and has a positive sign while a small effort is required to turn it upwards and hence a negative sign used.

When a hand is held in *Natyarambhe* position (similar to the hand shown in AppendixC.b)), the **palm** position bend towards finger are positive and to move it in upwards direction has a negative sign.

A **shoulder jerk** is a special and subtle movement done very quickly and adds special emphasis on the *Nritta* choreography. If the shoulder is pulled in a positive sign is used and a negative sign is used when its pulled out.

5.3.4 Legs Orientation

The Leg has 5 attributes. They are as follows: L_LX, L_LY, L_LZ, L_An, L_Kn. These are for the Left leg and hence similarly 5 more attributes for the Right leg are used. The first three attributes denote the X, Y and Z axis for the Leg position followed by the ankle and knee positions. The main position of a dancer is actually determined by the knee attribute. This has the signature BN step called as *Ardhamandala* which is the half-seated position. Also it has the normal standing in place position called as *Sthanaka*

Table 8: Leg Orientation

Leg Subparts	Attributes	Orientation in Degrees °						
		-90	-45	-30	0	30	45	90
Thigh/Hip	L_LX	NA	-2	-1	0	1	2	3
	L_LZ	-3	-2	-1	0	1	2	3
	L_LY	Above ground: 1	Touching ground: 0					
Ankle	L_An	An : -1	Sm: 0	St: 1	Kun: 1	Suc: 2		
Knee	L_Kn	Sthanaka: 0	ArdhMandala: 1			Mandi: 2		

L_LX, L_LY, L_LZ : Leg Left X-axis, Y-Axis and Z-Axis; L_An: Left Ankle; L_Kn: Left Knee.
An: Anchita, Sm: Sama, St: Sthanaka, Kun: Kunchita, Suc: Suchi

and the full seated position called as *mandi* (Refer Appendix **??**). The ankle has certain positions which can be determined depending on the knee position. For example if knee is in *Sthanaka/ Samapada*, all positions of ankle can be done. Whereas if knee is in *Ardhamandala* position, *suchi, anchita* and *kunchita* positions are only possible with one leg while the other remains in half-sitting position. If knee is in *Mandi* position, then none of the ankle positions specified are possible but one leg touching the floor through the knee is only possible (Refer Appendix **??**). It is to be noted that the code for *Sthanaka* in knee and ankle positions are different since they denote different stances. The X axis has -60 to 90 degrees as shown in the Table 8 while the Z axis has -90 to 90 degrees. The right leg on the right side shall have positive values and negative on the left side and vice-versa. A (zero) 0 indicates that the leg is in same place; 30, 45 and 90 degrees indicate to what extent the leg is moving on that axis. If the right leg has -30 or -45 degrees, they indicate that the right leg has been kept on the left side to 30 or 45 degrees. Keeping the right leg to -90 degree position on the left is not physically possible and hence shown as Not Applicable. The Y axis denotes if the leg is touching the ground or raised up. Depending on the X and Z angles, the Y axis can easily represent whether the leg is raised and folded in the front direction (in the shape of a triangle) or raised straight 90 degrees up in the X axis. This is explained in detail with an example in the next Section.

5.4 Pose Notation for representing *Adavus*

We have represented all the 13 *adavus* along with their variations (Refer Appendix **??**) with our pose notation system of 30 attribute DP vector. While representing the *adavu* and saving it in the table care was taken so as to codify only those variations of an *adavu*, that could add variety in the dance pose. Any repetitions which were noticed were not recorded. For example the first *adavu* called as *Tattadavu* has 7 different variations taught to a beginner for learning the first steps of a leg movement. Each variation has a difference from the other only in the form of the beats or the number of foot taps in a rhythm. *Tatta* means to strike. Thus a dancer learns to tap her foot with this *adavu*. In the first variation of *Tattadavu*, the student learns only 1 tap and second variation has two taps and so on. Thus if we would be codifying all these beats, we would not get any difference in the codes nor in the result. Hence only 2 of this *adavu* code has been recorded. Similar procedure was followed for all the other *adavus*. Codifying all the

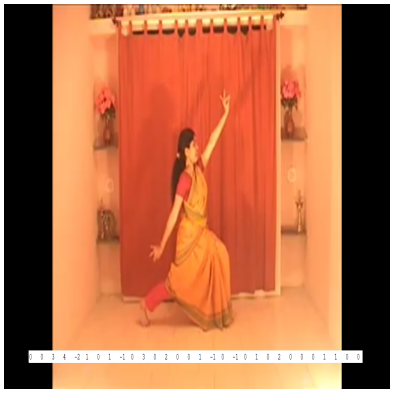

Figure 7: An Adavu depicted through Vector.

adavus helped us to verify the efficacy of the modeling system proposed by us and also in generating novel poses.

5.4.1 *Adavus*

Adavus are the basic fundamental unit of BN dance. It is a combination of the following:

- Leg and feet positions (*Sthankas*)
- Standing posture (*Mandalam*)
- Body movement (*Charis*) and
- Hasta mudra (*Hasta Mudra*)

Correct posture and rhythm (*Angashuddha* and *Talashuddha*) are the two essentials while executing an *adavu*. An *adavu* is practiced in three speeds, viz. slow, medium and fast. *Nritta* (pure dance) comprises of graceful, rhythmic movements and *adavus* form the basics of these *Nritta* movements. Thus adavus are taught to the beginner students and they are very popular since they are pure dance without conveying any meaning. *Nritta* is meant to produce beauty and captivate the mind. Thus anyone who isn't trained or even learnt BN can enjoy a complicated *adavu* sequence. It is thus considered to be a decorative item of a classical dance.

The Dance Position vector for the Figure 7 can be represented as shown below:

[0 0 3 4 -2 1 0 1 -1 0 3 0 2 0 0 1 -1 0 -1 0 1 0 2 0 0 0 1 1 0 0]

The 30 DP vector can be explained further as follows:

Head (position, orientation) - The Head has 2 attributes namely the positions like *sama, uttana, parivartita, adhomukha* and so on and orientations like turning left, right and looking straight as can be seen in Table 5. **Right Hand** (*mudra*, x, y, z, elbow, wrist, palm, shoulder) - The Right hand comprises of 8 attributes namely the *Hasta mudra*, the position of the hand in X, Y or Z direction, the elbow angle, the wrist position, Palm

Figure 8: *Adavu* depicted through Vector showing waist twist and a slight bend.

position and shoulder jerk given or not. Refer Table 7. **Left Hand** (*mudra*, x, y, z, elbow, wrist, palm, shoulder)- Similarly the left hand also has 8 attributes and these positions may be different than the right hand since both the hands may not be having similar *mudra* or directions. **Waist** (twist, bend) - These 2 attributes of the waist are as per BN norms as seen in Table 6. **Right Leg** (ankle, knee, x, y, z) - The leg has 5 attributes. The position of the ankle and the knee positions are very important in BN. The dancer can be either sitting, standing or in half- sitting position; which is a characteristic of BN dance. These pictures can be seen from Appendix **??**. The 5 attributes of **Right Leg** are (ankle, knee, x, y, z) - Similarly the left leg has 5 attributes. Refer Table 8 for these 5 attributes and its values.

5.4.2 Coding of complicated *Adavus*

This Section will depict how our system of coding can take care of some unusual complicated moves. In Figure 8 the vector represents an *adavu* where waist twist is necessary for the sliding movement. The Vector can be represented as follows: [1 -1 8 4 3 0 1 1 0 0 8 4 0 0 3 1 0 0 **1 -1** 0 0 1 0 -1 0 0 0 0 1]. Thus the 19^{th} DP Vector depicts a twist and 20^{th} DP Vector a bend. Similarly Figure 9 depicts a vector with a waist twist of -45° . This becomes necessary for depicting a waist twisting movement, as seen in the depiction of the *Natta adavu* XII^{th} variation (Figure 9), where *Natta* means to stretch. Although the twist isn't visible for a layman in the picture, it's utmost necessary to have this subtle movement for a perfect BN pose. Without making a twist from right to left direction (depicted as -45°), the dancer couldn't have achieved that pose.

When a dancer has completely turned back to the audience, both her hands and legs are in Z direction depicted with -1 as shown in Figure 10. The DP vector for the hands and legs are marked in bold in the 6th, 14th, 25th and 30th position in the following vector [0 0 3 3 -1 **-1** 3 1 -1 0 3 3 -1 **-1** 3 1 -1 0 0 0 1 2 0 0 **-1** 1 2 0 0 **-1**]. These DP vector denote the Z axis of hands and legs respectively. Whereas a twist of 90° can be easily seen in the Figure 11, where the dancer has turned back to the audience first and later twisted and turned front. The DP vector is as follows: [1 1 7 4 -2 1 0 -1 0 0 7 4 2 1 0 -1 0 0 **2 -1** 0 1 0 0 -1 1 0 3 0 -1].

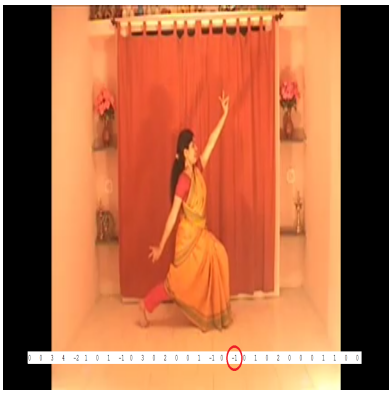

Figure 9: *Adavu* depicted through Vector showing waist twist.

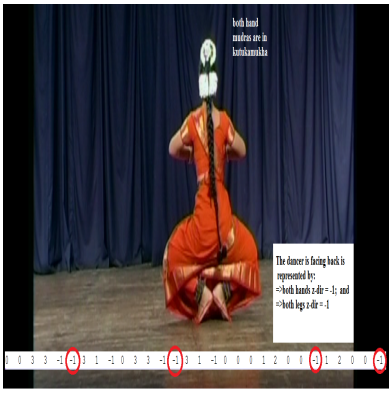

Figure 10: The dancer has turned completely back which is depicted through the highlighted hands and feet position.

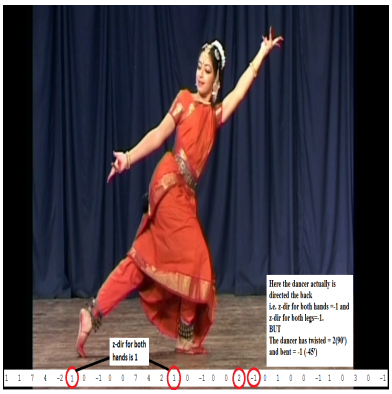

Figure 11: Dancer turned completely back and then twisted (at 90°) and bent (at 45°) to look front.

Figure 12: Leg folded in the front in *Kuchipudi* dance.

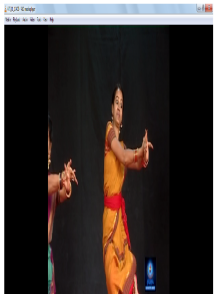

Figure 13: Leg folded in the front like a triangle *Kuchipudi* dance.

Note that our DP vector can show only a static position which is at the **end** of the pose and hence transitions (like in above example the turn and twist) **are not captured** while executing the pose. Since these positions are often done by trained dancers hence it becomes easy for them to interpret how these twists and turns occur. BN is a very formalized dance and every practicing dancer has this knowledge.

5.4.3 Coding of various Leg positions in *Kuchipudi* Dance

As we have already noted from the Introduction Chapter that BN and *Kuchipudi* come from the same trend of dance called as *Dakshinatya* hence these ICDs have many similarities and very few differences.

The differences between BN and *Kuchipudi* as mentioned in websites are listed as below:

- Bharatnatyam is a form of Classical dance from Tamil Nadu whereas Kuchipudi is a classical dance form from Andhra Pradesh.
- Bharatnatyam has more sculptured poses whereas Kuchipudi has more rounded poses.

- Bharatnatyam is termed the fire dance replicating the inner fire within the human body. On the other hand, Kuchipudi replicates man's undying desire to unite with God.
- The Bharatnatyam costumes have three fans of dissimilar lengths. But the Kuchipudi dresses have a single fan that is lengthier than the lengthiest fan in the former.

An overview of *Kuchipudi* dance through the DVDs of Associate Professor, Department of Dance, Potti Sreeramulu Telugu University, Telangana and Kendra Sangeet Natak Acedemi Awardee Dr. Alekhya Punjala's videos show the *adavu* basics of learning *Kuchipudi* dance style. Although the author is not an expert in this form of dance, a detailed study of the above DVD has shown that most of the form of dance is similar and the main differences can be noted for the few hand gestures and leg movements. For example while performing an *adavu* sequence of BN, rarely we see both the hands in *alapadma* position at chest level but Kuchipudi has this trait. Also few of the leg positions are a bit different and we shall explain how they too can be coded with our pose notation system.

Due to XY, YZ and XZ planes, coding of leg positions are easily achieved. For example if leg is up in the front direction then it has to be folded front ways as in Figure 12 or sideways as in Figure 13. This is because in an ICD a leg is never raised straight in front towards the audience. The front folded leg can be codified with specifying the 23^{rd} attribute R_LX=0, 24^{th} attribute R_LY=1 and 25^{th} attribute R_LZ=0 of the DP vector. The sideways triangle shaped leg can be codified with specifying the 23^{rd} attribute R_LX=30, 24^{th} attribute R_LY=1 and 25^{th} attribute R_LZ=0 of the DP vector. This specification of the $30°$ to the X axis while raising the leg up will specify the triangle shaped leg fold.

The leg thrown sideways straight up as seen in Figure 14 can be codified with specifying the 23^{rd} attribute R_LX=$90°$, 24^{th} attribute R_LY=1 and 25^{th} attribute R_LZ=0 of the DP vector. The leg kept diagonally straight up as seen in Figure 15 can be codified with specifying the 23^{rd} attribute R_LX=45, 24^{th} attribute R_LY=1 and 25^{th} attribute R_LZ=0 of the DP vector. For representation purpose we have shown only the right leg here, the same is possible for left leg too. The other attributes of head, hand and waist can also be codified as earlier, which is similar to BN. This proves that the modeling of major ICD can be done with the help of this technique.

6 Similarities and differences between DP vector and Labanotation

We have noticed certain similarities with our modeling method to the existing Labanotation system which are as follows:

Implicit/ assumed motion in Labanotation: When a limb is directed to bend, there are several constraints on it depending on the way it was facing. These constraints are due to human physiology constraints and also a particular dance style constraint

Figure 14: Leg sideways up in *Kuchipudi* dance.

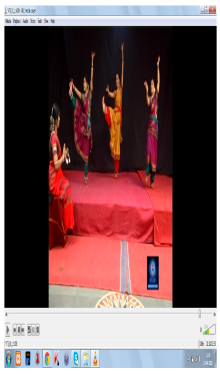

Figure 15: Leg diagonally up in *Kuchipudi* dance.

which is BN in this case.

Labanotation specifies an end position: While transitioning from one position to another, the path that the limb can take has certain assumptions. For example the arm passing from front to back will not rotate 180° from the shoulder but wrist will move toward the shoulder and then behind the body in a straight line.

Semantic representation: A semantic representation for Labanotation would be a representation of the meaning of the individual symbols and their relation to each other says J.Hatol in his Masters of Science Thesis, MovementXML ([Hatol, 2006]) at the School of Interactive Arts and Technology. Many of our data representations are relating to this dynamics of movements as represented by Hatol.

- **Degrees:** for e.g the degrees assigned to the leg is positive in right direction and negative in left. The levels are specified as 90° for high/top, 0 for middle and -90° for low/bottom. We also have the levels and direction measures in degrees.
- **Co-ordinates:** represents an exact point in 3D space and we have used X,Y and Z axis to represent the hand and leg positions.
- **Body part representations:** the various parts of the body are represented as head, neck, shoulder, chest, waist, and so on, we have kept most of them according to the ICD tradition.
- **Foot part:** These are also considered as per ICD norms and hence whole, full-heel, half-heel, full toe are considered (Refer Appendix **??**) whereas the other positions like toe-nail, etc. are not considered since they are *Ballet* movements.
- **Center of Gravity:** In MovementXML center of gravity is just treated like any other body part whereas BN is distinguished due to its low center of gravity (due to the half-sitting position), rhythmic footwork, erect spine positions and extensive hand gestures.
- **3*rd* dimension:** MovementXML has extended Labanotation to the 3*rd* dimension and so has our X, Y and Z axis.
- **Shifting the center of weight:** The knee and feet positions in BN cater to this criteria example the half-sitting, full-sitting and standing positions are determined through the knee positions whereas the only toe position is *suchi* (see Appendix C) (where one leg has the weight of the body and the other leg is stretched and only the toe is touching the floor).

The differences in our system and Labanotation are as follows:

Path and floor plans: The movement path for specific body parts in Labanotation is not specified and also how the whole body is moving in space. Since BN was designed for solo performance initially hence complex situations of floor plans are not considered.

Connections: Labanotation uses a bow sign to indicate 2 simultaneous movements overlapping in time. We have no such symbol to show overlapping movements and it indicates the pose notation only at the end of the dance pose.

Quantity signs: which indicates how is something done. For example steps are long or short, clapping sounds are loud or soft, leg is turned out for *ballet* (key signatures). We have not used any such sign and this is done with the assumption that the choreographer will use his/her abilities for such a representation.

Turns: ICD do not use cartwheel movements (front-back axis). In BN we move only around the vertical axis.

7 Conclusion

Thus we can conclude that we have been able to model the human body with our pose notation system. We haven't used the existing Western dance notation system, Labanotation nor have we utilized any data capture techniques like Kinect camera or any other device. The reason for not choosing existing systems was that we wanted a novel method of modeling the body along with innovative and unexplored choreography. We can say that we have modestly been capable of capturing dance poses using our notation system. This has been achieved by modeling the body with 30 attribute DP vector. Since these poses are static in nature and recorded at the completion of the pose, transitions happening during the pose are not being captured. So even if a dancer twists, turns or uses various *mudras* for performing a pose, only the final static posture along with the final *mudras* can be captured through this method. There appears certain similarities between our method of modeling the human body for dance and Labanotation but these are due to physical constraints or a particular dance form related ones. The differences are due to the fact that path and floor plans are not considered, turns are in different axis for BN, overlapping movements and quantity signs are not utilized.

Despite the differences in Labanotation and Kinect with our system, we notice many similarities although this was not done deliberately. MS Kinect SDK enumerates 20 joints out of which 3 of them are not used by us. They are Hip center, Shoulder center and the Spine. We have used head, right hand, left hand, waist and leg position attributes to define 30 DP vector. This pose notation system can uniquely represent the major limb positions of the body for an ICD especially BN.

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