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Representation of yoga postures based on joint angle values along with Range of motion limitations of joints to classify time series yoga asanas

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ABSTRACT--*The practice of yoga poses, or asanas, was developed as an approach to align, strengthen, and balance the structure of the body. Further, it has been used to enhance dynamic control of core stabilizing muscles to reduce lower back pain (LBP) and spinal flexibility. Yoga postures comprise simple body movements such as standing, sitting, forward and backbend, twist, inversion, and lying down in supine position. In this paper proposes a method to classify yoga asana postures based on joint angles. Not every joint is involved in all asanas. Set of joints that contributes a lot for a particular asana and their range of motion has studied in order to classify asanas based on the joints involved. Applicability using BVH and softmax classification has been discussed.*

Keywords-- *Representation of yoga postures based on joint angle values along with Range of motion limitations of joints to classify time series yoga asanas*

I. INTRODUCTION

All living and non-living objects are affected by universal gravitation. Mechanical interactions with the environment and within the biological system influence the motion and function of all the objects in the universe. Biomechanics is the study related to the study of influence of mechanics on the body's movement, shape at all levels ranging from molecular level to system level [10]. Coordinated interactions of the various parts of musculoskeletal system such as bones, muscles, and joints are essential to achieve human body movement [11].Thus, it becomes essential to understand and represent them in the proper methodology so that it will be helpful for preventing injury, to correct abnormality, to use in healing and rehabilitation.

For instance, older individuals who are having less hip flexors and reduced plantarflexors will have gait features such as walking slowly with shorter step length[26.].We use these gait features to identify whether there is a decline in muscle strength,range of motion of joints, instability in postures[27].

Yoga has been considered as a means to strengthen, align and balance the structure of body and hence to enhance the stabilization of the body during activities.Too be fit, human body has to work in all the three planes namely sagittal plane, frontal (coronal) plane and transverse plane. The primary aim of yoga asanas is to make body movements in all the three planes. Most of the yoga asanas have postures like standing, sitting, bending

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forward and backward, hand balances, twists etc. In every posture, the individual joints and segments may be rotated, or shifted to particular angle value.

Yoga also improves the gait functions [28.], joint flexibility [29], range of Motion-[30] and most importantly the isokinetic and isometric musclestrength. Some of the yoga asanas have been used as remedial activity for issues like lower-back pain [1]. Yoga improves hip and spinal flexibility which helps in reducing lowering back pain [2],[3].

Describing motion patterns in terms of human body’s biomechanics especially in terms of joint angles will be useful in analysing gait and daily living activities of human beings. Describing yoga movements in terms of joint angles would help to understand how every yoga posture has to be completed, so that self-assisted yoga practice can be done as effective as if practiced with yoga teachers. Also, to evaluate the benefits of yoga for various ailments, identifying the biomechanical motion patterns of every yoga posture [31] has to be known.

II. BACKGROUND

1.1 Orientation and direction of joint movements

Human body parts and the movement joints are always described relative to the anatomical position. Anatomical position is standing upright, arms by the sides and palms facing forward. Anatomical position is also termed as anterior and toward or back of the body is called as Posterior direction.

2.2 Body movement types

Biomechanics is the study of forces acting on the human body and the reactive forces generated by the body, the deciding factors of the movement of every human body parts, movement type and the degree of movement of any joint depends on the structural type of the joint. Every joint in human body is capable of performing four possible movements namely *flexion, extension, axial rotation (twisting) and lateral flexion (side bending).*

Axial rotation (twisting movement) produces symmetrical compressive forces, whereas, flexion, extension and lateral flexion produces asymmetrical movements.

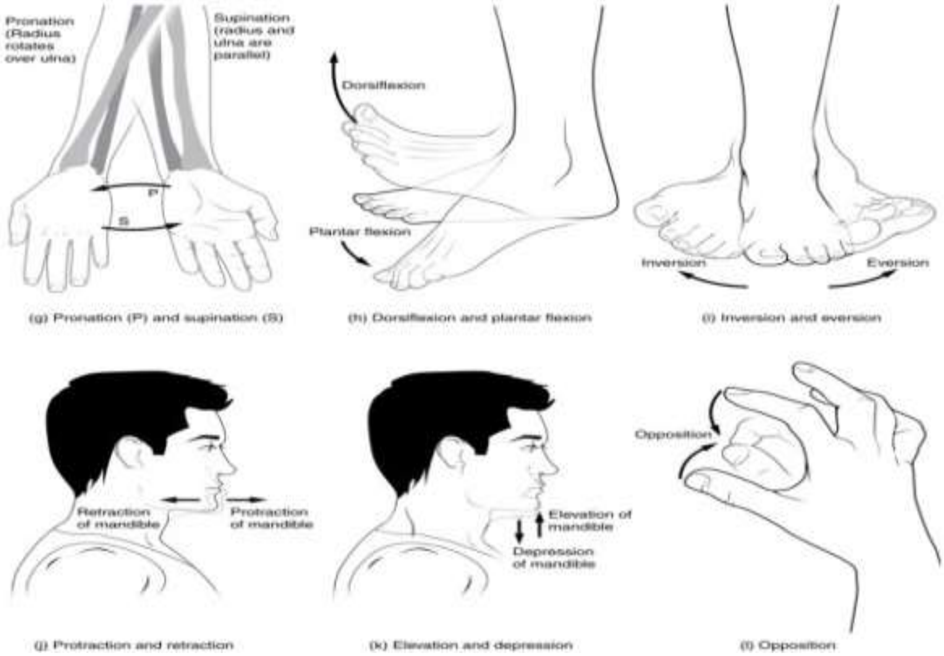

Figure 1: Types of movements I (Source: Anatomy & Physiology [25])

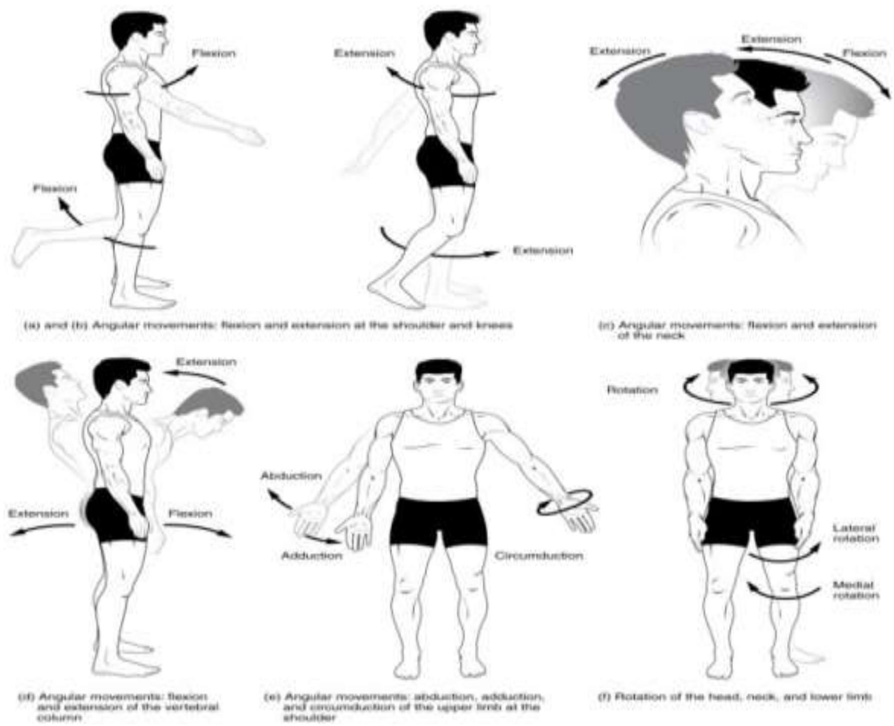

Figure2 : Types of movements I (Source: Anatomy & Physiology [25])

III. METHODOLOGY

Motion captured during yoga practice in the form of video will be translated into Bio-Vision Hierarchical representation. Bio-Vision Hierarchical (BVH) form is a convenient way of representing skeletal information of human being. It is in the tree format. Root of BHV is considered as hip the centre of human skeleton. The segment above hip (joint) is called as upper extremity, and below this joint is referred to as lower extremity. Bio-Vision hierarchy format is explained in section 3.1.

From BVH format, angle value of every joint can be calculated. Calculation of joint angles can be found in author's paper [ ]. Since the coordinate values of every child joint will be represented in relative magnitude of its parent joint, the joint values should also be represented in terms of transformation vectors (angle values for rotation, and the direction of rotation). With these values the skeleton's joint position in the next frame may be calculated. As the motion captured will 30 frames per second, it is enough to take into consideration of every fifth frame.

Based on the joint angle values it is possible to classify the asana and find out which asana the particular posture belongs to. Center of gravity for every posture in the asana will be calculated, and the weight bearing points location. If the weight bearing points are not properly aligned to maintain the CoG along with the CoM of the body, feedback will be give to the practitioner. Effect of CoG, and its calculation will be discussed in section 3.3.

IV. PROPOSED SYSTEM DESIGN

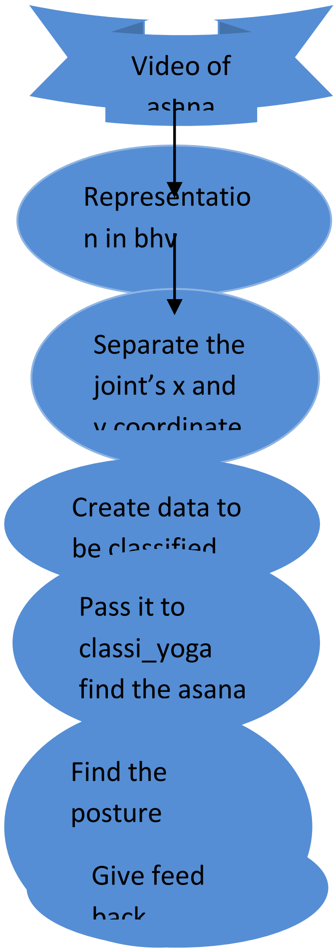

Figure 3: System design

1. Steps of the asanas are described based on angle variations from the starting position
2. We classify the asanas into 5 types based on its base support. For this study we have taken only 5 asanas each belongs to one group.

3. From the video formart***_to_bhv*** will generate BHV file for the corresponding image. The x,y coordinate values of the joints can then be extracted , joint angles are calculated (only 20 joint angles as specified in the bhv format has been used for calculation). This will create the data to be classified.

4. Calculations for variations from the expected positions will be detected and intimated.

V. GENERAL YOGA DESCRIPTION

Every yoga asana will start from a particular posture and move to various postures with variation in the positions of segments or joints and will be ended with a particular posture. The time elapsed between every posture will also be in a particular range.

Starting positions specifies the body part which is (are) on the ground, and by which the weight-bearing forces are transmitted down to the earth.Most of the time, these parts will be legs or pelvis. If we use our hands for transmitting weights then we can say that as arm support. Starting positions of any asana will be from any one of the following:

Table 1: postures and weight bearing parts of human body

S.No	Starting Position	Weight-bearing Part
1	Standing	*Supported on legs*
2	Seated	*Supported on base of pelvis*
3	Kneeling	*Supported on knees, shins and tops of feet*
4	Supine	Supported on the back of the body
5	Prone	Supported on the front surface of the body

We propose the classification based on the base support and then represent the postures based on the joint angles that are important for that particular asana as given in Table 2.

Table 2: Asana descriptions

Asana name	Posture	Asana classification	Base support	Joints involved	Angle value/ Range of motion
Trikonasana (triangle pose)		Standing	feet	ankle, hip, shoulder, elbow and wrist	The ankle, hip, shoulder, and wrist joints are in their neutral positions, midway between flexion and extension. The knee joints are extended (but not hyper extended); the elbow joints are

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					extended and the forearms are pronated.
Dandasana (Staff Pose)		Seated	Pelvis	ankle, hip, elbow, wrist , spine, knee	Spine neutral or axial extension; sacroiliac is neutral; hip flexion to 90 degrees, adduction and internal rotation; knee extension; ankle dorsiflexion; scapula neutral on rib cage; glenohumeral neutral extension; elbow extension; wrist dorsiflexion (depending on arm length).
Vajrasana		Kneeling	Knee	Spine, hip, knee, ankle, elbow, sacroiliac joint, tibia, scapula, glenohumeral	Spine axial extension (in the full version of the pose); sacroiliac joint counternutation; hip extension, internal rotation, and adduction; knee flexion and tibia medially rotated; ankle plantarflexion; scapula upward rotation, abduction, elevation; glenohumeral joint flexion, external rotation; elbow flexion.
Bhujangasana (Cobra Pose)		*Prone*	Front face of the body	Spine, sacrum, hip, knee, ankle, scapula, glenohumeral, elbow, forearm	Spine extension; sacrum counternutation; hip extension, internal rotation, adduction; knee extension; ankle plantarflexion; scapula neutral (possibly upward rotation); glenohumeral joint external rotation; elbow extension; forearm pronation.

3.2 Description of Yoga asana in terms of joint angle values and segments.

Following table specifies a sample descriptions of the starting position of the class ‘seated ‘asasnas.

Table 3: represents the steps for Bhujangasana .

Description of asana	Description in terms of angles
Sit with an erect spine on the floor and stretch your legs in front of you.	Shoulder-hip-knee triangle with 90 degree at hip.
Feet should touch each other.	Distance between the l-ankle and r-ankle is zero.
Head straight.	Joint-head and joint-neck centre of the shoulder 180 degree
Place your both the palms on the floor.	Shoulder-elbow-wrist in 180 degree inferior direction.
Duration	30-60 seconds

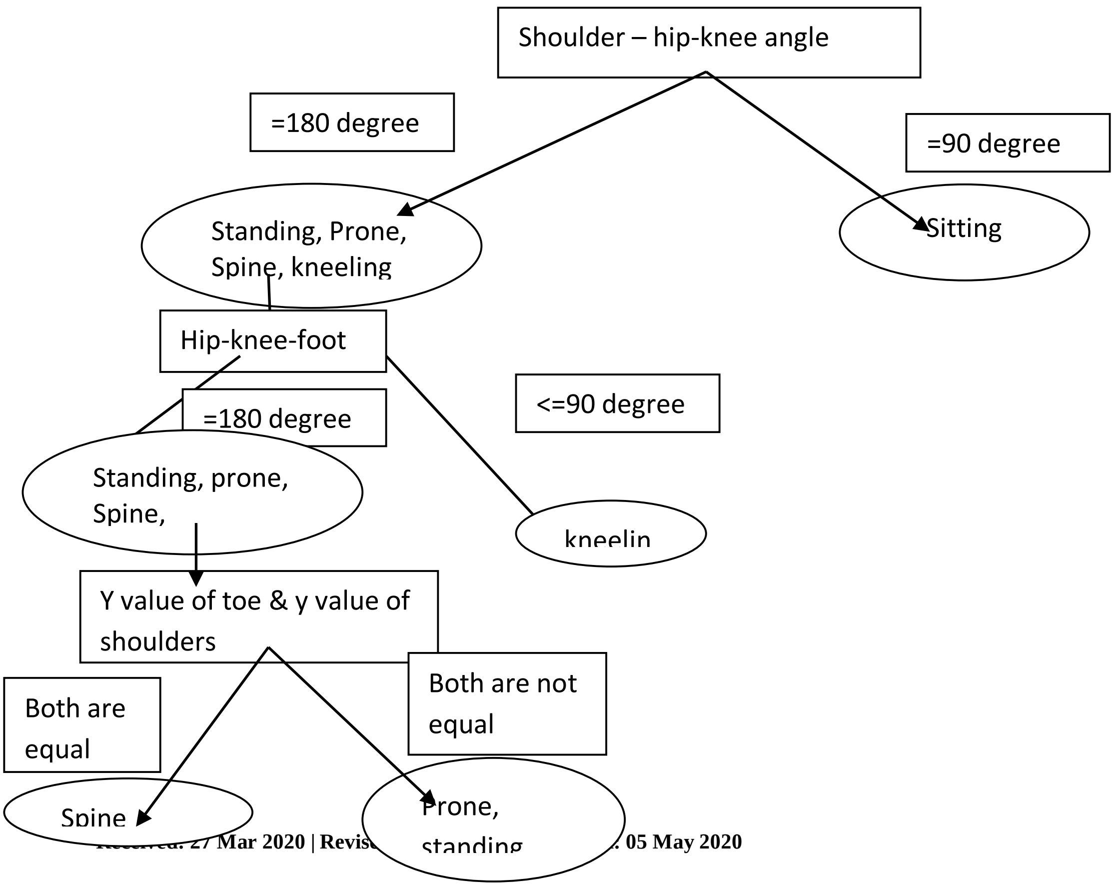
Table 3: Dandasana (Staff Pose) description using joints and segment angle values

Bhujangasana **(Cobra pose) Steps**

Table 4: Bhujangasana **(Cobra pose) description** using joints and segment angle values

Description of asana	Description in terms of angles
Step 1:	
Lie prone on the ground	Shoulder-hip-knee 180 degree.
forehead touching the floor	Head neck straight line.
legs together	Distance between the l-ankle and r-ankle is zero.
hands by the side of thighs	l-shoulder:l-arm:lwrist 180 degree r-shoulder:r-arm:rwrist 180 degree
Step 2:	
Fold the hands at elbows and place the palms by the side of the shoulders, thumbs under armpits, with tip of the fingers not crossing the shoulder line.	l-shoulder:l-elbow:lwrist acute angle; lwrist(x) = lshoulder(x);
Step 3:	
Slowly raise the head, neck and shoulders. Shoulders should be shrugged backwards.	In distal direction; torso- shoulders-neck acute angle in counter-clock direction;
Step 4:	
Raise the trunk up to the navel region. Raise the chin as high as possible.	Hip-shoulder-knee > 90 degree.Shoulder-centre-neck-head acute angle.

3.3 Classification of yoga asanas based on angle



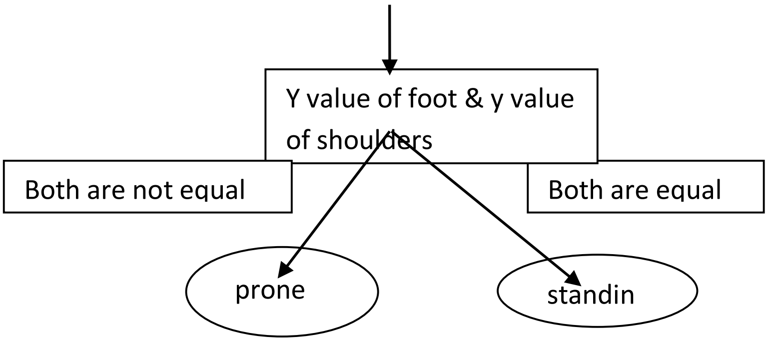


Figure 4: Asana classification

3.4 Representation of postures

With the above said representation, We will represent every posture based on the joint angle values and segmental values.

Difficulties in pose estimation are due to the factors like

(i) variability in human physique

(ii) complexity of human skeletal structure,

(iii) high dimensionality of the pose

3D postures can be estimated by joint or angular values among skeletal image. The bio-mechanics of joints angular values and range of motion (ranges depending on other group of joints involved) can be used as constraints. For example, knee joints cannot be rotated beyond 180 degrees, where as neck can rotate 360 degrees, The constraint mobility of joints reduces the information to be stored for a posture.

Because of the bio-mechanics of joints, the search space may also be limited. The search will begin from the root joint. In yoga, the asanas are grouped based on their initial or starting postures. Every asana will move from its initial to a final posture with time varying postures for some period of time.

We can represent knowledge about human body such as dependencies and relations, composition processes of joint-part-pose, including kinematics, symmetry, motor coordination in BHV format itself.

3.4.1 Capturing &representing Human postures

All the motion capturing devices collects values of important or key joints of the objects being tracked. Values of these joints are recorded for a period of time, and they are translated into 3-Dimensional digital representation.Key joints selected will represent the orientation of the objects too. The two kinds of representation that commonly used by many motion capturing companies are ASCII and binary.

Decoding and understanding the information is easy in the case of ASCII format. In this paper, we use the BioVision Hierarchy format, which is a ASCII based text format.

Keywords that will be used in this format to represent the objects, in this case the human body, and to describe the manipulations to be done on the key joints to actualize motion are:

- **skeleton** – the whole human body

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➢ **bone** – It is the smallest entity or segment used to represent a skeleton.To produce animation or motion, individual translation and the orientation changes will be applied to these entities.Bones are associated with mesh of vertices, which represents a particular part in the skeleton in hierarchical to produce the whole structure.

➢ **Degrees of freedom** – This part is used to specify the transformation details of the skeletal joints such as orientation change (rotation), positional change(translation) and the scale change during motion. In BVH format, these details are given as channels. Executing the channel data will produce the required posture change.

➢ **Frame** – Frame corresponds to one posture. Many number of frames may be needed for an animation, Each frame will have the channel details of every bone to be implemented to produce a posture.

3.4.2 Human joints hierarchy (in BVH format)

We are representing skeleton having joint_hips as center as that of given in [12]. We have selected BVH format for representing asana postures because aBiovision Hierarchy file format is used to describe relationship among joints human body and it considers hips as centre.

Hierarchical data format has two parts:

(i) First part to represent the initial position of any asana sequence.

(ii) Second part to specify the sequences of postures as a time framed sequence,so that the subsequent posture changes of a asana sequence can also be represented.

VI. DESCRIPTION OF FIRST PART

Initial pose i.e. representation of the bones of the skeleton, starts with *ROOT* which specifies the start of new skeletal information. Root key word is followed by the name of the bone which is to be considered as root for this hierarchy. Usually this will be hips. Also it follows the definition of children bones in a recursive form.

For each bone, we can also specify the translation factor in x, y and z axis in the origin of the bone with respect to its parent's origin. *OFFSET* keyword is used for representing these details. It also defines the direction (by using +ve and -ve values) and length of the parent's bone.

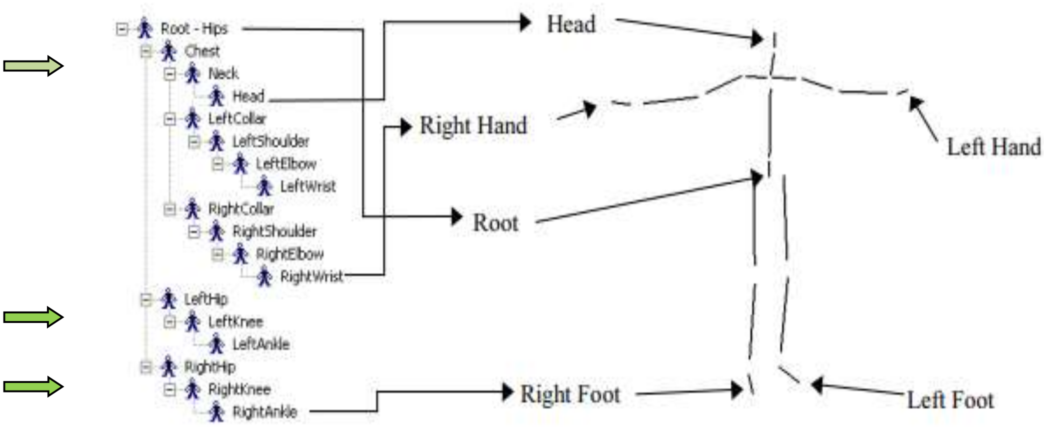

Figure 5: Hierarchical structure of human skeleton

```
HIERARCHY
ROOT Hips
{
        OFFSET  0.00      0.00      0.00

        CHANNELS 6 XpositionYpositionZpositionZrotationXrotationYrotation

        JOINT Chest
        {
                OFFSET   0.00      6.275751         0.00
                CHANNELS 3 ZrotationXrotation
        JOINT Neck
                {
                        OFFSET   0.00      14.296947         0.00
                        CHANNELS 3 ZrotationXrotationYrotation
        JOINT Head
                                        {
                                OFFSET   0.00      2.637461         0.00
                                CHANNELS 3 ZrotationXrotationYrotation
                                End Site
```

Initial x,y,z axis values

Chest has x value as that of its parent, but y value has changed

Figure 6: Skeleton description of First part in BVH format

Figure 6 is a representation of the initial pose of an asana. The hip joint has been considered as root and its position in x, y and z axis is 0,0,0 respectively. Joint chest, left hip, right hip are the children of this joint(which is indicated by green arrow in figure 5). The offset of the chest in x axis is not changed means that it is located as that of its parent hips, where as its y value is 6.2 higher than hips.

The information related to the degrees of freedom can be given after the keyword CHANNELS. Underwhich, we may give translation in all the three directions and rotation in all the axis. We may omit translation or rotation whichever is not needed. We need to provide number of channel. (For example, number 6 after channel in the indicated line in figure 6). We need to give the correct order of rotation as this will be the order of representation of values given in the motion part of the file. Figure 7 gives the visual display of the file in bhvhacker software.

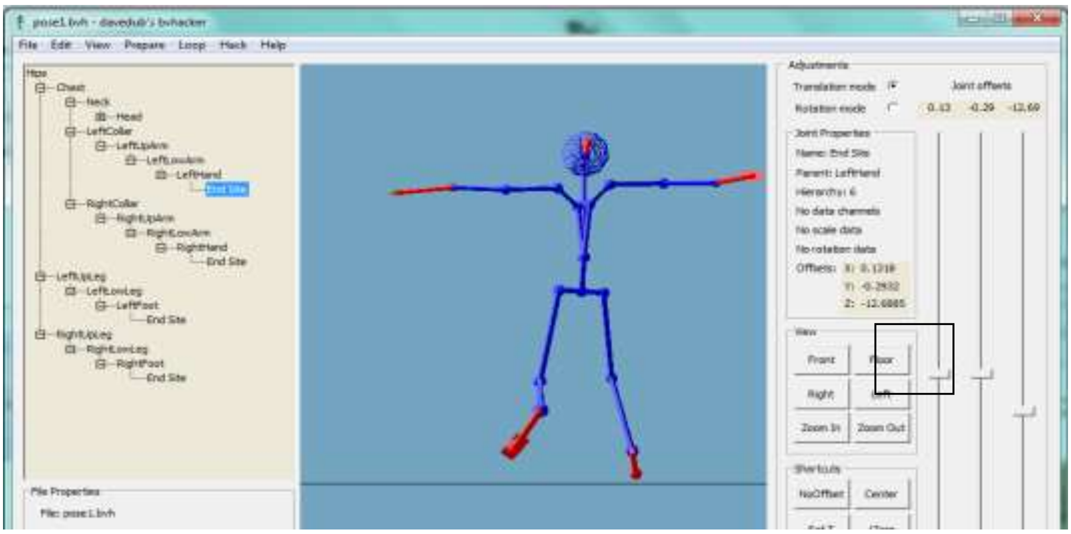

Figure 7: Display in the bhv viewing software

- Description of Second Part

This part is used to specify the number of frames in sequence to create animation. Keyword MOTION denotes the starting of the second part. We can specify the duration of a single frame which is used to specify the amount of time the current posture should maintain. Other details that we will specify in this section are number of frames in the data, frame rate etc. which is followed by the channel data to be used to calculate the transformation matrix.Based on the channel data, a composite matrix will be created. The matrix manipulation will be in the order specified in equation 1.1:

$$\mathrm{M} = \mathrm{T} * \mathrm{R} * \mathrm{S} \qquad (1.1)$$

where T,R,S represents Translation Matrix, Rotation Matrix and Scaling Matrix respectively.Since rotations will be applied to a vertex based on the axis for vertex there may be three matrices namely R_x , R_y , R_z for the axis of X, Y and Z respectively. Hence, it is necessary to create a composite rotational matrix. R in equation represents the composite matrix of rotational matrices in the order as specified in equation 1.2

$$R = Rx * Ry * Rz \qquad (1.2)$$

This transformation matrix will be applied to the points representing the particular bone as in equation 1.3

$$J' = J * M \qquad (1.3)$$

Transformation data will be provided as that of the hierarchy of the human skeleton. So, the joint J may be applied with the transformation matrix as that of equation 1.3. But this effect should pass on to the parent of this joint J , and to its parent and so on till the root. We term this as local transformation and the repeated application till the root may be termed as global transformation $M_f$which may be represented as in equation 1.4

$$Mf = \prod_{i=0}^{n} Mi \qquad (1.4)$$

Classi_yoga

Input : f1: Posture file represented in the form of BHV , f2: sequence of postures performed in BHV format (data to be classified).

Output: classified asana name

Step 1: Calculate the angles values of every joints and segments

Step 2: Compare them and classify (as specified in the diagram 3)

Step 4: use the motion section of the file 1 ; repeat step 1 and 2

Step 5: if any deviation in the sequence find the difference in terms of angle values.

Step 6: Give Feed back

VII. IMPLEMENTATION

4.1 Pre-processing

We have collected data of yoga asanas sequence from two persons for every asana for all the selected 5 classes. We have processed images by passing many rotation and other geometrical values of the Method DataGenerator to create various randomly ransformed images based on the input and geometric values to get a total of 1000 images. This kind of augmentation will be useful to avoid over fitting.

To avoid overfitting we have used only very few features such as the joint angles of hip-knee, shoulders, elbow and the directional details such as distal, and proximal etc. that are relevant to those asana sets chosen for study. We have selected these features as they are most significant and relevant. To suite the entropic capacity, we used these features for classification and assigned weightages to them. Data set has been split into 75% and 25% for training and testing respectively.

3.2 Angular Kinematics used in Classification

Depending on the joints involved in the asana, we calculated these values : (i) Angle at shoulder joints (ii) Angle at the elbow joint (iii) Angle at the wrist joint (iv) Angle at right ankle joints(v) Angle at right knee joints(vi) Angle at right hip joints

```
>>> X_train, X_test, y_train, y_test = train_test_split(X, Y, random_state=0)
>>> from sklearn.preprocessing import MinMaxScaler
>>> scaler = MinMaxScaler()
>>> X_train = scaler.fit_transform(X_train)
H:\ponmozhi\project\lib\site-packages\sklearn\utils\validation.py:595: DataConve
rsionWarning: Data with input dtype int64 was converted to float64 by MinMaxScal
er.
  warnings.warn(msg, DataConversionWarning)
>>> X_test = scaler.transform(X_test)
>>> from sklearn.tree import DecisionTreeClassifier
>>> clf = DecisionTreeClassifier().fit(X_train, y_train)
>>> print('Accuracy of Decision Tree classifier on training set: {:.2f}'
... .format(clf.score(X_train, y_train)))
Accuracy of Decision Tree classifier on training set: 1.00
>>> print('Accuracy of Decision Tree classifier on test set: {:.2f}'
... .format(clf.score(X_test, y_test)))
Accuracy of Decision Tree classifier on test set: 0.78
>>>
```

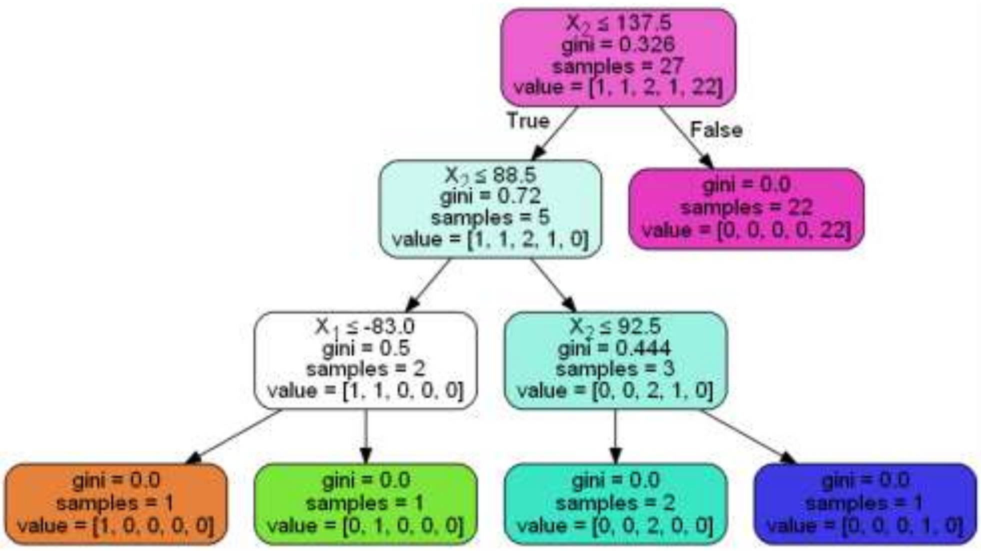

Figure 8: Decision tree for given sample set

VIII. RESULTS & DISCUSSIONS

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To get better accuracy, we have added the units as 5 and activation as softmax to have multiclass softmax classification. Accuracy has been increased to 95 % after training for 50 epochs. This may be due to smaller set of data and clean and simple pictures. The pictures of sagittal plane have been considered for kneeling and seated postures. This will make it easy to calculate the coordinate values and angle values.

We are using this format for representing postures and asana sequences. The fact is that there will be differences among the human being in their skeletal structure. For example, knee can stretched only upto 180 degrees, but some person may be able to hyper extend as shown in figure 8.

Figure 9: hyper extended knee.

Similarly, hyper extended elbows may also possible. To cope with these differences, the skeletal information will be normalized using the method proposed in [13]. This will better classify the postures even though they are hyper extended.

IX. RELATED WORK

In this paper we are creating BVH files for asanas where 2D images are used to get the skeletal values. Once the matching and classification is over we will convert it to a 3D image for display.

In order to do the process of 2d to 3d matching features such as edge direction histogram[14],shape context[15],SIFT descriptors[16]. Technique of getting 3d details from 2d colorimgae [17],and using machine learning technique such as end-to-end deep architectures [18] are also utilized.

Machine learning approach such as supervised learning [19][20][21] to identify discerning features, using the structure of known objects to infer poses [22][23], inferring postures based on joint angles and segments[24] are some of the approaches used to get 2d details from 3d images.

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