Virtual Percussion for Bharatanatyam

Project Report

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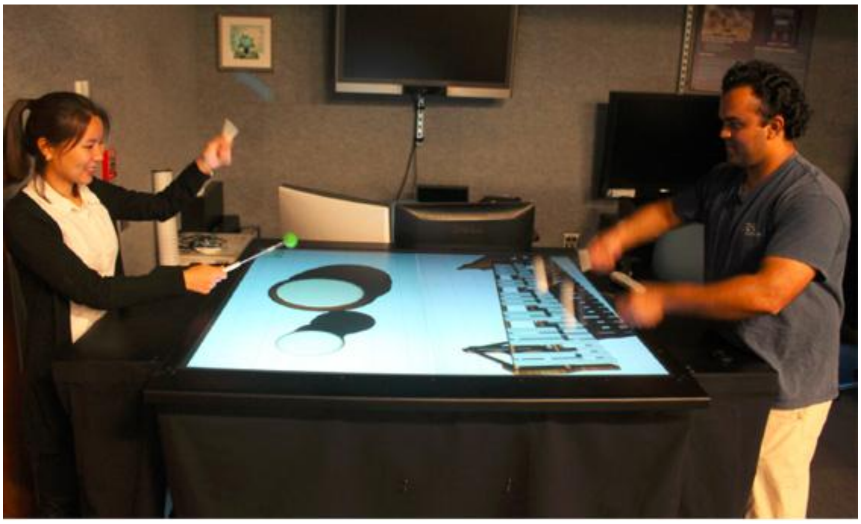
INTRODUCTION

Virtual Musical Instruments can be understood as systems that can simulate the playing of physical musical instruments. Following are some definitions of virtual musical instruments given in the 1990s.

- A. Mulder describes about Virtual Musical Instruments as:
  "..., analogous to a physical musical instrument, as a gestural interface, that will however provide for much greater freedom in the mapping of movement to sound. A musical performer may control therefore parameters of sound synthesis systems that in real time performance situations are currently not controlled to their full potential or simply not controlled at all."
- H. Katayose et al talk about their system, Virtual Performer :
  "... the Virtual Performer which is a system composed of gesture sensors, a module analyzing and responding obtained information, and a facility for presentation."

While early virtual musical instruments were imitations of traditional musical instruments, many of the more recent ones may not have a physical counterpart, thus defining entirely new ways of musical expression.

By extension, a virtual percussion instrument is one that can simulate an effect similar to that of playing a percussion instrument. Some examples are given below.



In the above picture, the surface of the table is mapped to that of a drum and the hand movements of the drummer are tracked to produce the appropriate sound.

In the picture below, an interface is shown where the user can click on the different components of a band-set to produce the required sound.

With time, the idea of using such instruments to give performances where the music is controlled by the performer gained momentum. Such an approach augmented a traditional performance to a great degree, thus giving to the audience, an ‘out of the world’ experience. Thus, virtual musical instruments have gained firm ground in the art community bringing to them new ways to augment a traditional performance and also evolving entirely new ways of musical expression.

In this project, one such novel way of musical expression is explored. The idea is to develop a system that can produce the percussion sounds to accompany a dance performance. Bharatanatyam, a south Indian classical dance-form was chosen for this project and the accompanying percussion instrument chosen was Mridangam. By mapping the foot movements of a Bharatanatyam dancer to the corresponding Mridangam sounds, it was possible to develop a system that can produce the Mridangam sounds to accompany a traditional Bharatanatyam performance.

Brief Introduction to Bharatanatyam

Bharatanatyam is a South -Indian classical danceform. A possible origin of the name is from Bharata Muni, who wrote the Natya Shastra to which Bharatanatyam owes many of its ideas. This etymology also holds up to scrutiny better since Bharatanatyam is pronounced with short forms of "bha", "ra" and "tha" whereas each of "bhavam", "ragam" and "talam" contain the longforms. Hence the initialization proposed above is more probably a backronym. Today, it is one of the most popular and widely performed dance styles in India and is practiced by both male and female dancers.

Brief Introduction to Mridangam

Mridangam is an ancient Indian percussion instrument. Nandi is said to have played the Mridangam during Lord Shiva's Tandava dance and for this reason, it is called the "Deva Vaadyam" or "Devine Instrument". 'Mrith' means mud and 'angam' means body. The Mridangam got its name because it was originally made of mud. The instrument has seen a transformation and today's Mridangam is made out of a single wood piece of Jackwood or Teakwood. Today, Mridangam has evolved to be the king of the percussion instruments and become an indispensible accompanying instrument for Bharatanatyam performances.

RELATED WORK

Controlling music and beats through body movements, gestures and emotions of the performing artist can lead to 'out of the world' performances. Many such systems have been developed.

- **Movement to emotions to music: using whole body emotional expression as an interaction for electronic music generation.**
  In this paper, the authors describe a novel interaction where the dancer's movements are tracked and these are in turn used to recognize the emotions that he depicts. The emotions so determined are used to generate music that evolves in real-time. This has been used to give an augmented ballet performance.
- **Creating Musical Expression using Kinect**
  In this paper, the body movements of the performer are used to generate music. The movements are tracked using the skeletal tracking feature of Microsoft Kinect. To generate the music, a Kinect to MIDI data converter is implemented.
- **Daft Datum- An Interface for Producing Music through Foot based Interaction.**
  Daft Datum comprises of a wooden plank under which a sensor is placed. The sensor takes input from the different foot movements and these are mapped to various sounds. Further, the pitch and octave of the sounds produced can be controlled by a hand-held controller.
- **LoopJam: turning the dance floor into a collaborative instrumental map**
  This system is also based on Microsoft Kinect. Here, different points on the dance floor are mapped to different sounds. The dancer generates different sounds by tapping on the corresponding points on the dance floor.

An essential factor for these applications is the predictability of the performer's moves. While this poses no problem in some dance-forms that follow a composed routine, such is not the case with most Indian classical dance-forms. In Indian classical dance and music, a large part of the performance is always impromptu. It is not a rehearsed performance where every member of the band knows exactly what every other will do. When the artists ascend the stage, the accompanying artists don't even know which number the dancer will present. This unpredictability is the jewel of our classical art forms and it is for this reason that mastering them is a lifelong penance. And this is also the greatest challenge while engineering any application to augment a classical dance performance.

While designing an application to accompany a classical dance performance, it is very important that it does not require the dancer to make any alteration in his/her technique. The application cannot be designed for a particular dance number or a set of moves. It has to be a general one.

Due to these reasons, there has been not much work towards developing automated systems to augment Indian classical dances even though many such systems have been developed for other dances in general. This being a first effort in this direction, the objective was to develop a system that can come as close as possible to the traditional counterpart.

ANALYSIS AND DESIGN

In this project we had to design a system to accompany a Bharatanatyam performance, given that the performance does not follow a composed routine and also that a system can never acquire the intuition of a Mridangist, that comes with years of practice. The fine structure of Bharatanatyam was harnessed in this project.

The basic idea was to map the footwork of a Bharatanatyam dancer to the corresponding Mridangam sounds. However, it has to be noted that this would only be suitable for nritta, where there is a direct relation between the footwork and mridangam sounds. Such a method cannot be applied during abhinaya. So this application is designed keeping a nritta performance in mind.

The problem was handled in two stages. The first was to accurately detect the different foot positions. The second was to map them to different mridanga sounds.

The Aramandala position shown below is a standard posture in Bharatanatyam.

Aramandala position

Naattu Position

The three standard ways to tap the floor in Bharatanatyam are Tattu, Mettu and Naattu.

Tattu means tapping the floor with ones entire foot in the aramandala position. Mettu involves tapping the floor with ones toes in the aramandala position and Naattu corresponds to tapping the floor with ones heel by stretching the leg.

As we have two legs, this leads to six different positions, namely,

- Tattu_right
- Tattu_left
- Mettu_right
- Mettu_left
- Naattu_right
- Naattu_left

There is another position where a dancer jumps on ones toes. This can be followed by slapping ones heels onto the ground. Alternately, it could be followed by a tattu. In this project, the jump on the heel was labelled Kuditta, slapping of the heels Kudittamettu, and a tattu following kuditta is either kudittatattu_right or kudittatattu_left.

These ten foot movements were identified for this project.

In course of discussion with Mridangists, it was found that there would be a number of ways to render a particular rhythmic pattern. Here, by ways, we mean different sound combinations. A Mridangist will simply play whatever appeals to him at that moment. But a system needs to be told exactly what sound to play. Also, given his training and experience, a Mridangist will almost always be able to guess the next step. Our system, however, has no such luxury. So, only the previous steps have to determine the present sound.

An algorithm was devised in which the previous four footsteps of a dancer are stored in memory at any instant and they characterize the next footstep. The footsteps are characterised and stored by their traditional names known as 'Sollus'. A particular foot movement may lead to different sounds depending on the context. Also, different foot movements may lead to the same sound. Thus there is a need to use the Sollus.

The sollus used in this project are:

- `Thaleft`
- `Ki`
- `Ta`
- `Ka`
- `Dhi`
- `Mi`
- `Tharight`
- `Gileft`
- `Giright`
- `Na`
- `Thom`
- `Di`
- `Tham`
- `Jham`
- `Dharight`
- `Dhaleft`

These are the traditional sollus used in Bharatanatyam, but extended wherever required. For example, when a natuvangist says 'tha', whether she refers to the right foot or left foot is clear in the given context. But as the system cannot determine this on its own, we need not one but two separate sollus, namely, tha_right and tha_left. Also, a natuvangist may use some of the sollus interchangeably without leading to any confusion. But this is strictly prohibited in our system. One system of sollu nomenclature has been abided to throughout.

The current footstep is mapped to a particular Mridangam sound, the mapping being determined by the current footposition and the previous four stored sollus.

The mridangam sounds used in this project are:

- Dhim1
- Dhim2
- Dhim3
- Thom
- Ki
- Gu
- Nam
- Dhi
- Chapu
- Tha

The sounds Chapu and Thom being played simultaneously has been referred to as Dhim1 in order to keep it concise. Dhim2 is the sound referred to as Dhim by the Mridangists. The sounds Dhim and Thom being played simultaneously has been referred to as Dhim3.

Initially, our array step is stored with the sollu ta as any footwork succeeding ta is expected to be the beginning of a new step by the system. The first tattu_right or tattu_left is associated with the sound Dhim1. Similarly, the first mettu_right is associated with the sound thom, mettu_left with tha and so on. If a tattu_right is followed by a tha_right, it is stored as ka and corresponds to the sound gu. The entire mapping of footsteps, sounds and sollus is tabulated below.

FOOTSTEP	STEP ARRAY				SOLLU	SOUND
Tattu_right	-	-	-	Tharight	Ka	Gu
	-	-	-	Na	Thom	Dhim3
	-	-	Tharight	Thaleft	Tharight	Dhim1
	-	-	-	Thaleft	Tharight	Dhi
	-	-	-	Gileft	Na	Nam
	-	-	-	Giright	Mi	Chapu
	-	-	-	Di	Tham	Chapu
	-	-	-	Dhi	Mi	Dhim2
	-	-	-	-	Tharight	Dhim1
Tattu_left	-	-	-	Tharight	Thaleft	Dhi

	-	-	-	Giright	Na	Nam
	-	-	-	Gileft	Mi	Chapu
	-	-	-	Dhi	Mi	Dhim2
	-	-	-	Dharight	Thaleft	Chapu
	-	-	-	Na	Thom	Dhim3
	-	-	-	Thaleft	Ka	Gu
	Tharight	Thaleft	Tharight	Ki	Ta	Dhim2
	-	-	Tharight	Ki	Ta	Ki
	-	-	-	Di	Tham	Chapu
	-	-	-	-	Thaleft	Dhim1
Mettu_left	-	-	-	Ka	Dhi	Dhim2
	-	Tharight	Thaleft	Tharight	Ki	Dhim2
	-	-	-	Tharight	Ki	Thom
	-	-	-	-	Di	Tha
Mettu_right	-	-	-	Ka	Dhi	Dhim2
	-	-	-	-	Di	Thom
Naattu_left	-	-	-	-	Gileft	Dhim3
Naattu_right	-	-	-	-	Giright	Dhim3
Kuditta	-	-	-	-	Jham	Dhim1
Kudittatattu_right	-	-	-	-	Dha_right	Dhim2
Kudittatattu_left	-	-	-	-	Dha_left	Dhim3
Kudittamettu	-	-	-	-	Ta	Dhim2

ALGORITHM

The algorithm, in brief, is given below. In the next section, each step is covered in detail.

1. Detect the floor plane.
2. Define a plane2 slightly above the floor plane.
3. Segment the dancer and display a binary image where only the part of the dancer below plane2 (dancer's feet) is coloured white.
4. Track the dancer's feet positions.
5. If a foot is raised above the plane2, wait for the foot to be brought below the plane2 in subsequent frames.
6. When foot is brought below the plane2, process the binary image to find the foot orientation.
7. Play the appropriate Mridangam sound.

IMPLEMENTATION

The tools and technologies used in this project are:

1. Microsoft Kinect

Kinect (Codenamed in development as ***Project Natal***) is a motion sensing input device by Microsoft for the Xbox 360 video game console and Windows PCs. Based around a webcam-style add-on peripheral for the Xbox 360 console, it enables users to control and interact with the Xbox 360 without the need to touch a game controller, through a natural user interface using gestures and spoken commands.

Microsoft Kinect being an interface that allows users to interact with a computer without the need for a traditional controller, there are huge possibilities offered by this device to the entertainment industry. Several of these possibilities have been harnessed to build applications that control music with hand movements, virtual percussion instruments, etc. and these augment a traditional performance to a great degree.

2. OpenNI SDK

OpenNI or *Open Natural Interaction* is an industry-led, non-profit organization focused on certifying and improving interoperability of natural user interface and organic user interface for natural interaction devices, applications that use those devices and middleware that facilitates access and use of such devices.

The OpenNI framework provides a set of open source APIs. These APIs are intended to become a standard for applications to access natural interaction devices. The API framework itself is also sometimes referred to by the name *OpenNI SDK*.

The APIs provide support for

- Voice and voice command recognition
- Hand gestures
- Body Motion Tracking

3. Sensor Kinect

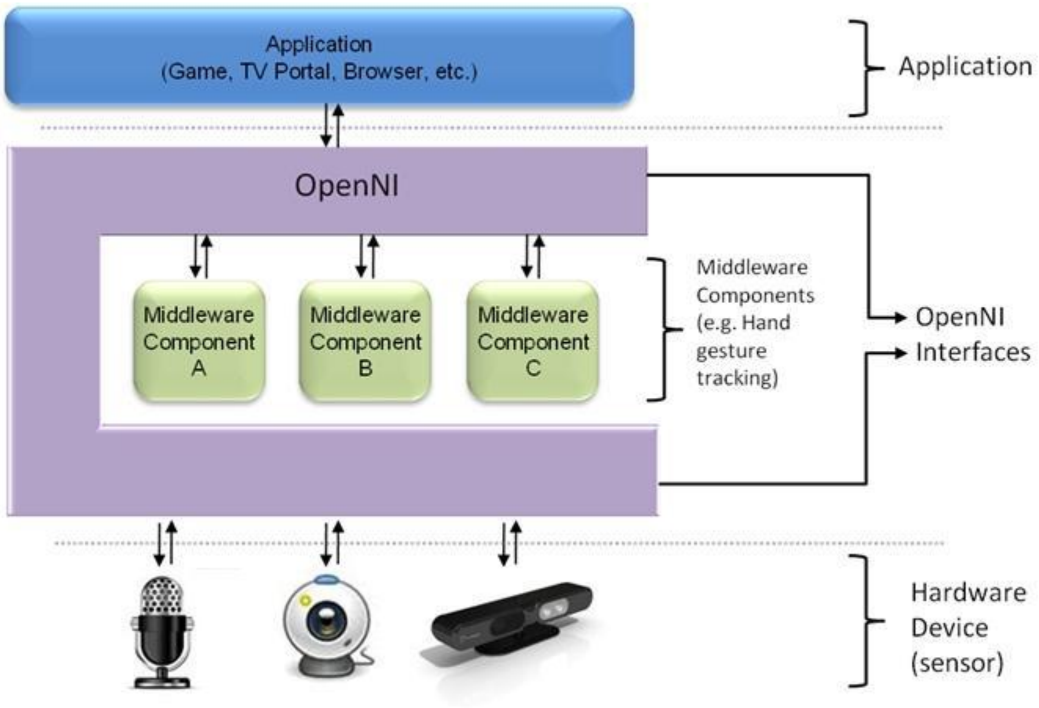
Sensor Kinect is the open source driver for Kinect given by Prime Sense.

4. NITE

The PrimeSense NiTE is a robust 3D computer vision middleware. This middleware provides the application with a clear user control API, whether it is hand-based control or a full-body control. The algorithms utilize the depth, colour, IR and audio information received from the hardware device, which enable them to perform functions such as hand locating and tracking, a scene analyzer (separation of users from background), accurate user skeleton joint tracking, various gestures recognition,etc.

5. **OpenCV**
   Open CV is the open source computer vision library. It is a cross-platform library focusing mainly on real -time image processing.

Abstract Layered View



1. Detecting the Floor Plane

- The Scene Analyzer Middleware was used to detect the floor plane.
- It analyzes the scene and returns the coordinates of a point on the floor.
- These coordinates were then mapped onto the 2-D image of the dancer.

The Scene Analyzer middleware returns the coordinates of the floor plane in real world coordinates. As the dancer moves forward or backward, the position of the floor plane in real world coordinates remains the same. However, its position on the 2-D image of the dancer varies. To achieve this, a transformation was used that converts the real world coordinates to projective coordinates.

2. Segmenting the Dancer

- The Scene Analyzer Middleware was used for the purpose of segmenting the dancer.
- This returns a labelled depth map, in which each pixel holds a label that states whether it represents a figure, or it is part of the background.
- This information was in turn mapped onto a binary image where only the part of the dancer below Plane2 is coloured white.

3. Tracking the feet and detecting Naattu

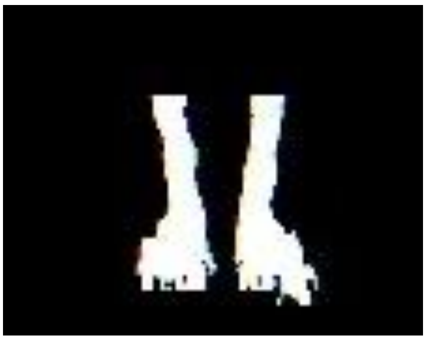
- The User Generator Middleware, which can track the positions of joints in the body, was used to track the feet.

- If the leg is stretched, it is the naattu position.
- If the leg is not stretched, it is either tattu or mettu position.
- The orientation of the knee-to-ankle bone is used to distinguish between the naattu and aramandala positions.
- The User Generator Middleware was used to track the bone orientation.

4. Detecting Tattu and Mettu

- Blur the image.
- Find edges using Canny's edge detection.
- Find contours in the image and find the largest two contours.
- Fit a hull around the largest two contours and fill them with white colour.
- Apply a mask to get the image of each foot separately.
- Find the ratio: length of contour of interest/length of the other contour.
- If ratio greater than 0.6, return tattu
- Else, return mettu.

Before finding the orientation, the number of white pixels in the image is found. This is divided by the number of white pixels when both the feet of the person were on the ground (this value is found in the first frame and consequently updated). If the ratio is less than a threshold value, the foot is not yet in the correct orientation. So this image is discarded and the next frame is taken up for processing. This feature is required in situations where the rhythm is very slow.



Tattu

Mettu

Detecting Kudittatattu and Kudittamettu

- If both the feet are above the plane2 simultaneously, the dancer is jumping on the toes. This position is referred to as Kuditta.
- A tattu with the right leg following a Kuditta is Kudittatattu_right.
- A tattu with the left leg following a Kuditta is Kudittatattu_left.
- If Kuditta is followed by the slapping of the dancer's heel onto the ground, it is a Kudittamettu.

Once the foot movement is detected, the corresponding Mridangam sound is determined from the mapping explained previously. Thus the task of generating percussion sounds to accompany a Bharatanatyam performance is accomplished.

CONCLUSIONS

- A Kinect based virtual percussion instrument was developed to accompany a Bharatanatyam performance.

- The virtual Mridangam can be used to give junior dancers the feel of a stage performance with accompanying artists.

- Unlike a Mridangist, the system will highlight, rather than cover-up any mistake made by the dancer. This would be of help to beginners in correcting any mistakes in their footwork.

- Experienced dancers are not likely to commit such simple mistakes in footwork. So it can be used in performances.

FUTURE WORK

- For a given rhythmic pattern, our system plays the same sound sequence. It can be taught a number of such sequences and made to play a suitable one each time. This would more closely approach a traditional performance.

  However, ‘suitable’ needs to be very well-defined such that the sequences of sounds played are not harsh on the ears.

- Similar systems can be developed for other Indian dances.

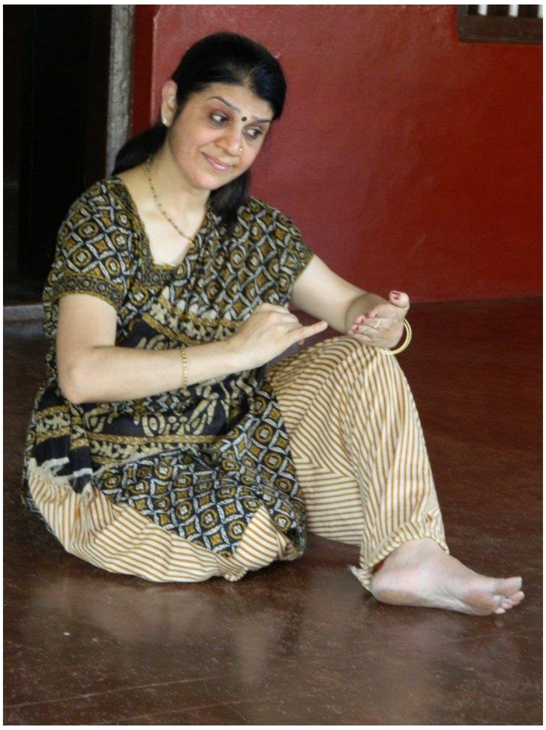
ACKNOWLEDGMENT

- My heartfelt thanks to Mridangam maestros **Anoor Ananthakrishna Sharma** and **Anoor Vinod Shyam** for their time, patience and invaluable advice. Their help was crucial in mapping the foot movements to Mridangam sounds and also to record the different sounds used in the project.

Vidwan Anoor Ananthakrishna Sharma

Vidwan Anoor Vinod Shyam

- My sincere thanks to my Bharatanatyam Guru, **Abhinayasharade Vidushi Sandhya Keshav Rao** for teaching me the divine artform. Her help was invaluable in this project.



Vidushi Sandhya Keshav Rao

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