EVALUATION OF VARIOUS PARAMETERS OF NATTADAVU IN BHARATANATYAM USING A RASPBERRY Pi-BASED SENSOR

EVALUACIÓN DE VARIOS PARÁMETROS DEL NATTADAVU EN BHARATANATYAM UTILIZANDO UN SENSOR BASADO EN RASPBERRY Pi

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Abstract

The Bharatanatyam dance requires excellent coherency and precision from the performer. In order to calibrate and gauge the physical moments of the performer, we propose a Raspberry Pi based sensor. Using the data obtained from the prototype, the classical Bharatanatyam dance movements of a performer have been sensed and analyzed. Based on the results, suggestions to improve the performance of Bharatanatyam are reported.

Keywords: Raspberry Pi, MPU9250, sensor, Bharatanatyam dance, measuring dance.

Resumen

La danza Bharatanatyam requiere una excelente coherencia y precisión por parte del intérprete. Para calibrar y medir los momentos físicos del intérprete, proponemos un sensor basado en Raspberry Pi. Utilizando los datos obtenidos del prototipo, se han detectado y analizado los movimientos de

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la danza clásica Bharatanatyam de un intérprete. Basándose en los resultados, se presentan sugerencias para mejorar el desempeño en el Bharatanatyam.

Palabras clave: Raspberry Pi, MPU9250, sensor, danza Bharatanatyam, medición de la danza.

Introduction

Bharathanatyam in Sangam literature was called as Koothu and later it was called as Sathir Attam. Now it is called Bharathanatyam. Bharatanatyam is a classical dance of Tamilnadu, which includes Bhava-expressions, Ragam, Music, and Thalam-beats [1–3].

A Bharathanatyam dancer taps the foot on the floor with a rhythmic beat and also expresses various expressions according to the song. Bharathanatyam for beginners usually starts with basic steps called "Adavu". It is basic for all new learners. There are 12 Adavus in Bharathanatyam.

Various Adavus are carried out in three speeds:
1. I speed - Vilambam
2. II speed - Mathimam
3. III speed - Thuritham

Dancer must perform the Adavu with proper "Angasutham"and "Thaalasutham". Angasutham is referred as proper hand position and leg position. Angasutham includes being erect in the vertebral column, i.e., the spinal cord. Thaalasutham is referred as the proper tapping of the foot on the floor according to Rhythm.

Mandalastham includes the positioning of both legs of the dancer at 180 degrees.

The symmetry between the left and right half of the body has to be maintained in Mandalasthanam. If the feet are together in Mandalam, the acceleration takes longer. Then, the center of force exerts at a single point, and the center of gravity is balanced by a dancer.

Raspberry Pi [4, 5] is a multi-purpose single-board computer. There is a lot of research automation implemented using Raspberry Pi.

The Raspberry Pi is implemented to measure temperature variations using sensors [6].

Andres Alejos et.al [7] explored the use of Raspberry Pi for data summarization in wireless sensor networks. They used Raspberry Pi to create a low-cost, low-power platform to collect and process data from multiple sources. The authors found that the Raspberry Pi was able to summarize data quickly and accurately and that could be used to create a low-cost and low-power distributed sensor network.

L. Shen et al. [8] developed a low-cost wireless sensor network for real-time monitoring of a tower movements due to bell-ringing.

Rustam et al. [9] evaluated the operability of a custom-built differential drive wheel mobile robot for self-driving applications. They focused on parameters, hardware implementation, steering algorithm, and the robot's operability.

Bommannan et al. [10] proposed a low-cost data glove embedded with a MPU9250 motion sensor for real-time numerical gesture recognition. They compared different machine learning and neural network models and achieved a high accuracy of 98.41 % with a low inference delay of 2 ms. Chunyang et al. [11] introduced a gesture detection system using a MPU9250 sensor and a MSP430F149 processor. They measured attitude angles using the gyroscope, accelerometer, and electronic compass of the sensor and applied data fusion analysis with the Kalman filter algorithm. The system achieved fast response characteristics and was successfully used in a self-balanced robot for motion gesture detection.

The MPU9250 is a motion-detecting sensor, which has a variety of applications [12]. It is used for detecting the motion of objects. The MPU9250 is a multi-chip module (MCM) consisting of two dies integrated into a single QFN package. It includes an accelerometer, a gyroscope, and a magnetometer, which work together to provide precise measurements of orientation, acceleration, and rotation. These sensors are located on a small circuit board, which can be attached to a person's hand or other body part using a flexible mounting system.

The MPU9250 sensor module is capable of handling a large amount of data, as it has a high sampling rate and a large FIFO buffer. The sampling rate determines how frequently the sensor captures data, and the FIFO buffer stores the data until they are read by the microcontroller. The MPU9250 sensor module can sample data at up to 8 kHz for the gyroscope and accelerometer, and up to 100 Hz for the magnetometer. The FIFO buffer can store up to 512 bytes of data, which is equivalent to 85 samples of 6 bytes each for the gyroscope and accelerometer, or 128 samples of 4 bytes each for the magnetometer. These specifications ensure that the sensor can capture and store data continuously without losing any information.

The main purpose of this work is to gauge the physical movements of the dance performer and, based on the obtained results, suggestions to improve the performances are provided. To achieve this, a Raspberry Pi-based sensor design is implemented.

Methodology

The Bharatanatyam dance movements can be measured using the device set up such as Raspberry Pi and MPU9250 motion sensor. The Raspberry Pi is an open-source platform that enables users to create custom applications and programs using Python. The MPU9250 is an inertial measurement unit (IMU) consisting of three primary sensors: accelerometer, gyroscope, and magnetometer. Each sensor measures the 3-axis signal in the cartesian reference X, Y, Z.

The wiring diagram for the MPU9250 and Raspberry Pi can be found in the datasheet. In order to read and write data via I2C, the user must enable the I2C ports first on the Raspberry Pi. This can be done using the command line or by navigating to the Preferences → Raspberry Pi Configuration. Once the I2C port has been enabled, the user can use Python to communicate with the MPU9250 and read the data from it. The data can then be used to create a graphical representation of the Bharatanatyam adavu, which can be used to analyze the performance of the dancer.

Bharathanatyam includes 12 types of Adavu. Here we have taken Nattadavu. It includes 8 steps. The dancer carried out 8 steps at three speeds.

It is possible to connect a Raspberry Pi to various devices, including sensors and actuators, in order to create interactive projects that incorporate elements of Bharatanatyam.

Each Raspberry Pi is equipped with an MPU9250 sensor, which is capable of measuring acceleration, gyroscope, and magnetometer readings. These sensors are used to track the movement of the Adavus as they are performed and gather data on their execution.

The sensor is set up in such a way that each Raspberry Pi is connected to one or more MPU9250 sensors, which are attached to the dancer's body or to a device being used during the performance of the Adavus. As the dancer performs the Adavus, the sensors collect data on the movement of the dancer's body, which is then transmitted back to the Raspberry Pi for processing. The Raspberry Pi then analyzes the data and sends it to a central server or computer, where it can be stored and analyzed further.

The data collected by the sensor can be used in a variety of ways. For example, it can be used to improve the accuracy and precision of the Adavus by identifying areas where the dancer's movements deviate from the desired form. It can also be used for research purposes, such as studying the impact of different dance training techniques on the performance of the Adavus. One of such hand positions of the dance performer is shown in Figure 1.

We have used Raspberry Pi Pico for these experiments. Also, we have tested the same experiment with Raspberry Pi 3B too regarding the possible prototype. We have understood that Raspberry Pi Pico provided good results.

FIGURE 1. *One of the hand positions of the dancer during the performance*

Raspberry Pi Pico is a microcontroller board that can be used for various applications, such as measuring the parameters of Nattadavu in Bharatanatyam. It has a dual-core ARM Cortex-M0+ processor running at 133 MHz, 264 KB of RAM, and a 40-pin GPIO header. It is much smaller in size and cheaper than Raspberry Pi 3B, which is a full-fledged computer with a quad-core ARM Cortex-A53 processor running at 1.2 GHz, 1 GB of RAM, and multiple ports and interfaces. Raspberry Pi Pico also consumes less power and can be powered by a micro USB port or a battery.

We have chosen Raspberry Pi Pico for our experiments because it allows us to carry out this type of research with greater technical possibilities. We have connected MPU9250 sensors to the GPIO pins of the Pico, to measure the hand movements of the dancers. We have also used a wireless module to transmit the data from the Pico to a computer for analysis. We have compared the performance of the Pico with the Raspberry Pi 3B, which has similar sensors and wireless capabilities.

We have found that Raspberry Pi Pico provided good results in terms of accuracy, reliability, and responsiveness. The Pico was able to capture the subtle variations and nuances of the Nattadavu gestures, such as speed, direction, angle, and force. The Pico was also able to send the data in real-time without any delay or loss. The Raspberry Pi 3B, on the other hand, had some limitations and drawbacks. The 3B was bulkier and heavier than the Pico, which made it uncomfortable for the dancers to wear on their hands. The 3B also consumed more power and generated more heat, which affected its performance and stability. The 3B also had some issues with the wireless communication, such as interference and latency.

Therefore, we have concluded that Raspberry Pi Pico is a better choice than Raspberry Pi 3B for our experiments. It is more suitable for measuring the parameters of Nattadavu in Bharatanatyam using a Raspberry Pi-based sensor system. It offers more advantages and benefits than the 3B in terms of size, cost, power consumption, and technical capabilities.

Using Python, the live data from the MPU9250 sensors can be logged and stored on the Raspberry Pi for later analysis. This data can be used to create an analysis of the hand's movement, to control virtual objects or machines, or to train machine learning models to recognize patterns in human movement. Here, the performer's hand is equipped with a Raspberry Pi and MPU9250-based prototype. The logging of various data, while the performed performs dance movements, are logged via the sensors. The logged data are stored locally in the Raspberry Pi and also transferred to the cloud storage. When the hand moves, the sensors on the MPU9250 circuit board will detect changes in acceleration and angle, and transmit this data to the Raspberry Pi. Using Python, the Raspberry Pi can log and store this data, and use it to analyze the movement of the hand. The block diagram for experiment design and the prototype is shown in the Figure 2, and Figure 3 respectively.

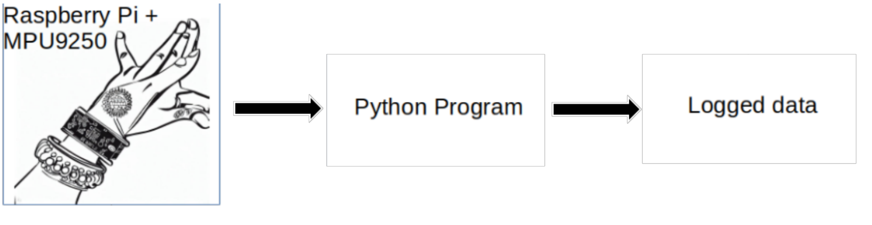

FIGURE 2. *Experiment design*

We have analyzed the data for only one dancer for the present paper. This is due to the fact that we can model the dance

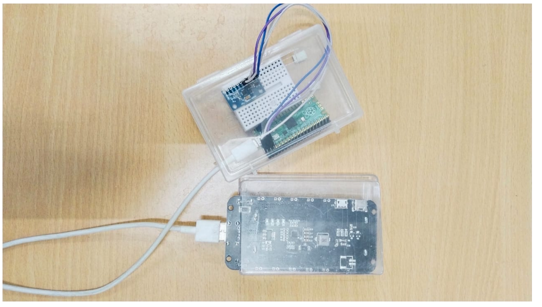

FIGURE 3. *The experiment design and prototype*

movements with sensors. We used a Raspberry Pi-based sensor system to capture the motion features of the dancer's hand movements in Nattadavu, a type of Bharatanatyam dance. The attachment of the prototype on the performer′s hand is shown in the Figure 4.

FIGURE 4. *Installation of the prototype on the performer's hand*

Here they installed a data identification point around the wrist of the dance trainer's body and matched the collected dance movements with a file.

However, we focused on only one sensor and one dance movement for this paper, as we wanted to test the feasibility and validity of our method. We will expand this to many dancers and many sensors in our future work, as we aim to build a comprehensive system for evaluating and teaching Bharatanatyam dance. We are also interested in exploring other methods for modeling dance movements with sensors, such as using deep learning techniques.

Results and Discussion

For each step of the Nattadavu in Bharatanatyam, the corresponding changes in angles and acceleration are obtained from the corresponding peaks in the MPU9250 data. The gyroscope measures the angular velocity of the hand movements, the accelerometer measures the linear acceleration of the hand movements, and the magnetometer measures the magnetic field of the hand movements. The data from these sensors are transmitted to a Raspberry Pi, which is a small computer that can process and analyze the data.

The peaks in the MPU9250 data are the points where the sensor values reach their maximum or minimum values. These peaks indicate the changes in the direction, speed, and force of the hand movements. For example, if the hand moves from left to right, there will be a peak in the gyroscope data along the y-axis, which is perpendicular to the direction of movement. Similarly, if the hand moves up and down, there will be a peak in the accelerometer data along the z-axis, which is parallel to the direction of gravity. The acceleration data is shown in the Figure 5. By detecting these peaks, we can calculate the changes in angles and acceleration of the hand movements for each step of the Nattadavu.

The changes in angles and acceleration are important parameters for evaluating the quality and accuracy of the Nattadavu. They can reflect how well the dancer performs each step according to the classical rules and standards of Bharatanatyam. They can also provide feedback and guidance for improving the dancer's skills and techniques. By using a Raspberry Pi-based sensor system with an MPU9250 module, we can measure these parameters objectively and quantitatively.

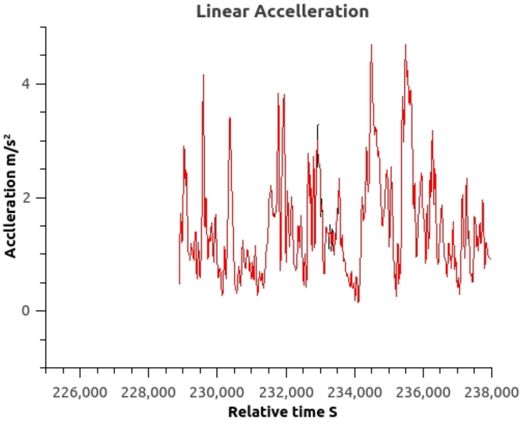

FIGURE 5. *Changes in acceleration*

From the data, it can be found that the linear acceleration of the hand is changing from 2.5 m/s^2 to 4.5 m/s^2 as the dancer performs various Adavus, which are specific dance movements or steps. These changes in acceleration can be logged and stored by the Raspberry Pi using Python and can be used to analyze the dancer's movements and understand how they are performing the Adavus.

Linear acceleration is just one of the many types of data that can be measured by the MPU9250 sensor. Other types of data that can be detected include angular velocity, which measures the rate of change of the orientation of the hand, and magnetic field strength, which measures the intensity of the magnetic field around the hand. All of these data points can be used to provide a more complete picture of the hand's movement and help researchers or artists understand and analyze the dancer's performance.

The MPU9250 sensor is able to detect changes in both acceleration and the angle of the hand, using a combination of accelerometers, gyroscopes, and magnetometers. The accelerometers measure linear acceleration, the gyroscopes measure angular velocity, and the magnetometers measure magnetic field strength.

The changes in the corresponding angles for the hand movement are reported in the Figure 6. Also, the changes in the acceleration as a consequence of changes in angles are shown in Figure 7. This

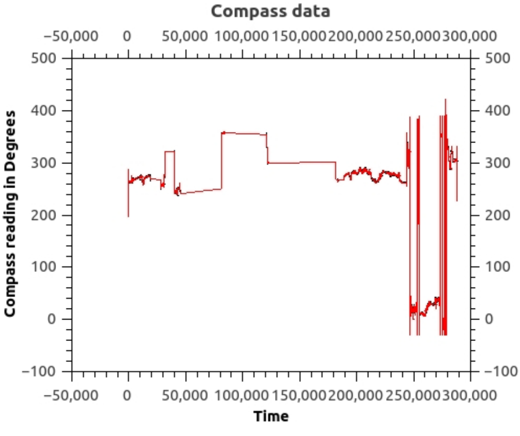

FIGURE 6. *Compass reading from MPU9250*

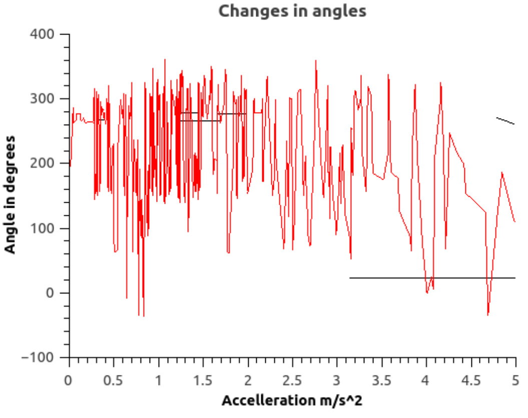

FIGURE 7. *Changes in acceleration with respect to angles*

data relate the various accelerations corresponding to the various positions of the dance movements.

The angular variation, or changes in the angle of the hand, can be used to understand the specific Adavu movements being performed by the dancer. By analyzing the angular variation in combination with the changes in acceleration, researchers or artists can gain a better understanding of the dancer's movements and how they are performing the performances.

Steps	KE value in X (J)	In Y (J)	In Z (J)
1	1.350	0.597	1.439
2	3.037	1.343	3.238
3	1.99	0.880	2.122
4	2.231	0.987	2.379
5	2.231	0.987	2.379
6	1.990	0.880	2.122
7	3.967	1.755	4.22
8	3.967	1.755	4.22
9	1.763,	0.780	1.879
10	1.35	0.597	1.439

Table 1. Various Kinetic energy values

Kinetic energy

The kinetic energy in the X, Y, and Z directions for the various dance steps in the given data varies significantly. For example, the following parameters have been obtained. In X direction the third step has a kinetic energy of 1.99 J, which is lower than the second step but still higher than the first step. Similarly, the third step of the Y direction has a kinetic energy of 0.88 J, which is lower than the second step but still higher than the first step. Also, in the seventh and eighth steps of the Z direction, both have a kinetic energy of 4.229 J, which is the highest value among all the steps.

To improve their performance, dancers should focus on increasing their kinetic energy in all directions and developing the strength and stamina needed to sustain high levels of energy throughout their performance. The kinetic energy values are presented in the Table 1.

Moment of Inertia

Similarly, the moment of inertia is obtained via the available set of data. The moment of inertia in the X direction is $0.547\, kg.m^2$, while the moment of inertia in the Y direction is $0.242\, kg.m^2$ and the moment of inertia in the Z direction is $0.584\, kg.m^2$. These values indicate the resistance of an object to change its rotational motion in each direction. In this case, it appears that the object has the highest moment of inertia in the z-direction, followed by the X direction, and the lowest moment of inertia in the Y direction.

Understanding the moment of inertia of an object in different directions can help dancers and choreographers design movement patterns that are stable and controlled. By manipulating the moment of inertia, dancers can create dynamic and expressive movements that engage the audience and enhance their performance.

Torque

In the next analysis, the torque is calculated. A torque can be defined as a force that causes a rotation like the hand turning a screwdriver. The torque is actually a combination of at least one pair of forces. Like above all, a dancer is moving with speed, velocity, and momentum. Every movement is completed by a dancer with a proper time limit. The dancer's direction, moment of inertia, angular momentum, work, kinetic energy, and power are the areas calculated here by means of Raspberry Pi device.

The average value for the torque in the X direction is $1.54\,Nm$. The average value for the torque in the Y direction is $0.703\,Nm$. The average value for the torque in the z direction is $1.681\,Nm$.

The values for the torque in the X and Z directions are generally higher than the values for the torque in the Y direction. The values for the torque in the X direction are also slightly lower on average than the values for the torque in the Z direction.

Power

Using the above data, the power value is obtained for the various dance movements. These values are reported in Table 2.

The mean of the power data in X direction is obtained as $16.072\,Ns^{-1}$. The standard deviation is calculated as $10.04\,Ns^{-1}$.

With these data driven power values, we can then compare each power value obtained for corresponding Adavus, to the mean to see

Direction	Mean Power Ns^{-1}
X	16.072
Y	6.872
Z	16.792

TABLE 2. Mean power values in X,Y,Z direction

how far it is from the average. For example, in the X direction, the power value for the first step is $5.996\,Ns^{-1}$, which is about 10.04 units below the mean, while the power value of second step is $20.236\,Ns^{-1}$, which is about 4 units above the mean.

We can also compare the power values to each other to see if there are any patterns or trends. One possible pattern that we might notice is that the power values tend to be higher in the middle steps of the performance, with lower values at the beginning and end. For example, the fifth and sixth power values in the dance steps are both around $12.7\,Ns^{-1}$, while the first and last step's power values are both around $6\,Ns^{-1}$.

This could also suggest that the dancer is building up power as the performance progresses and then tapering off at the end.

Another pattern that we might notice is that there are two pairs of power values that are very close to each other. The third and fourth step's power values are both around $12.7\,Ns^{-1}$, as like the fifth and sixth step's power values. This could indicate that these positions in performance are similar in terms of power requirements. Similarly, there are differences between each power value corresponding to each step of the dance and the mean, expressed as multiples of the standard deviation.

We can see that some of the power values are close to the mean (within about 0.5 standard deviations), while others are more significantly higher or lower. For example, the seventh and eighth power values are both about 1.5 standard deviations above the mean, which could indicate that they are unusual or noteworthy values. Based on these values, it appears that the power values in the X and Z directions are relatively similar, while the power values in the Y direction are lower. The data says that the performer maintains symmetry in the X and Z plane.

Conclusion

In this paper, we have proposed and implemented a Raspberry Pi-based sensor system to measure and analyze the parameters of Nattadavu, one of the basic steps in Bharatanatyam dance. We have used an MPU9250 motion sensor module to capture the acceleration, angular velocity, and magnetic field data of the dancer's hand movements. We have also used a Raspberry Pi Pico microcontroller board to process and transmit the data to a computer for further analysis. We have calculated the kinetic energy, moment of inertia, torque, and power of the hand movements for each step of the Nattadavu and compared them with the classical rules and standards of Bharatanatyam. We have found that our system can provide objective and quantitative feedback on the performance and quality of the Nattadavu, as well as identify areas for improvement. Our system is low-cost, low-power, and easy to use, making it suitable for various applications in dance research and education. Our system can also be extended to other types of Bharatanatyam dance movements and other dance forms. We have demonstrated the feasibility and validity of our method by using only one sensor and one dance movement for this paper. We plan to expand this to multiple sensors and multiple dance movements in our future work, as we aim to build a comprehensive system for evaluating and teaching Bharatanatyam dance. We are also interested in exploring other methods for modelling dance movements with sensors, such as using deep learning techniques.

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