A Robotic Solution for Traditional Drums in Sri Lanka- Thammattama

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Abstract. Sri Lanka has a unique, proud and precious music culture that is based on traditional drums. Traditional drums are very important to Sri Lanka as they are frequently used for both religious and cultural occasions. At present, this valuable drum music culture is dying out gradually, due to the lack of talented drum players. This paper describes an automated robotic player for traditional drum Thammattama which is one of the major four traditional drums in Sri Lanka. The developed system has two robotic arms that play the instrument like a drummer. As the first step of the research, required characteristics factors of Thammattama have been identified, including musical notes, location of the drum, the amount of stress applied and drumming styles. Then identified characteristics values have been applied for the robotic system with trial and error approach. This robotic solution comprises of six modules namely power module, a processing module, solenoid control module, servo-motor controller module, input module and display module. The system has been successfully tested with human players, and successful results were obtained.

Keywords: Robotic Arms, Robotics, Thammattama

1 Introduction

The world is a mixture of different cultures, and these cultures have their own model of music. Sri Lanka also has a unique music culture which is consisted of three roots as Buddhists religious traditions, Hindu religious traditions and ancient folk rituals [1]. The music culture of Sri Lanka consists of a variety of traditional instruments, traditional songs and dances. Among them, traditional instruments take a significant position. Sri Lanka has many types of drums from ancient time, and this drum tradition is believed to go back more than 2500 years. Not only that but also, some of the classical literature such as Dalanda Siritha, Pujawaliya and Thupawansaya are providing evidence for this [2]. Mainly, these traditional drums are unique to Sri Lanka and have own style of drumming. Buddhists and Hindus in Sri Lanka use different types of traditional drums for their religious aspects. Buddhists frequently use some of the traditional drums such as Getaberaya, Dawla, Thammattama and Yakberaya for Bodhi Pooja, Hevisi Pooja, Pirith ceremonies, Perehera and etc. Hindus also use drums such as Maddalaya, Tavil and Mridangam for their religious purposes. At the same time, Sri Lankans use these traditional drums for traditional dancing, folk rituals and for variety of festivals such as Jana Kavi (folk poems), Virindu, Kolam and rituals, as Bali, Thovil, Madu and Atanatiya.

The traditional drum music culture of Sri Lanka faces a lot of problems, unfortunately, due to a number of reasons. The major problem is the lack of traditional drum players and the dearth of talented drummers. This situation has been arisen due to several reasons. Today, education has become an important and essential qualification. Accordingly, every person is trying to obtain a good education. As a result, most of the traditional drum playing families have directed their children to get a good education and many drummers have moved to other jobs as they are being treated badly and faces a lot of problems financially [3]. Besides, drummers and this culture do not receive sufficient formal recognition, proper appreciation and state patronage. Therefore, this precious industry is dying out gradually, and as a result, there is a significant drain number of people in this sector today.

The arose problem has been seriously impacted by religious places in the country, such as Buddhist temples and Hindu Kovils as their culture, offerings, and rituals highly depend on these traditional drums. Due to the shortage of drummers, these places are in big trouble. As a result, they have resorted to alternative methods. Recorded music has become the most common alternative these days as it is an easy and inexpensive method. But, it is not a viable solution as recorded music doesn't produce the real and natural sound of the instrument. Besides, highly advanced tools that are capable of processing music are very expensive. To overcome the above problems, an automated robotic system can be introduced that can be used to play traditional drums in Sri Lanka.

The paper is going to discuss an automated robotic system that has been designed for one of the traditional drums in Sri Lanka named Thammattama. This robotic system consists of two robotic arms that are holding the two playing sticks of the Thammattama. These two robotic hands are used instead of a drummer and perform the role of the drummer. This system has been designed to play two major and common drum rhythm beats that are often played using the Thammattama such as rhythm beats playing at pirith ceremony and hewisi pooja. The advantage of this system is, it can be used in places of worship where there is a shortage of drummers and the ability to play the drum rhythm beats continuously for long periods. Further, this system can be used to train amateur drummers.

The rest of the paper is structured as follows. Section 2 describes the related works and technologies related to robots, robotic arms and robotic musical instruments. Then, Section 3 gives an overview of the Thammattama; Section 4 presents the design of the robotic system. Section 5 describes how the developed system works in the laboratory environment, Section 6 presents the

evaluation, and finally, Section 7 gives a conclusion and further works of the project.

2 Robotic Technology

Most of the systems and devices available today are computer-based and automated. So, most of these systems and devices have been bond with the power of artificial intelligence and robotics. These technologies are used to develop machines that can be replaced instead of humans and replicate human actions. Robotics is an interdisciplinary branch of science and engineering that includes mechanical engineering, electronic engineering, computer science and other related disciplines [4]. Nowadays, robotics has been become a rapidly growing field due to the advancement of technology and researching.

There are different types of robots used in several environmental conditions for different uses. Although these robots being very diverse in application, their construction is the same. A robot is created with three fields as mechanical engineering, electrical engineering, and computer science. A robot has a mechanical construction that is designed to achieve a particular task by dealing with physics. Secondly, it has an electrical component that can be used to control the machinery. Besides, electrical power is used for movement, sensing and also for operation. A computer program is the essence of a robot that is consisted of a sequence of instructions that tell a robot when or how to do a particular task. Robotic programs can be divided into three types as remote control programs, artificial intelligence programs, and hybrid programs. Moreover, the construction of a robot has a variety of components and belong to the mentioned core fields. They are a power source, actuation, sensing, manipulation, locomotion, environmental interaction, navigation, and human-robot interaction. Robots can be classified into several groups according to the application area such as military robots, agricultural robots, industrial robots, cobots, medical robots, musical robots, nanorobots, domestic robots, etc. [5]. Besides, they are several types of modern and advanced robots that have been designed with a blend of artificial intelligence technologies as natural language processing, computer vision, reinforcement learning, and edge computing.

Robotics and Artificial Intelligence are often misconceived as similar terms. But, they are entirely two different fields. Robots can be grouped into four categories according to technology such as artificially intelligent robots, non-artificially intelligent cobots, artificially intelligent cobots and software robots [6]. Artificially intelligent robots are a type of robot, exists between robotics and artificial intelligence that are controlled using AI programs. Non-artificially intelligent cobots can be easily programmed to pick and place several objects. They continue the given task until it is turned off and also known as simple collaborative robots. Artificially intelligent cobots have several capabilities that are designed with the use of AI algorithms. A software robot is a type of computer program that autonomously operates to perform a virtual task. They are not physical robots and only exists in a computer. Not only that but also, some of the advanced software robots contain AI algorithms.

3 Related Works

Robotic arms are one of the major parts in robotic systems that can be introduced as a mechanical product. At present, these robotic arms have been become very valuable interim due to many reasons. As a result, there are different types of robotic arms are available in the market that can be used for specific purposes. Robotic arms are used in different conditions where humans are not able to work such as a polluted air zone, high temperature, and heavy weight lifting. In addition, they are very famous because of increased efficiency, higher quality, improved working environment, increased profitability, longer working hours and prestige.[7] Robotic arms are designed using different parameters like a number of axis, degree of freedom, working envelope, working space, kinematics, payload, speed and acceleration, accuracy, repeatability, drive and motion control [8].

The "animator" is a robotic arm that is designed to overcome many challenges in daily life. This arm generates a realistic velocity distribution to manipulate several types of motions. Therefore, it uses the mechanism and the mechanical structure of ASR K-250 to perform human-like manipulation motions. This arm has been implemented and tested successfully for the 4 degrees of freedom (DOF) [9].

“MR999” is an E-wireless robotic arm that was designed using wireless technology. This arm has used to support various applications such as surgery and remote monitoring. The arm performs five types of movements to grab or release, lift or power, rotate wrist and pivot sideways that is controlled using five separate servo motors. Not only that but also, this arm has a graphical user interface application to make it more user-friendly. MR999 has been modelled and programmed in the Visual Basic environment and performs real-time, simultaneous movements [10].

Aparnathi and Dwivedi have designed a robotic arm for industrial applications that control along six axes. The arm has been designed with the use of automation technology. The arm has been manufactured using several hardware components such as manipulators with end effectors, power supply, controller and sensor feedback to perform different processes in many industries [11].

Megallingam and Gadela have developed a robotic arm that solves kinematics problems using the Jacobian Iteration method and can be used in agriculture applications. Not only that but also, this robotic arm can be controlled with Kinect. The system is designed based on two main areas as hardware implementation and software implementation [12].

Robotics are created based on the application area. At present, musical robots that can be used to play different instruments without getting the involvement of humans are evolving day by day. As a result, some of the robots can be used to play musical instruments very well and easily without using any human players. While there are a

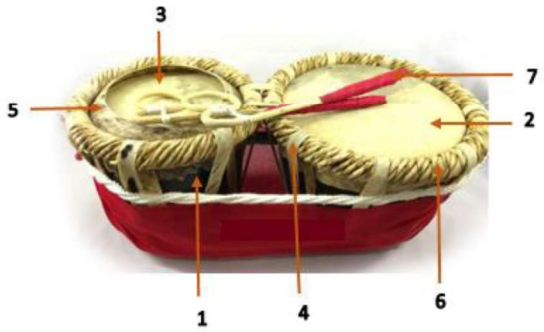
lot of robots for different applications, there are a few numbers of robots have been designed to play instruments. As a starting point, Kapur has done a review of the history of robotic musical instruments. Most of the robots in the past have been designed with the use of motors, gears, and solenoids. Besides, he has discussed several musical robots and their technologies such as piano robots, percussion robots, woodwind robots and strings robots [13].

Sobh and Wang have developed a robot musician band that was established at the Bubble Theatre of the Arnold Bernhardt Center of the University of Bridgeport. The significance of this band is, each one who plays an instrument is a robot. Accordingly, they play real musical instruments through the usage of several mechanical devices like servo-motors and solenoids. The research has been linked with three main areas such as; robotic technology, computer science, and music. Not only that but also, each robot in the band has been constructed with hardware and software design and adopted a three-module architecture consists of a software module, a control module and a motion module [14].

"A Comparison of Solenoid-Based Strategies for Robotic Drumming" is a research done by Kapur that was related to a robot named "MahaDeviBot". This musical robot is a custom-built 12-armed MIDI-controlled mechanical device that plays a variety of Indian folk instruments. Besides, it includes some other instruments like bells, shakers, and frame-drums to decorate music. "MahaDeviBot" has been designed with the use of solenoids, and finally, it has been evaluated using a haptic feedback system [15].

4 Thammattama: A Traditional Drum in Sri Lanka

The precious drum art in Sri Lanka has four major drums as Getaberaya, Yakberaya, Dawla, and Thammattama [20]. When considering Getaberaya, Yakberaya, and Dawla, they exist as single drums, and Thammattama consists of two drums. Accordingly, Thammattama is named as a twin drum or "Pokuru Beraya". But, they are of different sizes. The large drum in size is named as "Mandama", and the small drum is named as "Handabeya". "Mandama" is used to produce low sounds while "Handabeya" is used to produce high sounds. The body of the two drums has been covered with a very strong wood such as; Kohomba, Ehela, and Jack. The top side of the drum has been covered with a cattle hide that is named as drum membrane. The drums are played using two sticks that are unique to the Thammattama and named as "Kadippu". Often, these two sticks are made of kirindi or rathmal. Not only that but also, these sticks can be used to perform several variations in sounds such as "staccato" (each note is sharply detached from the other note) and "legato" (notes are connected and bounded) [17]. The sticks must be beaten to the middle of the drums to produce the correct sound. Fig. 1. shows the parts of the Thammattama.



1. Body of the Thammattama
2. Mandama
3. Handabeya
4. Warapati
5. Kepum-Hama

Fig. 1. Parts of the Thammattama

Tabel 1. Shows the chracteristic factors identified in Thammattama

Tabel 1. Percussion variety of the Thammattama

Music Note	Drum	Performance Technique	Type of Sound	Drum Location	Number of Sticks	Amount of Stress Applied to the Drum
Don	Mandama	Legato	Very Low	Middle	One	Very High
Kun	Mandama	Legato	Low	Middle	One	Very Low
Thon	Mandama	Legato	Low	Middle	One	Medium
Kita	Handabeya	Legato	Very High	Middle	Two	Very High
Kruu	Handabeya	Arpeggio	Low	Middle	One	High
Thari	Handabeya	Legato	High	Middle	Two	High
Thath	Handabeya	Staccato	Very High	Middle	One	Very High
Jen	Mandama and Handabeya	Legato	High	Middle	Two	High
Raj	Mandama and Handabeya	Legato	Low	Middle	Two	Low
Digi	Mandama and Handabeya	Staccato	High	Middle	Two	Very High

5 Design

The design of this robotic system is a combination of electronics, mechanical principles, computer programming, and music. This means the design of this robotic system involves the disciplines and principles of electronics engineering, mechanical engineering, computer science, and eastern music. Also, the design of this system can be categorized into two sections, as hardware development and software development.

Hardware development of the system can be categorized as developing the two robotic arms and the system. The robotic arms have been designed with the use of hardware components such as solenoids and servo-motors. First of all, the element used to create these two robotic arms are Aluminium. Then the tip of the arm is attached to the sticks of the Thammattama. These two robotic arms illustrate the nature of a drummer who is holding the two sticks of the Thammattama. When considering an arm, it consists of a solenoid and a servo-motor. Fig. 2. shows the construction of the robotic arm.

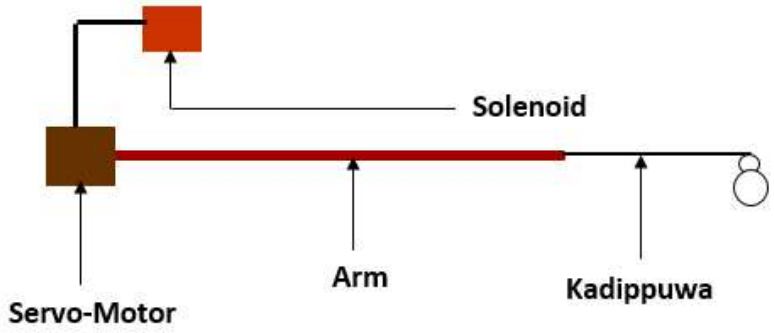


Fig. 2. Construction of the Robotic Arm

The design of the robotic system is comprised of six main modules named power supply module, processing module, solenoid module, servo-motor module, switch-input circuit module and LED circuit module. Fig. 3. shows the architecture of the automated robotic system and a brief description of each module given below.

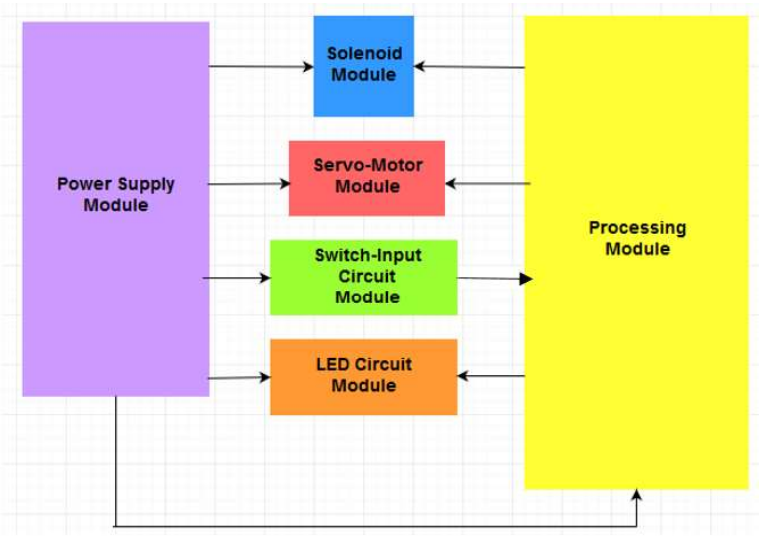


Fig. 3. Architecture of the Automated Robotic System

5.1 Power Supply Module

The power supply module is one of the major modules in this system. Not only that but also, it has been connected with every module in the system. When considering the power supply module, it is a combination of several components such as switch-mode power supplies (SMPS), voltage converters, linear regulators, diode bridges, connectors, etc. First, the system has been connected to a 230V AC voltage. Then it has been converted into a 12V AC voltage using a switch-mode power supply. As the second step, the two wires coming from SMPS have been connected to a diode bridge that it a bridge of four diodes. The output coming from the diode bridge has been smoothed by two capacitors. Then the output will be entered into a voltage regulator named LM317. The output coming from LM317 has been gone across a diode and again connected to the LM7805 linear regulator that gives 5V DC voltage as the output. Fig. 4. shows the block diagram of the power supply module.

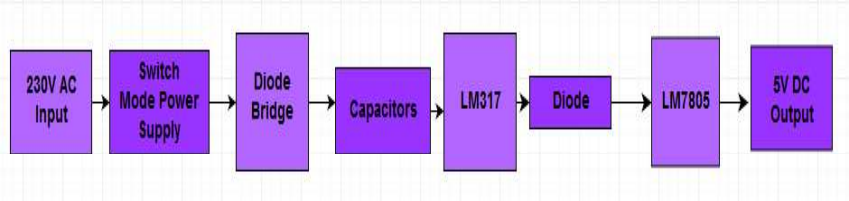


Fig. 4. Power Supply Module

5.2 Processing Module

The processing module is one of the major modules in this automated robotic system and can be introduced as the heart of the system. In this system, the PIC 16F877A microcontroller has been used as the processing element. The PIC 16F877A has a lot of advantages such as reliability, operational flexibility, fast performance, low cost, easy interfacing, and also very easy in programming [17]. Not only that but also, all the other modules in the system have been connected to the processing module. Besides, the behaviour of the two robot arms and the system has been controlled by the microcontroller. It contains a sequence of instructions that give commands to each module to work correctly and accurately. Mainly, processing module starts to work according to the input given by switch-input circuit module, and as the output it delivers the commands to the solenoid module and servo-motor module. In addition, the tension that should be applied to the drum face will be controlled by the processing module. In this system, there is one solenoid. Therefore, to produce three types of tensions using this single solenoid has been programmed with the use of the processing module. Fig. 5. shows the block diagram of the processing module.

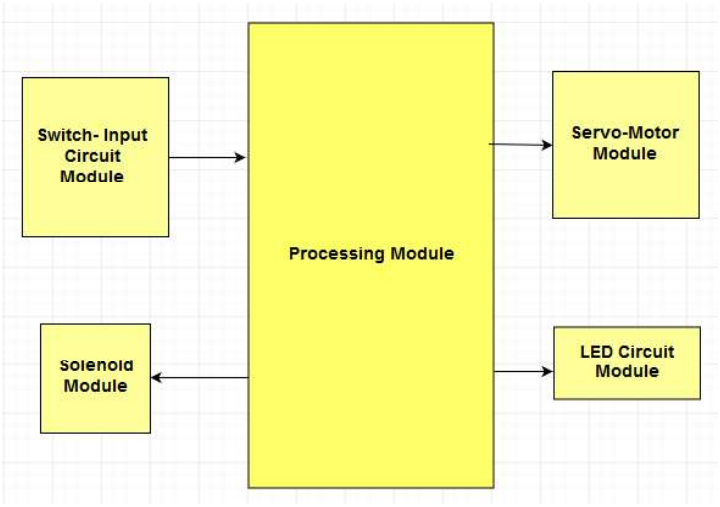


Fig. 5. Processing Module

5.3 Solenoid Module

A solenoid is a kind of electromagnet that generates a controlled magnetic field. It has a coil of wire, magnet, and an iron shaft. When current is supplied to the coil, a magnetic field will be created, and as a result, the shaft will be pushed. When the current is removed, the magnetic field no longer exists, and the shaft will return to its original position [18]. The solenoid module of the system has consisted of six solenoids. That is, one arm has three solenoids. The internal solenoids of LC1-D1810 contactors have been used as they are very powerful. The purpose of this equipment is to create linear motion and to move sticks up and down along the Y-axis. Besides, on the one hand, three solenoids are used to produce three types of sounds. Fig. 6. shows the movement of the arm using solenoids.

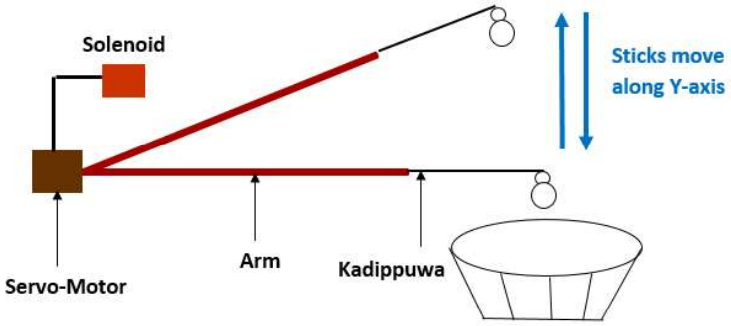


Fig. 6. Movement of the Arm using Solenoids

Fig. 7. shows the schematic diagram of the solenoid module.

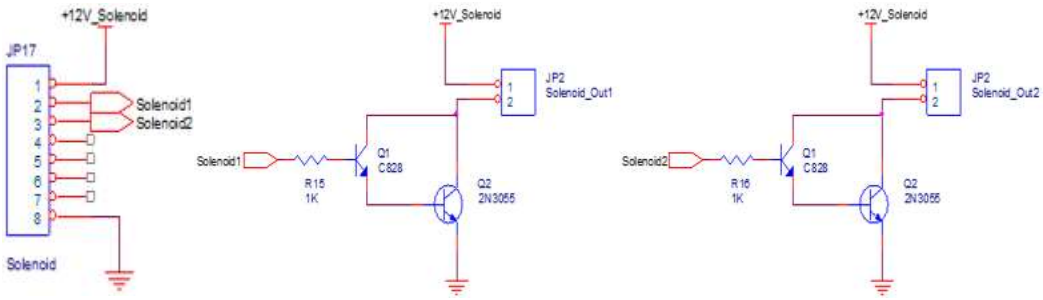


Fig. 7. Schematic diagram of the Solenoid Module

5.4 Servo-Motor Module

Servo Motor is a self-contained electrical device works according to the PWM (Pulse Width Modulation)

principle. This equipment is used to rotate the parts of a system with high efficiency with appropriate angles [19]. The developed automated robotic system has two servo-motors to rotate the arms along X-axis. One arm has one servo-motor, and it will be rotated with high efficiency to the correct positions of the drums to play drum beats correctly. Fig. 8. shows the movement of robotic arms with the use of servo-motors.

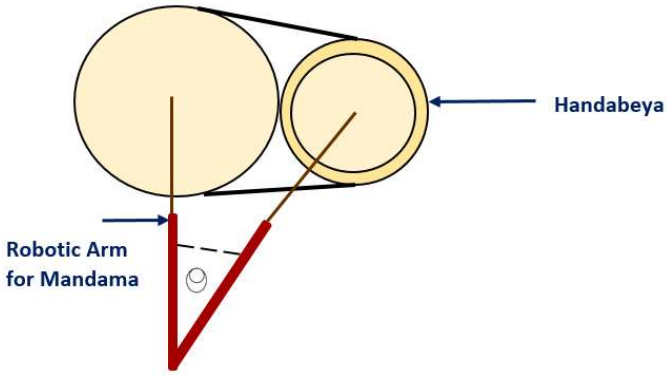


Fig. 8. Movement of arms using servo-motors

5.5 Switch Input Circuit Module

The automated robotic system is very easy to use and operate. A user can interact with this system using two switches. One switch is used to ON or OFF the system while another switch can be used to change the rhythm beats. When the user switches ON the system, the system automatically starts to play the first drum rhythm beat until the user switches OFF the system. Not only that but also, another switch can be used to change drum beats. Fig. 9. shows the schematic diagram of the system. Sw_Select has been assigned to selects drum rhythm beats while Sw_Run is used to ON or OFF the system.

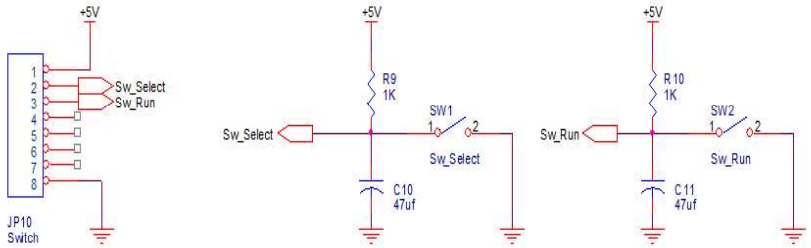


Fig. 9. Schematic Diagram of Switch-Input Circuit Module

5.6 LED Circuit Module

The system has been designed to play three different Thammattama rhythm beats that are commonly played at temples and on other Buddhist occasions. Each of these drum rhythm beats is represented with several coloured LEDs and can be adjusted using a switch named Sw_Select in switch-mode power supply module, depending on the user's convenience. Fig. 10. shows the schematic diagram of the LED circuit module.

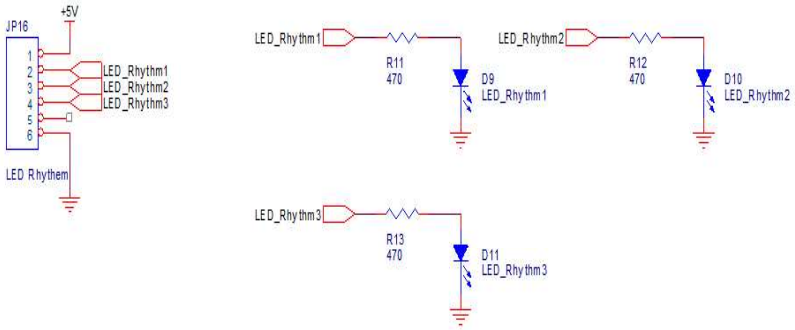


Fig. 10. Schematic Diagram of LED Circuit Module

Fig. 11. Shows the developed automated robotic system that plays standard drum rhythm beats that are played from Thammattama without the intervention of humans. This system has been designed to play two drum tunes. The first

tune can be used to produce the sound for the arrival of Buddhists priests to a bodhi pooja and pirith ceremony. The second tune is a very commonly used tune in many religious offerings in Buddhist's temples and also for "Hewisi Pooja". in The advantage of this system is, it could be replaced to play drum tunes instead of using a drum player for Thammattama. Moreover, this system may very useful to the places where drum players are very rare.

Fig. 11. Automated Robotic System

6 Testing and Evaluation

The developed automated robotic system has been successfully tested and evaluated in a laboratory environment using human evaluators. When considering the testing of this developed system, it was divided into two parts. At first, system was tested with use of five experts in the field of traditional drum music tradition in Sri Lanka. As such, they were given the opportunity to check the playing accuracy of each of these ten notes of the Thammattama without showing this system. Besides, they were also given the opportunity to score for the each sound. Table 2 shows the marks given by experts.

Person	Don	Thon	Kun	Kita	Kruu	Thari	Thath	Jen	Raj	Digi
01	4	5	4	5	3	4	4	5	4	4
02	5	4	4	5	3	5	3	5	4	5
03	4	4	3	4	2	4	4	4	4	4
04	3	4	4	4	2	4	3	4	3	3
05	5	3	3	5	3	4	5	4	4	3

1-Very Poor
2-Poor
3-Moderate
4-Good
5-Very Good

Table 2. Results Obtained from the Experts

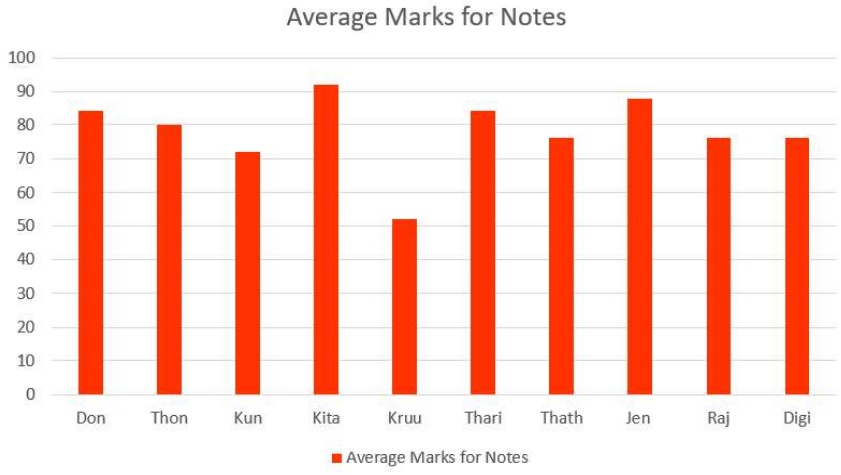


Fig. 12. Summary of Evaluation 01 Results

The testing 02 has been done with the use of 25 people. Accordingly, two components have been used to evaluate the system. A drum player for the Thammattama, and the developed automated robotic system have been used as the factors. Then, listeners were allowed to hear the same drum rhythm beats played by the drum player, and automated robotic system. There they were granted one censorship. That is, instead of allowing them to look at them, they are only allowed to listen. Not only that but also the testing has been done for two different drum rhythm tunes and allowed scoring for each tune. Fig. 13. shows a summary of the evaluation.

Drum Player	**Automated Robotic System**
5	3
5	3
4	3
5	4
5	3
5	2
4	2
4	3
4	3
5	4
5	4
5	3
4	3
4	3
5	3
5	3
5	4
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5	4
4	3
5	3
4	4
5	3
4	3

Table 3. Evaluation Results for Rhythm Tune 01

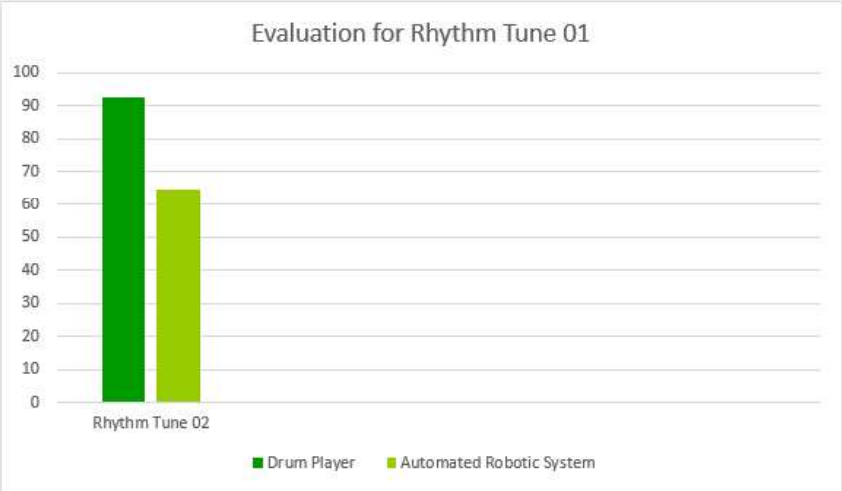

Fig. 13. Summary of the Evaluations Results for Rhythm Tune 01

Table 4. Evaluation Results for Rhythm Tune 02

Drum Player	Automated Robotic System
5	4
5	4
4	3
4	3
4	3
5	3
5	3
5	4
5	4
5	4
5	4
5	3
4	3
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5	3
5	4

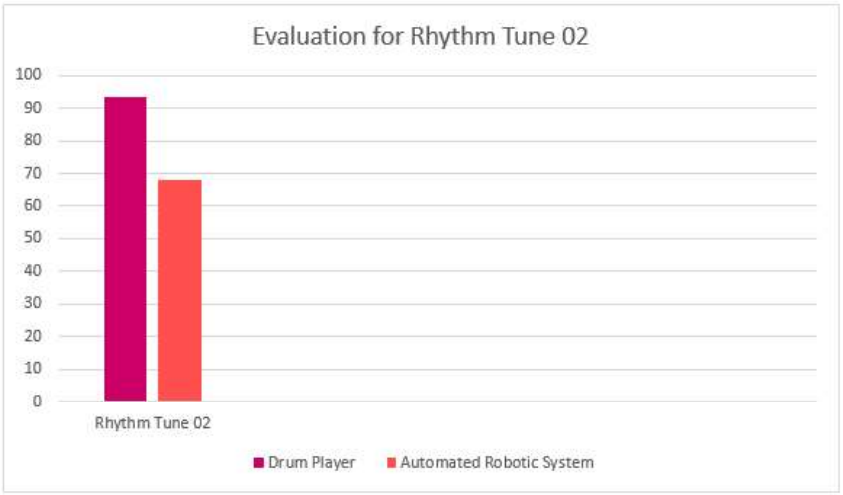

Fig. 14. Summary of the Evaluations Results for Rhythm Tune 02

7 Conclusion and Further Works

Sri Lanka has a very precious traditional drum music culture that has a very long history. However, this traditional culture faces a lot of problems due to a lack of traditional drum players. As a solution, people and religious people have to get used to recorded music. But this recorded music is not a successful alternative as it doesn't produce the real and the natural sound of the instrument. Accordingly, this culture can be kept going and protected with the use of robotic technology. This research was about an automated robotic system that was designed for the Thammattama which is one of the major four drums in Sri Lanka. This system is capable of playing standard drum rhythm beats that are playing using the Thammattama. In addition, this system can be replaced instead of using a drum player for the Thammattama. Besides, this system can be very useful for the places where drum players are rare and also to play drum tunes for a long time. The system has been successfully tested and evaluated in a laboratory environment and has obtained successful results. As further work, it is better to improve this system as a humanoid robot that will first listen to a particular drumbeat, detecting it, processing it and play.

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