International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 05 Issue: 04 | Apr-2018 www.irjet.net p-ISSN: 2395-0072

A Haptic Feedback System for Teaching Indian Music

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Abstract – *A glove system with haptic feedback was constructed to teach Indian music. The feedback was provided by small vibration motors attached to the fingers of a hand glove. A wearable Arduino controller with Bluetooth data link was used to drive the actuators. A main unit with another Arduino board was employed to send music data to the glove. It also interfaced with a LED matrix to provide visual cues for teaching key presses. Indian music has certain requirements for teaching not present in western music. The system proved useful in teaching users to play keyboard instruments like harmoniums.*

Key Words: **Haptic feedback, Wearable system, Indian music**

1. INTRODUCTION

A haptic feedback hand glove was constructed for the purpose of teaching to play Indian music, or any task requiring a fixed sequence of finger movements. It was theorized that repetitions of finger movements directed by the glove would lead the user to memorize easily their sequence and rhythm [1].

2. SYSTEM DESIGN

The system was designed around Arduino microcontroller boards with two separate units - a main unit attached to the instrument to be played and a glove unit fitted to the teaching glove. Since the glove unit falls under the category of a wearable system, it was important that it should not hamper the user's movements with dangling wires. So the two units were designed to wirelessly communicate over Bluetooth.

Since music files can be large, storage is provided by means of an SD card attached to the main unit. The main unit also drives a linear LED array to make available visual cues to the learner.

The glove unit is deliberately kept simple with output pins driving small vibrators attached to each finger of the glove. The main unit sends data over Bluetooth to the glove unit which responds by actuating the appropriate vibrator.

The system block diagram is given below:

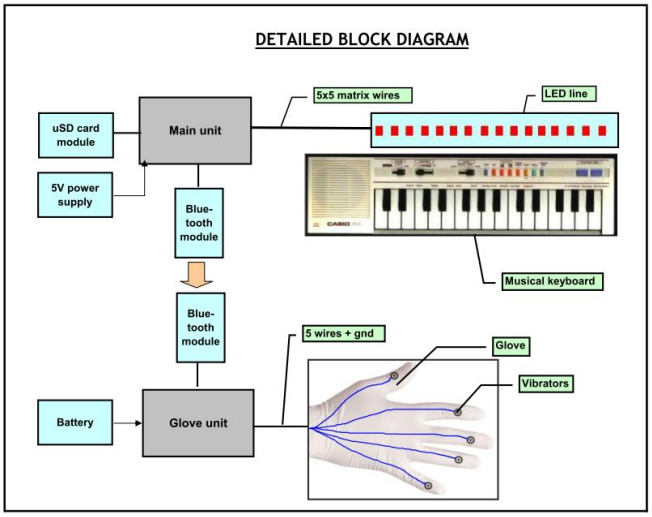

Fig. 1 Detailed system block diagram

The units are described in detail in what follows.

2.1 Main Unit

The main unit is the heart of the system. It is based on an Arduino Nano with built in USB connectivity [2]. Simplicity of programming, easy availability, access to a broad spectrum of libraries for almost any kind of hardware and a vibrant community [3] led to the adoption of the Arduino platform as the controller of choice.

A Bluetooth module HC-05 [4], an SD card breakout board [5], a buzzer for audio indication and a pushbutton are interfaced to the Arduino. The SD card stores music files locally without needing any connection to a PC.

Most importantly visual indication of the key where the user's fingers are to be directed is afforded by fitting a 25 LED strip to the instrument being taught, in this case an electronic keyboard. This strip was connected to the main unit by means of a ribbon cable. The LEDs form a 5x5 line matrix for easy drivability and saving of output lines of the microcontroller. It should be noted that the LED strip has to be customized for the particular keyboard used because of different key widths.

The Arduino with its 14 digital lines and 6 analog pins was almost fully utilized in the design. It is powered by a wall-wart type adapter with 5V output.

The schematics and the printed circuit boards for the main unit and the LED strip were designed in EAGLE PCB. The boards were made using the toner transfer method and later etched.

2.2 Glove Unit

The glove unit was also designed around an Arduino – the Pro Mini variant being used in this case to achieve possible power optimization. It is interfaced to 5 small electromagnetic vibrators – the kind used in cell phones – attached to each finger of the glove. A Bluetooth HC-05 breakout module forms the communication link. The whole unit was fitted in a plastic box glued to the glove.

The glove needs to be strong to sustain the weight of the electronics and the power source. But it also needs to be supple enough not to impede the learner's finger movement. After failed experimentation with latex and leather gloves, a woolen knitted glove was adopted. Its fingers were cut at the ends to let the learner's fingertips access the keys directly.

A major consideration in a wearable system such as this is the power supply. The power source has to be light enough to be carried on the body of the wearer, at the same time it has to have sufficient capacity to be able to run the system for as long as possible. After some consideration and assessment of the current draws, 4 normal AA size carbon-zinc batteries in series were selected for use. They are capable of running the unit for almost 15 hrs of continuous operation.

The printed circuit board of this unit was also designed with EAGLE PCB and etched in a H_2O_2 bath.

3. SOFTWARE

The Arduino IDE makes it quite easy to program any Arduino board. The bootloader incorporated into every Arduino further eases program loading and revisions. Both the main unit and the glove unit were programmed using the IDE.

Indian music differs from western music in some important aspects. First, there are no fixed note designations meaning that you can assign any key as the start of a *saptak*. Second, there is generally no chording i.e. simultaneous playing of notes one or half octave below the note to be played. This simplifies the system which can be monophonic, while western music would have required it to be polyphonic. Third, unlike western music which is played to a simple beat, Indian music is played to a specific repetitive cadence or *taal*, as it is called. The *taal* can have a quite complex sequence and its tempo can be speeded up *(drut)* or slowed down *(vilambiti)*. It was felt to that incorporation of all these factors into the system will make it very difficult to implement, at least initially. A solution was found by recovering the starting time of every note from the beginning of the song and using it to play the notes.

At the outset, it was decided that the main unit would carry the maximum processing load while the glove unit will have a very simple program. The main unit program has to carry out the following tasks:

1. Check if the SD card is present and if the song file can be opened
2. Read the song file from the SD card
3. Send the data from the file to the glove board over the Bluetooth link
4. Light the appropriate LED on the LED strip board

The microcontroller first checks the SD card, and then tries to open the song file. The song file is a comma delimited text file with a custom format giving note-by-note details of a song or note sequence to be learned. Each line of the file gives the musical note number (as specified in the industry-standard MIDI specification), note label (such as Sa,Re,Ga etc), absolute note start time (time to sound the note from the start of the song) and the finger code (specifying the finger to play the note). This file has to be generated from the notations of the song.

The looping routine reads the file line-by-line, to get the note playing data to fill a buffer. When the note starting time is reached, it retrieves the details from the buffer and then it sends the finger code to the glove unit to start vibration. Next it searches the note-to-LED mapping data to get the row number and column number of the correct LED. The last lit LED is extinguished and the current LED is lit. In this way the contents of the entire file are sequentially played with the vibrators on the glove indicating the finger to be used and the LEDs guiding the learner to the key to be pressed with that finger.

The glove unit has a very straightforward task only. It simply receives the finger code on the Bluetooth link from the main unit and starts vibration in the finger specified by it. The vibration is continued for a small time, sufficient to prompt the user to move the particular finger to the key on which the main unit has lit a LED.

4. TESTING AND EVALUATION

All the parts were made and assembled on printed circuit board. A photograph of the complete system appears below:

Fig. 2 Complete system with a keyboard

Testing of each functional unit was carried out followed by complete system testing with a simple note sequence. The system performed as expected. Clearly distinguishing the finger having vibration switched on was bit difficult at first. The round 5mm green LEDs employed for cueing also cause confusion, they need to be replaced with 2x5mm rectangular or SMD LEDs for better distinction between the music keys.

Song patterns were later loaded and their recall studied. The system proved helpful in teaching the user to play the keys.

5. CONCLUSION

The system is able to help in teaching keyboard instruments, though with some problems. Note and rhythm analysis would have to be strengthened to make the system more useful.

ACKNOWLEDGEMENT

Aabha Chaware wishes to thank to Dr. S. A. Ladhake, principal of Sipna's college of engineering and technology, for his valuable guidance.

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BIOGRAPHIES

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