

**ICON College of Technology and Management**

**Department of Information Technology, BCS Hons Computing**

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**Bachelor Dissertation and Final Project**

**Music Education and Entertainment System: A Digital Guitar Instrument Hardware with an Integrated Web Application**

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*A person playing a guitar

Description automatically generated with low confidence*

*"*I long for instruments ob*e*dient to my thought and which, with their contribution of a whole new world of unsuspected sounds, will lend themselves to the exigencies of my inner rhythm.*"*

*Edgard Varese, 1917*

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# 1. | Introduction

We, Earthly creatures, are very fortunate. Extremely few places in the vast vacuum-filled Universe have a suitable medium that supports audio signals to travel. However, here on Earth, sound vibrations can move through the atmosphere, providing information about our environment. As a result, mammalian evolution adapted to transform soundwaves into electrical signals, genetically engineering us to detect sounds. Hearing sounds increased our survival chances by identifying danger outside our visual zone and extending our communication channels.

Even though humans are not the only species communicating by creating sounds, we discovered a way of self-expression that conveyed a broader spectrum of emotional range beyond mere spoken words; music. And from as early as 40000 years ago, music has played an essential part in our everyday life. Our humans' innate musicality drove us to experiment with new ranges of sounds, inventing the primary types of instruments. Ideophones (clapping and bells), membranophones (drums), aerophones (flute), and most importantly, chordophones (harp).

Although the exact origin of the modern guitar is debated, the instrument is already mentioned in the Bible, and it can be traced back to the Greek kithara **κιθάρα** and Arabic qitharah **قيثارة** words. By the 17th century, it became popular among amateurs. With the advent of the jazz age, the electric guitar's success elevated its status to become the instrument of virtuosos and rock stars. However, this is not the final step on the guitar's evolution ladder. The modern digital era opened opportunities to combine the latest technology with musical skills. This project's goal is to bring digital technology, musical entertainment, and education under the same roof.

## 1.1 | Inspiration

I hold in my hand my old buddy, Gabriel's Guitar Hero. Again, I am ready for the next round; this time determined to overdo his performance. Little did I suspect that years of sketchy guitar practices on my side would not score against a seasoned hero like him. After several failed attempts to show off my talent, he concluded that even though I had guitar experience, rhythm sense, and some music theory in my pocket, my chances of winning against him were astronomical as a first-timer.

How about him, I asked myself, what type of guitarist would he make, with all those hours of playing the virtual guitar console? The answer came weeks later when he visited me, and I handed him my electric guitar and taught him the intro of a song I knew he liked. Soon enough, he could play a simple piece surprisingly well, though. So, I asked him.

- Why do you waste your time practising an imaginary instrument? You'd become a great guitarist by this time.

- You'll see me playing when they invent guitars for the console. – He answered with a smirk on his face.

Since then, I have been thinking about the wasted talent playing on five plastic buttons and a strum bar. If I could create a lightweight device that resembles an actual guitar, I would be able to develop an online interface that is free, available for everyone, vendor-independent, and educational. I am confident it would be at least as attractive an entertainment option as playing Guitar Hero. Well, the time has come to wipe off the smirk from Gabriel's face; he will be the first to play.

## 1.2. | Outlining the Aim and Objectives

To create a bespoke and successful entertainment or educational product, one must set themselves apart from the crowd and clarify the aim and objectives of the project in reflection of the existing market. Hence, before proceeding to any project specification, we must explore the current gaming and musical entertainment devices that might be relevant to our project. A brief precautionary research will prevent us from reinventing the wheel and will refine the project's outline more accurately.

### 1.2.1. | Existing Technologies

**Guitar Hero**

As this pop culture phenomenon was the initial inspiration behind the project's idea, it might as well serve as a perfect starting point. Harmonix Music System, the former owner of Guitar Hero, defined the project in its patent as "*a simulated musical instrument may be used to alter the audio of a video game*" (Eric*, 2008*). It was first released in 2005 and has seen several iterations since then. The product features five fret buttons, a strum bar, a whammy bar, and some additional control buttons relevant to Xbox's console interface. One of the main limitations of this console is the restricted number of fret buttons and the single strum bar, which prevents it from being used as an authentic educational device. However, the product shows several similarities to the project idea; therefore, some parts of it might be a perfect blueprint for our hardware prototype, such as its hollow, emptied plastic body.

**Diagram

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Figure 1| Guitar Hero Controller Layout (https://fccid.io/VFIBW95123805/User-Manual/Users-Manual-814804, 2022)

**MI Digital Guitar**

Numerous products have attempted to bring this acoustic instrument closer to the digital world; thus, our project is not a unique invention in this aspect. One of the most prominent technologically-enhanced instruments is the MI Digital Guitars from Magic Instruments, which is in a prototyping phase. MI will have an excellently smooth, modern design and will be a stand-alone instrument rather than an entertainment console because it can be run on an amplifier. Among the digital devices on the market, the MI's layout resembles the most to an actual guitar because of its fret design and built-in digital strings. Unfortunately, the device is only meant to teach rhythm and fundamental chord progressions and lacks features of finger-style playing or riffs. Although the instrument is not in the premium price category, it can cost as much as a decent acoustic or electronic instrument.



Figure 2 | MI Digital Guitar Series (https://www.digitalmusicnews.com/2016/08/01/mi-guitar-easy-to-learn, 2022)

**RockSmith**

A video game developed by Ubisoft brought music education to the next level. The game teaches acoustic, electric or bass guitar, adjusting its difficulty to the player. It utilises accurate, real-time play feedback and is currently one of the leading software technologies focusing on musical autodidactic training. However, RockSmith is exclusively a software solution, and the player must own a guitar that can be connected to the game through a real tone cable. Therefore, RockSmith can be considered a specialised training software rather than a video game. Some of its characteristics resemble the iconic Guitar Hero, such as the practice play or riffs, while others, like tuning and uploading the players' music, are unique features.

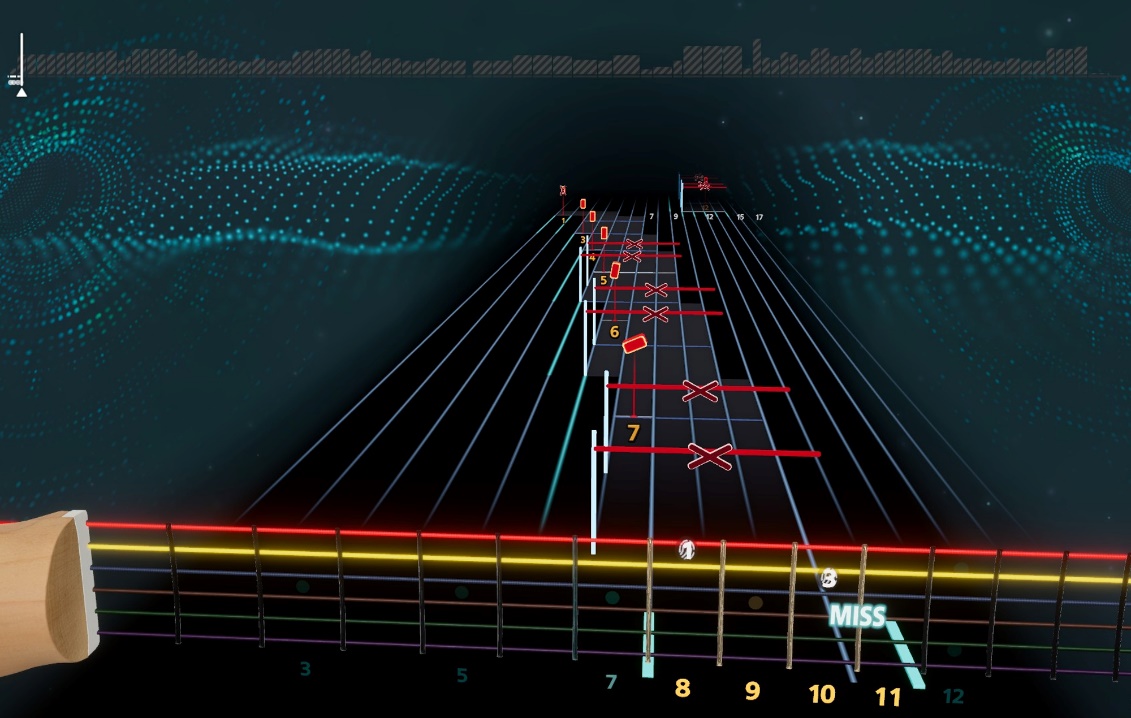


Figure 3 | RockSmith Screenshot

### 1.2.2. | Comparison

Even though the examples mentioned above are only a fraction of the myriad of applications and devices currently available on the market, we can see that they all serve different purposes and have a specific user target. And because the project will mainly focus on playfully learning guitar riffs, chords and songs, it will be referred to RiffMaster from this point forward. The following table concludes our findings and some further specifications.

Table

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Figure 4 | Technology Comparision

## 1.2.3. | Gap in Current Technologies

As we can see, the presented options have decent coverage of usability and functionality that a novice guitarist would require. But unfortunately, they are sparsely isolated throughout several projects and products with distinct merits and limitations. Ideally, these features should be consolidated into one comprehensive product.

Firstly, while Guitar Hero has outstanding gameplay, it lacks a realistic user experience because of its console layout. Similarly, MI Digital Guitar has an excellent practical and artistic design and a more natural interface but inaccurate fret distances. Unfortunately, it cannot play notes, only limited chords through approximate button presses. Therefore it is an artificially invented music system, not unlike Guitar Hero. Thirdly, while RockSmith offers an exceptionally realistic application that teaches fundamental music skills, the user has to buy a decent-quality instrument to be able to play.

Finally, all these systems are vendor-specific, proprietary or licenced. As a software developer, I want to be able to write applications around a digital guitar instrument free from licences or the concern of litigations. Additionally, this device should have specifications, protocols and documentation available for the software developer community.

## 1.3. | Project Aim and Objectives

**Aim**

RiffMaster aims to offer a comprehensive simulated music experience, providing a hardware component with a naturalistic guitar layout and software to learn and play the instrument. The console device should have a minimalistic design to be affordable to a broader range of players. Apart from the actual device, the users are not required to own or buy any software licence; therefore, the software application will be written for the browser. Users should be able to connect the device to any computer via a USB cable and enjoy the application using the internet. The software will support the requirements of learning the instrument from the basics, and users should be able to track their progress after creating an account.

**Objectives**

**Objective 1**: Create a digital guitar device with a realistic layout to simulate the instrument. The instrument's look, dimensions, and operability must be of a guitar, while the materials used may differ and be similar to a mock guitar. However, the guitar's neck and the frets' distances must translate to a real guitar's exact proportions to enhance the players' accuracy in muscle memory and help them gain an easily transferable skill.

**Objective 2**: Ideally, six strings, alternatively six strum bars, may be used to activate a note, and follow-up research and experimentations will be included in the document regarding the design decision. As guitars are polyphonic instruments, one or more strings must be able to play simultaneously. If string activity is detected, the device should communicate the uppermost active frets position on the respective lines. The activated note must be transmitted through a USB port using a well-defined, simple protocol. The hardware must be safe to use and in accordance with safety regulations.

**Objective 3**: Design and develop a software application that accepts and listens to user inputs from the USB port without interrupting keyboard events. Translate these inputs similarly to DOM key event states, such as note started, playing, and stopped. Optimise the application to accept and process simultaneous input information asynchronously.

**Objective 4**: Build a user-friendly frontend web application with a home page with sign-up and login options. Validate user login, and after successful sign-in, the following options should be available:

* **Jam Option**: the user can play the RiffMaster device and listen to the generated music,
* **Compose option**: the user can record the device, and the produced music is translated into tablature notation, which can be manually edited, saved, or deleted.
* **Practice Option**: the user can load a tablature, play along with a song, and practice at different speeds. Different sections of the music may be selected for repeated practice.
* **Play Option**: the user can play a piece of selected music. The application will score the performance according to accurate real-time feedback, considering the player's number of mistakes in note accuracy or rhythm precision.
* **Chords Explorer**: chords will be clickable throughout the application. When pausing a running session, the player may check chords.

Finally, create demo songs and tablatures to test the prototype.

**Objective 5**: Build a backend application that reflects a rudimental business model that will serve the web app. The backend should communicate to a database and store user information, such as user name, songs, tablatures and scores.

## 1.4. | Requirements

### 1.4.1 | User Requirements

### 1.4.2. | System Requirements

### 1.4.3. | Scope and Limitations

## 1.5. | Critical Review of Concept

### 1.5.1. | Feasibility

### 1.5.2. | Cost and Marketability and Target Users

### 1.5.3. | Patents and Litigations

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### 2.2.1. | System, Platform and Browser Compatibility

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## 3.5. | Tools

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## 3.5.2. | Software Technologies

# 4. | Design

## 4.1. | Hardware: Designing the Instrument

### 4.1.1. | Electric Wiring

### 4.1.2. | Microcontroller Programming

### 4.1.3. | Instrument Design Implementation

## 4.2. | Middleware

## 4.2.1. | Communication and Protocols

### 4.2.2. | Skeleton Prototype

## 4.3. | Software: Designing the Application

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#### 4.3.1.1. | Webdesign and Wireframes

#### 4.3.1.2. | Components

#### 4.3.1.3. | Visual Design Standards

### 4.3.2. | Backend

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#### 4.3.2.2. | Database

#### 4.3.2.3. | Restful Queries

# 5. | Development

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## 5.2. | Middleware: Communication

## 5.3. | Software: Developing the Web Application

### 5.3.1. | Frontend Development

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#### 5.3.1.2. | Reusable Functionalities

#### 5.3.1.3. | Gameplay

#### 5.3.1.4. | Composing

#### 5.3.1.5. | Additional Functionalities

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## 6.2. | Testing Hardware: Electronic Requirements

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## 6.8. | User Acceptance Testing

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## 7.1. | The End Product

## 7.2. | Fulfillment of the Objectives

## 7.3. | Critical Review and Opportunities for Future Improvements

## 7.4. | Conclusion

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# Appendices