Project Report On

Groov

Submitted in partial fulfillment of the requirements for the award of the degree of

Bachelor of Technology

in

Computer Science and Engineering

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CERTIFICATE

This is to certify that the project report/seminar report entitled ***Groov*** *is a bonafide record of the work done by* ***Aaditya Nair (U2103001)**,**Aathira K (U2103004)**,**Abhinand Santosh (U2103006)**,**Aldrin Lyju(U2103023)***, *submitted to the Rajagiri School of Engineering & Technology (RSET) (Autonomous) in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology (B. Tech.) in Computer Science and Engineering during the academic year 2024-2025.*

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Abstract

Traditional musical instruments are often bulky, expensive, and require dedicated space, which makes them less accessible for casual practice and everyday use. This project addresses these challenges by developing a portable and affordable virtual instrument set that allows users to play the Tabla, drums, and keyboard using simple hand gestures and taps on a flat surface. The system relies on sensors to detect these actions and generates corresponding sounds through a mobile app, eliminating the need for physical instruments and making music-making more accessible.

The device ensures consistent and clear sound output regardless of tap force, offering a reliable musical experience. It also includes recording and playback features, allowing users to capture and revisit their performances. To enhance interactivity, the system integrates haptic feedback through sensors, providing tactile responses that simulate the feel of real instruments without adding bulk. Mobile integration allows users to play sounds through headphones or phone speakers, offering flexibility in how the music is heard.

This project presents an innovative solution for musicians, hobbyists, and educators, providing an easy-to-use, portable platform for music practice and performance. By combining gesture detection, mobile technology, and haptic feedback, it offers a creative way to simulate traditional instruments without the constraints of physical equipment, making it an ideal tool for music enthusiasts on the go.

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Chapter 1

Introduction

1.1 Background

Traditional musical instruments often present challenges, such as requiring significant space, being costly, and necessitating consistent usage to justify their acquisition. Learning to play these instruments demands substantial investments of time, money, and energy, which can deter beginners or those on a tight budget. Additionally, the physical equipment needed for practice can discourage casual engagement and limit performance opportunities.

Recent advances in digital and mobile technologies have opened new avenues for music creation, enabling more individuals to engage with music without relying on traditional instruments. Virtual instruments and mobile applications offer simulations of musical experiences, though they often lack the tactile feedback and immersive interaction of real instruments.

The GROOV system aims to address these limitations by providing a portable, cost-effective solution. It allows users to play instruments such as the Tabla, Drums, and Keyboard using hand gestures on flat surfaces. By leveraging sensors and mobile technology, GROOV mimics the sound and feel of physical instruments. Additionally, it incorporates features like haptic feedback, recording, and playback to enhance usability and creativity. The primary goal of this research is to lower the barriers to music-making, making it accessible to individuals of all skill levels and backgrounds.

1.2 Problem Definition

Maintaining and purchasing traditional musical instruments can be financially burdensome, requiring significant investments of time and money. This often hinders musicians, particularly during live performances where switching instruments mid-performance can be cumbersome and disruptive. A more streamlined, affordable, and versatile solution is needed to overcome these obstacles.

1.3 Scope and Motivation

This device offers an innovative and accessible way for users to explore and create music without the need for expensive or bulky traditional instruments. Designed for simplicity, the system enables users to generate sounds of instruments like the Tabla, Drums, and Keyboard through intuitive gestures and taps.

The GROOV system eliminates the need for prior musical knowledge, making music creation enjoyable and interactive for users of all ages and skill levels. Features such as haptic feedback, recording, and playback encourage creativity and experimentation. By facilitating seamless switching between different instrument sounds, the device provides a flexible and engaging musical experience. It addresses common challenges such as steep learning curves, space constraints, and high costs, thus promoting widespread participation in musical activities.

1.4 Objectives

1. **Affordable Music Exploration-** Develop a cost-effective platform for beginners to explore and master various instruments without requiring substantial investments in traditional equipment.

2. **Compact Design-** Create a portable, user-friendly device for practicing, creating, and performing music at home, eliminating the need for bulky instruments.

3. **Seamless Instrument Switching-** Enable effortless transitions between instrument sounds, encouraging creativity and self-expression.

4. **Enhanced Learning Features-** Incorporate functionalities like haptic feedback, recording, and playback to improve the learning experience and foster skill development.

1.5 Challenges

Key challenges include achieving accurate gesture recognition and producing high-quality sound output. Developing an intuitive, user-friendly interface that appeals to both novices and experienced users is essential. Other obstacles include integrating effective haptic feedback, ensuring energy efficiency for portability, and balancing cost with functionality. Additionally, creating a seamless and stable mobile application is critical for enhancing the device's usability.

1.6 Assumptions

This project is based on several assumptions: 1. Users will find gesture-based interfaces intuitive and comfortable, even without prior musical training. 2. Sensors and technology will reliably translate hand movements into sound with minimal latency. 3. Mobile devices will possess the necessary processing capabilities and compatibility to interact seamlessly with the device for sound output and recording. 4. Users will value portability and affordability over the tactile experience provided by traditional instruments.

1.7 Societal / Industrial Relevance

The GROOV system has significant societal and industrial implications. By lowering the cost and complexity of music-making, it democratizes access to musical creation for individuals of all ages and skill levels. The device caters to casual users, hobbyists, and budding musicians, fostering creativity and skill development across diverse demographics.

From an industrial perspective, GROOV aligns with the growing convergence of technology and music. It leverages advancements in mobile applications, wearable technology, and smart devices to create innovative opportunities in entertainment, education, and tech industries. By integrating sensors, haptics, and connectivity, the system redefines how people interact with music, offering new possibilities for learning, performance, and creative expression.

1.8 Organization of the Report

The report is divided into five main chapters. Chapter 1, titled "Introduction," provides background, problem definition, scope, and motivation for the project. It also discusses the objectives, challenges, assumptions, and societal/industrial relevance. Chapter 2, "Literature Survey," reviews relevant literature and existing methods in areas such as Digital Musical Instruments (DMIs), MIDI, and haptic feedback, highlighting gaps in current research. Chapter 3, "System Design," describes the system architecture, component design, datasets, and work division for the project. Chapter 4, "Results and Discussion", presents the results of the project and analyzes the outcomes and finally Chapter 5, "Conclusion and Future Scope", which prvoides a detailed conclusion of the report and the future implementations for GROOV.

Chapter 2

Literature Survey

Technological advances have made a significant impact in the world of music, providing effective means of self-expression as well as interactive experience. This chapter reviews the literature on DMIs, gesture-controlled musical interfaces, haptics, music recognition, and intelligent music systems. The scope is to describe the state-of-the-art and the state of the challenges in the designated fields, which are relevant for the further progress of Groov.

2.1 Introduction to Digital Musical Instruments (DMIs)

DMI can, with tolerance, be said to have been invented at the verge of a drift where music meets technology: for the creator, it is a means of extending their sound capabilities beyond what acoustic instruments can do. User input is processed using sensors, software, and algorithms to produce the sound[1].

2.1.1 Evolution of DMIs

DMIs can be traced back to the electronic instruments of the previous century, such as the Theremin and Moog synthesizer, that went on to define today's electronic music.

2.1.2 The Origin of DMIs

The story of DMIs begins in the 20th century with instruments like the Theremin, which emerged in 1920. These were built to be played using no physical contact-eschewing normal touch control of pitch and volume. Yet another instrument was the ondes Martenot-the 1928 example comprised a keyboard combined with ribbon control for modulating sound such that expressiveness became an inevitable feature[2].

2.1.3 Rise of Synthesizers

The Moog synthesizer of the 1960s was first to introduce, among other instruments, voltage-controlled oscillators and filters, upon which electronic music would be made, with, for example, Wendy Carlos producing Switched-On Bach and bands such as Kraftwerk using it as a basis of new sounds.

2.1.4 Introduction of MIDI

MIDI, or Musical Instrument Digital Interface, was established in 1983. It revolutionized music production because it allowed electronic instruments and computers to communicate seamlessly. MIDI allowed musicians to control multiple devices simultaneously and allowed for infinite flexibility during the sequencing and automation of live performances and home studios.

2.1.5 Contemporary Trends of DMIs

In the 21st century, Digital Musical Instruments (DMIs) have significantly evolved by integrating advancements in machine learning, gesture recognition, and haptic feedback, thereby enhancing musical expression and interaction. Machine learning algorithms have enabled DMIs to learn and adapt to performers' gestures, allowing for more personalized and responsive musical experiences. Gesture recognition technologies have advanced to accurately interpret complex human movements, facilitating intuitive control over musical parameters. Additionally, the incorporation of haptic feedback has provided tactile sensations that mimic the feel of traditional instruments, offering musicians a more immersive and expressive performance environment. These contemporary trends collectively contribute to the development of DMIs that are more interactive, expressive, and aligned with the nuanced needs of modern musicians.

2.1.6 Machine Learning in DMIs

Today, DMIs utilize machine learning capabilities to generate adaptable soundscapes. GANs and RNNs are some examples of the type of neural networks that contribute to dynamic music created for user input dependency. A gesture recognition system based on deep learning can recognize hand movements, so the virtual instrument can be operated intuitively.

2.1.7 Gesture-Based Controllers

Some of these devices, for instance the Myo armband, include an electromyography (EMG) sensor that tracks muscle movement and allows users to manipulate sound parameters with gestures. These controllers allow more expressiveness with digital musical instruments, as physical movements become expressions of music.

2.1.8 Haptic Feedback in DMIs

It can be very hard to reproduce in DMIs the tactile feedback inherent in the conventional instruments. It is possible that haptic feedback can reproduce key-striking and string-plucking or even hitting a drum sound..

2.1.9 Types of Haptic Feedback

- **Vibration Feedback:**Utilizes the use of motors to replicate how it feels playing on an instrument.
- **Force Feedback:** Makes things resist, hence replicating a key or a string pressure.
- **Electrotactile Feedback:** It delivers electrical impulses to replicate touch sensations.

The **Groov Glove** enhances user experience by integrating vibration motors to provide feedback for actions like playing drums or piano, making the digital experience more immersive.

2.1.10 Emerging Trends in DMIs

Advancements in Digital Musical Instruments (DMIs) have significantly broadened their applications beyond traditional performance, notably impacting therapy and education. In music therapy, technologies like motion-tracking digital instruments have been developed to assist individuals with motor disabilities, enabling them to engage in musical activities and facilitating rehabilitation processes. Similarly, in educational settings, digital tools such as interactive apps and virtual classrooms have transformed music learning, making it more accessible and engaging for students of varying abilities. These innovations underscore the evolving role of DMIs in fostering inclusive and effective approaches to music performance, therapy, and education.

2.1.11 Augmented Reality (AR) and Virtual Reality (VR)

An immersive music performance, in which the audience may interact with virtual instruments, has been brought into existence with the application of AR and VR. This technology is transforming live shows and interactive installations.

2.1.12 AI in Music Therapy and Education

AI-driven DMIs find application in music therapy to create adaptive soundscape insituations that change according to the emotional state of the user. In education, these can be applied to give personalized feedback to the student for enhanced learning.

2.1.13 Open-Source and Modular Synthesizers

With modular synthesizers and open-source platforms like Pure Data and SuperCollider, musicians are now building instruments of their own, fostering an environment of experimentation.

2.2 Future Directions

Through these, great changes have occurred in the manner in which the musicians relate with the technology. There is a lot still that has to be done and great room for improvement in this area. Much of the real world work in this area will however be on the realism, responsiveness and DMIs accessibility. This section details the possible development in AI, haptics, and immersion technologies that would define the future of digital music interfaces[3].

2.2.1 Advancements in Haptic Feedback Mechanisms

One of the important challenges in creating DMIs would be low latency, realistic feel, and tactile rendering, which means that the feel will be as close as possible to reproducing the feelings of playing real music instruments. Vibrating motors and other force feedback allow for some minimalistic tactile expression but are so far from adequately simulating detailed touch and sensitive pressure, in particular for great musicians.

2.2.2 Development of Next-Generation Haptics

It can be anticipated that these advanced haptic technologies will be studied in the future as well: • Ultrasonic Haptics: Using ultrasonic waves to feel touch-for example perfecting the mid-air contact with a virtual instrument without touching it. This could open a whole different scheme:

- **Ultrasonic Haptics:** Through the application of ultrasonic waves, touch can be simulated. For example, perfecting the use of a virtual tool in space can eliminate the need for touch. This may give rise to an entirely new scheme within DMIs: a tactile contact concept with the Musician-author over the air.
- **Soft Actuators:** With the use of flexible materials that mimic the feel of an instrument's surface, who can say that these materials don't improve the comfort and feel of a glove and sleeve wearable separately or together.
- **Neuro-Haptics:**Neural interfaces can facilitate the stimulation of the tactile perception centers within the brain directly to give a deeper feeling of immersion in haptic feedback. This allows for the possibility that even musicians dealing with a virtual instrument may be able to feel a sense of touch.

2.2.3 Integration of Artificial Intelligence and Machine Learning

Artificial intelligence will be crucially influencing the progress of DMIs. The means for such is through machine learning algorithms that analyze the gestures, style of playing, and preferences of the performer, thereby helping them in real-time by mapping the instrument's response to the creative process.

2.2.4 Personalized Adaptive Learning

Future digital musical instruments could use AI to provide personalized feedback to musicians to hone their techniques and learn new styles. Analyzing the patterns that emerge through the user's playing, AI could suggest ways of playing, highlight mistakes, or even create complementary melodies and harmonies. This could be their biggest boon in educational settings, where DMIs can act as virtual music tutors.

2.2.5 Predictive Gesture Recognition

AI-powered gesture recognition will allow DMIs to predict and respond to a musician's movements, reducing latency and improving the fluidity of musical expression. Future systems based on deep learning modeling, such as Convolutional Neural Networks and Long Short-Term Memory networks, can make a more sophisticated interpretation of gestures and anticipate the subsequent action of the musician to bring the playing experience more seamlessly.

2.2.6 Augmented Reality (AR) and Virtual Reality (VR) for Immersive Experiences

The convergence of AR and VR with DMIs allows for captivating musical experiences to be created. Such hybrid technologies facilitate and change the performance, composition, and engagement by musicians in their craft with audiences..

2.2.7 Virtual Music Studios and Live Performances

Augmented and Virtual Reality will empower musicians to design virtual studios in which sound objects can be arranged and manipulated in 3D space. This could provide for more intuitive composing in which spatial arrangements inform the final sound output. In a live context, VR could enhance audience engagement by providing a user with the experience of listening to music in an interactive, 360-degree environment.

2.2.8 Collaborative Music Creation in Virtual Spaces

An even wider outlook on the future of DMIs could encompass collaborative platforms, where musicians jam with each other in real-time within a shared virtual space, regardless of physical distance. Completely immersive, musicians could interact with each other's virtual instruments via VR headsets and haptic feedback and work as one beyond the limits of physical boundary.

2.2.9 Expanding Accessibility and Inclusivity

Exiting as they present new opportunities for musicians, DMIs must be made available to as many people as possible, especially realizing that the disabled users comprise a considerable part of a far larger user community.

2.2.10 Designing for Musicians with Disabilities

In the future, DMIs would formulate functional design-based models that will help musicians with limited movement or eyesight engage in music composition. For instance, a gesture-based interface could be developed to accommodate subtle head or eye rotation or movement so that someone not able to use the hands very well could still play an instrument on a screen.

2.2.11 Low-Cost, Open-Source Solutions

Bringing the DMIs closer to accessibility in many rural places with larger virtual society, works are ongoing to generate low-cost open-source platforms using general components such as smartphones, and microcontrollers like Arduino. These will potentially empower hobbyists, students, and independent musicians to craft their one-off instruments to catalyze innovation and creativity.

2.2.12 Improving Latency and System Efficiency

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2.2.14 Edge Computing and AI Acceleration

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2.3 Conclusion

The future of DMIs is exciting because of the advancements in AI and haptics and immersive technologies. In fact, by addressing the issues of latency, tactile feedback, and accessibility, it can make music creation intuitive, expressive, and inclusive in ways no one has yet dreamed of. These technologies will augment the creative process, redistribute how music is learned, performed, and experienced, and create new opportunities for musicians and fans alike[4].

2.4 Gesture-Based Music Interfaces

Gesture-based interfaces for music have changed the way musicians interact with digital music systems. The interfaces utilize sensors to sense body movements, thereby allowing the control of sound parameters from a distance[2].

2.4.1 Wearable Devices for Gesture Recognition

Wearable devices that are known for such a task include data gloves, smart wristbands, and motion, gesture, and/or position sensors. During the last two decades, Inertial Measurement Unit (IMUs) and accelerometer and gyroscope-based tablets have detected the changes in orientation and motion and enabled gestures to be translated into musical expressions.

For instance, the Groov system uses an IMU-fitted glove for hand gesture recognition. Machine learning algorithms like CNNs are also used to achieve high accuracy for gesture classification. The system will be able to distinguish between gestures that represent the playing of a violin, drum, or piano[3].

2.4.2 Comparative Analysis of Gesture-Based Systems

Table 2.1: Comparison of Gesture-Based Music Interfaces

System	**Advantages**	**Disadvantages**
Leap Motion	Contactless control; High precision	No haptic feedback; Sensitive to lighting
Kinect	Full-body tracking; Low latency	Bulky hardware; Limited gesture accuracy
Groov Glove	Real-time feedback; Haptic response	Requires training for gestures; Power-intensive

Table 2.1 provides a comparative analysis of three gesture-based music interfaces: Leap Motion, Kinect, and Groov Glove. Leap Motion offers contactless control with high precision but lacks haptic feedback and is sensitive to lighting conditions, which can affect performance in varying environments. Kinect enables full-body tracking with low latency; however, its bulky hardware and limited gesture accuracy may hinder portability and precise control. Groov Glove provides real-time feedback with haptic response, enhancing the tactile experience, but requires users to undergo training for effective gesture use and is relatively power-intensive, potentially affecting prolonged usage. Each system presents unique advantages and challenges, and the choice among them should be guided by the specific requirements of the intended musical application.

2.5 Haptic Feedback in Music Devices

Haptic feedback is a powerful tool in the domain of Digital Musical Instruments (DMIs), giving the user a sense of the digital music experience as if it were played on real, hands-on instruments. Tied with sensory experience like that found on traditional instruments, musicians are enabled to explore their digital counterparts in very rich and instinctive ways. This chapter discusses what haptic feedback does in music devices, its applications, challenges, and how it's advancing into the future[4].

2.5.1 Importance of Haptic Feedback in Musical Interaction

The tactile role given by an instrument through their resistance, in piano keys or the sensation produced when they collide with something, is key in the interactions between a musician and the medium of music being created. There are dynamics associated with feedback with expressiveness within performance. The lack of feedback in an instrument in any digital music-based system often relates a musician to its instrument dynamically rather than losing on expression.

Haptic feedback addresses this gap through technologies that provide the musician with the experiences of traditional instrument-based tactile sensations. The haptic-enabled DMIs offer an authentic playing experience to the musicians using force feedback, vibration, or even pressure sensitivity, making it relatively easy for musicians to shift from digital to acoustic instruments.

2.5.2 Applications of Haptic Feedback in DMIs

Haptic feedback is most lentient for those most dependent on touch sensitivity and dynamics that is:

- **Digital Pianos and Keyboards:** Using haptic feedback to make digital pianos able to reproduce the resistance and hammer action of acoustic pianos will enable musicians to perform with finer gradations of volume and tone, closely mimicking the feel of a traditional piano.

- **Electronic Drums:**For drummers, the feel and rebound of drumsticks is a definite essential. Haptic feedback can recreate sensations like striking different drum surfaces, such as snares or cymbals, thereby increasing the realism in perceived

- **Wearable Devices:** Haptic gloves or wristbands with housed sensors could provide tactile feedback on playing virtual instruments. Especially in air-instrument types, this can be an incredible aid in performing, as the musicians could play their instruments without really touching anything while still feeling responsive feedback.

2.5.3 Types of Haptic Technologies Used

The DMI employs these and other haptic modalities in the generation of realistic tactile sensations:

- **Vibration Motors:** Small motors giving a tactile vibration which can simulate the sensation of touch or impact. They are frequently used in music wearables and digital drum kits for providing instant feedback to the musician.
- **Force Feedback Mechanisms:**Force feedback systems provide the tactile sensation which simulates resistance in physical keys or strings by providing varying levels of resistance by actuators. Therefore, force feedback makes digital instruments more realistic.
- **Electrostatic and Ultrasonic Feedback:**Electrostatic haptics create friction-These based sensations are provided through electrical charges, and ultrasonic waves give tactile feedback in mid-air so that one can interact without touch with virtual instruments.

2.5.4 Challenges in Implementing Haptic Feedback

In spite of their promise, however, this also poses an enormous challenge for effective haptic feedback in DMIs:

- **Latency Issues:** The reason is that low latency in feedback is important as even the smallest delay can break a musician's groove and timing. Processing delays are, in fact, one of the major failures of current systems, especially for wireless systems.
- **Realism and Precision:**Recreating the proper tactile feedback cues of traditional instruments is an art in itself-a tough nut to crack. For that matter, simulating the variation of touch on a violin string compared to that of a piano key requires some very profound underlying algorithms and precise actuation.
- **Ergonomics and Comfort:**A wearable haptic device, a glove, or a wristband must be light enough to bear on for hours on end and to not hamper the musician's normal movements; this presents a major design challenge.

2.5.5 Future Directions for Haptic Feedback in DMIs

Some of the further advances on the horizon for haptic feedback in music devices include:

- **Advanced Materials and Soft Robotics:**The flexible, adaptive materials that can be used in haptic devices provide further improvements in comfort as well as closer ways to modes of expression than traditional instruments.

- **Neural Interfaces:** This research on BCI is not intended to bypass traditional systems of sending sensations through the nervous system, but it's to touch people firsthand, instantaneously so that feedback might travel almost instantaneously.

- **AI-Driven Adaptation:** Ultimately, using machine learning, such systems could be individualized to mirror a musician's playing style for the delivery of customized feedback regarding improved technique and expression.

2.5.6 Conclusion

Haptic feedback would give the musicians a method through which to touch and explore the digital instrument so that their playing would become much more intuitive and natural with respect to feel and expression. With these new technologies and everything else they can offer, we are confident that the DMIs could potentially provide experience, both realistic, responsive, and fully immersed, whereby the musician could then utilize the discrepancy between the physical and digital definitions of music production.

2.5.7 Types of Haptic Feedback Mechanisms

- **Vibration Feedback:**Each motor simulates physical sensations-such as drumming hits or plucking guitar strings-that would play across its surface.

- **Force Feedback:**Sets resistance, providing an impression of pressing keys or plucking strings to make it more touch-and-go.

- **Electrotactile Feedback:** Enacts electrical impulses that create the sense of touch, although yes, in the absence of any physical components.

2.5.8 Integration in Groov

Groov's glove uses built-in vibration motors to instantaneously translate the users' actions into feedback during simulations of instruments. The strength with which the feedback is generated is determined in relation to the user, creating a whole newgear of realistic effects.

2.6 Research Gaps and Future Directions

The literature review reveals several gaps:

- Few include haptic feedback on their gesture-based systems.
- The cost and complexity of wearable haptic devices is quite high.
- An attempt to focus on song recognition without deeper analysis of musical composition.
- No personalization in gesture recognition systems.

Future research should focus on the development of low-cost, lightweight devices that integrate haptic feedback and AI-audio analysis to provide an immersive experience for musicians.

2.7 Conclusion

This chapter presented a summary of literature related to DMIs, gesture recognition, haptic feedback, and audio analysis technologies. Groov is also aware of the lack and plans to integrate gesture-based control with real-time haptic feedback and better song recognition capabilities.

Chapter 3

System Design

This chapter includes overall framework and detailed structural design of the project. Work division and timeline of the project are also detailed.

3.1 System Architecture

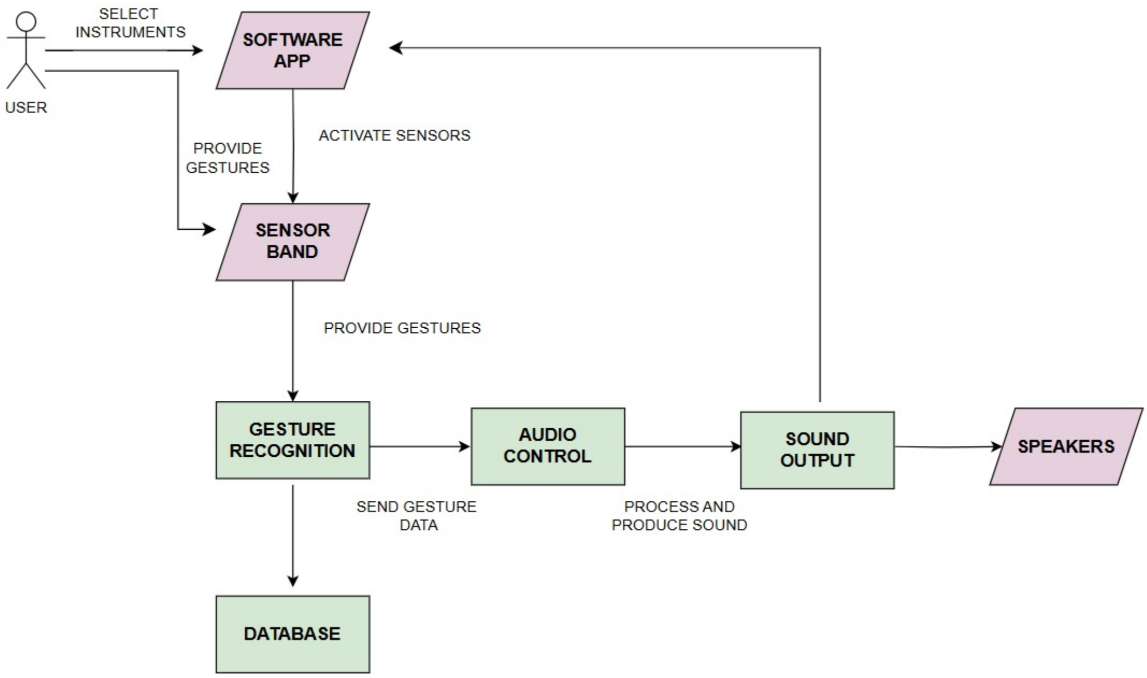


Figure 3.1: System Architecture diagram.

3.2 Component Design

3.2.1 Microcontroller

The Seeed Studio XIAO nRF52840 Sense incorporates the Nordic nRF52840 chip with FPU, operating up to 64 MHz, mounting multiple development ports, carrying Bluetooth 5.0 wireless capability and can operate with low power consumption. It also incorporates multiple built-in sensors like IMUs[1].

nRF52840 MCU

This is the main central processing unit of the board. It is a 32-bit ARM Cortex-M4 processor running at 64MHz. It provides the processing power needed to run complex algorithms and sensor data. It also includes bluetooth 5.0 integrated into it for communication and connectivity.

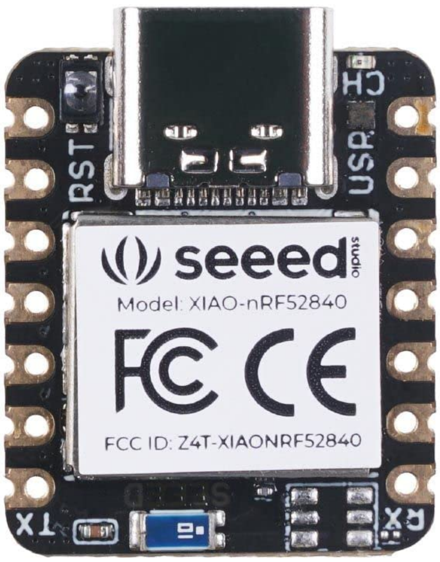


Figure 3.2: Peripersonal space in the front, rear, left and right directions for audio-tactile multisensory integration.

LSM6DS3TR-C IMU

The LSM6DS3TR-C is a system-in-package featuring a 3D digital accelerometer and a 3D digital gyroscope performing at 0.90 mA in high-performance mode and enabling always on low-power features for an optimal motion experience for the consumer.[2][3]

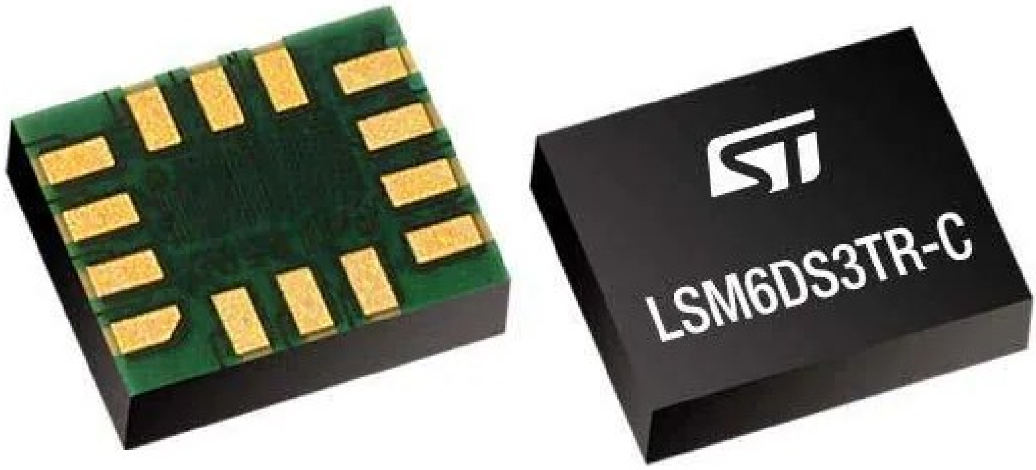


Figure 3.3: LSM6DS3TR-C IMU

3.2.2 Force resistive sensor RP-C10-LT

The Force Sensitive Resistor RP-C10-LT (20g-3kg) is a specialized sensor designed to detect and measure varying levels of force applied to its surface. Featuring a wide range of sensitivity from 20 grams to 3 kilograms, this sensor is particularly versatile in applications where precise force measurement is required[4].

3.3 Algorithm Design

1. Initialize.
2. Set up fingertip sensors, microphone, and audio output.
3. Map gestures to instrument actions (piano notes, violin bowing, drum hits).
4. Enable instrument switching and store the selected mode.identification and analysis of objects

Figure 3.4: Force Resistive Sensor RP-C10-LT

5. Main loop, Continuously read sensor input for gestures (tap, swipe, hold).
6. Detect instrument-switching gestures and update the mode.
7. Map gestures to sounds based on the active instrument.
8. Capture humming via the mic, analyze pitch, and suggest or match instruments.
9. Output the corresponding sound.

3.4 Use Case Diagram

3.5 Hardware and Software Requirements

3.5.1 Hardware requirements

Seeed studio xiao nrf52840 sense microcontroller

Power Supply: Lithium-Ion Battery

Sensors: Accelerometer, Gyroscope, Magnetometer

Wireless module: Bluetooth

Glove: 3D modeled enclosure

Jumper Wire

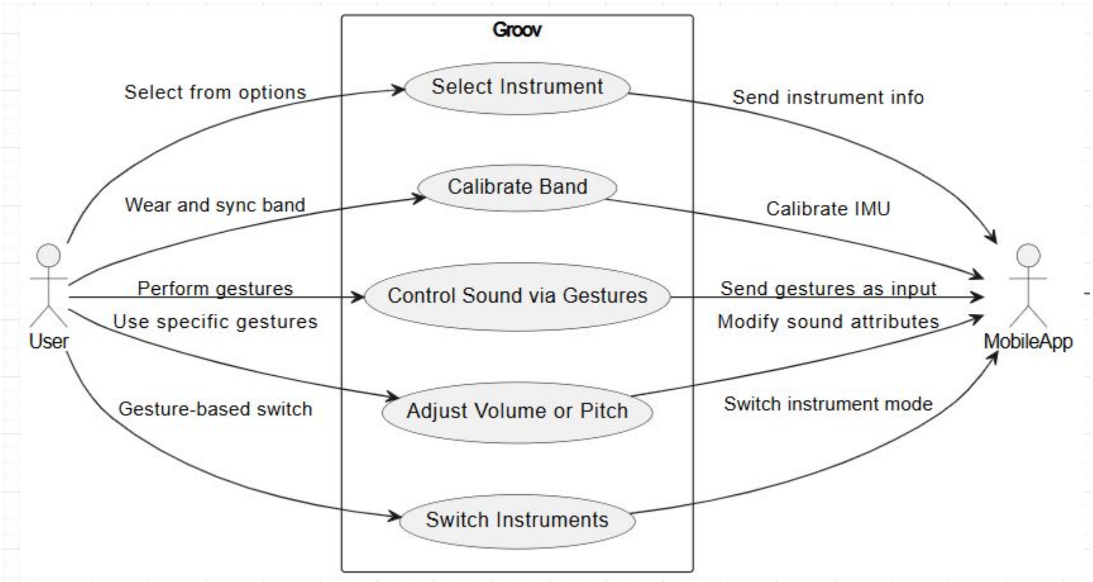


Figure 3.5: Force Resistive Sensor RP-C10-LT

3.5.2 Software requirements

Flutter

Arduino IDE

Python

3.6 Work Division

All four team members contributed equally to the project. Each member had an equal share of responsibilities and tasks, ensuring that the workload was evenly distributed among the team. This collaborative approach helped maintain balance and fairness, fostering teamwork and accountability. The team members worked not only on designing and developing their respective modules, but also on testing the model's accuracy, creating documentation, reports, presentations, etc.

3.7 Expected Outputs

The expected output is a fully functional IOT based device that provides Instrument Simulation allowing users to play multiple instruments (drums, violin, piano) using natural

Table 3.1: Assignment of Modules to Team Members.

Sl. no.	Team Member	Assigned Module
1	Aaditya Nair	Evaluation and result presentation
2	Aathira K	Model training and validation
3	Abhinand Santosh	Documentation and presentation
4	Aldrin Lyju	Dataset management and preprocessing
5	All members	Component integration and design of the device

hand gestures with real-time sound feedback with Accurate Gesture Recognition that ensures high precision in tracking gestures for realistic and responsive sound generation and also to provide a Mobile App Integration that allows wireless control via a user-friendly app for instrument selection and settings adjustment. The main goal is to provide an intuitive and user-friendly platform that allows users to learn music in a concise, interactive, and imperceptible way.

3.8 Project Timeline

The project timeline is represented by the Gantt chart below:

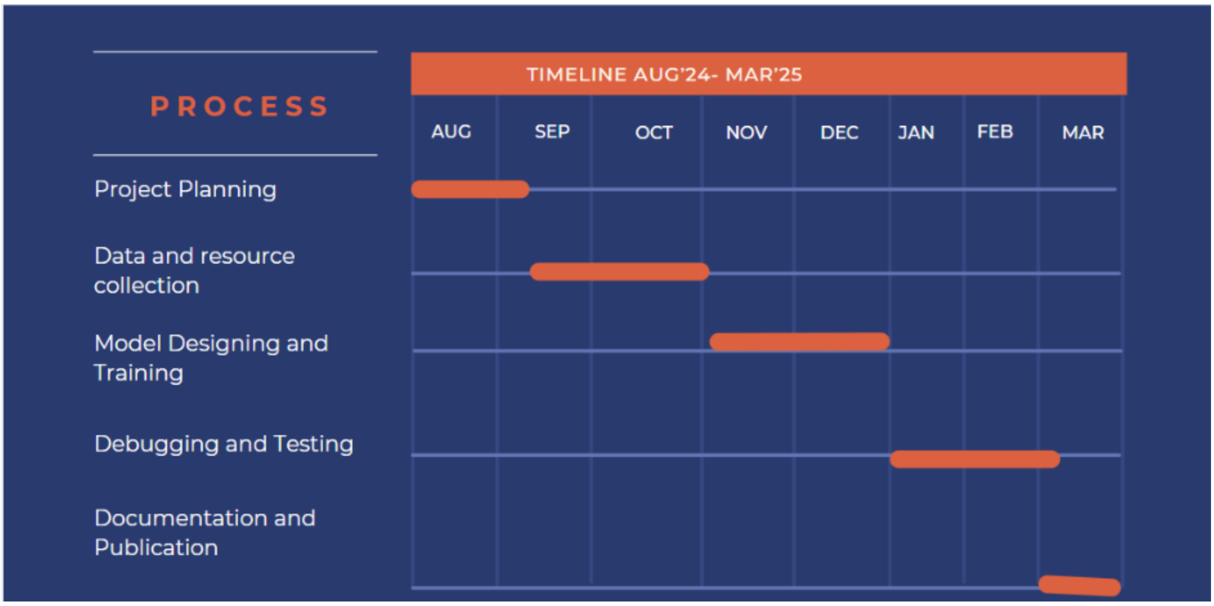


Figure 3.6: Gantt Chart.

3.9 Summary

This chapter encompasses the System Architecture of our project. It includes the Algorithm used, datasets included, Software and Hardware specifications, work division and the expected output of the project.

Chapter 4

Results and Discussion

4.1 Introduction

This chapter presents the results of the project and analyzes the outcomes. It includes a performance evaluation and highlights the main findings. The chapter also discusses the significance of these results in relation to the project's goals.

4.2 Quantitative results

The Quantitative results of the Gesture Detection Module, Sound Generation Module and Wireless Communication Module are as follows:

4.2.1 Gesture detection Module

The Gesture Detection Module is designed to accurately capture and interpret users' hand movements and taps on flat surfaces, enabling the simulation of various musical instruments. This module integrates Inertial Measurement Units (IMUs), which are compact sensors combining accelerometers and gyroscopes to monitor both linear and rotational motions. Accelerometers measure linear acceleration, effectively capturing movements such as up/down or left/right gestures, while gyroscopes detect angular velocity, allowing the system to recognize rotational gestures like wrist twists or circular motions.

To ensure precise gesture recognition, the system employs sensor fusion techniques that combine data from both accelerometers and gyroscopes within the IMUs. This approach enhances the accuracy of motion tracking by mitigating individual sensor limitations, such as drift in gyroscopes and noise in accelerometers.

Extensive testing involved users performing predefined gestures corresponding to different musical instruments namely Drums, Piano and Violin. The system demonstrated high accuracy in recognizing these gestures, effectively differentiating between subtle variations in movement. This precision ensures that each gesture is consistently mapped to the correct musical note or instrument sound, providing an intuitive and responsive user experience.

Few of the primary challenges encountered was minimizing the latency between gesture input and system response. High latency can disrupt the synchronization between the user's actions and the generated musical output, leading to a disjointed experience. To address this, data processing algorithms like Kalman Filters were used to enhance computational efficiency, resulting in a reduction of latency to imperceptible levels. Furthermore, addressing sensor drift and noise was crucial for maintaining long-term accuracy. Regular calibration routines were implemented, allowing the system to recalibrate sensors periodically and correct any deviations.

n summary, the integration of IMUs within the Gesture Detection Module has resulted in a robust and accurate system capable of translating nuanced hand gestures into corresponding musical outputs. This technology not only broadens access to musical exploration but also offers a versatile platform for various applications in human-computer interaction.

4.2.2 Sound Generation Module

The Sound Generation Module is responsible for converting user gestures into authentic musical instrument sounds, providing an immersive and responsive playing experience. This module utilizes a combination of high-fidelity sampled audio and advanced sound synthesis techniques to accurately emulate the timbres and articulations of various instruments.

High-quality recordings of real instruments, such as the Violin, Drums, and piano, serve as the foundation for the module's sound library. These samples are meticulously captured across different dynamic levels and articulations to ensure a realistic reproduction of each instrument's sonic characteristics. When a user performs a gesture corresponding to a specific instrument, the system triggers the appropriate sample, matching the gesture's intensity and nuance to the corresponding dynamic layer in the sample library.

To maintain synchronization between user gestures and audio output, the module incorporates real-time audio processing algorithms. Low-latency processing ensures that sounds are produced instantaneously in response to gestures, preserving the natural feel of playing a physical instrument. Additionally, dynamic effects such as reverb and delay are applied to enrich the sound and provide a more immersive experience.

In summary, the Sound Generation Module combines high-quality sampled audio with real-time processing to deliver authentic and responsive musical instrument sounds. Through careful optimization and adaptive processing, the module provides users with a realistic and immersive musical experience.

4.2.3 Wireless Communication Module

The Wireless Communication Module is integral to the GROOV system, facilitating seamless data transmission between the gesture detection hardware and the mobile application. This module employs Bluetooth Low Energy (BLE) technology, chosen for its low power consumption and efficient short-range communication capabilities. BLE is particularly suited for applications requiring minimal energy usage while maintaining reliable connectivity.

In the GROOV system, the BLE module operates with optimized connection parameters to achieve low latency and high responsiveness. The connection interval, which dictates how frequently data packets are exchanged, is set to a minimum of 7.5 milliseconds—the lowest allowable by the BLE specification . This configuration ensures that the system can promptly relay gesture data from the detection hardware to the mobile application, resulting in immediate auditory feedback.

One of the challenges faced was Power consumption, given the need for the GROOV system to be portable and have a long battery life. While reducing the connection interval improves latency, it can increase power consumption. To balance this, the system utilizes the peripheral latency feature of BLE, allowing the peripheral device (gesture detection hardware) to skip a predetermined number of connection events, thus conserving energy without significantly impacting performance.

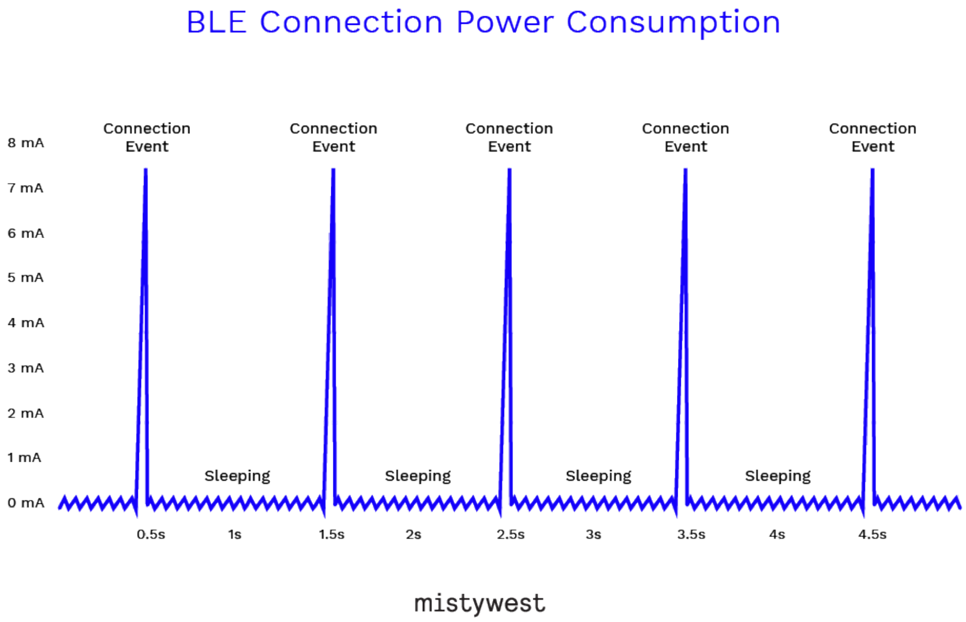


Figure 4.1: BLE connectivity power consumption.

In summary, the Wireless Communication Module of the GROOV system effectively leverages BLE technology to provide low-latency, reliable, and energy-efficient data transmission. Through careful optimization of connection parameters and implementation of adaptive techniques, the module ensures seamless communication between components, contributing to a responsive and immersive musical experience.

4.2.4 Outputs

Sensor Values and Interpretation:

- FSR Pressure (Blue Line) [200 to 350]: Higher values mean more pressure. Crossing 300 triggers a piano note.
- IMU Gyro Y - Snare Drum (Red Line) [50 to 150]: Measures rotation speed. Crossing 100 triggers a snare drum sound. Frequent fluctuations indicate continuous movement.

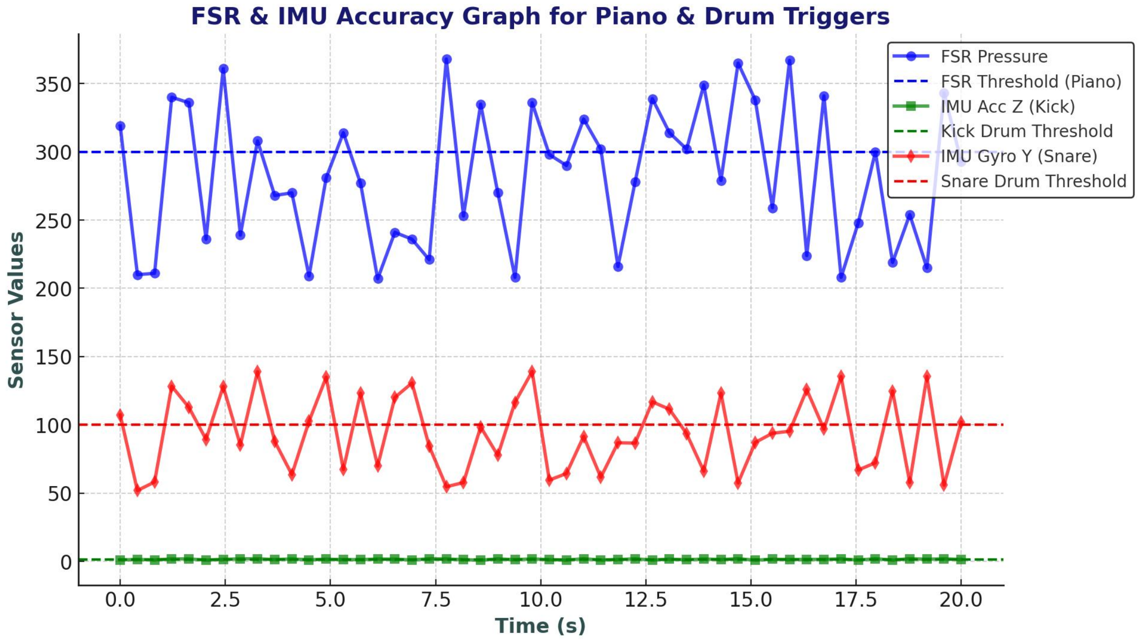


Figure 4.2: FSR and IMU Accuracy graph.

- IMU Acc Z - Kick Drum (Green Line) [Near zero]: Measures up/down acceleration. No significant movement detected, so no kick drum is triggered.

Interpretation and notable points:

- Piano notes are frequently triggered.
- Snare drum is played often due to repeated movements.
- Kick drum is inactive as no strong movements are detected.

4.2.5 Summary

This chapter presented an analysis of the results obtained from the Gesture Detection, Sound Generation, and Wireless Communication modules of the GROOV project. The Gesture Detection module effectively utilized Inertial Measurement Units (IMUs) and sensor fusion techniques to accurately interpret user movements, achieving high precision in translating gestures into musical inputs. The Sound Generation module was able to produce authentic instrument sounds. Despite the high-quality output, challenges such as balancing computational efficiency with sound fidelity were identified, suggesting areas for further optimization. The Wireless Communication module employed Bluetooth

Low Energy (BLE) technology to facilitate real-time data transmission between hardware components and the mobile application. While the system maintained low latency and stable connections, potential improvements in power consumption were noted. Future work should focus on addressing these limitations to further optimize the system's performance across all modules.

Chapter 5

Conclusions & Future Scope

The Groov system is a revolutionary way to make music using cutting-edge features of gesture recognition, wearable tech, and machine learning. By using mobility, accessibility, and affordability in unison, Groov serves as a bridge between traditional instruments and digital solutions, thus opening up music creation to all and making it fun for all levels. The device employs IMU sensors to capture natural hand gestures and map it to a musical output, actually simulating the sound and feel of real instruments, allowing for drumming, keyboard, and tabla play.

The development of Groov offered severe challenges, particularly in precise gesture recognition and real-time sound generation. The project had to involve both hardware and software design, from the calibration of sensors towards accurate gesture-to-sound mapping. The project succeeded in making considerable progress toward realizing its objective of providing immersive musical experiences and firmly and consistently interpreting the user's input since the inception of that project, through iterative testing and subsequent improvements, demonstrating the reliability of the system.

The impressive feature of Groov is the haptic feedback features allowing the user to experience contact with the machine beyond touch, by enabling him/her to feel grooves of music. This kind of feeling adds a more realistic touch to the already feeling-less digital realm. Among other things, the lightweight of the unit contributes to ergonomic comfort to the user; this approach makes use of very available types of components that cut production costs for adoption at a larger scale.

A revolutionary piece of technology, Groov isn't just the future-it enables the extensive democratization of music creation as well. It gives hobbyists, teachers, and budding musicians a venue to navigate and experiment free of financial constraints and space limitations of the traditional instruments. The ability to simulate many instruments with intuitive gestures opens up a new aspect for music education, therapy, and even performance.

Future development may include much potential in Groov. There is a lot of potential for upcoming versions of Groov, in terms of introducing some more advanced AI models to facilitate a more nuanced type of gesture recognition, and personalized responses. The future version could also expand the system's capabilities to support collaborative music-making in virtual spaces and hence could potentially define the way live performances happen, not to mention the social interaction within a musical community. Adding augmented reality for visual feedback and improving battery life might take user experience to another level.

The Groov is a milestone illustration of the future of digital musical interfaces by merging the world of music with technology and thus conquering the limits by making traditional instruments more redundant towards the future innovative exploration for music creation and music interaction. Groov is a prime example of how technology truly inspires people to create and makes artistic expression more accessible to everyone.

References

[1] L. Turcher, F. Antoniazzi, F. Viola, and F. Giunchiglia, "The internet of musical things ontology," *Journal of Web Semantics*, vol. 60, p. 100548, January 2020.

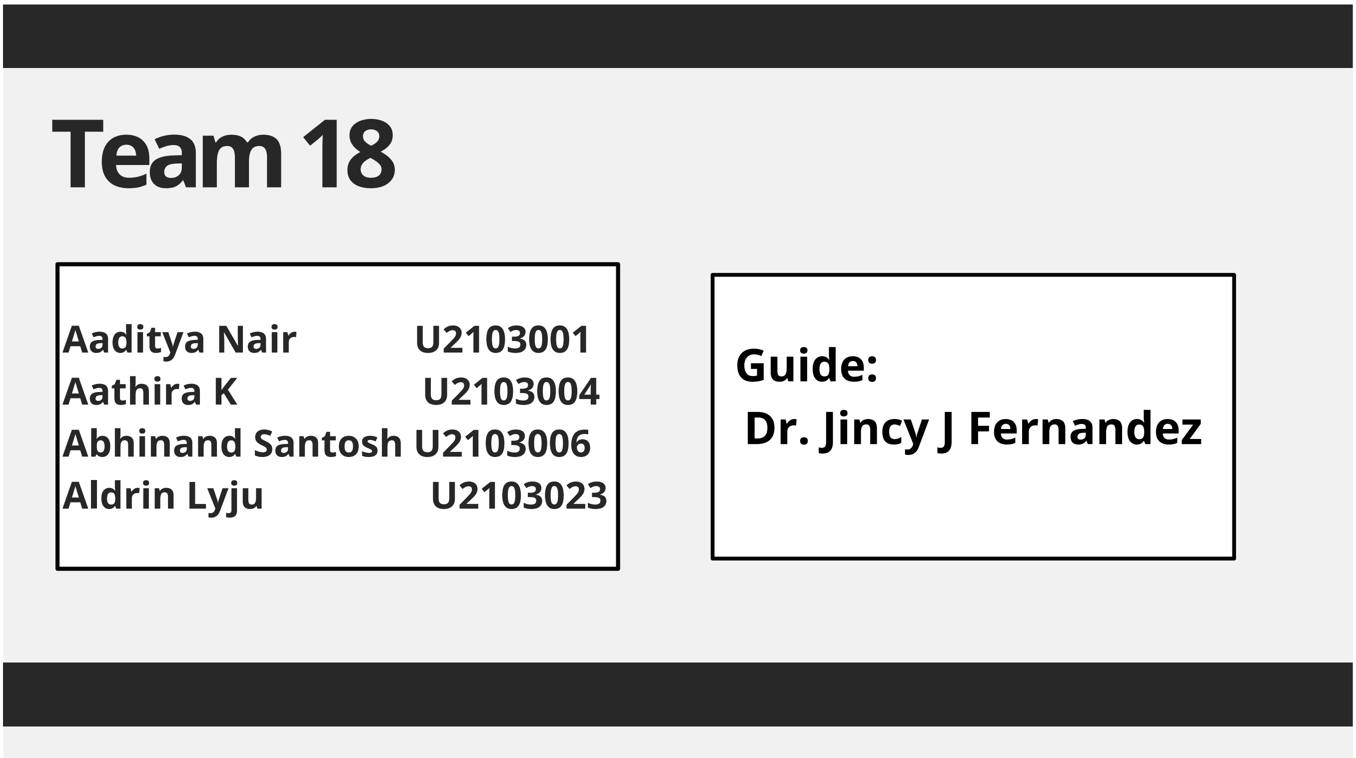
[2] H. Wang, "Research on the application of wireless wearable sensing devices in interactive music," *Journal of Sensors*, vol. 2021, October 2021.

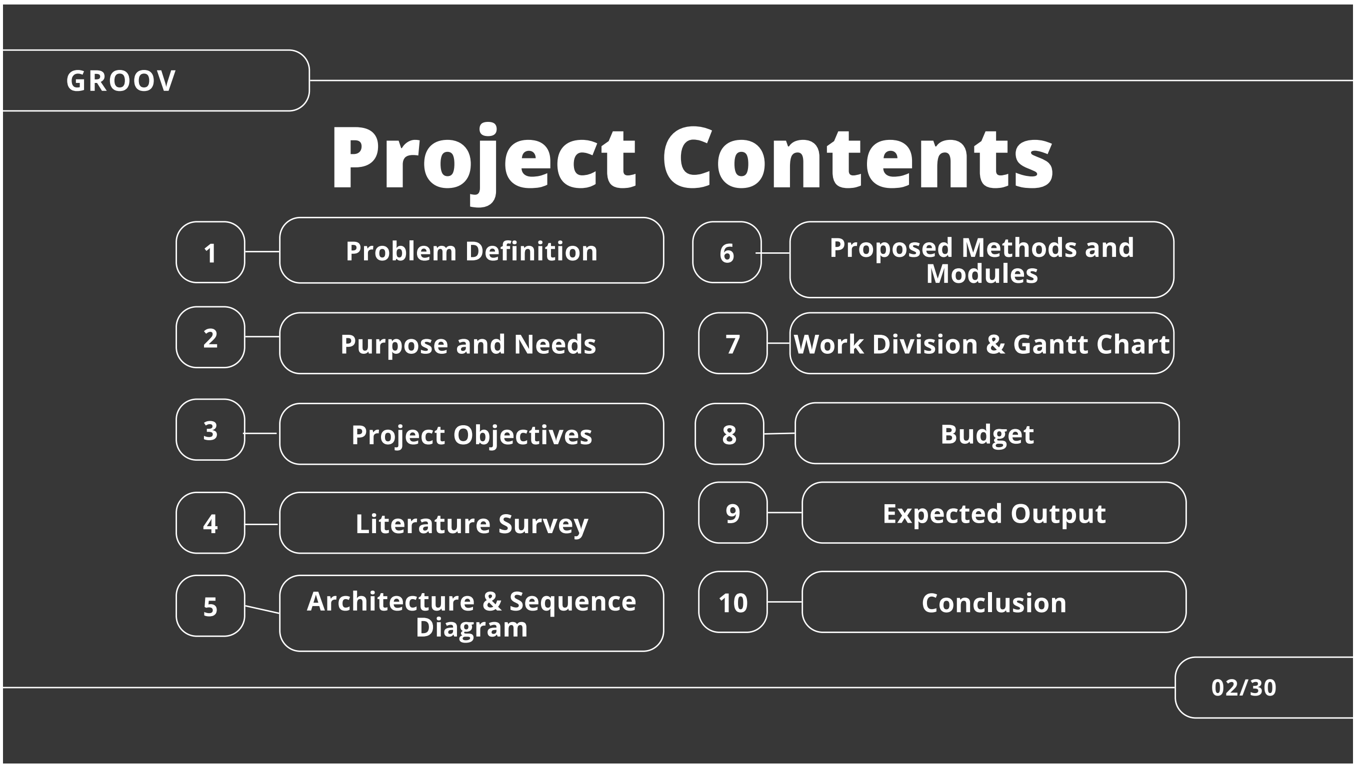
[3] D. Wexler, J. Yip, K. Lee, X. Li, and Y. Wong, "Touch on musical innovation: Exploring wearables and their impact on new interfaces for musical expression," *Sensors*, vol. 24, no. 250, December 2023.

[4] Z. Zhou, "Wearables haptic feedback system and interfaces," *Highlights in Science Engineering and Technology*, vol. 45, pp. 18–24, April 2023.

Appendix A: Presentation


GROOV
FINAL PROJECT PRESENTATION


Team 18
Aaditya Nair U2103001
Aathira K U2103004
Abhinand Santosh U2103006
Aldrin Lyju U2103023
Guide:
Dr. Jincy J Fernandez


GROOV
Project Contents
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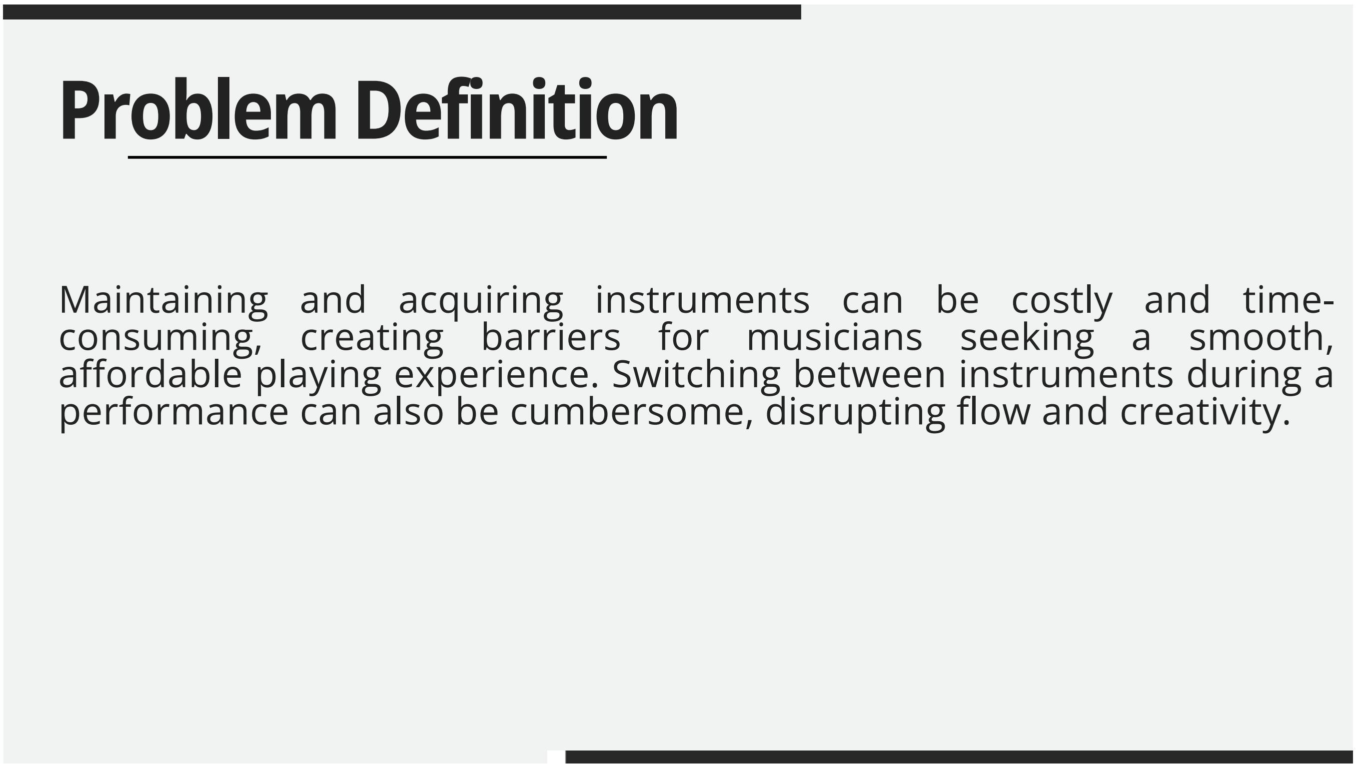
Problem Definition
2
Purpose and Needs
3
Project Objectives
4
Literature Survey
5
Architecture & Sequence Diagram
6
Proposed Methods and Modules
7
Work Division & Gantt Chart
8
Budget
9
Expected Output
10
Conclusion
02/30


Problem Definition
Maintaining and acquiring instruments can be costly and time-consuming, creating barriers for musicians seeking a smooth, affordable playing experience. Switching between instruments during a performance can also be cumbersome, disrupting flow and creativity.

Purpose & Need

The purpose of this device is to provide a fun, intuitive way for casual users to explore and create music by mimicking instrument sounds through simple actions.

It addresses the need for an accessible, affordable solution that makes switching between instruments easy, making music-making enjoyable and approachable for everyone.

Project Objective

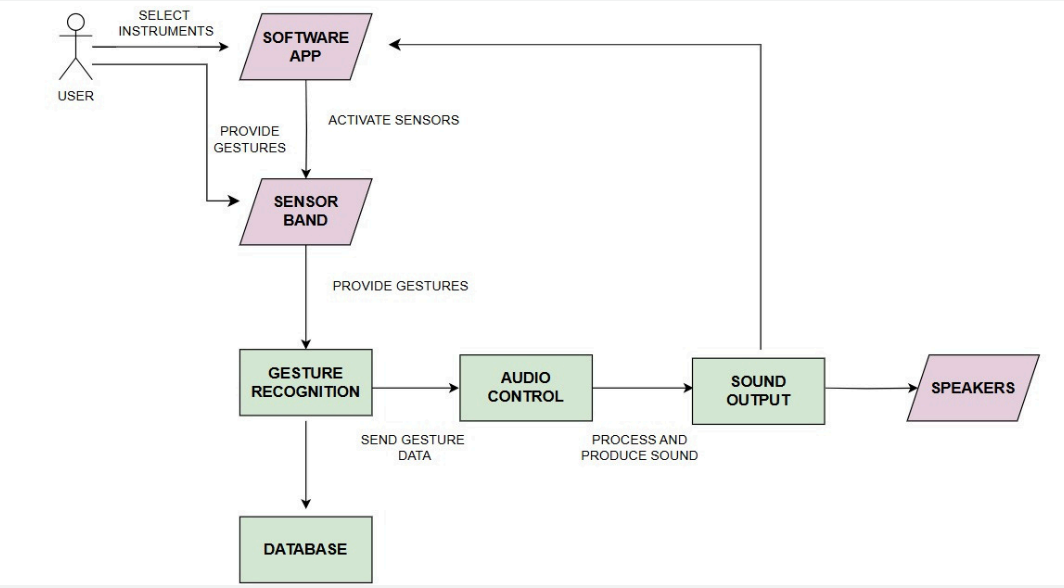
To create a device that allows beginners and aspiring musicians to learn and explore various instrument affordably and without needing much space, enabling them to express their creativity and develop their skills at home

Literature Survey

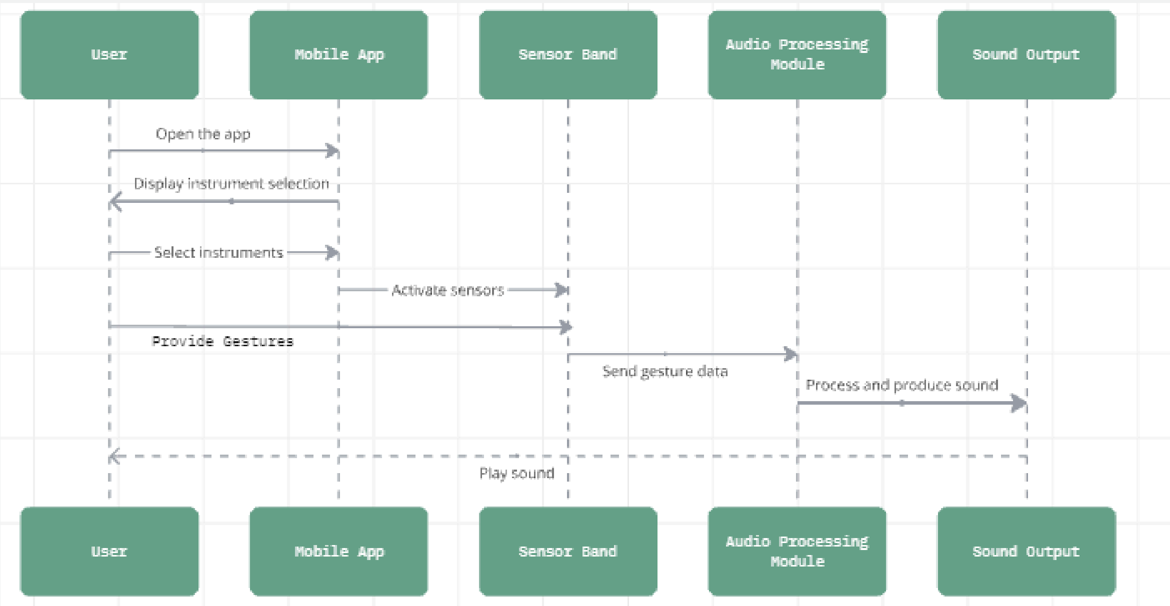
Paper	Advantages	Disadvantages
Turcher L; Antoniazzi, F; Viola ,F; Giunchiglia ,F. The Internet of Musical Things Ontology. Journal of Web Semantics, 60(16): 100548, January(2020)	• Interoperability • Applicable to both IOT and music field	• Relies on other ontologies • Not evaluated in real IOMusT settings
Zhou, Z; Wearables Hapic Feedback System and Interfaces, Highlights in Science Engineering and Technology, Vol. 45, 18-24, April(2023)	• Comfort and Flexibility • Enhanced Interaction	• Thermal Sensitivity • Integration Complexity

Paper	Advantages	Disadvantages
Xu, P. Research on the Application of Computer Music Software in College Traditional Music Course. Phys: Conf. 2021 022178	• Real time feedback • Personalized learning	• Software limitation • Cost and Access
Wang,H. Research on the Application of Wireless Wearable Sensing Devices In Interactive Music. Journal of Sensors. Vol.2021,October(2021)	• Enhanced Immersion • Multi-sensor Integration	• Battery and Energy issues • Latency Issues
Wexler ,D; Yip ,J; Lee, K; Li, X; Wong, Y. Touch on Musical Innovation: Exploring Wearables and Their Impact On New Interfaces for Musical Expression. Sensors 2024, Vol. 24, 250, December(2023)	• Increased Interactivity • Cost efficient	• Latency issue • Limited responsiveness

Architecture Diagram



Sequence Diagram



Modules

- **Hardware:** To design and build the physical device to incorporate the sensors.
- **Gesture Recognition**: Utilize IMU's to detect user movements and translate them into audio.
- **MIDI Protocol Implementation**: To facilitate effective communication between devices
- **Sound Processing Software**: To ensure the production of high quality sound output.
- **User Calibration**: A calibration feature to adjust sensitivity and responsiveness based on individual user preferences and playing styles.

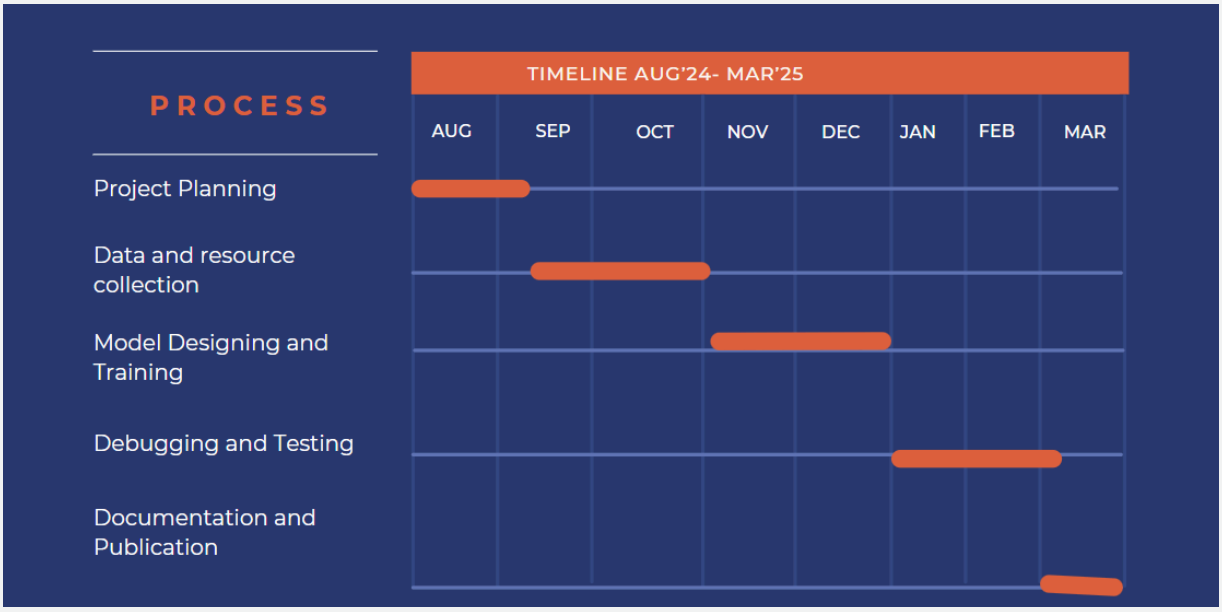
Assumptions

- **User Engagement:** The device is expected to be intuitive and engaging, encouraging interest in music-making.
- **Gesture Accuracy:** Gesture recognition is assumed to reliably interpret user movements for a smooth experience.
- **Sound Quality:** The software is expected to deliver high-quality, realistic instrument sounds.
- **User Learning Curve:** Users are assumed to adapt quickly, with minimal effort required for beginners.

Requirements:

Hardware:	Software:
• seeed studio xiao nrf52840 sense microcontroller • Power supply: lithium polymer battery • Wireless module: bluetooth • Glove/Band : 3D moduled enclosure	• Xcode : Swift • Arduino ide

Gantt Chart



Budget

DESCRIPTION	QTY	PRICE	TOTAL
Microcontroller	1	2900	2900
Power Supply	1	219	219
Sensors (IMUs,Touch Sensors)	2	1288+170	2746
Glove/Band	1	256	256
Jumper Wires	2	200	400
		TOTAL	**6521.00**

Risk and Challenges

- **Gesture Accuracy:** Misrecognition could lead to incorrect musical output.
- **User Adoption:** Some users may need guidance to use gesture controls effectively.
- **Market Adoption:** Tech-based instruments may face competition and skepticism.
- **Cost Management:** Balancing quality with affordable production is a challenge.
- **Hardware Integration:** Ensuring accurate IMU-based tracking can be complex.

Expected Output

- **Instrument Simulation:** Users can play multiple instruments (drums, violin, piano) using natural hand gestures with real-time sound feedback.
- **Minimal Hardware**: A lightweight wearable device with sensors, eliminating the need for physical instruments or controllers.
- **Accurate Gesture Recognition:** High precision in tracking gestures for realistic and responsive sound generation.
- **Mobile/PC App Integration**: Wireless control via a user-friendly app for instrument selection and settings adjustment.

Conclusion

Groov transforms natural hand gestures into dynamic musical expressions, offering musicians an intuitive and portable platform for creativity. Its minimalist design eliminates the need for extensive equipment, enabling artists to compose and perform music seamlessly in diverse settings.

References

1.Wang,H. Research on the Application of Wireless Wearable Sensing Devices In Interactive Music. Journal of Sensors. Vol.2021,October(2021)

2.Wexler ,D; Yip ,J; Lee, K; Li, X; Wong, Y. Touch on Musical Innovation: Exploring Wearables and Their Impact On New Interfaces for Musical Expression. Sensors 2024, Vol. 24, 250, December(2023)

3.Zhou, Z; Wearables Hapic Feedback System and Interfaces, Highlights in Science Engineering and Technology, Vol. 45, 18-24, April(2023)

4.Xu, P. Research on the Application of Computer Music Software in College Traditional Music Course. Phys: Conf. 2021 022178

5. Turcher L; Antoniazzi, F; Viola ,F; Giunchiglia ,F. The Internet of Musical Things Ontology. Journal of Web Semantics, 60(16): 100548, January(2020)

THANK YOU

Appendix B: Vision, Mission, Programme Outcomes and Course Outcomes

Vision, Mission, Programme Outcomes and Course Outcomes

Institute Vision

To evolve into a premier technological institution, moulding eminent professionals with creative minds, innovative ideas and sound practical skill, and to shape a future where technology works for the enrichment of mankind.

Institute Mission

To impart state-of-the-art knowledge to individuals in various technological disciplines and to inculcate in them a high degree of social consciousness and human values, thereby enabling them to face the challenges of life with courage and conviction.

Department Vision

To become a centre of excellence in Computer Science and Engineering, moulding professionals catering to the research and professional needs of national and international organizations.

Department Mission

To inspire and nurture students, with up-to-date knowledge in Computer Science and Engineering, ethics, team spirit, leadership abilities, innovation and creativity to come out with solutions meeting societal needs.

Programme Outcomes (PO)

Engineering Graduates will be able to:

1. Engineering Knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

2. Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

3. Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

4. Conduct investigations of complex problems: Use research-based knowledge including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

5. Modern Tool Usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

6. The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal, and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

9. Individual and Team work: Function effectively as an individual, and as a member or leader in teams, and in multidisciplinary settings.

10. Communication: Communicate effectively with the engineering community and with society at large. Be able to comprehend and write effective reports documentation. Make effective presentations, and give and receive clear instructions.

11. Project management and finance: Demonstrate knowledge and understanding of engineering and management principles and apply these to one's own work, as a member and leader in a team. Manage projects in multidisciplinary environments.

12. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and lifelong learning in the broadest context of technological change.

Programme Specific Outcomes (PSO)

A graduate of the Computer Science and Engineering Program will demonstrate:

PSO1: Computer Science Specific Skills
The ability to identify, analyze and design solutions for complex engineering problems in multidisciplinary areas by understanding the core principles and concepts of computer science and thereby engage in national grand challenges.

PSO2: Programming and Software Development Skills
The ability to acquire programming efficiency by designing algorithms and applying standard practices in software project development to deliver quality software products meeting the demands of the industry.

PSO3: Professional Skills
The ability to apply the fundamentals of computer science in competitive research and to develop innovative products to meet the societal needs thereby evolving as an eminent researcher and entrepreneur.

Course Outcomes (CO)

Course Outcome 1: Model and solve real world problems by applying knowledge across domains (Cognitive knowledge level: Apply).

Course Outcome 2: Develop products, processes or technologies for sustainable and socially relevant applications (Cognitive knowledge level: Apply).

Course Outcome 3: Function effectively as an individual and as a leader in diverse teams and to comprehend and execute designated tasks (Cognitive knowledge level: Apply).

Course Outcome 4: Plan and execute tasks utilizing available resources within timelines, following ethical and professional norms (Cognitive knowledge level: Apply).

Course Outcome 5: Identify technology/research gaps and propose innovative/creative solutions (Cognitive knowledge level: Analyze).

Course Outcome 6: Organize and communicate technical and scientific findings effectively in written and oral forms (Cognitive knowledge level: Apply).

Appendix C:
CO-PO-PSO Mapping

Course Outcomes

After completion of the course the student will be able to:

SL.NO	Description	Bloom's Taxonomy Level
CO1	Model and solve real-world problems by applying knowledge across domains.	Level 3: Apply
CO2	Develop products, processes, or technologies for sustainable and socially relevant applications.	Level 3: Apply
CO3	Function effectively as an individual and as a leader in diverse teams to comprehend and execute designated tasks.	Level 3: Apply
CO4	Plan and execute tasks utilizing available resources within timelines, following ethical and professional norms.	Level 3: Apply
CO5	Identify technology/research gaps and propose innovative/creative solutions.	Level 4: Analyze
CO6	Organize and communicate technical and scientific findings effectively in written and oral forms.	Level 3: Apply

CO-PO Mapping

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
1	2	2	1	1	-	2	1	-	-	-	-	3
2	3	3	2	3	-	2	1	-	-	-	-	3
3	3	2	-	-	3	-	-	1	-	2	-	3
4	3	-	-	-	2	-	-	1	-	3	-	3
5	3	3	3	3	2	2	-	2	-	3	-	3

CO-PSO Mapping

CO	PSO 1	PSO 2	PSO 3
1	3	1	2
2	3	2	2
3	2	2	-
4	3	-	3
5	3	-	-

Justification for CO-PO Mapping

Mapping	Level	Justification
101003/CS722U.1-PO1	M	Knowledge in the area of technology for project development using various tools results in better modeling.
101003/CS722U.1-PO2	M	Knowledge acquired in the selected area of project development can be used to identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions.
101003/CS722U.1-PO3	M	Can use the acquired knowledge in designing solutions to complex problems.
101003/CS722U.1-PO4	M	Can use the acquired knowledge in designing solutions to complex problems.
101003/CS722U.1-PO5	H	Students are able to interpret, improve and redefine technical aspects for design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
101003/CS722U.1-PO6	M	Students are able to interpret, improve and redefine technical aspects by applying contextual knowledge to assess societal, health and consequential responsibilities relevant to professional engineering practices.
101003/CS722U.1-PO7	M	Project development based on societal and environmental context solution identification is the need for sustainable development.
101003/CS722U.1-PO8	L	Project development should be based on professional ethics and responsibilities.
101003/CS722U.1-PO9	L	Project development using a systematic approach based on well-defined principles will result in teamwork.
101003/CS722U.1-PO10	M	Project brings technological changes in society.
101003/CS722U.1-PO11	H	Acquiring knowledge for project development gathers skills in design, analysis, development and implementation of algorithms.
101003/CS722U.1-PO12	H	Knowledge for project development contributes engineering skills in computing and information gatherings.
101003/CS722U.2-PO1	H	Knowledge acquired for project development will also include systematic planning, developing, testing, and implementation in computer science solutions in various domains.
101003/CS722U.2-PO2	H	Project design and development using a systematic approach brings knowledge in mathematics and engineering fundamentals.
101003/CS722U.2-PO3	H	Identifying, formulating, and analyzing the project results in a systematic approach.
101003/CS722U.2-PO5	H	Systematic approach is the tip for solving complex problems in various domains.

Mapping	Level	Justification
101003/CS722U.2-PO6	H	Systematic approach in the technical and design aspects provides valid conclusions.
101003/CS722U.2-PO7	H	Systematic approach in the technical and design aspects demonstrates the knowledge of sustainable development.
101003/CS722U.2-PO8	M	Identification and justification of technical aspects of project development demonstrates the need for sustainable development.
101003/CS722U.2-PO9	H	Apply professional ethics and responsibilities in engineering practice of development.
101003/CS722U.2-PO11	H	Systematic approach also includes effective reporting and documentation which gives clear instructions.
101003/CS722U.2-PO12	M	Project development using a systematic approach based on well-defined principles will result in better teamwork.
101003/CS722U.3-PO9	H	Project development as a team brings the ability to engage in independent and lifelong learning.
101003/CS722U.3-PO10	H	Identification, formulation and justification in technical aspects will be based on acquiring skills in design and development of algorithms.
101003/CS722U.3-PO11	H	Identification, formulation and justification in technical aspects provides the betterment of life in various domains.
101003/CS722U.3-PO12	H	Students are able to interpret, improve and redefine technical aspects with mathematics, science and engineering fundamentals for the solutions of complex problems.
101003/CS722U.4-PO5	H	Students are able to interpret, improve and redefine technical aspects with identification, formulation and analysis of complex problems.
101003/CS722U.4-PO8	H	Students are able to interpret, improve and redefine technical aspects to meet the specified needs with appropriate consideration for public health and safety, and the cultural, societal, and environmental considerations.
101003/CS722U.4-PO9	H	Students are able to interpret, improve and redefine technical aspects for design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
101003/CS722U.4-PO10	H	Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools for better products.
101003/CS722U.4-PO11	M	Students are able to interpret, improve and redefine technical aspects by applying contextual knowledge to assess societal, health and consequential responsibilities relevant to professional engineering practices.
101003/CS722U.4-PO12	H	Students are able to interpret, improve and redefine technical aspects for demonstrating the knowledge of, and need for sustainable development.

Mapping	Level	Justification
101003/CS722U.5-PO1	H	Students are able to interpret, improve and redefine technical aspects, apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
101003/CS722U.5-PO2	M	Students are able to interpret, improve and redefine technical aspects, communicate effectively on complex engineering activities with the engineering community and with society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
101003/CS722U.5-PO3	H	Students are able to interpret, improve and redefine technical aspects to demonstrate knowledge and understanding of the engineering and management principle in multidisciplinary environments.
101003/CS722U.5-PO4	H	Students are able to interpret, improve and redefine technical aspects, recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.
101003/CS722U.5-PO5	M	Students are able to interpret, improve and redefine technical aspects in acquiring skills to design, analyze and develop algorithms and implement those using high-level programming languages.
101003/CS722U.5-PO12	M	Students are able to interpret, improve and redefine technical aspects and contribute their engineering skills in computing and information engineering domains like network design and administration, database design and knowledge engineering.
101003/CS722U.6-PO5	M	Students are able to interpret, improve and redefine technical aspects and develop strong skills in systematic planning, developing, testing, implementing and providing IT solutions for different domains which helps in the betterment of life.
101003/CS722U.6-PO8	H	Students will be able to associate with a team as an effective team player for the development of technical projects by applying the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
101003/CS722U.6-PO9	H	Students will be able to associate with a team as an effective team player to identify, formulate, review research literature, and analyze complex engineering problems.
101003/CS722U.6-PO10	M	Students will be able to associate with a team as an effective team player for designing solutions to complex engineering problems and design system components.
101003/CS722U.6-PO11	M	Students will be able to associate with a team as an effective team player to use research-based knowledge and research methods including design of experiments, analysis and interpretation of data.

Mapping	**Level**	**Justification**
101003/CS722U.6-PO12	H	Students will be able to associate with a team as an effective team player, applying ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
101003/CS722U.1-PSO1	H	Students are able to develop Computer Science Specific Skills by modeling and solving problems.
101003/CS722U.2-PSO2	M	Developing products, processes or technologies for sustainable and socially relevant applications can promote Programming and Software Development Skills.
101003/CS722U.3-PSO3	H	Working in a team can result in the effective development of Professional Skills.
101003/CS722U.4-PSO3	H	Planning and scheduling can result in the effective development of Professional Skills.
101003/CS722U.5-PSO1	H	Students are able to develop Computer Science Specific Skills by creating innovative solutions to problems.
101003/CS722U.6-PSO3	H	Organizing and communicating technical and scientific findings can help in the effective development of Professional Skills.