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Design And Implementation of IoT-Based Endodontic File Measurement Instrument For Dental Practitioners

Sanjay Pujari
Department of ECE
KLE College of Engineering and Technology
Chikkodi, India
pujarisap@klecet.edu.in

Shreya K. Kattimani
Department of ECE
KLE College of Engineering and Technology
Chikkodi, India
kkattimani77@gmail.com

Aishwarya U. Patil
Department of ECE
KLE College of Engineering and Technology
Chikkodi, India
patilaishwarya038@gmail.com

Poornima A. Khaddannavar
Department of ECE
KLE College of Engineering and Technology
Chikkodi, India
poornimakhaddannavarabc123@gmail.com

Mayuri A. Koot
Department of ECE
KLE College of Engineering and Technology
Chikkodi, India
mayurikoot99@gmail.com

Rahul J. Teradal
Department of ECE
Jain College of Engineering and Research
Belagavi, India
rahulteradal45@gmail.com

ABSTARCT

Precise determination of working length during root canal treatment is critical to ensuring successful endodontic outcomes. Traditional techniques for measuring file length are often manual, time-consuming, and susceptible to human error. This research introduces an IoT-based endodontic file measurement instrument aimed at improving accuracy, usability, and efficiency for dental practitioners. The proposed system integrates ultrasonic sensing for file length detection, a microcontroller (ESP32) for processing, and Wi-Fi-based IoT communication for real-time data transfer to a digital interface. Additional components, such as an OLED display and touch-sensitive interface, enhance user interaction. A mobile application was developed using the Blynk IoT platform to enable wireless monitoring and data logging.

Testing of the prototype revealed that the device could measure file length with a high degree of precision, maintaining an error margin within ±0.5 mm. Real-time updates and remote monitoring were successfully demonstrated, offering enhanced convenience and reliability for clinicians. This IoT-based instrument provides a promising alternative to conventional techniques, offering improved ergonomics, digital integration, and potential for data-driven decision-making in dental procedures. Future work will focus on miniaturization, integration with electronic apex locators, and clinical validation across diverse patient scenarios to enable widespread adoption in modern dental practice.

Chapter 1

INTRODUCTION

Endodontics is a crucial branch of dentistry that deals with root canal treatments. A critical aspect of this treatment involves accurately measuring and controlling the length of endodontic files used to clean and shape root canals. Traditionally, manual measurements have been prone to human error, which can impact the procedure's success.

The Endo-file Measurement System using Arduino is an innovative and efficient tool designed to enhance precision and ease in measuring the length of endodontic files, which are crucial in dental procedures. This system combines automation and accuracy by integrating various components such as an Arduino microcontroller, a keypad, a servo motor, and an LCD display. The Arduino serves as the core controller, processing inputs from the keypad to execute precise adjustments via the servo motor. The system's LCD interface provides real-time feedback, allowing users to easily read and confirm the measurements. This eliminates the errors associated with manual measurements, streamlining the process for dental practitioners. Compact, user-friendly, and reliable, the system offers a modern approach to ensuring accurate file length determination, making it an invaluable tool for dental clinics and laboratories.

This system offers precision, automation, and user-friendly operation, enhancing accuracy and efficiency in endodontic procedures. Compact and efficient, the Endofile Measurement System not only enhances accuracy but also improves workflow in dental clinics and laboratories, offering a reliable and cost-effective alternative to traditional manual measurement methods. This innovative approach underscores the growing role of technology in advancing healthcare practices.

Chapter 2

LITERATURE SURVEY

The integration of IoT in dental practices has led to the development of automatic endo-file measurement systems, enhancing the precision and efficiency of dental diagnostics. These systems utilize advanced technologies to monitor and measure dental conditions, particularly focusing on occlusal characteristics and root canal lengths.

According to Mohammed and et.al an IoT-based wireless capsule endoscopy (WCE) system that integrates various sensors for accurate gastrointestinal diagnostics. However, it does not specifically address an automatic endo-file measurement system. But there is limitations of current wireless capsule endoscopy technology [1].

The paper focuses on an IoT-based teeth pitfall measurement system. It emphasizes dental health monitoring using force sensors, Arduino, and cloud connectivity for real-time data analysis and remote healthcare access. But the problem is early detection of teeth-related issues is crucial [2].

Another method for automated dental measurements by acquiring a digital model of teeth and computing measurements related to occlusal characteristics, but it does not specifically address an automatic endo-file measurement system using IoT. But the problem is it is applicable only to the digital tooth [3]. The next paper focuses on the IOTeeth system for continuous monitoring of occlusal diseases through piezoelectric sensing array integrated into a dental retainer. But the Occlusal diseases are underdiagnosed and cause tooth loss [4].

According to Riccucci and other the apical limit of root canal instrumentation and obturation is one of the major controversial issues in root canal therapy. For decades this subject has been, and still continues to be, a topic of discussion between endodontists. The related literature often generates confusion and uncertainty for the practitioners who are looking for adequate clinical solutions based on facts rather than on opinions [5].

According to Mehlawat R and others teeth were mounted and canals were injected with India ink to stain the canal walls. Canal preparation was done as per the group. After instrumentation, teeth were demounted, decalcified and cleared to make them transparent for scoring according to the extent of removal of India ink. Timing of instrumentation and cleaning efficacy of canals in coronal, middle and apical thirds were assessed in each sample [6].

Finally the automatic endo-file measurement system is possible using the Arduino, servo motor, keypad, 5v adapter and LCD display.

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Chapter 3

PROBLEM STATEMENT AND OBJECTIVES

3.1 Problem Definition

- In endodontic procedures, accurately determining the working length is essential for successful root canal treatment.
- In the current system, measuring working length involves using pre-calibrated, stainless-steel or Ni-Ti files with precise diameters and tapers to estimate canal depth.
- These endodontic files are of various types such as K file, H file, protaper, etc.,
- Techniques such as radiographic assessment and electronic apex locators (EAL) are commonly employed to obtain accurate measurements, ensuring thorough cleaning and shaping without causing damage beyond the apex.
- Precise working length determination in root canals minimizes post-treatment complications and enhances long-term outcomes.
- While performing endodontic treatment, series of files are required in a defined sequence for biomechanical preparation.
- The process of measuring each file and adjusting it to the defined working length manually is time consuming and tedious.

3.2 Objectives

- **Precise Measurement of Endo-file Length**
  To accurately measure the length of endodontic files used in dental procedures, ensuring precision for better outcomes.
- **User-Friendly Interface**
  To provide a simple interface using an LCD display and keypad for ease of operation by dental professionals.
- **Automation of the Measurement Process**
  To use a servo motor for automating file positioning or measuring mechanisms, reducing manual effort and improving consistency.
- **Data Display**
  To display real-time measurements and user instructions clearly on the LCD screen for enhanced usability.
- **Calibration and Adjustment**
  To allow easy calibration of the system via the keypad, ensuring accurate measurements over time.
- **Compact and Cost-Effective Design**
  To create a portable, reliable, and cost-efficient solution for dental practices compared to commercially available alternatives.

Chapter 4

METHODOLOGY

4.1 Working

1. Define the Objective

The primary goal of this project is to create a system that can measure the length of an Endo- file accurately and display the measurements on an LCD.

2. Design the System Architecture

Break the system into functional components:

- Input Devices:

Keypad: For user input, such as setting measurement modes or calibrating the system.

Arduino Microcontroller: Handles input processing, calculations, and controls the servo motor.

- Output Devices:

Servo Motor: Moves the Endo-file or measuring arm for precise positioning. LCD Display: Shows the measured length and user prompts.

3. Hardware Requirements

- Arduino Board: Choose a compatible model (e.g., Arduino Uno, Nano).
- Servo Motor: For precise mechanical adjustments.
- 16x2 LCD Display: To display data.
- 4x3 Keypad: For user input.

4. Write the Arduino Code

- Libraries: Use libraries like **Servo.h** for the servo motor, **Keypad.h** for the keypad, and **LiquidCrystal.h** for the LCD and **Wire.h**.
- Initialization:

  Set up pins and initialize the LCD, keypad, and servo motor.

- Keypad Functionality:

  Program the keypad to accept inputs for settings or calibration.

  Map servo motor movements to adjust the position for measurement.

- Display Data:

  Update the LCD with real-time measurements and instructions.

5. Testing and Validation

- Test the system with different Endo-file lengths.
- Validate the results against known standards.

6. Documentation and User Guide

- Provide a detailed user guide for operating the system, including setup, calibration, and troubleshooting steps

4.2 Function Block Diagram

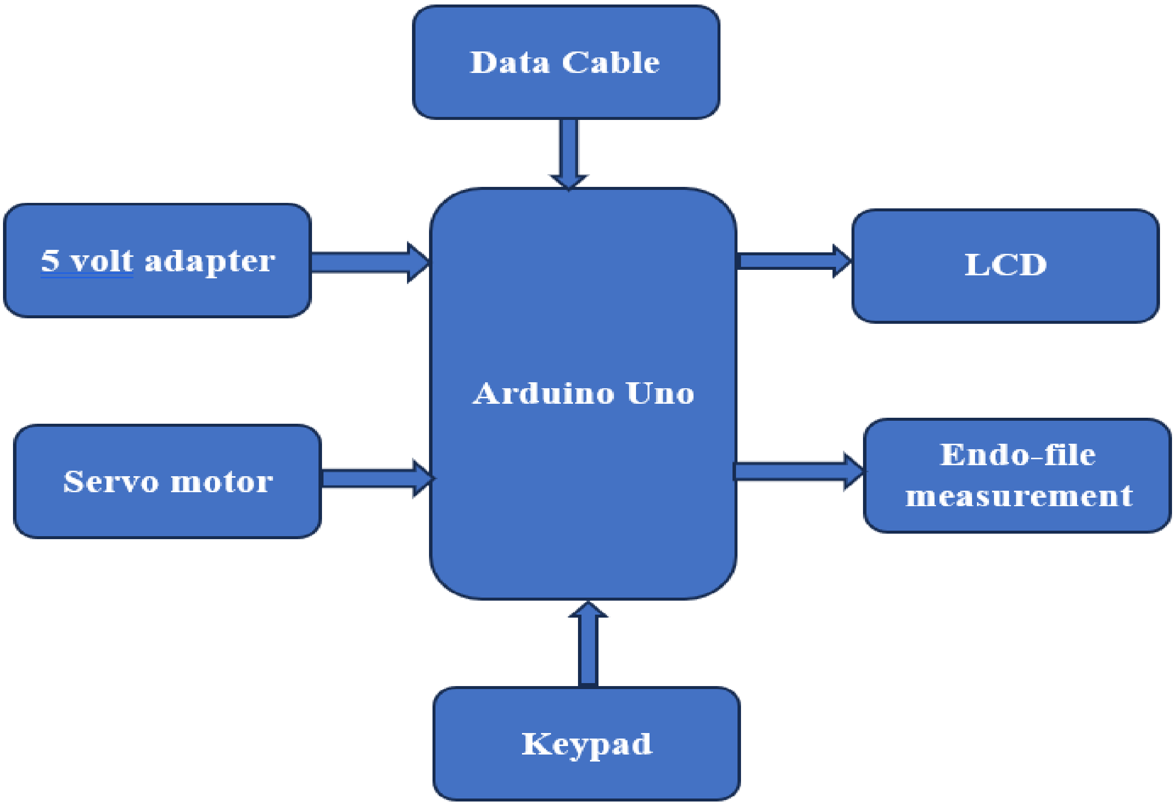

Fig No. 4.1: Block Diagram of Module

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4.3 Circuit Diagram

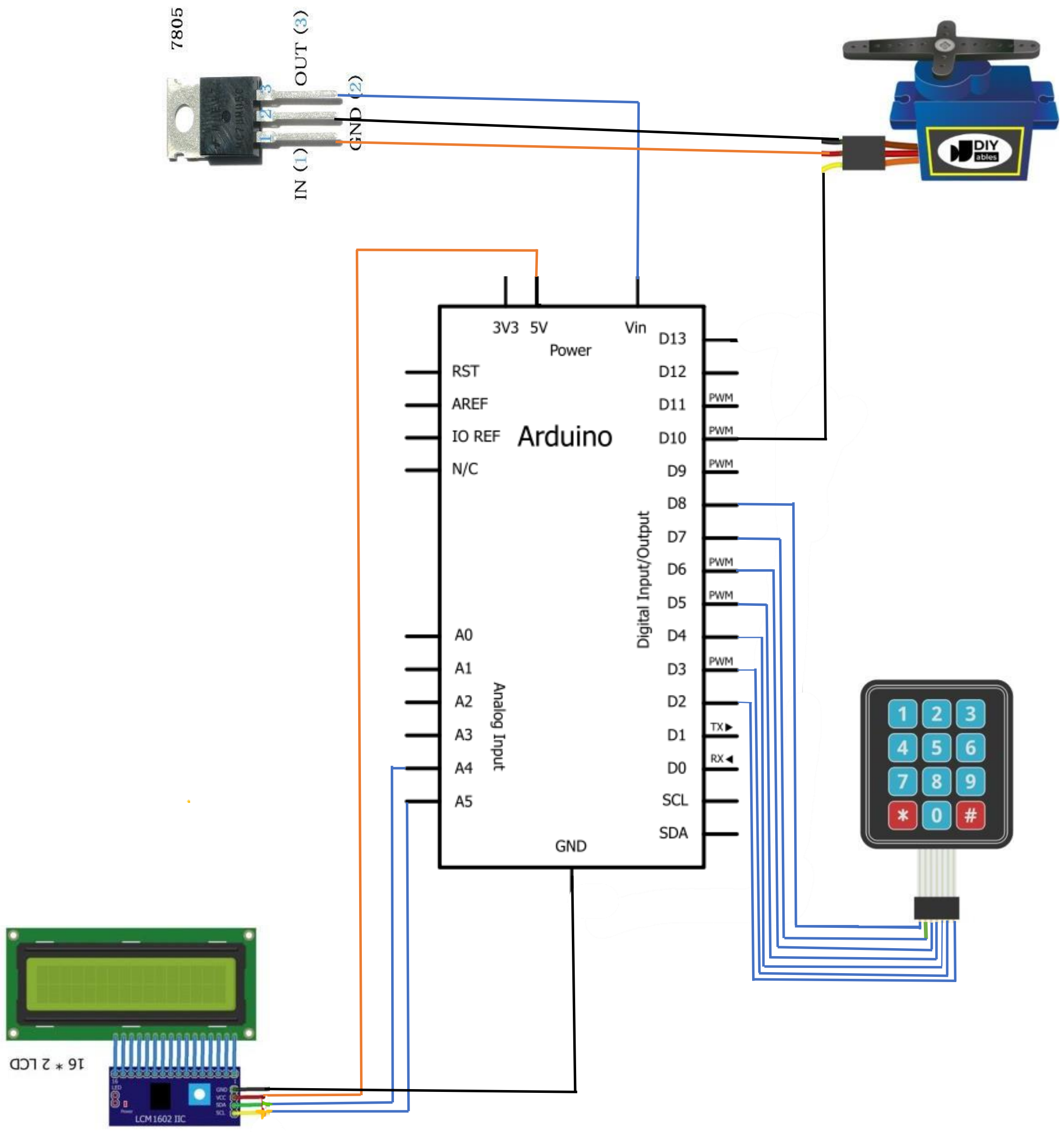

Fig No. 4.2: Circuit Diagram

The circuit connection is made as per the above figure. The 5V adopter's VCC and GND pins are connected to positive and negative terminals of servomotor respectively. The out pin of the adopter is connected to Vin of the Arduino. The keypad typically has rows and columns connected as a matrix. Connect the keypad rows and columns to designated digital pins on the Arduino (e.g., D2–D8). The GND and VCC pins of LCD and Arduino are connected to each other. SCL and SDA pin of LCD are connected to A5 and A4 pin of Arduino respectively.

4.4 Hardware Requirements

4.4.1 ARDUINO CONTROLLER

Fig No 4.3: Arduino Uno

The Uno is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. You can tinker with your UNO without worrying too much about doing something wrong, worst case scenario you can replace the chip for a few dollars and start over again.

"Uno" means one in Italian and was chosen to mark the release of Arduino Software (IDE) 1.0. The Uno board and version 1.0 of Arduino Software (IDE) were the reference versions of Arduino, now evolved to newer releases. The Uno board is the first in a series of USB Arduino boards, and the reference model for the Arduino platform; for an extensive list of current, past or outdated boards see the Arduino index of boards.

Technical specs

Microcontroller	ATmega328P
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limit)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
PWM Digital I/O Pins	6
Analog Input Pins	6
DC Current per I/O Pin	20 mA
DC Current for 3.3V Pin	50 Ma
Flash Memory	32 KB
SRAM	2 KB (ATmega328P)

EEPROM	1 KB (ATmega328P)
Clock Speed	16 MHz
Length	68.6 mm
Width	53.4 mm
Weight	25 g

4.4.2 DISPLAY

16X2 LCD interface (JHD162A – HD44780 compatible Display Controller):-

The LCD interfaced to the system was 16 characters and 2 lines type JHD162A from Jin Hang Displays Co. China. The LCD module consists of a Hitachi HD44780 type LCD controller with a Character generator ROM andDisplay Data Ram. The module consists of 16 interface pins and signals as listed below.

Fig No 4.4: 16*2 Display

Table No 4.1: Pin configuration of LCD display

Pin No.	Signal	Description
1	GND	Power Ground
2	VCC	+5VDC Power Input
3	VEE	Contrast Voltage
4	RS	Register Select (0=Command, 1=Data)
5	R/W'	Read/Write Select (0=Write, 1=Read)
6	EN	Strobe Input (A high to low transition latches data to input registers)
7-14	D0-D7	Data Input / Output Lines
15	A	Backlight +5V Power
16	K	Backlight Power Ground

4.4.3 I2C MODULE

Very useful module to interface serial connection to parallel data, specially used for LCD displays etc. I2C Module has inbuilt PCF8574 I2C chip that converts I2C serial data to parallel data for the LCD display. I2C modules are currently supplied with a default I2C address of either 0x27 or 0x3F, you can check which version by verifying underside of the module. If there a 3 sets of pads labelled A0, A1, & A2 then the default address will be 0x3F. If there are no pads the default address will be 0x27.

The module has a contrast adjustment pot on the underside of the display. This may require adjusting for the screen to display text correctly.

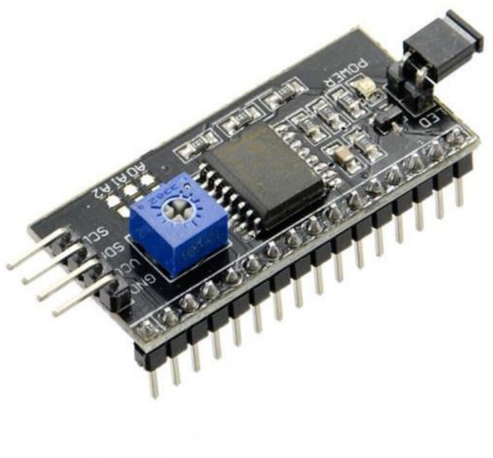

Fig No 4.5: I2C module

Specifications:

- Operating Voltage: 5V
- Backlight and Contrast is adjusted by potentiometer
- Serial I2C control of LCD display using PCF8574
- Come with 2 IIC interface, which can be connected by Dupont Line or IIC dedicated cable
- Compatible for 16x2 LCD
- This is another great IIC/I2C/TWI/SPI Serial Interface
- With this I2C interface module, you will be able to realize data display via only 2 wires.

Applications

Used for various display control units/projects.

4..4.4 KEYPAD

A keypad is a set of buttons arranged in a block or pad which bear digits, symbols or alphabetical letters. Pads mostly containing numbers and used with computers are numeric keypads.

Fig No 4.6: 4*3 Keypad

Features

- Size: 4 rows and 3 columns.
- Keys: 12 keys labeled 0-9, *, and #.
- Connection: It has 7 pins (4 for rows and 3 for columns) to interface with microcontrollers or other systems.

4.4.5 SERVO MOTOR MICRO SG90

Fig No 4.7: Servo motor

The Servo Motor Micro SG90 work well for basic servo experimentation and can be used in applications where small size is a virtue and that don’t require a huge amount of torque, but they are still pretty strong. Gears are nylon, which is the case with most lower-cost Servos. Servo motors can be commanded to go to a specific position and so are the usual go-to motors when accurate positioning is needed, such as for turning the front wheels on an RC model for steering or pivoting a sensor to look around on a robotic vehicle. Servo motors are comprised of a DC motor, gears, a potentiometer to determine its position, and a small electronic control board. Standard servos have a specified limited range. This is usually specified as 180 degrees. Frequently, the actual range is less than the full 180 degrees and is limited by the mechanical gears and the potentiometer used for position sensing that is contained in the device. If the motor is run all the way to 0 or 180, it may start making unhappy sounds and start vibrating as it tries to drive to a position that it cannot get to. This causes a high stall current condition and has the potential of stripping gears and damaging the motor, so it is best to either drive it to a safely reduced range, such as 20-160, or experiment a bit to determine the actual usable range if you want to maximize the range.

Servos expect to see a pulse on their PWM pin every 20 mSec. The pulse is active HIGH and the width of the pulse determines the position (angle) of the shaft of the servo. The pulse can vary between 1mSec and 2mSec. A 1mSec pulse positions the shaft at 0 degrees. A 1.5mSec pulse positions the shaft at 90 degrees (centered in its range). A 2 mSec pulse positions the shaft at 180 degrees. Pulses with values between these can be used to position the shaft arbitrarily.

KEY FEATURES OF SERVO MOTOR MICRO SG90:

- Very small micro size
- Can lift 3.75lb positioned 1cm from center of shaft
- 180-degree rotation
- Analog drive
- Low cost

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4.5 Software Requirement

Arduino IDE

The Arduino IDE is open-source software, which is used to write and upload code to the Arduino boards. The IDE application is suitable for different operating systems such as Windows, Mac OS X, and Linux. It supports the programming languages C and C++. Here, IDE stands for Integrated Development Environment. The program or code written in the Arduino IDE is often called sketching. We need to connect the Genuino and Arduino board with the IDE to upload the sketch written in the Arduino IDE software. The sketch is saved with the extension '.ino.

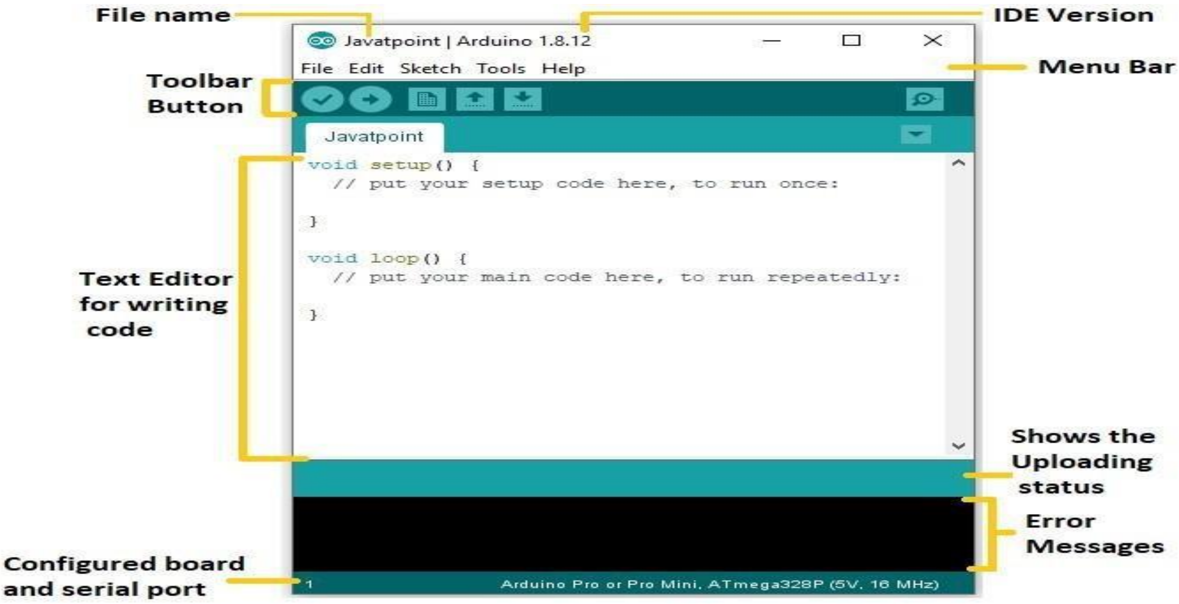

Fig No. 4.8: Arduino IDE.

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Chapter 5

RESULT, ADVANTAGES, DISADVANTAGES AND APPLICATIONS

5.1 Results

Fig No 5.1: Result analysis

When the supply is given to Arduino and adapter, the display ask you to enter the distance.

Fig No 5.2: Result analysis

Fig No 5.3: Result analysis

If we give input as 2 on a keypad, the endo-file holder moves upto 16mm, the corresponding movement is shown in compass as it is in figure 5.3. The moved distance is displayed on LCD display, as '16 mm Displayed' as shown in figure 5.2.

After giving input as 3, the endo-file holder moves upto 21mm and the corresponding movement of holder in compass is shown in figure 5.4. after that LCD will display as 'Enter the distance' for different inputs.

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Fig No 5.4: Result analysis

Fig No 5.5: Result analysis

Fig No 5.6: Result analysis

Fig No 5.7: Result analysis

Then another input is given as 4, the endo-file holder moves upto 25mm. The corresponding movement in compass is shown in figure 5.6. Again it displays as 'Enter the distance' for different inputs.

So by pressing appropriate numbers on keypad, the endofile holder moves to corresponding distances as shown above figures.

5.2 Advantages

1. Cost-Effectiveness

The system is relatively inexpensive compared to commercial alternatives due to the low cost of Arduino boards and components such as the LCD and keypad.

2. Customizability

The Arduino platform allows for easy customization and updates to the system based on user needs or specific measurement requirements.

3. User-Friendly Interface

The LCD provides a clear display for real-time feedback, and the keypad enables easy input of commands or settings, improving user experience.

4. Energy Efficiency

Running on a 5V adapter ensures low power consumption, making the system efficient for prolonged use.

5. High Accuracy and Precision

Arduino can handle precise calculations and provide accurate measurement outputs, essential for applications like dental file length determination.

6. Elimination of Human Error

It gives accurate output hence there is no chance of human error which reduces the injuries while root canal process and it also saves the time.

7. Open-Source Ecosystem

Arduino and related libraries are open-source, providing access to a large community for troubleshooting, modifications, and further enhancements.

5.3 Disadvantages

1. Scalability:

The system might not be scalable for large-scale or high-throughput Endo-file measurements.

2. Risk of Malfunction:

Errors in the software or hardware design can pose risks to patients during medical use.

3. Scalability:

The system might not be scalable for large-scale or high-throughput Endo-file measurements.

5.4 Applications

1. Dental Applications

Root Canal Length Measurement: Used to measure the length of root canals during endodontic procedures, providing an affordable alternative to commercial apex locators.

Dental Training and Education: Helps dental students and trainees understand the principles of root canal measurement through hands-on practice.

2. Educational Applications

Practical Learning: Demonstrates the integration of electronics and mechanics for measurement purposes in engineering or dental education.

Microcontroller Programming: Used in educational setups to teach programming concepts and hardware interfacing with Arduino.

Control Systems: Serves as an example project for learning servo motor control, LCD interface, and keypad input handling.

3. Research and Development

Prototype Development: Acts as a base for designing advanced endodontic devices or improving existing systems.

Automation Testing: Used in research to explore automation in dental procedures.

Affordable Innovations: Supports the development of low-cost alternatives to high-end dental instruments for use in resource-limited settings.

4. Remote and Field Dentistry

Portable Dental Devices: Suitable for use in mobile clinics or field setups where lightweight and compact equipment is required.

Emergency Dental Care: Offers a quick and cost-effective tool for basic dental measurements in emergency situations.

5. General Measurement Systems

Non-Dental Applications: Adapted for measuring lengths, depths, or positions in non-medical contexts.

CONCLUSION AND FUTURE SCOPE

Conclusion

In conclusion, the automated Endo-file measurement system using Arduino is a pioneering advancement in dental technology, with significant potential for future growth and development. The design and implementation of an IoT-based Endodontic File Measurement System using an Arduino, servo motor, I2C module, and LCD display successfully provide an efficient and precise method for measuring endodontic files. By continuing to innovate and refine this technology, we can further enhance dental care quality, efficiency, and accessibility, ultimately benefiting both dental professionals and patients. This system allows for accurate measurement and control of endodontic files, thereby improving the quality and reliability of root canal treatments. Overall, this project demonstrates the effective use of embedded systems and IoT technology in medical applications.

Future Scope

The future scope of the automated Endo-file measurement system using Arduino is vast and promising. Advancements in sensor technology, such as using optical or ultrasonic sensors, could enhance measurement precision and broaden the system's applications. Additionally, incorporating artificial intelligence and machine learning could provide adaptive and personalized recommendations based on individual patient data. Finally, pursuing regulatory approvals and conducting extensive clinical trials will be crucial for validating the system's effectiveness and ensuring its adoption in dental practices worldwide. By addressing these future developments, the automated Endo-file measurement system can significantly advance dental technology and patient care.

REFERENCES

[1] Mohammad, Wajih, Alam., Hanif, Ali, Sohag., Alimul, Haque, Khan., Tanin, Sultana., Khan, Arif, Wahid. (2019). IoT-Based Intelligent Capsule Endoscopy System: A Technical Review. 1-20. doi: 10.1016/B978-0-12-815553-0.00001-X.

[2] S., Mahalakshmi., K., Valarmathi., P., Krishnaleela., S.Suriya, Narayanan., K.S., Sivadharsan., S., Sridhar. (2024). IOT Based Teeth Pitfall Measurement System. 1-6. doi: 10.1109/iccigst60741.2024.10717494.

[3] Vadim, Matov., Fuming, Wu., Eric, Kuo., Luong, Jenghuei, Gene. "Method for facilitating automated dental measurements." null (2017).

[4] Zhizhang, Hu., Amir, Radmehr., Yue, Zhang., Phuc, Nguyen. (2024). IOTeeth: Intra-Oral Teeth Sensing System for Dental Occlusal Diseases Recognition. Proceedings of the ACM on interactive, mobile, wearable and ubiquitous technologies, 8:7:1-7:29. doi: 10.1145/3643516

[5] Ricucci, D., & Siqueira, J. F. (2010). Apical limit of root canal instrumentation and obturation, part 2. A histological study. International Endodontic Journal, 43(11), 855-866.

[6] Mehlawat R, Kapoor R, Gandhi K, Kumar D, Malhotra R, Ahuja S. Comparative evaluation of instrumentation timing and cleaning efficacy in extracted primary molars using manual and NiTi rotary technique - Invitro study. J Oral Biol Craniofac Res. 2019;9(2):151-155. doi:10.1016/j.jobcr.2019.03.0