Embedded Intelligence Based Portable Uroflowmetry Device

A BS Final Year Project by

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بسم الله الرحمن الرحيم

In the name of Allah (SWT), the most beneficent and the most merciful

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For the award of the degree of

Bachelor of Science in Electrical Engineering

Declaration

We hereby declare that this work, neither as a whole nor as a part there of has been copied out from any source. No portion of the work presented in this report has been submitted in support of any application for any other degree or qualification of this or any other university or institute of learning. We further declare that the referred text is properly cited in the references.

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Tools Used:

- Arduino IDE
- Android Studio (java)

Abstract

We plan to design a portable uroflowmetry device named as URO-CALC that is capable enough to determine urine flow rate accurately, efficiently and cost effectively. The uroflowmetry device also includes the feature of plotting the urodynamics (flow rate, volume etc.) wirelessly using statistical tools at run time. The design of the proposed device will be built using strong foundations of the embedded system and data analytics. Our system will be comprised of a weight transducer, A/D converter, Arduino Uno, Rechargeable battery, Bluetooth module, laser printer and a device (base station) to run the application. It is observed that urine diseases are common nowadays[1] like bladder cancer, prostate cancer and urinary blockage[2]. The challenge is to diagnose these diseases at early stages by performing appropriate urine tests like uroflowmetry test, urine culture test etc. [3]. Moreover, the existing uroflowmetry devices are so much expensive that a common person is not capable of bearing the huge cost of a test and the disease remain undiagnosed. Our aim is to design accurate, cost efficient, portable, wireless, easy to operate and intelligent device with the capability of generating customized test reports. Patients with urine flow problems need to visit hospital multiple times for a proper diagnosis through uroflowmetry test. Therefore, our proposed device will be cost effective with easy operating mechanism. One of the vital goals is to provide ownership to the citizens so that they can make the best use of the device anytime anywhere as per their desire. This project involves modern tools usage with a great societal impact. The idea has a wide scope in terms of futuristic research and innovation. URO-CALC is a worthwhile product for revenue generation at National and international level

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List of Abbreviations

UTI	Urinary Tract Infection
FYDP	Final Year Design Project
ICT	International Continence Society
NLM	National Library Of Medicine
LUTS	Lower urinary Tract Symptoms
PVR	Post Void Residual

Chapter 1
Introduction

This chapter contains brief motivation/background information about the project, problem statement, objectives, the methodology implemented for problem-solving, and the outlines of the results and future scope of the project. It also contain graphical illustrations for better understanding of work.

1.1 Motivation

Urine diseases are common nowadays like bladder cancer, prostate cancer, UTI or urinary blockage. To diagnose such diseases at early stages to avoid severe diseases such as permanent kidney failure, it is important to do uroflowmetry test. Actively used uroflowmetry devices are expensive, environment specific, gender specific, with difficult operating mechanisms and limited features. It is observed that uroflowmetry devices installed in clinics need a controlled environment for the reliable and accurate uroflowmetry procedure. Moreover, it is noticed that uroflowmetry device must be user friendly (user will be able to perform test itself) to save the cost of trained professionals deputed dedicatedly for performing the uroflowmetry test. Due to high cost of devices citizens are impotent to bear the cost of test and the disease remain undiagnosed. If the device cost will be low automatically test price will reduce that will make the process reliable for common person. Motivated from the deficiencies mentioned above, our aim is to design and develop a uroflowmetry device with the capability to perform uroflowmetry test accurately, efficiently, cost effectively with high embedded intelligence. Our desire is to design a compact and portable hardware (device) with easy working mechanism and the ability to generate a customized report. It will provide ownership to citizens so that they can make the best use of the device anytime anywhere as per their desire.

1.2 Project Overview

The project aimed to develop a product that enables the measurement of urodynamics for the diagnosis of different urine diseases via smartphone application. The main objective is to design a cost effective, portable and easy to use uroflowmetry device that can be used by patient at home comfortably[4][5]. The device is used to work with a mobile application that plot the real time data received by the Arduino via Bluetooth wirelessly. Moreover, the report will be generated at the end of the process and the reports data will be stored in app data base for further analysis.

The project is implemented in following steps:

- ❖ Design and development of basic circuitry interfaced with Arduino board.
- ❖ Interfacing of Bluetooth communication module with Arduino and enable wireless communication between Arduino board and mobile device.
- ❖ Development of mobile application using android studio that will receive the data at real time and plot that data for better visualization of uroflowmetry curves.
- ❖ Integration of hardware into a compact device that is portable and easy to use.
- ❖ Testing of device and analysis of accuracy.

The final outcome of the project will be cost effective, accessible and portable uroflowmetry device with advance features and standard accuracy.

1.3 Problem Statement

Urinary tract infections (UTIs) are some of the most common bacterial infections,[6][7][8] affecting **150 million** people each year worldwide. Urine diseases are common nowadays like bladder cancer, prostate cancer or urinary blockage. To diagnose such diseases at early stages, it is important to do uroflowmetry test. Actively used uroflowmetry devices are expensive, environment specific, gender specific, with difficult operating mechanisms and limited features. Recently, proposed uroflowmetry devices have unique approach and specific dynamics. It is observed that uroflowmetry devices installed in clinics need a controlled environment for the reliable and accurate uroflowmetry procedure. Moreover, it is noticed that uroflowmetry device must be user friendly to save the cost of trained professionals deputed dedicatedly for performing the uroflowmetry test properly. For the diagnosis of UTI diseases, patients usually consult urologist multiple times and sometimes need hospitalization. In comparison, doing such examination at patient’s home is more effective for conducting the test multiple times with patient’s ease to achieve average accuracy. Due to high cost of devices citizens are impotent to bear the cost of test and the disease remain undiagnosed.

Motivated from the deficiencies mentioned above, our aim is to design and develop a uroflowmetry device with the capability to perform uroflowmetry test accurately, efficiently, cost effectively with high embedded intelligence. Our desire is to design a compact and portable hardware (device) with easy working mechanism and the ability to generate a customized report. It will provide ownership to citizens so that they can make the best use of the device anytime anywhere as per their desire.

1.4 Project Objectives

- ❖ Designing of a cost effective uroflowmetry device through incorporating a simpler hardware with easy gravimetry phenomenon.
- ❖ Accurate calibration of weight scale to meet the accuracy standards provided by ICS (International Continence Society)[9].
- ❖ Development of a user-friendly android application for better visualization of urodynamic curves and to save the previous test reports of the patients and save the cost of trained staff deputed dedicatedly for the proper operation of uroflowmetry device.
- ❖ Proposing a portable solution through compact hardware.
- ❖ Providing a wireless connectivity between app and the hardware for smart information sharing.
- ❖ Designing of a market competitive cost effective uroflowmetry device by minimizing the hardware to develop a compact design with enhanced characteristics.

1.5 Brief Project Methodology

The methodology opted for project development is as follows:

Step 1: Development of accurate weight scale with gravimetry technique to meet the ICS standards of flow rate for uroflowmetry using Arduino coding.
Step 2: Code writing for Arduino Uno to display the desired result on serial monitor.
Step 3: Temporary placement of hardware for perform the test to analyze accuracy.
Step 4: Plot the volume vs time and flow rate vs time in MS excel and analyze results.
Step 5: Using the foundations of app development creation of an android application for better visualization for urodynamic curves.
Step 6: Integration of Bluetooth module HC 05 and wireless transmission of data to application
Step 7: Extraction of prominent features (i.e. average flow rate and max flow rate) of test report for the better understanding of urologist.
Step 8: Generation of real time, high quality, and color report with customizable headers according to hospital name or patient bio data.
Step 9: Development of compact hardware and designing of prototype.

Operating mechanism of device is simple and known as gravimetry, i.e. weighting of voided urine dynamically. A load cell is used as a weight transducer which send analog signal to hx711 which is basically a load cell amplifier as well as analog to digital converter. It will convert the analog signal to digital and amplify the signal as well. The digital signal is fed to

Arduino which is programmed to calculate the flow rate and show on serial port as per user commands. The acquired data is then transmitted to application using Bluetooth connectivity. Application will be capable to plot the curves accurately and show the prominent features of graph on screen at run time. Then a customized report will be generated.

Time of the beginning of the urination and time to start test are not identical. The precision in extracting exactly the same time is crucial. Therefore a start and stop button is there to start the test when patient start urination to increase the precision of the system.

1.6 Report Outline

This report presents the development and evaluation of an app-based advance and portable uroflowmetry device. The introduction provides background information, project objectives and report structure. The literature review examines the principles of uroflowmetry, existing devices, recent advances, and application-based solutions. The methodology section details device design, sensor selection, mobile application integration, testing and ethical aspects. The system description describes the hardware components, mobile application features, user interface, and data storage and connectivity options. Validation and performance evaluation include experimental setup, data collection, statistical analysis, and accuracy evaluation. User experience and feedback examine acceptance, usability and suggestions for improvement Future directions and challenges highlight potential improvements, regulatory aspects, and technical obstacles. The conclusion summarizes findings, contributions, implications, and concluding remarks.

Chapter 2
Literature Review

This chapter contains the comprehensive review of the related research on the topic. It also relates the current work with the previous one. It also includes the limitations and the contribution to overcome the unavoidable factors affecting the performance of the device.

In addition, it forms the basis for the creation of research hypotheses and the selection of suitable research methodologies. Overall, this literature review chapter presents a synthesis of existing knowledge, identifies areas for further investigation, and sets the stage for the following chapters of the thesis.

2.1 Background of Project/Topic

Uroflowmetry is a diagnostic procedure commonly used in urology to measure and evaluate urine flow during urination. It provides valuable insights into the functioning of the urinary system and is essential for the diagnosis and monitoring of various urological conditions such as urinary tract obstruction, bladder dysfunction and prostate enlargement. Traditional uroflowmetry devices have limitations in terms of portability, user-friendliness, and data management.

With rapid advances in technology, the development of portable and advanced app-based uroflowmetry devices has gained momentum. These devices integrate state-of-the-art sensors, wireless connectivity and smartphone applications to provide a more affordable, convenient and advanced solution for uroflowmetry testing.

Portable and advanced uroflowmetry devices typically consist of a compact and lightweight sensor or urine collection device that is connected to a smartphone or tablet via Bluetooth or other wireless technology. A companion mobile application captures and analyzes urine flow data and offers real-time measurements, graphical representation and advanced analysis capabilities.

The introduction of portable and advanced app-based uroflowmetry devices offers several advantages over traditional methods. First, these devices provide greater portability and flexibility, allowing patients to perform uroflowmetry tests in the comfort of their own home or at any location of their choice. This eliminates the need for frequent visits to medical facilities and offers a more convenient and patient-centered approach to urological diagnosis.

Second, the advanced features and functions of these devices increase the accuracy and reliability of uroflowmetry measurements. Mobile apps can provide real-time feedback, allowing patients to ensure proper testing technique and achieve more consistent results. In addition, advanced algorithms and data analysis capabilities integrated into the app can provide a comprehensive view of urine patterns, flow characteristics and other parameters, aiding in the diagnosis and treatment of urological conditions.

In addition, it allow patients to actively participate in their own health care[10][11] as displayed in Figure 1. User-friendly interfaces, interactive visualizations and personalized data tracking allow patients to track their urinary health, track progress and communicate more effectively with healthcare providers. This promotes patient engagement, self-management and early detection of potential problems, leading to improved patient outcomes.
However, the development and implementation of device requires rigorous testing and evaluation. Factors such as accuracy, reliability, user experience, data security, and interoperability with different smartphone platforms need to be thoroughly assessed to ensure their effectiveness and safety in the clinical setting.

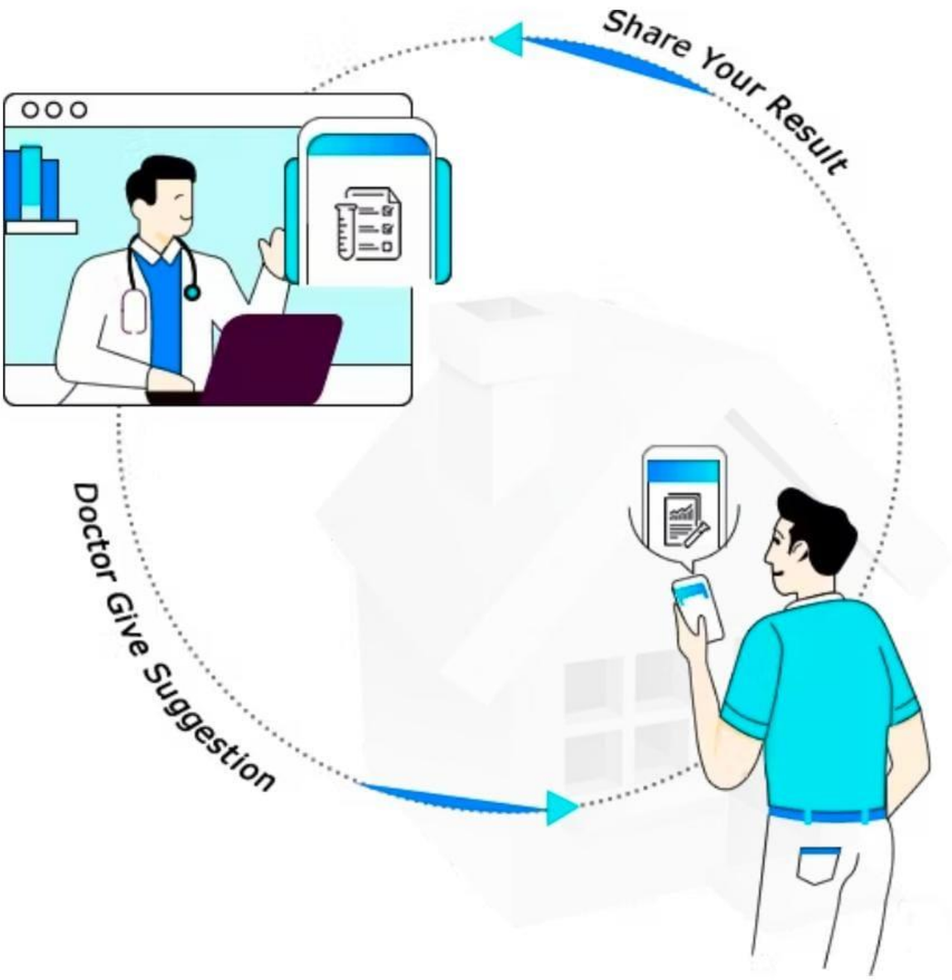

Figure 2.1: Self-Monitoring of Health

Understanding the background and significance of portable and advanced app-based uroflowmetry devices is critical to evaluating their potential impact on urologic diagnosis, patient care, and the overall advancement of urology. By leveraging the capabilities of modern technology, these devices have the potential to revolutionize uroflowmetry testing, improve the patient experience, and increase the accuracy and efficiency of urological evaluations.

2.2 Related Work

Urinary track diseases affect the quality of life specifically for old age people[12]. According to google statistic it affect millions of people annually specially women because there urethras are shorter and close to rectum. The shape of the uroflowmetry curve may indicate an abnormality in the urinary tract[13], however, further diagnosis is required to identify the cause of the abnormality. Urine flow, detrusor contractility, bladder flow resistance, bladder volume and the measurement technique itself are influenced by several factors.

One of the most common method used for the diagnosis of UTI is uroflowmetry[14][15][16]. Uroflowmetry can be performed using different techniques while each technique have its unique approach and specific dynamics. One of the technique used in known as spinning disc method [17]. The urine fell onto the spinning disc which is driven by a servo motor. A constant spinning speed is maintained. The speed of the spinning disc increase due to the weight of the urine. The power needed to rotate disc at constant speed is Q which is used to generate the flow diagram of urine. The flow cycle of above mentioned method is shown in Figure 2.

The rotary disc flowmeter works on the principle of rotary movement. It consists of a disk with a central axis, which is connected to a flow sensor. As urine passes through the device, it hits the disc and causes it to rotate. The speed of rotation of the disk is directly proportional to the flow of urine. During uroflowmetry testing, the patient urinates into uroflowmeter equipped with a rotating disk. Urine flows through the inlet of the device and comes into contact with the rotating disk. When the urine hits the disc, it imparts a force that causes the disc to rotate. A sensor or sensor attached to the disc measures the rotational speed and converts it into a flow value.[18]

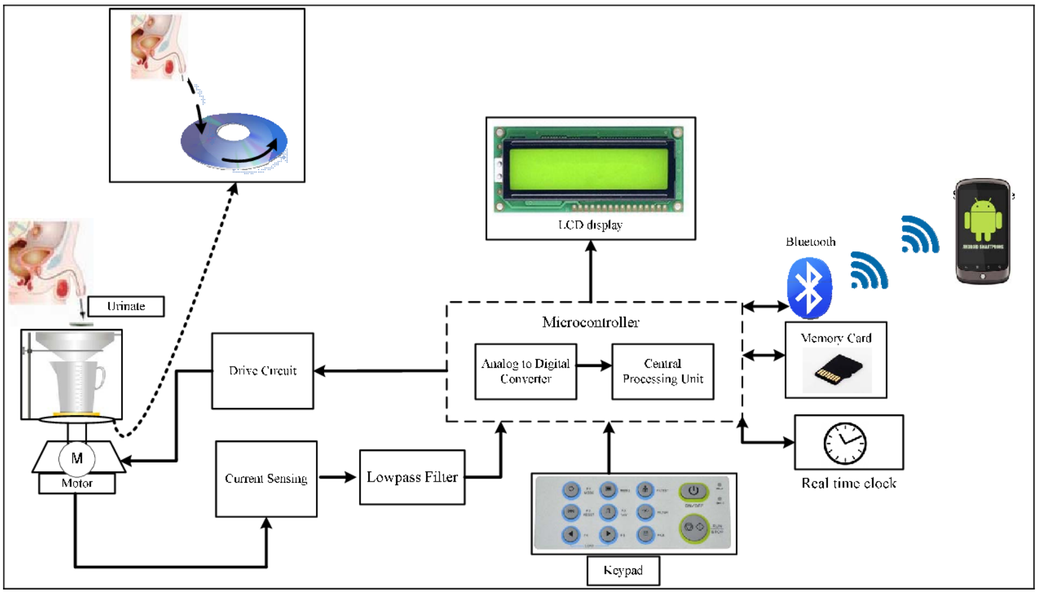

Figure 2.2: Spinning disc method

This technique will be proved beneficial when we place the mechanism in home used toilets. But as the hardware is expensive so it will increase cost. The drawback of this technique is its long reconstruction time which make it unable to use in daily clinical practice. Moreover the structure is complex with difficult operating mechanism and high expense.

The other technique used for uroflowmetry is called capacitance based uroflowmetry. It need a metal strip capacitor which is attached to dipstick vertically and dipped into the urine container. Due to conduction of electricity the overall capacitance will change. The change in capacitance is equal to the flow rate. For performing this technique a controlled environment is required as well. Due to low accuracy capacitance technique is not widely used.

The next technique is gravimetric technique which has simple phenomenon and widely used commercially. Gravimetry is basically weighting of voided urine dynamically[19]. A weight transducer is used to determine weight of urine through which we will be able to determine the flow rate. Hardware used in this mechanism is not expensive and it doesn't need a controlled environment to work properly. A patient will be able to perform test at any place as per their desire[20]. It is concluded that max flow rate is measured by self-conducted uroflowmetry not by assistant supervised uroflowmetry, which ensure patient's privacy.

Due to above mentioned advantages of gravimetric method we will be using this technique for development for our project.

2.3 Project Contribution

The project is an advancement in the currently available uroflowmetry device. The contributions of the project are as follows:

- ❖ URO-CALC is a market competitive, cost effective uroflowmetry device by minimizing the hardware to develop a compact design with enhanced characteristics.
- ❖ URO-CALC provides the user friendly and adaptive app based system. Android app will be able to plot the urodynamics at run time.
- ❖ The test report includes different report evaluation parameters i.e. max flowrate, time to max flow etc. which are calculated automatically for the better understanding of uroflowmetry report.
- ❖ The requirement of trained professional for operating of device become unnecessary due to easy operating mechanism of device.
- ❖ The device includes the feature of digital calibration according to ICS standards.
- ❖ The system will be able to maintain the record of previous patient's history. There is no need to maintain the data in hard document form.
- ❖ URO-CALC is a worthwhile product for revenue generation at National and international level.

2.4 Summary

The project aimed to design and develop uroflowmetry device with enhanced features to transform the traditional method of test into convenient and user friendly procedure. The health care sector is revolutionized by monitoring of patients health using smart phone. Moreover, the emergence of app based uroflowmetry device enhanced the convenience and efficiency of urological diagnosis. Extensive calibration and testing procedure were conducted to ensure the accurate results. The device demonstrated accuracy comparable to traditional uroflowmetry machines, ensuring reliable measurements for diagnosing and monitoring urological conditions. Results are validated by comparing the results of URO-CALC and standard uroflowmetry device. The outcome of project hold significant promises in the field of urology, improving patient's care and it also revolutionize the medical sector.

Chapter 3
System Design and Implementation Details/Design Procedures

This chapter includes all the in-depth information about the projects implementation. This chapter also involves the basic theoretical information about each and every component & aspect of the project, such as hardware assembly, application designing, methodological details, software implementation, and so on. The appropriate information is accompanied by pictorial representations, diagrams, flow charts and graphical illustrations.

3.1 System Design

The integration of hardware components, software architecture and user interface is a crucial phase for the completion of project. Section 3.1.1 includes the comprehensive description of system architecture. It also includes multiple flow charts for better understanding of cycle.

3.1.1 System Architecture/Flow Diagram

The section includes the description of work through flow diagrams. Where Figure 3 represents the work cycle of whole working mechanism and Figure 4 represents the working of android application for better understanding of device. Load cell is a weight sensor that transmit weak electrical signal to load cell amplifier which transmit the digital and amplified signal to control unit (Arduino Uno). The programmed Arduino send the desired output wirelessly to android app as shown in figure 6**.**

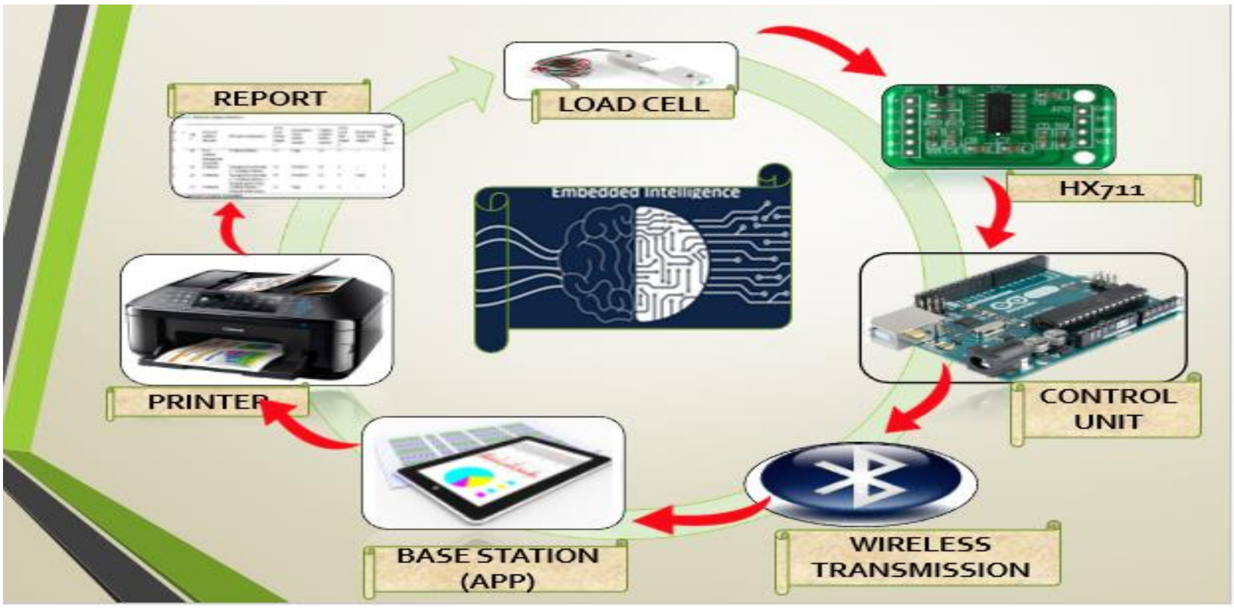

Figure 3.1: Flow chart of working mechanism

Further, after receiving data android app continue the process as shown in Figure x. Bluetooth connection of device Bluetooth with Arduino Bluetooth module HC-05 is established initially. After successful connection patient personal data will be entered for record. Than user will start passing urine after pressing start button and stop button will be pressed after completion. Pdf report with all parameters will be generated by pressing create pdf button. Moreover application will maintain all the previous history of the user.

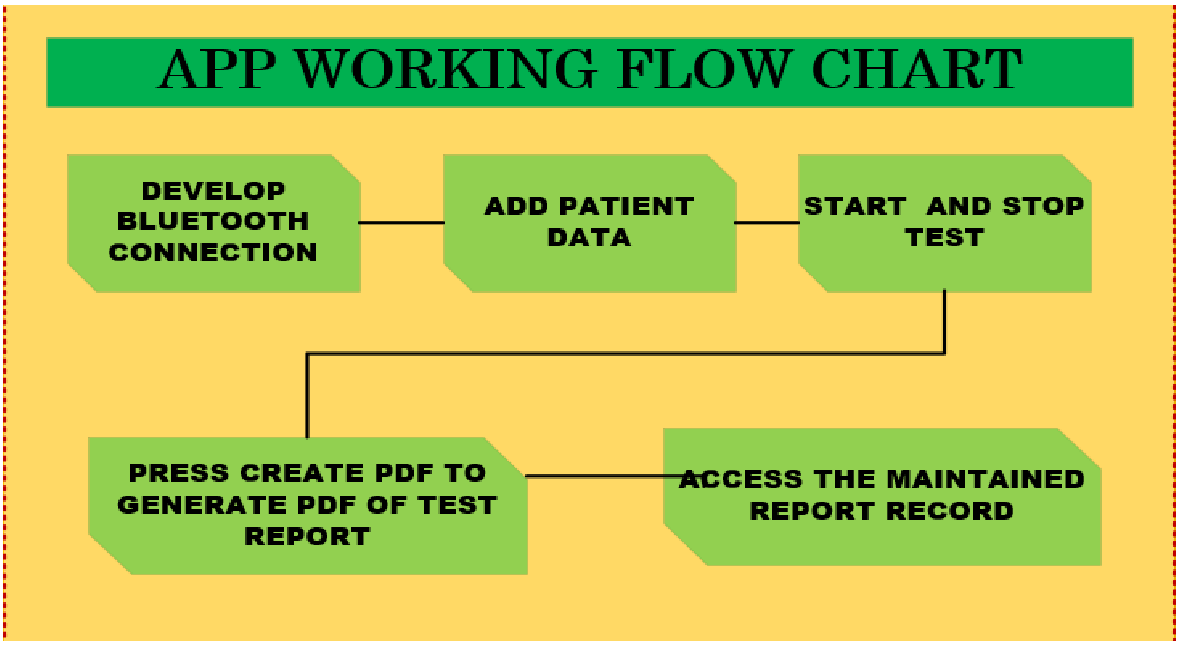

Figure 3.2: App working flow chart

3.2 Methodological/Implementation/Experimental Details

The implementation of the project is divided into different phases.

Design and build the Basic hardware:

At the initial stage its necessary to design a weight machine using Arduino though which we will extract the flow rate. We used load cell weighing 1kg and its driver circuit connected with programmed Arduino. The Arduino is programmed for the dynamic output. So that the user will get the readings at the desire time by sending the start test and stop test key. The output of the Arduino at that stage is weight and time of the observed weight reading. The output will be in the form of packet, where each packet will be in the form of (weight, time) as shown in Figure 5.

Initially, a stand is designed for the testing of the hardware. To observe the basic working of the device the reading are copied manually from the serial monitor and plots for flowrate and volume are plotted in MS Excel. Moreover, Flowrate is derived manually by taking derivative of volume with respect to time.

For the accurate reading it is important to calibrate the device properly. So that we have digitally calibrated our device using the calibration factor method.

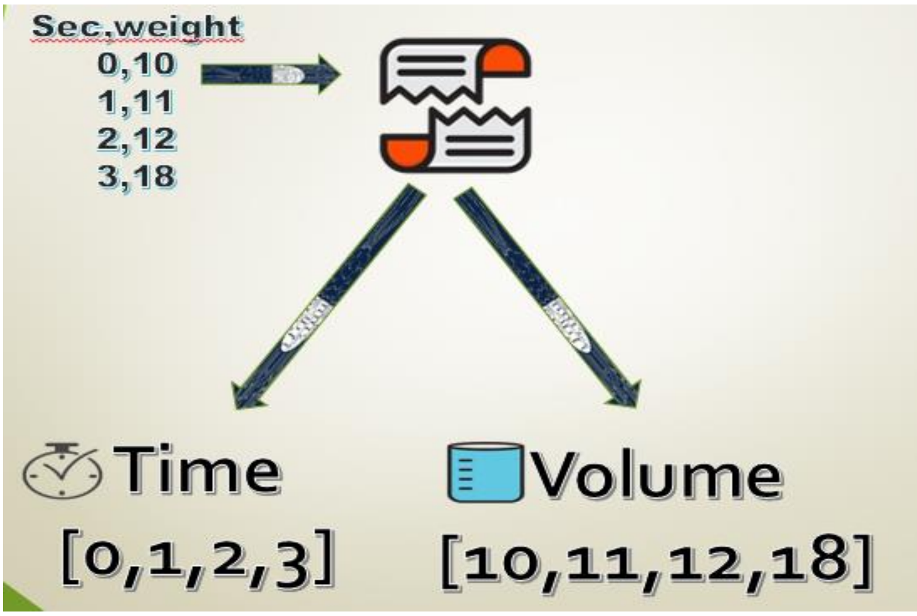

Figure 3.3: Transmitted data from Arduino

Development of android application

Initially an android app is developed with basic functionality of receiving data using Bluetooth connection and plotting of data after multiple computations. The data is split into two arrays as shown in Figure 5. The received data is initially observed on the screen before plotting as shown in Figure 6 then by applying formulas the desired data is plotted using android charts on screen.

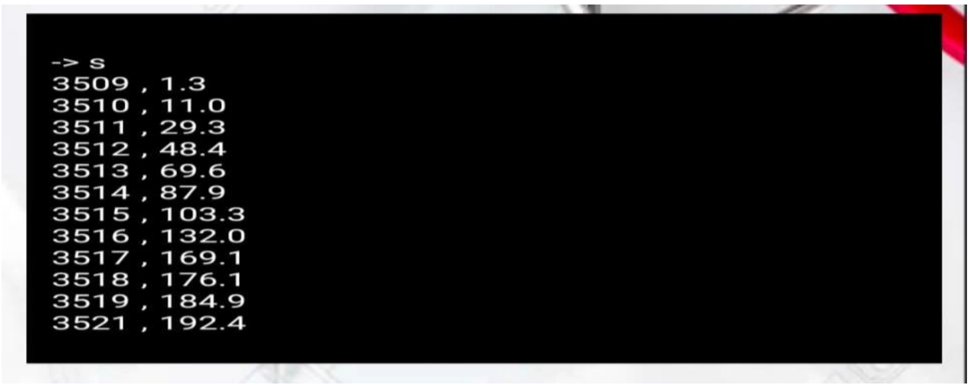

Figure 3.4: Wirelessly received data by Application

After observing the basic functionality of the app we started adding multiple features. Next step was to add a tab for manual entry of the patient data as shown in Figure 7.

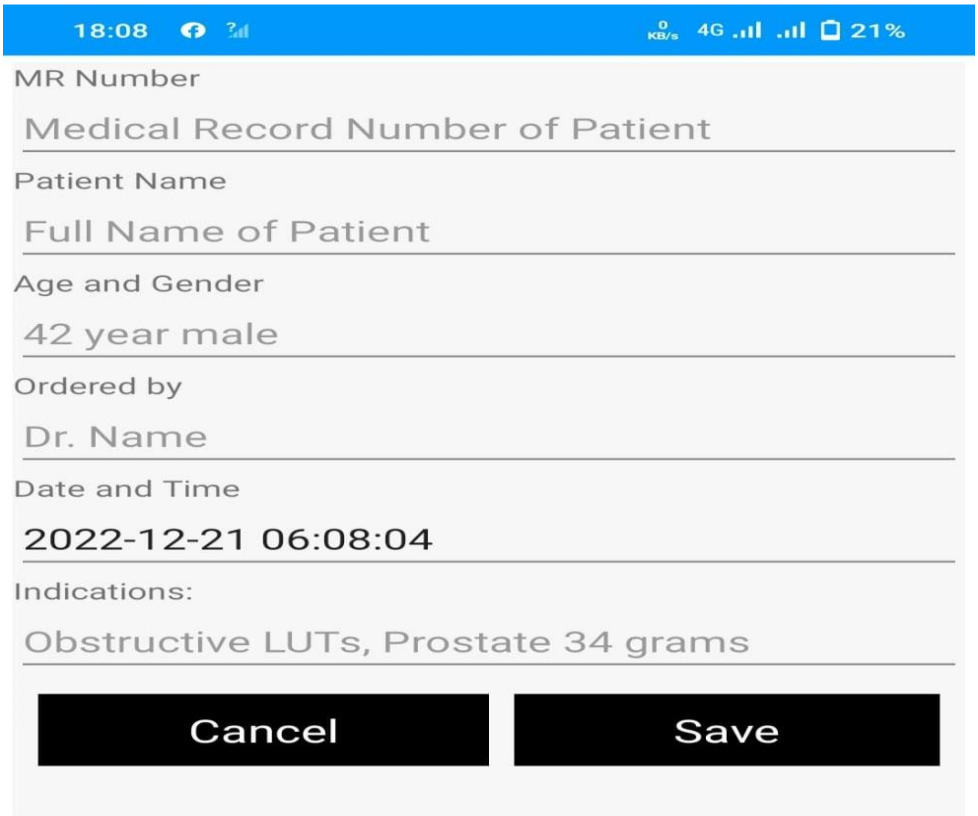

Figure 3.5: Tab for patient's data entry

The next essential step was to create a professional pdf report which includes the patient's data, uroflowmetry plots and multiple parameters extracted from the curves such as max flow rate, time to max flow and max volume etc. and siroky nomograms. Moreover the app will also be able to maintain the record of previous patient reports. The sample pdf report is shown in Figure 8.

Prototyping and Testing

In this phase, the device is tested and hardware is assembled in a final delicate design. The correctness of the device reading is observed through multiple tests. In the first section, it is observed that either the device is providing the expected curves or not. The expected curves for different types of patients are shown in Figure 9.

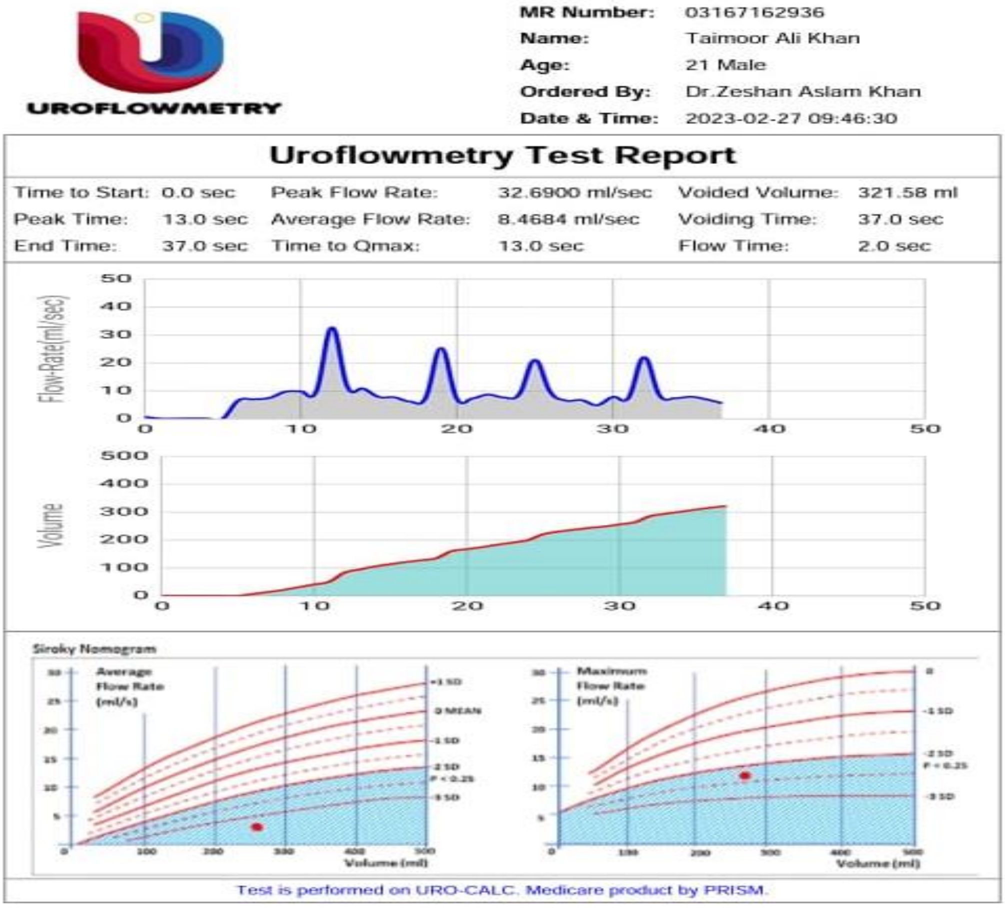

Figure 3.6: Automatically generated pdf report of uroflowmetry test

Further the results of similar patients are compared after performing test on URO-CALC and other available devices to verify the authenticity of the device. At the end the hardware assembly of device is designed delicately and professionally.

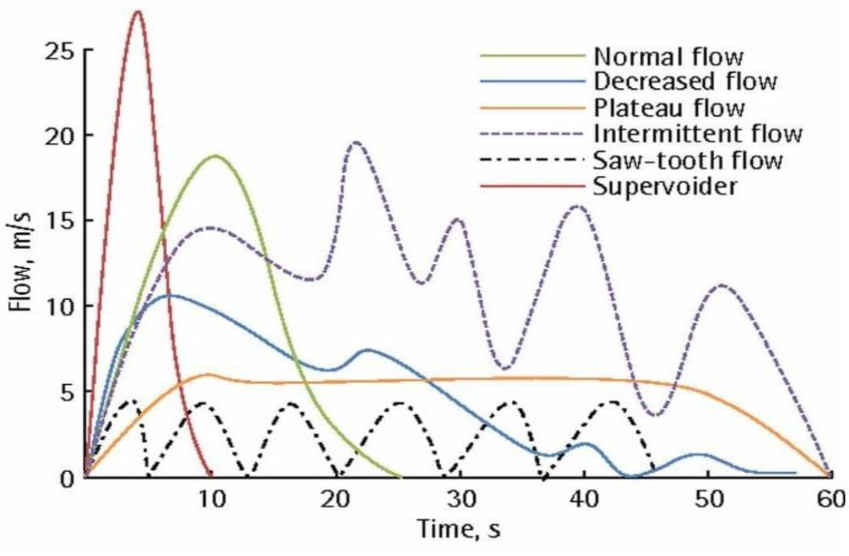

Figure 3.7: Common flow patterns of urine patients

3.2.1 Hardware/Development Setup

The hardware assembly of the device is shown in Figure 10.

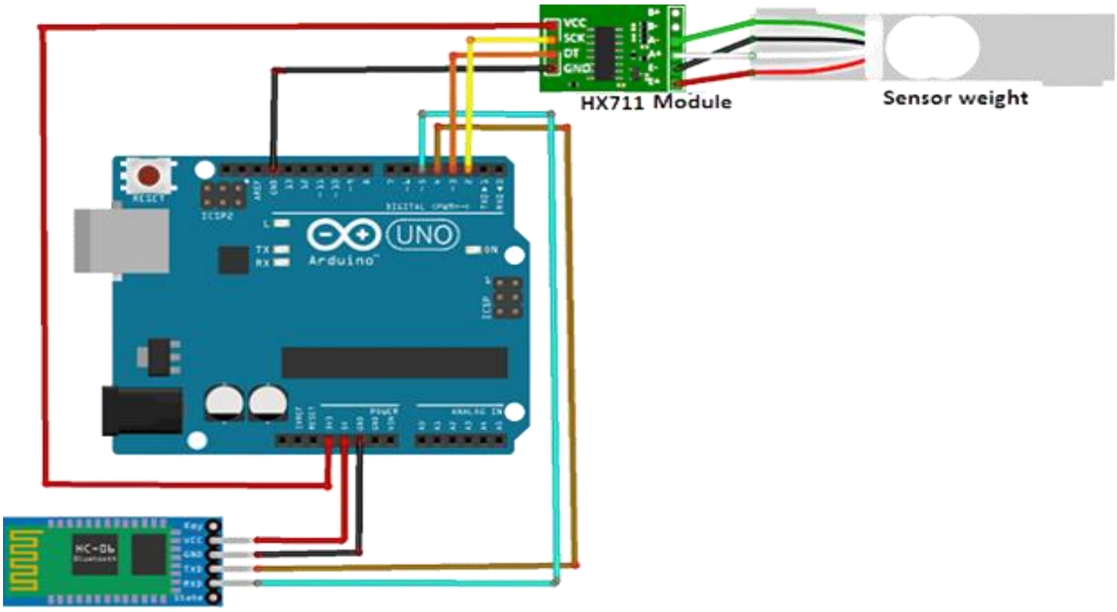

Figure 3.8: Hardware Connection Scheme

3.2.2 Hardware Details

Arduino Uno

The Arduino is a microcontroller board based on ATmega328P microcontroller. It has 14 digital input/output pins, 6 analog input pins and a 16 MHz quartz crystal. The Arduino Uno serves as a versatile and cost-effective microcontroller board for the production of uroflowmetry device. Its capabilities in sensor integration, data processing, display and user interface, data logging and storage, connectivity and customization make it an attractive choice for creating uroflowmetry devices that are accurate, user-friendly and adaptable to specific needs.

Bluetooth module (HC-05)

HC05 is Bluetooth module used for the wireless transmission of data from Arduino to android application. It is based on the Bluetooth 2.0 standards and support the serial port profile (SPP) which enables it to act as a virtual serial port. The range of module is up to 10 meters.

HX711

Hx711 is an integrated circuit (IC) that act as an analog to digital converter as well as an amplifier. It convert the analog signal to digital signal that id further processed by microcontroller. The HX711 includes a high-resolution analog-to-digital converter that enables accurate conversion of analog signals to digital values. Provides selectable gain settings to accommodate different load cell configurations and required measurement ranges. The high resolution of the ADC ensures accurate and detailed measurement of weight or force, which is crucial for determining urine flow rate in a uroflowmeter device

Load cell (1kg)

Load cell measures the weight by converting the applied force into electrical signal. As urine flows it exerts a force on the load cell. The strain gauges change their electrical resistance and creates a small electrical signal which is further amplified.

Urine flow measurement:

In a uroflowmeter device, a strain gauge is integrated into the urine flow path, typically in a collection funnel or urinal container. As urine flows through the device, it applies a force or load to the load cell. This force will cause deformation of the flexible element of the strain gauge, which will subsequently change the resistance of the strain gauges. The strain gauge converts this change in resistance into an electrical signal, which is then processed and analyzed to determine urine flow.

Stand

A portable stainless steel stand is designed on which all the hardware modules are assembled. The stand is adjustable according to height of patient.

Moreover, beakers, funnels, jumper wires, weight stones and vero board are also required for manufacturing of device.

3.2.3 Software/Tools

Arduino IDE

The role of Arduino integrated development environment (IDE) is to program and control the microcontroller for performing desired operation. It also program the microcontroller that interface with the various component of the device. This feature is particularly useful for uroflowmetry devices as it allows patients to perform tests at home while securely transmitting data to healthcare providers or to a centralized database for analysis. The

Arduino IDE offers libraries and functions to implement wireless communication protocols, facilitating seamless integration into uroflowmetry equipment.

Android Studio

Android studio provide environment for designing of android applications. In our project Android studio is used to develop a mobile application that connects the device via Bluetooth. The application provides a user friendly interface for controlling device and better visualization of urodynamics with additional features. Here are some important aspects of Android Studio's functionality in this context:

Application development:

Android Studio provides a comprehensive Android application development environment, making it an ideal choice for creating the application component of a uroflowmetry device. Developers can use the Java programming language to create the application's user interface, data processing algorithms, and communication protocols.

User Interface Design:

Android Studio includes a visual layout editor that simplifies the design and creation of an application's user interface as shown in Figure 11. Using drag-and-drop functionality, developers can easily arrange user interface elements such as buttons, text boxes, and graphs to provide a visually appealing and intuitive user experience for uroflowmetry devices.

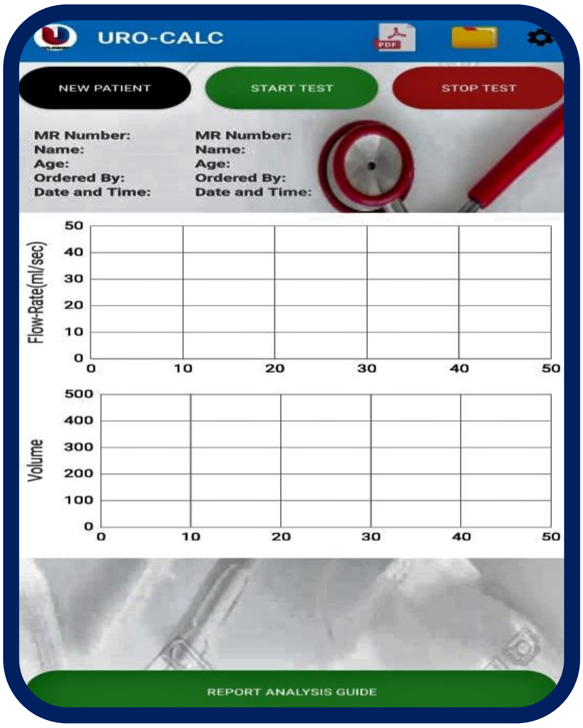

Figure 3.9: User Interface of App

Data acquisition and processing:

Android Studio enables seamless integration with various sensors and data acquisition methods. In the case of uroflowmetry device, it can communicate with external devices or sensors, such as Bluetooth-enabled flow meters or pressure transducers, to capture and collect real-time data. The obtained data can then be processed within the application using algorithms implemented in Java.

Connectivity and communication:

Android Studio provides extensive libraries and tools for establishing communication between an application and other devices or services. This feature is essential in app-based uroflowmetry devices as it enables wireless data transfer between the device and external platforms such as cloud storage or medical databases. Bluetooth, Wi-Fi or Internet connection can be implemented for seamless data transfer and remote monitoring.

Data storage and visualization:

Android Studio allows storage and retrieval of uroflowmetric data within the application or external databases. SQLite, a built-in database engine, can be used to store and organize data locally on the device. Additionally, Android Studio's graphical capabilities make it easy to visualize uroflowmetric data, such as flow graphs or urination patterns, improving the user's understanding and analysis of urine flow..

Chapter 4
Testing and Validation/Discussion

This chapter presents the results and discussion of a study conducted to evaluate the performance and effectiveness of URO-CALC. The chapter begins with an overview of the data collected and the statistical analysis performed. The findings are then discussed in detail, focusing on key results, trends and implications. In addition, the results are compared and contrasted with relevant literature to provide understanding of device performance.

4.1 Testing and Results

In order to evaluate the performance and functionality of URO-CALC series of different tests are conducted. The testing phase aimed to access the accuracy, reliability, user-friendliness and overall efficiency of device. The various tests performed during the evaluation process are discussed below.

4.1.1 Accuracy testing

The accuracy of URO-CALC is assessed by comparing the results of URO-CALC with standard uroflowmetry devices. Moreover the results parameters of healthy young person are compared with the probable result reading provided by NLM [21]. Figure 12 represent the uroflowmetry test report of 22 year old young and healthy person. The urodynamics are compared with NLM readings as shown in Table 1.

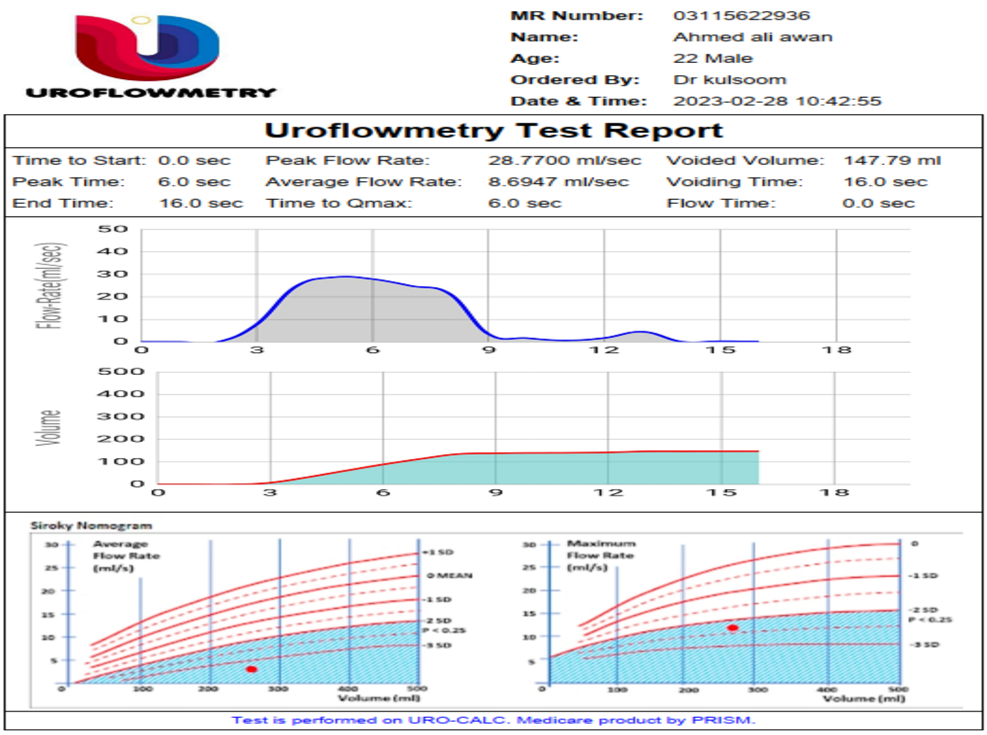

Figure 4.1: Report of a Healthy Person (male)

4.1.2 Performance Testing

The overall performance of the device is evaluated through multiple parameters including respond time, connectivity, response to different smart phone and android version. It is ensured that the android app is compatible with all android version including the latest android version 13. Further the device also provides fast connectivity and user friendly behavior.

4.1.3 Calibration Accuracy

It is important to calibrate a device accurately for the accuracy in final results[22]. The device is calibrated digitally using Arduino code. Initially reading received by the android device is weight and time. To check the calibration accuracy of the device a standard 100g weight stone was placed on the scale and observed the reading on the serial monitor as shown in Figure 13.

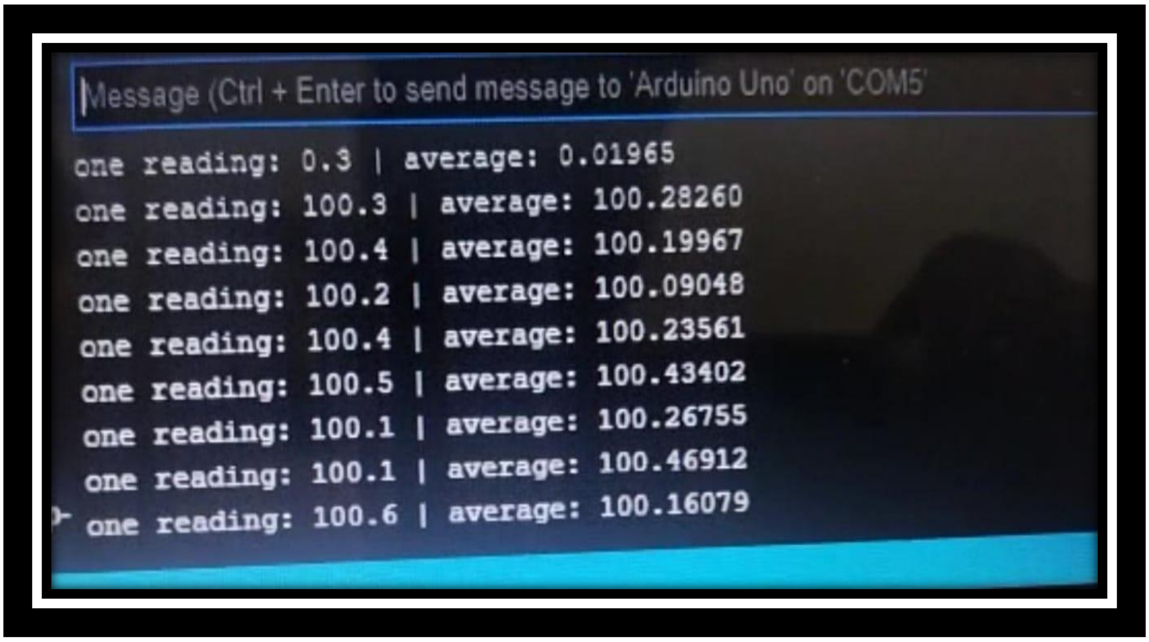

Figure 4.2: Serial monitor reading with 100g weight on scale

4.1.4 Results/Output/Statistics

Statistical analysis revealed that the portable uroflowmetry device showed a high level of accuracy and precision compared to the reference method. The average difference between device measurements and the reference method was found to be within an acceptable range, indicating minimal bias.

Figure 14 validates that error received at the output is <=0.06.

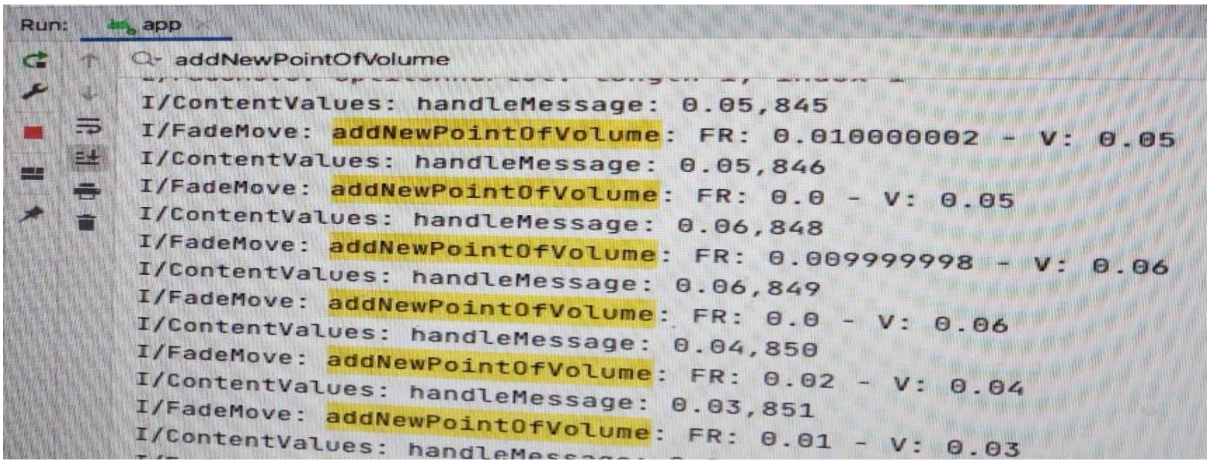

Figure 4.3: Error received at output

Further, the reliability of application in terms of wireless connection establishment, response time and friendliness of user interface is also ensured. Some of the snaps of the application are shown in Figure 15 and 16.

Figure 4.4: Application Interface (a)

Figure 4.5: Application Interface (b)

It is also ensured that the after performing test multiple time the performance of the app did not disturb. The application perform reliably on all android version inkling latest 13 version.

Table 1: Comparison of various flow parameters in between (16-50 years old), (>50 years old) male and URO-CALC results

Parameters evaluated(Mean ± S.D)	Group I (16-50 year) males (x = 262)	Group II (>50 year) males (x =239)	Results of URO-CALC Age (22 years)
Maximum flow-rate(ml/sec)	22.5 ± 9.2	17 ± 7.16	28.7
Average flow-rate(ml/sec)	13.05 ± 6.12	8.9 ± 4.06	8.6
Voiding time(sec)	37 ± 19.33	37.68 ± 19.08	16
Time to Q max	8.49 ± 3.82	10.94 ± 9.28	6

Chapter 5
Conclusion and Future Recommendations

The conclusion and recommendations part summarizes the whole report by highlighting all the chapters and their significance and the importance of the project and the achievements. The Recommendations are interlaced with the conclusion. The conclusion drawn from the project report can be further implemented in the recommendation section to overcome the constraints of the project.

5.1 Conclusion

In conclusion, the development and evaluation of the app-based uroflowmetry device have shown its potential as a reliable, user-friendly, and cost-effective solution for urological testing. The device demonstrated accuracy comparable to traditional uroflowmetry machines, ensuring reliable measurements for diagnosing and monitoring urological conditions. Additionally, the user-friendliness of the app and its compatibility with various smartphones and operating systems contribute to its convenience and accessibility.

The detailed explanation of Project objectives, development methodology and system architecture is also discussed in above chapters. Further the results and accuracy of device is also verified using multiple techniques as discussed in earlier sections.

The project have deep societal impact as it revolutionized the health care sector by providing ownership to citizens to make the best use of device. As the project was aimed to address the limitations in traditional uroflowmetry by providing the portable solution so URO-CALC offers numerous advantages over traditional process. The cost efficiency and advance salient features of URO-CALC prove him a candidate product for revenue generation.

5.2 Future Recommendations

There is always room for further enhancement and refinements. Future work recommendations as the extension of project are as follows:

- ❖ Post validation of results by using intelligent **Machine learning algorithms** for improved prediction of symptoms
- ❖ Authenticating the efficiency of the machine learning methods through benchmark datasets
- ❖ Verifying the performance of the methods via standard evaluation metrics.

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