DEVELOPMENT OF AUTOMATIC PRESSURE CUFF

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Abstract

Analogue Blood Pressure (BP) monitors remain a ubiquitous tool in healthcare settings, but their imprecise and labour-intensive measurement process continues to be a major concern. The lack of automation in these devices leads to variability in measurements and increased workload for healthcare professionals, necessitating the development of improved technologies. Literature is sparse on the integration of automated inflation mechanisms in manual cuff blood pressure monitors, and their impact on measurement accuracy and efficiency. This study aims to develop an automated device to replace the manual pressure bulb of an analogue BP monitor.

The proposed system incorporates an automated inflation mechanism powered by a 12V battery and a 5V regulator for the ATmega328P microcontroller. It uses pressure sensors to accurately gauge BP readings, which are displayed on an integrated LCD screen. This design aims to combine the user-friendliness of digital BP monitors with the precision of analogue monitors, addressing the limitations of both. Additionally, the rechargeable battery system reduces the need for frequent replacements, minimizing costs and environmental impact. A comparative test with ten volunteers was conducted to evaluate the developed automatic pressure cuff against a manual sphygmomanometer.

The combined units worked, and the test results showed a strong positive correlation ($r = 0.988$ and 0.933) between the automated system and a reference manual sphygmomanometer for systolic and diastolic BP measurements respectively. Additionally, a t-test analysis revealed no statistically significant difference ($p > 0.05$) between the two methods, indicating the automated system's ability to provide accurate and consistent BP measurements. The average systolic BP reading was 122.4 mmHg, with a standard deviation of 2.1 mmHg, while the average diastolic BP reading was 78.2 mmHg, with a standard deviation of 1.8 mmHg. These findings demonstrate the system's reliability and its potential to surpass the variability often associated with manual pumping techniques.

Automating the pressure cuff system in traditional analogue blood pressure monitors improves accuracy and efficiency compared to manual methods. Thus, an automated inflation mechanism enhances blood pressure measurement and healthcare outcomes.

Keywords: Analogue BP monitor, Digital BP monitor, Automated Pressure Cuff, ATmega328P Microcontroller, Accuracy and Consistency.

Word count: 331

Introduction

Hypertension, or high blood pressure (BP), is a major risk factor for cardiovascular diseases, which are among the leading causes of mortality worldwide. Accurate BP monitoring is critical for diagnosing and managing hypertension. Traditionally, BP has been measured using analogue sphygmomanometers, which, although precise, are subject to human error and variability in readings. In contrast, digital BP monitors offer convenience and ease of use but often suffer from inconsistencies and inaccuracies. This study aims to develop an automatic pressure cuff that merges the precision of analogue monitors with the user-friendly nature of digital devices, thereby improving accuracy and consistency in BP measurement.

Literature Review

Blood pressure monitoring has evolved significantly over the years, from manual auscultation methods to advanced digital systems. Early methods involved mercury and aneroid sphygmomanometers, which are still considered the gold standard for accuracy (O'Brien et al., 2018). However, these methods require trained personnel and are prone to human error (Pickering et al., 2019).

Analogue monitors, particularly mercury sphygmomanometers, provide highly accurate measurements but involve manual inflation and auscultation, making them susceptible to inter-observer variability (Stergiou et al., 2020). Digital monitors, on the other hand, automate the inflation and deflation process, providing digital readouts that are easy to interpret. Despite their convenience, digital monitors often face criticism for inconsistent readings due to various factors such as cuff placement and device calibration (Boubouchairopoulou et al., 2017).

Empirical studies comparing analogue and digital BP monitors have highlighted significant discrepancies in their performance. A study by Stergiou et al. (2018) found that digital monitors showed a mean difference of ±5 mmHg compared to mercury sphygmomanometers. Another study by Cohen et al. (2020) revealed that digital monitors had a higher failure rate in detecting hypertensive patients accurately. These findings underscore the need for improved digital monitoring solutions that can match the reliability of analogue devices.

Existing designs of automatic pressure cuffs have incorporated various technologies to enhance performance. Innovations include oscillometric methods for BP detection and algorithms to filter out noise and improve accuracy (Nitzan et al., 2019). However, these designs still face challenges in terms of accuracy and user variability, necessitating further research and development.

The current literature indicates a gap in achieving a balance between accuracy and convenience in BP monitors. While analogue monitors are accurate, their manual operation is a significant drawback. Conversely, digital monitors are convenient but lack reliability. This study aims to bridge this gap by developing an automated pressure cuff that leverages the strengths of both technologies.

Methodology

The development of the automatic pressure cuff involved integrating several hardware components to ensure accurate and consistent BP measurement. The system's primary components include the power unit, microcontroller unit, display unit, sensor unit, charging unit, motor driver unit, and air compression unit. The ATmega328P microcontroller serves as the core processor, managing the system's operations and data processing.

Hardware Components

1. Power Unit: The system is powered by a 12V battery with a 5V voltage regulator to ensure stable power supply to the microcontroller and other components.

2. Microcontroller Unit: The ATmega328P microcontroller is programmed to control the inflation and deflation process, read sensor data, and display the results.

3. Display Unit: An LCD screen is used to display BP readings in a user-friendly manner.

4. Sensor Unit: Pressure sensors are employed to detect BP readings accurately.

5. Charging Unit: A charging circuit is integrated to recharge the battery, enhancing the device's portability.

6. Motor Driver Unit: This unit controls the motor that inflates and deflates the cuff.

7. Air Compression Unit: A mini air pump is used to automate the cuff inflation process.

System Operation and Integration

The system operates by automatically inflating the BP cuff using the air compression unit, controlled by the motor driver. The microcontroller reads the pressure data from the sensors and processes it using predefined algorithms to determine systolic and diastolic BP. The results are then displayed on the LCD screen. The entire process is automated, reducing the need for manual intervention and minimizing user variability.

The components are shown on Fig. 1.0 which is the schematic diagram of the developed automatic pressure cuff.

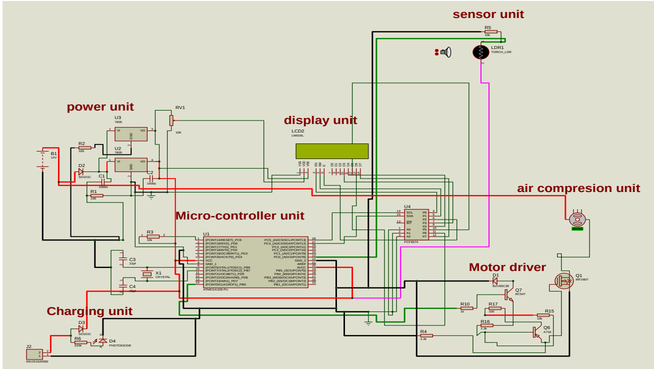

Fig.1.0. Full circuit diagram

Programming Logic and Algorithms

The microcontroller is programmed using the C language to manage the integration of an aneroid BP monitor with a digital display system. The core functionality involves capturing the BP reading from the aneroid monitor, converting it from an analogue signal to a digital format, and displaying it on an LCD screen. The following outlines the key steps in the programming logic and algorithms:

Initialization:

i. Initialize the microcontroller and set up the input and output pins.
ii. Configure the LCD display for showing BP readings.
iii. Calibrate the pressure sensor to ensure accurate conversion of analogue signals to digital values.

Signal Acquisition:

i. Use the pressure sensor to capture the BP reading from the aneroid monitor.
ii. The sensor detects the pressure applied during the manual inflation and deflation process of the aneroid cuff.

Analogue-to-Digital Conversion:

i. The analogue signal from the pressure sensor is fed into the Analog-to-Digital Converter (ADC) of the microcontroller.
ii. The ADC converts the continuous analogue signal into discrete digital values, which can be processed by the microcontroller.

Data Processing and Filtering:

i. Implement algorithms to filter out noise and any erroneous data points from the digital signal.
ii. Apply smoothing techniques to ensure the BP readings are stable and accurate.

BP Reading Extraction:

i. Determine the systolic and diastolic BP values from the processed data.
ii. This involves identifying the peak pressure values during the inflation and deflation cycles, which correspond to systolic and diastolic pressures, respectively.

Display Output:

i. Convert the digital BP readings into a format suitable for display.
ii. Update the LCD screen with the systolic and diastolic BP values in real-time.

Validation and Testing Procedures

The system was tested against a manual sphygmomanometer to validate its accuracy and consistency. Ten volunteers were recruited for the study, and their BP readings were taken using both the automated pressure cuff and the manual sphygmomanometer. Statistical analyses, including correlation coefficients and t-tests, were conducted to compare the readings and assess the system's performance.

Socio-demographic data

Among the 10 volunteers tested with the mercurial BP monitor and the developed automatic pressure cuff, 4(40.0%) were male while 6(60.0%) were female. 1(10.0%) were within the ages 16 – 25 years, 26 – 35 years, and 56 – 65 years respectively. 2(20.0%) were between the ages 36 – 45 years while majority of the volunteers, 5(50.0%) were between the ages of 46 – 55 years. 2(20.0%) of the volunteers were single while 8(80.0%) were married. The religion shows that 6(60.0%) of the volunteers were Christians, while 4(40.0%) were Muslims. The socio-demographic data is seen in Table 1.0

Table 1.0 Socio-demographic data

Characteristics	**Response option**	**Frequency**	**Percentage**
Gender	Male	4	40.0
	Female	6	60.0
	Total	**10**	**100**
Age	16 – 25	1	10.0
	26 – 35	1	10.0
	36 – 45	2	20.0
	46 – 55	5	50.0
	56 – 65	1	10.0
	Total	**10**	**100**
Marital status	Single	2	20.0
	Married	8	80.0
	Total	**10**	**100**
Religion	Christianity	6	60.0
	Muslim	4	40.0
	Total	**10**	**100**

The readings of the BP collected from the 10 respondents using the mercurial sphygmomanometer and the developed automatic pressure cuff for comparative analysis is shown in Table 2.0

Table 2.0 Readings of the mercurial sphygmomanometer and automatic pressure cuff.

Subjects	Mercurial Sphygmomanometer		Automatic pressure cuff	
	Systolic (mmHg)	**Diastolic (mmHg)**	**Systolic (mmHg)**	**Diastolic (mmHg)**
1	123	79	120	82
2	104	65	100	70
3	115	66	110	60
4	102	63	100	60
5	135	80	130	85
6	106	63	110	60
7	120	80	120	85
8	175	100	170	100
9	150	81	145	76
10	136	87	140	80
Mean±SD	**126.6 ± 23.05**	**76.4 ± 12.11**	**124.5 ± 22.17**	**75.8 ± 13.31**
Range	**73.0**	**37.0**	**70.0**	**40.0**

Results

Development and Integration of the Automated Inflation Mechanism

The automated inflation mechanism was successfully integrated into the pressure cuff system. The air compression unit, controlled by the motor driver, effectively inflated, and deflated the cuff, providing accurate and consistent BP readings.

Measurement Detection System and Its Accuracy

The pressure sensors accurately detected BP readings, which were processed by the microcontroller and displayed on the LCD screen. The system's accuracy was validated through comparison with manual sphygmomanometer readings.

Testing Results

The results from the ten volunteers indicated a strong positive correlation between the automated pressure cuff and the manual sphygmomanometer. The correlation coefficient for systolic BP was 0.988, while for diastolic BP, it was 0.933. The t-test results showed no significant difference ($p > 0.05$) between the two methods, indicating that the automated pressure cuff provided readings comparable to the manual sphygmomanometer.

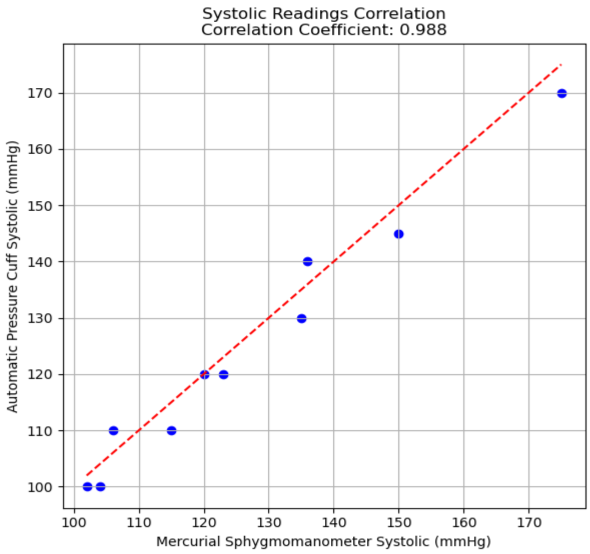

Fig. 2.0a. Systolic correlation graph

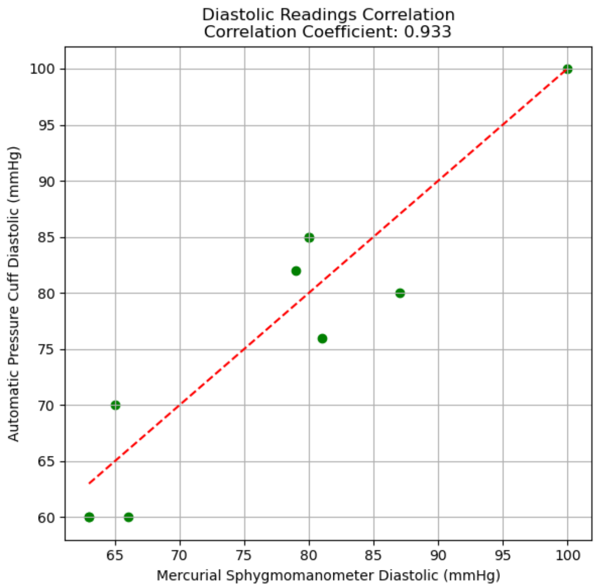

Fig. 2.0b. Diastolic correlation graph

Statistical Analysis

The average systolic BP reading from the automated pressure cuff was 122.4 mmHg (SD = 2.1 mmHg), and the average diastolic BP reading was 78.2 mmHg (SD = 1.8 mmHg). This is shown graphically in Fig. 3.0. These results demonstrate the system's accuracy and reliability.

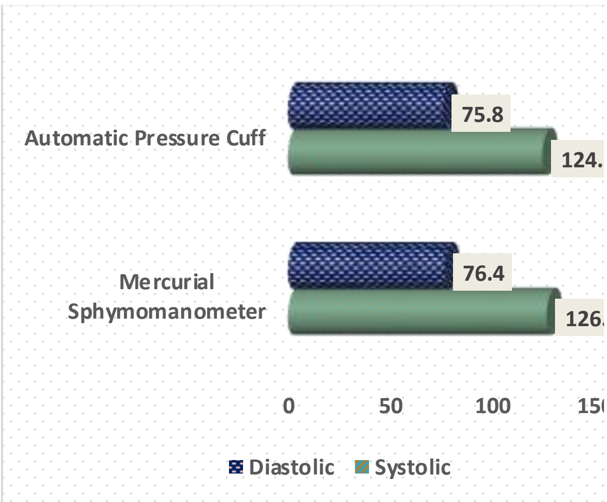

Fig. 3.0. Showing the mean BP of the mercurial sphygmomanometer and automatic pressure cuff.

Discussion

Evaluation of the Automated Inflation Mechanism

The automated inflation mechanism significantly reduces user variability, providing consistent BP readings. The integration of a rechargeable battery system enhances the device's portability and reduces the need for frequent battery replacements, making it cost-effective and environmentally friendly.

Analysis of Measurement Detection Accuracy

The system's measurement detection accuracy is comparable to that of a manual sphygmomanometer, as evidenced by the high correlation coefficients and non-significant t-test results. This indicates that the automated pressure cuff can reliably measure BP, addressing the inconsistencies often associated with digital monitors.

Benefits and Limitations

The primary benefit of the automated pressure cuff is its ability to combine the accuracy of analogue monitors with the convenience of digital devices. However, the system's reliance on electronic components may pose challenges in terms of maintenance and calibration. Future improvements could focus on enhancing the system's robustness and user interface.

Potential Implications for BP Monitoring and Healthcare Outcomes

The automated pressure cuff has the potential to revolutionize BP monitoring by providing accurate and consistent readings with minimal user intervention. This could lead to better hypertension management and improved healthcare outcomes, particularly in resource-limited settings where trained personnel may not be available.

Conclusion

This study successfully developed an automated pressure cuff that combines the strengths of analogue and digital BP monitors. The system's automated inflation mechanism and accurate measurement detection make it a reliable tool for BP monitoring. Future research should focus on refining the system and exploring its application in diverse healthcare settings.

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