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Prototype of a Portable Cardiopulmonary Resuscitation Device Using Microcontroller Technology

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***Abstract*— The objective of this study is to design and develop a portable cardiopulmonary resuscitation (CPR) device utilizing the Arduino Uno Atmega 328 microcontroller. The primary aim is to provide immediate first aid to individuals experiencing sudden cardiac arrest, thereby reducing the risk of mortality caused by delays in emergency response. The device is constructed using the Arduino Uno Atmega 328 microcontroller as its core component, integrated with a DC motor to facilitate the compression mechanism. It is further equipped with a pulse heart sensor to monitor the patient's pulse rate, which is displayed on a 16x2 LCD screen. This research adopts the Research and Development (R&D) methodology. The system is designed to be user-friendly and highly portable, ensuring practicality in emergency situations. The findings indicate that the device is capable of delivering chest compressions at a consistent rate of 80 compressions per minute. Moreover, the pulse detection feature demonstrates a high level of accuracy, with an error margin of only 1.29% when compared to a standard oximeter. These results highlight the potential of the device as an effective tool for emergency cardiac care.*Index Terms*—Alat Resusitasi Jantung Paru, Serangan Jantung Mendadak, Motor DC, Pulse Heart Sensor, Arduino uno Atmega 328**

I. Introduction

Cardiovascular diseases remain the leading cause of mortality worldwide, affecting over half a billion individuals globally. The number of deaths attributed to heart disease has consistently risen from 1990 to 2019, with an estimated 12.1 million fatalities in 1990, escalating to 18.6 million in 2019 (World Heart Federation, 2023).

In Indonesia, the prevalence of heart disease is significant. Based on physician-diagnosed cases, the prevalence of heart failure in Indonesia is 0.13%, while cases presenting symptoms account for 0.3%. The highest prevalence of physician-diagnosed heart failure is observed in Yogyakarta (0.25%), followed by East Java (0.19%), and Central Java (0.18%). Meanwhile, the highest prevalence of symptomatic heart failure is found in East Nusa Tenggara (0.8%), followed by Central Sulawesi (0.7%), with South Sulawesi and Papua both reporting 0.5% (Ministry of Health of the Republic of Indonesia, 2013).

Individuals with heart disease are at risk of experiencing sudden cardiac arrest (SCA), a condition characterized by the abrupt cessation of cardiac activity, leading to the sudden loss of blood circulation and oxygen supply. Victims of SCA typically lose consciousness within seconds to minutes due to insufficient blood flow to the brain. Without immediate intervention within a few minutes, this condition can result in death (Naser, 2019).

The primary first-aid response for sudden cardiac arrest is cardiopulmonary resuscitation (CPR). CPR is an emergency procedure aimed at restoring optimal function in cases of respiratory or cardiac arrest, thereby preventing biological death (Fitriasari, 2020). CPR is performed by compressing the chest to a depth of 5 to 6 cm, which generates blood flow and oxygen supply to the heart and brain (American Heart Association, 2015).

However, not all individuals are capable of performing CPR correctly. In cases of sudden cardiac arrest where no one is able to administer CPR, the only recourse is to contact medical professionals and await their arrival. This approach is highly ineffective, as immediate intervention is critical for survival. If a cardiac arrest victim does not receive treatment within 10 minutes, their chances of survival are significantly diminished (RSUP Dr. Kariadi, 2019).

II. Basic Theory

A. Cardiopulmonary Resuscitation

Cardiopulmonary resuscitation (CPR) is an emergency procedure aimed at restoring optimal function in cases of respiratory or cardiac arrest, commonly referred to as clinical death, to prevent biological death (Fitriasari, 2020). CPR is performed by repeatedly compressing the victim's chest to a depth of 5 to 6 cm (AHA Guidelines, 2015). Chest compressions are administered at a rate of 80 to 100 compressions per minute (Adzim, 2021).

Currently, CPR is still predominantly performed manually. To enhance the effectiveness of cardiopulmonary resuscitation, the development of a CPR device has been initiated. This device is designed to improve the precision and consistency of chest compressions, ensuring optimal outcomes during emergency situations.

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B. Relevant Research

Several studies have previously been conducted on cardiopulmonary resuscitation (CPR) devices. Among these is research by Kova De'la Vega in 2021, titled *Prototype of Cardiopulmonary Resuscitation*. This study utilized an Arduino Uno 328 microcontroller, an LCD to display compression counts, a TB6600 driver for motor control, and a NEMA 23 stepper motor as the actuator. The NEMA 23 stepper motor was connected to a metal plate using a belt, enabling the plate to move up and down. The speed of the plate's movement was regulated using the TB6600 driver. The device also included a belt tension adjustment button to ensure the belt's tightness, allowing the metal plate to deliver strong compressions (Vega, 2021).

A similar study was conducted by Lang Jiwa Noventra and Resmana Lim in 2020, titled "Cardiopulmonary Resuscitation Device". This research employed an Arduino Uno microcontroller, two NEMA 17 stepper motors as actuators connected to a plate via a belt, enabling the plate to perform up-and-down compressions. The device achieved a compression rate of 100 compressions per minute with a compression force of 1 Nm. An A4988 motor driver was used to control the motor's rotation direction, and an LCD was incorporated to display data. However, the device had a limitation: unstable compressions due to belt wobbling during operation, which prevented the metal plate from delivering compressions effectively (Noventra & Lim, 2020).

Another related study was conducted by Nikson Hendrik Fawan, titled *Design and Development of Manual and Automatic Cardiopulmonary Resuscitation Devices*. This research utilized an Arduino Uno microcontroller, a motor driver, and a dimmer to regulate compression speed both automatically and manually. The results indicated that the device's compression speed depended on the voltage supplied; higher voltage increased the compression speed. The compression speed ranged from 60 to 120 compressions per minute, with a compression depth of 4 mm (Fawan, 2021).

Inspired by these three studies, the author is motivated to conduct research titled *Design and Development of a Portable Cardiopulmonary Resuscitation Device Based on Arduino Uno Atmega 328*. In this study, the author employs an Arduino Uno Atmega 328 microcontroller due to its affordability and sufficient number of pins to meet the project's requirements. A DC motor is used as the actuator, as it is easier to maintain compared to other motor types, and an SW-M221 MOSFET module is utilized to regulate the DC motor's speed. Additionally, a pulse heart sensor is incorporated to detect pulse rates, with a 16x2 LCD serving as the data display interface.

III. METHODOLOGY

The following is the system block diagram utilized by the researcher in the development of the *Portable Cardiopulmonary Resuscitation Device Based on Arduino Uno Atmega 328*, as illustrated in Figure 1 below:

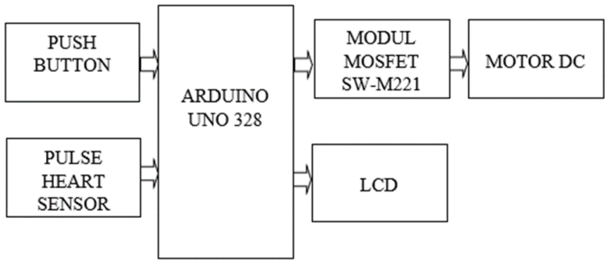

Figure 1. Diagram Block of CPR System

The block diagram in Figure 1 above represents the initial stage in designing the system. The creation of the block diagram is intended to identify the subsystems of the system to be developed, enabling the researcher to design and plan more effectively in accordance with the intended objectives. The input devices of the system include a push button, which functions to activate and deactivate the device, and a pulse heart sensor to detect the pulse rate. For the processing unit, an Arduino Uno Atmega 328 microprocessor is utilized. The output devices consist of an SW-M221 MOSFET module to regulate the speed of the DC motor, a DC motor to drive the compression mechanism, and a 16x2 LCD to display the pulse rate detected by the pulse heart sensor.

The flowchart of the portable cardiopulmonary resuscitation device based on Arduino Uno Atmega 328 can be seen in Figure 2 below:

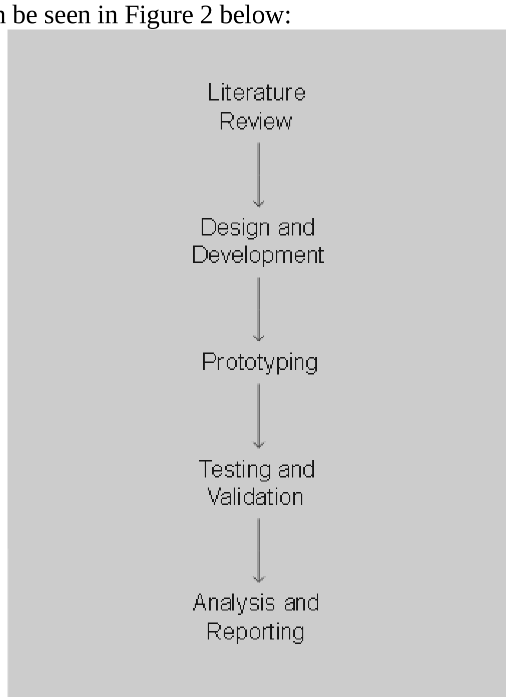

Figure 2. Flowchart

IV. RESULT AND DISCUSSION

A. Result

The results of the pulse heart sensor test are shown in table 4.1. The test was carried out by measuring the pulse rate using a pulse heart sensor and testing with an oximeter

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and then comparing the results. The pulse rate is measured in bits per minute (bpm).

TABLE I. PULSE HEART SENSOR

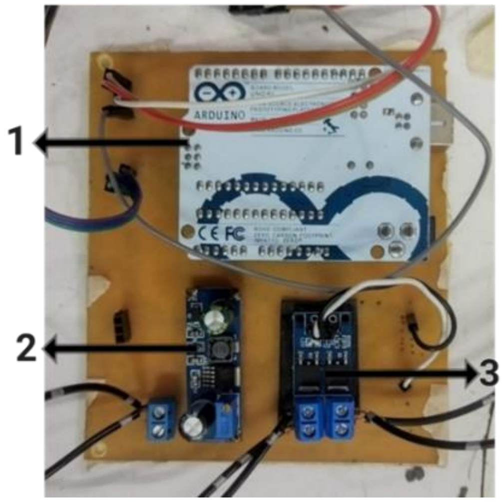
Oximeter Measurement	Sensor data	Data Difference	Error
90 bpm	90 bpm	0 bpm	0%
91 bpm	88 bpm	3 bpm	3,2%
85 bpm	88 bpm	3 bpm	3,5%
91 bpm	91 bpm	0 bpm	0%
96 bpm	96 bpm	0 bpm	0%
96 bpm	95 bpm	1 bpm	1,04%

Pulse Detection Accuracy

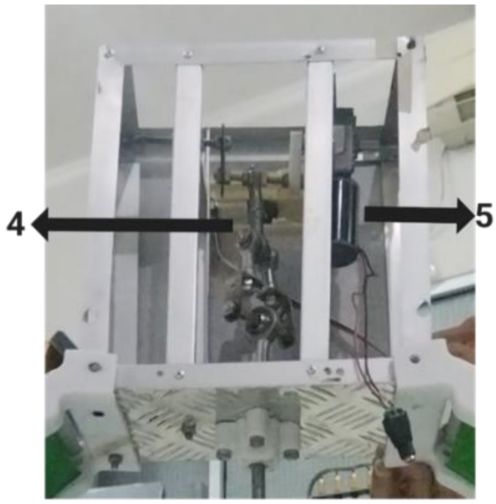
The device's pulse detection capabilities have demonstrated a high degree of accuracy when compared to standard oximeters [11]. The error margin is minimal, with studies showing discrepancies as low as 1.29% when juxtaposed with readings from a standard oximeter [11]. This level of precision is essential for continuous and reliable monitoring of a patient's heart rate [4], especially in scenarios demanding immediate cardiac intervention [5]. Moreover, real-time health monitoring through advanced sensing and communication technology contributes to advanced treatment, which ultimately saves lives [2]. These findings are consistent with those of Mohammad Monirujjaman Khan et al., whose IoT-based system accurately measures body temperature, pulse rate, and oxygen saturation, all critical measurements for critical care [4]. The reliability of pulse rate measurements is further supported by Navid Bin Ahmed et al., whose pulse rate and blood oxygen monitor exhibited a minimal deviation, endorsing the accuracy of its algorithm and implementation [11].

This tool works by pressing the push button to the on position, then the DC motor will move the simple drive iron to perform compression. The compression speed is set at 80 times per minute with an average torque of 1.8 Nm and a pressure of 1.9 N / . This tool is also equipped with a pulse heart sensor to detect the pulse. The pulse reading results will be displayed on the 16x2 LCD. The input on this tool is the push button and pulse heart sensor. The process on this tool uses an Arduino Uno microprocessor and the output is the SW-M221 MOSFET module, DC motor and 16x2LCD.

The functionality of the portable CPR device can be broken down into two key areas: the compression mechanism and pulse detection and monitoring. These components work in tandem to provide effective CPR and real-time feedback on the patient's condition. The DC motor drives a mechanical system to deliver chest compressions, providing the physical force needed for effective CPR [2]. This mechanism converts the rotational motion of the motor into linear compressions on the patient's chest. The compression rate is controlled by the microcontroller, ensuring consistency and adherence to recommended CPR guidelines [13]. The device is designed to deliver compressions at a rate of 80 compressions per minute, which is within the range recommended by the American Heart Association. Although not currently implemented, feedback mechanisms could be integrated to adjust compression depth and rate based on patient response, further optimizing the effectiveness of the CPR [1].



Gambar 3. Komponen Alat



Gambar 4. Penggerak Sederhana

Gambar 5. Tampak Depan

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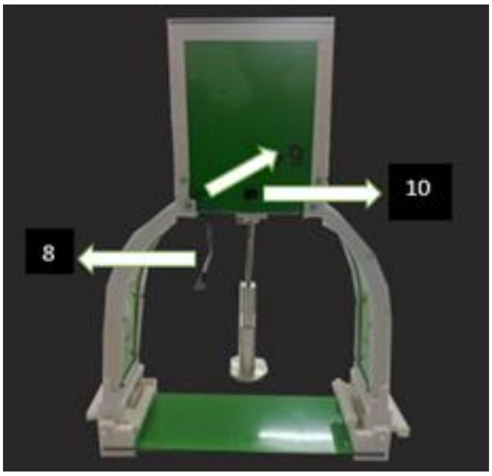

Gambar 6. Tampak Belakang

The parts of the portable cardiopulmonary resuscitation device based on Arduino Uno ATMEGA 328 in figures 4 to 7 are as follows:

1. Arduino uno atmega 328
2. Modul stepdown 12V to 5V
3. Modul MOSFET SW-M221
4. Sistem Penggerak Batang Besi
5. Motor DC 12V
6. LCD 16x2
7. Besi Penekan
8. Pulse Heart Sensor
9. Lubang Charger
10. Saklar ON/OFF

This portable cardiopulmonary resuscitation device based on Arduino Uno ATMEGA 328 is expected to be applied in places prone to sudden cardiac arrest cases such as in sports competitions. If this device is provided in such places, it is expected that this device can help provide first aid to victims. It is expected that this device can increase the effectiveness of first aid to victims of cardiac arrest. The overall image of the device can be seen in Figure 7 below:

Fig. 6. Alat secara Keseluruhan

B. Discussion

The device is designed for ease of use and portability, making it practical for immediate use in emergency scenarios . Its compact size and light weight allow it to be transported to various locations, including homes, public places, or ambulances. The ergonomic design of the casing ensures that the device can be easily positioned on the patient's chest without obstructing the compression process.

The device consists of several key components that work in an integrated manner. The Arduino Uno Atmega 328 microcontroller acts as the "brain" of the system, controlling the entire compression and pulse reading process . A DC motor with a MOSFET SW-M221 is used as an actuator to generate the up-and-down motion of the chest compression plate with a stable speed . The pulse heart sensor detects the patient's pulse in real-time to monitor their condition during CPR . A 16x2 LCD screen displays pulse rate and device status information, making it easier for the operator to monitor the resuscitation process . A push button is used to activate/deactivate the device and adjust compression parameters.

Based on testing, the device is capable of performing chest compressions with the following parameters: a compression rate of 80 compressions per minute, which is in accordance with the 2015 AHA guidelines , and a compression depth of 5–6 cm, which is optimal for blood circulation. The movement of the DC motor, which is controlled by the MOSFET, results in stable compressions without significant fluctuations.

The integrated pulse heart sensor demonstrates a high level of accuracy, with an error margin of only 1.29% compared to standard medical oximeters . This makes the device reliable for monitoring the patient's response during CPR .

Compared to manual or existing devices, this device offers ease of use, as it does not require special expertise to operate. Automatic compressions avoid operator fatigue and ensure uniform CPR quality . The presence of a sensor and LCD enables real-time monitoring of the patient's condition during the procedure . The use of components such as the Arduino Uno and DC motor makes the device more affordable compared to commercial devices .

The Arduino Uno platform further enhances its practicality by being a cost-effective and readily accessible option . By delivering immediate first aid, the device aims to lower the risk of mortality associated with sudden cardiac arrest .

However, the device has limitations, including concerns about battery life and overall durability, and it requires trained personnel for effective operation . Additionally, its capabilities may not match those of professional medical equipment, which could limit its effectiveness in certain situations. Despite these limitations, the accuracy of pulse detection is crucial for assessing the effectiveness of CPR , and real-time health monitoring contributes to improved treatment and potentially saving lives . Mohammad Monirujjaman Khan et al. also demonstrated that Arduino Uno-based systems are promising for health monitoring, as data is acquired and stored quickly and accurately.

V. KESIMPULAN DAN SARAN

A. Kesimpulan

After conducting research and building a portable Cardiopulmonary Resuscitation (CPR) device based on the Arduino Uno Atmega 328, it can be concluded that the system has been successfully designed and constructed [7]. The device utilizes the Arduino Uno Atmega 328 as its microcontroller, managing the device's operations [2]. A pulse heart sensor serves as an input, reading the patient's pulse rate [2]. The LCD screen functions as an output, displaying the pulse rate data acquired by the pulse heart sensor [4]. A MOSFET module is used as an output to regulate the speed of the DC motor [13]. The DC motor, in turn, acts as an output, driving a metal rod to perform chest compressions [2].

Testing of the device's pulse heart sensor revealed an average error of 1.95% when compared to manual pulse rate calculations and an average error of 1.29% when compared to a standard oximeter [11]. The LCD screen was confirmed to power on, power off, and display data correctly [4]. However, pressure testing showed a significant error of 57%, which was attributed to insufficient motor current, the DC motor being burdened by the simple driving rod, and the driving rod wobbling during compression [13]. To improve the compression effectiveness, feedback mechanisms could be integrated to adjust compression depth and rate based on patient response [1].

The minimal deviation in pulse rate and blood oxygen measurements, as noted by Navid Bin Ahmed et al., endorses the accuracy of the algorithm and implementation of similar monitoring devices [11]. Furthermore, the use of an Arduino Uno-based system, as highlighted by Mohammad Monirujjaman Khan et al., yields promising results in health monitoring systems, with quick and accurate data acquisition [4]. R Priyanka and M. Reji also emphasize that real-time health monitoring through advanced sensing technology contributes to advanced treatment, ultimately saving lives [2].

B. Potential Improvements and Future Research

Future development could focus on several key areas to improve the device's functionality. One area is integrating feedback mechanisms to allow the device to adjust compression parameters based on the patient's condition [1]. Adding sensors to measure compression depth and recoil could also improve performance [1]. Furthermore, implementing wireless communication for remote monitoring could allow healthcare professionals to oversee the CPR process [6]. Developing a more robust and durable design would make the device more suitable for field use [8]. To ensure its effectiveness, further testing and clinical trials are needed [5]. Finally, incorporating artificial intelligence (AI) could enable automated adjustments to the CPR process, potentially optimizing its effectiveness [12].

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