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Perspective of Creating a Low-Cost Medical Assistant Robot Based on the WafflePI4 Platform with a Palm Vein Pattern Scanner

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Abstract: Military medical service is an important component of the Armed Forces of any country [1]. In wartime, healthcare performs critical functions of medical support for military operations, providing effective and qualified care to the wounded and sick. Consequently, it is imperative to equip military hospitals with state-of-the-art materials and technical resources commensurate with the predefined requirements. In this study, we examine a series of enhancements applied to the TurtleBot 3 Waffle Pi-based medical assistant robot, tailored for deployment in military hospital settings.

Keywords: robot; turtlebot; raspberry pi; biometrical scanner; Convolutional Neural Network

1. Introduction

Military medical facilities and the personnel who serve them play a particularly important role under martial law. Military medicine is currently a fairly developed field in Ukraine that meets all the modern trends typical of developed countries in Europe and the world. Nevertheless, given the overcrowding in hospitals, it is very difficult for staff to provide timely and appropriate assistance to all victims. After analyzing the infectious diseases typical of the military risk group (such as pulmonary tuberculosis, viral hemorrhagic fevers, etc.) [2], it was decided to develop a robotic system, using the best practices of our group's previous studies [3,4]. It is capable of autonomously performing the typical functions of nursing staff, allowing workers to provide emergency care to soldiers who have suffered serious injuries, such as shrapnel.

2. Materials and Methods

The TurtleBot 3 Waffle Pi was chosen as a platform for modification due to: 1) open-source software; 2) portability of the design; 3) compatibility with ROS (Robot Operating System); 4) modularity. In the article, the robot platform paired with OpenCR module (power supply, spatial orientation) and the Raspberry Pi 3 Model B microcomputer (remote control, control of sensors, disinfection module, and UI-UX interface).

In this research, we propose to replace the Raspberry Pi 3 with the Raspberry Pi 4, as a strategic move designed to yield multiply performance benefits, as substantiated by prior studies [5,6]. Implemented modifications and schematic diagram of the medical robot -assistant is shown on Figure 1. The anticipated advantages encompass heightened processing capabilities and augmented data transfer speed [7,8], expedited processing of graphical data [7,8], elevated data transfer rates facilitated by the inclusion of a 1Gb Ethernet chip and multi-channel Wi-Fi connectivity compliant with 802.11 b/g/n/ac standards [9,10], and the prospect of swifter data transmission and an expanded capacity for connected devices, courtesy of BLE 5.0 technology [11]. This proposition stands to

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enhance the operational efficiency and overall capabilities of the robotic system under proposed research.

The OpenCR module using SLAM (simultaneous localization and mapping) for spatial navigation [12–14] remains unchanged. SLAM technique is using probabilistic approach which applies a probability distribution to predict the robot and landmark's location from the generated map. The probability distribution form, P is defined as:

$$P(x_k, m \mid Z_k, U_k),$$

where, k – time constant, x_k – robot location, Z_k – sequence of measurements between robot and landmarks assuming one measurement per time step, U_k – sequence of robot odometry or relative motion.

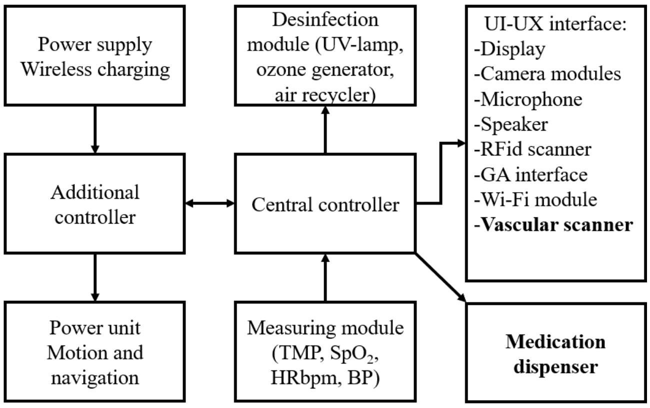

Figure 1. Block diagram of the medical robot assistant with implemented modifications.

The proposed mechanism comprises a matrix of capsules, each housing a specific medication, and a controlled delivery system that employs a rotary mechanism. This rotary mechanism is actuated by a servo drive, facilitating the controlled ejection of the desired medication from the respective capsule. A critical aspect of this system is the implementation of a dispensing control system, which incorporates a matrix of optocouplers [15]. This control system acts as a fail-safe, guarding against erroneous medication dispensing. By interrogating optocouplers into the system, it becomes capable of accurately verifying and confirming the correct dosage and medication identity before dispensing to the patient. Incorporating this level of precision and error reduction in medication dispensing is paramount, especially in healthcare settings where patient safety and accurate dosing are of utmost importance. This study introduces a novel approach to enhance the reliability and precision of medication dispensing, ultimately contributing to improved patient outcomes and healthcare quality.

3. Results

A palm vein pattern scanner is used to provide contactless identification. This type of biometric identification was chosen due to its high level of identification accuracy, high resistance to changes over time and injuries to the palm veins, and the absence of the need for physical contact with the scanner.

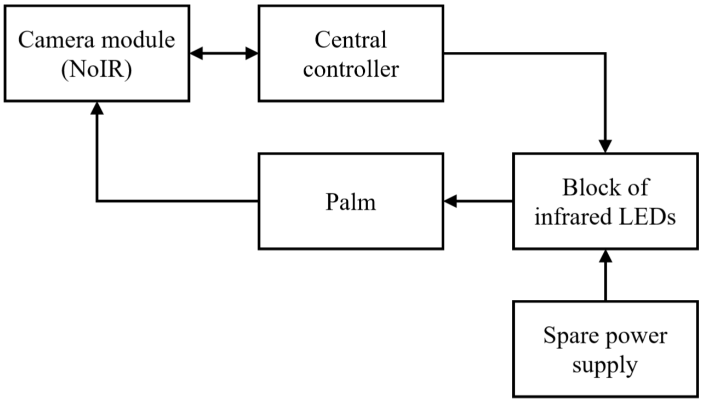

Figure 2. Block diagram of the palm vein pattern scanner.

The identification system consists of a computing module, a camera without an IR filter, and an IR LED unit. The computing module is a central robot controller (Raspberry Pi 4), and the camera is a Raspberry Pi Camera module 3 NoIR. The block diagram of the device is shown in Figure 2.

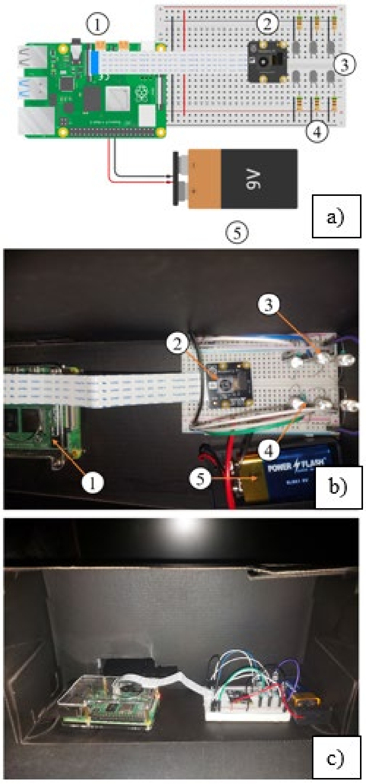

Figure 3. a) Schematic of the experimental setup with connected modules; b) top view of implemented experimental setup; c) side view of implemented experimental setup.

The implemented device consists of: Raspberry Pi 4B (1), Raspberry Pi Camera module 3 NoIR (2), IR LEDs (3), resistors (4) and a crown battery (5) and is shown in Figure 3 a). The assembled experimental setup is shown in Figure 3 b) and c). Notably, the Raspberry Pi 4b empowers the robot to gather and transmit data across longer distances at elevated speed, all while reducing overall energy consumptions. Algorithm of the device operation [16] is shown on Figure 4, and goes by following steps:

1. camera initialization and power supply to the LEDs;
2. taking a picture of the palm;

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3. image processing;
4. patient identification.

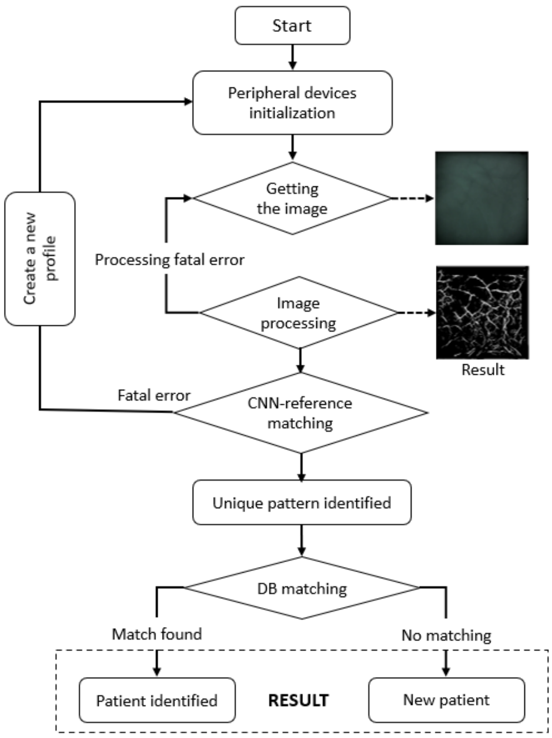

Figure 4. Algorithm of the device operation.

To perform image processing, we implemented the code using the Python programming language, leveraging the capabilities of the OpenCV and NumPy libraries. The sequence of image processing steps is illustrated in Figure 5, delineating the various stages involved in the computational manipulation of the image data.

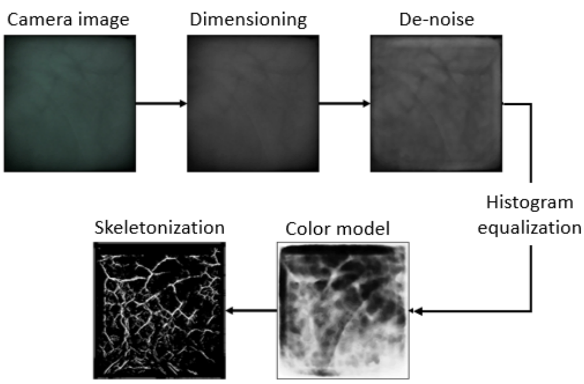

Figure 5. Stages of image analyzing and processing.

In this work, we employ a Convolutional Neural Network (CNN) as a robust methodology for the identification and recognition of user's venous patterns. A Convolutional Neural Network is a specialized architecture within the domain of neural networks, extensively employed by the processing and analysis of images and videos [17–19]. Its design is tailored to excel in pattern recognition tasks, showcasing inherit properties that enhance its effectiveness in discerning intricate patterns within visual data. The CNN serves as a powerful tool for the precise identification of venous patterns in the context of our study. The structure of a CNN is shown in Figure 6.

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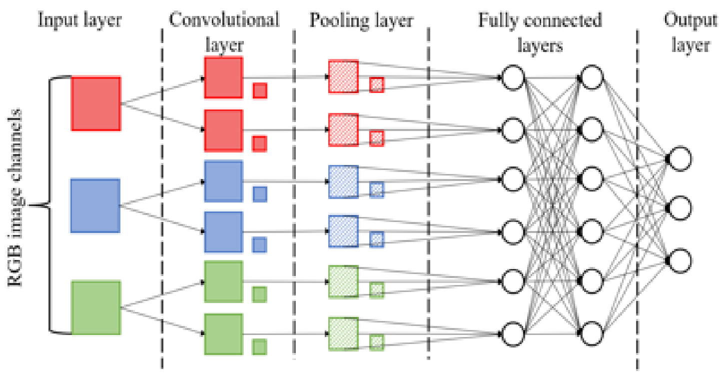

Figure 6. The structure of Convolutional Neural network (CNN).

The construction of the neural network was undertaken using the Python programming language as well as for the imaging processing, wherein we utilized the TensorFlow Keras library – an open-source machine learning software framework. This framework provides a comprehensive suite of tools and functionalities for the development, training, and evaluation of neural networks, ensuring a robust and efficient implementation of our model. Figure 7 illustrates the fundamental operational principles underlying this manuscript, which is centered around the unique palm vein pattern.

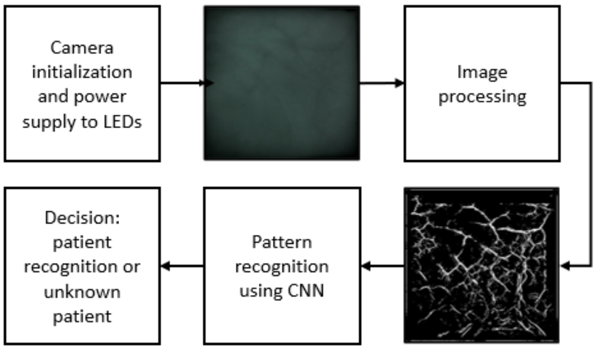

Figure 7. Working principle of the biometric identification system.

The depiction in the manuscript expounds on the intricate workings of the system, elucidating how it harnesses the distinctive features within the palm vein pattern for accurate and reliable biometric identification. The graphical representation serves as a visual guide, providing a detailed insight into the underlying mechanisms that drive the functionality of the developed biometric identification system.

5. Conclusions

The scope of this research work has revealed the tremendous potential for the adaptation and enhancement of a cost-effective medical robot-assistant, poised for both military and civilian applications. The core innovation underpinning this progress revolves around the replacement of the Raspberry Pi 3b microcomputer with its more advanced counterpart, the Raspberry Pi 4b. This transition has ushered in significant advancements, particularly in the domain of computational efficiency. One of the most notable improvements stemming from this microcomputer upgrade is the remarkable acceleration in the robot's computational capabilities. By harnessing the enhanced processing power of the Raspberry Pi 4b, our robot can perform calculations with remarkable celerity, contributing to quicker decision-making and more responsive interactions. Moreover, we have

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achieved an innovative milestone through the development of a unique prototype featuring a biometric personal identification system predicted on the venous pattern of a palm. This pioneering approach to biometric identification holds great promise, offering heightened security and precision in identifying individuals, particularly within healthcare contexts. In conclusion, our study underscores the transformative potential of integrating the Raspberry Pi 4b microcomputer into robotic medical assistance systems, offering advancements in computation, data transmission, and energy efficiency. Simultaneously, the introduction of a palm-based biometric identification system holds promise in reshaping healthcare. These innovations collectively represent a step forward in leveraging technology to enhance the quality and efficiency of healthcare services. The outcome of this work, ripe for further exploration and refinement, has the potential to redefine the landscape of healthcare and military assistance.

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Conflicts of Interest: The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: H. Hlukhova and O. Glukhov are family members, but they have lived and worked in different countries for more than 6 years, and they do not have any conflict of interest for the submitted work.

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