IoT Robotic Medication Dispenser for Elderly Care

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Abstract. This study addresses the urgent need for automated solutions in elderly care, particularly for medication dispensing, to reduce the burden on caregivers. A gap in integrated IoT-enabled robotic systems specifically designed for reliable and accurate medication dispensing in elderly care has been identified. This research developed a prototype of an IoT-enabled robotic arm that enhances automation and provides real-time monitoring for medication delivery in elderly care. The methodology included constructing the ROT3U robotic arm and performing detailed stress, displacement, and strain analyses using SolidWorks. The system was enhanced with Arduino code, connected to the Blynk app for real-time monitoring, and integrated with IoT components such as the ESP8266 microcontroller and PCA9685 driver. A Network Time Protocol (NTP) client was utilized to ensure precise medication dispensing schedules. Initial results indicated that the robotic arm was resilient under operational stresses. Further evaluations were done on improving the arm's performance through additional stress, strain, and displacement analyses. This research bridges the gap by offering an integrated IoT-enabled robotic system developed for accurate and reliable medication dispensing in elderly care. It also promotes the use of technology to alleviate the workload of caregivers, ensuring that elderly patients receive their medication as prescribed. The study presents a viable approach to advancing elderly care with more sophisticated assistive robotic systems.

Keywords: Internet of Thing; ESP8266; ROT3U; PCA9685.

1 Introduction

Managing elderly care presents significant challenges, particularly in administering medications that require precise accuracy and consistency. Caregivers must ensure correct dispensing and adherence to dosing schedules for these medications. Health systems have long waited for patient care [1], and late detection of health problems, and hospitalization [1] are some of the challenges faced by health systems with the rise of aging populations. However, leveraging the Internet of Things (IoT) and robotics can address these challenges by providing autonomous health monitoring and assistance systems for elderly households. There are opportunities for these technologies to support independent living by enabling telehealth and maintaining the patient-

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healthcare provider relationship [2]. Nonetheless, deploying IoT medical devices for the senior population may face several challenges, including user requirements, hardware, caregivers, legal regulations, and technological aspects. As pointed out by Soubutts [3], the design of IoT technologies for independent living should include device-multi-homing to accommodate multiple household residents, and issues of trust, identity, privacy, and security should be addressed. It was recommended by [4] that IoT networks incorporate strong user authentication and access control. In addition, IoT solutions for vulnerable populations should address constraints such as limited processing capability and intermittent communication [5]. Technological developments, especially in robotics and the Internet of Things (IoT), provide promising solutions to these problems. Medication dispensing may be automated and monitored with the help of robotic systems and IoT-enabled devices, which will enhance the standard of care given to senior citizens. Using IoT for real-time reminders and monitoring, especially for forgetful patients and the elderly, is highly beneficial [6][7].

Improving medication distribution to the point where no human intervention was required would reduce the efforts needed from caregivers and enhance patient outcomes [8]. This approach helps address the cubicle effect and represents the primary motivation for developing the automated solution discussed in this study. Automated medication dispensers are evolving with an emphasis on simplicity, cost-efficiency, and user-friendliness [9].

There is a need for fully integrated IoT-enabled robotic systems that offer high precision and consistency in medication dispensing for elderly care. Automated drug dispensing systems have been demonstrated to reduce the time spent managing medications and improve patient care quality [10][11]. However, current solutions often lack essential features, fail to provide real-time monitoring, or are overly complex for practical use in care settings. Additionally, securing patient data from medical devices presents significant challenges [12], and applying IoT in healthcare faces issues such as interoperability, data privacy, and security [13]. This study addresses these gaps by designing a scalable robotic arm solution for an IoT-enabled automated medication dispensing system. It aims to enhance the flexibility of assistive robotic solutions in healthcare by improving existing systems.

This research design focuses on studying and developing an IoT-based robotic arm specifically for medication dispensing. The primary objectives are to enhance elderly care with an automated medication dispensing system, facilitate remote monitoring and control of the system, assess stress, strain, and displacement in the robotic arm to ensure its reliability and performance and integrate IoT components such as the ESP8266 microprocessor and PCA9685 servo driver for smooth real-time monitoring and control through the Blynk mobile application.

2 Methodology

Figure 1 illustrates the flowchart for the overall research methodology The flowchart outlines the key steps involved in developing a smart robotic system that automates medication dispensing for elderly patients. The project started with 3D modeling using SolidWorks, followed by displacement, strain, and stress analysis. After assembling the robotic arm and integrating the IoT components, Arduino code was uploaded. The final stage involved testing and calibrating the system to ensure precise operation.

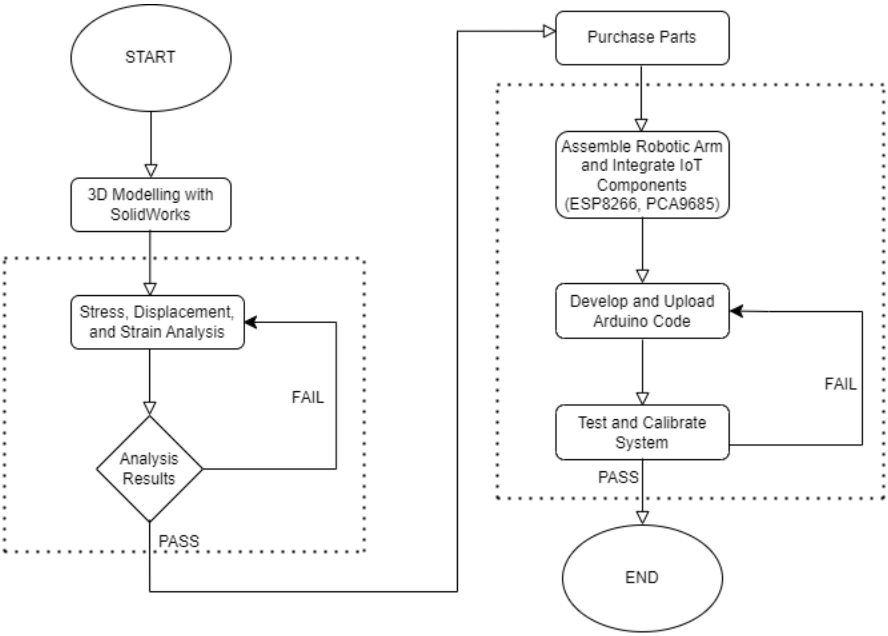

Fig.1. Flowchart for this research

2.1 Design And Development of ROT3U Robotic Arm

The ROT3U Robotic Arm was specifically developed for medication dispensing in nursing care. Its six degrees of freedom (6-DOF) provide the necessary range of motion for precise control. The arm was conceptualized and thoroughly simulated using SolidWorks, and then optimized for structural integrity and functionality. For the design, Aluminium 6061-T6 was selected due to its lightweight and durable properties, with a yield strength of 276 MPa. Research has shown that using aluminum alloys in automotive control arms significantly reduces weight [14]. The robotic arm utilizes the MG996R servo, which has a stall torque of 9.4 kg/cm at 4.8V.

2.2 Stress, Displacement and Strain Analysis

The ROT3U robotic arm was thoroughly analyzed for stress, displacement, and strain using SolidWorks. This analysis was conducted to ensure the arm could withstand both static and dynamic forces involved in medication dispensing. The evaluation included assessing displacement limits, strain thresholds, and maximum permissible stress to gauge the arm's performance under various conditions. Simulations were performed to visualize how the arm deforms and how stress is distributed when subjected to different loads and constraints. This thorough analysis helps ensure that the arm is robust and reliable for its intended application.

2.3 Integration of IoT Components

A key aspect of the system development was the integration of IoT modules. Arduino coding was used to control the robotic arm, while the ESP8266 microprocessor enabled wireless communication. The PCA9685 servo driver was used to control the servo motors, ensuring accurate and synchronized movement of the robotic arm. The PCA9685 offers benefits such as saving time, reducing the workload on physicians, and minimizing medication errors [15]. Enhancements to the PCA9685, such as using prior data and models, improve the accuracy of parameter estimates and data consistency [16]. Real-time operation control and monitoring were facilitated through the Blynk app, which involved setting up communication protocols between devices and developing the necessary software, including extensive configuration efforts.

Related work includes studies by Ambekar [17] and Durani [18], who utilized the ESP8266 microcontroller and the Blynk app for home automation. Ambekar focused on remote control and monitoring of home appliances, while Durani's work addressed control of lighting, fans, and other devices. Lakshmi et al. [19] proposed using the ESP8266 and Blynk app for home automation, specifically for controlling lights and fans. These studies demonstrate the versatility of integrating the ESP8266 with the PCA9685 and Blynk app across various applications.

2.4 Time Management with NTP Client

The system's timing was synchronized with an external time server using an NTP (Network Time Protocol) client, which managed the medication dispensing schedule. Ashokbhai [20] explored timing accuracy in embedded power protection systems, where NTP was used for real-time time synchronization. This approach ensures that the robotic arm dispenses medication only at the correct times, maintaining adherence to the medication schedule to ensure accurate timing, the NTP client was integrated into the ESP8266 microprocessor, which regularly updates the system clock.

3 Results And Discussion

3.1 Analysis Results

Initial testing of the ROT3U robotic arm confirmed its ability to handle the operational stresses involved in medication dispensing. The arm maintained its structural integrity under various load conditions, with displacement, stress, and strain values remaining within acceptable limits. The SolidWorks analysis provided in-depth insights into the performance of the ROT3U robotic arm. It focused on displacement, stress, and strain at critical joints and other key locations on the arm under operational conditions. The simulation used a load of 10N (approximately 1 kg).

Displacement Analysis: The simulation results, as depicted in the static displacement plot indicate a maximum displacement of 0.04554 mm (45.54 micrometers). The regions exhibiting the highest displacement are highlighted in red, in Figure 2 which correspond to the areas most affected by the applied load. The maximum displacement values are significantly low, indicating that the structure deforms only slightly under operational conditions. This suggests that the robotic arm maintains its shape and structural integrity well during use, with minimal bending or distortion. The overall average displacement recorded is 0.04518 mm, with the minimum displacement being 0.04491 mm. These findings suggest that the ROT3U robotic arm is durable and maintains structural stability under the expected load, ensuring reliable performance during medication dispensing. The low displacement values across the assembly confirm the design is well-suited for the intended application, with negligible risk of structural failure or excessive wear.

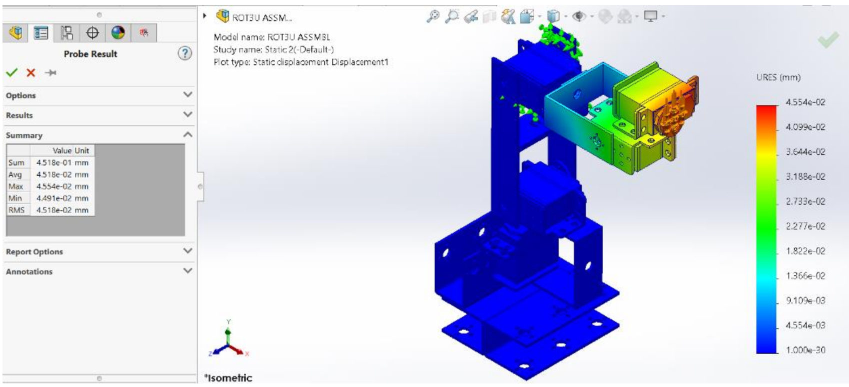

Fig.2. Static displacement analysis

Stress Analysis: The von Mises stress plot shows that the maximum stress experienced by the structure is 1.939 MPa (1.939e+06 N/m²), which is well below the yield strength of Aluminum Alloy 6061-T6, which is 275 MPa (2.75e+08 N/m²). The regions with the highest stress are marked in red in Figure 3, while most of the structure displays lower stress levels, highlighted in blue and green. The average stress recorded is 1.772 MPa, with the minimum stress at 1.703 MPa. These results indicate that the robotic arm operates safely within its design limits, ensuring the material will not fail under the applied loads. The consistently low-stress values across the assembly confirm the robustness of the design, demonstrating that the robotic arm can withstand operational stresses without risk of structural failure. This confirms that the ROT3U robotic arm is well-suited for its application, ensuring reliable and safe operation.

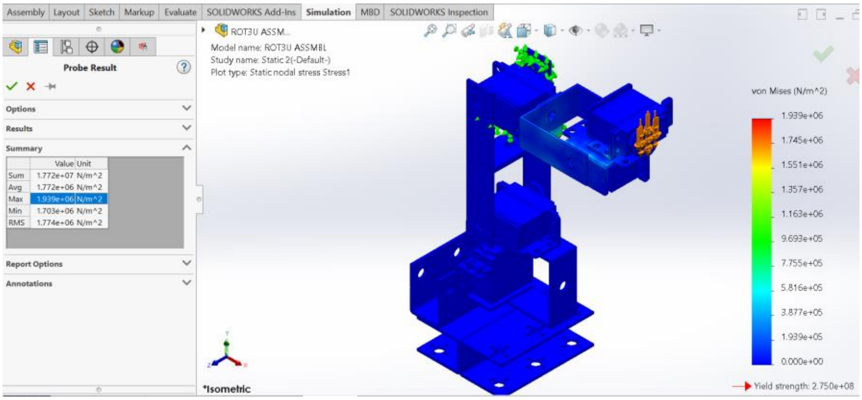

Fig.3. Stress analysis

Strain Analysis: The static strain plot shows the distribution of strain value across the robotic arm, with a maximum strain value of 4.074e-05. The average strain recorded is 3.272e-05, and the minimum strain is 3.002e-05. Areas with the highest strain are marked in red in Figure 4, indicating regions that experience the most deformation. These results suggest that the robotic arm undergoes minimal deformation, maintaining structural stability and reliability under operational conditions. The consistently low strain values indicate that the material's elastic limit is not exceeded, preventing permanent deformation. This ensures the robotic arm will remain durable and functional throughout its use in medication dispensing for elderly care.

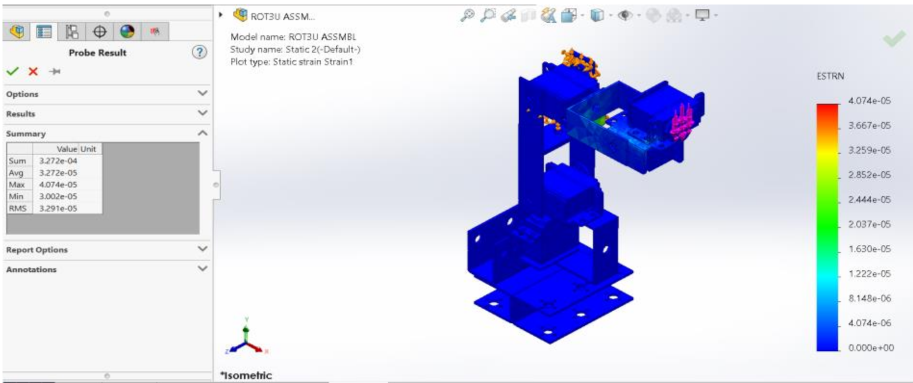

Fig.4. Strain analysis

Maximum Weight Analysis: As depicted in Figure 5, the von Mises stress distribution plot indicates that the maximum stress experienced by the structure is 2.75e+08 N/m² (or 275 MPa), which reaches the yield strength of Aluminum Alloy 6061-T6. The stress level is depicted using a color gradient, with red areas representing the highest stress and indicating that the material is approaching its yield limit. The analysis was conducted with an applied load of 58.72 N, which matches the maximum weight capacity of the robotic arm. This load represents the maximum weight the arm can handle safely without exceeding the material's yield strength. When subjected to this load, the robotic arm reaches its yield point, suggesting that any additional load beyond 58.72 N would result in permanent deformation or failure of the structure. These results highlight the importance of adhering to the specified weight limit to ensure the structural integrity and reliability of the ROT3U robotic arm in its applications.

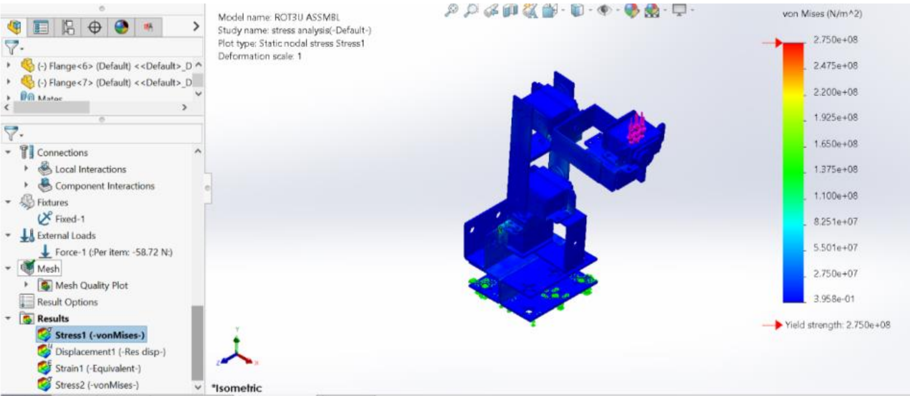

Fig.5. Max Weight Analysis

3.2 Development of ROT3U Robotic Arm Prototype

The findings from the stress, displacement, and strain analyses guided the development of the ROT3U robotic arm prototype (Figure 6). During assembly, each component was carefully aligned and tested for proper operation. The robotic arm was then connected to IoT components, including the PCA9685 servo driver and ESP8266 microcontroller, which are central to the system's functionality.

Fig.6. ROT3U Robotic Arm Prototype

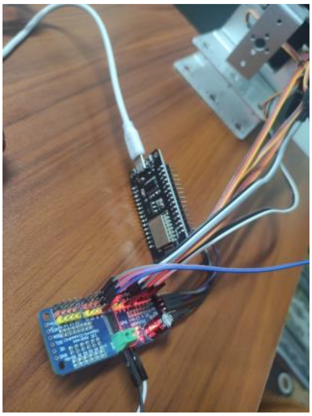

Fig.7. Set up of Arduino and IoT components

The Arduino code for controlling the robotic arm's movements was developed and uploaded to the microprocessor. This predefined code enabled the system to perform precise and synchronized movements according to set schedules. Figure 7 displays the configuration of the Arduino and IoT components, demonstrating how the system is arranged to ensure accurate operation. This setup enables the robotic arm to follow the programmed instructions for medication dispensing reliably.

The entire system was tested and calibrated to confirm its performance. The response time of the robotic arm, its accuracy in medication delivery, and the reliability of the Internet of Things components were all evaluated. The system demonstrated high accuracy and reliability, with the robotic arm dispensing medication precisely and on schedule. The Blynk App (Figure 8) was used to set the start and stop times, which it converted into seconds since midnight to control the dispensing schedule. This process ensured that the medication was dispensed at the correct times as programmed.

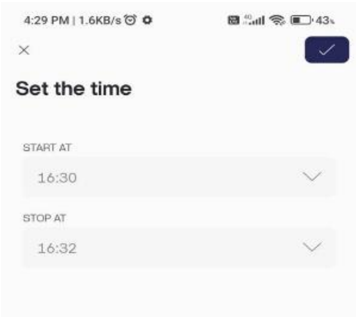

Fig.8. Blynk App time setting

Practical testing and analysis confirmed that the robotic arm is suitable and operationally feasible for senior care medication dispensing. The system's potential for practical application in healthcare settings was demonstrated through its validated ability to accurately and appropriately dispense medication. This validation confirms that the robotic arm can effectively perform its intended function in real-world healthcare environments.

4 Conclusion

In summary, the ROT3U robotic arm, integrated with IoT technology, has the potential to address medication adherence issues and reduce the workload for caretakers. Stress, displacement, and strain evaluations confirmed that the robotic arm is structurally sound and operates reliably within acceptable limits. To boost the system's performance and reliability in the future, improving the control algorithms and strengthening network stability is recommended. Additional features, such as the ability to adjust schedules in real-time or interface with other healthcare scheduling systems, could further increase the utility of this system and improve elderly care. This research aligns with Sustainable Development Goal (SDG) 3: Good Health and Wellbeing, which aims to ensure healthy lives and promote well-being for people of all ages.

Achieving good health and well-being is essential for everyone, especially senior citizens, to live a healthy life.

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Disclosure of Interests. The authors have no competing interests to declare that are relevant to the content of this article.

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