Design and Development of a Drinking Water Dispensing System with Volume Control Based on IoT for the Elderly

Luthfi Adi Syahputra[1], Mila Kusumawardani[2*], Nugroho Suharto[3]

[1,2] Digital Digital Telecommunication Network Study Program, Department of Electrical Engineering, State Polytechnic of Malang, 65141, Indonesia

[3] Telecommunication Engineering Study Program, Department of Electrical Engineering, State Polytechnic of Malang, 65141, Indonesia

[1]luthfiadisyahputra@gmail.com, [2]mila.kusumawardani@polinema.ac.id, [3]nugroho.suharto@polinema.ac.id

***Abstract*— The issue of adequate water intake becomes increasingly relevant for the elderly who experience a decline in motor function, often leading to difficulties in pouring water accurately. This can result in spills or inaccurate filling, potentially compromising their daily hydration needs. Therefore, this research focuses on the design and development of an automatic water dispenser system to assist the elderly in meeting their hydration needs. The proposed system utilizes the HC-SR04 sensor to detect the water container's height, the XKC-Y25-V sensor to measure the water filling level, and Firebase as a storage medium for user water quota data. The testing results show that the water filling rate reaches 35 ml per second, with a filling error rate of 23.15% at a sensor height of 7 cm and 15% at a sensor height of 14 cm. Additionally, the NFC reader sensor demonstrates 100% accuracy with a maximum detection range of 3 cm. Ultrasonic sensor data indicates a reading difference of 13.6% longer for the sensor positioned at a height of 7 cm, and -3.6% shorter for the sensor at a height of 14 cm, with a 100% object detection success rate. The water sensor records a value of 0 when no water is being poured and a value of 1 when water filling is in progress.**

Keywords*— *Dispenser, Drinking Water, Elderly, Firebase, NFC, XKC-Y25-V.

I. INTRODUCTION

Water is a vital necessity for human survival and supports daily activities [1]. The human body requires at least 1 to 2.5 liters of water daily, equivalent to 6 to 8 glasses, to maintain metabolism and physical endurance [2][3]. Adequate water intake is crucial for nutrition, but many individuals fail to meet their daily needs due to busy schedules. Additionally, access to drinking water is not always readily available in all places. Those who are environmentally conscious often carry personal water containers, typically around 700 mL, covering only about 35% of the daily water requirement [4]. This hydration issue is particularly relevant for the elderly and individuals with disabilities who face challenges in performing simple tasks, such as pouring water, which may lead to spills or inaccurate water filling, reducing their independence in meeting hydration needs [5][6].

Currently, the implementation of the automatic filling system only can fill cup or glass because the wide mouth area to filling the water [7], or an automatic filling system that requires users to manually input the amount of water they want to fill into their bottle [4]. For elderly individuals with vision problems, this can pose challenges in determining how much water they want to fill in their cup or bottle. Based on these problems, this research aims to develop an automated water-filling system with volume control based on IoT while monitoring remaining water levels in the gallon. The study is titled "Design and Development of a Drinking Water Dispensing System with Volume Control Based on IoT for The Elderly" The system uses ESP32 for the micro control [8][9][10] and utilizes NFC for user identification, ultrasonic sensors to measure the container's maximum height at different levels, limit switch to trigger and detect the water container [11], contactless water level sensor [12][13] to monitor and limit the water volume, and buzzer to alert [14] the user when the filling process is finished. Additionally, the user water data will be saved in firebase [12][15], and monitored for delay to assess the connection quality [16][17] before being stored in the database for the user records.

II. METHOD

A. System Block Diagram

The workings of the tools that will be used in the system are made in the form of a block diagram shown in Figure 1.

*Corresponding author

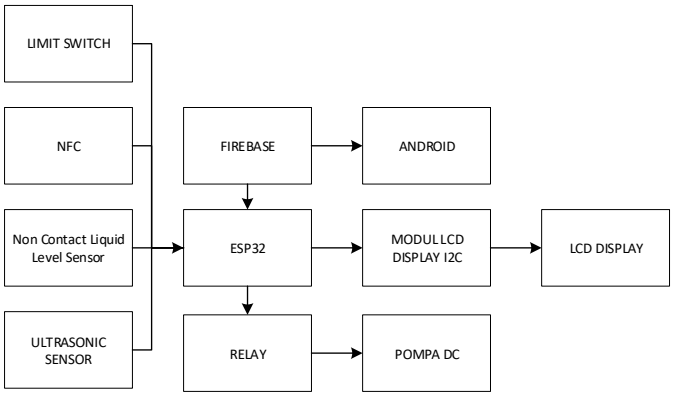

Figure 1 System Design Block Diagram

System block diagram explains the system planning in the study. The explanation of the function of each component is as follows: First the limit switch functions as a trigger for the operation of the ultrasonic sensor and the contactless water level sensor, as the contactless water level sensor requires the water container to be in contact with the sensor for accurate water level detection.

The second process, the NFC module reads the NFC card to retrieve user data for operating the automatic dispenser, and this data is later used to track the available water quota.

Then, the ultrasonic sensors are placed at two different heights to detect the height of the water container and to adjust the position of the contactless water level sensor, one in 7 cm and the other one in 14 cm accordingly. The relay activates the DC pump, based on commands from the ESP32, to pump water until the level reaches the maximum height detected by the ultrasonic sensor.

Final is contactless water level sensor detects the height of the water in the container, and when the water reaches the maximum level detected by the ultrasonic sensor, the contactless water level sensor sends a signal indicating that the water has reached the predetermined level. The LCD Display module provides information such as the remaining water quota and the name of the user operating the dispenser. Firebase serves as the database for storing the water quota data of registered users and for controlling the machine, which can be managed by the admin.

B. Mechanical Design

The mechanical design is created to illustrate the mechanical structure that will be implemented in the research. Below is the system's mechanical design intended for use in the study.

Figure 2 illustrates the 3D model of the machine. The machine is shaped like a cube, measuring 14 cm in length, 48 cm in width, and 54 cm in height. The water filling compartment has dimensions of 12 cm in length, 14 cm in width, and 21 cm in height.

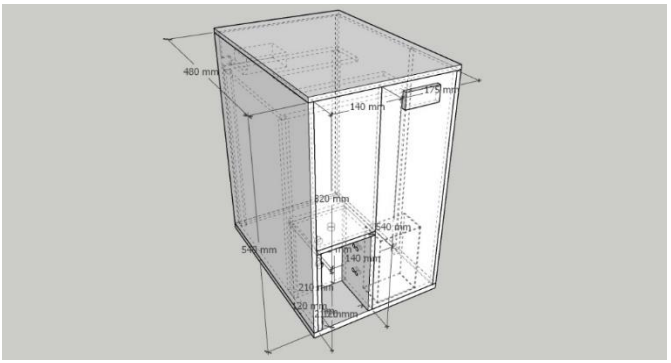

Figure 2 Hardware Design (full covered)

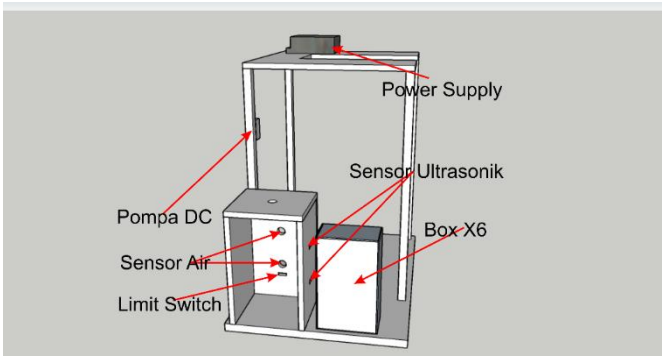

Figure 3 Hardware Design

Figure 3 illustrates the arrangement of the components used in constructing the machine. The power supply is positioned at the top, with the DC pump located beneath it. The filling compartment houses the limit switch, ultrasonic sensor, and water level sensor. Additionally, the NFC reader, relay, and LCD display are installed within the control box.

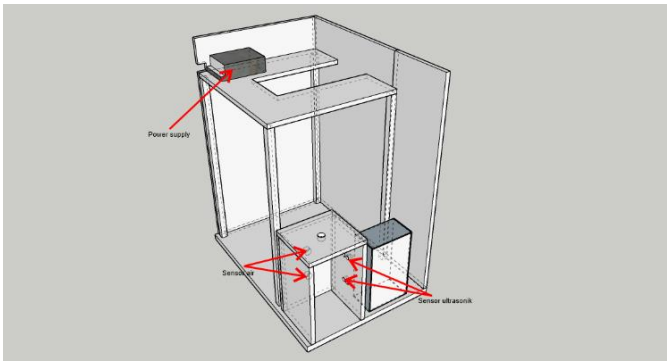

Figure 4 Hardware Design (with side cover)

Figure 4 shows the 3D model of the water filling control housed in a box case. The water filling station includes an ultrasonic sensor, a water level sensor, and a limit switch. The ESP32 controller is placed in a darker gray box adjacent to the water filling station. The NFC reader is positioned at the front of the microcontroller box to read NFC cards.

C. Overall Schematic Design

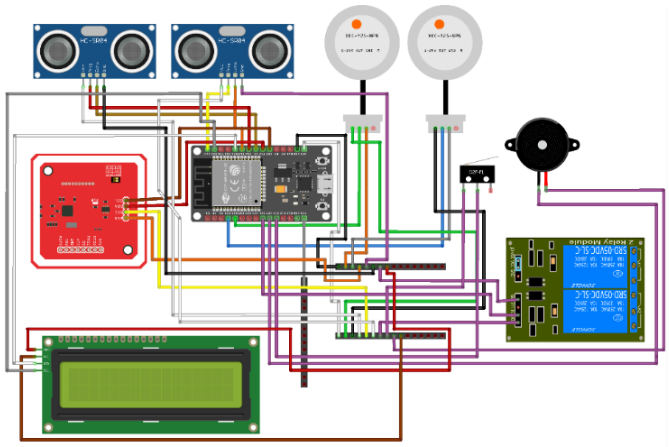

Figure 5 Schematic Design

Figure 4 shows the entire series of sensors used to create an automatic water filling control system. The input data used are water sensors, ultrasonic sensors, and NFC sensors connected to ESP32. This data will later be processed by ESP32, the processed data will later be entered into a database placed on Firebase, such as remaining water quota data, equipment status, and user status.

III. RESULTS AND DISCUSSION

A. Research Result

1) Mechanical Implementation Result

The Mechanical manufacture of the drinking water dispensing system, mainly using wood with a length of 14 cm and a width of 48 cm. This machine is designed using ScetchUp software, as shown in the Figure 6.

Figure 6. Mechanical Implementation

The overall design of this machine is made of wood with a length of 14 cm and a width of 48 cm, and height 54 cm. On the top left side, there is the power supply as a main power for the machine, under it, there is a DC Pump to pump the water from the gallon to the filling box, on the right side of the pump there are contactless water censor, ultrasonic censor, and the limit switch that attached in the filling box, while the NFC Reader and the LCD are attached to the black 3D printed box on the right side, as well as the ESP 32, buzzer, and the Relay.

2) Hardware Implementation Results

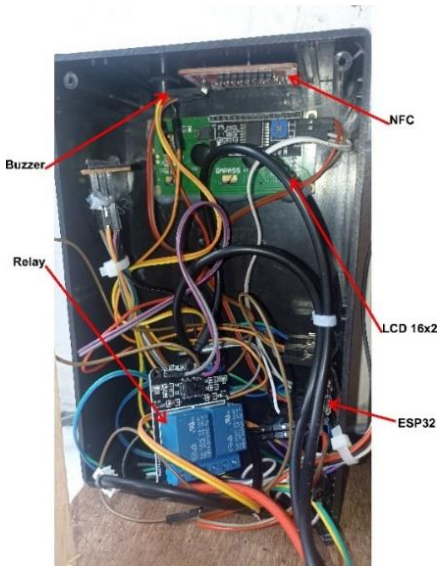

Figure 7. Hardware Implementation Results

Figure 7 is a documentation of the overall hardware implementation results on the dispensing system that has been successfully made in accordance with the design that has been made. In this part, installed ESP32, LCD, NFC reader, buzzer, and the relay

3) Software Implementation Result

The following are the results of the overall software implementation in the design of a dispensing system with volume control based on IoT has been successfully made according to design. The application design is made with the aim of describing the application design that will be implemented in the research. The following is a system application design that will be used in this research.

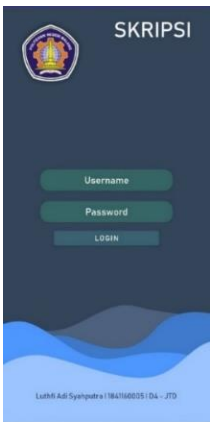

Figure 8. Login page

Figure 8 is the login page that serves as a gateway that differentiates the user and admin authorities available in the application.

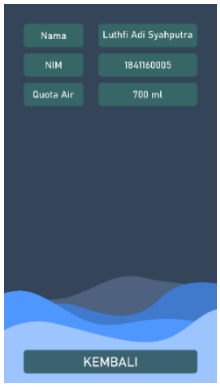

Figure 9. User page

On Figure 9, the user page, after the user has successfully entered the correct username and password, the user will be taken to the user page which displays the identity of the name, student identity number, and water quota contained in the firebase database according to the data owned by the user.

Figure 10. Admin page

On Figure 10, the admin page after entering the username and password with admin authority, it will be forwarded to the admin page, on the admin page there are two buttons that can forward to a different page, the top button is tool management which functions to see the status of the tool, whether it is enabled or not, and the remaining gallon quota inside.

Figure 11. Tools management page

On Figure 11, the tool management page, the admin can set whether the tool will be enabled or not and can see the remaining gallons of water on each tool placed. Admin User Control page

Figure 12. Admin user control page

Figure 12. The admin user control page is the page where all users are displayed. Admin can select one by one user, to be seen, and change the data inside.

Figure 13. Admin to user control

On the Admin to User Control page, after the admin selects a user on the page admin user control, admin can see NIM, Name, and remaining quota of users. Admins can also control whether user it can be blocked or not, and also adds a drinking water filling quota for each user.

B. NFC Reader Accuracy Testing Result

The NFC Reader installed on this machine is for user unique identification. This test carried out to determine whether the reader used in this machine can read the card correctly, and test how far the reader can read the card. This test is done by

TABLE I
NFC CARD IDENTIFICATION TEST

No	NFC ID	Quota	Status
1	227166204	9999999	Valid
2	35342530	3000	Valid
3	16323414617	30000	Valid
4	6711994174	2025	Valid
5.	19519166165	3000	Valid

Table I presents the results of the NFC card testing for previously registered cards. The data in Table I indicates that the NFC reader module functions as expected and performs reliably within the system.

C. Filling Water Accuracy Testing

The accuracy test of water filling into the drinking container was conducted using a digital scale. This experiment aimed to evaluate the accuracy of the amount of water dispensed from the dc water pump into the container, which would then be used to deduct the water quota in the database.

TABLE II
FILLING WATER ACCURACY TESTING

No	Test	Time	Amount
1	1	5 Second	176 ml
2	2	5 Second	179 ml
3	3	5 Second	176 ml
4	4	5 Second	178 ml
5	5	5 Second	175 ml
6	6	5 Second	185 ml
7	7	5 Second	177 ml
8	8	5 Second	178 ml
9	9	5 Second	170 ml
10	10	5 Second	179 ml
Average			177 ml

There is an inconsistency in the water filling performed by the DC pump, which dispenses water into the container. The variation between the filling trials and the average shows a maximum difference of 11 ml, which will affect the inaccuracy of the water quantity reduction in the database.

D. User Quota Subtraction Testing

In this experiment the user quota is 2800 ml, water was filled into two containers of different heights. The water dispensed by the device was then compared with a digital scale. This allowed the observation of whether there was a difference between the water volume deducted from the water quota in the database and the volume measured using the digital scale.

TABLE II
FILLING WATER TESTING

No	Water Container	Time	Volume	Water Quota
1	Cup	11 Second	368 ml	2720 ml
2	Cup	14 Second	496 ml	2335 ml
3	Bottle	24 Second	849 ml	1600 ml
4	Bottle	25 Second	881 ml	865 ml

E. Filling Water Scenario Testing

Filling water testing aims to determine whether all the censor can detect correctly the user water quota, also the user using cup or bottle when operating the machine to determine the operation of the contactless water level censor that will detect the water when filling process executed, and whether the contactless water level censor can detect correctly when the filling process is running. This test is using cup and bottle, for the cup, the height is 8 cm, and for the bottle the height is 20 cm.

TABLE IV
FILLING WATER TESTING

No	Test Scenario	Expected Result	Result Status
1	The user is using a cup, and the user status is not locked.	The machine first checks the user account status; if it is not locked, it then detects that the user is using a cup. The machine fills the cup with water until it reaches the sensor height of 7 cm, and the LCD displays the updated water quota once the process is complete.	Success
2	The user is using a cup, and the user status is locked.	The machine first checks that the user account status, because it's locked, the LCD displays 'Invalid'.	Success
3	The user is using a bottle, and the user status is not locked	The machine first checks the user account status; if it is not locked, it then detects that the user is using a cup. The machine fills the cup with water until it reaches the sensor height of 14 cm, and the LCD displays the updated water quota once the process is complete.	Success
4	The user is using a bottle, and the user status is locked.	The machine first checks that the user account status, because it's locked, the LCD displays 'Invalid'.	Success

IV. CONCLUSION

Based on the explanation of the system components, starting from the preparation of tools and materials, system design, and the construction process. The automatic water filling control system has functioned well according to the planned design. All modules and features work as intended. The NFC reader module is capable of detecting NFC cards with 100% accuracy, the HC-SR04 ultrasonic sensor can detect water levels, and the XKC-Y25-V water sensor effectively detects the presence of water in the container. Additionally, the authority system for admin and users also functions properly, where users can view their remaining water quota, and admins can manage the device, monitor water quotas, and add quotas for users. Although there is an error in water filling, with 23.15% at low levels and 15% at high levels, and a data communication packet loss of 43.42%, which is categorized as poor, the system as a whole operates well, with a communication delay of 123.169 ms, which is categorized as excellent.

ACKNOWLEDGEMENTS

This section (Optional) gives appreciation to individuals and organizations (e.g. sponsorshipt or financial support) that provide assistance to the author.

REFERENCES

[1] M. Fatimura, R. Masriatini, And A. Pratama, "Analisa Kualitas Air Minum Isi Ulang Dan Kemasan Di Kelurahan Kenten Laut Kabupaten Banyuasin."

[2] R. Salim And T. Taslim, "Edukasi Manfaat Air Mineral Pada Tubuh Bagi Anak Sekolah Dasar Secara Online."
[3] I. Lorenzo, M. Serra-Prat, And J. Carlos Yébenes, "The Role Of Water Homeostasis In Muscle Function And Frailty: A Review," *Nutrients*, Vol. 11, No. 8, Aug. 2019, Doi: 10.3390/Nu11081857.
[4] J. W. Simatupang, B. Prasetyo, M. Galina, And A. Suhartomo, "Prototipe Mesin Penjual Air Mineral Otomatis Berbasis Arduino Mega 2560 Dan Rfid-Rc522," *Elkomika J. Tek. Energi Elektr. Tek. Telekomun. Tek. Elektron.*, Vol. 10, No. 2, P. 484, Apr. 2022, Doi: 10.26760/Elkomika.V10i2.484.
[5] I. Rahayu, "Fasilitas Khusus Penyandang Disabilitas Dan Lansia Pada Masjid Raya Makassar," *Nat. Natl. Acad. J. Archit.*, Vol. 6, No. 1, P. 50, 2019, Doi: 10.24252/Nature.V6i1a5.
[6] I. Tornero-Quiñones, J. Sáez-Padilla, A. E. Díaz, M. T. A. Robles, And Á. S. Robles, "Functional Ability, Frailty And Risk Of Falls In The Elderly: Relations With Autonomy In Daily Living," *Int. J. Environ. Res. Public Health*, Vol. 17, No. 3, Pp. 1–12, 2020, Doi: 10.3390/Ijerph17031006.
[7] R. Kurnia And A. Chusyairi, "Rancang Bangun Dispenser Penuangan Air Minum Otomatis Berbasis Arduino Menggunakan Metode Prototype," *Aisyah J. Informatics Electr. Eng.*, Vol. 3, No. 2, Pp. 153–162, 2021, [Online]. Available: Http://Jti.Aisyahuniversity.Ac.Id/Index.Php/Ajiee
[8] L. O. Aghenta And M. T. Iqbal, "Low-Cost, Open Source Iot-Based Scada System Design Using Thinger.Io And Esp32 Thing," *Electron.*, Vol. 8, No. 8, Pp. 1–24, 2019, Doi: 10.3390/Electronics8080822.
[9] Ade Elbani Nugroho Farhan, Muhammad Saleh, "Perancangan Sistem Kendali Kipas Angin Otomatis Berbasis Nodemcu V3," No. Perancangan Sistem Kendali Kipas Angin Otomatis Berbasis Nodemcu V3 Farhan, P. 10, 1995.
[10] M. Haghi Kashani, M. Madanipour, M. Nikravan, P. Asghari, And E. Mahdipour, "A Systematic Review Of Iot In Healthcare: Applications, Techniques, And Trends," Oct. 15, 2021, *Academic Press*. Doi: 10.1016/J.Jnca.2021.103164.
[11] M. Saleh And M. Haryanti, "Rancang Bangun Sistem Keamanan Rumah Menggunakan Relay," *J. Teknol. Elektro*, Vol. 8, No. 2, Pp. 87–94, 2017.
[12] Rouhillah, Inzar Salfikar, And Javid Hamar, "Rancang Bangun Alat Monitoring Nutrisi Kebun Hidroponik," *J-Innovation*, Vol. 10, No. 2, Pp. 44–49, 2021, Doi: 10.55600/Jipa.V10i2.114.
[13] M. K. Anam, I. Hikmah, And S. I. Purnama, "Prototipe Sistem Pemantau Dan Pengendali Volume Air Pada Tangki Berbasis Internet Of," Vol. 25, No. 1, Pp. 20–31, 2024.
[14] F. A. Ghani And A. Zariman, "Smart Cane Based On Iot," Pp. 12–18, Doi: 10.36079/Lamintang.Ijeste-0201.15.
[15] Z. I. Faqih, E. Kurniawan, And U. K. Usman, "Penerapan Iot Sebagai Monitoring Jarak Jauh Untuk Mengetahui Proses Elektrolisis Air Mineral," Vol. 1, No. 2, Pp. 70–74, 2023.
[16] R. Wulandari, "Analisis Qos (Quality Of Service) Pada Jaringan Internet (Studi Kasus : Upt Loka Uji Teknik Penambangan Jampang Kulon-Lipi)," 2016.
[17] D. Fitri Brianna, "Analisis Qos (Quality Of Service) Pada Jaringan Komputer Sinkron Dan Asinkron (Studi Kasus : Fakultas Ilmu Komputer-Universitas Sjakhyakirti)".