IoT-Based Smart Village Transaction System Using RFID and Load Cell Modules

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Abstract. MSMEs (Micro, Small and Medium Enterprises) in the village play an essential role in improving the welfare of business owners and consumers. MSMEs in the village meet the living needs of the villagers. Research is developing an IoT-based smart village transaction system using RFID and load cell modules. The research aims to simplify transactions in the village environment, which is unique to its agricultural and livestock businesses. The system was developed using a raspberry pi, the web server. RFID is used to record transactions made by villagers by scanning their resident cards. Load Cell records the number of transactions for products measured by weight, such as agricultural and livestock products. The system prioritizes user interaction by scanning the RFID card of the transaction actor, product representation, and product weight. The system is tested using black-box testing, producing valid results for hardware and software. System performance evaluation was carried out by comparing the performance of the raspberry pi 3 with 76,789% CPU, 47.67MB RAM, 54.69C heat, and raspberry pi zero with 82.679% CPU, 102.78MB RAM, and 49.78 heat. The system is also calibrated and compared to regular scales and produces a slight difference with the tested load, an average of 1,440 g. The electrical system was also tested and resulted in low average electricity consumption, namely a voltage reduction of 0.044v for the raspberry pi three and 0.022v for the raspberry pi zero, so that it is suitable to be applied portable and in rural areas with limited electricity.

Keywords: Internet of Things · Smart Village · RFID

1 Introduction

MSMEs (Micro, Small and Medium Enterprises) in the village play an essential role in improving the welfare of business owners and consumers [1]. MSMEs in the village meet the living needs of the villagers [2]. These needs can be in the form of food from agriculture and animal husbandry from the village itself to clothing and other products from outside the village [3]. Agriculture and livestock businesses do not always have a

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regular income, so they sometimes borrow money from cooperatives to meet their daily business needs, such as fertilizer and animal feed [4].

Research is developing an IoT-based smart village transaction system using RFID and load cell modules. The research aims to simplify transactions in the village environment, which is unique to its agricultural and livestock businesses [5]. The system was developed using a raspberry pi, the web server. RFID is used to record transactions made by villagers by scanning their resident cards [6]. Load Cell records the number of transactions for products measured by weight, such as agricultural and livestock products [7].

The system prioritizes user interaction by scanning the RFID card of the transaction actor, product representation, and product weight. The system also supports lending by adopting the pay later concept for agricultural and livestock business actors [8]. The system is tested using black-box testing and produces valid results in terms of hardware and software [9]. The system is also calibrated against market scales. The electrical system was also tested to obtain the average electricity consumption for the feasibility of implementing it portable and in rural areas with limited electricity.

2 Related Research

The use of HX711 and load cells for IoT has been carried out in previous studies, such as for calculating calories in bright rice boxes [10], inventory systems for stock management [11] too smart pet feeders [12]. The research focuses on product transactions requiring weighing scales in innovative village applications with low electricity consumption.

RFID has also been carried out using raspberry pi for audio-visual playback purposes [13], bird feeders for remote monitoring of wild bird populations [14], and petrol bunk management [15]. The research uses RFID for uncomplicated transactions that do not involve smartphones because for implementation in villages, using smartphones will make it difficult in terms of user availability and internet signal [16].

3 Review of the Presented System

An overview of the system is shown in Fig. 1. The system consists of four parts: load cell, RFID scanner, web interface, and OLED display. RFID scanner is used to scan user data and products from RFID cards. User data is on the consumer's RFID card, and product data is on the seller's side. Products are represented on a card for shelf efficiency. Load cells measure the mass of products that need to be weighed first, such as vegetables and meat. The admin uses the web interface to input user and product data. OLED displays display the transaction process without a computer and aim for operation's electrical power efficiency.

The flow chart of the system is shown in Fig. 2. The process in the system begins with the preparation of IoT devices and web interfaces. To start, the system admin needs to input user data and products that are the subject of the transaction.

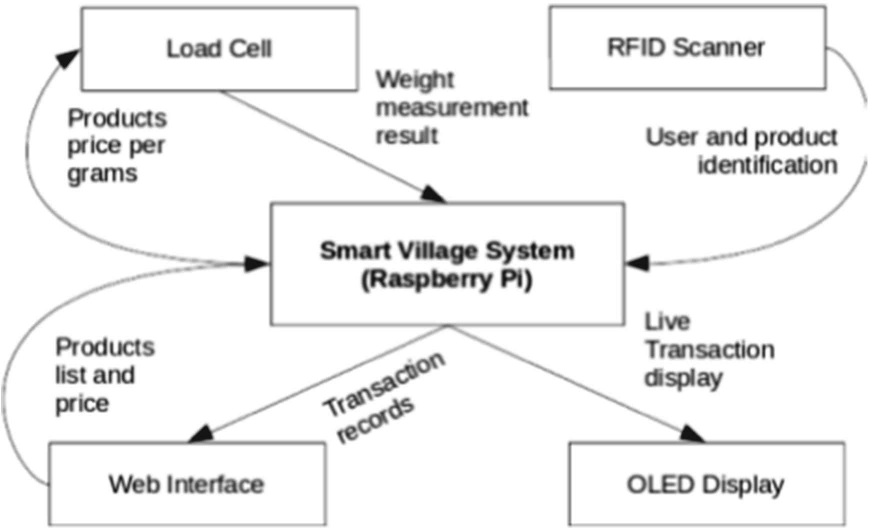

Fig. 1. General View of The System

The transaction begins with the user scanning the RFID to indicate the user is making a transaction on the system. After the user data is read in the transaction session, the seller scans the chosen product by the user. If the product is marked as needing to be weighed, the load cell is active, and the product is weighed before entering the transaction. After the product is listed with the price, then the quantity of the product is inputted. If there are other products, then the product scan is repeated.

After there are no more products to buy, the process continues with payment. Payment can be made in cash, balance (added through village fees), or pay later, which will record the nominal outside the balance. After payment, the transaction is considered valid.

4 Detail of the Presented System

The system connection circuit is shown in Fig. 3. The OLED module and HX711 are connected to 5v and GND on the raspberry pi pins. The 20 kg load cell is connected to the HX711 by four wires, two for power and two for data. The RFID module RC522 relates to a 3.3v Vcc and four connections for data.

The realization of the IoT circuit is shown in Fig. 4. The circuit is contained in a 7 $\times$ 5 cm double-side PCB. The double side is used because the components are placed at the top, while the connection to the raspberry pi at the bottom uses a 2 $\times$ 40 pin header. At the bottom, there is also a TP4056 module for future charging batteries and solar panels. The HX711, load cell, and OLED display fit perfectly to the size of the PCB. In comparison, the RC522 is out of the PCB because of its large size.

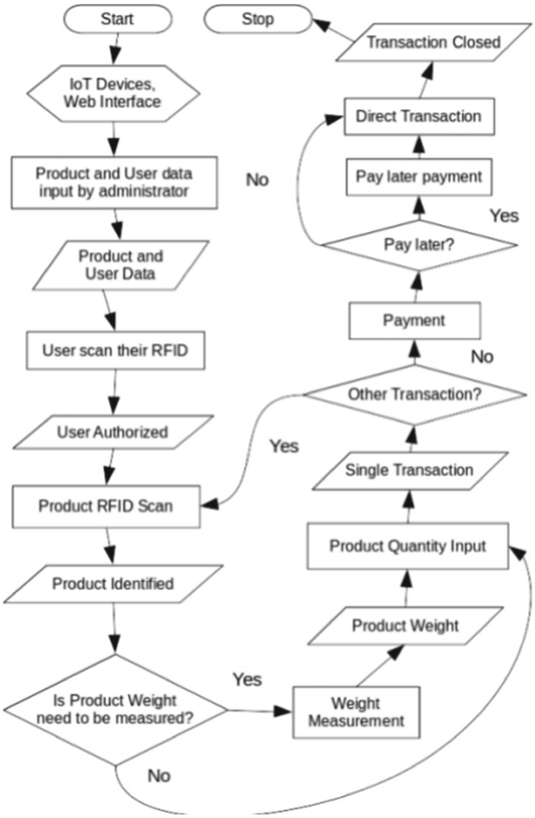

Fig. 2. Flow Chart of The System

Figure 5 shows the implementation on the raspberry pi 3. Due to the location of the raspberry pi three serial pins, the OLED module is slightly out of the raspberry pi three board. However, the RC522 module fits well, covering the USB and LAN ports of the raspberry pi 3. Apart from the OLED module, the system size is according to raspberry pi three, which is 56.5 × 85.6 mm.

Figure 6 shows the implementation on the raspberry pi zero. The Raspberry pi zero measures only 66.0 × 50.5 mm, making it smaller than a system PCB. Figure 6 also shows the TP4056 module, which can connect electricity to batteries and solar panels and charge via micro-USB with a 5v adapter.

5 Result and Evolution

5.1 Black Box Testing

The results of black box testing for hardware are shown in Table 1. The evaluation is generally divided into load cells, RC522 RFID modules, OLED modules, and electricity

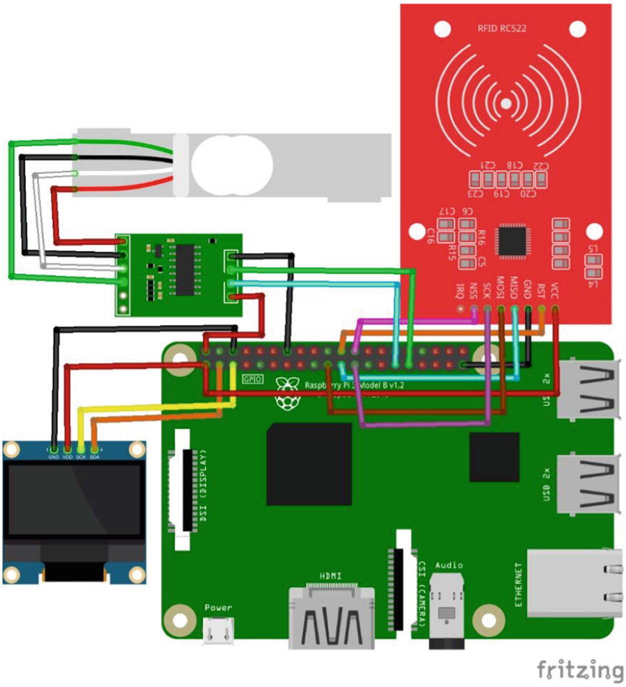

Fig. 3. Electricity Circuit of The System

Fig. 4. PCB Connection

Fig. 5. Implementation on Raspberry Pi 3

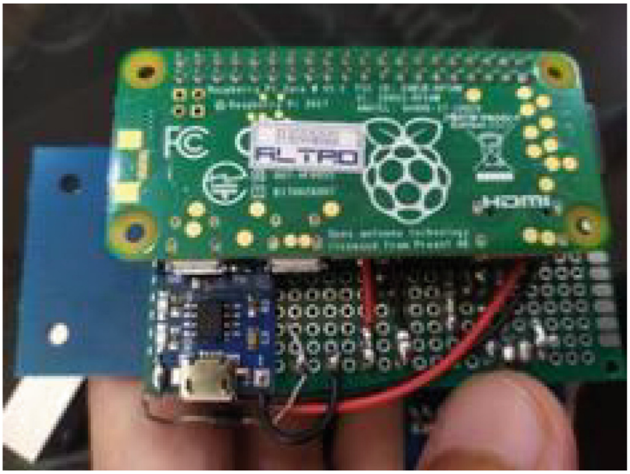

Fig. 6. Implementation on Raspberry Pi Zero

with power supply. Each test was carried out with more than one experiment, such as writing and reading RFID, using 20 cards.

Table 2 shows the results of the black box evaluation for software, namely the web interface and functional data communication between the sensor and the raspberry pi. Tests are divided based on data objects: users, balances, pay later, products and transactions. Transaction testing is done by validating user data relations, products that are data relations, and balances or paying later with additional transaction information.

Table 1. Blackbox Testing Result for Hardware

No	Evaluation	Expectation	Result
1	A raspberry pi can read Load Cell.	read	read
2	RC522 can write RFID card user data through raspberry OS shell by testing 20 cards	20 cards can be written	20 cards can be written
3	RC522 can read RFID card user data through the raspberry OS shell by testing 20 cards	20 cards can be read	20 cards can be read
4	OLED Displays can display printed output through the shell for display		
4.1	Write RFID	valid	valid
4.2	Reading RFID	valid	valid
4.3	Reading load cell input	valid	valid
4.4	Show payment results	valid	valid
5	The whole set of raspberry pi can run with a 5v power supply.	Can be supplied	Can be supplied

Table 2. Blackbox Testing Result for Software

No	Evaluation	Expectation	Result
1	User data management	valid CRUD	valid CRUD
2	Balance data management	Can be added after the user's RFID is read	Can be added after the user's RFID is read
3	Pay later data management	When the transaction and balance are less, the balance is deducted for pay later.	When the transaction and balance are less, the balance is deducted for pay later.
4	Product data management	valid CRUD	valid CRUD
5	Product data management	CRUD Valid dengan relasi data user, produk, saldo dan paylater. Valid CRUD with the user, product, balance, and pay later data relations.	CRUD Valid dengan relasi data user, produk, saldo dan paylater. Valid CRUD with the user, product, balance, and pay later data relations.

5.2 Computational Comparison

A comparison between CPU load (%), RAM(MB), and heat(oC) between raspberry pi three and zero is shown in Table 3. The test is carried out based on three aspects: web server (Nginx) [17], use of RFID, and load cell. The web server runs continuously if it is on. In comparison, RFID and load cells are only done during transactions. Raspberry

Table 3. Comparison Of Raspberry Pi Performance

	Measurement	raspberry pi 3	rpi zero
web server (nginx)	CPU Usage (%)	45.456	67.786
	RAM (MB)	12.45	13.67
	heat (°C)	45.56	39.78
using RFID	CPU Usage (%)	56.786	69.789
	RAM (MB)	34.46	45.67
	heat (°C)	48.67	45.78
using load cell	CPU Usage (%)	76.789	82.679
	RAM (MB)	47.67	102.78
	heat (°C)	54.69	49.78

Table 4. Comparison Of Load Cell and Regular Scale

mass(gram)	scale		load cell	
	measured	error	measured	error
1000	998.78	1.220	997.677	2.323
500	489.78	10.22	498.896	1.104
200	198.65	1.350	197.787	2.213
100	98.78	1.22	99.654	0.346
50	49.89	0.110	48.788	1.212
		2.824		1.440

Pi zero generally shows higher CPU and RAM load but lower heat generation. The peak load occurs when using a load cell.

The comparison of the mass load measurement between the 20kg loadcell used by the system and the regular 20 kg scale is shown in Table 4. The mass load measured is adjusted to standard scales available in the market. The results show that the load cell has a standard error of 100 g. Regular scales produce a high error of 500 g. In general, the difference in accuracy does not have a definite pattern.

The comparison of power usage by raspberry pi and zero is shown in Table 5. The test includes current, voltage, and voltage reduction per two hours [18]. In general, raspberry pi zero has lower energy consumption with an average reduction of 0.022v compared to raspberry pi 3 with 0.044v. Generally, both devices leave voltage above 3v after 24 h.

Table 5. Comparison Of Energy Availability

raspberry pi 3			raspberry pi zero		
current (mA)	voltage (V)	Decr (V)	current (mA)	voltage (V)	Decr (V)
128	3.826	0	87	3.801	0
172	3.778	0.048	85	3.789	0.012
167	3.679	0.099	73	3.779	0.010
182	3.678	0.001	65	3.772	0.007
127	3.629	0.049	43	3.759	0.013
123	3.612	0.017	78	3.712	0.047
124	3.589	0.023	37	3.699	0.013
152	3.529	0.060	79	3.669	0.029
162	3.469	0.060	76	3.619	0.049
179	3.392	0.077	59	3.592	0.027
172	3.381	0.011	68	3.581	0.011
192	3.298	0.081	87	3.528	0.052
156.666	3.5716	0.044	69.75	3.691	0.022

6 Conclusion

Research is developing an IoT-based smart village transaction system using RFID and load cell modules. The system is tested using black-box testing, producing valid results for hardware and software. System performance evaluation was carried out by comparing the performance of the raspberry pi 3 with 76,789% CPU, 47.67 MB RAM, 54.69 C heat, and raspberry pi zero with 82.679% CPU, 102.78MB RAM, and 49.78 heat. The system is also calibrated and compared to regular scales and produces a slight difference with the tested load, an average of 1,440 g. The electrical system was also tested and resulted in low average electricity consumption, namely a voltage reduction of 0.044v for the raspberry pi three and 0.022v for the raspberry pi zero, so that it is suitable to be applied portable and in rural areas with limited electricity.

References

1. P. Kijkasiwat, N. H. Wellalage, and S. Locke: The impact of symbiotic relations on the performance of micro, small and medium enterprises in a small-town context: The perspective of risk and return. In: Res Int Bus Finance, vol. 56 (2021)
2. I. D. Utami, I. Santosa, and M. R. Vidya Leila: Priority resilience strategy for micro, small, and medium enterprises for dealing with natural disasters. In: International Journal of Disaster Risk Reduction, vol. 55 (2021)
3. C. Park and J. Cha: A Trend on Smart Village and Implementation of Smart Village Platform. In: International Journal of Advanced Smart Convergence, vol. 8, no. 2 (2019)

4. T. T. H. Tambunan: Development of micro, small and medium enterprises and their constraints: A story from Indonesia. In: Gadjah Mada International Journal of Business, vol. 13, no. 1 (2011)
5. E. Purwaningsih and Suhaeri: Empowerment model of micro, small, and medium enterprises (Msmes) village tourism business in e-commerce transactions and legal protection. In: Journal of Advanced Research in Law and Economics, vol. 10, no. 3 (2019)
6. S. Chalasani and R. v. Boppana: Data architectures for RFID transactions. In: IEEE Trans Industr Inform, vol. 3, no. 3 (2007)
7. A. Ringe: Smart Refrigerator Using Load Cell and IOT Protocols. In: Int J Res Appl Sci Eng Technol, vol. 7, no. 5 (2019)
8. Y. Pratika, S. Salahudin, D. W. U. Riyanto, and T. Ambarwati: Analysis of Pay Later Payment System on Online Shopping in Indonesia. In: Journal of Economics, Business, & Accountancy Ventura, vol. 23, no. 3 (2021)
9. M. S. Aliero, I. Ghani, K. N. Qureshi, and M. F. Rohani: An algorithm for detecting SQL injection vulnerability using black-box testing. In: J Ambient Intell Humaniz Comput, vol. 11, no. 1 (2020)
10. M. Hanif, M. Abdurohman, and A. G. Putrada: Rice consumption prediction using linear regression method for smart rice box system. In: Jurnal Teknologi dan Sistem Komputer, vol. 8, no. 4 (2020)
11. B. Nagaria, P. Shroff, and R. Mehrotra: IoT Based Inventory System for Stock Management. In: International Research Journal of Engineering and Technology (IRJET), vol. 6, no. 4 (2019)
12. M. K. R. Et.al: Smart Pet Feeder System and Big Data Processing to Predict Pet Food Shortaget. In: Turkish Journal of Computer and Mathematics Education (TURCOMAT), vol. 12, no. 3 (2021)
13. Á. Z. Lendvai, Ç. Akçay, T. Weiss, M. F. Haussmann, I. T. Moore, and F. Bonier: Low-cost audiovisual playback and recording triggered by radio frequency identification using Raspberry Pi. In: PeerJ, vol. 2015, no. 4 (2015)
14. M. Youngblood: A Raspberry Pi-based, RFID-equipped birdfeeder for the remote monitoring of wild bird populations. In: Ringing and Migration, vol. 34, no. 1 (2019)
15. B. Naveen, B. K. Rashmitha, K. S. Parthasarathi, B. C. Sandhya, and S. Lohith: IoT based petrol bunk management for self-operation using RFID and raspberry PI. In: International Journal of Recent Technology and Engineering, vol. 8, no. 1 (2019)
16. S. Zhang et al.: Smartphone versus pen-and-paper data collection of infant feeding practices in rural China. J Med Internet Res, vol. 14, no. 5 (2012)
17. C. Ma and Y. Chi: Evaluation Test and Improvement of Load Balancing Algorithms of Nginx. In: IEEE Access, vol. 10 (2022)
18. W. Wedashwara, C. Ahmadi, I. W. A. Arimbawa, and I. G. E. W. Putra: Internet of Things based Smart Energy Audit using Evolutionary Fuzzy Association Rule Mining. In: 2019 International Conference on Sustainable Information Engineering and Technology (SIET), pp. 142–147 (2019)