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Integration of Multi-Modal Sensors and Images for Monitoring Book Stock Inventory in an Internet of Things- Based Warehouse

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ABSTRACT

Study This designing system supervision inventory stock books in a warehouse based on the Internet of Things (IoT), with combining multi-modal sensors and digital images . The system This developed For increase accuracy recording stock , reduce errors caused humans , as well as monitor condition goods in a way directly Components device hard used includes Raspberry Pi 5 as controller , loadcell sensor for measure weight , ultrasonic sensor For evaluate capacity , and Raspberry Pi camera for needs visual verification . The information generated will sent to the IoT platform via MQTT protocol and visualized with using Node-RED. Approach study following the Research and Development (R&D) model based on ADDIE, including stages analysis needs , design , development , implementation , and assessment system . The results of implementation show that system This capable monitor stock with precise and provide announcement automatic moment capacity storage reaching the minimum limit. The combination of multi-modal sensors and imagery allows manager warehouse For get information about weight , capacity , and appearance condition goods in a way simultaneously , so that decision For filling repeat can done more fast and accurate . Trial show that this IoT technology capable increase efficiency operational , pressing cost power work , and minimize risk lost goods , making them the right modern solution For management inventory in the warehouse .

I. INTRODUCTION

One of element crucial in operational world of industry business is management stock good in the sector retail , manufacturing , and logistics . One of the aspect important in management stock is management inventory stock goods in the warehouse . Stock is supply goods stored by the company or the shop that will sold in the period next (KBBI, 2012). Management effective stock with ensure availability goods in accordance needs , prevent emptiness , and increase satisfaction customers . However , in In practice , many people experience challenge problem like excess or lack stock , error recording , delay in the process of restocking, upgrading cost operational and lack of visibility to condition stock in real time so that moment service will hampered .

The current digital era Nowadays , Internet of Things (IoT) technology is here as solution innovative For overcome various existing problems . IoT allows integration between device physical , sensors, and digital systems , so that the process of monitoring , sending , and processing data can be done in a way automatic . In the context of warehouse , IoT implementation can optimize inventory monitoring system with utilizing multi-modal sensors and digital images . Multi-modal sensors, which include RFID, weight sensors, and optical sensors , enable data accuracy in general more comprehensive For reduce error in recording stock . Meanwhile that , technology processing image allows visual verification of condition and quantity stored items . System This give notification automatic when stock approaching the minimum limit, resulting in more reports accurate .

Frequent obstacles experienced in management stock warehouse book is often happen difference stock between stock physical and stock system caused various one of the factors is human error. Error individual caused by Because lack of accuracy in run a company SOP that can result in difference stock. Therefore it is very necessary A monitoring system that can help minimize mistakes recording stock or caused by human error Alone.

Integration between multi-modal sensors and imagery in system IoT based will give various benefits, such as improvement accuracy in recording stock, reduction error human error, and monitoring condition goods in real-time. With existence automatic monitoring system this company can increase efficiency operational, reducing cost power work , and minimize risk lost goods. The application of IoT in monitoring stock No only increase efficiency operational , but also supports company in taking more decisions fast and precise . Generated data real -time possible prediction need stock based on trend consumption and market demand. With Thus , the risk emptiness stock that can bother activity operational or lower level satisfaction customer can minimized in a way significant

II. METHOD

A. *Research Design*

Methodology research used in study This is approach Research and Development (R&D) research with using the ADDIE model, which is abbreviation from Analysis, Design, Development, Implementation, and Evaluation. Approach This used as framework general in development system optimization Internet of Things (IoT) based inventory management . This model focus on analysis need user , design appropriate solutions , development system , implementation technology in the field , as well as evaluation For ensure success and effectiveness developed solutions.

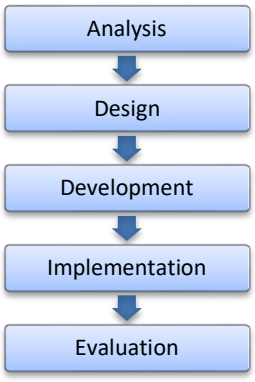

Figure 1 Research Design

Based on information in Figure 1, The analysis stage begins by carrying out analysis comprehensive related condition inventory management in a company . Analysis This covers inspection and evaluation inventory management in a company, obstacles and what is faced in inventory management

After analyze, steps furthermore is designing development appropriate system with need inventory management . This step covering design system intelligent based on the Internet of Things (IoT) which is capable of optimize management inventory management and monitoring goods in storage .

After stage design finished , device installed one by one, all device connected to the Raspberry Pi as controller main. Program then entered to Raspberry Pi for integrate sensor function , capture visual imagery , and connections to the Blynk platform to monitor data in real-time.

At the stage implementation done installation system on the shelf storage goods located in the inventory warehouse , for conduct a trial monitoring every day . This is aim ensure system walk with Good in accordance planning . Next , do testing data accuracy with compare results from ultrasonic sensors and loadcell sensors with tool manual measurement to find out level accuracy and consistency developed system. Then, practice party related , such as manager or officer technical, regarding procedures use systems and applications IoT based .

At the stage evaluate , observe performance systems and applications whether walk with Good in monitoring storage in real-time. Evaluation covers ability system in give notification automatic and easy recording and monitoring condition goods. In addition, make questionnaire For get feedback from users, such as inventory officer or officer technical, as input For improvement and development systems in research furthermore.

B. *Block Diagram*

Block diagram is type of system diagram used For describe connection functional between component or subsystem in something system in a way simple and structured, where each function main represented by interconnected blocks connected with lines or arrow indicating flow signal, data, or energy. This diagram Lots used in field engineering, design device hardware, electronics , development device software and analysis channel Work For visualize interaction between part system, helps the process of designing, analyzing, and communicating ideas in a more efficient without displays complex technical details.

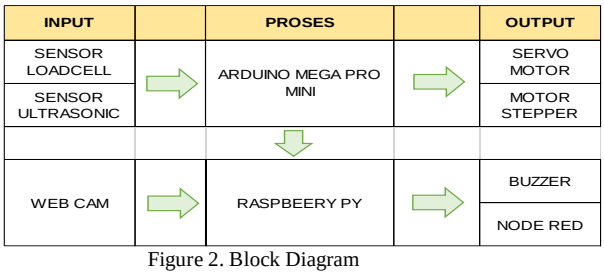

Figure 2. Block Diagram

Based on The information in Figure 2 shows connection between component main in system *Stock Monitoring* Internet of Things (IoT) based system This consists of on a number of part main components , namely sensors, microcontrollers , actuators , devices data processors , as well as interface users based Node-RED *dashboard* .

In a way general channel Work system started from sensors read condition physique in the form of weight and distance then the data will sent going to microcontroller Arduino to be processed, the results of the process Then continued to the Raspberry-Pi via protocol communication , from raspberry then the data will sent For displayed on the red node via MQTT connection . Users can do command to scan books located in storage with enter commands via Node-RED, from order the will delivered to the Raspberry-Pi, which will then will run the camera scanning process , to reach overall shelf , after accept input from Raspberry Pi, Arduino will running stepper motors and servo motors, from camera scanning results will enter to Raspberry-Pi for displayed on Node-Red

III. Results and Discussion

Shelf monitoring system book built with a number of device integrated hardware For optimize the monitoring process in the warehouse . Components mainly covering frame shelves , boards base , path rails , cameras , ultrasonic sensors , loadcell sensors, servo motors, and stepper motors. The system This Work through sensor and module integration controller , where the camera functioning do *image acquisition* , loadcell sensor measures weight , and ultrasonic sensors detect capacity shelf . All data obtained sent through MQTT protocol to Node-RED for Then processed and visualized in form *dashboard* interactive . On the side device software , MQTT is used as a data communication medium between device , while Node-RED plays a role in integration , processing , and presentation of data in real-time, so that system capable give information condition rack book in a way accurate and efficient .

Review implementation system show that studies This has produce shelf monitoring system book Internet of Things (IoT) based designed For monitor conditions and capacity rack in a way automatic and efficient . System This consists of on a number of component main , namely cameras , ultrasonic sensors , load cell sensors , servo motors , stepper motors , and functioning microcontroller as center controller . The camera is used For do *image acquisition* to detect condition rack , loadcell sensor measures heavy books , while ultrasonic sensors used For monitor capacity shelves . All the results data acquisition sent through protocol MQTT to the Node-RED platform For processed and visualized in form *dashboard* interactive . Implementation system carried out in simulation rack book smart in the environment warehouse , where the data acquisition process is carried out in a way periodically For test performance and accuracy system . Figure 3 and Figure 4 display configuration device hardness used in study This .

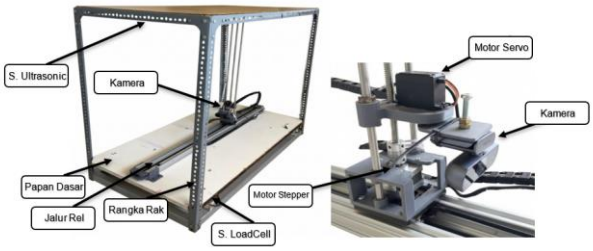

Figure 3 . Implementation Device hard

Figure 3 shows method Work device hard a system consisting of from a number of part main , namely frame functional shelves as buffer all over structure , board the basis used For put the object being tested , as well as track rails that allow camera move straight . The camera is mounted on a mechanism operated by a stepper motor to arrange horizontal position and servo motor for arrange corner taking image . Ultrasonic sensor used For measure distance between camera and object , while the load cell sensor functions measure heavy or burden objects placed on the board basic . All component the Work together in a way integrated For support the data retrieval process automatic with level high accuracy .

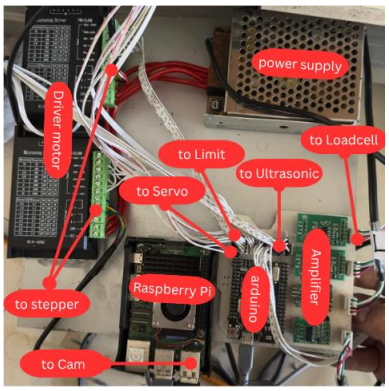

Figure 4 . Series Component Device hard

Shelf monitoring system book This integrate various sensors and modules controller in architecture distributed data processing . Camera do *image acquisition* For read barcode and send decoding results to Raspberry Pi as center processing . Load cell sensor measure total mass of books processed through HX711 and Arduino Uno , meanwhile ultrasonic sensor detect capacity rack in a way *real-time* . The camera is mounted on a linear mechanism with stepper motor and *timing belt* For determine position book in a way automatically . All data, including identity , number copies , capacity shelves , and positions storage , sent through MQTT to Node-RED For visualized in *dashboard* monitoring *real-time* .

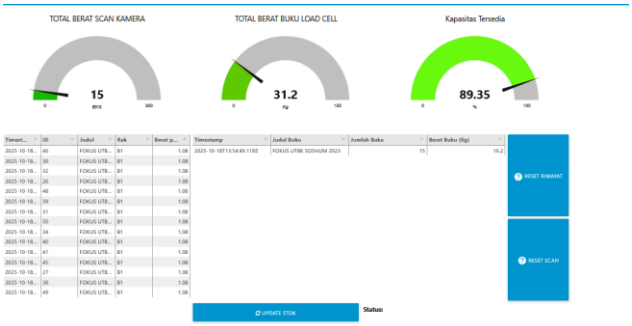

Figure 5 . Node-RED View

Node-RED is used as a data integration and visualization platform in the stock monitoring system books , allowing design node -based data flow for connect MQTT broker with *dashboard* monitoring . This platform display stock status book in a way interactive through web interface , manage automation like notification minimum stock , as well as can save data to the database. With Thus , Node-RED makes it easier monitoring at a time increase connectedness and capability based monitoring system IoT .

NO	HASIL UKUR TIMBANGAN (KG)	NILAI ANALOG (ADC HX711, 24-BIT)	HASIL SENSOR LOADCELL (KG)	AKURASI	KETERANGAN
1	10.15	1,693,821	10.15	100%	AKURAT
2	20.35	3,396,571	20.35	100%	AKURAT
3	30.45	5,081,945	30.45	100%	AKURAT
4	40.60	6,776,797	40.60	100%	AKURAT
5	50.75	8,471,558	50.75	100%	AKURAT
6	61.00	10,173,875	61.00	100%	AKURAT
7	70.85	11,813,289	70.85	100%	AKURAT
8	80.35	13,407,928	80.35	100%	AKURAT
9	90.15	15,061,693	90.15	100%	AKURAT
10	100.55	16,777,215	100.55	100%	AKURAT
RATA RATA				**100%**	**AKURAT**

Figure 6 . Appearance Testing Loadcell sensor accuracy

Figure 6 shows results Loadcell sensor testing with put burden in the form of book with variation burden different from 10.15 Kg to 100.55 Kg. Testing the done as much as ten times with compare between results measurement scales with results measurement using an existing Loadcell sensor built , table results testing the show that results measurement use scales and loadcell sensors show similar results Where mark accuracy show the number 100%, and from ten times testing the the average value obtained also shows number 100% accuracy , with information accurate .

NO	HASIL UKUR METERAN (CM)	ULTRASONIC 1 (CM)	AKURASI	ULTRASONIC 2 (CM)	AKURASI	ULTRASONIC 3 (CM)	AKURASI	ULTRASONIC 4 (CM)	AKURASI
1	22	22	100%	22	100%	22	100%	22	100%
2	27	27	100%	27	100%	27	100%	27	100%
3	31	31	100%	31	100%	31	100%	31	100%
4	36	36	100%	36	100%	36	100%	36	100%
5	45	45	100%	45	100%	45	100%	45	100%
6	50	50	100%	50	100%	50	100%	50	100%
7	55	55	100%	55	100%	55	100%	55	100%
8	60	60	100%	60	100%	60	100%	60	100%
9	69	69	100%	69	100%	69	100%	69	100%
10	74	74	100%	74	100%	74	100%	74	100%
RATA-RATA			**100%**		**100%**		**100%**		**100%**

Figure 7 . Appearance Ultrasonic Sensor Testing

Figure 7 shows safe ultrasonic sensor testing done as many as 10 times with variation distance between 22 cm to 74 cm, and the results show that four ultrasonic sensors own level suitability perfect with results measuring meter on each experiment . On the whole testing , including distance 74 cm, 50 cm, up to 22 cm, the sensor provides results identical with manual measurement . The accuracy value obtained reached 100% on all sensors without existence difference between results measure , so that the average accuracy the total is also 100%. With thus , it can concluded that ultrasonic sensor Work very well and capable give results accurate measurements throughout variation tested distance .

NO	JUMLAH AKTUAL (EKS)	JUMLAH PEMBACAAN KAMERA (EKS)	AKURASI	KET
1	10	10	100%	VALID
2	20	20	100%	VALID
3	30	30	100%	VALID
4	40	40	100%	VALID
5	50	50	100%	VALID
6	60	60	100%	VALID
7	70	70	100%	VALID
8	80	80	100%	VALID
9	90	90	100%	VALID
10	100	100	100%	VALID
RATA RATA			100%	VALID

Figure 8. Display Camera Testing

Figure 8 shows testing Testing camera done with compare amount current the object being tested with results reading camera . Testing done as much as ten times with amount various objects start from 10 copies up to 100 copies . based on table results testing result reading camera always in accordance with amount current books that are used sample testing , as example in testing First Where placed 10 books For scanning was performed and the results reading camera show the same amount , as well as testing next , whether in quantities of 20 copies , 50 copies , 70 copies , up to 100 copies , the results from reading camera show suitability between amount book in a way actual.Thing This show that No There is difference between amount book current with results reading camera , with thus mark 100%

accuracy and results reading valid camera based on amount current book .

Test results show that shelf monitoring system designed book capable Work with accurate , consistent , and appropriate with objective design . All sensors, including ultrasonic sensors , load cells, and cameras , provide results valid and stable readings at every scenario testing . Integration process between components , start from data acquisition up to delivery information through MQTT protocol to the Node-RED platform, running fluent without disturbance communication system notifications also work in accordance with established rules , such as give warning when capacity rack approaching the maximum limit or happen mismatch between amount book detected with database. Compared with study previously , the system This show superiority in multi-sensor integration , implementation architecture distributed data processing , as well as ability give information and notifications in real time through an interactive dashboard . This prove that system No only effective in monitor stock books , but also have potential For developed more carry on as solution automation management inventory efficient and adaptive IoT - based .

IV. CONCLUSION

Based on results research and testing , can concluded that system rack book IoT- based developed succeed implemented with Good through integration of load cell sensors, ultrasonic sensors , and cameras , so that capable detect weight and quantity book in a way accurate , with mark accuracy reach 100% in position books that have been determined . System the notification applied also works effective , sending warning in a way automatic when amount book reach a certain limit or happen difference between reading camera and weight book , so that make it easier users in monitor availability stock without must do manual checking . Compared with study previously , research This show novelty in the form of multi-sensor integration with accuracy tall as well as system applicable real-time notifications For management inventory book . In overall , system This proven worthy used as solution digitalization inventory books and able increase efficiency in the monitoring process availability and management rack book .

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