Role of Radio Frequency Identification (RFID) in Warehouse and Logistic Management System using Machine Learning Algorithm

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Abstract

The world today is advancing towards a digital solution for every indusial domain varying from advanced engineering and medicine to training and management. The supply cycles can only be boosted via an effective management of the warehouse and a stronger hold over the logistics and inventory insights. RFID technology has been an open source tool for various MNCs and corporal organization who have progressed along a considerable drift on the charts. RFID is a methodology of analysing the warehouse and logistic data and create useful information in line to the past trends and future forecasts. The method has a high tactical accuracy and has been seen providing up to 99.57% accurate insights for the future cycle, based on the organizational capabilities and available resources. This paper discusses the implementation of RFID on field and provides results of datasets retrieved from controlled data of a practical warehouse and logistics system.

Keywords:

RFID, ML, Radiofrequency Identification, Logistics, Warehousing

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1. Introduction

With the progress of time, mankind has leaped multiple boundaries so as to ensure that connectivity and ease of access is maintained. Small transactions have now turned to corporate deals and month or yearlong delivery timings have now been shortened to hours or days. In the present age, technology has been highly integrated with day-to-day life, from communications to transportations. With the emergence of IOT and Industry 4.0, industries are now able to cater clients from all around the globe. However, this substantial increase in clientele has also come with multiple issues from recording transactions to delivery mishaps, not to mention the ever long presence of human error. To tackle such issues, companies have now turned to solutions that will handle the logistic demands of their respective industries. One such solution is a RFID and ML based warehouse management system that upon implementing resolves all the clutter left behind after the production phase.

RFID tags use electromagnetic fields to identify and trace the objects they are attached. These tags are traceable using a RFID reader which is a device that emits radio waves of specific frequencies and amplitudes to catch and transfer data present in the nearby desired tags. RFID tags come in two types: active and passive. The former requires to operate whereas the latter converts the energy it receives from the radio waves it receives.

Machine learning is a crucial technique used in Industry 4.0 to automate processes that had once been performed by manual smart labour. This way human errors and technical redundancies are heavily reduced. The technique creates network similar to the neurons present in the human brain. These neural network act almost exactly like a human brain which either learns are after repeated trials (CNN) or by taking data from trails done previous by other (ANN).

2. LITERATURE REVIEW

Smart management systems are nowadays considered very popular among high end companies with a large number of product lines as these companies are more prone to disruptions when certain crises arise. A research conducted by Ian M. Cavalcante, Enzo M. Frazzon, Fernando A. Forcellinia and Dmitry Ivanov in 2018 shows a simulation using machine learning to select product suppliers and predict disruptions within the delivery timings.

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In their work, they've utilized a simulation models using Any logic software. The simulations use system dynamics, agents and related events to make interaction and support of life-like. They then constructed a ML model using the python Scikit-Learn Python module which enables multiple ML tools and algorithms for sizable supervised and unsupervised issues. They've further used module such as Numpy, Matplotlib and Pandas python modules for the data analysis and pre-processing. Their pre-processing stage consists of the removal of the trash data collected by the ML model along with the classification and representations of said data. To identify manufacturing products supervised machine learning (SML) is used as regression algorithms can better identify continuous and discrete datasets. For their work, they've made use of the

k-NN and logistic regression (LR) SML models. They then began organizing previous data by delivery timings. After this the LR assesses the risks and then generates the probability of success for the provided data. Then k-NN algorithm uses the same data set provided to the LR model and gives a prediction of the probability of success of the delivery. Two hybrid algorithms were then constructed for the data evaluation. One algorithm takes the classifications of both SMLs without taking the accuracy into consideration and the other does the opposite. The accuracy of the LR model is determined by the area under curve (AUC) of the receiving operations curve (ROC) which ranges from 0 to 1, with 0.5 considered as random performance while the accuracy of the k-NN model by the rate at which it correctly identifies the result of an event.

They then integrated both the simulation and ML models by the exchanging the hybridized data of both SML models to the simulation and then puts it in the database for future use. The SML then provides the decision after utilizing the previous data within the database. Events simulations data consisted of a 4-year time frame. The hybrid algorithms in this experiment were trained with simulation generated events for a 2-year time period. The remaining data was then used for model validation and testing. Afterwards, results were generated from 5 different scenarios, the results of the first algorithm which does not take model accuracy in account was shown to give 44.03% reliability whereas the other one was which did consider the accuracy was giving a reliability of 46.16%. This showed that the SML models gave limited results with data of up to 4 years and thus required a larger training dataset. Furthermore, the experiment showed at a larger number of supplier surmounted to a better operations system [1].

Another research conducted by C.K.M. Lee, William Ho, G.T.S. Ho and H.C.W. Lau; proposes the construction of a responsive logistics workflow system (RLWS) which utilize RFIDs rather than barcodes as RFIDs allow for more diversification of products; enable both read and write features; and have a higher read range when compared to barcodes. Their RLWS 's component is the knowledge discovery unit (KDU) which consists of an artificial neural network that will be used to identify knowledge within a dataset. Another crucial component of the system is logistics information exchange module (LIEM) which will be used to generate operating strategies in fluctuating markets. This module will also be adopting the electronic product codes advocated by EPCGlobal so as to enable transference of RFID data. For the decision-making process they propose the usage of OLAP which is a database application used for such systems. This allows for faster data analysis and extraction from multiple corporate database networks. The system further adds a rule-based mechanism to diversify retail orders by dividing them into different categories by identifying different order elements thus prioritizing them. The ANN used in this system is a basic feed forward network consisting of an input, output and hidden layer which enable efficient human-like analysis of very large amount amounts of data. The ANN would also be used to handle errors generated by the RFID readings and automatically correct them by performing cross validation checks. For the training period of the ANN, the network will then be handed multiple error scenarios to check whether it identifies them as errors or not and then plot a training error versus the training epoch graph. Once the error margin is crossed the training will stop. Overall, the RLWS does provide a decent accuracy at minute training periods but the accuracy increase rate is very slow despite variations in the transfer functions of the LIEM. [2]

A research done by Pengcheng Fang, Jianjun Yang, Lianyu Zheng, Ray Y. Zhong and Yuchen Jiang use RFIDs to construct a Cyber-Physical Production System. The system consists of four layers with two being physical and the other two being cyber. The first physical layer consists of the smart service layer. In this layer physical objects are converted to smart logistic objects by the deployment of the MES system and RFID sensors where the MES monitors the object's work and the RFIDs keep track of the locations of the object in the physical world. The second physical layer is edge processing which will perform redundancy checks of the data sent by the sensors in the physical world. This layer consists of a Bayesian inference engine which will perform the check and also remove trash data accumulated online. The first cyber layer consists of the data analytics which acts as a failsafe measure which will further analyse the data sent by the edge processing layer and then record the rectified data to the historical database. This layer also connects the physical and cyber domains. The second cyber layer is the smart service layer which takes the data provided by the other layers and gives a visual feedback. Order and task management is performed through this layer. This research concludes that the CPPS is a fully reliable system however it is unable to process complex events and therefore requires a neural layer to address said events. [3]

Another research was conducted in 2015 done by Jongsawas Chongwatpol which integrated the use of RFIDs in trade fairs. This was achieved by used of Gen1 and Gen 2 passive RFID tags that are attached to the attendees and Alien ALR-9800 RFID readers placed all around the venue. The traceability services of the RFIDs allowed for the attendees' location to be tracked. This tracking data was then sent to the neural network, decision trees and multiple regression algorithms which generate data on product popularity. The end result of the research concluded with multiple technical redundancies in tracing due to the varying moving speeds of attendees passing the reader. This implied that a more efficient reader was to be placed to overcome this limitation. [4]

An experiment done by David Bogataj, Marija Bogataj and Domen Hudoklin by constructing a cyber-physical system composed of RFIDs and other sensors to monitor the parameter of growing plants and then using the data to predict the expiration date of the produce. The parameters gathered were location, humidity, gas and temperature. This data was the sent to a neural logistics network which the computed the shelf life of the perishable products and sent to the supplier who then vary the amount given to retailers and customers depending upon expiration date. [5]

A study conducted by Francisco Ballestín, Ángeles Pérez, Pilar Lino, Sacramento Quintanilla and Vicente Valls discussed the static and dynamic policies with DRFID and SRFID of a warehouse storage system. Here they considered the layout of the warehouse to be rectangular with four types of forklifts. Each type of forklift has different functioning capabilities which refer to level and depth reachable. The policies discuss the movements and restrictions of each type of forklift. The policy is further implemented by RFIDs which only enable the forklift designated to the specified radio frequency. RFID data is stored in a historical database which when called upon for retrieval or storage will be sent to the forklift. A route management algorithm then generates the optimal route and picks nearby and available forklift. After the order is complete, the data on the RFIDs will be rewritten. The policies further discuss the priority placement and execution of orders. [6]

Another study done in 2019 by Ilaria Giustia, Elvezia Maria Cepolina, Edoardo Cangialosi, Donato Aquaro, Gabriella Caroti and Andrea Piemonte proposes the implementation of a RFID cargo management system to reduce human error and enhance performance. To do this risk assessment would be performed on multiple simulated scenarios, which have been provided with the database containing expected human errors, and then a risk matrix was to be generated for each scenario. This matrix would further be assessed using the Monte Carlo technique which then updates the damage values after rerunning the scenarios which slightly modified parameters. Once this stage is complete, a risk value is generated by the sum of all components of the updated risk matrix. The risk value is then used to categorize the scenario by severity with higher value. The system was shown to be very effective in assessing the probability of simulations however the limiting factor of the system shows that it would give redundant data if real time delay constants are not added. [7]

For most RFID systems to work properly, traceability plays a vital role. A research done by Yong-Shin Kang and Yong-Han Lee describes the development of RFID traceability services. This development relies on the framework provided by EPCglobal network. The trace and track framework by using multiple query algorithms. These algorithms keep updating when the product is demanded by providing movement routes of said object. The research further discusses to implementation of the system using three layers: interface, business logic and client layer. The interface layer uses a GUI to allow RFID tag data to be read and rewritten. The business logic layer consists of the trace and tracking query algorithms whereas the client layer works in tandem with the business layer to provide working feedback on the interface layer. The results provided by this research are efficient and can further be applied as Near Field Communications (NFCs) when combined with EPC. [8]

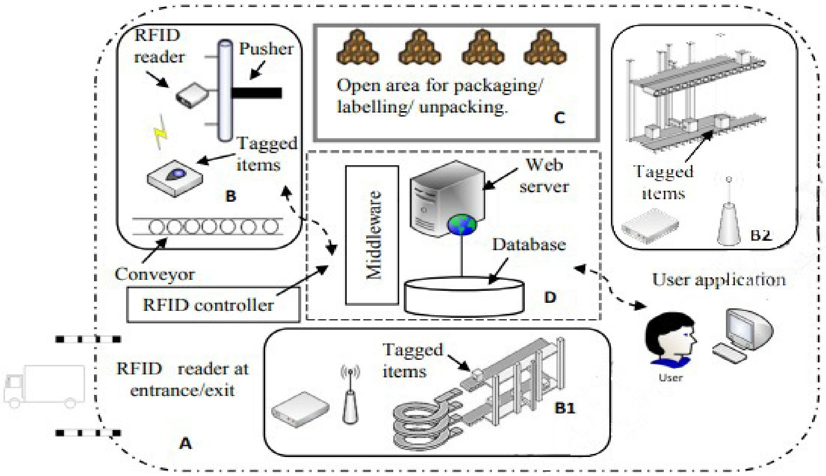
A study done on reverse logistics systems was conducted by C.K.M. Lee and T.M. Chan which allows efficient data transfer between collectors and recyclers. This system is composed of GA and RFID where the latter is using in the examination of products while the former is used to determine the best point of collection with respect to the quantity of returned products. The results provided by this research show that this system is implementable on small to medium-scaled number of transactions done per day. For usage in large-scaled environments a neural interface must also be integrated with the system to reduce redundancies. [9]

An experiment done by Prakash.G, Pravin Renold. An and Venkatalakshmi provided a system for cold chain management using RFIDs. Cold chain is a temperature reliant supply chain which usually operate at very low temperatures causing most electronics to malfunction. The RFID proposed in this experiment is Thermochromics iButton as its 16mm casing allow for low temperature operations. The system working using the 1-Wire protocol which is half-duplex hence one-way communication to-and-fro is possible at the same time. The user interface is designed using Java which then allows for real time monitoring. The results show that iButton easily monitors data without malfunctioning at lower temperatures. [10]

A research illustrated that leaching the network protocols at the system sensor nodes whilst the machine learning algorithms traverse across the data is a significant approach to qualify for a better output. As a fact, chances in the configurations of WSN protocols, connectivity and access control concerns can affect the data fed into the neural networks which ultimately has an adverse impact on the system maintenance as training unclear datasets can also affect the outputs and may lead to security concerns. The Leaching methodology over WSN can also provide a secure layout for the warehouse and logistics management systems where each node has its security protocols [12].

3. PROPOSED METHODOLOGY

The proposed design for the RFID warehouse management system consists of the design by Saleh Alyahya, Qian Wang and Nick Bennett. The systems consist of RFID readers at the entrance and exit of the warehouse so as to get information on good being sent out or added in (mentioned in A). After unpacking, the goods will then be transferred onto the storage racks (seen in B1) which can also send them back via conveyor (seen in B2) by a pusher device (seen in B). The pushers themselves have RFID readers that receive signals from each RFID tagged item on the rack. The data receiver is then updated in WMS (seen in D).



A. RFID reader. B. Storage area. C. Open area for packaging/labelling/unpacking. D. Data center.

Figure 1 - System architecture of RFID networks

If an item is ordered for pickup, the inventory management will automatically select the RFID of the desired item and activates a pusher via PLC to push the item onto the output conveyor (seen in C). Figure below further describes the algorithm for the pushers. [11]

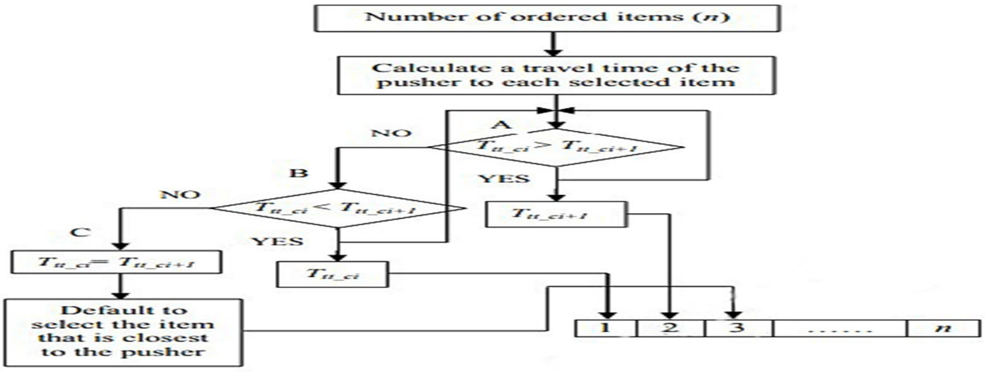


Figure 2 - RFID PLC algorithm flow

Since actual parameters will vary from factory to factory. The design features and dimensions can be viewed as followed:

Table 1 - Variable description

I	Item at (m_x, n_y)
P	Pusher at (i, j)
Lsb	length of a tote in a storage room of an AS/RR.
Lsc	length from a position of a selected item in a tote to be pushed onto an output conveyor to a position where this item in a tote travels at an end of an output conveyor.
Lss	length of a single spiral conveyor.
Lsp	length from an end of a spiral conveyor to a collection point.
Ld	distance between a pusher and a selected item
Vc	speed of an output conveyor
Vp	speed of a moving pusher along Ld
Vpp	speed of a moving pusher to push an item onto an output conveyer
Vs	speed of a spiral conveyor
Ci	chosen item, (where ci = 1, 2…… n)
Tm_Ci	time needed for a pusher to move to a selected (chosen) item ci
Tp_Ci	time needed for a pusher to push a selected item ci onto an output conveyor from an input conveyor (i.e., a storage rack)
Ts_Ci	travel time of a selected item ci in a tote along an output conveyor to a spiral conveyor.
Tsc_Ci	travel time for a selected item ci in a tote to move from the top level to the bottom level of a spiral conveyor
Tsc_Ci	travel time of a selected item ci from an end of a spiral convey to a collection point. - n: number of chosen items. - Ttt_ci: total travel time of each of selected items from the moment when the pusher is activated to push the selected item to the moment when the selected item arrives at a collection point
Ttt	least travel time of one of selected items from the moment when the pusher is activated to push the selected item to the moment when the selected item arrives at a collection point.

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$$L - d = ,-,,,[(m - x - i^2)^{-2} + (,,,n - y - j \ldots - \cdots)^2]^{0.5}$$

Equation 1 - Calculating distance between the selected item and the designated pusher

Where Ld is the distance between activated pusher and selected item.

Travel Time Tm can be determined by:

$$Tm = \frac{Ld}{Vp}$$

Equation 2 - Calculating the travel time based on the distance

Where Vp is the pusher speed.

Pusher travel time is:

$$Tp = \frac{D}{Vpp}$$

Equation 3 - Calculating travel time for the pusher

where D is rack depth.

Spiral travel time of item is

$$Ts = \frac{mx \ \times Lxx}{Vs}$$

Equation 4 - Calculating travel time with allocated variables

$$Ts = \frac{Lsb \ \times (ny \ \mp 0.5) \pm Lsc}{Vc}$$

Equation 5 - Calculating travel time with biased complexities factors

The total travel time is:

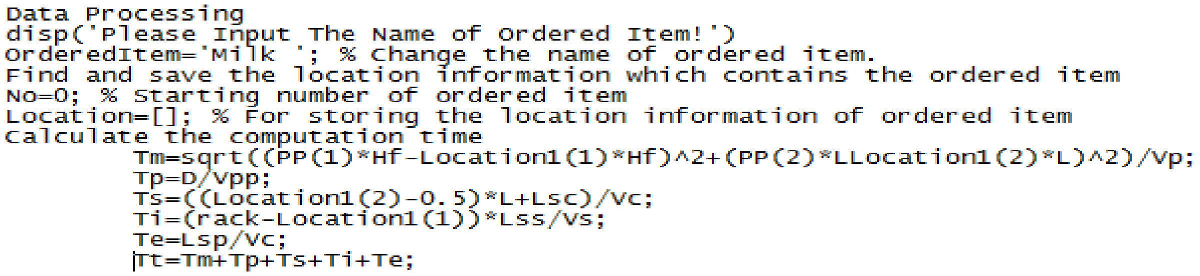
$$Ttt_{Ci} = Tm_{Ci} + Ts_{Ci} + Tsc_{Ci} + Tp\_Ci + Tse\_ci$$

Equation 6 - Total travel time for the performed function

(where ci = 1, 2…… n)

The next component of their design is inventory management system which executes predefined rules set up by the user to search the item inventory present in its database. Figure below illustrate the algorithm of the system. The warehouse parameters were constructed using MATLAB programming as seen below:

a



```
Data Processing
disp('Please Input The Name of Ordered Item!')
OrderedItem='Milk '; % Change the name of ordered item.
Find and save the location information which contains the ordered item
No=0; % Starting number of ordered item
Location=[]; % For storing the location information of ordered item
Calculate the computation time
        Tm=sqrt((PP(1)*Hf-Location1(1)*Hf)^2+(PP(2)*LLocation1(2)*L)^2)/Vp;
        Tp=D/Vpp;
        Ts=((Location1(2)-0.5)*L+Lsc)/Vc;
        Ti=(rack-Location1(1))*Lss/Vs;
        Te=Lsp/Vc;
        Tt=Tm+Tp+Ts+Ti+Te;
```

Figure 3 - MATLAB Code implementation sample

For the testing of the system, three items were randomly generated and placed within a 5 meter by 5-meter storage rack that has been simulated using MATLAB.

These three items will be placed randomly in the following order: smallest distance from pusher, average distance from pusher and furthest distance from pusher.

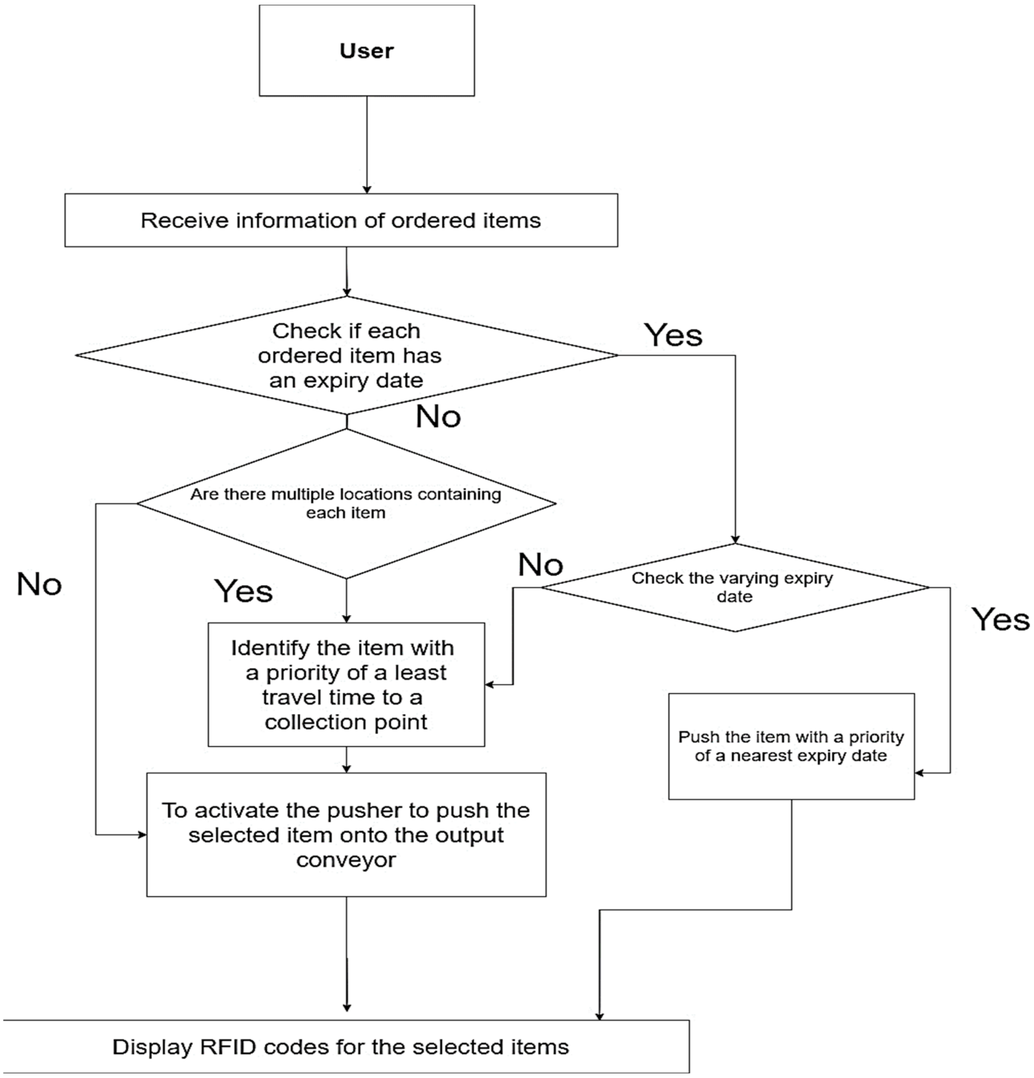


Figure 4 - Pusher Algorithm using RFID judgements

4. RESULTS

The datasets working on this algorithm are usually system integrated and coordinate directly with the operating system of the host computing device. The system doesn't have a predefined sheet or array of dataset, rather, the data is generated simultaneously with the system operations. In this way, we can assume that the system can have the same number of datasets being fed on the algorithm as the general computing speed of system. For instance, the system with 1.2 GHz of computing speed can process $1.2\text{x}10^9$ datasets on the system. This number can reduce if the operating system and the processor are busy in other system calls. If we use the same dataset of the system to test this algorithm, our charts and analysis tools can burnout due to load and excess data. Therefore, the ideal case is to process the data based on an assumed dataset which is ultimately beneficial to check the credibility of the algorithm. Therefore, we have taken a basic set of 25 ordered pairs for this system.The WMS was then tested via a MATLAB simulation by generating three items at different locations of the storage rack. S_1 (Green), S_2 (Yellow) and S_3 (Orange)

Table 2 - Visualized and comprised Dataset for computation against RFID

(5,1)	(5,2)	(5,3)	(5,4)	(5,5)
(4,1)	(4,2)	(4,3)	(4,4)	(4,5)
(3,1)	(3,2)	(3,3)	(3,4)	(3,5)
(2,1)	(2,2)	(2,3)	(2,4)	(2,5)
(1,1)	(1,2) Yy	(1,3)	(1,4)	(1,5)

The longest time taken for the item travel was 47.6 seconds of item S_3whereas the shortest duration was 33.32 seconds of item S_2. The system itself is very efficient with there being no scenario where the travel time exceeded past 50 seconds.

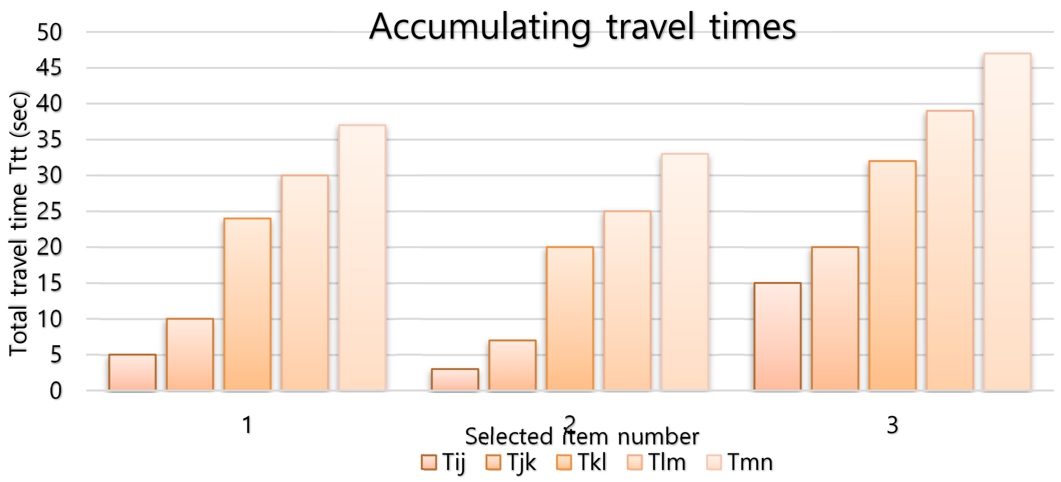


Figure 5 - A comparison of Accumulating time estimation using MATLAB and RFID

The results further show that when two or more items of the same travel time are selected the system will be set to default meaning that the item nearest to the pusher will be given the highest priority unless the user gives priority to a certain item.

The graph shows the allotted travel time for each phase of the item calling process. Where Tij refers to the time taken the pusher i reaching object j. Tjk refers to the time taken for the object j to be pushed on to the output conveyor k. Tkl refers to the time taken for the object j on the output conveyor k to reach the spiral conveyor m. Tlm is the time taken for the object to reach from the top layer l to the bottom layer m of the spiral conveyor. Tmn is the time taken for the object to reach the collection point n via the spiral conveyor m.

It was further noted that the time phase Tij of the items contributed to the majority of the total travel time whereas other phases were of the same magnitude due to all three items being in the same section of the warehouse simulation.

Overall, the system itself can be considered very efficient with there being no scenario where the travel time exceeded past 50 seconds. However, since the simulation takes place in only one section of the warehouse the travel time of items present in other areas of the warehouse is still unknown. This further implies that the system must also have commands that allow for the variation of the speed of the output conveyors to further reduce the travel time of the items from start to finish.

5. CONCLUSION

It is high priority for an inventory data to be very accurate as these tags consist of vital transaction data along with the location of a product itself. The warehouse management system simulated in this research is partially integrated with the inventory management system therefore to further automate the management, thorough integration of both inventory and warehouse system must be performed. The system presented in this paper is completely autonomous however for future research it is high considered to integrate a graphical user interface for users to give and edit commands to system with ease. Furthermore, the testing phase of this system was performed with a very minute number of items. In actual warehouses, there will be thousands of RFID tags present for identification which maybe cause the radio waves signals of different frequencies to overlap and collide with each hence distorting the data that is being transferred. To resolve such issues further study must be performed to mitigate the loss of data in high radio wave density environments.

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