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Product Tracking and Identification using RF Identification

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Abstract: ***Now a days tracking of products in a given range has become a crucial task that has to be managed in a short time. The existing system is not so efficient because of the increased time for searching for the products thereby increasing the working time. We propose this product tracking system to determine the location of a product where multiple products are stored in a warehouse or shopping floors. This project detects the location of the target in a given range and notifies the manager or the administrator in a reliable and economic way using different identification and alert approaches to facilitate an efficient, cost – effective and reliable system.***

Keywords: Asset Tracking, IOT, Low – cost tracking

1. Introduction

Smart manufacturing is the primary focus of CPS (Cyber – Physical System) – based digitalization trends, logistics – particularly resource planning and warehouse management – and supply chain management (SCM) can also benefit from the interplay between physical and digital planes. Autonomous cars transferring assets from one location to another based on data from various areas of the supply chain to accomplish just - in – time and just – in – sequence delivery is a goal of CPS driven warehouses.

Meanwhile, because each object can be tracked back to its Digital Twin counterpart, the inventory automatically changes. Various levels of automation exist in the business at the same time, depending mostly on the size of a firm, but the traceability of a product or asset tracking has always been the most important factor. This comprises not only physically tracking assets on the manufacturing floor (for example, shop floors and warehouses), but also following their lifecycles and updating, controlling their statuses. This paper currently focuses on the aspect of asset tracking.

Small and medium – sized business often operate in less automated or non – automated environments. In most cases, there is hardly any digital capability to track a product; other than to manage the product's characteristics on a single sheet of paper attached to the asset. This way of handling product results in a warehouse where locating assets due to usage loads can be a tedious task in Last – In – First – Out storage method. In such situations where finding or accessing a product is tedious, the preferred solution may be to keep the desired asset and find easily accessible new products. This approach greatly increases the overall time spent for searching the asset or product, so does increase in production time, which reduces the overall efficiency and productivity.

There are various solutions for a cost effective, automated asset tracking and management system which can aid logistical tasks, such as

- A real – time indoor based positioning subsystem based on Ultra – wideband (UWB) radio technology which provides accurate and precise location information.
- An Ultra High Radio Frequency Identification (UHF - RFID) based tracking system using an identification scheme.
- The bar code or the Universal Product Code (UPC) serves as the most inventory tracking method designed for use in the retail environment.
- Bluetooth / BLE can be used for indoor positioning such as asset tracking. It usually establish their own wireless networks with a combination of Beacon and Hub devices.
- GNNS (GPS) depends on a network of in – orbit satellites that understand each other's locations and synchronize their clocks to match precisely. It can also be used for asset tracking.

This paper proposes the use of an Ultra High Radio Frequency Identification (UHF - RFID) based tracking system using identification scheme.

2. Background Study

There are various solutions for a cost effective, automated asset tracking and management systems which can aid logistical tasks. There are certain advantages and disadvantages for each of the technique. They are as follows,

1) Ultra – wideband (UWB):

UWB – not to be confused with Verizon's technology called 5G UWB – is one of the newer terms for asset tracking and real – time location, but it generally outperforms other locations in terms of accuracy, scalability and even cost and tracking technology.

The technological promise of UWB can explain its meteoric rise as a powerful native process technology. For example, many automakers are using UWB for secure / keyless entry. Samsung and Apple have implemented UWB in their recent line of smartphones, and WISER uses UWB as a key element of their locator solutions.

Figure: A WISER Locator tracker tag used for UWB asset tracking

The term UWB refers to a technology that transmits data over most of the wireless spectrum. It works by transmitting short, low – power pulses over a considerable bandwidth. Essentially, UWB is a low – power way of sending huge amounts of data.

Advantages:

- Data transmission through walls and obstacles and have real time updates.
- Non – interference with most other RF signals and devices.
- Enables top location accuracy – often within inches.
- Unique radio signatures and improved ability to avoid multipath propagation.

Disadvantages:

- Less mature standards and protocols for interoperability and has less market acceptance and recognition.
- Requires more power than other wireless tracking technologies.

2) Barcodes:

Barcodes are perhaps the most enduring asset tracking technology to date. Barcodes provide unique identification but not necessarily time or location, and are affordable, reliable, and massively scalable. Due to the widespread use in numerous industries, barcode systems also offer a great advantages in terms of technical identification and trust.

While new encoding techniques such as invisible or matrix barcodes (QR codes) are constantly emerging, the concept has remained largely the same since the invention of barcodes: physical items are given a barcode that identifies the item, and barcode scanning systems record that each item needs to be checked point.

Figure: Barcode Reader

With simple code and scanning configuration, barcodes have gained traction in retail, manufacturing, warehousing, public transportation, and virtually every other industry in the world.

Advantages:

- Inexpensive and extremely small and lightweight.
- Can be used to account for massive numbers of assets with no theoretical limit on quantity.
- Barcode scanners are typically much affordable than RFID scanners.

Disadvantages:

- Requires manual scanning and searching which is often labour – intensive.
- Scanning requires line - of - sight and often very short range.
- May prone to human error like missed or erroneous scans.
- Does not show real - time status or location and depends on data from last point of scan.

3) GNNS (GPS):

GNNS also known as Global Network Positioning is not a panacea for real - time positioning. However, examples such as GPS in the United States are among the most widely used tracking technologies in the world today. While the following rules generally apply to GNSS, we primarily use the term GPS (Global Positioning System). GPS relies on a network of orbiting satellites that know where each other is and accurately synchronize their clocks. Based on these known synchronization points, it can provide fairly accurate positioning and relative motion tracking etc.

Advantages:

- Worldwide visibility for tracked assets and global availability of satellite signals.
- Large library of stable GPS tracking applications and integration of GPS to many professional and consumer devices.

Disadvantages:

- High power consumption and requires line - of - sight with satellites.
- Limitations in urban and indoor settings and end users cannot repair or adjust the space or control segments.

4) RFID:

RFID, or radio - frequency identification, has proven useful in a wide range of applications and environments. It's also held up well throughout time, and after decades of usage and improvement, it's still worth a lot of money. The maturation of RFID technology has also prepared the way for a wide range of asset monitoring configurations to be included under the RFID umbrella.

In the sense that they employ a kind of radio identification for asset tracking, Wi - Fi, Bluetooth, UWB, and other wireless technologies might all be considered RFID solutions. RFID, on the other hand, is usually used to refer to a more specialised set of devices and technology, such as ISM - band RFID.

RFID systems rely on a mix of electromagnetic scanners and tags to function. Tags include identifying data that can be read by RFID readers, both fixed and handheld. Readers, or interrogators as they're often known, detect the presence of tags. The reading process identifies the tags being scanned, but it might also offer other information. A fixed - location reader, such as a doorway scanner, can, for example, record the precise time an RFID tag passes through that doorway, storing its present location at the time of the scan. For inventory processing, security checks, and other activities, both fixed and portable scanners can be employed.

Advantages:
- Device longevity
- Small tags—especially passive ones
- Various low - cost options for tags
- Small radio signature

Disadvantages:
The main disadvantages of RFID are its cost and maintenance. If one can maintain RFID then it will be one of the best technologies that can be used for asset or product tracking or maintenance.

	ACCURACY	SCALABILITY	RANGE	DATA TRANSFER RATES	SUMMARY
BARCODES	accurate to scanning location	very scalable within limits of manual scanning	very short / needs line-of-sight	N/A	effective for identification but not asset location
RFID	varies widely; accurate to last-scan only	very scalable	up to 600 m	N/A	effective for object detection but not true localization
WISER UWB	~1 m - 10 cm	very scalable	up to 100 m	up to 27Mbps	effective for localized, precise asset tracking
BLE	~2 - 3 m	limited	up to 100 m	up to 2Mbps	effective for localized zone-based tracking
WIFI	~3 m	very limited	up to 50 m	up to 1Gbps	effective for zone-based tracking at a small scale
LPWAN	~50 - 800 m	very scalable	up to several km	variable	many effective tracking options depending on region
CELLULAR	~30 - 100 m	scalable outdoors	~30 km	100Mbps+	effective for tracking large / high-value assets outdoors
GPS	~7 - 10 m	scalable outdoors	global access within satellite line-of-sight	N/A	effective for tracking large assets outdoors

Figure: Various technologies and their properties.

3. System Architecture

Our proposed system ensures to detect and safeguard the product in a warehouse or in an indoor location where all multifarious products are stored. The system uses the RFID technology to detect all the tags which are attached to products in a given range efficiently and transient manner. This system scans all the products at regular intervals or at given command to check whether the products are missing. If so, then the proprietor will be notified. The connections of the RFID with the Arduino will be as follows.

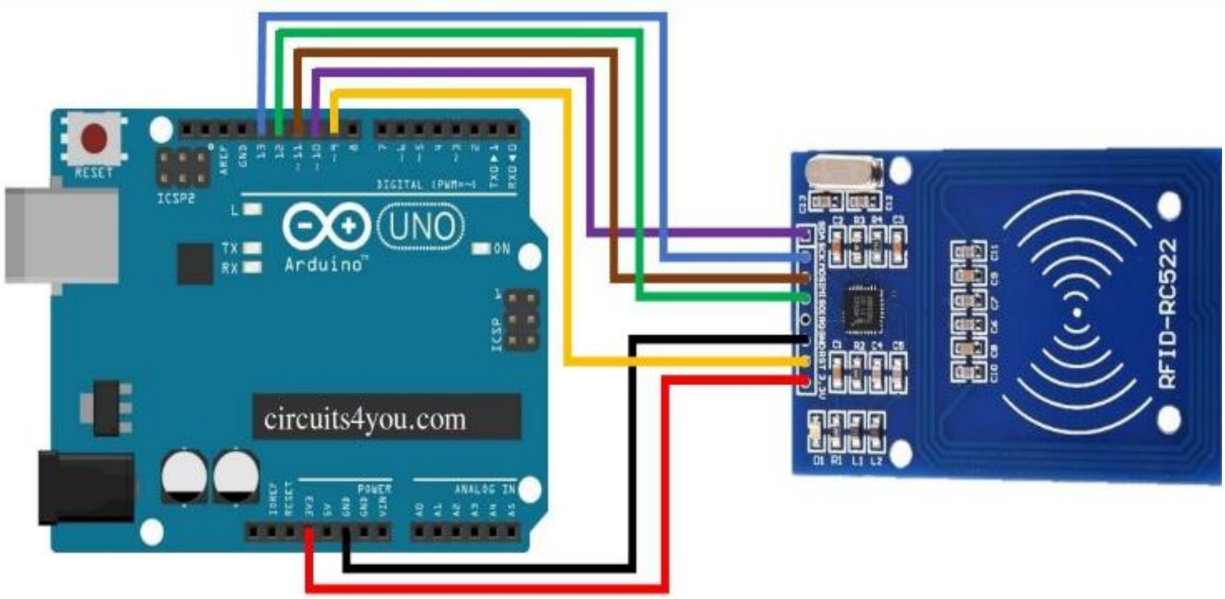

Figure: Arduino connection with RFID

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The pin connection between Arduino and RFID is as follows.

Arduino Board	RFID pins
10	SDA
13	SCK
11	MOSI
12	MISO
GND	GND
9	RST
3.3V	3.3V

The system architecture of the system will be as follows

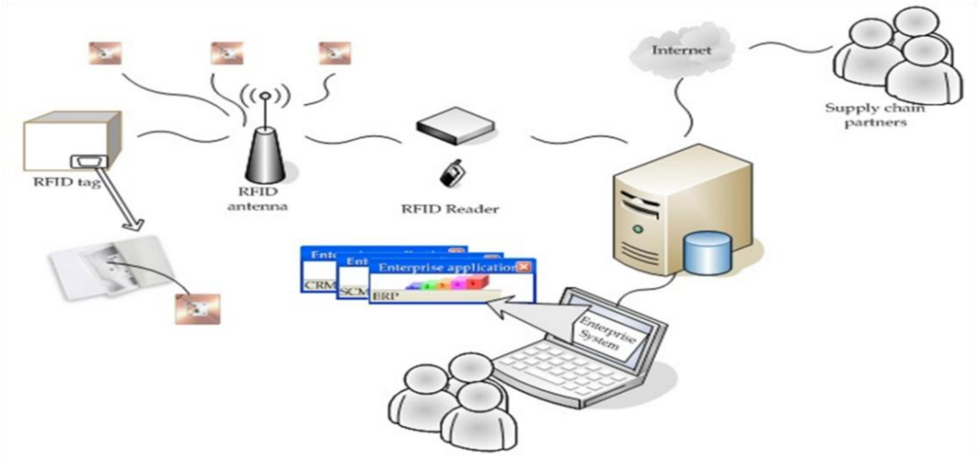

Figure: System Architecture

Work Flow

The workflow of our system will be as follows. First, the RFID tags that are with in the vicinity of the reader are read and checks with the details of the data in the database. If any new tags are found then we can able to add the RFID tag along with the necessary details that are necessary.

The process continues in a regular intervals. If any of the tags have missed, then the proprietor of the warehouse or the organisation along with other respective persons will be notified. So that they can take necessary actions.

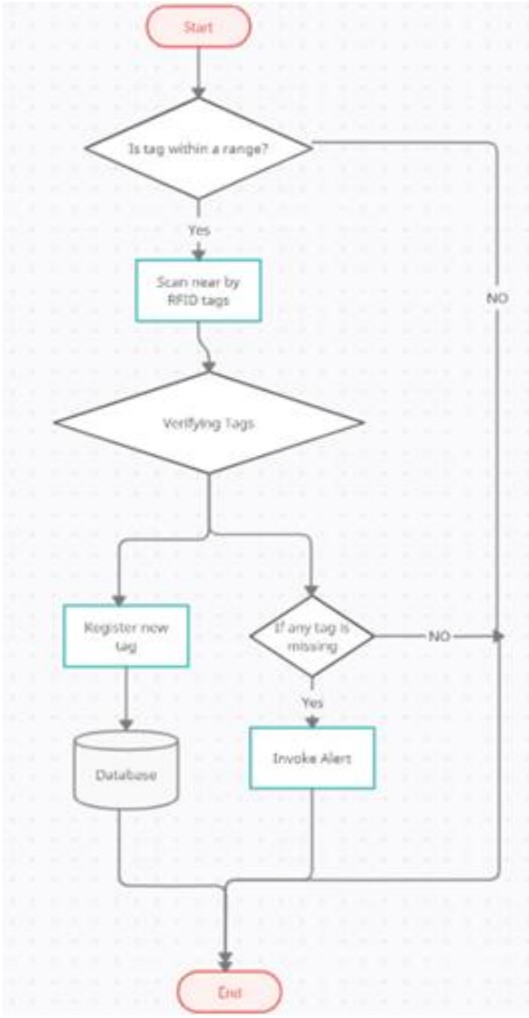

Figure: Work Flow

4. Methodology

1) RFID Reader – Synchronisation:

Reader synchronisation is a concept in which all RFID readers in a certain location, such as a warehouse, are networked together through a single control unit. The connecting mechanism might be an Ethernet connection or something similar. Because all of the readers are connected, they may be told to convey orders at the same time. They can also be given channels on a dynamic basis, allowing for better spectrum management while reducing reader collisions.

When the maximum radiated power, 2W ERP, is employed, European regulation permits for ten channels. According to EPC C1G2, five of these, the even - numbered channels, were employed for reader questioning. All of the readers are compatible with "Listen Before Talk". They're set up to start listening at the same time, and then, at the conclusion of the listen period, they may all start "Talking" at the same time, as indicated in the diagram. This is because, according to ETSI 302 208, the "Listen" period is fixed if no signal is found in the targeted channel of interest. As a result, all readers who begin "Listening" at the same moment will also begin "Talking" at the same time. If a reader is turned on at a different time than the others, or if it loses synchronisation, it will restart in time with the others when the last reader has ended its "Talk" session.

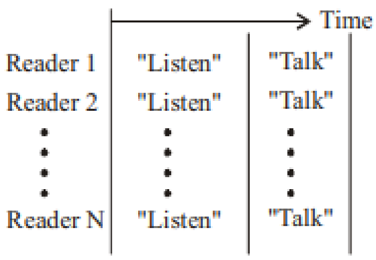

Figure: Synchronization of RFID readers

2) KNN:

Assume that an RFID system has n readers and m reference tags, and that u target tags must be placed. The RSS vector of the target tags is s = (s_1, s_2, s_3, …., s_n), which represents the RSS value of the target tags identified by reader i, i in this case belongs to (1, n). θ = (θ_1, θ_2, θ_3, …. ., θ_n) is the matching RSS vector for reference tags. The Euclidean distance is determined as $E_i = \sqrt{(\theta_i - s_i)}$ where j in (1, m) depending on the target tag and reference tag. The Euclidean distance E is used to determine the closeness of the target tag and the reference tag; the E value should be less when the reference tag is nearer to the target tag. As a result, when there are m reference tags, the E value of the target tag p should be reduced, as should the E value of all reference tags. As a result, the E value vector of the target tag p and all reference tags may be written as E = (E_1, E_2, E_3, ……, E_m) and ranked from small to big as E prime = (E_1‘, E_2‘, E_3‘, ……., E_m‘). The k reference tags are chosen from this sequence, and the weighted average value is computed using the known tag location to predict the approximate position of the target tag.

The k - NN technique is a very successful inductive inference method that finds the attribute of a query point by taking the weighted average of the k nearest neighbours to the point. The coordinates of a target point are obtained as in the following equation in RFID - based positioning using the k - NN algorithm:

$$(x, y) = \sum_{i=1}^{k} w_i (x_i, y_i) / \sum_{i=1}^{k} w_i$$

The coordinates of a target point are (x, y) and (x_i, y_i) in Equation 1, and the i - th reference point, w_i, is a weight factor. In the signal domain, the weight factor is inversely proportional to the Euclidian distance between the reference point and the target point, or the signal intensity differential between the two sites. The root mean squared error, or RMSE, is a statistic that measures how far an estimator or a model deviates from the real value of the quantity being estimated. For one - dimensional spaces, the RMSE may be calculated using the equation below.

$$RMSE_{1D} = \sqrt{\frac{\sum_{i=1}^{n} \left[(\hat{x}_i - x_i)^2 \right]}{n}}$$

The simulation of the object in the 2 – dimensional space is as follows,

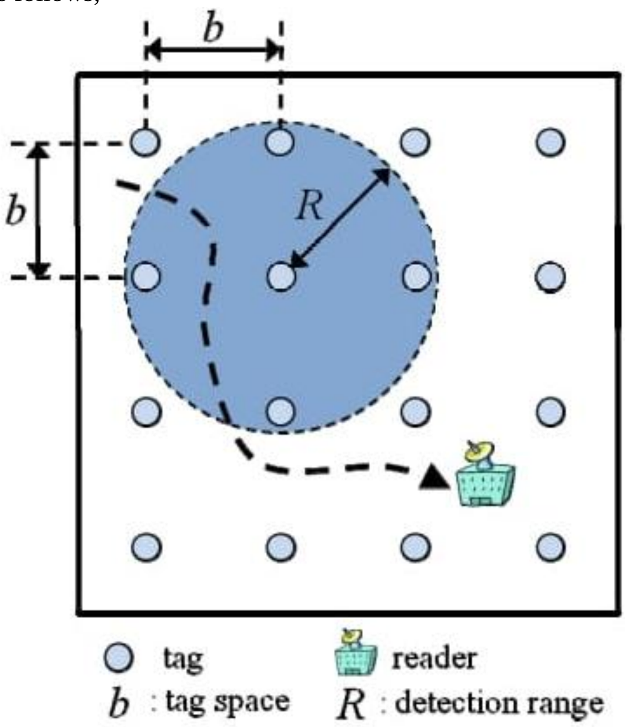

Figure: Simulation of Object in 2 - dimensional space

The numerical technique was used to validate the results of the analytical approach. The genuine positions in the numerical technique were assumed to be the regularly sampled points between 0 and b, at intervals of 0.1 percent, in the section, whereas the true locations in the analytical approach were deemed to be continuous values between 0 and b. If the tag spacing distance b is 10, then the true positions are assigned to 1001 points between 0 and b.

The detection ranges were varied from 100 percent of b to 300 percent of b in increments of 0.1 percent of b in a simulation with the tag space b set to 8 and the detection ranges changing from 100 percent of b to 300 percent of b in increments of 0.1 percent of b.

The graph below depicts an RMSE fluctuation curve for every 50 percent increase in the detection range.

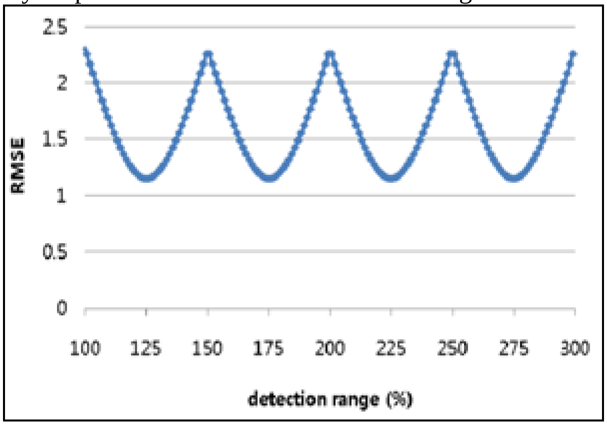

Figure: RMSE Fluctuation Curve

3) RNN

It works by deploying a grid of UHF - RFID tags on the floor underneath the gate, each with a single reader antenna. When a trans pallet passes through the gate, it casts a distinct shadow on the deployed grid's tags depending on whether it is going in or out. A recurrent neural network is fed with this distinguishing characteristic as input. The number of readings for each tag is summed over small time intervals, and a series of binary read/missed tag data is retrieved over time. A Long Short - Term Memory neural network is trained using such temporal sequences. A collection of measurements in an indoor situation demonstrate the suggested method's classification ability.

Recently, machine learning techniques have been used in RFID systems for locating and classifying tag actions in UHF RFID gates We present a new solution for distinguishing crossing goods from non - crossing through UHF - RFID gates in a warehouse scenario There are two types of cargo that pass through the crossing: incoming cargo and outgoing cargo. The system uses a recurrent neural network (RNN) to exploit data acquired by a single reader antenna and a grid of UHF - RFID reference tags.

To perform the transpallet action classification, a recurrent neural network (RNN) was trained. This type of neural network is effective at processing non - sequence data. The basic working principle of RNN is that when the network has an input x_t, it calculates a new state h_t based on the previous state ht - 1 and the input based on the activation function f:

$$h_t = f(W_{hh}h_{t-1} + W_{xh}x_t).$$

In sequence labelling problems, the output is usually computed based on the last state. In the proposed system, we used a particular kind of recurrent neural network, the Long Short - Term Memory (LSTM) network. LSTM networks are great at solving the problems of vanishing or exploding gradients, which has led to their widespread use in speech recognition and image captioning applications. Each cell in the block has an internal cell state (c_t) and a hidden state (h_t). The parameters for the network are updated based on the input x_t at time t, and the previous hidden state, h_{t-1}.

$$\boldsymbol{c}_t = \boldsymbol{f} \circ \boldsymbol{c}_{t-1} + \boldsymbol{i} \circ \boldsymbol{g},$$
$$\boldsymbol{h}_t = \boldsymbol{o} \circ \tanh(\boldsymbol{c}_t),$$

where ◦ denotes the element - wise product. The other parameters are the network input gate i and the cell candidate g, which control the input amount which is written into the cell; the forget gate f, which controls how much the cell state of the previous time step is forgotten; the output gate o, which computes the hidden state of the current time state. These parameters can be calculated throughout the following equation:

$$\begin{pmatrix} \boldsymbol{i} \\ \boldsymbol{f} \\ \boldsymbol{o} \\ \boldsymbol{g} \end{pmatrix} = \begin{pmatrix} \sigma \\ \sigma \\ \sigma \\ \tanh \end{pmatrix} \boldsymbol{W} \begin{pmatrix} \boldsymbol{h}_{t-1} \\ \boldsymbol{x}_t \end{pmatrix}$$

Where W is the weighting matrix; σ is the sigmoid function, and tanh is the hyperbolic tangent function. The size of the network input, x_t, corresponds to the number of input features of the network, N_f eat. The size is of the hidden state vectors, h_t, as well as the size of the internal cell state, ct, i, f, o and g, is given by the number of hidden units (NHU) of the cell, which controls the amount of information remembered between time steps. Finally, the size of the weighting matrix W is $(4 \cdot \text{NHU}) \times (N_f \text{eat} + \text{NHU})$

The experimental analysis of various trajectories of tags (datasets) and their results are as follows. The trajectories are always in similar proportion of incoming, outgoing or not – crossing trajectories to keep them in balance. The trajectories are shown as below.

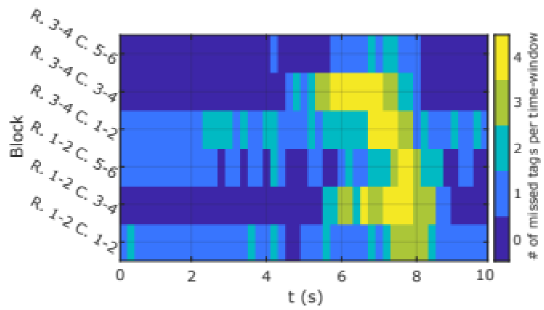

Figure: Incoming clustering of tags in missing tags

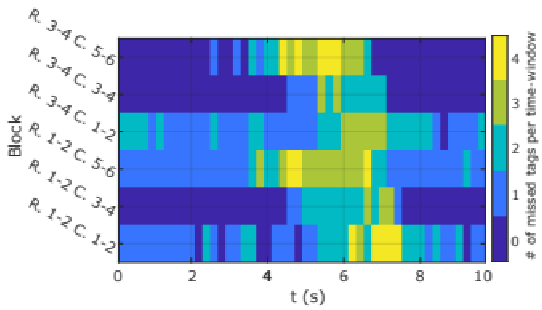

Figure: Non – trajectory clustering of tags in missing tags

For different values of the time window period, the LSTM network was trained with a variable number of hidden units. In terms of Test Accuracy, which is the ratio between the number of correctly categorised actions and the total number of classified actions, the findings are represented in the

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following figure. As can be seen, the test accuracy approaches 1 for 50 concealed units and a 400 - millisecond time window. For the other tested values of time window duration, the use of 50 concealed units offers an accuracy better than 0.9. The test accuracy drops as the number of hidden units increases, indicating that the network may be overfitting.

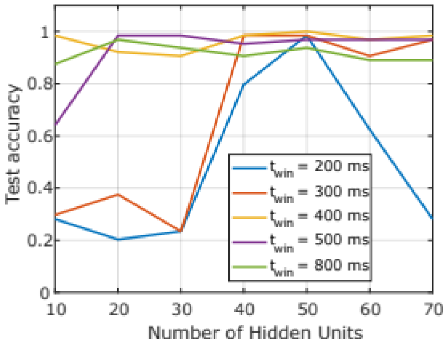

Figure: For varying length values of the time windows, test accuracy as a function of the number of hidden units in the LSTM network.

4) Work Analysis

The main changes in the working of RFID tags can be seen, when we uses various kinds of readers. As each tag has a unique frequency, the accuracy of reading the tags in their vicinity changes with the reader. There are basically two types of readers – An Active Reader and A Passive Reader.

The main difference between the Active Reader and the Passive Reader is the reading range. The Active Reader has more reading range compared to a Passive Reader. The reading range and their other differences are depicted as follows.

	MAIN FREQUENCY RANGE	RANGE TO READ	AVERAGE TAG COSTS
LOW FREQUENCY	125 - 134 kHz	10 Centimeters	$0.75 - $5.00
HIGH FREQUENCY	13.56 MHz	30 Centimeters	$0.20 - $10.00
ULTRA-HIGH FREQUENCY (PASSIVE)	433 MHz	30 - 100+ Meters	$25.00 - $50.00
ULTRA-HIGH FREQUENCY (ACTIVE)	860 - 960 MHz	25 Meters	$0.09 - $20.00

Figure: Various reading ranges of RFID tag readers.

The tags are used based on the applications that we need to implement, as RFID tags can be used for various applications such as livestock tracking, inventory management, asset tracking and management, logistics etc.

The logic behind reading tags is similar to K - Nearest Neighbour (KNN) algorithm, where outliers are detected and is a supervised technique. In RF Identification, the tags that are not available within the reading range of a reader is considered as an outlier. These outliers are considered as missing tags in the range.

5. Conclusion

The use of automated inventory management systems and asset tracking solutions is a critical step toward full digitalization of the logistics industry. Nonetheless, even in less automated contexts, production and asset tracking may significantly enhance overall efficiency and productivity.

The most major downside of the aforementioned strategy is that, due to the indirect approach, the asset monitoring scheme might be error - prone. Our solution employs an identification strategy based on multiple trigger sources and filtering methods to eliminate false detection and offer correct location information of any asset in a dependable manner, in order to make the implemented systems trustworthy.

This paper shows the reliable method of using RFID tags for asset tracking and management. It shows the basic use of RFID tags but it can be used along with many other technologies, to create new solutions. There are various applications such as using in livestock tracking (Using both RF technology and GPS technology), Tracking systems, Geo

- fencing systems, customer service and loss control, inventory management and control, cargo and supply chain logistics etc.

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