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EVALUATION OF THE USAGE OF RFID AS IDENTIFICATION FOR STACKED OBJECT DATA RECORDING

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ABSTRACT

Radio Frequency Identification (RFID) technology recently has revolutionized inventory management and object tracking. The research begins by utilizing RFID technology to check and process data concurrently for multiple mineral water cup boxes. Furthermore, processing multiple objects that are being read by an RFID reader with various approaches for managing concurrency and parallelism related to data. The result shows the benefit of employing RFID technology in scenarios where multiple objects need to be checked and processed concurrently. The RFID system showcases improved efficiency and scalability compared to traditional methods, allowing it to handle larger volumes of objects with reduced processing time and improved accuracy. This paper shows the number of mineral water cup boxes that could be detected and describe handling data with the utilization of asynchronous mechanisms.

Keywords: *RFID Technology, Object Tracking, Inventory Management, Parallel Computing, Kotlin Coroutines*

1. INTRODUCTION

Inventory management plays a crucial role in meeting customer demand. Effectively controlling stock levels and preventing stockouts are key factors in accurately forecasting product needs. The Internet of Things (IoT) has become an inevitable aspect of modern business operations. Among its components, Radio-frequency Identification (RFID) stands out as a prominent technology [4]. RFID can be applied in a diverse range of scenarios, including detecting passing objects, conducting stocktaking, verifying shopping lists, access control, enabling cashless payments, and many more [20]. RFID utilizes radio waves to facilitate data exchange between a reader and a controlled tag system.

The market growth of RFID is projected to increase by 9.9% annually, with expectations of continued growth until 2027 [5]. Consequently, RFID holds significant promise in terms of its practical applications. One existing study utilized RFID as tags for both employee and inventory tracking [1]. The researchers successfully read the items by individually attaching tags and using them solely for input and output purposes.

Another study focused on reading bus stops to notify when a bus is approximately 6 meters away from the stop, utilizing long-range RFID technology [2]. Based on the success of various studies that have leveraged long-range RFID, primarily focused on single-object identification. This led research to be motivated by the need to extend this technology to identify multiple objects simultaneously. So, this research aims to explore the potential of reader capabilities in detecting objects with varying depths and accelerating data processing on a larger scale compared to conventional RFID usage.

Objective other than previous studies, this research aimed to explore the potential of long-range RFID readers in detecting objects with varying depths and optimizing data translation on a larger scale than conventional RFID usage for stocktaking. In term to determine the RFID potential, this research will only use 1 RFID reader and 2 variety types of RFID tag passive which normal and anti-metal one.

Since stocktaking itself can have a significant impact on maintaining the quality of goods. However, stocktaking typically requires time due to the extensive depth of inventory and large

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quantities involved. So, selecting object for the research also considered as an important one. Motivated from fast moving consumer goods, mineral water prices tend to be relatively stable and not subject to significant fluctuations between from consumer perspective and business perspective as well.

Furthermore, data accuracy and fast recording are crucial in stock recording to ensure high accuracy and efficient inventory management. So, with a large volume of data, this research indicated the data processing that could be a challenge and expect the usage of parallel processing to enhance the speed of the process. It does not include for detailing the query process, but assuming there's time process taken before it saved.

In terms of findings, this research evaluated various scenarios that encompass variations in depth or maximum distance, reader orientation, passive tag types, total tracked objects and readable RFID frequencies which represents a departure from previous studies that primarily focused on single-object identification. Additionally, the research evaluates the speed of recording RFID data translations for storage on the server with stress test as well.

This finding had practical implications for warehouse such as logistics even in high-density scenarios on data processing, where the efficient tracking and management of multiple items could paramount for optimizing processes and reducing operational costs.

2. RELATED WORKS

This literature criteria indicated with publication date within the last 11 years to ensure the inclusion of recent research. Also, relevance to this paper focus on usage from RFID from tag passive, reader normal and reader long-range as well. So, these will add more context on how RFID has been tested on different condition.

First research used the UHF RFID CTU 1861-8 reader and passive tags are used for scanning incoming and outgoing goods [3]. The UHF RFID technology allows for effective communication within a maximum range of 8 meters, with an average scanning time of 2.4 seconds, without any obstacles.

The results obtained from using UHF RFID technology demonstrate its capability to communicate effectively within a maximum range of 8 meters. The average scanning time of 2.4 seconds indicates a relatively quick and efficient process. It is worth noting that these results were achieved without any obstacles or interference, further highlighting the reliability of the UHF RFID system.

Other research that uses sensitivity Class-3 harmonic ultra-high-frequency (UHF) RFID reader is utilized along with harmonic semi-passive tags. This combination is used for various applications such as inventory management and asset tracking.

The evaluation of the RFID system using the high sensitivity Class-3 harmonic UHF RFID reader and harmonic semi-passive tags yielded successful communication results [6]. Under ideal conditions, without any obstacles, the system achieved communication distances of up to 20 meters. The system operates at a frequency of 1.8 GHz, providing reliable and efficient tracking capabilities.

Usage of VM-5GA UHF-RFID system with passive tags is utilized for identifying the presence of new items in the lost and found area. The RFID system, operating at a frequency of 860-960 MHz, did not yield specific quantitative results regarding RFID readings [7]. However, based on user surveys, the system has achieved a satisfactory level of performance with an average user satisfaction rate of 85% and accurate results. These findings indicate that the VM-5GA UHF-RFID system with passive tags has been effective in identifying new items in the lost and found area.

Implementation from low-power and high-accuracy RFID system, along with active tags, is implemented in an open space environment. The system incorporates a sleep mode feature to conserve power.

The RFID system operates at a frequency of 2.4 GHz and has demonstrated impressive performance [8]. It achieves a maximum reading distance of 80 meters and a high reading speed of 170 tags per second. These results highlight the system's efficiency and effectiveness in accurately identifying and tracking items at their office's open space area.

Other implementation from the long-range RFID model EPC-Gen2, along with passive tags, is utilized for detecting the next bus stop [2]. The RFID system, operating at a frequency of 860-960 MHz, has successfully detected the upcoming bus stop. It achieves a maximum detection range of 10 meters without any obstacles. This capability allows for efficient tracking and notification of bus stops, enhancing the overall transportation experience for blind passengers.

Take advantage from the ID-20LA RFID reader to be used in conjunction with Arduino ESP8266 as a scanner for goods [9]. Using RFID technology with a frequency of 13.56 MHz, the system achieved a success rate of 89.86% in reading each item. This indicates a high level of accuracy and reliability in scanning and identifying goods using the ID-20LA RFID reader with Arduino ESP8266. The implementation has proven to be effective in warehouse environment, facilitating efficient inventory management and tracking.

RFID technology operating at a frequency range of 12.5-13.4 MHz, it has been successful in reading tags at a maximum distance of 5.5 cm. Furthermore, this RFID system has the capability to penetrate cardboard boxes, allowing for seamless identification and tracking of objects even when enclosed within such packaging [10]. The use of this specific frequency range enables efficient and reliable communication between the RFID reader and the tags, facilitating accurate data retrieval and enabling seamless integration into various applications and industries.

According to the reference, most of them mentioned no obstacle when identifying the object also only single-object identification. Then led this paper for identifying the same multiple objects simultaneously. This problem was chosen because the simple thing to identifying the multiple objects were started from the same objects which had same dimension to become its obstacle.

3. THEORY AND METHODS

3.1. Stock Management

Stock management, otherwise known as inventory management, is one of the processes of the entire warehouse management system or warehouse management system [11]. Basically, this process is a warehouse process where the stock level is affected by both external (purchase orders) and internal (goods supply) factors. The aim of the system is to balance the two factors at a reasonable level.

3.2. RFID

The process of identifying objects using radio transmission, by reading tags/transponders (transmitter and responder). The tag will recognize itself when it detects a signal from a suitable device, namely a reader [18]. The theory behind RFID involves several key concepts and components that work together to enable the identification and communication process. Generally, RFID attached to an object that can carry unique information, the data obtained is also a data transmission process from the tag [19]. The data is a unique number array that contains usable identification information such as serial number, color, or other object data [12].

3.3. RFID Tag

RFID tags are comprised of passive and active tags, where passive tags do not have a battery, while active tags use a battery as a power source. Passive tags are more commonly used due to their lower cost and smaller size. RFID tags are often seen as a replacement for barcodes because they offer greater convenience compared to scanning barcodes. Additionally, RFID tags have the unique ability to be tracked from a remote location, minimizing product loss for companies. in terms of cost, it is still challenging for RFID tags to completely replace barcodes. Barcodes are significantly cheaper, especially when used extensively [20]. Despite the advantages of RFID tags, the cost factor remains a hurdle for widespread adoption as a barcode substitute.

3.4. RFID Reader

RFID reader is a device that is used to communicate with RFID tags. There are two main types of RFID readers: passive readers and active readers. A passive RFID reader operates with a passive reading system, meaning it relies on the radio signals transmitted by active RFID tags. The passive reader receives these signals and uses them to extract the information stored in the tags. This type of reader is commonly used in applications where the RFID tags are powered by the energy from the reader itself or from the surrounding environment. In terms of usage, RFID technology requires specific frequencies for tag reading [21]. Therefore, different countries have regulations in place to govern the usage of RFID readers, particularly for the Ultra High Frequency (UHF) range. The UHF range for RFID typically falls between 860-960 MHz. These regulations ensure that RFID readers operate within acceptable limits and do not interfere with other communication systems or devices.

3.5. UHF RFID

UHF (Ultra High Frequency) refers to the range of electromagnetic waves that includes frequencies commonly used for various communication and data transmission purposes with frequency range between 300 MHz to 3 GHz. (3,000 MHz), known as decimeter waves which refers to waves within the UHF range with wavelengths between 10 cm and 1 meter. [13]. In

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addition, modern cell phones often operate within the UHF frequency spectrum for wireless communication.

3.6. API

API (Application Programming Interface) is a way for two different applications to connect to each other through a network using a language that is understood by both applications. So that the API service is a service provided/hosted to provide API.

REST API stands as one of the most widely embraced and adaptable APIs available on the internet today. REST, establishes a framework of operations including GET, PUT, DELETE, and more, which enable clients to seamlessly access and interact with server data [14]. Facilitated by the HTTP protocol, data exchanges between clients and servers occur with remarkable efficiency. A defining attribute of REST is its statelessness, ensuring that the server refrains from retaining client data across requests.

3.7. Asynchronous Process

Process that has a non-blocking communication allows the recipient to only use the resource when it is active, reducing system overhead. Concurrency, which is one of non-blocking communication will handle many ongoing tasks at the same time but do not have to be executed concurrently. Parallelism, the simultaneous execution of many things. Jobs in all tasks can be inserted in some arbitrary order, like

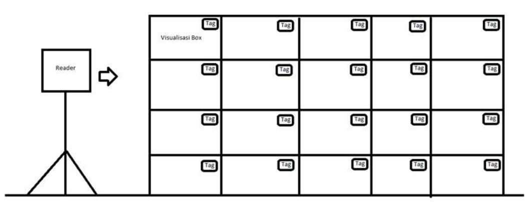

Figure 1: Visualization RFID reader and tags.

the objects used by each thread [15].

Coroutines, a concurrent design patterns that can be used in the Kotlin programming language to simplify code that executes asynchronously [16]. Each thread created by Coroutines so it can be made as minimal as possible to save memory, light weight, support for canceling actions through the Coroutine hierarchy [17]. All coroutines must be executed within a dispatcher, even if they are running on the main thread. Coroutines can suspend themselves, and it is the dispatcher's responsibility to resume them. Kotlin provides three dispatchers that can be used to determine where to run a coroutine [17]:

1. Default: This dispatcher is used when no specific dispatcher is specified. It is backed by a shared pool of threads and is suitable for most general-purpose use cases.
2. Main: This dispatcher is specifically designed for running coroutines on the main thread of an Android application or the event dispatch thread in other UI frameworks. It ensures that the coroutine code runs on the UI thread and is safe for updating UI components.
3. IO: This dispatcher is optimized for performing I/O operations such as network requests or disk operations. It uses a pool of threads that are appropriate for blocking I/O tasks without occupying the CPU cores.

4. PROPOSED METHOD

4.1 Method of RFID Detection

The passive RFID tags will be placed on the side of the cardboard boxes. The placement will cover a relatively wide area, so it is necessary to position the reader in a location that can reach the maximum possible area with optimal accuracy. Therefore, for the planned reader testing, it will be visualized according to Figure 1, with the reader placed at 3/4 height of the total stack of objects. Thus, this research will involve several aspects that need to be considered, such as the orientation of the reader placement and the maximum obstruction that can be read with various types of passive tags used at different frequencies.

Each box arranged with 3 layers of depth, with each depth has 25 boxes. So, each pallet could handle maximum in total 75 boxes of mineral water cup. Every RFID tag was put on the top of each box, so there's no obstacle in front of the first box like Figure 2.

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Figure 2: Scan a Pallet of Box.

Since on the real situation at the warehouse could be more 1 pallet at one time, this test scanned 3-line up pallets at once.

Table 1: Tools Specifications.

Tools	Specification
RFID Tag passive (UHF WET Inlay RFID Tag)	• Chip: Alien H3 • Memory: 512-Bits • Frequency: 860-960MHz • Protocol ISO18000-6C (EPC Class 1 Gen 2) • Material: Polyethylene Terephthalate • Size (WxH): 23 x 74mm
RFID tag passive anti-metal (UHF Anti Metal Sticker Alien H9)	• Chip: Alien H9 Chip • Memory: 1024-Bits • Frequency: 860-960MHz • Protocol ISO18000-6C (EPC Class 1 Gen 2) • Material: Polyethylene Terephthalate + Ferrit Anti Metal • Size (WxH): 23 x 74mm • Thickness: 0.2mm
RFID reader (UHF Reader & Writer - CT-I809)	• Brand: Cardteck • Type: CT-i809 • Built-in 7dBi antenna, read up to 6m, write up to 3m depends on tag and environment. • Frequency: 902 - 928MHz • Protocol: ISO18000-6B, ISO18000-6C (EPC Gen 2) protocol • RF Power: 0-30dbm. • Interface: TCPIP/RJ45, RS232/UART, RS485, Weigand26/34, Relay Output. • Size: 235mm x 235mm x 57mm, ABS Waterproof, IP54 Compliant
Reader Software	SDK from the reader.

With tool's specification from Table 1, these will affect the internal factor. Meanwhile, the surrounding environmental factors that affect the reading of RFID data can be classified as follows:

1. Variations in the orientation of the reader's orientation, where the position was perpendicular to the object and the position at 5° and 10° bent as Figure 3.
2. The box's length x height x width with 18 x 24 x 35.5 cm that contains mineral water cup and empty box only.
3. The maximum frequency was 927.75 MHz according to the options in the reader software.
4. The Boxes was placed on the pallet that could handle maximum 7 box in height and 3 box in depth.
5. Each sampletested up to 10 times

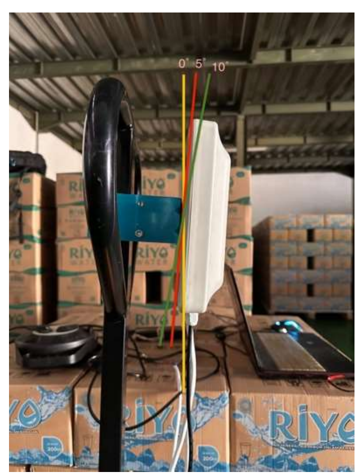

Figure 3: Reader's Orientations.

4.2. Method of Data Recording

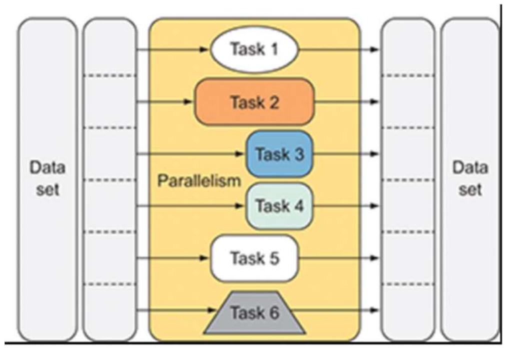

Figure 4: Asynchronous's Process Visualization.

If the successfully identified RFID data can be read by the RFID reader with many tags, the role of the API service as a gateway for data storage becomes crucial in delivering efficient and prompt responses. Therefore, for the testing design, it can be compared to Figure 4 by increasing the number of processes performed simultaneously. By doing so, this research will compare various processes with different quantities of processes.

To support the development process of the API service, this research will utilize the IntelIJ software as the integrated development environment (IDE). For data storage, MySQL will be used, connected through the Kotlin Spring framework version 3.0.1 with Spring JPA version 1.8. The testing will be assumed there's a time process 15ms for each data with the following variations:

1. Standard Mapping, this approach involves dividing the workload into multiple tasks and processing them concurrently using standard mapping techniques.
2. Coroutine's Channel, using Kotlin's Coroutine's Channel, you can create a single channel or multiple channels to handle parallel processing. Total channels are the total iteration.
3. Parallel Coroutine's Job, leveraging Kotlin's Coroutine framework, you can create parallel coroutines using the launch or async functions with the Dispatchers.IO.
4. Non-Parallel Coroutine's Job, this approach involves the execution of coroutines sequentially without parallelization.

Each process/task also determined the result, then to make other stress test to every processing variant then there were 3 process lengths on 15 ms, 150 ms, and 300 ms for each process/task which executed 10 times for each test.

4.3. Evaluation of RFID Detection

For testing the RFID detection at different frequencies, it will be conducted at the same distance, based on the best detection results obtained between the tag and reader, while utilizing the same power level of 26 dBm. The frequency range used will be from 902.75 MHz to 927.75 MHz, depending on the available options in the software. To meet the sample size limitation, comparing the research findings with the actual field data. This can be done using the general formula for comparison:

$$Success\ Rate = \frac{D_{result}}{D_{total}} * 100\% \quad (1)$$

With:

- $Success\ Rate$ is result percentage.
- D_{result} is total detected data.
- D_{total} is total real data.

Next, for the farthest distance data, the Euclidean Distance can be used to determine the distance between the reader and the tag at the same height, using a two-dimensional measurement. The calculation can be done using the following formula:

$$d(p,q) = \sqrt{\sum_{i=1}^{n}(q_i - p_i)^2} \quad (2)$$

With:

- $d(p,q)$ is total distance
- n is total dimension
- $q\ ,p$ is the coordinates of the position
- $q_i\ ,p_i$ is *Euclidean* Vector for the position of the reader and tag.

By substituting the appropriate values into the formula, calculate the Euclidean Distance between the reader and the tag at the farthest distance. This measurement can provide insights into the effectiveness and range of the RFID system, particularly in terms of distance coverage.

4.4. Evaluation of Data Recording

By conducting a maximum of 3 trials for the same data subject, data recording can be evaluated as achieving 100% accuracy in data reading. In addition to accuracy, another crucial factor was the speed of each data recording process. The speed can be measured by calculating the average time from successful experiments, with a maximum of 10 trials. The following formula can be used for the speed calculation:

$$m = \frac{\sum t}{n} \quad (3)$$

With:

- m is average data recording time.
- t is time that required to complete the data recording process
- n is number of successful trials.

In this calculation, variables are related to the speed calculation mentioned earlier, where the average time was determined by dividing the total time of successful trials by the number of successful trials.

5. RESULT AND DISCUSSION

5.1. Evaluation Results of RFID Detection

By conducting proposed method above, for RFID detection conducting some tests for scenario will reflect as Table 2 for normal RFID tag and Table 3 for anti-metal RFID tag to summarizes the results of the first attempt with highest frequency from the device (927.75 MHz) & 0˚ to penetrate the obstacles.

Table 2: Summary of Normal RFID Tag Detection.

Length (m)	Angle (degree)	Success Rate (%)		
		No obstacle	Box with mineral water	Empty box
0	0	100	40	60
0.5	0	100	40	60
1	0	100	40	60
1.5	0	100	0	50
2	0	100	0	50
2.5	0	100	0	0
3	0	100	0	0
3.5	0	100	0	0
4	0	100	0	0
4.5	0	0	0	0
5	0	0	0	0

From Table 2, normal RFID tag could only support up to 4 meters when there's no object get in the way, 1 meter if it was blocked by box with mineral water cup, and 2 meters if it's just an empty box. This max result for detected RFID tag also had a low probability, with 40% for box with mineral water cup and up to 50% for the box only. Of course, with this low success rate result then hard can't proceed deeper for the object's depth. So, this could be tested on the farthest only (max 2 meters).

Table 3: Summary of Anti-Metal RFID Tag Detection.

Length (m)	Angle (degree)	Success Rate (%)		
		No obstacle	Box with mineral water	Empty box
0	0	100	50	60
0.5	0	100	50	60
1	0	100	40	60
1.5	0	100	40	60
2	0	100	0	50
2.5	0	100	0	50
3	0	100	0	0
3.5	0	100	0	0
4	0	100	0	0
4.5	0	0	0	0
5	0	0	0	0

From Table 3, anti-metal RFID tag performed better where this could read up to 1.5 meters for box with mineral water, and 2.5 meters for an empty box. Meanwhile the farthest one for no obstacle remained the same since the antenna remained the same (same RFID reader). For the probability it was better yet no higher than 10% for the success rate compared to normal RFID tag.

Result for angle on 5˚ and 10˚, there's no different with 0˚. These were tested from the highest frequency that available from the device, yet reader barely read the box intermittently. This happened because for penetrate the box, RFID reader needed higher frequency. Meanwhile 927.75 MHz is the highest frequency that eligible from the system also higher than that was prohibited by law from Indonesia's government. Also with the current

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antenna configuration, the RFID reader has the capability to read tags at up to 4 meters, provided there were no obstacles. It's important to note that the range of the reader was directly influenced by the strength of the antenna.

According to Table 2 and Table 3's data, continuing test for the maximum box that could be detected at once with farthest distance between reader and all tags up to 2.5 meters.

Table 4: Total Detected Box

Length (m)	Tag Normal		Tag Anti Metal	
	Depth (box)	Total box	Depth (box)	Total box
0	1	25	1	25
0.5	1	39	1	39
1.5	1	54	1	54
2	1	59	1	62
2.5	1	59	1	62

The farthest the distance between RFID reader and tag will make it increased the line of sight for the reader thus the total detected box as well. Based on Table 4, the RFID reader only could detect the total of first depth box only. So, on the closest range, only one pallet that was detected. In the further testing, reader detected the right and left pallets. With the around 60 boxes in total, this conclude that RFID reader could read up to 7 stacking boxes height and 8 line-up boxes.

5.2. Evaluation Result of Data Recording

In total, there's up to 60 boxes could be detected at once. So, the test started with 60 items, 600 items and 1200 items.

Table 5: Result Data Processing with 15ms Each.

Data Recording Method	Average (millisecond)		
	60 items	600 items	1200 items
Standard Mapping	1119,57	2274,95	9647,88
Non-Parallel Coroutine Job	38,09	45,62	235,68
Parallel Coroutine Job	40,19	45,42	302,04
Multi Coroutine Channel	40,56	52,78	308,29

On the first data processing test from Table 5, found that by using parallel processing it made the process speed way much better. Almost 30 times better than synchronous mapping from around 1 second to 38,09 milliseconds. Among the others parallel's process, all the test and stress test were won by non-parallel coroutine, this result had slightly different for non-parallel coroutine had faster than others parallel process around up to 5% for 60 items, 10% for 600 items and 20% for 1200 items.

Table 6: Result Data Processing with 150ms Each.

Data Recording Method	Average (millisecond)		
	60 items	600 items	1200 items
Standard Mapping	9344,39	timeout	timeout
Non-Parallel Coroutine Job	200,06	253,94	299,07
Parallel Coroutine Job	203,66	275,02	333,04
Multi Coroutine Channel	204,38	278,38	373,90

Table 6 showed result for the result for increasing each data processing by 10 times. For standard mapping, it took almost 10 second for the first 60 items but it exceeded the maximum response time from API for 600 and 1200 items because already higher than 10 seconds. For the fastest was still being taken by non-parallel coroutines with 200,06 milliseconds for the first 60 items. So, non-parallel coroutine had faster than others parallel process around up to 2% for 60 items, 8% for 600 items and 10% for 1200 items. Which the gap between them was reduced by up to 50%.

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Table 7: Result Data Processing with 300ms Each.

Data Recording Method	Average (millisecond)		
	60 items	600 items	1200 items
Standard Mapping	timeout	timeout	timeout
Non-Parallel Coroutine Job	355,92	390,48	417,31
Parallel Coroutine Job	359,28	403,14	432,68
Multi Coroutine Channel	361,65	405,66	439,99

Table 7 showed the final stress test for increasing each data processing by 20 times from the first test. Standard mapping had timeout on every items. Meanwhile non-parallel coroutine job still winning with non-parallel coroutine only need 355,92 milliseconds to finish it. This process had faster than others parallel process around 4-5% for all items. The gap between them almost none because the total process that still lower than 0,5 seconds.

So, reflecting on all stress test result from Table 5, Table 6, and Table 7 then concluding that for asynchronous process wouldn't double the process length like normal process do. Also, Non-Parallel Coroutine job had a better performance between other asynchronous processes, with keep the won streaks for 3 times. Within the result, the process Coroutine Job will be better without using any parallel computation anymore since Coroutine Job could handle the parallel independently. That's made Non-Parallel Coroutine Job became the fastest approach for data processing. For Multi Coroutine Channel, it took the third place since the asynchronous process limited from the total processed items which was less effective to iterate the total items.

6. CONCLUSION AND FUTURE WORK

While the data collection process was rigorous, there may have been some minor inconsistencies in recording data due the object (box with mineral water). In future studies, implementing other object that had smaller dimension could maximize potential object's detection. The result of all the tracked objects only available for the first row of depths which unreliable to track all the boxes object at once. Yet it was able for tracking down all tags for the farthest distance of 2.5 meters on a line-of-sight area of 1.5 meters high and 3 meters wide with no obstacle. However, it's important to note that the improvement, while keep the mineral water box as the object, use multiple reader at multiple side would work since it could detect the first row of the multiple objects.

Furthermore, the research highlighted the importance of using concurrency mechanisms, such as multi-threading and parallel computing, to handle multiple objects effectively. The system architecture and software framework played a crucial role in achieving seamless data synchronization and resource allocation for the API, contributing to the overall success of the data processing. Which in this research, using current multiple coroutines algorithm worked well on improving data process. In the future work could compare another innovation from coroutines implementation as well.

The discussion provides a thorough interpretation of the results between data result and its process, but it focuses primarily on technical aspects. To enhance the discussion, this research should also consider the broader implications of the improved RFID tag such as potential cost savings and efficiency gains for supply chain management by the object (box with mineral water) to measure if it's worth it to use RFID as stocktaking. But in general, since this needs more readers to determine the bunch stack of boxes, this won't worth the price for 3 meters wide only on each side.

Overall, the implementation of RFID technology in inventory management and object tracking still showed great potential for various industries. The real-time identification and data processing capabilities of support all the of the collected data. Even for the stress test, with Kotlin Coroutines it was perfectly executed.

In conclusion, this research showed result that how RFID's capable on identifying mineral water box only from the first row of boxes. Also, with the proposed algorithm in parallel processing using coroutines significantly improves data from RFID for processing. While this improvement is statistically robust, its practical significance may vary depending on specific use cases. This underscores the importance of considering both practical implications of RFID reader and statistical significance from data processing in evaluating RFID technology enhancements.

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Based on the findings, this research recommend that RFID technology implementers assess the suitability of the algorithm for their specific applications, considering the potential benefits in terms of accuracy gains and operational efficiency. There were still several areas that warrant further investigation and improvements yet to make sure everything would better and better. Such as:

1. Adjust the objects, current mineral water's box was too thick to be penetrated by the reader, with thinner box would help deliver maximum benefits from the reader but this should be adjusted with what business needs.
2. Multi sensor integration, if we found the better way at object's detection then exploring the integration of RFID technology with other sensor technologies would be interesting, such as GPS and temperature sensors, to obtain additional contextual data and ensure better object tracking and monitoring in challenging environments.
3. Security and privacy enhancements, for security and privacy concerns related to RFID Technology, especially in large-scale deployments. Develop robust encryption and authentication mechanisms to protect sensitive data and prevent unauthorized access.
4. Kotlin experimental, there were some new Kotlin's library that still beta like the new way manage the memory for the data proceed. This could be improving the performance of the data processing.

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