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RTLS IN ACTION: VISUALIZING AND ANALYZING DATA FOR ENHANCED WORKPLACE PRODUCTIVITY

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Abstract

The implementation of Real-Time Location Systems (RTLS) in workplaces offers transformative potential for optimizing workflow, ensuring equipment and personnel tracking, and supporting predictive maintenance. This paper explores the development and application of RTLS technologies at Tormási Ltd. within the framework of the project Development of Digitalization Solutions to Enhance Efficiency and Customer Trust. By leveraging Bluetooth Low Energy (BLE), Wi-Fi, and Ultra-Wideband (UWB) technologies, the project aimed to streamline operations, ensure better quality assurance, and predict equipment maintenance needs. Real-world testing, data analysis, and integration with a digital twin were conducted to visualize and simulate data, thus enhancing layout planning and productivity. The study identifies challenges, including signal interference and data volume management, while emphasizing the potential for RTLS to optimize workplace layouts, improve decision-making, and elevate operational efficiency.

1 Introduction

The advent of Real-Time Location Systems (RTLS) has revolutionized workplace productivity, offering unprecedented levels of operational visibility, efficiency, and data-driven decision-making. RTLS technology provides real-time tracking of objects and individuals within a designated space, empowering industries to optimize workflows, improve equipment management, and enhance overall operational transparency. The Development of Digitalization Solutions to Enhance Efficiency and Customer Trust project at Tormási Ltd. represents a significant application of these capabilities, integrating various RTLS technologies to achieve key goals. These include optimizing workflow, ensuring predictive maintenance of critical equipment, and building customer trust through quality assurance measures.

RTLS relies on technologies such as Bluetooth Low Energy (BLE), Wi-Fi, and Ultra-Wideband (UWB), each offering distinct benefits depending on the environment and operational needs. BLE, for instance, is known for low power consumption, making it ideal for long-term, battery-operated applications. Wi-Fi-based RTLS leverages existing infrastructure, offering a cost-effective solution for large facilities. UWB, on the other hand, excels in precision, with accuracy that can reach sub-meter levels, making it particularly useful in industrial settings that require high accuracy and reliability.[4] The integration of these technologies with digital visualization tools like Unity and software such as Sewio[1] facilitates a comprehensive understanding of real-time movements, bottlenecks, and workflow inefficiencies.

This paper explores how Tormási Ltd. deployed these technologies to track workflows, enhance layout planning, and facilitate predictive maintenance. It will discuss the methodologies used, challenges encountered, and the transformative impact of RTLS on workplace productivity.

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2 Overview of RTLS Technologies

Real-Time Location Systems (RTLS) offer powerful solutions for tracking and managing assets and personnel in real-time. By using a combination of sensors, anchors, and tags, RTLS can pinpoint the location of tracked items with remarkable accuracy. The system typically employs multilateration techniques, where the difference in arrival times of signals from tags to multiple anchors is used to triangulate positions. This enables businesses to obtain precise location data and gain actionable insights.

RTLS can be implemented using several types of technologies, each with unique attributes suited to different environments:

- **Bluetooth Low Energy (BLE):** BLE technology is a popular choice due to its low power consumption and long battery life, making it ideal for applications where continuous tracking is required without frequent battery changes. BLE is widely used in sectors such as healthcare, where small, battery-powered tags can be attached to medical equipment and patient ID badges.
- **Wi-Fi-Based RTLS:** This system utilizes existing Wi-Fi networks, making it a cost-effective solution for large facilities that already have extensive Wi-Fi infrastructure. It offers the advantage of quick deployment and can leverage the network's existing security protocols. Hospitals and large office buildings often adopt this type of RTLS to monitor assets and optimize staff movements.
- **Ultra-Wideband (UWB):** UWB technology provides higher accuracy than other systems, often down to sub-meter levels. Its ability to measure the time-of-flight of radio signals makes it highly precise, even in environments with obstructions. UWB is particularly beneficial in industrial settings where detailed tracking of equipment and personnel is required for process optimization and safety.[2]

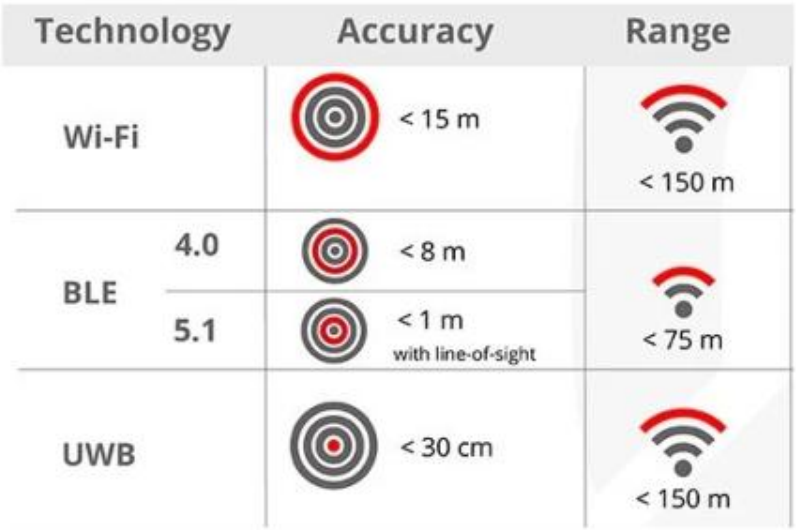

Figure 1: Comparison of the different RTLS technologies.
Source: infsoft.com.

Figure 1 provides a detailed comparison of the accuracy and range of various technologies (Wi-Fi, BLE, UWB). As can be seen from the figure, UWB is the most suitable technology for indoor tracking. Each of these RTLS technologies comes with its own set of strengths and limitations. BLE offers power efficiency but less accuracy compared to UWB. Wi-Fi RTLS is economical but can struggle with precise location tracking in complex layouts. UWB, while accurate, may require a higher initial investment and more infrastructure setup. The choice of technology depends on the specific requirements of the industry, whether it's cost-effectiveness, accuracy, or integration capabilities.[4]

RTLS, when effectively implemented, provides valuable insights into workflow optimization, equipment maintenance scheduling, and overall productivity improvements, forming an integral part of digital transformation strategies across various industries

3 Results and Analysis

3.1 Accuracy and Data Collection

One of the primary objectives of the RTLS project at Tormási Ltd. was to assess and ensure the system's accuracy. The DecaWave UWB system was tested in various environments to understand its performance. Open areas posed significant challenges, with the system exhibiting a decreased accuracy that required a higher number of anchors to maintain reliable tracking. In contrast, more enclosed spaces allowed for better precision, with results achieving sub-meter accuracy, reaching levels of around 0.2 meters in some cases. Similar approaches utilizing thermal sensor-based detection methods have been studied for human presence detection, demonstrating the feasibility of alternative tracking techniques [5]. These measurements were obtained through multiple test scenarios, showcasing the system's capability to adapt to different settings. Prior to installation, simulation software was used to determine the optimal network configuration, which is shown in Figure 2. It shows a maintenance hall and uses red circles to indicate the fixed anchor points connected to the network, which measure the signals sent by the moving devices. The simulation also allows for the simulation of signal strengths with different anchor installation layouts. The rectangular shapes illustrate vehicle lifts, which block the signal. Therefore, as shown in the figure, the signal strength is critically low (white) in those areas.

Figure 2:Test simulation in the search of the best system configuration
Source: Authors own work in the SEWIO's simulation software [1].

A critical component in achieving this level of accuracy was the use of 3D scanning. The factory's layout presented unique challenges due to the presence of machinery, walls, and other obstructions that could interfere with the RTLS signals. To ensure optimal placement of anchors and to achieve the highest possible precision, it was essential to map the physical space accurately. 3D scanning with an iPad equipped with a LiDAR sensor was employed to capture detailed data on the factory's environment. This sensor combined images with 3D points to generate a precise digital representation of the factory space. The scanned data enabled the team to plan anchor placements more effectively and identify potential blind spots that could impact signal strength. This approach helped create an accurate and comprehensive blueprint that served as the foundation for the simulation and anchor placement strategy. Without this level of detail, the accuracy of the system would have been compromised, leading to potentially unreliable tracking data.

A brief, visual representation of the 3D scanning process and its output is provided in the figure below. This visualization illustrates a partial, in-progress 3D scan of a section of the assembly stand, rendered in true color, based on real factory data. While the scanner device shown is purely for illustration and does not represent the actual equipment used (the LiDAR-equipped iPad), the depicted scanned area is derived from the genuine spatial data. This dataset served as the foundation for subsequent project phases, providing the critical geometric context for simulation and planning.

Figure 3 illustrates the LiDAR-based 3D scanning process and the resulting color-coded point cloud.

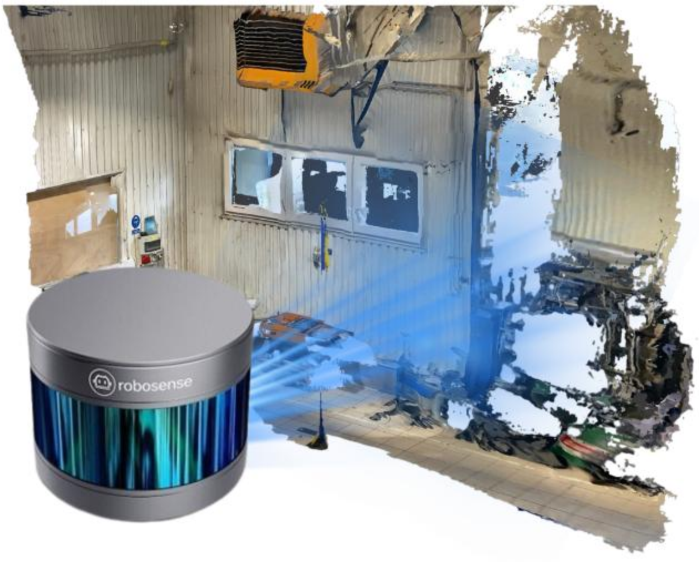

Figure 3: Illustration of the 3D scanning, and the real scan in the background. Source: Authors own work.

3.2 Data Visualization and Interpretation

The project incorporated advanced data visualization techniques to interpret and analyze the extensive amount of location data collected through the RTLS system. Each technician wore a Tag device connected to the RTLS system, which transmitted a Blink signal whenever they moved. The device fit on their wrists like a watch and, thanks to its low power consumption, could operate on battery power for several days. Thus, whenever they put it on and moved, the system received a continuous stream of data.

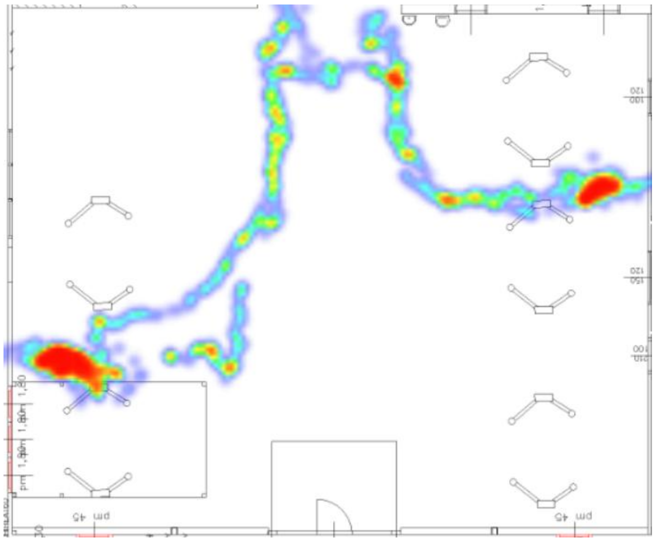

Figure 4: Heatmap of few hours of movement by a repairman.
Source: Authors own work.

One of the most effective tools used was heatmapping, which provided a visual representation of personnel movement patterns and areas of frequent activity within the factory. Heatmaps proved invaluable for quickly identifying high-traffic zones, understanding the flow of movement, and pinpointing areas that might require process adjustments or layout changes. Figure 4 shows a heat map representing the movement path of a repair technician over several hours

To complement the heatmap visualizations, custom Python algorithms were developed for data filtering and advanced calculations. These algorithms enabled the extraction and processing of critical data points from the raw output of the RTLS system. By utilizing Python, the team could create tailored scripts that filtered data based on specific parameters, such as time of day, location, and movement speed. This allowed for a deeper analysis of zone attendance, highlighting areas where workers were most frequently present and mapping out the frequency of visits to different parts of the shop floor. Additionally, Python was used to compute daily distances traveled by employees, providing insights into the efficiency of workflows and identifying potential bottlenecks. The raw data of movement traces was processed to produce illustrations of individual and collective patterns of movement, referred to as “spaghetti maps,” which further detailed how workers navigated through the space. These analyses collectively helped identify inefficiencies and suggest optimal layout changes for improved workflow. Figure 5 illustrates the combination of RTLS data and the workshop’s 3D model, which forms the basis of the digital twin.

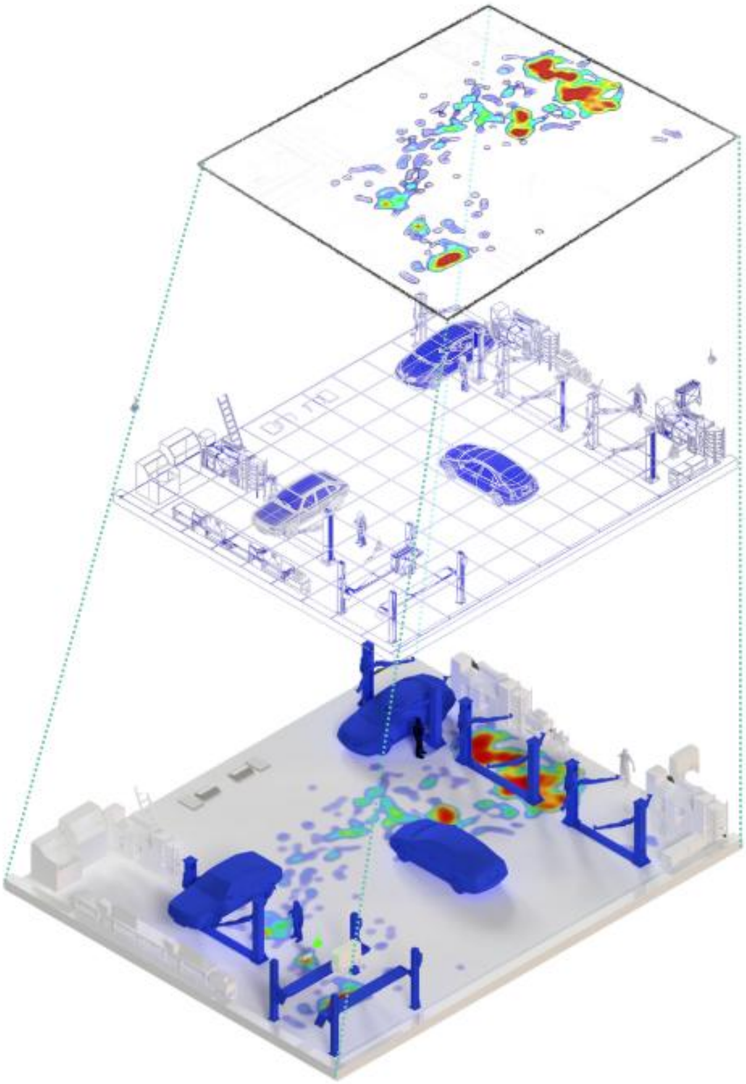

Figure 5: Illustration of combination the RTLS data and the 3D copy of the repair shop.
Source: Authors own work.

By combining these data visualization techniques with Python-driven analytics, the team was able to better interpret the raw tracking data and make data-driven recommendations for workflow improvements. This approach ensured a practical and visual means of understanding the spatial dynamics within the facility, fostering an environment where productivity enhancements could be effectively planned and executed.

3.3 Digital Twin Integration

The integration of RTLS data with Unity software played a pivotal role in advancing the project. This integration facilitated the creation of a 3D digital twin of the factory space, which acted as a real-time simulation environment. With Unity's support for C# programming and seamless API connectivity to the Sewio system, the real-time data was ingested and processed to construct dynamic models of the factory. These models allowed for simulations that demonstrated potential changes in layout, workflow, and equipment use without disrupting actual operations. By leveraging the digital twin, planners could visualize and test various scenarios, predicting how modifications would impact efficiency and productivity. In Unity, there are plenty of possibilities for using machine learning algorithms, which would further increase the range of possibilities.[3] The use of augmented reality tools further enhanced the spatial understanding of the factory layout, helping to identify areas for improvement more intuitively.

4 Benefits and Implications

The implementation of RTLS at Tormási Ltd. had a direct and measurable impact on productivity. Through continuous monitoring and data collection, inefficiencies in the shop layout and workflow were identified and addressed. The heatmap visualizations and movement pattern analyses provided actionable insights into worker routes and the frequency of tool usage. As a result, the layout was optimized to streamline the movement of personnel and equipment, significantly reducing unnecessary travel time and boosting overall workflow efficiency. This data-driven approach enabled a proactive reorganization that minimized downtime and improved task allocation, leading to enhanced productivity.

RTLS technology also played a crucial role in building customer trust through improved transparency and quality assurance. The system’s ability to monitor critical operations in real-time and document processes ensured that tasks were performed as intended. The implementation of AI-powered cameras for task monitoring further reinforced this commitment by providing clear oversight and allowing for the verification of quality standards. By integrating these elements into the operational model, Tormási Ltd. was able to offer clients detailed documentation of the repair processes, establishing greater transparency and trust in the company’s services.

These combined benefits demonstrate how RTLS technology can transform operational practices, leading to a more productive, transparent, and reliable working environment that fosters trust and supports long-term business growth.

5 Conclusion

The deployment of Real-Time Location Systems (RTLS) at Tormási Ltd. has demonstrated significant potential for enhancing workplace productivity and operational efficiency. Through a careful combination of RTLS technologies such as BLE, Wi-Fi, and UWB, and the integration of 3D scanning and digital twin simulations, the project successfully improved workflow planning, equipment management, and predictive maintenance capabilities. By employing advanced data analysis techniques, including Python-based data filtering and heatmap visualizations, Tormási Ltd. was able to identify key inefficiencies and make data-driven decisions that streamlined operations, reduced travel time, and optimized layout planning.

Despite these achievements, challenges such as signal interference and the management of large data volumes highlighted the need for ongoing development in system infrastructure and algorithmic capabilities. Addressing these issues through further refinements in hardware placement, real-time data processing, and robust machine learning models will be crucial for advancing the system's reliability and applicability.

The findings from this study provide valuable insights for other industries considering RTLS implementation. The combination of visual data interpretation, predictive maintenance, and digital twin simulations can create a framework for proactive workflow optimization and support long-term productivity gains. Future research should focus on integrating RTLS with more advanced AI-driven analysis tools and exploring additional use cases to maximize the system’s potential across diverse operational environments.

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