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A procedure for optimization of placement products in large industrial areas of a Greek soft drinks company

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***Abstract*—In this paper we present the process of optimal placement of industrial products (pallets) in mapped warehouses and specifically in a soft drink company in Greece. The optimization criterion is to minimize the cost of moving the lifting machine that places the products in specific positions. The computational method of optimal placement of industrial products receives data from the automatic product count of the mapped warehouse and from the sales predictive model. Therefore, the computational method, having knowledge of the location and number of products in the warehouse and the prediction of sales for each product, places the products produced in an optimal way. Automatic product counting is carried out using an unmanned aerial vehicle (UAV) which developed and applied in soft drink company in Greece. The sales prediction is carried out through a prediction model which developed in a soft drink company in Greece.**

***Index Terms*—LiDAR, UAVs, Inventory Detection, Warehouse Measurement**

I. Introduction

Efficient warehouse management and the optimal placement of products within large industrial areas are crucial for enhancing operational efficiency and minimizing costs, especially in high-demand industries such as the beverage sector. Previous research has demonstrated that effective warehouse operations can significantly reduce logistics costs, streamline workflows, and improve service levels [1], [2], [3]. In particular, product placement strategies that minimize travel times for material-handling equipment have been shown to play a pivotal role in optimizing warehouse operations [4], [5], [6], [7].

In the context of a soft drinks company in Greece, where diverse inventory turnover and high product demand create substantial operational challenges, optimizing product placement can yield significant benefits. This study aims to develop a computational method for the optimal placement of industrial products, specifically pallets, within the company's mapped warehouses. The optimization criterion is to minimize the operational cost of moving lifting machines that place products in designated storage locations, a challenge also addressed in broader industrial settings [8], [9].

The computational method we propose integrates two essential data sources: (1) an automated product counting system utilizing unmanned aerial vehicles (UAVs) [10], [11], and (2) a predictive sales model that forecasts demand for each product. UAV technology has gained attention in recent years for its potential to automate inventory management and improve accuracy in large-scale warehouses. The UAV system used in this study, developed specifically for the soft drinks company, ensures real-time monitoring of product quantities and locations. Concurrently, the sales forecasting model, based on machine

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learning algorithms, provides accurate demand predictions, enabling the system to optimize product placement based on future needs, a method aligned with recent advancements in predictive analytics for warehouse optimization.

By combining real-time inventory data and predictive sales analytics, the proposed method minimizes the need for unnecessary product movements, thereby reducing operational costs and increasing efficiency. In this paper, we present the details of the computational method, its implementation, and the results of its application in a real-world setting within the soft drinks industry in Greece.

II. Methodology

The methodology employed in this paper consists of three key steps, each contributing to the optimization of product placement in a mapped warehouse. The integration of automated data collection, sales forecasting, and computational optimization techniques ensures that products are placed in the most efficient positions, minimizing operational costs and enhancing warehouse performance. Below is a detailed analysis of the methodology.

A. Warehouse Inventory Counting Using UAV

The first step involves using unmanned aerial vehicles (UAVs) to perform an automated inventory count within the warehouse. Before this process begins, the warehouse has already been mapped, ensuring that the UAV operates within a predefined, structured environment. This mapping provides crucial data about the layout, including aisles, shelves, and storage sections, which is essential for the efficient navigation of the UAV.

Based on the warehouse mapping, a detailed flight plan is developed for the UAV. The flight plan is optimized to minimize the UAV's travel distance while covering the entire warehouse area. This not only reduces the time needed for the UAV to complete its task but also maximizes the efficiency of its battery life and overall performance. Additionally, the flight path is designed to enable the UAV to capture product data in a manner that supports the highest accuracy of the counting algorithm.

The UAV is equipped with cameras and sensors that collect real-time data on the location and quantity of products (pallets) stored in the warehouse. The performance of the inventory-counting algorithm is optimized by ensuring that the UAV flies at appropriate altitudes and speeds, considering the warehouse layout and environmental conditions. This allows the UAV to gather accurate and comprehensive data without missing any sections or requiring redundant passes.

The optimized flight path, combined with the enhanced performance of the counting algorithm, ensures that the UAV can complete the inventory process quickly and accurately. This step significantly reduces the labor and time costs associated with manual inventory checks while maintaining a high level of precision.

B. Sales Prediction Using a Forecasting Algorithm

The second step involves forecasting future sales using a predictive model that has been specifically developed for the soft drinks company. This forecasting model leverages historical sales data and external factors, such as seasonality and market trends, to predict the future demand for each product in the warehouse.

By accurately predicting which products are likely to be in higher demand, the company can ensure that these items are placed in more accessible locations within the warehouse. This minimizes the movement of lifting machines and reduces the time required to retrieve products, leading to cost savings and operational efficiency.

Predictive analytics has been increasingly applied in warehouse management, offering a data-driven approach to decision-making. In this case, the forecast results are integrated into the optimization algorithm to inform product placement decisions.

C. Optimal Placement of New Products in the Existing Warehouse

The final step involves the actual placement of new products in the warehouse based on the information gathered from the previous two steps. The optimization algorithm receives the UAV-generated inventory data and sales predictions, using this information to determine the best positions for the incoming products.

The goal of the optimization is to minimize the distance and time required for the lifting machines to transport products from their storage positions to the dispatch area. This is achieved by strategically placing high-demand products closer to the exits or frequently accessed areas, while lower-demand products are stored in less accessible locations. This approach is aligned with the principles of class-based storage, which has been shown to improve order-picking performance in industrial settings.

The algorithm takes into account various factors, such as the available space in the warehouse, the physical dimensions of the products, and the predicted sales volume. By optimizing the placement of products, the company can not only reduce operational costs but also improve the overall efficiency of its warehouse operations.

III. Research Results

In this section, we present the outcomes of implementing the UAV-based inventory counting system and the optimization algorithm for product placement, using real data from the soft drinks company. The results are compared with those obtained through conventional methods of manual inventory counting and traditional product placement strategies.

The user of the application utilizes the following key characteristics to operate the system effectively:

Warehouse Characteristics

- Width: 1590 units,
- Length: 680 units,

- Height: 700 units,
- Aisle Width: 50 units.

The warehouse is designed to store products on pallets and has a systematic layout with aisles that are 50 units wide. The height of 700 units allows for stacking multiple layers of pallets, with drone flights planned at a height of 600 units to scan the uppermost layers (Figure 1).

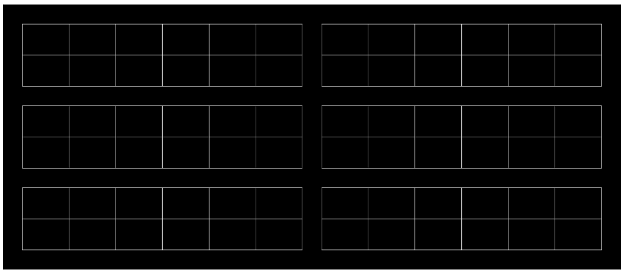

Fig. 1. Detailed mapping of the warehouse layout

Product Details

Each product is stacked on pallets, and the heights of the pallets are as follows: A: 53, B: 57,C: 41, D: 63, E: 47. The width and the length of the pallet are 120 and 80 units respectively. The products will be stacked in layers within the warehouse, and the heights of the pallets will determine how the drone targets its scanning at specific altitudes for optimal counting and mapping.

Drone Flight Route

The drone follows a predetermined route through the warehouse to scan the products efficiently. The flight path ensures that the entire width and length of the warehouse are covered without unnecessary overlap. The drone starts at a height of 600 units to capture data from the highest possible pallet stacks and follows this systematic route:

- Starting Point: (20, 90).
- Move across the warehouse width:
  - From (20, 90) to (1570, 90).
  - Turn at the end of the aisle: From (1570, 90) to (1570, 170).
  - Return across the next section: From (1570, 170) to (20, 170).

  Continue in a zig-zag pattern: This pattern continues across several rows (300, 380, 510, 590), covering the full length and width of the warehouse.

This back-and-forth flight pattern ensures comprehensive coverage, allowing the drone to scan every part of the warehouse and capture product positions and quantities without redundancy (Figure 2).

Flight Height

Flight Height: 600 units. The drone operates at a flight height of 600 units, which is just below the warehouses maximum height of 700 units. This height ensures that the drone can scan all the products stacked up to the topmost layers, even those stacked at maximum pallet height.

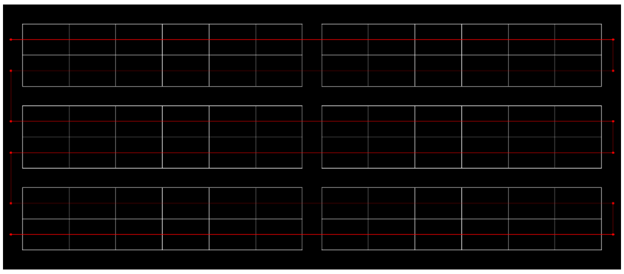

Fig. 2. UAV flight path within the mapped warehouse, optimized for minimal travel distance

Optimization of the Process

The drone is equipped with LiDAR sensors to scan only the required pallet heights. The pre-mapped warehouse layout allows the drone to focus on specific areas at the predefined pallet heights, avoiding unnecessary data processing. By using a structured flight route and focusing on key areas, the system optimizes the entire scanning and inventory counting process. This setup provides an efficient and streamlined process for counting inventory with the drone, minimizing redundant movement and focusing on the exact areas and pallet heights necessary for accurate data collection.

A. Warehouse Inventory Counting Using UAV

The initial phase of the UAV-based inventory counting process involved the detailed mapping of the warehouse. This map served as the foundation for planning the UAV's flight path, ensuring that it covered all necessary areas of the warehouse in the most efficient manner. Figure 1 presents the complete warehouse map, including the storage zones, aisles, and shelving structures. To further optimize the UAVs performance, the following key data points were considered:

Warehouse Dimensions: The full extent of the warehouse, including the height of storage shelves and the width of aisles, was taken into account to ensure the UAV could safely navigate through the space.

Product Locations: The mapped positions of existing products provided initial reference points for inventory tracking.

Obstacle Identification: Fixed obstacles, such as machinery, columns, or restricted zones, were identified to prevent UAV collisions and ensure smooth flight.

Flight Path Optimization: The flight path was calculated to minimize travel distance while ensuring comprehensive coverage. This involved calculating the shortest routes between aisles and shelves while adhering to the UAVs technical constraints (e.g., battery life, sensor range). Figure 2 displays the optimized flight path of the UAV, showing how it efficiently navigated through the warehouse to minimize time and maximize accuracy.

The accurate mapping of the warehouse allows for the optimization of the inventory counting process, as it enables the system to process specific data from the LiDAR sensors rather than the entire set of flight data(Figure 3. By focusing only on the relevant spatial information, the algorithm becomes more efficient, reducing the processing time and improving the accuracy of the counting. This targeted approach ensures that the UAV captures and analyzes only the necessary data related to product positions, leading to a streamlined and optimized inventory management process (Figure 4).

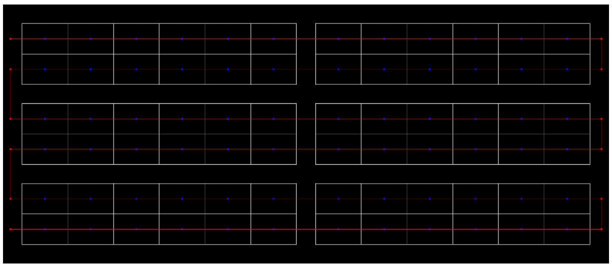

Fig. 3. UAV flight path with specific points

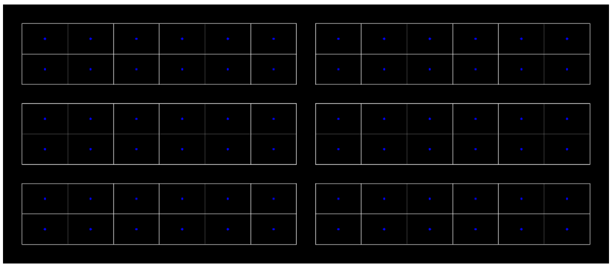

Fig. 4. The specific points

The data captured by the UAV during its flight was used to create an accurate real-time inventory map, which was then fed into the inventory-counting algorithm (Figure 5). The performance of the algorithm, enhanced by the optimized flight path, provided highly accurate inventory data.

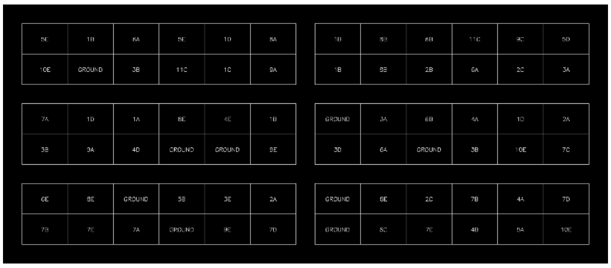

Fig. 5. The warehouse with counting products

The total quantities of each product in warehouse are:
A: 82, B: 66, C: 49, D: 29, E: 109 (units)

TABLE I
UAV-BASED INVENTORY COUNTING VS. MANUAL COUNTING

Metric	UAV-Based System	Manual Counting
Total Time (min)	20	80
Counting Accuracy (%)	100%	92.5%
Labor Requirement	1 UAV operator	3 workers
Operational Cost (relative)	Low	High

The UAVs total operational time, accuracy, and efficiency were recorded, as shown in Table I, which compares these metrics with traditional manual inventory counting.

B. Product Placement Optimization

After completing the inventory count, the optimization algorithm placed the new products based on predicted sales data. Figure 3 shows the placement of products within the warehouse before and after the optimization process.

The remaining positions in which specific products should be placed are as follows:
A: 62, B: 62, C: 47, D: 27, E: 41 (total quantities in units).
Additionally, to the warehouse, there are 9 positions in which there is no pallet, then any product can be placed (Figure 6)

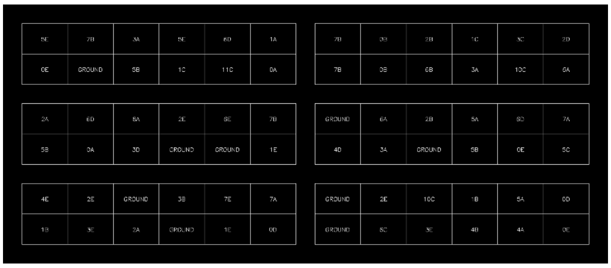

Fig. 6. The remaining quantities for each stack

The optimal placement algorithm works as follows:
First, it checks if the sales forecasts for each product exceed the remaining available storage positions. For products that can be placed in the existing positions, they are positioned based on the criterion of minimizing the travel distance for the lifting machine.
For products that exceed the corresponding available positions, they are initially placed in the available slots using the same criterion. Subsequently, the remaining products are alternately placed in the free positions.
The data of the warehouse are the following:

- Initial quantities for each product:
  A: 82, B: 66, C: 49, D: 29, E: 109 (units)
- Remaining quantities for each product:
  A: 62, B: 62, C: 47, D: 27, E: 41 (units)
- Prediction quantities for each product:
  A: 180, B: 40, C: 40, D: 40, E: 190 (units)
- Placement quantities for each product:
  A: 98, B: 0, C: 0, D: 11, E: 81 (units)

TABLE II
COMPARISON BETWEEN OPTIMIZED PRODUCT PLACEMENT AND TRADITIONAL PLACEMENT METHODS

Metric	Optimized Placement	Traditional Placement
Average Travel Distance (meters)	150	350
Time to Retrieve Products (hours)	1.5	3.5
Operational Cost (relative)	Low	Moderate

The results of the algorithm's application are shown in the Figure 7

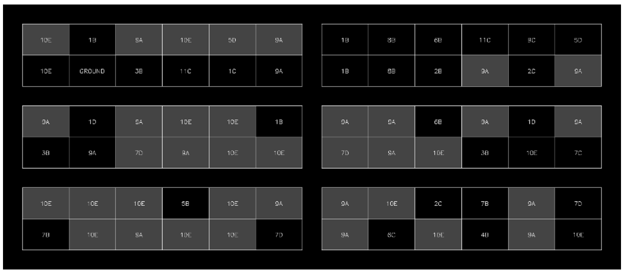

Fig. 7. Placement of products

C. *Comparison with Conventional Methods*

A comparison between the optimized product placement and the traditional placement method reveals significant improvements in operational efficiency. Table II summarizes key performance indicators, demonstrating the benefits of the optimization approach.

The results indicate that the optimized placement strategy not only reduced travel time and distance for the lifting machines but also led to lower overall operational costs. This is particularly important in high-demand periods, where efficiency gains can lead to significant cost savings.

IV. FUTURE RESEARCH WORK

In future research, we aim to advance the detection of inventory within a warehouse where pallets and products are placed in dynamic, unspecified positions. This presents a crucial challenge, as most industrial warehouses undergo continuous modifications to accommodate diverse product types and quantities. Unlike the current setup, where product positions are predetermined, this phase of the research will target scenarios where rapid adaptability and flexibility are required in inventory management.

Moreover, the long-term goal is to achieve real-time, continuous inventory scanning using UAV technology with specialized hardware and software. By leveraging advanced sensor integration and enhanced computational techniques, the UAV system could autonomously detect, map, and monitor the entire warehouse in real time, even under varying environmental conditions or storage configurations. This would significantly reduce manual interventions, further optimizing operational efficiency and reducing costs.

Additionally, future work will explore how machine learning algorithms can improve not only sales forecasting but also dynamic warehouse reorganization, anticipating changes in inventory demand and automatically adjusting product placements accordingly. We also aim to experiment with different drone configurations and sensor technologies, such as advanced LiDAR systems, to enhance the UAVs precision and reduce operational time.

Our ultimate goal is to build a fully automated warehouse management system that adapts to unpredictable industrial environments, offering real-time inventory management and product placement optimization without the need for manual oversight.

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