R4TLI
ISSN : 2513-2504

EFFICIENCY AND SAFETY IN COLD STORAGE STOCKTAKING: UAV INTEGRATION AND ROUTING STRATEGIES

Thanuja Wickramasinghe[1], Amila Thibbotuwawa[2]
Department of Transport Management and Logistics Engineering, Faculty of Engineering, University of Moratuwa.
thanujaruchira@gmail.com[1]
amilat@uom.lk[2]

ABSTRACT -Stock take refers to the process of physically verifying the amounts and conditions of all commodities present in the warehouse. Instead of conducting this task on an annual basis, it would be more effective to perform it on a monthly basis. Workers in a cold storage warehouse face hazards throughout the stock-taking process, such as being exposed to low temperatures and working in elevated areas with ladders and heavy gear. Hence, conducting stocktaking operations using UAVs (Unmanned Aerial Vehicle) can effectively reduce these risks and enhance the operational effectiveness of the facility. The objective of this study is to identify an effective approach for stocktaking in cold storage using UAVs and creating an efficient routing system for the selected UAV system. UAV with a UGV selected as the UAV system and the routing algorithm is 25.6% efficient compared to traditional system.

Keywords: Cold Warehouse, UAV Stocktaking, UAV Routing, Warehouse Automation, Smart Warehousing.

1. INTRODUCTION

UAV, colloquially known as drones, have emerged in the twenty-first century as an exceptionally captivating and revolutionary technological advancement [1]. Initially designed with military objectives in mind, this technology has since been implemented across various sectors, including the logistical industry. In the logistics sector, there has been a significant surge in the implementation of drone technology over the past decade. Warehouse operations are currently implementing the use of drones for the purpose of inventory management. This substantially enhances the efficacy of the process. An essential component of efficient inventory management, inventory stocktaking entails the physical verification and reconciliation of quantities of inventory in physical possession with data that has been recorded [2].

Working in cold warehouses presents significant challenges, primarily attributable to the extremely low temperatures that employees are required to endure. Due to the potential for a variety of cold-related consequences, employees' work hours within the warehouse are restricted. This contributes to an elongation of the warehouse inventory stocktaking process [3]. Consequently, minimizing worker exposure to cold environments can significantly enhance safety. As a result, the implementation of UAVs for cold warehouse inventory management will substantially enhance operational efficiency by drastically reducing the time needed for stocktaking and improve the overall safety of warehouse personnel.

This study aims to determine the most efficient method of operating a warehousing drone in a cold warehouse in order to conduct inventory checks. An essential consideration when deploying an UAV system in a cold warehouse is the extremely low temperature that the UAV must be able to endure. Generally, exposure to low temperatures results in a reduction in the duration of operation.

The main objective of the study is to find an optimal stocktaking system using UAV that can be used in cold storage efficiently. Then create a routing system that focuses on energy usage which help to reduce the energy consumption of the UAV making capacity to handle longer operation. The main focus of these objectives is to theoretical prove that UAVs can be used in cold warehouse, and they provide significant advantages to cold warehouses.

2. MATERIALS AND METHODS

For the study we selected cold warehouse that is maintain a temperature of -15 Celsius. This the minimum temperature that can be withstand by a UAV without failure [4]. In this temperature operation time of the UAV will reduce by 52% compared to operating temperature of 30 Celsius [4]. Therefore, managing the energy of the UAV is important. With that in mind this study we selected a UAV equipped with UGV (Unmanned Ground Vehicle) [5]. There are several reasons behind this choice. UGV will serve as transporting platform and charging platform within warehouse racks [6], UGV will reduce the number of complex maneuvers required within the warehouse and it made possible to use 2D VRP (Vehicle Routing Problem) instead of computationally intensive 3D VRP for the UAV routing. The UGV act as a safety layer if UAV required a sudden landing. UGV act as local positioning system for UAV eliminating the requirement of complex navigation system. As a result, this system possesses numerous advantages that are absent in other systems. We presumed that the UGV would be continuously connected to power in our study.

For the inventory procedure, an RFID (Radio-frequency Identification) scanner was intended to be implemented because it facilitates a more efficient and precise inventory process [5]. The UAV will be outfitted with a camera for physical verification and secondary verification. UGV will use Li-DAR and local submap for navigation [5].

Once the platform had been determined, research shifted its focus to developing an energy-efficient routing system that could facilitate more operations with the same amount of power as conventional routing systems [7]. We have learned from prior research that the energy requirements of various UAV maneuvers vary for example vertical movement use additional power compared horizontal movement [8]. In light of this, we developed an energy-aware routing system that considers the varying power demands of distinct maneuvers. For development of the algorithm, we used Python and Google OR-Tools.

Following the development of an energy aware routing method utilizing metaheuristic VRP, a comparison was made with a conventional VRP that primarily aimed to decrease distance. We utilized a simulated warehouse rack consisting of eight stacks and five levels making forty bins. There, fourteen containers were selected at random for scanning, and the algorithms to determine the route were executed. Once the route was determined, the energy consumption for both operations was computed [9] [10].

3. RESULTS AND DISCUSSION

Comparing the two methods, we discovered that the energy-aware routing method reduced energy consumption by 25.6%. This beneficial when conducting extended operations.

We also executed the same algorithms using two UAVs on a single UGV as part of this study. There, we observed 3.5% reduction in energy consumption from energy-aware routing method. When comparing same operation involving two UAVs and a single UAV, we discovered that the energy consumption per UAV is 29.5% lower in the two UAVs configuration. Although combined energy consumption is 27.3% greater than that of a single UAV. Lower power consumption per UAV will facilitate the ability to do higher number of operations per charge, which is particularly advantageous in warehouses of considerable scope.

A comparison was made between the durations required to complete stocktaking operations in these systems by employing the routes obtained from the energy-aware algorithm. We make assumptions about safe operating speeds for the purposes of this study, based on data collected from prior research. The time required by the multi-UAV system was 36.7% less than that of the single-UAV system. This is a substantial time-saving that, depending on the size of the warehouse, will prove invaluable.

4. CONCLUSION

The primary application of this system is in cold storage warehouses, where its implementation offers substantial safety and efficiency benefits. However, the system is applicable to any warehouse. A multi-UAV system is extremely advantageous for a company that conducts inventory-related tasks. (3rd party stocktaking companies)

Future avenues of research may encompass practical simulations, further optimization of the energy-conscious algorithm through refinement using different type of UAVs, and an examination of the system's compatibility with established warehouse management software in order to optimize its capabilities and adaptation across the entire supply chain.

REFERENCES

1. Hassanalian, M., & Abdelkefi, A. (2017). Classifications, applications, and design challenges of drones: A review. Progress in Aerospace Sciences, 91, 99–131. https://doi.org/10.1016/J.PAEROSCI.2017.04.003
2. Gupta, S. G., Ghonge, M. M., & Jawandhiya, P. M. (2013). Review of Unmanned Air-craft System (UAS). In International Journal of Advanced Research in Computer Engineering & Technology (IJARCET) (Vol. 2, Issue 4). www.ijarcet.org
3. Johnson, A., & Wilson, F. (2015). Efficiency and Cost Savings in Cold Storage Inventory Management: A Case Study. Journal of Supply Chain Management, 23(2), 45–55.
4. Li, N., Liu, X., Yu, B., Li, L., Xu, J., & Tan, Q. (2021). Study on the environmental adaptability of lithium-ion battery powered UAV under extreme temperature conditions. Energy, 219. https://doi.org/10.1016/j.energy.2020.119481
5. Kalinov, I., Petrovsky, A., Ilin, V., Pristanskiy, E., Kurenkov, M., Ramzhaev, V., Idrisov, I., & Tsetserukou, D. (2020). WareVision: CNN Barcode Detection-Based UAV Trajectory Optimization for Autonomous Warehouse Stocktaking. IEEE Robotics and Automation Letters, 5(4), 6647–6653. https://doi.org/10.1109/LRA.2020.3010733
6. Alyassi, R., Khonji, M., Karapetyan, A., Chau, S. C. K., Elbassioni, K., & Tseng, C. M. (2023). Autonomous Recharging and Flight Mission Planning for Battery-Operated Autonomous Drones. IEEE Transactions on Automation Science and Engineering, 20(2), 1034–1046. https://doi.org/10.1109/TASE.2022.3175565
7. Bocewicz, G., Nielsen, P., Banaszak, Z., & Thibbotuwawa, A. (2018). Deployment of Battery Swapping Stations for Unmanned Aerial Vehicles Subject to Cyclic Production Flow Constraints. Communications in Computer and Information Science, 920, 73–87. https://doi.org/10.1007/978-3-319-99972-2_6
8. Derpich, I., Miranda, D., & Sepulveda, J. (2018). Using drones in a warehouse with minimum energy consumption. 2018 7th International Conference on Computers Communications and Control, ICCCC 2018 - Proceedings, 97–102. https://doi.org/10.1109/ICCCC.2018.8390444
9. Thibbotuwawa, A., Nielsen, P., Bocewicz, G., & Banaszak, Z. (2020). UAVs Fleet Mission Planning Subject to Weather Fore-Cast and Energy Consumption Constraints. Advances in Intelligent Systems and Computing, 920, 104–114. https://doi.org/10.1007/978-3-030-13273-6_11
10. Dewmini, J., Fernando, W. M., Nielsen, I. I., Bocewicz, G., Thibbotuwawa, A., & Banaszak, Z. (2023). Identifying The Potential Of Unmanned Aerial Vehicle Routing For Emergency Blood Distribution. Applied Computer Science, 19(4), 68–87. https://doi.org/10.35784/acs-2023-3