Innovative Uses of Drones for Logistics in Healthcare and Production

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This ICORES 2024 keynote seminar discusses novel approaches for employing drones to accomplish logistical tasks in diverse environments. Drones, working in tandem with traditional transportation vehicles and with humans, offer environmentally friendly and cost-effective alternatives for moving small items such as medicines, electronic devices, and assembly parts. This talk will cover two research projects which involve a combination of mathematical modeling, computational optimization, simulation in virtual environments, and actual physical experimentation and trials. While using drones has challenges in terms of human interaction and practicality of operating in certain environments, they are more pragmatic than might be expected for some situations. One focus is on rural last mile healthcare supplies delivery where drones resupply trucks with newly available medical supply orders and prescriptions. Another focus is on production assembly facilities where drones bring needed parts to workers at their stations on the line. This latter setting is indoors where GPS cannot be used for drone positioning and guidance so alternative methods must be employed.

The first part of the talk addresses last-mile logistics systems where drones can be used to send newly arrived orders to delivery trucks while en route, allowing the trucks to continue their distribution without needing to return to the depot periodically. We begin by studying the situation where last-mile logistics operators know the order ready times when planning the day's operations. Using mixed-integer linear programs and effective, decomposition-based solution approaches to define truck routes, synchronized with drone resupply, the completion time of the delivery process is minimized. Compared to a traditional truck-only scenario, where trucks must return to the depot to collect any newly arrived orders, we show that drone resupply reduces completion times and also the number of truck return trips to the depot under various problem settings.

We then consider the more complex situation where orders arrive dynamically throughout the delivery horizon and the decision maker must determine, in real time, whether to accept them and how to adjust the ongoing distribution plan. We develop a Markov Decision Process and an efficient online policy to dynamically route a truck that can receive newly arrived orders along its route via drones dispatched from a depot. We show that drone resupply increases order fill rates by as much as 20% compared to a conventional truck-only resupply system. Computational times to make each decision are in the hundredths of a second, thus allowing real-time feedback to customers regarding their eligibility for same-day delivery.

Complementing this analytic work, we demonstrate through an animated simulation and an actual proof of concept physical trial how this approach will work in practice. Pragmatic considerations will also be briefly discussed. Along with improved efficiency of operations, drone have considerable environmental benefits in terms of reduced emissions and a reduction in road traffic.

The second part of the talk focuses on the automation of material handling in production facilities using drone assist. Automation has served as a fundamental catalyst in the evolution of logistics chains. However, amid labor shortages and higher land prices in the post-pandemic world, it is necessary to now make the next technological leap. Automated material handling systems are usually sizeable and require processes built around them, but with mass customization as a key component, Industry 5.0 needs a cost-effective, flexible, highly scalable, and low-footprint material handling system to meet future demand. Uncrewed aerial vehicles (UAVs), i.e., drones, can fill the role of a viable alternative to more traditional material handling systems. They are affordable, do not need significant investments in infrastructure, can change routes dynamically, and have been used successfully in swarm configurations.

Our research involves the development and application of mathematical models to schedule and route drones in 3D space to aid in material replenishment tasks. In this approach, we use a version of the capacitated vehicle routing problem (CVRP), with a discretized representation of a

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realistic manufacturing environment. As a proof-of-concept, we outfitted a commercially available drone with pickup-and-carry capabilities using a magnet attach and detach device. Even with a single drone and limited carrying capacity, using drones for material handling improve operational efficiency compared to a traditional ground-based material handling system. In addition, drones enable part storage in previously undesirable space such as vertically elevated. This can reduce the footprint of manufacturing facilities by utilizing the near ceiling area, which would be unsafe and impractical for human material handling. This approach is in its infancy and we have identified potential challenges and safety considerations when developing pickup and carrying mechanisms.

REFERENCES

"The traveling salesman problem with release dates and drone resupply," Juan C. Pina-Pardo, Daniel F. Silva and Alice E. Smith, *Computers & Operations Research*, vol. 129, May 2021. https://doi.org/10.1016/j.cor.2020.105170

"The selective traveling salesman problem with release dates and drone resupply," Juan C. Pina-Pardo, Daniel F. Silva and Alice E. Smith, *Proceedings of the TSL Second Triennial Conference*, May 2020, TSL2020.024.

"Same day delivery vehicle routing problem with drone resupply," Juan Carlos Pina Pardo, Daniel F. Silva Izquierdo, and Alice E. Smith, *Optima 2019 XIII Congreso Chileno de Investigación Operativa*, November 2019. Best Paper of the Conference Award.

"Fleet resupply by drones for last-mile delivery," Juan C. Pina-Pardo, Daniel Silva, Alice E. Smith, and Ricardo A. Gatica, accepted to *European Journal of Operational Research*.

"Sustainable last mile parcel delivery and return service using drones," Nawin Yanpirat, Daniel Silva, and Alice E. Smith, *Engineering Applications of Artificial Intelligence*, special issue on Metaheuristics for Sustainable Supply Chain Management, vol. 124, June 2023, 106631. https://doi.org/10.1016/j.engappai.2023.106631

"Exploring the benefits and challenges of drone-assisted material handling in manufacturing," Julio Jimenez Sarda, Daniel Silva, and Alice E. Smith, *IFORS 2023 Proceedings of the 23rd International Conference of the International Federation of Operational Research Societies*, (Alice E. Smith, Jorge R. Vera, and Bernard Fortz, Editors), 2023, Instituto Chileno de Investigación Operativa (ICHIO), Santiago, Chile, ISBN: 978-956-416-407-6, DOI: https://doi.org/10.1287/ifors.2023

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