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Risk And Reliability Analysis Of A Drone Logistic Network For Healthcare System

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In recent years, use of unmanned aerial vehicles (UAVs) or drones into healthcare systems, has garnered significant attention. One promising application is the use of drones for the logistics and transportation of medical supplies, especially in remote or hard-to-reach areas. NHS Scotland is also exploring this possibility of using drones for medical delivery to meet the expectations of registered patients across Scotland. However, operating this drone logistic network involves several complex factors. To begin with, in the design phase we must be extremely careful about the risk factors involving a UAV as the failure of the drone whilst flying can lead to several harmful impacts. Moreover, we also need to ensure that the drone network serves most of the requests from local clinics and surgeries. This leads to the question of reliability of the drone logistic network. In this contribution, we explore these two aspects of risk and reliability of a drone logistic network and show how we can integrate this model with telemetry data to make an efficient system.

Our analysis begins by identifying and categorizing potential risks associated with the drone logistic network. These risks encompass a broad spectrum, including technological challenges, hazardous environment, and operational issues. Technological challenges may include issues related to navigation systems, payload capacity, and communication reliability. Environmental factors such as weather conditions and natural disasters can impact the drone's performance, while operational issues encompass maintenance, battery life, and overall system failures. In this contribution, we only address the last two aspects. In general, there are other associated risks of a drone failure as an incomplete delivery might lead to mortality factors. However, those may not be quantifiable so, we check the immediate impact of a drone failure. For this, we investigate the ground risk of a drone failure, for this we rely on population data of Scotland to see the chances of mortality from this. However, to compute this value, we need to find the area of impact, velocity of the drone and drone failure probability. Clearly, the velocity of the drone can only be obtained from a differential model which is expensive to compute. So, we used a surrogate assisted model to estimate the velocity of the drone based on the wind velocity at that moment. Moreover, we construct a wind model over Scotland to check the areas with higher wind speed as well as gust which affects the drone failure significantly. This way, we construct an intuitive but explainable model to compute the ground risk of a drone failure for the network design phase. This also accounts for the case, when a drone might experience a mid-air failure due to adverse weather conditions. However, at the development stage, we need to rely on the numbers provided by the manufacturer, that is the probability of mid-air failure. In the later stages, we will plan to incorporate a more sophisticated approach that can take results from trial runs.

For the network reliability aspect, a systematic approach is employed. We treat the drone network as a graph and see how the graph behaves when a node is removed. We associate a probability of node failure for each node and compute a reachability factor based on the time taken by the drone through alternative paths. Clearly, when we remove certain nodes, there will not be an alternative path, in those cases, the reliability will be 0. We use this aspect and combine the two parameters to compute the reliability of the network.

The findings of this analysis are then expected to be integrated with telemetry data from trial runs of the drones to improve our model and update the design of the drone logistics network. By understanding the potential risks and quantifying reliability, drone operators can formulate effective risk mitigation strategies, enhance system robustness, and ensure the smooth operation of the network. Moreover, during the trial runs we will also gather data related to the technical efficiency of the drone which will further enhance our model.

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