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Weather analysis

Introduction

The aim of this technical paper is to assess the feasibility of establishing healthcare drone logistics between the cities Odense and Svendborg in Denmark with regards to weather conditions. Weather data from the year 2016 is analyzed to determine time intervals where drones are unable to fly due to extreme weather conditions. The analysis builds upon results from my master's thesis and the weather theory and analysis methodology are described herein.

Figure 1: *Clear ice protrusions on the propeller of a DJI Phantom 3 Advanced UAV disrupting the airflow and thus reducing the resulting lift. The image was taken after a 10 minutes flight in Odense Municipality, Denmark, March 12 2016 at 08:50 where the surface temperature was 0.8 [°C] and the dewpoint temperature −0.97 [°C], according to the historical data provided by IBM, thus resulting in a temperature-dew point spread of 1.77 [°C] and icing risk.*

Dataset

Source: IBM (The Weather Company)
Period: 2016 (full year)
Locations: Odense and Svendborg, Denmark
Data rate: 1 sample set/hour
Total data sample sets: 8760

Weather limits

UAV Weather parameter	DJI Phantom 4	Sky-Watch Cumulus V1	Expected HealthDrone UAV
Wind speed limit [m/s]	10	12	15
Wind gust limit [m/s]	15.14[1]	17.14[1]	19.17[1]
Operational temperature range [°C]	0 to 40	-20 to 45	-10 to 40
Rain limit [mm/h]	0[2]	< 7.6 (moderate)	< 7.6 (moderate)
Snow limit [mm/h]	0[2]	< 5 (light[3])	< 5 (light)

***Table 1:** Weather limits for 2 commercial off-the-shelf (COTS) Unmanned Aerial Vehicles (UAVs) along with the expected weather limits for a HealthDrone UAV.*

Additionally, the risk of icing is estimated based on the temperature-dew point spread (5°F = 2.7°C)[4] along with a temperature range where icing is likely to occur (0 to -20°C)[5]. It should be noted that the aerodynamic effect can lead to low-temperature zones on propellers, wings etc. of UAVs.

Test

The test is performed by assessing each sample, equivalent to one hour, in the data set according to the above-listed weather limits. If one or more of the limits are violated Unmanned Aerial Vehicle (UAV) flight is not recommended in the given sample; which includes the risk of icing. The result is thus a percentage estimate based on the number of hours in the year where UAV flight is not recommended.

[1] This value is calculated based on the wind speed limit added 5.14 m/s since gusts are first reported in METAR weather reports when the wind gusts exceed the wind limit by 5.14 m/s (10 kts).
[2] DJI Phantom 4 Disclaimer and Safety Guidelines: “DO NOT use the aircraft in severe weather conditions. These include wind speeds exceeding 10 m/s, snow, rain, smog, heavy wind, hail, lightning, tornadoes or hurricanes.”
[3] This value is estimated since it is not provided by Sky-Watch but a demonstration has been given by Sky-Watch in light snow
[4] Air Sports Net, NASA
[5] Atmospheric Structure, Student Guide for Preflight Q-9B-0020, Naval Aviation Schools Command

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Results

UAV / Location	DJI Phantom 4	Sky-Watch Cumulus V1	Expected HealthDrone UAV
Odense, Denmark	37.37%	4.06%	2.15%
Svendborg, Denmark	42.13%	6.91%	3.35%

Table 1: *Weather analysis results for Odense and Svendborg based on the three UAVs presented in table 1. The percentage estimates correspond to the amount of the year 2016 where flying is discouraged.*

Figure 2-4 visualize the weather analysis for the year 2016. The visualization depicts dates on the horizontal axis and the hours of a day on the vertical axis. The colour coding is as follows:

- Light green: all weather parameters are within the limits.
- Red: wind, icing, precipitation, snowfall, and temperature exceeding the limits.
- Orange: wind exceeding the limit
- Brown: icing risk
- Pink: rain exceeding the limit
- Magenta: snowfall exceeding the limit
- Blue: temperature is exceeding the allowed range
- The dashed white lines represent the average spring daytime (08:09-20:09);

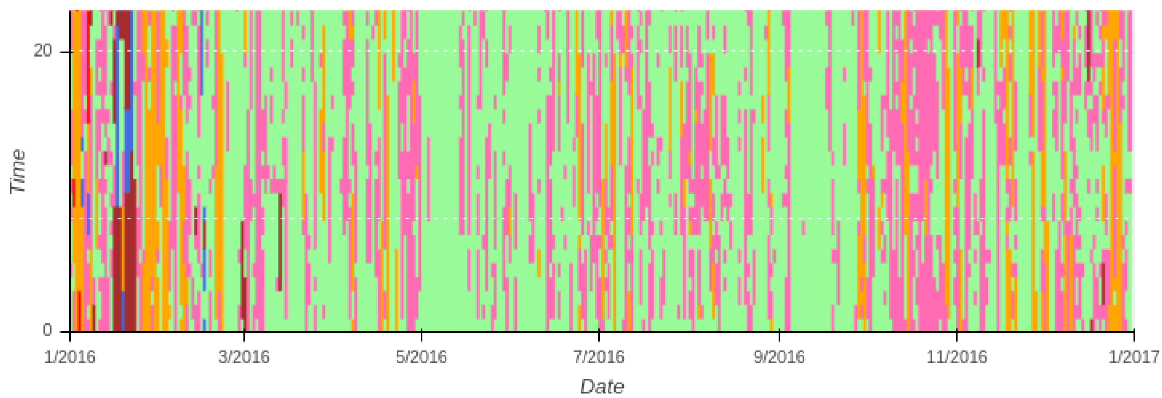

Figure 2: *Visualization of the weather analysis performed on the DJI Phantom 4 for the year 2016 in Svendborg, Denmark.*

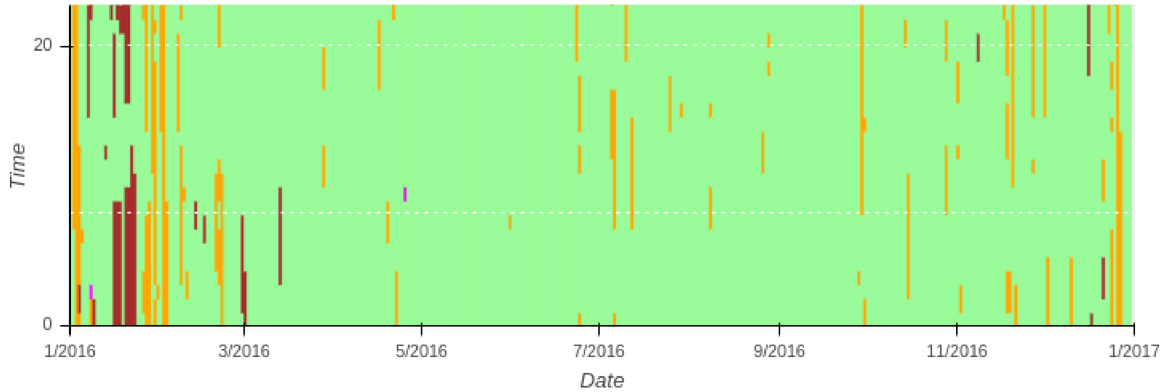

Figure 3: *Visualization of the weather analysis performed on the Sky-Watch Cumulus V1 for the year 2016 in Svendborg, Denmark.*

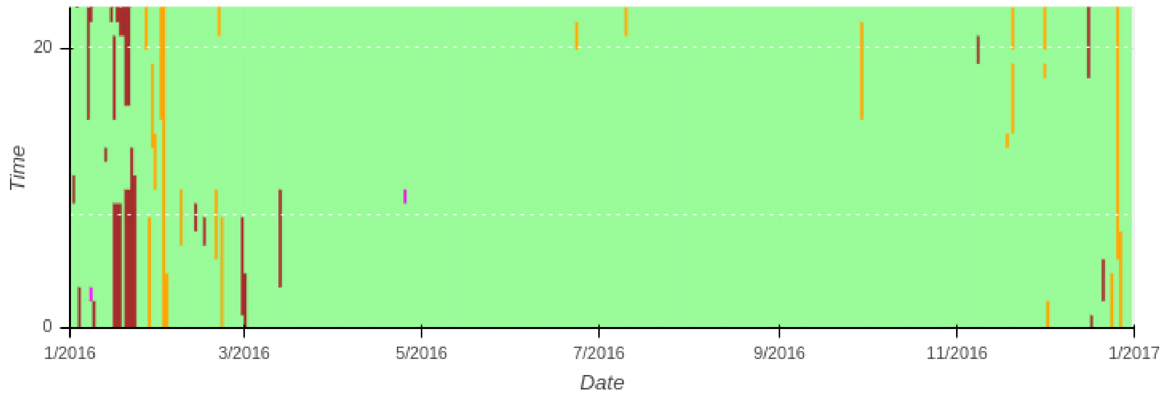

Figure 4: *Visualization of the weather analysis performed on the Expected HealthDrone UAV for the year 2016 in Svendborg, Denmark.*

Conclusion

The results show that the manufacturer specified weather limits have a large impact on the specific UAVs feasibility in regards to healthcare drone logistics. The DJI Phantom platform will only be able to fly in about 58% of the time, mostly due to the requirement of no rain. The Sky-Watch Cumulus will be able to fly in about 93% of the time and the expected HealthDrone specifications will be able to fly in about 97% of the time. The results of this technical paper are intended to provide a basis for a conference publication in 2019 concerning weather impact on UAS ranging from cargo transport using small UAS (sUAS) to human carrying UAS.

Acknowledgement

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References

- Title: Towards a framework for UAS route planning optimized in space and time based on aviation safety and operational efficiency parameters Towards a framework for UAS route planning optimized in space and time based on aviation
- Author: Tobias Lundby
- Year: 2018
- Pages: 73
- City: Odense
- Institution: University of Southern Denmark
- URL: https://goo.gl/dCyxLn
- Abstract: *Aerial flight using an Unmanned Aerial System (UAS) is of special interest to the industry due to the broad range of tasks in which they are applicable. The tasks include cargo transportation and monitoring, where the Unmanned Aerial Vehicle (UAV) has to maneuver over varying landscapes, structures etc. The goal is to carry out these tasks autonomously, and requires a permit for Beyond Visual Line Of Sight (BVLOS) flight. This thesis covers the aviation safety and operational efficiency aspect of such flights.*
  Using external data sources, representing aviation safety and operation efficiency, an optimized route plan can be computed for an Unmanned Aerial Vehicle (UAV). The route planning is divided into a global- and local planner, where the global planner computes an optimized global path, and the local path planner uses the optimized global path as a basis and recomputes segments if unforeseen events occur, in order to reach the goal.
  A framework for UAS route plan optimization has been developed, which is capable of computing an optimized global path, using a global planner. The local planner is capable of recomputing optimal segments if events along the global path occur, to reach the goal without compromising the aviation safety aspect. The framework is controlled using a Graphical User Interface (GUI), which provides the user with options for configuring the path planner along with providing feedback.
  The developed framework combines different data sources to compute an optimized global path using the global planner, and the local planner is capable of manipulating the optimized global path, to replan around dynamic no-fly zones and towards rally points, if it is required to ensure aviation safety.