Impact of Wind on UAV Collision Avoidance

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Outline of Presentation

- Introduction
- Collision Avoidance
- Proposed Framework
- Results and Discussions
- Conclusions

Applications of UAV@ Wireless Connectivity

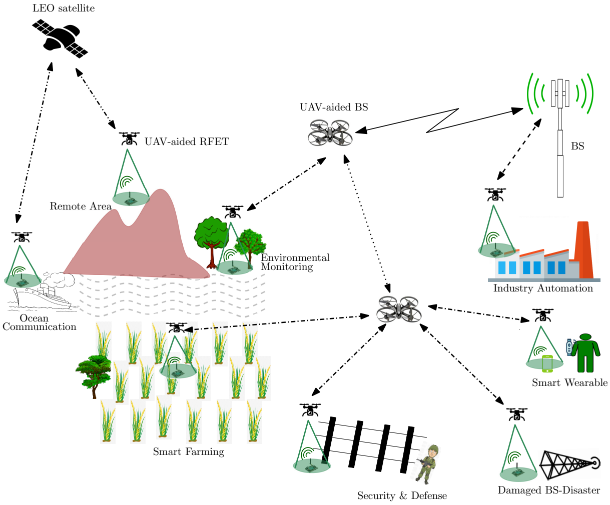


Figure 1: UAV-aided architecture

Collision-free movement

Challenges towards UAV Operation:

- Endurance
- Payload
- Security
- Malfunctioning
- Safety: Collision-free movement

Importance of collision avoidance:

- Safe Operation of UAV
- Avoid crashes
- Risk for people
- Cost of Infrastructure
- Need for Conflict Management solutions
- Navigation in close proximity to obstacles

Collision-Avoidance Mechanism

To avoid collision:

- UAV should make turn from sufficient distance (turning radius)
- UAV should make turn with appropriate angle (semiapex angle)

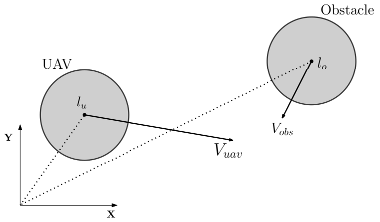


Figure 2: System model for collision-avoidance mechanism

Collision-Avoidance Mechanism (Contd.)

These parameters depend upon the velocity of UAV and Obstacle

Research Gap @ Literature:

- Existing works do not explicitly consider the effect of wind
- Modelling of wind is complex
  - random nature
  - variation with altitude
  - direction as well as magnitude both are important

Consideration of wind profile is important, why?

Wind Profile

Variations over year in:

1. Wind Speed
2. Wind Direction

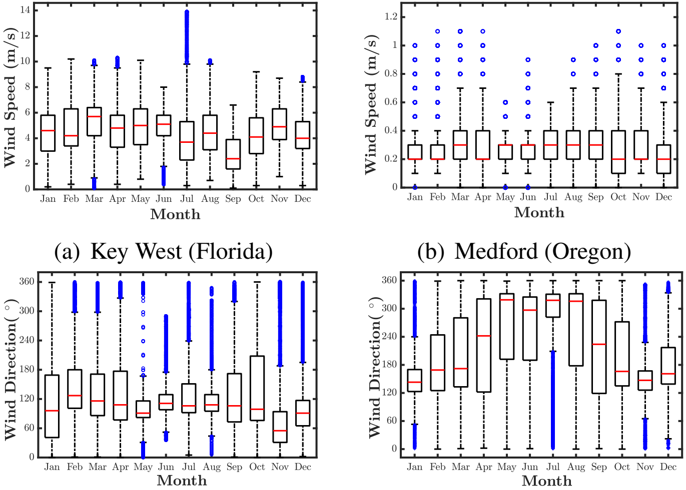


Figure 3: Variation of wind profile in different months for two cities of USA

System Model

Semi-apex Angle

$$\alpha = \cos^{-1}\left[\frac{\left\langle \vec{V}_e, \overrightarrow{l_\mathrm{u} l_o} \right\rangle}{\left|\vec{V}_e\right| \left|\overrightarrow{l_\mathrm{u} l_o}\right|}\right]$$

Turning Radius

$$R = \frac{|V_e|^2}{g \tan \varphi_{\max}}$$

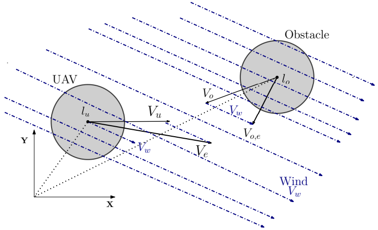


Figure 4: System Model

where,
V_e is effective velocity,
g is gravitational coefficient, and
$\varphi_{\max}$ is maximum roll angle.[a]

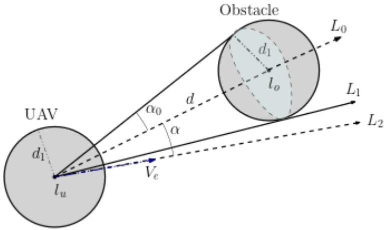
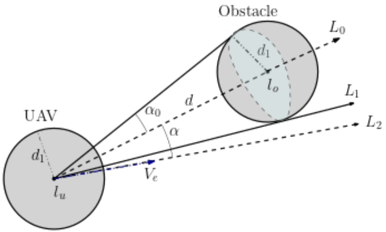


Figure 5: Obstacle Cone

[a] X. Zhou *et al.*, "UAV collision avoidance based on varying cells strategy", *IEEE Aerosp. Electron. Syst.*, vol. 55, no. 4, pp. 1743–1755, Aug., 2019. DOI: 10.1109/TAES.2018.2875556.

Modeling Parameters



To avoid a collision

- *Turning Radius,* $R < d$
- *Semi-apex angle,* $\alpha > \alpha_0$

R and α are random in nature, how to model?

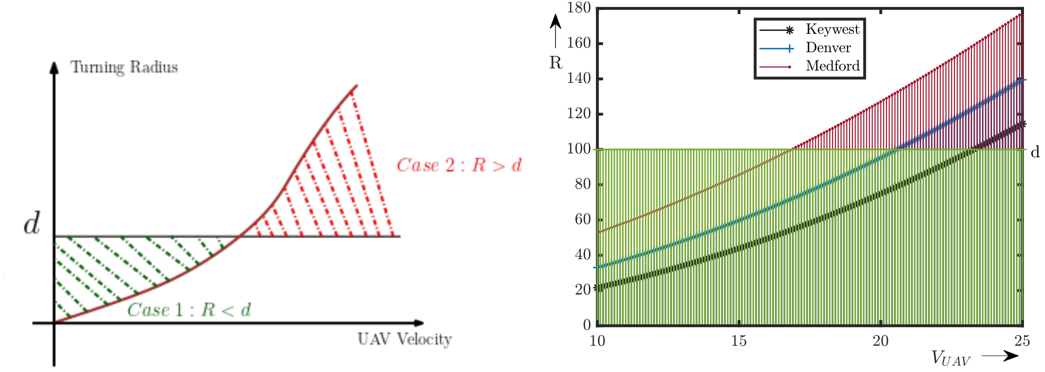
- Wind data of four years (2018-22) have been considered in the analysis
  Source: NREL[1]
- **Discrete-time Markov Chain (DTMC)** is used to model the parameters R and α

[1] "Wind resource data, tools, and maps, national renewable energy laboratory (NREL),USA", (), [Online]. Available: https://www.nrel.gov/gis/wind.html.

Estimation of Probability of Collision Avoidance

We propose that P_{CA} can be estimated as Eq.(1) if $R < d$; otherwise $P_{CA} = 0$

$$P_{CA} = \Pr\{R < d\} \cdot \Pr\{\alpha > \alpha_0\} \tag{1}$$



(a) Depiction of two cases (b) Simulation

Figure 6: Variation of R with different windy cases

Simulation Results

Simulation considers: $g = 9.8$ m/s^2, $\varphi_{\max} = 30^\circ$, and step sizes of 1° for the semiapex angle and 0.5 m for the turning radius.

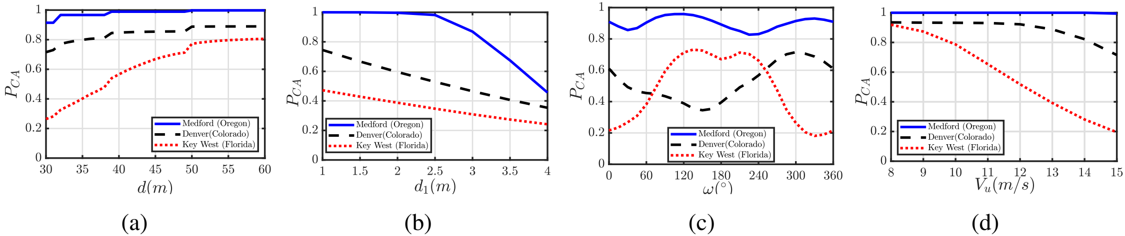


Figure 7: Effect on P_{CA} when there is a change in
(a) Spatial distance (b) Obstacle dimension (c) Direction of UAV movement (d) UAV speed

Concluding Remarks and Future Works

- A framework to incorporate the effect of wind has been proposed
- Statistical modeling of probability of collision avoidance has been presented
- Ignoring the effect of wind will lead to inaccurate system design, which may have severe consequences
- UAV must be aware of its direction and speed of movement as well as wind profile while making the turn to avoid collision
- Optimization of UAV velocity profile according to wind profile to improve collision avoidance probability