A guiding vector field algorithm for path following control of drones

ISARRA 2016, Toulouse, France

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Trajectory tracking problem

Trajectory tracking problem

Drone

Trajectory tracking problem

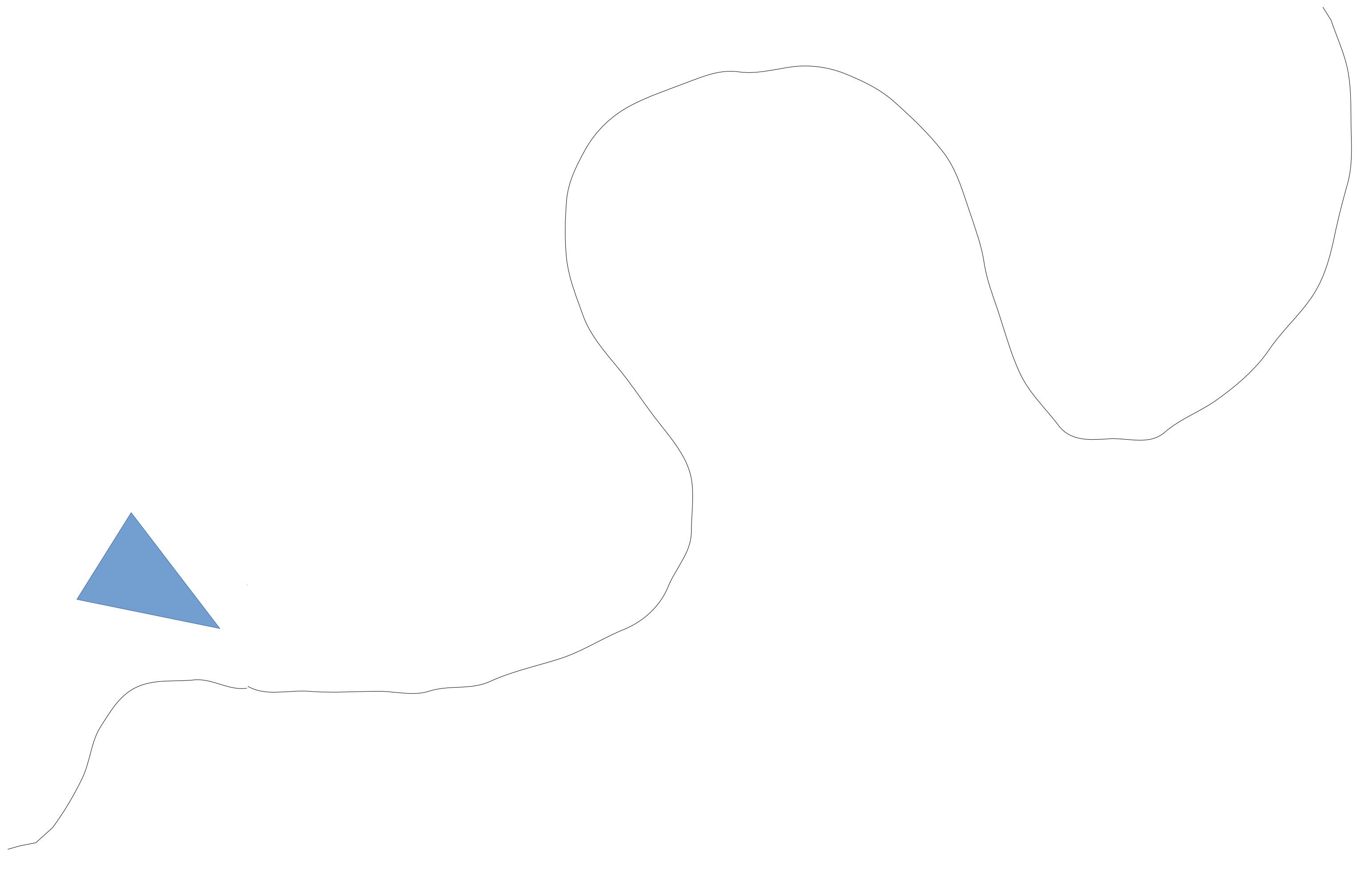
Drone

Traveling in 3D with an almost constant speed.

We can rotate (steer) the velocity vector.

Trajectory tracking problem

$$\varphi(x, y) = 0$$



Trajectory tracking problem

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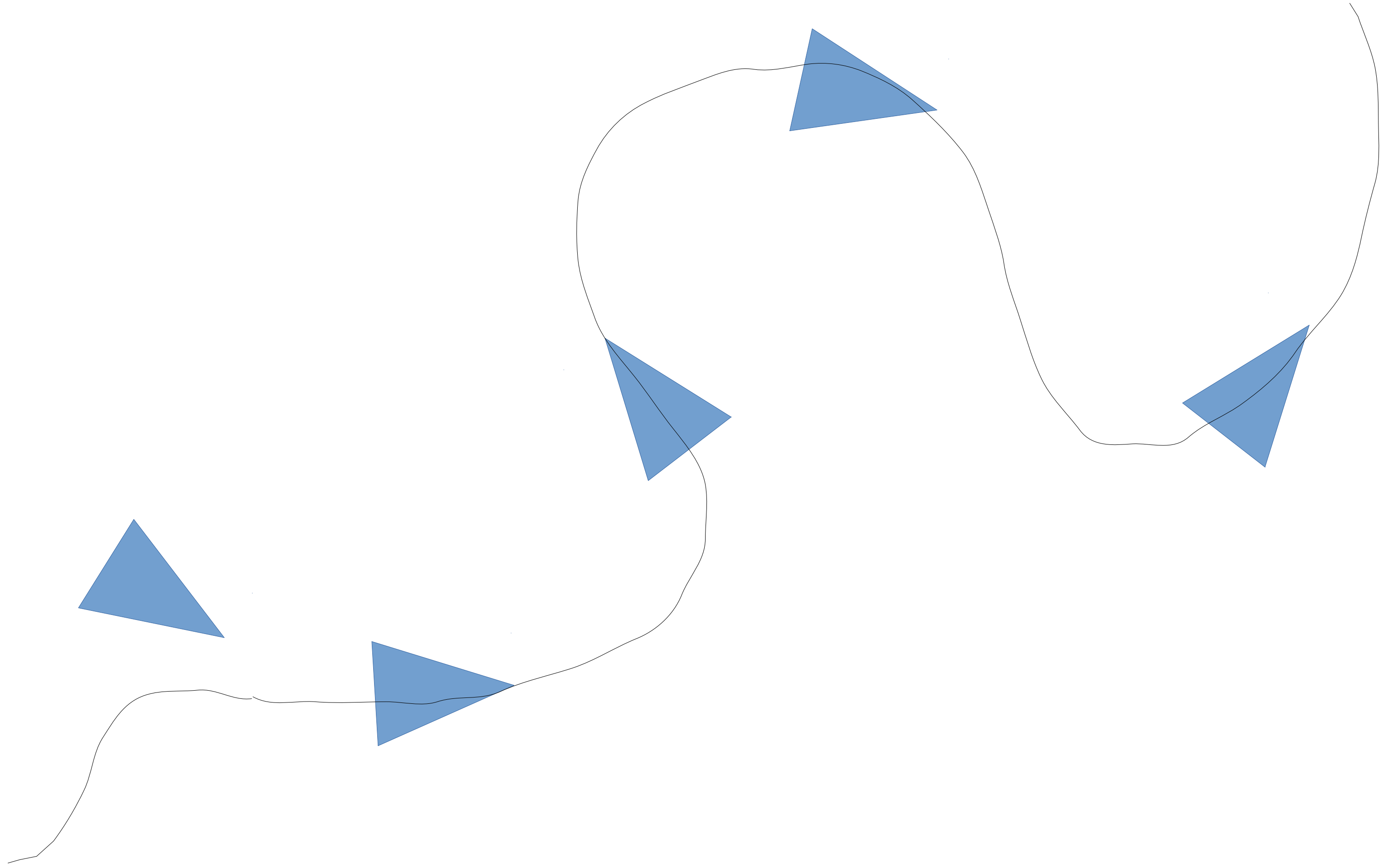
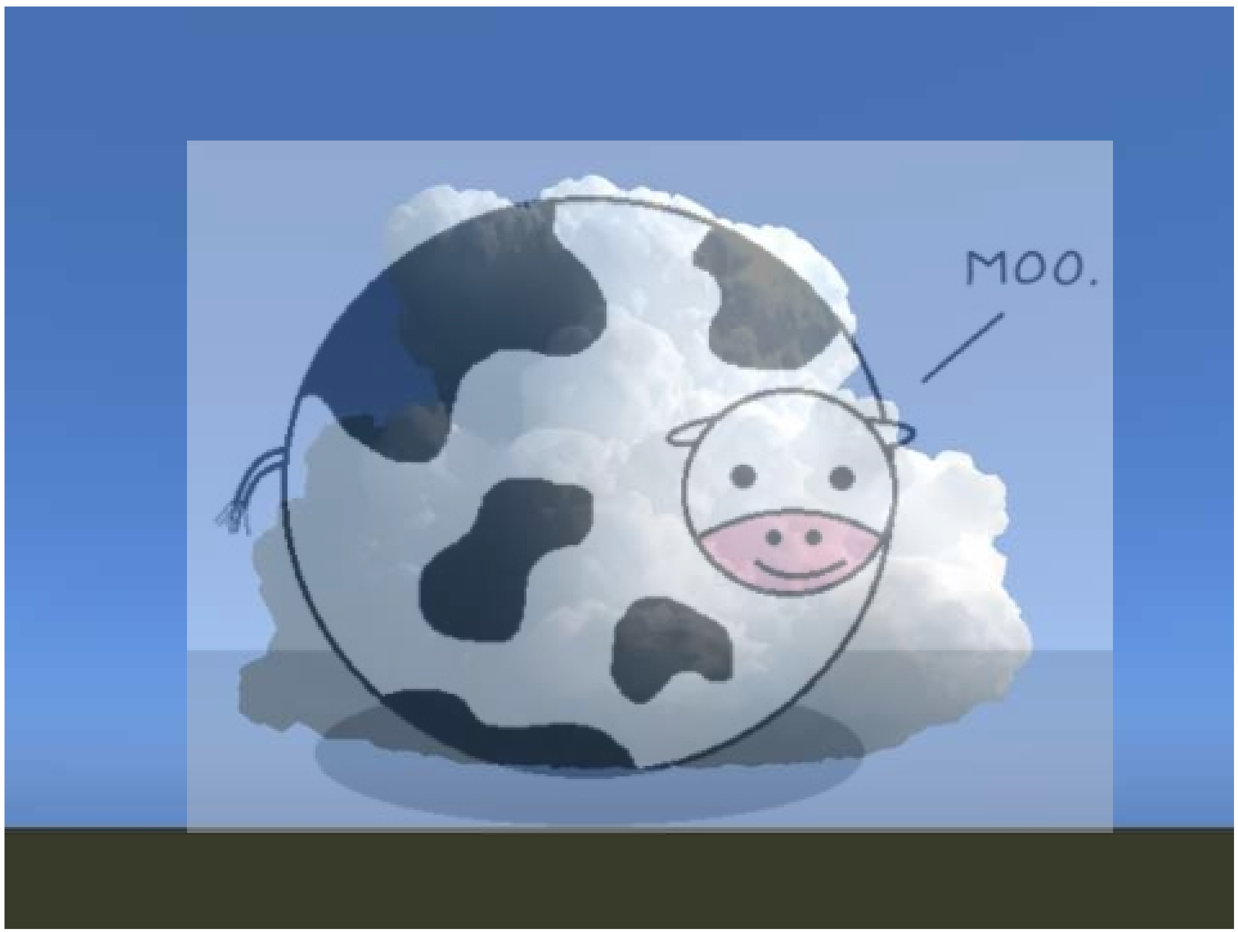


Tracking clouds

Model your cloud as a more simple object,

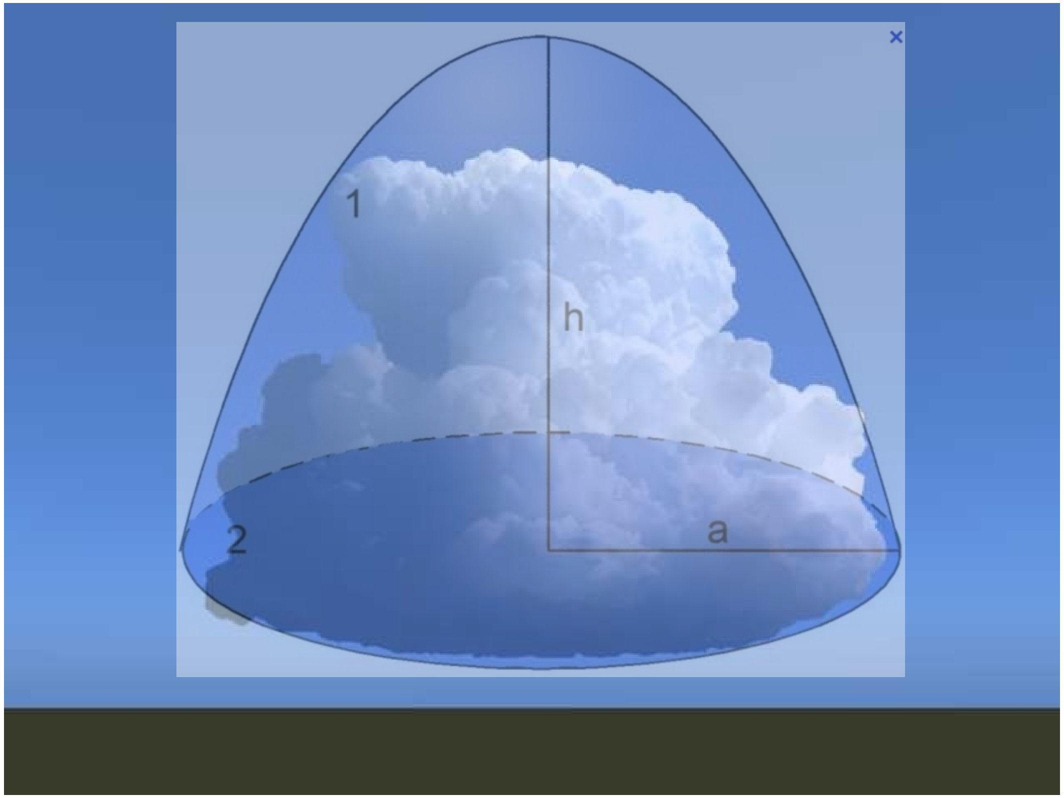
Tracking clouds

Model your cloud as a more simple object, such as a spherical cow



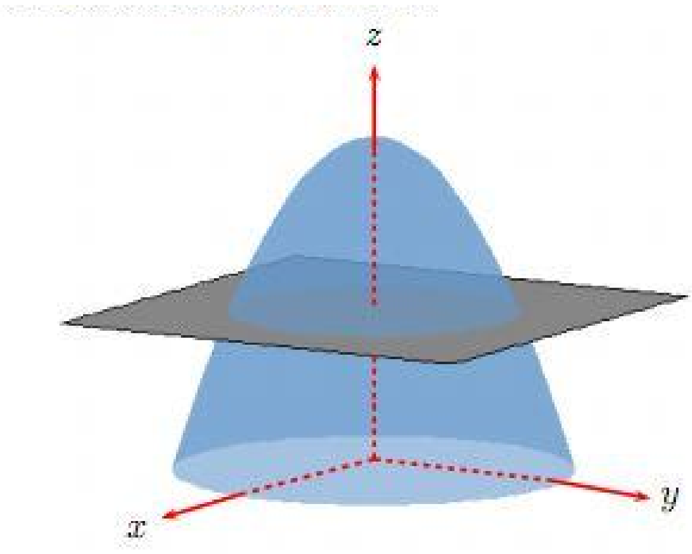
Tracking clouds

Model your cloud as a more simple object, or a paraboloid or any other smooth surface



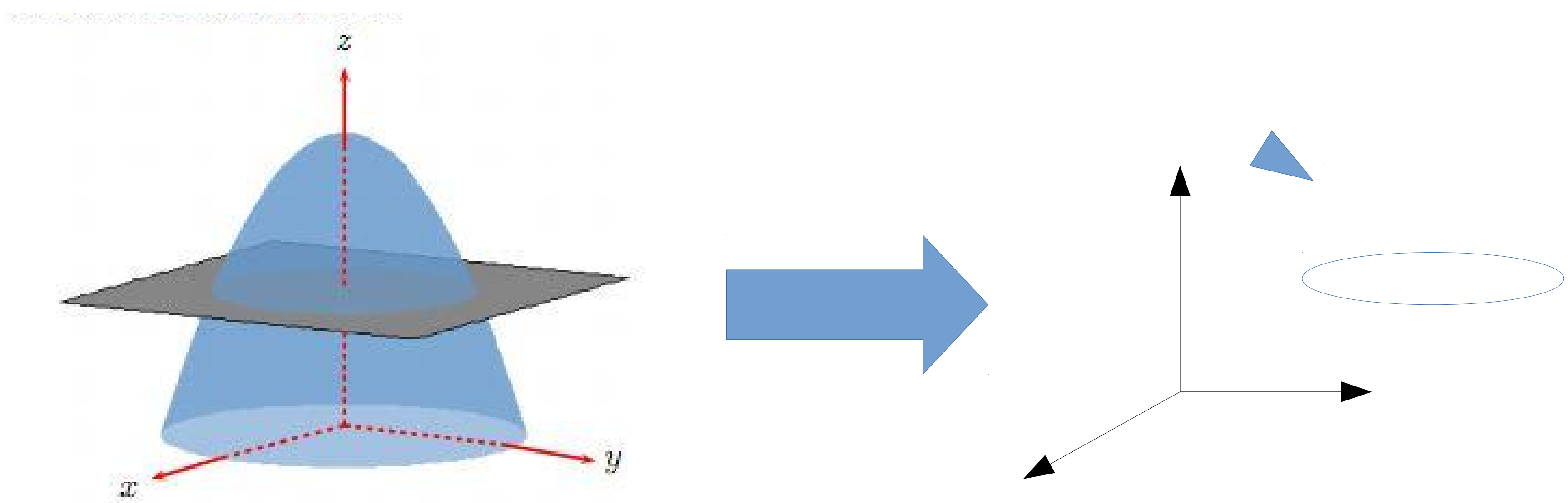
Tracking clouds

Trajectory as the intersection of two 3D surfaces



Tracking clouds

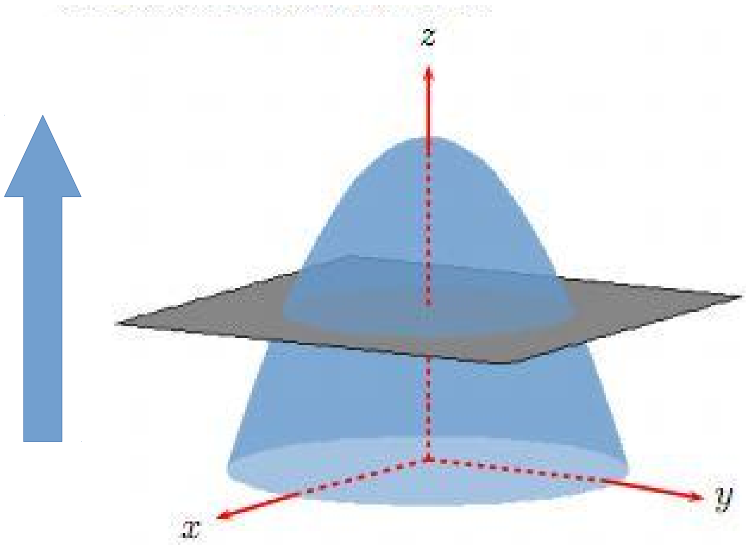
Trajectory as the intersection of two 3D surfaces



$$\varphi(x, y, z) = \text{Paraboloid} - \text{Plane} = 0$$

Tracking clouds

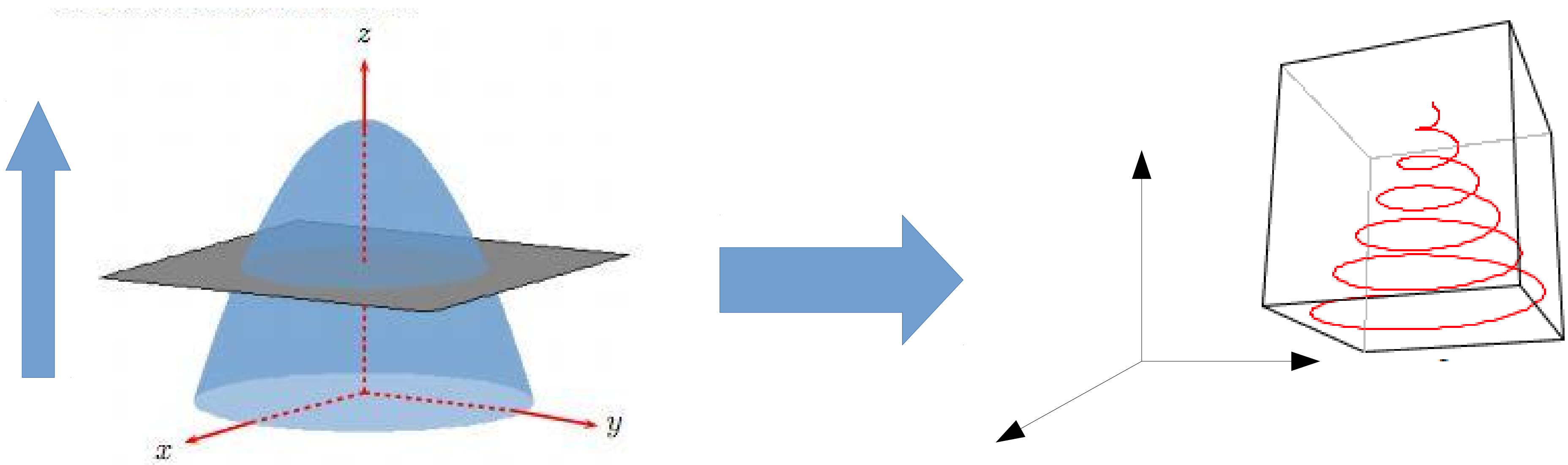
Trajectory as the intersection of two 3D (travelling) surfaces



$$\varphi(x, y, z) = \text{Paraboloid} - \text{Plane}(t) = 0$$

Tracking clouds

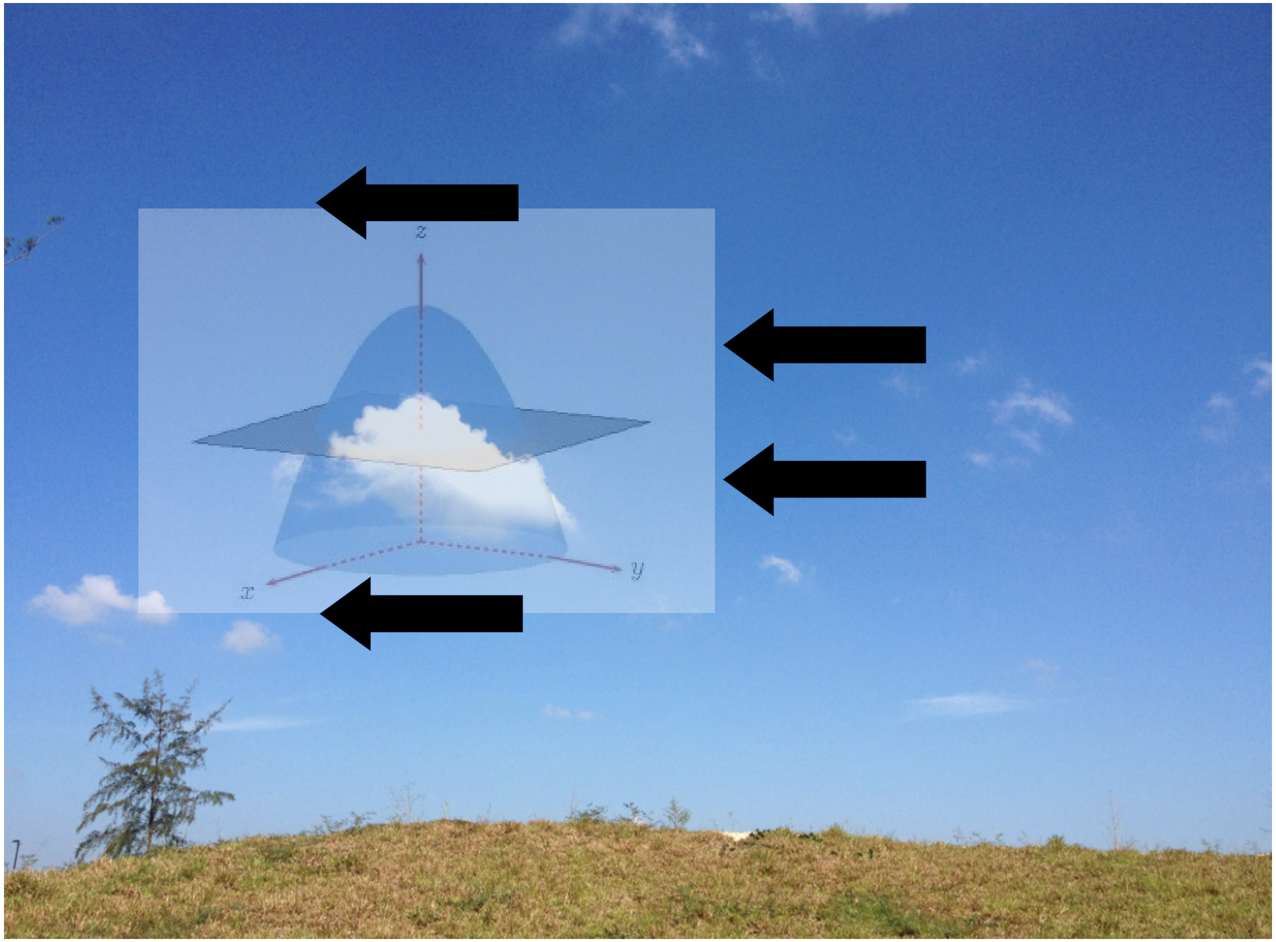
Trajectory as the intersection of two 3D surfaces



φ(x, y, z, t) = Paraboloid – Plane(t) = 0

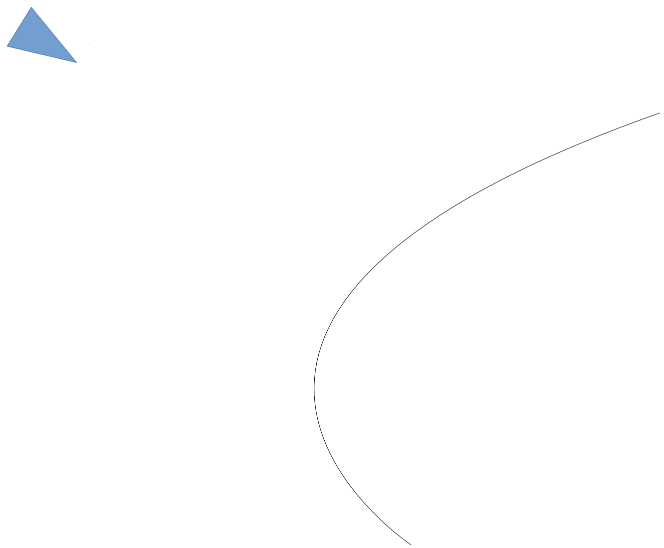
Tracking clouds

Trajectory as the intersection of two 3D surfaces



$$\varphi(x, y, z, t) = \text{Paraboloid}(t) - \text{Plane}(t) = 0$$

How to track the desired trajectory?



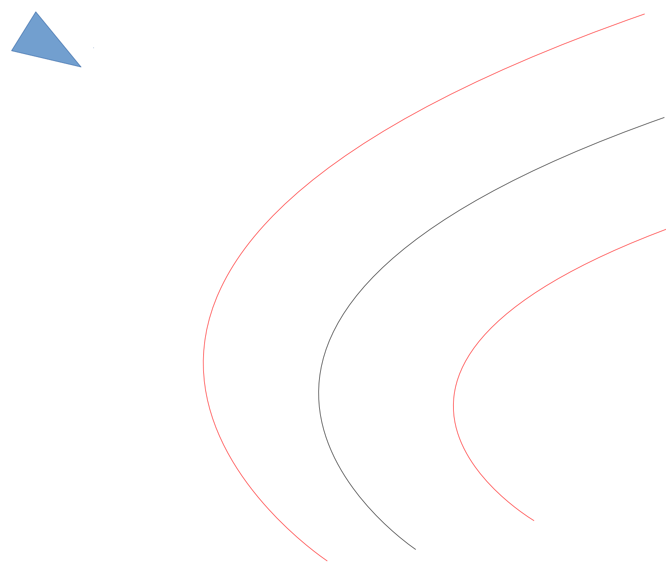
$\varphi(x, y, z, t) = 0$

How to track the desired trajectory?

$\varphi(xd, yd, zd, t) = c$

$\varphi(x, y, z, t) = 0$

How to track the desired trajectory?



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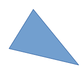

$\varphi(x, y, z, t) = const > 0$

$\varphi(x, y, z, t) = 0$

$\varphi(x, y, z, t) = const < 0$

Information needed:

1. $\varphi(xd, yd, zd, t)$, it measures how far we are from the trajectory

How to track the desired trajectory?

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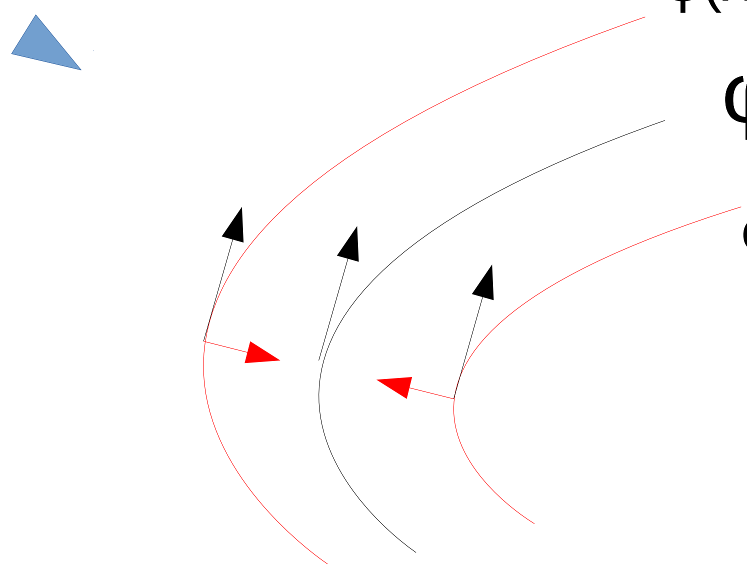

Information needed:

1. φ(xd, yd, zd, t), it measures how far we are from the trajectory

2. grad φ(xd, yd, zd, t), tangent and normal to the trajectory

How to track the desired trajectory?

$\varphi(xd, yd, zd, t) = c$

$\varphi(x, y, z, t) = \text{const} > 0$

$\varphi(x, y, z, t) = 0$

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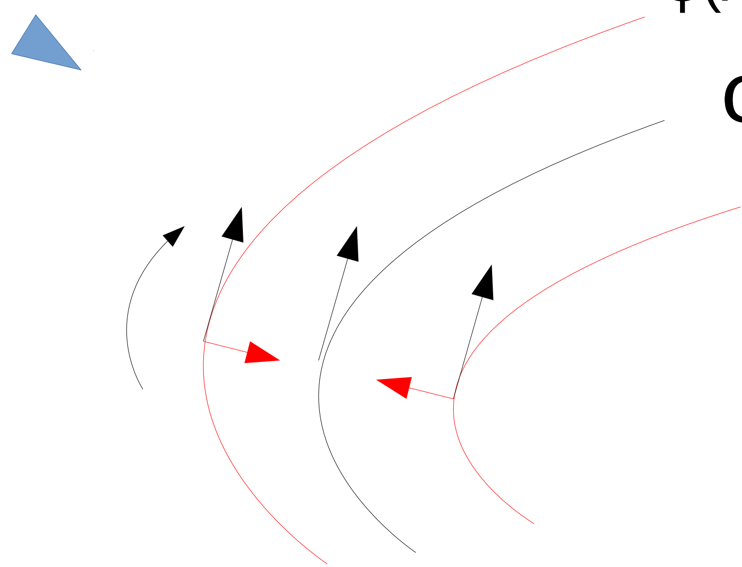


Information needed:

1. $\varphi(xd, yd, zd, t)$, it measures how far we are from the trajectory

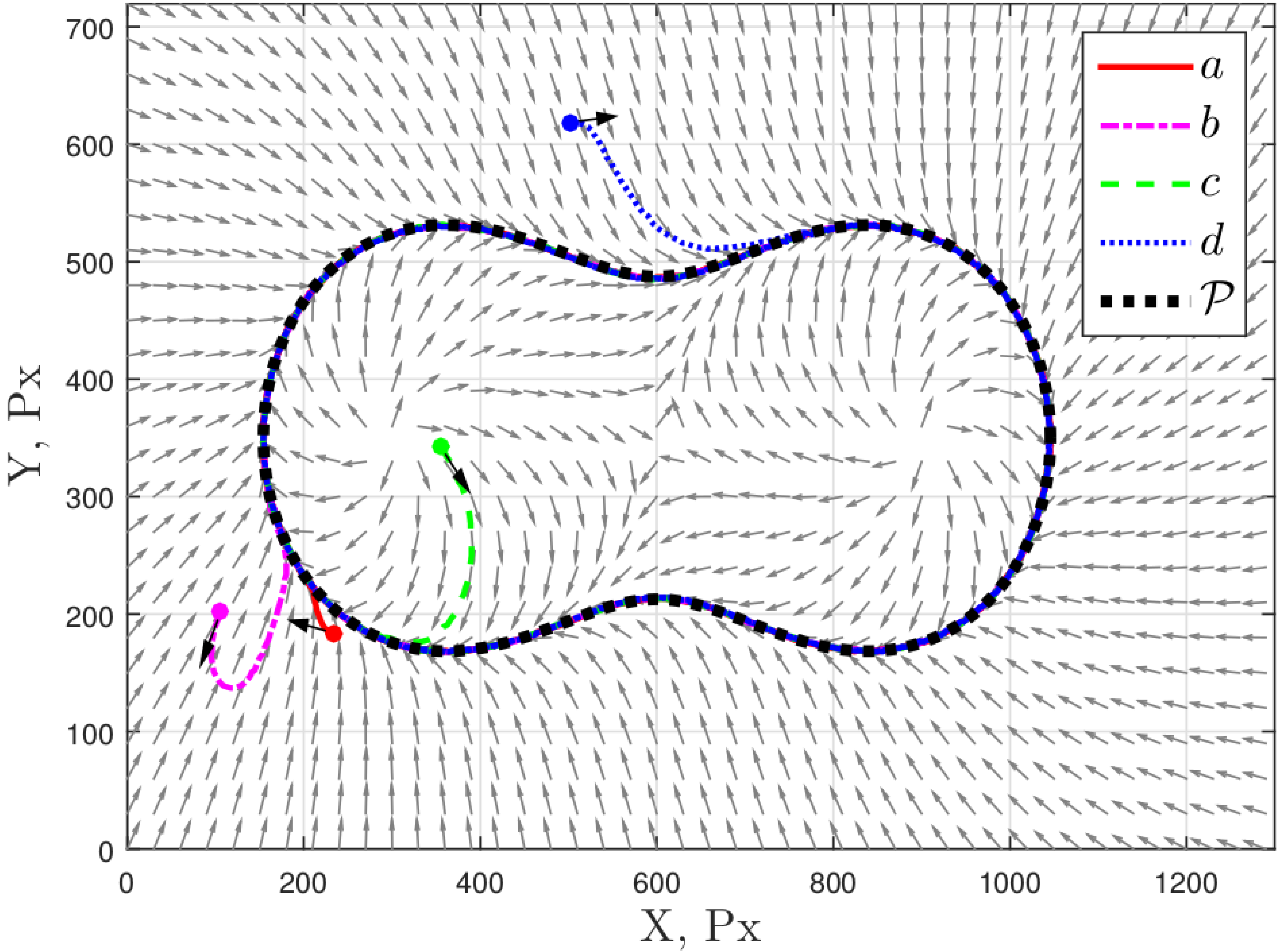
2. grad $\varphi(xd, yd, zd, t)$, tangent and normal to the trajectory

3. grad (grad $\varphi(xd, yd, zd, t)$), how the curvature of the trajectory changes

How to track the desired trajectory?

$$\varphi(x,y) = k_s\left[\left(\Delta x^2 + \Delta y^2\right)^2 - 2c^2\left(\Delta x^2 - \Delta y^2\right) - a^4 + c^4\right] = 0,$$

$$\Delta x = (x - x_0),\ \Delta y = (y - y_0).$$



Conclusions

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Conclusions

- Trajectory tracking for drones in order to study clouds
- The 3D trajectory can be constructed as the intersection of smooth surfaces e.g. one modeling the cloud and another the path of interest
- The surfaces can travel and evolve over time!
  e.g. a shrinking traveling sphere
- The guidance algorithm only needs of the EXPLICIT
  - $\varphi(xd, yd, zd, t)$
  - Grad ($\varphi(xd, yd, zd, t)$)
  - Grad (Grad ($\varphi(xd, yd, zd, t)$))

Ongoing work

- Implementation of the guidance algorithm in the opensource Paparazzi autopilot for actual flights
- Extension of the algorithm considering wind as a disturbance
- Extension to teams of drones

Thanks and questions?

References

- Yuri A. Kapitanyuk, Anton V. Proskurnikov and Ming Cao.
  “A guiding vector field algorithm for path following control of nonholonomic mobile robots.”
  (2016)

- Wang, Jian, Yuri A. Kapitanyuk, et al. "Geometric path following control in a moving frame."
  IFAC-PapersOnLine 48.11 (2015): 150-155.