# Trajectory optimization for motion planning in aerial cinematography

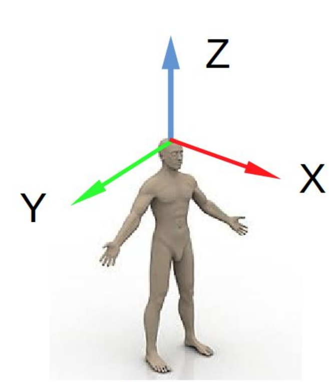
Rogério Bonatti

## Motivation

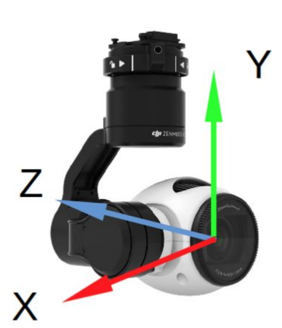
- Despite availability of hand-held cameras today, taking visually attractive videos is inhibited by difficulty of capturing scenes with a multitude of viewpoints
- Today's cameras require humans to pay attention to the act of filming and constantly make decisions
- Drones can be used for automatic camera placement; however trajectories are not trivial

## Objectives

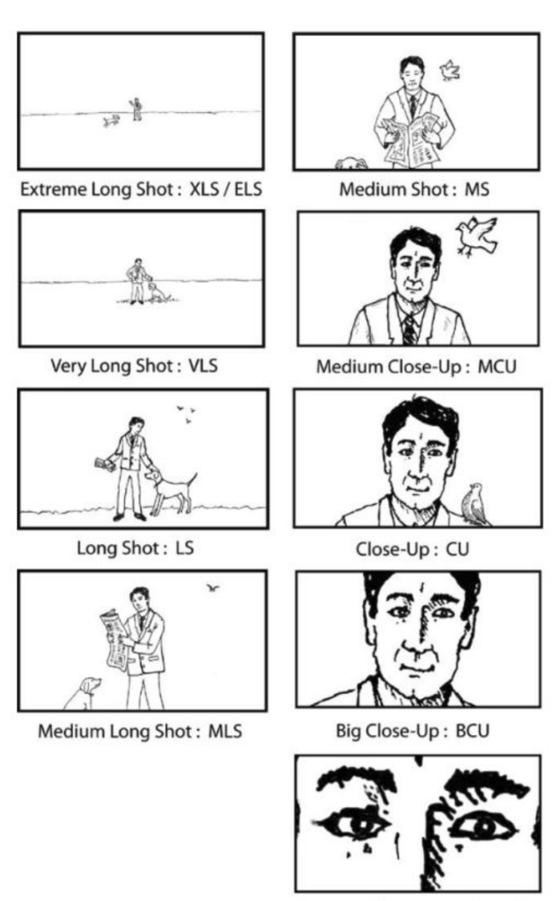
- Develop an intuitive drone control interface for making movies autonomously
- Use cinematographic and artistic principles for viewpoint selection in aerial cinematography
- Develop an optimization algorithm that finds a locally optimal trajectory for the drone to make a film of a moving actor

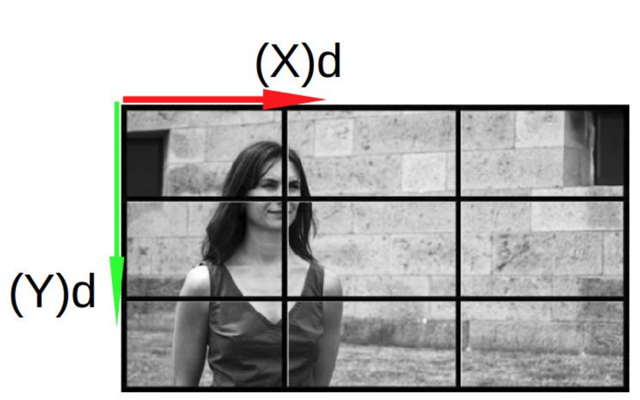


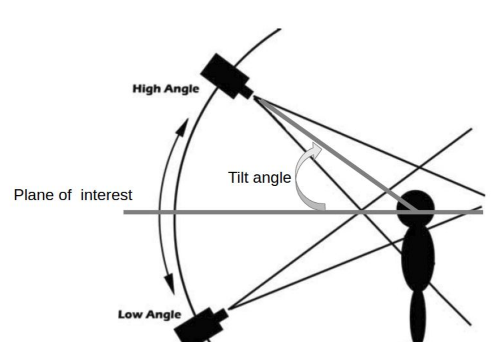

B act




B cam




## Single viewpoint optimization

- We consider the following costs, minimized with the SQP algorithm:
  - Image scale
  - Camera orientation
  - Image positioning

$$x_{opt} = \begin{bmatrix} p_{cam_x} \\ p_{cam_y} \\ p_{cam_z} \\ \psi_{cam} \\ \phi_{cam} \end{bmatrix}$$

$$C_{scale} = \frac{|Z - Z_d|}{Z_d} \qquad Z_d = \frac{f}{S_d}$$

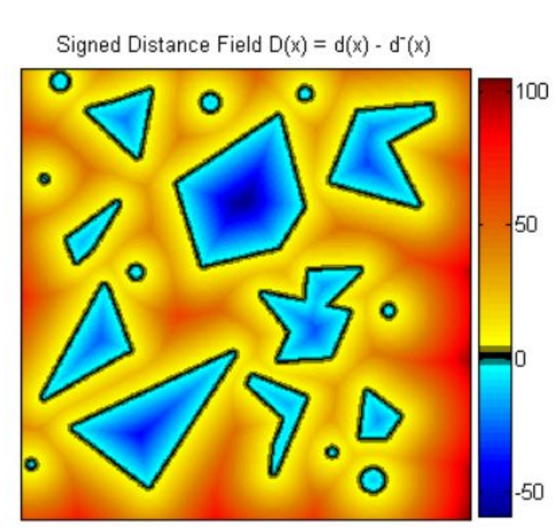
$$C_{orientation} = acos(z_{cam}|_{B_{world\_view}} \cdot (z_{cam})_d|_{B_{world\_view}})$$

$$C_{position} = ||(X_d, Y_d) - (X, Y)||^2$$

## Trajectory optimization

- We optimize in 2 steps:
  - Find each optimal independant waypoint
  - Optimize jointly over trajectory considering smoothness, obstacle cost and occlusion cost, using CHOMP algorithm (quasi-newton)

Signed distance field must be pre-computed:




$$c(x) = \begin{cases} -\mathcal{D}(x) + \frac{1}{2}\varepsilon, & \text{if } \mathcal{D}(x) < 0 \\ \frac{1}{2\varepsilon}(\mathcal{D}(x) - \varepsilon)^2, & \text{if } 0 < \mathcal{D}(x) \leq \varepsilon \\ 0 & \text{otherwise} \end{cases}$$

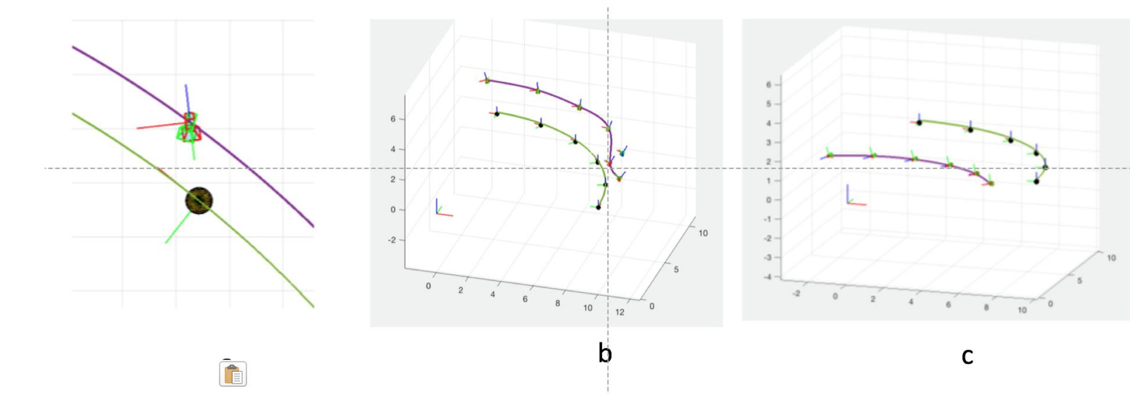
$$\mathcal{F}_{smooth}[\xi] = \frac{1}{2}\int_0^1 \left\| \frac{d}{dt}\xi(t) \right\|^2 dt$$

$$F_{occl} = \int_{t=0}^{1}\int_{\tau=0}^{1} c(p(\tau)) * ||\frac{d}{d\tau}p(\tau)||d\tau dt$$

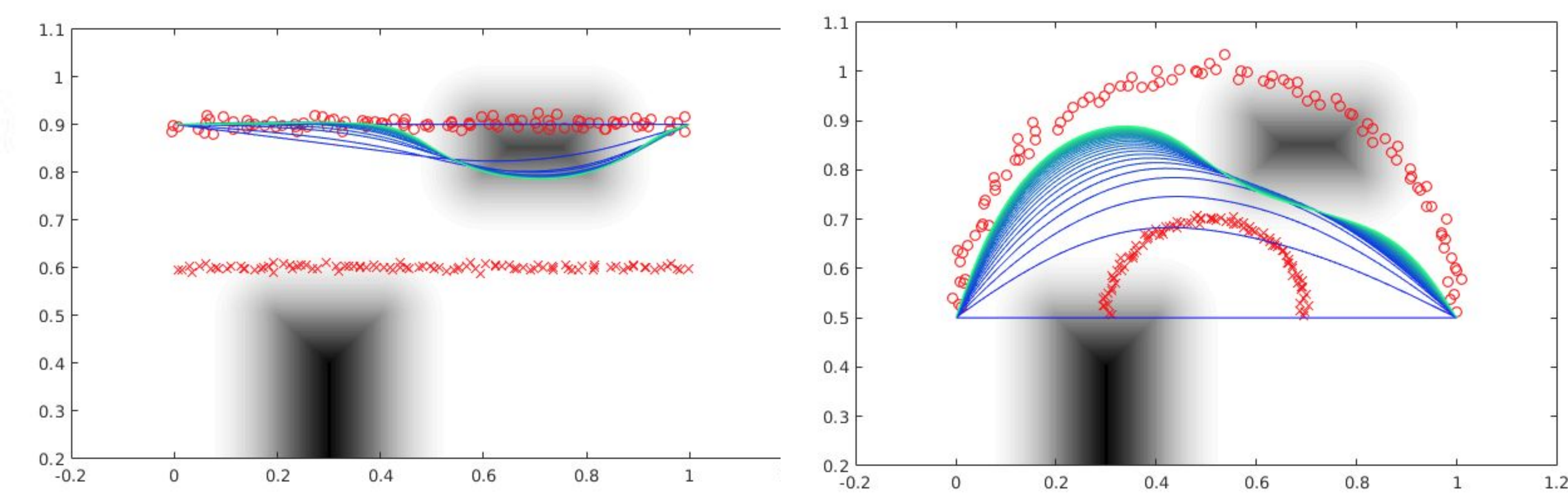
$$\mathcal{F}_{obs}[\xi] = \int_0^1 \max_{u \in \mathcal{B}} c(\ x(\xi(t), u)\ ) \left\| \frac{d}{dt}x(\xi(t), u) \right\| dt$$

## Results and conclusions

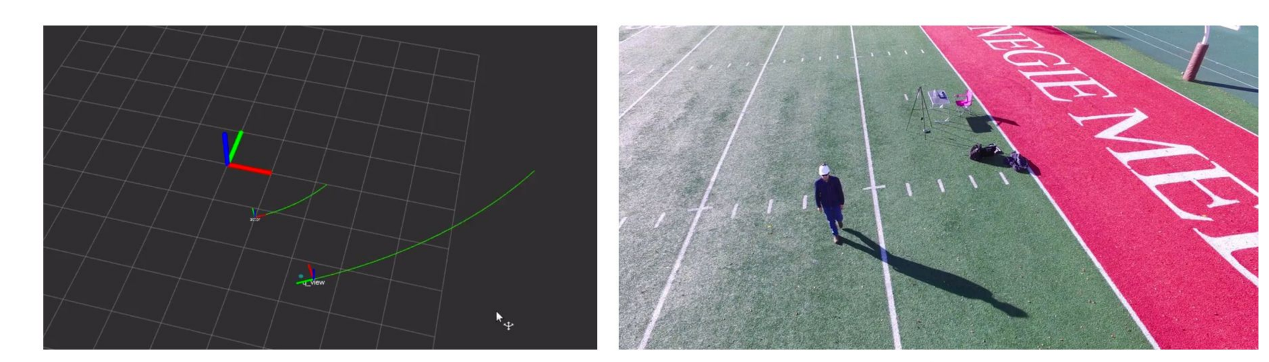
- Simulation results for single viewpoint opt:




- Simulation results for trajectory opt: occlusion cost handles obstacle avoidance



- Field test results:




## Future Work

- Increase dimensionality of full trajectory optimization from 2D to SE(3)
- Adapt trajectory opt code to run onboard
- Include uncertainty of actor position in opt

## References

- [1] Christopher J Bowen and Roy Thompson. Grammar of the Shot. Taylor & Francis, 2013
- [2] Nathan Ratliff, Matt Zucker, J Andrew Bagnell, and Siddhartha Srinivasa. Chomp: Gradient optimization techniques for efficient motion planning. In ICRA'09. IEEE International Conference on, pages 489–494. IEEE, 2009