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Distant Object Localisation from Noisy Image Segmentation Sequences

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Outline

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- Solutions:
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  - Multiview triangulation
  - Particle filtering
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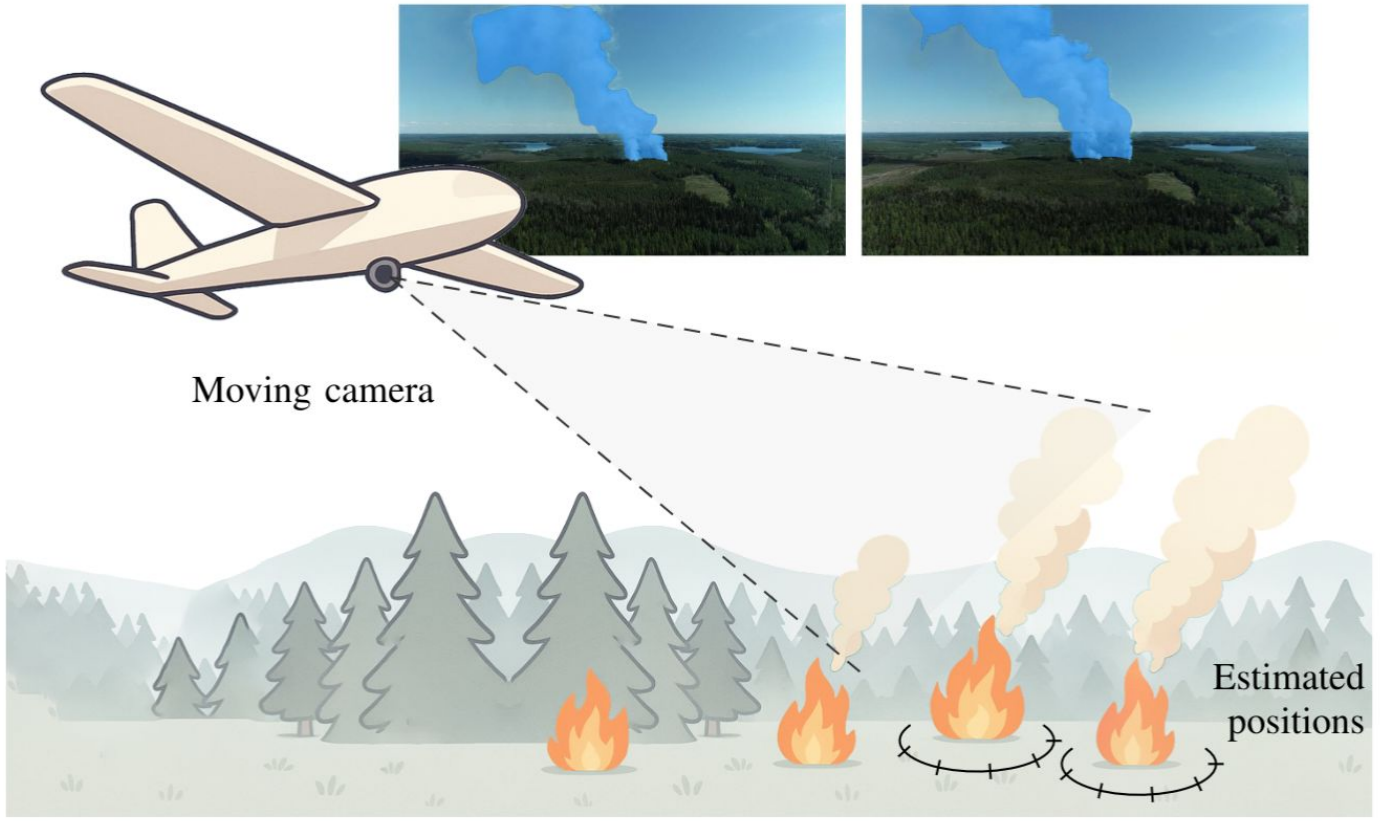
- Conclusions



The problem

- Localising distant objects from a moving camera
- Useful for e.g. automated wildfire detection and localisation
- How can we obtain a robust target position with noisy segments
- We assume that slightly noisy camera positions are known

Camera position

[7.74, 0.07, -1.47]

Target position estimate

[11586.21, 9316.33, 1607.06]

Simulation

- What’s the most simple way to simulate the target scenario
- Target segments from cubes in 3D space
- Simple pinhole camera model matching the parameters of the real test camera
- Noise added into both segments and camera extrinsic parameter estimates

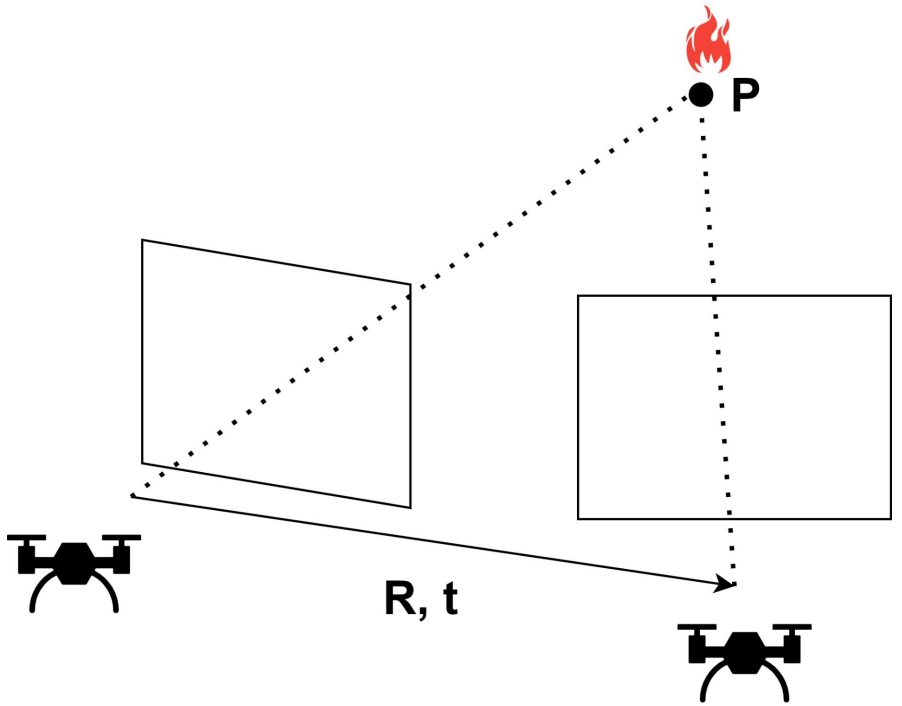
Simulation

Noiseless simulation

Noisy simulation

Multiview triangulation

- Reduce the target object to a point
- Compute the point that is nearest to rays drawn from the camera position to the measured target centre
- Can be made more robust to noise using RANSAC

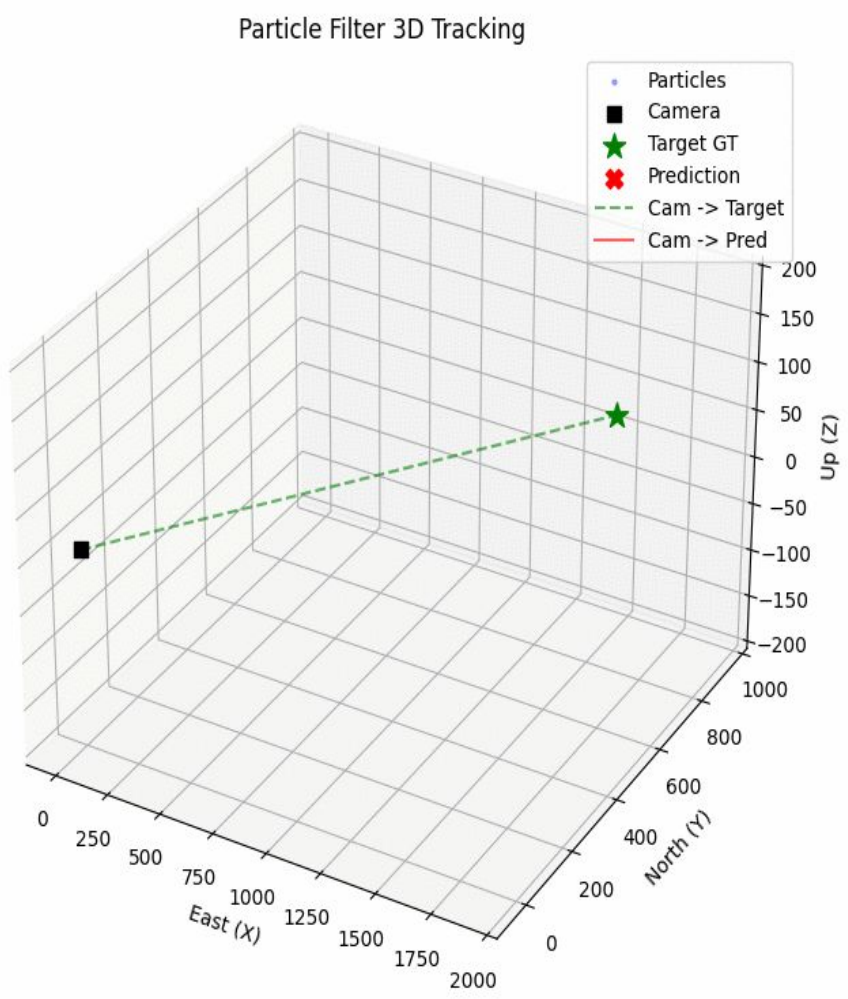


Multiview triangulation downsides

- Loss of all target size and shape information
- Non-feasible to triangulate all detected pixels
  - Computation cost increases drastically
  - Number of positive pixels varies with targets like smoke clouds
  - Requires finding correspondence between detections
- Computation requirements increase by the number of frames
- Lack of uncertainty estimates

Particle filter

- Model the target position as a distribution represented as points in 3D space
- Potential to provide uncertainty + target shape and size estimates
- Computation does not increase by the number of measurements as the model is updated only based on the most recent observation



Particle filter details

1. **Initialisation**: Create a distribution of particles in the direction of the target
2. **Prediction**: Estimate target position based on the particles + project them back to the camera
3. **Update**: Weigh the particles based on the discrepancy between the observation and predictions
4. **Resample**: Draw new samples from the distribution based on the weights + add gaussian noise

Parameters from the simulation:

Number of particles: 100 000

Step size: 10 m

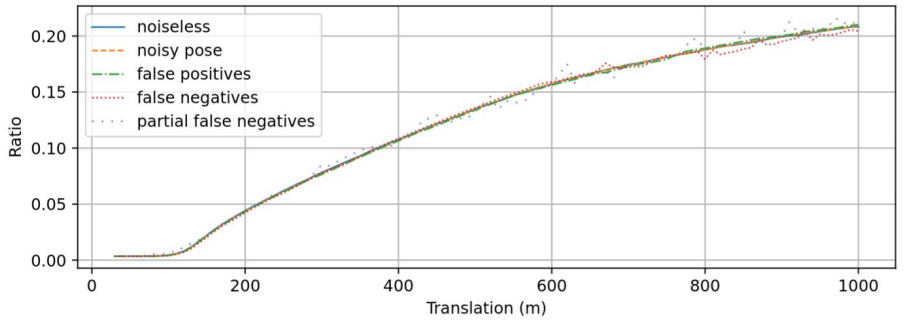
Single particle variance: 5 m

Bootstrap filter = resampling at every step

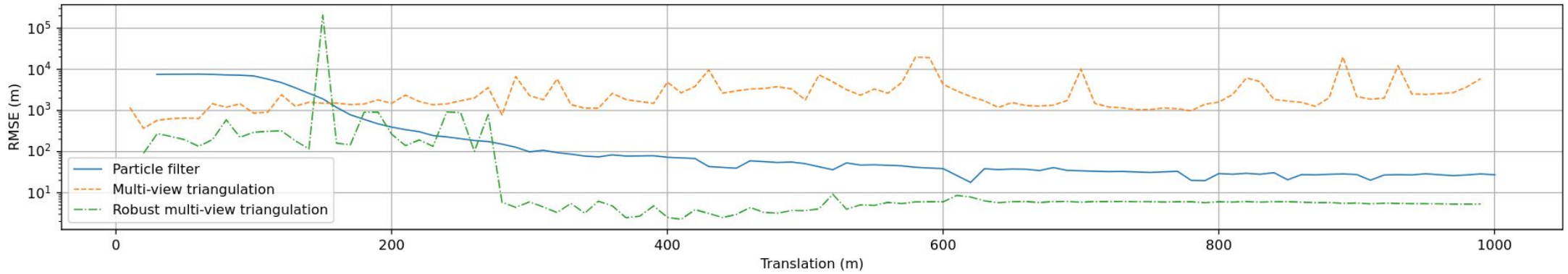
Simulation results

TABLE I
SIMULATED FILTER POSITION ESTIMATION RESULTS WITH DIFFERENT NOISE AND TARGET CONFIGURATIONS.

Method	Noise	RMSE min (m)	RMSE 200-1k (m)	Ratio 200-1k
Multiview triangulation	None	1.06	3.95	-
Multiview triangulation	Full	1.54	257.67	-
RANSAC multiview triangulation	None	1.06	3.92	-
RANSAC multiview triangulation	Full	1.20	3.94	-
Particle filter	None	9.44	44.83	0.15
Particle filter	Full	17.87	63.97	0.15



Particle filter ratio over time

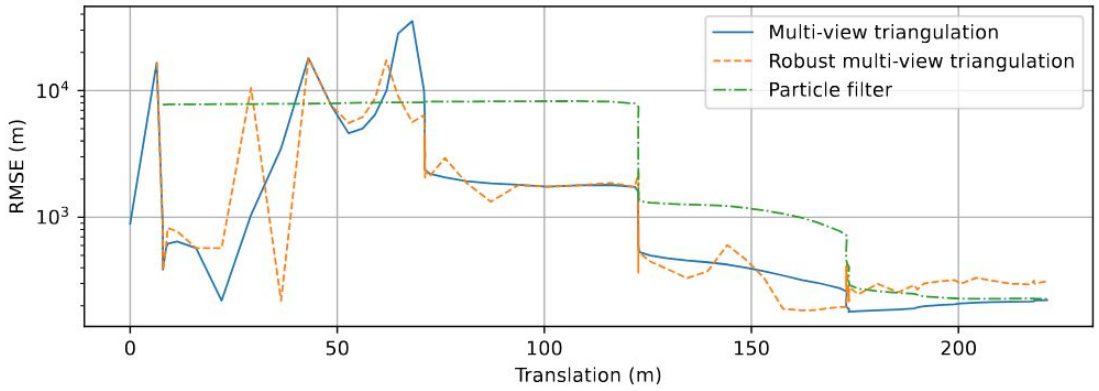


Noisy simulation RMSE over time with different models

Real world results - experiment 1: Mast

- All models struggled:
  - Not enough inlier frames for RANSAC MVT
  - PF most consistent but converged to ~300 m error position

Real world results - experiment 2: Smoke



- All models converged to a similar solution with 200 - 360 m RMSE
- Errors computed from the chimney

Conclusions

- Both tested methods work for the task with particle filters providing some extra benefits
- The simulation works for development
- Limitations:
  - Undefined which parts of the particle distribution correspond to uncertainty and which to the target properties
  - Particle filter has to be adjusted for the desired task
  - Limited test scenarios
- Future directions:
  - More extensive testing in both the real world and with more complex simulations
  - Multitarget scenarios
  - Edge cases (e.g. targets moving out of frame vs. disappearing)

Thank you!

My homepage

Project page