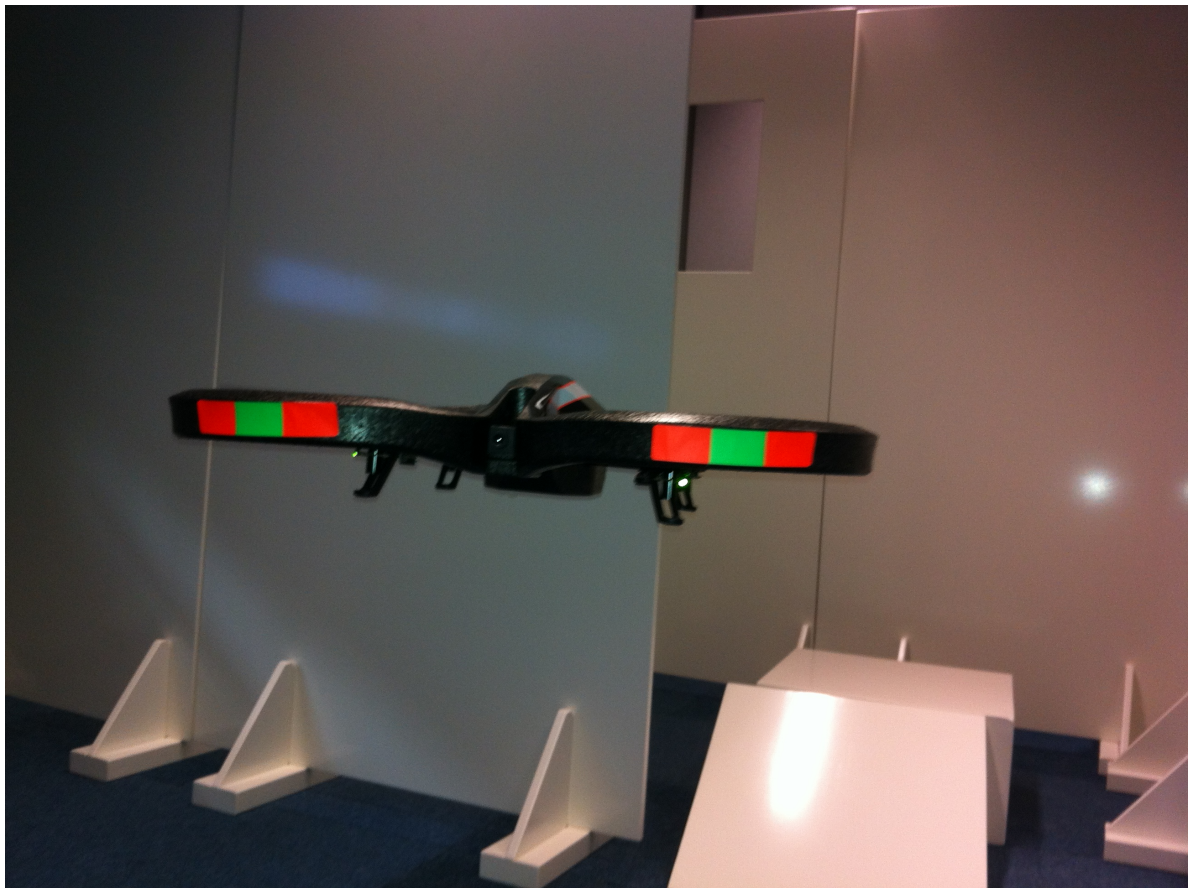
Sensor Fusion on a mini Unmanned Vehicle

Integrating vision-based algorithms on an Parrot AR.Drone to autonomously follow linear shaped structures in a landscape.



A BACHELOR THESIS BY CAMIEL R. VERSCHOOR

Sensor Fusion on a mini Unmanned Vehicle

Integrating vision-based algorithms on an Parrot AR.Drone to autonomously follow linear shaped structures in a landscape.

C. R. Verschoor

Faculty of Science (FNWI)
University of Amsterdam

July 26, 2012

Supervisors

Dr. Arnoud Visser
Assistant Professor
University of Amsterdam

Drs. Gerald Poppinga
R&D Manager for mini UAS
National Aerospace Lab (NLR)

National Aerospace Lab NLR

NLR is the main knowledge enterprise in the Netherlands in the field of aviation and aerospace.

Outline

Outline

Motivation

- Autonomous Robots require navigation.
- GPS is unreliable in indoor and urban environments.
- **Possible alternative:** vision-based line-following.

Motivation

- Various approaches of vision-based line-following.
- Edge and motion detection suitable candidates [Bills et al., 2011, Gerke et al., 2011], but have weaknesses.
- **Solution:** combine them to strengthen each others weaknesses.

Research Question

- To examine how edge and motion detection can be combined to strengthen each other in a line-following task.
  - What is the optimal camera configuration?
  - What are the experimental settings that demonstrate the strength and weaknesses of these algorithms?
  - What is the performance and robustness of these vision-based methods to navigation?

Platform and Framework

Platform Parrot AR.Drone.

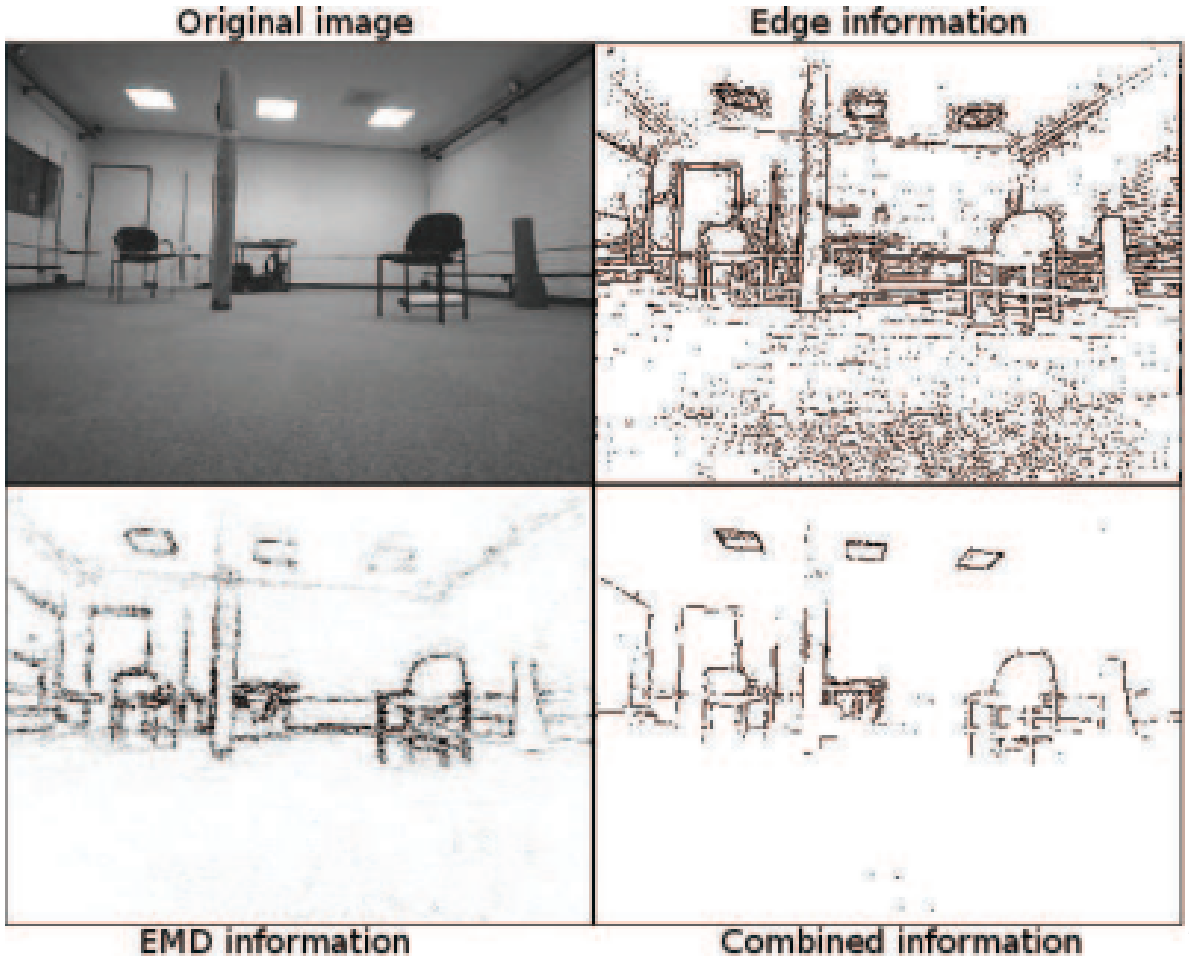
- Top and bottom camera.

Framework AR.Drone SLAM[1] a development framework.

[1] [Dijkshoorn, 2012]

Related Work

- Corridor and Stair Following [Bills et al., 2011].
- Power Line Detection [Golightly and Jones, 2005, Li et al., 2008, Katrasnik et al., 2010].
- Obstacle Avoidance [Jurriaans, 2011].
- Elementary Motion Detectors [Gerke et al., 2011].



[2]

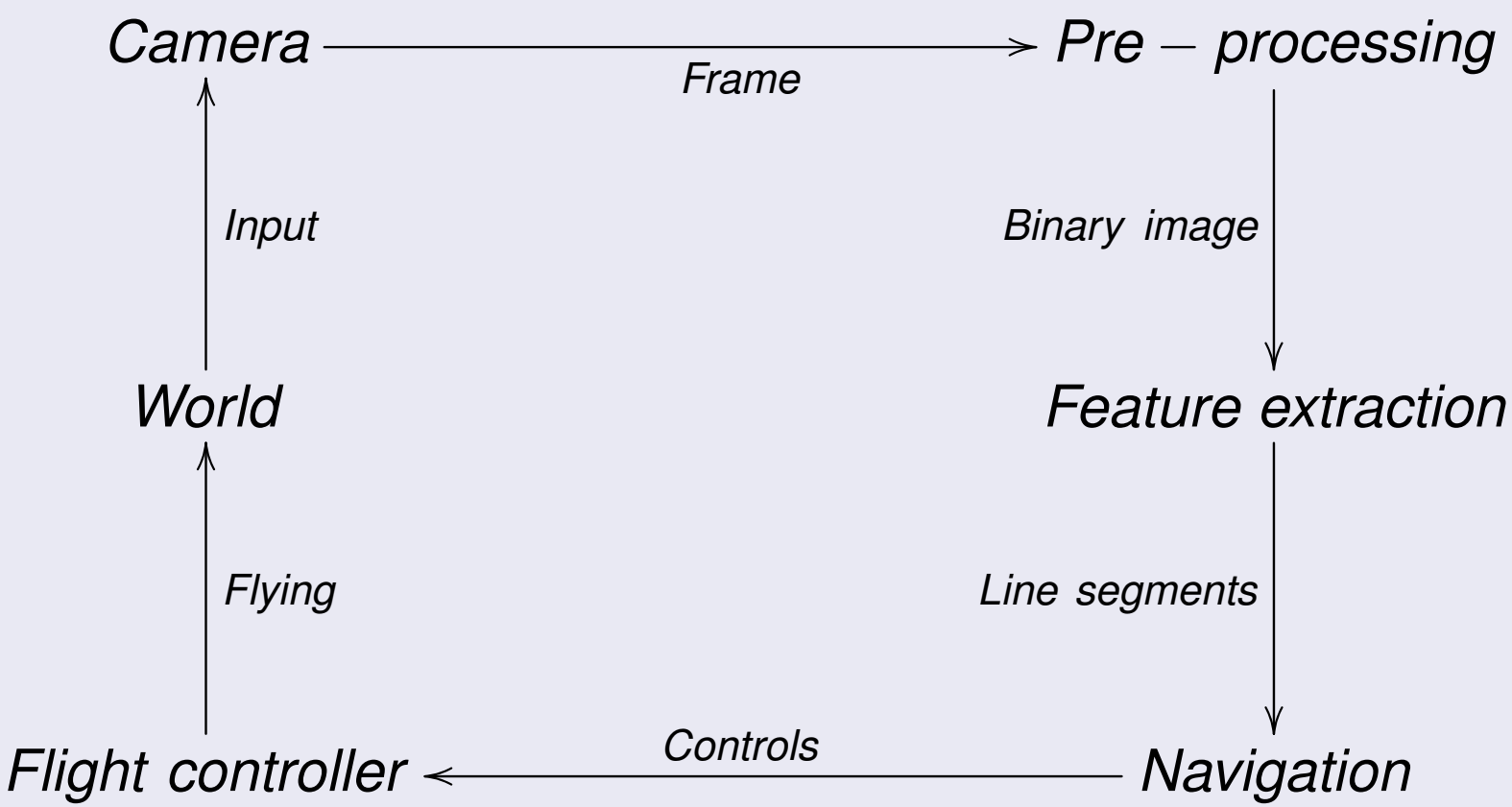
[2][Gerke et al., 2011]

Related Work

- Nearly all proposed methods use Hough Transform for feature extraction.
- Edge and Motion detection have been suitable techniques for navigation .
- Combination of Edge and Motion detection gave promising results.

Outline

Main Approach



Main Approach

- Pre-processing.
  - Canny edge detector (Brightness changes).
  - Monocular stereo vision (Apparent motion).
- Feature extraction.
  - Probabilistic Hough Transform.
- Navigation.

Pre-processing

- Canny edge detector (Brightness changes).
- Monocular stereo vision (Apparent motion).

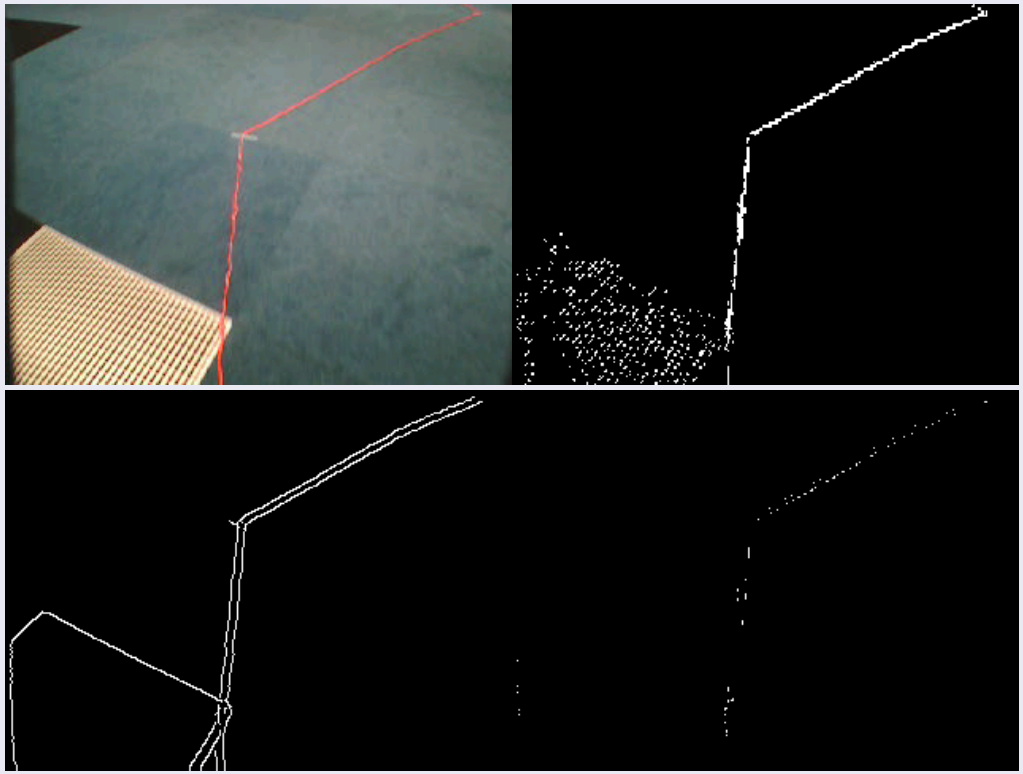
Edge detection

- Colour filter.
- Gaussian Smoothing (Removes noise).
- Canny edge detector (Brightness changes).

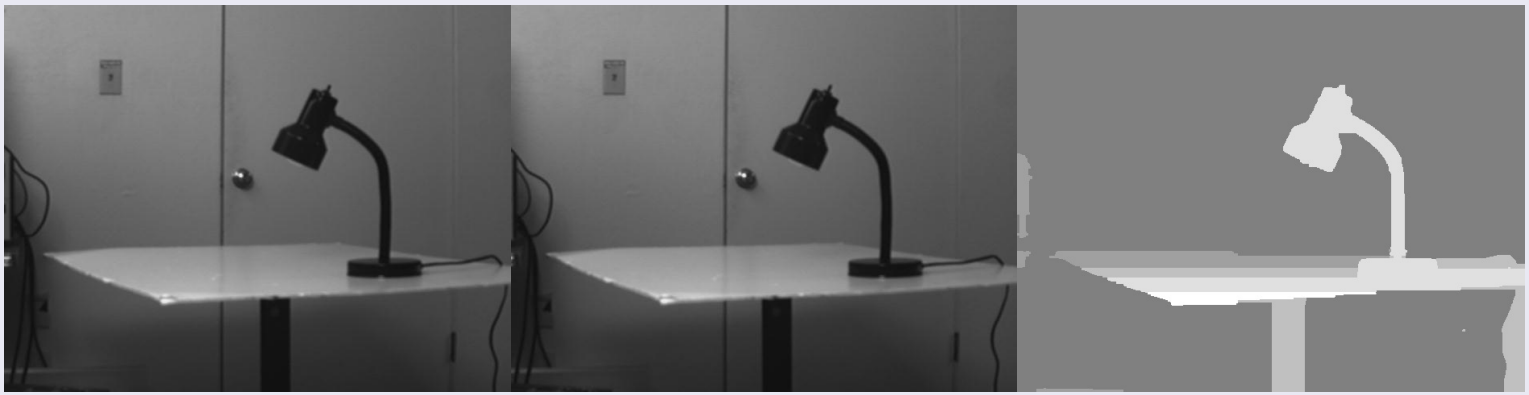
Result

Binary image.

Edge detection



Monocular Stereo Vision



Monocular Stereo Vision

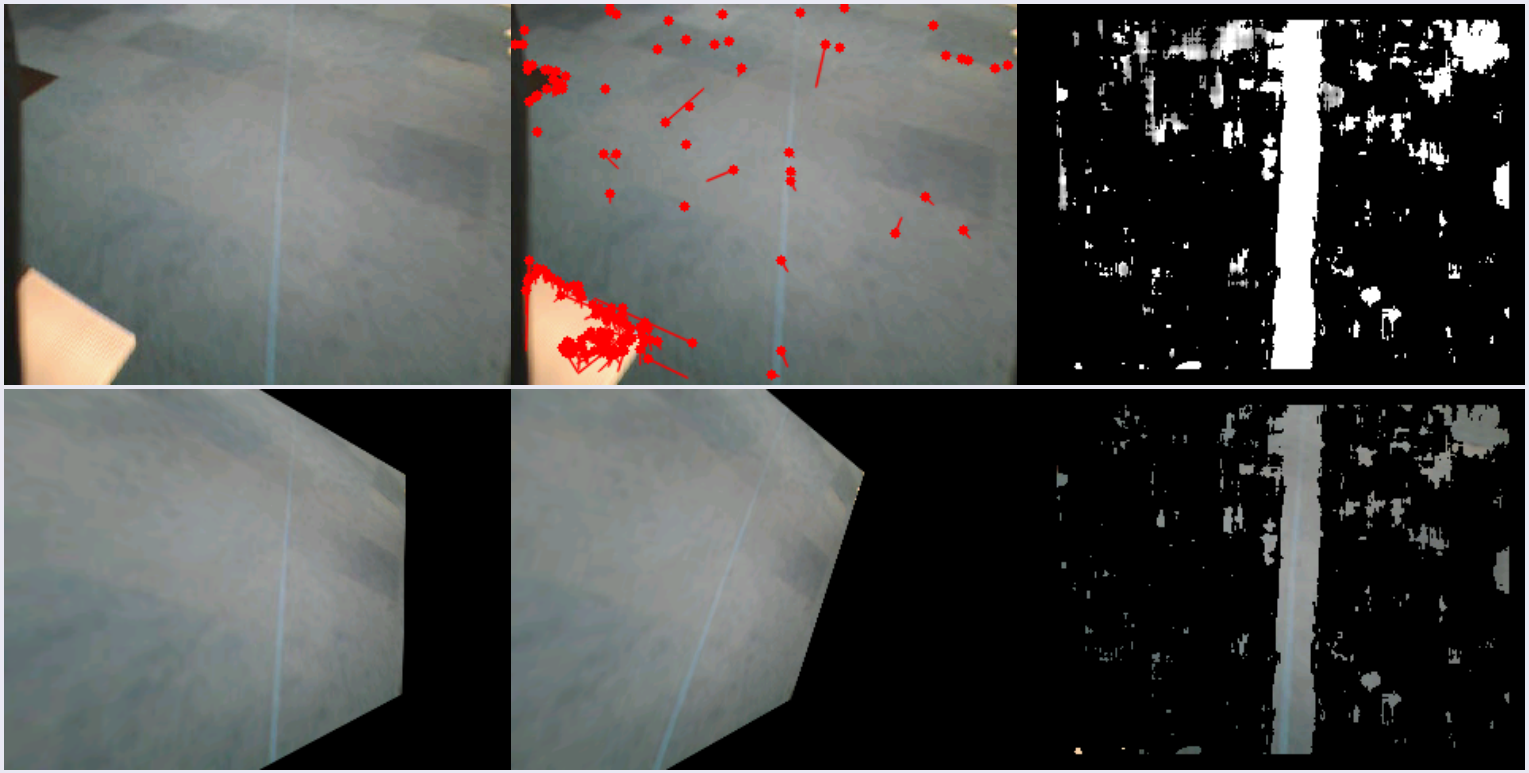
- Find features [Shi and Tomasi, 1994].
- Optical Flow.
- Determining fundamental matrix (mapping between frames).
- Rectify images.
- Stereo matching.
- Thresholding.

Result

Binary image

Optical Flow

Monocular Stereo Vision



Feature extraction

- Probabilistic Hough Transform [Kiryati et al., 1991].
  - Grouping points of parametrized image objects.
  - Voting procedure.
  - Takes only subset of the found points.

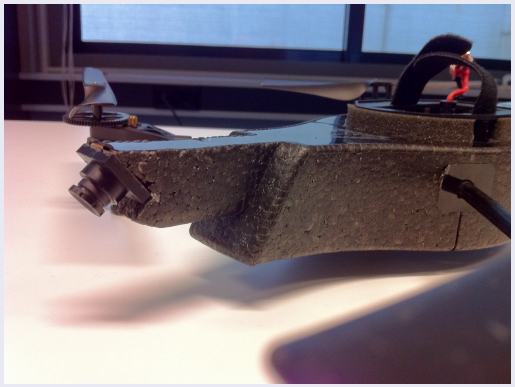
Probabilistic Hough Transform

Navigation

- Fly towards line.
- Fly over it.

Outline

Camera Configuration



Experiments

Evaluation Criteria

- Detection of line.
- Direction of line.

Outline

Camera Configuration

Mirror Construction

- Distorted images.
- No optimal angle.

Modification

- Sharp images.
- Optimal angle.

Experiment 1

Edge detection

Performance	True	False
Detected	528 (97.8%)	12 (2.2%)
Direction	503 (93.1%)	37 (6.9%)

Motion Detection

Performance	True	False
Detected	53 (9.8%)	487 (90.2%)
Direction	37 (6.9%)	503 (93.1%)

Conclusion Experiment 1

- Shows the strength of edge detection.
- Shows the weakness of motion detection.
- Edge detection can strengthen motion detection.

Experiment 2

Edge Detection

Performance	True	False
Detected	69 (29.0%)	169 (71.0%)
Direction	58 (24.4%)	180 (85.6%)

Motion Detection

Performance	True	False
Detected	96 (40.3%)	142 (59.7%)
Direction	87 (36.6%)	137 (63.4%)

Conclusion Experiment 2

- Shows the weakness of edge detection.
- Motion detection worked suboptimal
  Possible solutions
  - Look at average motion.
  - Other datasets.
  - Other algorithms, Elementary Motion Detectors [Gerke et al., 2011].

Video

- AR.Drone follows line.
- Monocular Stereo Vision

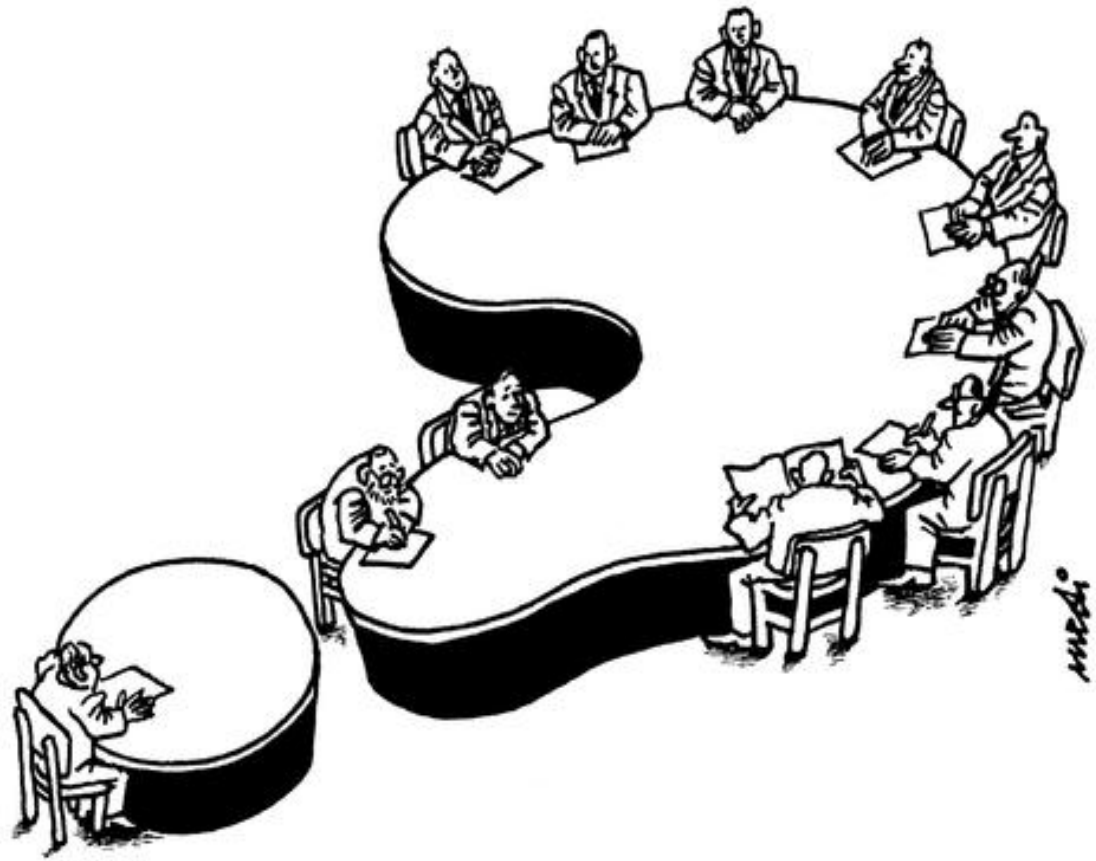
Outline

Conclusion

- **Camera configuration:** Modification was the most optimal solution.
- **Experimental settings:** Contrasting line on the ground and low contrast line in the air.
- **Performance and robustness:** Algorithms can strengthen each other, improvements can be made.

Outline

Questions?



Acknowledgements

I would like to thank for their guidance and support :

- Arnoud Visser
- Gerald Poppinga

Outline

Relevant videos

- Corridor following
- Various tasks

Relevant Literature I

Bills, C., Chen, J., and Saxena, A. (2011).

Autonomous mav flight in indoor environments using single image perspective cues.

In *Robotics and Automation (ICRA), 2011 IEEE International Conference on*, pages 5776 –5783.

Dijkshoorn, N. (2012).

Simultaneous localization and mapping with the ar.drone.

Master's thesis, Universiteit van Amsterdam.

Relevant Literature II

Gerke, P., Langevoort, J., Lagarde, S., Bax, L., Grootswagers, T., Drenth, R.-J., Slieker, V., Vuurpijl, L., Haselager, P., Sprinkhuizen-Kuyper, I., Otterlo, M., and de Croon, G. (2011).

Biomav: bio-inspired intelligence for autonomous flight.

In *Proceedings of the International Micro Air Vehicle conference and competitions, 12-15 September (IMAV 2011)*.

Golightly, I. and Jones, D. (2005).

Visual control of an unmanned aerial vehicle for power line inspection.

In *Advanced Robotics, 2005. ICAR '05. Proceedings., 12th International Conference on*, pages 288 –295.

Relevant Literature III

Jurriaans, R. (2011).

Flow based obstacle avoidance for real world autonomous aerial navigation tasks.

Bachelor's thesis, Universiteit van Amsterdam.

Katrasnik, J., Pernus, F., and Likar, B. (2010).

A survey of mobile robots for distribution power line inspection.

Power Delivery, IEEE Transactions on, 25(1):485 –493.

Kiryati, N., Eldar, Y., and Bruckstein, A. (1991).

A probabilistic hough transform.

Pattern Recognition, 24(4):303 – 316.

Relevant Literature IV

Li, Z., Liu, Y., Hayward, R., Zhang, J., and Cai, J. (2008).

Knowledge-based power line detection for uav surveillance and inspection systems.

In *Image and Vision Computing New Zealand, 2008. IVCNZ 2008. 23rd International Conference*, pages 1 –6.

Shi, J. and Tomasi, C. (1994).

Good features to track.