Machine Learning-based Indoor Localization for Micro Aerial Vehicles

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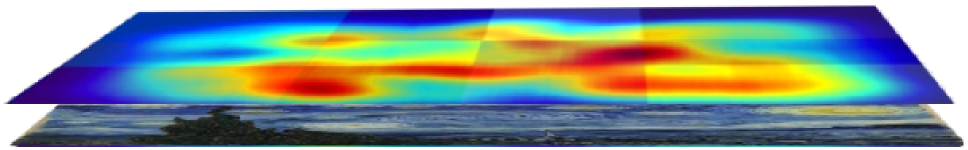


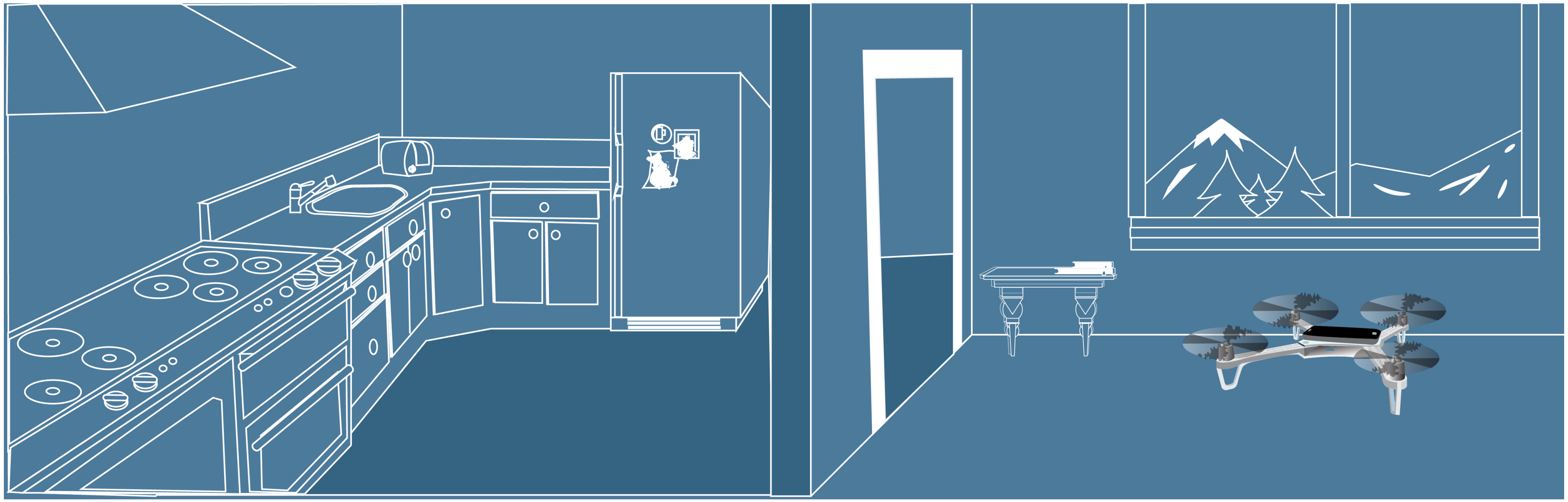
Radboud Universiteit

Louis Vuurpijl

TU Delft
Delft University of Technology

Guido de Croon
Roland Meertens

MOTIVATION

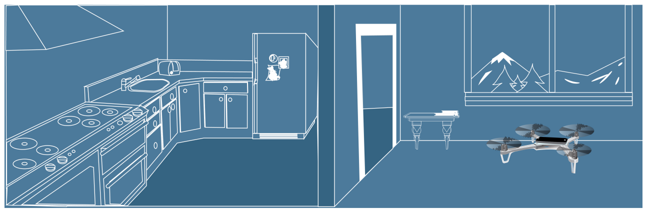


MOTIVATION

Tools

x,y-coordinates in real time

environment



modifiable known fixed planar

MOTIVATION

Research Question

Can vision-based indoor localization be done on a very limited platform?

RESEARCH QUESTIONS

Research Question 1

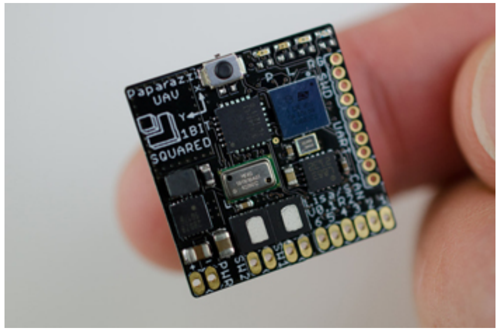
Can vision-based indoor localization be done on a very limited platform?

Research Question 2

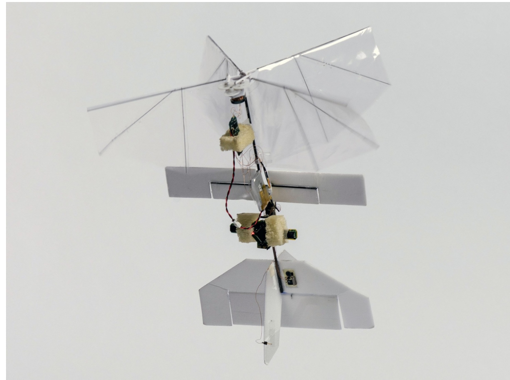
Can we predict the suitability of an environment for the proposed localization algorithm?

x,y-coordinates in real time

Micro Air Vehicle Lab



Miniaturization



OUTLINE

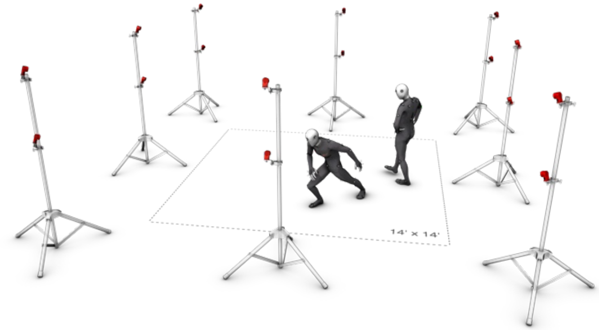
- Existing Methods
- Machine Learning-based Approach
- Simulations & Flight Tests
- Discussion & Future Work

OUTLINE

- Existing Methods
- Methods
- Experiments and Results
- Discussion
- Conclusion

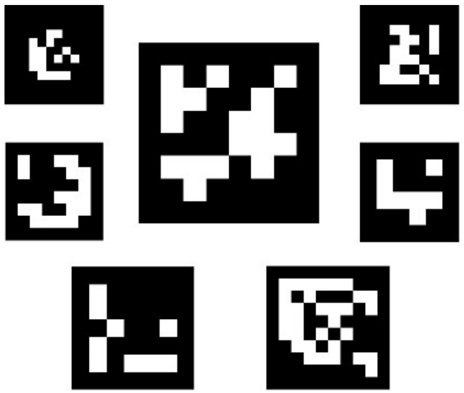
METHODS FOR INDOOR LOCALIZATION

Laser range finder

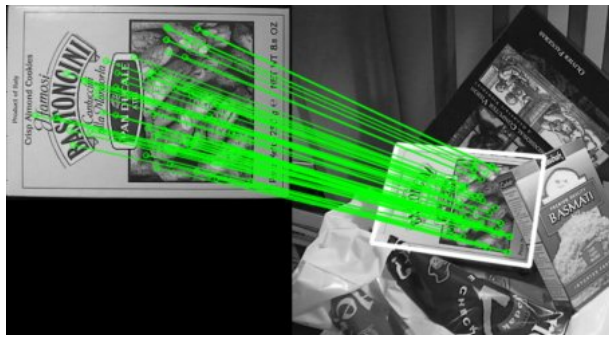


Motion tracking system

Visual odometry
(acumulating
error)



Markers

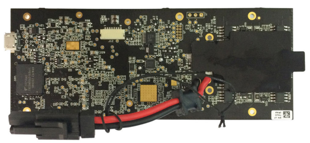


SIFT + homography finding

CHALLENGES / CONTRIBUTIONS

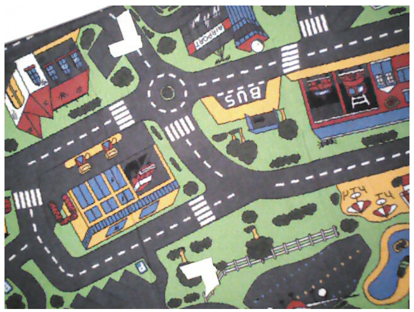
Low-performance platform

Low-level embedded programming (C)

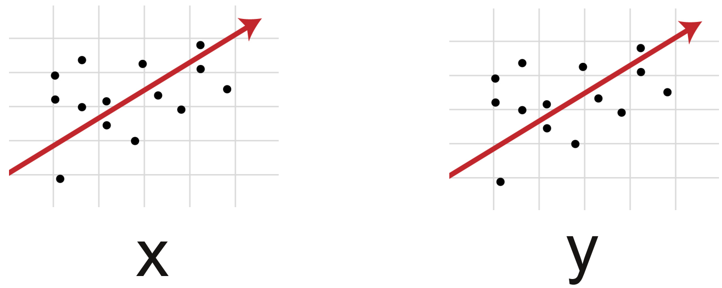


Ground truth estimation

x?
y?



Regression with 2 dependent variables

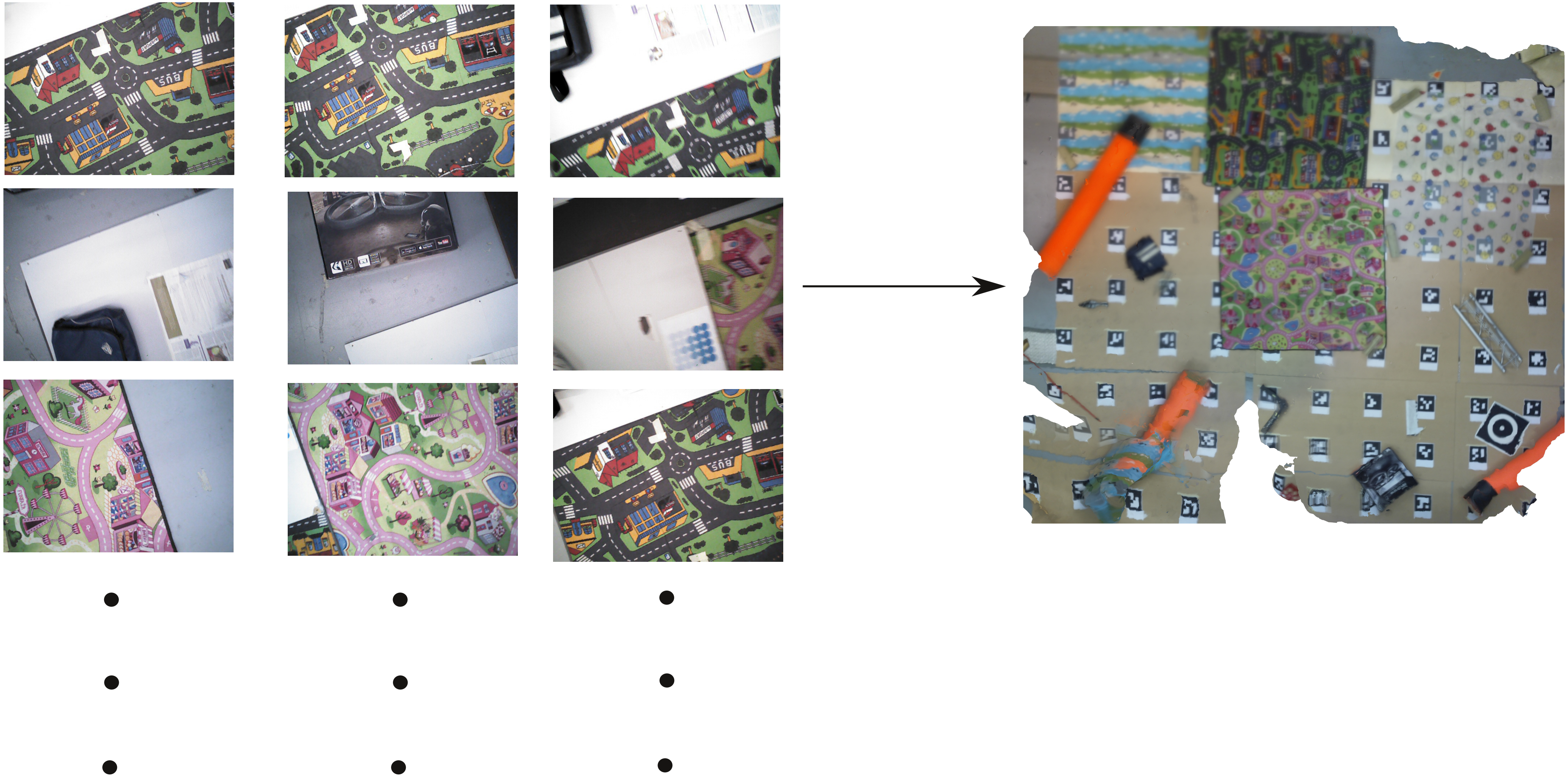


CHALLENGES / CONTRIBUTIONS

Which map is good?

GROUND TRUTH ESTIMATION

GROUND TRUTH ESTIMATION



DUMMY: INSERT SIFT

APPROACH

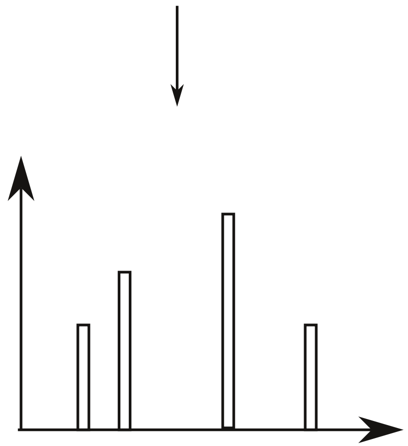
Flight phase

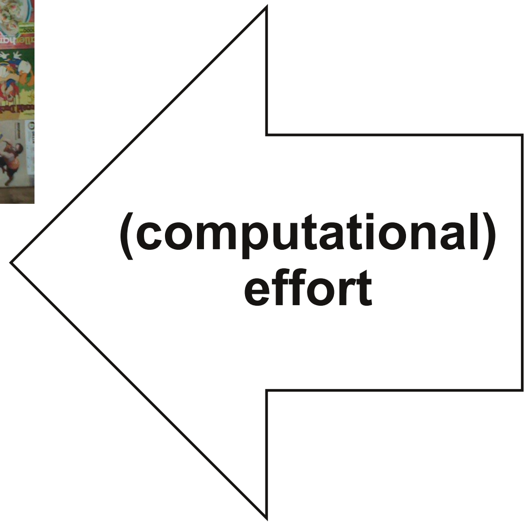
1 Image / sec

IDEA

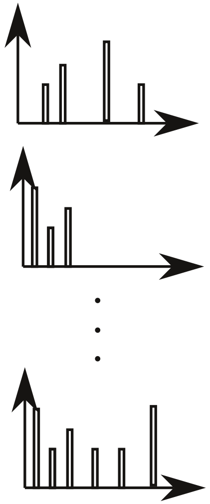
Preflight phase

Flight phase





Training Data

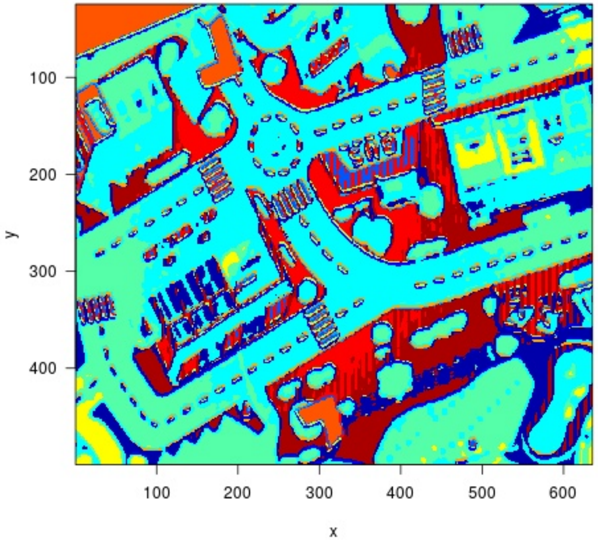


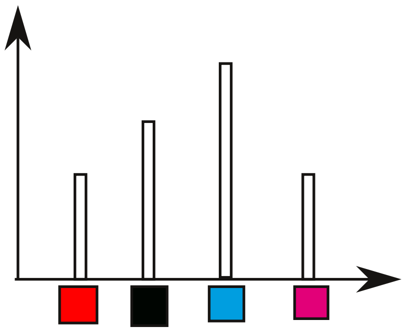
frequencies	x	y
	200	300
	700	210
⋮	⋮	
	111	210

OUTLINE

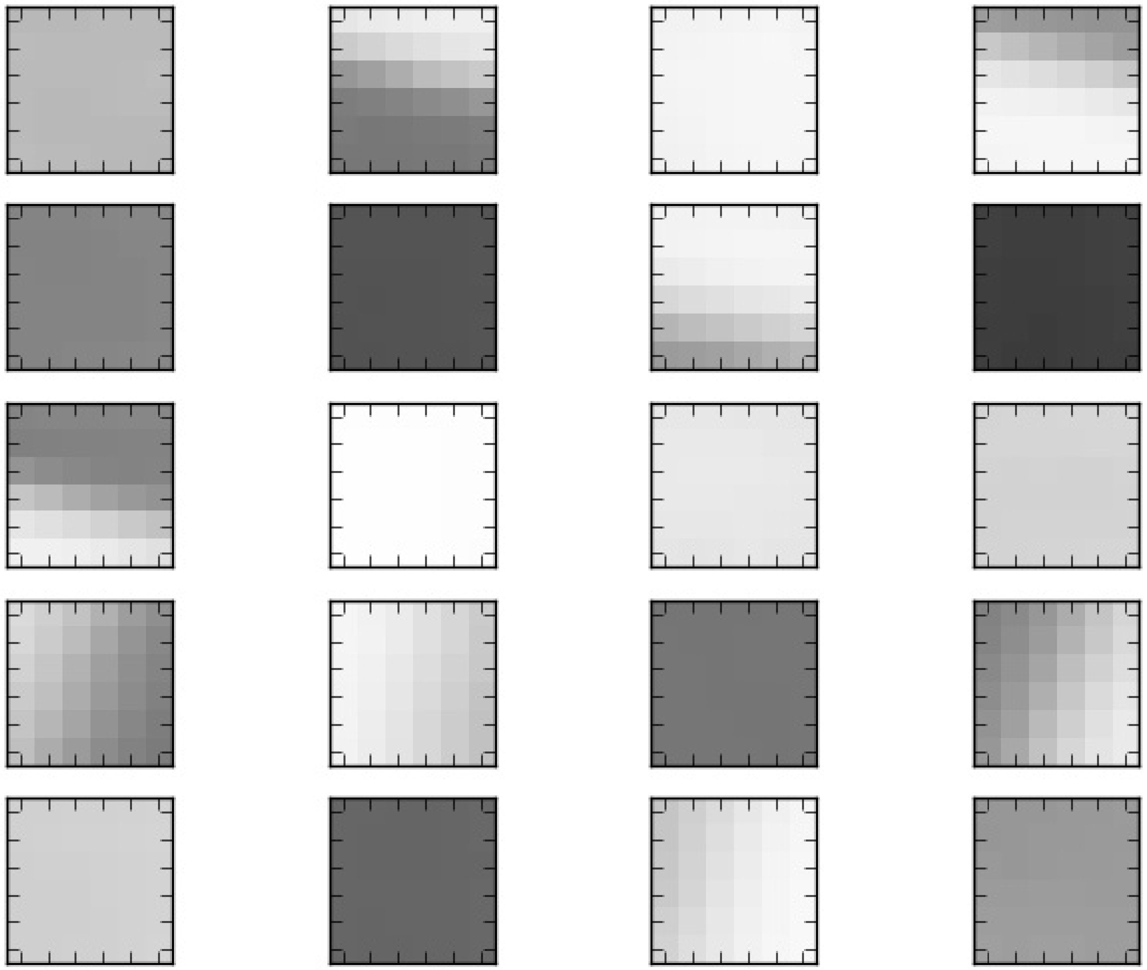
- Related Work
- **Methods**
- Experiments and Results
- Discussion
- Conclusion

TEXTONS

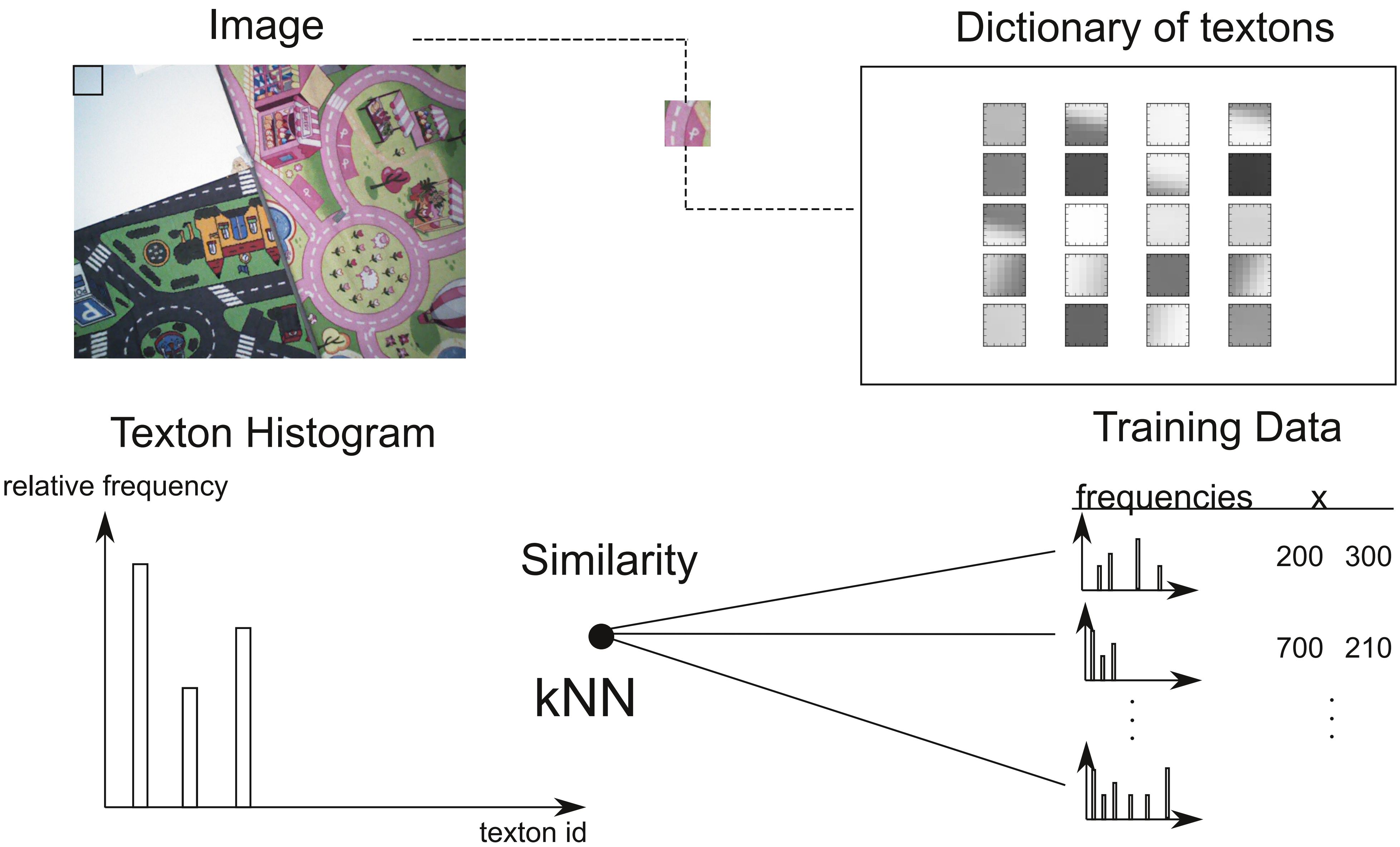




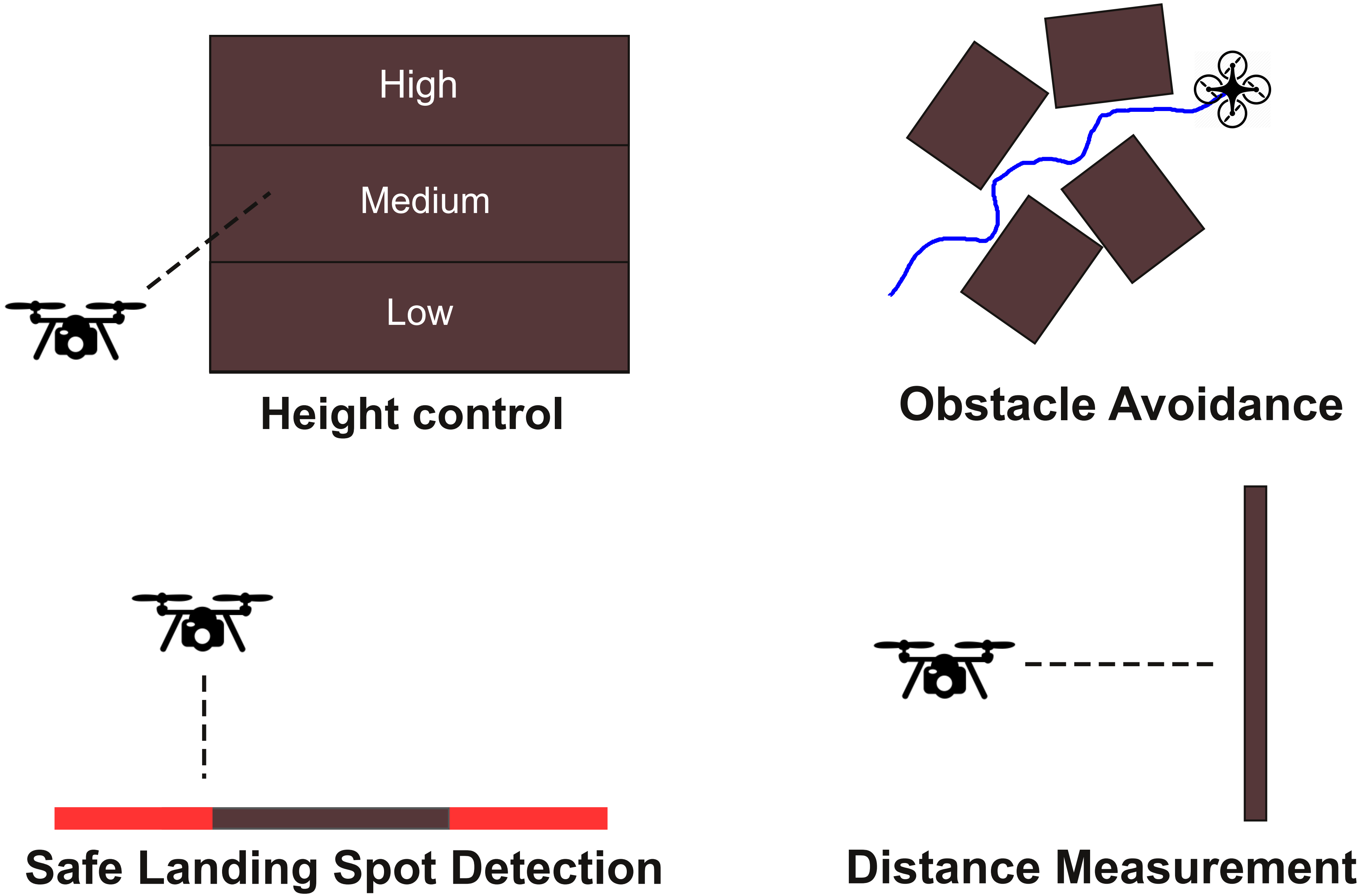
TEXTONS



MACHINE-LEARNING APPROACH



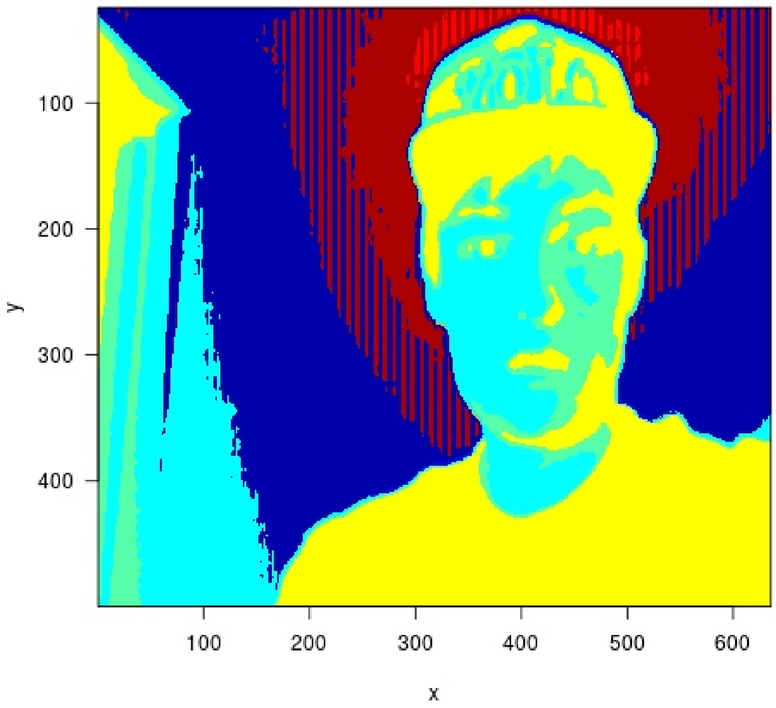
FOUNDATION

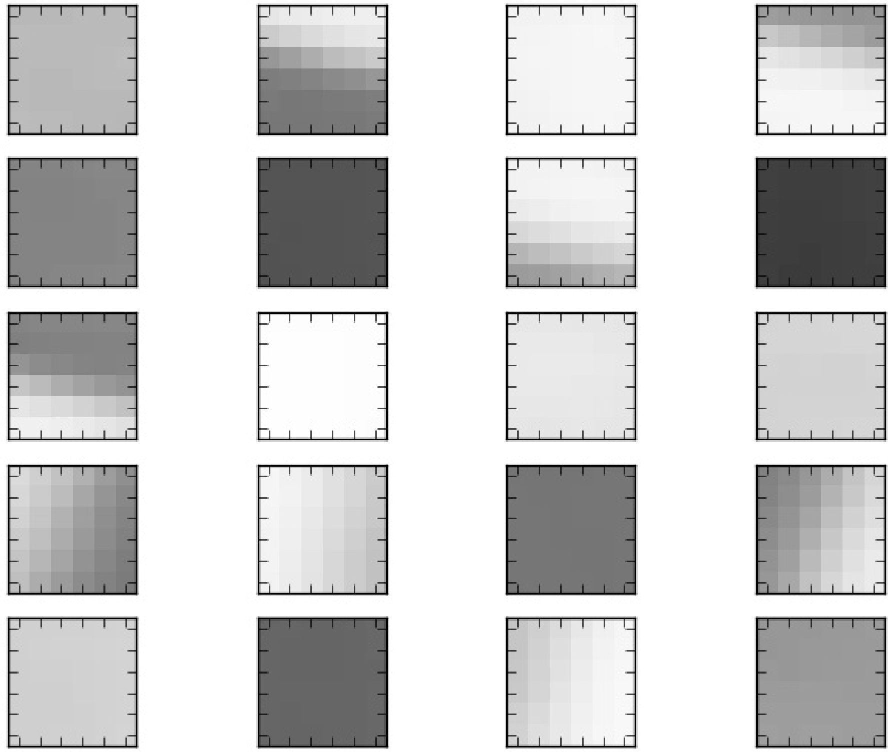


High
Medium
Low
Height control
Obstacle Avoidance
Safe Landing Spot Detection
Distance Measurement

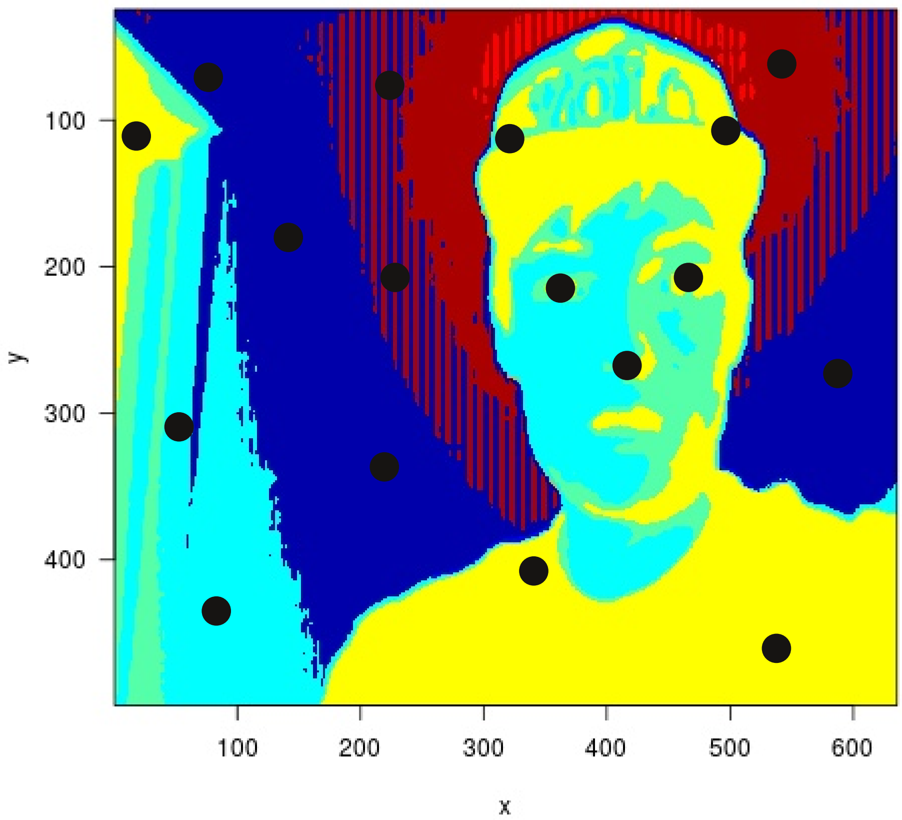
DUMMY: INSERT CYBERZOO_FLIGHT

MACHINE-LEARNING APPROACH

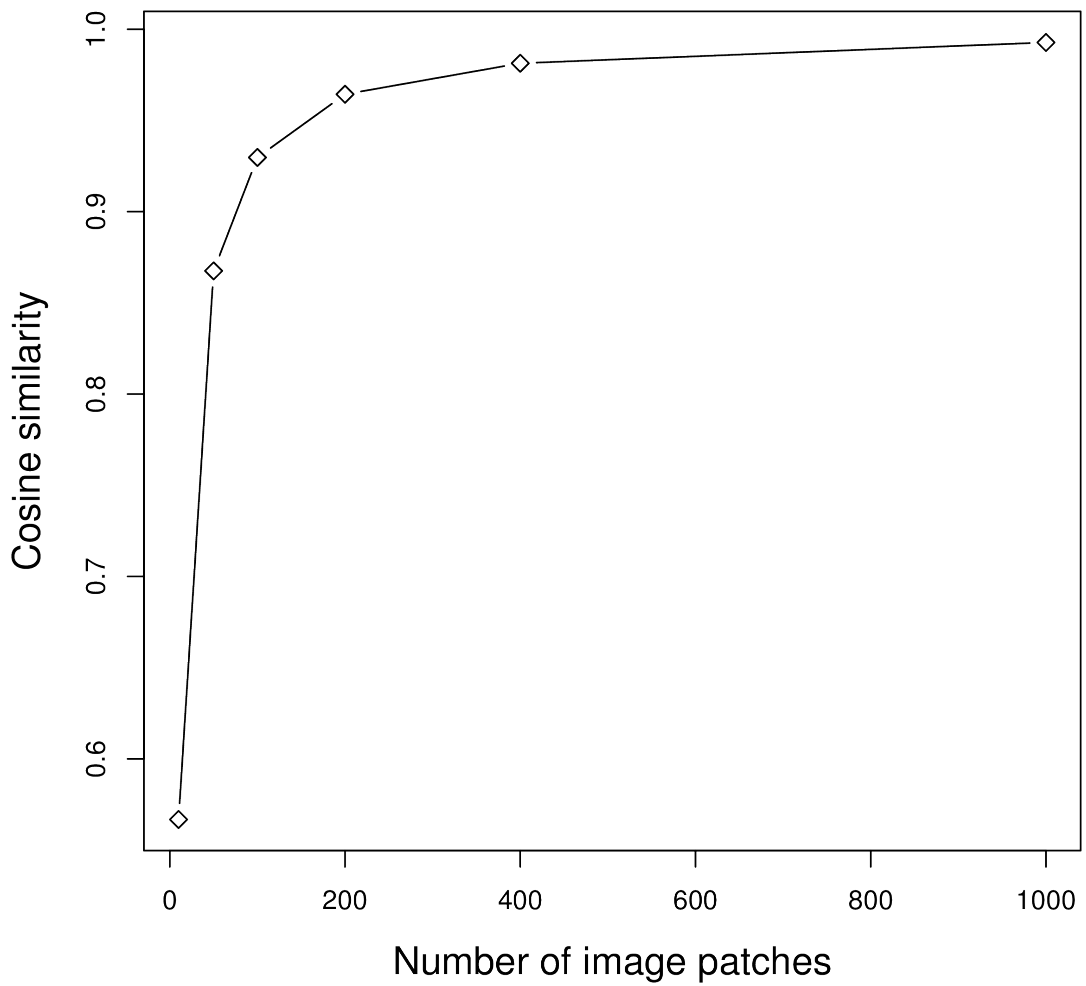




MACHINE-LEARNING APPROACH

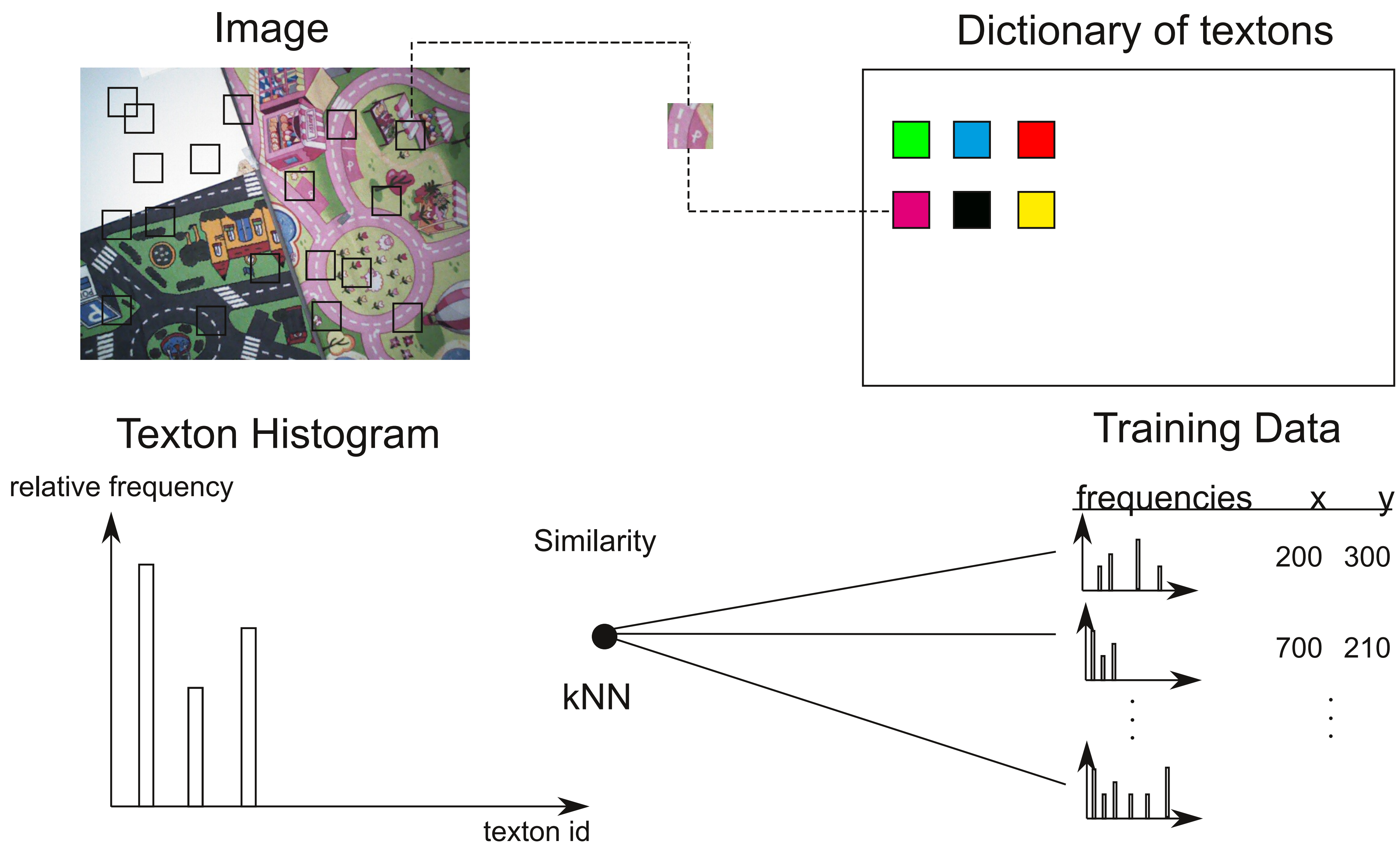


MACHINE-LEARNING APPROACH

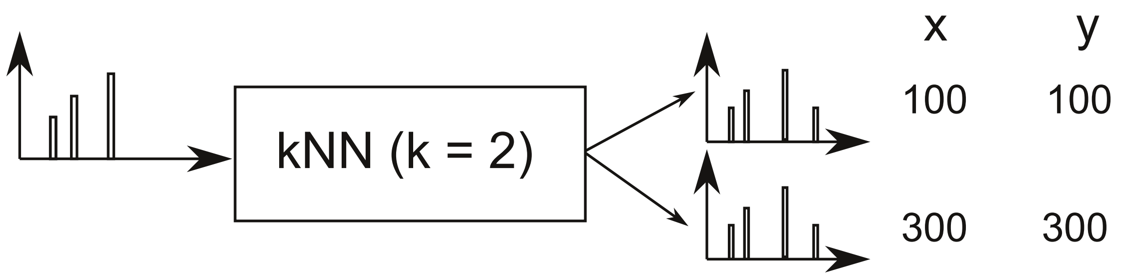


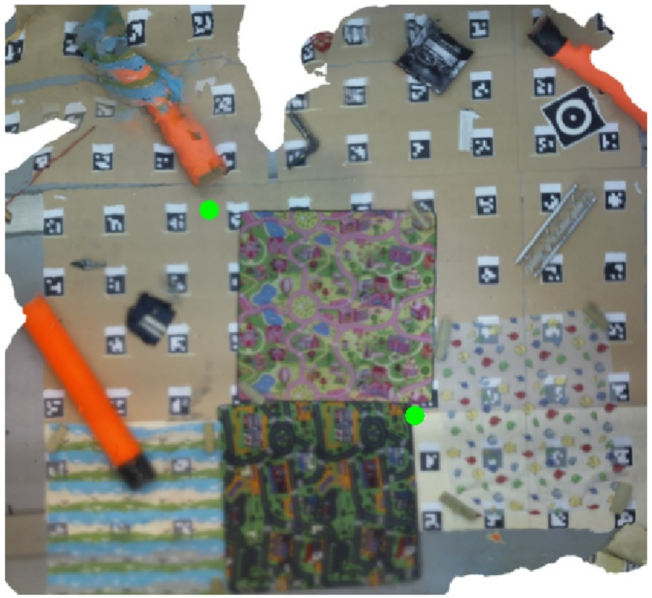
307200!

MACHINE-LEARNING APPROACH

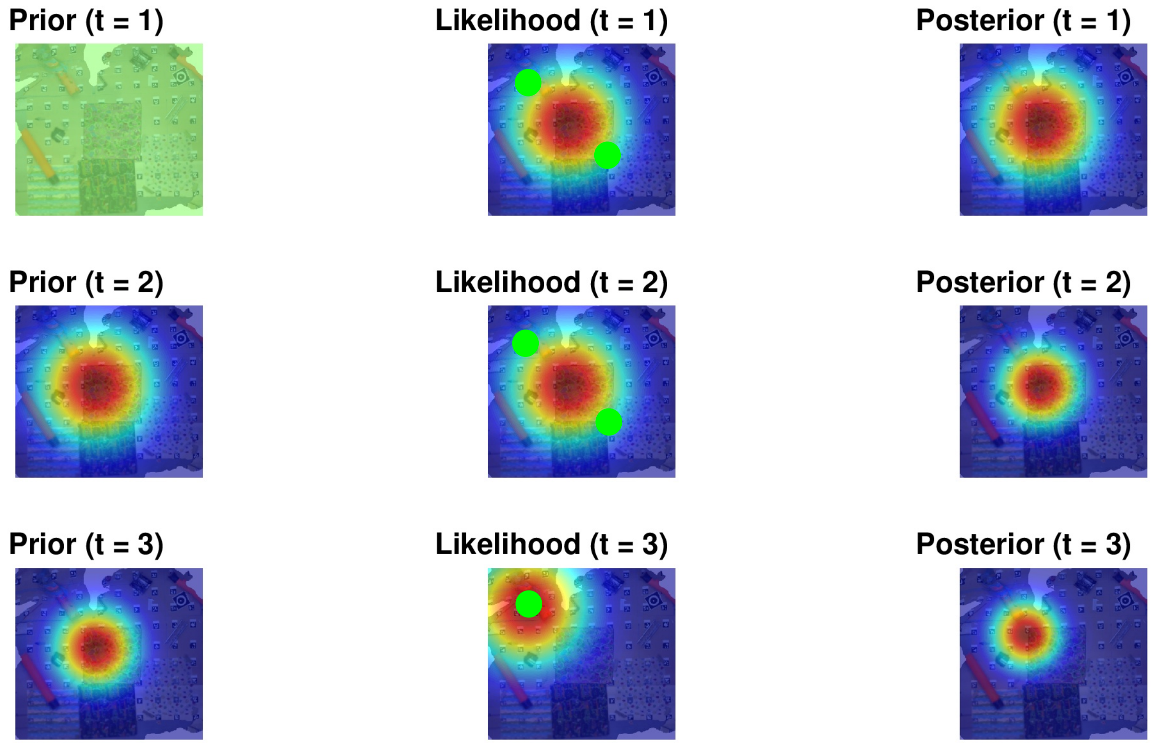


FILTERING

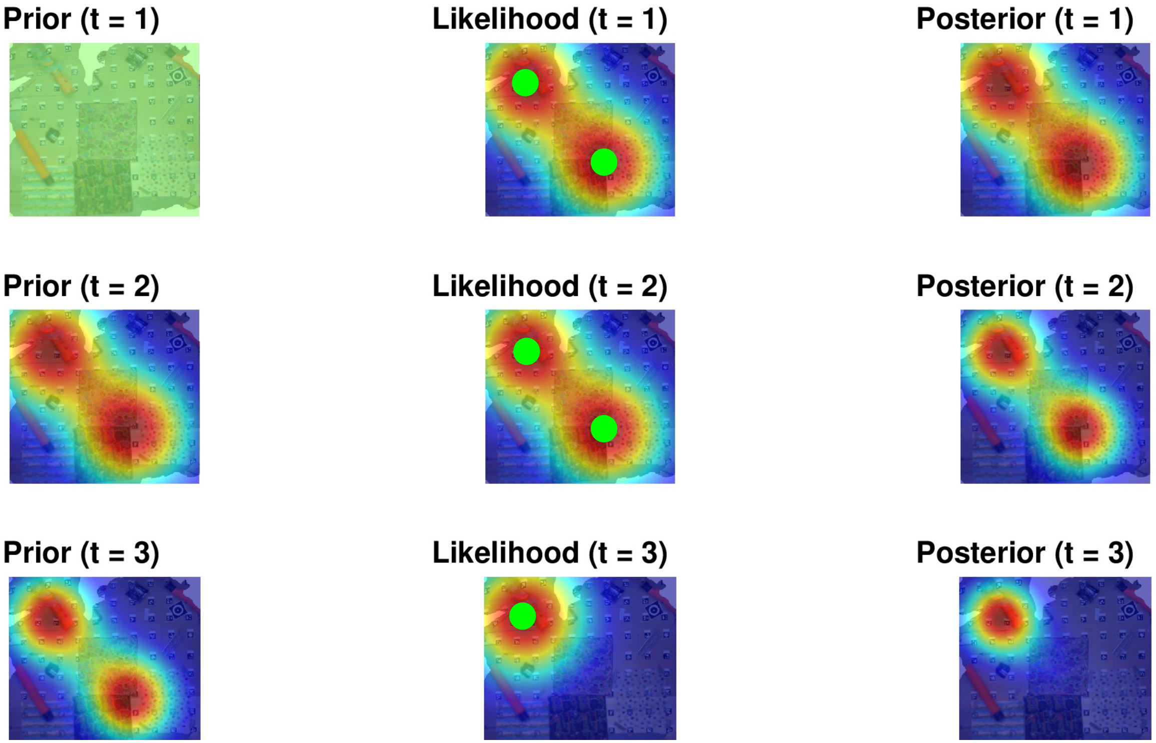




FILTERING


Prior (t = 1)
Likelihood (t = 1)
Posterior (t = 1)
Prior (t = 2)
Likelihood (t = 2)
Posterior (t = 2)
Prior (t = 3)
Likelihood (t = 3)
Posterior (t = 3)

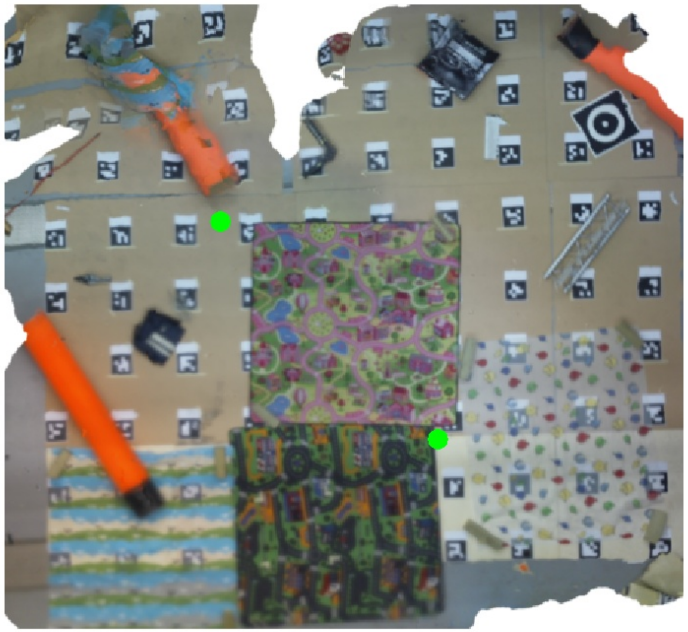
FILTERING



Prior (t = 1)
Likelihood (t = 1)
Posterior (t = 1)
Prior (t = 2)
Likelihood (t = 2)
Posterior (t = 2)
Prior (t = 3)
Likelihood (t = 3)
Posterior (t = 3)

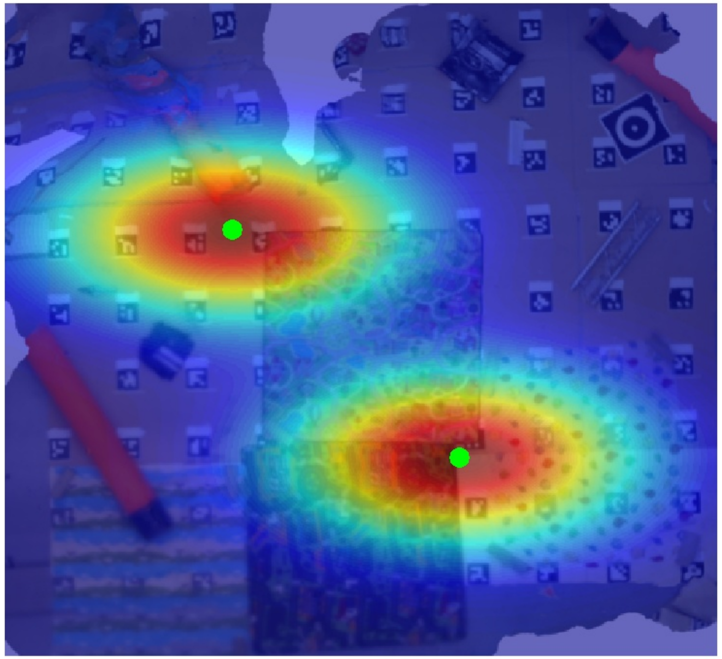
FILTERING

Sensor model



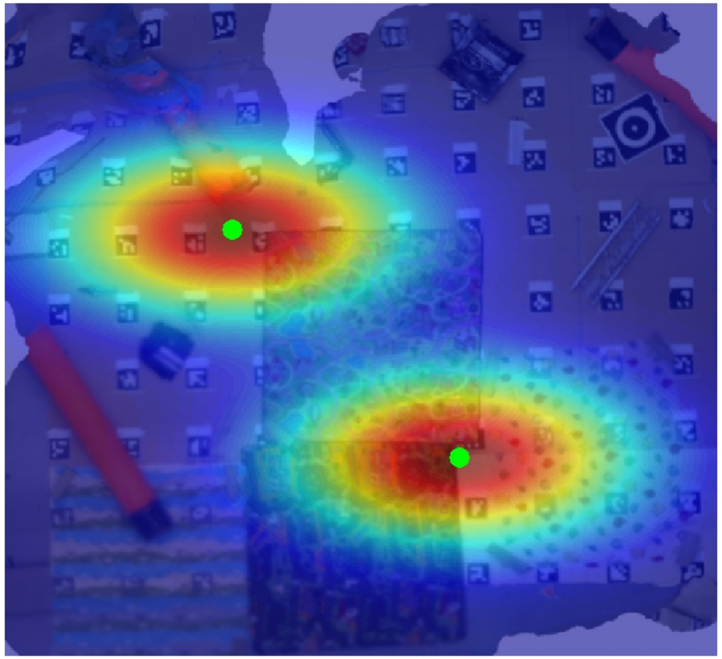
FILTERING

Sensor model



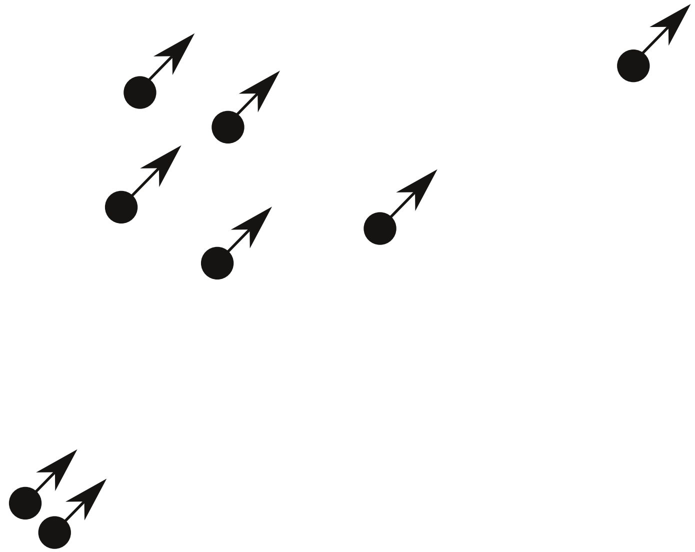
FILTERING

Sensor model



Motion model

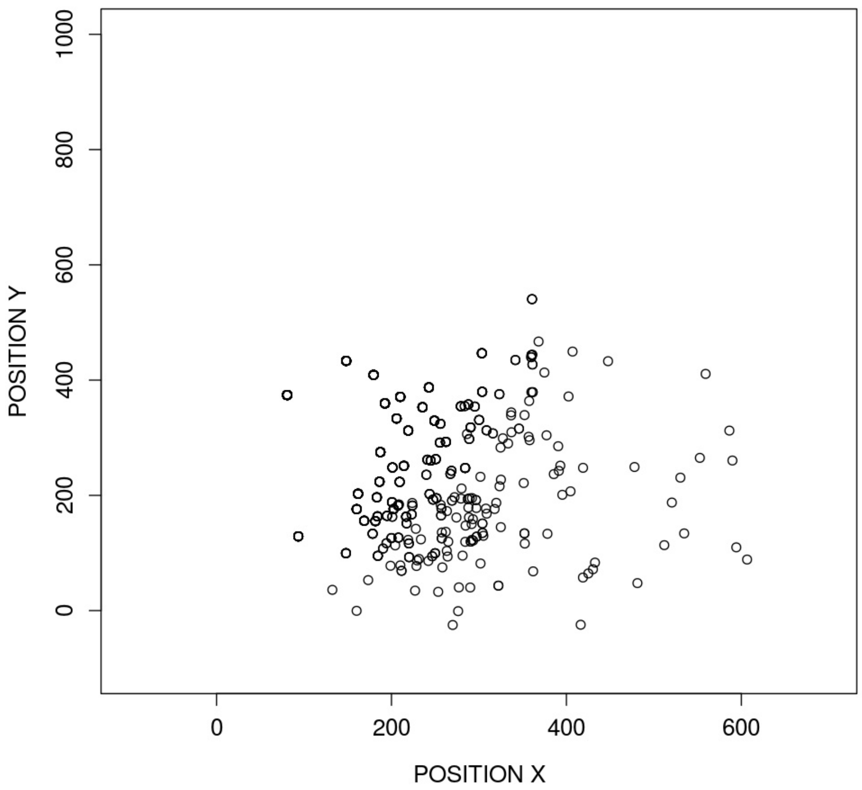
Determine optical flow and add noise ~ N(0, 10)

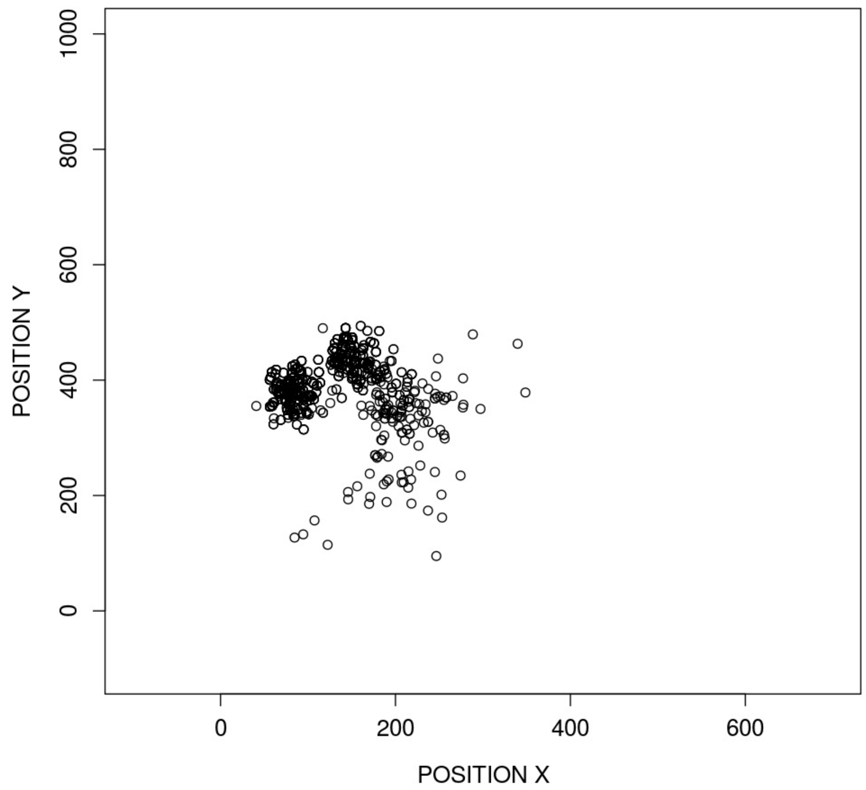


FILTERING

GREAT
BUT
SLOW

PARTICLE FILTER

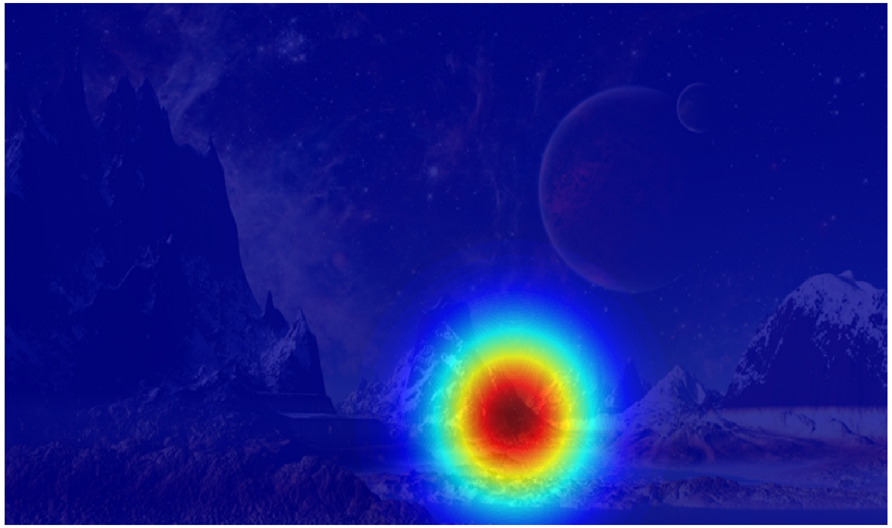




DUMMY: PARTICLE FILTER

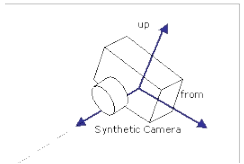
ENVIRONMENTAL MODIFICATION

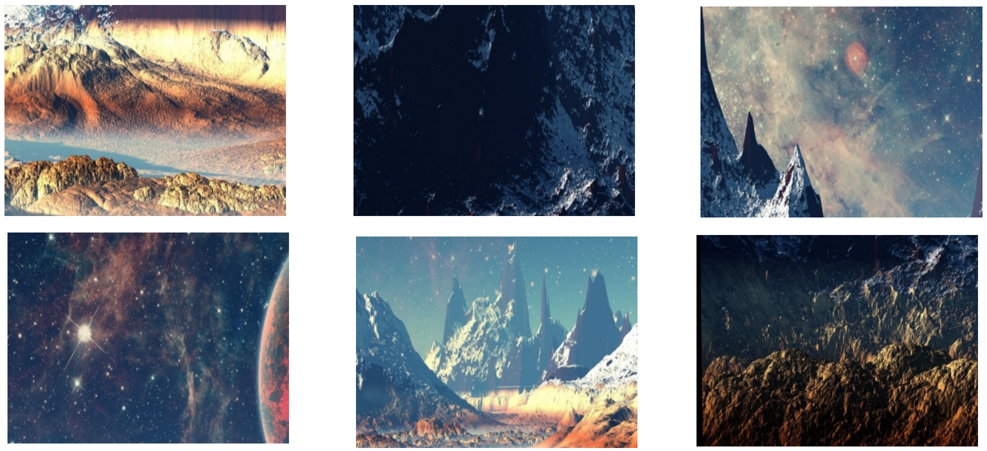
MAP EVALUATION



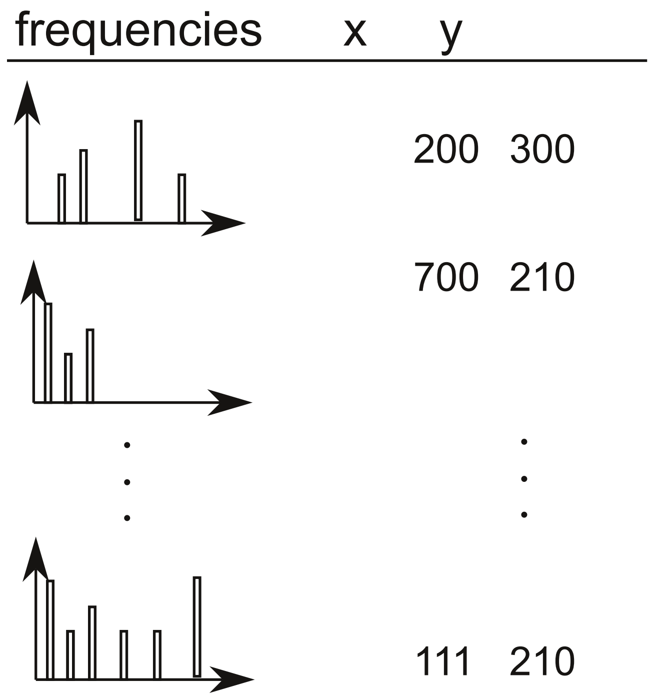
IDEAL SIMILARITY OF HISTOGRAMS FOR FIXED POSITION

MAP EVALUATION - SYNTHETIC FLIGHT



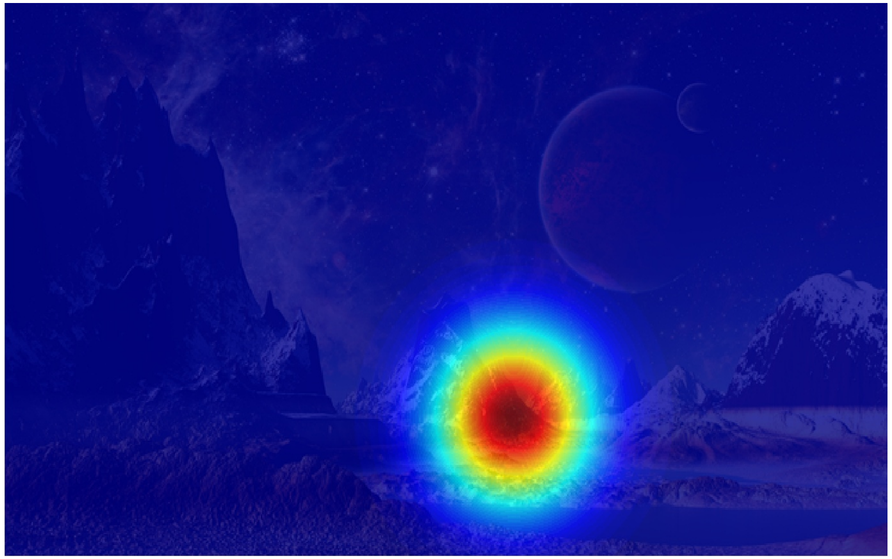


1000 patches



Training Data

MAP EVALUATION



IDEAL SIMILARITY OF HISTOGRAMS FOR FIXED POSITION

TODO

ACTUAL SIMILARITY

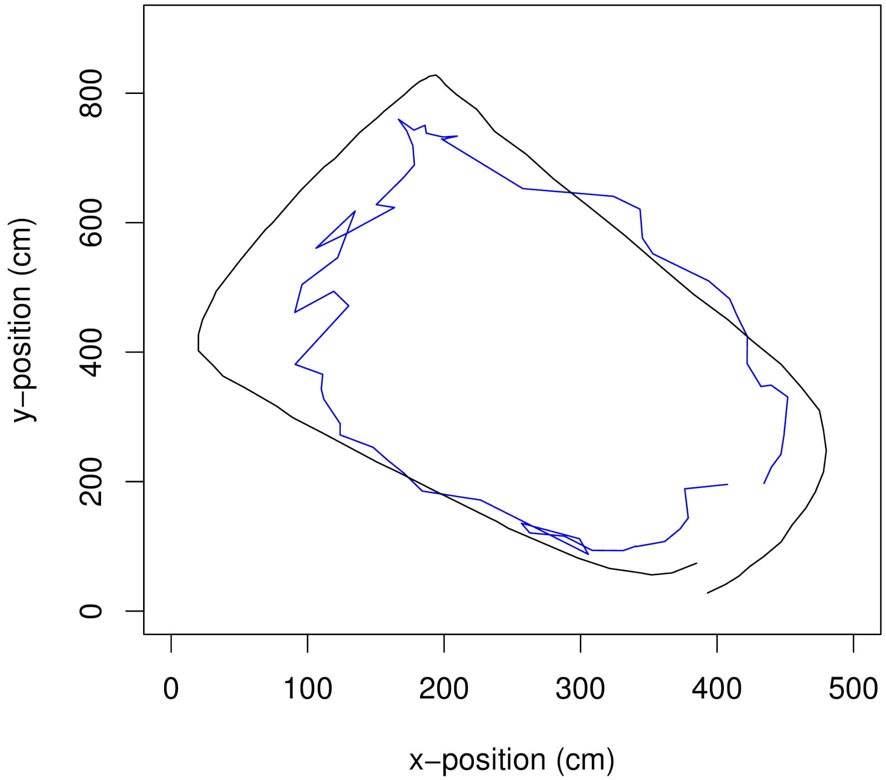
OUTLINE

- Related Work
- Methods
- **Experiments and Results**
- Discussion
- Conclusion

EXPERIMENTS

- Simulated flights
- Map evaluation
- Real-world Target Landing
- Real-world Navigation

FLIGHT ACCURACY



OptiTrack vs. treXton

Average distance

Standard deviation of errors

TRIGGERED LANDING

PLOT DELTA X Y OF SINGLE RUNS

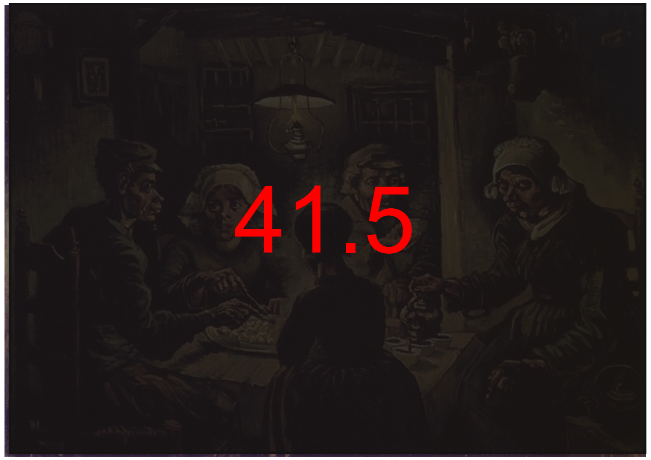
OR USE TABLE

DUMMY: VIDEO TARGET LANDING

MAP EVALUATION

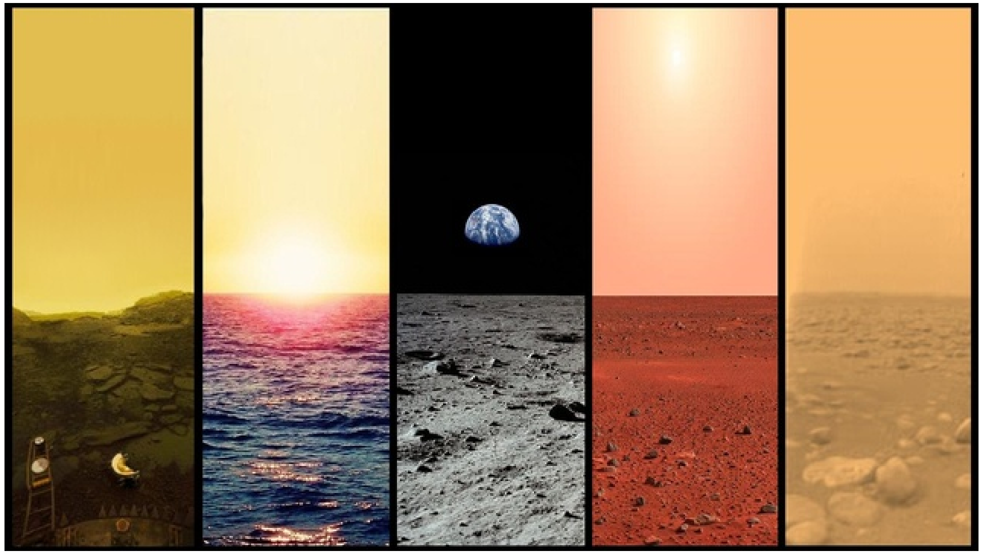
47 images

MAP EVALUATION



MAP EVALUATION

GOOD



BAD

RESEARCH QUESTIONS

Research Question 1

Can accurate indoor localization be done on a very limited platform?

Research Question 2

Can we predict the suitability of a given map for the proposed localization algorithm?

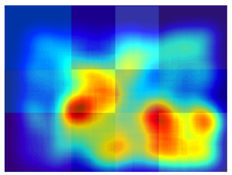
DISCUSSION

Implications:

- adaptable to different platforms

- robustness to motion blur

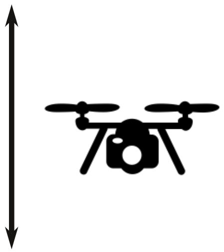
- detect safe landing spots

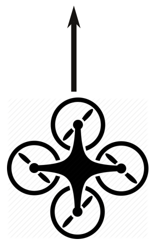


DISCUSSION

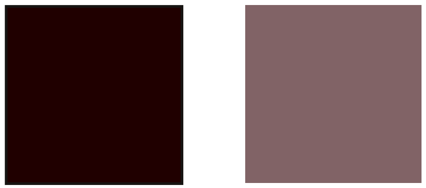
Limitations:

- assumes constant height and no rotations





- robustness to differerent lighting conditions



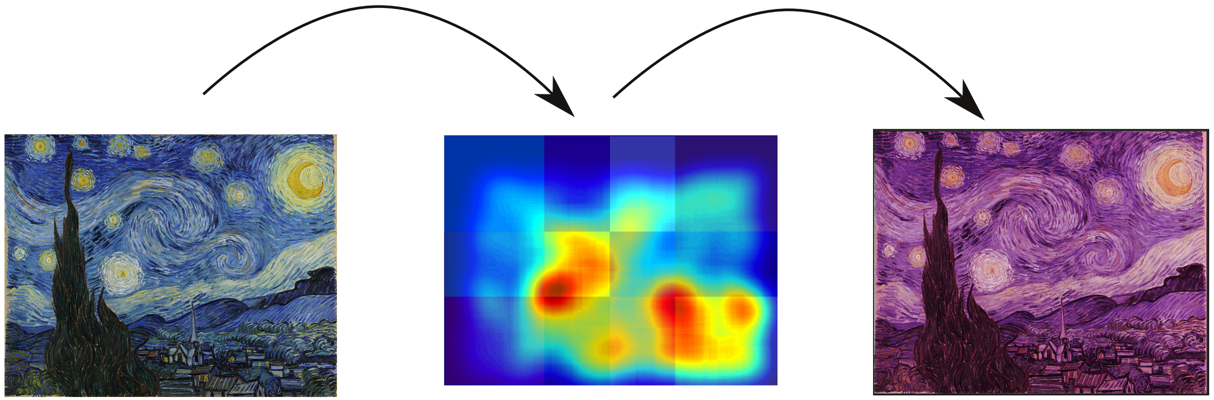
- Particle filter does not include velocity or heading

DISCUSSION

Future research:

- bridge reality gap

- automatic map generation (evolutionary algorithm)



CODE CONTRIBUTIONS

- Image augmentation with synthetic views (C++)

  https://github.com/Pold87/draug

- Map evaluation (MATLAB)

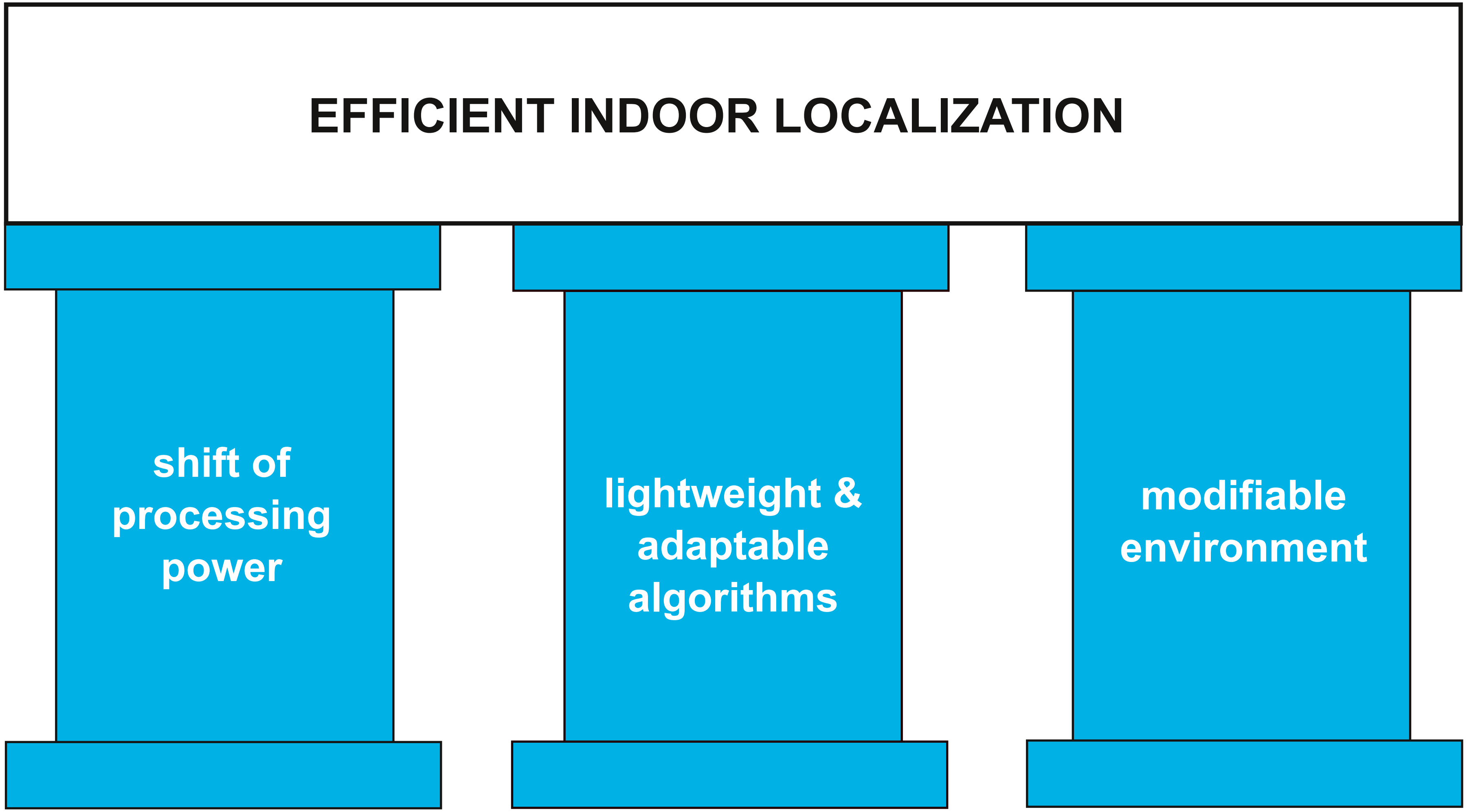
  https://github.com/Pold87/evaluation-thesis

- Localization: SIFT matching, particle filter, texton-based approach (C)

  C: https://github.com/Pold87/paparazzi   Python: https://github.com/Pold87/treXton

PAPARAZZI
The Free Autopilot

CONCLUSION


EFFICIENT INDOOR LOCALIZATION
shift of processing power
lightweight & adaptable algorithms
modifiable environment