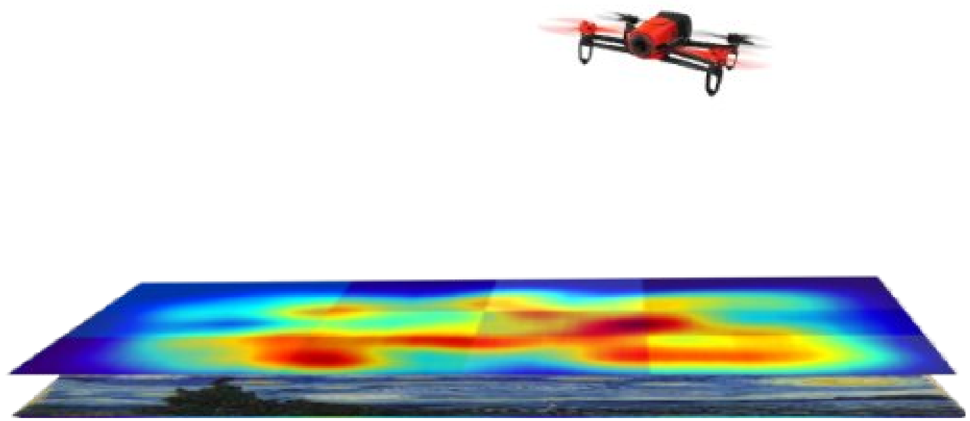
Machine Learning-based Indoor Localization for Micro Aerial Vehicles



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14th July 2016

Radboud Universiteit

Louis Vuurpijl

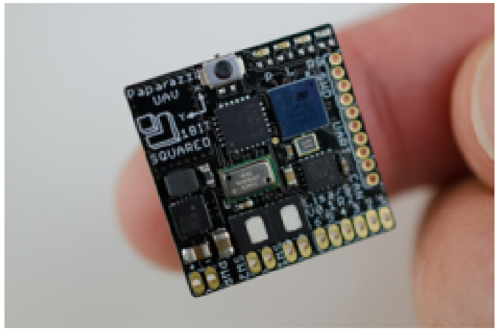
TU Delft Delft University of Technology

Guido de Croon
Roland Meertens

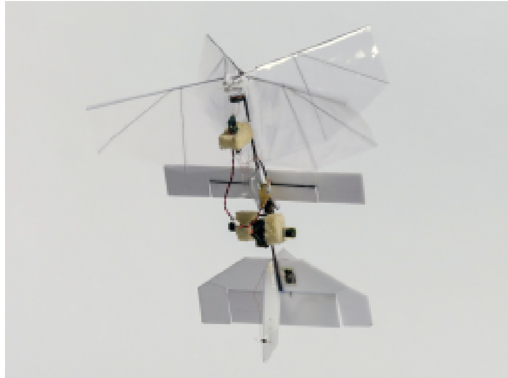
Micro Air Vehicle Lab

TU Delft Delft University of Technology

MAVLab™



Miniaturization



OUTLINE

Motivation & Setting

Existing Methods

Prosposed Method

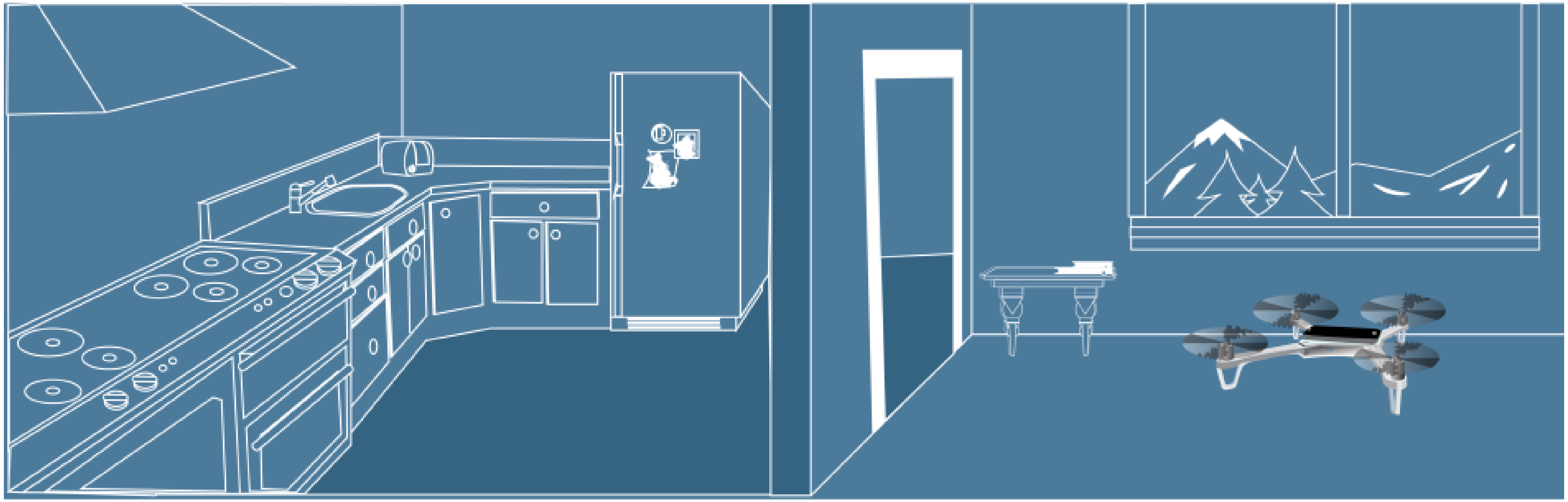
Flight Tests & Simulations

Discussion & Conclusion

OUTLINE

Motivation & Setting → Existing Methods → Proposed Method → Flight Tests & Simulations → Discussion & Conclusion

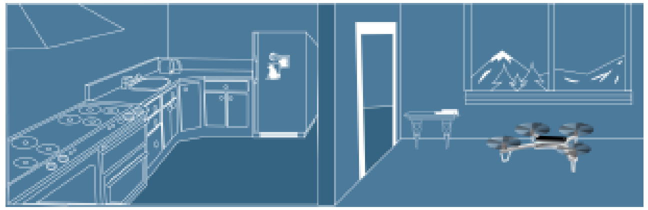
MOTIVATION



MOTIVATION

Tools

Environment

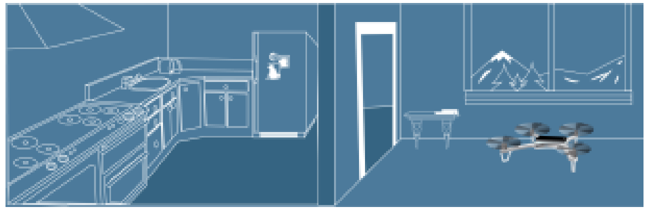


modifiable known fixed planar

MOTIVATION

Tools

Environment

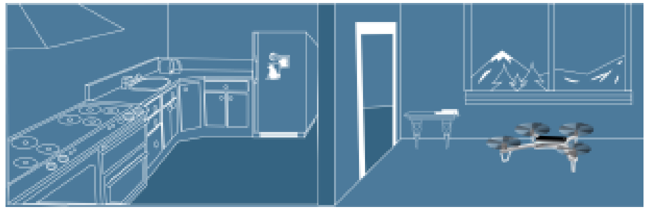


modifiable known fixed planar

MOTIVATION

Environment

Tools

modifiable known fixed planar

x,y-coordinates

accurate on-board real-time fixed height

MOTIVATION

Research Question

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

anar

accurate on-board real-time

RESEARCH QUESTIONS

Research Question 1

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

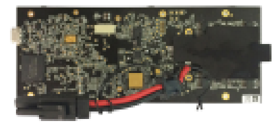
Research Question 2

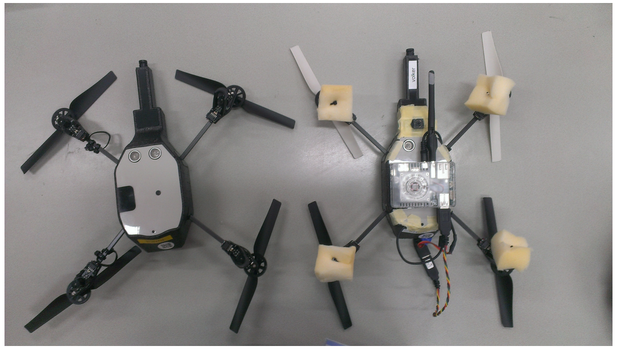
Can we predict the suitability of an environment for the proposed localization algorithm?

CHALLENGES

Low-performance platform

Low-level embedded programming (C)





Real-world

EFFICIENT INDOOR LOCALIZATION

shift of processing power

lightweight & adaptable algorithms

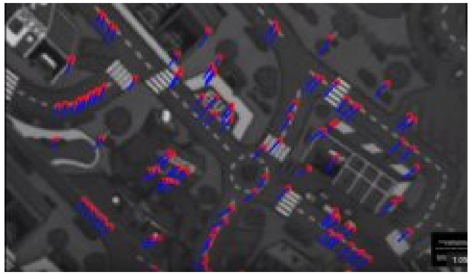
modifiable environment

OUTLINE

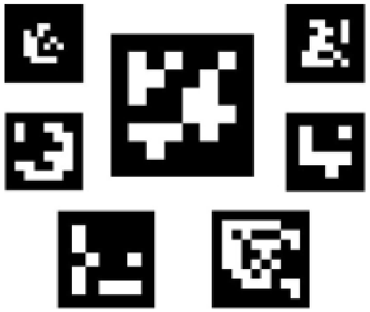
Motivation & Setting → **Existing Methods** → Proposed Method → Flight Tests & Simulations → Discussion & Conclusion

METHODS FOR ONBOARD LOCALIZATION

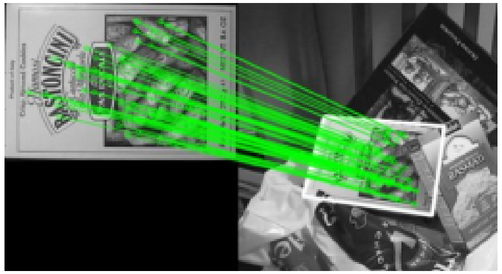
Laser range finder



Optical flow



Markers



Homography finding

DUMMY: INSERT SIFT VIDEO

APPROACH

Flight phase

APPROACH

Flight phase

1 Image / sec

OUTLINE

Motivation & Setting

Existing Methods

Proposed Method

Flight Tests & Simulations

Discussion & Conclusion

APPROACH

Flight phase

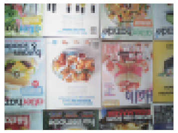
1 Image / sec

APPROACH

~~Flight phase~~

Pre-flight phase

Dataset

	x	y
	200	300
	210	320
⋮	⋮	⋮
	111	210

APPROACH

~~**Flight phase**~~

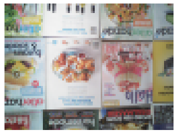
Pre-flight phase

Flight phase

create

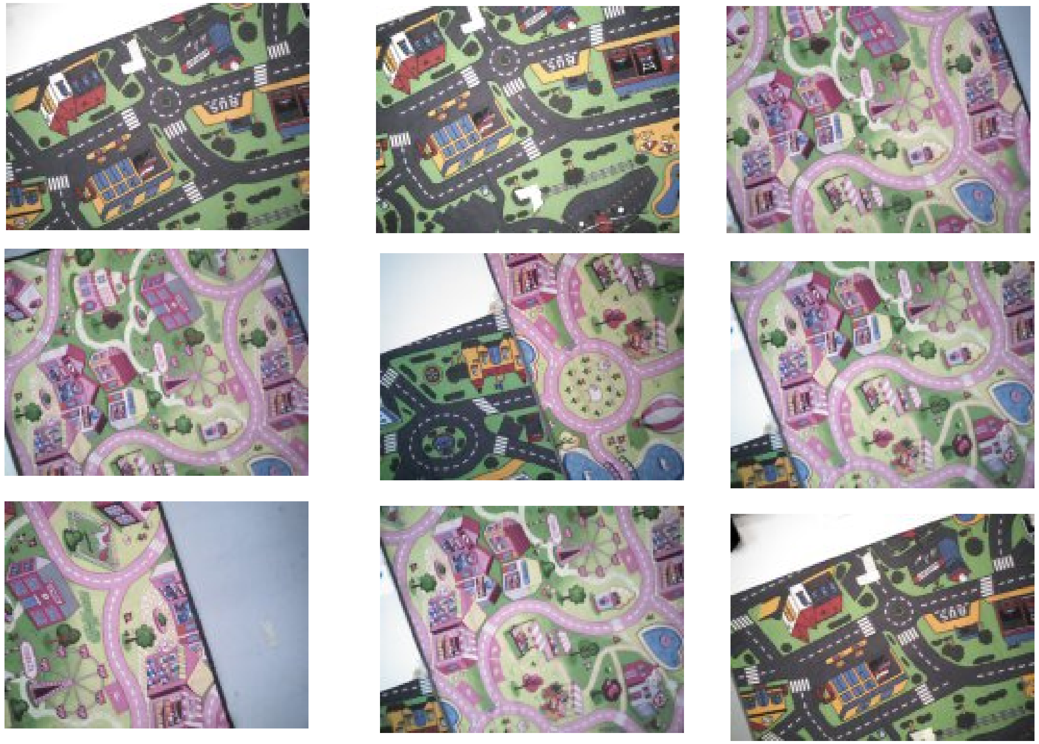
compare

Dataset

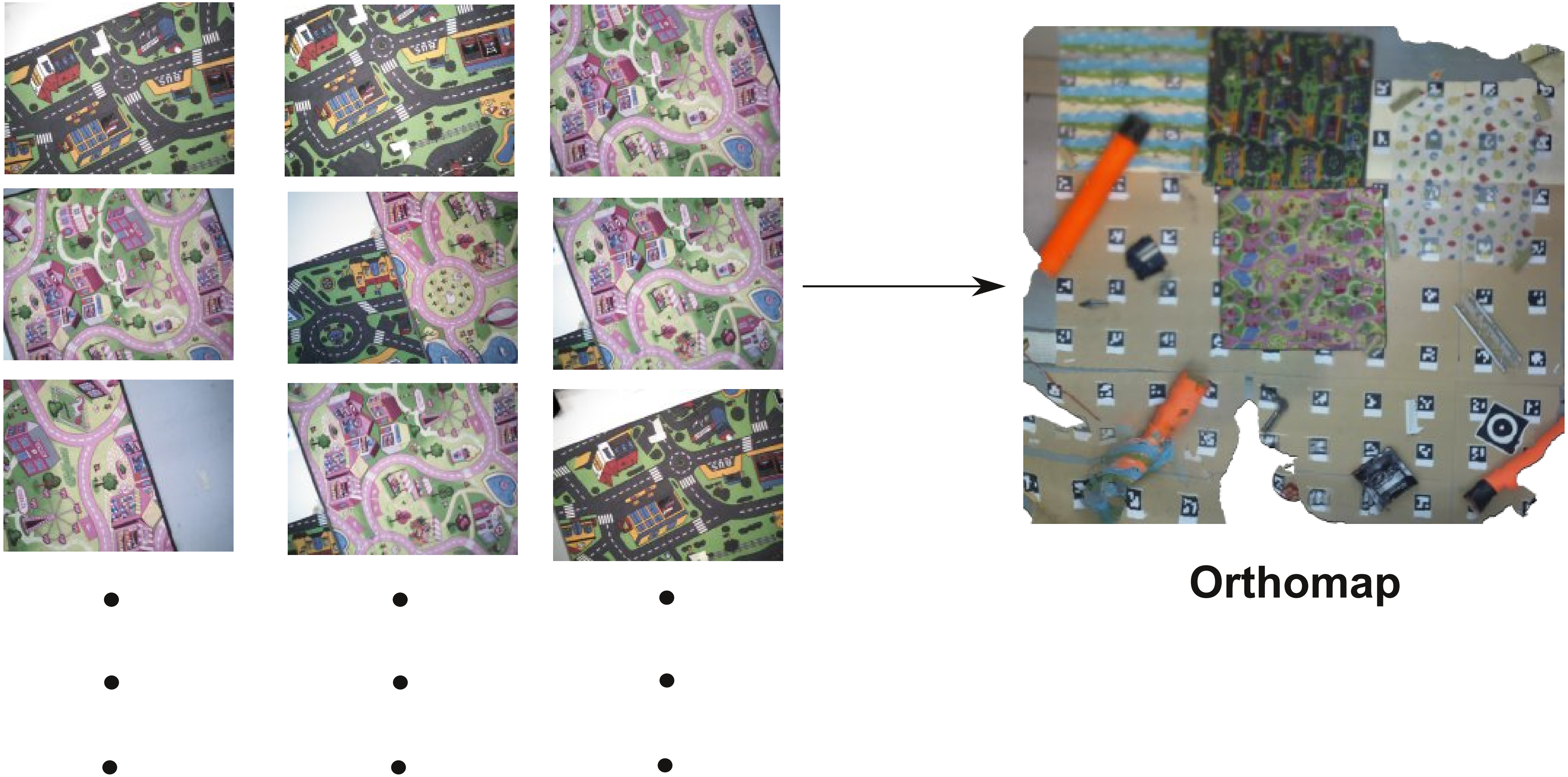


x	y
200	300
210	320
⋮	⋮
111	210

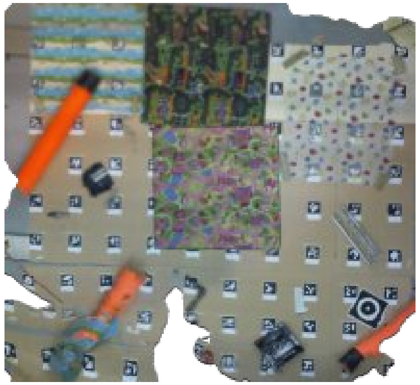
SCALABILITY



SCALABILITY



GROUND TRUTH ESTIMATION

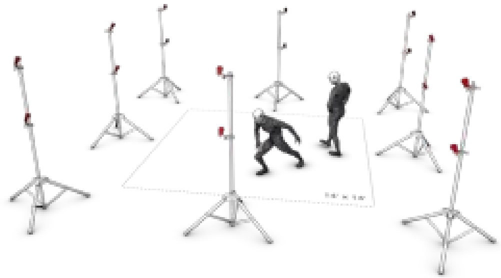


Orthomap

OR

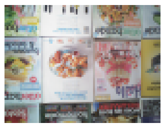
Poster

OR



Motion tracking

Dataset

	x	y
	200	300
	210	320
⋮	⋮	⋮

GROUND TRUTH ESTIMATION

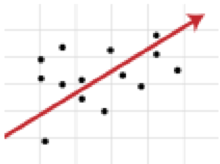
Orthomap

Motion tracking

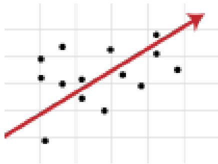
shift of processing power

CHALLENGES

2-dimensional regression

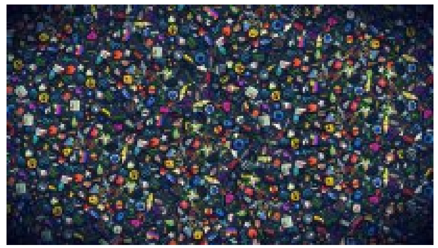


x

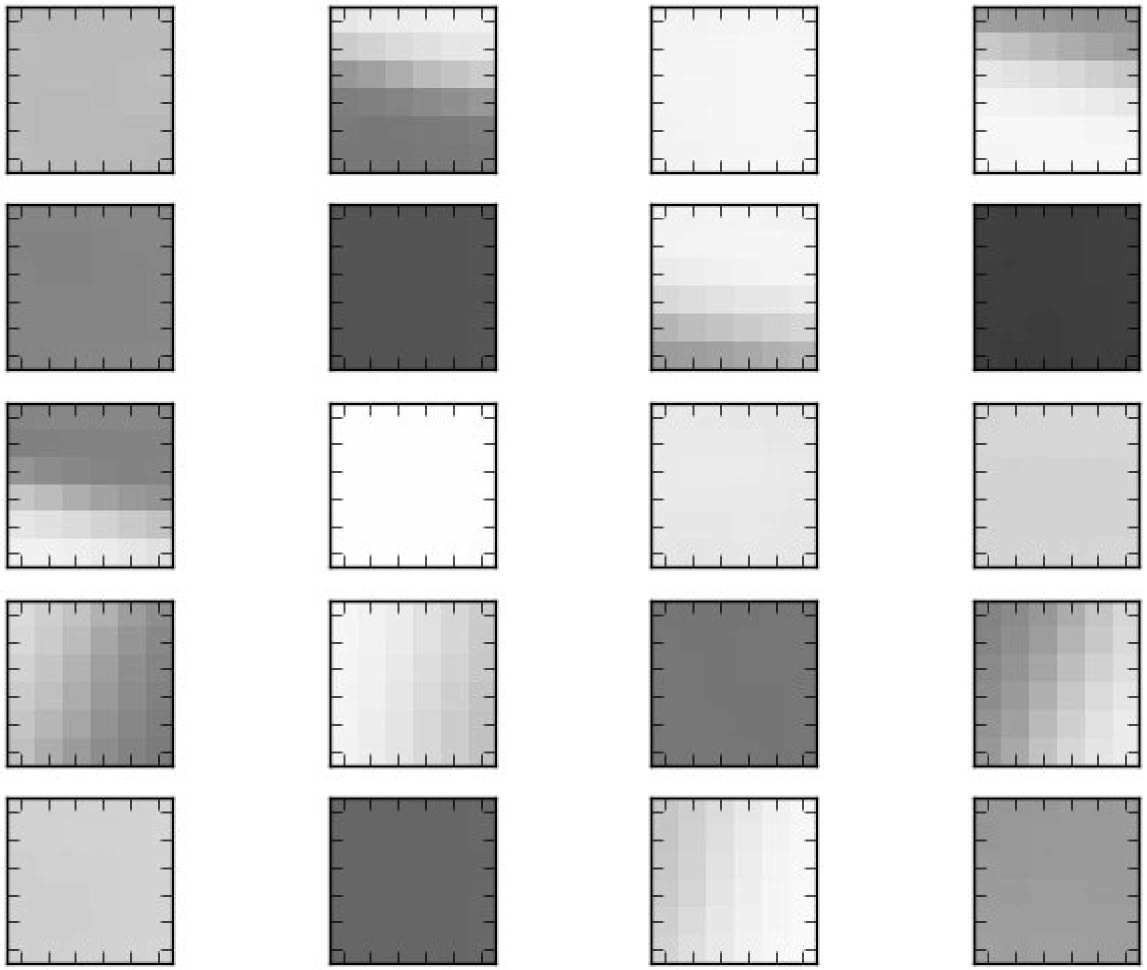


y

Which map is good?

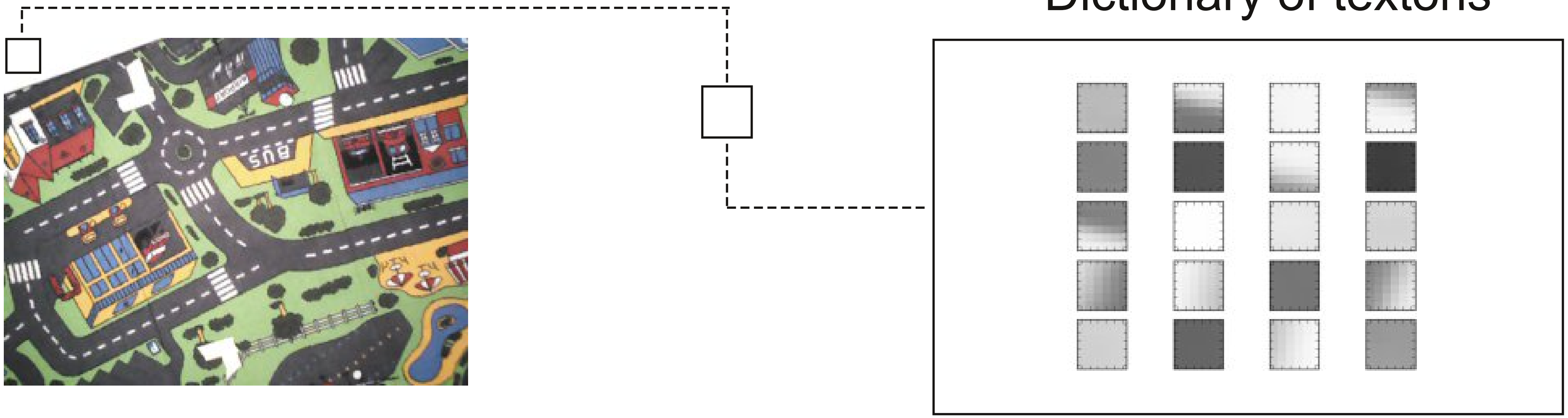


TEXTONS AS IMAGE FEATURES



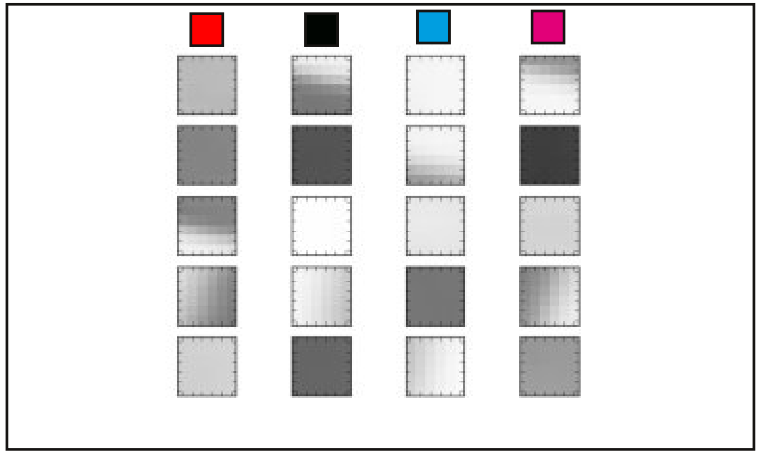
MACHINE-LEARNING APPROACH

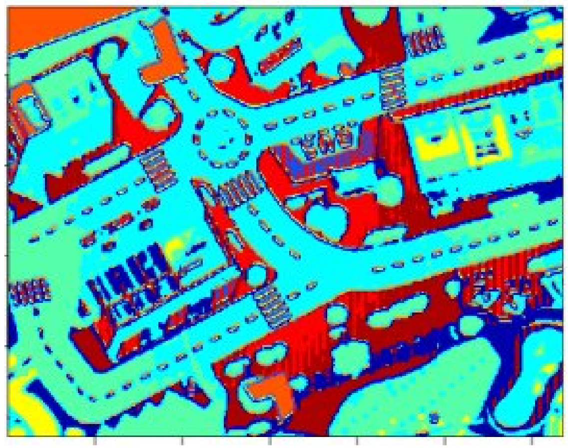
Dictionary of textons



MACHINE-LEARNING APPROACH

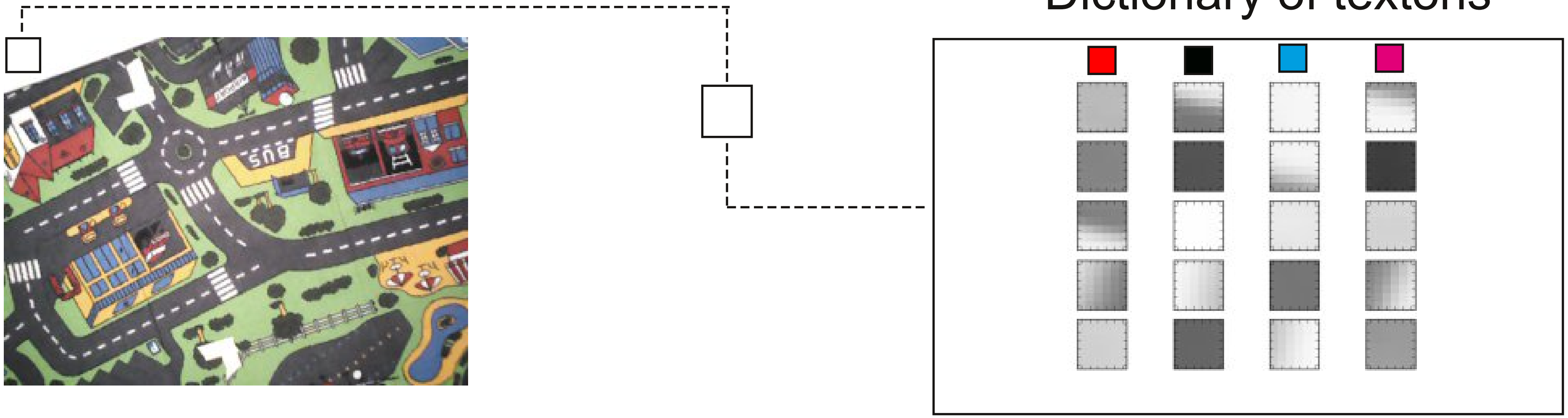
Dictionary of textons



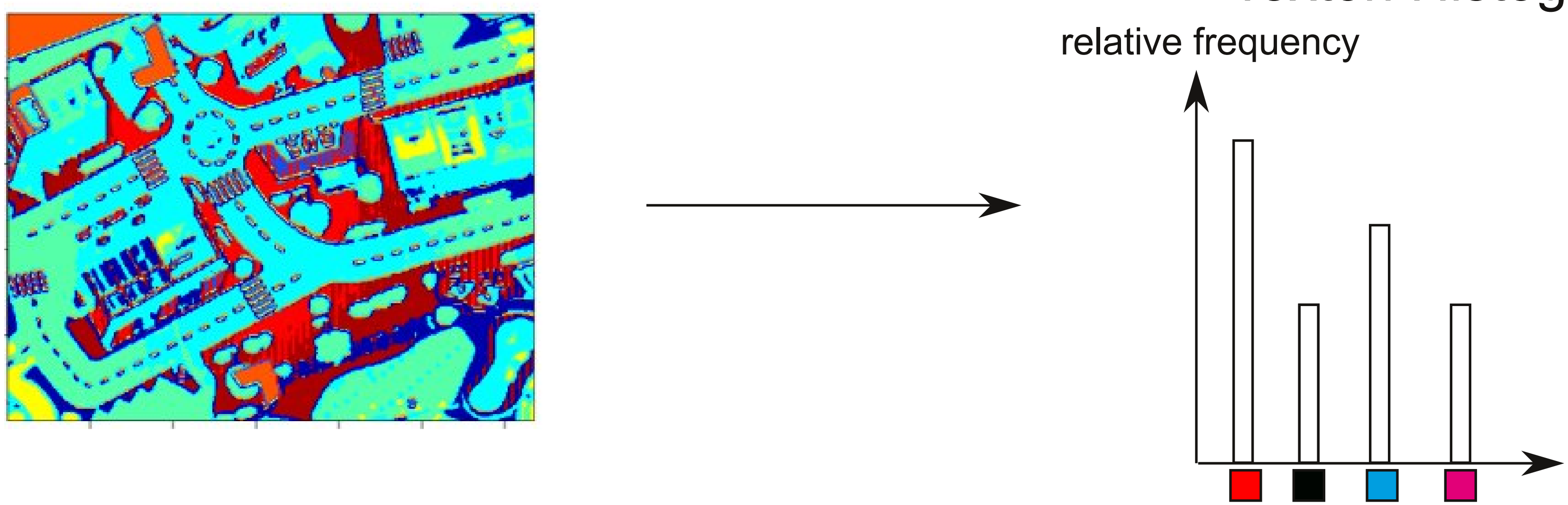


MACHINE-LEARNING APPROACH

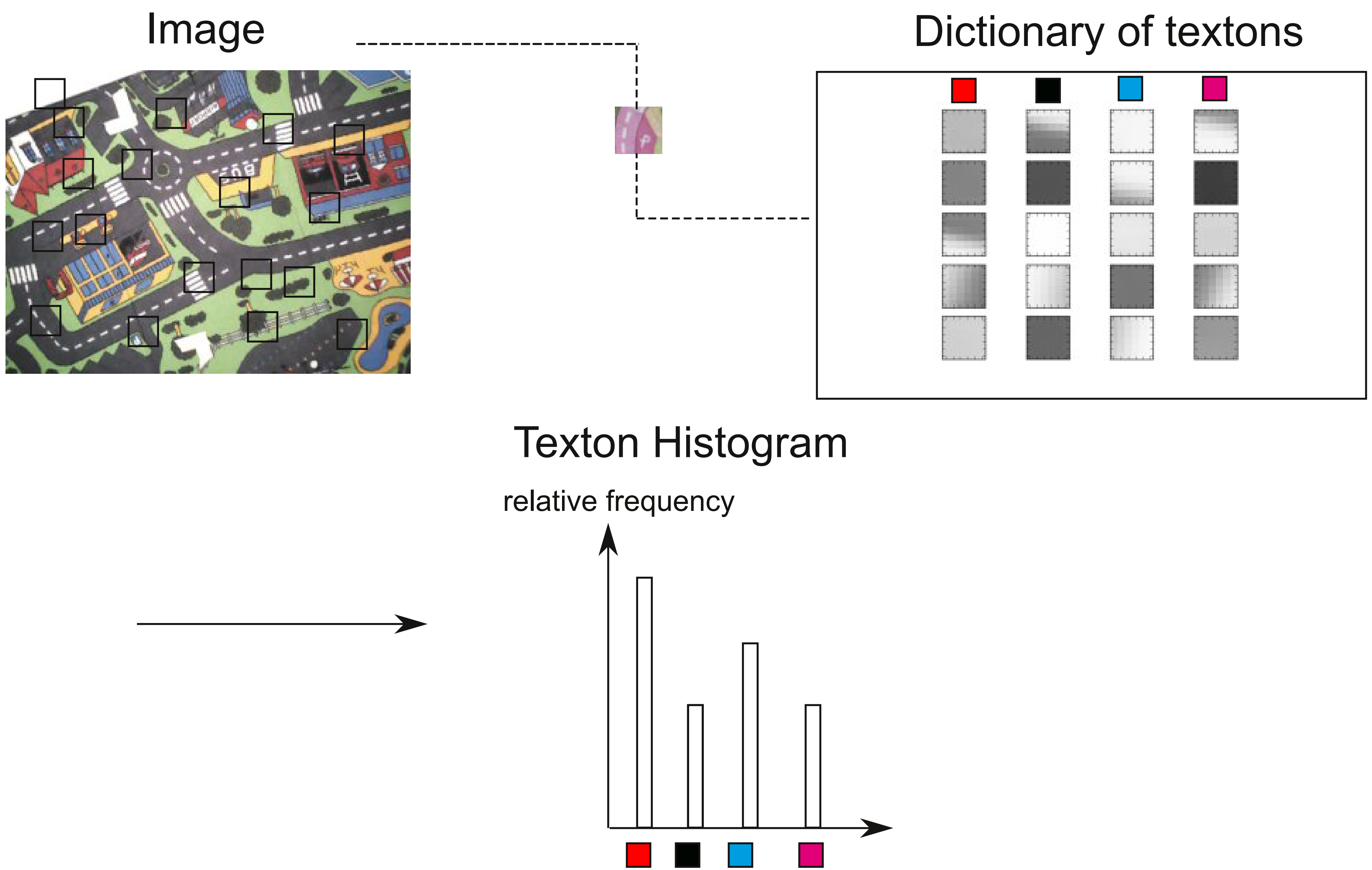
Dictionary of textons



Texton Histogram

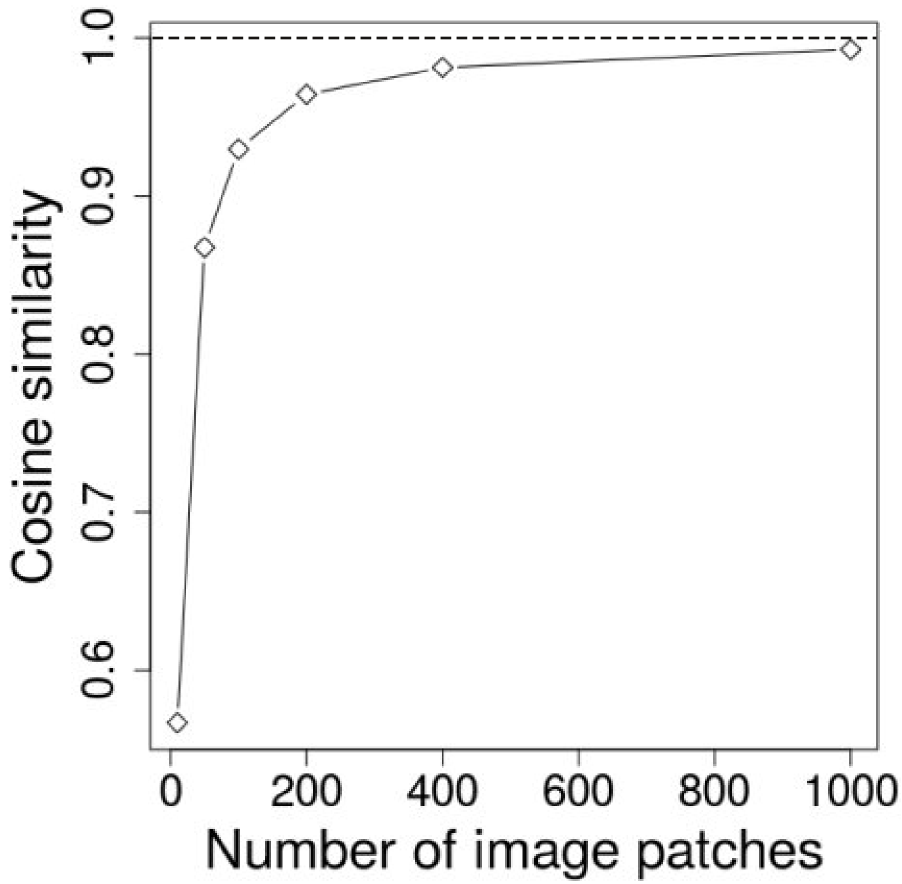


MACHINE-LEARNING APPROACH



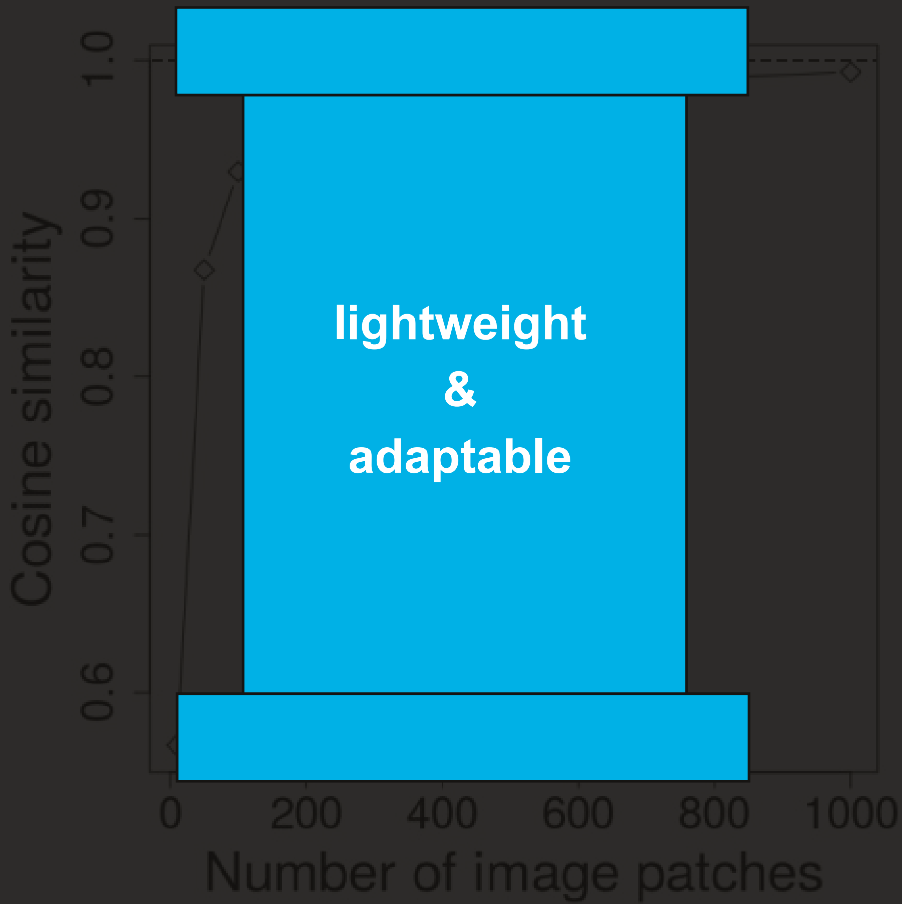
MACHINE-LEARNING APPROACH

307200!



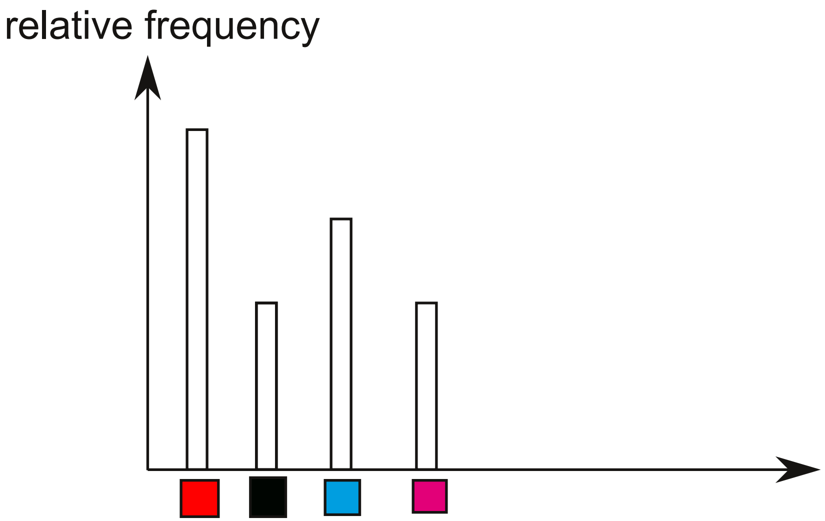
MACHINE-LEARNING APPROACH

307200!

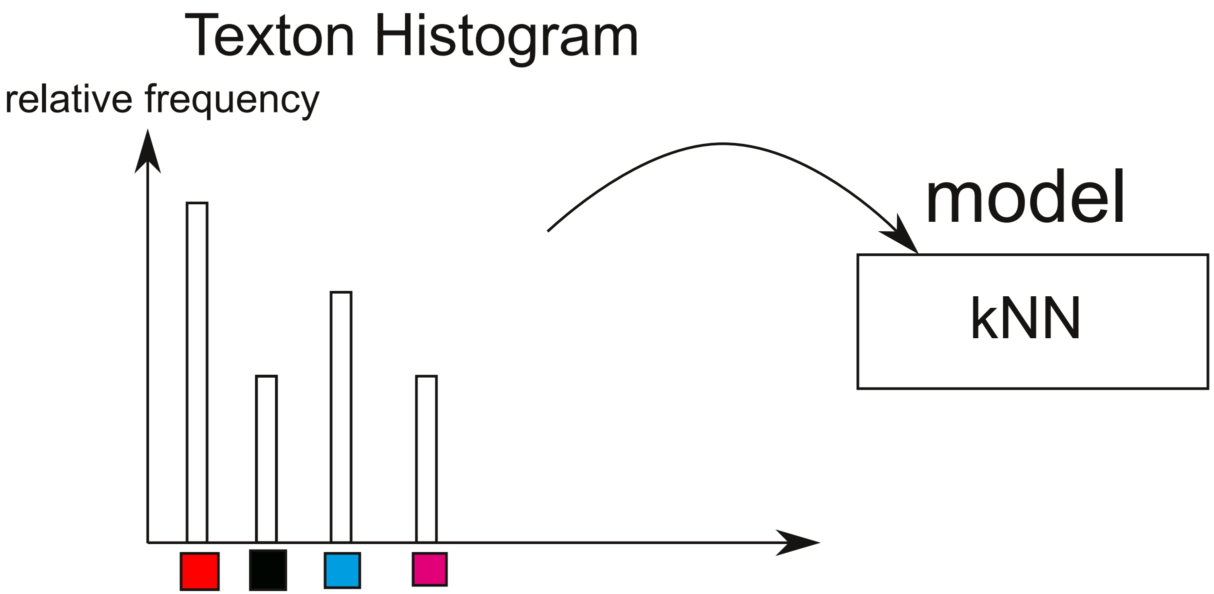


MACHINE-LEARNING APPROACH

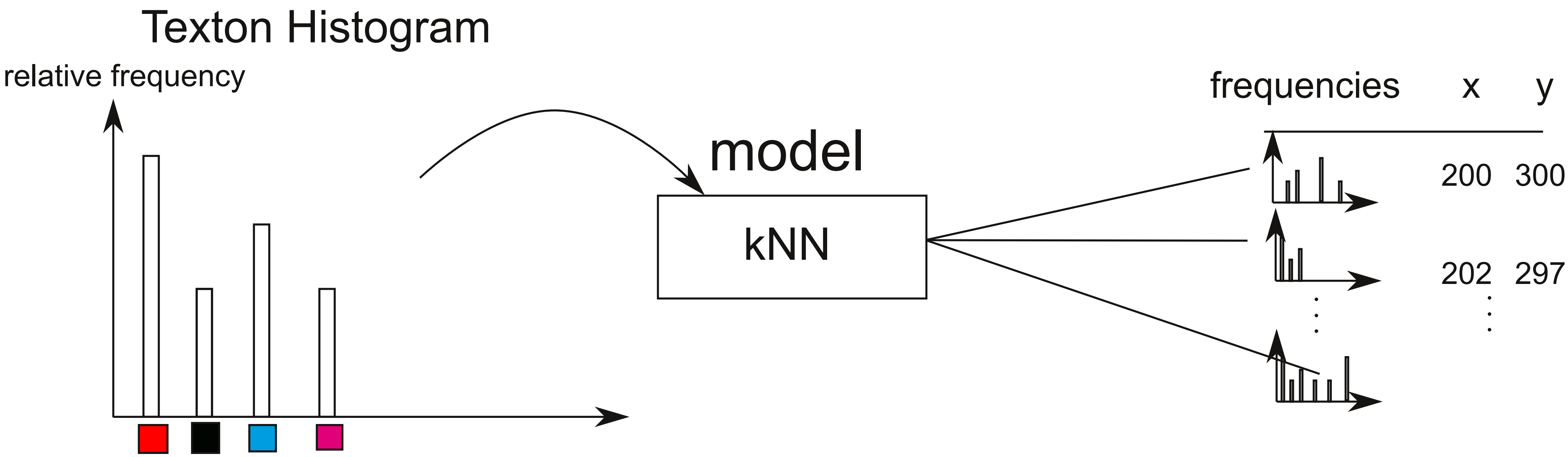
Texton Histogram



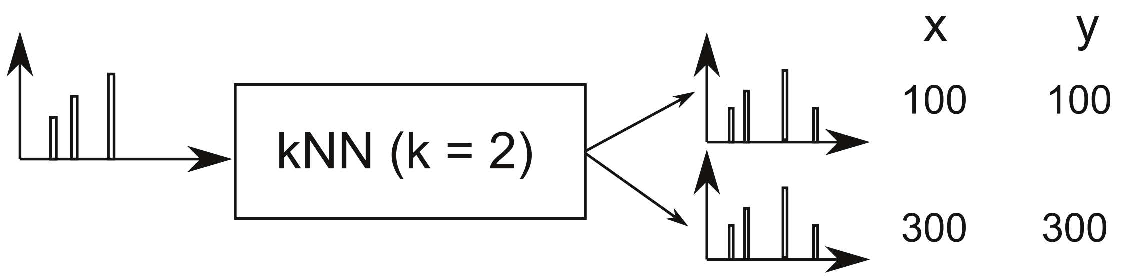
MACHINE-LEARNING APPROACH

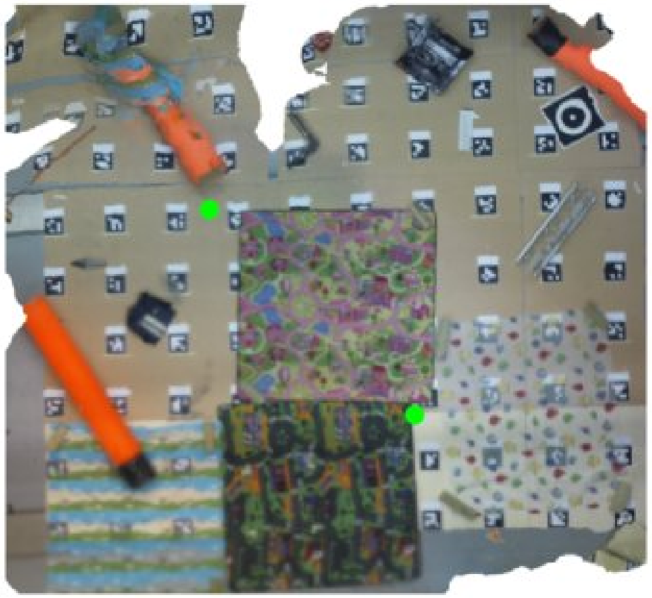


MACHINE-LEARNING APPROACH



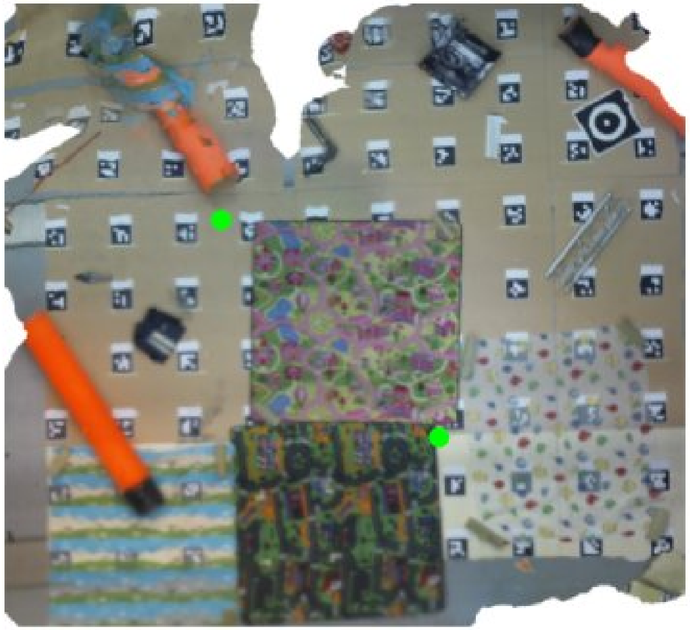
FILTERING





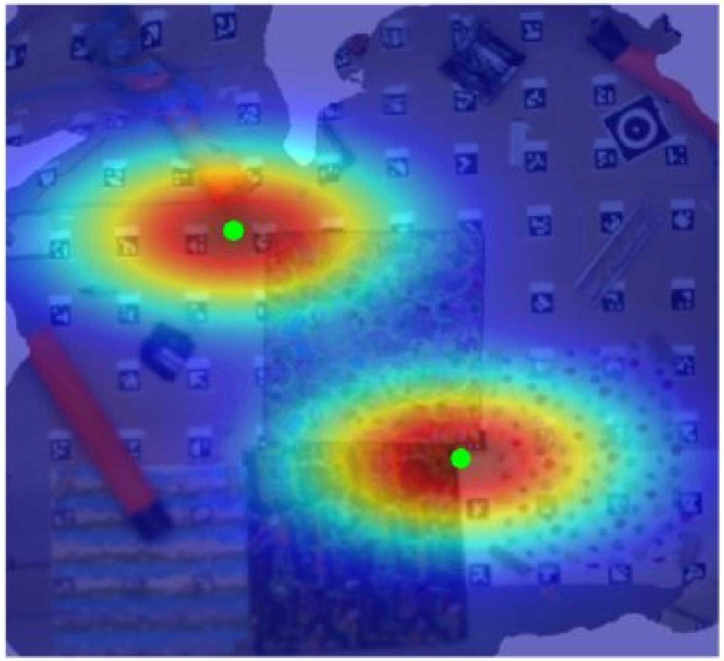
FILTERING

Sensor model (Likelihood)



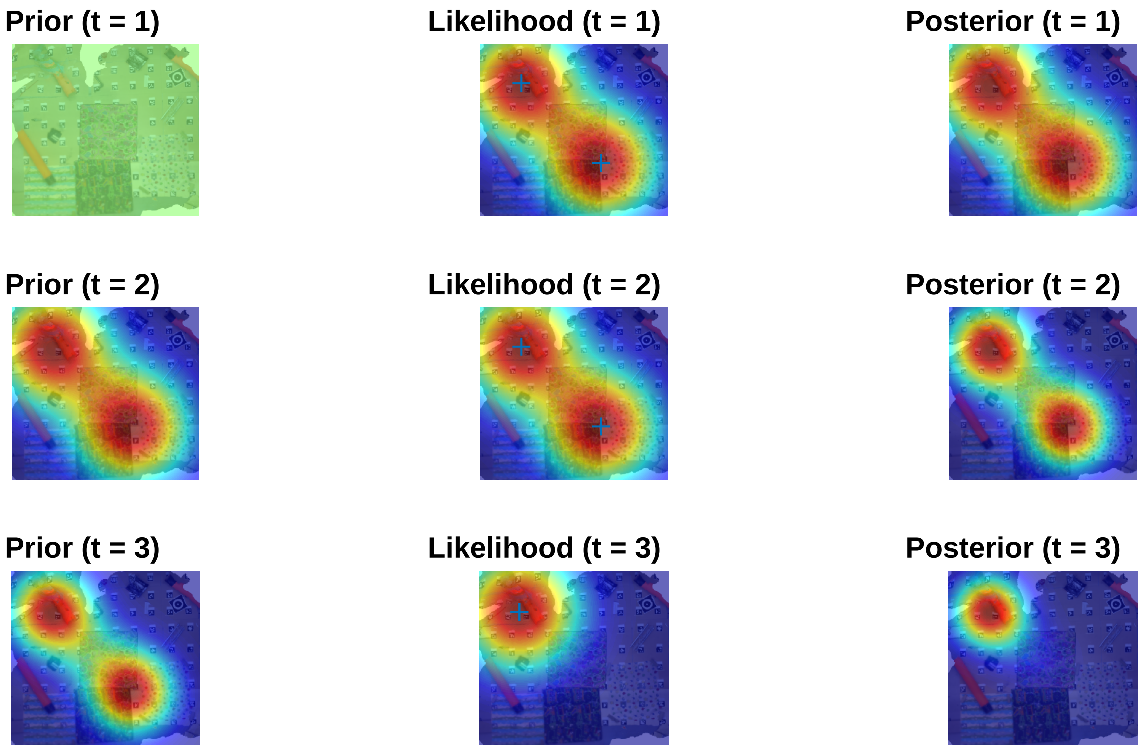
FILTERING

Sensor model (Likelihood)

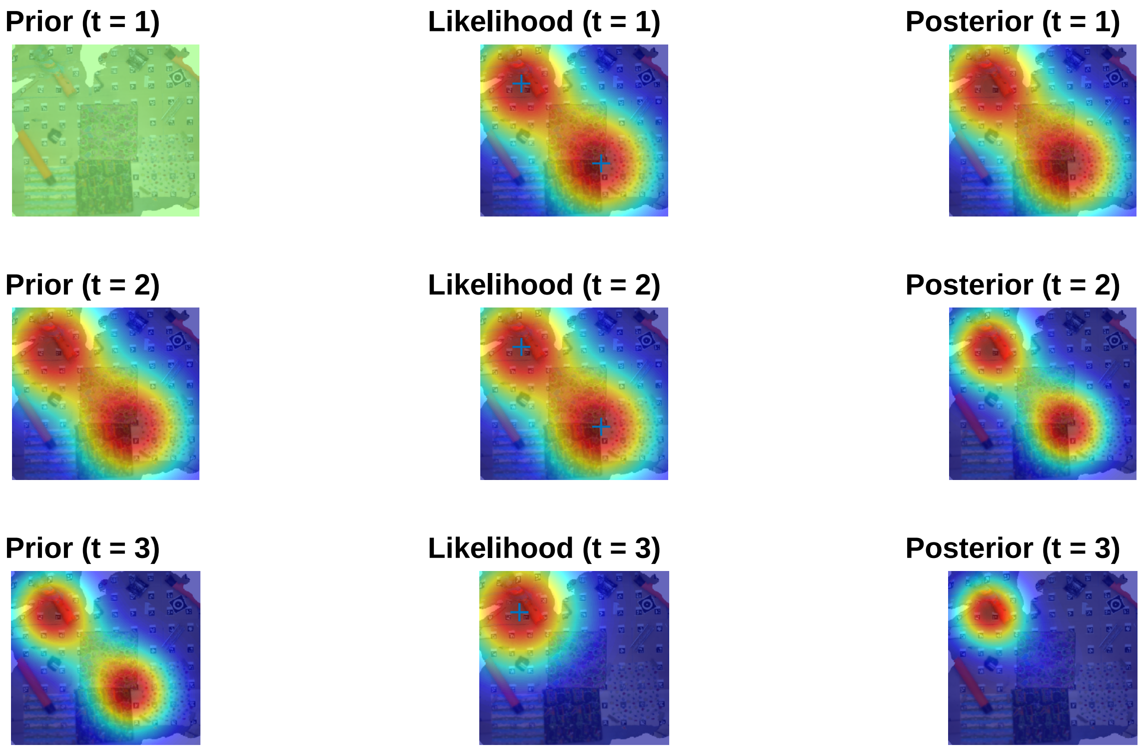


2-D Gaussian mixture model

FILTERING

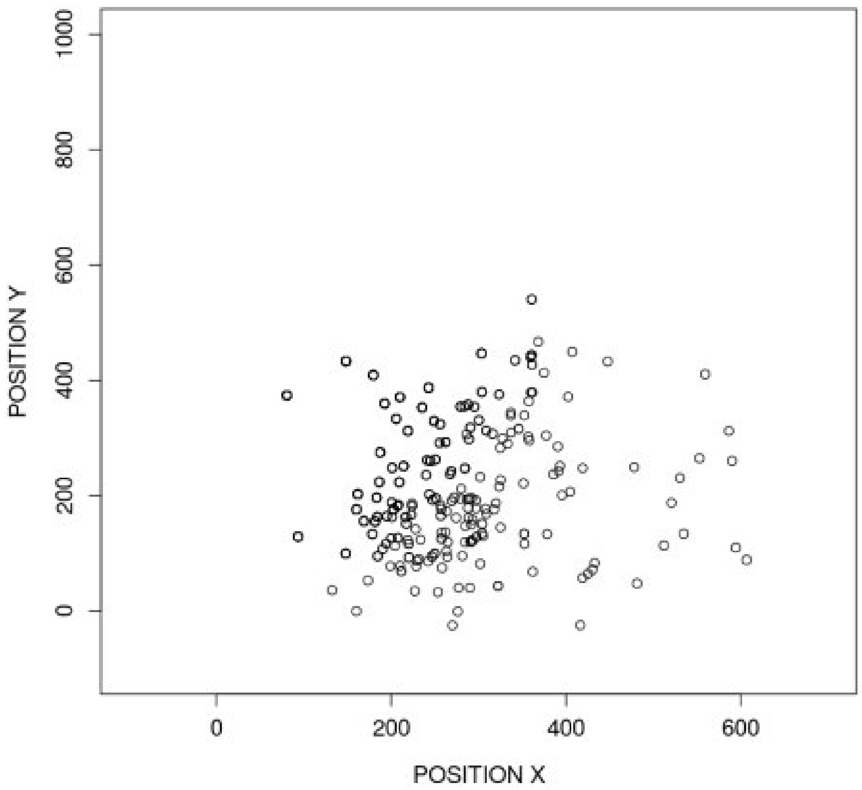

Prior (t = 1)
Likelihood (t = 1)
Posterior (t = 1)
Prior (t = 2)
Likelihood (t = 2)
Posterior (t = 2)
Prior (t = 3)
Likelihood (t = 3)
Posterior (t = 3)

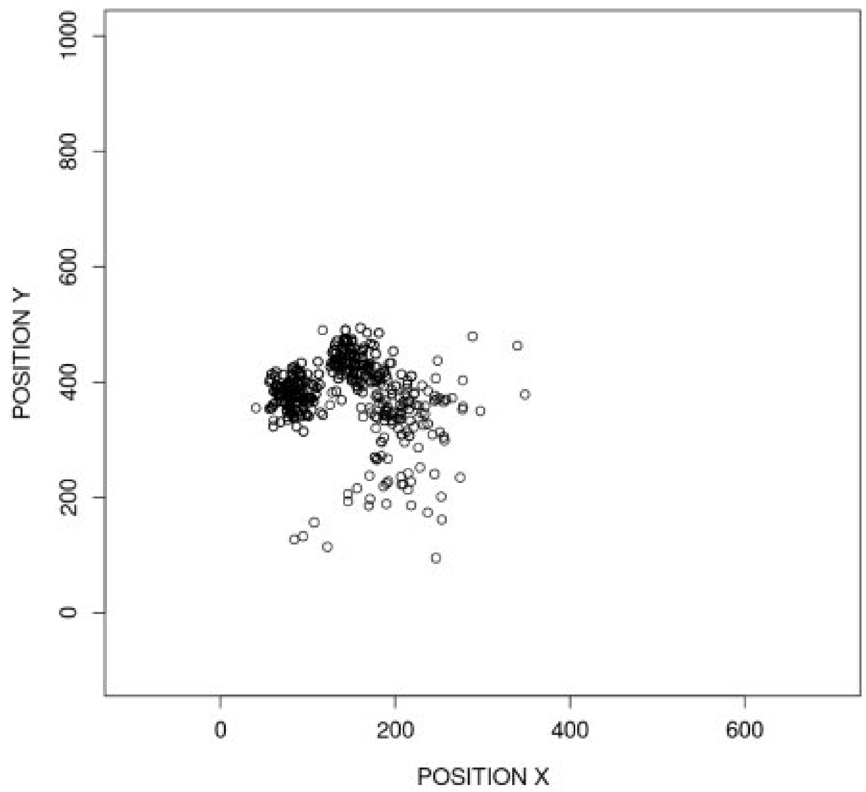
FILTERING



+ proximity-based motion model

PARTICLE FILTER





DUMMY: VIDEO FAST FLIGHT

DUMMY: PARTICLE FILTER

lightweight
&
adaptable

MAP EVALUATION

MAP EVALUATION

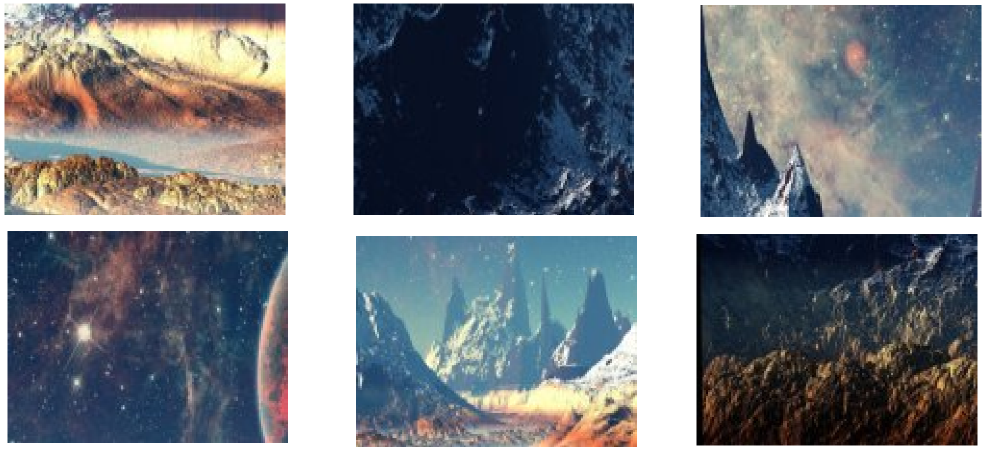
IDEAL SIMILARITY OF HISTOGRAMS FOR FIXED POSITION

MAP EVALUATION - SYNTHETIC FLIGHT

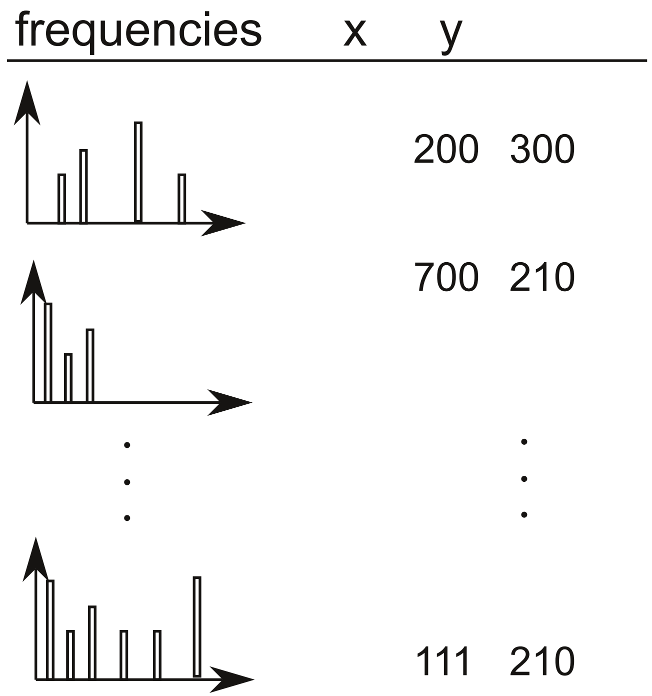
MAP EVALUATION - SYNTHETIC FLIGHT

synthetic flight

MAP EVALUATION - SYNTHETIC FLIGHT

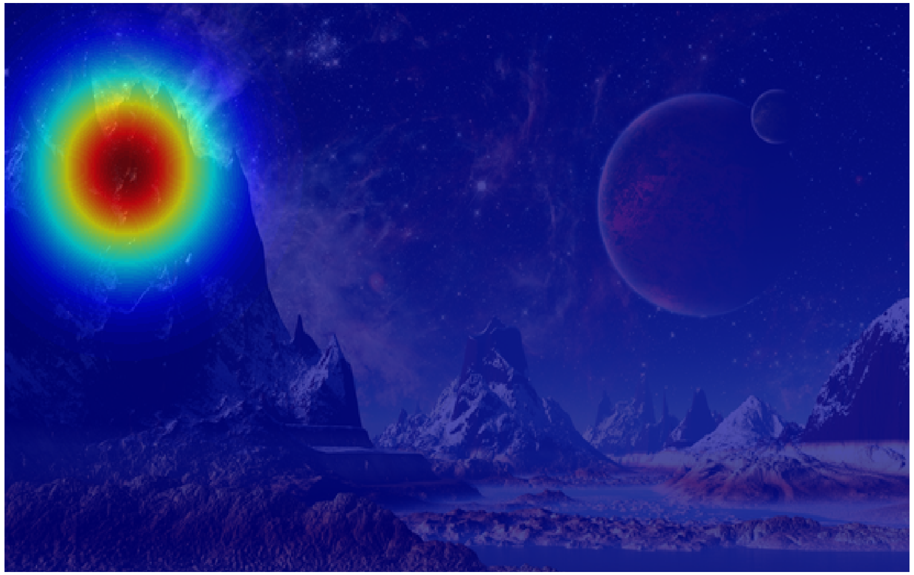


1000 patches

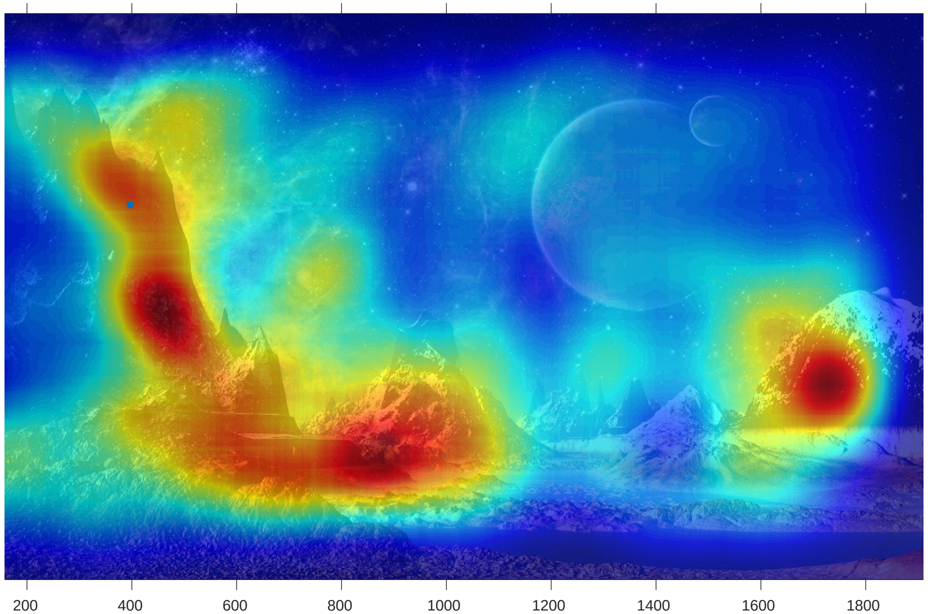


Training Data

MAP EVALUATION

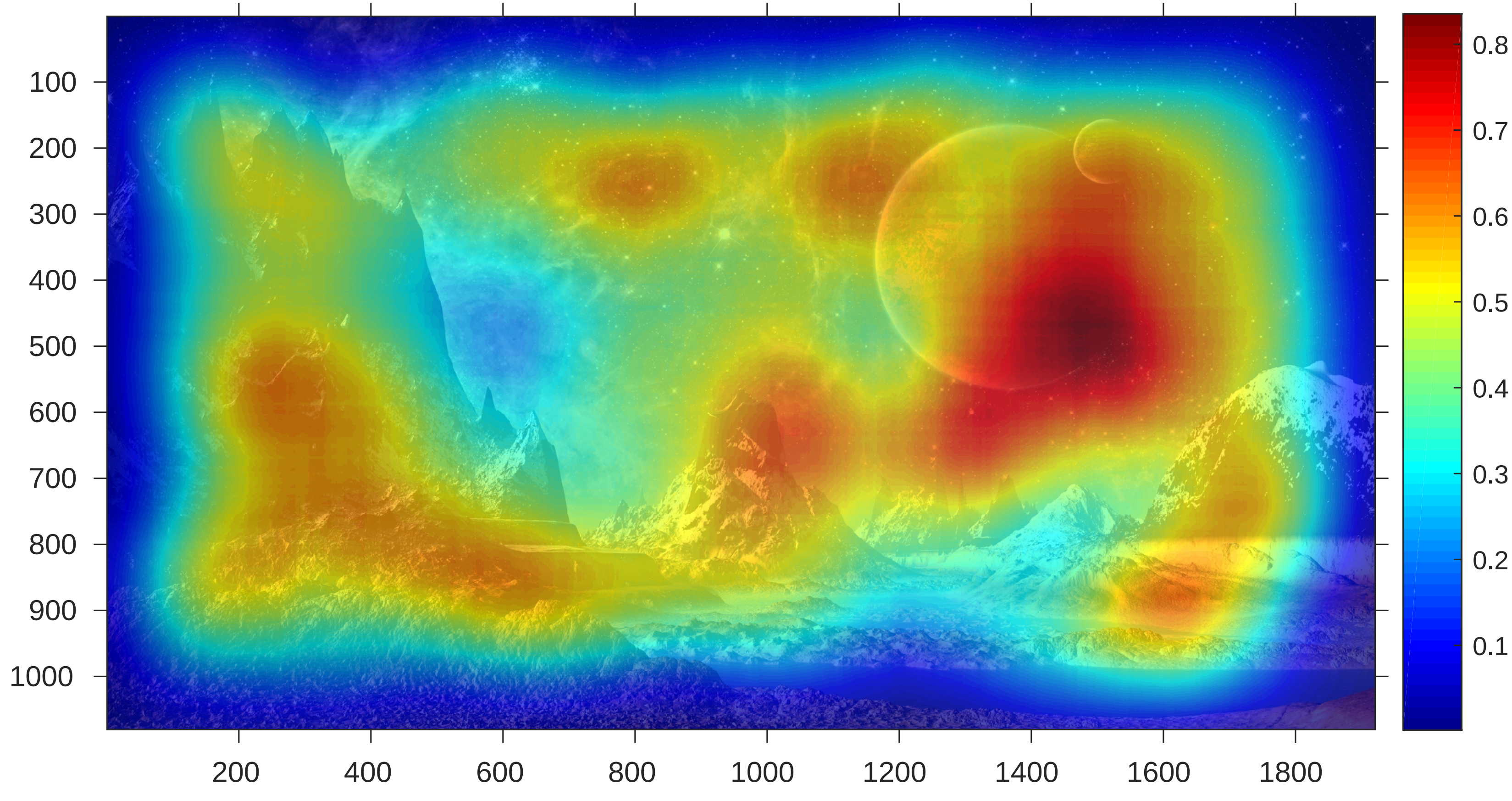


IDEAL SIMILARITY OF HISTOGRAMS FOR FIXED POSITION



ACTUAL SIMILARITY
(Gaussian smoothing)

MAP EVALUATION



GLOBAL LOSS (1000 patches)

0 < global loss < 1

MAP EVALUATION

GLOBAL LOSS (1000 patches)

0 < global loss < 1

OUTLINE

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Methods

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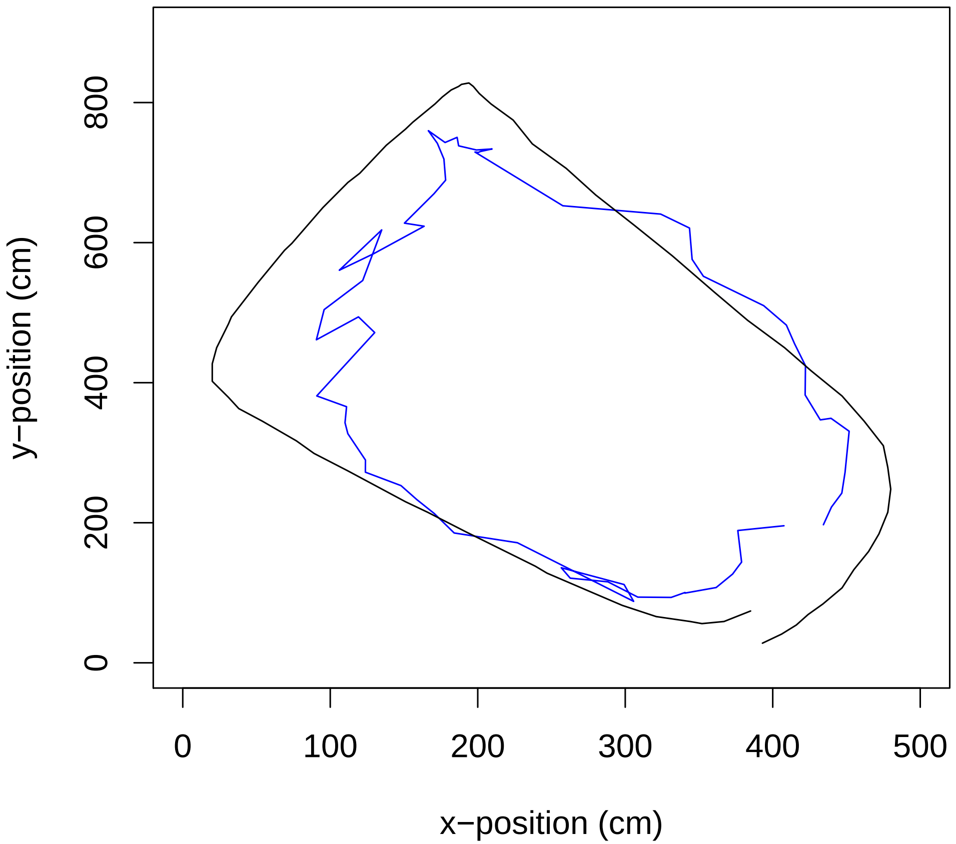
Discussion & Conclusion

FLIGHT ACCURACY

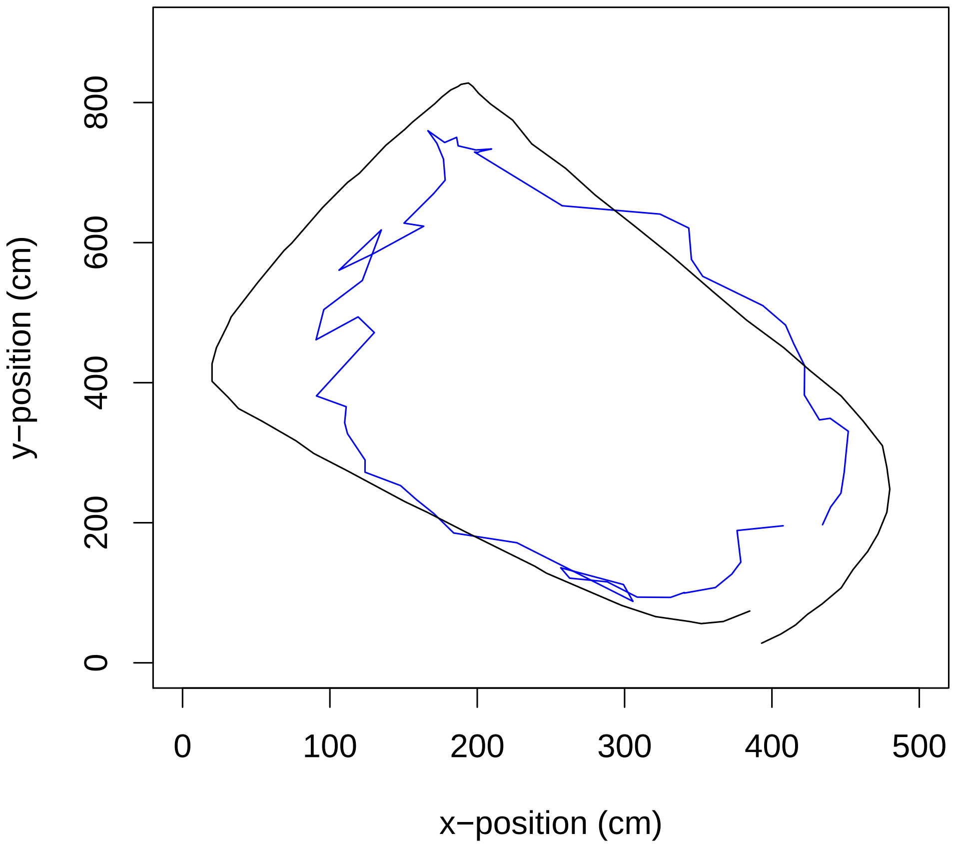


Flight with 400 images

Mean distance x: 46 cm

Mean distance y: 54 cm

FLIGHT ACCURACY



Flight with 400 images

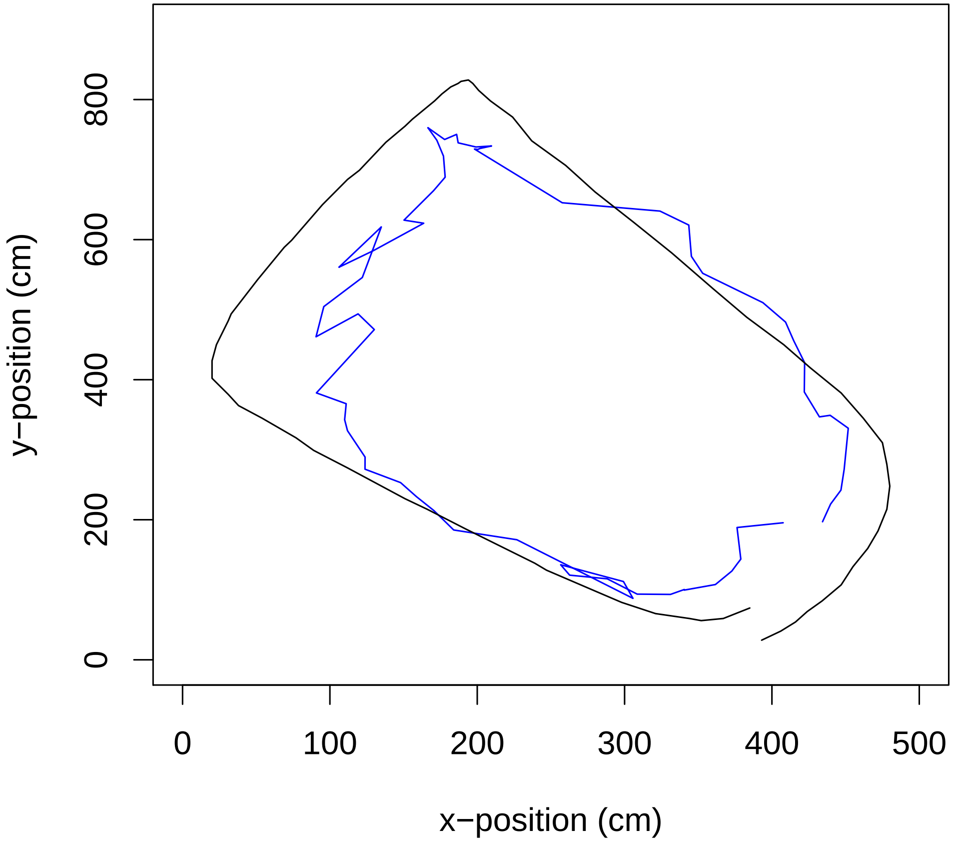
Mean distance x: 46 cm

Mean distance y: 54 cm

SD distance x: 56 cm

SD distance y: 71 cm

FLIGHT ACCURACY



Flight with 400 images

Mean distance x: 46 cm

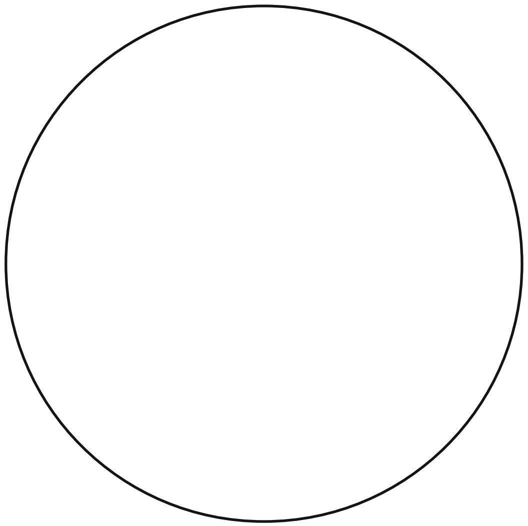
Mean distance y: 54 cm

SD distance x: 56 cm

SD distance y: 71 cm

Frequency: 12 Hz

TRIGGERED LANDING



6 Landings

criterion:
distance < 60 cm

safety criterion:
low variance of particles

DUMMY: VIDEO TRIGGERED LANDING

MAP EVALUATION









46 images

MAP EVALUATION - LOSSES

OUTLINE

Motivation & Setting | Existing Methods | Proposed Method | Flight Tests & Simulations | **Discussion & Conclusion**

RESEARCH QUESTIONS

Research Question 1

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

Research Question 2

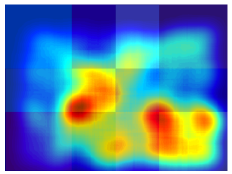
Can we predict the suitability of an environment for the proposed localization algorithm?

DISCUSSION

Implications:

- paves the way to indoor flight
- adaptable to different platforms

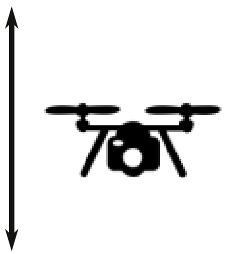
- detect safe landing spots

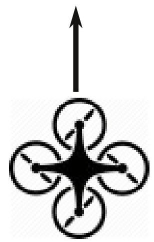


DISCUSSION

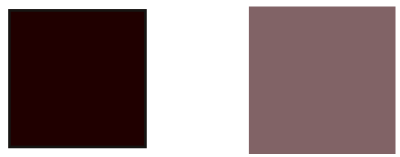
Limitations:

- assumes constant height and no rotations





- robustness to differerent lighting conditions

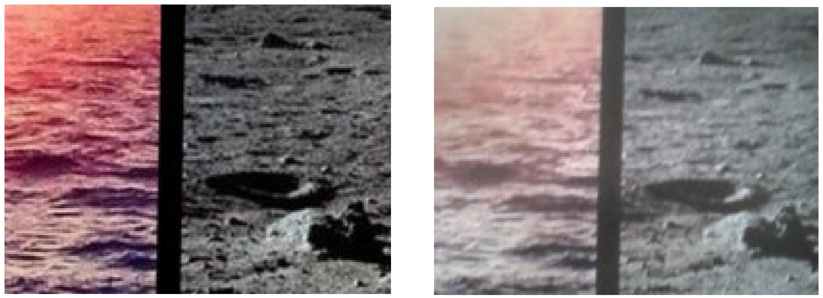


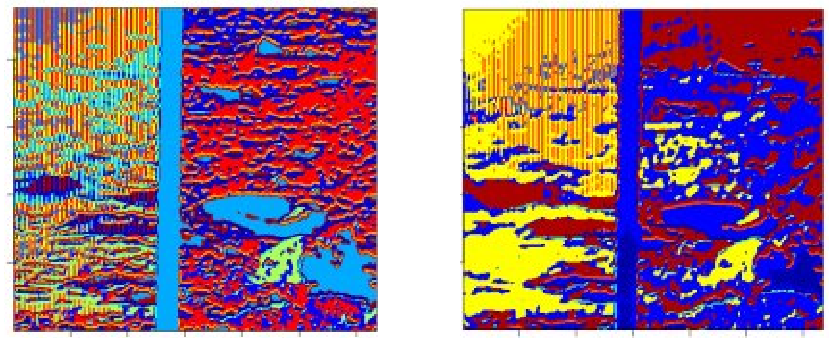
- particle filter does not include velocity or heading

DISCUSSION

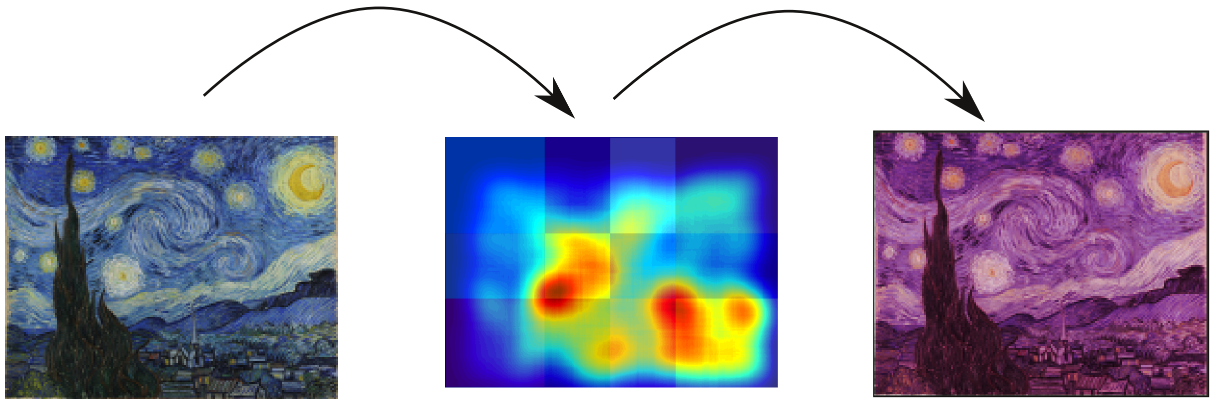
Future research:

- bridge reality gap





- automatic map generation (evolutionary algorithm)



CODE CONTRIBUTIONS

- draug: Image augmentation with synthetic views (C++)

  https://github.com/Pold87/draug

- Map evaluation (MATLAB)

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

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

  TODO: PULL REQUEST C: https://github.com/Pold87/paparazzi Python: https://github.com/Pold87/treXton

PAPARAZZI
The Free Autopilot

CONCLUSION

EFFICIENT INDOOR LOCALIZATION

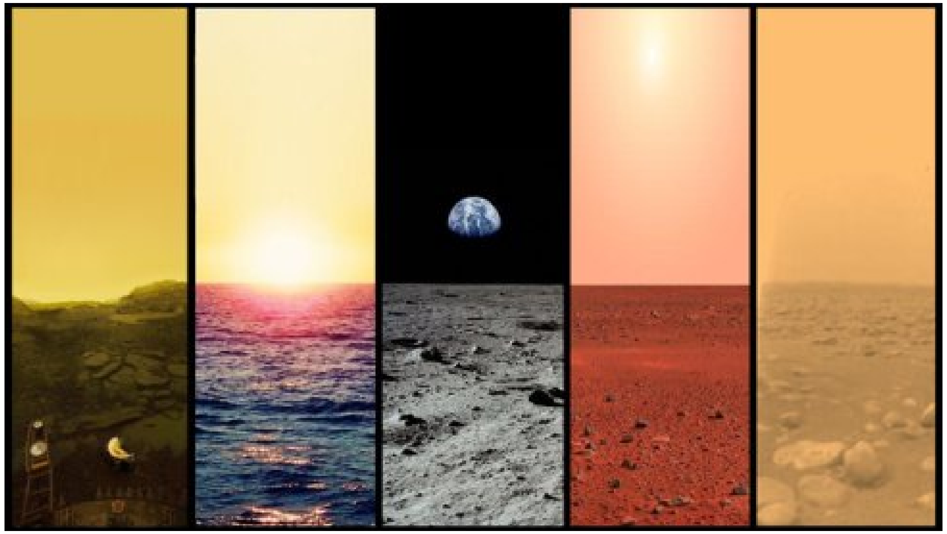
shift of processing power

lightweight & adaptable algorithms

modifiable environment

MAP EVALUATION

GOOD

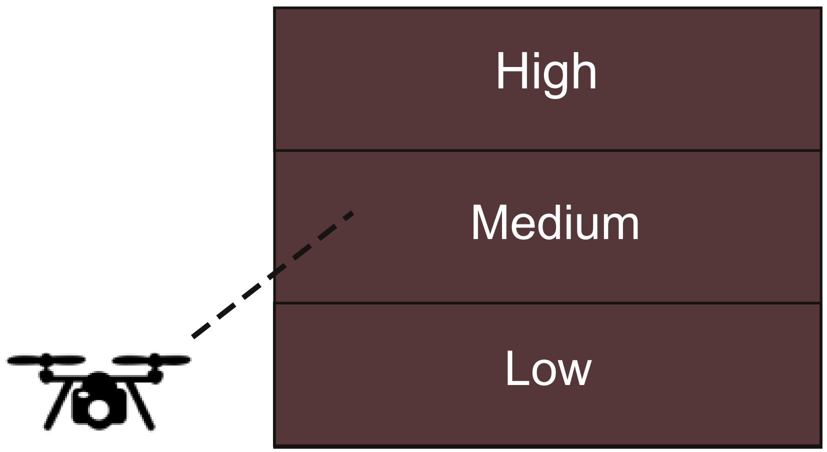


0.57

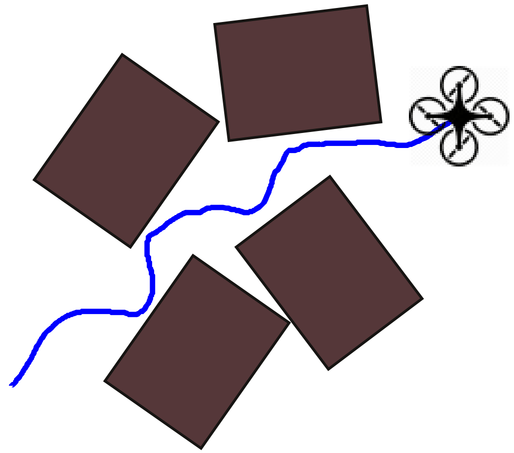
BAD

0.98

FOUNDATION

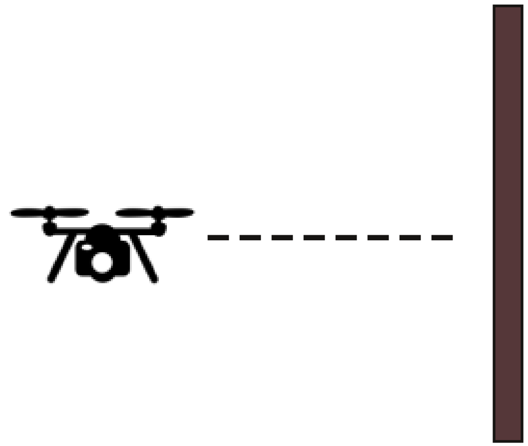


Height control



Obstacle Avoidance

Safe Landing Spot Detection



Distance Measurement

PARTICLE FILTER

Motion model

2D-Gaussian noise