No GPS Drone Navigation

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BFH > HuCE > cpvrLab
Benjamin Fankhauser & Marcus Hudritsch

Berner Fachhochschule
Haute école spécialisée bernoise
Bern University of Applied Sciences

cpvrLab: Who We are:

- **cpvrLab** stand for: **C**omputer **P**erception & **V**irtual **R**eality **Lab**
- We are an Applied Research & Development Group within the **HuCE** Institute.
- We currently have 520% R&D employees:

C. Blanc
Cand. PhD.
MSc. Microtech.

B. Fankhauser
MSc. CS

L. Girod
MSc. CS

P. v. Niederhäusern
MSc. CS

L. Renfer
MSc. Robotics

C. Wyss
BSc. CS

M. v. Wattenwyl
Apprentice

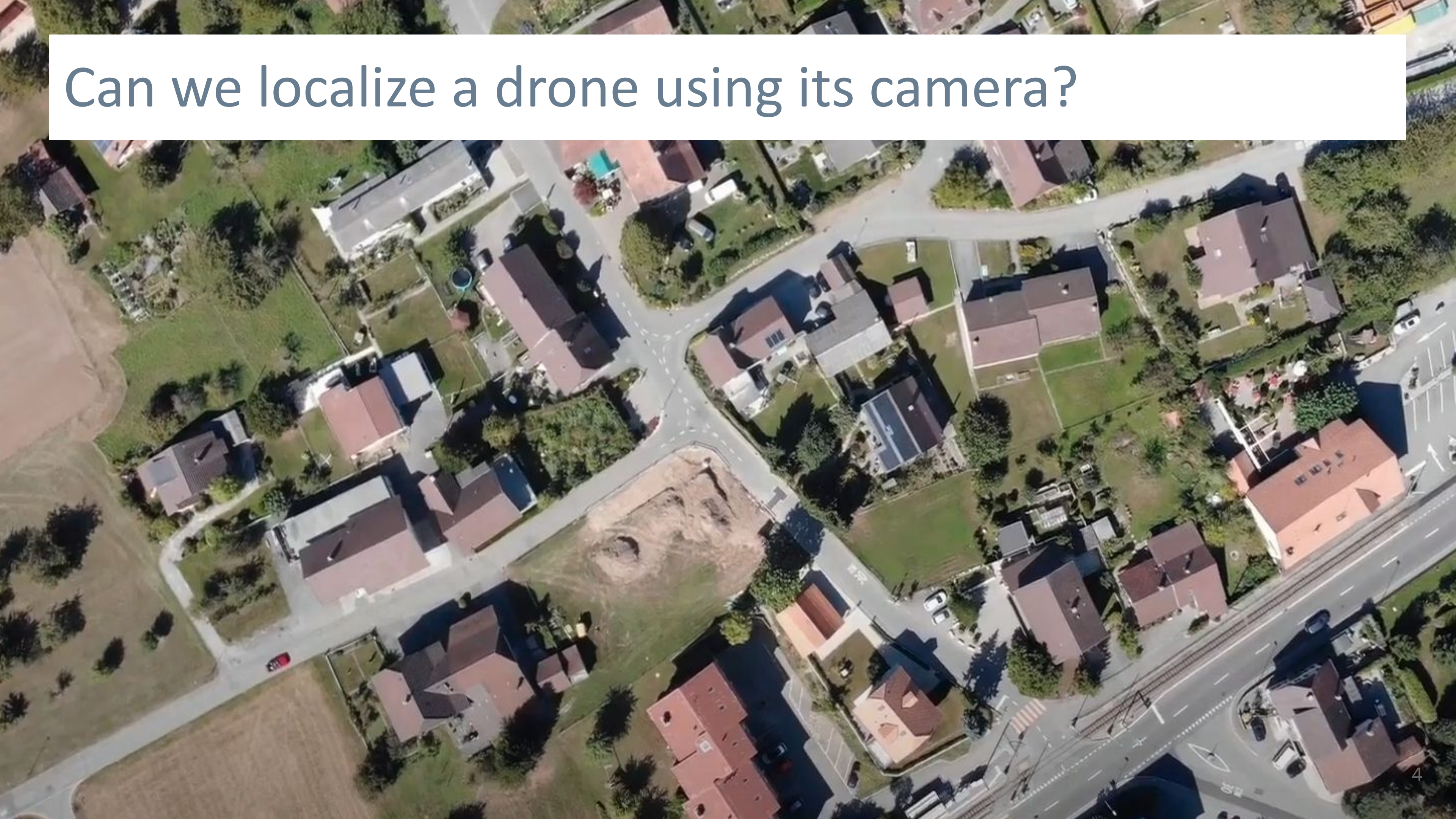
cpvrLab: Who We are:

- We are also a Specialization within the BFH - Computer Science department.
- We are currently 6 lecturers:

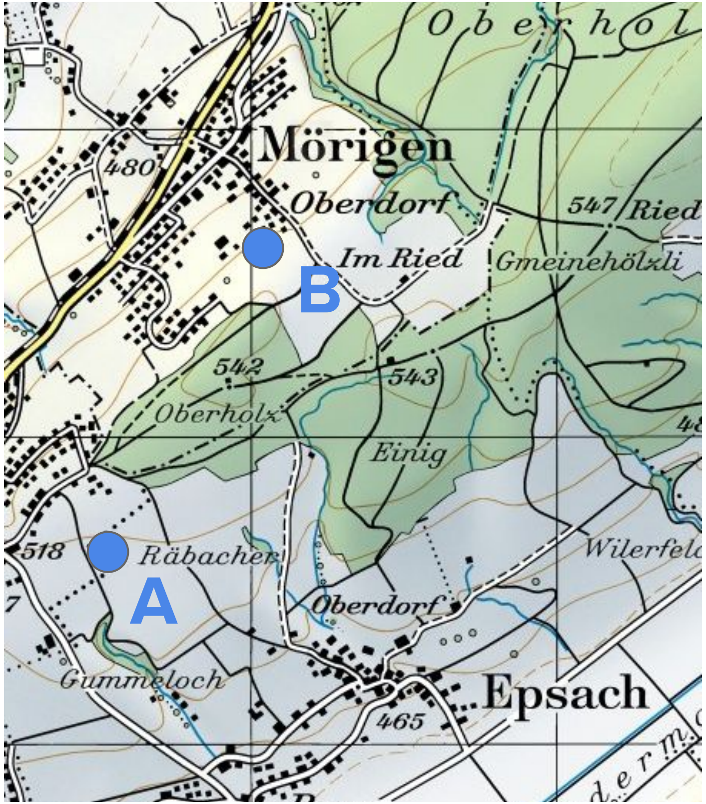
B. Anrig | S. Dégallier | J. Eckerle | C. Furrer | M. Hudritsch | U. Künzler

and try to teach
image analysis &
image synthesis
to ~40 students
in 2 semesters:

Can we localize a drone using its camera?



Can we localize a drone using its camera?



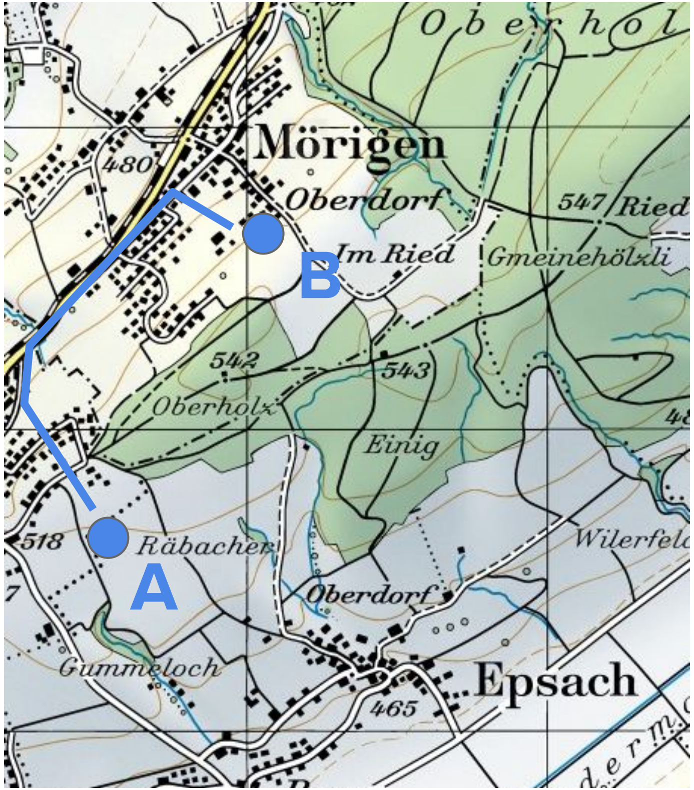
- Could we fly from A to B without GPS?

Outline

- Absolute and relative pose estimation
- Autoencoders
- Results

Feasibility study: "Can a drone navigate inside a GPS denied environment?"
armasuisse 2019

Flight from A to B: Conditions:



- We can choose the flight path
- We know position A and B
- We have swisstopo data
- We have sensors:
  - Barometer (height)
  - Compass (yaw)
  - Stabilized Camera (pointing downwards)

- **Solve for: x, y.**

Localization Problem

- Short term localization:
  - **Relative** position from frame to frame
  - ORB Slam, Optical flow, etc
  - Error sums up over frames (Drift)
  - Can (and will) loose tracking

- Long term localization:
  - Find **absolute** position
  - Few literature
  - Outdoor environment is challenging

Baseline: Template Matching

(requires same orientation and scale)

$T:$ $I:$

u x

v y

x, y = Match(

100px

,

16000px

)

- Compute similarity score at each location
- Maximum score is returned location
- 56% Recall* on frames on validation flight

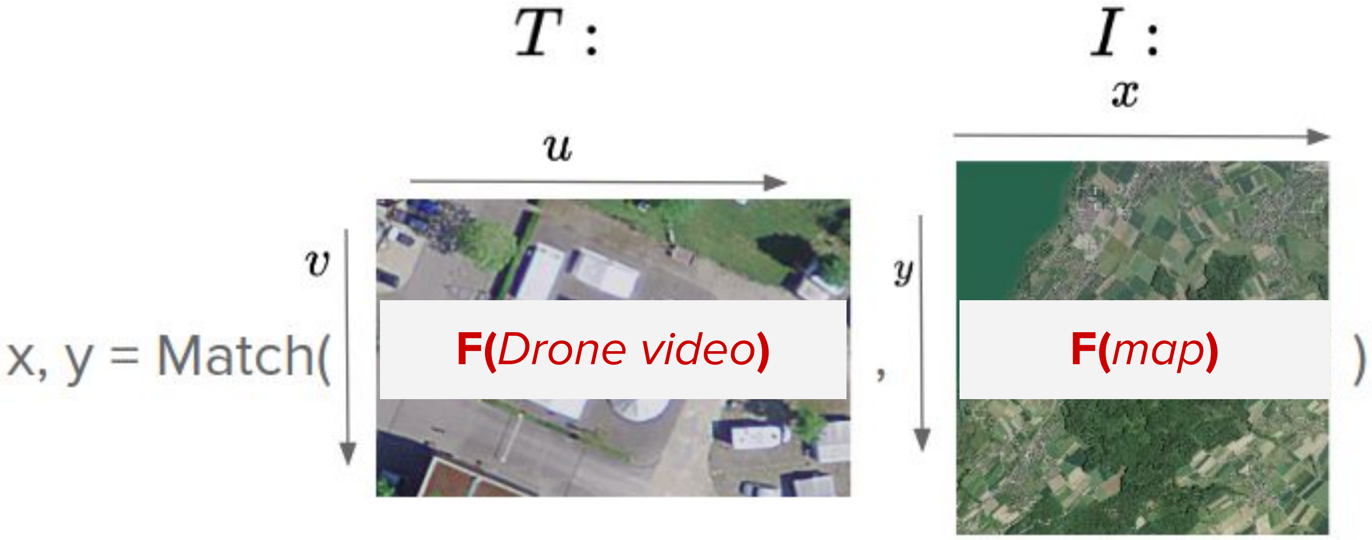
*56% of the frames were correctly localized (within 50m to the actual GPS location)

Baseline: Template Matching

Drone video

Ortho map

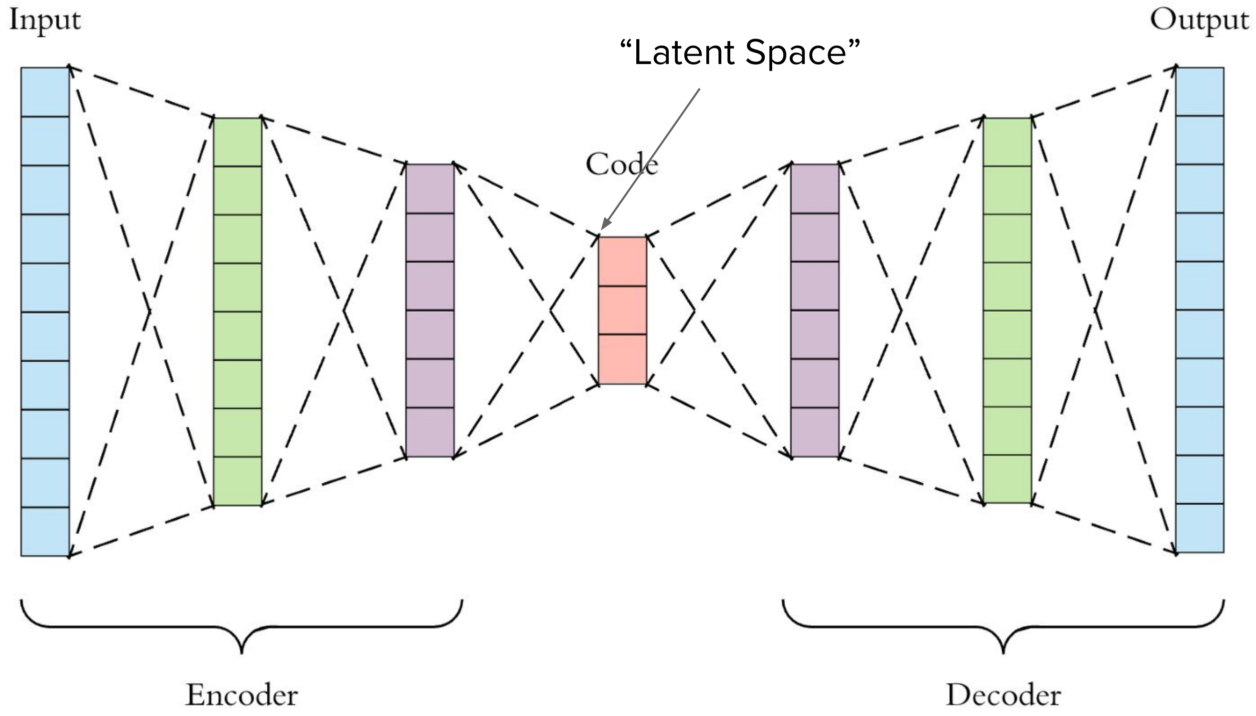
Reduction approach



F: reducer function

- Matches reduced version of video on reduced version of map

Auto Encoder

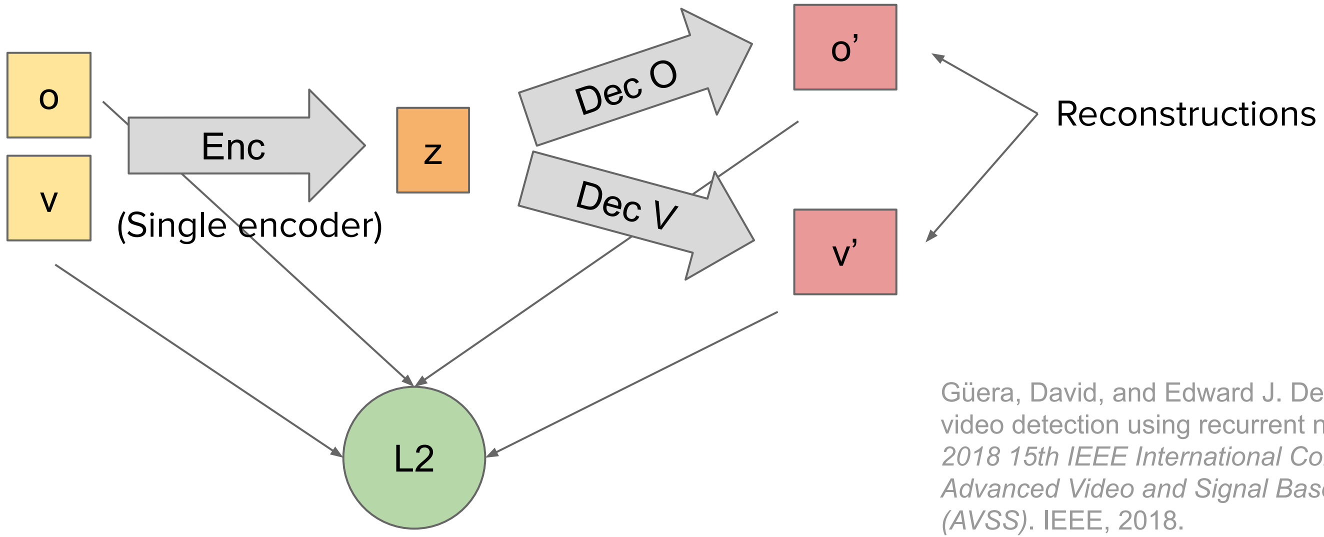


- train by minimize L2: ||in - out||
- Bottleneck in middle enforces compression
- Denoising, Compression, ...

Source: https://towardsdatascience.com/applied-deep-learning-part-3-autoencoders-1c083af4d798

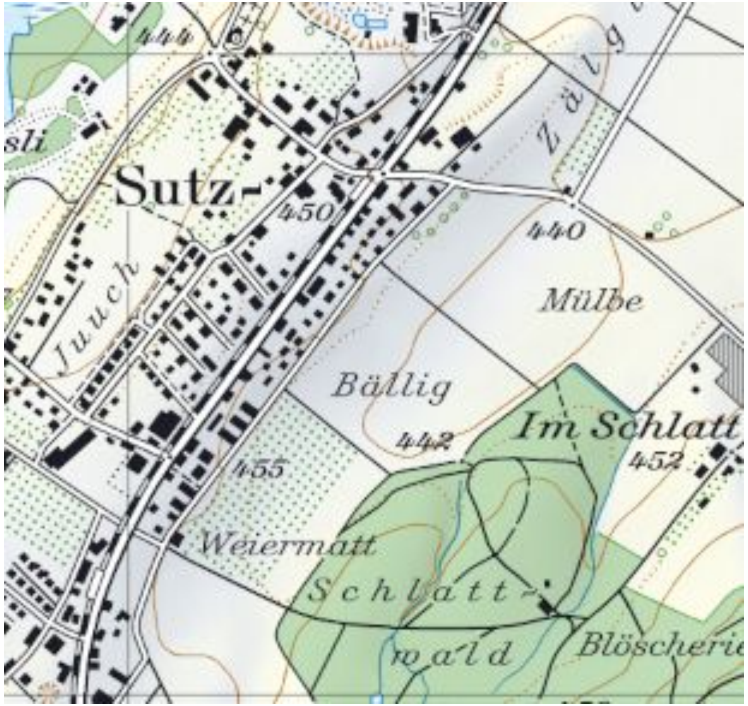
Deep Fake Approach

- Compress images using auto encoders.
- Swisstopo ortho image (o) and video (v) share same point in latent space (z) at the same location!



Güera, David, and Edward J. Delp. "Deepfake video detection using recurrent neural networks." *2018 15th IEEE International Conference on Advanced Video and Signal Based Surveillance (AVSS)*. IEEE, 2018.

Improvement: heavy image reduction



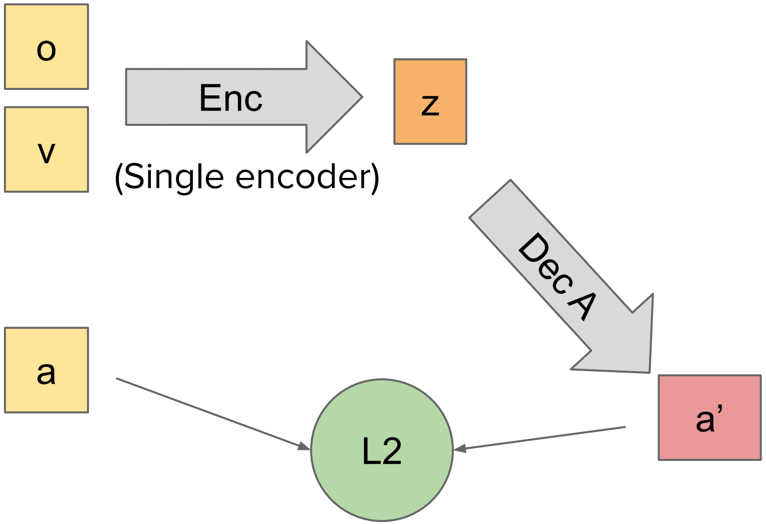
- Destroy anything unrelated to localization.
- Preserve anything related to localization.

- Reduces houses to black squares
- No cars, No details
- Reduce trees to circles or forests
- Unify color of fields

like this!

Supervised Approach

- Swisstopo ortho image (o) and video (v) share same point in latent space (z) at the same location!
- Decode to the abstract map (a')



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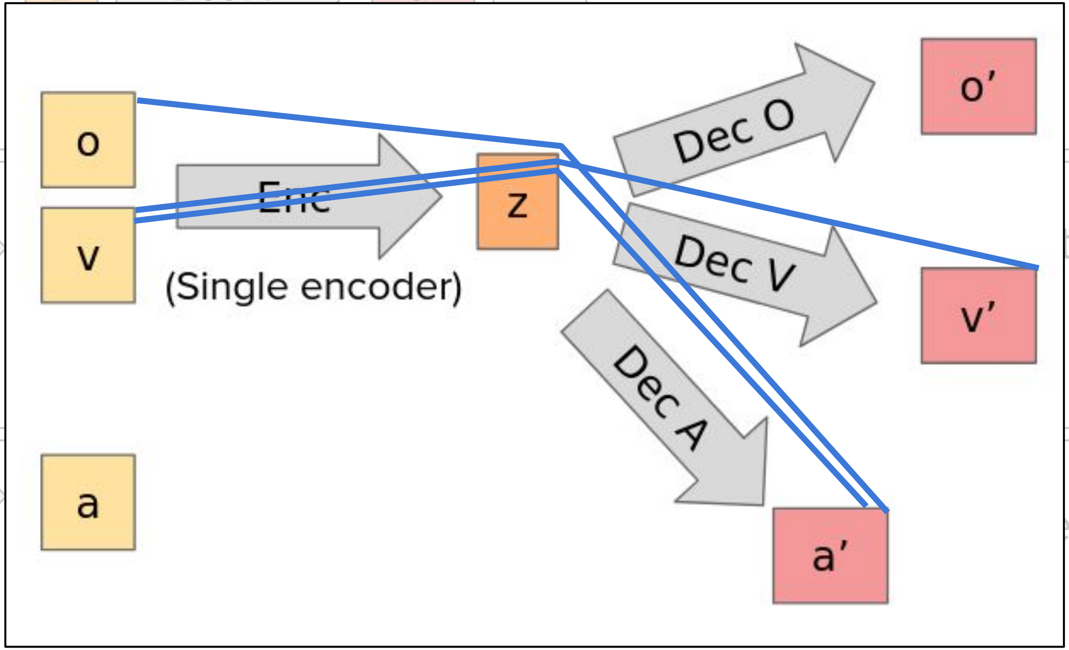
Deepfake Training Losses

- “Ortho to abstract”



tract”

eo”

Training Tripplets

Fully convolutional

We trained only convolutions, invariant to the size of the input.
We apply the learnt convolutions on the full 4x4 km patch:

Abstract patch

Reconstructed patch

In action

Precise Matching

Camera center

Our prediction

(GPS position at orange dot)
(large yellow circle has a radius of 12.5m)

- Crop around estimated position
- Run full resolution template matching

Results

- Trained on 3 flights. Reported numbers on flight 4:

Method	Recall Centers	Precision tiles	Fatal errors (>50m)
Template Matching	0.567	0.540	0
Autoencoder	0.533	0.493	0
DF w/o abstract maps	0.767	0.693	0
CycleGAN*	0.633	0.557	-
pix2pix*	0.633	0.557	-
DF with abstract maps	**0.950**	**0.927**	**0**

* Thomas Vögelin, MSE Project 1 “GPSless drone navigation”

Flight 2.1: Tissot Arena

- Construction sites

Flight 2.2: Biel city center

- Large shadows

Flight 2.3: Biel harbor

- Special place

Flight 2.4: Sutz forest

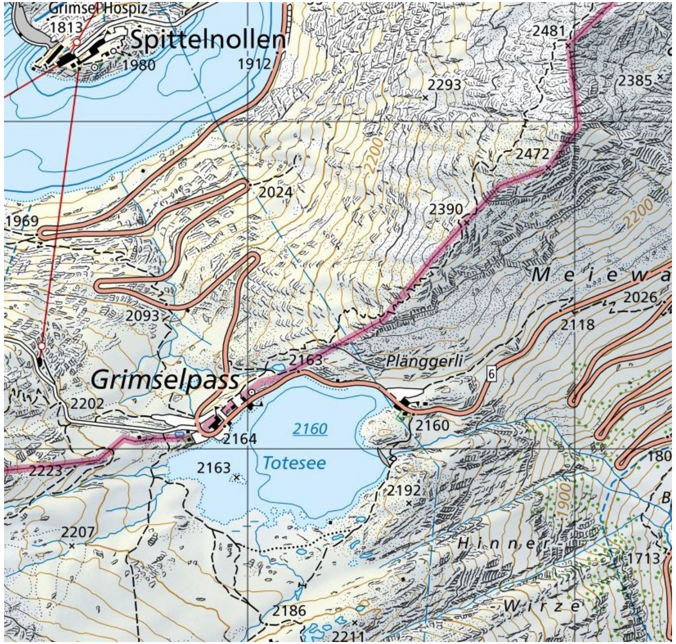
- No features

Results on challenging test flights

Flight	Recall*	False Positives*
Sutz 4	98.3%	1
Biel Tissot Arena	47.5%	0
Biel city center	82.0%	0
Biel harbor	80.0%	1
Sutz forest	30.0%**	0

* False Positives: predicted position was wrong
** With relative tracking and trust region: limit the search space depending on last localization

Future



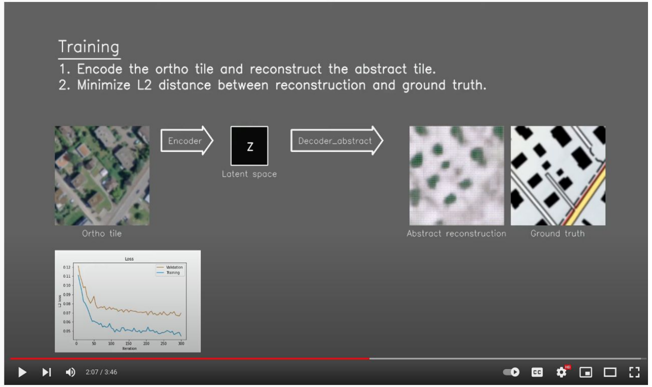
- Part 3: Localization in mountainous or alpine regions
- Part 4: Build an onboard processing box that outputs the location.
- Part 5: Build a No-GPS-drone!

Thank you.

Visit our YouTube channel: https://www.youtube.com/c/HuCEcpvrLab

or watch our
summary videos:

https://www.youtube.com/watch?v=iIlBzMu8QDY



https://www.youtube.com/watch?v=5JEFe2_L4So

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