No GPS Drone Navigation

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BFH > HuCE > cpvrLab
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cpvrLab: Who We are:

- **cpvrLab** stand for: **Computer Perception & Virtual Reality Lab**
- We are an Applied Research & Development Group within the **HuCE** Institute.
- We currently have 520% R&D employees:

![Profiles of team members]

- 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:

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?
Feasibility study: “Can a drone navigate inside a GPS denied environment?”
aramasuisse 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

\[ T : \]
\[ I : \]

\[ x, y = \text{Match}( \quad , \quad ) \]

- 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

- Matches reduced version of video on reduced version of map
Auto Encoder

- train by minimize L2: \|\text{in} - \text{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!

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’)

Deepfake Training Losses

- "Ortho to abstract"
- "Video to abstract"
- "Video to video"

\[
\begin{align*}
\text{Enc} & \rightarrow z \\
\text{Dec} & \rightarrow a'
\end{align*}
\]

\[
\begin{align*}
\text{Enc} & \rightarrow z \\
\text{Dec} & \rightarrow v'
\end{align*}
\]

\[
\begin{align*}
\text{Enc} & \rightarrow z \\
\text{Dec} & \rightarrow a'
\end{align*}
\]
Training Triplets

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

- Crop around estimated position
- Run full resolution template matching

Camera center

Our prediction

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

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

<table>
<thead>
<tr>
<th>Method</th>
<th>Recall Centers</th>
<th>Precision tiles</th>
<th>Fatal errors (&gt;50m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Template Matching</td>
<td>0.567</td>
<td>0.540</td>
<td>0</td>
</tr>
<tr>
<td>Autoencoder</td>
<td>0.533</td>
<td>0.493</td>
<td>0</td>
</tr>
<tr>
<td>DF w/o abstract maps</td>
<td>0.767</td>
<td>0.693</td>
<td>0</td>
</tr>
<tr>
<td>CycleGAN*</td>
<td>0.633</td>
<td>0.557</td>
<td>-</td>
</tr>
<tr>
<td>pix2pix*</td>
<td>0.633</td>
<td>0.557</td>
<td>-</td>
</tr>
<tr>
<td>DF with abstract maps</td>
<td>0.950</td>
<td>0.927</td>
<td>0</td>
</tr>
</tbody>
</table>

* 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

<table>
<thead>
<tr>
<th>Flight</th>
<th>Recall*</th>
<th>False Positives*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sutz 4</td>
<td>98.3%</td>
<td>1</td>
</tr>
<tr>
<td>Biel Tissot Arena</td>
<td>47.5%</td>
<td>0</td>
</tr>
<tr>
<td>Biel city center</td>
<td>82.0%</td>
<td>0</td>
</tr>
<tr>
<td>Biel harbor</td>
<td>80.0%</td>
<td>1</td>
</tr>
<tr>
<td>Sutz forest</td>
<td>30.0%**</td>
<td>0</td>
</tr>
</tbody>
</table>

* 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=illBzMu8QDY
https://www.youtube.com/watch?v=5JEFe2_L4So