Monitoring of Reforestation Projects
Design Project

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Objective

Establish an all-round method to monitor reforestation projects...

- ...applicable to different circumstances.
- ...usable with different data sources.

The project report was presenting the method using *satellite* images of the area of interest for the external partner. This presentation focuses on *unmanned airborn vehicles (UAVs)* images created for the project.
**Data Source**

### UAV

<table>
<thead>
<tr>
<th>Drone</th>
<th>Mavic Air</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSD</td>
<td>3[cm]</td>
</tr>
<tr>
<td>Location</td>
<td>Les Voëttes(VD)</td>
</tr>
</tbody>
</table>

### Satellite

<table>
<thead>
<tr>
<th>Sensor</th>
<th>WV-4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution</td>
<td>30[cm]</td>
</tr>
<tr>
<td>Location</td>
<td>Sindhupalchowk(NPL)</td>
</tr>
</tbody>
</table>
Flight planning for UAVs’ missions is necessary to create useful data sets. **Pix4D Mapper** software was used and provides post-processing tools for generation of mosaic orthophoto, point clouds, DSM, DTM, etc. Efforts focus on optimizing two main resulting characteristics:

**Ground Sampling Distance (GSD)**
Resulting resolution on ground is a function of camera parameters.

**Overlap**
The quality of the resulting orthophoto and 3D model (structure from motion) is a function of the overlap.
The pose (X,Y,Z, pitch, yawl, roll) of the sensor at each take (image view) is also required for good reconstitution. A gimbal insures the nadir view at all time, cancelling with some precision\(^1\) the actual pose of the platform.

\(^1\)Not provided for this type of low-cost drones.
### UAV Data Acquisition II

**Table: GSD: used hardware**

<table>
<thead>
<tr>
<th>Platform</th>
<th>DJI Mavic Air</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensor</td>
<td>1/2.3” CMOS (12MP)</td>
</tr>
<tr>
<td>Best single shot interval</td>
<td>2 [sec]</td>
</tr>
</tbody>
</table>

**Table: Overlap: used parameters**

| Side overlap | 0.6 |
| Front overlap | 0.4 |
| View mode    | Nadir |

*Source: toppng.com*

*Source: Pix4D quality report*

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Single Tree Detection [1],[2],[3],[4]

Used tool: Detect object using Deep Machine Learning from ArcGIS Pro.

**Sample**: sufficient amount of manually identified trees on the image that feeds the neuronal network.

**Train**: based on the PyTorch deep learning framework using the fast Single Shot Detector model. It uses the *ResNet34* as pre-configured model.

**Detect**: some parameters are adjusted to filter the model interpretation: confidence threshold and overlap ratio.

**Accuracy**: assessment points randomly generated over ground truth manually created data are updated over the results of detected objects. The main parameters are the number of points generated and the number of classified objects on the ground truth layer. The number of assessment points can’t be greater than the number of classified objects.
## Results: Single Tree Detection

<table>
<thead>
<tr>
<th>Sample</th>
<th>Detection</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Samples</td>
<td>Trees detected</td>
<td>Accuracy</td>
</tr>
<tr>
<td>Image chips</td>
<td>Threshold</td>
<td></td>
</tr>
<tr>
<td>ca. 200</td>
<td>1003</td>
<td>100</td>
</tr>
<tr>
<td>ca. 4000</td>
<td>0.98</td>
<td>random</td>
</tr>
<tr>
<td></td>
<td>Overlap ratio</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.1</td>
<td></td>
</tr>
</tbody>
</table>

Accuracy: green is successful classification, red is unsuccessful classification (not found trees)
Satellite image preparation: **Pansharpening** [5]

Panchromatic (450–800 nm) sensors band obtain the best resolution. Coupling multispectral bands to the panchromatic one is a process known as **Pansharpening**. It yields a **colored imaged at the panchromatic resolution**. Several methods exist. The most common is Gramm-Schmidt’s:

It uses information from all 5 bands (Pan,R,G,B,IR) by **orthogonalizing** each band’s vector. The algorithm attributes a weight to each band depending on the sensor properties.

**Table**: Pansharpening: used parameters

<table>
<thead>
<tr>
<th>Sensor</th>
<th>WV-4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weights(R,G,B,IR)</td>
<td>0.38,0.25,0.2,0.16</td>
</tr>
</tbody>
</table>
Satellite image preparation: Georeferencing

Two methods of georeferencing were tested:

Superposing images and shifting one with respect to the other. Less reproducible but more user friendly.

Standard georeferencing using coordinates of 6 control points. Very reproducible but may induce distortion.

Area of interest, 03.03.2018

Full image, 03.03.2018

The image preparation is limited due to geometric deformation, the use of different sensors, nadir angles, etc.
NDVI provides with additional information for reforestation monitoring by computing biomass and leaf area index. The change detection strongly depends on the accuracy of the georeferencing.

Data must provide with red and infrared bands:

\[
NDVI = \frac{\rho_{\text{NIR}} - \rho_{R}}{\rho_{\text{NIR}} + \rho_{R}}
\]
**Satellite results: NDVI**

**Value**

- **Recent Epoch:** 16.03.2018

- **Old Epoch:** 03.03.2018

**Difference**

**Legend**

- **NDVI 2018 Value**
  - 0.14 Very low vegetation cover
  - 0.24 Low vegetation cover
  - 0.31 Medium vegetation cover
  - 0.40 High vegetation cover
  - 0.68 Very high vegetation cover

- **Difference NDVI Value**
  - 0.24 Very high vegetation reduction
  - 0.1 to 0.25 High vegetation reduction
  - 0.05 to 0.055 No vegetation change
  - 0.05 to 0.15 Very high vegetation growth
  - 0.15 to 0.3 High vegetation growth
  - 0.3 to 0.65 Very high vegetation growth
  - 0.65 to 0.75 High vegetation growth
Discussion: Data Acquisition

Data acquisition is an important step which predefines the potential results quality.

Nowadays, with use of high-end **UAVs** (drones) very satisfactory results can be obtained with little background knowledge. Post-processing software as Pix4D Mapper make this step very accessible.

**Satellite imagery** acquisition demands more specific skills. Specific parameters have to be chosen carefully (nadir angle, resolution, bands, etc.). Although some platforms try to make the acquisition more user friendly, the high number of different image types and providers makes the choice still complicated. Also very high resolution imagery still comes at a non-negligible price.
## Data acquisition: SWOT analysis

<table>
<thead>
<tr>
<th>Data source</th>
<th><strong>UAV</strong></th>
<th><strong>SATELLITE</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Strength</strong></td>
<td>Temporal/Spatial resolution are selectable</td>
<td>Data acquisition is independent</td>
</tr>
<tr>
<td><strong>Weakness</strong></td>
<td>Flying length is drone battery dependent</td>
<td>Spatial resolution is limited</td>
</tr>
<tr>
<td><strong>Opportunities</strong></td>
<td>More precise Single Tree Detection</td>
<td>NDVI computation possible</td>
</tr>
<tr>
<td><strong>Threats</strong></td>
<td>Data acquisition is time consuming</td>
<td>Georeferencing and data availability</td>
</tr>
</tbody>
</table>
Discussion: Method

The method adapts well to different data sources. The important difference in resolution between UAVs and satellite images greatly impacts the amount of information (pixels) for each objects (trees). Steps of the method can be adapted accordingly:

▶ **Sampling**: for a same result less samples are needed with higher resolution. This step becomes less time consuming.

▶ **Confidence threshold**: can be increased greatly. In this project, the used values are: 0.05 for satellite images, 0.98 for UAVs images.

The **accuracy assessment** quality highly depends on the statistics. The more assessment points the better. To compare works, same number of assessment points must be used. Also independent ground truth data would improve this assessment quality.
Method overall SWOT analysis

<table>
<thead>
<tr>
<th>Strength</th>
<th>All-Round Method, NDVI and Single Tree Change Detection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weakness</td>
<td>Strong dependence on training data</td>
</tr>
<tr>
<td>Opportunities</td>
<td>Possibility to publish results on a ArcGIS Online for direct use.</td>
</tr>
<tr>
<td>Threats</td>
<td>Insufficient georeferencing precision</td>
</tr>
</tbody>
</table>
Conclusion

This project includes:

▶ Not very complex content, but multiple isolated specific steps which must be carefully conducted.
▶ Results are promising but more experience is needed.
▶ Adaptation to each case is still necessary.

Further work should focus on:

▶ Creating a large various sample data set and test the model on different types of site.
▶ Satellite data acquisition and preprocessing for geometric deformation.
▶ Creating a manual for standard UAVs data acquisition (will be delivered to the external partner).
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ESRI.

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