Geological layers detection and characterisation using high resolution 3D point clouds: example of a box-fold in the Swiss Jura Mountains

based on
Humair et al. (2015)
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Since the development of remote sensing techniques and methods, it has become easy to investigate the remote and inaccessible areas.

3D point clouds is a set of points in some coordinate system, \((x, y, z)\) represent the external surface of the object.

Traditional or modern methods for 3D point cloud generation are; 3-D scanners, Terrestrial laser scanning (TLS), Terrestrial radar, Photogrammetry technique and Structure from Motion….etc.

In this study, two different techniques (TLS and terrestrial photogrammetry) were used to generate the 3D point clouds.

Similar to Sonar and Radar (Light detection & ranging)
Range = travel time \(\times\) speed of light/2
Record = (azimuth, range, intensity)

Photogrammetry: Two overlapping photographs taken from different positions allow each feature in the overlapping area to be defined by a unique 3D position.
**Study site**

- The study area is located in Swiss Jura Mountains.
- The outcrop under investigation is a 30 m high box-fold anticline, which was cut by a sub-vertical tear fault.
- The stratigraphic sequence shows marlstone, limestone, interbedded by mudstone of Upper Jurassic age (about 145.5 ± 4.0 million years ago).
OBJECTIVES

The main objectives:

- (I) generating 3D point clouds for detection and characterisation the geological layers, also

- (II) developing integral and alternative tools to traditional field surveys specific to structural geology and lithological applications.

Specific objectives:

- (I) modelling of layers geometry such as the orientation of discontinuity of layers.

- (II) mapping of layers according to the point clouds’ intensity.
Data acquisition and pre-processing

- TLS and terrestrial photogrammetry were used for acquiring high resolution 3-D point clouds, in addition to
- Field geological survey (including lithology, stratigraphic logging, fold axis & bedding orientation measurements).

Optech Ilris 3D ER was performed, because the Leica Scan Station device does not allow accessing to the RAW intensity data for correction objectives which constitutes a critical step for lithological mapping.
3D point clouds were acquired by (TLS)

Photograph showing the extent of the TLS and photogrammetric point clouds, which focuses only on the upper part of the outcrop.

The results show that, no clear correlation between lithological classes and intensity values with the \( (I_{\text{LIDAR \ raw}}) \) data, after correction it has became easy to distinguished the different layers \( (I_{\text{LIDAR \ corrected}}) \).
Photogrammetry data

- 3-D point cloud of the study area was generated by SFM approach.
- **SFM**: is the process of estimating the 3-D structure of a scene from a set of 2-D images.
- This work was performed by Agisoft Photo-scan software, to generate a 3-D point cloud.

Scaling and georeferencing of the point cloud were done by using the Cloud-Compare software.

The results show that, there is clear relationship between lithology and the intensity values.

In addition, highlights relationship between the \( I_{\text{PHOTO}} \) and intensity data, which is the primary control of the lithology based on the \( I_{\text{PHOTO}} \) values.
**Geometrical analysis of geological layers**

- **Methodology** based on field mapping and point clouds acquired by Leica Scan Station II.

| Box-fold characterization |
|---------------------------|
| - Bedding orientation (Points picking)  |
| - Fold axis (Pi diagram)  |
| - Layers thickness  |

**Results:**

3D fold modelling and semi-automatic cross-sections

Bedding orientation was measured by (Cloud-compare software). The fold axial traces 084°/plunge 03° to E

The thickness along the anticline is not constant.

Also, the layer thickness values at hinges are greater than the crest.

Manual mapping of the layers thickness across the box fold, showing the different stratigraphic layers.
Results:

- 3-D Fold modelling.
  - This model allows the visualization and interpretation of fold geometry and variation of layer thickness.
  - This model is used to generate a series of cross-sections perpendicular to the fold axis.
**Segmentation (mapping of layers) using intensity information**

*Methodology;* based on 3-d point cloud acquired from Optech Iliris and photogrammetry ($I_{PHOTO}$).

- a) **Identification of the lithological classes**
- b) **Determine intensity value for each lithological class**
- c) **Denoising** (Filtering the intensity value for each point).
- d) **Filtering according to lithological classes**
- e) **Filtering according relative point cloud density**
- f) **Clustering** (algorithm).

**Results**

- The stratigraphic sequence was mainly composed of marlstone, limestone interbred by mudstone.
- The limestone is more reflective than marlstone, which displays higher intensity values than mudstone.
Mapping of layers to identify the lithology

a) TLS (Optech Ilris) - corrected intensity

- A long the profile all layers corresponding to the limestone lithological class (N° 5b, 6, 7, 9a, 9b, 10, 12, 13) and three from the four layer marlstone (5a, 5c and 11).
- The different layers are not continuously segmented along the fold.
- Layer-8 is correctly classified as marlstone at other parts of the outcrop.

Comparison between intensity log and stratigraphic profile conducted by combining fieldwork and manual mapping on the 3-D point cloud.
Mapping of layers to identify the lithology

b) Photogrammetry intensity ($I_{PHOTO}$).

The lithological boundaries for each layer were identified except in the center of the fold where the procedure fails to connect the layers from one side to the other.

This is not a segmentation problem but the result of blasting that occurred during quarry work one week before data acquisition.

The semi-automatic segmentation data derived form ($I_{PHOTO}$), is more precise than the point cloud segmentation resulted by TLS.
Conclusions

- The results show that the procedures proposed in this study are fast, reliable and accurate tools for gathering and interpreting geological data.
- Mapping of layers using the photogrammetric point cloud was more precise than the TLS dataset.
- These methods are objective and rigorous, and can be reproduced by different users.
- In mapping of layers, the fieldwork is also required to correspond between the intensity values and the lithology.
- The high-resolution dataset allows very detailed quantitative analysis of the outcropping layers which could be hardly targeted based on fieldwork only.
- Compared to field work, this technique is more expensive but everything is automatic or semi-automatic.
Lungchuan area

- In this area there is recent deformations but no argument about the Lungchuan fault is active or no.
- Le Béon et al. (2017) proposed that the Lungchuan is back thrust, based on the interpretation of leveling data & InSAR.

Recent work

- Modify this section using different methodology if this fault is back thrust or no.

The other possibility

- New fault.
- Mud dipper.

Tools

- Field geological survey (including lithology, and bedding orientation measurements).
- UAVs survey and Core drilling (borehole).
Thank you.
Future work

- Generating 3D point clouds for identification and interpretation the geological layers using UAVs.

- Developing integral and alternative tools to measure planar geological structures such as strike and dip of bedding planes, fault planes and jointing surfaces using UAV of an outcrop.

- Evaluate the accuracy of geologic measurements derived from photogrammetric reconstruction when compared to traditional field collection methods.