Pyoints: A Python package for point cloud, voxel and raster processing.

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Summary

The evolution of automated systems like autonomous robots and unmanned aerial vehicles leads to manifold opportunities in science, agriculture and industry. Remote sensing devices, like laser scanners and multi-spectral cameras, can be combined with sensor networks to all-embracingly monitor a research object.

The analysis of such big data is based on geoinformatics and remote sensing techniques. Today, next to physically driven approaches, machine learning techniques are often used to extract relevant thematical information from the data sets. Analysis requires a fusion of the data sets, which is made difficult conceptually and technically by different data dimensions, data structures, and various spatial, spectral, and temporal resolutions.

Today, various software to deal with these different data sources is available. Software like GDAL (GDAL/OGR contributors, 2018) and OpenCV (Bradski, 2000) are intended for image processing. Libraries, like PCL (Rusu & Cousins, 2011), Open3D (Zhou, Park, & Koltun, 2018) and PDAL (PDAL contributors, 2018) focus on 3D point cloud processing. Each of these software packages provide an API specially designed to solve the problems of their field efficiently. When developing algorithms for automated processing of various types of input data, the differing APIs and programming languages of these software packages become a drawback. To support fast algorithm development and a short familiarization, a unified API would be desirable.

Pyoints is a python package to conveniently process and analyze point cloud data, voxels, and raster images. It is intended to be used to support the development of advanced algorithms for geo-data processing.

The fundamental idea of *Pyoints* is to overcome the conceptual distinction between point clouds, voxel spaces, and rasters to simplify data analysis and data fusion of variously structured data. Based on the assumption that any geo-object can be represented by a point, a data structure has been designed that provides a unified API for points, voxels, and rasters. Each data structure maintains its characteristic features, to allow for intuitive use, but all data is also considered as a two or three dimensional point cloud, providing spatial indices that are required in many applications to speed up spatial neighborhood queries.

During development, great emphasis was put on designing a powerful but simple API while also providing solutions for most common problems. *Pyoints* implements fundamental functions and some advanced algorithms for point cloud, voxel, and raster data processing, like coordinate transformation, vector algebra, point filters, and interpolation. *Pyoints* also provides a unified API for loading and saving commonly used geo-data formats.

Pyoints was designed to support research activities and algorithm development in the field of geoinformatics and remote sensing. Early versions of the software have been

used for some pre-studies at Trier University (Lamprecht, Hill, Stoffels, & Udelhoven, 2017; Lamprecht, Stoffels, Dotzler, Haß, & Udelhoven, 2015). *Pyoints* is also used in the PANTHEON project (PANTHEON consortium, 2018) to monitor hazelnut orchards.

The source code of *Pyoints* is on GitHub (Lamprecht, 2019a). The documentation can be found on GitHub Pages (Lamprecht, 2019b).

Acknowledgements

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