Geometrical Approximation and Segmentation of Laser Scanning Point Clouds

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Introduction
Segmentation of the point clouds
Surface approximation
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Outlines

Scanning Systems - Hardware

Main fields of usage:
- Terrestrial Laser scanning - 25 up to 100 m
- Geo referencing – identical points – tacheometry
- Airborne Laser scanning – hundreds of meters
- Geo referencing – identical points, GPS, INS

Very quick and efficient technology
Automated data acquisition
This huge amount of data can not be processed manually
Forcing the automated data processing

Surface and Feature Line Extraction

Two methods for the feature lines extraction:
- Automatic extraction of sharp edges based on robust curvature analysis of the whole point cloud. This is the high end solution but needs very powerful hardware
- Interactive extraction of sharp edges and/or smooth edges (semi-automatic method). Focus – second method

Automatic extraction of feature lines

Once the neighbors of each point \( p \) of the point cloud within the search radius \( R \) have been determined, best fit planes \( E_i \) in each point depending only on the neighbors of \( p \) can be computed.

The best fit plane \( E \) can be interpreted as being a local approximation of the surface near the point \( p \). The normal vector of the plane \( E \) can then be interpreted as an approximation of the normal surface vector of the measured part (sliding planes)
Fitting Planes and feature lines

Fitting planes to point data is a well-known problem and is normally solved using least-squares methods. Once the normal vectors $n_j$ for the relevant points within the search radius $R$ have been computed, point curvature values will be determined by applying a formula which gives an approximation of the average curvature of the surface of the part.

Adjacency Preserving

The orientation of the normal vectors of the neighbor points must be homogenous and depend on the reference system.

The semi automatic strategy

Important! the segmentation leads to so called functional patches.

- Fitting of free form Surfaces - NURBS
- Comparison between the point cloud and the fitted geometry (Measuring against CAD)

Segment based computation of feature lines

Special attention for producing results of high quality in means of accuracy to the measured point cloud and smoothness of the resulting feature lines.

- A theoretical edge line (NURBS representation), which specifies the position of the intersection curve of the extended surfaces, adjacent to the segments to construct.
- Of course the input for the method consists of the measured point cloud only

Surface Approximation

Computations of the Theoretical Edge Line

- The "used" boundary line is defined by the restriction of the segment follows
- the segment end points in a section are computed
- the computation of the theoretical edge point will be done, simply by intersection of the tangents of the curve in the extracted segment end points.
- 2D intersection of the tangent can be used, because the fitting curve and consequently the tangents are expected to be located within the cross sectioning plane.
Automated Multiple Spline Fitting for Curvature Analysis of Cross Section Points

1. The resulting spline curve should be accurate respectively to the cross section points, means the distances of the points to the fit curve need to be checked and should be rather small.

2. On the other hand, if the resulting spline curve would follow the cross section points too closely, oscillations appear in the spline curve, if the scan data would be noisy (and it always is). The amount of oscillations of the spline curve normally will increase, if the distance to the points should decrease.

3. Oscillating spline curves can be used for curvature analysis only with great difficulties.

4. Necessary to separate the errors by sources, spline optimization.

Plane / Surface Approximation

Noise in the Single Shoots

Measurement Noise – against approximation Oscillations

1. Physical differences from the theoretical (CAD) surface.

2. Accuracy of the used laser scanner.

3. Preconditions
   - No big errors in the laser source
   - No temperature drift
   - The scanner is frequently calibrated and checked

4. Gauss – normal distribution of errors, very high redundancy

5. Adjustment methods

Curvature Analysis

Segmentation

The surfaces to be reverse engineered consist of two cylindrical segments with radius $R=1$, connected with a plane.

Consequently the intersection curve (intersection perpendiculars to the axis of the cylinders) consists of two quarter circles connected with a line.

The curvature values of the line is zero and of the circles constantly equal 1. The run of the curvature values is characterized by a discontinuity exactly in the segment end points.
Conclusions

- The calculation of surfaces and feature lines using adjustment methods with respect a priori and resulting accuracy with quality improvement.
- The Automatic feature line detection is an important tool for engineering applications.
- With the described algorithms the workflow for computing of segmented surfaces in 3D scanner data will be continuously automated.
- The method can handle even dense huge point clouds in real time.

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