List of software tools

Introduction

Implementation

- The modules are based on various runtime and memory optimized algorithms and data structures
- All methods are implemented as 64-bit version which is especially useful for handling large mounds of data > 2 GB
- By using parallel algorithms in combination with cache optimized memory access, the advantages of modern multi-core architectures will be fully utilized

Delivery

- The modules will usually be delivered as a DLL for Windows 7, Windows 8 or Windows 10
- Optionally, the complete source code can be delivered as well

Alignment

Matching

- Fully automated correction of calibration errors between several overlapping scans using simultaneous multiple-view best-fit-matching (Gauss). Matching up to 100 scans in acceptable runtime. Matching of unstructured or triangular meshed point clouds in arbitrary combination

Registration

- Best-Fit-Registration (Gauss) of measured data to nominal model for unstructured or triangular meshed point clouds
- Fully automated, semi-automatic and interactive modules for pre-registration of one or more scans (unstructured or triangular meshed point clouds)

Auto-Align

- Fully automated, consecutive alignment of scans done by a handheld sensor (e.g. intraoral scanner)

Meshing

Unstructured point clouds

- Meshing of unstructured point clouds according to J.-D. Boissonnat („incremental surface reconstruction"). The result contains the exact measuring points.
- Meshing of unstructured point clouds using marching cubes according to H. Hoppe („implicit surface reconstruction"). Automated orientation of point normals by „minimum spanning tree" or considering the "line of sight", which is even more efficient

Structured point clouds

- Meshing of voxelmodels in computed tomography using the marching cubes algorithm
- Meshing of pixelarray or depth cards e.g. by structured light sensors

Filter

Confidence-Filter

- Erosion-Filter
- Leap-Filter
- Gradient-Filter

Artifact-Filter

- Automated filtering of outliers
- Automated filtering of turret-shaped artifacts
- Separation of distinct surfaces

Smoothing general

- Smoothing of unstructured or triangular meshed point clouds using Gauss, Laplace or median filter
- Smoothing of polylines using Gauss, Laplace, median or spline filter
- Anisotropic smoothing of unstructured or triangulated point clouds preserving volume according to Taubin

Mesh sharpening

- Sharpening of model edges in triangulated point clouds
- Feature enhancing mesh denoising

Mesh-Processing

Reduction

- Curvature based reduction according to a given tolerance or a given number of triangles

Holefill

- Filling of holes in triangle meshes with homogenous transition, can be automated (fill all holes up to a given size)

Mesh-Clipping

- Planar clipping of triangle meshes
- Projection of curves onto triangle meshes
- Curve clipping of triangle meshes

Offset surfaces

- Construction of clean offset surfaces for triangle meshes, variable offset value

Modeling

- Tools for interactive modeling (deforming) of triangle meshes

Boolean operations

- Combining triangle meshes using the basic Boolean operations

Splitting

- Separation of distinct surfaces within triangle meshes

Wall thickness

- Automated calculation of the wall thickness for triangle meshes (testing for minimum wall thickness)

Volumetric operations

- Interactive Boolean operations in real-time (3D modeling)
- Virtual milling based on volumetric models

Feature extraction

Automated detection arbitrary feature lines

- Detection of sharp edges for unstructured or triangulated point clouds
- Detection of radial feature lines (e.g. dental preparation margin) for unstructured or triangulated point clouds
- Detection of equator and fissures of tooth stumps

Analysis tools

Inspection

- Nominal/actual value comparison for unstructured or triangulated point clouds featuring deviation plot and statistical information (e.g. RMS-error, percentage within given tolerance, etc.)

Dynamic slicing

- Calculation of parallel sections through unstructured or triangulated point clouds. Dynamical scrolling through sections (analog to CAD clipping), visualization of deviations in sections

Curvature analysis

- Curvature analysis of surfaces with color-coded visualization for unstructured or triangular meshed point clouds

Fitting of geometric entities

Detect tools

- Automated segmentation and fitting of the geometric entities plane, cylinder and sphere within unstructured or triangulated point clouds

Gauss & Chebyshev Fitting

- Fitting of the entities line, circle, ellipse, plane, sphere, cylinder and cone according to Gauss and Chebyshev with constraints
- Fitting of Bezier and B-spline curves

Voxelmodels & computed tomography

Threshold calculation

- Histogram analysis for grey values

Surface extraction

- Local threshold methods, subvoxeling
- Extraction of the surface within a CT-voxelmodel including block by block reduction

Viewer

- Player-software to render the separate CT-layers

Modules for Dental CAD/CAM

Preparation margin

- Automated detection of preparation margin for crowns and inlays
- Freehand correction of preparation margin using cubic splines
- Semi-automatic correction (curvature based)
- Scrolling of whole preparation margin via slider
- Segmentation of the stump along the preparation margin (Clipping)

Undercuts

- Calculation of optimal insertion direction
- Calculation of undercut areas including color plot due to undercut depth per measuring point
- Undercut removal to be done before the milling step
- Preparation check: Calculation of surface gradients per measuring point including color plot

Features

- Automated equator detection for tooth stumps
- Automated fissure detection for tooth stumps

Offset surfaces

- Construction of clean offset surfaces e.g. for simple caps
- Various methods for constructing the transition along the preparation margin
- Different offset values for each vertex (variable offset, anatomical reduction)

Alignment

- Fully automated, semi-automatic and interactive modules for pre-registration of one or more scans
- Alignment of implants out of a library into a concrete restoration
- Alignment of upper jaw and lower jaw using mushbite or vestibular scans

Digital Model Creation

- Creation of a digital volume model based on the scanned surface, optionally with removable preparations
- Attaching of a bed-plate for the use in an articulator
- Volume models for milling or rapid prototyping with adjustable material thickness
- Virtual wax-knife tool for adding / removing material or even local smoothing

Crown module

- Individual cement gap creation
- Maintaining minimum wall thickness
- Placement of library teeth, adaption to margin line and adjacent teeth
- Anatomic free-forming
- Offset crowns including lingual band
- Full and partial anatomic reduction

Additional modules

- Automated detection of occlusion plane of a given upper jaw
- Generation, manipulation and merging of simple geometric objects like connectors, clasps or lingual bars for model castings
- Digital design of full dentures

Process chain 3D scan data processing

Complete procedure from range images to meshed surface

- Calculation of confidence values
- Matching of 3D scan data from different views
- Merging of scans regarding confidence values
- Filtering of artifacts and distinct surfaces up to a given size
- Uniform sampling of merged point clouds
- Anisotropic smoothing of point clouds preserving volume
- Meshing of point clouds
- Curvature based reduction according to a given tolerance
- Filling of holes in triangle meshes

CAM

Milling simulation

- Simulation of an NC milling process including visualization and load test

Nesting

- 2D irregular-shaped nesting including cutter radius offsets

Mold design

- Construction of dental molds for prefabricated teeth including virtual evaluation

Others

- Engraving of 3d text into 3d surfaces / volumes
- Calculation of energy-minimized patches / membranes for creating organic surfaces e.g. gingiva