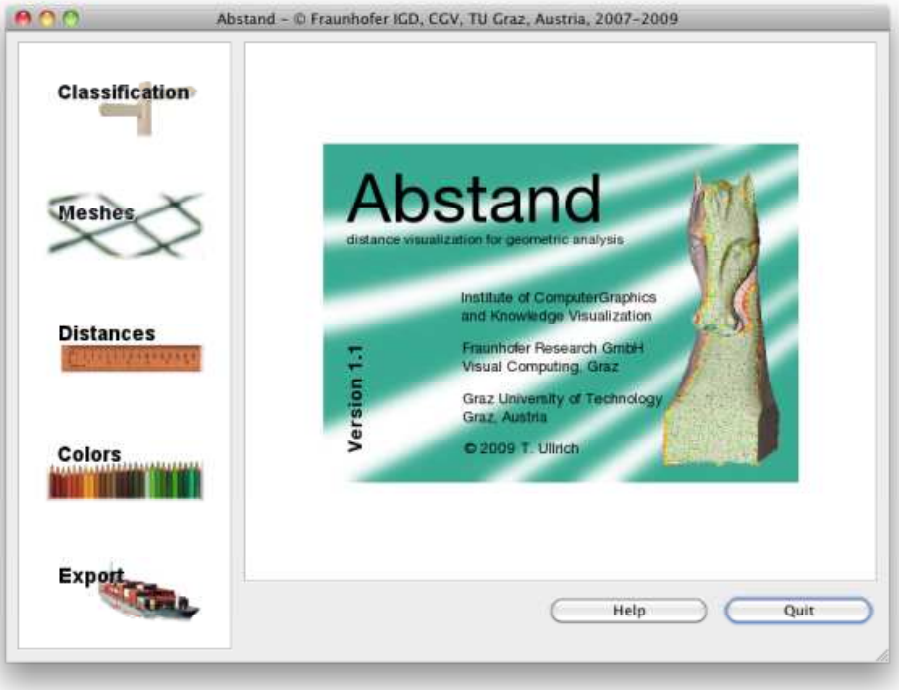
Abstand (Version 1.1)

distance visualization for geometric analysis



The need to analyze and visualize differences of very similar objects arises in many research areas: mesh compression, scan alignment, nominal/actual value comparison, quality management, and surface reconstruction to name a few. Although the problem to visualize some distances may sound simple, the creation of a good scene setup including the geometry, materials, colors, and the representation of distances is challenging. *Abstand* is an application which optimizes the work-flow to visualize distances.

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Introduction

Motivation

Analyzing differences between surfaces is a necessary task in many fields of research. Measuring the distance between two surfaces is a common way to compare them.

In computer graphics, for example, differences of surfaces are used for analyzing mesh processing algorithms such as mesh compression. They are also used to validate reconstruction and fitting results of laser scanned surfaces. As laser scanning has become very important for the acquisition and preservation of artifacts, scanned representations are used for documentation as well as analysis of ancient objects. Detailed mesh comparisons can reveal smallest changes and damages.

A meaningful visualization of surface differences is a challenging task. The goal is a clean representation of facts without overextending the observer.

This application optimizes the work-flow to create such visualizations. It uses a classification scheme to group typical scenarios. Reasonable presets of settings are provided for quick output generation. The results can then be imported into common visualization tools like Maya™, 3ds Max™, or Deep Exploration™ to support the overall visualization task.

Software Requirements

Abstand is known to run on Microsoft Windows™, MacOS X™, and Linux™. It requires:

- a Java™ Virtual Machine (JVM) version 1.4+,
- less than 5mb disk space,
- a lot of memory space (depending on the size of your geometric models),
- internet access to display the online manual.

Abstand supports 64bit systems and can take advantage of 64bit memory. It has been tested with two models larger than 3gb each.

Licence

Installation & Configuration

Using the Java™ Web Start™ technology the application can be started via web browser. Further installations are not needed. Additionally, an executable JAR-file is available via the *Abstand* web page.

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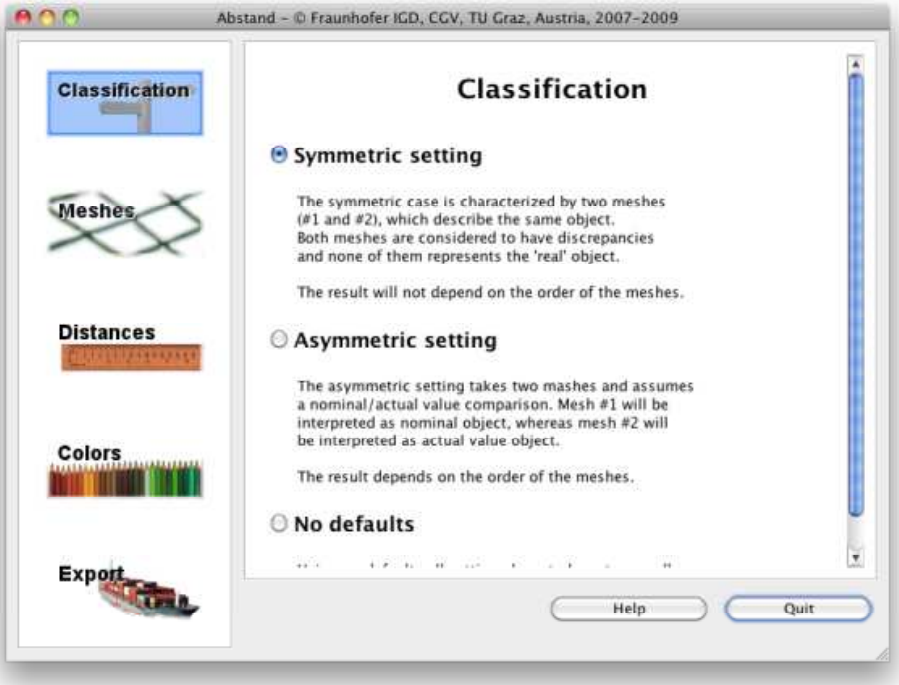
Classification

Scenarios

All distance visualization problems belong to one of two distinct groups. The *asymmetric* case analyzes two geometric objects assuming that the first object is the reference respecively nominal object. The second object is the actual object to be validated. Such a configuration can be found e.g. in the context of quality management using a CAD model as reference to check the resulting product.

The *symmetric* case is characterized by the absence of a reference model. Both objects are on a par. In contrast to the asymmetric case the results of the symmetric one do not change, if the order of the imported objects is swapped. A typical, symmetric situation is the comparison of two range maps of a laser scanning process. If overlapping regions of aligned scans are analyzed, none of them can be considered to be the ground truth.

These two main groups require different settings. *Abstand* uses this classification scheme to select default settings.



Symmetric Configuration

For the two analyzed meshes, a unobtrusive coloring is suggested. Their transparency values may vary according to the signed distance. Transparent surfaces enable to display inner parts which would otherwise be covered by opaque surfaces.

Asymmetric Configuration

As one surface is considered as ground truth, this visualization emphasizes the actual object. The reference object plays a minor role in the visualization. Its main purpose is to provide orientation in 3D; especially, if the actual objects (e.g. scanned remains of a vase) are much smaller than the reference object. The actual object may also be colorized according to the assigned distances.

No Defaults

If no defaults are desired, *Abstand*'s classification panel offers the possibility to deactivate all defaults. In this case all following settings have to be set manually.

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Meshes

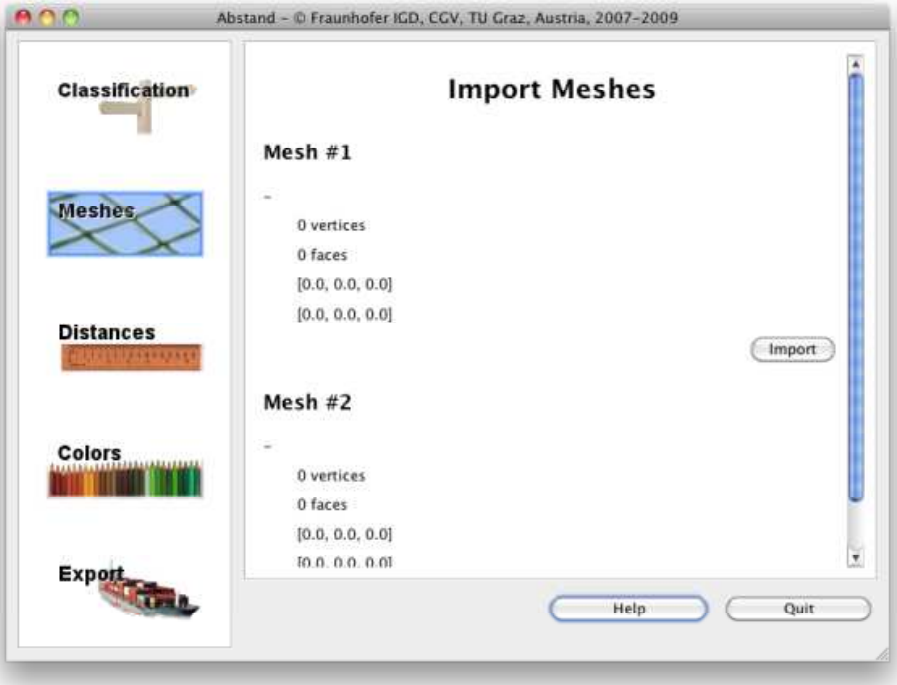
The distance calculation is based on meshes and point clouds. The geometry to analyze has to be a polygonal mesh. *Abstand* supports a subset of the 3D Object format (OBJ) introduced by Alias Wavefront™. It extracts the vertices and faces of a polygonal mesh and does neither interpret other kinds of geometry (NURBS, etc.) nor any materials.

Import

In order to load and to compare two meshes, switch to the mesh panel by clicking the mesh icon on the left. Use the import buttons to load some meshes.

In case of an asymmetric configuration the first mesh will be interpreted as nominal object, whereas the second one will be interpreted as actual value object.

In symmetric scenarios the order of the meshes is not important.

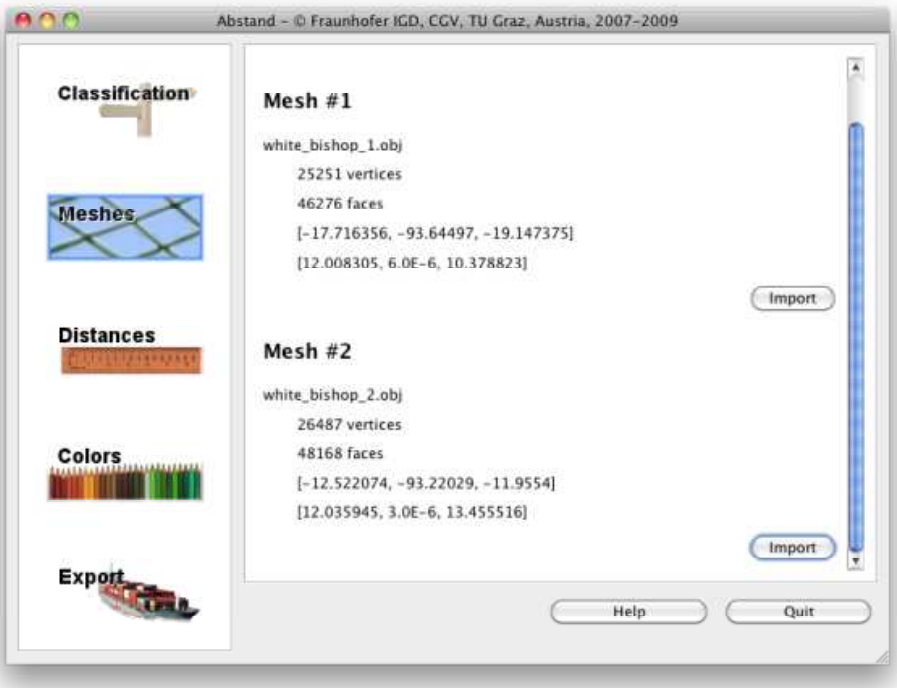


Information

Having imported some meshes *Abstand* shows some mesh attributes. For both meshes it displays

- the file name,
- the number of vertices,
- the number of faces,
- the axis-aligned bounding box (AABB) of the mesh.

The AABB is given by a minimum $[x_{min}, y_{min}, z_{min}]$ and a maximum $[x_{max}, y_{max}, z_{max}]$ point in 3D.



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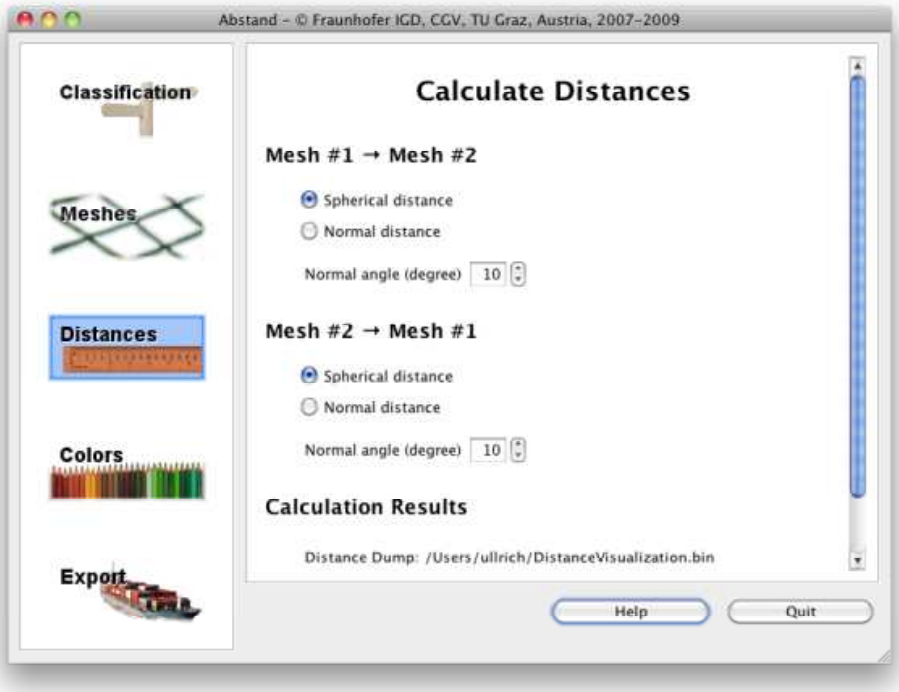
Distances

The distance analysis starts by generating samples of both input objects and calculates their normals. The normal vectors are used to define half-spaces. With these half-spaces the inside and outside of the difference space in-between is defined. To work properly, the normals have to point outwards of tessellated objects. There is no way to determine correct inside and outside spaces fully automatically in all cases, especially for non-manifold surfaces.

Having calculated the normal vectors the one-sided distances are computed. The distance calculation is based on a nearest-neighbor-search and provides signed distances for each subpart.



Spherical Distance

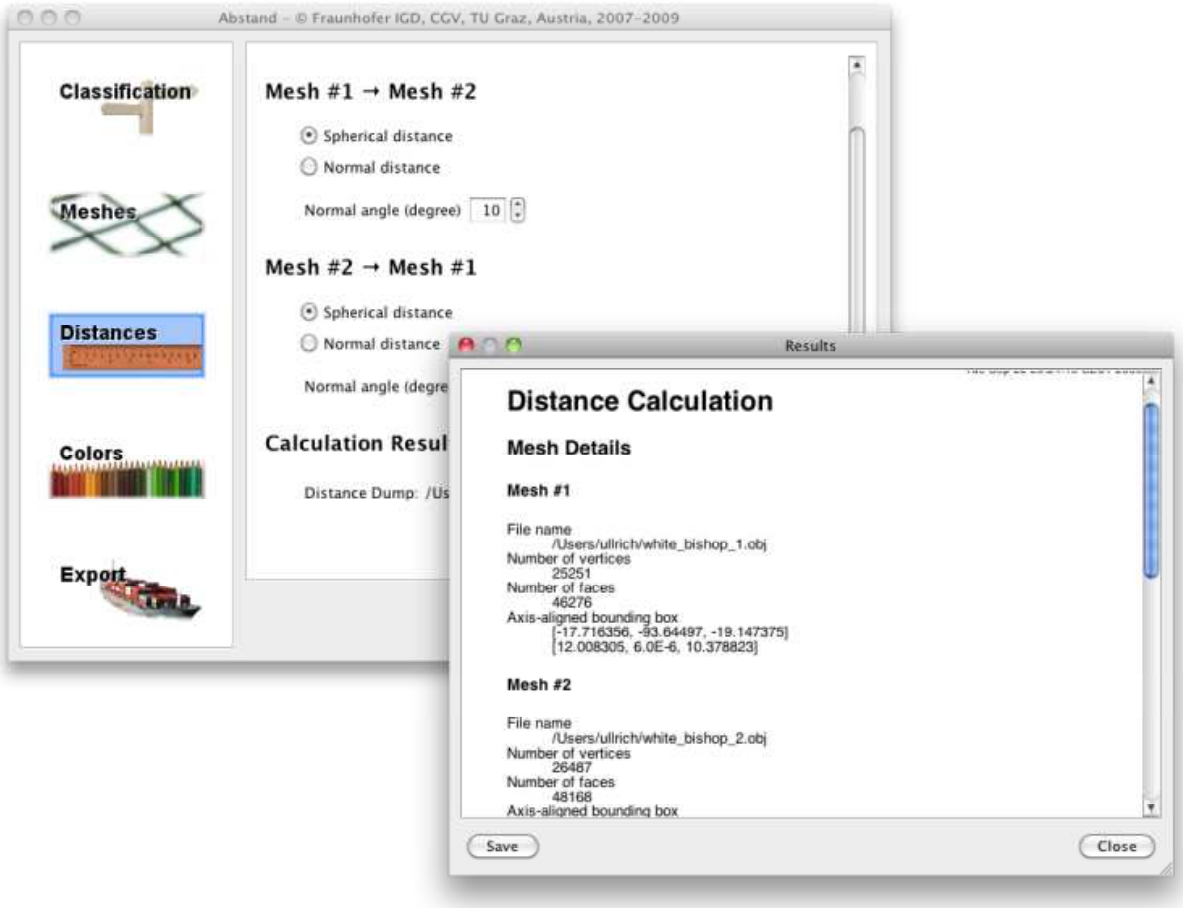
The default for all distance calculations is set to spherical distance. Starting the distance calculation in a point in 3D, the spherical distance searches the nearest neighbor geometry without any restrictions.

Normal Distance

For some cases it is useful to restrict the search area to a double cone along the surface normal. This is called normal distance. The opening angle of the normal cone can be changed easily. Its value has to be between 0 and 90 degree, of course.

Distance Results

Use the calculate button to start the distance calculation. As soon as the calculation is ready, *Abstand* presents its results. The results can be saved as a simple HTML file.



The distance calculation may need some time. In order to avoid multiple calculations on the same data set, the calculation results are automatically stored in the user's home directory in a file named "DistanceVisualization.bin". Start *Abstand* with a file name to reuse already calculated distance results.

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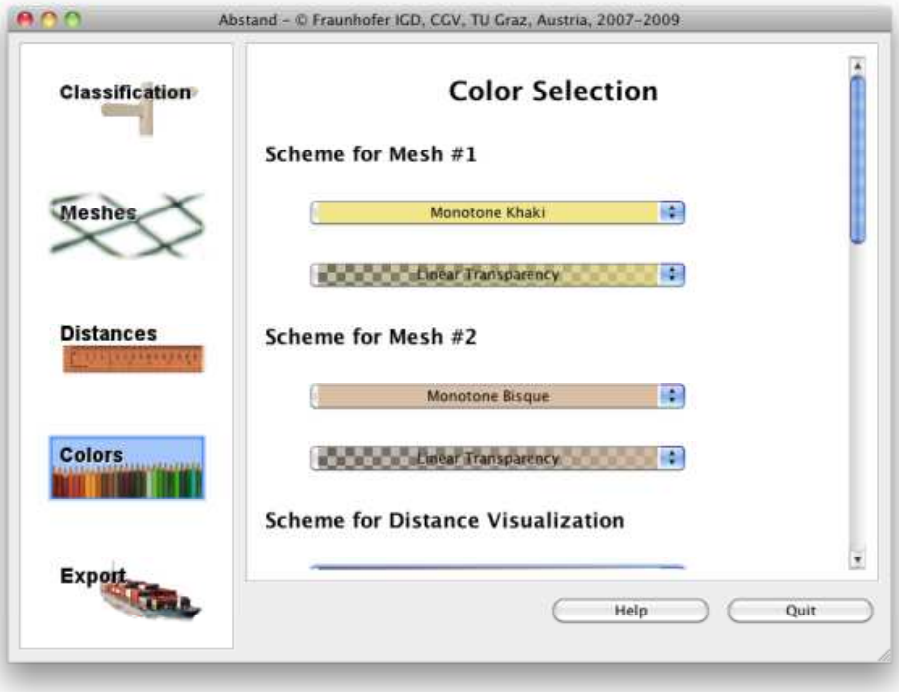
Colors

The choice of a good color table to visualize differences between 3D geometry depends on various factors. Color perception and depth perception are the two most important ones. An overview on colors and color perception can be found in Maureen Stone's *field guide to digital color*.

The set of predefined color maps contains the luminance-based maps with only small variations in the hue value as proposed by Haim Levkowitz and Gabor T. Herman and by Lawrence D. Bergman, Bernice E. Rogowitz, and Lloyd A. Treinish as well as the maps proposed in *Rainbow Color Map (Still) Considered Harmful* .

The predefined color maps also contain neutral color settings. These settings do not have "signal colors" such as red. The selection of the neutral color ranges are based on *How NOT to lie with visualization* by Bernice E. Rogowitz, Lloyd A. Treinish, and Steve Bryson.

Color Schemes for Meshes



The geometric objects / meshes can easily be colorized using preconfigured color scales. These schemes include color maps with good order properties in terms of human perception.

For surfaces isoluminant color maps with opponent colors are suggested. These surface colorizations do not compromise the depth perception. Neutral color tables are also available, if extra highlighting of differences is not desired.

The meshes may be drawn without / with constant / with varying transparency. Reasonable color and transparency configurations for each mesh can be selected in the drop-down box. The meshes may be colored accoring to the measured distances.

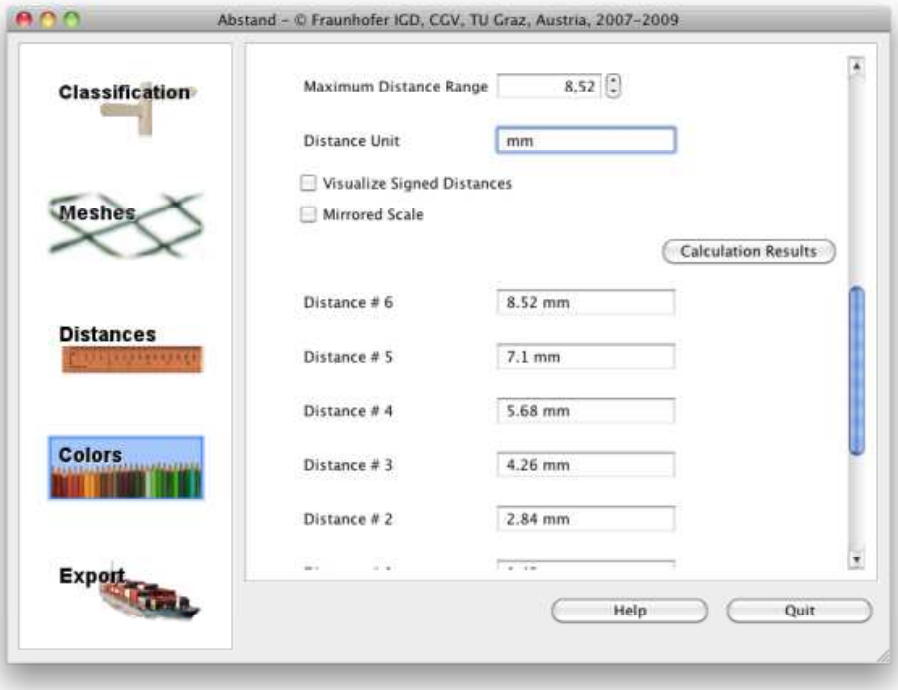
Color Schemes for Distances

It is possible to encode the measured distances in the mesh coloring. Another possibility to visualize distances are solid cylinders (or prisms with a lower polygon count). These are generated to visualize the distances in a rather volumetric style.

While surfaces should be colored with an isoluminant color map, the distance visuals (the small cylinders) should use luminance-based scales, for example the black-body radiation spectrum.

Distance Range

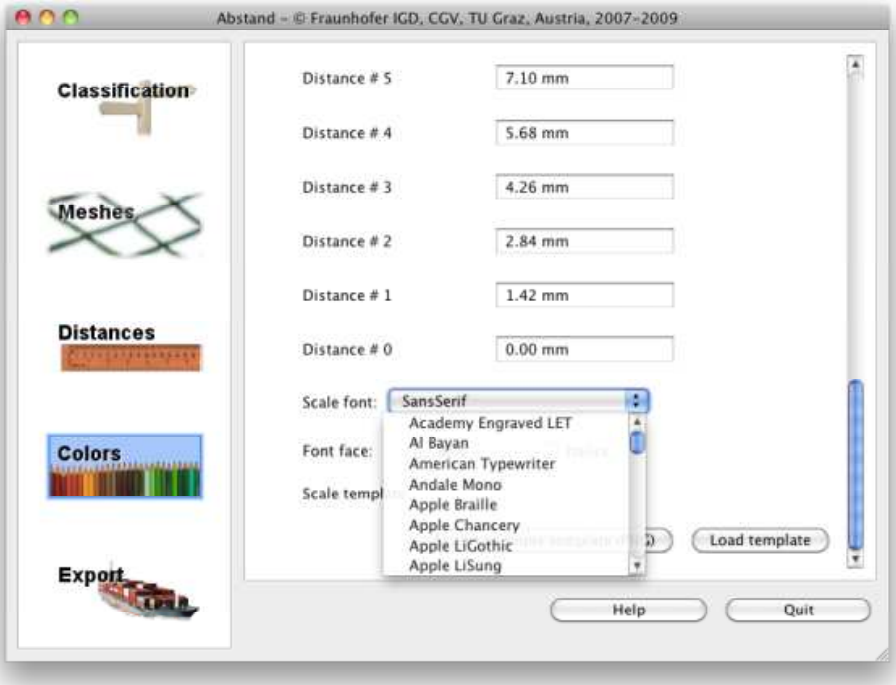
Each visualization and each diagram should have a legend respectively a scale. *Abstand* can generate an appropriate one based on a few inputs.



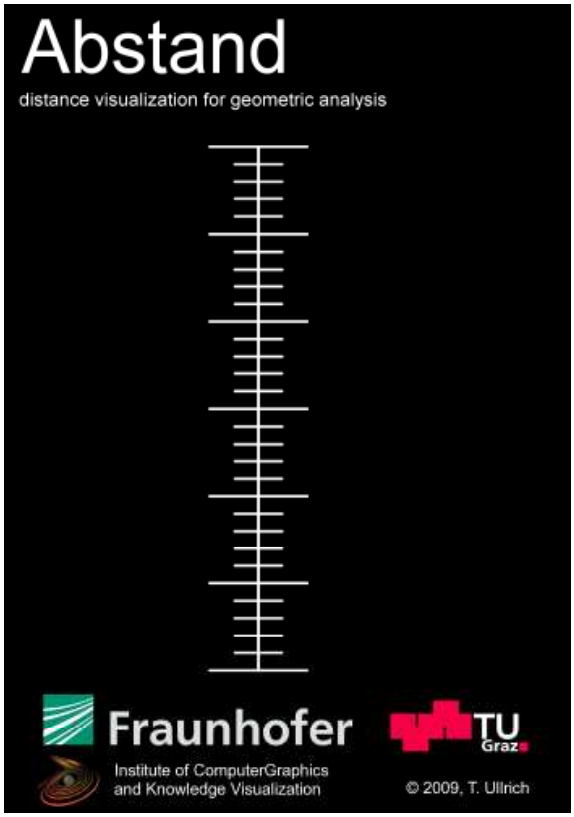
The maximum distance range is the upper limit of the scale. A reasonable value is set automatically. As the upper limit should be chosen with regard on the distance calculation results, an overview on these results can be opened: just click on the calculation results button. Having set the maximum distance value and the distance unit, *Abstand* generates the scale labels. Each one can be modified separately.

Scale Layout

The distance scale will be printed into a legend template. Select a font family and a font face of the text which will be written into the template. Click on the export example template button to store a template on your hard disk. The template is a simple PNG file and can be edited using an image processing application. Import the modified template via the load template button. If no template is loaded, a default template will be used instead.



The following image shows the default template. Please note: if you design your own scale template, the result should be a PNG file without any transparencies. Its size should be 2100 (width) times 2970 (height). Furthermore, the number of pitch lines and their positions should not be changed.



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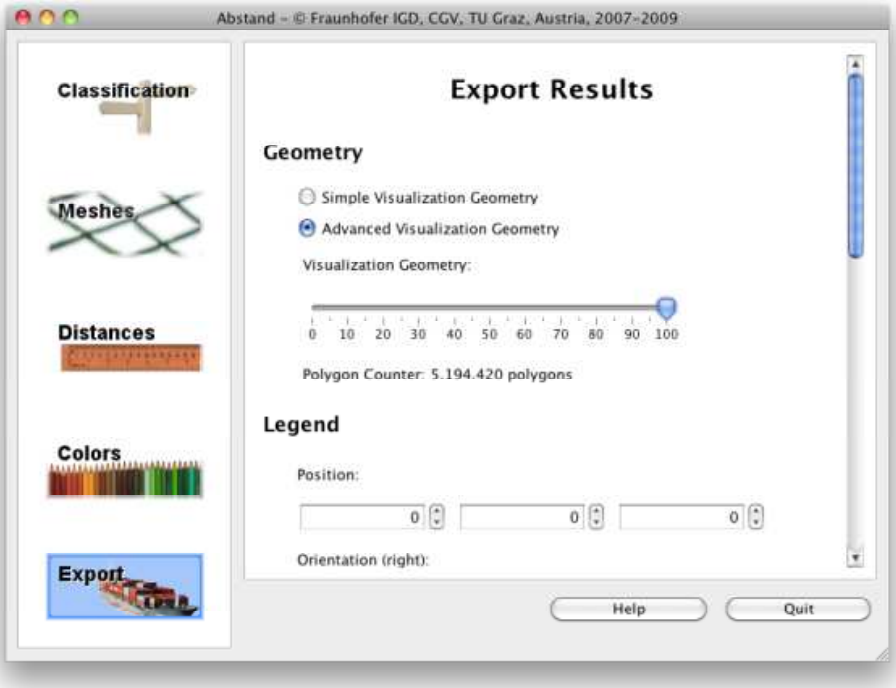
Export

Abstand offers various possibilities to adjust the distance results.

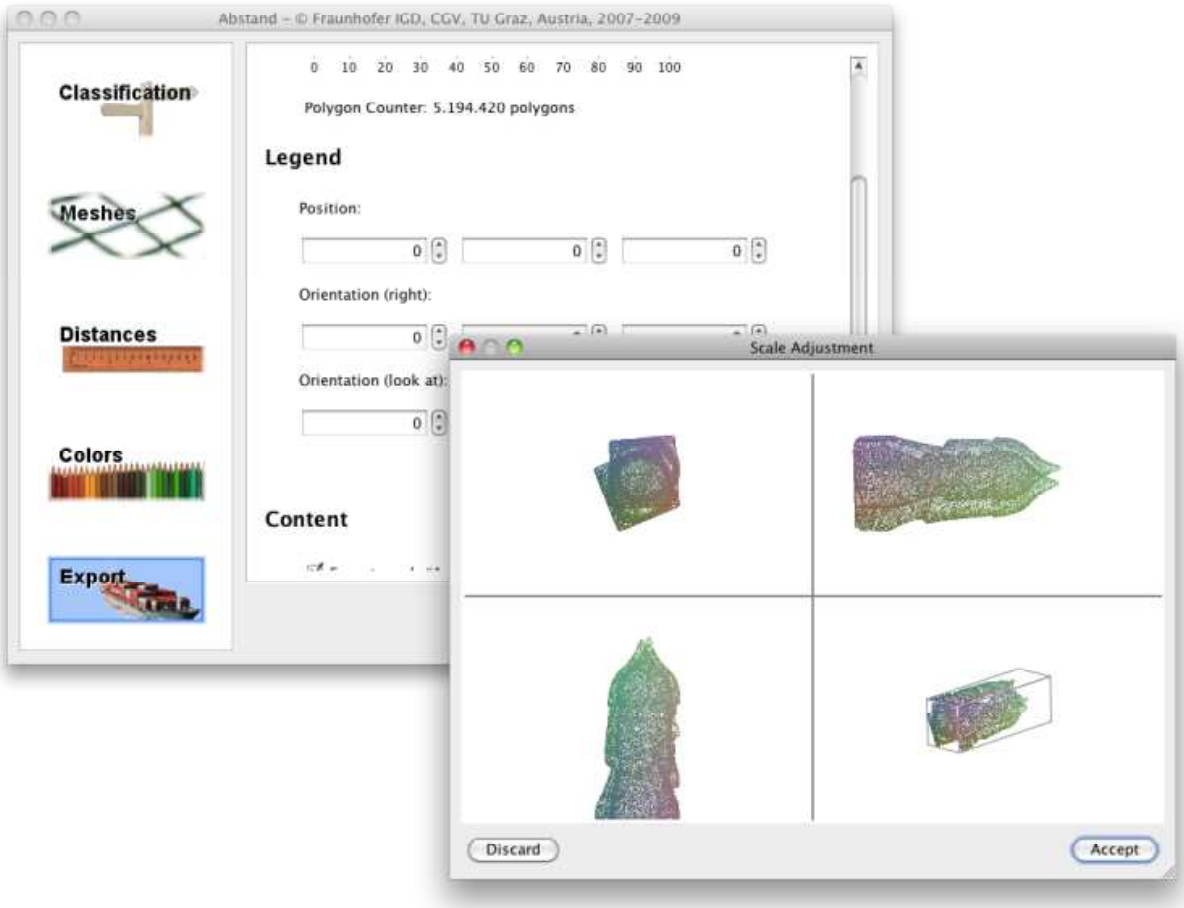
Geometry

As the number of polygons may be very high, an integrated level-of-detail algorithm can be used to reduce the polygon count. Please note that the polygon counter is only a rough estimation.

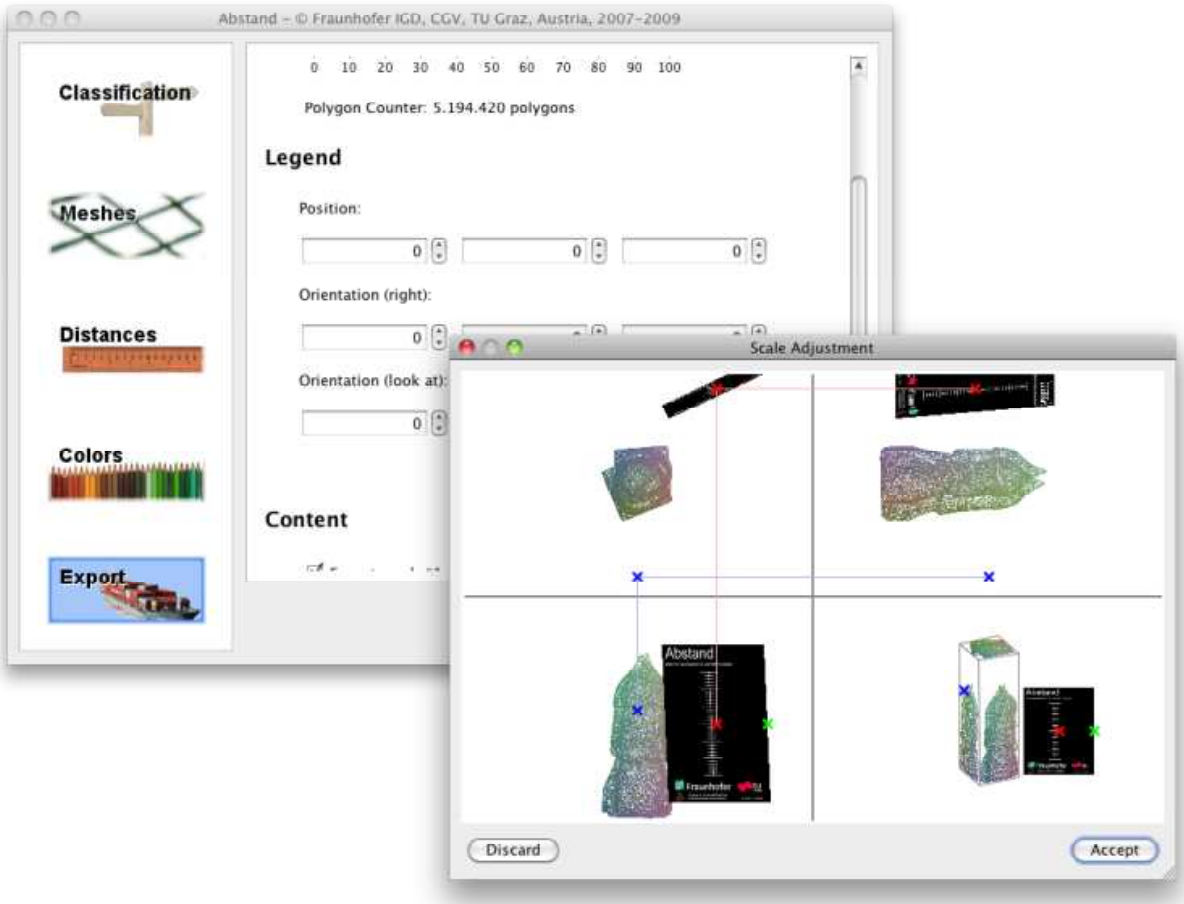


Legend

Each visualization and each diagram should have a legend respectively a scale. *Abstand* generates appropriate scales which can be include into the geometric scene. Click on the adjust orientation button in the legend section of the export panel to open a 3D preview. The 3D preview is an isometric visualization of the geometry's bounding box.



Use the mouse and its buttons to adjust the geometry's orientation and click into the lower right window (isometric 3D preview) to include the legend.

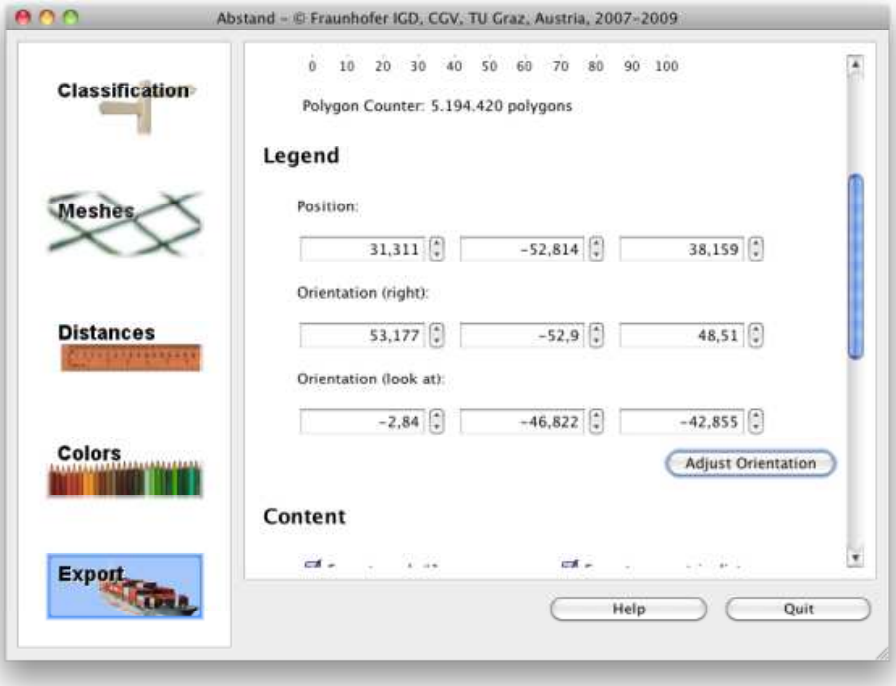


The legend's geometry is defined by three points in 3D. Its center position is always located at the red cross.

Its size is determined by the distance between its center (red cross) and its right border midpoint (green cross).

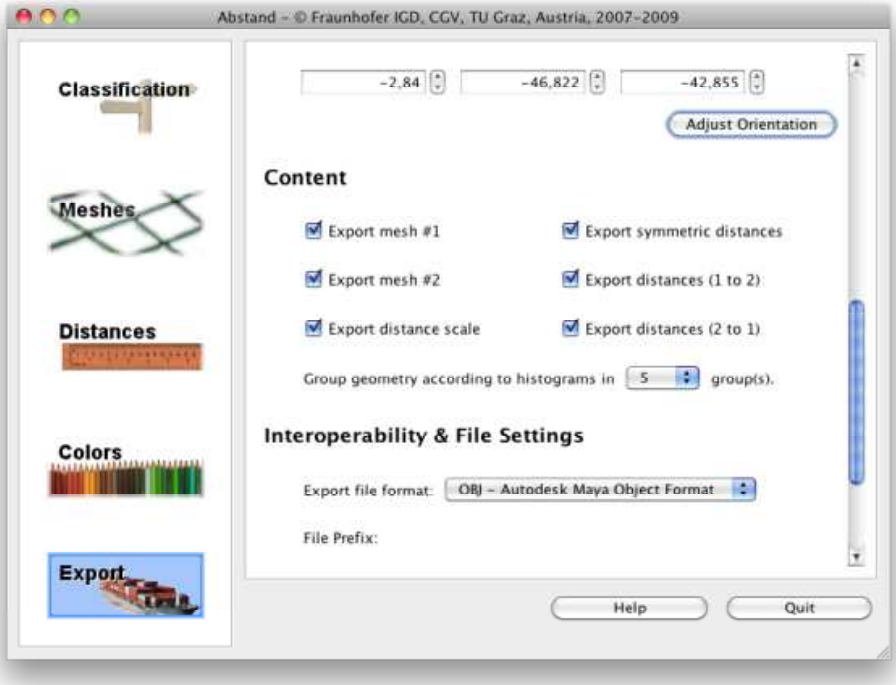
Its orientation is defined by the center point (red cross), its border midpoint (green cross) and a look at point (blue cross). The vector starting at the center to the look at point is the legend normal. This defines a plane in which embeds the scale. Within this plane the border midpoint (green cross) defines the legend orientation.

The position of the red, green, blue points can be edited in the 3D preview interactively. Furthermore their coordinates can be entered manually.



Content

In some cases it is useful to export only some results of the distance calculations. With *Abstand* you have the choice the select which results shall be included into the visualization. Beside the option to export the meshes and the distance scale, the one-sided distances and the symmetric distances can be selected separately. Furthermore the distance visuals can be group according to the distance histogram.



Interoperability

Abstand offers two export file formats: Autodesk Maya Object Format (OBJ) and Persistence of Vision Raytracer Fromat (POV).

In most cases the visualization contains two surface layers rendered with transparencies. While in

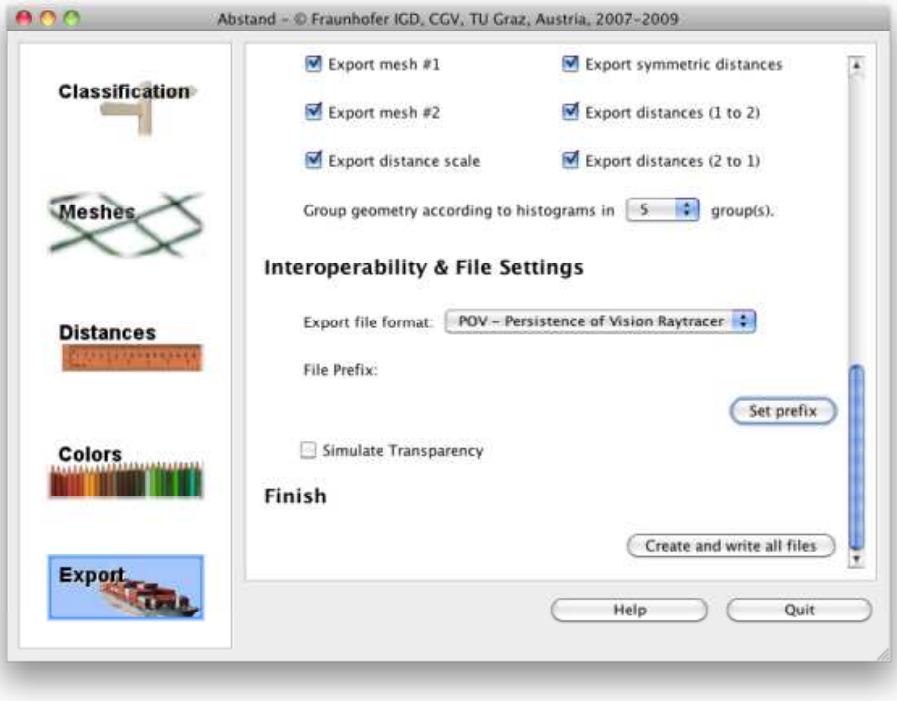
general it is no problem to render still images with transparency, interactive viewers may not always render transparencies correctly. Correct rendering of transparent objects needs a back-to-front sorting of all surfaces. Special care has to be taken for interpenetrating objects.

To have an appealing visualization for the interactive rendering, we offer a transparency simulation by a varying wire frame representation. Each transparent triangle, for example, is replaced by three quads. The area of the quads is inversely proportional to the triangle's transparency. For high transparency values, the quads almost form lines along the borders of the triangle. For low values, the triangle appears rather opaque leaving only a small hole in the middle of the face. This technique offers a comparable illustration in viewers, which do not render transparency correctly, at the expense of the polygon count.

Select simulate transparency to activate this technique.

File Settings

In the final step select a file name prefix and click on the create and write all files button to finish the distance visualization.



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Further Readings

Abstand

Ullrich, T., Settgast, V. & Fellner, D.W. (2008), *"Distance Visualization for Geometric Analysis"*, Proceedings of the Conference on Virtual Systems and MultiMedia Dedicated to Digital Heritage (VSMM), pp.334-340.

References

Aspert, N., Santa-Cruz, D. & Ebrahimi, T. (2002), *"MESH: Measuring Error between Surfaces using the Hausdorff distance"*, Proceedings of the IEEE International Conference on Multimedia and Expo 2002 (ICME). Vol. 1, pp. 705-708.

Baltsavias, M., Gruen, A., Van Gool, L. & Pateraki, M. (2006), *"Recording, Modeling and Visualization of Cultural Heritage"*, Taylor & Francis.

Bergman, L.D., Rogowitz, B.E. & Treinish, L.A. (1995), *"A rule-based tool for assisting colormap selection"*, Proceedings of the 6th Conference on Visualization. Vol. 6, pp. 118-125.

Borland, D. & Taylor II, R.M. (2007), *"Rainbow Color Map (Still) Considered Harmful"*, IEEE Computer Graphics and Applications. Vol. 27(2), pp. 14-17.

Cignoni, P., Rocchini, C. & Scopigno, R. (1998), *"Metro: Measuring error on simplified surfaces"*, Computer Graphics Forum. Vol. 17(2), pp. 167-174.

Dubuisson, M. & Jain, A.K. (1994), *"A Modified Hausdorff Distance for Object Matching"*, Proceedings of the 12th IAPR International Conference on Pattern Recognition. Vol. 1, pp. 566-568.

Farin, G., Hamann, B. & Hagen, H. (2003), *"Hierarchical and Geometrical Methods in Scientific Visualization"*, Springer.

Gonnet, G.H. & Baeza-Yates, R. (1991), *"Handbook of Algorithms and Data Structures"*, Addison-Wesley Publishing.

Hege, H. & Polthier, K. (2002), *"Mathematical Visualization: Algorithms, Applications and Numerics"*, Springer.

Klein, R., Liebich, G. & Strasser, W. (1996), *"Mesh Reduction with Error Control"*, Proceedings of IEEE Visualization. Vol. 1, pp. 311-318.

Levkowitz, H. & Herman, G.T. (1992), *"Color Scales for Image Data"*, IEEE Computer Graphics and Applications. Vol. 12(1), pp. 72-80.

Moore, A.W. (1991), *"An introductory tutorial on kd-trees"*, Technical Report, Computer Laboratory, University of Cambridge. Vol. 209, pp. 1-20.

Rogowitz, B.E., Treinish, L.A. & Bryson, S. (1996), *"How NOT to lie with visualization"*, Computers in Physics. Vol. 10, pp. 268 - 273.

Stone, M. (2003), *"A Field Guide to Digital Color"*, AK Peters, Ltd..

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