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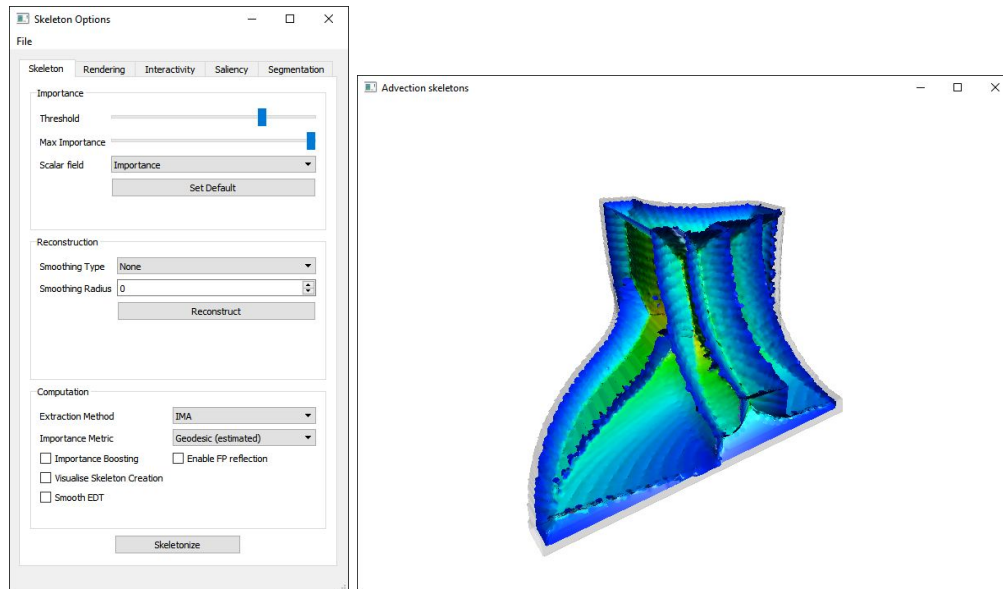
Overview

This is a short manual how to use the software implementation of the thesis "Salient edge preserving noise removal using surface skeletons", and how the steps of the pipeline can be applied.

The codebase is largely based on the "Advection Skeleton" codebase used for the Tpmi'16 paper. However, with large changes to the GUI, rendering and processing pipeline. In particular the GUI has been changes from GLUI to QT, the rendering from point-based rendering to splat-based rendering, and lot of parameters of the skeleton creation can now be changed in the GUI. Additionally, the saliency pipeline as described in the thesis has been added as well as the noise creation (both interactive and automatic) .

In the following section the individual steps are explained, which show how to replicate the results of the thesis. These steps include: opening models, adding noise, extracting skeleton, importance filtering, saliency filtering, reconstruction and exporting the resulting filtered models.

In this manual and in the software the distinction is made between an importance measure, which allows filtering skeletons based on local size characteristics of the skeleton points, and the saliency measure, which is a function of the importance measure, but has extra filtering steps to keep features of the model in tact. The importance filtering is explained in "skeleton extraction and importance", and the saliency filtering is shown in "Saliency filtering".



Opening voxel models

Opening a model can be done by supplying the filename as a command line argument to the application. For example: `Voxelskeleton normalcube.vtk` . Alternatively, one can open a voxel model using the file-> open dialog. When opening the model using the file -> open dialog no padding is added (this is chosen so that we can easily compare previously exported models). Therefore, if you want to add noise to the model, one should always open the model using the command line arguments.

The following file types are supported: Vtk and fld

Adding noise

Optionally, one can add noise to the model after opening it. This can be done in the following two ways:

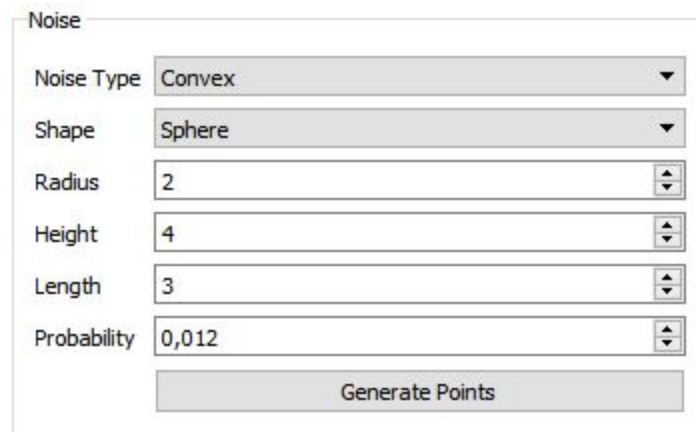
- Interactively: When the pick type dialog is set to 'adding noise' one can interactively add protuberances by clicking on specific parts of the model.
- Automatic: The generate noise button can be used to generate the noise using the specified parameters.

The noise parameters are the same for both methods. However, only the incidence / probability value is used for the automatic noise generation, and not for the interactive mode.

The synthetic noise has the following parameters:

- p (probability): The incidence value, the probability that a on a point $x \in M$ a protrusion is generated.
- r (radius): The radius of the kernel of the protrusion. In all cases in this thesis it is the radius of a sphere.
- h (height) : The height of the protrusion in the direction of the normal of $x \in M$.
- l (length): The 1D noise length of the protrusion in voxels. Setting the parameter $l > 1$ will cause curvilinear elements in random directions. If set to $l = 1$ the synthetic noise will be 0D.

To generate the noise interactively one can set these parameters (or leave them default) and click on generate. To add noise interactively the pick type under the tab interactivity must be set to 'Add noise'.



The screenshot shows a panel titled "Noise" with the following controls:

- Noise Type**: A dropdown menu currently set to "Convex".
- Shape**: A dropdown menu currently set to "Sphere".
- Radius**: A numeric input field with the value "2".
- Height**: A numeric input field with the value "4".
- Length**: A numeric input field with the value "3".
- Probability**: A numeric input field with the value "0,012".
- Generate Points**: A button located at the bottom of the panel.

Skeleton extraction and importance

The voxel skeletons supports multiple extraction methods, and multiple importance metrics defined on the skeleton which are computed after the skeleton extraction process. These settings are controlled using two dropdown boxes on the skeleton tab.

The following extraction methods are supported:

- USM : Unified Skeleton Model as defined in the Tpami'16 paper.
- IMA: Integer Medial Axis
- Implicit Euclidean (**recommended**): IMA estimation without using the feature transform, as defined in thesis

If one wants apply USM extraction as in the "Advection Skeleton", then you should enable "Importance Boosting" and "FP reflection". The recommended extraction method is "implicit Euclidean", as it gives the cleanest and most centered skeleton when noise is added.

The following importance metrics are supported:

- USM: Max density lambda from USM
- Geodesic: Graph geodesic (shortest path over the surface)
- Geodesic (estimated): Fast estimation of the geodesic measure, but with loss of precision
- Implicit Euclidean: Estimated euclidean length between the feature points

The recommended importance measure is the geodesic measure for the final results, and the estimated geodesic for quick testing.

The skeleton can be pruned using the importance by changing the importance slider, which is equalized and normalized from the minimum to maximum.

Computation

Extraction Method

Implicit Euclidean

Importance Metric

Geodesic (estimated)

☐ Importance Boosting

☐ Enable FP reflection

☐ Visualise Skeleton Creation

☐ Smooth EDT

Skeletonize

Importance

Threshold

Max Importance

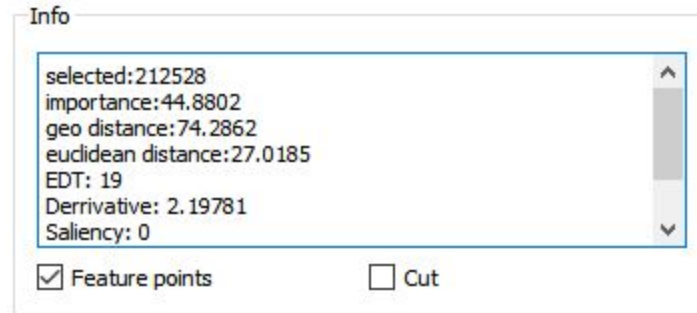
Scalar field

Importance

Set Default

Show Info

If the pick mode is set to "Show Info", then clicking on the skeleton points will show information of the selected skeleton point. For example, the geodesic measure, the current importance, the euclidean distance, the EDT, the derivative (as defined in the thesis), and the current saliency measure. It also shows the skeleton index of the selected point (useful for debugging).



Saliency Filtering

After pre-pruning (reducing the regular importance with a small threshold), one can apply saliency filtering to reduce ligature branches corresponding to noise, without affecting much of the core skeleton (depending on the saliency method). The method and related setting can be selected in the 'Saliency' tab. The following methods can be chosen:

- Classical filtering (original saliency measure as defined by A. Telea)
- Derivative measure: Saliency measure based on the derivative as is introduced in my thesis.
- Inverse Mapping: Uses inverse feature transform to remove insignificant skeleton points (not recommended)
- Global importance (streamline): Streamline-based filtering approach of creating monotonic metric
- Global importance (order) (**Recommended**): Global streamline approach as defined in the thesis.

With the exception of classical filtering all of the above methods use the threshold based on the original importance, but only try to remove points under the threshold that are part of the ligature sheets, so that core skeleton points with low importance do not get removed.

The threshold of the saliency measure can be altered after the saliency measure has been computed. This can be done by moving the threshold slider or combobox under the saliency tab. If required (in the case of classical filtering or the derivative method) one should enable the "filter largest component" option, which should only retain the core skeleton and remove the tips from the ligature branches.

Importance

Threshold 14,6388492584

Method Global Importance (order)

☐ Only Retain Largest Component

Reconstruction

The (filtered) skeleton can be reconstructed in the "skeleton" tab . It outputs a new voxel model, which can be viewed using the "view reconstruction" option under the "rendering" tab. Note that to get the best view of the reconstructed model, it is best to set the input rendering mode to "splat-based rendering", and set the skeleton rendering to none (so that there is no z-fighting with both models).

The reconstruction method allows different filtering options on the EDT before reconstruction:

- None: No filtering is applied
- Minification (**Recommended**): Min filter plus inflation of the EDT.
- Mean: local average of EDT
- Median: local median of EDT
- Opening: Min filtering followed by a max filter
- Flat projection: flattens the EDT by adding constraints to the reconstruction
- Least Squares: Projects EDT values to the least squares plane.

There is also a combobox which can influence the radius's of the filtering methods. The default ($r = 3$) works well on most methods.

Reconstruction

Smoothing Type None

Smoothing Radius 0

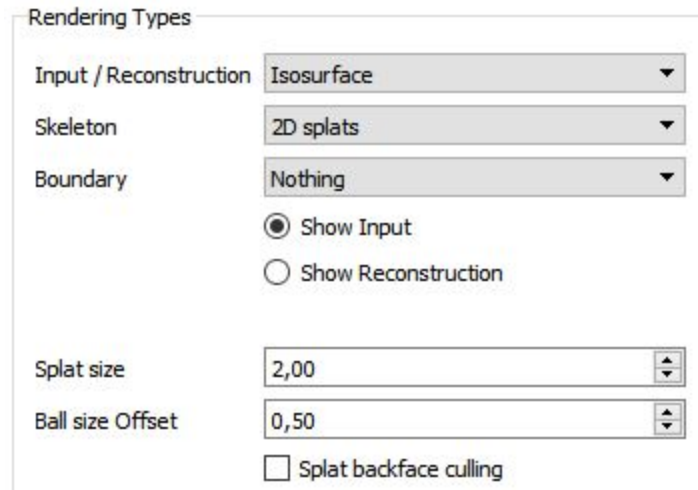
Reconstruct

Rendering

There are multiple rendering options. Some of them carry over from the 'advection skeletons' codebase (such as that alpha settings and the slopes). A new setting is the 'splat backface

culling', which enables backface culling of the splats (for rendering skeletons this should be disabled, so that both sides of the potentially voxel-thin skeleton can be shown)

Under the skeleton tab the rendering of the scalar volume can be changed. Specifically the following options can be set: Importance, Saliency, and EDT. You can also change the maximum visual importance, using the max importance slider under the skeleton tab.



Rendering Types

Input / Reconstruction: Isosurface

Skeleton: 2D splats

Boundary: Nothing

☒ Show Input

☐ Show Reconstruction

Splat size: 2,00

Ball size Offset: 0,50

☐ Splat backface culling

Exporting models

When noise is added it is useful to export the model so that an experiment can be repeated with different parameters. Similarly, it is useful to export the reconstructed model for comparison. The models can be exported as a mesh (in obj format), or as a voxel model (vtk).

To choose which model is exported (the input model or the reconstruction), change the corresponding radio boxes under the rendering tab.

Exporting / Importing Importance

The current selected saliency or importance can be exported using file -> export Importance.

It is also possible to import the importance using file -> import importance, but this can be done **only** after the skeleton has been extracted!