SRP-HPC 2022

Wendy Sears
Data and Visualization
Project Mentor: Mark Miller PhD (VisIt – Parallel, interactive, visualization software)

Use criteria (preliminary, below) to evaluate 3-4 volumetric data analysis tools:

Slicer https://www.slicer.org/

MIPAV (Medical Image Processing, Analysis, and Visualization) https://mipav.cit.nih.gov/

MITK https://www.mitk.org/wiki/The_Medical_Imaging_Interaction_Toolkit_(MITK)

ITK-SNAP http://www.itksnap.org/pmwiki/pmwiki.php

MedInria https://med.inria.fr/

Convert3D https://sourceforge.net/p/c3d/git/ci/master/tree/doc/c3d.md#about-convert3d

Meshlab https://www.meshlab.net/

MevisLab https://www.mevislab.de/

Assessment platform	Asus ZenBook flip laptop
Operating system name/version	Windows 11 Home. Version 21H2 OS build 22000.675 64-bit operating system, x64-based processor
CPU designation	Intel(R) Core(TM) i7-8550U CPU @ 1.80GHz 1.99 GHz
GPU designation (if any)	Nvidia GeForce MX150
Amount of main memory	16.0 GB
Free disk space	99 of 500 GB ; 36.6 of 500 GB

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-Tool name: Slicer https://www.slicer.org/

Data handling (on 3 different datasets: small < 100Mb, medium < 1GB, large > 50GB)

Small √
Medium √
Large X (largest one able to open was 11.5 GB).

-After 7 mins opening liver dataset (8.71GB) "successfully" it ended up saying no reader available for the image path on all of them.

-Slicer crashed while creating labelmap for stl cleaner foot.

op1. Produce a 3D model (stl) file
op2. Applying various filters (anisotropic smoothing might be a good one to test if available)
op3. Subset the volume into some number of pieces (if possible)
op4. Convert formats (maybe dicom to brick of value (bov) or something else)

Operations timings

Inconsistent. Varied on type and size of dataset for the same operation.

Robustness (poor/average/superlative)

Superlative overall but dataset size and extensions used affect it. There seems to be some extension compatibility issues (at least on this PC).

Useability (poor/average/superlative)

Average

Numerical analysis features

Segment statistics: This is a module for the calculation of statistics related to the structure of segmentations, such as volume, surface area, mean intensity, and various other metrics for each segment.
Labelmap statistics are calculated using the binary labelmap representation of the segment.
Voxel count: the number of voxels in the segment
Volume mm3 the volume of the segment in mm3
Volume cm3 the volume of the segment in cm3
Centroid: the center of mass of the segment in RAS coordinates
Feret diameter: the diameter of a sphere that can encompass the entire segment
Surface area mm2: the volume of the segment in mm2

Roundness: the roundness of the segment. Calculated from ratio of the area of the sphere calculated from the Feret diameter by the actual area. Value of 1 represents a spherical structure.
Flatness: the flatness of the segment. Calculated from square root of the ratio of the second smallest principal moment by the smallest. Value of 0 represents a flat structure.
Elongation: the elongation of the segment. Calculated from square root of the ratio of the second largest principal moment by the second smallest.
Principal moments: the principal moments of inertia for each axes of the segment
Principal axes: the principal axes of rotation of the segment
Oriented bounding box: the non-axis aligned bounding box that encompasses the segment. Principal axis directions are used to orient the bounding box.

Scalar volume statistics

- Voxel count: the number of voxels in the segment
- Volume mm3 the volume of the segment in mm3
- Volume cm3 the volume of the segment in cm3
- Minimum: the minimum scalar value in the segment
- Maximum: the maximum scalar value in the segment
- Mean: the mean scalar value in the segment
- Median: the median scalar value in the segment
- Standard deviation: the standard deviation of scalar values in the segment (computed using *corrected sample standard deviation* formula)

Closed surface statistics

- Surface area mm2: the volume of the segment in mm2
- Volume mm3 the volume of the segment in mm3
- Volume cm3 the volume of the segment in cm3

Quality (poor/average/superlative)
Superlative

List of supported formats and notes

Two major types of data:

DICOM
Non-DICOM: Images (.nrrd, nii.gz,…); Models (stl, ply, obj,…); Tables (csv, txt); Point lists (json).

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DICOM (.dcm, or any other): Slicer core supports reading and writing of some data types, while extensions add support for additional ones. Coordinate system: LPS (as defined by DICOM standard).

Supported DICOM information objects:

Slicer core: CT, MRI, PET, X-ray, some US images; secondary capture with Slicer scene (MRB) in private tag

Quantitative Reporting extension: DICOM Segmentation objects, Structured reports

SlicerRT extension: DICOM RT Structure Set, RT Dose, RT Plan, RT Image

SlicerHeart extension: 2D/3D/4D ultrasound (GE, Philips, Eigen Artemis, and other)

SlicerDMRI tractography storage

SlicerDcm2nii diffusion weighted MR

Support of writing DICOM Segmentation Objects is provided by the Reporting extension

NRRD (.nrrd, .nhdr); **NRRD sequence** (.seq.nrrd); **MetaImage** (.mha, .mhd); **VTK** (.vtk); **Analyze** (.hdr, .img, .img.gz); **Nifti** (.nii, .nii.gz); **Tagged image file format** (.tif, .tiff); **PNG** (.png); **JPEG** (.jpg, .jpeg); **Windows bitmap** (.bmp); **BioRad** (.pic); **Brains2** (.mask); **GIPL** (.gipl, .gipl.gz); **LSM** (.lsm) ; **Scanco** (.isq); **Stimulate** (.spr); **MGH-NMR** (.mgz); **MRC Electron Density** (.mrc).

SlicerRT extension

Vista cone beam optical scanner volume (.vff)

DOSXYZnrc 3D dose (.3ddose)

SlicerHeart extension: 2D/3D/4D ultrasound (GE, Philips, Eigen Artemis, and other; reading only)

Philips 4D ultrasound: from Cartesian DICOM exported from QLab

GE Kretz 3D ultrasound (.vol, .v01)

Eigen Artemis 3D ultrasound

Any 3D/4D ultrasound image and ECG signal: if the user obtains Image3dAPI plugin from the vendor (GE Voluson, Philips, Siemens, etc.).

RawImageGuess extension

RAW volume (.raw): requires manual setting of header parameters

Samsung 3D ultrasound (.mvl): requires manual setting of header parameters

SlicerIGSIO extension:

Compressed video (.mkv, .webm)

IGSIO sequence metafile (.igs.mha, .igs.mhd, .igs.nrrd, .seq.mha, .seq.mhd, .mha, .mhd, .mkv, .webm): image sequence with metadata, for example for storing surgical navigation and position-tracked ultrasound data

OpenIGTLink extension:
PLUS toolkit configuration file (.plus.xml): configuration file for real-time data acquisition from imaging and tracking devices and various sensors
Sandbox extension:
Topcon OCT image file (.fda, reading only)
Models
Surface or volumetric meshes.

VTK Polygonal Data (.vtk, .vtp).
VTK Unstructured Grid Data (.vtk, .vtu).
STereoLithography (.stl).
Wavefront OBJ (.obj).
Stanford Triangle Format (.ply).
BYU (.byu, .g; reading only).
UCD (.ucd; reading only).
ITK meta (.meta; reading only).
FreeSurfer extension:
Freesurfer surfaces (.orig, .inflated, .sphere, .white, .smoothwm, .pial; reading only)
SlicerHeart extension:
CARTO surface model (.vtk; writing only).
Segmentations
Segmentation labelmap representation (.seg.nrrd, .nrrd, .seg.nhdr, .nhdr, .nii, .nii.gz, .hdr).
Segmentation closed surface representation (.vtm).
Labelmap volume (.nrrd, .nhdr, .nii, .nii.gz, .hdr).
Closed surface (.stl, .obj).
SlicerOpenAnatomy extension: **GL Transmission Format** (.glTF, writing only)
Sandbox extension: **Osirix ROI file** (.json, reading only); **sliceOmatic tag file** (.tag, reading only).
Transforms
ITK HDF transform (.h5).
ITK TXT transform (.tfm, .txt).

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Matlab MAT file (.mat).
Displacement field (.nrrd, .nhdr, .mha, .mhd, .nii, .nii.gz).
SlicerRT extension**: Pinnacle DVF** (.dvf).
Markups
Markups JSON (.mkp.json).
Markups CSV (.fcsv).
Annotation CSV (.acsv).
Scenes
MRML (Medical Reality Markup Language File) (.mrml).
MRB (Medical Reality Bundle) (.mrb, .zip).
Data collections in XNAT Catalog format (.xcat; reading only)
Data collections in XNAT Archive format (.xar; reading only)
Others
Text (.txt, .xml., json)
Table (.csv, .tsv)
Color table (.ctbl, .txt)
Volume rendering properties (.vp)
Volume rendering shader properties (.sp)
Terminology (.term.json, .json)
Node sequence (.seq.mrb)
-Much babysitting needed
Manual, semiautomatic, automatic segmentation available
-Programming interface: Python, C++

-Open source or commercially licensed. Open source

-Can it use parallel resources and if so how (multi-core, GPU, ...) *

-Platform availability
Windows (10 or later)
macOS (High Sierra 10.13 or later on both Intel and ARM based systems)
Linux: Ubuntu 18.04 or later
RedHat
CentOS 7 or later
Build from sources

-Other unique features

- Multi organ: from head to toe.
- Support for multi-modality imaging including MRI, CT, US, nuclear medicine, and microscopy.
- Real-time interface for medical devices, such as surgical navigation systems, imaging systems, robotic devices, and sensors.
- Highly extensible: can add more capabilities by installing additional modules from Extensions manager, running custom Python scripts in the built-in Python console, run any executables from the application's user interface, or implement custom modules in Python or C++.
- Tubular structures/vessel segmentation extensions available

-Ranking among those you've assessed

1

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Data and Visualization
Project Mentor: Mark Miller PhD (VisIt – Parallel, interactive, visualization software)

-Tool name: MITK https://www.mitk.org/wiki/The_Medical_Imaging_Interaction_Toolkit_(MITK)

Data handling (on 3 different datasets: small < 100Mb, medium < 1GB, large > 50GB)

Small √
Medium x
Large X (largest one able to open was ~3 GB).

2 mins to open dataset 1. Went from using 2% memory to 70%. Constantly displaying not responding every time I did simple scrolling through the image. This has not happened with other large CT scans.

Croc dataset could not get opened. Crashed. MITK crashed my pc the worst (required restart).

op1. Produce a 3D model (stl) file
op2. Applying various filters (anisotropic smoothing might be a good one to test if available)
op3. Subset the volume into some number of pieces (if possible)
op4. Convert formats (maybe dicom to brick of value (bov) or something else)

Operations timings NA

Robustness (poor/average/superlative)
Poor

Useability (poor/average/superlative)
Average

Numerical analysis features
The measurement toolbox:

Measurement view: measure distances, angles, paths and several geometric figures on 2D images or image slices of 3D and 4D images. The measurement view is repeatedly useable with the same or different measurement figures that are related to the chosen image and can be saved together with it for future use.

Image statistics view: provides an easy interface to quickly compute some features of a whole image or a region of interest. An example of parts of the calculated statistical features (Mean, Median, StandardDeviation, RMS, Max, MaxPosition, Min, MinPosition, Voxel, Volume [mm^3], Skewness, Kurtosis, Uniformity, Entropy, MPP, UPP and Variance) for different timesteps and different masks is pictured below.

quality (poor/average/superlative)
Average***

list of supported formats and notes

countour file .cnt, countour model set file .cnt_set .dcm, geometries .mitkgeoimetry, Inmages (.mha, he5 nrrd vtk img jpg nii h5 rec img.gz .gipl.gz .PIC .spr .mrc .dc3 .gipl mnc nua nhdr jpeg nii.gz .ima .mhd hdf5 lsm gdcm jpt vti .hdr.gz .he4 h4 jp2 MITK planar fidure .pf, MITK scenes .mitk,, matchpoint registratuion file .mapr.xml .mapr, navigation dataset .csv .xml, pointsets .mps, surfaces .vtk, .stl, obj, pvtp, vtp, ply VTK unstructured grid .vtk pvtu vtu, Vtk unstructures grid vtk, vtu

-Much babysitting needed? Manual, semiautomatic

-Programming interface? Python, C++

-Open source or commercially licensed? Open source

-Can it use parallel resources and if so how (multi-core, GPU, ...)

-Platform availability: macOS, Windows, Linux

-Other unique features

Can be used as a standalone application or to develop your own framework and used MITKs data structures and algorithms (as a toolkit, etc.); or using MITK and blueberry software framework to develop your own software by using the MITK workbench and extend its capabilities or creating your own application based on MITK.

MITK miniapps: small command line tools with a general purpose for each of these tools to fulfill one simple task, e.g. resample an image or extract image statistics of a given region of interest (ROI).They are intended to provide command line access to a variety of features of MITK, thus facilitating batched processing of data.

System load indicator/memory usage gives infgo about memory reqs for MITK.

Has a log window so you know if it is taking long because it is doing a process or if it crashed.

Notes: The segmentation plugin makes a number of assumptions: Images must be 2D, 3D, or 3D+t. Images must be single-values, i.e. CT, MRI or "normal" ultrasound. Images from color doppler or photographic (RGB) images are only partially supported (please be aware that some tools might not be compatible with this image type).

Segmentations are handled as multilabel images of the same extent as the original image.

-Ranking among those you've assessed

3

*Despite frequently freezing/crashing, software has a lot of capabilities and features, and other software is based on it. It is a possibility that the PC/hardware used was not robust enough to handle it. Meaning it could be both positive and negative, i.e. all the features work on a more robust system but also, a higher than above average system is required to use the software properly.

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-Tool name: Meshlab https://www.meshlab.net/

Data handling (on 3 different datasets:
small < 100Mb √
medium < 1GB √
large > 50GB) NA (Largest file opened ~7GB

op1. Produce a 3D model (stl) file
op2. Applying various filters (anisotropic smoothing might be a good one to test if available)
op3. Subset the volume into some number of pieces (if possible)
op4. Convert formats (maybe dicom to brick of value (bov) or something else)

Operation timings

operation	small	med	large
op1	10s	44s	≤120s
op2	7s	30s	≤140s
op3	na	na	na
op4	20s	40s	≤60s

Robustness
Average-Superlative

Useability
Superlative

Numerical analysis features
*This tool is used primarily for polygonal mesh pre/post processing (“cleaning”, editing, rendering,revision, 3d print prep).
Measurement and analysys of point to point geometric and topological model information mainly through filters/algorithms applied (e.g. geodesic distance, local vertex density).

Quality
Average-Superlative

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List of supported formats and notes.

Import mesh

Eisen Script File (*.es)
3D-Studio File Format (*.3ds)
Stanford Polygon File Format (*.ply)
STL File Format (*.stl)
Alias Wavefront Object (*.obj)
Quad Object (*.qobj)
Object File Format (*.off)
PTX File Format (*.ptx)
VCG Dump File Format (*.vmi)
FBX Autodesk Interchange Format (*.fbx)
Breuckmann File Format (*.bre)
Collada File Format (*.dae)
OpenCTM compressed format (*.ctm)
E57 (E57 points cloud) (*.e57)
Expe's point set (binary) (*.pts)
Expe's point set (ascii) (*.apts)
XYZ Point Cloud (with or without normal) (*.xyz)
GL Transmission Format 2.0 (*.gltf)
Binary GL Transmission Format 2.0 (*.glb)
Protein Data Bank (*.pdb)
TRI (photogrammetric reconstructions) (*.tri)
ASC (ascii triplets of points) (*.asc)
TXT (Generic ASCII point list) (*.txt)
X3D File Format - XML encoding (*.x3d)
X3D File Format - VRML encoding (*.x3dv)
VRML 2.0 File Format (*.wrl)

Save mesh as

Standard Polygon File Format (*.ply)
Multiresolution Nexus Model (*.nxs)
Compressed Multiresolution Nexus Model (*.nxz)
3D-Studio File Format (*.3ds)
Stanford Polygon File Format (*.ply)
STL File Format (*.stl)
Alias Wavefront Object (*.obj)
Object File Format (*.off)
VRML File Format (*.wrl)
DXF File Format (*.dxf)
Collada File Format (*.dae)
OpenCTM compressed format (*.ctm)
E57 (E57 points cloud) (*.e57)
XYZ Point Cloud (with or without normal) (*.xyz)
JavaScript JSON (*.json)
U3D File Format (*.u3d)
IDTF File Format (*.idtf)
X3D File Format (*.x3d)

Import raster

Windows Bitmap (*.bmp)
Joint Photographic Experts Group (*.jpg *.jpeg)
Portable Network Graphics (*.png)
Truevision Graphics Adapter (*.tga)
Tagged Image File Format (*.tif *.tiff)
X11 Bitmap (*.xbm)
X11 Bitmap (*.xpm)

-Much babysitting needed? Manual and semiautomatic
-Programming interface? Python, C++

-Open source or commercially licensed? Open source

-Can it use parallel resources and if so how (multi-core, GPU, ...) NA

-Platform availability: macOS, Windows, Linux

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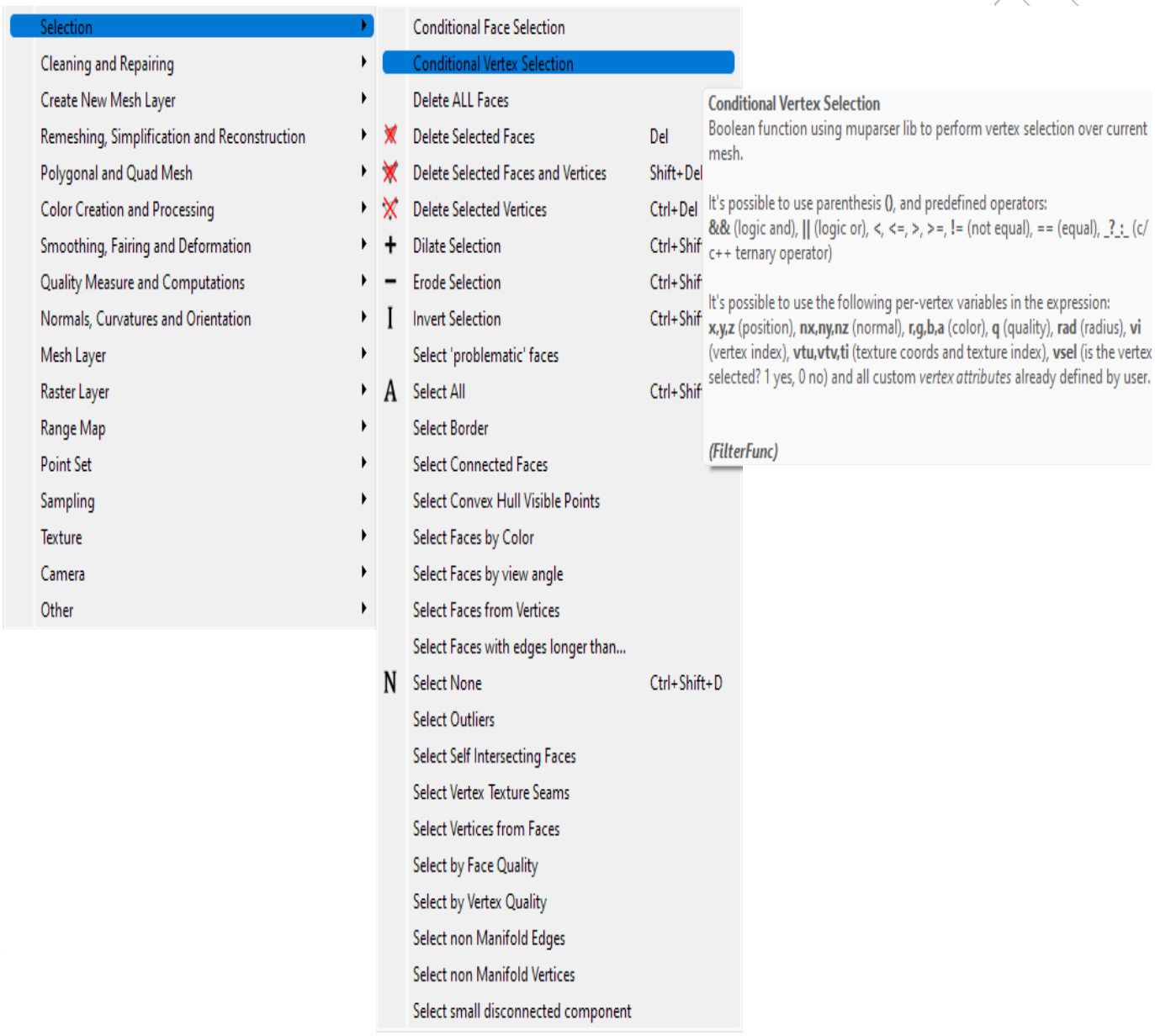
-Other unique features

Provides information on filters/algorithms available. Helpful for non-experts.
Easy GUI.
Displays memory used/needed on bottom right of the screen as well as filter application progress, timing, and script of operations used/filters applied.



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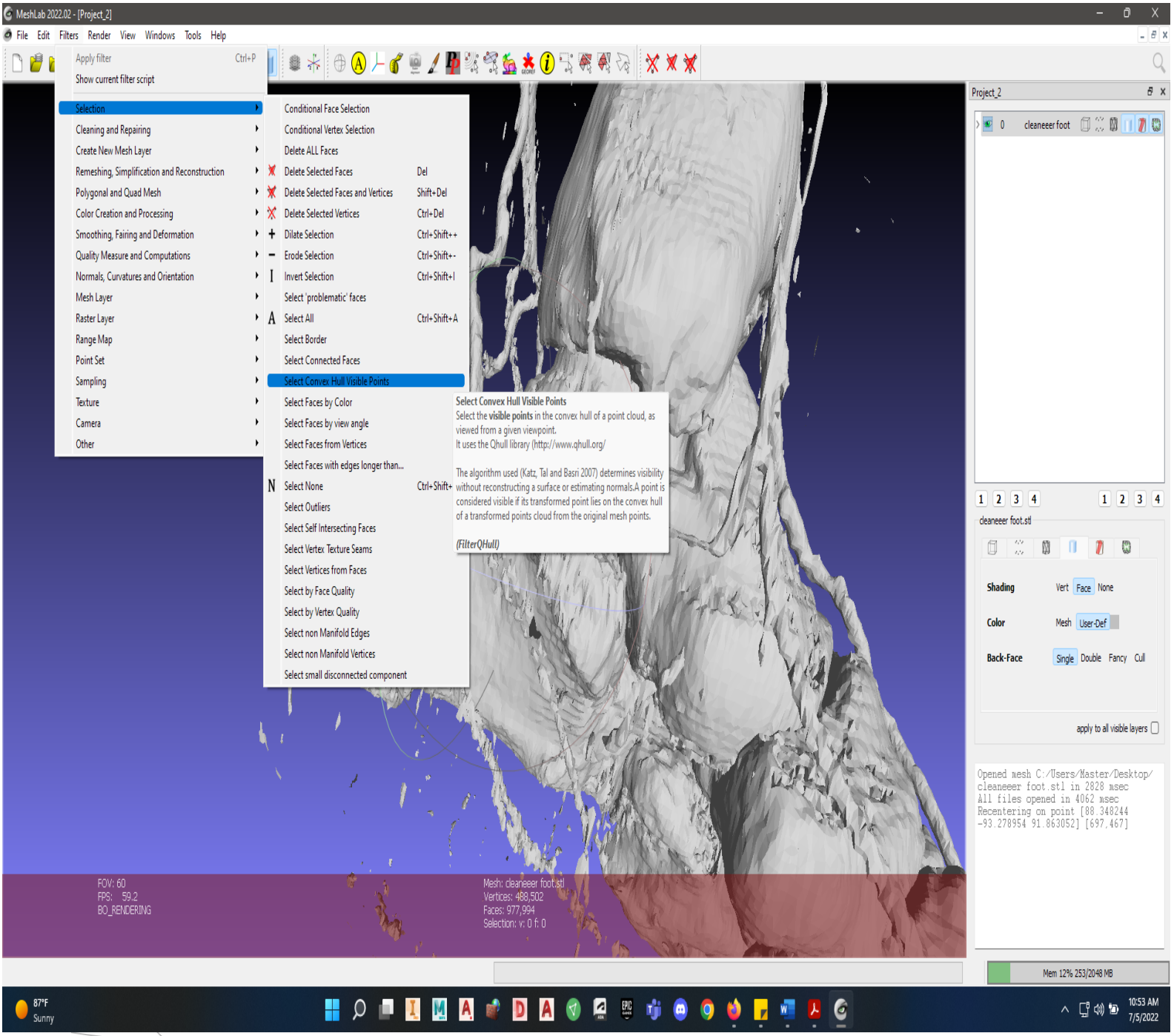

-Ranking among those you've assessed

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-Tool name: MevisLab https://www.mevislab.de/

Data handling (on 3 different datasets: small < 100Mb, medium < 1GB, large > 50GB)

Small √
Medium √
Large X (Largest file opened <4GB)

Operations timings NA

operation	small	med	large
op1			
op2			
op3			

Robustness (poor/average/superlative)
Average-superlative

Useability (poor/average/superlative)
Average*

Numerical analysis features

Quality (poor/average/superlative)
Average (could be related to PC used/limited by hardware)

list of supported formats and notes [data format(s) of input(s) and output(s)]

- dicom
- tiff
- png
- STL (binary)
- STL (ascii)
- other format 1
- other format 2

-Much babysitting needed? Manual and semiautomatic segmentation.
-Programming interface? C++, Python (scripting support).

-Open source or commercially licensed? Open source

-Can it use parallel resources and if so how (multi-core, GPU, ...) NA

-Platform availability

macOS
Windows
Linux

-Other unique features

- Full 6D image processing (x, y, z, color, time, user dimensions)
- Paging
  Caching
- Multithreading support
- Scripting support (Python)
- Macro system
- Defining of GUI elements with the MDL scripting language
- C++ programming interface
- Pure C++ and object-oriented design
- Self-descriptive module and application interfaces
- Error handling: configurable exception usage; configurable error handling; diagnosis modules, automatic module tester
- Runtime type system
- Extensible voxel type
- Resources-friendly memory usage
- Supports highly complex module networks
- Based on standard libraries
- Currently around 960 Standard modules in the MeVisLab SDK core, around 3300 modules delivered in total (with around 350 ITK modules, around 1400 VTK modules, and around 440 modules in the Fraunhofer MEVIS release)
- Long time maintenance
- Development available as plug and play (graphical programming interface), with macro modules and python scripts or with C++ programming modules and independent class library.

-Ranking among those you've assessed

4

Other tools worth mentioning:

Tool name	MIPAV	ITK-SNAP +Greedy	Convert3D	MedInria
Programming interface	Java	C++	C++	C++
License type	Open source	Open source	Open source	Open source
Parallel capabilities	NA	NA	NA	NA
Platform availability	Windows Solaris MacOS	Windows Mac Linux	Windows Mac Linux	Windows Mac Linux Fedora redhat ubuntu