Structure, Concept and Result Reproducibility of the Benchmark on Vesselness Filters

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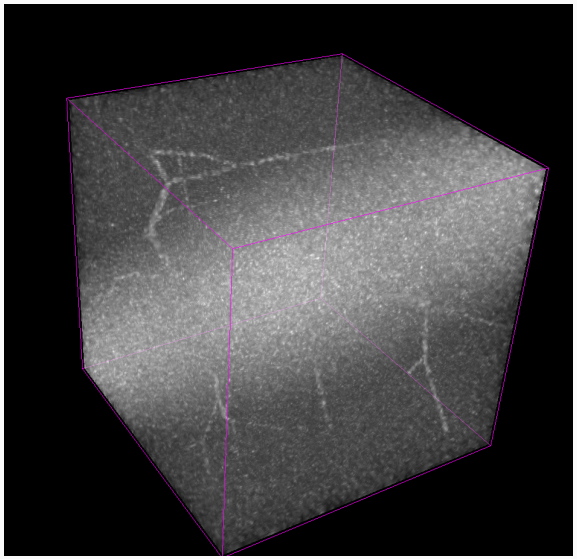
Overview

1. Overview of Benchmark

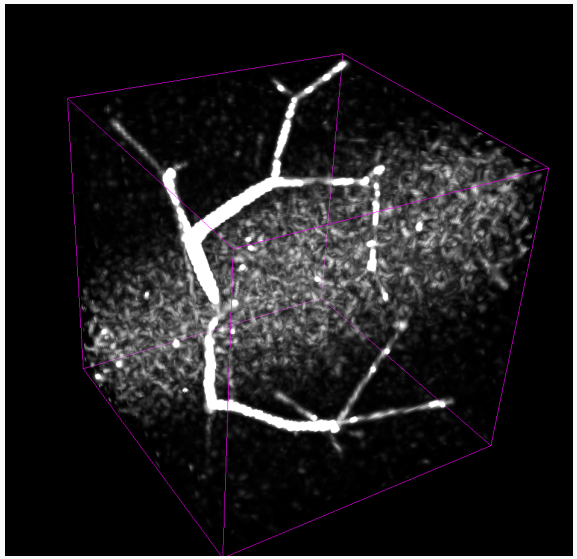
Introduction

Context

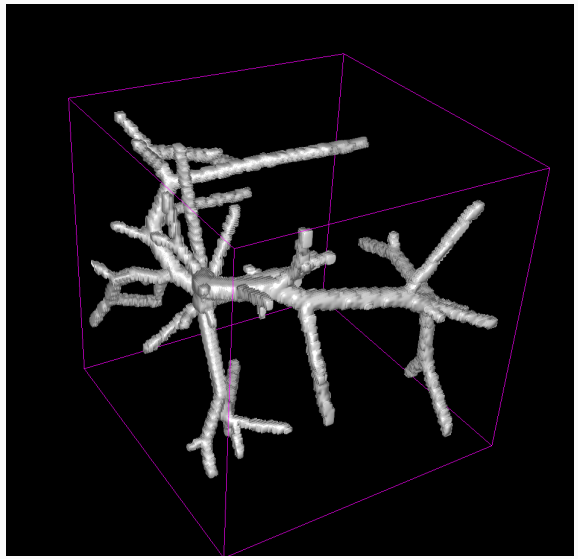
- Accurate liver vessels segmentation is still an open problem.
- Most segmentation schemes rely on a vessel enhancement filter (vesselness filters).
- No easy way to compare different filters.



Vascusynth volume



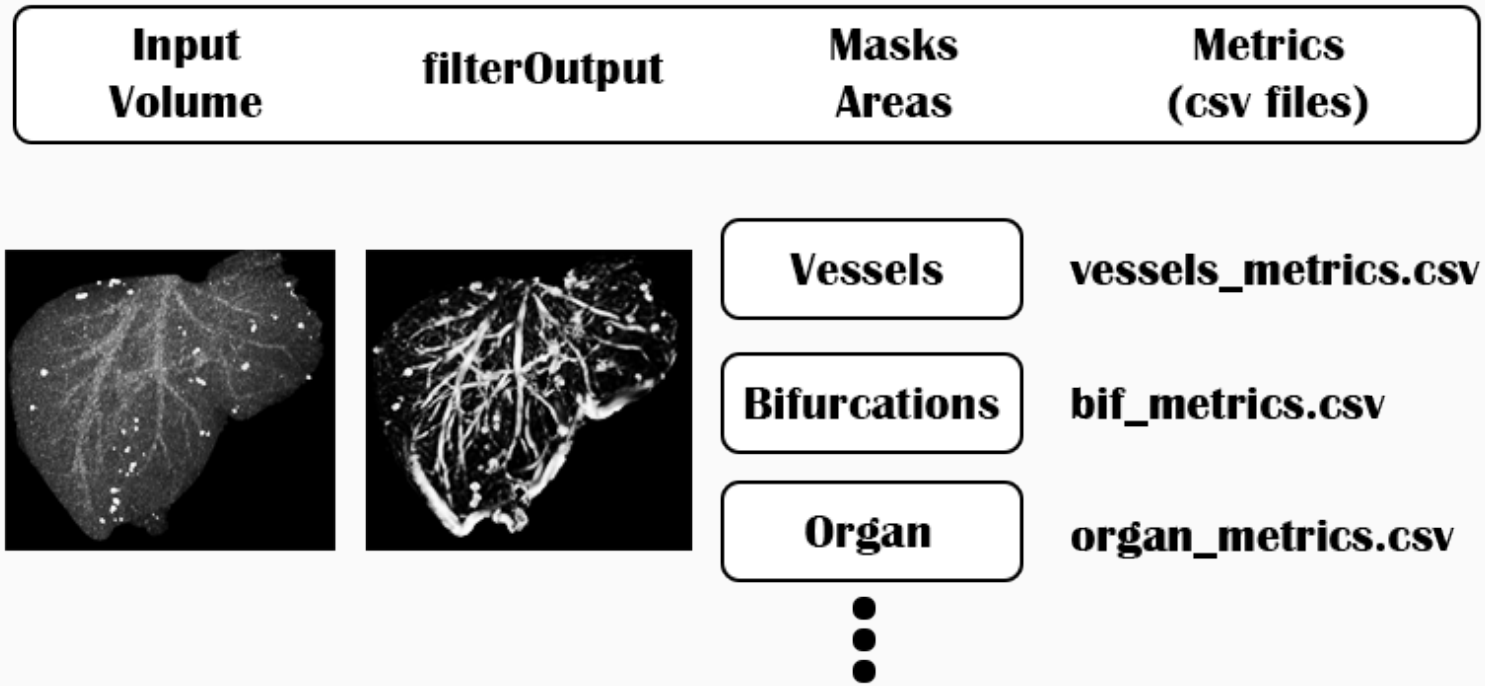
Jerman vesselness output



Ideal segmentation

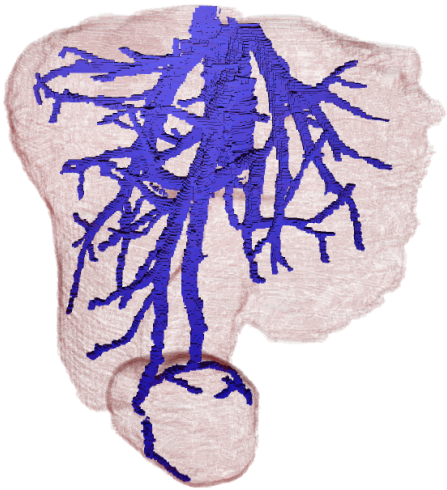
Goal

We created a framework that quantitatively assesses the quality of a vesselness filter given a 3D input volume and the corresponding ground truth.

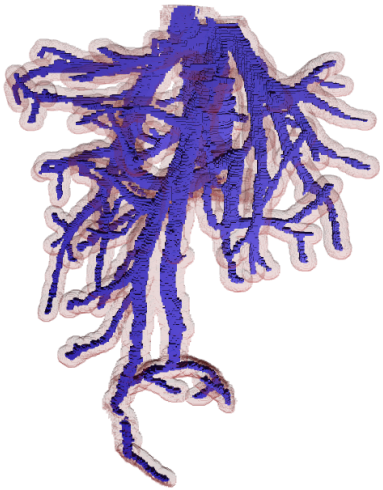


Additional goal

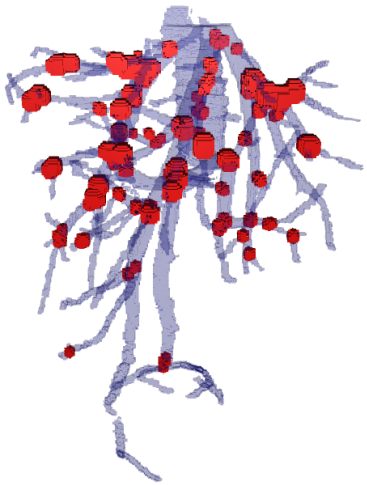
In particular we wanted to assess the performance of the filters depending on three areas of interest.



Liver



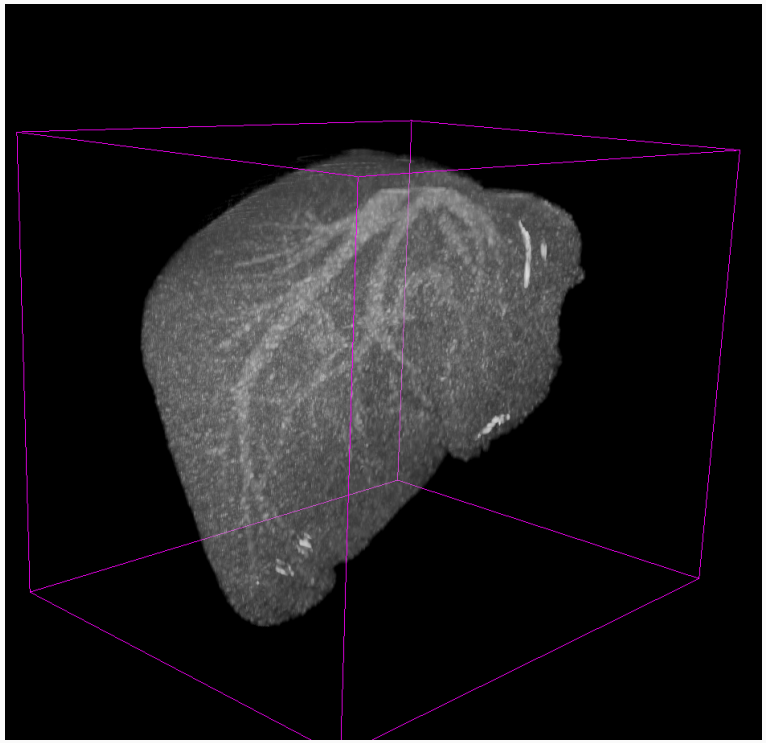
Dilated vessels



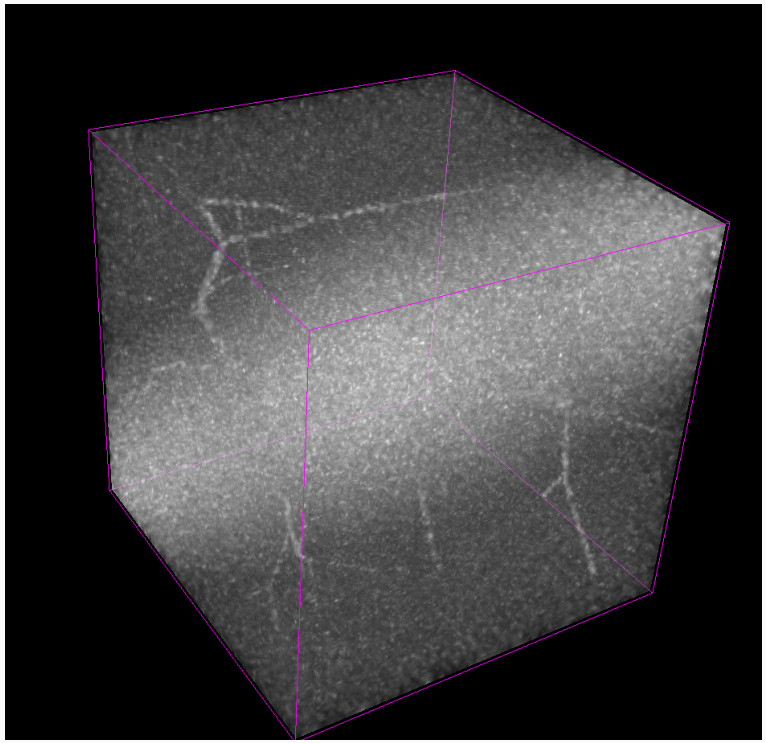
Bifurcations

Datasets

- Ircad dataset (CT scan - 20 patients)
- Vascusynth dataset (Synthetic data with Rician noise (sigma=10) and Gaussian artefacts)



Ircad sample (MIP)



Vascusynth sample (MIP)

Volume data

Two datasets

- Each instance of input volume, ground truth, and masks are listed in a single file.
- The benchmark takes any number of regions of interest.

```
3Dircadb1.10 // Name
PathToFolder/patientIso.nii //input image
PathToFolder/vesselsIso.nii  // groundtruth
PathToFolder/liverMaskIso.nii // first mask
PathToFolder/dilatedVesselsMaskIso.nii // second mask
.
.
.
```

Assessment methods

Assessment

Quality assessment made into two steps:

- Successive thresholdings of filter output.
- Comparison of binary results with ground truth.

Metrics

- Matthew's correlation coefficient (MCC)
- Dice
- ROC curve

1. Introduction - Overview of Benchmark

Vesselness filters

- Seven methods are currently evaluated in the benchmark framework.
- All methods can also be used outside the benchmark.

Method	Base	Main ideas	Date
Sato *et al.*[SNA+97]	Hessian	Vessel re-connection, noise control	1997
Frangi *et al.*[FNVV98]	Hessian	Blobs and plates removal with noise control	1998
Meijering *et al.*[MJS+04]	Hessian	Neurite detection	2004
OOF [LC08]	Hessian	Analysis restricted by a sphere	2010
Jerman [JPLS16]	Hessian	Volume ratio of tubular structures	2016
Zhang [ZZW+18]	Hessian	K-mean with sigmoid using Jerman base	2018
RORPO [MTNP18]	Morphology	Vote on path opening	2018

Parameters set

Vesselness filters

For each filter, parameters can be separated in two sets:

- **Scale parameters**.
- Method parameters.

```
{
        "Frangi" :
        [
                {
                   "Output":"Frangi.nii",
                   "Arguments":[
                       {"sigmaMin":"1.0"},
                       {"sigmaMax":"2.5"},
                       {"nbSigmaSteps":"5"},
                       {"alpha":"0.5"},
                       {"beta":"0.5"},
                       {"gamma":"5"}
                   ]
                }
        ]
    }
```

Parameters set

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                       {"alpha":"0.5"},
                       {"beta":"0.5"},
                       {"gamma":"5"}
                   ]
                }
        ]
    }
```

Parameters set

In the benchmark experiment, the parameters for each filter are optimized in two steps:

- A first optimization step on scale parameters with fixed methods parameters.
- A second optimization on method parameters using fixed best scales found at the previous step.

$\rightarrow$ Optimization done over the best mean MCC across all volumes.

2. Benchmark Results and Reproducibility

Benchmark Reproducibility

Reproducibility

It consists of reproducing the results from a different research team by using the same experimental setup (ACM definition):

- Benchmark parameter files ready to use for both optimization steps.
- Python scripts available to generate results in pdf format using the metrics csv files.

```
{
    "Settings":{
        "name":"MyBenchmark",
        "path":"PathToDirectory",
        "inputVolumesList":"fileLists/DatabaseFileList.txt",
        "algorithmSets":"paramSets/all_algorithms.json",
        "maskList":["Organ","Vessels"],
        "enhancementMask":"",
        "nbThresholds":200,
        "removeResultsVolumes":false
    }
}
```

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```
SerieName,    Name,          Threshold, sensitivity,specificity, Dice,       MCC
3Dircadb1.13, 0.6-1.6-4.nii, 0.83,      0.00154596, 0.999829,    0.00307362, 0.0196581
3Dircadb1.13, 0.6-1.6-4.nii, 0.82,      0.0028762,  0.999682,    0.0056896,  0.0268478
3Dircadb1.13, 0.6-1.6-4.nii, 0.81,      0.00497942, 0.999427,    0.00976642, 0.0347772
3Dircadb1.13, 0.6-1.6-4.nii, 0.8,       0.00767585, 0.999123,    0.0149017,  0.0432828
3Dircadb1.13, 0.6-1.6-4.nii, 0.79,      0.0105161,  0.998716,    0.0201554,  0.0493792
3Dircadb1.13, 0.6-1.6-4.nii, 0.78,      0.0139855,  0.998252,    0.026415,   0.0563973
```

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Table 1: Best scale parameter sets maximizing MCC.

	Ircad - Whole liver				Vascusynth - Whole volume			
Method	σ_{min}	σ_{max}	nb steps	Best MCC	σ_{min}	σ_{max}	nb steps	Best MCC
Sato *et al.* [SNA+97]	1.4	2.4	4	0.269 ± 0.065	1.4	2.8	4	0.541 ± 0.044
Frangi *et al.* [FNVV98]	1.4	3.0	4	0.344 ± 0.061	1.4	2.8	4	0.543 ± 0.040
OOF [LC08]	0.6	2.8	4	0.191 ± 0.039	0.6	1.6	4	0.382 ± 0.038
Meijering *et al.* [MJS+04]	1.2	2.2	4	0.138 ± 0.038	1.4	2.8	4	0.356 ± 0.040
Jerman *et al.* [JPLS16]	1.4	2.4	4	0.282 ± 0.063	1.4	2.6	4	0.612 ± 0.039
Zhang *et al.* [ZZW+18]	1.4	2.4	4	0.344 ± 0.106	1.4	3.0	4	0.432 ± 0.040
Method	path size	factor	nb steps	Best MCC	path size	factor	nb steps	Best MCC
RORPO *et al.* [MTNP18]	60	1.2	3	0.384 ± 0.077	10	1.6	4	0.311 ± 0.032

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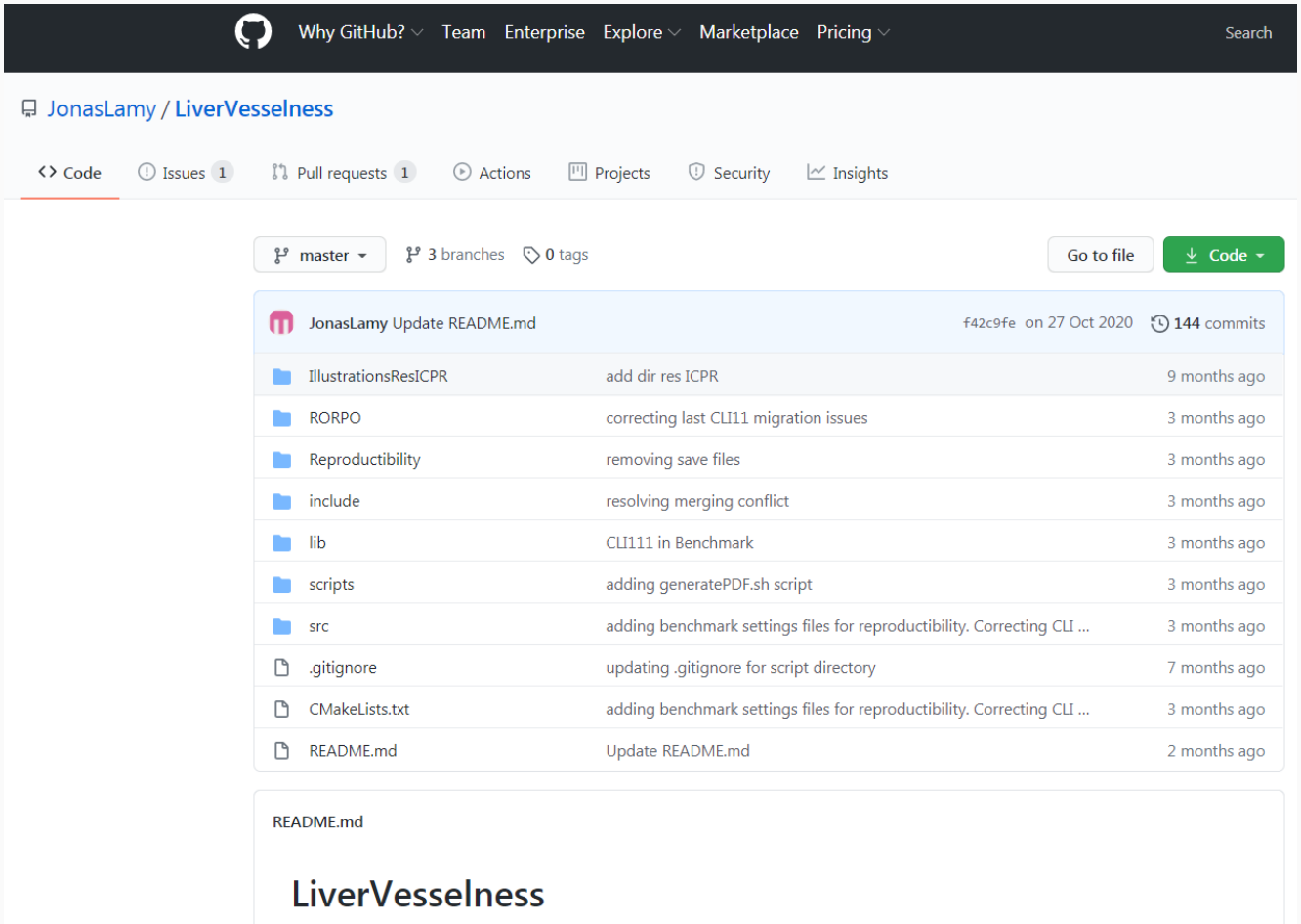
Table 2: Results of best MCC

	Ircad - Liver mask	Vascusynth - Whole volume
Sato	0.275 ± 0.066	0.544 ± 0.043
Frangi	0.356 ± 0.079	$\mathbf{0.602} \pm 0.042$
Meijering	0.138 ± 0.038	0.356 ± 0.040
Jerman	0.318 ± 0.081	0.612 ± 0.040
Zhang	0.346 ± 0.106	0.478 ± 0.041
OOF	0.190 ± 0.041	0.343 ± 0.035
RORPO	$\mathbf{0.384} \pm 0.077$	0.311 ± 0.032

Repository

- https://github.com/JonasLamy/LiverVesselness

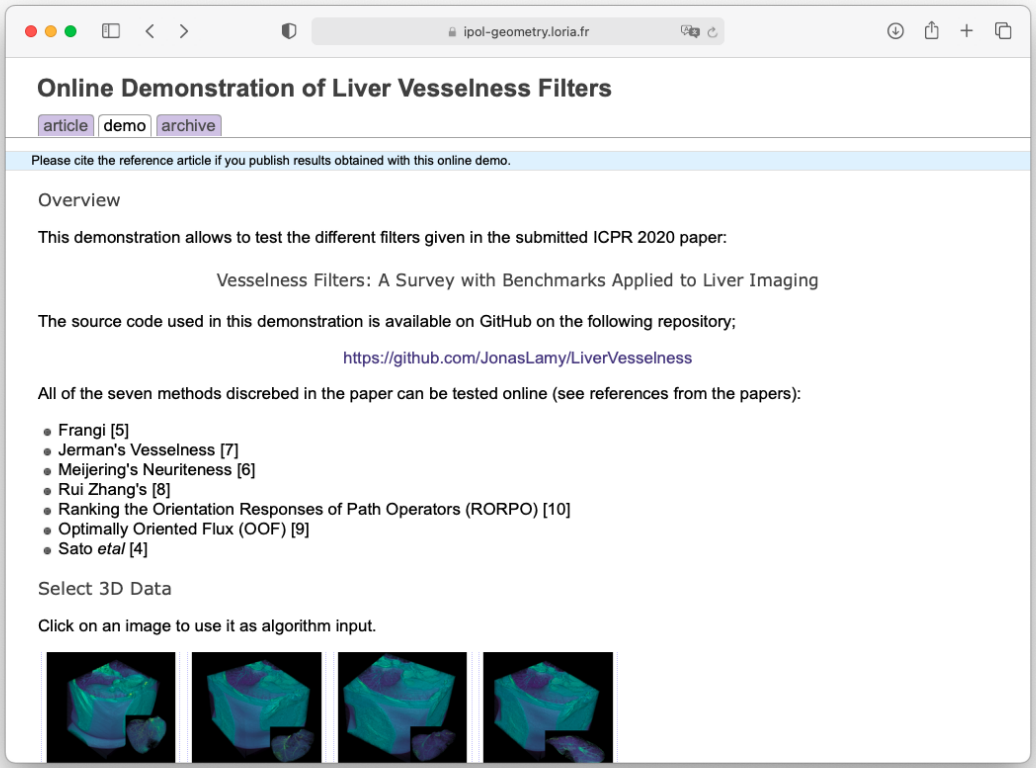


4. Online Demonstration

4. Online Demonstration for Custom Experiments

Online demonstration

- https://kerautret.github.io/LiverVesselnessIPOLDemo/
- Experiments from sample of Ircad and Vascusynth data base.
- Allows to upload any images of type (.vol, .nii, .mhd, or .mha)



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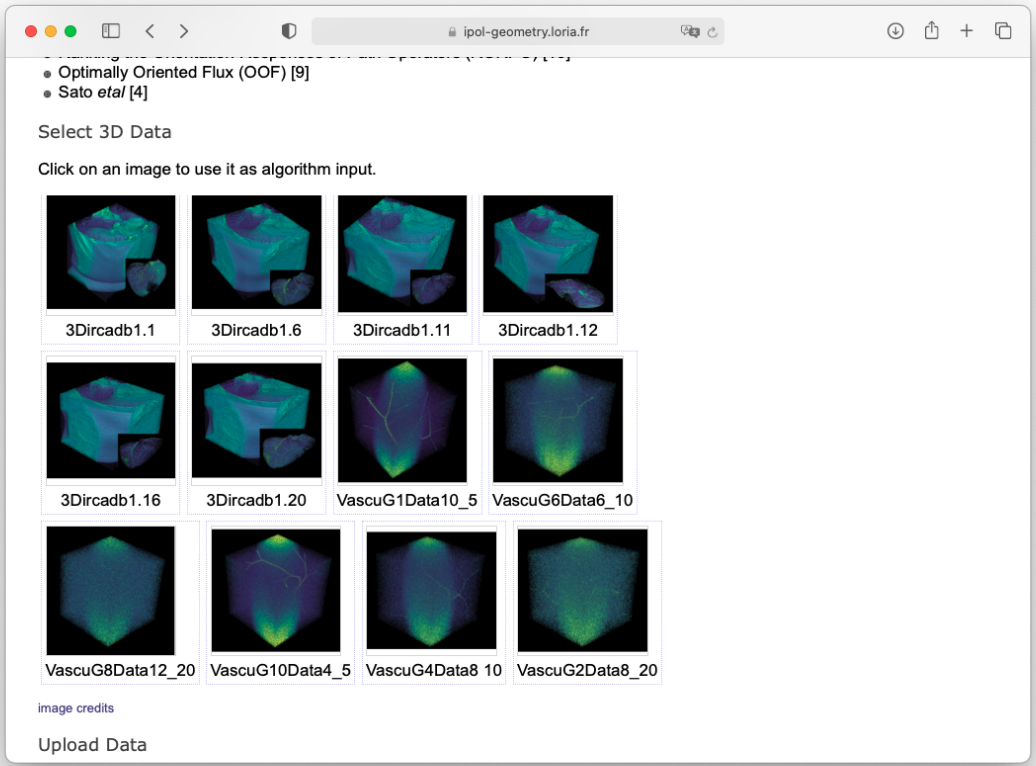

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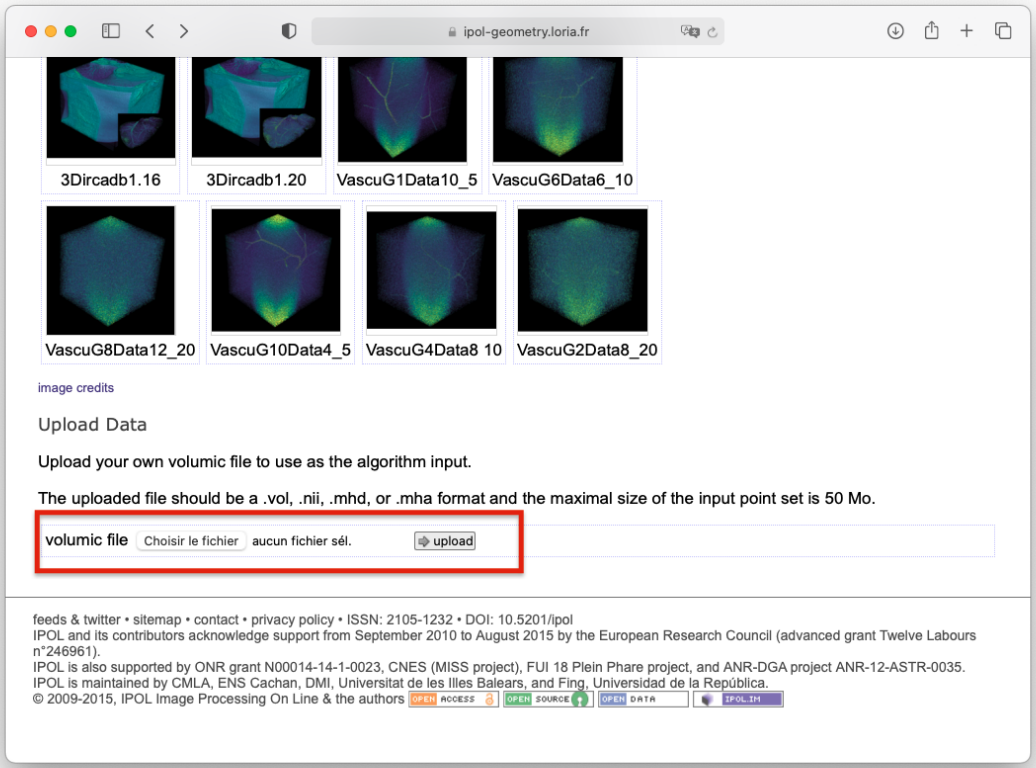

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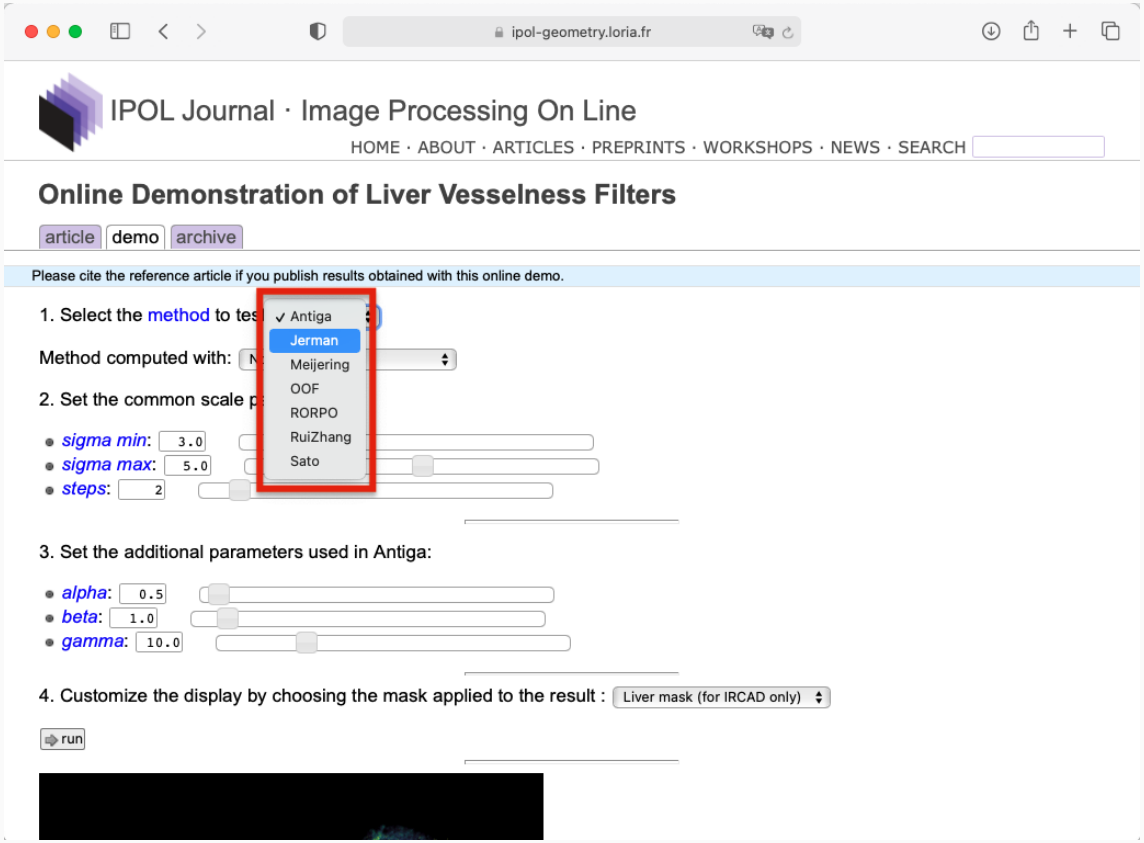
Custom choice

- Select one of the seven algorithms.
- Set the potential parameters: scale or intern.
- Mask with specific areas (for instance liver, dilated vessel).



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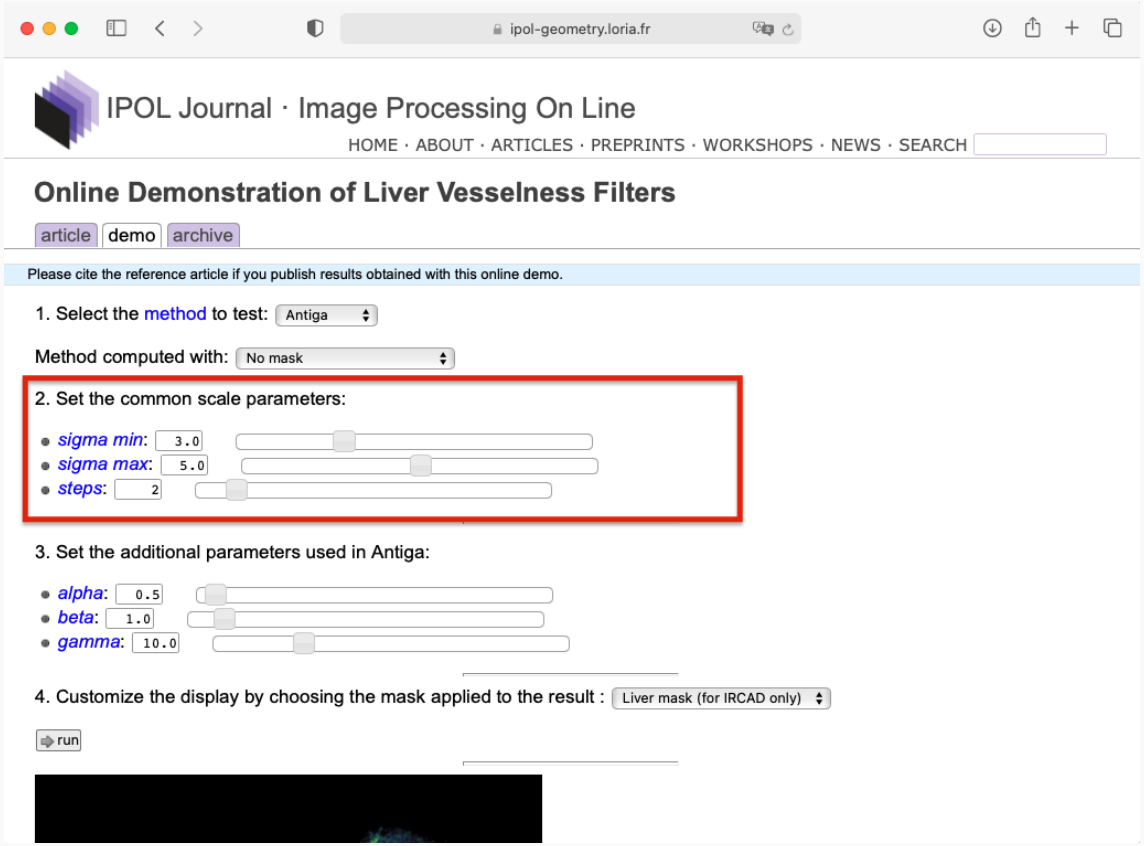

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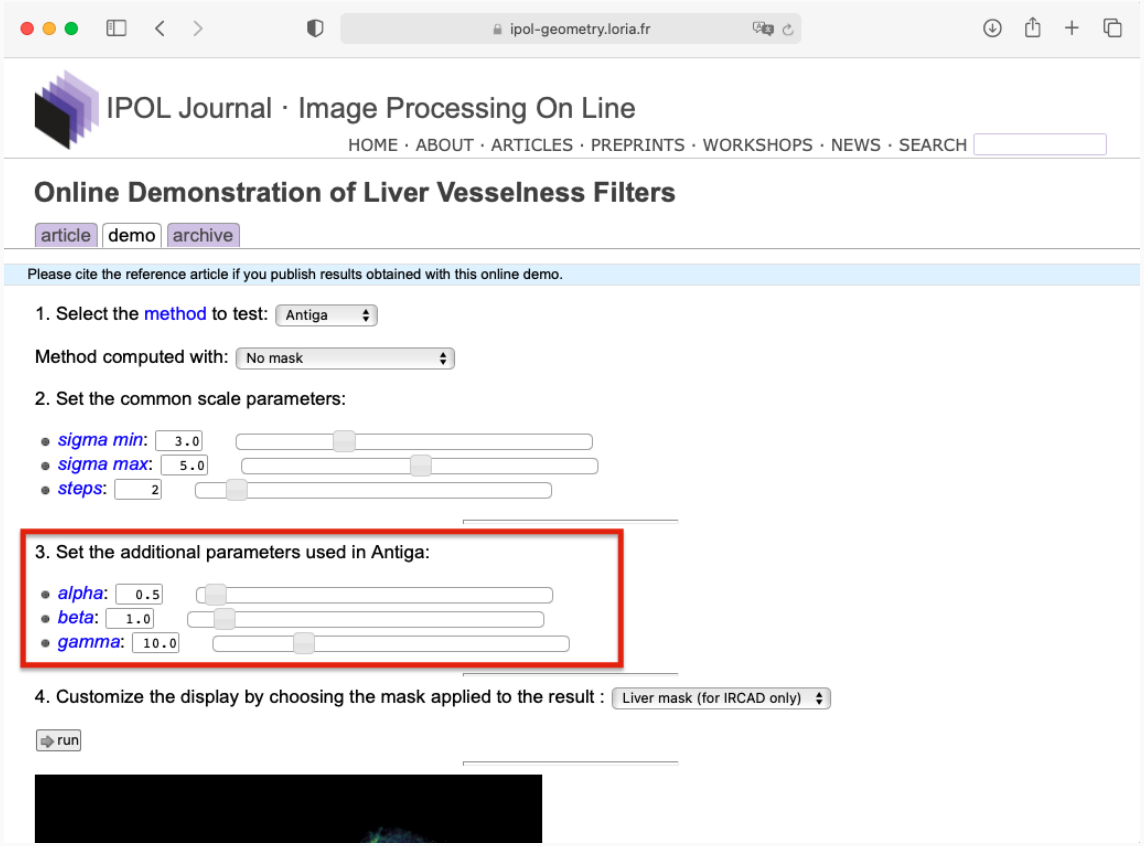

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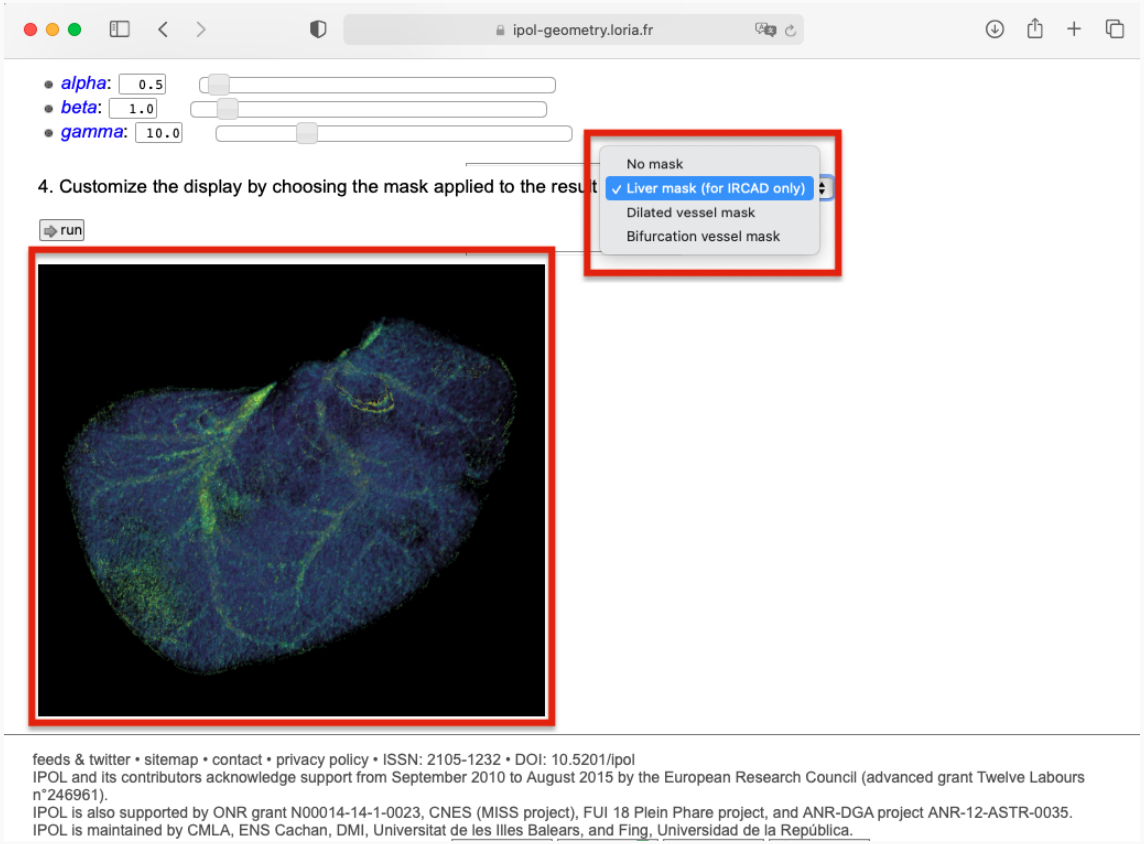

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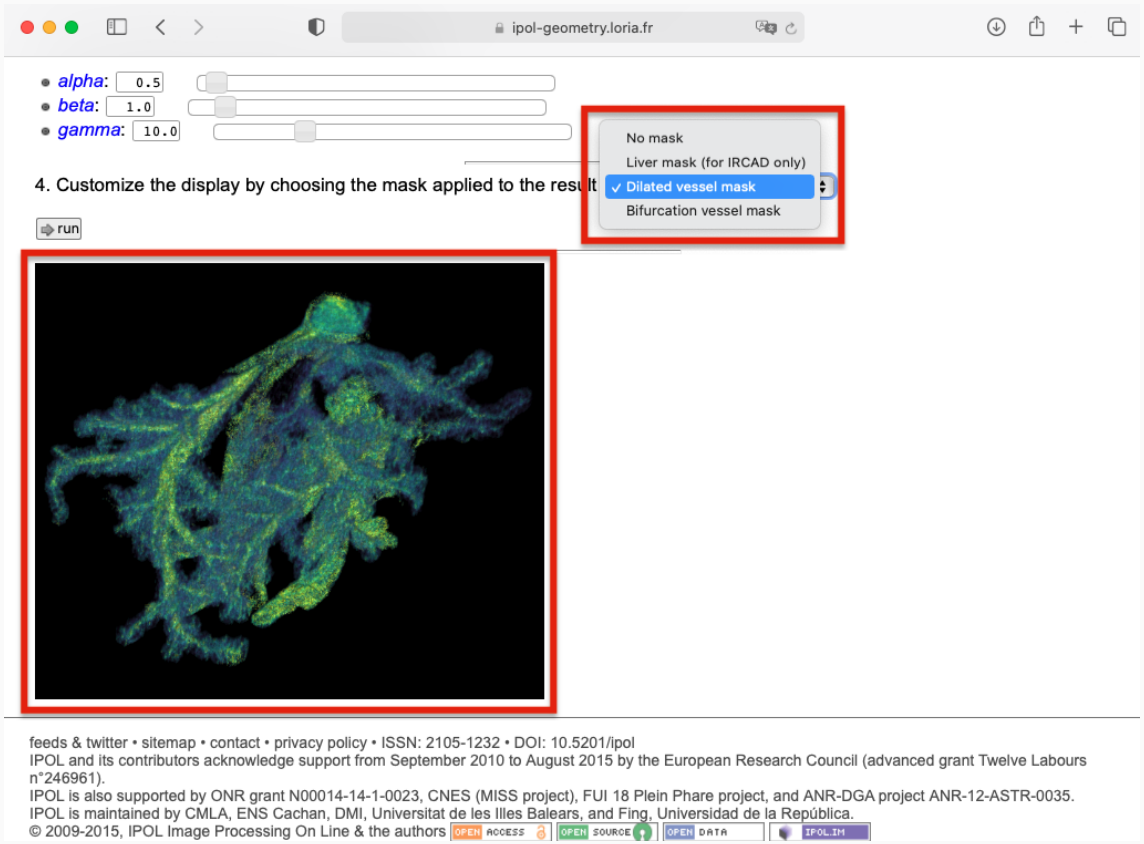
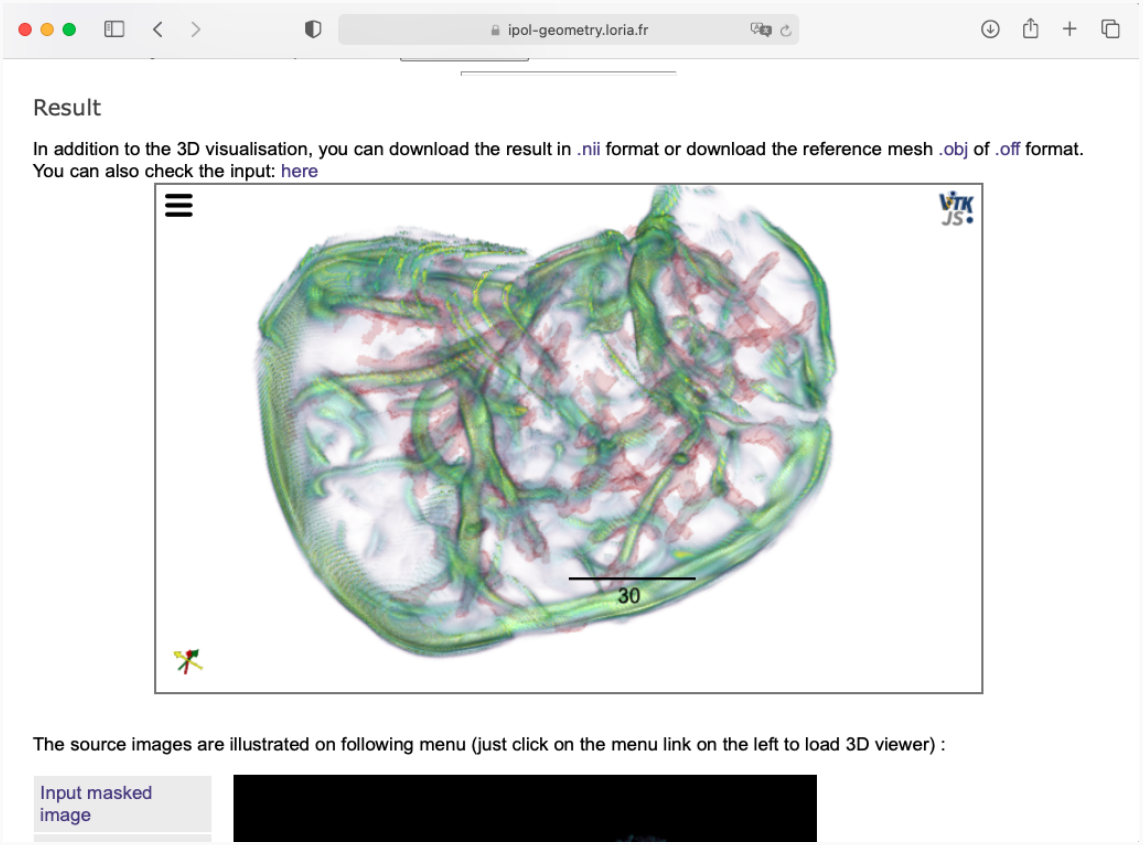


4. Online Demonstration for Custom Experiments (3)

Result visualization

- 3D interactive volume visualisation.
- Superposition of filter results with ground truth.
- Access to the history of experiments with volume preview.



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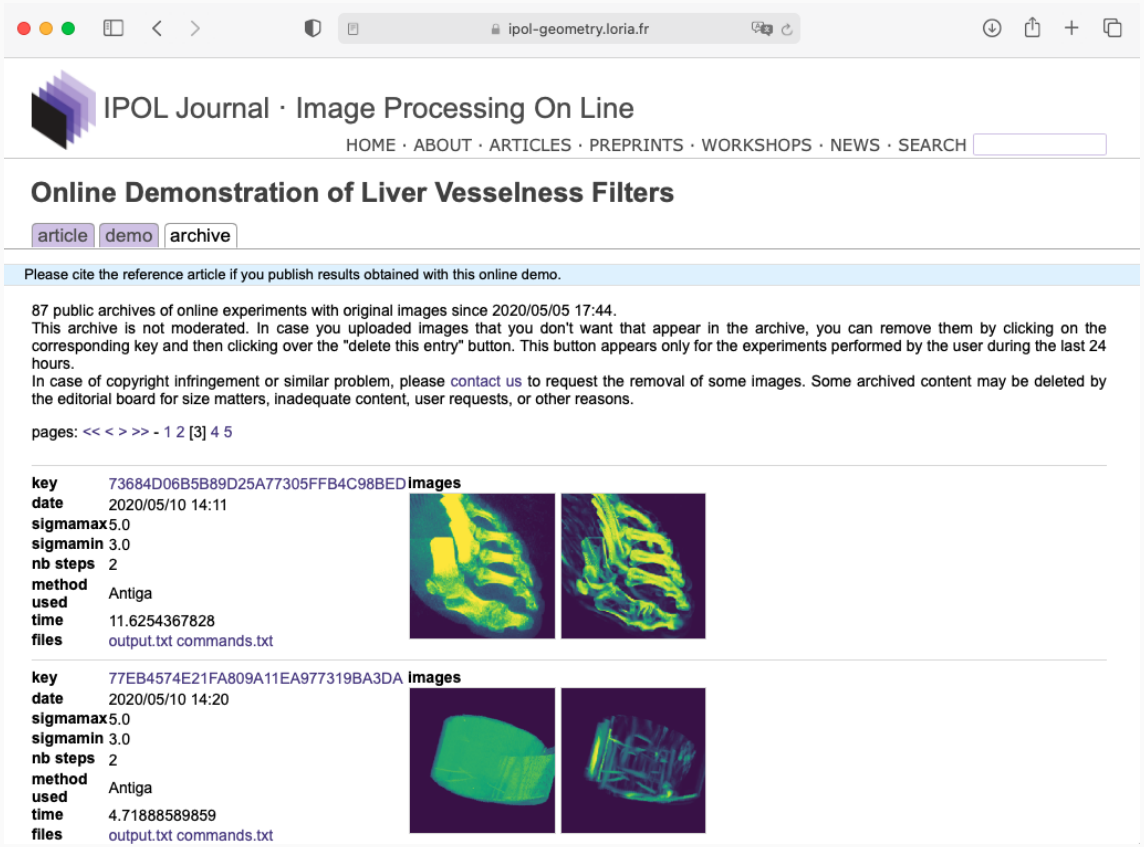

Online demonstration: evolution

Integration of new methods

- Source of demonstration available on *GitHub* (1).
- New method can be added in coordination to the benchmark repository.

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Main steps to add a new methods

- **Step 1:** add a *Pull Request* including your algorithm in the benchmark repository:

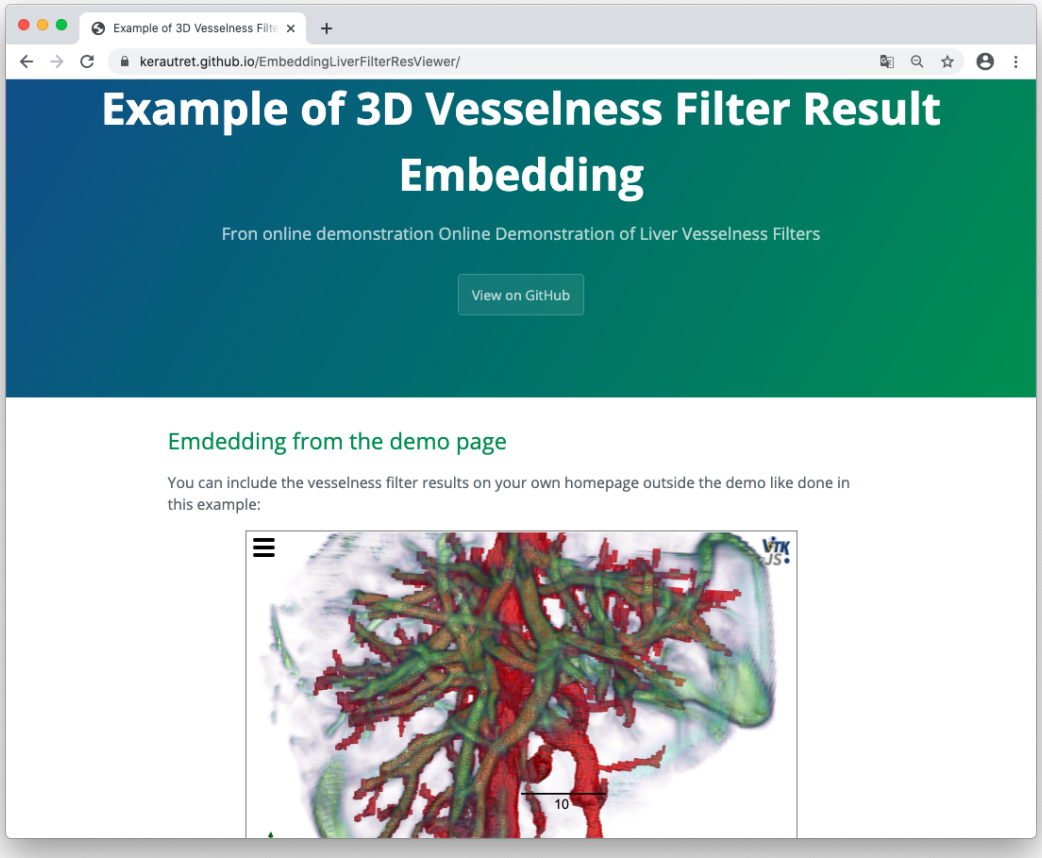
  https://github.com/JonasLamy/LiverVesselness

- **Step 2:** submit an issue to request the addition of method on repo (1).
  → including default parameters and options.

Online demonstration: export result in other pages

Embedding filter results on other pages

- Displays results on other pages without any particular installation.
- Simple code copy/past of sample code and link URL update.



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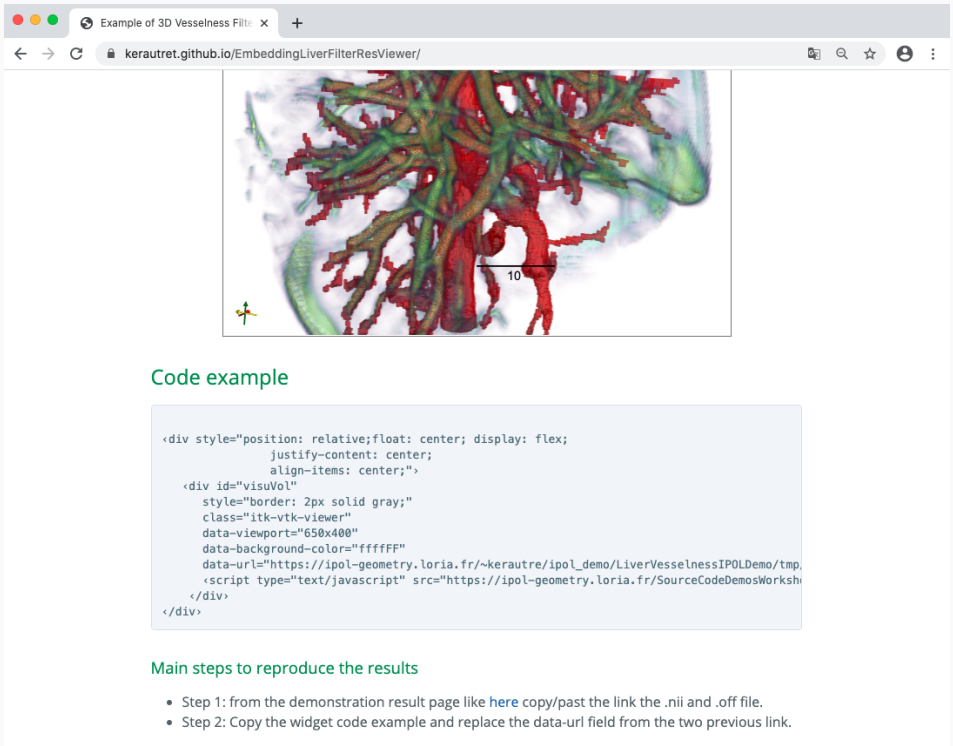

Example: https://github.com/kerautret/EmbeddingLiverFilterResViewer

5. Conclusion

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- 7 vessels enhancement filters readily available.
- A customizable benchmark framework.
- An online demonstration for testing filters on your own data.

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Thanks for you attention

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ICPR Poster session (ID 1031) : 4pm Thursday 14th, PS T5.6

References


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