

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

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Overview

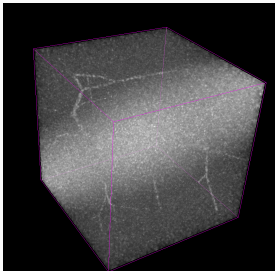
1. Overview of Benchmark
2. Benchmark Results and Reproducibility
3. Benchmarking on a Cloud Platform
4. Online Demonstration for Custom Experiments
5. Conclusion

1. Overview of Benchmark

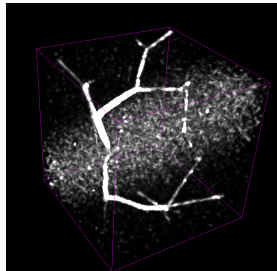
Introduction

Context

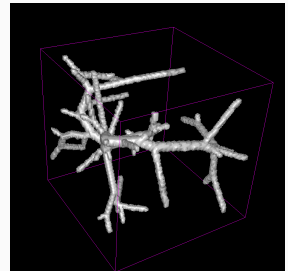
- Accurate liver vessels segmentation is still an open problem.
- Most segmentation schemes rely on a vessel enhancement filter (vesselness filters).
- No easy way to compare different filters.



Vascusynth volume



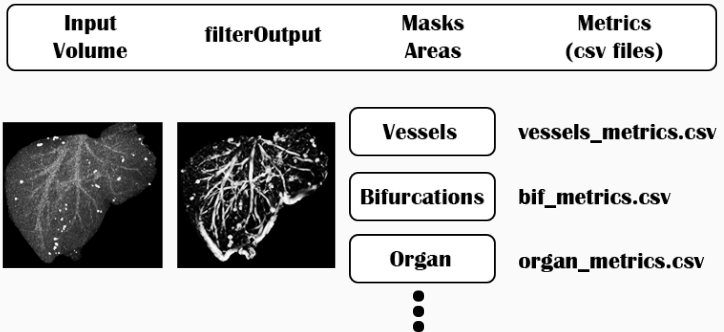
Jerman vesselness output



Ideal segmentation

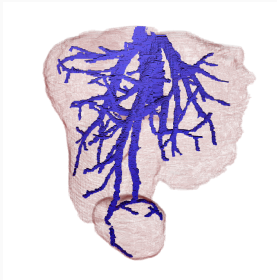
Goal

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

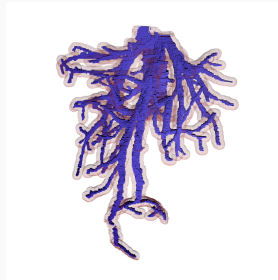


Additional goal

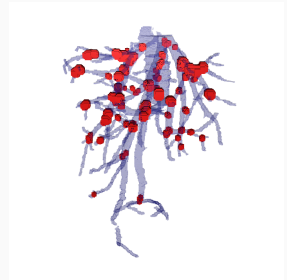
In particular we wanted to assess the performance of the filters depending on **three areas of interest**.



Liver



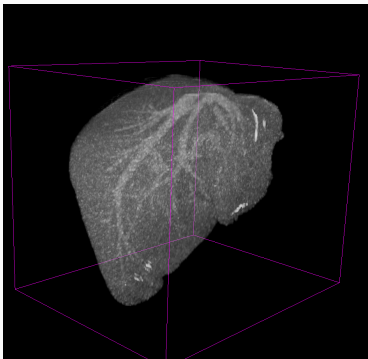
Dilated vessels



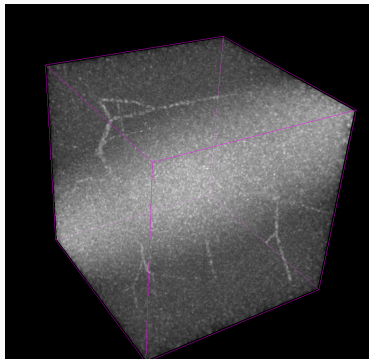
Bifurcations

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 <i>et al.</i> [SNA ⁺ 97]	Hessian	Vessel re-connection, noise control	1997
Frangi <i>et al.</i> [FNVV98]	Hessian	Blobs and plates removal with noise control	1998
Meijering <i>et al.</i> [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.**

```
1  {
2      "Frangi" :
3      [
4          {
5              "Output":"Frangi.nii",
6              "Arguments":[
7                  {"sigmaMin":"1.0"},
8                  {"sigmaMax":"2.5"},
9                  {"nbSigmaSteps":"5"},
10                 {"alpha":"0.5"},
11                 {"beta":"0.5"},
12                 {"gamma":"5"}
13             ]
14         }
15     ]
16 }
```

Parameters set

Vesselness filters

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

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

```
1  {
2      "Frangi" :
3      [
4          {
5              "Output":"Frangi.nii",
6              "Arguments":[
7                  {"sigmaMin":"1.0"},
8                  {"sigmaMax":"2.5"},
9                  {"nbSigmaSteps":"5"},
10                 {"alpha":"0.5"},
11                 {"beta":"0.5"},
12                 {"gamma":"5"}
13             ]
14         }
15     ]
16 }
```

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.

→ 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
  }
}
```

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.

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

Benchmark Reproducibility

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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.

Table 1: Best scale parameter sets maximizing MCC.

Method	Ircad - Whole liver				Vascusynth - Whole volume			
	σ_{min}	σ_{max}	nb steps	Best MCC	σ_{min}	σ_{max}	nb steps	Best MCC
Sato <i>et al.</i> [SNA ⁺ 97]	1.4	2.4	4	0.269 ± 0.065	1.4	2.8	4	0.541 ± 0.044
Frangi <i>et al.</i> [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 <i>et al.</i> [MJS ⁺ 04]	1.2	2.2	4	0.138 ± 0.038	1.4	2.8	4	0.356 ± 0.040
Jerman <i>et al.</i> [JPLS16]	1.4	2.4	4	0.282 ± 0.063	1.4	2.6	4	0.612 ± 0.039
Zhang <i>et al.</i> [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 <i>et al.</i> [MTNP18]	60	1.2	3	0.384 ± 0.077	10	1.6	4	0.311 ± 0.032

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.

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	0.602 ± 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	0.384 ± 0.077	0.311 ± 0.032

Repository

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

The screenshot shows the GitHub repository page for JonasLamy/LiverVesselness. At the top, there is a navigation bar with links for 'Why GitHub?', 'Team', 'Enterprise', 'Explore', 'Marketplace', and 'Pricing', along with a search bar. Below the navigation bar, the repository name 'JonasLamy / LiverVesselness' is displayed. A secondary navigation bar contains links for 'Code', 'Issues' (1), 'Pull requests' (1), 'Actions', 'Projects', 'Security', and 'Insights'. The main content area shows the repository's file structure. At the top of this area, there are buttons for 'master' (selected), '3 branches', and '0 tags', along with 'Go to file' and 'Code' buttons. Below this, a commit history table is visible, listing recent commits by JonasLamy. The table includes columns for the commit message, the commit hash and date, and the number of commits. The most recent commit is 'Update README.md' from 2 months ago. Below the commit history, the 'README.md' file is shown, containing the repository name 'LiverVesselness'.

Commit Message	Commit Hash & Date	Commits
JonasLamy Update README.md	f42c9fe on 27 Oct 2020	144
illustrationsRestCPR	add dir res ICPR	9 months ago
RORPO	correcting last CL111 migration issues	3 months ago
Reproducibility	removing save files	3 months ago
include	resolving merging conflict	3 months ago
lib	CL111 in Benchmark	3 months ago
scripts	adding generatePDF.sh script	3 months ago
src	adding benchmark settings files for reproducibility. Correcting CLI ...	3 months ago
.gitignore	updating .gitignore for script directory	7 months ago
CMakeLists.txt	adding benchmark settings files for reproducibility. Correcting CLI ...	3 months ago
README.md	Update README.md	2 months ago

README.md

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)

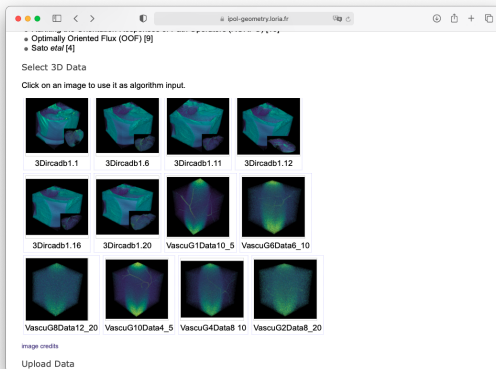


A screenshot of a web browser displaying the 'Online Demonstration of Liver Vesselness Filters' page. The browser's address bar shows 'ipol-geometry.torla.fr'. The page has a navigation bar with 'article', 'demo', and 'archive' tabs, with 'demo' selected. Below the navigation bar, there is a blue banner with the text 'Please cite the reference article if you publish results obtained with this online demo.' The main content area includes an 'Overview' section, a paragraph stating 'This demonstration allows to test the different filters given in the submitted ICPR 2020 paper:', a sub-section 'Vesselness Filters: A Survey with Benchmarks Applied to Liver Imaging', and a note that the source code is available on GitHub at 'https://github.com/JonasLamy/LiverVesselness'. A list of seven methods is provided, each with a reference number in brackets: Frangi [5], Jerman's Vesselness [7], Meijering's Neuriteness [6], Rui Zhang's [8], Ranking the Orientation Responses of Path Operators (RORPO) [10], Optimally Oriented Flux (DOF) [9], and Sato et al [4]. At the bottom, there is a section titled 'Select 3D Data' with the instruction 'Click on an image to use it as algorithm input.' Below this text are four small thumbnail images showing 3D liver vesselness filter results.

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)



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)



ipol-geometry.loria.fr

3Dircadb1.16 3Dircadb1.20 VascuG1Data10_5 VascuG6Data6_10

VascuG8Data12_20 VascuG10Data4_5 VascuG4Data8_10 VascuG2Data8_20

image credits

Upload Data

Upload your own volumic file to use as the algorithm input.

The uploaded file should be a .vol, .nii, .mhd, or .mha format and the maximal size of the input point set is 50 Mo.

volumic file Choisir le fichier aucun fichier sélé

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4. Online Demonstration for Custom Experiments (2)

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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Online Demonstration of Liver Vesselness Filters

article demo archive

Please cite the reference article if you publish results obtained with this online demo.

1. Select the **method** to test:
 - Method computed with: **Antiga** (dropdown menu showing: Antiga, Jerman, Meijering, DOF, RORPO, RuiZhang, Sato)
2. Set the common scale parameters:
 - σ min: 3.0
 - σ max: 5.0
 - steps: 2
3. Set the additional parameters used in Antiga:
 - α : 0.5
 - β : 1.0
 - γ : 10.0
4. Customize the display by choosing the mask applied to the result: Liver mask (for IRCAD only)

run

4. Online Demonstration for Custom Experiments (2)

Custom choice

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

ipol-geometry.loria.fr

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Online Demonstration of Liver Vesselness Filters

article demo archive

Please cite the reference article if you publish results obtained with this online demo.

1. Select the **method** to test: Antiga
- Method computed with: No mask
2. Set the common scale parameters:
 - **sigma min**: 3.0
 - **sigma max**: 5.0
 - **steps**: 2
3. Set the additional parameters used in Antiga:
 - **alpha**: 0.5
 - **beta**: 1.0
 - **gamma**: 3.0, 0
4. Customize the display by choosing the mask applied to the result : Liver mask (for IRCAD only)

run

4. Online Demonstration for Custom Experiments (2)

Custom choice

- Select one of the seven algorithms.
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The screenshot shows a web browser window displaying the IPOL Journal website. The page title is "Online Demonstration of Liver Vesselness Filters". The navigation menu includes "HOME", "ABOUT", "ARTICLES", "PREPRINTS", "WORKSHOPS", "NEWS", and "SEARCH". There are three tabs: "article", "demo" (selected), and "archive". A blue banner asks users to cite the reference article. The interface is divided into four steps:

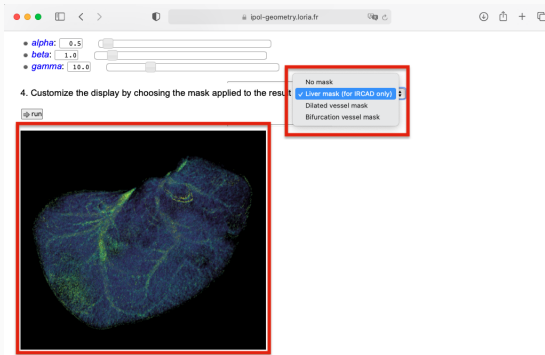
1. Select the method to test: **Antiga** (dropdown menu).
2. Set the common scale parameters:
 - **sigma min**: 3.0 (slider)
 - **sigma max**: 5.0 (slider)
 - **steps**: 2 (input field)
3. Set the additional parameters used in Antiga: (highlighted with a red box)
 - **alpha**: 0.5 (slider)
 - **beta**: 1.0 (slider)
 - **gamma**: 3.0, 0 (input fields)
4. Customize the display by choosing the mask applied to the result: **Liver mask (for IRCAD only)** (dropdown menu).

At the bottom, there is a "run" button and a dark image area showing the results of the processing.

4. Online Demonstration for Custom Experiments (2)

Custom choice

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



4. Online Demonstration for Custom Experiments (2)

Custom choice

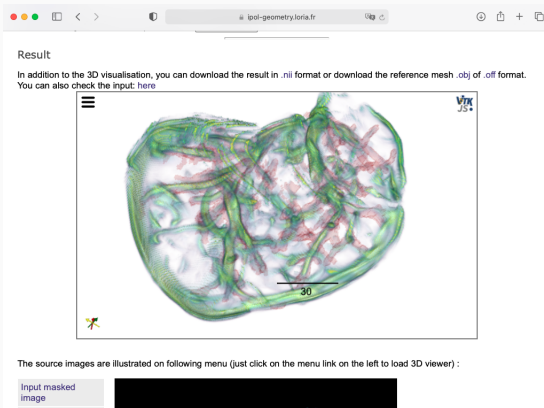
- Select one of the seven algorithms.
- Set the potential parameters: scale or intern.
- Mask with specific areas (for instance liver, **dilated vessel**).

The screenshot shows the IPOL online demonstration interface. At the top, there are three sliders for parameters: **alpha** (set to 0.5), **beta** (set to 1.0), and **gamma** (set to 10.0). Below these is a section titled "4. Customize the display by choosing the mask applied to the result" with a "run" button. A dropdown menu is open, showing three options: "No mask (for IRCAD only)", "Dilated vessel mask" (which is selected), and "Bifurcation vessel mask". Below the dropdown is a 3D visualization of a vessel network, rendered in green and blue, with a red border around it.

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.



Result

In addition to the 3D visualisation, you can download the result in `.nii` format or download the reference mesh `.obj` of `.off` format. You can also check the input: [here](#)

The source images are illustrated on following menu (just click on the menu link on the left to load 3D viewer) :

Input masked image

4. Online Demonstration for Custom Experiments (3)

Result visualization

- 3D interactive volume visualisation.
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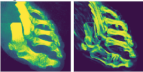
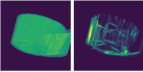
Online Demonstration of Liver Vesselness Filters

[article](#) [demo](#) [archive](#)

Please cite the reference article if you publish results obtained with this online demo.

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In case of copyright infringement or similar problem, please [contact us](#) to request the removal of some images. Some archived content may be deleted by the editorial board for size matters, inadequate content, user requests, or other reasons.

pages: << < > >> - 1 2 [3] 4 5

key	73684D06B5B89025A77305FFB4C98BED	Images
date	2020/05/10 14:11	
sigmax	5.0	
sigmin	3.0	
nb steps	2	
method used	Antiga	
time	11.6254367828	
files	output.txt commands.txt	
key	77EB4574E21FA809A11EA977319BA3DA	Images
date	2020/05/10 14:20	
sigmax	5.0	
sigmin	3.0	
nb steps	2	
method used	Antiga	
time	4.7188858959	
files	output.txt commands.txt	

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.



(1) <https://github.com/kerautret/LiverVesselnessIPOLDemo>

Online demonstration: evolution

Integration of new methods

- Source of demonstration available on *GitHub* (1).
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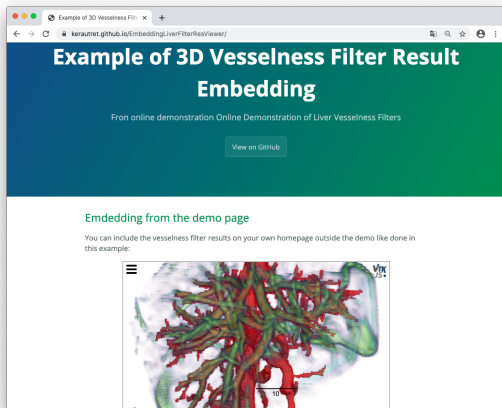
Main steps to add a new methods

- **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

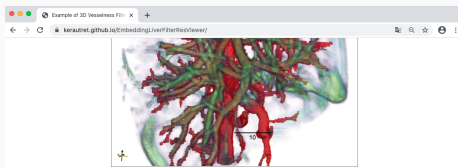
- Displays results **on other pages** without any particular installation.
- Simple code copy/past of sample code and link URL update.



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.



Code example

```

<div style="position: relative;float: center; display: flex;
  justify-content: center;
  align-items: center;">
  <div id="visual01"
    style="border: 2px solid gray;"
    class="vtk-vtk-viewer"
    data-viewport="658x488"
    data-background-color="ffffff"
    data-url="https://jipol-geometry.loria.fr/~kerautre/jipol_demo/Liver/VesseLess3D01Demo/tep"
    <script type="text/javascript" src="https://jipol-geometry.loria.fr/SourceCodeDemoWorksh
  /</div>
</div>

```

Main steps to reproduce the results

- Step 1: from the demonstration result page like [here](https://kerautre.github.io/EmbeddingLiverFilterResViewer/) copy/past the link the .nii and .off file.
- Step 2: Copy the widget code example and replace the data-uri field from the two previous link.

Example: <https://github.com/kerautre/EmbeddingLiverFilterResViewer>

5. Conclusion

5. Conclusion

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







5. Conclusion

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

Thanks for you attention
jonas.lamy@univ-lyon2.fr

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

References

-  Alejandro F. Frangi, Wiro J. Niessen, Koen L. Vincken, and Max A. Viergever, *Multiscale vessel enhancement filtering*, MICCAI, 1998, pp. 130–137.
-  Tim Jerman, Franjo Pernus, Bostjan Likar, and Ziga Spiclin, *Enhancement of vascular structures in 3D and 2D angiographic images*, IEEE Transactions on Medical Imaging **35** (2016), 2107–2118.
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