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# Dafne

Deep Anatomical Federated Network

## Collaborative lifelong learning for MR image segmentation with Dafne: a reproducible research project

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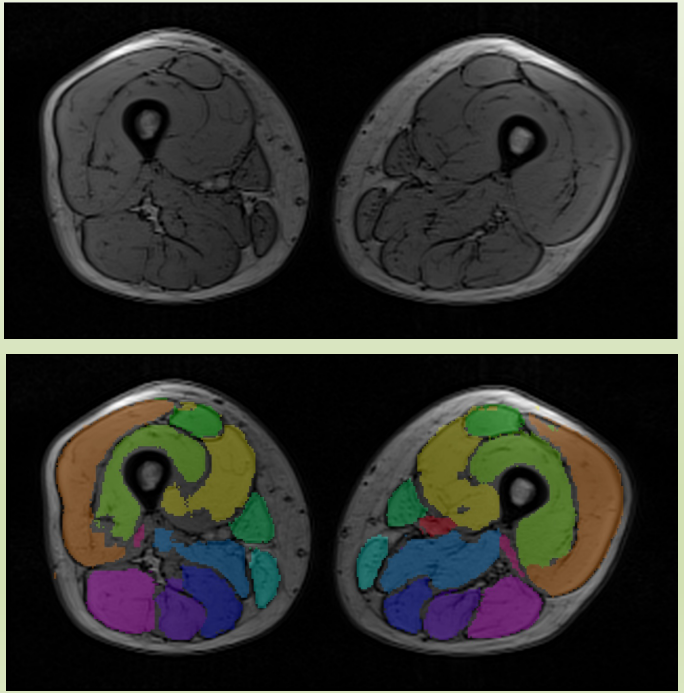
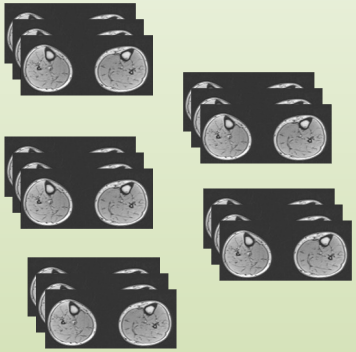
Basel Muscle MRI

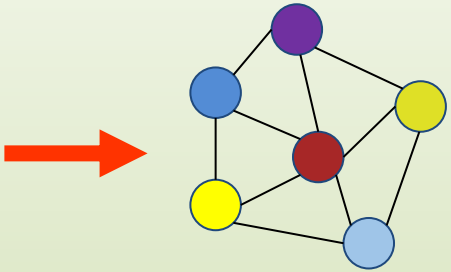
# Muscle segmentation

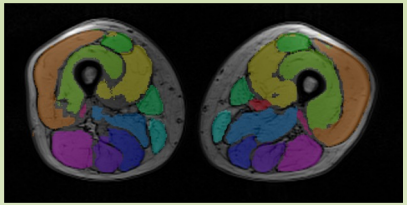
- Quantitative methods rely on segmentation
- Time consuming to do manually
- Complex to automate
  - Deformable geometry
  - Different appearance
  - Rare diseases
  - Multiple contrasts/parameters
- Deep learning is the current standard



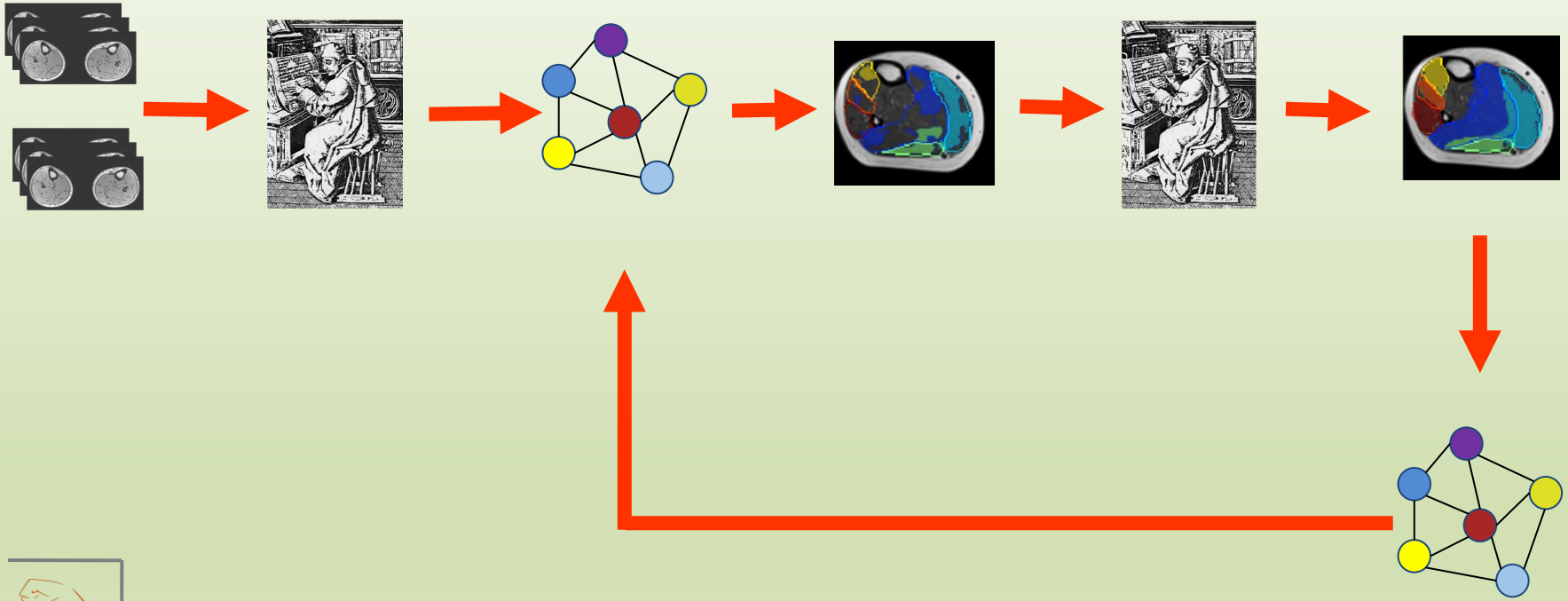
# Typical segmentation workflow





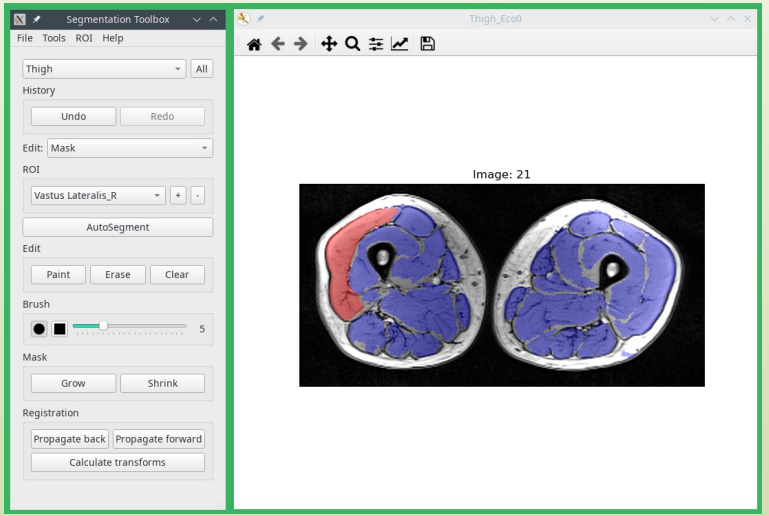


# Incremental learning



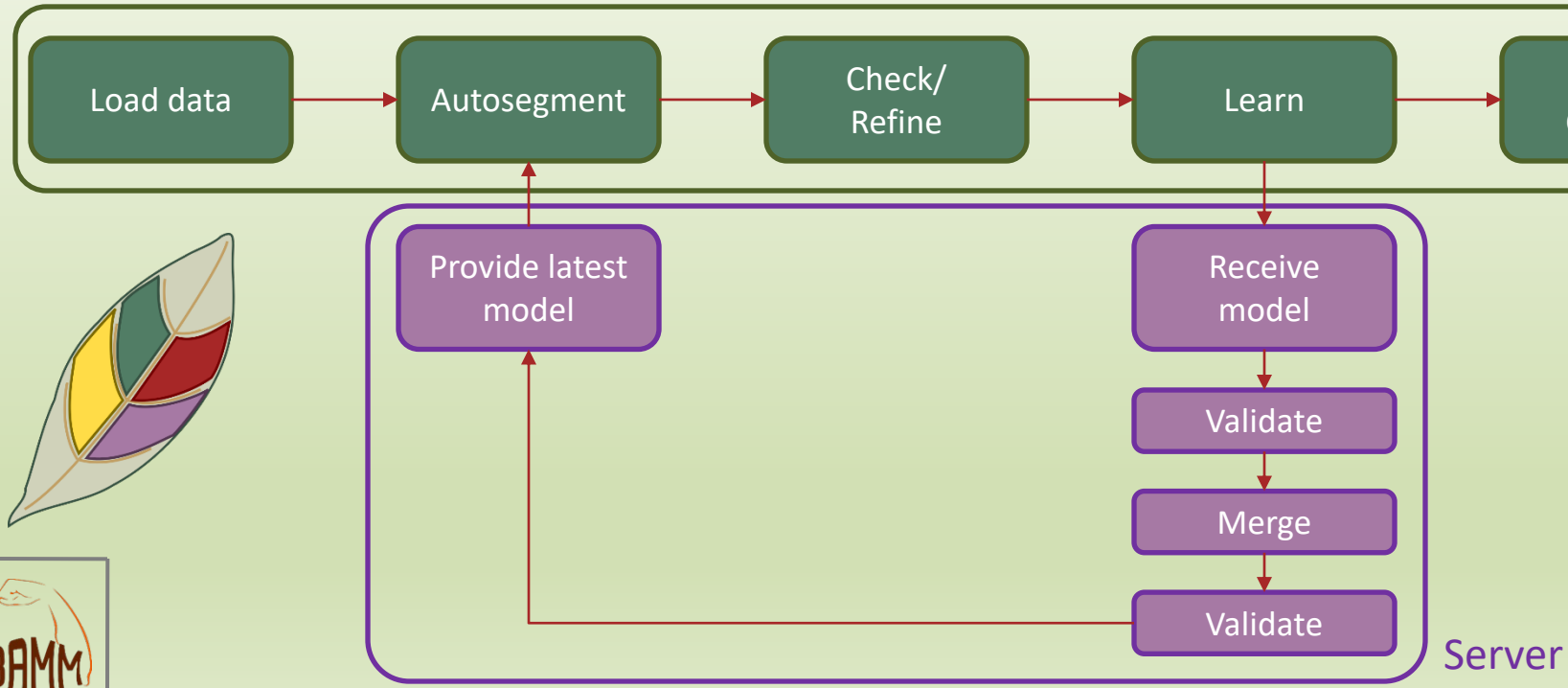
# Here comes Dafne *

- Dafne is free software for muscle segmentation based on continuous collaborative learning.
  - **Thigh and Leg models included**
  - **Federated learning**
    - It collects improvements from all users
    - It preserves data privacy!
  - **Continuous incremental learning**
    - It learns from your own expertise, even from few examples!
- It has an easy **user interface**
  - You always check the segmentation before exporting.
- **Get it at https://dafne.network/**




* Dafne is the Greek name for bay leaf – and also a girls' name

# Dafne Workflow



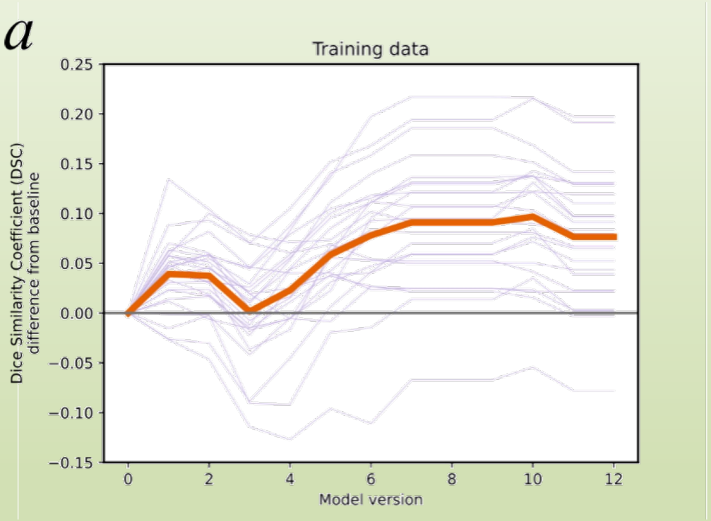
# Does it work?

- We validated it on
  - 38 local datasets, and
    - T1-w images of the calf
  - 18 months of usage statistics!
    - Dice scores collected for thigh and calf

| Jun 2021 | Dec 2022 |
| --- | --- |
| 1 | 31  |

# Local validation: training

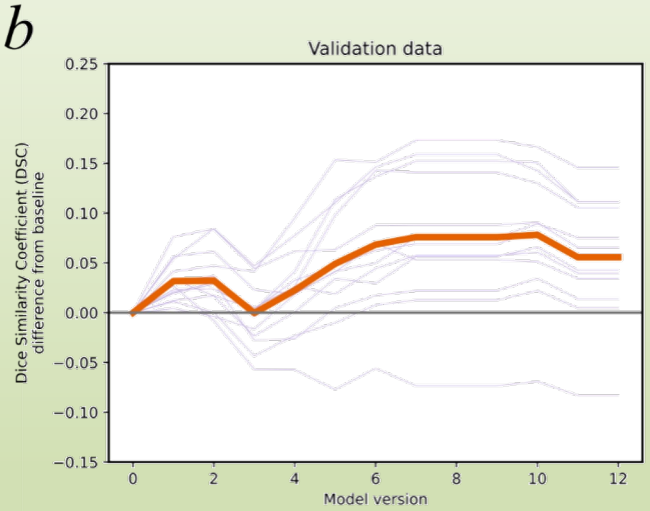
- 25 datasets used for incremental learning
  - Adaptation to the contrast
- Significant linear increase
  - 0.009 dice points/epoch
  - $p < 0.001$
  - LMM, random slope



# Local validation: validation

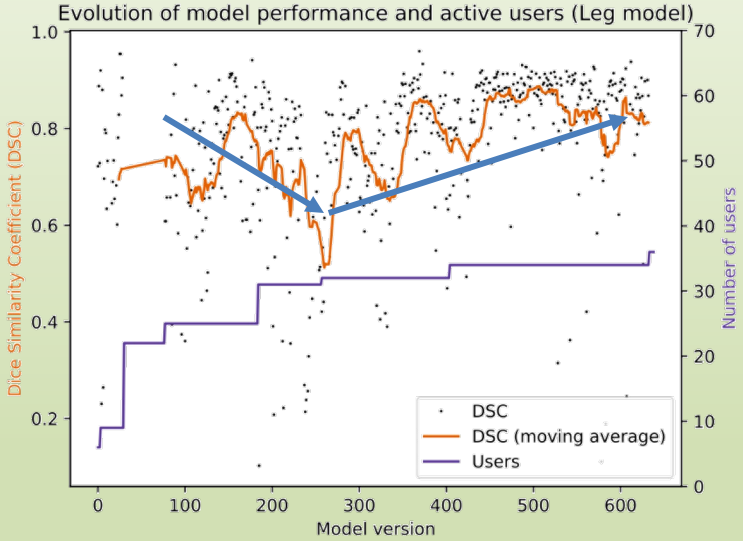
- 13 datasets used for validation
  - Tested on the model versions from the previous group

- Significant linear increase
  - 0.007 dice points/epoch
  - $p < 0.001$
  - LMM, random slope

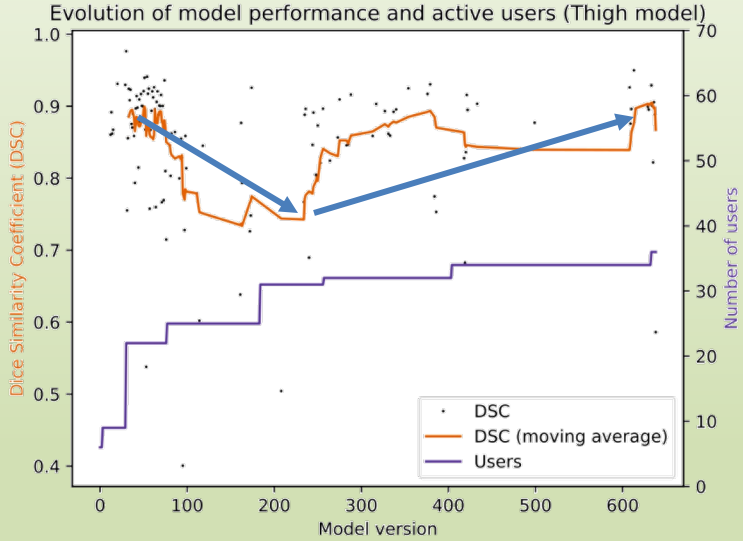


# Real-world data

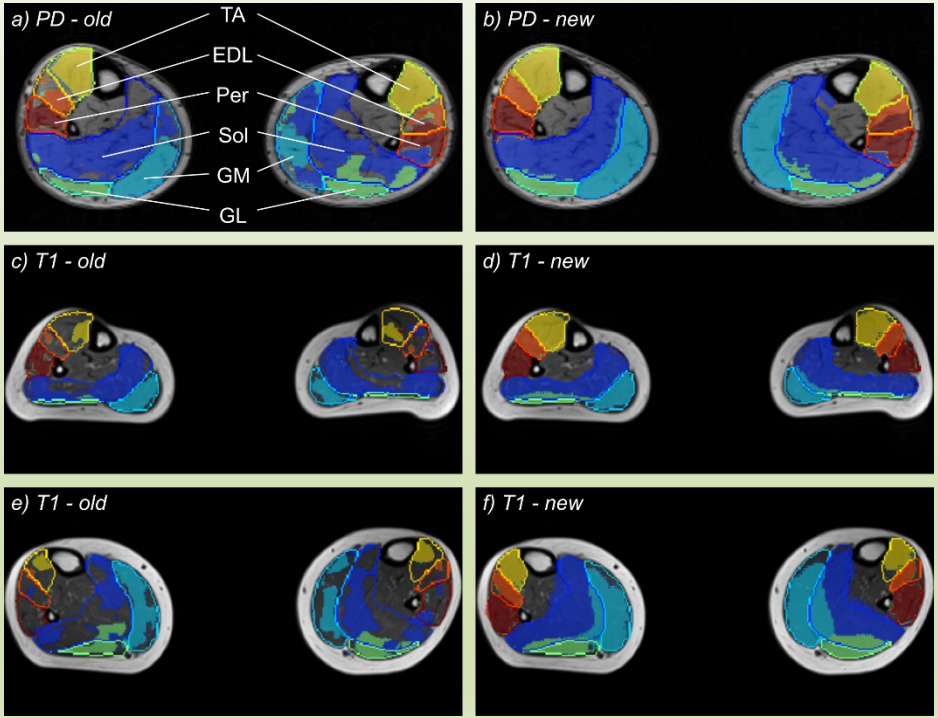
*a*




*b*



# Segmentation example

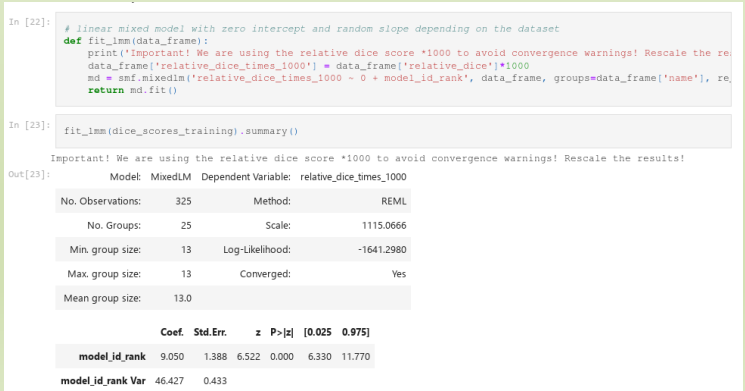


# Reproducibility

- All development was made public since the beginning
  - Client (GPL): https://github.com/dafne-imaging/dafne
  - Server (GPL): https://github.com/dafne-imaging/dafne-server
  - Models (GPL): https://github.com/dafne-imaging/dafne-models
  - Model interface/common tools (LGPL): https://github.com/dafne-imaging/dafne-dl
- All analysis to generate the figures available at – public since the beginning
  - https://github.com/dafne-imaging/dafne-evaluation
- Dafne available at
  - https://dafne.network/
    - Multiplatform distributions

# Evaluation

- Jupyter notebook that produces the images and the statistics
  - Includes data
  - Timestamped (Zenodo)
- Paper on arXiv: [https://arxiv.org/abs/2302.06352](https://arxiv.org/abs/2302.06352)



```
In [22]:
# linear mixed model with zero intercept and random slope depending on the dataset
def fit_lmm(data_frame):
    print('Important! We are using the relative dice score *1000 to avoid convergence warnings! Rescale the re
    data_frame['relative_dice_times_1000'] = data_frame['relative_dice']*1000
    md = smf.mixedlm('relative_dice_times_1000 ~ 0 + model_id_rank', data_frame, groups=data_frame['name'], re
    return md.fit()

In [23]:
fit_lmm(dice_scores_training).summary()
```

```
Important! We are using the relative dice score *1000 to avoid convergence warnings! Rescale the results!
```

Out[23]:

| | | | |
|---|---|---|---|
| Model: | MixedLM | Dependent Variable: | relative_dice_times_1000 |
| No. Observations: | 325 | Method: | REML |
| No. Groups: | 25 | Scale: | 1115.0666 |
| Min. group size: | 13 | Log-Likelihood: | -1641.2980 |
| Max. group size: | 13 | Converged: | Yes |
| Mean group size: | 13.0 | | |

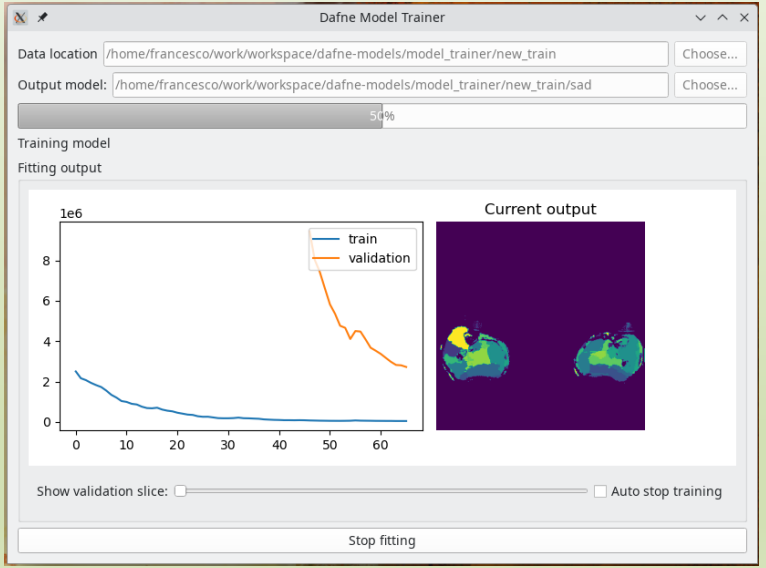
| | Coef. | Std.Err. | z | P>\|z\| | [0.025 | 0.975] |
|---|---|---|---|---|---|---|
| model_id_rank | 9.050 | 1.388 | 6.522 | 0.000 | 6.330 | 11.770 |
| model_id_rank Var | 46.427 | 0.433 | | | | |

launch binder DOI 10.5281/zenodo.7629712

Evaluation repository for the Dafne project

# Latest development

- Generic model trainer
- Testing it of kidney images
- Much room for improvement
  - Transfer learning
  - New architectures
    - Transformer (Kanishka)
  - 3D models



# Acknowledgment


Our collaborators:

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