

Automatic Non-rigid Histological Image Registration challenge

Jiri Borovec, Jan Kybic, Arrate Muñoz-Barrutia

<https://anhir.grand-challenge.org>



Organizers

J. Borovec, J. Kybic, A. Muñoz-Barrutia et al. - ANHIR workshop ISBI2019



Jiri Borovec



Jan Kybic



A. Muñoz-Barrutia



Ignacio Arganda



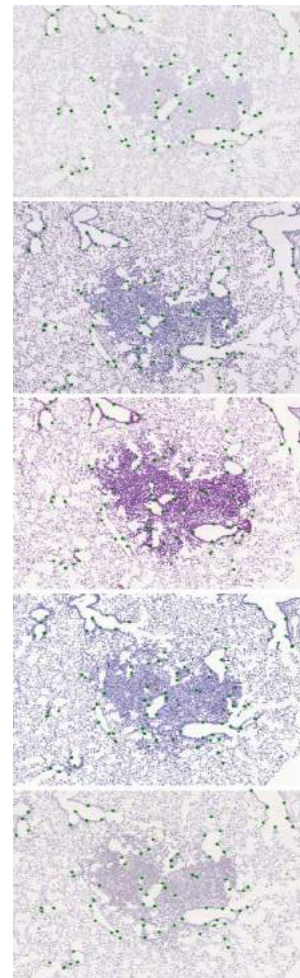
Dmitry Sorokin



Alexander Khvostikov



Maria Gloria Bueno Garcia

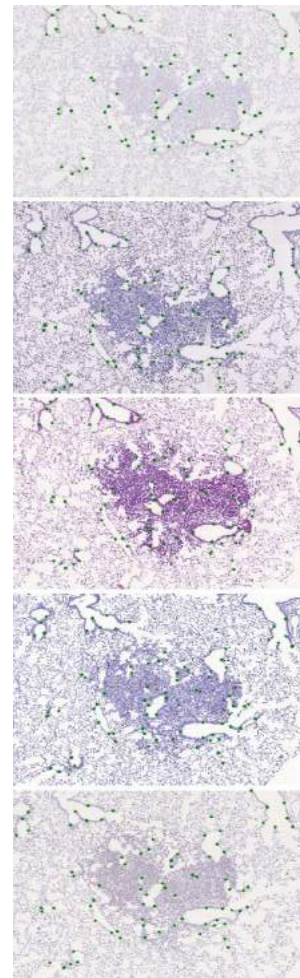


Motivation

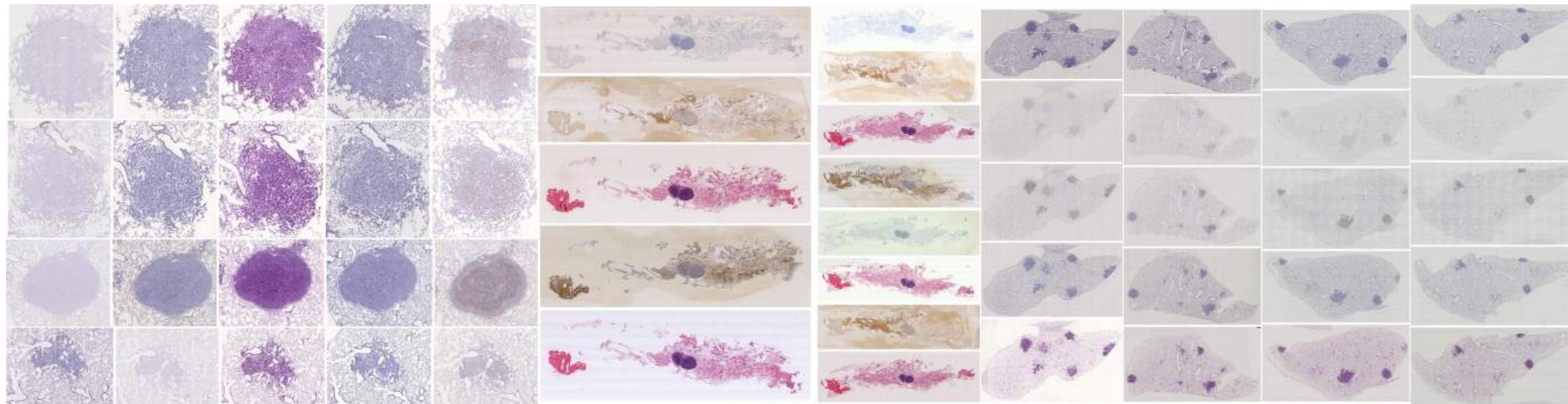
- Consecutive histological slices
- Deformation due to cutting and handling, very thin cuts
- Registration needed to
 - combine information from different stains - protein/antigen colocalization
 - registration for 3D reconstruction

Challenges

- Large size (*most algorithms worked on scaled-down images*)
- Appearance differences
- Repeating structures
- Few unique landmarks



Task statement



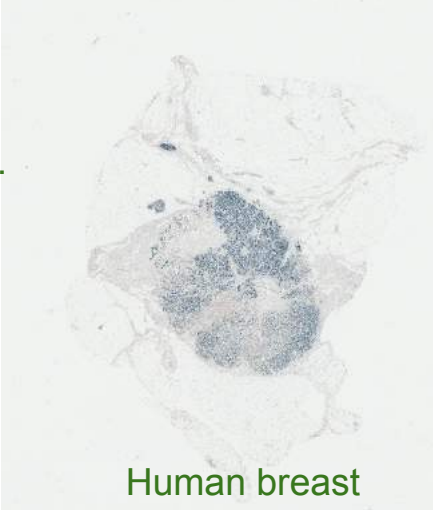
- Sets of images
- Non-linear registration of pairs of images
- Submit transformed landmarks coordinates

Dataset overview

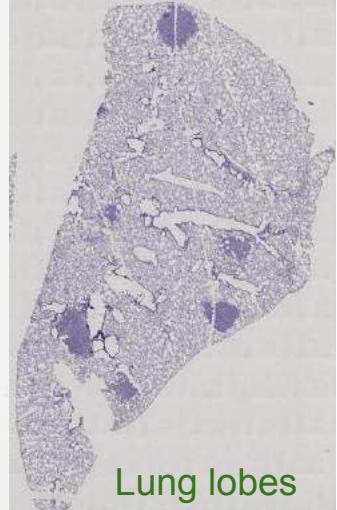
- 49 image sets
 - 5 institutions - CIMA, MMIP, AIDPATH, IBA, RWTH
 - Average 5 images per set with min 3 and max 9
 - 481 image pairs - 230 training and 251 testing
- 8 tissue kinds
 - Lung lesion, Lung lobes, Mammary glands, Mice kidney, COlon ADenocarcinoma, Gastric mucosa and gastric adenocarcinoma tissue, Human breast & kidney
- 18 different stains
 - CD1a, CD31, CD4, CD68, CD8, CNEU, Cc10, EBV, ER, HE, HER2, Ki67, MAS, PAS, PASM, PR, Pro-SPC, aSMA
- Original image sizes from 11k×6k up to 60k×75k pixels
- 5 resolutions - 0.174, 0.227, 0.468, 1.274, 2.294, 0.2528 [$\mu\text{m}/\text{pixel}$]



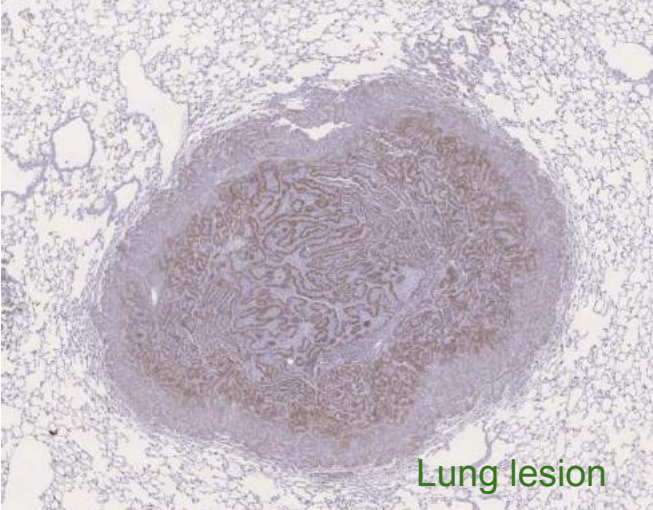
Colon
Adenocar.



Human breast



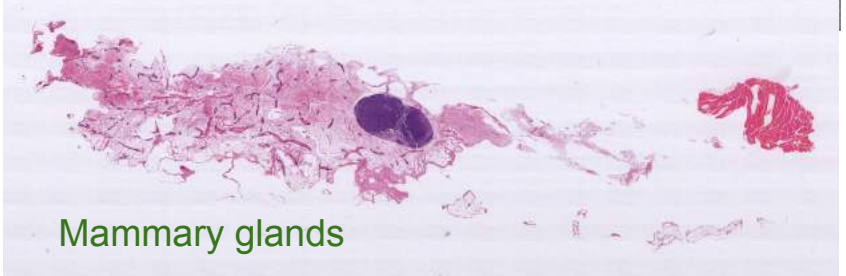
Lung lobes



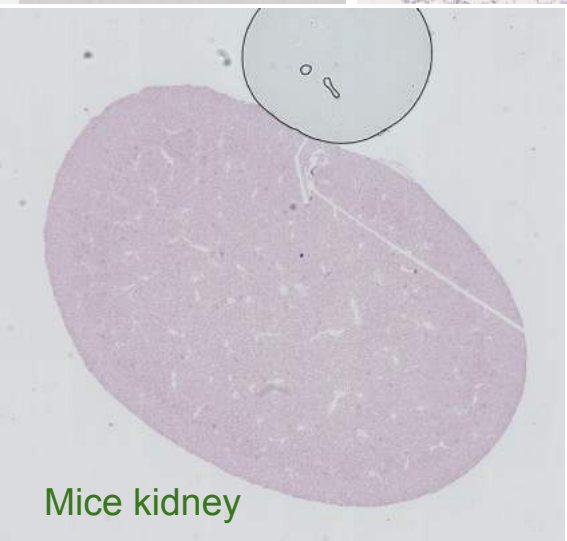
Lung lesion



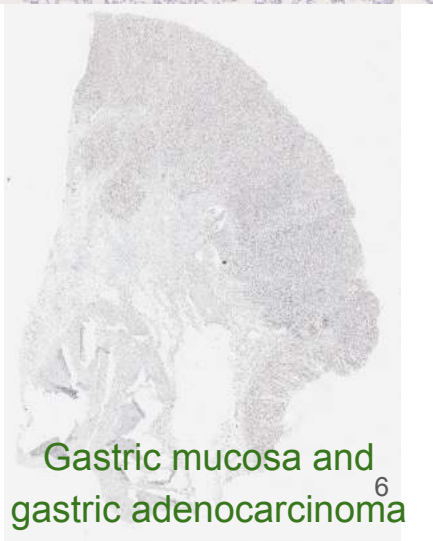
Human
kidney



Mammary glands



Mice kidney

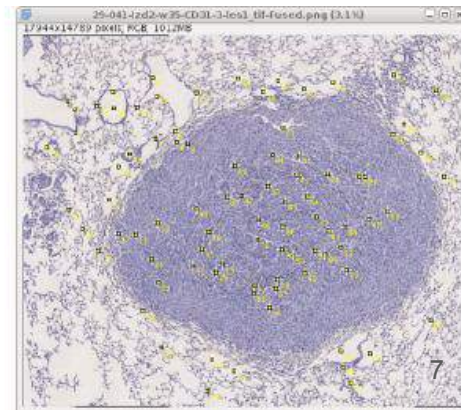
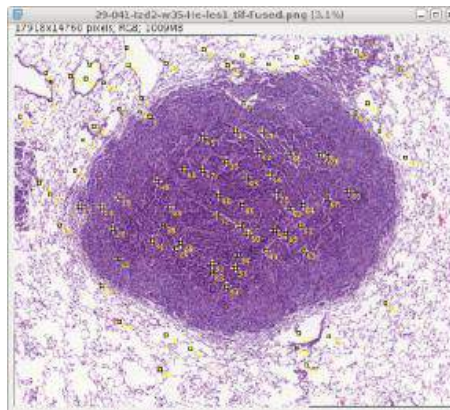


Gastric mucosa and
gastric adenocarcinoma⁶

Landmark annotation

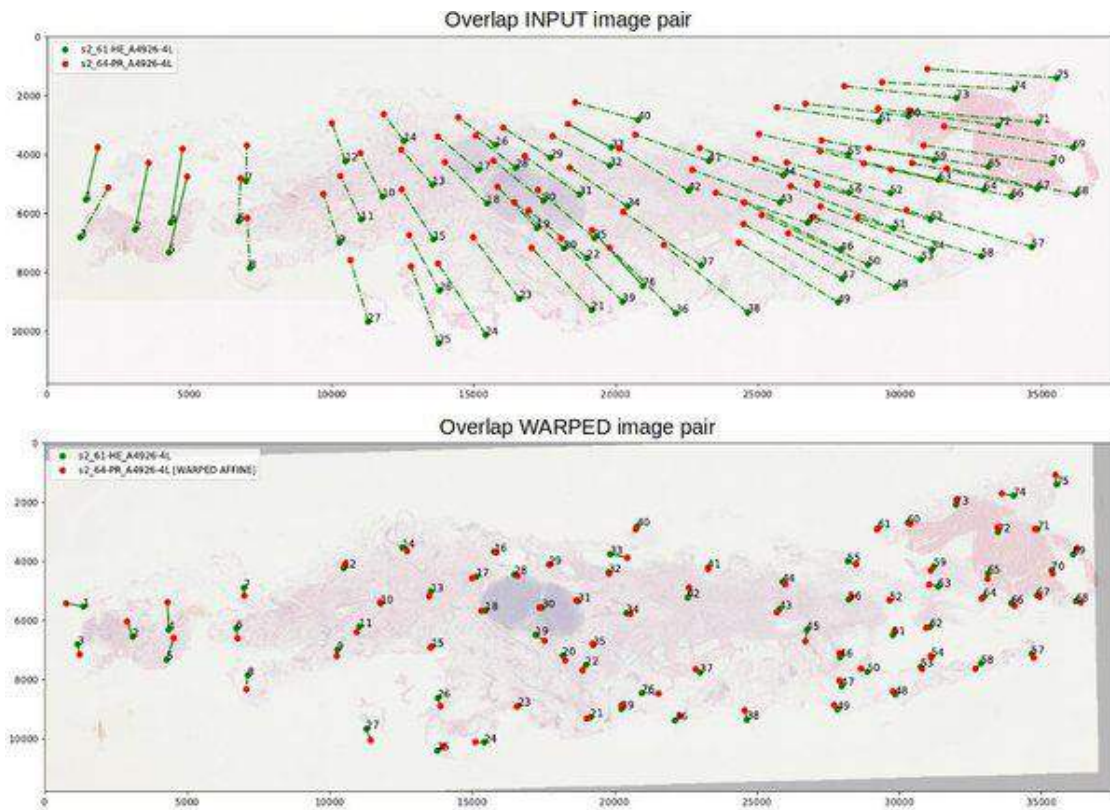
- Manual landmark identification using ImageJ
- Average scale used for annotation 25%
- Each image set was annotated once and validated independently
- Annotation time 113 + 106 hours and validation 32 + 5 hours
- 9 annotators and 3 validators

| Annotations | mean | std | min | max | median |
|-------------|-------|-------|-----|-----|--------|
| Images | 5.02 | 1.34 | 3.0 | 9.0 | 5.0 |
| Landmarks | 86.44 | 28.87 | 27 | 163 | 80.0 |
| #1 [hours] | 2.29 | 0.82 | 1.0 | 4.0 | 2.25 |
| #2 [hours] | 2.16 | 0.77 | 1.0 | 4.0 | 2.0 |



Landmark verification

- Validation after fitting an affine transformation
- Co-annotation precision - 0.05%
rTRE



Registration pairs

- We provide - all images, landmarks only for "training" images; for a set of 5:
 - 3 training image pairs (green) - with landmarks for both images
 - 6 testing image pairs (red) - with landmarks for one of the images
- Drop "symmetric" registration pairs - bottom left part of the table

| | <i>HE</i> | <i>PR</i> | <i>Ki67</i> | <i>CD31</i> | <i>Cc10</i> |
|-------------|-----------|-----------|-------------|-------------|-------------|
| <i>HE</i> | | 1 | 2 | | 3 |
| <i>PR</i> | | | 4 | 5 | 6 |
| <i>Ki67</i> | | | | 7 | 8 |
| <i>CD31</i> | | | | | 9 |
| <i>Cc10</i> | | | | | |

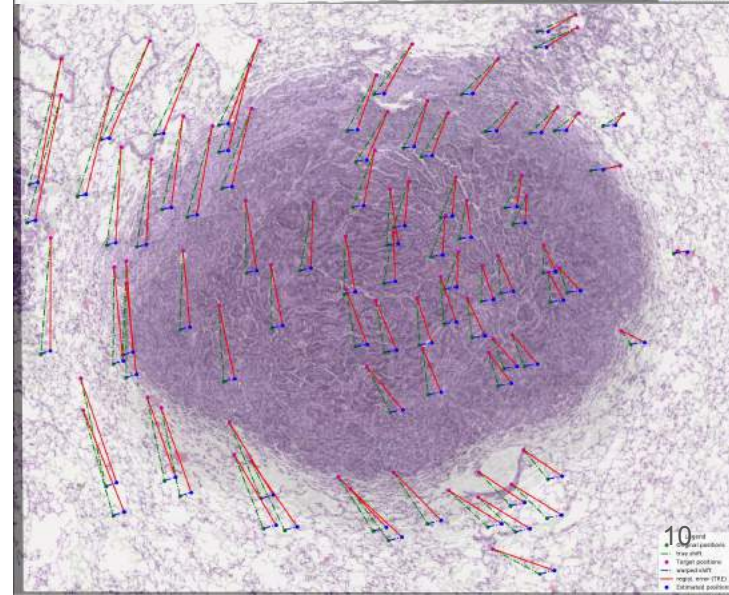
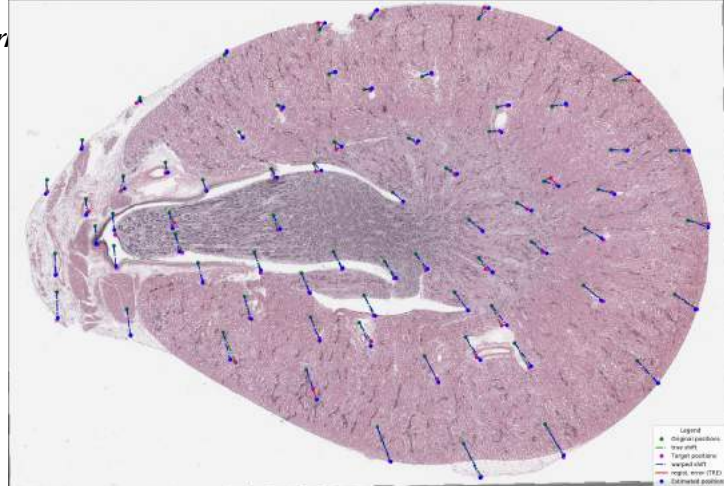
Evaluation criteria

- Target registration error (TRE)

- $TRE = d_{\Delta}(x_i^T, x_i^W)$; Euclidean distance between target and warped landmarks; [pixels]
- Relative TRE (rTRE), TRE normalized by image diagonal [%]

- Criteria

- $Average_{dataset} Rank Median_{image} rTRE$ - *winning criteria*
- $Average_{dataset} Median_{image} rTRE$ - *automatic leaderboard*
- $Average_{dataset} Robustness - avg_{image} TRE^{final} < avg_{image} TRE^{initial}$
- Normalized execution time [minutes]
- $Median_{dataset} Median_{image} rTRE$



Implementation (web & frameworks)

- Hosting web and evaluation
 - <https://anhir.grand-challenge.org>
- Dataset: histology landmarks
 - <https://borda.github.io/dataset-histology-landmarks>
- BIRL: Benchmark on Image Registration methods with Landmark validation
 - <https://borda.github.io/BIRL>

View on GitHub

dataset-histology-landmarks

Dataset: landmarks for registration of histology images

tar.gz zip

Dataset: histology landmarks

Build [passing](#) | [codecov](#) [tests](#) | [codeclimate](#) [tests](#) | [marcohanzini](#) [tests](#) | [test-coverage](#) [pass](#)

Feel free to use following communication channel: [chat](#) [issues](#) in any room.

This dataset presents user landmarks annotation for [CIMA histology images](#).

The dataset consists of 20 histological microscopy tissue slices differently stained. The main challenges for the registration of these images are the following: very large image size, appearance differences, and lack of distinctive appearance objects. Our dataset contains 300 image pairs and manually placed landmarks for registration quality evaluation.

Grand-Challenges

ALL CHALLENGES

SIGN IN / REGISTER

HOME

- [DATASET](#)
- [EVALUATION](#)
- [DOWNLOAD](#)
- [ORGANIZERS](#)
- [CONTACT](#)

Welcome to the Automatic Non-rigid Histological Image Registration (ANHIR) challenge website. This challenge is a part of the IEEE International Symposium on Biomedical Imaging (ISBI) 2019.

This challenge aims at the automatic nonlinear image registration of 2D microscopy images of histopathology tissue samples stained with different dyes. The task is difficult due to non-linear deformations affecting the tissue samples, different appearance of each stain, repetitive texture, and the large size of the whole slide images.

BIRL

BIRL: Benchmark on Image Registration methods with Landmark validations

[View on GitHub](#) [Download .zip](#) [Download .tar.gz](#)

BIRL: Benchmark on Image Registration methods with Landmark validation

[test](#) [status](#) [passed](#) [github](#) [testing](#) [test](#) [problems](#) [colocate](#) [tools](#) [code-coverage](#) [testimonials](#) [chat](#) [helpdesk](#)

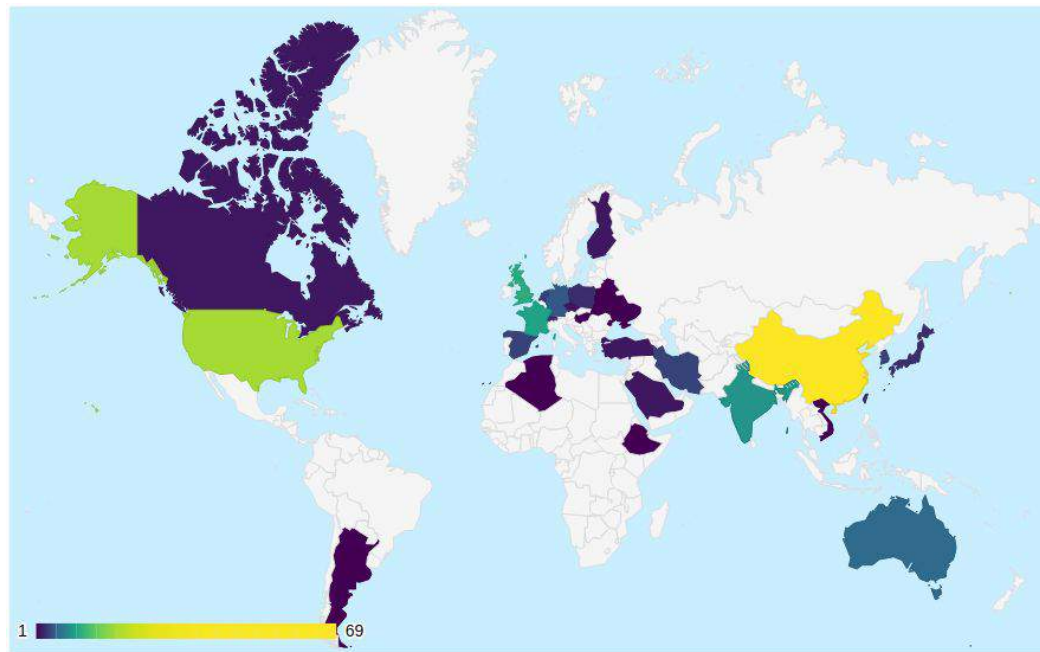
This project is the key component of [Automatic Non-rigid Histological Image Registration \(ANHIR\)](#) hosted at ISBI 2019 conference. The related challenge discussion is hosted on [forum.image.sc](#).

The project contains a set of sample images with related landmark annotations and experimental evaluation of state-of-the-art image registration methods.

11

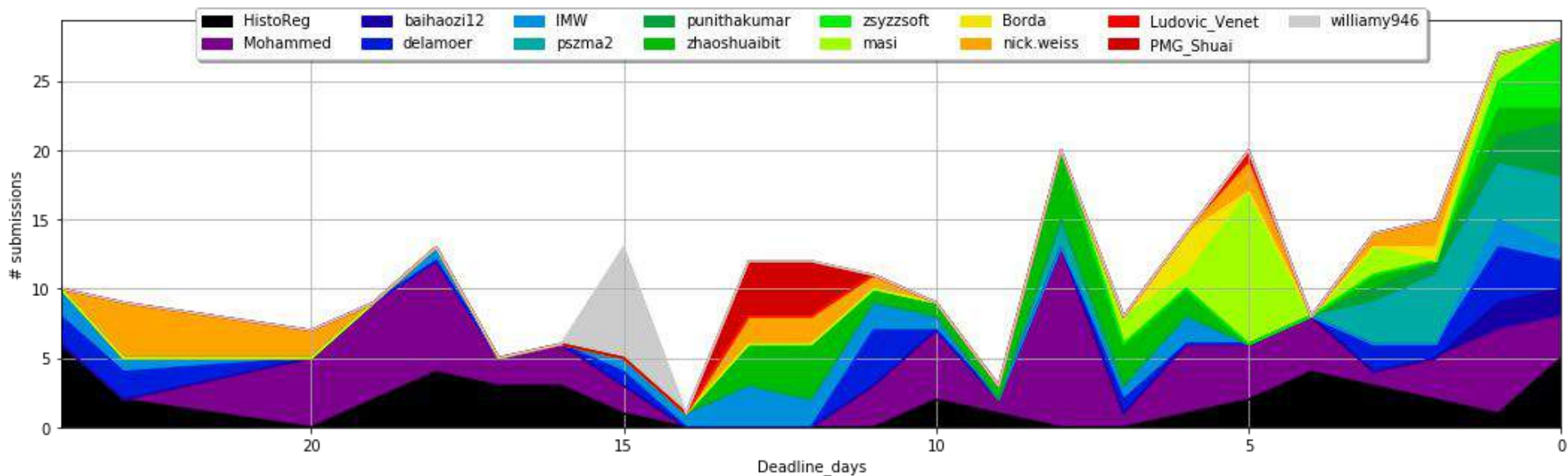
Statistics of the participants

- Participants counts
 - 256 joined
 - 250 data downloads
 - 11 submitting
 - 6 invited to ISBI'19 workshop
- Geographical distribution
 - 32 countries
 - 162 institutions
 - 143 departments

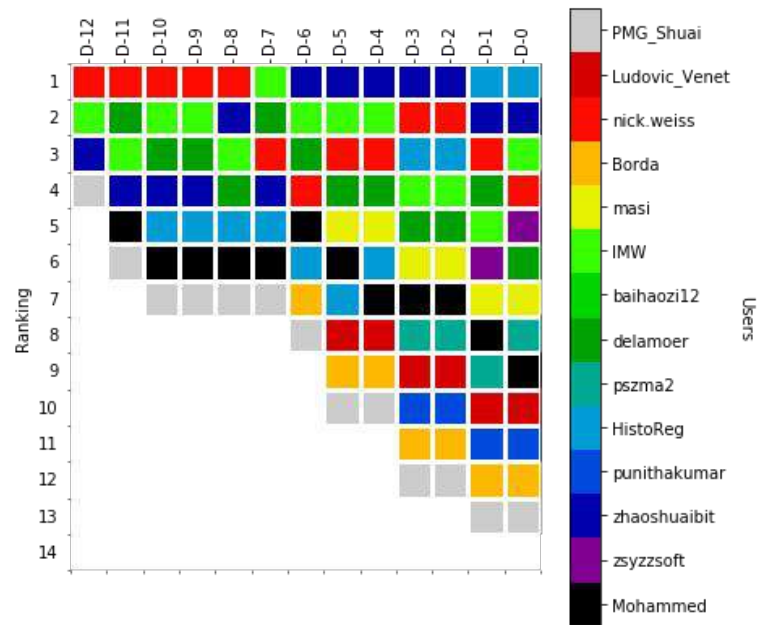
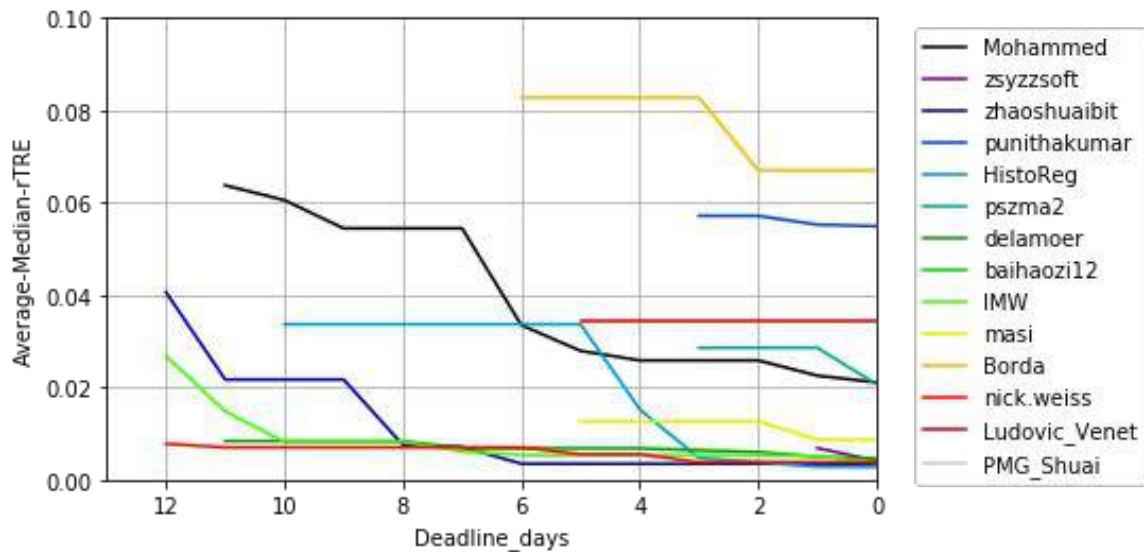


Submissions over time

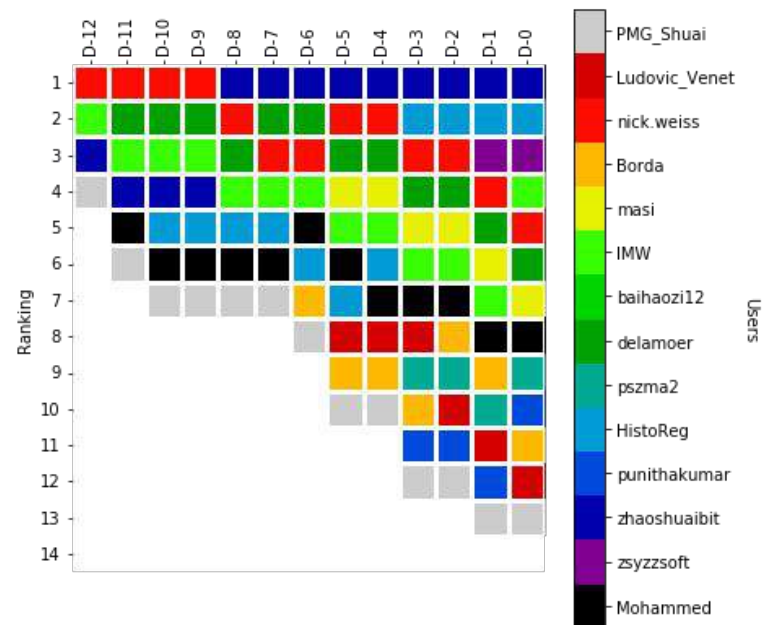
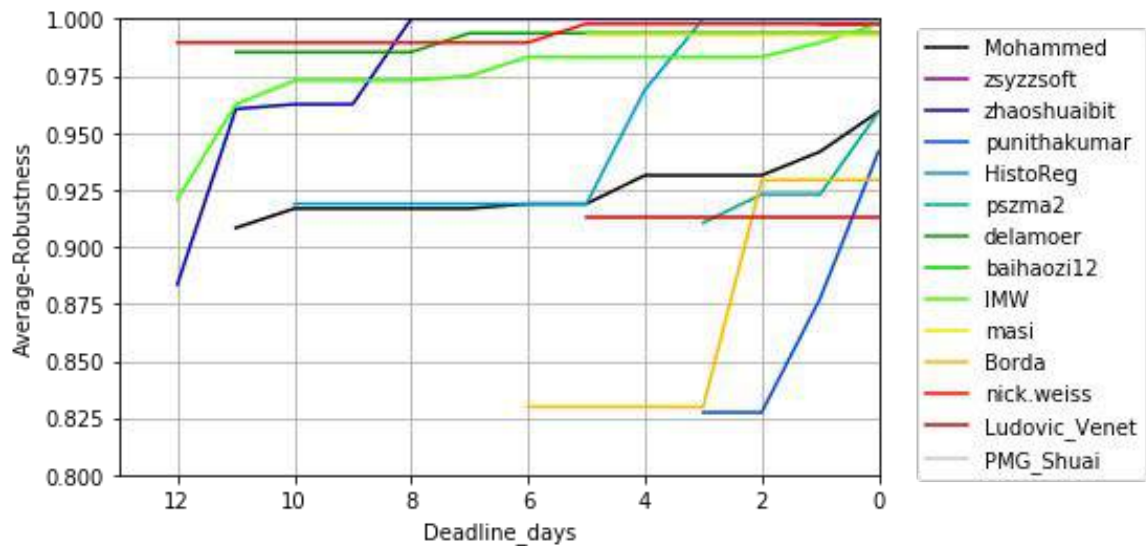
The time is the count to deadline in days



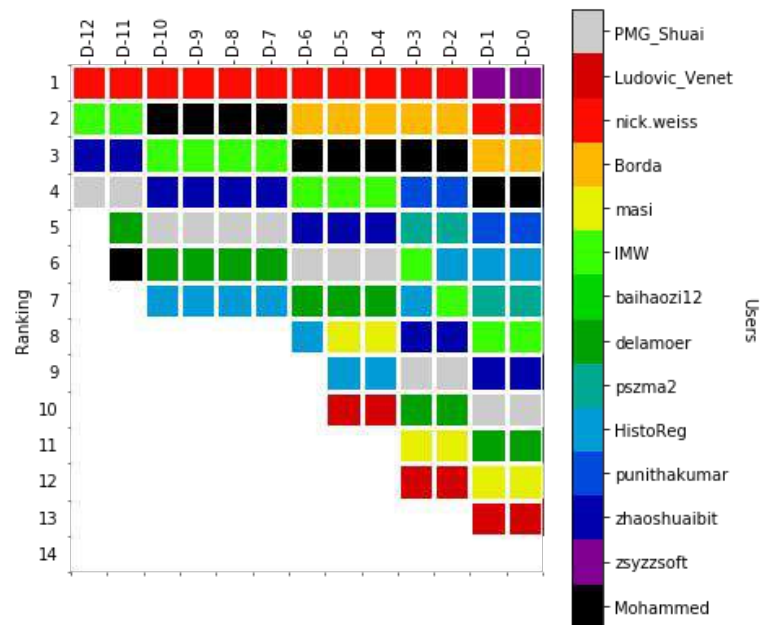
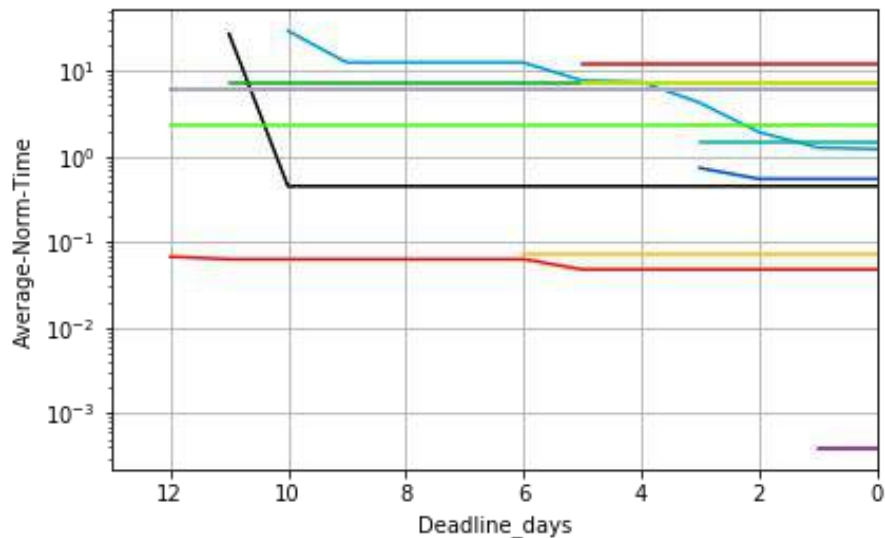
Timeline: Avg. Median rTRE



Robustness



Execution time [minutes/image pair]



Leaderboard

Results

Show entries

Additional metrics Hide additional metrics

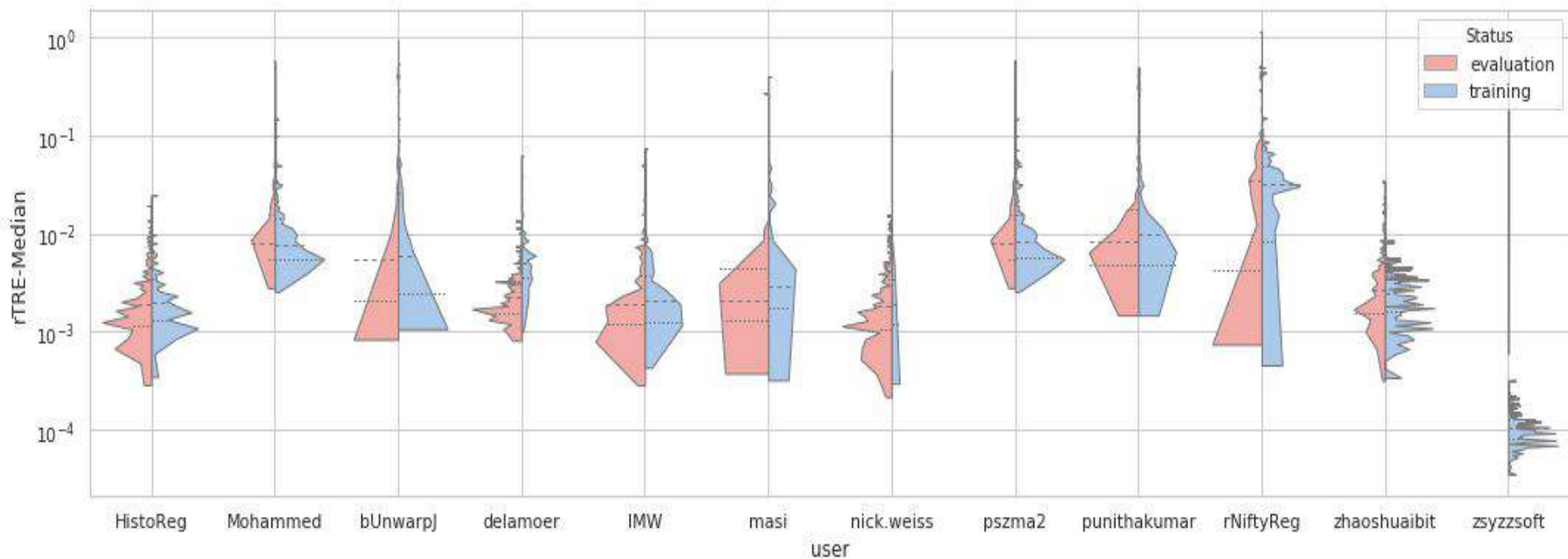
| # | User (Team) | Created | rTRE | Time | Robustness | Comment | Publication |
|------|-------------------------------------|---------------|----------------|---------|------------|----------------------------|-------------|
| 1st | HistoReg | 31 March 2019 | 0.00279 | 1.45119 | 1.00000 | final_40_4%_6_5 | |
| 2nd | zhaoshuaibit (CASIA-Genowis) | 1 April 2019 | 0.00347 | 6.09852 | 0.99792 | submit_final_x25b | |
| 3rd | IMW (AGH UST) | 31 March 2019 | 0.00380 | 6.86368 | 0.99792 | Maybe a final submission.. | |
| 4th | nick.weiss (Fraunhofer MEVIS) | 29 March 2019 | 0.00385 | 0.14539 | 0.99792 | | |
| 5th | zsyzzsoft | 1 April 2019 | 0.00410 | 0.00071 | 0.99792 | Weakly supervised test | |
| 6th | delamoer | 31 March 2019 | 0.00462 | 7.12714 | 0.99376 | | |
| 7th | masi (Bioimage informatics Tampere) | 31 March 2019 | 0.00873 | 9.62843 | 0.93763 | | |
| 8th | pszma2 (NMPN) | 31 March 2019 | 0.02071 | 2.52150 | 0.95570 | | |
| 9th | Mohammed (NMPN) | 1 April 2019 | 0.02112 | 2.54054 | 0.95931 | | |
| 10th | punithakumar | 31 March 2019 | 0.05497 | 1.47093 | 0.84615 | | |

Showing 1 to 10 of 10 entries

Only the best published result for each participant is listed.

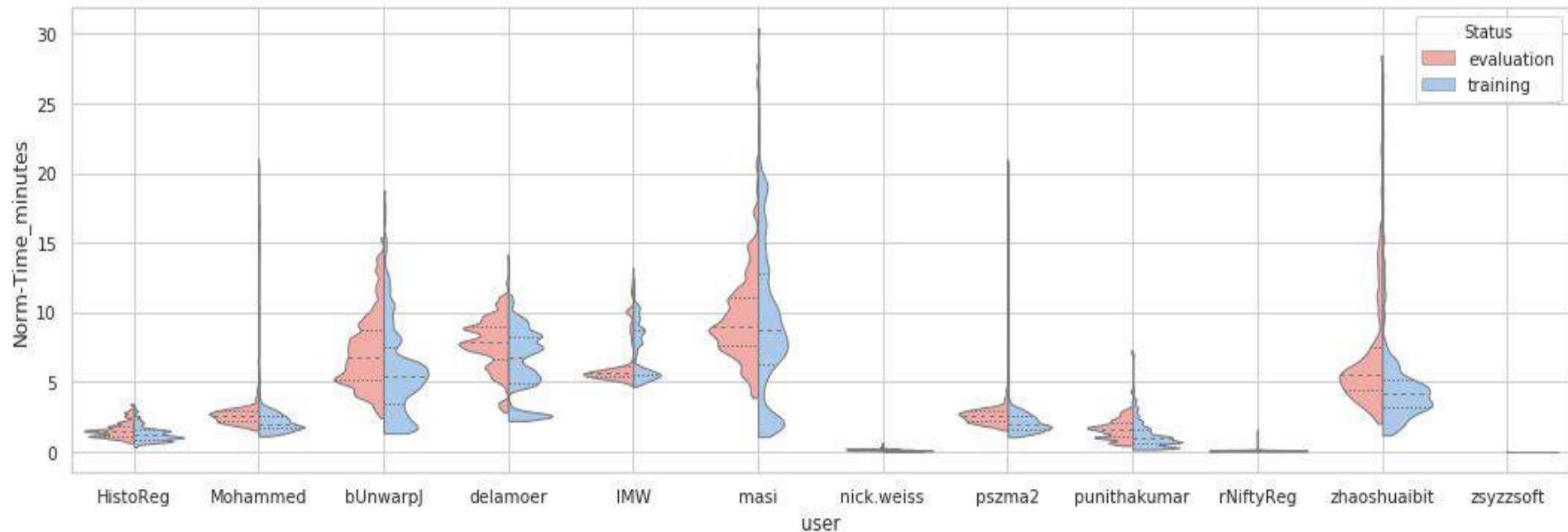
Previous **1** Next

Median rTRE, evaluation vs. training



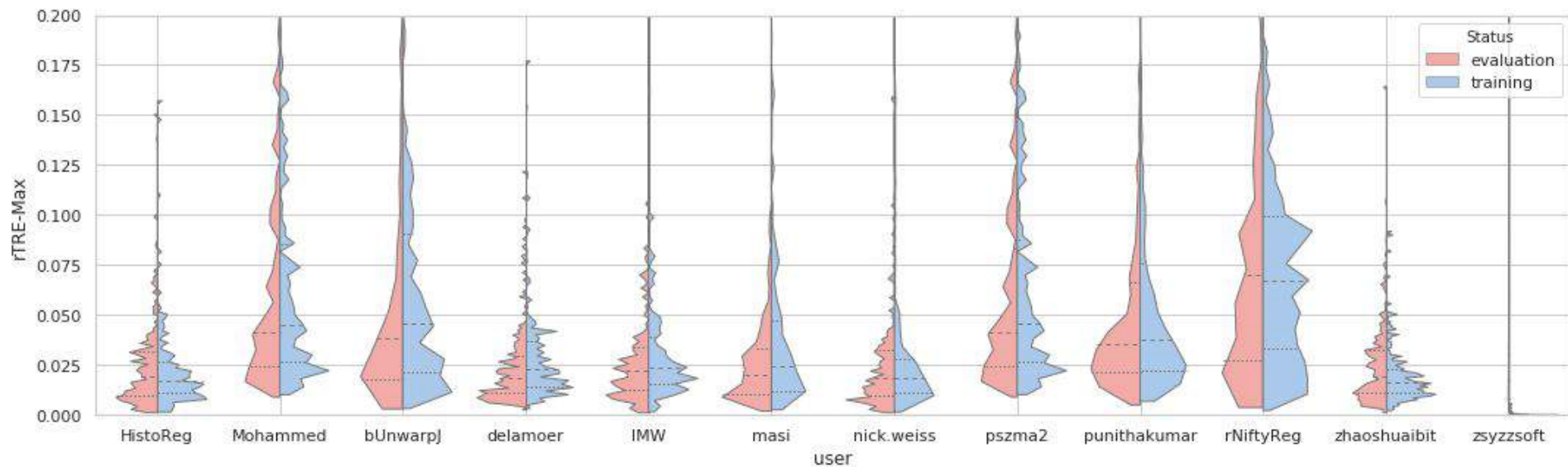
Execution time, evaluation vs. training

[minutes per image pair]

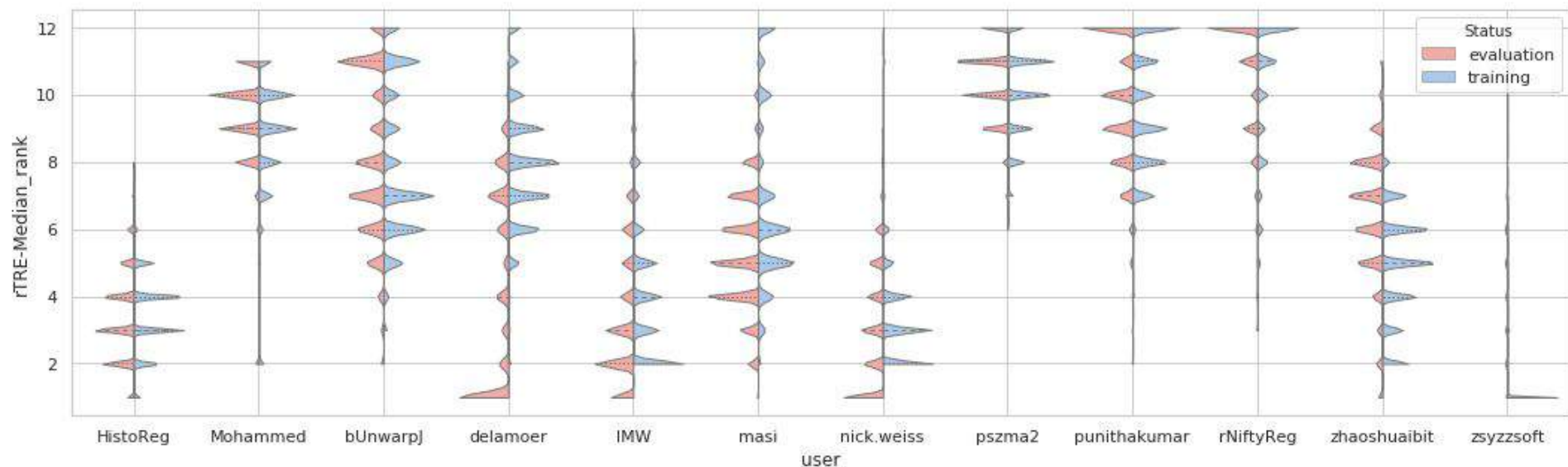


Max rTRE, evaluation vs. training

Maximal rTRE from each image reg. pair



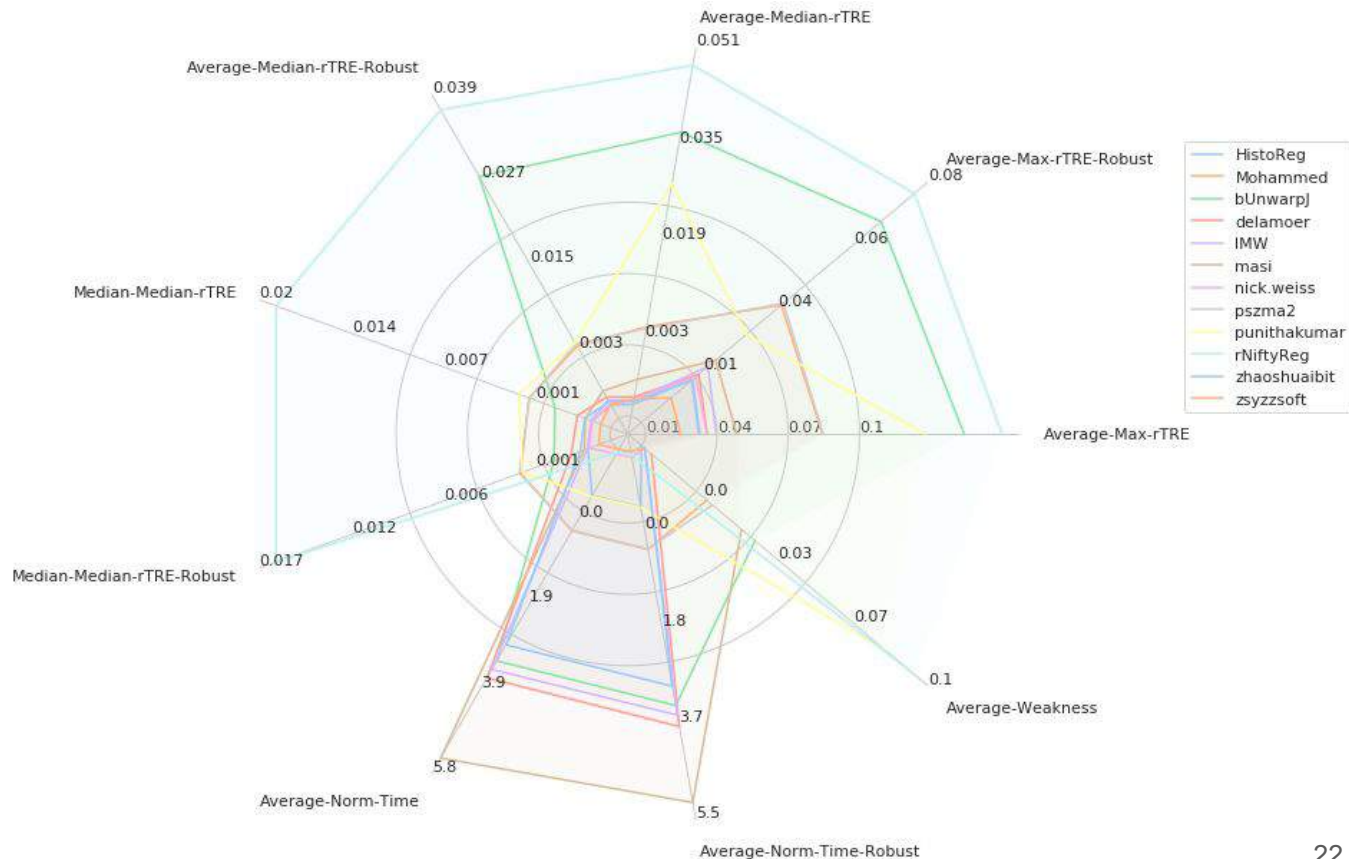
Ranks of median rTRE, evaluation vs. training



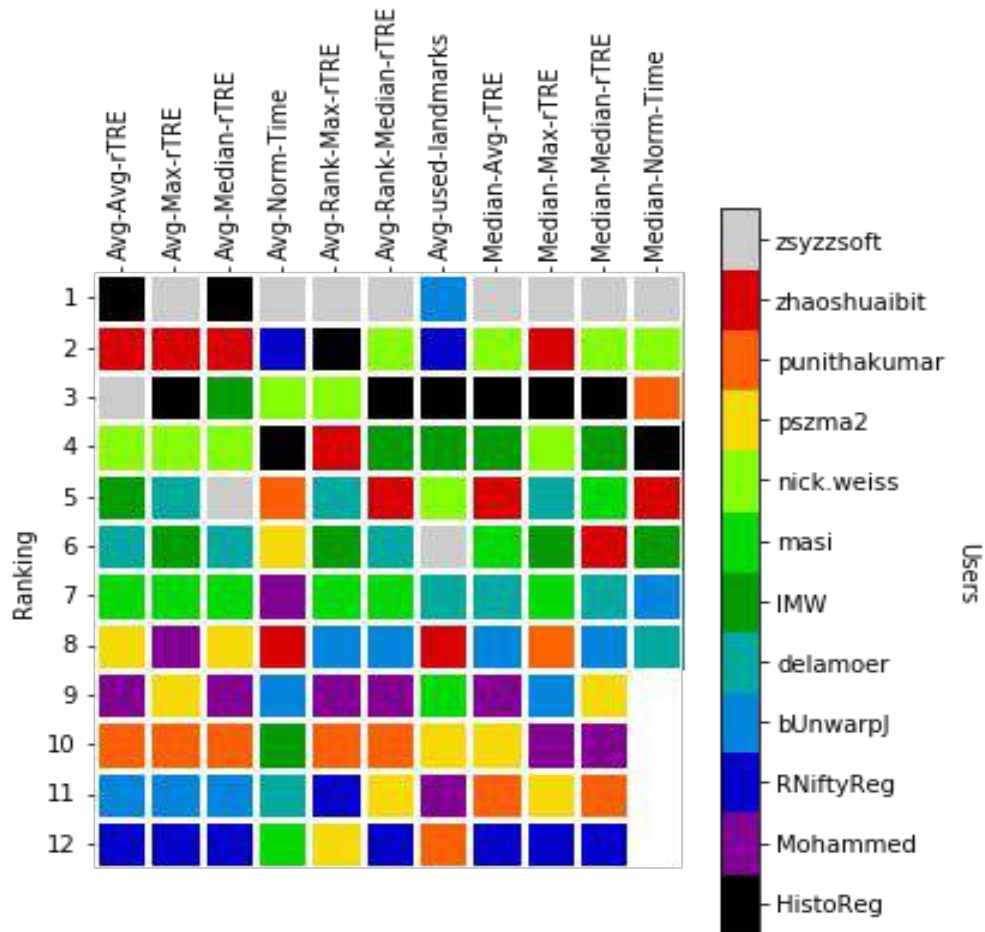
Results

Weakness = - Robustness

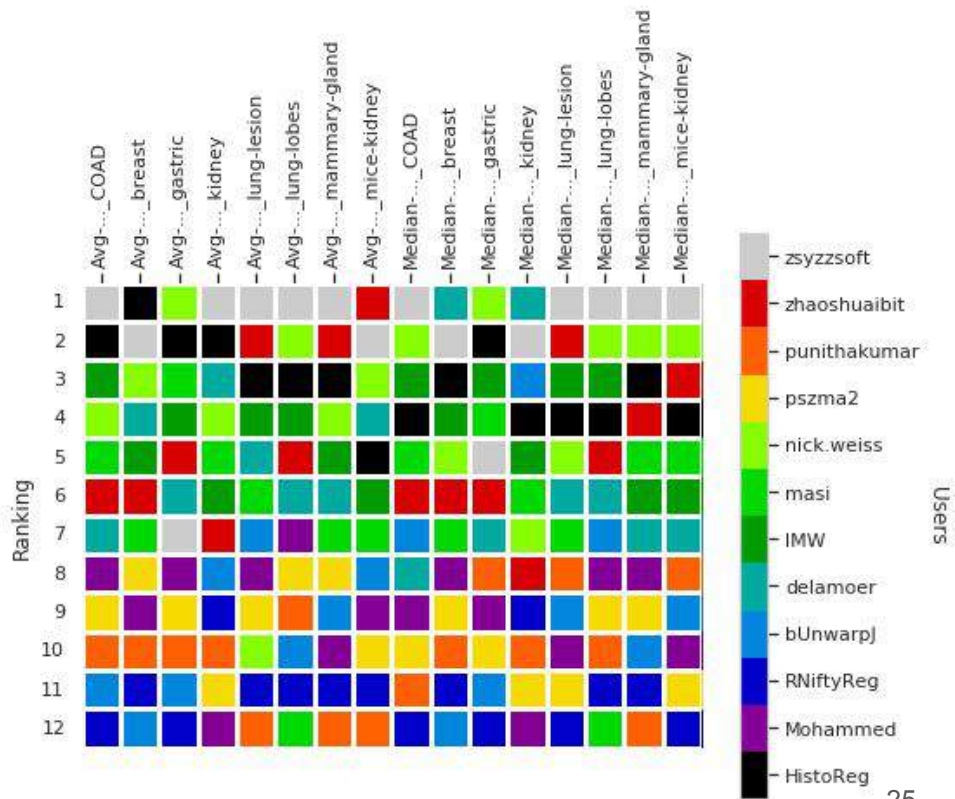
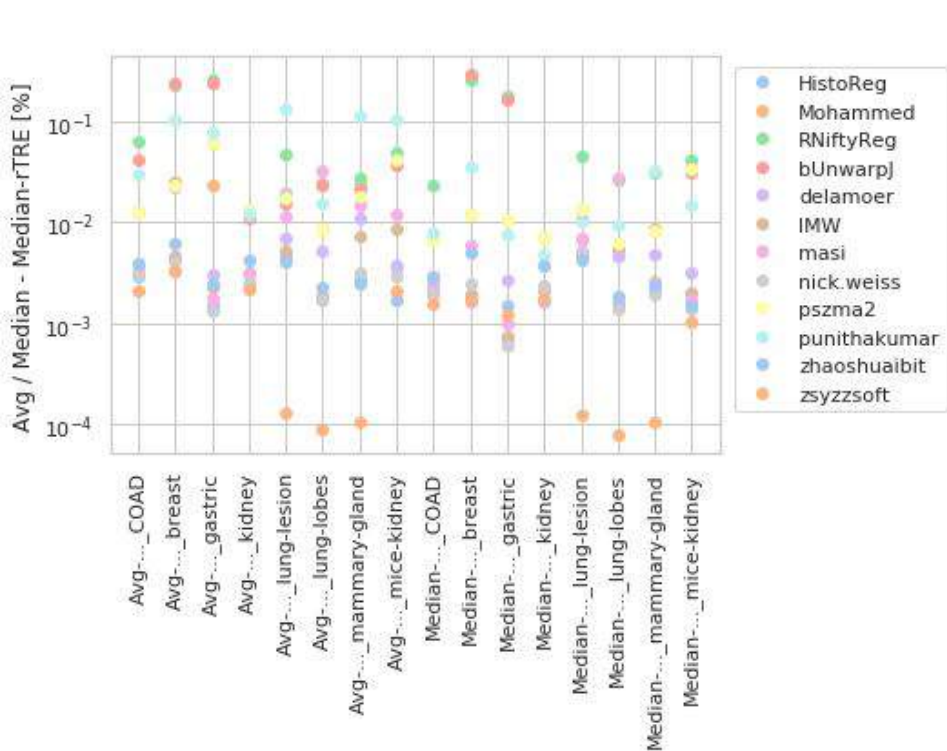
Smaller is better



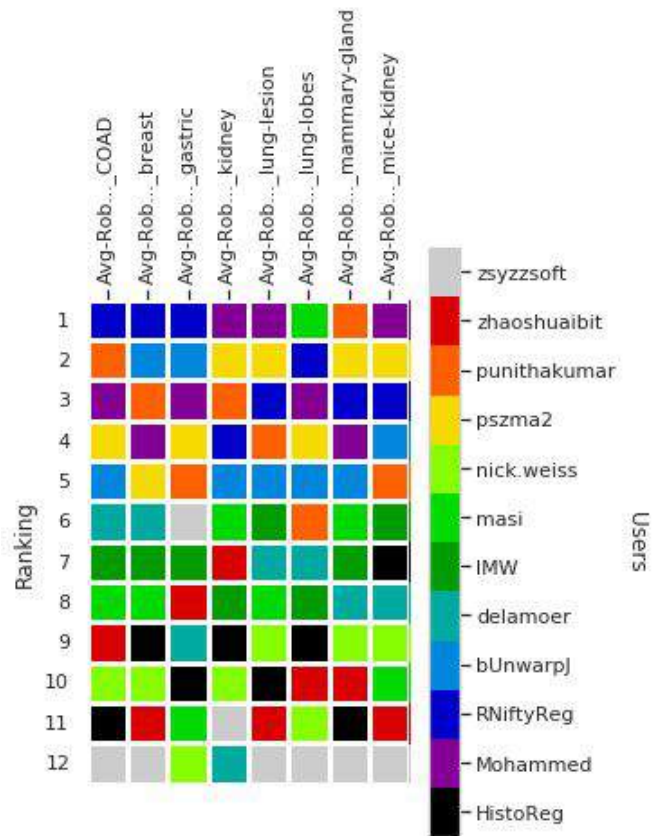
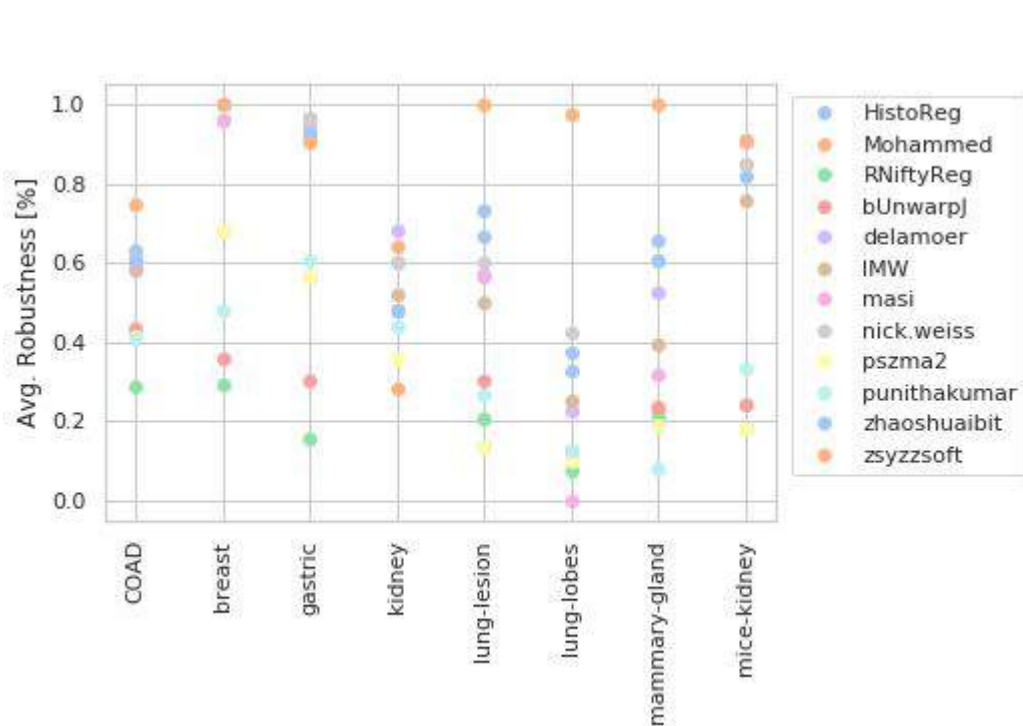
Ranks by criterion Avg. & Median



Avg. Median rTRE by tissue type



Avg. Robustness by tissue type

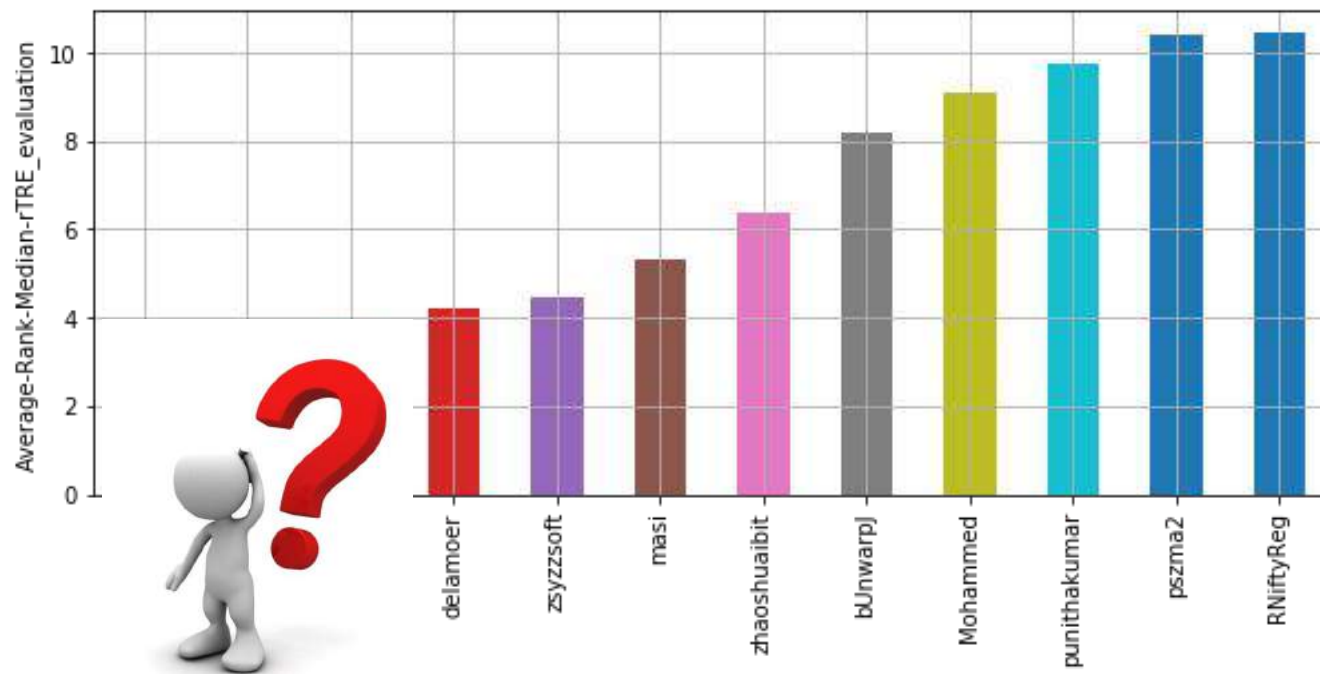


Participants presentations

| Time | | Authors | Title |
|-------|-------|---|--|
| 14:45 | 15:00 | <i>organizers</i> | <i>Introduction, challenge description and some statistics</i> |
| 15:00 | 15:20 | Nazanin Tahmasebi, Michelle Noga, and Kumaradevan Punithakumar | Cascaded Rigid Multi-Resolution and Moving Mesh Image Registration Frameworks for Histological Image Registration |
| 15:20 | 15:40 | Masi Valkonen, Kimmo Kartasalo, Leena Latonen, Pekka Ruusuvoori | Stain invariant elastic registration of histological sections |
| 15:40 | 16:00 | Yu Xiang | Stain deconvolution based pathological image registration |
| 16:00 | 16:30 | | <i>coffee break</i> |
| 16:30 | 16:50 | Johannes Lotz, Nick Weiss and Stefan Heldmann | Robust,fast and accurate: A 3-step method for automatic histological image registration |
| 16:50 | 17:10 | Marek Wodzinski and Andrzej Skalski | Automatic nonrigid histological image registration with adaptive multistep algorithm |
| 17:10 | 17:30 | Ludovic Venet, Sarthak Pati, Paul Yushkevich, Spyridon Bakas | Accurate and robust alignment of variable-stained histological images using a general-purpose greedy diffeomorphic registration tool |
| 17:30 | 17:40 | <i>organizers</i> | <i>prize giving ceremony, closing remarks</i> |
| 17:40 | 18:00 | <i>organizers</i> | <i>article planning (by invitation, for active participants)</i> |



Final results





**AND THE
WINNERS ARE...**

Automatic Non-rigid
Histological Image Registration
(ANHIR) challenge



The ANHIR challenge organizers recognize the team formed by

**Marek Wodzinski,
Andrzej Skalski**

*as the final #3 ranked team in the image registration
competition.*

*J. Borovec, J. Kybic, A. Muñoz-Barrutia, I. Arganda-Carreras,
D. Sorokin, A.-- Khvostikov, M. G. Bueno Garcia*

The organizers

Sponsored by:



April 11, 2019

Automatic Non-rigid Histological Image Registration (ANHIR) challenge



The ANHIR challenge organizers recognize the team formed by

**Ludovic Venet, Sarthak Pati,
Paul Yushkevich, Spyridon Bakas**
*as the final #2 ranked team in the image registration
competition.*

*J. Borovec, J. Kybic, A. Muñoz-Barrutia, I. Arganda-Carreras,
D. Sorokin, A.-- Khvostikov, M. G. Bueno Garcia*

The organizers

Sponsored by:



April 11, 2019

Automatic Non-rigid
Histological Image Registration
(ANHIR) challenge



The ANHIR challenge organizers recognize the team formed by

**Johannes Lotz, Nick Weiss,
Stefan Heldmann**

*as the final #1 ranked team in the image registration
competition.*

*J. Borovec, J. Kybic, A. Muñoz-Barrutia, I. Arganda-Carreras,
D. Sorokin, A.-- Khvostikov, M. G. Bueno Garcia*

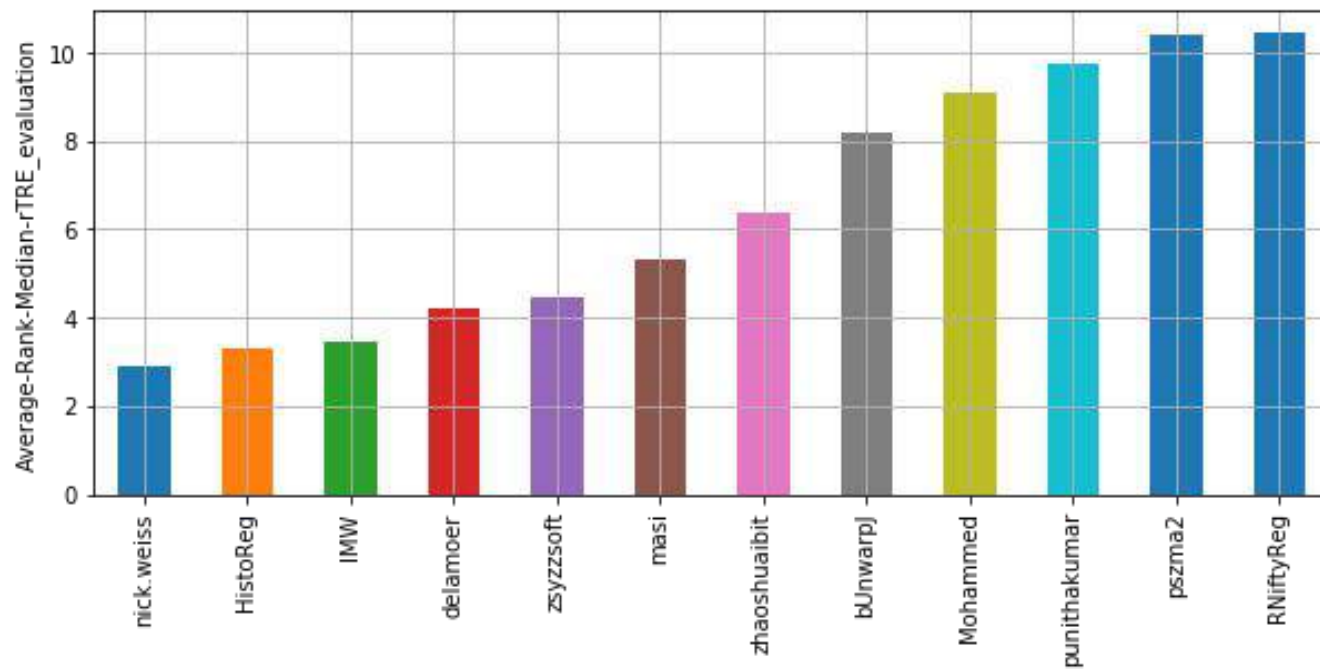
The organizers

Sponsored by:



April 11, 2019

Final results

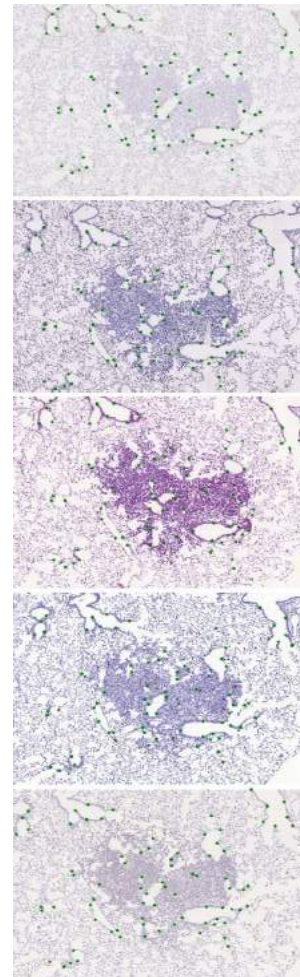


Final results

| | Avg-Median-rTRE | | Avg-Norm-Time | | Avg-Rank-Median-rTRE | | Avg-Robustness | | Median-Median-rTRE | |
|---------------------|-----------------|----------|---------------|----------|----------------------|----------|----------------|----------|--------------------|----------|
| | evaluation | training | evaluation | training | evaluation | training | evaluation | training | evaluation | training |
| <i>nick.weiss</i> | 0.00287 | 0.00492 | 0.16661 | 0.12224 | 2.91633 | 3.30435 | 1 | 0.99565 | 0.0018 | 0.00186 |
| <i>HistoReg</i> | 0.00286 | 0.00272 | 1.59568 | 1.29352 | 3.34263 | 3.42609 | 1 | 1 | 0.0019 | 0.00195 |
| <i>IMW</i> | 0.00359 | 0.00404 | 6.54809 | 7.20808 | 3.43825 | 3.9087 | 0.99602 | 1 | 0.00191 | 0.00202 |
| <i>delamoer</i> | 0.0027 | 0.0067 | 7.79555 | 6.3977 | 4.18327 | 7.90435 | 1 | 0.98696 | 0.00226 | 0.00505 |
| <i>zsyzzsoft</i> | 0.00775 | 0.00011 | 0.00088 | 0.00051 | 4.41434 | 1.09565 | 0.99602 | 1 | 0.00206 | 0.00011 |
| <i>masi</i> | 0.00479 | 0.01303 | 9.72578 | 9.51425 | 5.31474 | 6.83043 | 0.99602 | 0.86916 | 0.00208 | 0.00311 |
| <i>zhaoshuaibit</i> | 0.00416 | 0.00273 | 7.17615 | 4.92249 | 6.34263 | 4.83913 | 0.99602 | 1 | 0.00265 | 0.00245 |
| <i>bUnwarpJ</i> | 0.09713 | 0.03409 | 7.22483 | 5.91475 | 8.16733 | 7.96087 | 0.92032 | 0.93913 | 0.0054 | 0.00587 |
| <i>Mohammed</i> | 0.0252 | 0.0167 | 2.72945 | 2.33206 | 9.21514 | 8.72609 | 0.95102 | 0.96847 | 0.00799 | 0.00821 |
| <i>punithakumar</i> | 0.05065 | 0.05949 | 1.70407 | 1.2165 | 9.70518 | 9.66087 | 0.84861 | 0.84783 | 0.00825 | 0.00999 |
| <i>pszma2</i> | 0.02523 | 0.01584 | 2.72945 | 2.29903 | 10.37849 | 10.03043 | 0.95102 | 0.9607 | 0.00791 | 0.00821 |
| <i>rNiftyReg</i> | 0.11358 | 0.04911 | 0.09219 | 0.0954 | 10.58167 | 10.31304 | 0.82996 | 0.82969 | 0.03626 | 0.03119 |

Closing remarks

- Picture time
- Future of the challenge
 - Re-opening submission with extended metrics
 - Future editions
- Journal publication
- Sponsors



ANNOUNCEMENTS

- Workshop on Biomedical Image Registration
- Special issue on [Computer Vision methods for Microscopy](#)
- COST action COMULIS (www.comulis.eu)

WBIR 2020



Research Topic

Computer Vision Methods for Microscopy

Submit your abstract

Submit your manuscript

Frontiers in
Robotics and AI
Robot and Machine Vision

Frontiers in
ICT
Computer Vision and Image Analysis