Histological validation and reconstruction

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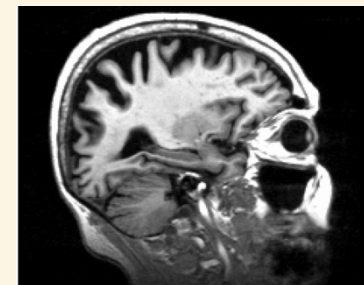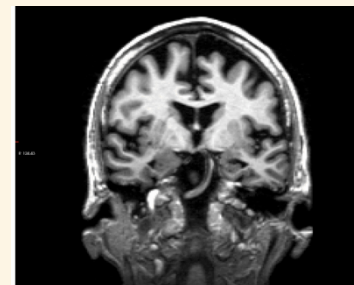University College London

Probabilistic atlases combining *in vivo* and *ex vivo* MRI

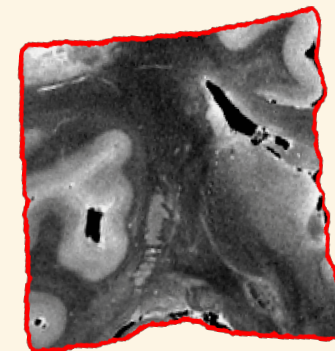Each has its own advantages

- *In vivo:*
  - Complete FOV.
  - Faster to label.
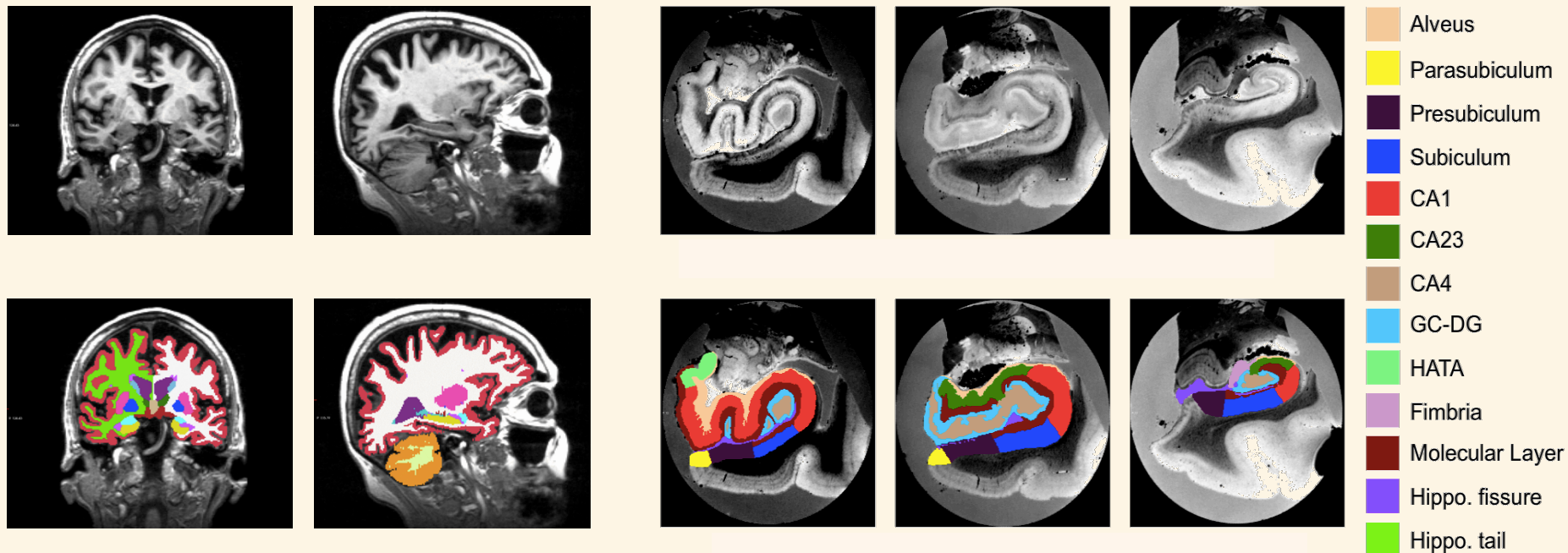 - Negligible geometric distortions.
- *Ex vivo:*
  - Higher resolution and / or contrast (no motion, dedicated coils).
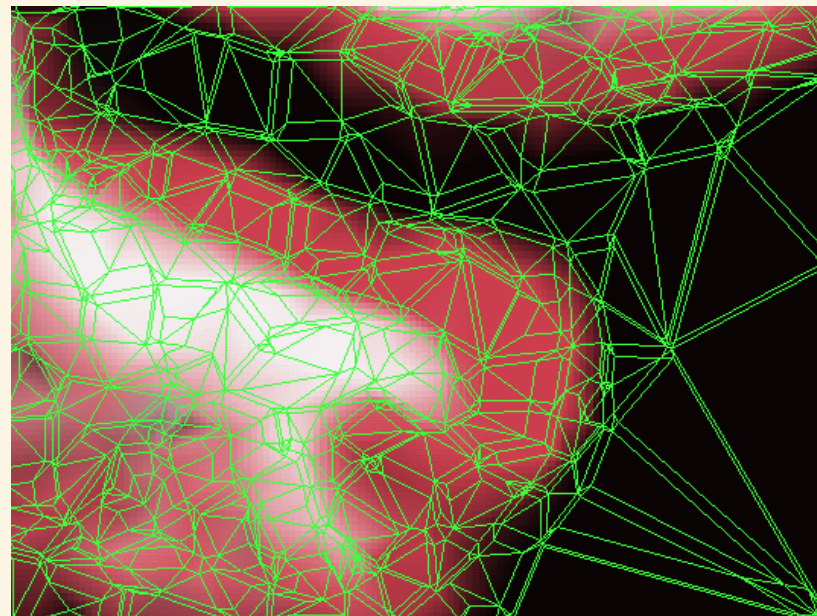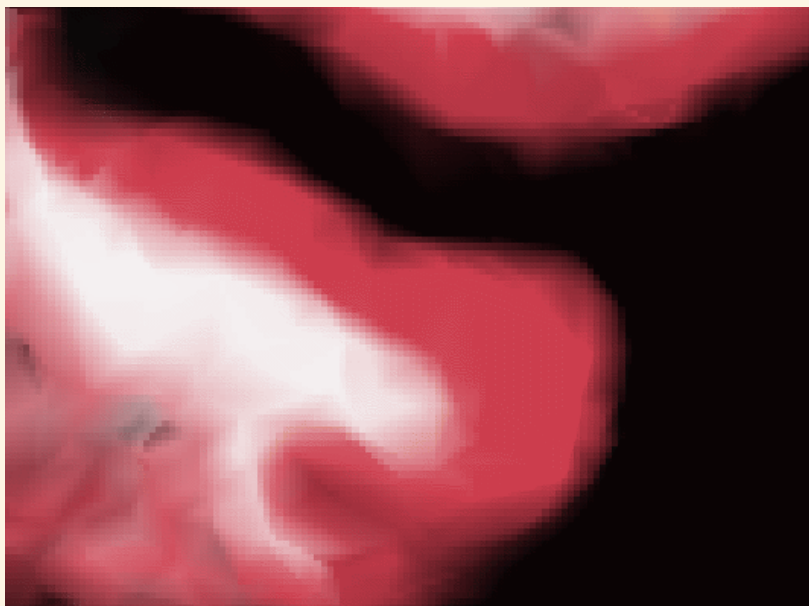 - Enables more detailed delineations
- We have a framework to combine both!

Example: atlas of hippocampal subfields

Alveus
Parasubiculum
Presubiculum
Subiculum
CA1
CA23
CA4
GC-DG
HATA
Fimbria
Molecular Layer
Hippo. fissure
Hippo. tail

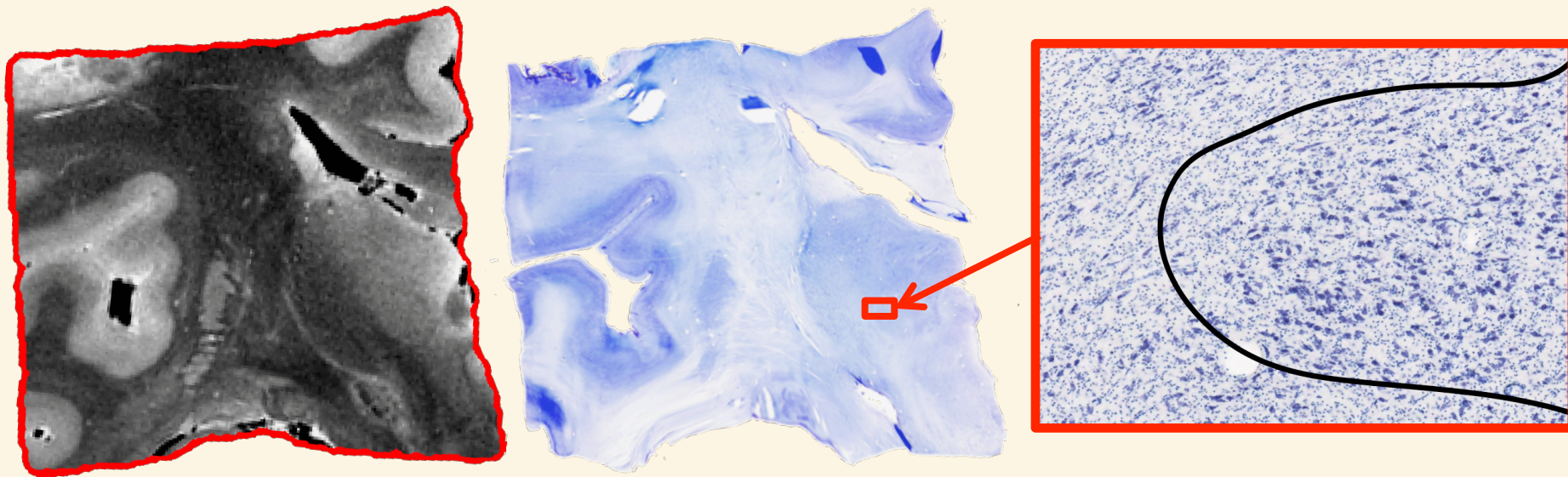# Example: atlas of hippocampal subfields

Represented as sparse, adaptive, tetrahedral mesh
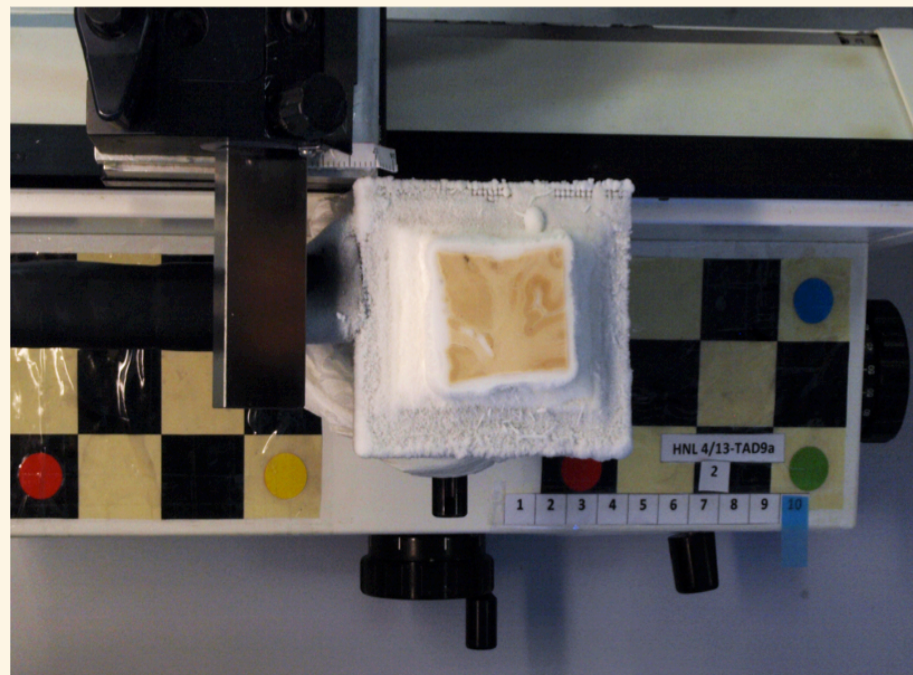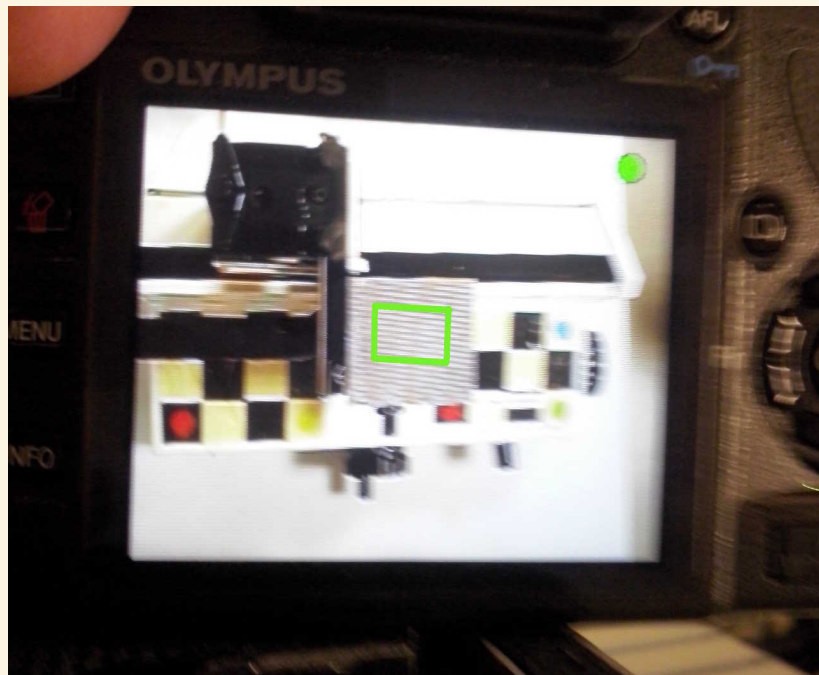

(Iglesias et al., Neuroimage, 2015)

However, *ex vivo* is MRI not always enough

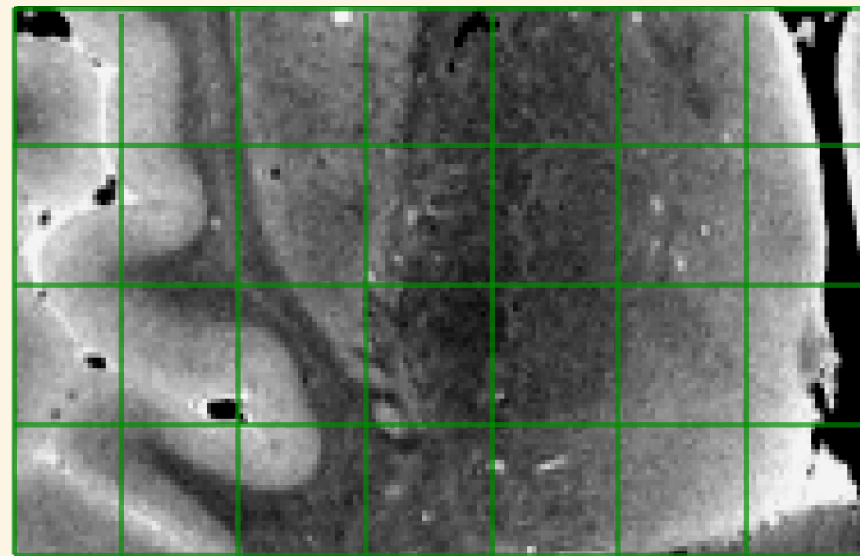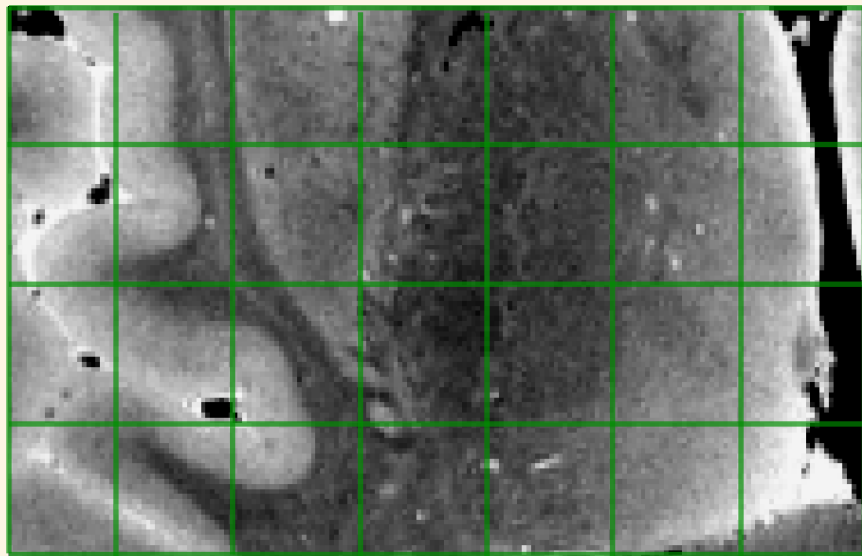Some boundaries are only visible in histology

Histology reconstruction: Blockface photos

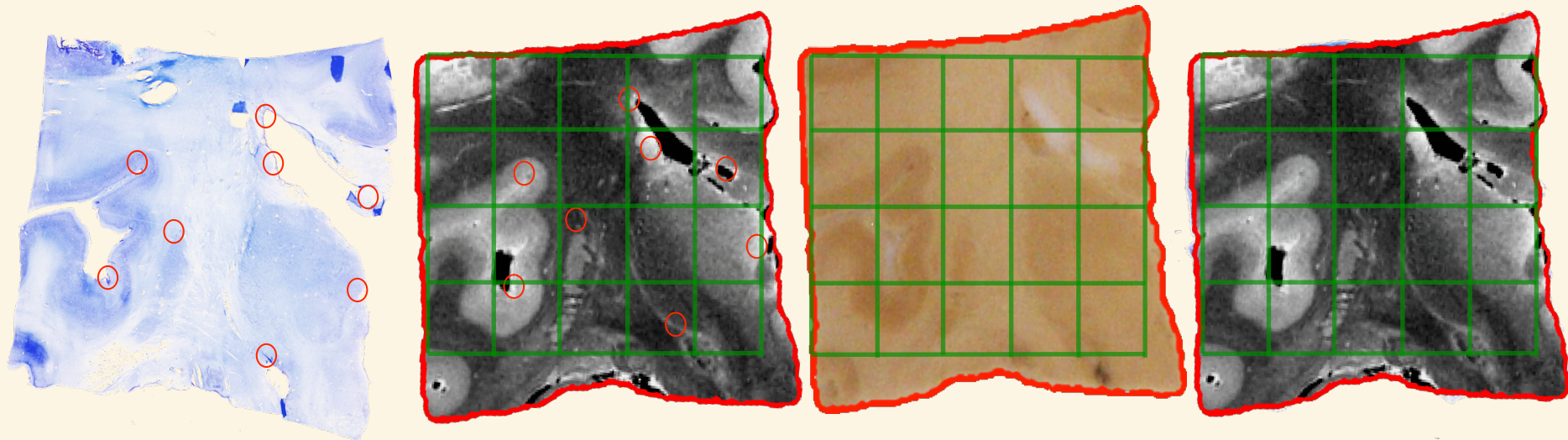Block-face photographs to assist reconstruction
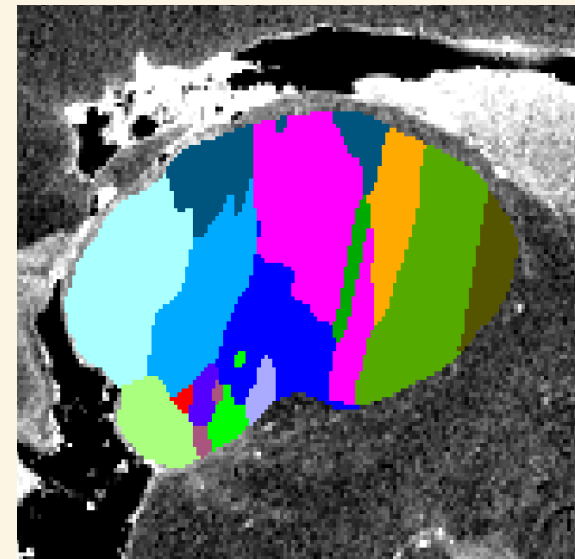
Example: Thalamic atlas
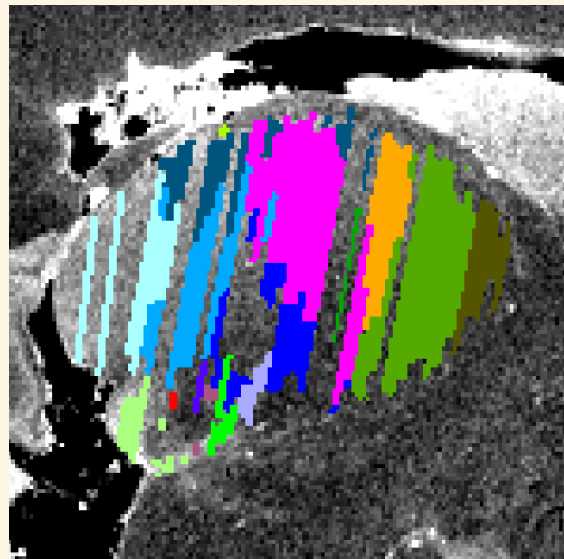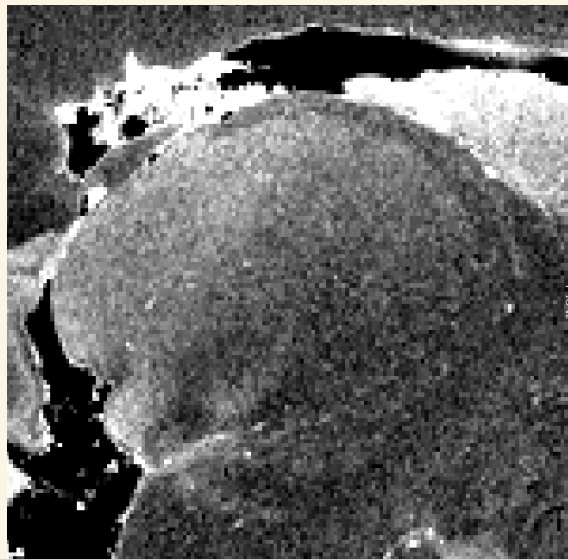
Block-face to MRI registration (rigid = easy!)
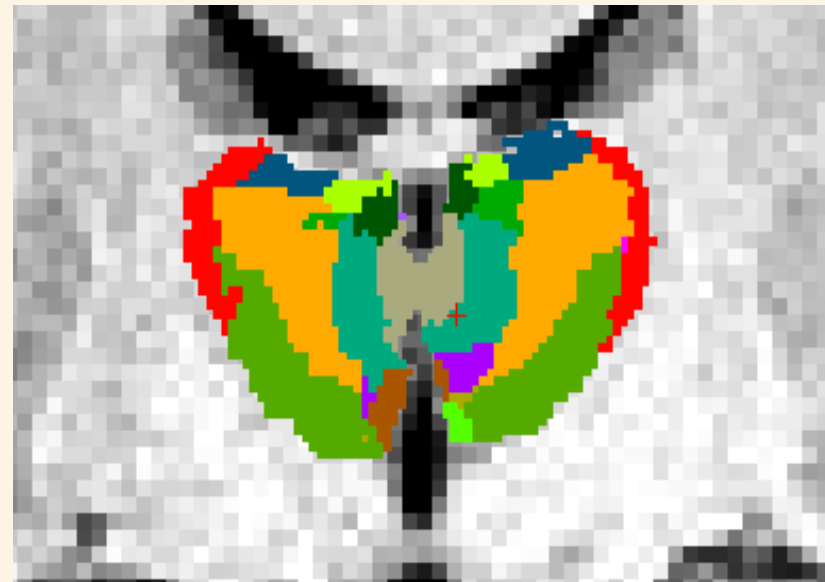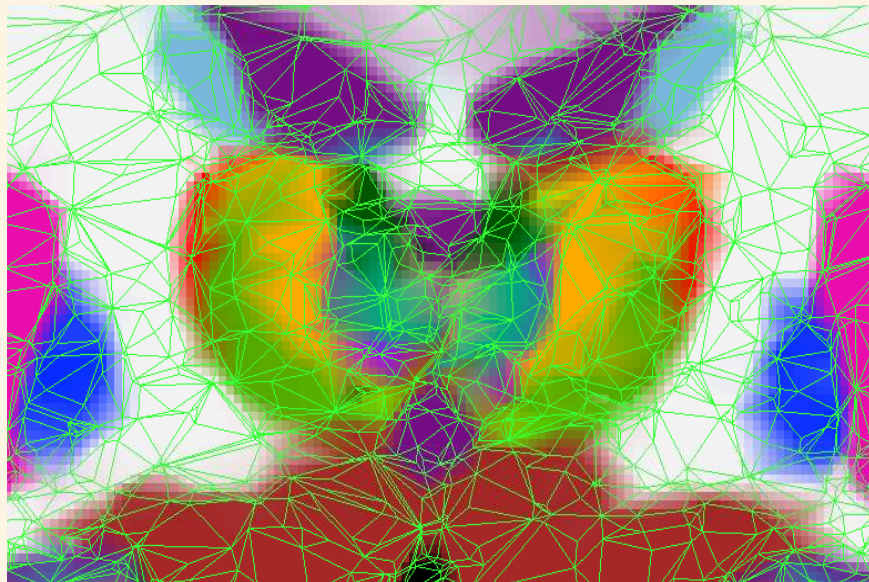
Thalamic atlas

Resampled MRI to histology

Thalamic atlas

Reconstructing segmentations with "smart" interpolation
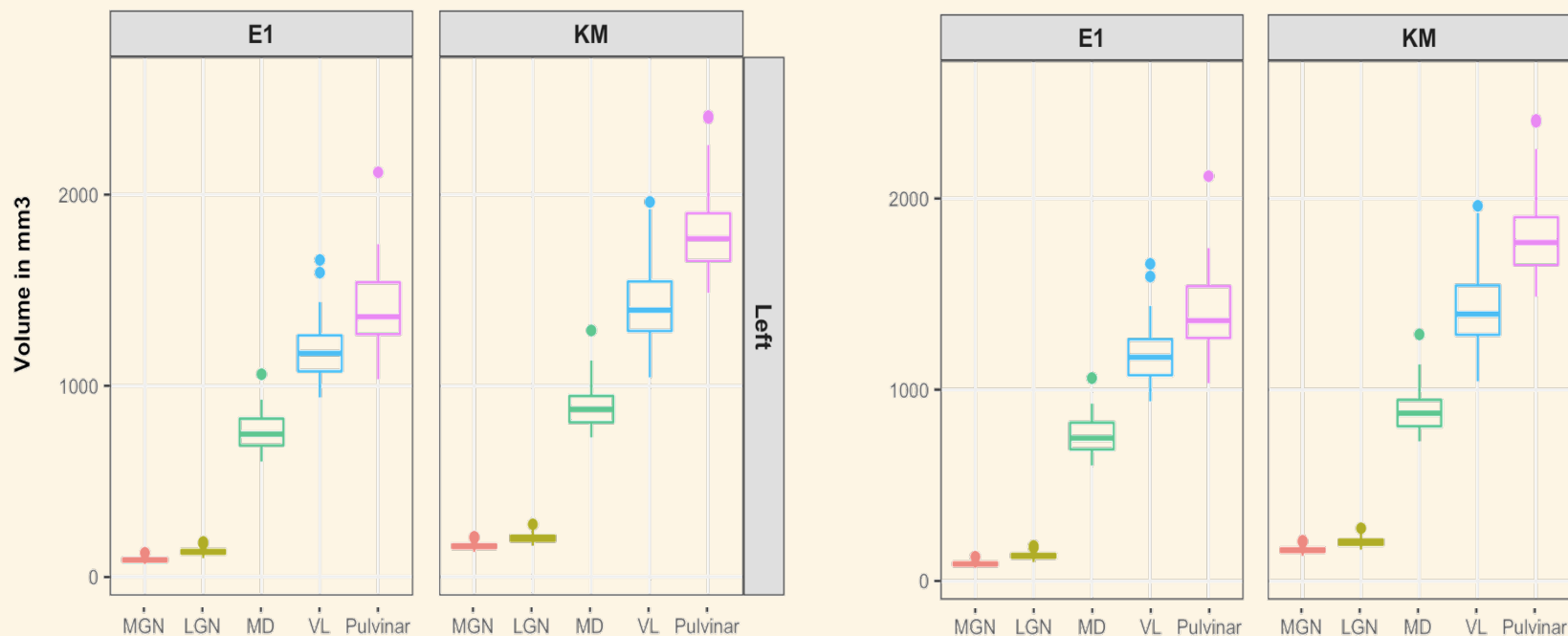(Gaussian mixture model + Markov random field)

Atlas construction and image segmentation

In vivo segmentations to learn surrounding structures
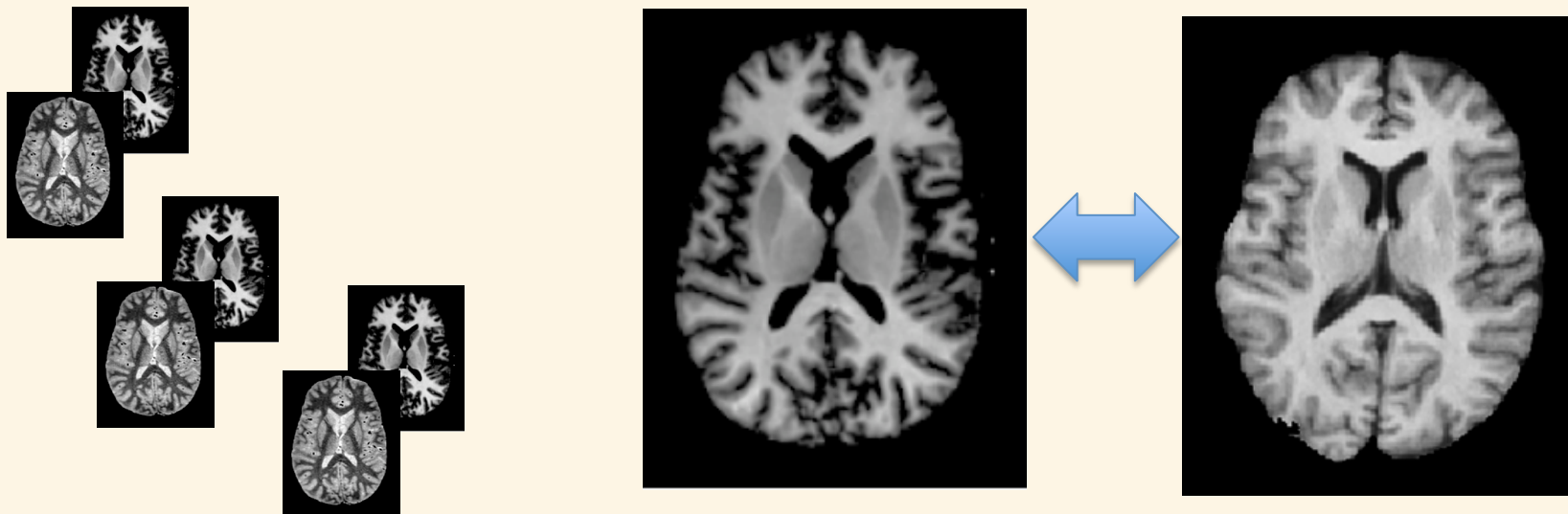
Thalamic atlas

Comparison with *Krauth, Morel, et al.* (also based on histology)

(Iglesias et al., SfN 2017, OHBM 2017)

How about the 2D inter-modality registration?
Synthesis and multimodal registration

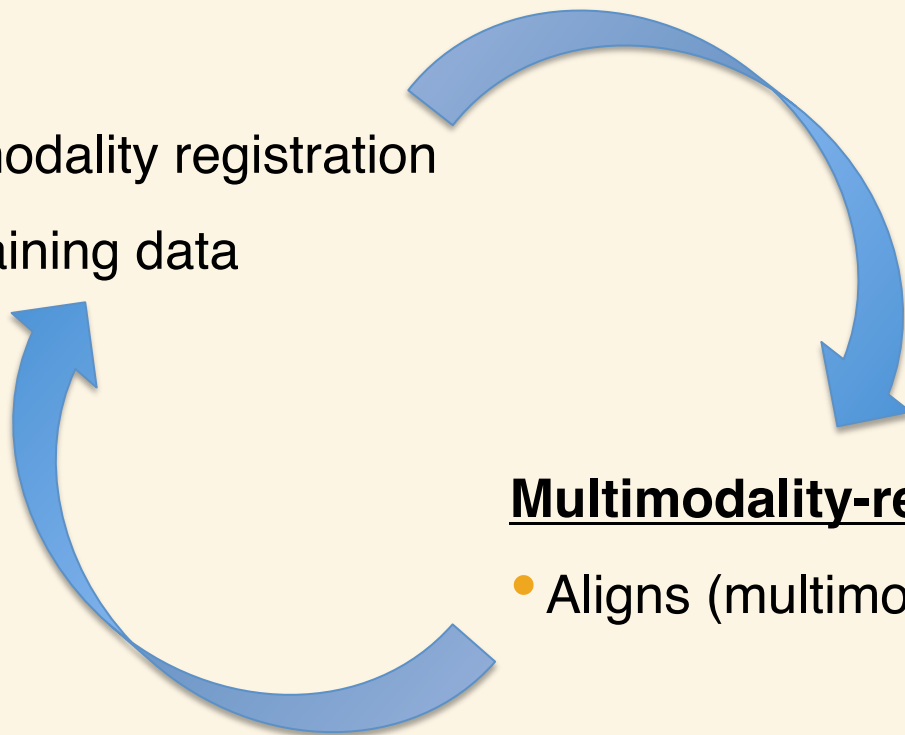*Iglesias et al., MICCAI, 2013.*

How about the 2D inter-modality registration?
Synthesis and multimodality registration

Synthesis:

- Can improve multimodality registration
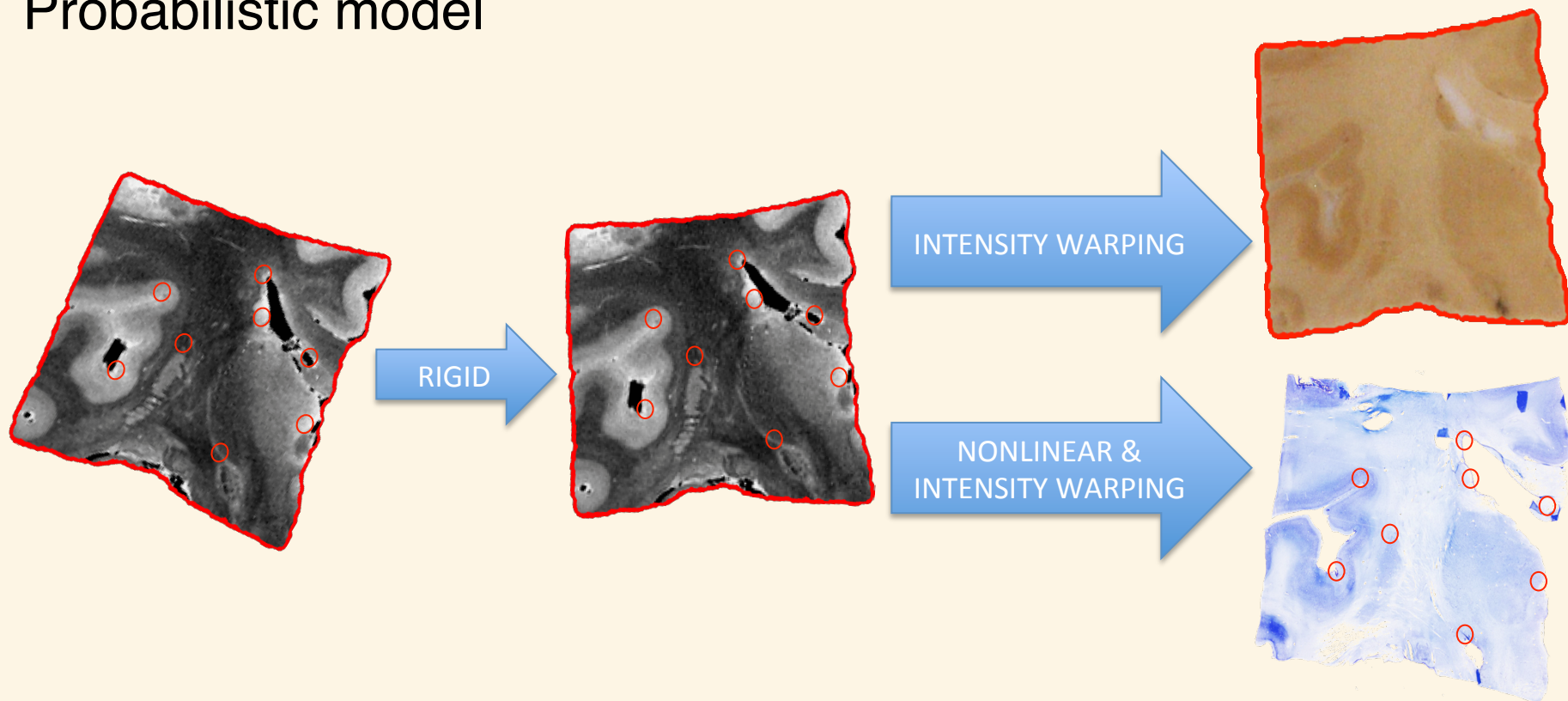
- Requires aligned training data

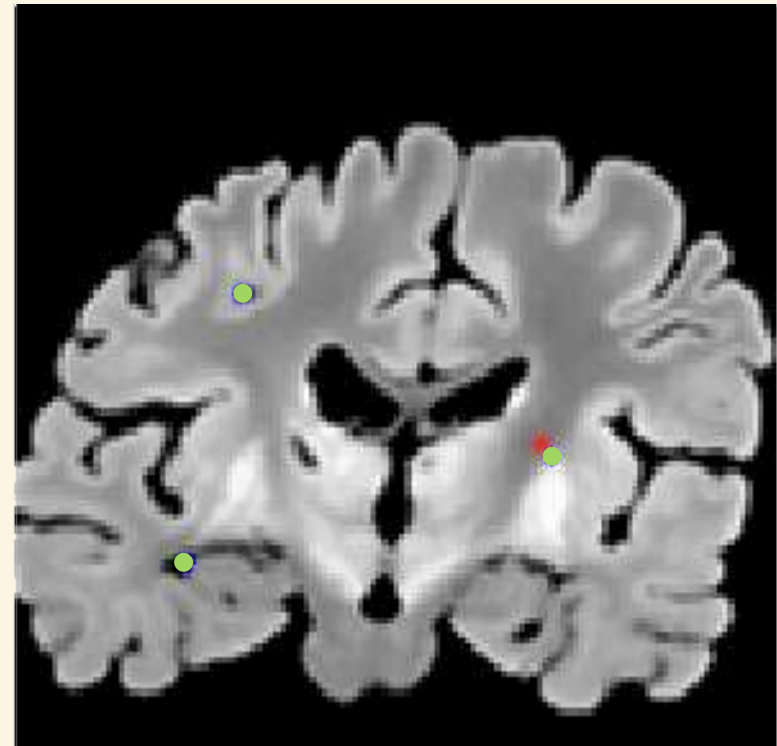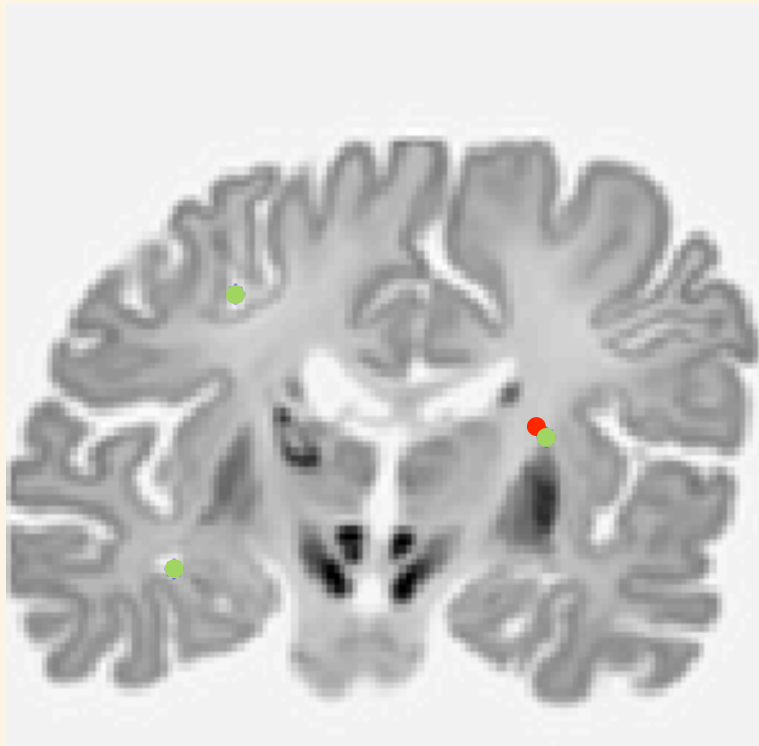**Multimodality-registration:**

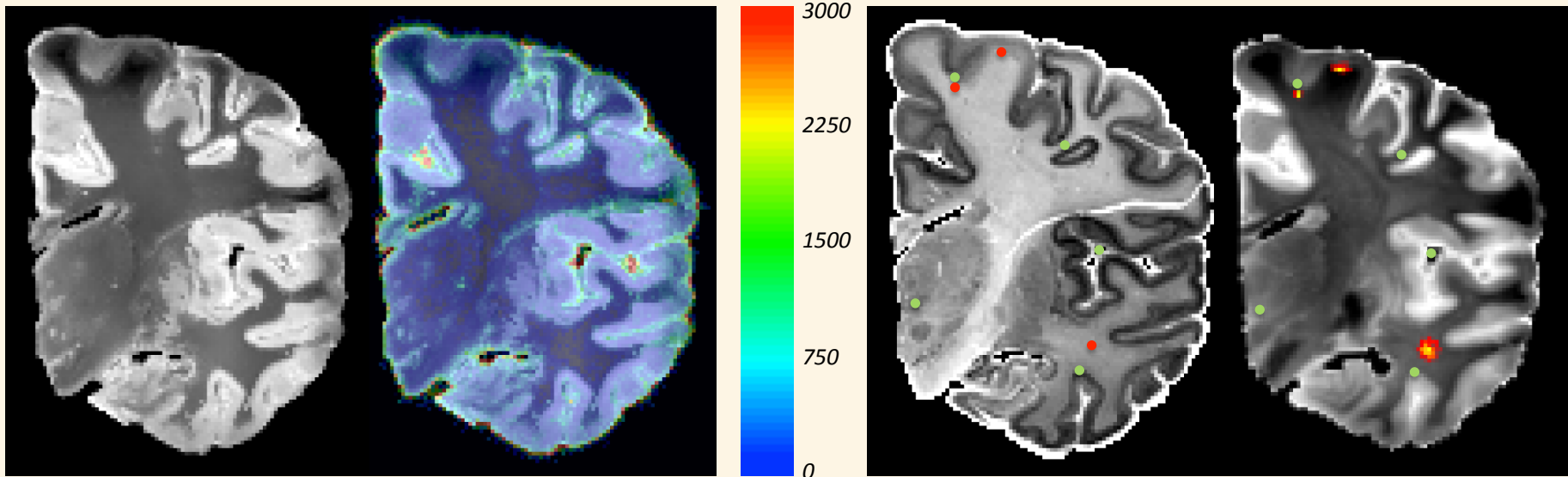- Aligns (multimodality) data

Histology reconstruction

Probabilistic model
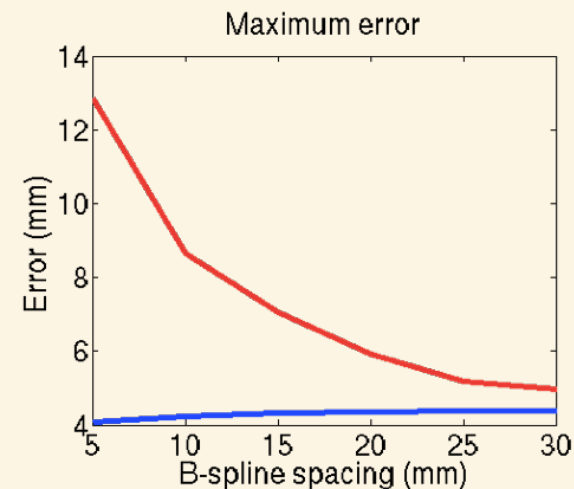
Uncertainty in registration (BigBrain)

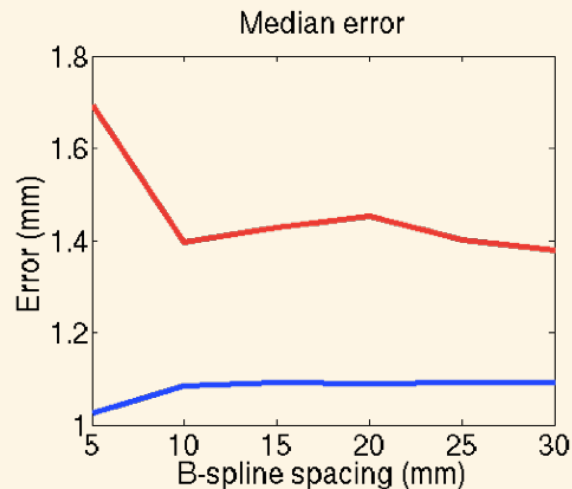# Uncertainty in registration (Allen)

Quantitative evaluation of registration

Simulated deformations on ADNI T1-T2 data (2D)

- 1 mm isotropic T1, 0.4x0.4x2.0mm T2 (coronal, resampled to 1mm)

- 1000 randomly selected coronal planes.

- Diffeomorphic random deformations, recovered with control points + Bsplines
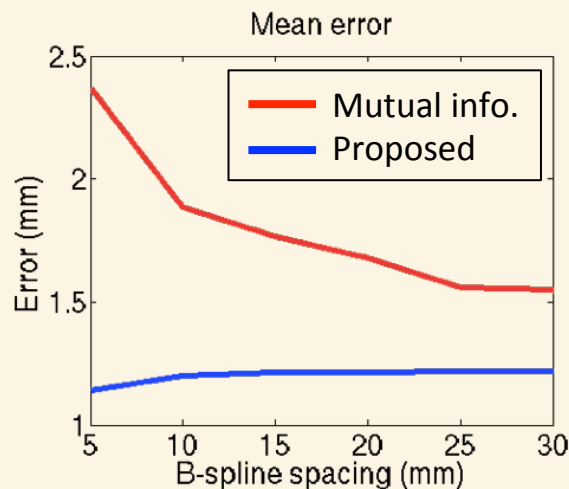
Example on synthetic data
T1-T2 MRI with known correspondence

T2 (floating)

Example on synthetic data
T1-T2 MRI with known correspondence

T1 (reference)

Example on synthetic data
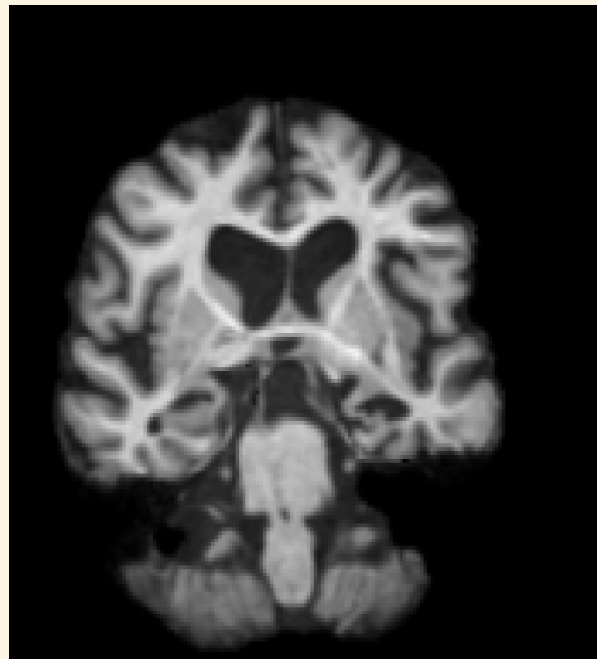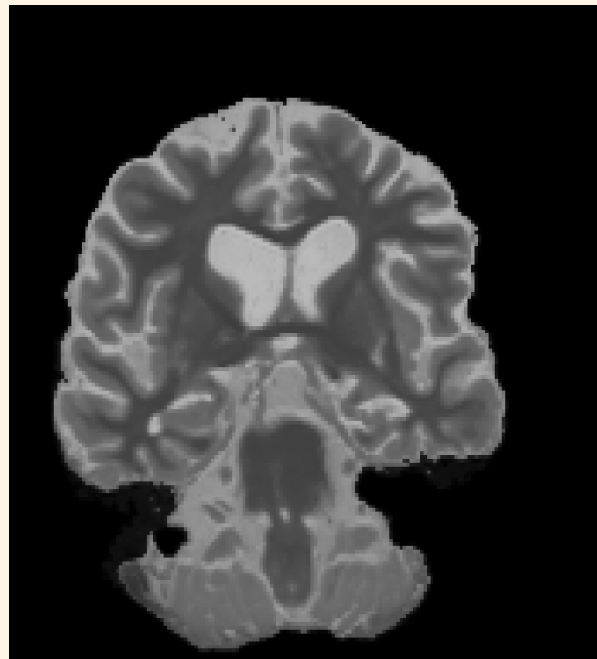## T1-T2 MRI with known correspondence
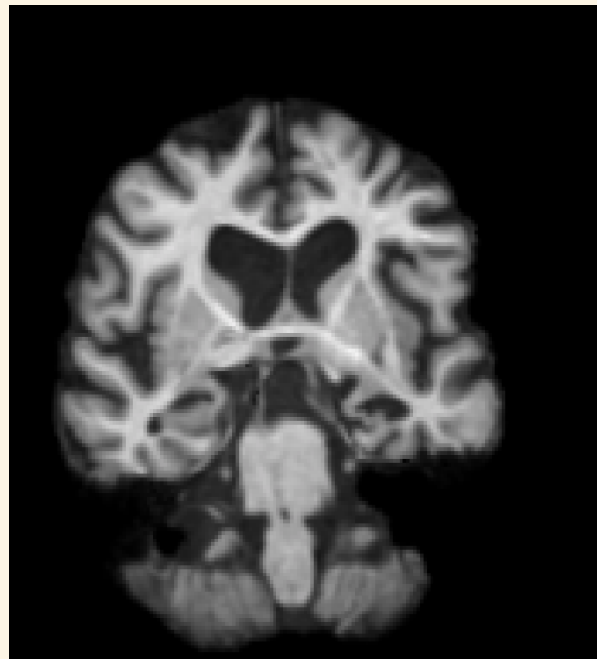
Real T2

Example on synthetic data
T1-T2 MRI with known correspondence

Synthetic T2

Example on synthetic data
T1-T2 MRI with known correspondence

T1 (reference)

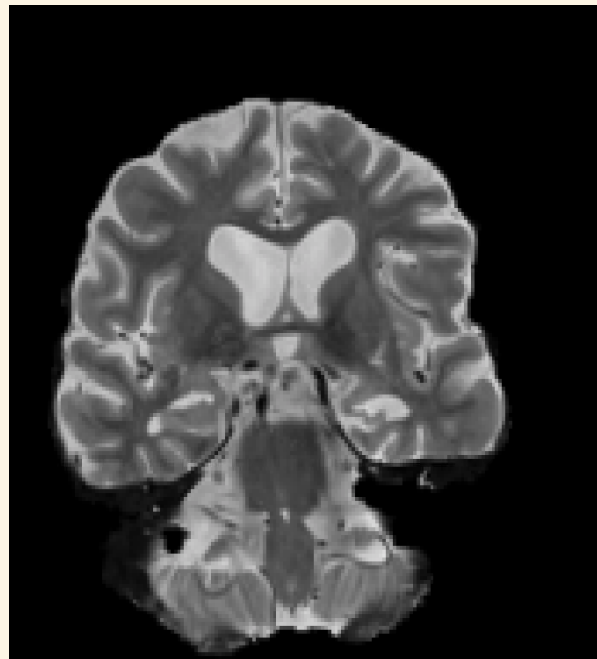# Example on synthetic data
T1-T2 MRI with known correspondence

Registered with MI

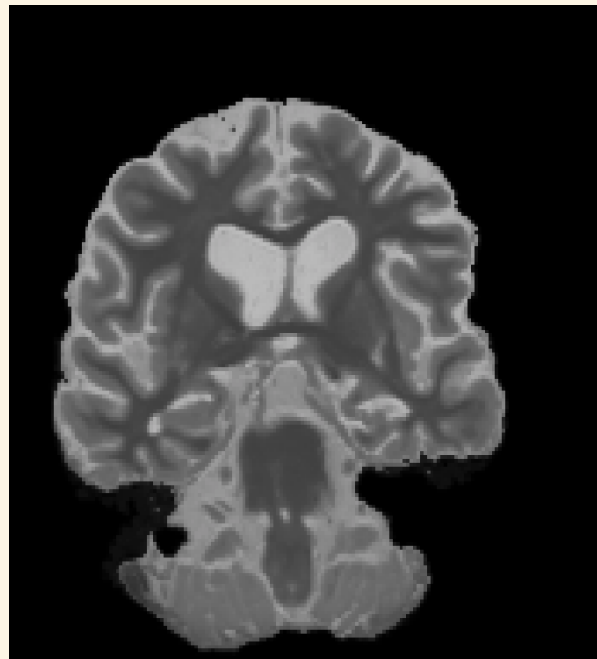(spacing: 6 mm)

Joint registration / synthesis
T1-T2 MRI with known correspondence

Registered with synthesis

(spacing: 6 mm)

Joint registration / synthesis
## T1-T2 MRI with known correspondence

Synthetic T2

Allen atlas

Publicly available at brain-map.org

- 106 coronal slices (histology) with manual segmentation of 806 structures

- Whole hemisphere microtome, but major cracks present on many sections.

- Manually placed ~200 landmarks.

- Problems:

  - **No blockface images available.**

  - Pixel dimensions are wrong for many sections.

  - Section thickness not consistent.

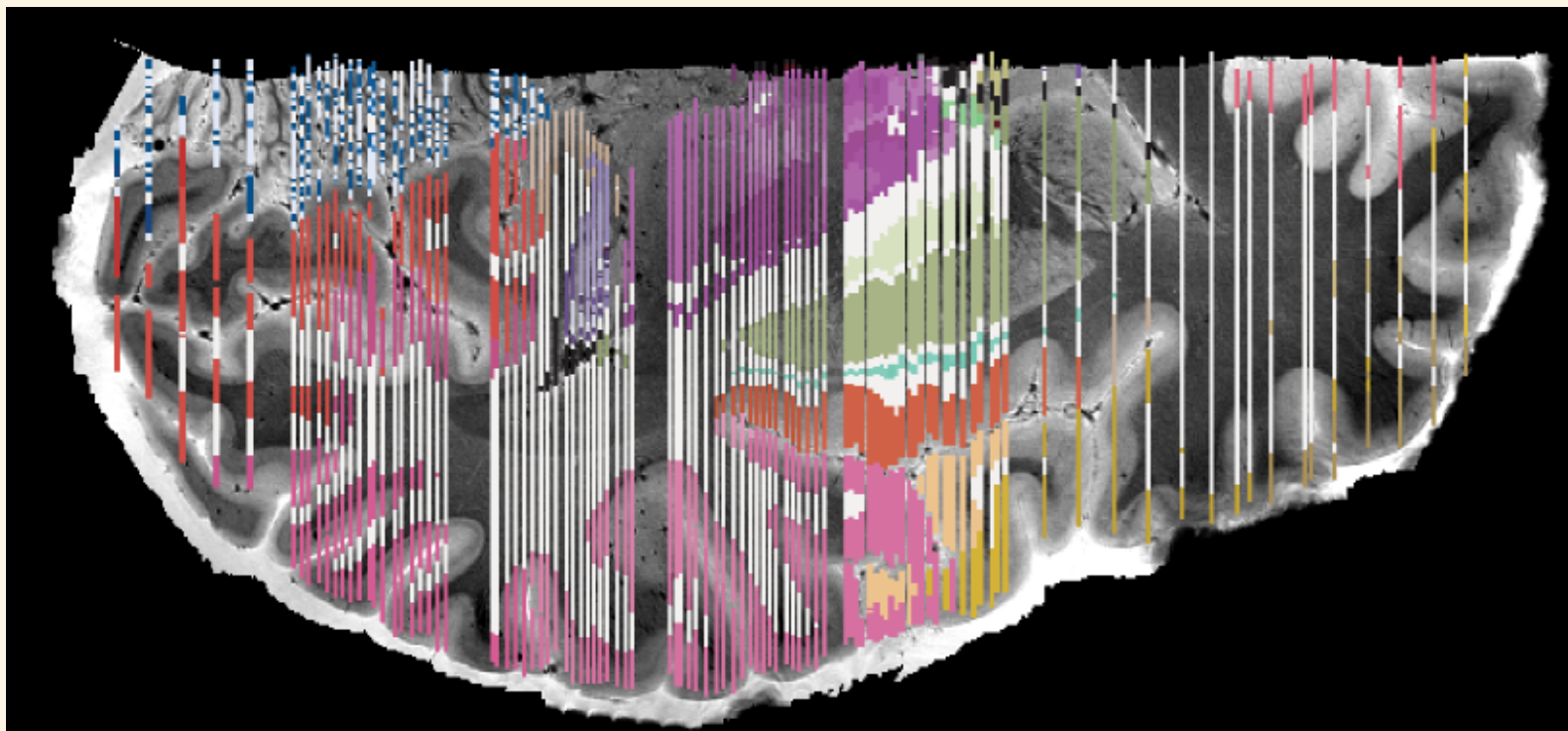 - Spacing between coronal slices very uneven.

Qualitative evaluation of registration (Allen)
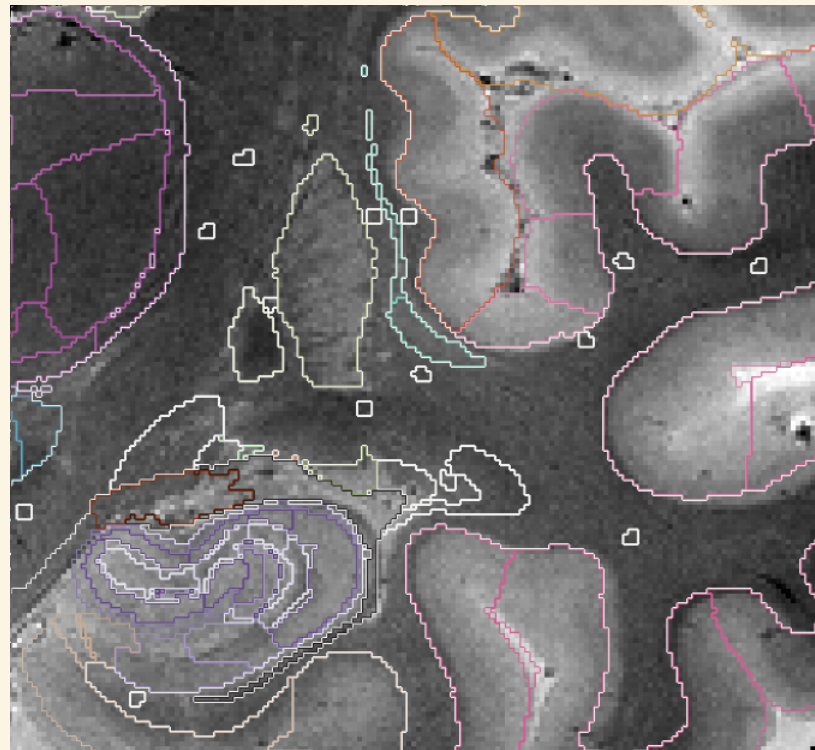
Qualitative evaluation of registration (Allen)
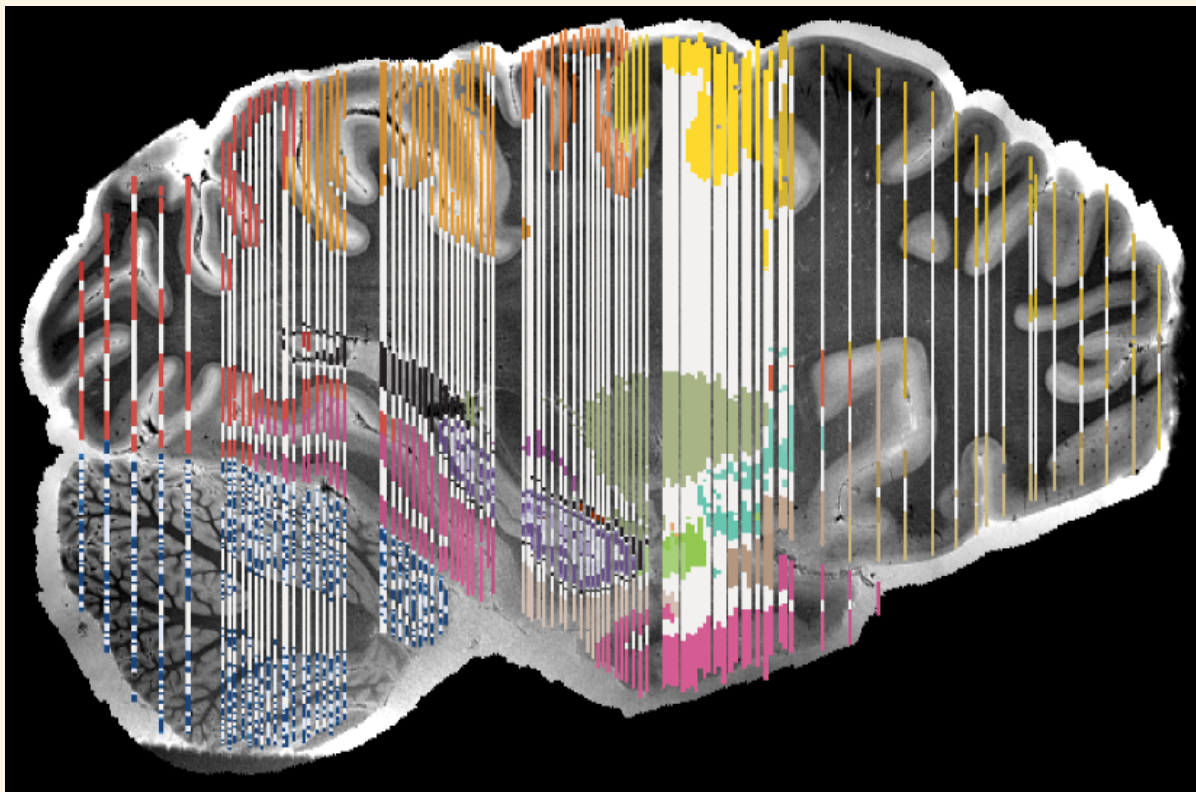
Qualitative evaluation of registration (Allen)

Extensions

And open questions

- Integration of multiple blocks (jigsaw puzzle) into probabilistic model.

- Make model robust when no blockface images and/or landmarks are given.

- Exploring smarter ways of interpolating segmentations*

- Smoothness priors in probabilistic model to make reconstructions visually more pleasant in orthogonal view.

- How do bridge (large) resolution gaps in Bayesian segmentation?
  Forward model is simple, but inference is complex (especially in multimodal).

Iglesias, IPMI, 2017

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Thank you for your attention!

Questions?