# Robust Registration of Multi-Modal Images

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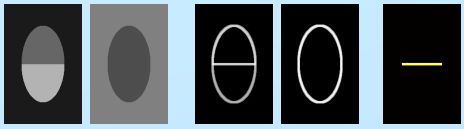
## 1. Introduction

- Accurate multi-modal registration is challenging due to imaging artifacts, noise, deformations and different appearance
- Robust registration approaches are helpful by identifying **outliers** and limiting their influence
- Robust estimation methods are **limited to mono-modal registration**
- Contribution: **robust, inverse-consistent, multi-modal registration**
- Calculation of **entropy images** to obtain mono-modal representation



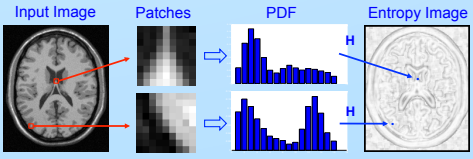
Multi-Modal Images | Entropy Images | Outliers

## 2. Methods

**1. Entropy Images**

i. Calculate entropy on small image patches

ii. Density estimation with non-parametric windows [3] to permit reliable estimation on small patches



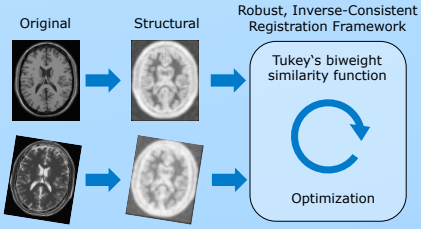

**2. Robust Registration on Entropy Images**

i. Robust, inverse-consistent registration on entropy images [1]

ii. Automatic detection of outliers

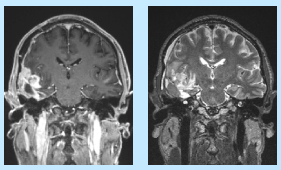
iii. Inverse-consistent transformation

iv. Iteratively reweighted least squares estimation

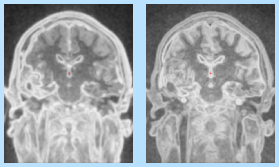



## 3. Results

**Multi-modal Brain Tumor Images (T1 MPRAGE <-> T2)**

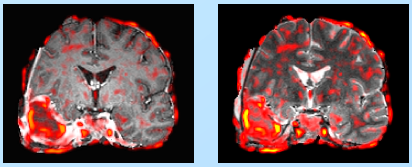


Calculation of Entropy Images

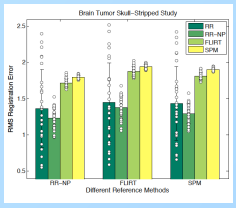


Automatic brain extraction (challenging, often needs manual refinement)

Registration of full head brain tumor images: contain additional outliers due to motion from jaw and tongue



- Registration of skull-stripped brain images.
- Tumor regions and other inconsistencies (e.g. brain extraction) are detected as outliers (red), due to different appearance in both modalities.
- Non-outlier regions drive the registration.




Comparison of results for skull-stripped ("ground truth") and full head registration. Methods:

- RR robust entropy registration,
- RR-NP with non-param. window,
- FSL FLIRT mutual information
- SPM COREG

## 4. Conclusion

- Registration of multi-modal images in a robust registration framework
- Accurate alignment of multi-modal images containing regions that do not comply with the model assumptions
  - Brain tumor images
  - Patient motion (jaw, tongue, head)
  - Histology <-> OCT

## 5. References

[1] Reuter, M., Rosas, H.D., Fischl, B., 2010, Highly accurate inverse consistent registration: A robust approach. NeuroImage 53, 1181–1196.

[2] Wachinger, C., Navab, N., 2012, Entropy and Laplacian Images: Structural representations for multi-modal registration', Medical Image Analysis, 16, 1, pp. 1-17.

[3] Joshi, N., Kadir, T., Brady, M., 2011, Simplified computation for nonparametric windows method of probability density function estimation. TPAMI 33, 1673–1680.

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