Radiomics and machine learning for brain metastases analysis

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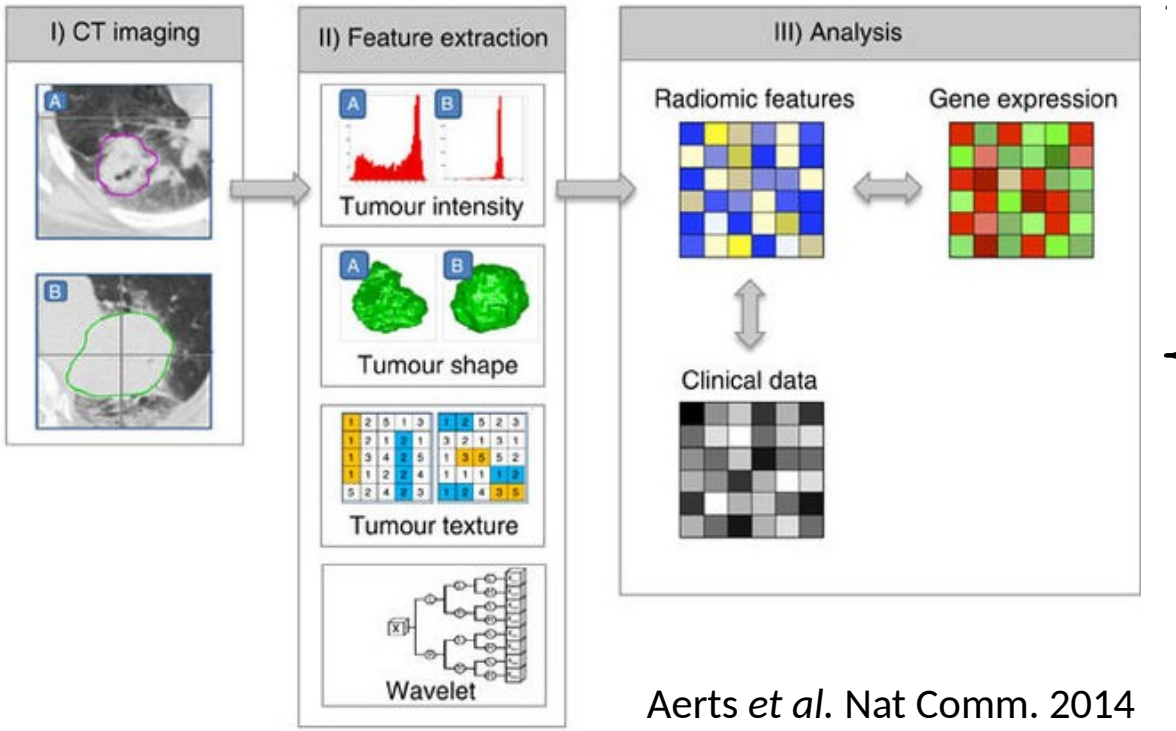
Radiomics



Aerts *et al.* Nat Comm. 2014

- Oncology
- All organs
- CT, (MRI, PET, US)

Radiomics : Proof of concept

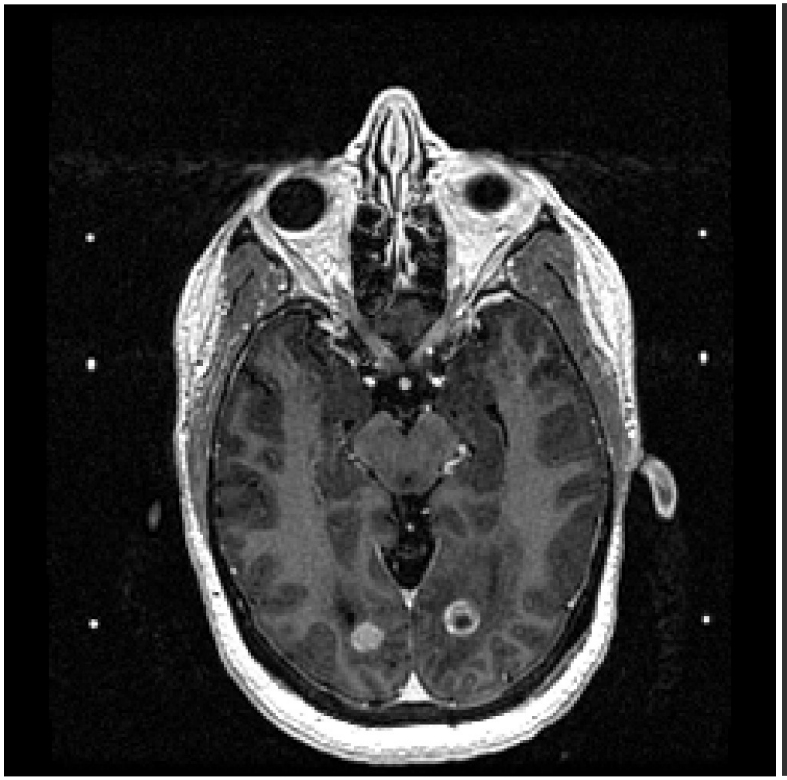
What is the contribution of the radiomic approach in the analysis of biomedical images in oncology ?

- Brain metastases that can be treated by GammaKnife
  - → homogeneous clinical recruitment
  - → high resolution MRI : T1 gadolinium enhanced and T2 FLAIR
- ~ 1000 patients : training and validation cohorts
- Various primary tumors :
  - Lung
  - Breast
  - Melanoma

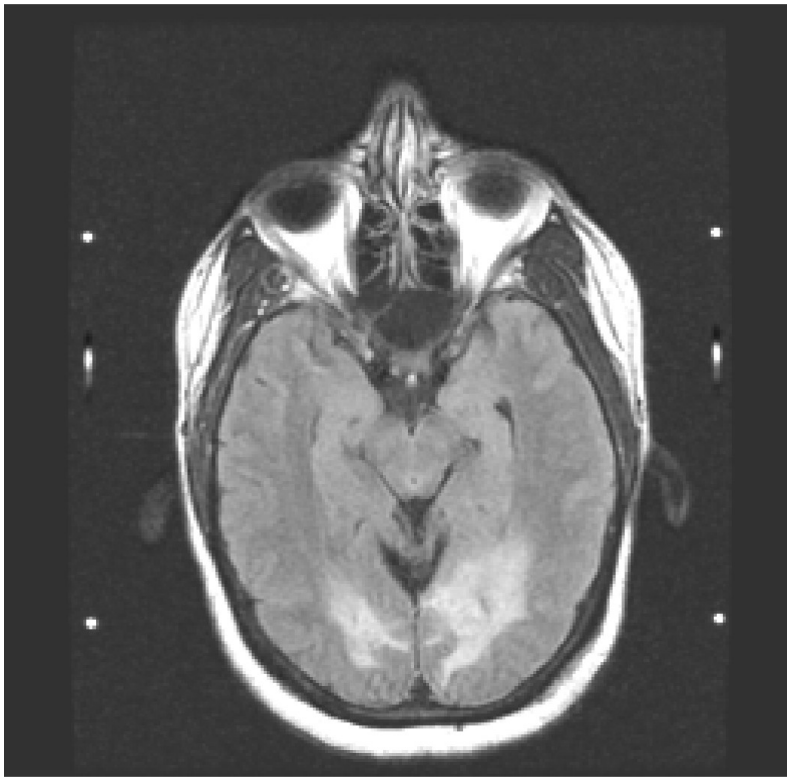
Outline

- Brain metastases cohort
- Analysis pipeline
- Results :
  - Technical validation :
    - Tumor vs normal
    - Segmentation step : inter-operator variability
  - Biomedical application :
    - GPA score
- Conclusion
- Future work

Brain metastases



T1 gadolinium enhanced



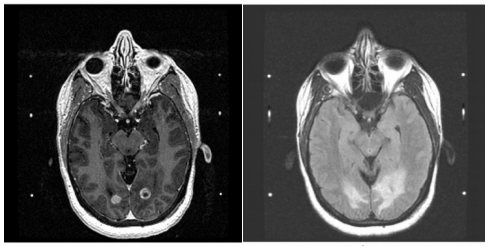
T2 FLAIR

Preliminary work on a subset of the brain metastases cohort

- 29 patients with lung cancer and brain metastases
  - 64 lesions segmented by operator 1
  - 46 lesions segmented by operator 2
  - 29 shams in healthy white matter
- MRI before GammaKnife treatment :
  - T1 gadolinium enhanced
  - T2 FLAIR
- Graded Prognostic Assessment score (GPA) for lung cancer
  - Age
  - # of brain metastases
  - Presence of extra-cerebral metastases
  - Karnofsky index

Analysis pipeline

T1-enh T2 FLAIR

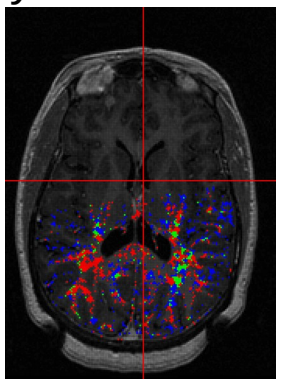


coregistration

N4 bias field correction

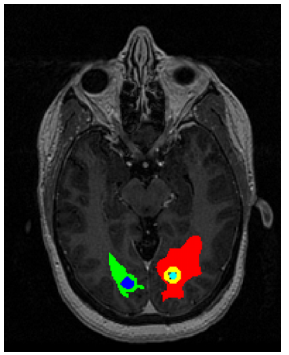
Intensity standardization WhiteStripe
(Shinohara et al. NeuroImage Clin. 2014)

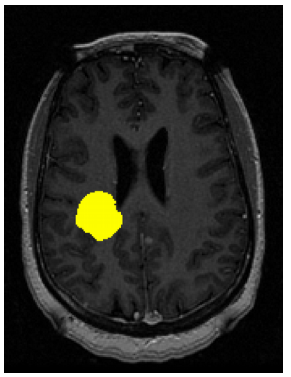
hybrid + closing



Segmentation

- Manual
- 2 different operators
- sham





Features extraction PyRadiomics
(van Griethuysen et al. Cancer Res. 2017)

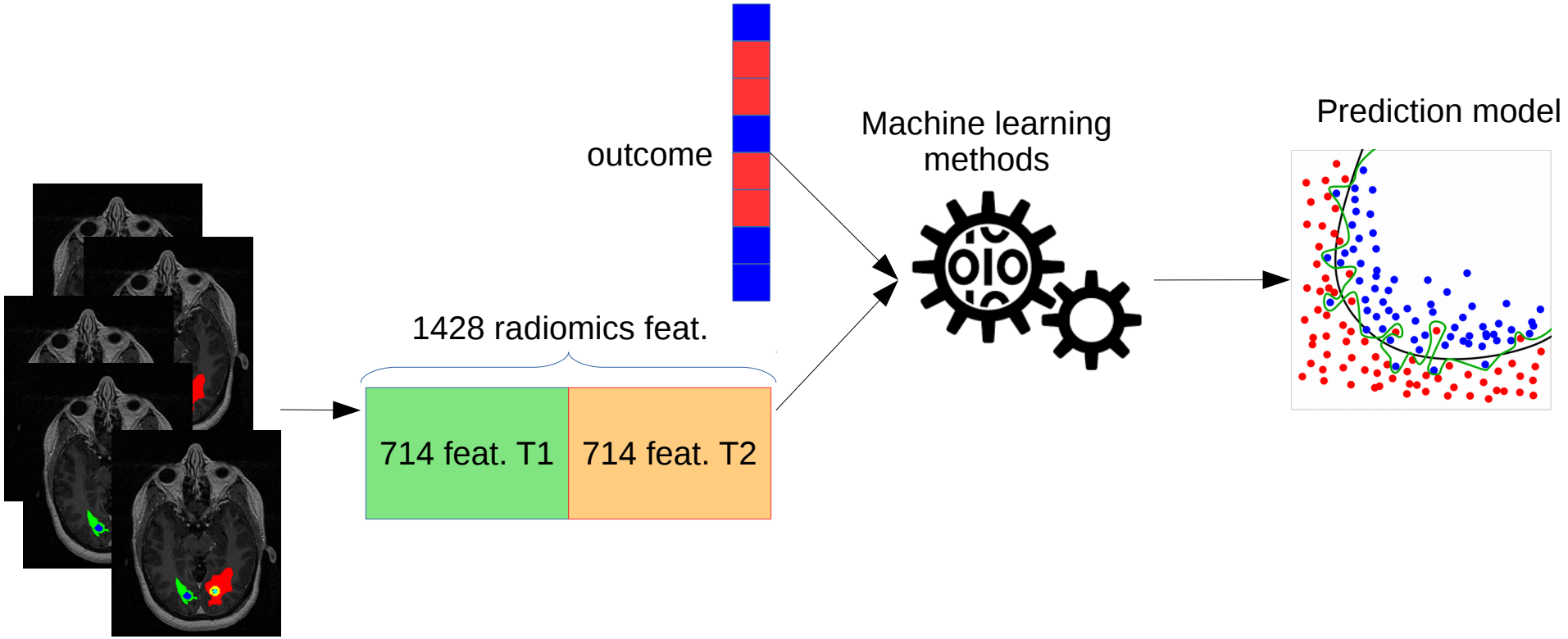
- Voxel size : 1 mm
- Bin width : 2

1428 radiomics feat.

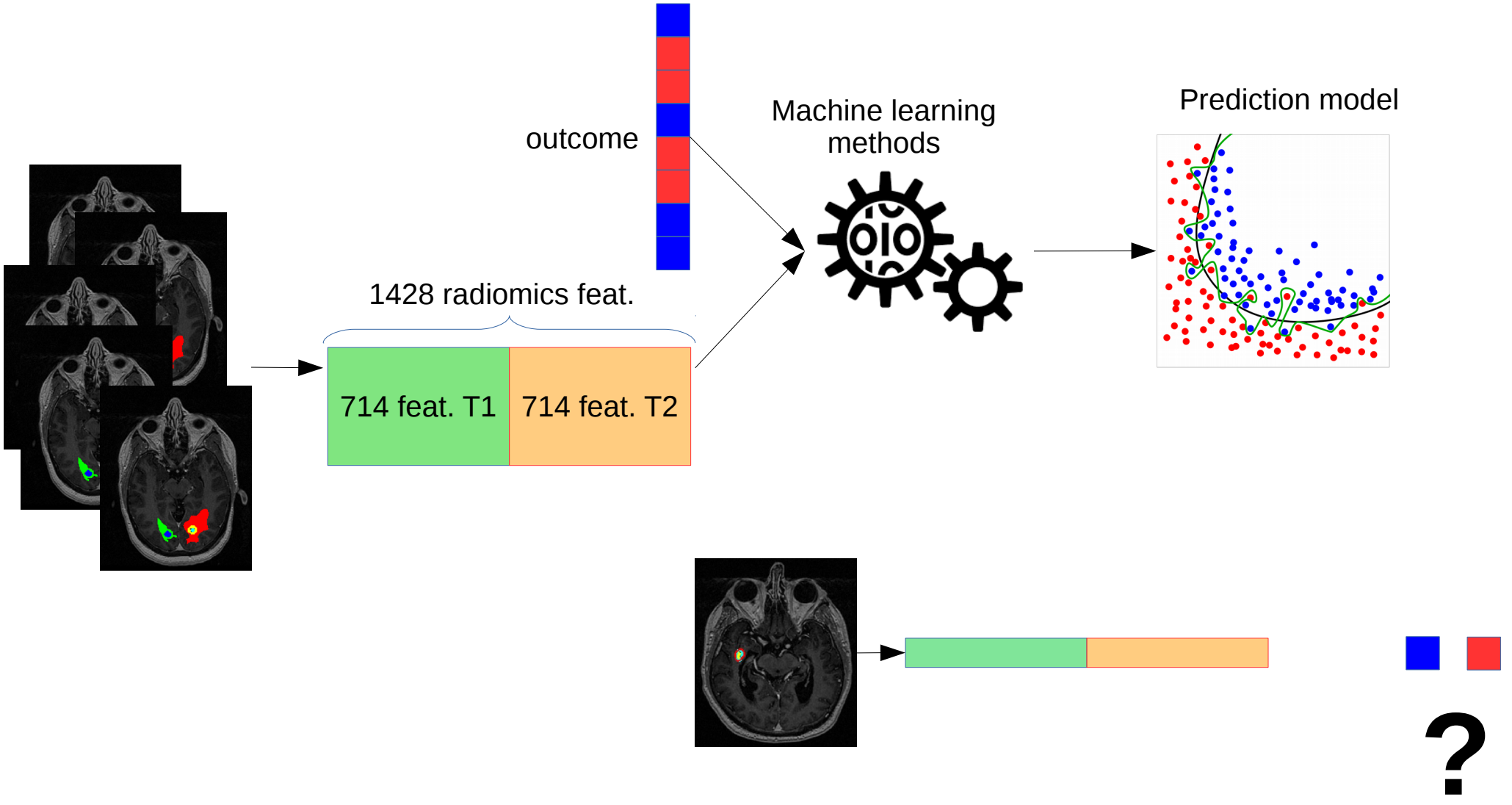
714 feat. T1 | 714 feat. T2

Machine Learning predictions

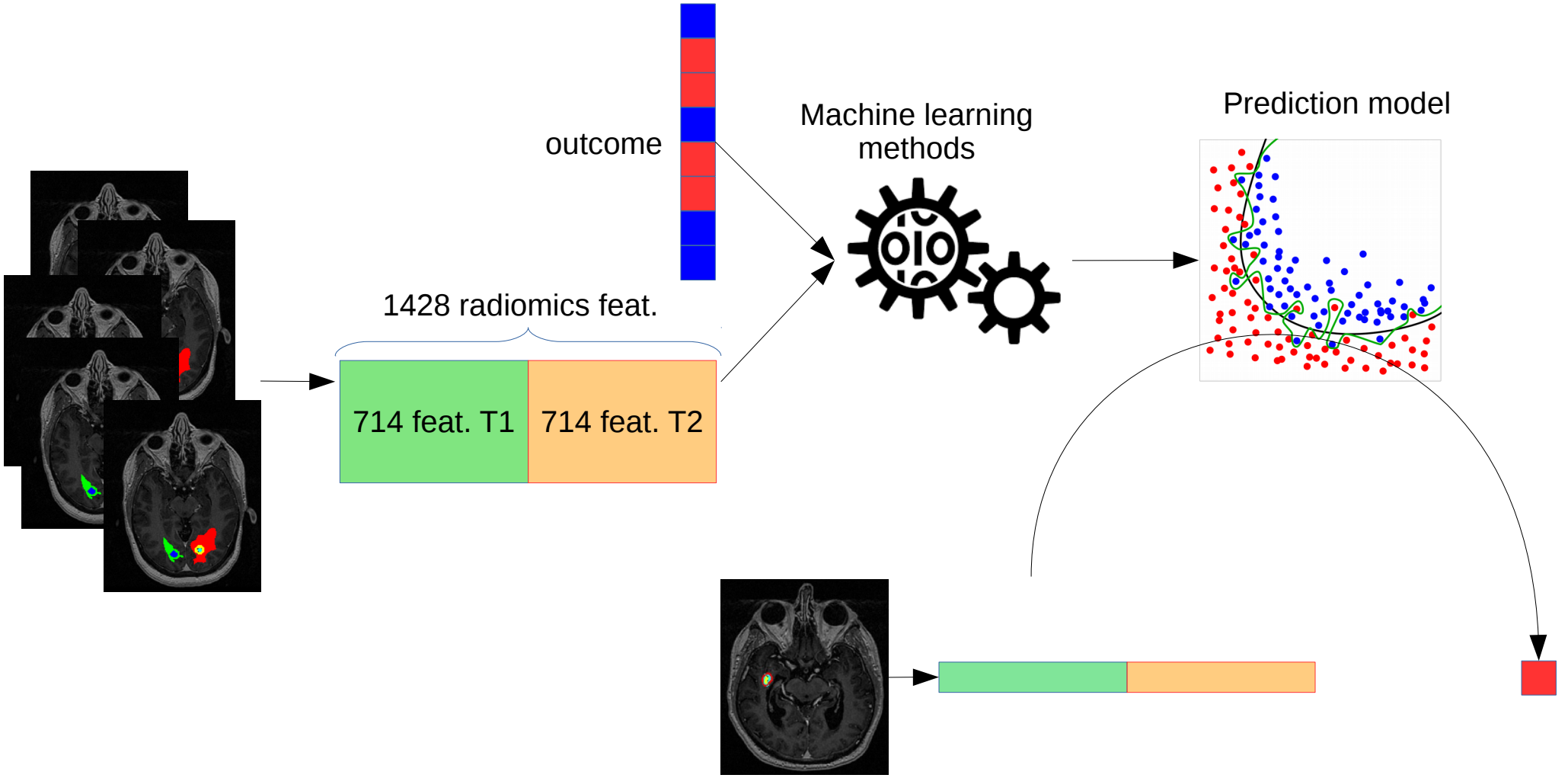
Machine learning for the assessment of radiomics contribution



Machine learning for the assessment of radiomics contribution

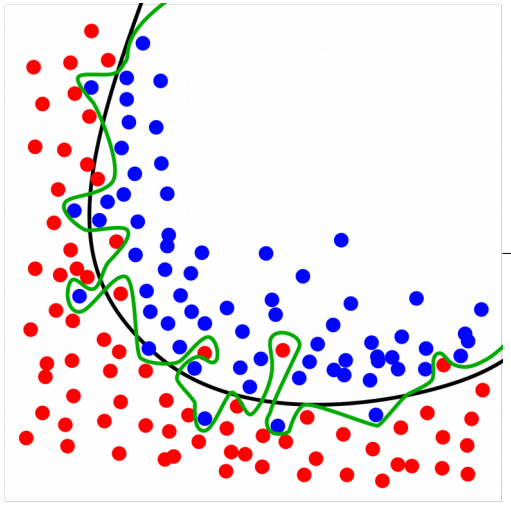


Machine learning for the assessment of radiomics contribution



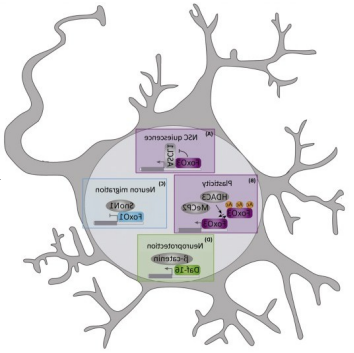
Machine learning for the assessment of radiomics contribution

Efficient prediction model



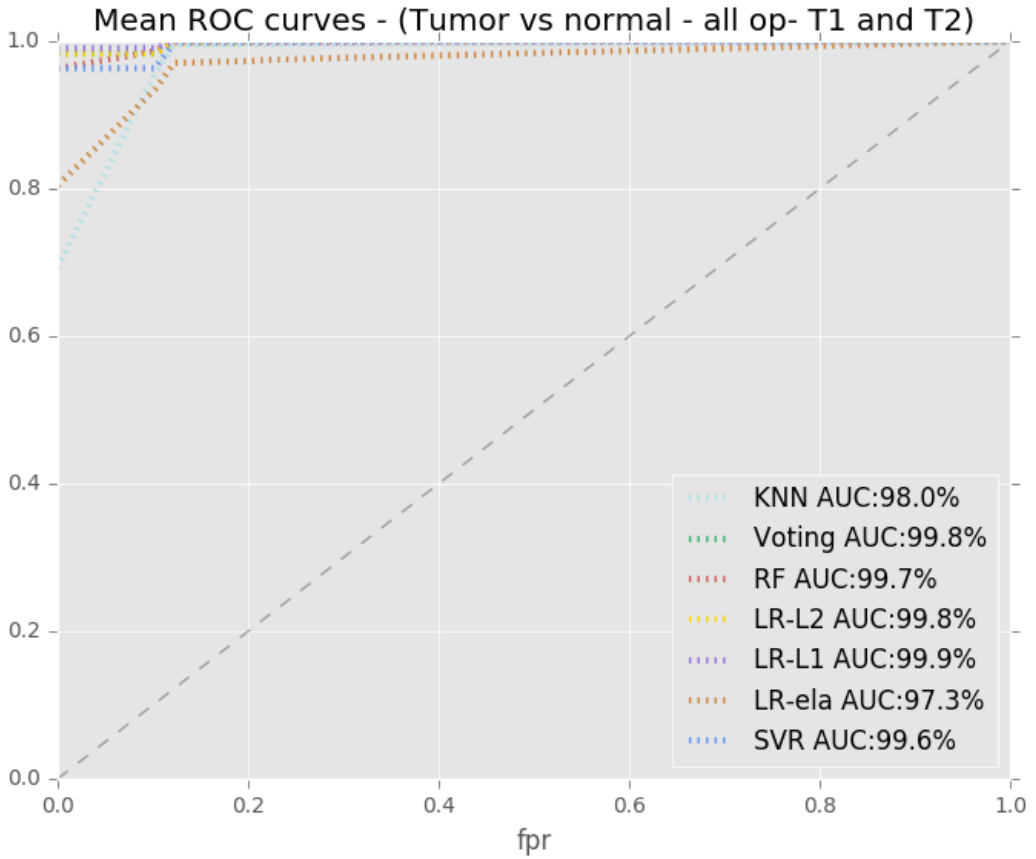
- Specificity
- Sensibility
- Selected variables
- ...

Biological interpretation



Results

Tumoral ROI vs normal ROI prediction performances



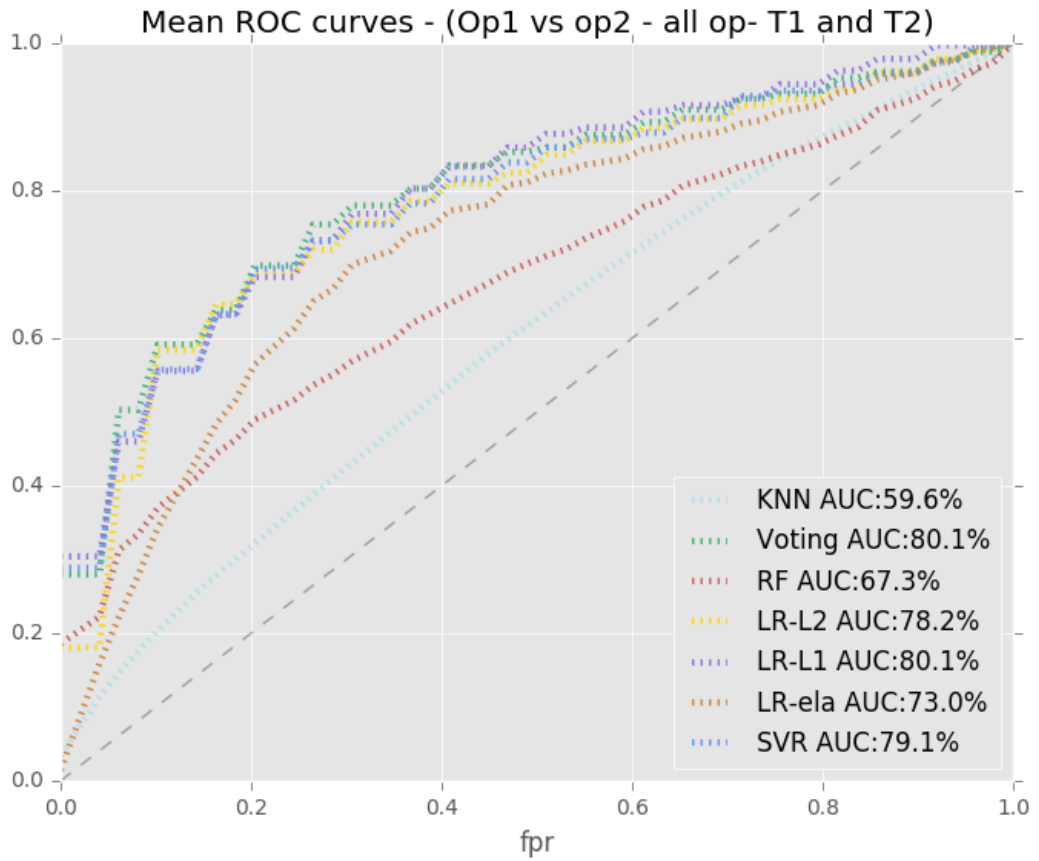
Tumoral ROI vs normal ROI selected features

- t1_original_firstorder_RootMeanSquared
- t1_wavelet-LLL_firstorder_Skewness
- t1_original_glcm_Imc2

- flair_original_glrlm_LongRunEmphasis
- flair_original_glszm_LargeAreaLowGrayLevelEmphasis
- flair_wavelet-LLL_glrlm_ShortRunEmphasis
- flair_wavelet-LLL_glrlm_RunVariance
- flair_wavelet-LLL_glrlm_RunLengthNonUniformityNormalized
- flair_wavelet-LLL_glrlm_LongRunEmphasis

Inter-operator variability assessment

Segmentation operator 1 vs operator 2
prediction performances



Inter-operator variability assessment

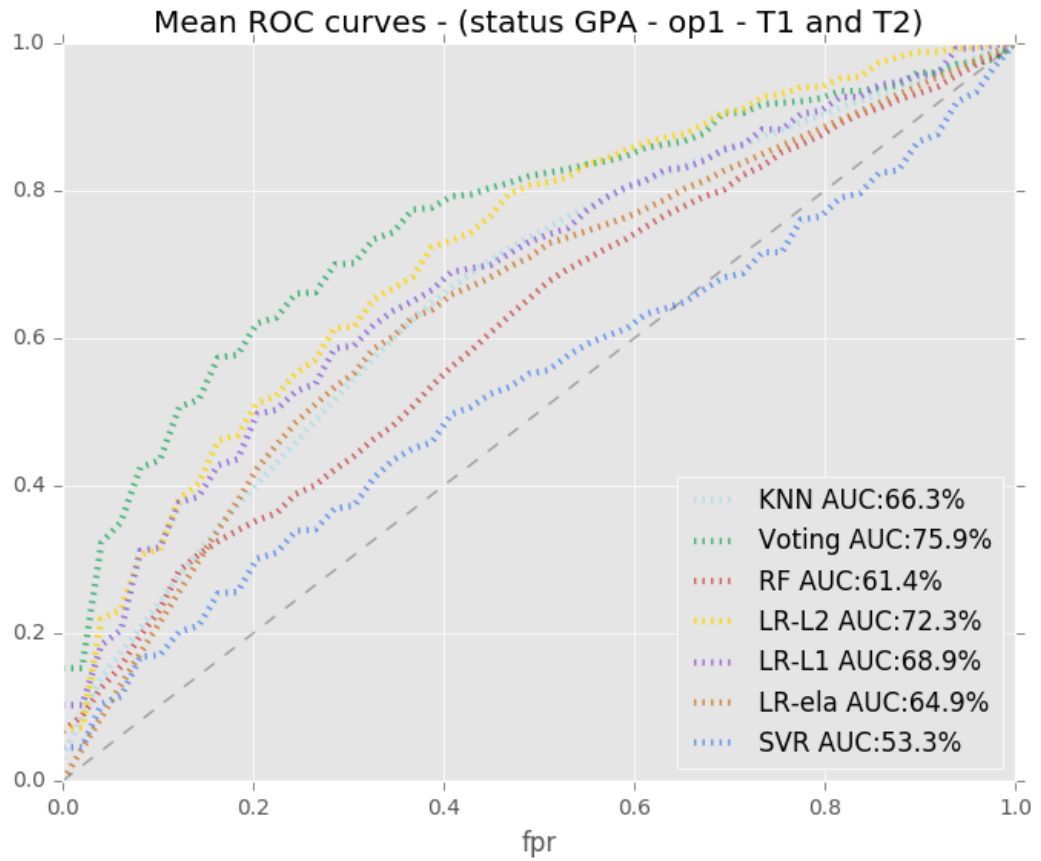
Segmentation operator 1 vs operator 2

selected features

- t1_original_shape_SphericalDisproportion
- t1_original_shape_Sphericity
- t1_wavelet-HLH_glszm_GrayLevelNonUniformityNormalized

- flair_original_shape_Sphericity
- flair_original_shape_SphericalDisproportion
- flair_wavelet-HHL_firstorder_Skewness
- flair_wavelet-LHL_firstorder_Median
- flair_wavelet-LLL_glcm_Imc2
- flair_wavelet-HLL_glrlm_LongRunEmphasis

GPA score prediction performances



GPA score
selected features

- t1_wavelet-HLH_firstorder_Skewness
- t1_wavelet-LLL_firstorder_Skewness
- t1_wavelet-LLL_firstorder_Kurtosis
- t1_wavelet-LLH_firstorder_Skewness

- flair_wavelet-HLL_glcm_ClusterShade
- flair_wavelet-HHL_glszm_LargeAreaLowGrayLevelEmphasis

To conclude

- Radiomics features can successfully predict a clinical score
- New insights into biological processes

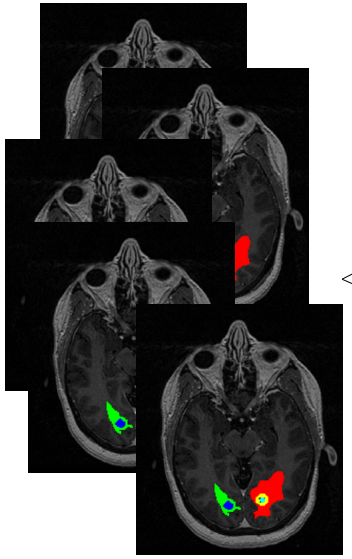
- Radiomic signatures are very short
  - Stability issue ?
  - Need to be assessed on larger cohorts

Future work

- **Radiomics : Prediction of primary tumor**
  - > 500 pts with various cancers and brain metastases
  - Same features
  - Improve the stability of radiomic signatures

- **Radiogenomics : Multiblock approaches**
  - Primary Central Nervous System Lymphoma
  - Pediatric High Grade Glioma and Diffuse Intrinsic Pontine Glioma

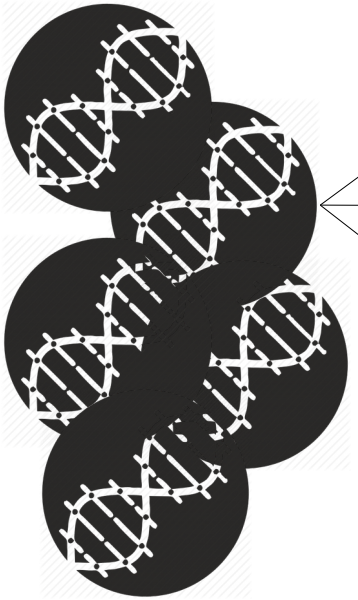
Multiblock approach for radiogenomics



Radiomic features

features T2

features T1



RNA

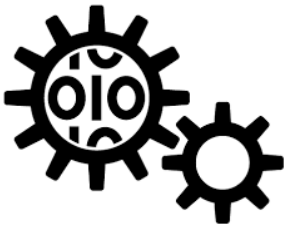
DNA

CH_3

Genomic features

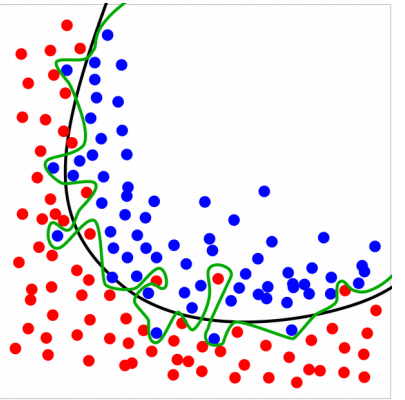
RGCCA

Tenenhaus *et al.*
Psychometrica 2011



outcome

Prediction model



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