Artificial
Intelligence in
Medicine

Collection of the dataset for Radiomic and Dosiomic analysis in RT

Part 1

03/02/2020 - Stefano Piffer

Purpose

Apply a retrospective exploratory MR-CT-based radiomics and dosiomic analysis based on ML, to investigate imaging biomarkers of clinical outcomes in paediatric patients affected by medulloblastoma.

Features from MR-CT scans and dose distribution (both PTV and OAR) will be associated with overall survival, recurrence-free survival, and loco-regional recurrence-free survival after IMRT.

1° year milestone → complete the database

To date almost completed

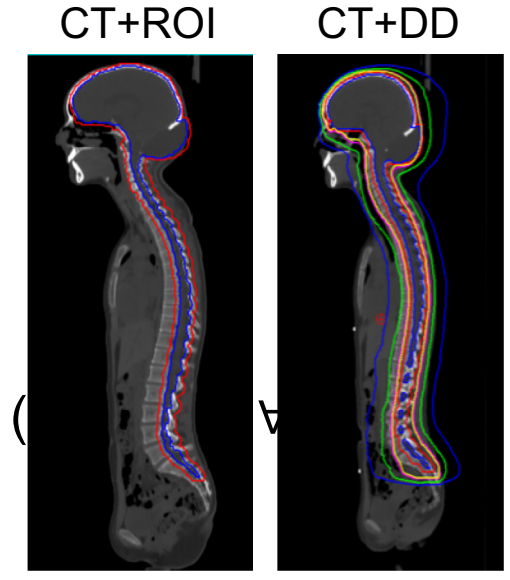
Treatment scheme for medulloblastoma

Multimodality approach:

Surgery → Histology (medulloblastoma)

Chemotherapy → Protocols & Drugs

Radiotherapy → CT, ROI,
Dose Distributions (DD)



Hospital centers involved for database build

AOU Meyer for clinical data and MRI
(1 MR scanner)

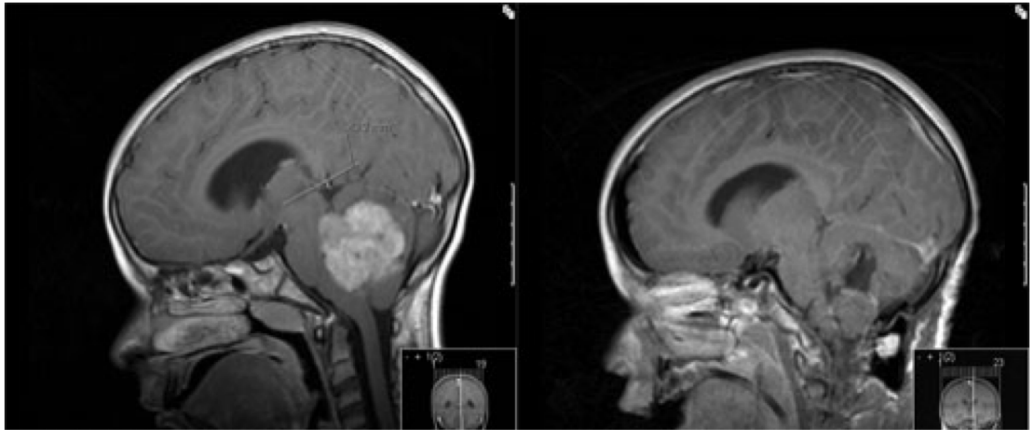
AOU Careggi for radiotherapy
(1 CT scanner & 1 machine for RT)

Difficulties encountered:

- Patient from 2011 to 2018
- Dearchiving and Anonimizing is a slow and meticulous process
- Several archives to access (1 for CT, 1 for Radiotherapy, 1 for MRI, 1 for Careggi clinical data, 1 for Meyer clinical data)
- Smooth all these data to make the database homogeneous
- Interconnect different professional figures (Radiologist, Radiotherapist, Medical Physicist, Physicist)

Magnetic Resonance Images

- MRI pre - and post - surgery and every three months until the end of the multimodal treatment.



- Time lapse: form 8 months to 8 years
- For each resonance exam at least 3 sequences that contain information: T1 - mdc, T2, FLAIR (Fluid Attenuated Inversion Recovery)
  (~30 GB ∀ patient)

Study Population

- Up to now 50 patients

- For each of them:
  - Imaging data (MRI & CT)
  - Radiotherapy data (dose distribution; prescription dose; fractionations; boost; machine parameters; structures)
  - Clinical data (histology; risk class; drugs; motor, cognitive and sensory deficits; possible radio-induced toxicity; metastasis; relapse; end state)

- A lot of data to interpret and analyze, to handle and storage (overall more than 1.5 TB)

Preliminary test

- Thanks to a preliminary test on a subset of patients (presented later), the features “Radiological evidence of neuro damage” was not so robust, it can be misinterpreted.

- We posed the problem to the radiologists of Meyer who is:
  - reviewing each patient's medical history
  - redefining clinical outputs
  - redefining the volume where to calculate the features (more local than the whole cranio-spinal axis)

Noteworthy

- At the moment the database is of modest size but it is possible to expand it with the data of patients from other hospitals.
- There are open-source online databases even more numerous than this but they are far more heterogeneous and incomplete.
- Only one MR, only one CT, only one RT machine: added value for the calculation of radiomic and dosiomic features extracted from the images (features are affected by the inter-scanner variability).
- Oral presentation at ViMaBi2019 (Salerno, Italy) - “Workshop on Visual Computing and Machine Learning for Biomedical Applications”.
- Oral presentation at RAD2020 (Herceg Novi, Montenegro) - “Eighth International Conference on Radiation in Various Fields of Research”
- Publisced on “Communications in Computer and Information Science” https://doi.org/10.1007/978-3-030-29930-9_6

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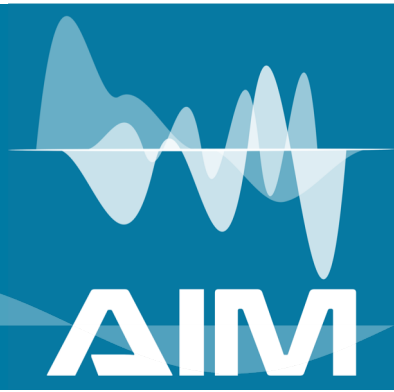

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Challenges in ML analysis implementation on RT data

Part 2

03/02/2020 - Leonardo Ubaldi

Tools

- Python:
  - SimpleITK
  - Pandas
  - Matplotlib
  - Scikit-learn
  - PyRadiomics

} Analysis

- Advanced Normalization Tools (ANTs) ⟹ Registration (CT on ADC)

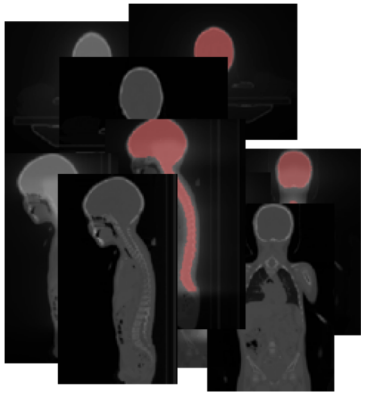
Pyradiomics: radiomic features

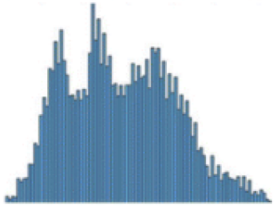
- First Order Statistics
- Shape based
- Gray Level Co-occurrence Matrix Features
- Gray Level Run Length Matrix Features
- Gray Level Size Zone Matrix Features
- Neighbouring Gray Tone Difference Matrix Features
- Gray Level Dependence Matrix Features

94 features

Workflow

Database (CT, Dose, Structures) → Feature extraction → Feature selection → Classification





pyradiomics
python
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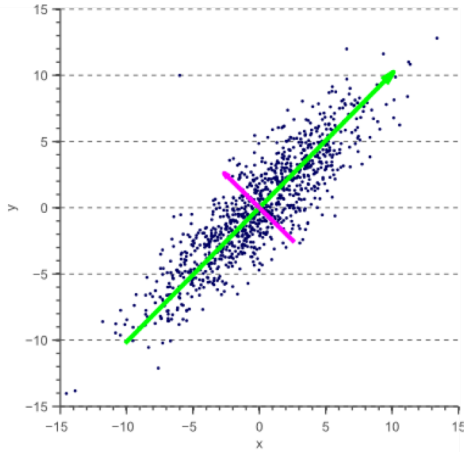
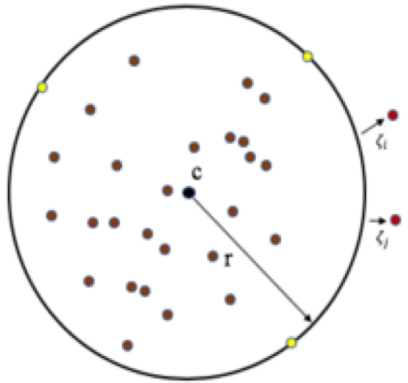
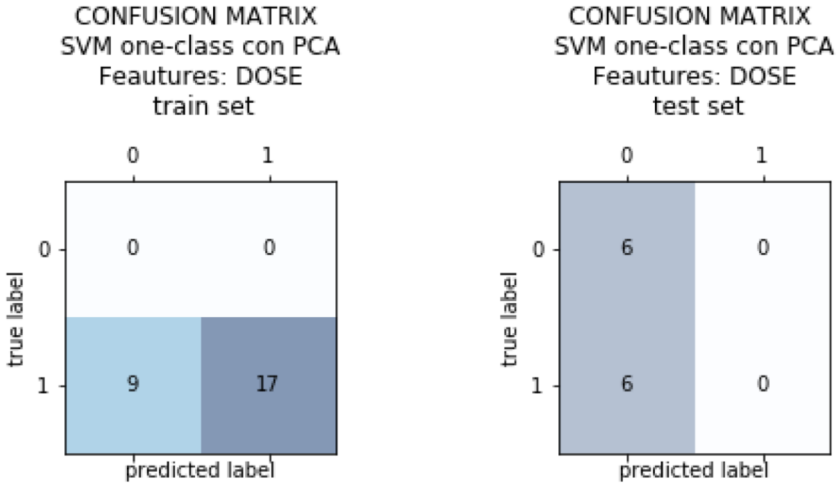
RADIOMICS





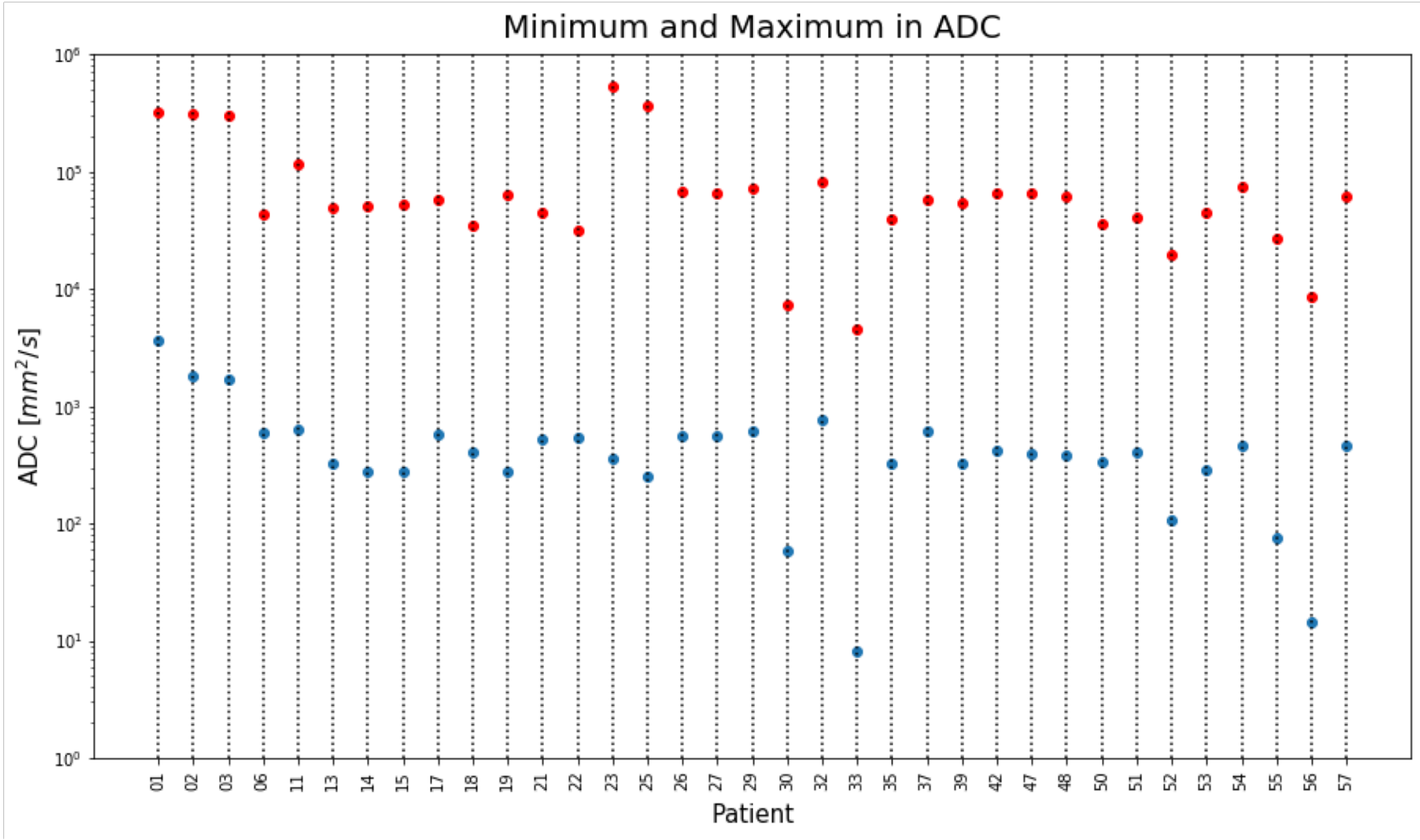
Preliminary results from dose distribution

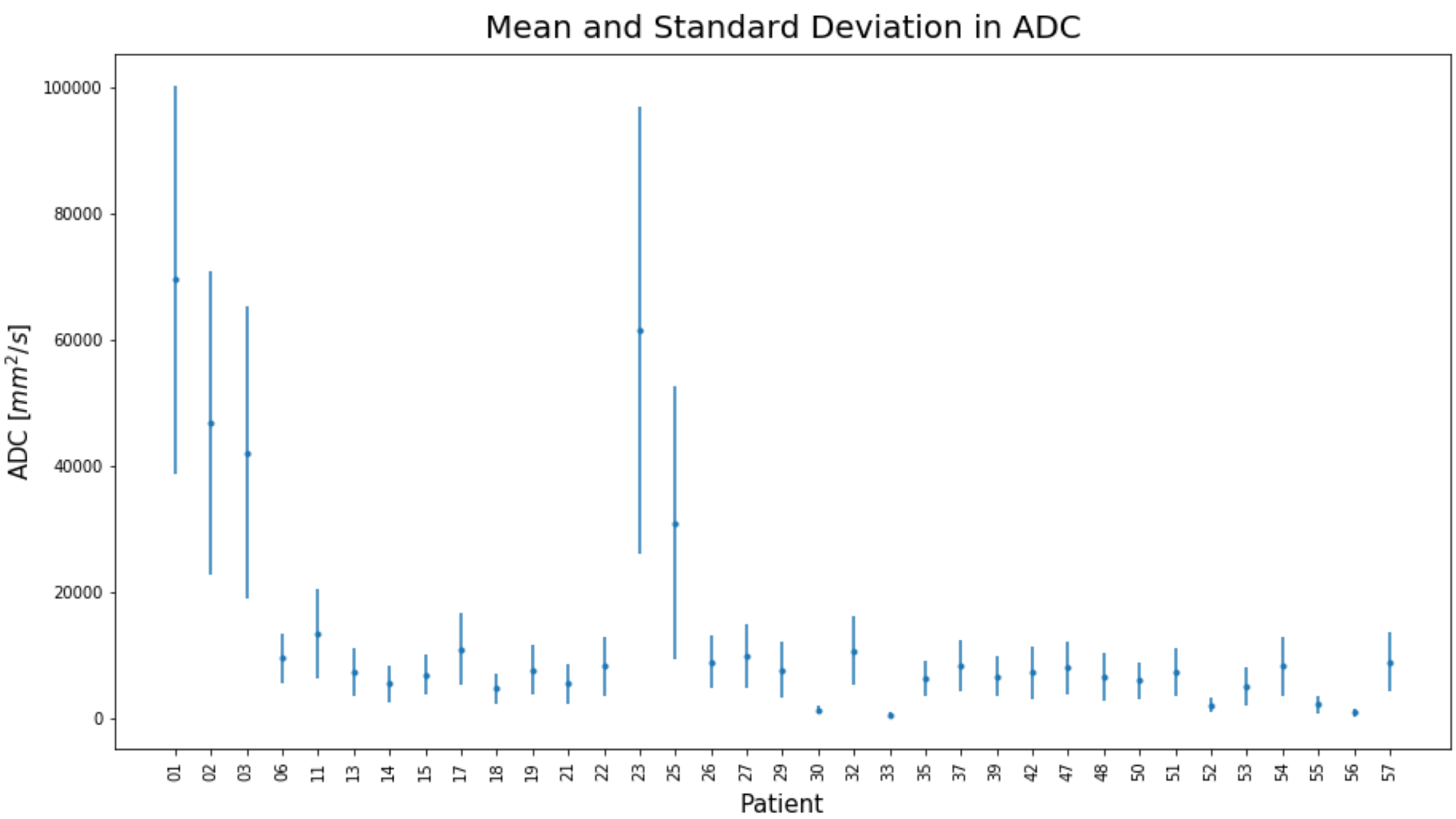
- ‘Radiological evidence of neuro damage’ → 38 subject
  - Outcome 0 → 6 subject
  - Outcome 1 → 32 subject
- Confusion matrix obtained with One-Class SVM using features extracted from dose distribution



Registration and features extraction from ADC

- ADC :
  - Apparent diffusion coefficient is a measure of the magnitude of diffusion (of water molecules) within tissue, and is commonly clinically calculated using MRI with diffusion-weighted imaging (DWI).
  - 35 subjects
- Registration:
  - CT on ADC
  - Registration with rigid transformation with ANTs
- Features extraction:
  - From ADC using ROI brain
  - Pyradiomics


Minimum and Maximum in ADC
ADC [mm^2/s]
10^0
10^1
10^2
10^3
10^4
10^5
10^6
01 02 03 06 11 13 14 15 17 18 19 21 22 23 25 26 27 29 30 32 33 35 37 39 42 47 48 50 51 52 53 54 55 56 57
Patient


Mean and Standard Deviation in ADC
ADC [mm^2/s]
100000
80000
60000
40000
20000
0
01
02
03
06
11
13
14
15
17
18
19
21
22
23
25
26
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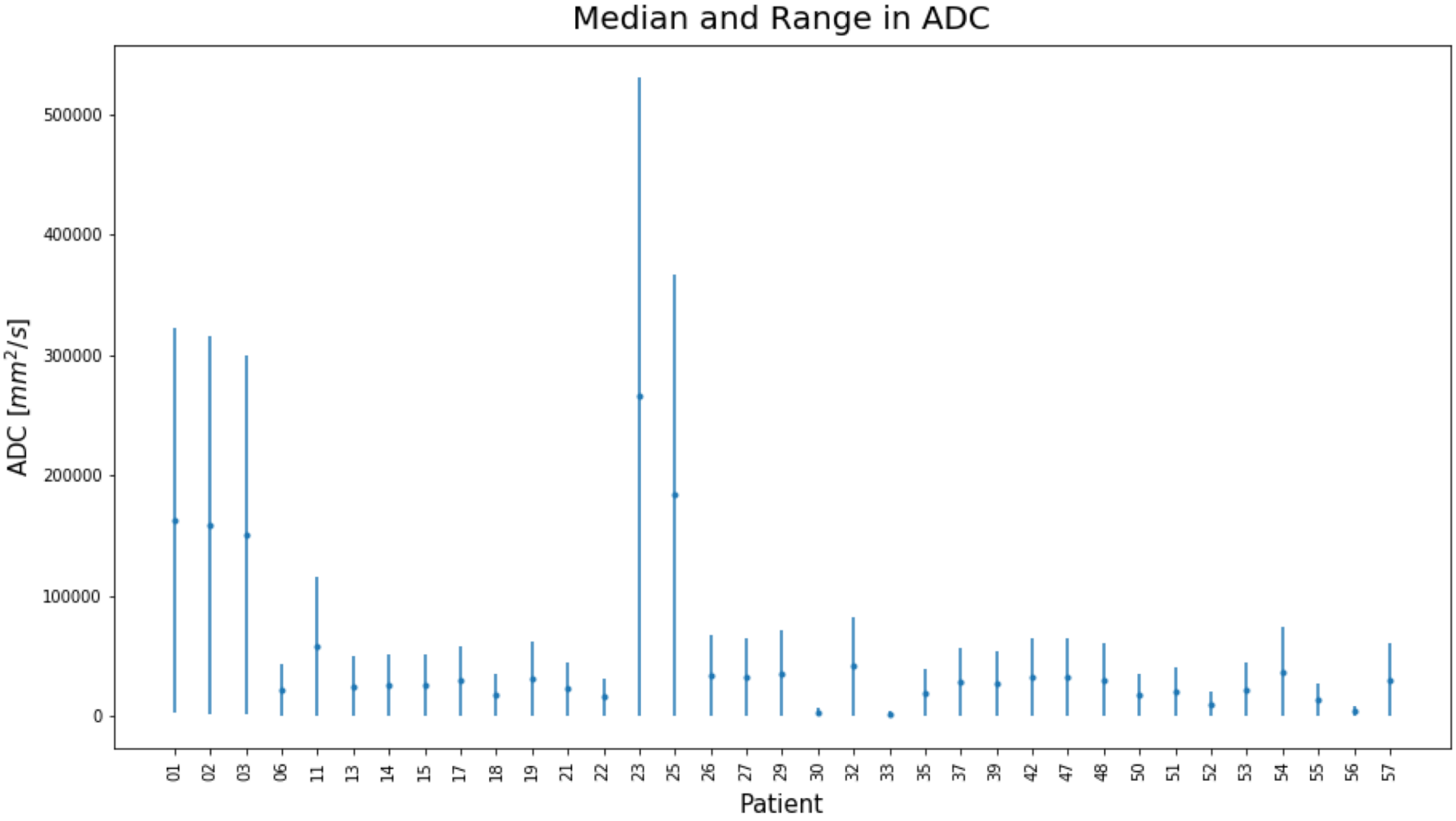
Patient


Median and Range in ADC
ADC [mm^2/s]
0
100000
200000
300000
400000
500000
01
02
03
06
11
13
14
15
17
18
19
21
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25
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42
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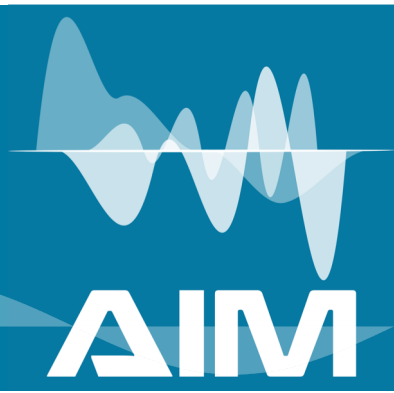
50
51
52
53
54
55
56
57
Patient

Problems

- Small database: 38 subjects
  - 32 subjects → outcome 1
  - 6 subjects → outcome 0
- Different protocol in MRI
- Clinical outputs

thank you



First Order Statistics

- Energy: sommatoria dei quadrati dei valori dei voxel
- Entropy: misura la quantità media di informazioni necessaria per codificare i valori dell'immagine
- Skewness: misura l'asimmetria di una distribuzione rispetto al valore medio
- Kurtosis: misura quanto una distribuzione è piccata rispetto alla distribuzione normale
- Uniformity: misura di omogeneità

Gray Level Co-occurrence Matrix

- Viene costruita la GLCM
  - E' una matrice che descrive le frequenze con cui ogni livello di grigio appare accanto ad altri livelli di grigio ad una distanza definita (offset)
- Vengono estratte features dalla matrice GLCM

Gray Level Size Zone Matrix

- Viene costruita la matrice GLSZM
  - Descrive il numero di voxel adiacenti che contengono lo stesso valore di intensità di grigio, nelle tre dimensioni
- Vengono estratte features dalla matrice GLSZM

Gray Level Run Length Matrix

- Viene costruita la matrice GLRLM
  - descrive con quale frequenza nell'immagine è possibile osservare file di elementi con una certa lunghezza e con una certa intensità
- Vengono estratte features dalla matrice GLRLM

Neighbouring Gray Tone Difference in Matrix

- Viene costruita la matrice NGTDM
  - Descrive le differenze esistenti fra ogni elemento dell'immagine e quelli immediatamente confinanti
- Vengono estratte features dalla matrice NGTDM

Recap database

- Distribuzione di dose → 57 soggetti
- Strutture → 55 soggetti
- MRI post-operatorie e pre-trattamento → 50 soggetti
  - T1 (3D) → ~ metà con MDC
  - DWI (ADC) → 50 soggetti
- 'Radiological evidence of neuro damage' → 40 soggetti
  - Outcome 0 → 7 soggetti
  - Outcome 1 → 33 soggetti
- Massima intersezione utilizzabile (utilizzando le ADC) → 35 soggetti
  - Outcome 0 → 6 soggetti
  - Outcome 1 → 29 soggetti