Artificial Intelligence in Medicine (AIM) related activities

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List of Activities

- **Magnetic Resonance Imaging** based artificial intelligence model to assess response to therapy in locally advanced **rectal cancer**
  - Submitted to European Journal Radiology

- **Neptune**
  - Enhancement of proton therapy using pF and pB reactions
  - Our task: 19F MR imaging optimization

- **Filoblu => Andrea**
  - "Sentiment" analysis of messages between oncological patients treated at home (or caregivers) and doctors

- **Possible future activities**
  - We have been contacted by Ospedale Bambino Gesu' and IFO
  - We are trying to understand if we can significantly improve the state of the art
  - Main limits: small number of images, different scanners

MR-based artificial intelligence model to assess response to therapy in locally advanced rectal cancer

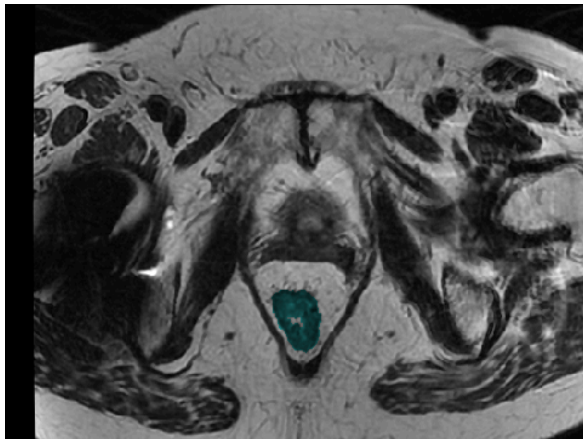
The Goal

- **Goal: stratify automatically the response to Chemo-Radio-Therapy (CRT) before surgery using textural analysis of T2-weighted MRI images**

- Identify Complete Responders (CR) after CRT to (possibly) avoid surgery (e.g. wait and watch strategy)

- Identify Non Responders (NR) during CRT to address them to a more effective strategy

- Two different classifiers trained
  => CR classifier
  => NR classifier



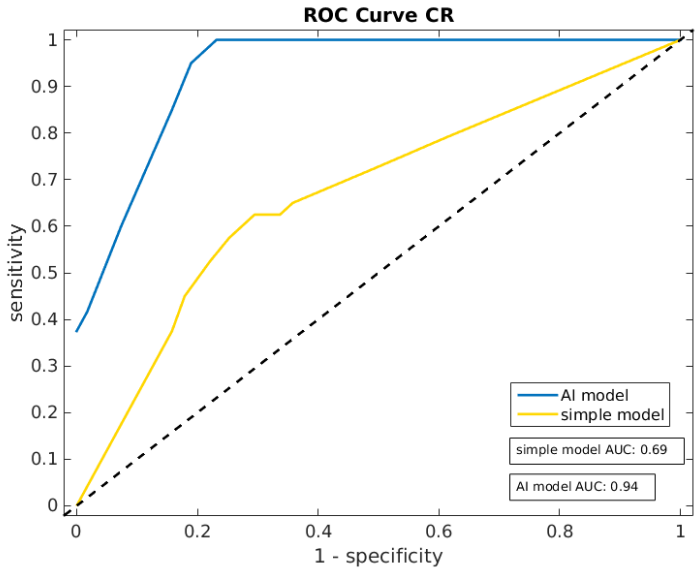
Results

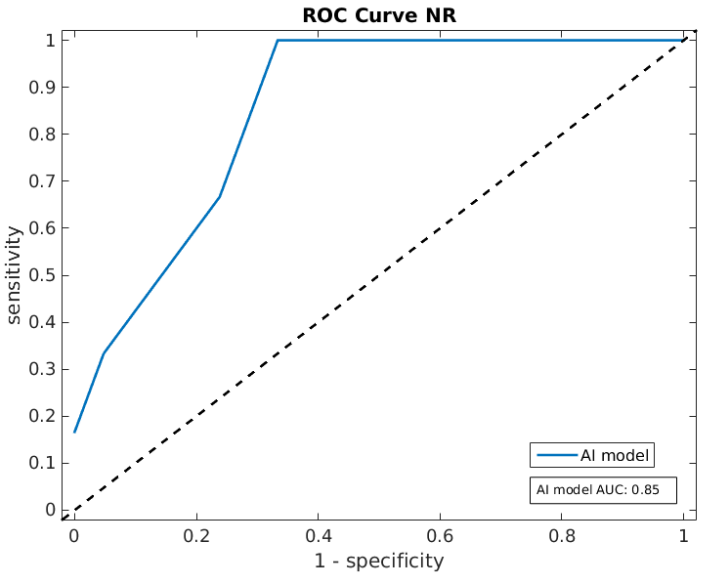
- **55 patients**

Image pre-processing (filters, gray level intensity normalization)

Feature extraction (textural analysis of gray level intensities)

Classifiers: Random Forest in our case





Perspectives

- Artificial intelligence analysis of medical images is a very promising and active field of research

- A possibile variant is the use of **(deep) neural network** directly on the images, skipping the feature extraction step

- Main limits:
  - the small number of images usually available
  - multi site images harmonization

- We are trying to understand if we can provide a significant contribution beyond the state of the art (e.g. transfer learning).

Possible future collaboration

- **IFO**
  - Multi-B IVIM DWI magnetic resonance images in horopharyngeal cancer to assess HPV status
  - 73 patients
  - images "ready" i.e. already segmented and labelled

- **Ospedale Bambin Gesu'**
  - automatic segmentation of infant brain
  - automatic loacalization of cortical dysplasia in infant brain

* Funded CSN5 call (2018)

The pB Nuclear Reaction

high let particles

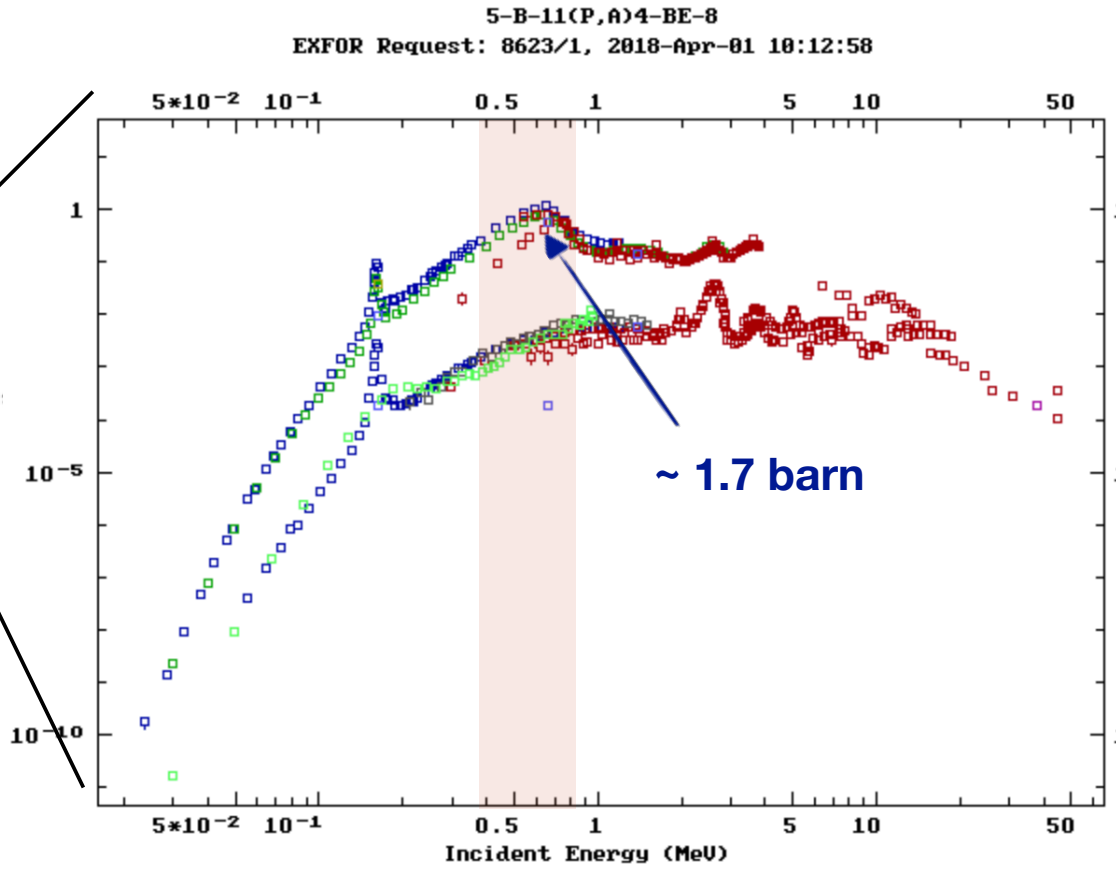
Reaction channels

$$^{11}B + p \rightarrow {}^{12}C^{*} \rightarrow {}^{8}B + \alpha_0 \rightarrow \alpha_{01} + \alpha_{02} + \alpha_0$$

$$^{11}B + p \rightarrow {}^{12}C^{*} \rightarrow {}^{8}B^{*} + \alpha_1 \rightarrow \alpha_{11} + \alpha_{12} + \alpha_1$$

$$^{11}B + p \rightarrow {}^{12}C^{*} \rightarrow \alpha_2 + \alpha_3 + \alpha_4$$

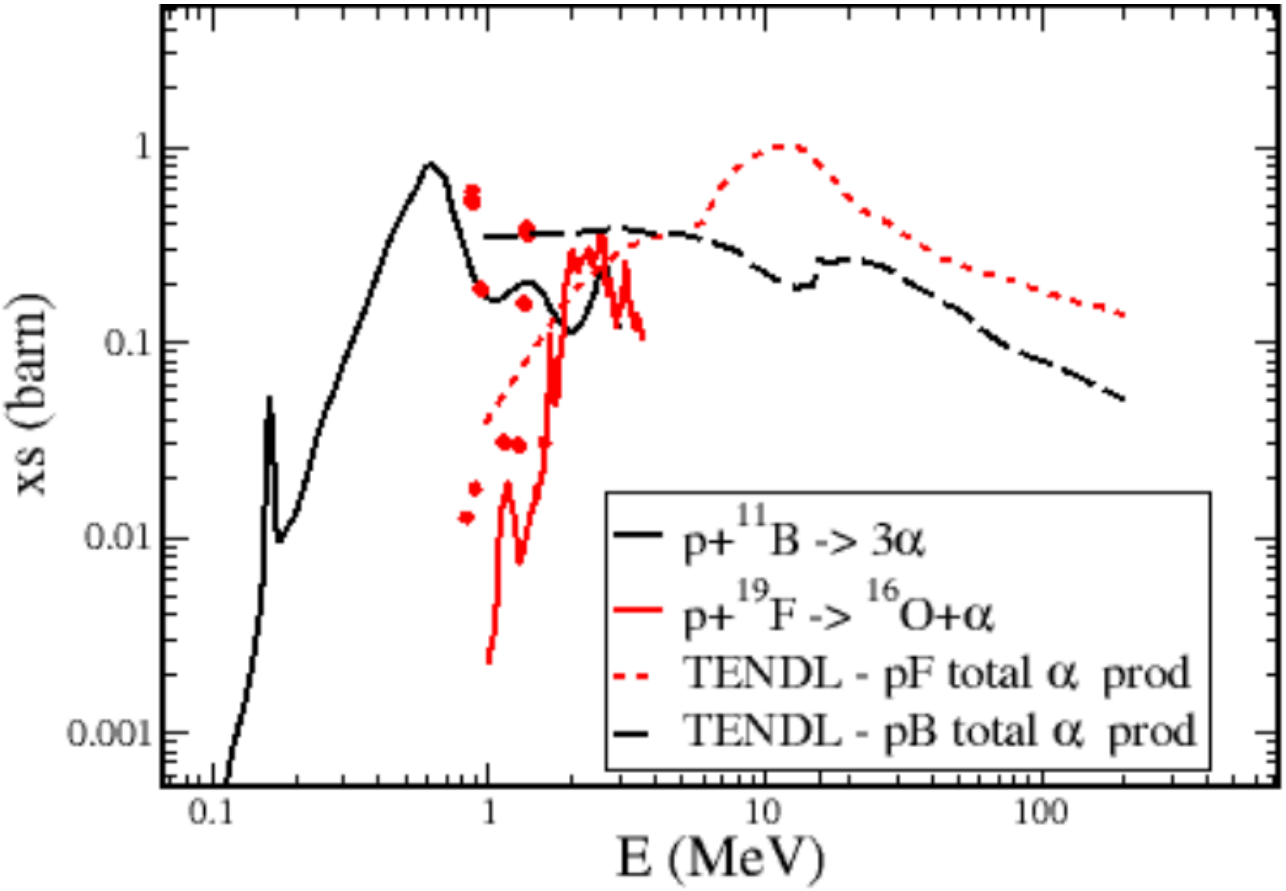
$$^{11}B + p \rightarrow {}^{12}C^{*} \rightarrow {}^{12}C + \gamma$$



- First experimental proof at CATANA (62 MeV proton beam)
- BSH on prostate cancer cell line DU145
- Observed increase of radiobiological effectiveness

The pF Nuclear Reaction

p + 19F —> 16O + alpha (up to 13 MeV)



WP2: Quantification & imaging

- Rome task: **evaluate bio-distribution of fluorinated tracers in patients with MRI with 19F**

- Absence of 19F intrinsic signal in living tissues allows in vivo visualization of exogenous fluorinated tracers

- 19F MRI is not currently used in clinical practice since it suffers from low Signal to Noise Ratio (SNR)

- Our strategy:
  - SNR optimization (new RF antenna, SDR technology, digital signal processing)

  - Optimization of the image analysis

Analysis Tasks

- Currently 19F images are extremely coarse because of low SNR

- **Noise reduction**
  - Recent developments in deep learning neural network (DNN) based denoisers show promising results in noise reduction tasks

- **Registration with 1H images**
  - Together with 19F images 1H high resolution images can be taken
    => Better estimate of the 19F noise from the correspondence with 1H image
  - Need automatic registration methods => DNN methods

- **Automated Segmentation of anatomical structure in 1H MRI**
  - Can help to study tissue-specific noise correlation
  - Can also be done with DNN

Image Denoising

- Recent DeepNN architectures have been shown to outperform conventional denoiser algorithms (BM3D, NCSR, GMM)

- Two different approaches under study

Denoising-AutoEncoders (DAE)

- extension of the basic autoencoder (more hidden nodes than input/output nodes)
- In order to avoid the risk that the algorithm learns the identity function in this configuration: randomly corrupt the input (i.e. introducing noise)

Convolutional-NN (CNN):

original | original + noise | CNN denoised

Image+Noise

DAE
PNSR = 25 dB

CBM3D
PNSR = 24 dB

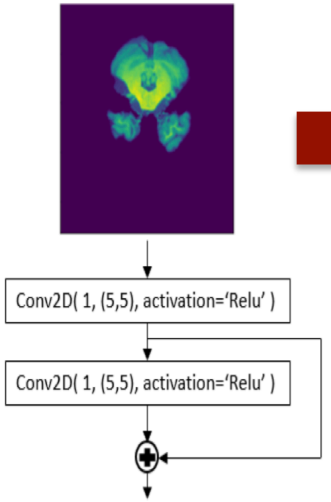
1H/19F Co-registration and Segmentation

- Several studies have leveraged deep learning techniques to improve medical image registration

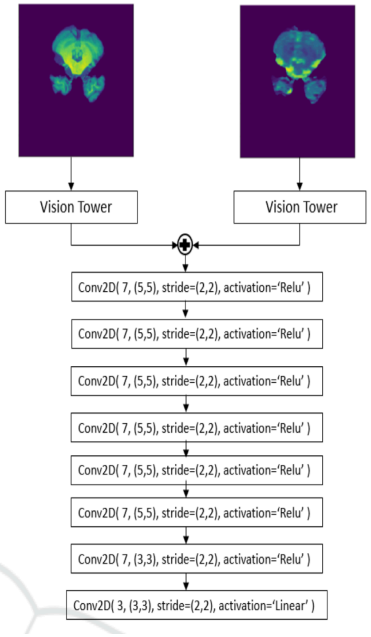
- DL algorithms typically adopt **convolutional neural networks** (CNNs) to learn informative image features and a mapping between the learned image features and spatial transformations that register images in a training dataset

  - predict spatial relationship between image pixel/voxels from a pair of images based on their image patches. The learned prediction model can then be applied to images pixel/voxel-wisely to achieve an overall image registration

vision tower: extract features from the input images



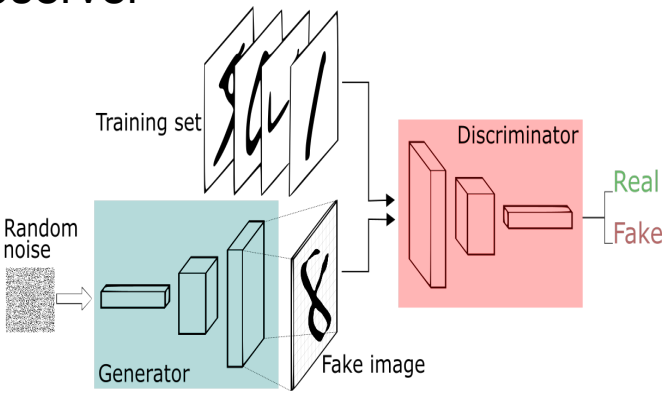
regress the transformation between a given reference and template image features extracted by the two vision towers



1H/19F Images Data-Augmentation

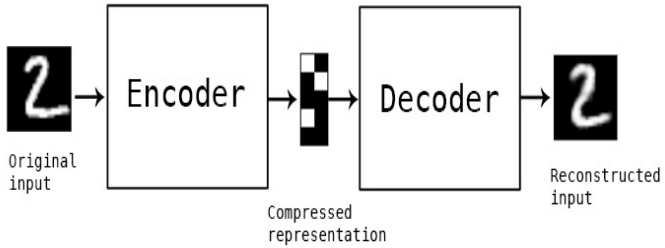
- **Could be necessary to artificially increase the number of images**
- **Generative Adversarial Network** (GANs)
  - class of artificial intelligence algorithms used in unsupervised machine learning, implemented by a system of two neural networks contesting with each other in a zero-sum game framework. They are able to generate images that look at least authentic to human observer

Generator: generate fake images and mix it with real images



Discriminator: try to recognise real from fake images

- **Variational Auto Encoder** (VAEs)
  - are DNN algorithms that learn a compressed representation of the image in a vector space called latent space of the image. Once this is achieved we can sample the latent space representation to produce realistic synthetic images

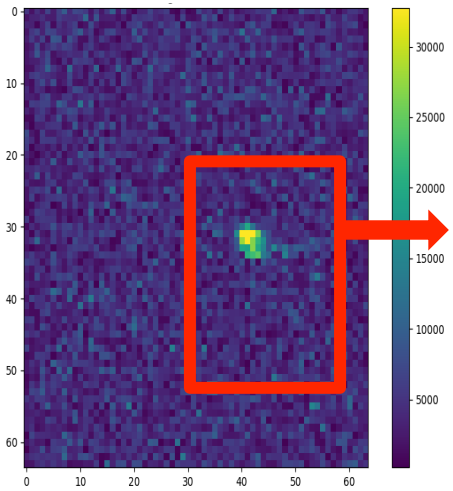


Preliminary analysis (Serena's thesis)

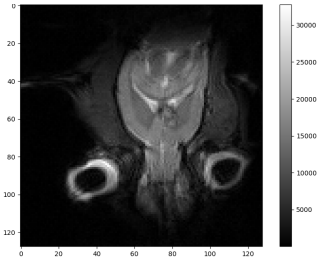
- **1H and 19F MR in-vivo images from S. Capuani (2007)**
- Rats with implanted brain tumor
- 19F-BPA fructose complex administrated (300 mg(Kg^{-1} b.w.))
- Imaging with a 7T scanner at different times after injection (t=0):
  - 1H T2-w images: t = 30min, 5h10min
  - 19F T2-w images: t = 2.5h, 4h, 5h

- **Analysis performed**
  - Study of the noise distribution
  - Resolution in 19F images
  - Signal to Noise Ratio
  - Correlation of noise in 19F-1H images (not found so far)

19F MRI



1H MRI



Current and future activities

- The 19F coil for Silvia's 9T scan will arrive in June
- In the meanwhile:

  - optimization of denoising NN on standard MRI in conditions similar to 19F MRI with low SNR samples concentration (glycerol-d8)

- In vitro test

  - optimization of 19F imaging, starting from Serena's thesis, on phantoms with different 19F concentrations

- Ex vivo-test (WP2)

  - optimization of 19F imaging on pancreas from rats with implanted tumor
  - Tracers: FBPA and 3FDG