Technique for Reliable Use of Images in Medical Physics
TRU-IMP
A Dynamic GUI

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Overview

Disclaimers

- Work in Progress!
- More features to be added with users' inputs and comments.

Context: Nuclear Medicine

- Nuclear medicine uses radiopharmaceuticals to detect functional activity in an organism;
- It is a type of functional imaging, i.e. not anatomical;
- An anatomical image (eg. CT, MRI, US) can be added to have both anatomical and functional features;
- Many physical factors affect the quality of the produced image.

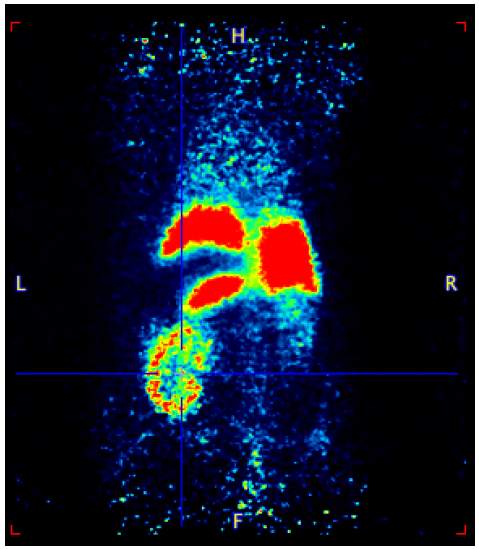

Figure: Nuclear medicine acquisition of a rat injected with a radiopharmaceutical gathering in the kidneys.

Context: Dynamic Imaging

- In a dynamic context, many timeframes are made to create an evolving acquisition;
- This allows to track the movements of the radiopharmaceuticals through the organism;
- This can be done, for instance, by using a Time-Activity Curve (TAC);
- New factors are present that reduce the quality of the image, among which movements between each timeframe.

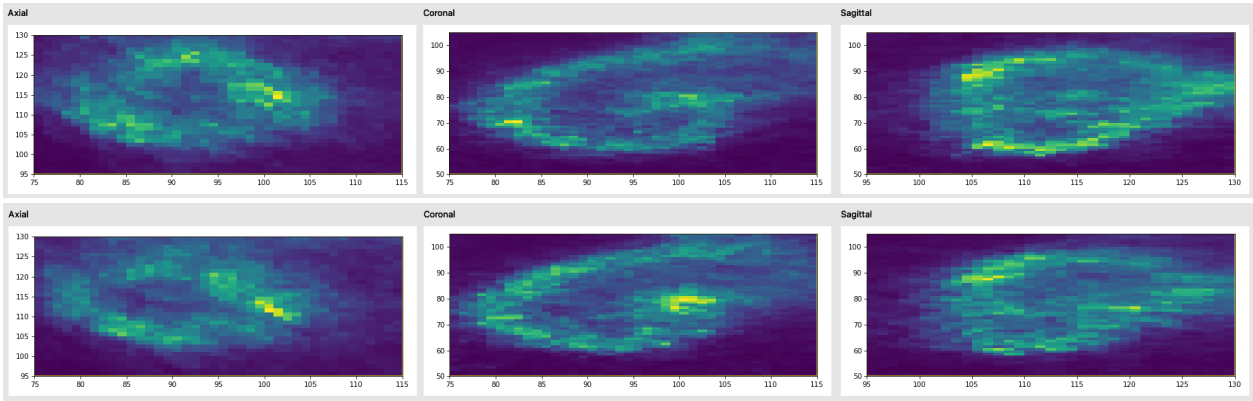

Figure: Two subsequent timeframes of a dynamic acquisition on a rat centered around the left kidney

Context: The Problem

- Segmentations is the act of selecting a Region of Interest (ROI);
- This can be done manually or automatically;
- With dynamic images, the notion of a good segmentation is **problematic**.

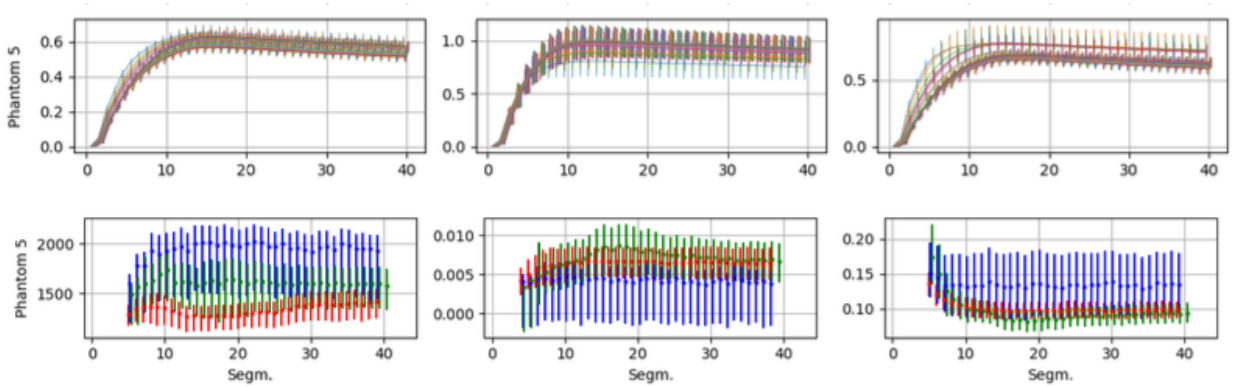

Figure: TACs and pharmacokinetics parameters for a simple dynamic phantom using 3 different segmentation schemes. What is seen is that the TACs agree, but not the parameters.

Context: Idea

- Develop a tool to analyze segmentations in a dynamic context;
- Determine the adequacy of current methods;
- Techniques for Reliable Use of Images in Medical Physics (TRU-IMP)

Where to Find It

- Currently hosted on GitHub

Figure: Scan Me (QR Code)

What is Needed

- If using the GUI packaged: **nothing**
- If using the source code: Python 3.X with some packages:
  - Numpy;
  - Scipy;
  - SkImage;
  - MatPlotLib;
  - Time, OS, Numba*;
  - Dynesty;
  - PyDicom;
  - Pickle.

TRU-IMP: The Basics

- A free tool to work on 4D Dicom Images (.dcm) and soon NIfTI (.nii) ;
- Main uses:
  - Segmentations;
  - Comparison of segmentations;
  - Uncertainty on TACs;
  - Extraction of pharmacokinetic parameters.

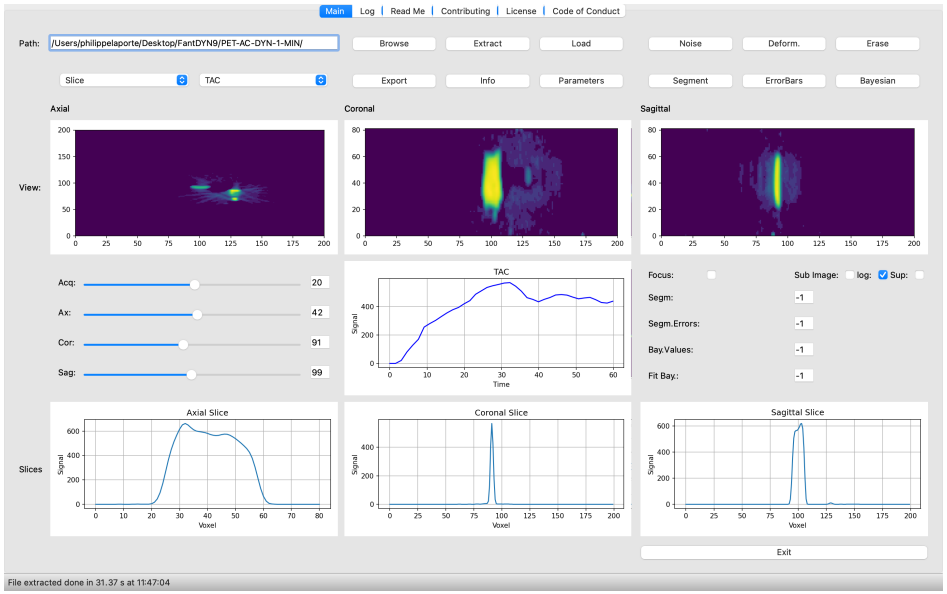

Figure: Basic view of the GUI, with an acquisition open

TRU-IMP: Segmentations

- Many segmentation schemes implemented:
  - Geometric;
  - Gradient-based;
  - Filling-based;
  - Statistics-based:
    - ICM;
    - Fuzzy C-Means (FCM).
- The user can select most of the hyperparameters manually;
- All segmentation schemes are based on a reference timeframe (static segmentation).

TRU-IMP: Comparisons

- In a dynamic setting, multiple timeframes can be used as a reference;
- Many segmentation schemes are available;
- To compare segmentations, many tools are available directly and graphically:
  - Dice & Jaccard coefficients;
  - Overlapping of segmentation and image;
  - The loss functions and convergence parameters (when relevant)

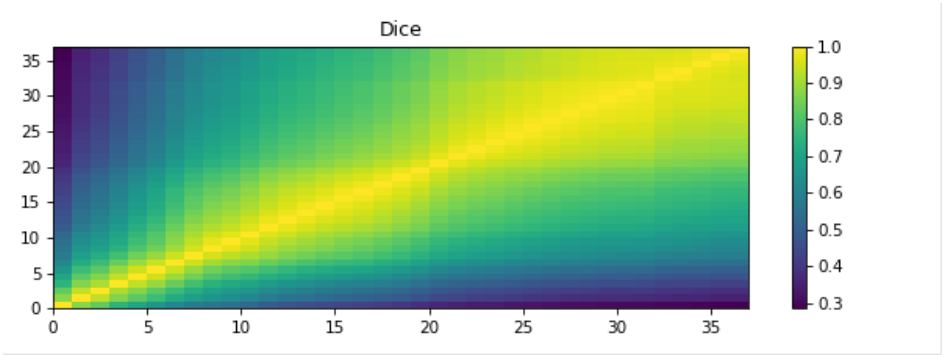

Figure: The Sørensen-Dice coefficients for different segmentation on a dynamic acquisition of a simple dynamic phantom

TRU-IMP: Uncertainties

- Comparing Time-Activity Curves (TACs) requires error bars;
- Segmentations normally don't produce them directly;
- The introduction of uncertainties is done by deformation of the Region of Interest (ROI):
  - Linear shifts;
  - Expansions/contractions;
  - Rotations;
- Another method is to sample the fuzzy segmentation (when relevant).

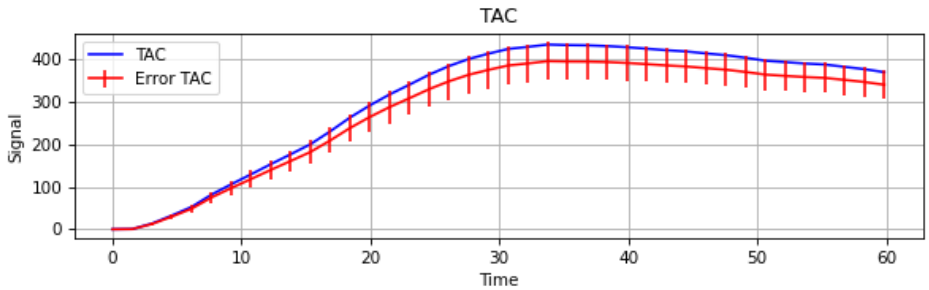

Figure: TAC and an associated uncertainty induced by linear shifts

TRU-IMP: Pharmacokinetic Parameters

- A model of displacement of the radiopharmaceutical can be used;
- Parameters dictate the flow between sections of the image;
- These parameters can be determined by fitting the TAC.

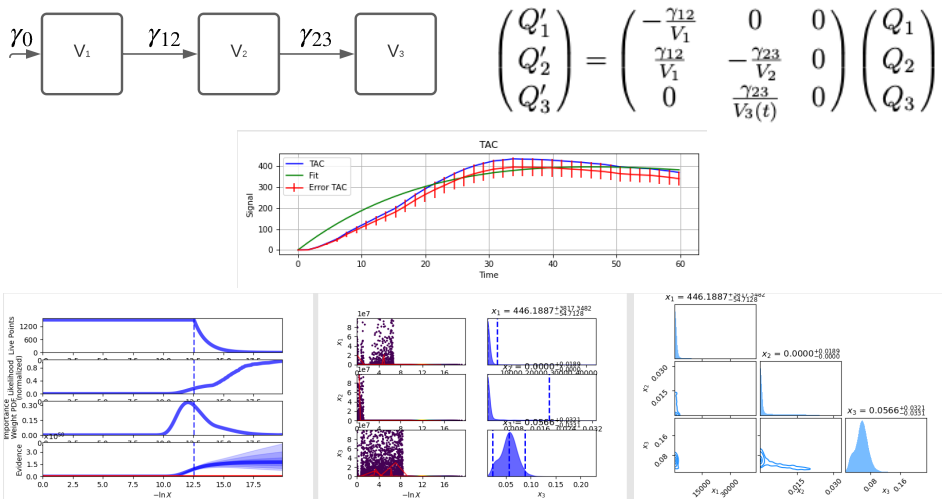

Figure: Pharmacokinetic model of the simple phantom with the fitted curve as per the extracted parameters.
The bottom image represents the convergence analysis of the *Dynesty* module

TRU-IMP: More Tools

- Adding noise to an image;
- Deforming a segmentation;
- Exporting the results (data or images);
- Saving intermediate work.

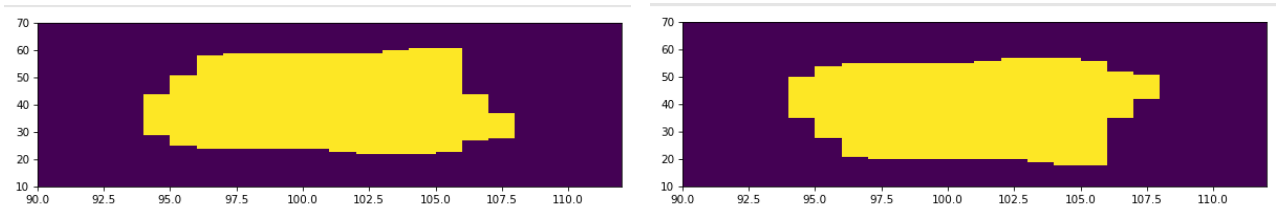

Figure: Reflection of a segmentation along the center of mass

TRU-IMP: Future Features

- Compatibility with .nii files;
- Export of the segmentations directly;
- Work with multiple acquisitions at the same time;
- Segmentations with errors from a propagation of uncertainties;
- Exploration of parameter space.

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