



Cardiac PET - SPECT Registration

Interdisciplinary Project Final Presentation

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Brian Jensen

Computer Aided Medical Procedures (CAMP),
Technische Universität München, Germany

Department of Nuclear Medicine
University Hospital Rechts der Isar, Germany



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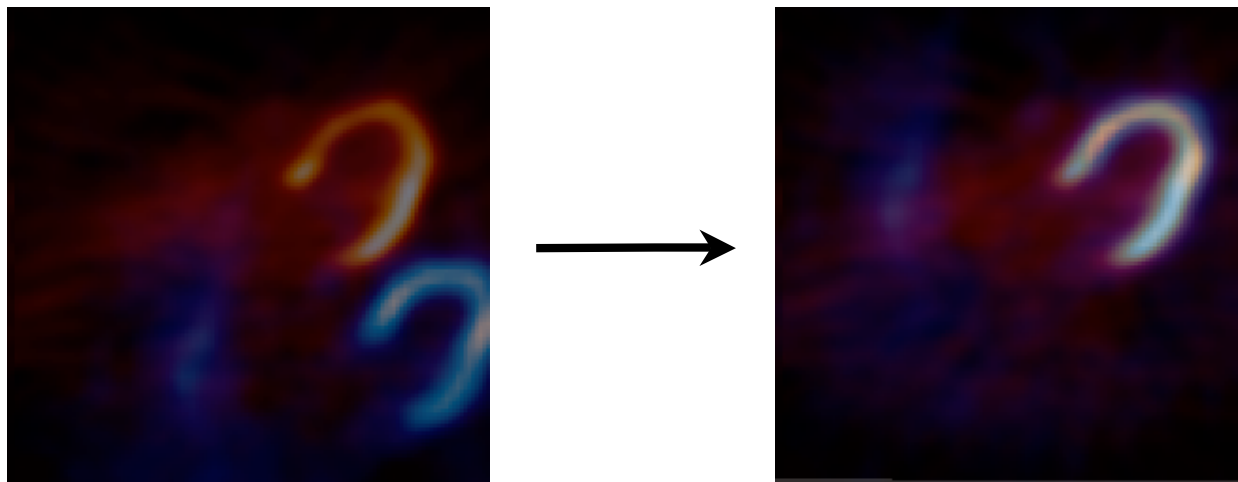
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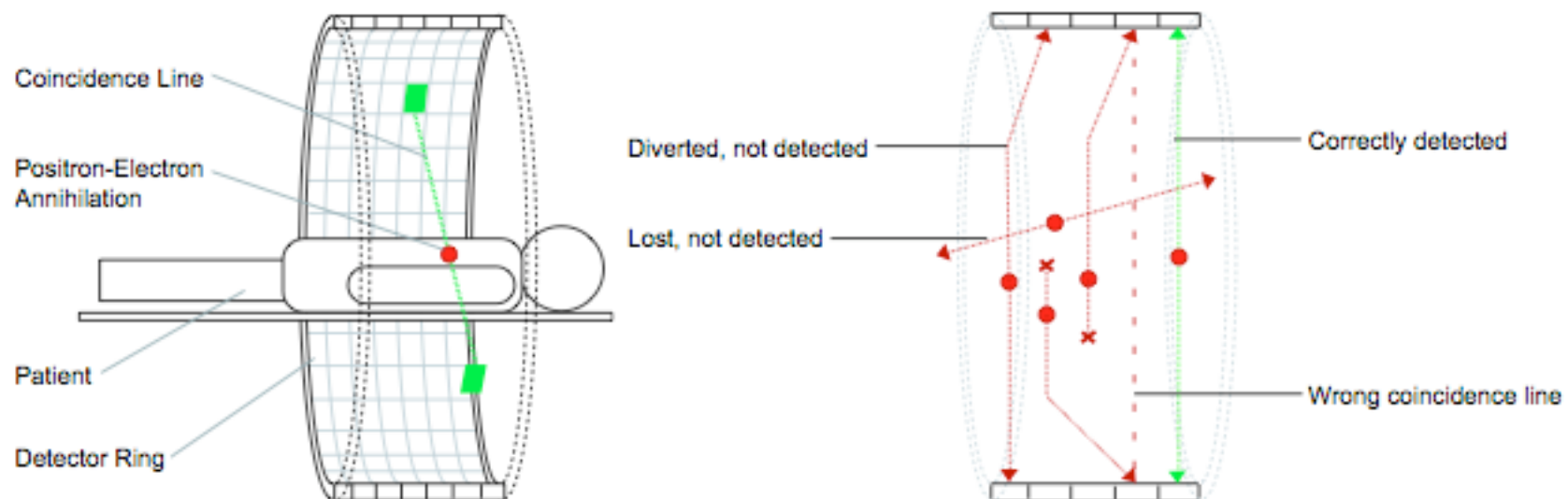
Introduction

- Interdisciplinary Project in the applied field of medicine
- Development of robust and fully automatic cardiac image registration
 - Analysis of available methods
 - Implementation of methods suitable for the integration into the clinical workflow
 - Evaluation of the limits of the chosen methods



PET Imaging Modality

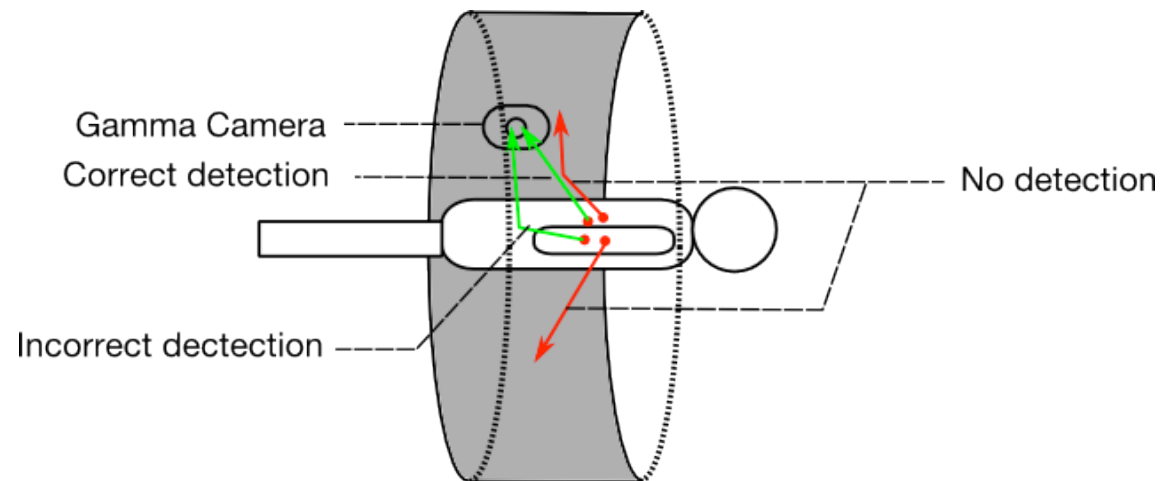
- PET Imaging gathers functional tissue information
 - Patient administered radio tracer with a known uptake pattern and positron decay
 - Positron emission is detected using a ring of detectors
- Generally offers higher resolution images compared to SPECT



Source: Loren Schwartz. MR-based Attenuation Correction for PET, August 2006

SPECT Imaging Modality

- SPECT Imaging also gathers functional tissue information
 - Used with radio tracers emitting gamma radiation
 - Detected using a gamma camera rotated around the patient
- Less robust against scatter than PET
- Images generally lower resolution than PET



Nuclear Cardiology

Assessment of

- **Myocardial Perfusion**
 - Technique used to detect ischemic heart disease
 - Patient is scanned under conditions of Stress and Rest
 - Rest and Stress images contrasted with each other to detect deficits
 - Both PET ($^{13}\text{N-NH}_3$) and SPECT ($^{99\text{m}}\text{Tc}$) can be used for the assessment
- **Myocardial Viability**
 - Technique used to diagnose viable myocardium tissue after a heart attack
 - One common protocol involves acquiring a metabolism image and a perfusion image
 - Metabolism image generated using PET ($^{18}\text{F-FDG}$)
 - Both PET ($^{13}\text{N-NH}_3$) and SPECT ($^{99\text{m}}\text{Tc}$) can be used for the perfusion image
 - Images are contrasted with each other to determine viable regions

Problem Statement

Current clinical protocol for the assessment of myocardial perfusion or viability can require the patient to have scans on different days or using different modalities

- In order to be of maximum use the images need to be registered
 - Standard procedure is for images to be registered manually
 - Manual registration introduces a varying bias and reduces reproducibility



Use a program to automatically register images



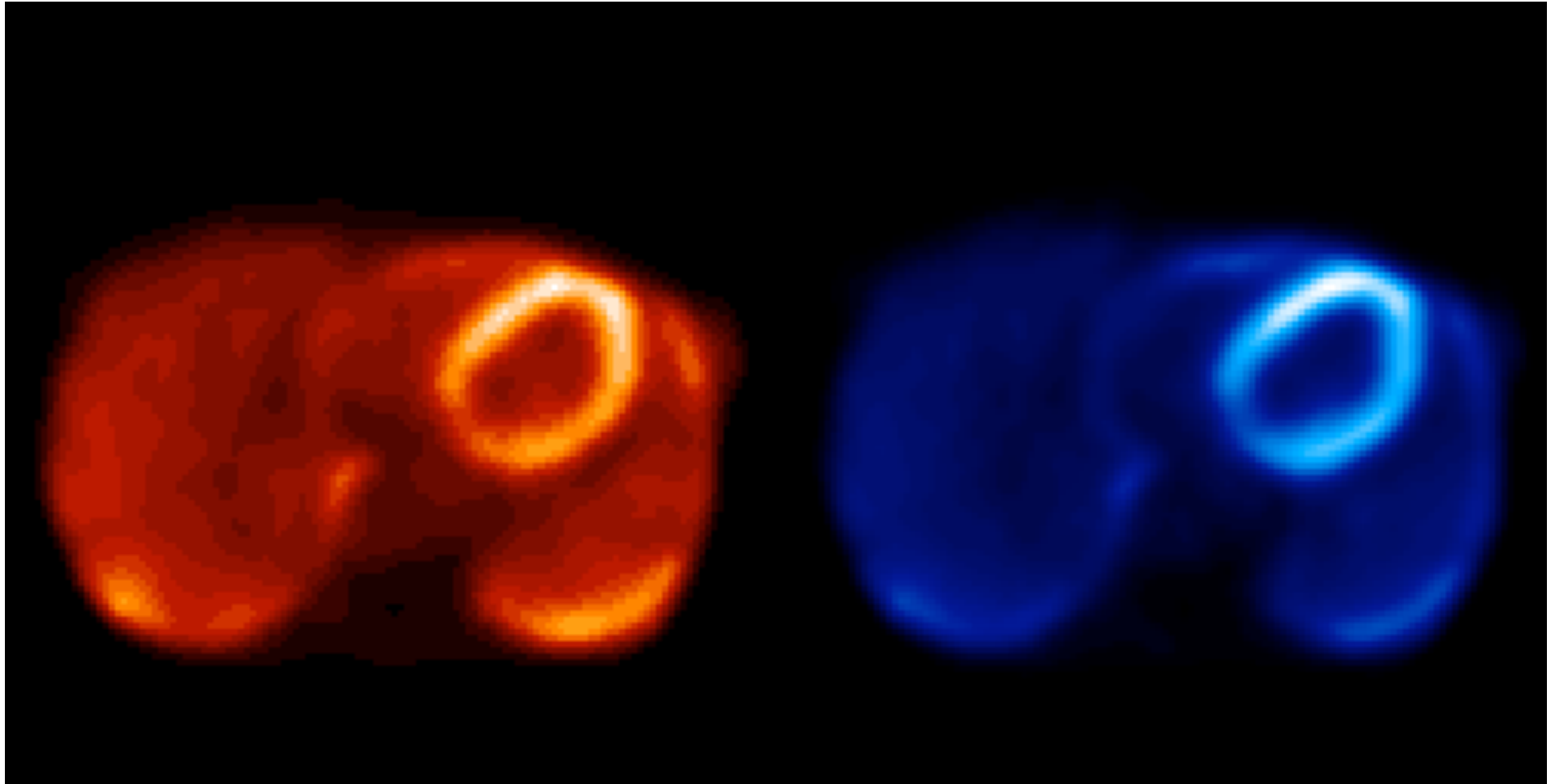
Project Goals

- Evaluation of the currently available methods
 - Selection the appropriate registration approach
 - Research of the available software tools / frameworks
- Implementation of a registration application to assist current clinical workflow
 - Robust registration of four different image pair types
 - Seamless handling of all four cases
 - Fully automatic as well as manual registration required
 - Development of GUI for observing the registration process
- Analysis of the effectiveness of the registration method chosen

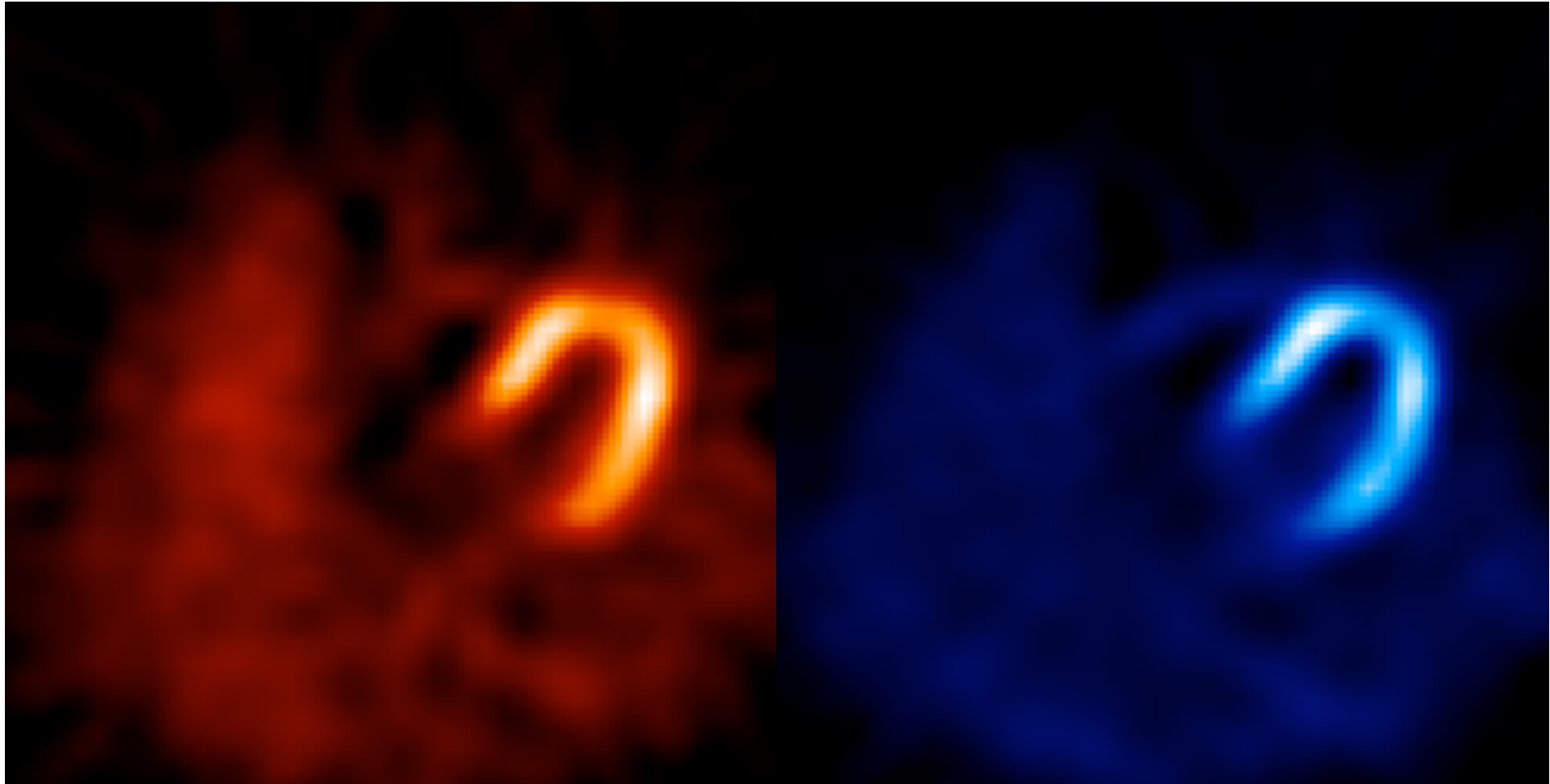
Registration Case Types

- Case Type 1
 - PET / PET (perfusion)
 - No Motion between scans
 - Same radio tracer ($^{13}\text{N-NH}_3$)
- Case Type 2
 - SPECT / SPECT (perfusion)
 - Motion between scans
 - Same radio tracer ($^{99\text{m}}\text{Tc}$)
- Case Type 3
 - PET / PET (viability)
 - No motion between scans
 - Different radio tracers ($^{18}\text{F-FDG}$ / $^{13}\text{N-NH}_3$)
- Case Type 4
 - PET / SPECT (viability)
 - Motion between scans
 - Different modalities ($^{18}\text{F-FDG}$ PET / $^{99\text{m}}\text{Tc}$ SPECT)

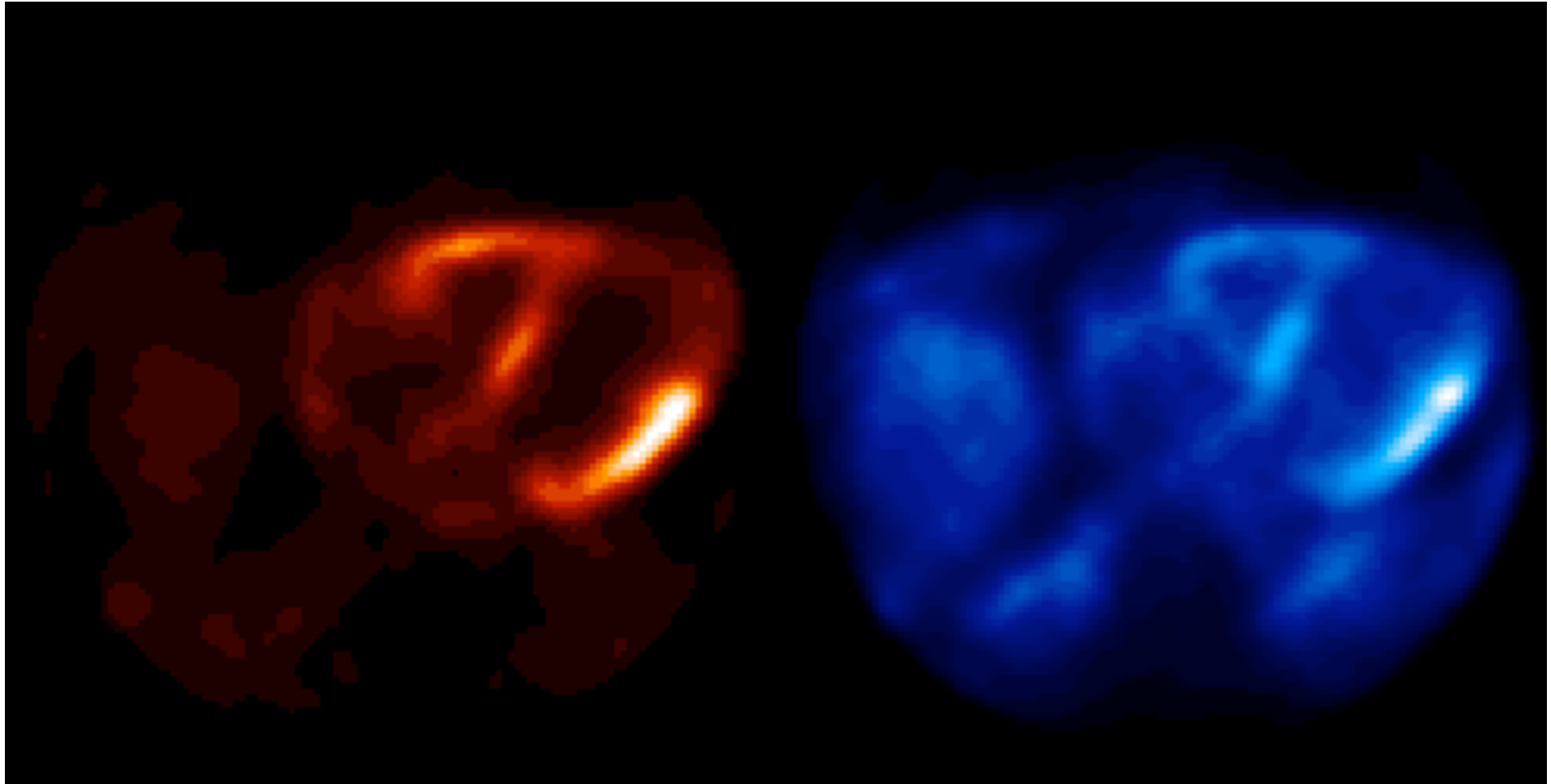
Case Type 1: PET Rest / PET Stress



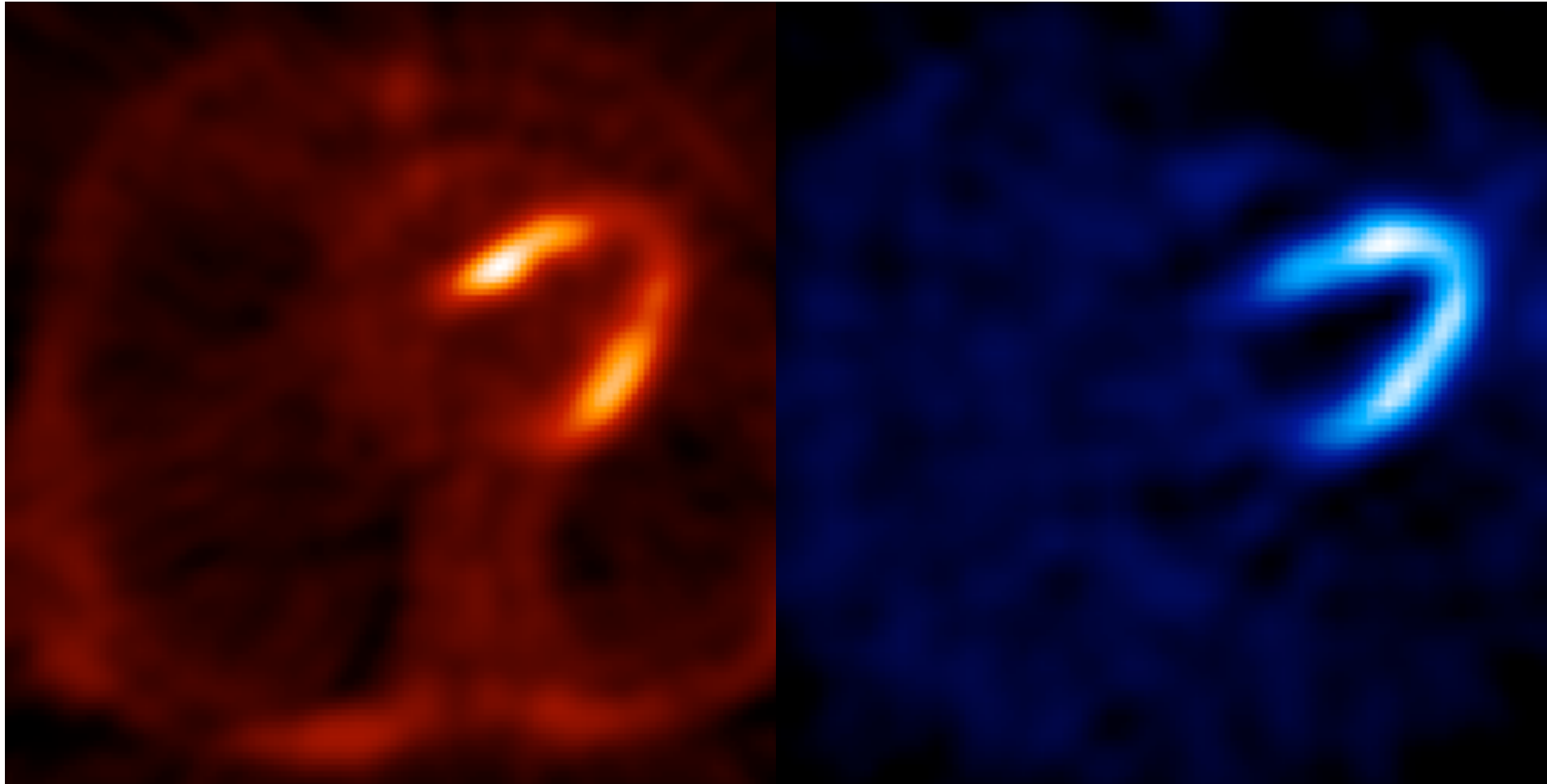
Case Type 2: SPECT Rest / SPECT Stress



Case Type 3: PET ^{18}F -FDG / PET ^{13}N -NH₃



Case Type 4: PET ^{18}F -FDG / $^{99\text{m}}\text{Tc}$ SPECT



Methods Overview

- Use of intensity based registration
 - Image contours not guaranteed to be the same in image pairs
 - Robust for registration involving different modalities
- Existing applications inadequate for goals of project
 - Existing CAMP applications did not easily support fully automated image registration
 - Problems registering images of different sizes and modalities
- Development of a new software application

Software Development

- ITK
 - Open source cross platform framework for image registration and segmentation
 - Extensive library of image manipulation functions
- CMake
 - Open source cross platform project builder
- Qt
 - Open source cross platform GUI framework
 - ITK offers no visualization functions



Source: <http://www.itk.org>

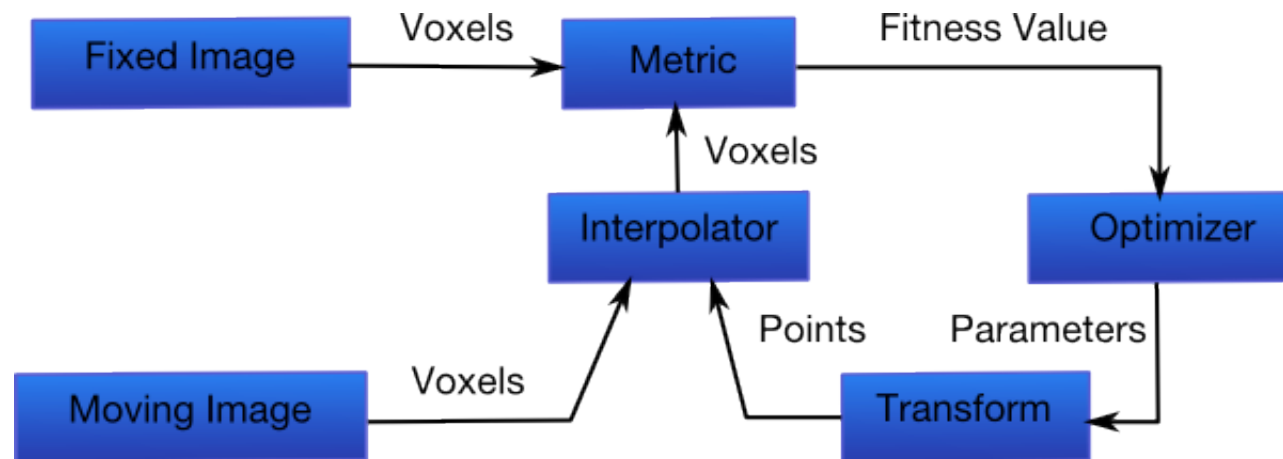


Source: <http://www.cmake.org>



Source: <http://www.qtsoftware.com>

Intensity Based Registration

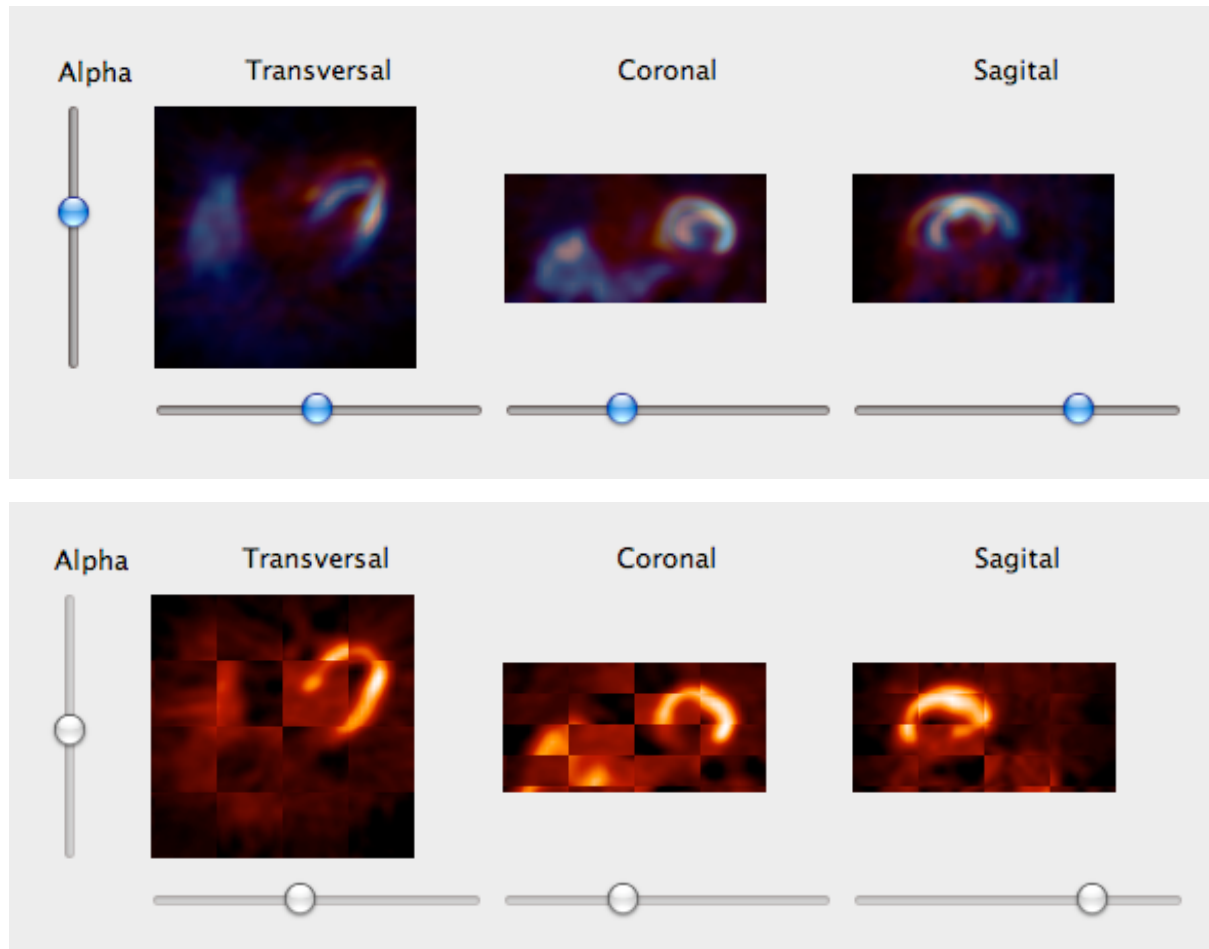


Derived from: Luis Ibanez, Will Schroeder, Lydia Ng, Josh Cates, and Insight Consortium.
The ITK Software Guide Second Edition. Kitware Inc, November 2005.

Registration Components

- Similarity measure: mutual information
 - Well suited for multimodality registration
 - Two specific implementations available for evaluation
 - Mattes et al. implementation
 - Viola-Wells implementation
- Transform type: versor rigid 3D transform
 - Rigid 3D transform that uses a versor for its rotational component
- Optimizer type: versor rigid 3D transform optimizer
 - Modified gradient decent optimizer that is aware of the special versor properties
- Interpolator: tri-linear interpolator

Visualization



Results

- Registration results quantified using manually determined parameters
- Best results achieved using Mattes' mutual information implementation

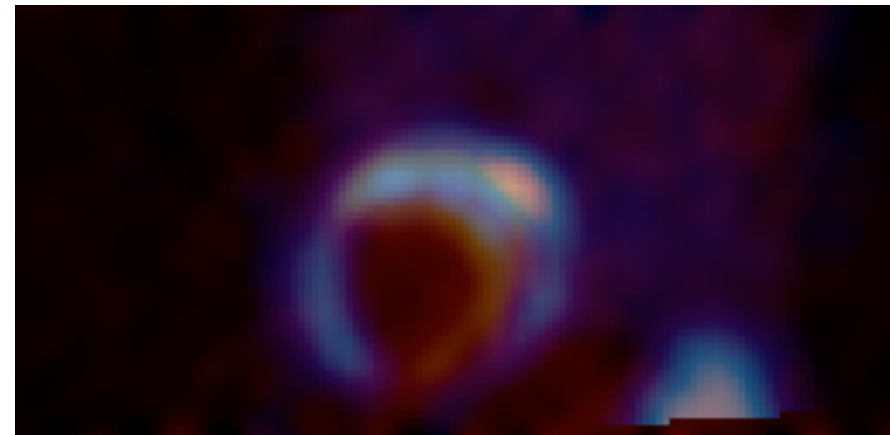
Case Type	Successful	Unsuccessful	Percent
Type 1	2	0	100,00%
Type 2	11	1	91,67%
Type 3	2	0	100,00%
Type 4	10	2	83,33%
Total	25	3	89,29%

Registration Accuracy

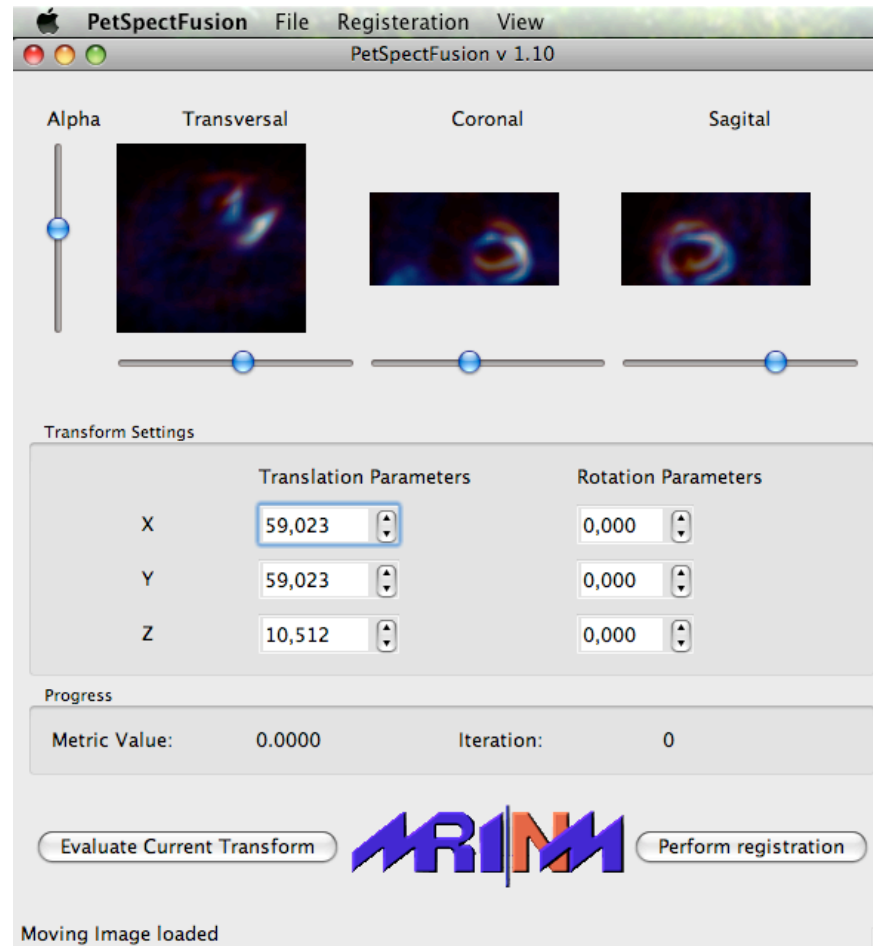
Case Type	Translation in mm			Rotation in radian			Iterations	time (s)
	X	Y	Z	X	Y	Z		
Type 1	0,0	0,0	0,0	0,0	0,0	0,0	5,5	3
Type 2	1,0	0,3	0,0	0,0	0,0	0,0	11,5	2
Type 3	0,0	0,0	0,0	0,0	0,0	0,0	6,0	3
Type 4	1,1	1,1	4,1	0,0	0,0	0,0	17,5	11,5
Total	0,9	0,6	1,8	0,0	0,0	0,0	13,3	6,2

Registration Errors

- Most registration cases had small error margin
- Mis-registered cases had fairly large and obvious error margin
- Mis-registration caused by problem with similarity measure
 - Similarity measure had local optimum in mis-registered pose



Demonstration





Conclusion

- Automatic registration viable for majority of registration cases
 - Increase of clinical quality through reproducibility
- Available open source frameworks well suited for image registration tasks
- Future developments
 - Add preprocessing steps to enhance image similarity
 - Expand application to work with additional types
 - OsiriX plugin for better visualization (already done)



Any Questions? Ideas?

Thanks for your attention!

References

1. Manuel D. Cerqueira and Arnold F. Jacobson. Assessment of Myocardial Viability with SPECT and PET Imaging. American Roentgen Ray Society, pages 477 - 483, September 1989.
2. Luis Ibanez, Will Schroeder, Lydia Ng, Josh Cates, and Insight Consortium. *The ITK Software Guide Second Edition*. Kitware Inc, November 2005.
3. Philipp A. Kaufmann, Paolo G. Camici, and S. Richard Underwood. The ESC Textbook of Cardiovascular Medicine, chapter 5, pages 141 - 158. Wiley, John & Sons, Incorporated, 2006.
4. D. Mattes, D. R. Haynor, H. Vesselle, T.K. Levellen, and W. Eubank. PET-CT Image Registration in the Chest Using Free-form Deformations. IEEE Transactions on Medical Imaging, 22:120 - 128, 2003.
5. Timothy G. Turkington. Introduction to PET Instrumentation. Journal of Nuclear Medicine Technology, pages 1 - 8, 2001.

For more detailed information see:

<http://campar.in.tum.de/Students/IdpPetSpectRegistration>