# ANR PhD fellowship
# Mathematics and Numerics of Dynamic Cone Beam CT and ROI Reconstructions

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## 1 The ANR DROITE project

In the ANR DROITE project, the laboratories TIMC-IMAG, LHC and CREATIS (located in Rhône-Alps region, respectively in Grenoble, St-Étienne and Lyon) open a PhD fellowship on the mathematics and numerics of Dynamic ROI Cone Beam (CB) Computed Tomography (CT).

Computed tomography aims at reconstructing images of internal physical quantities (attenuation coefficients, radioactivity concentrations) from external measurements (X-ray projections, radiation detectors). To first order, these measurements can be mathematically modeled by the Radon transform: straight line integrals of the unknown function. The problem to solve is the reconstruction of a function from a set of line integrals. Solving this problem led to the development in medicine of CT scanners, PET scanners and SPECT scanners. However, open questions remain that restrict the use of such systems in certain circumstances:

- In case of patient movement during the data acquisition, solving the inverse problem (even when the exact movement is known) is an open problem, except for some very particular motion classes.

- The use of a relatively small detector compared to the patient size, and the need to minimize the X-ray dose to the patient, lead to the problem of reconstruction from truncated projections. This is a challenging open problem that will be addressed in the project.

- Finally, the third open question which we will attack is the combination of patient motion with truncated projections, for which virtually no theoretical results exist today.

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The objective of the DROITE project is to make theoretical contributions to the field of dynamic CT (reconstruction of moving objects) and Regions Of Interest (ROI) reconstruction (reconstruction from truncated projections). The objectives are to solve mathematical problems arising from the open questions presented above, i.e. to obtain results on existence, uniqueness, and stability for dynamic ROI reconstruction, to develop the associated reconstruction algorithms, and to experimentally validate the results using simulated and real data.

## 2 Objectives and research program

The aim of the PhD project is to improve Dynamic CB CT reconstruction. We want to extend our understanding of ROI reconstruction and dynamic Cone Beam CT. We first want to combine ROI and Dynamic reconstruction based on known results in each domain. A second direction of research would be to consider more complex deformations such as deformations transforming the measured lines into circles or ellipses. Reconstruction of functions from integrals on circles or spheres is an active research field. A third direction would be to be to separate a moving organ (typically cancer calcification in lungs) within a fixed attenuation function and, knowing the deformation, to reconstruct the moving organ and the fixed one. A fourth direction of research would be to identify both the movement and the function from the data. Generalizations within the framework of 2D ROI and 3D CB ROI reconstruction should also be considered. Numerical experiments and validation on real data (acquired locally or at Centre Léon Bérard in Lyon) will be necessary. Laurent Desbat and Rolf Clakdoyle will be the PhD advisers. The PhD project will additionally benefit from the two other key players of the ANR DROITE team (Catherine Burnier (CPE-Lyon) and Simon Rit (CREATIS-CLB, Grenoble and Lyon).

## 3 Candidate qualifications and contacts

### 3.1 Qualifications

The candidate must hold a MSc in mathematics or applied mathematics. Good mathematical skills in Fourier analysis and integration, basic knowledge in 3D geometry, measure theory, functional analysis, topology, are required. Her/His scientific interest should be in mathematics (inverse problems, tomography) with real applications (In DROITE, medical imaging is used for radiotherapy treatment or computer-assisted medical interventions). Good programming skills (C++ or matlab or scilab or python or IDL, etc.) are required for the computer simulations and tests of the proposed methods on simulated or real data.

English language proficiency is necessary, french is optional.
The research will take place in Grenoble at TIMC-IMAG within the ANR
DROITE project. The salary is 1300/month (net) for 3 years starting fall
2014.

## 3.2   Contacts

Send **before 10 June 2014** an email to both Rolf Clackdoyle and Laurent
Desbat: rolf.clackdoyle@univ-st-etienne.fr,laurent.desbat@imag.fr, ("subject:
DROITE PhD application") containing

- a CV

- a brief statement of interest

- a list of courses and marks over the past 3 years

- the name (+email/tel) of two persons (we will contact them for recommandation if your application is selected)

If your application is selected, you will be contacted for an interview 16 or
17 June 2014.

# Acknowledgment

# References

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[3] L. Desbat, C. Mennessier, and R. Clackdoyle. Dynamic tomography, mass preservation and ROI reconstruction. In *CT 2012, Salt Lake City*, pages 318–322, 2012.

[4] L. Desbat, S. Roux, and P. Grangeat. Compensation of some time dependent deformations in tomography. *IEEE transaction on Medical Imaging*, 26(2):261–269, 2007.

[5] F. Natterer. *The Mathematics of Computerized Tomography.* Wiley, 1986.

[6] S. Roux, L. Desbat, A. Koenig, and P. Grangeat. Exact reconstruction in 2D dynamic CT: compensation of time-dependent affine deformations. *Phys. Med. Biol.*, 49(11):2169–82, June 2004.