Advances in 3D X-ray imaging and associated inverse problems

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X-ray CT which has been a pioneer technique in medical imaging has evolved from a single slice to a fully three dimensional imaging technique. Today, many developments are in progress to achieve time and spatially resolved quantitative images with different contrasts from the organ to the cell level.

Basic tomographic reconstruction relies on the inversion of the Radon Transform but the evolution of acquisition systems required the adaptation of algorithms. After recalling the principles of 3D CT, we will describe recent advances in CT and the progress and needs in associated inverse problems to be solved. The following aspects will be described :

- Time-resolved imaging is an important issue for moving organs like the heart. In particular, since 3D rotational angiography systems do not provide a sufficient acquisition rate, it is necessary to handle motion in the reconstruction process. This topic will be illustrated by two examples, one based on a motion corrected analytic method for the 3D reconstruction of cardiac stents, the other on the compressive-sensing principles applied to gated cardiac imaging.
- Spatially resolved CT is necessary to image thin structures such as bone micro-architecture. Imaging trabecular bone has been a driving application in the development of X-ray micro-Computerized Tomography (CT) ex-vivo. With new high resolution CT systems, imaging bone micro-architecture in vivo has become possible. Nevertheless, due to radiation dose restriction, the spatial resolution remains limited. The work in progress to improve spatial resolution without increasing dose will be presented.

- Quantitative CT imaging is also a major goal for a better differentiation of tissues. With the development of spectral CT and phase CT, new contrasts become available. We will particularly describe phase contrast X-Ray CT which may be particularly be well suited to image soft tissue. With this technique, phase retrieval has to be performed prior to CT reconstruction. The underlying inverse problem will be described, and results will be illustrated to image the complex three-dimensional organization of the bone cell network at the nanometric scale.