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Image processing for X-ray transmission radiography with 3D voxel detector

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The first prototype of a 3D voxel detector was recently developed as a layered stack of several Timepix pixel detectors. The single Timepix device (256 x 256 pixels with pitch of 55 μm) consists of a sensor chip (typically silicon 300 μm thick) bump bonded to a pixelated readout chip. The readout chip is thinned down to 120 μm to reduce the amount of insensitive material in the stack. The voxel detector can be used in many particle tracking applications and it has also many advantages in conventional X-ray transmission radiography as well. Imaging with such device brings a lot of benefits such as higher detection efficiency, improved spatial resolution, presence of a directional information and mapping of beam-hardening effects.

During radiographic measurement the voxel detector is operated in integrating (counting) mode. The acquired information has the form of a 3D matrix containing the number of X-ray photons registered by individual volume elements - voxels. In order to retrieve an image from such data a number of correction and processing steps has to be applied:

1. Corrections of response of individual voxels: Each voxel is connected to its own analog processing chain, therefore, the response of all voxels is never fully uniform. This non uniformity has to be determined and corrected.
2. Detector alignment corrections: The individual detector layers are physically slightly shifted and rotated to each other due to imperfection of the device assembly.
3. Beam geometry determination: The distance and position of the X-ray source is determined from the measured data.
4. Evaluation of the beam hardening effect: Comparing attenuation levels observed in different detector layers can be used for the estimation of the level of the beam-hardening effect in the imaged object.
5. Assembling of final image(s). All information acquired in steps 1-4 is used and the final image is produced.

In terms of image processing, most of the described correction steps result in a series of affine transformations between images from individual detector layers. These affine warps are found using Lucas-Kanade algorithm based on the least square optimalization. The result of data processing is not only an assembled image of a transmitted object but also the position of X-ray source relative to detector which is very useful in many applications (e.g robotic CT). Results together with evaluation of the techniques are demonstrated on radiogram of real samples.

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