Interventional 3D-Angiography:
Calibration, Reconstruction and Visualization System

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Abstract

3D reconstruction of arterial vessels from planar radiographs obtained from multitude of angles around the object has gained increasing interest. The motivating application has been interventional angiography. In these procedures data acquisition, visualization, decision making, and the action are all incorporated in one loop that is time critical. This project encompasses an entire workflow: from system calibration, data acquisition, and image reconstruction, to the effective presentation of the results for the right action.

Neurointerventions are carried out on X-ray angiography systems similar to the one illustrated in Figure 1. In this figure the smaller C-arm rotates about the patient's head by roughly 200°. A total of 50-100 projections are acquired that are transferred to a post-processing workstation for 3D reconstruction.

The 3D reconstruction is based on cone-beam filter-backprojection. This method requires the parameters of the X-ray perspective projection, and it also requires the geometry of the C-arm gantry in relation to the patient coordinate system. A calibration procedure is run which involves taking X-ray images from a calibration phantom. The calibration phantom is an acrylic cylinder on which a large number of small steel balls are arranged in a pattern. Figure 2 illustrates this calibration phantom. The arrangement of the spheres is designed such that from any partial view, the geometry of the C-arm and the parameters of the X-ray projection can be determined without ambiguity.

![Figure 1. X-ray Angio system with C-arm gantry used for data acquisition.](image1)

![Figure 2. X-ray and geometry calibration phantom](image2)
The X-ray images obtained from the machine have geometry distortion due to; (1) the effect of earth’s magnetic field on the image intensifier and (2) the curvature of the detector surface. A second phantom consisting of a 2D array of small spheres is imaged at every angle of the C-arm. These images are used to compute the warping that is needed to correct for the geometric distortion of the X-ray images.

The intensity response of the image intensifier is a non-uniform function of detector surface. This non-uniformity is also corrected for by taking a bright field image (X-ray image of the air). N. Navab et al. [3] give a more complete description of the reconstruction procedure.

Virtual endoscope is an important notion in Fly-Through. It is a tool for navigating around. The user can easily maneuver the endoscope interactively. The endoscope has two important functions: first, it is used to generate endoscopic views from within the organs, secondly, it carries a plane for computing MPR. If the loaded data set contains pre-segmented organs, then the segmented objects can be converted to models. The models are used by the endoscope for path planning and collision avoidance [4]. Collision avoidance is important, especially for navigating complex structures such as blood vessels. Figure 5 shows the rendering of the arterial model along with the virtual endoscope. A plane orthogonal to the endoscope is attached to the endoscope for the computation of MPRs. This provides a useful tool for examining the vessel cross sections based on raw data. Fly-Through was selected among 45 most innovative technologies by the Discover Magazine [5].