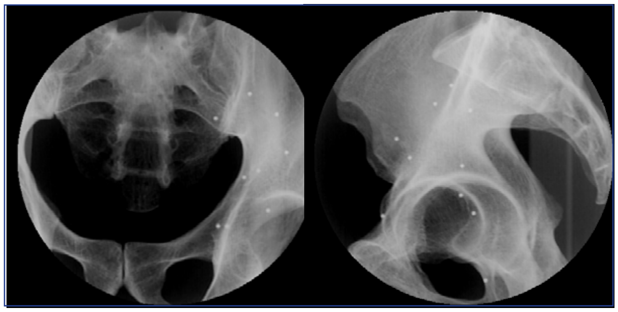

Fig. A5: X-Ray images of a dry pelvis bone taken with a mobile C-arm. Note image truncation.

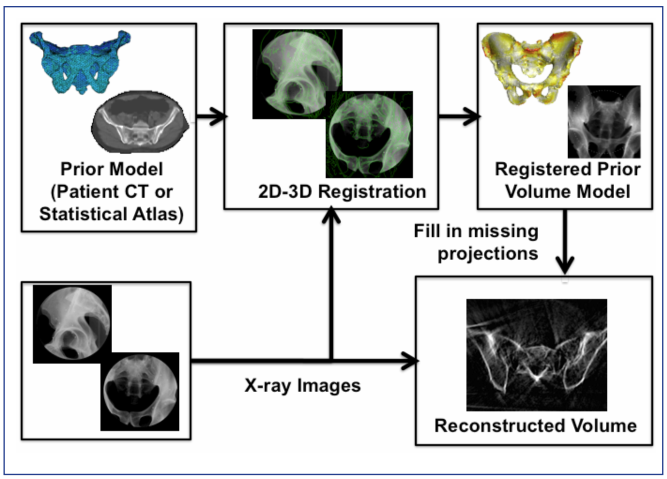

Fig. A6: Hybrid tomographic reconstruction from limited x-ray projection images and a prior CT scan of the patient or statistical atlas of patient anatomy.

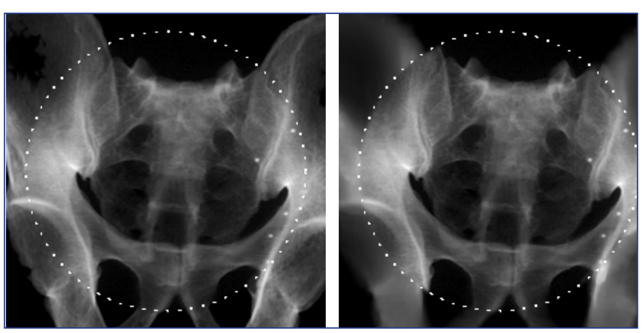

Fig. A7: Fusion of pelvis x-rays (in circle), registered to prior CT (left) and statistical atlas (right) outside the circle. The projections outside the circle compensate for image truncation.

Researchers at the CISST ERC are developing a method to produce three-dimensional (3D) reconstructions of bone from a limited collection of x-rays, that would give orthopedic surgeons 3D information about the patient during surgery using the mobile fluoroscopic x-ray "c-arms" commonly available in orthopaedic operating rooms.

Three-dimensional reconstruction from x-ray projections is at the heart of x-ray computed tomography (CT) and is a well-studied problem. Standard reconstruction methods require the knowledge of x-ray projection intensity for every ray through every reconstructed volume element (voxel). "Cone beam" reconstruction methods of 3D volumes from multiple 2D x-ray projection images are known and are widely available on high-end x-ray systems (such as those found in angiography suites). Only a relative handful of smaller mobile x-ray c-arms, typically found in orthopaedic operating room systems, have such capabilities, and even in these cases there are many limitations such as, it is often impractical to rotate the c-arm far enough around the patient to provide the required x-ray projections. The relatively small detectors in mobile systems also cause the view of the patient's anatomy to be incomplete (Fig. A5) especially in wide parts of the body, including the pelvic and spinal regions. The repeated acquisition of large numbers of intraoperative x-rays can be undesirable both for the patient and operating room personnel. The fluoroscopic detectors and structural components of most mobile c-arms introduce image distortions and other effects that complicate tomographic reconstruction.

We have developed a hybrid reconstruction tomographic reconstruction method that combines intraoperative x-ray images with prior information about the patient in the form of a CT scan or

Discovery

Hybrid Tomographic Reconstructions From Prior Models and a Limited Number of Projection Images

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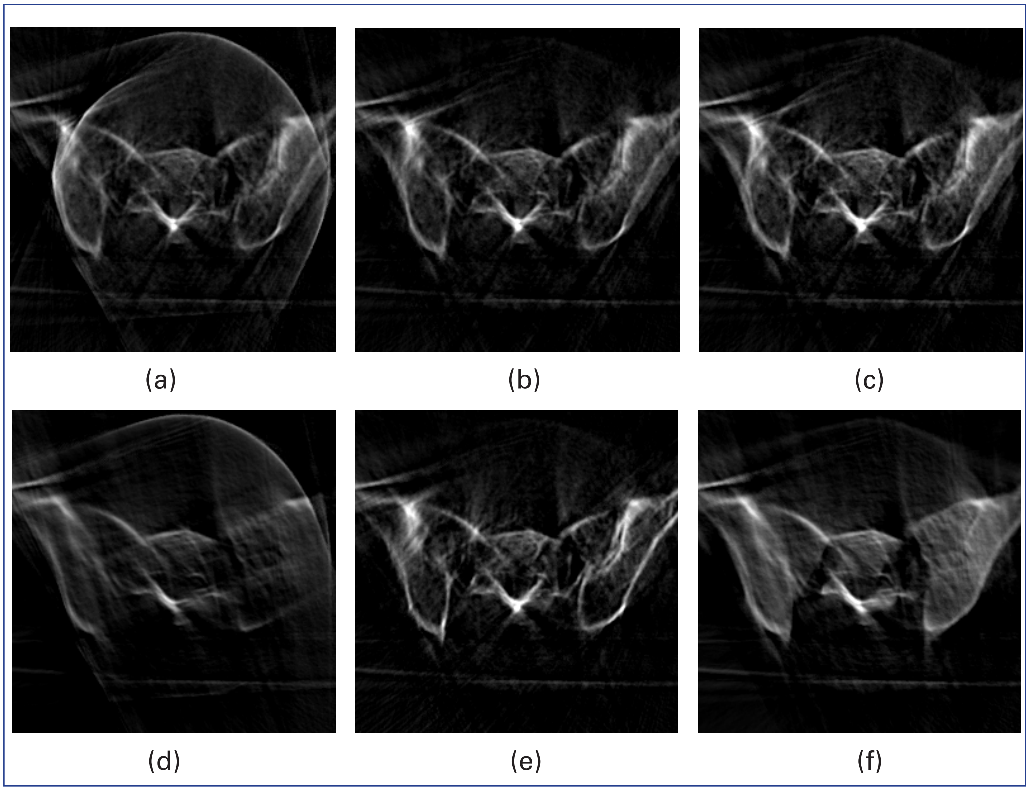

Fig. A8
Hybrid reconstruction of x-ray and prior models. Top row: using a 200° x-ray "short scan." Bottom: using 110° of x-ray scan and 90° of prior model. (a) Cross section reconstructed from truncated x-rays only. (b) Reconstruction from image fusion with prior CT. (c) Reconstruction from fusion with statistical atlas. (d) Reconstruction from 110° x-rays without prior. (e) Reconstruction using 90° projections of prior CT. (f) Reconstruction using 90° projections of deformable atlas.

statistical "atlas" constructed from multiple patients (Fig. A6). The steps of this reconstruction method are as follows. First, a "scan" of x-ray images of the patient from multiple projection angles is obtained. Second, these images are corrected to account for image distortions and other geometric and calibrated intensity-response characteristics of the c-arm. Then the 2D projection images are registered to either the prior CT scan (rigid registration) or the atlas (non-rigid registration). In the current implementation, after the atlas is aligned to the available data the pixel intensities of the projected atlas images are matched to those of the x-ray images. This allows a smooth fusion of both modalities to be obtained (Fig. A8). To compensate for image truncation or missing x-ray views, the data from x-rays and atlas are blended together as inputs to a conventional cone-beam reconstruction algorithm.

Results of this method on a cadaveric human pelvis phantom using a typical mobile fluoroscopic c-arm (OEC 9600) are shown (Fig. A7), using both a prior CT model and a shape/density atlas constructed from CT images of 110 normal adult male subjects. As this is written (May 2008) our immediate plans are to apply this method in cadaver trials to reconstruct intraoperative changes such as cement injections in bone augmentation and to extend the method to other anatomic structures.