A Hybrid Three-dimensional Reconstruction Method from Limited X-rays

Researchers at the CISST ERC have developed a method to produce three-dimensional (3D) reconstructions of bone from a limited collection of x-rays. The intended application is to give orthopedic surgeons a picture of the surgical field during surgery while keeping the x-ray dose to the patient and surgical personnel low.

Two-dimensional (2D) reconstruction from x-ray projections is at the heart of x-ray computed tomography (CT), and is a well-studied problem. In the surgical suite, it is common to have a conventional x-ray/fluoroscopic unit known as a c-arm, a device that provides 2D projections of the body. Use of the c-arm in 3D reconstruction is a considerably more difficult problem -- mathematically and practically -- than that of conventional CT. For one, it is often difficult to rotate the c-arm fully around the patient or patient table. As well, each 2D image is typically truncated, which means that the whole patient anatomy is not captured in a given image. For safety issues, it is also desirable to limit the number of images acquired.

The hybrid method (see Fig. 1) combines the observed projections with a statistical atlas of the imaged bone, which initially comprises the pelvis and is therefore suitable to surgeries such as total hip replacements and pelvic fracture repairs. The statistical atlas is constructed from a set of normal male pelvises from which normal variation in both shape and CT density are learned. The first step in the hybrid reconstruction process is to register the atlas to the observed x-ray images. This process uses digitally reconstructed radiographs of the atlas (reported in another nugget) to compare to the observed x-rays. The atlas is successively warped using the statistically relevant modes of both shape and density deformations until there is high agreement between the atlas and the observed images. After the atlas is aligned to the available data, the reconstruction process is carried out using conventional cone beam reconstruction algorithms. Results are demonstrated on simulated data (Fig. 2).

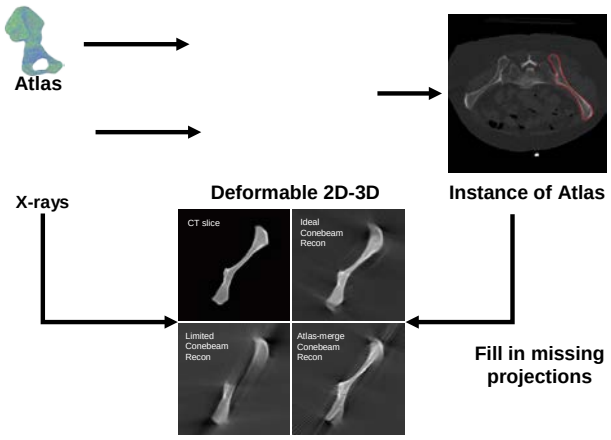

Figure 1: Data flow for hybrid reconstruction

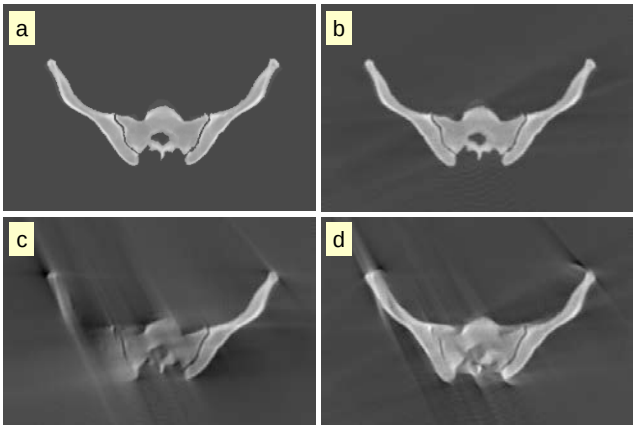

Figure 2: Visual comparison of different reconstruction methods. (a) A slice from a CT scan. (b) A slice reconstructed from a 207° short-scan. (c) A slice reconstructed from a 120° partial scan. (d) A slice from a 120° partial-scan and 87° registered atlas projections. All dynamic ranges have been scaled uniformly so that zero maps to the gray background in (a), and white is the maximal intensity value.

The method will be further developed to include both male and female pelvises and to incorporate soft tissue. Theory and experiments will be conducted in order to determine the limits of performance of the approach and to determine suitable formats for display of results to the surgeon. Additional atlases will be built for the femur and spine.