# GP-GPU ACCELERATED INTENSITY-BASED 2D/3D REGISTRATION PIPELINE

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**Background:** The possibilities of computer-aided preoperative planning based on plain X-ray images have recently been brought into focus in orthopaedic surgery. One of the main tasks in orthopeadic surgery is the identification of the best shaped bone implant or bone replacement for a specific patient. The essential moment of the planning process is the construction of 3D patient-speficic bone model from a set of X-ray images. The construction is performed using a deformable 2D/3D registration where a statistical shape model is being fitted into a set of calibrated X-ray images. The deformable registration is a time-consuming process, especially in case of intensity-based registration methods. On the other hand, beyond the shape reconstruction, intensity based methods allow modeling bone densities which can be further exploited for FEM simulations.

**Aims:** In order to speed-up the preoperative planning process, we are working on a pipeline for intensity-based 2D/3D registration fully accelereted using graphics hardware (GP-GPU).

**Methods:** We have created a statistical shape and intensity model [1], based on a set of CT images of femoral bones and corresponding segmentations. The bone model is represented as a tetrahedral mesh (see Figure 1 left); the bone density is described in each tetrahedron using Bernstein polynomials of a certain degree. Using this representation it is possible to model anatomical structures such as a compact and spongy bone that are observable in X-ray images of femora. The CT data sets were obtained from anonymized clinical cases and from `Virtual Skeleton Database`. Registration of CT images was performed using the `Elastix` software.

Before the registration is performed, the input X-ray images of patient's femur must be calibrated and roughly segmented by the user. Once a rough position of the shape model is initialized interactively by the user, the registration is performed as an optimization of parameters and position of constructed shape model. In each iteration of the optimization, digitally reconstructed radiographs are rendered from the SSIM. Rendering is performed according to [2] in graphics hardware, using low-level GLSL implementation. The similarity between rendered DRRs and original X-ray images is evaluated using the mutual information metric. Consequently, the SSIM position and parameters are adjusted for the next iteration. The patient-specific model is found when the differences between original X-ray images and DRRs are minimized.

For evaluation of the registration pipeline, two data sets have been created. The first data set contains virtual X-rays rendered from CT images with and without tissues surrounding femoral bones. The second data set comprises from the real X-ray images of a leg phantom.

**Results:** Figure 1 middle shows DRRs rendered from instaces of the constructed SSIM. The instances were created by varying the first principal components of the shape and intensity models.

Rendering of DRRs from a bone model consisting of 65 thousand vertices and 104 thousand tetrahedra with density described by Bernsterin polynomials of the $3^{rd}$ degree is performed with framerate 87 FPS on average on `NVIDIA GeForce GTX460` graphics card.

Figure 1 right contains a bone model reconstructed from two calibrated virtual X-ray images. The mean Euclidean distance between the reconstructed and ground-truth bone model surfaces was 0.69 mm, the maximum distance between surfaces was 2.86 mm.

**Conclusions:** We have proposed a framework for the accelerated multiview intensity-based 2D/3D registration. The whole registration is performed in graphics hardware (GP-GPU), benefiting from the computation locality and parallel implementations of chosen methods. Certain parts of the pipeline implementation will be released as open-source software. Following work will be focused on the extensive evaluation of the pipeline.

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**References:**

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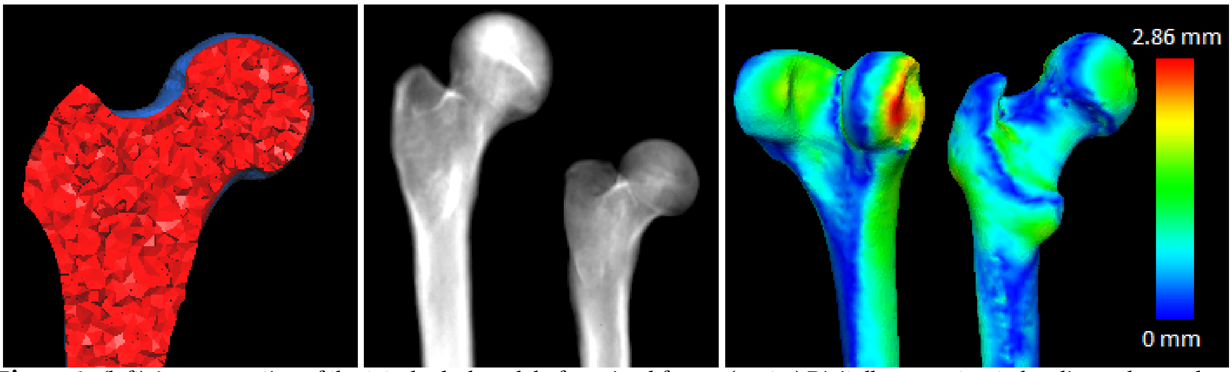


**Figure 1:** *(left) A cross-section of the tetrahedral model of proximal femur. (center) Digitally reconstructed radiographs rendered from instances of the shape and intensity model. The value of the first principal components of the left and right bone corresponds to $2\sigma$ and $-2\sigma$ respectively. (right) A bone model reconstructed from two calibrated virtual X-ray images. The reconstruction accuracy is visualised using a heat map.*