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SCHNELLE UND PRÄZISE INTENSITÄTSBASIERTE 2D/3D FUSION FLUOROSKOPISCHER RÖNTGENAUFNAHMEN MIT CT UND DEREN OBJEKTIVE EVALUIERUNG DURCH GOLD STANDARD-DATENSÄTZE

FAST AND PRECISE 2D/3D INTENSITY-BASED FUSION OF FLUOROSCOPIC IMAGES WITH CT -- AN OBJECTIVE EVALUATION USING GOLD STANDARD DATASETS

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PURPOSE

The key advantage of an intensity-based fusion is its robustness to outliers as well as its ability to use the whole available image information. There is no need for error-prone and time-consuming preprocessing steps like segmentation. However, one essential step within intensity-based registration, the calculation of DRRs (digitally reconstructed radiographs), is computationally very expensive.

We present our fast and robust algorithm for rigid 2D/3D registration of fluoroscopic images with CT together with an evaluation of its accuracy, speed and robustness.

The main contributions of our work are
- using a specific search- and optimization strategy (pattern search)
- using standard graphics hardware support for significant speedup of DRR generation
- evaluation of accuracy using a well-known freely available „gold standard" data set.

MATERIAL & METHODS

Intensity-based fluoroscopy-to-CT registration always involves the following crucial steps:

1) eneration of DRRs for each fluoroscopic viewpoint based on a given initial pose of the CT volume
2) omparison of the DRRs with the real fluoroscopic X-Ray images using a similarity measure
3) daptation of the pose parameters, so that the value of the similarity measure increases.

These steps are repeated until no more improvement is possible. For each of these steps there have been proposed a lot of different techniques during the last few years.

We want to introduce a new optimization technique for step 3: pattern search. Pattern search algorithms are a class of derivative-free direct search algorithms for nonlinear optimization. Using pattern search the overall number of function evaluations (i.e. DRR calculations) needed is very small compared to other algorithms.
Beside using pattern search we also take advantage of state-of-art graphics hardware features. Based on texture mapping it is possible to speed-up step (1), i.e. the calculation of DRRs significantly.

RESULTS

To evaluate our registration algorithm regarding its robustness, accuracy and speed we performed several experiments (simulation, in-vitro and cadaver based) using image data of a proximal femur and the spine of a deer. Moreover we conducted several tests using the freely available „gold standard" data of a human cadaver spine.

Using our own in-vitro datasets we are able to reach convergence in about 10sec, using two fluoroscopic images with half of the PAL resolution (384x288) on a 1.4 GHz Pentium PC. The average resulting target registration error was 1.1mm (max 2.4mm).

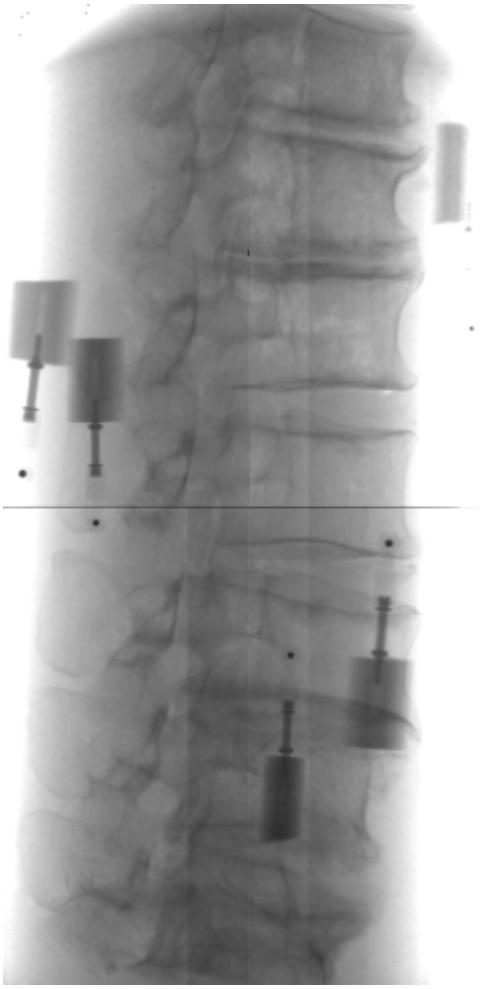
Using the gold standard datasets the results were very promising, too: sucessfull registration was reached in more than 92% of all cases. The resulting root-mean-squared errors were 0.32 to 0.96 millimeters and 0.81 to 1.87 degrees.

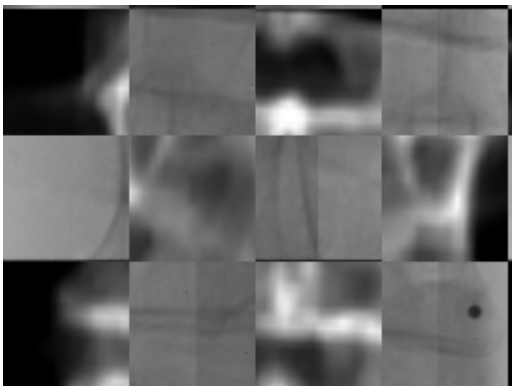
CONCLUSIONS

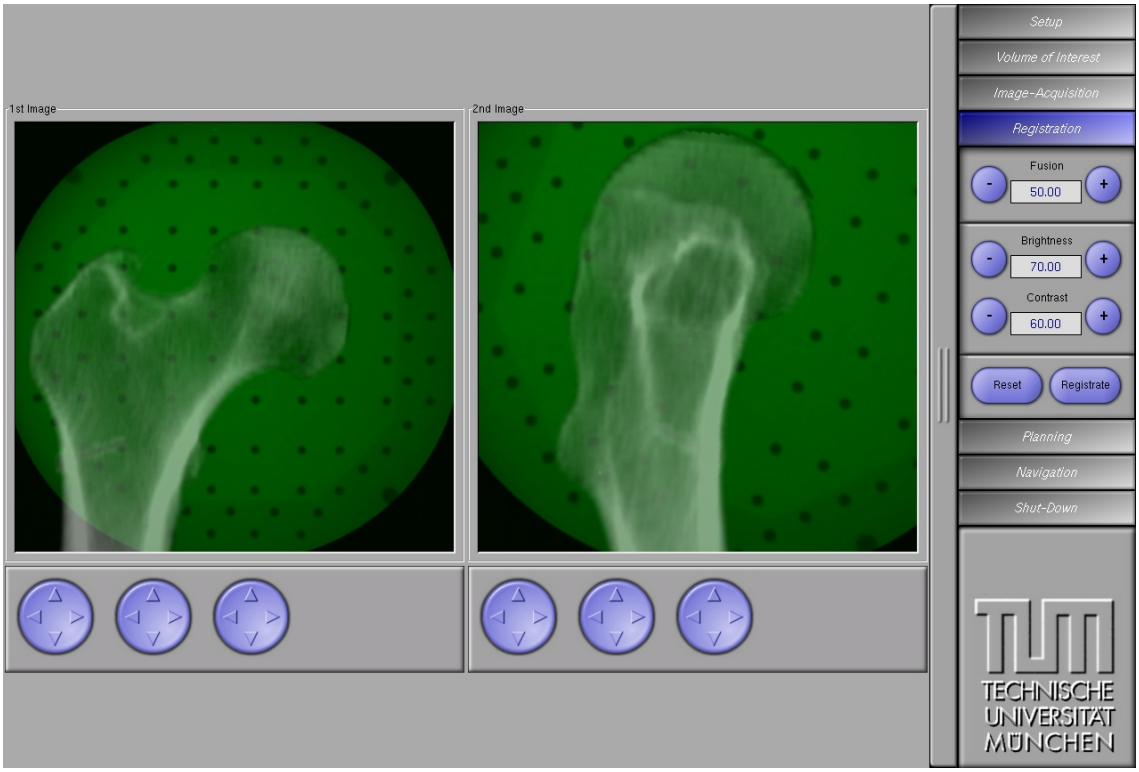
We present our algorithm for intensity-based fluoroscopy-to-CT registration.
Pattern search, a specific optimization strategy, is introduced. This technique is particularly well suited with regard to speed due to its implicit minimization of the overall number of function evaluations (i.e. DRR calculations during registration).

An additional speed-up is obtained by using state-of-the-art graphics hardware for DRR generation. Several experiments show that our generic approach may be suitable for orthopaedic scenarios with respect to robustness, accuracy and speed as well.

We conducted these experiments using our own datasets as well as a freely available „gold standard" dataset of a human cadaver spine.



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