Abstract
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Titel
Röntgenbasierte Bohrerführung zur Unterstützung von Marknageloperationen

Title
X-Ray based Drill Guidance to Support Intramedullary Nailing

Keywords
Hough Transformation, Image Analysis, X-Ray, Drill Guidance, Bayesian Estimation

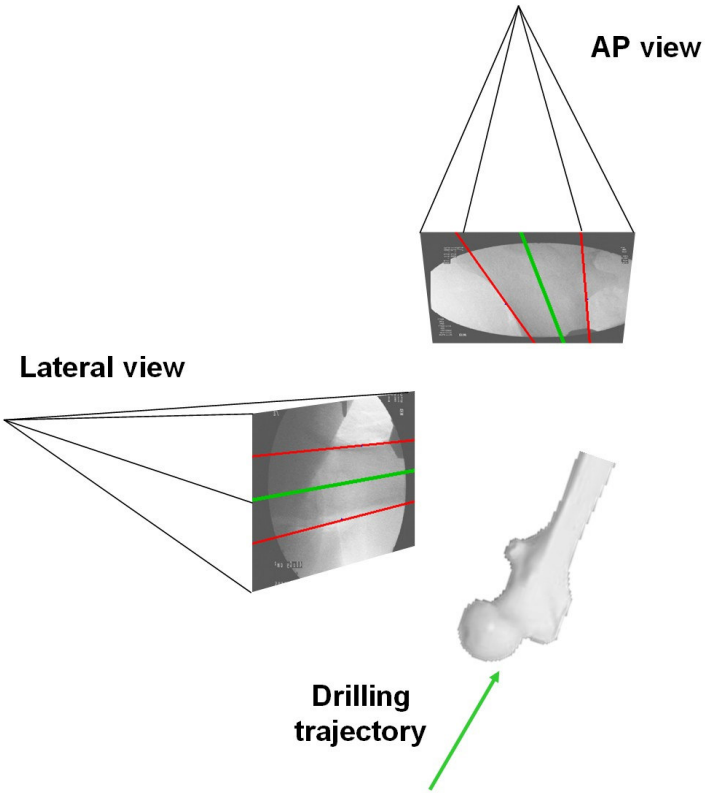
Purpose
The intramedullary nailing procedure as treatment for femoral shaft fractures requires the insertion of an intramedullary nail into the bone's cavity. The approach to the insertion point at the fossa piriformis at the hip, in extension of the femoral shaft axis, is complicated by the musculus glutaeus medius and can lead to soft tissue damages which might result into abduction weaknesses (Trendelenburg), heterotopic ossifications, and hip pain.
The distal locking of the completely inserted nail often requires a great number of X-ray images to correctly place screws into given holes of the nail.
The presented algorithms to automatically compute the required drilling trajectories can reduce operation time, X-ray exposure, and soft tissue damage.

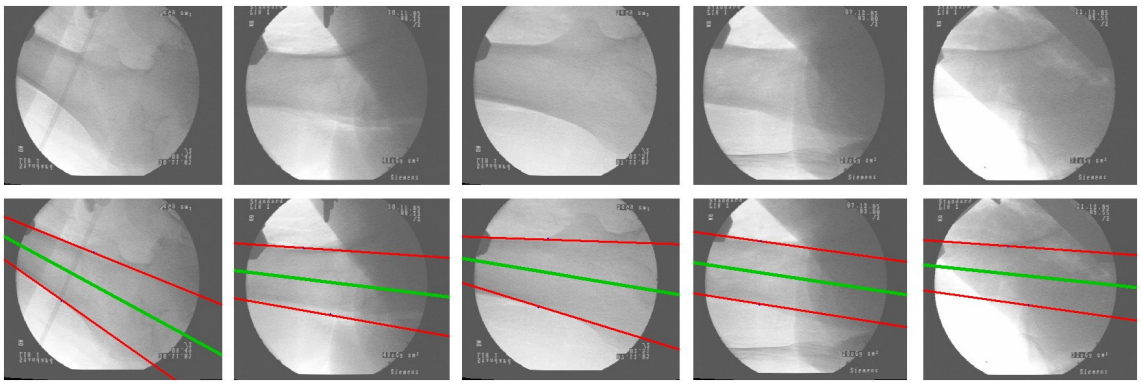
Method
The 3D drilling trajectories are computed from 2D X-ray images with feature detection algorithms solely based on 2D image analysis methods.
For the opening of the medullar cavity, we assume an almost straight line bone silhouette in the relevant region of the X-ray image. Furthermore, the desired drilling trajectory is assumed to be in the center between the two bone border lines. To detect these border lines, we begin with a preprocessing step consisting of median filtering and edge detection. On the resulting gradient image, we execute a weighted Hough transformation for lines. In order to reliably detect all relevant clusters in the Hough space, we use an extension of the Hough transformation called "identify and replace". From the eventually great number of possible lines returned from the Hough transformation, the two, which are most likely to being the bone borders, have to be selected. Therefore we use Bayesian probability estimation, with which we compute probabilities for all combinations of two lines. The probability estimation

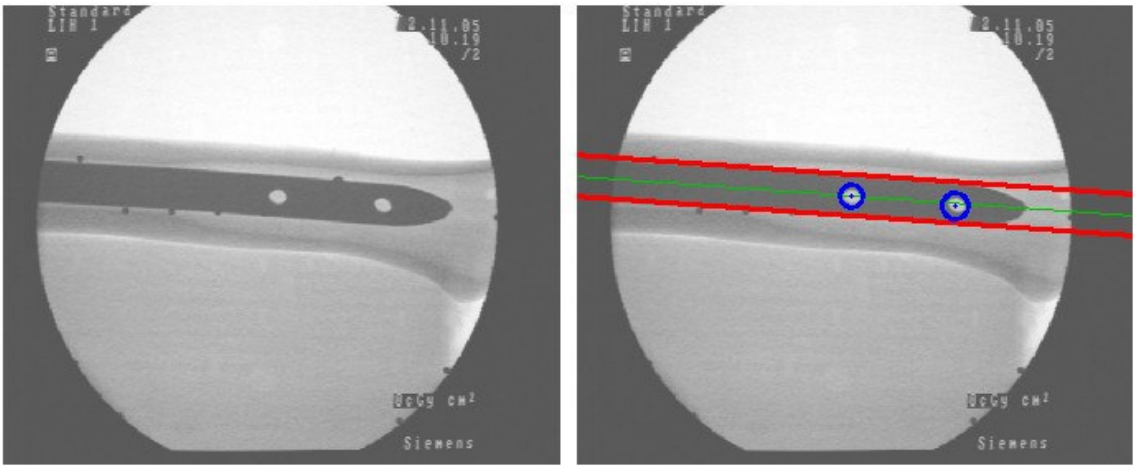
is a combination of several measurements like gradient, distance, parallelism, and grayscale profile between the lines. The combination of two lines with the highest probability is used as the bone border from which the drilling trajectory is computed as line in their center within the X-ray image. By using two X-ray images from (approximately) orthogonal viewing directions, the 3D drilling trajectory can be computed.
Computing the drilling trajectories for the distal locking is very similar. To detect the nail within the images only the distance weighting function and the grayscale profile have to be adapted. The screw holes are detected using the Hough transformation for circles within the region between the two border lines of the detected nail.

Results
We tested the algorithms on X-ray images acquired from human specimens. The desired drilling trajectories could be computed for all images. The computation of the drilling trajectory for nail insertion takes about 5 and for the distal locking about 17 seconds on an AMD Athlon XP 2000+ for a 716x564 pixel X-ray image.

Conclusion
The presented algorithms performed absolutely reliable on all X-ray images which we have acquired so far. As these images have been acquired on complete human specimens under conditions comparable to real surgeries, we are very confident, that they will work in real surgical situations as well.
The required computation times make this algorithm unsuitable for real-time applications. However, for the presented application, these execution times are absolutely sufficient, in our opinion. There are surely possibilities to further improve computation times, for example by using a multi-resolution approach starting with a downscaled X-ray image.
The presented algorithms can be integrated easily into available surgical navigation systems. We have integrated these methods into our set-up for robot assisted fracture reduction. In this way, we can use a robot as completely automated drill guidance system. Our next steps will be to evaluate accuracies of the computed drilling trajectory and the robotized drill guidance.


AP view
Lateral view
Drilling
trajectory

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