# Tracking of Anatomical Structures in 4D Kinematic MRI

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## Introduction

Starting in the late eighties, MRI has been used for imaging of moving joints [1-3]. Most approaches were based on fast 2D imaging, which limited the study to a single predefined view of a few anatomical structures. In addition, devices are needed to restrain a part of the joint, so as to keep the anatomy of interest in the imaging plane [4], thereby limiting the freedom of movement.

MRI is capable of acquiring time series of n 3D images, which gives a 4D examination that can be used for kinematic joint imaging of an unrestricted joint. Furthermore, 4D data acquisition greatly simplifies scan planning, because it obviates the need for defining and tracking the diagnostically relevant 2D view during image acquisition. However, slice-by-slice viewing of the 4D images is cumbersome, and does not allow to appreciate the movement. Simply presenting slice data in a cine-loop will be compromised by through-plane displacements of anatomy and "jerks" between frames, both of which hamper visual analysis of the movement.

We have implemented a workstation for viewing 4D kinematic MRI datasets that addresses the following requirements. 1) The motion of any anatomy can be viewed from any perspective. 2) The user can define an object of interest, e.g. the distal femur in kinematic joint imaging of the knee, which should remain fixed in the viewing plane during the movement. 3) The user interaction is reflected immediately in the viewing plane.

## Method

The key functionality of our application is the fixation of any user-defined object by image post processing. This fixation comprises two steps. First, the movement of an anatomical structure through all 3D data sets is calculated by motion tracking. The object of interest is defined interactively by setting reference points in *one* of the 3D data sets. These points are propagated to the other data sets using a motion estimator, calculated in advance by an elastic registration of all data sets. The tracking of the object of interest is then calculated by rigid point-based registration of the *n* sets of reference points using singular value decomposition [5]. Secondly, the inverse of the transformation defined by the tracking is used to align the 3D data sets, such that the defined objects of interest remain stable when presented in cine-loop. Four-dimensional kinematic MR datasets of the knee and the shoulder were obtained using T1-weighted 3D gradient echo sequences (FoV $400^2$x$180mm^3$, Matrix $256^2$x100, TR/TE 3,2/1,6ms ,$\alpha$ $30^o$) for 7 different positions of the joint studied.

## Results

Our approach has been tested by tracking various user-defined objects like the femur, the tibia and the scapula in 4D kinematic MR images (Fast Gradient Echo Sequences) of the knee and the shoulder. In all cases, the defined objects of interest are fixed sufficiently, preventing in-plane and through-plane motion. The fixation of the femur is depicted in Fig.1. The position of the distal part of the femur and the orientation of the femur's shaft remain the same during the movement from the fully stretched (Fig.1 A) to the maximally inflected knee (Fig.1 C). Following new user interaction, e.g. changing the viewing perspective or redefining the anatomy of interest, a tracked kinematic sequence is calculated instantaneously from the 4D MR data set, the stored elastic registration and the user-defined reference points.

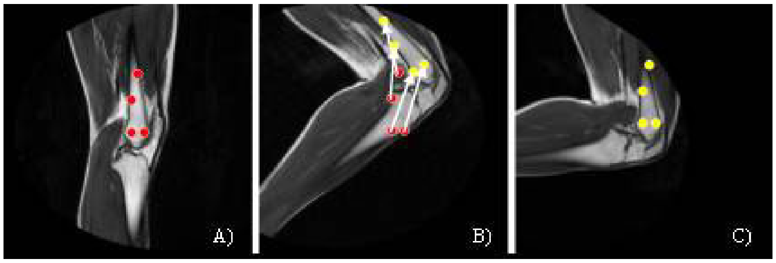


Figure1: A) Reference points are placed in the first frame. B) The motion of reference points is estimated from pre-computed elastic registration. C) The viewing plane is adapted to remove motion of reference points.

## Discussion

The calculation of the motion estimator is one of the crucial steps of the proposed approach. We have tested two different methods based on B-Splines [6] and adaptive Gaussian forces [7], respectively. Both methods provide acceptable motion estimators that differ only marginally from each other. Another crucial step is the definition of reference points by the user. At least 3 non-collinear points are required to define an object, where the points should be distributed evenly at its borders.

In conclusion, we have developed a workstation that facilitates viewing of 4D kinematic data sets. It allows looking at *any* user defined anatomical structure from *any* viewing perspective. Smoothly displaying the movement in a cine-loop is realized by image post processing, fixing any user defined anatomical structures *after* image acquisition.

## References

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