

Checking b-vector alignment

Chris Rorden, Michael Harms, Jolinda Smith, Nytavia Wallace :: March 31, 2011

In diffusion tensor imaging (DTI) we construct tensors by collecting a series of direction-sensitive diffusion images. In addition to recording the images, the scanner saves these directions, which are later used to reconstruct diffusion properties. Therefore, popular DICOM image conversion tools (dcm2nii, MRIconvert) will generate both NIfTI format images (e.g. 'dti.nii') as well as gradient vector ('dti.bvec') and b-value ('dti.bval') files. A potential concern is that the scanner manufacturers can choose to either report the vectors with reference to the scanner bore, or with reference to the imaging plane (i.e., imaging grid). This is not a problem if the images are always acquired precisely orthogonal to the scanner bore (Figure 1), as the image and scanner have the same frame of reference. However, problems can arise when the image plane is not aligned with the scanner bore (i.e., oblique acquisitions). In this situation, it is important to ensure that the vectors provided to FSL or MedInria are in the same frame of reference as the image, regardless of how they were stored in the DICOM file. It should be noted that these angulation errors will have little influence on DTI parameters that are invariant to tensor rotation, such as ADC, MD and FA. However, the eigenvectors of the tensor, and consequently tractography programs are sensitive to proper interpretation of the bvecs relative to the imaging plane.

Unfortunately, there remains some confusion regarding how different scanner manufacturers, and different software versions for a given manufacturer, store gradient vectors within their DICOMs. Therefore if you plan to use the tensor eigenvectors or conduct tractography we recommend that you collect test datasets to ensure that your data is converted correctly for your scanner type and software version. Here we describe an easy way to do this. Importantly, small angulation errors in bvec orientation are hard to detect as the vectors are three dimensional, and most tracts curve across your imaging plane. Therefore, a good place to look for errors in bvec orientation is the corpus callosum – a major fiber bundle where the fibers run in an almost perfect left-right direction at the midline. Therefore, to check tract directions, we recommend acquiring an image where the roll angle of the imaging plane is dramatically different from the scanner bore, but the pitch and yaw remain orthogonal to the scanner bore (Figure 2). In this case, a dramatic error will be seen in the corpus callosum if the bvec directions created by your image conversion software are not aligned with the image grid (assuming that the DTI software you are using expects the bvecs to be specified relative to the image grid, which is the case for FSL).

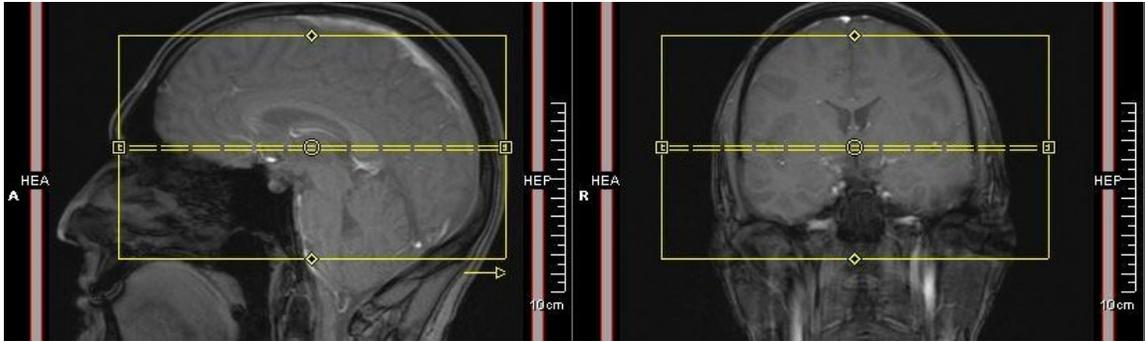


Figure 1: Image acquired orthogonal to scanner bore

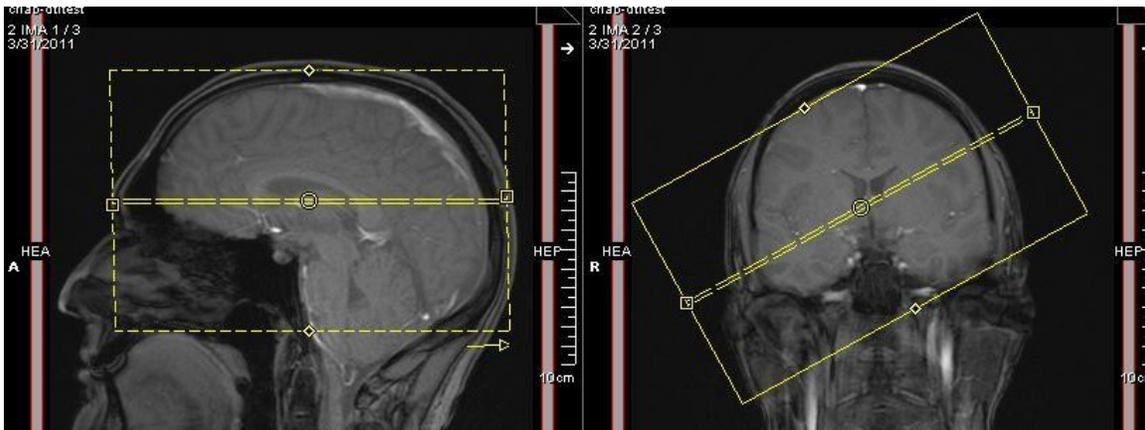


Figure 2: Image acquired with slice orientation rotated relative to the scanner bore (a roll has been applied in this example).

We suggest computing the first eigenvectors of the tensor with FSL, and then displaying these vectors as lines, using a procedure described on our web page (www.cabiatl.com/Resources/Course/tutorial/html/dti.html). Figure 3 shows an example of an accurately aligned versus a misaligned set of first eigenvectors.

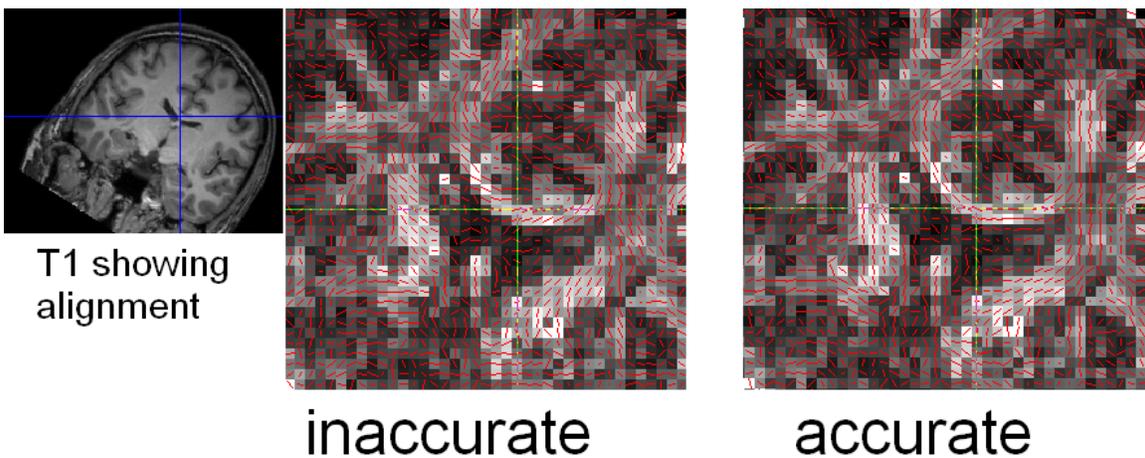


Figure 3: Lines on each voxel show the estimated fiber direction based on the first eigenvector of the calculated diffusion tensor. Cross-hairs indicate the corpus callosum, which should run from the left to right hemisphere. Note the first eigenvectors of the

tensor in the middle panel are misaligned, whereas they are accurately aligned with the anatomy in the right panel.

Note that you need to make sure the *lines* follow the anatomy of the oblique acquisition. If a *color (RGB)* display of the directions was used above, the colors will not match what you typically expect because of the oblique nature of the acquisition (i.e., pure red would reflect the direction of the first axis of the image grid, which will NOT be equivalent to the true left-right axis of the subject's own anatomy due to the roll applied to the acquisition, and thus voxels in the center of the corpus callosum would NOT show as pure red).

When creating image conversion software, we try to set default conversion values that we believe will yield bvects whose direction is defined relative to the image grid. However, we only have access to a limited number of scanners and systems, and therefore we encourage all users who wish to have accurately oriented tensors to conduct a quick validation with their system, and report any problems to the developers of dcm2nii and MRIconvert.

As regards Siemen's scanners specifically, the latest versions of dcm2nii (from April 2011) now include three different values that allow you to customize how dcm2nii converts your Siemens DICOM images. These can be seen by editing your .ini file with a text editor (the location of this ini file is reported when you run dcm2nii and dcm2niigui).

These values and their current default settings are:

- SiemensDTIUse0019If00181020atleast=15
- SiemensDTINoAngulationCorrectionIf00181020atleast=1000
- SiemensDTIStackIf00181020atleast=15

The number for each value allows you to adjust how images will be converted, relative to the version of Siemens software you are using. When you convert a Siemens DTI image with dcm2nii you will be told the version of Siemens software detected and the current conversion defaults. For example:

Number of diffusion directions = 31

Note: detected Siemens Software version [0018:1020] = 17

-Will use 0019:000E or 0019:100E instead of 0029:1020 if version >= 15

-Will stack across Acquisitions if version >=15

-No slice angulation correction of vectors if version >=1000

To adjust, edit C:\pas\mricron\dcm2nii\dcm2niigui.ini

The meaning of these settings are as follows:

- SiemensDTIUse0019If00181020atleast=15: Siemens stores the vector values in both the main DICOM header (tags 0019:000E or 0019:100E) as well as a hidden shadow header (part of the CSA header in 0029:1010). In older versions of Siemens software the DICOM values in 0019:100E were either absent or considered inaccurate.

- `SiemensDTINoAngulationCorrectionIf00181020atleast=1000`: As long as the system version is less than 1000, the `bvec` values extracted from the DICOM header will be rotated to compensate for the image plane. For higher versions, images will not be rotated (note that the current Siemens software version is VB17 (and VD11), so by default all Siemens DTI data will be rotated).
- `SiemensDTIStackIf00181020atleast=15`: While most sequences store data from a single sequence as a single acquisition with a series of images, Siemens scanners can actually save each direction and each average as a different acquisition. This feature should automatically collapse across these, creating a single NIfTI file. If this is not set correctly, you may find that your DICOM image is converted into a series of NIfTI images (e.g. one image per `nEx`). These problems are usually pretty easy to detect.

Last, two additional notes:

- 1) The issue of `bvec` rotation is not strictly limited to oblique acquisitions. For example, if you collect a strictly coronal acquisition under Siemens VB13, VB15, or VB17, and you don't apply an angulation correction to the directions stored in the DICOM, then your ensuing `bvecs` will not be correctly specified relative to the imaging grid. [Specifically, the NIfTI file returned by `dcm2nii` will be oriented +LSP (left-superior-posterior), while the directions coded in the DICOM itself will follow a +LPS convention (consistent with the DICOM standard)]. Similarly, strictly sagittal acquisitions would require angulation correction (i.e., rotation) of the `bvecs` stored in the Siemens' DICOMs as well.
- 2) If you manually reorient the imaging grid following use of `dcm2nii` (e.g., using `'fslreorient2std'`), then you also need to account for that reorienting on the `bvecs` as well.