Representative Colour Schemes For Visualisation Of Diffusion Tensor Tractography Data

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Introduction: RGB colour schemes for representing the orientation of the principal diffusion direction from diffusion tensor images (DTIs) have previously been reported (1). Here we present novel techniques for generating tract specific RGB colours based on streamline diffusion tensor tractography (DTT) termination coordinates in standard space. These allow visualization of the anatomy of streamlines through the entire brain coloured according to the location of termination coordinates in stereotaxic space. These colour schemes therefore allow visual comparisons between similar white matter pathways delineated in multiple subjects. Two techniques are presented; firstly a technique for colouring streamlines throughout the entire brain (referred to as the streamline termination colour map (STC)), and secondly a technique that colours streamlines according to mirror symmetry about the mid-sagittal plane (x = 0) in standard space (referred to as the symmetrical streamline termination colour map (SSTC)). A novel technique for modulating the STC and SSTC brightness by streamline length is also presented.

Methods: *MRI data acquisition:* Two young healthy subjects were scanned on a 1.5T GE Signa MRI system (max. field gradient strength 22mTm^{-1}). DTI was achieved using a single shot echo planar sequence with 12 diffusion sensitised directions as described previously (2). Two interleaved acquisitions comprising 25 slices each provided whole brain coverage (resolution: in plane 2.5mm; through plane 2.8mm). Each DTI was normalised to standard space by affine transformation (3).

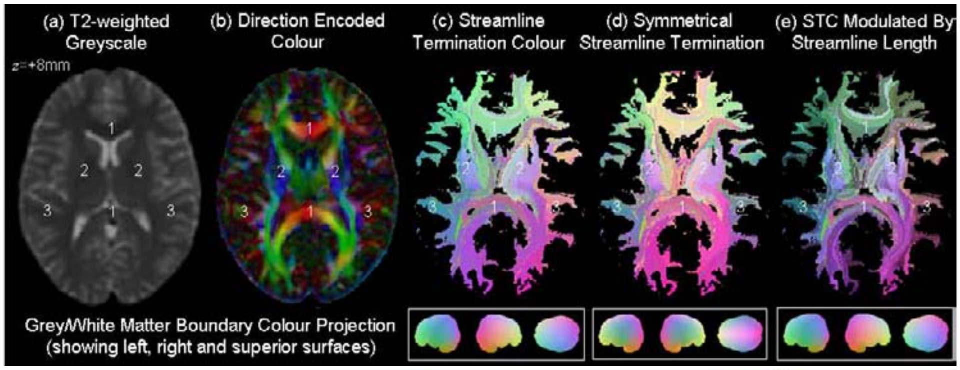
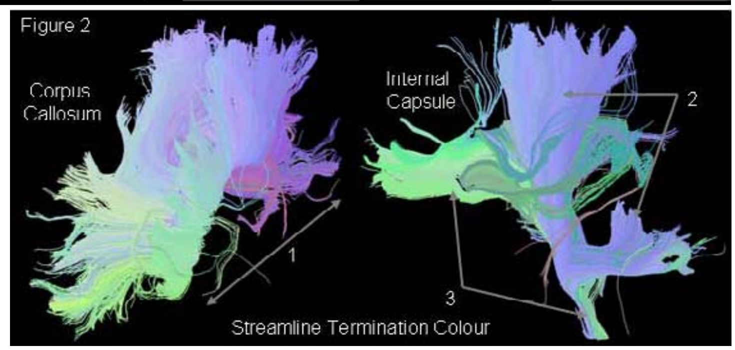


Figure 1

Tractography: Subvoxel streamline DTT was performed as described previously (2). Streamlines (vector step length 1.0mm, termination criteria FA < 0.1) were initiated from every voxel centre in the acquired space of each DTI. Streamline lengths and termination coordinates $t_1(x,y,z)$ and $t_2(x,y,z)$ were computed and transformed to standard space. Coordinate t_1 was defined as lying more inferior to t_2 in standard space.



Streamline Termination Colour Schemes: For the STC, x termination coordinates were converted to 8bit numbers such that all coordinates lay between 0 (at the left of standard space) and 255 (at the right). For the SSTC, x termination coordinates were scaled to 8bit numbers such that all coordinates lay between 0 and 255 (from 0 at the left of standard space to 255 at the mid-sagittal plane and then to 0 at the right of standard space). In both the STC and SSTC maps the y (and z) termination coordinates were scaled from 0 at the posterior (inferior) of the brain to 255 at the anterior (superior) of standard space. These termination coordinates were then converted to 4bit numbers (using division by 16) and placed adjacent to one another to form 8bit numbers representing both termination coordinates. These composite numbers were mapped to an RGB colour such that RED corresponds to the x coordinate, GREEN to y and BLUE to z. Modulation of colour brightness by length was provided by a scaling factor proportional to the length of the tracked streamline.

Results: STC and SSTC allow visualisation of individual white matter structures in the human brain. Axial slices in standard space are shown in Figure 1 where numeric labels highlight several white matter pathways that connect different brain regions. White matter pathways are coloured differently from anterior to posterior along the corpus callosum (Figure 1, Label 1) in the STC and SSTC. In addition, white matter pathways ascending and descending through the internal capsules (Figure 1, Label 2) are coloured differently in the left and right hemispheres of the STC (Figure 1c), but the same in the SSTC due to mirror symmetry (Figure 1d). The same effect is visible in the superior temporal lobe (Figure 1c&d, Label 3). Modulation by streamline length allows short and long pathways to be visualised (Figure 1e) by representing shorter (arcuate fibres) and longer (association and commisural) pathways with darker and lighter colours.

Figure 2 shows normalised STC streamlines. The left image shows different colours from anterior to posterior along the corpus callosum (Label 1). These are coloured from green (at the anterior) through blue to pink (at the posterior). Furthermore, different white matter structures forming the lateral surface of the left internal capsule pathways are coloured differently (right image). Pathways passing between the cerebellum/brain stem and the anterior frontal and superior frontal and parietal lobes are coloured according to their termination coordinates in standard space (light green [Label 2] and blue [Label 3], respectively) with temporal lobe pathways coloured dark green.

Figure 3 shows the left motor and somatosensory pathways between the spinal cord and the cerebral cortex using radiological convention in the acquired space as coloured by SSTC. Anatomically the motor pathways pass from the motor cortex through the ventral part of the brain stem, whereas the somatosensory pathways pass through the dorsal section of the brain stem and the thalamus to the sensory cortex. As somatosensory pathways have greater curvature and consequently greater length the two pathways may be visually discriminated by modulating streamline termination colour maps by length. Figure 3 shows that the two pathways are of different brightness (Label 1 corresponds to the [darker/shorter] motor pathway and Label 2 to the [lighter/brighter] somatosensory pathway).

Discussion: We have presented novel techniques for visualising tract anatomy in standard space as inferred from streamline DTT. These schemes will allow visual comparisons between similar white matter pathways delineated in multiple subjects. Furthermore, we have shown the utility of the length modulated technique for distinguishing between pathways with similar termination coordinates but different pathway morphology. These techniques may be useful for neurosurgical planning and other clinical applications in which unambiguous visualisation of white matter pathways is required.

References

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