2019-08-01

Virtual Dissection of White Matter Tracts in a Human brain using applied Game Design and Virtual Reality imaging

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Virtual dissection of white matter tracts in a human brain using applied Game Design and Virtual Reality imaging

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Introduction

Spatial visualisation of tractography and human brain structures

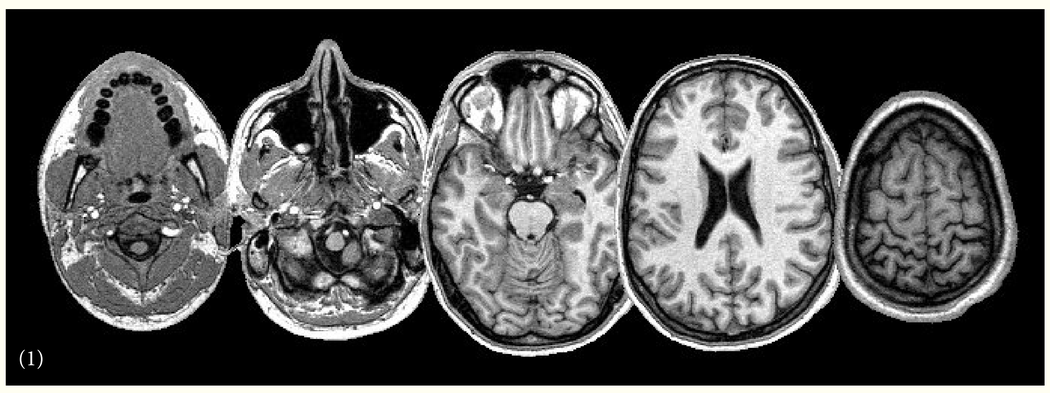
Visualisation of neural tracts in the human brain has previously been accomplished using two dimensional (2D) representational formats.

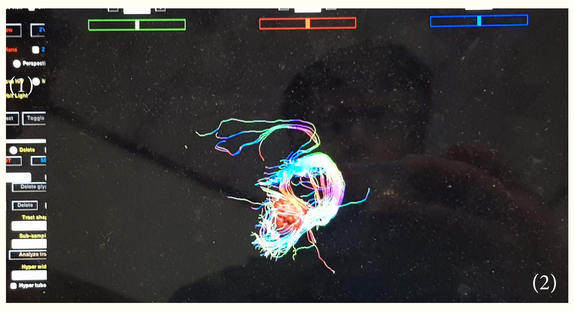
In most cases, pre-operative visualisation is through the medium of greyscale 2D MRI image slices. These MRI image slices can only represent a slice or cross section of a human brain, and generally are only viewed from one Cartesian axis at a time.

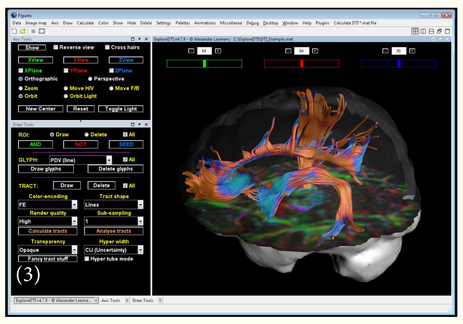
Software such as ExploreDTI can assist with visualising off-axis viewpoints - however this method is limited to 2.5D image representations, which lack depth perception and spatial control. The use of such 2D representations can require significant training in order to contextualise real-world 3D positions and accurately locate and identify neural tract pathways in the brain.

Aims

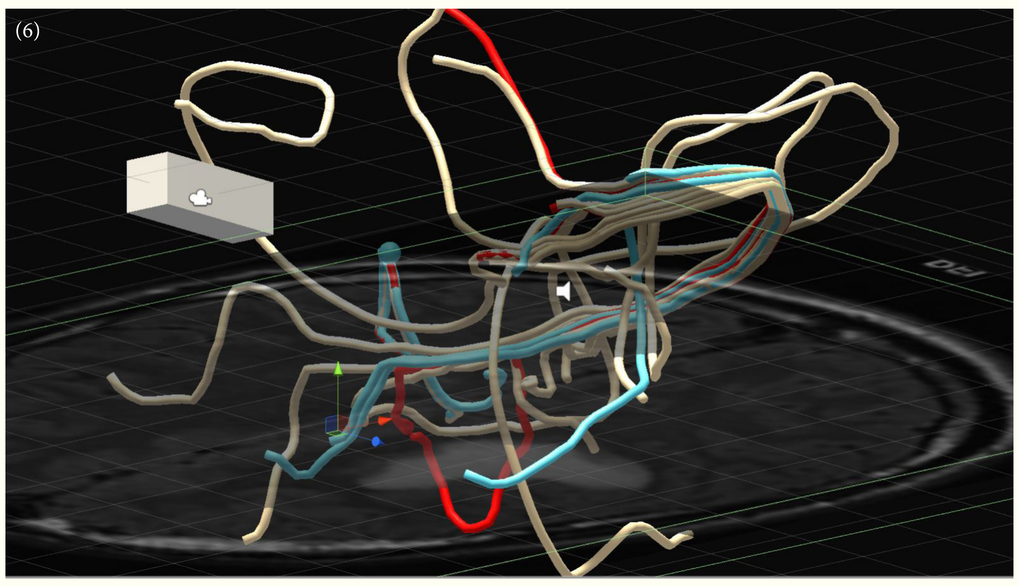
To investigate the possibility of addressing the above limitations of current visualisation software, a prototype tractography visualisation tool was created using a game engine (software typically used to create video games).

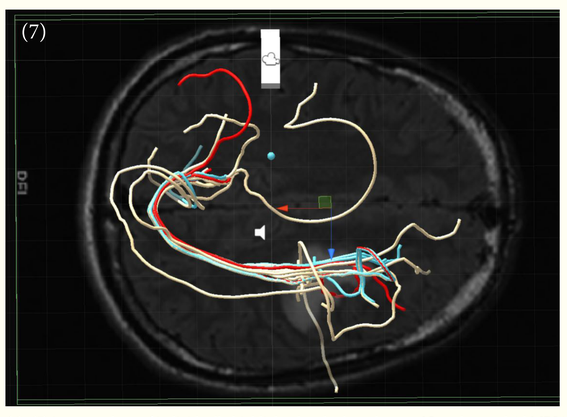






(1) is a 5 slice collection of MRI images showing different depths on the axial plane. Note while it is possible to identify the axial depth of each image, it is difficult to reconcile with an actual patient's head. Additionally, a tract moving through these slices would only be represented by a point on each slice, making it difficult to track a tract direction.
(2) and (3) are representations of tractography taken from the open source software ExploreDTI. While it is much easier to distinguish the direction of tract travel, it is still difficult to identify and distinguish individual tracts and to follow direction of tract travel.





(6), (7) in-game shots of individually highlighted and selected tracts. Note the overlaid MRI image scan as proof of concept of the ability to integrate traditional MRI image scans
(8) An undergraduate student testing the prototype application - time from training to full use was under 2 minutes (permission to use image granted by student)

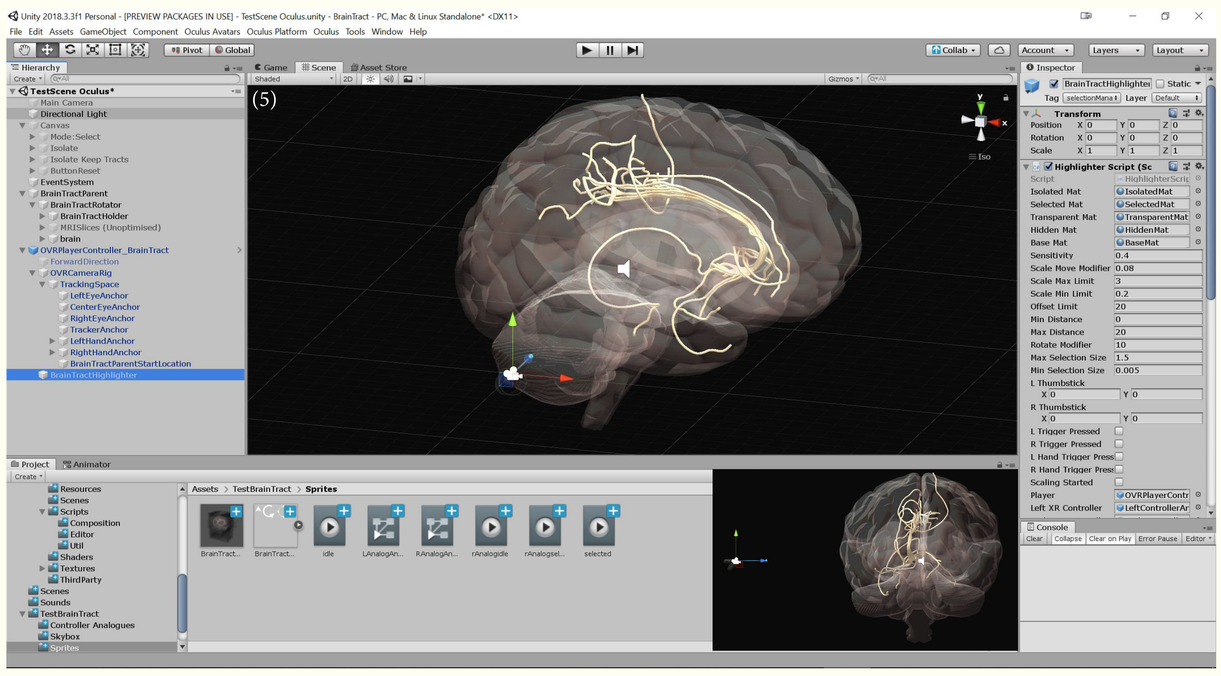
Method

(4) iAn Oculus Rift Touch Virtual Reality headset. The Main headset allows a viewer to experience a 3D environment, in this case a 3D model of a human brain and associated tractography. Two controllers, one in each hand, allow manipulation of the scene and selecting/deselecting tracts for easier visualisation. The four trackers allow for extremely accurate tracking of the viewer's head and hand movements.
(4.1) Unity 3D logo - Unity 3D was the primary software utilised to create the virtual reality environment for tractography visualisation, as well as to provide user feedback through visual and audio cues.

Format conversion and scale compensation

Utilising anonymised tract data and advanced neuroimaging technologies pioneered by Trinity College Institute of Neuroscience (TCIN), the Technological University Dublin (TU Dublin) School of Media created an interactive visualisation environment using the Unity 3D game engine. This virtual reality visualisation utilises the Oculus Rift Virtual Reality (VR) peripheral to realise the first ever virtual dissection of the fornix in-vivo in a highly interactive full 3D environment.
Ethical approval was granted by St James/Tallaght Research & Ethics Committee.

MRI tract coordinate point to point pathway data was converted to .wrl format 3D objects. They were then further converted to game-engine ready formats such as .obj through a 3D editing program (3DS Max) and imported into Unity. A virtual representation of a human brain was created, and scale, position, and rotation manipulation of the VR environment implemented, using natural motion tracking and minimal button usage. Isolation of individual or groups of neural tracts was achieved using hand tracking and spatial selection. Positional data was mapped to MRI image planes in order to overlay traditional MRI images at each position to aid diagnostic accuracy.



(5) A screenshot of the Unity project - note the ability to track head space, eyes and hand positions, as well as the options to create an array of tracts for individual manipulation (hiding, moving, highlighting etc.) In addition to manipulation of the tracts, full movement, scale and position control of the brain representation is possible. User avatar movement was not implemented due to an associated need to provide spatial references and movement feedback, as well as to avoid potential nausea.

Conclusion

Prototype Application

In summary, virtual dissection of the fornix pathway in the human brain, first individuated by TCIN was transcribed into a 3D VR gaming environment for spatially intuitive visualisation, manipulation, and analysis.
The use of universal game design principles allowed extremely quick training of unfamiliar users, often under 5 minutes for basic navigation.

Initial tests suggested greater depth perception, spatial accuracy and ease of navigation. Users reported greater understanding of tract pathways, suggesting potential application in education or pre-operative visualisation.

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(4) OculusVR, Oculus Logo, OculusVR, image accessed https://en.oculusbrand.com/wp-content/uploads/2019/04/o_vert.jpg 31 July 2019
(4.1) Unity Technologies, Unity Logo, Unity Technologies, image accessed from repository: https://unity3d.com/public-relations/downloads 31 July 2019
(5) Basil Lim, 26 Mar 2019, Screen capture BrainTract Unity project
(6), (7) Basil Lim, 26 Mar 2019, Screen capture BrainTract Unity project (in-game) with highlighted tracts and MRI slices overlaid
(8) Basil Lim, 26 Mar 2019, image taken of test user (name withheld) testing BrainTract project

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