CHAPTER 1

DIGITAL. DICOM. VOXELS

Computer representation makes every image inherently mutable –
creating signs that are no longer just mobile but also forever
modifiable

(Manovich, 2001, p. 174)

…as we move into the digital, the aesthetics of form become more
and more involved in the aesthetics of the mutable form

(Lunenfeld, 2000, p. 65)

In the area of medical imaging, inscription technologies such as
X-ray, Ultrasound, and endoscopy seek to dispose of mediation
(such as an artist's drawing) and instead record the interior body
directly onto machine. The mechanical gaze into *living* bodies not
only enhanced the body's transparency, but also its manipulability.
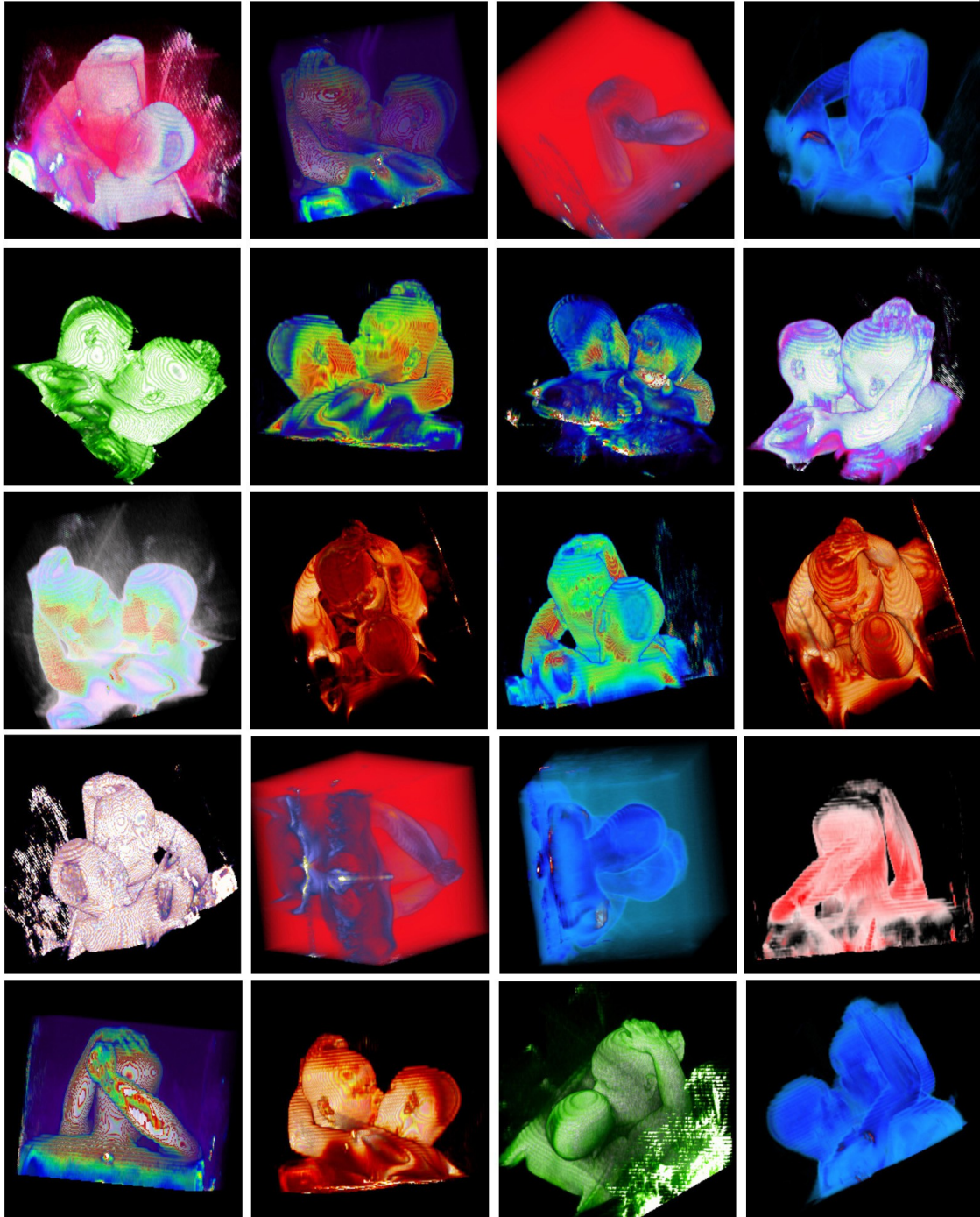
(van Dijck, 2005, p.15)

fig. 3 Composite of volume renderings of Kiss data

The x-ray, the first technology to see inside the body without having to cut it open, marked an important shift in the history of anatomy, especially in the relationship between the anatomical scientist and the anatomical artist. During the Renaissance, anatomists relied on artists to show the world what they had discovered. Artists were needed to promote the work of the anatomist and render it palatable. Artists framed anatomy with classical and mythological iconography: Andreas Vesalius' anatomical subjects adopt powerful and majestic poses reminiscent of Greek sculptures, arms raised or open, fingers pointing to the sky or ground, reminding us that the human body is God's divine creation. The Specola Collection in Florence offers encounters with wax female anatomical subjects presented on silk sheets, long hair flows around the curves of breasts and hips, eyes and mouths half open suggesting the sexual openness reminiscent of classical depictions of Venus.[i] Artists cleansed the anatomical subject of blood, putrification and decay through subjective and art historical aesthetisation.

Fig 4. Detail of *Ostetricia, 968, Specola Collection*

In the nineteenth century the subjective interpretation of anatomical subjects was no longer favoured and 'scientists hoped to eliminate artistic contamination' (Van Dijck, 2005, p. 50). X-ray and the subsequent interior body imaging facilitated just that – the artist/draughtsman was no longer needed to render the interior body visible – machines could now do it in their place objectively. Since the first ever X-ray taken by Röntgen in 1897, non invasive medical

imaging technologies have developed to such an extent that radiology departments have become central to almost all hospitals and MRI, CT and PET scans are now part of our visual vocabulary. We now accept and are familiar with representations of the body as grayscale and high contrast (as with the x-ray aesthetic) or colourful and map-like (as with the colour coded PET scans regularly used by newspapers to illustrate science stories).

The evolution of these imaging technologies is complex and has involved many different industries including photography, television and physics. One of the most important recent contributors to the development of radiological imaging was the computer in the 1980s. Like photography, medical scanning has become increasingly digital and traditional methods of scans being exposed and stored on film have now been largely replaced by digital archiving, with scans remaining entirely screen-based.[ii] Through a series of complicated technical procedures (some of which will be outlined later in this chapter) machines now 'render the body, or more precisely the appearance of the body, into digital information, decomposing the body's fleshy complexity into the simple on/off logic of binary code' (Waldby, 2000, p. 28). Raphael Cuir (2008) argues that the desire to "Know Thyself"[iii] as anatomical knowledge has now been replaced with a desire to "Know Thyself" as matter, as space, as an object of science, an object of science fiction. The body converted to code/data facilitates this kind of quest for knowledge. Digital medical imaging technologies and the software created to work with the data they acquire (generically referred to by the acronym DICOM (Digital Imaging and Communications Data Digital)) allow us to convert our bodies to data and make it possible to plot our of inner and outer physical boundaries, measure and chart our physical matter, experience of ourselves as objects of science and, as will be discussed in Chapter 3, enable us to animate ourselves as objects of science fiction.

Although most commonly viewed as flat images, DICOM data actually has three dimensions. The units of data within the scanned volumes are called voxels. Voxels are similar to pixels in that they are a unit of data with colour and opacity values but instead of being flat squares, they are cubes and thus have additional width, depth, height and positional x,y and z values. Whereas an image file is made up of many pixels with different colour and opacity values that come together to create a flat image, voxels come together to create dense cubes, of images or in radiology terms, a 3D DICOM dataset.

The fact that DICOM is a 3D volumetric dataset makes it in many ways superior to previous

anatomical representations. An x-ray would only allow a pathology to be viewed from one angle and one set density, with DICOM, pathologies can be viewed and understood from every angle. Like the corpses they represent, wax sculptures cannot be cut open without inflicting permanent damage whereas DICOM datasets can be sliced and resliced endlessly. As a result of increasingly sophisticated DICOM viewer software, a single DICOM dataset can be viewed as a time based movie (Flythrough), a volume rendering, a polygonal surface, as well as a series of static images.
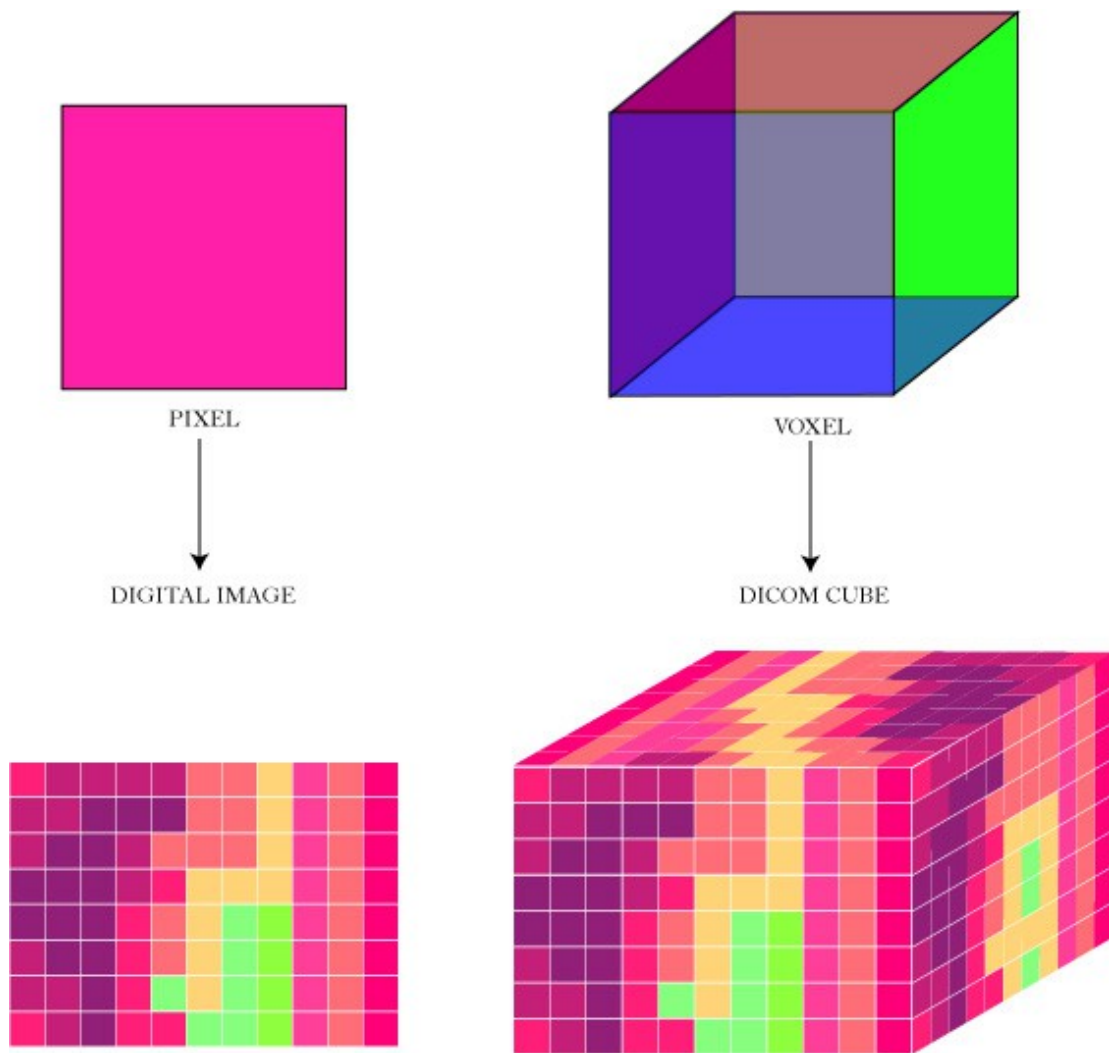

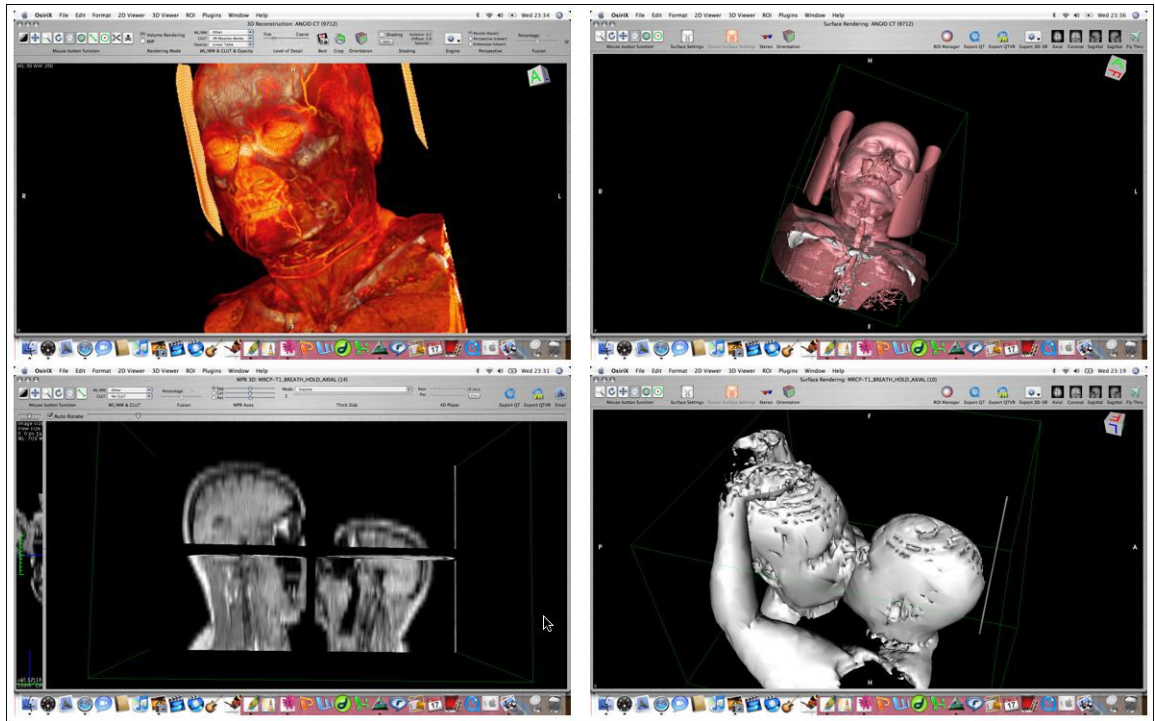Fig. 5 Diagram to show difference between a pixel and a voxel

Fig. 6 Screen grabs from OsiriX showing (from top left to bottom right) a volume rendering of MANIX dataset, a surface rendering of MANIX dataset, a mutliplanar reconstruction of Kiss dataset and surface rendering of Kiss dataset.

Here follows a brief technical explanation of the two most common scanning modalities that yield DICOM data: Magnetic Resonance Imaging and Computer Tomography. The explanations are informed by both theoretical radiology textbooks and a period of observation at the Paul Strickland Scanner Centre[iv].

MAGNETIC RESONANCE IMAGING

MRI works at an atomic level in the body in order to create images with very high soft tissue definition. Generally the two extremes of contrast in MRI are fat and water. As its name suggests, MRI involves altering the magnetic field surrounding the body so the patient / subject has to go inside a large magnetic coil. The scanner works by applying a hydrogen specific radio frequency pulse through the coil. The pulse causes the protons in the part of the body being scanned to absorb energy, which makes them spin, or precess, in a different direction (called resonance). When the radio frequency pulse is turned off, the hydrogen

protons begin to slowly return to their natural alignment within the magnetic field and release their excess stored energy. When they do this, they give off a signal that the magnetic coil picks up and sends to the computer system. What the system receives is mathematical data that is most commonly converted into a grayscale image. Depending on when the computer hears back from the unwinding protons the image either shows fat as dark and water bright (**T1** recovery) or fat as bright and water as dark (**T2** relaxation).[v]

Different scanners have different strength magnets. The strength of the magnets is measured in **Teslas**. In clinical radiology the most commonly used magnets have a strength of between 1.5 Teslas and 3 Teslas. The higher the Teslas count, the higher the resolution and the faster the scan can be acquired. Relative to other scanning modalities, MRI scanning is slow and as a result radiographers only scan the area needed. As a result the scans are bespoke: radiographers decide the frequency, angle, distance between the scans before the scan is performed. Other than the heating of the body and the loud clanging noise of the magnets during the scan there are no known harmful side effects (as long as you have no metal implants which can be dislodged by the magnets). This means that MRI is commonly used for research scans and can be used safely by artists for non-clinical reasons.
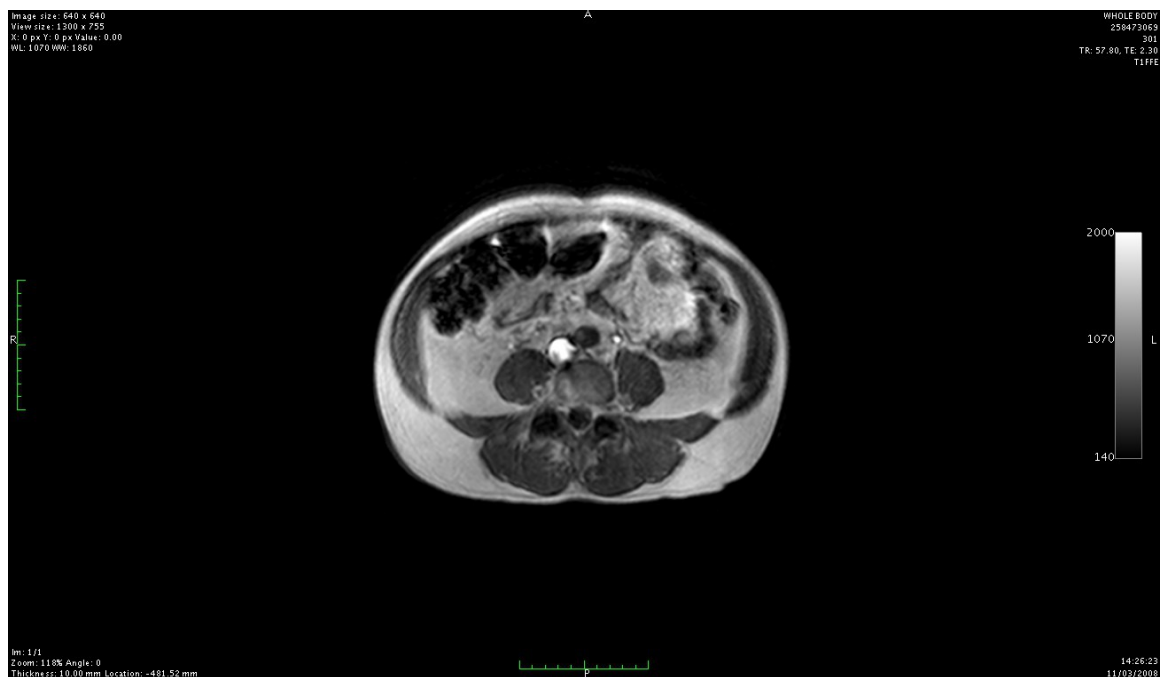

Fig. 7 MRI scan through abdomen (Dad dataset)

COMPUTER TOMOGRAPHY

Unlike MRI, CT scans cannot be performed for non-clinical research as the body is exposed to radiation during the scan. CT uses the same technology as the x-ray, a beam of light with a very small wavelength (smaller than UV and invisible to the eye). When x-rays travel through the body they are absorbed by the tissue and bone (different kinds of atoms); the harder the tissue (the bigger the atom) the more is absorbed. In a CT scanner an x-ray tube emits a fan of x-ray beams. This x-ray tube rotates around the subject of the scan. Outside the rotation sphere of the beam is a fixed ring of detectors that measures how many of the x-rays are being absorbed by the body. Rather than spin around the body, CT scanners now spiral around the body allowing dense and continuous datasets to be acquired. In recent years there has been a rapid development in CT scanners and the latest 64 slice machines boast being able to scan at sub millimetre intervals. [vi]

CT scans are much faster to acquire than MRI scans and as a result many more people can be scanned in a day. Although this is positive for NHS targets, it does not make for a pleasant scanning environment. Whereas in MRI the radiographer has the time to ensure the patient is comfortable and relaxed, the radiographer in CT needs to make sure they scan their patients as quickly as possible so as not to get behind on their long lists of patients.

Fig. 8 CT scan through head and raised arms (MELANIX DATASET)

Because CT takes such high-density information of the body there is no need for the radiographer to spend too much time setting up the scans – they just need to make sure the body is in the scanning range and then they perform the scan, which takes approximately two minutes. The data is post processed in order to give the radiologist/consultant the images of the body they need. To make organs more visible almost all patients are asked to drink a contrast agent before they have the scan as well as being administered an injection of iodine during the scan.

That which the two imaging modalities measure/show is therefore very different: MRI measures hydrogen in the body thus display the body as a system of fluids of varying viscosities, CT measures density so shows the body as hard and soft matter. Each voxel within a DICOM dataset is a representation of a level of hydrogen in the body (MRI) or density of tissue (CT).

Like all 3D virtual space, DICOM relies on the Cartesian Co-ordinate system. As Mark J.P. Wolf explains (2000, p. 84) Descartes, in his book *Geometria* brought together geometry and algebra and thus created the XYZ co-ordinate system upon which DICOM now relies. Descartes is of course most famous for his statement 'I think therefore I am' and the philosophical splitting of body and mind, which has since formed the basis of modern thought. Interestingly Descartes, as well as being a philosopher and mathematician was also an anatomist. Jonathan Sawday claims this practice was intrinsic to his most famous legacy, the Cartesian subject.

> It was in the anatomy theatres of Leiden and Amsterdam that Cartesian man was born, in the person of a grotesquely twitching criminal corpse, at the behest of the medical and judicial authorities of the city (Sawday, 1995, p. 158)

DICOM is certainly Cartesian in all senses: it allows us (aided by hardware and software) to see the body as a virtual object, fully visible, manipulable, separate from and thus controllable by the mind. The mind is freed from a body it cannot trust or rely on for true knowledge. A machine, not the bodily senses, measures and quantifies the body objectively. Those measurements are then processed through a complex series of algorithms. The body becomes an object of reason, an object of logic, sublime algebra and geometry.[vii]
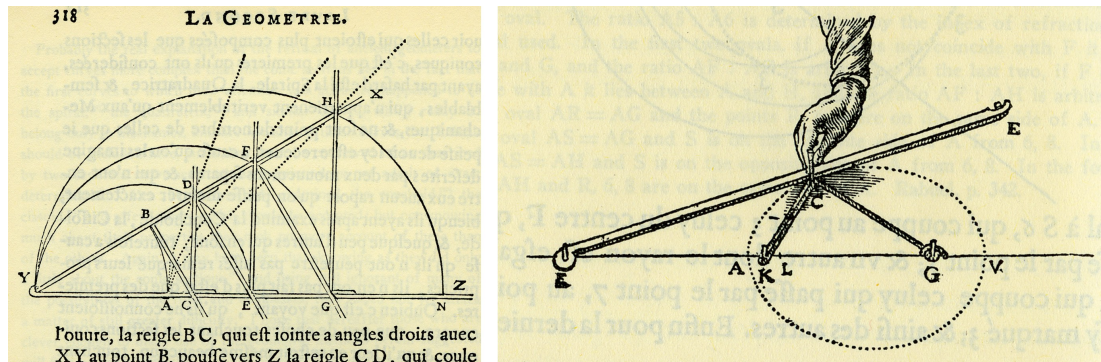
Fig. 9 Images from Descarte's *Geomteria* (1637) left p.154 right p.122

As the title of this dissertation suggests, I find DICOM holds connotations of spiritual transcendence as well as Cartesian transcendence. Although some scientists would argue that MRI and CT are purely measuring devices and should only be considered as data to be reasoned with the mind.[viii] The way in which MRI and CT have evolved now means that output is most commonly highly visual and has a very strong aesthetic power. X-rays and the subsequent imaging technologies that now create DICOM and the software that processed it were created in the 20th Century and therefore inherit 19th and 20th century aesthetic values[ix]. When considered as images, visualisations of DICOM are often beautiful – they conjure aesthetic sensibilities, especially I believe when they are rendered as 3D volumes and are isolated on black backgrounds (see Fig. 10).

Having been brought up a Catholic where imagery and artefacts with a high aesthetic value are instrumental in proving the existence of an almighty and perfect God, I find that DICOM datasets have transcendental qualities of the images of celestial beings (such as the Holy Spirit/Angels) I was presented with so intensively as a young child; they are free of abject matter (substances that seep, smell, stain). They float: in the datascape they are everywhere and nowhere. They can be found in each and everyone of us for we all have the potential to be scanned and yield data. Being digital, they are infinity unfixed, transformable, mutable and inexhaustible.

These powerful and evocative transcendental qualities make DICOM a rich and fertile area to explore the way in which the virtual age and our increasing investment in disembodied activities (such as online social networking via sites such as Facebook and role playing

games via avatars) are changing how we see and therefore know ourselves. DICOM allows us to create pictures of digitised living bodies, even possibly our own digitised living body and to view it in virtual space as a virtual object.
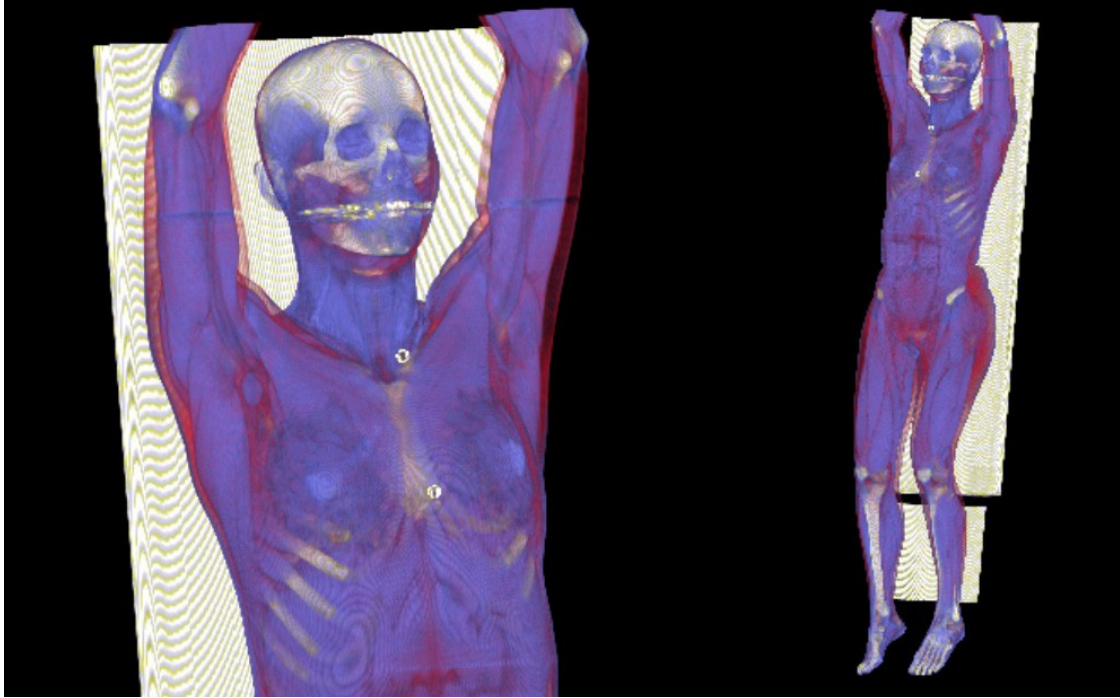

Fig. 10 Volume renderings generated in OsiriX from MELANIX data

The next two chapters focus on my work as an artist working with DICOM datasets. They intend to further explore the implications of working with DICOM whilst comparing the two modalities of MRI and CT that have been explained in this chapter. As will be seen, my commitment is to a material and embodied contemplation of DICOM and thus I insist that the artefacts I produce exist in the real world as real objects. Like Katherine Hayles (who I refer to in chapters 4 and 5) I believe that the image/text must be considered primarily as matter – that we must re 'export' the digitised body into a real space and time, so that it can be considered as material by embodied beings.

Although my work primarily deals with anatomical information, I do not consider myself an 'anatomical artist', my aim is not to render palatable medical imaging (for mechanisation of imaging and processing software now does this automatically). I work with DICOM to explore Cuir's list of "Know Thyself" categories (matter, space, object of science, object of science fiction) to which I add "Know Thyself" as a Digitally Processed Subject.

i Such as Bronzino's An Allegory with Venus and Cupid (circa 1540), National Gallery collection, London.

ii The NHS is currently rolling out a PACS system which is aims to replace all film based radiography with digitally stored radiography in the coming years. For more information see http://www.e-health-insider.com/news/item.cfm?ID=730 (accessed 30th April 2008)

iii The term 'Know Thyself' is a translation of the Nosce Te Ipsum, which was first inscribed on the Temple of Apollo at Delphi. This later became the tag of anatomical art used to justify dissection and a recognition of the body as a divine work of God. For more detailed explanation see Introduction chapter "Know Thyself" in: Kemp, M. (2000) Spectacular Bodies: The Art and Science of the Human Body from Leonardo to Now

iv See Appendix II for diary of Shadowing at Paul Strickland Scanner Centre.

v For a more detailed and visual explanation of MRI see Westbrook, C (2005) MRI in Practice

vi For more technical information on CT scanning see Robb, R (1997) Three-dimensional Biomedical Imaging: Principles and Practice and Jackson, S (2004) Cross-sectional Imaging pgs 3 - 16

vii The Sublime is something that cannot be reasoned or imagined – it is too vast, too infinite for the human subject to contemplate. I would argue that when one tries to imagine the process of translation from physical matter to MRI data we experience the sublime. Imagine 700000000000000 atoms in a human body being excited or wound up by a radiofrequency and then the rate at which 700000000000000 atoms unwind being detected (simultaneously) and then those measurements being processed by a complex algorithm (again simultaneously) and then that measurement being displayed on a computer screen as a voxels, which in turn requires a whole new level of computer processing and algorithm to be displayed.

viii Anne Beaulieu (2000) clearly explains in her essay The Brain at the End of the Rainbow, that not all scientists appreciate the seductive images created as a result of DICOM, stressing that digital medical imaging is a process of measuring rather than imaging.

> Visualization is to assist in understanding measurements, but the investigation is not visual, scanning is not making pictures. This distinction is crucial in understanding neuroscientific vision. It is further reinforced by an emphasis on the work that leads to the production of images. The image refers to a set of numbers, of measurements and it is the production of measurements which is stressed (Beaulieu, 2000, p. 44)

ix In the Renaissance the aesthetic values were classicism (as explained earlier in the chapter), in the late 2oth century the most obvious aesthetic influences on DICOM software I believe are photographic (scans look like black and white photographs), cinematic (scans can be exported as short movies), full abstract colour (there are multiple options for viewing scanning in different colour modes reminiscent of abstract painting) and multiple levels of transparency (there are options for viewing the data at all levels of transparency).