X-ray tomography teachers notes

Introduction:

This experiment demonstrates the ability of x-ray computed tomography machines to take a set of 2-dimensional images and create a 3-dimensional image.

Learning Outcomes:

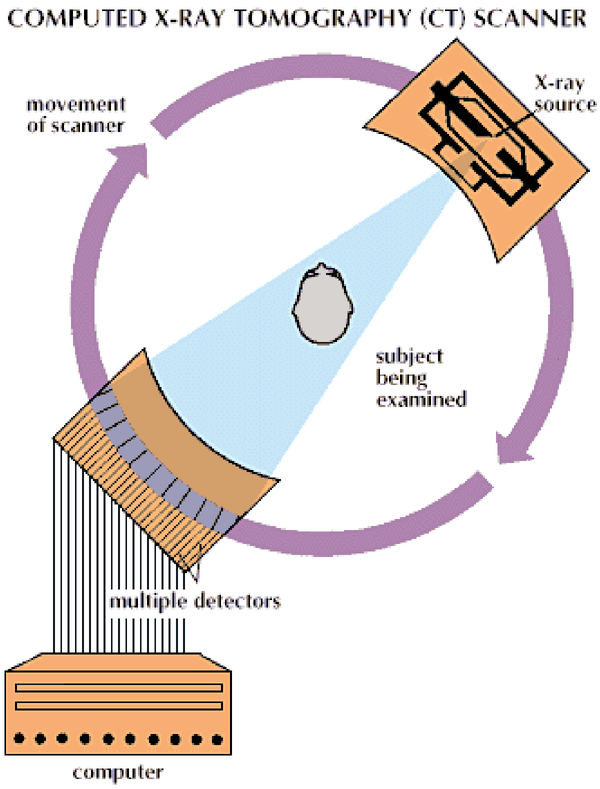
- Students will be introduced to the concept of 3D imaging and the various industries and areas where 3D imaging is used
- Students will learn how the number of 2D images is directly related to the "uniqueness" of the solution so that a greater number of projections will solve the problem of non-unique solutions.

Experiment Summary:

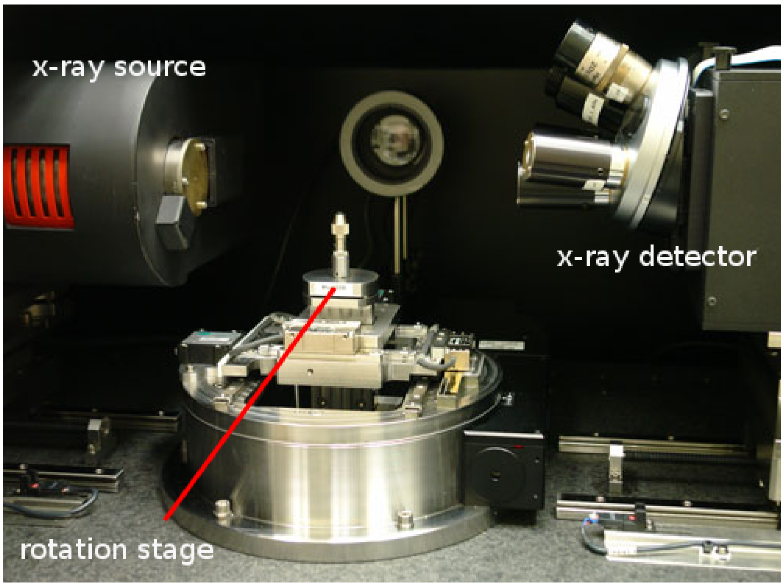
Students are guided through the idea of projections by taking images from different perspectives or angles. By stacking all the projections on top of each other a "sinogram" is produced.

There are two ways of taking images from different perspectives. We can either rotate the x-ray source and detector around a stationary object or keep the source and detector fixed and rotate the sample. Both of these techniques are widely used.

For example, in a hospital setting, a patient wouldn't appreciate being spun around so they're kept still while the source and detector rotate around them – the circular structure in commercial x-ray CT scanners houses the source and detector.



In many industrial CT scanners that use physically larger sources and detectors, and typically analyse smaller samples (with greater precision) it becomes far easier to simply rotate the sample.



Expected Results:

The first task in the Explore tab is called “Explore projection space”. The task is to observe how perspective (when taking images) changes the appearance of the object. The user has four simple geometrical objects and can see how viewing them from different angles changes the projected image. For symmetrical objects like a circle, this effect cannot be observed unless the centre of the object is different to the centre of rotation. This effect is shown in the second object which is a circle that is offset from the centre of rotation.

The next task, “Reconstruction simulator” allows students to see how the reconstruction quality changes by varying two different parameters. These are the number of projections and the amount of noise or randomness in each image. Note that any image (not just x-ray images) contain noise – even images taken by your phone camera contain some level of noise.

Intuitively, taking more projections will lead to a better reconstruction. For example, taking images at one degree intervals (180 images in total) will be better than taking images at two degree intervals. The finer angular sampling creates more images and produces a better reconstruction. In addition, noise will also impact on the reconstruction quality. The algorithm that produces the reconstruction cannot separate the noise from the real signal. Therefore any noise in the recorded images will be transferred to the reconstruction. Students can see how both the number of projections and the amount of noise affects the final reconstruction.

These concepts are tested in the final task, “Reconstruction puzzle”. A patient has arrived in the hospital and the student is required to make an accurate diagnosis by taking images of different body parts (arms, head, legs, torso). However, the student only has 200 projections in total so they shouldn't use most of them on one body part (to take a good image) and only have very few projections for the next body parts. By balancing the need for a good image with the need to image various different parts, the student will be able to see the injury *clearly enough* to make the right diagnosis.

Answers to Evaluate questions:

1. X-ray CT scanners work by taking 2D images of samples from different angles. An entire dataset is comprised of hundreds of 2D images separated by very small angles. A 3D image is generated from this data collection by projecting the 2D images back towards their common rotation axis.

2. A single 3D image requires hundreds of individual 2D images. This is a huge exposure to harmful x-ray radiation which carries a small but appreciable risk of forming cancer later in life. For serious conditions, that require highly detailed diagnosis, this is acceptable since the risk of doing nothing is greater than the risk of the harmful effects of CT scans.

3. Radio waves, microwaves, infrared, yellow light, blue light, soft x-rays, hard x-rays, gamma rays

4. Other uses for x-ray imaging
   1. Industrial x-ray imaging – scanning baggage in airports, shipping containers etc. Visualising processes in extreme environments (for example, ultra fast x-ray imaging has been used to watch how fuel injectors work in engine cylinders. The results showed that the fuel is injected at supersonic speeds resulting in a Mach cone).
   2. Non-destructive testing – checking for faults and/or cracks

in load bearing materials, checking for conduction faults in electronic equipment (quality control),

3. Mining – checking for oil flow rates in porous rocks