Hounsfield units

Physics > Modern Physics > Production & use of X-rays

Difficulty level	Group size	Preparation time	Execution time
hard	2	45+ minutes	45+ minutes

General information

Application

Setup

Most applications of X rays are based on their ability to pass through matter. Since this ability is dependent on the density of the matter, imaging of the interior of objects and even peaple becomes possible. This has wide usage in fields such as medicine or security.

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Other information (1/2)

Prior knowledge

The prior knowledge for this experiment is found in the Theory section.

Main principle

Depending on the type of CT scanner and the settings, the result of a CT scan of the same material can be different attenuation coefficient (grey-values). In order to make it easier to compare CT data, espe-cially in medicine, the grey-values of a CT scan are often rescaled to a standard scale. Hounsfield units is such a scaling that uses air and water as a calibration material which is regularly used in medicine.

Other information (2/2)

Learning objective

The goal of this experiment is to learn about hounsfield units.

Tasks

1. Perform a CT scan of the calibration material.
2. Recalculate the results to Hounsfield units.

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Theory

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Depending on the type of CT scanner and the settings, the result of a CT scan of the same material can be different attenuation coefficient (grey-values). In order to make it easier to compare CT data, especially in medicine, the grey-values of a CT scan are often rescaled to a standard scale. Hounsfield units (HU) is such a scaling that uses air and water as a calibration material which is regularly used in medicine. To calculate the HU:

$$\mathrm{HU} = 1000 \times \frac{\mu_{\mathrm{x}} - \mu_{\mathrm{water}}}{\mu_{\mathrm{water}} - \mu_{\mathrm{air}}}$$

With μ_{water} and μ_{air}, the linear attenuation coefficients of water and air respectively and μ_{x} the linear attenuation coefficient of the components that needs to be defined. With this formula, the HU of watter is 0 and the HU of air is - 1000. Although HU are very practical, they can cause wrongful interpretation of the data. CT artefacts such as beam hardening and metal artefacts (see experiment 8) generate errors in this principle. Also, the linear attenuation coefficient of different materials is energy dependant in a non-linear way. Using different Xray photon spectra will cause variations in the HU conversions that is not consistent to compare data across different scans.

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Equipment

Position	Material	Item No.	Quantity
1	XR 4.0 expert unit, 35 kV	09057-99	1
2	XR4 X-ray Plug-in Cu tube	09057-51	1
3	XR 4.0 X-ray Computed Tomography upgrade set	09185-88	1

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Setup and Procedure

Setup

Attach the XRIS to its stage.
Place the Digital X-ray detector XRIS on the rail at position 30 cm. The back side of the XRIS stage corresponds to its position on the rail. This position is called the 'source to detector distance' SDD (mm).

Place the rotation stage XRstage on the rail at position 25 cm. The back side of the XRstage corresponds to its position on the rail. This position is called the 'source to object distance' SOD (mm).

Connect the XRstage cable with the 'Motor' connection block in the experiment chamber. Attach the sample table to the XRstage with the fastening screw.

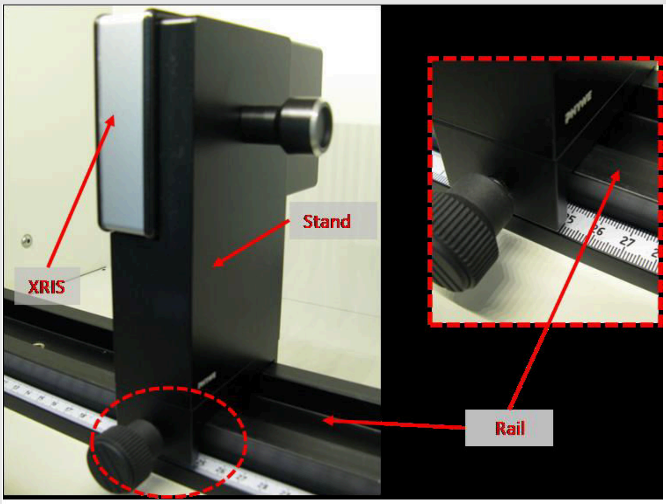

Fig. 1: Set-up of the XRIS

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Procedure (1/2)

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- Connect the X-ray unit via USB cable to the USB port of your computer (the correct port of the X-ray unit is marked in Fig. 2).
- Connect the usb cable of the detector to the computer
- Start the “measureCT” program. A virtual X-ray unit , rotation stage and Detector will be dis-played on the screen. The green indication LED on the left of each components indicates that its presence has been detected (Fig. 3)
- You can change the High Voltage and current of the X-ray tube in the corresponding input windows or manually on the unit. (Fig. 3)
- When clicking on the unit pictogram additional information concerning the unit can be re-trieved(Fig. 3).

Fig. 2: Connection of the computer

Procedure (2/2)

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- The status pictogram indicate the status of the unit and can also be used to control the unit such as switching on and off the light or the X-rays (Fig. 3).
- The position of the digital detector can be ad-justed to its real position either by moving the XRIS pictogram or by filling in the correct value in the input window. (Fig. 3).
- The settings of the XRIS can be adjusted using the input windows. The exposure time controls the time between two frames are retrieved from the detector, the number of frames defines how many frames are averaged and with the binning mode the charge of neighbouring pixels is aver-aged to reduce the total amount of pixels in one frame.

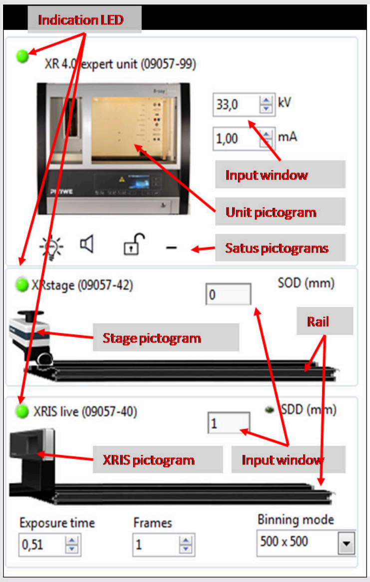

Fig. 3: Part of the user interface of the software

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Experiment execution

Task 1

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- Adjust the XRIS settings and X-ray unit settings according to Fig. 4 or load the configuration from the predefined CTO file 'Experiment 9' (see Fig. 5).
- Start a new experiment, give it a unique name and fill in your details (Fig. 5). Alternatively it is also possible to load this experiment with pre-recorded images and open this manual. The correct con-figuration will be loaded automatically as well but the functionalities of the software will be limited to avoid overwriting the existing data.

Overview of the settings of the XRIS and X-ray unit:

- 35kV, 1.00mA
- exposure time 0.5 sec
- Number of frames: 1
- Binning mode 500x500
- SDD= 300, SOD= 250

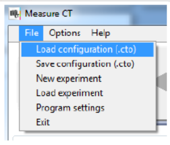

Fig. 4: The settings for this experiment (left panel)and the method load and adjust the settings (right panel)

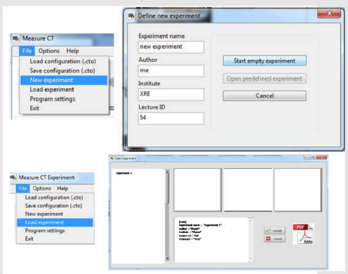

Fig. 5: How to create a new or open an existing experiment

Task 1 (part 2)

- Switch on the X-rays (Fig. 6.1) and activate the 'Live view' (Fig. 6.2). When the Live view is activated, every new image that is retrieved from the X-ray detector is displayed. The Detector exposure load bar (Fig. 6.3) indicates the average degree of fill for each pixel. It is very important to remain be-low the maximal fill degree of the detector. Otherwise the detector will be saturated and won't work properly. If the saturation level is reached, the 'detector exposure' load bar will turn red. (see experiment 1 for more details)
- Calibrate the detector by clicking on "Calibrate'(Fig. 6.4). When the calibration is successfully per-formed, the indication LED (Fig. 6.5) will turn green. The Load bar (Fig. 6.3) will disappear and the Contrast/intensity cursor (Fig. 6.6) will become available. (see experiment 1 for more information)

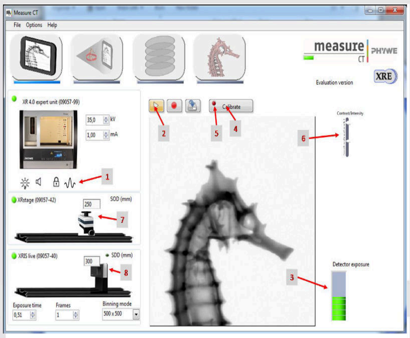

Fig. 6: Settings to set before start of a CT-scan, part 1

Task 1 (part 3)

- Place object XXXX on the sample stage and close the door.
- Adjust SOD (Fig. 6.7) and SDD (Fig. 6.8) in the software according to the actual position.
- Go from the "Live view page" to the "CT scanning page". The indication pictogram will turn blue when the page is activated.

Fig. 7: CT scanning page

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Task 1 (part 4)

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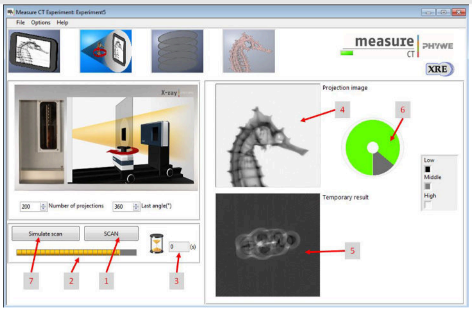
- Start a CT scan (Fig. 8.1). During the CT scan the progress (Fig. 8.2) as well as the remaining time (Fig. 8.3) is displayed. The current image (Fig. 8.4) being recorded is shown and the temporary result (Fig. 8.5) is calculated during the scan. It is also possible to track the position of the rotation (Fig. 8.6). When the scan is finished it is possible to replay the acquisition as a simulation (Fig. 8.7).
- When the CT scan is finished it is possible to proceed to the reconstruction. Go from the "CT scanning page" to the "Data reconstruction page". The indication pictogram will turn blue when the page is activated.

Fig. 8: Start a CT-scan



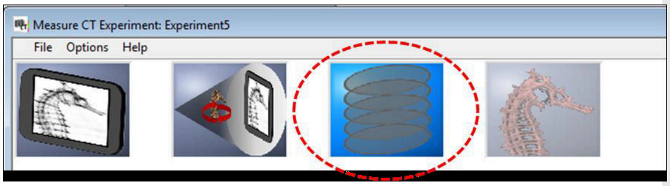


Fig. 9: Data reconstruction page

Task 1 (part 5)

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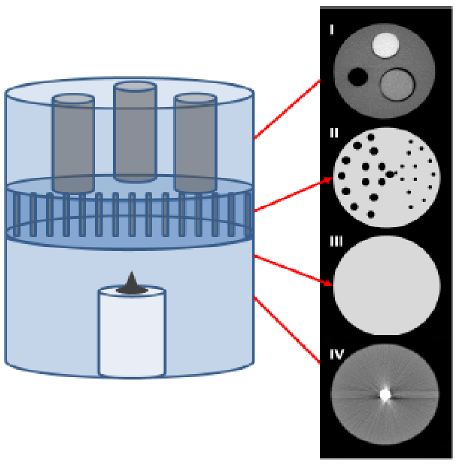
- Find the slice in the centre of the object that looks like Fig 10.II.
- Optimise the centre of rotation (see experiment 5 and 6 for more information).
- Open the image viewer, the corresponding slice will be visible. Click on save (see experiment1), select the radiographies folder in the experiment and save the image as tif with the name bin250_50_250.

Fig. 10: CT experiment sample



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Task 2

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- In the image viewer, select a region inside each of the holes by adjusting the position of the cursors (Fig. 11.1) and click on calculate (Fig. 11.2) o calculate the average attenuation coefficient.
- Use the attenuation coefficient of the air and the water to calculate the Hounsfield units of the 'bone'-plastic.
- Repeat this but with different kV settings. report and explain the differences.

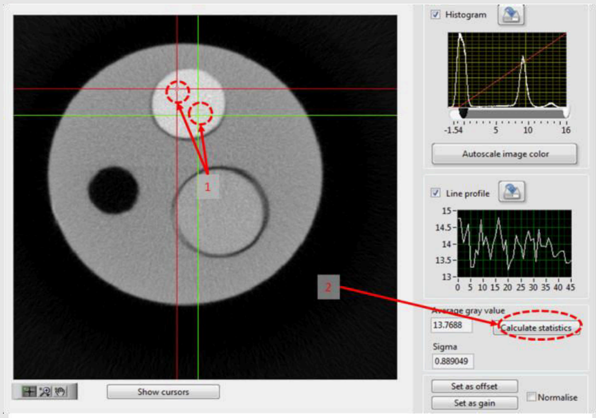

Fig. 11: calculate the average grey value in each of the holes

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