Manual for the Varex Imaging's XRD 4343N Flat Panel Detector

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This manual is an addition to the paper I have written which is about the pixel sensitivity correction of the Varex Amorphous Silicon EPID for HDR brachytherapy which can be found on GitHub. It is recommended to read this paper prior to the manual since it gives a nice overview of the different acquired calibration methods. This manual provides information on how to use the Varex Imaging's XRD 4343N flat panel X-ray detector. The manual starts with the mechanical characteristics of the electronic portal imaging device (EPID) and it will give an overview of technical specifications of the panel. This is important since the EPID has different read-out modes. Secondly, the connection of the EPID with the computer and power supply will be described and visualized. Lastly, the MATLAB functions for the third dataset (D3) of the paper are included in this manual for future use.

GitHub: https://github.com/mandyyuen/Maastro.git

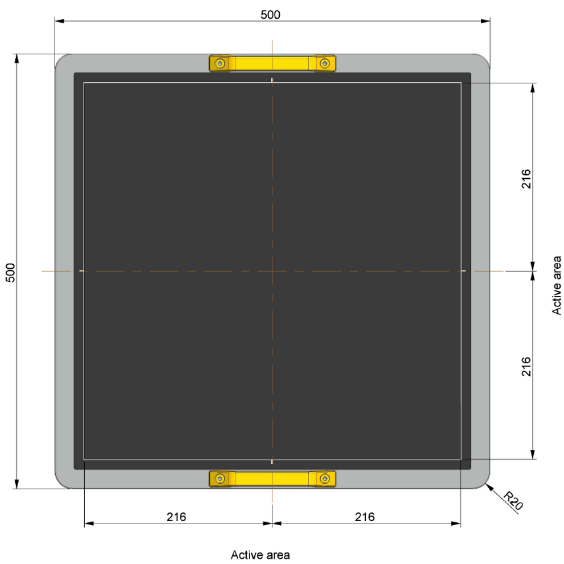
Contents

1 XRD 4343N flat panel detector

The Varex Imaging's XRD 4343N is an amorphous silicon flat panel X-ray detector which is used for high dose applications (see Figure 1a) [1] . The EPID has an ultra high sensitivity layer. The panel supports a full field of view of 432x432 mm^2 with a pixel matrix of 2880x2880 pixels and pixel pitch of 150μm (see Figure 1b). It can use energies up to 450 kV. In addition, there are seven field of view options, five gain modes and four binning modes with frame rates up to 115 fps. An overview of the different read-out modes of the EPID can be found in Table 1. To acquire the frames using the EPID, the the gain mode, the binning mode and the frame rate need to be defined correctly. First, the gain is the amplification of the signal which defines the sensitivity of the panel. If the input signal is low, the gain should be increased since this increases the sensitivity of the panel. However, setting the gain too high will result in saturation and information will be lost, which has to be avoided. Therefore, the gain mode has to be adjusted to maintain an adequate signal and to avoid saturation. Secondly, binning combines neighbouring pixels which results in faster readout speeds and improves the signal to noise ratio at the price of reduced spatial resolution. Lastly, the frame rate defines how many frames are acquired per second. Increasing the frame rate means that there is less time between acquisitions.

Further information about the EPID can be found in the literature [2].

(a) XRD 4343 flat panel detector



(b) Mechanical characteristics (dimensions in mm)

Figure 1: XRD 4343N flat panel detector with its mechanical characteristics [2].

1.1 Connection of the X-ray detector

The XRD flat panel detector and XRD power supply both consist of several input ports (Figures 2a and 2b). The panel and power supply is connected by a XRD-EPS-B2 DC cable and XRD-FXC PC connection cable. The XRD-EPS-B2 DC cable uses the DC input of the panel and the DC output of the power supply (number 1 in Figures 2a and 2b). The XRD-FXC PC connection cable uses the opt interface of the panel and AC input of the power supply (number 2 in Figures 2a and 2b).

Table 1: Technical specifications: read-out modes of the XRD 4343N panel [2]

Field of view (mm^2)	Pixel matrix	Binning	Pixel pitch (μm^2)	Frames per second (fps)
432 × 432	2880 × 2880	1 × 1	150	15
	1440 × 1440	2 × 2	300	30
	960 × 960	3 × 3	450	45
	704 × 720	4 × 4	600	60
288 × 288	1920 × 1920	1 × 1	150	20
	960 × 960	2 × 2	300	40
	640 × 640	3 × 3	450	60
	480 × 480	4 × 4	600	75
216 × 216	1440 × 1440	1 × 1	150	25
	736 × 720	2 × 2	300	50
	480 × 480	3 × 3	450	70
	384 × 360	4 × 4	600	85
432 × 216	2880 × 1440	1 × 1	150	25
	704 × 240	4 × 4	600	100
432 × 216	2880 × 480	1 × 1	150	60
	704 × 120	4 × 4	600	115

The power supply of the panel can be switched on and off using the power button (number 3 in 2b). More technical information of the power supply can be found in Figure 2c. Lastly, the EPID is connected to the computer with an interface cable.

2 MATLAB functions

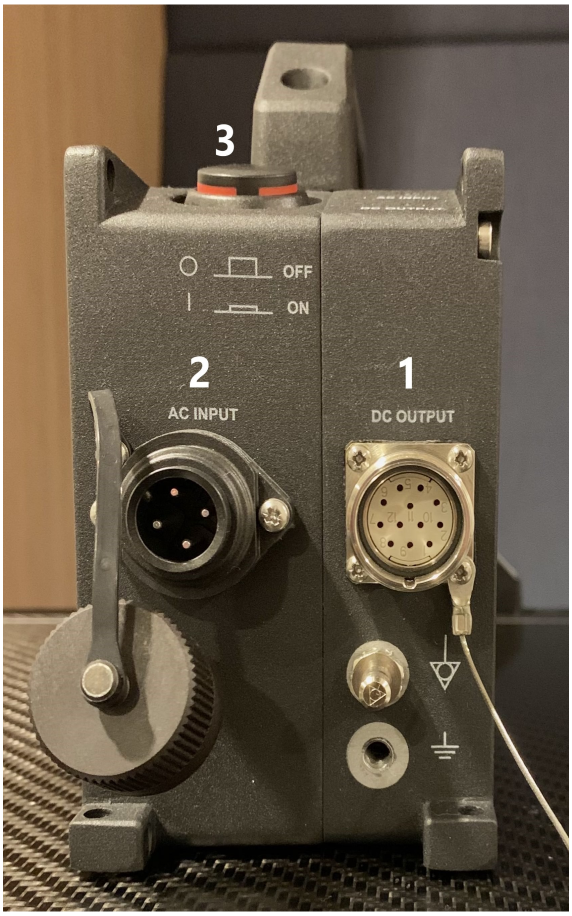
MATLAB functions have been created to develop a calibration method to correct for the pixel sensitivity of this EPID. From the paper, the first two datasets (D1 and D2) have been acquired using the XIS application which saved the images (average over all frames) as .his files. Since this application was not ideal, it will not be used in the future and the corresponding MATLAB functions will not be described in this section. Meanwhile, a code was generated by dr. G. Paiva Fonseca which replaces the XIS application. This code has been used to acquire the third dataset (D3) and each individual acquired frame is saved as .IrIS file. For future reference, this code should be used instead of the XIS application. Therefore, the MATLAB functions which use the IrIS files for the pixel sensitivity calibration (D3), will be described in this section. Further information of the executed experiments and the acquired datasets can be found in the paper.

The functions can be found in the following GitHub repository: `https://github.com/mandyyuen/Maastro.git`

This is an overview of the MATLAB functions in the GitHub repository which are used to acquire D3:

1. open_IrIS
2. open_his

(a) Connector ports of XRD flat panel detector. 1 = DC input cable, 2 = AC input cable.



(b) Connector ports of XRD power supply. 1 = DC input cable, 2 = AC input cable, 3 = power button.

(c) Information of XRD EPS power supply

Figure 2: Connection of XRD flat panel detector with XRD power supply.

3. MeanImage
4. ImageReg
5. int_fig
6. im_int_plots
7. sensitivity_map_IrIS

2.1 open_IrIS

When the EPID is being read out, frames are acquired which are saved as .IrIS files. This function reads the .IrIS files and stores them in one matrix. The input contain one variable 'varargin' which needs to be set to zero. When running this function, a folder opens and all frames can be selected at once. In addition, the function replaces the outliers (3 standard deviations from the mean) with zeroes and interpolates all negative and zero values with their neighbours.

2.2 open_his

This function will probably not be used in the future, however, it is included on GitHub since other MATLAB functions included the open_his function to open .his files. The open_his function is the same as the open_IrIS function, but has three extra input arguments: FOV_x is the field of view in the x-direction, FOV_y is the field of view in the y-direction and binning is the binning mode.

2.3 MeanImage

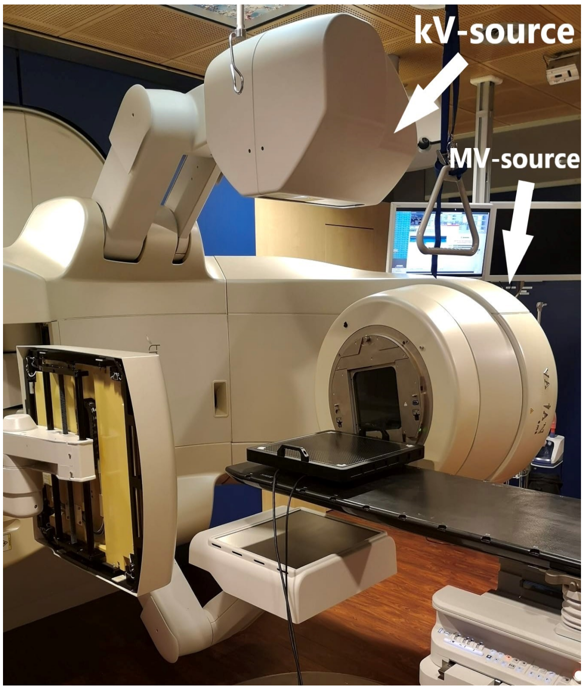


Figure 3: kV-source of cone beam CT

For D3, a kV-source of the cone beam CT (CBCT) has been used to irradiate the EPID with the same field (24x12 cm^2) while the panel is shifted between each irradiation (Figure 3). This resulted in a total of 35 field positions and for each position 100-120 frames have been acquired. For each field position, an average has to be taken over the frames. However, each frame contains a horizontal line since the EPID is not synchronized with the CBCT (Figure 4). This function ensures that these lines will not be taken into account in the average image. For the images of D3, the image is not averaged over all frames, but are averaged over a subset of frames. This method looks at each pixel in a specific pixel location for all frames and calculates the median value. If the pixel intensity value is smaller than this median value, the frame containing this value will not be taken into account when calculating the average intensity value for that location. This has been done for all pixel locations. In this manner, the pixel intensity values from the horizontal lines will not be taken into account when calculating the average image over all frames.

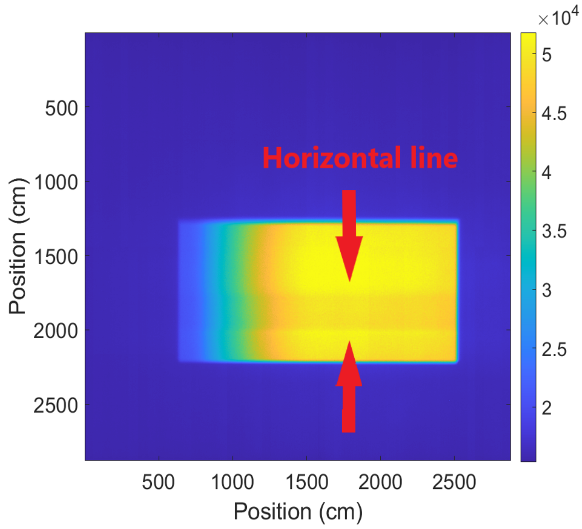


Figure 4: Horizontal line is visible in one of the frames

Hence, this function is used for all 35 field positions. When running the MeanImage function, the open_IrIS function is used and all 100-120 frames are selected for each field position. The output of this function is the average image over all frames.

2.4 ImageReg

To acquire a reference image, image registration is used. The function has the inputs: moving, fixed, thresh_bg, initial_x and initial_y. The moving image (input moving) needs to be registered to the fixed image (input fixed). Subsequently, the background of these images needs to be set to zero which needs to be defined manually (input thresh_bg). For the registration, rigid translation has been applied on the images since the panel is only displaced laterally or longitudinally. Moreover, the imaging modality is specified as monomodal since the images are similar in brightness and contrast. A perfect registration is also necessary since the reference response for each pixel should be accurate. For this reason, prior to the image registration, an initial translation has been applied on the images located at the boundaries to move them in the right direction (inputs initial_x and initial_y). After the images are registered, the mean of all pixel values at each pixel location has been taken over these images which gives the reference response.

2.5 int_fig

For the evaluation, images are acquired with a HDR brachy source. By applying the dark field, dead line and PSM corrections on a RAW evaluation image, the EPID intensity profiles at positions 21.6

cm and 10.8 cm on the y-axis of the RAW image (input original_im) and corrected image (input correction_im) are acquired using this function. In addition, this function calculates the line length of the RAW and corrected image and determines the noise level improvement in percentage.

2.6 im_int_plots

This function can display multiple images (inputs Images, Sx and Sy) in one figure (output f1) with their corresponding intensity profiles in another figure (output f2).

2.7 sensitivity_map_IrIS

This function file contains code to acquire a pixel sensitivity map (PSM) using D3. First, the MeanImage function is used to acquire the average image over all frames per field position. Since D3 contains 35 field positions, the MeanImage function has been executed 35 times to obtain 35 images. This will be saved in one matrix which is called 'moving'. Subsequently, the background image is read out using the open_his function and this image is acquired without radiation while using the same settings as the acquired frames. This background image needs to be subtracted from all 35 images (dark field correction). Then the dead line is removed from every image and replaced with the values from its neighbours using interpolation. This is done by selecting the region where the artefact line is occurring. Next, the fixed image is defined as one of the moving images. It is important to take an image which is located in the center of the panel. Further, the sensitivity for each pixel can be obtained by comparing its individual response against a reference value. The function ImageReg has been used on all images to acquire the reference response. The images located at the boundaries, uses a different initial translation. Subsequently, the output 'T_inverse' is used to translate the reference response to each field position. This way, the pixel sensitivity of each pixel can be obtained by dividing each individual pixel response by its reference response. By combining the pixel sensitivities for each pixel while excluding values lower than 0.9 and higher than 1.1, the PSM for D3 can be determined. Lastly, for the evaluation, images have been acquired with a HDR brachy source and each of these images are loaded in and are corrected for the dark field, dead line and PSM. The function int_fig is used to visualize the intensity profiles of the RAW and corrected image and to see the noise level improvement. The function im_int_plots can also be used to visualize the RAW or corrected image with its corresponding intensity profile.

References

[1] Varex Imaging Corporation, *XRD 4343N — Varex*, 2019. [Online]. Available: https://www.vareximaging.com/products/flat-panel-detectors/xrd-4343n.

[2] ——, *XRD 4343N Flat Panel Detector*, 2020.