BSQA Analysis Code User Guide

1 Introduction

This user guide was written for BSQA_analysis_v1_0.py and gives and brief overview of the overall architecture as well as how to use the analysis package.

2 Architecture

The overall architecture surrounding the code can be seen in Figure 1.

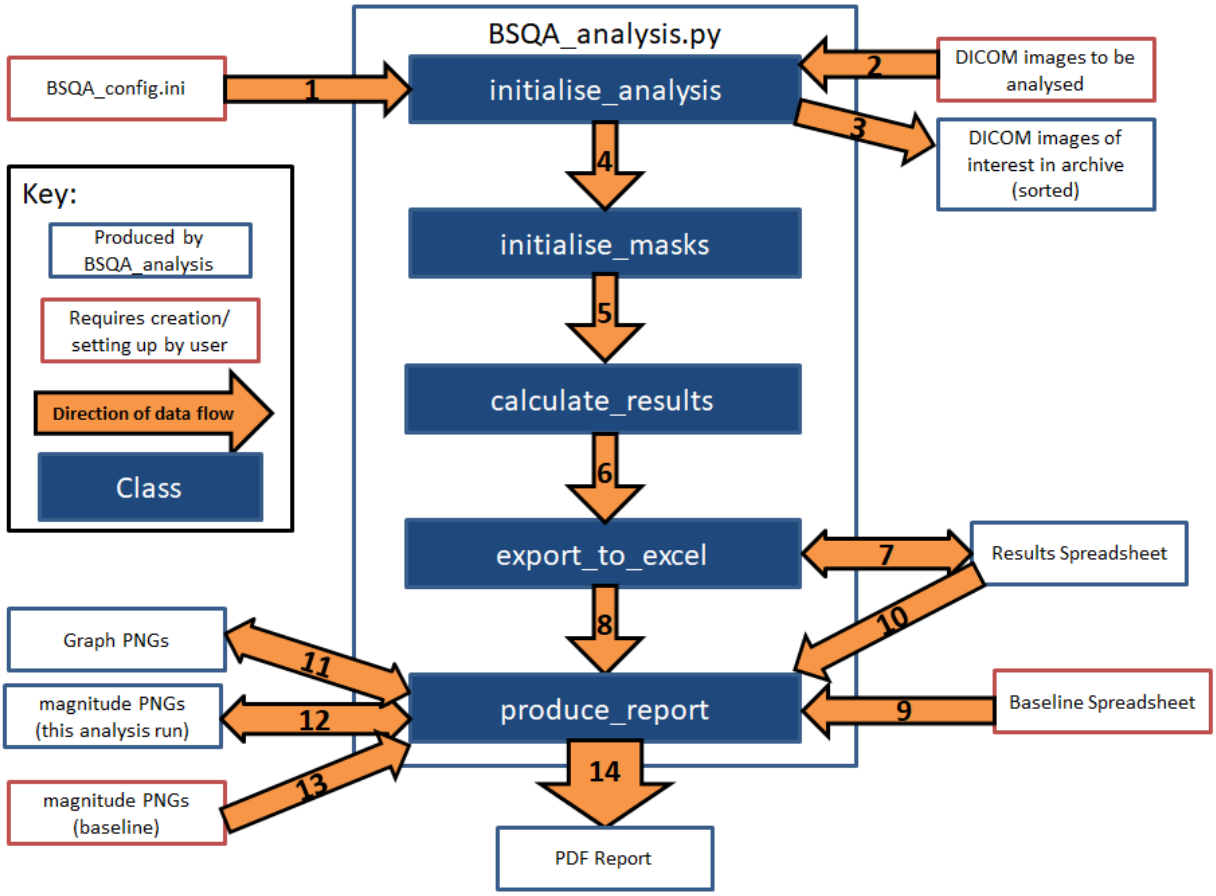


Figure 1 Overall analysis architecture. See section 2.2 for an explanation of dataflow through the program.

2.1 Elements Requiring Editing/ Initialising

For the full analysis package to run some elements need initialising / editing prior to running BSQA_analysis.

2.1.1 Config File

NHSBSP_analysis requires a config file to specify default parameters for the analysis. This should be in the same directory as BSQA_analysis and called BCQA_config.ini. An example config file can be found in Appendix 1. It is envisaged tha, under normal operation and once baselines have been established, the config file should not require editing.

The config file is split into the following sections:

- [user_input] : If “ask_overwrite_analysis” = True AND an attempt is made to reanalyse images for which results have already been inputted into the results spreadsheet: The user is asked if they want to overwrite the previous analysis. Otherwise, the user is notified that the results from the current analysis will not be inputted into the results spreadsheet. The default is to not overwrite.

- [default_paths]: Default paths for the analysis. The actual paths used for the analysis can be edited by the user in the Tkinter GUI.
- [sequence_names]: Specifies the sequence names of the DICOMS of interest (dcm.SeriesDescription). The NHSBSP requires images for SNR analysis (T2w SE sequence) and images for suppression effectiveness and contrast analysis (T1w GRE sequence with and without suppression)
- [coil_spec]: Specifies the number of elements as well as the default threshold values used to generate the phantom mask
- [sheet_names_to_report]: Specifies from which spreadsheet to report results from for different parameters. Note the same sheet name is used in the baseline and results spreadsheet. It is recommended that the group average sheets are used once repeats over multiple days have been performed.
- [pdf_header_image]: Specifies file path to a png to be input as the header of the final report pdf
- [pdf_text_sizes]: Specify text sizes in the report pdf
- [pdf_default_comment]: Default comment summarising report results.
- [pdf_glossary]: Glossary to be input in the cover page of the report – the keys are the terms and values are the definitions
- [report_sections]: Summary of each report section to be input in the cover page of the report

2.1.2 DICOM Images to be Analysed

The DICOM images to be analysed should be placed within a single directory (there can be sub directories within this). The directory containing the DICOMs to be analysed can contain DICOMS with different dcm.SeriesDescription tags (e.g. Scout images); these are ignored. All DICOMS with the correct dcm.SeriesDescription tags will be analysed so the directory to be selected should be unique for this analysis run.

2.1.3 Baseline Spreadsheet

An example sheet of the baseline spreadsheet can be seen in Figure 2 and the corresponding results sheet in Figure 3.

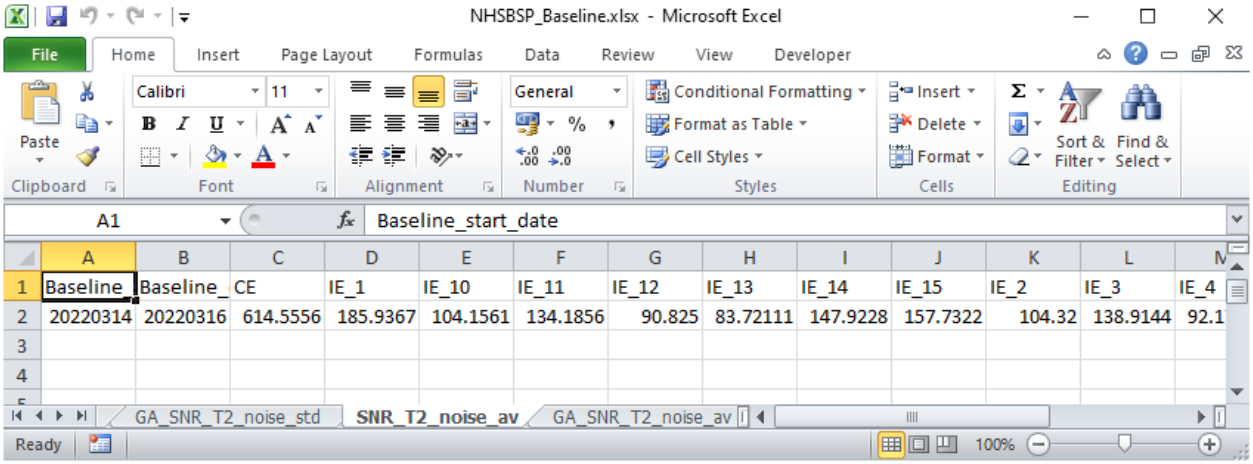
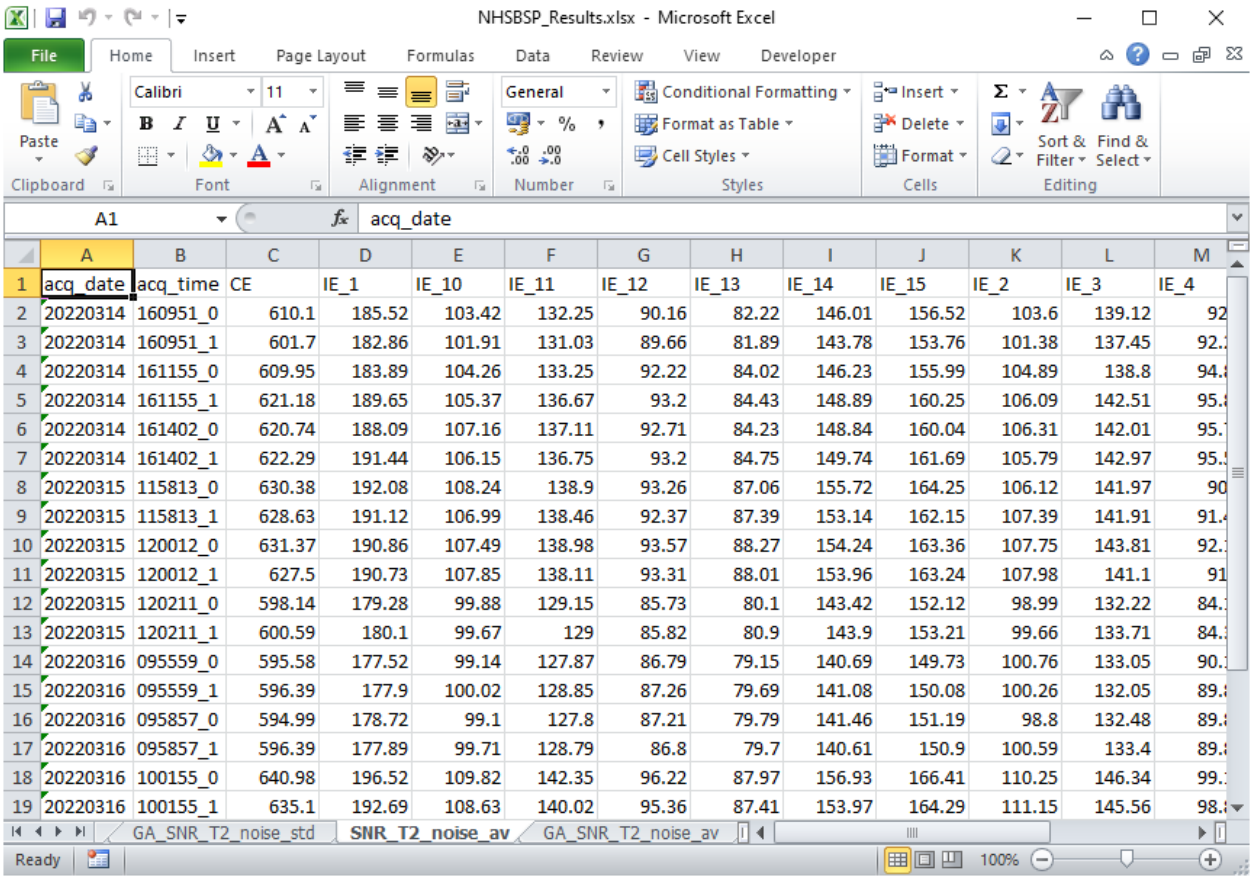


Figure 2 Baseline sheet for SNR calculation of T2w images via the "noise_av" method.



	A	B	C	D	E	F	G	H	I	J	K	L	M
1	acq_date	acq_time	CE	IE_1	IE_10	IE_11	IE_12	IE_13	IE_14	IE_15	IE_2	IE_3	IE_4
2	20220314	160951_0	610.1	185.52	103.42	132.25	90.16	82.22	146.01	156.52	103.6	139.12	92
3	20220314	160951_1	601.7	182.86	101.91	131.03	89.66	81.89	143.78	153.76	101.38	137.45	92.
4	20220314	161155_0	609.95	183.89	104.26	133.25	92.22	84.02	146.23	155.99	104.89	138.8	94.
5	20220314	161155_1	621.18	189.65	105.37	136.67	93.2	84.43	148.89	160.25	106.09	142.51	95.
6	20220314	161402_0	620.74	188.09	107.16	137.11	92.71	84.23	148.84	160.04	106.31	142.01	95.
7	20220314	161402_1	622.29	191.44	106.15	136.75	93.2	84.75	149.74	161.69	105.79	142.97	95.
8	20220315	115813_0	630.38	192.08	108.24	138.9	93.26	87.06	155.72	164.25	106.12	141.97	90
9	20220315	115813_1	628.63	191.12	106.99	138.46	92.37	87.39	153.14	162.15	107.39	141.91	91.
10	20220315	120012_0	631.37	190.86	107.49	138.98	93.57	88.27	154.24	163.36	107.75	143.81	92.
11	20220315	120012_1	627.5	190.73	107.85	138.11	93.31	88.01	153.96	163.24	107.98	141.1	91
12	20220315	120211_0	598.14	179.28	99.88	129.15	85.73	80.1	143.42	152.12	98.99	132.22	84.
13	20220315	120211_1	600.59	180.1	99.67	129	85.82	80.9	143.9	153.21	99.66	133.71	84.
14	20220316	095559_0	595.58	177.52	99.14	127.87	86.79	79.15	140.69	149.73	100.76	133.05	90.
15	20220316	095559_1	596.39	177.9	100.02	128.85	87.26	79.69	141.08	150.08	100.26	132.05	89.
16	20220316	095857_0	594.99	178.72	99.1	127.8	87.21	79.79	141.46	151.19	98.8	132.48	89.
17	20220316	095857_1	596.39	177.89	99.71	128.79	86.8	79.7	140.61	150.9	100.59	133.4	89.
18	20220316	100155_0	640.98	196.52	109.82	142.35	96.22	87.97	156.93	166.41	110.25	146.34	99.
19	20220316	100155_1	635.1	192.69	108.63	140.02	95.36	87.41	153.97	164.29	111.15	145.56	98.

Figure 3 Results sheet for SNR calculation of T2w images via the "noise_av" method.

This spreadsheet is in the same format as the results spreadsheet. The sheet names and first row headings for each parameter of interest should be the same. However, each sheet in the baseline spreadsheet should only have two rows with the first row specifying the parameters and the second row specifying the baseline values for each parameter.

The baseline spreadsheet is only used to generate graphs and tables for the final report. Therefore the recommended method of creation of the baseline spreadsheet is to run BSQA_analysis on multiple datasets without producing the report (the report can be produced, but without the baseline spreadsheet tables won't contain baseline values and the graphs won't have thresholds). Once enough data has been analysed to establish a baseline, the results spreadsheet can then be copied and renamed as the baseline spreadsheet. The User should then go through each sheet and put the average value for each parameter across all repeats in row 2 and delete all the other rows.

2.1.4 Baseline Magnitude PNGs

The program will attempt to input baseline magnitude PNGs alongside magnitude PNGs for this analysis run in the final report.

In order to create the baseline PNGs run BSQA_analysis on the baseline dataset and ensure a report is produced. This will produce magnitude PNGs for each coil element and all elements combined (see Figure 4). The files will be saved within the report directory under the subfolder "magnitude_images_T2" and sorted by date (see Figure 5). Within the "magnitude_images_T2" subfolder, copy folder containing the baseline dataset magnitude PNGs and rename it from the date to "Baseline" (see Figure 5). Do not change the file names within the "Baseline" folder

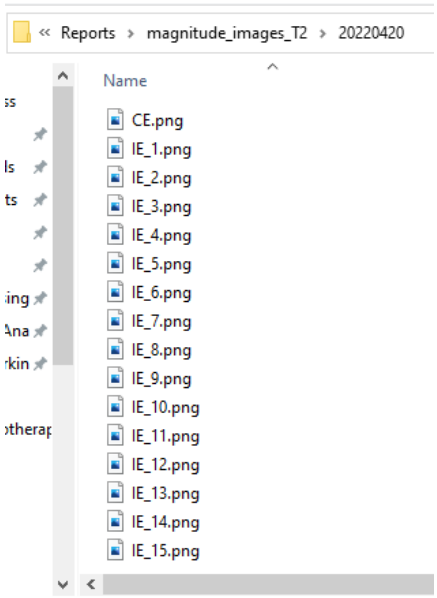


Figure 4 Magnitude PNGs

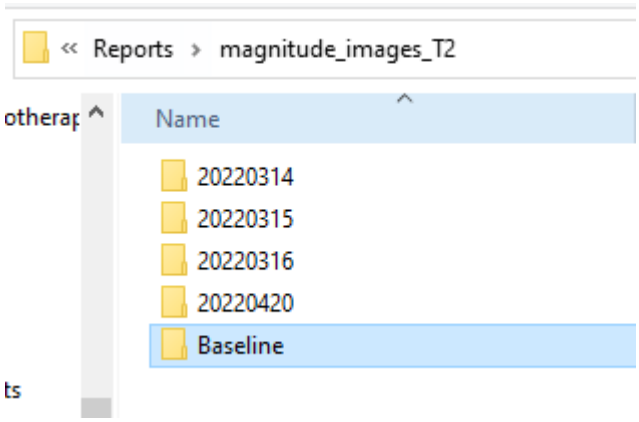


Figure 5 Magnitude images file structure.

2.2 Program Walkthrough

See **Error! Reference source not found.** for data flow index numbers.

2.2.1 initialise_analysis

The initialise_analysis class is first called. This looks for the config file and get the default parameters for the analysis (**data flow 1**).

The function initialise_analysis.Setup_Analysis is next called which produces a Tkinter window allowing the user to specify certain analysis parameters (see Figure 6). Under normal operation the user should not have to modify any of the default paths. Default values can be specified in the config file.

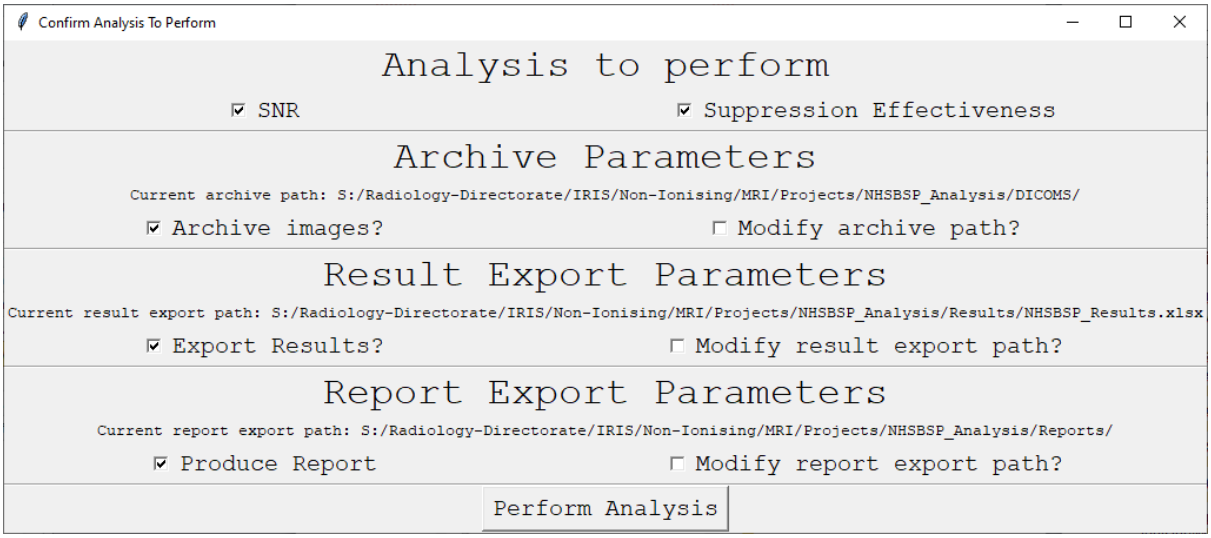


Figure 6 Tkinter GUI allowing the user to specify analysis parameters.

The user is next asked to select the directory containing all the DICOM images to be analysed on this analysis run (see section 2.1.2). DICOMS with a dcm.SeriesDescription tag of interest (tags of interest are specified in the config file) are sorted and input into a dictionary (**data flow 2**). If requested by the user the sorted images are then archived under the specified path (**data flow 3**).

2.2.2 initialise_masks

The sorted dictionary of DICOMS and the coil specification is next fed into the initialise_masks class (**data flow 4**). An assumption made that all images selected are in the same location (this is why the user needs to take care that the selected directory containing DICOMs to be analysed only contains the DICOMs from the run of interest. Masks are initially produced using the thresholds established in the class initialise_analysis and the user is asked to confirm that the mask is acceptable. The default is to use a T2w combined element image to produce the "image mask", but if one doesn't exist a T1w image is used. The ideal "image mask" should cover the entire phantom (see Figure 7).

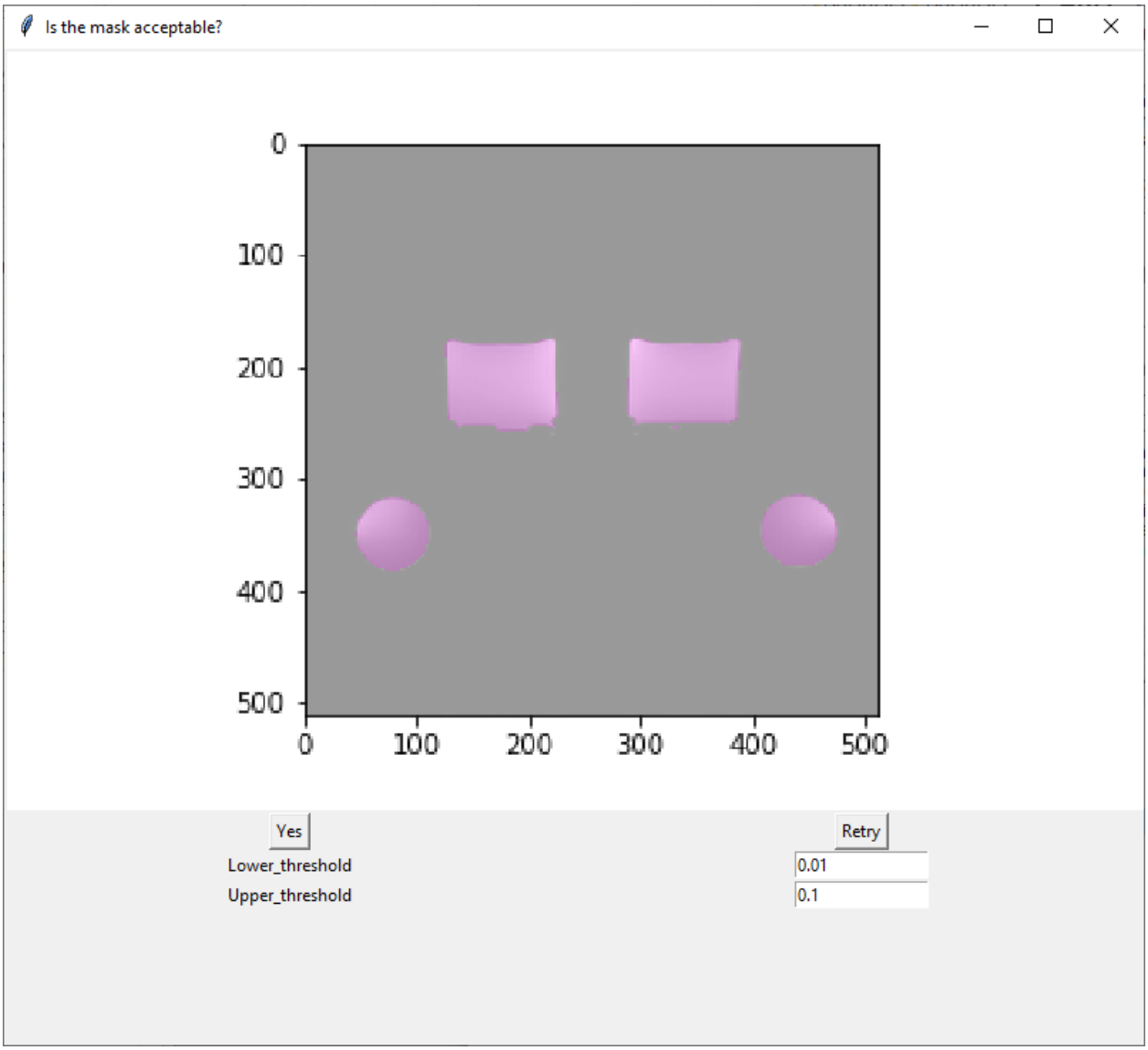


Figure 7 Acceptable phantom mask.

Under normal operation, the default thresholds will not need to be modified. If the mask is unacceptable this is likely due to at least one of the following: incorrect image acquisition, the program has attempted to produce the mask using a different type of image to previously, or there has been a coil failure. Before editing thresholds, the user should try isolate the issue. The same mask is used for the T1w and T2w images. The program then produces a "phantom mask" by contracting the "image mask" by 4 pixels and an "air mask" by inverting the accepted "image mask" and contracting by 5 pixels. Finally the program produces a "TM_1 mask" representing the sections of the "phantom mask" which should not be suppressed and a "TM_2 mask" representing the sections of the "phantom mask" which should be suppressed.

2.2.3 calculate_results

The sorted DICOMs, masks and number of coil elements are next fed into the calculate_results class (**data flow 5**). Four types of results are calculated (SNR, Uniformity, Contrast and Suppression Effectiveness). "Group average" results are also calculated, which are produced by averaging over the repeats for this analysis run.:

- **SNR:** SNR is calculated for all images via three methods. For more details on SNR calculation please refer to the document "RF Coil Testing - The Simply Physics way" by Moriel NessAiver:
  - **noise_av** (preferred method): SNR calculated using the assumption that the noise in the image is proportional to the mean of the signal in air (see Eqn. 1). k_{mean} is a scale factor dependent on the number of elements, BW is the receive bandwidth, $BW_0$is 130 Hz/px, $\overline{S}$ is the average signal across the "phantom mask" and $\overline{N}$ is the average signal across the "air mask".

$$SNR = k_{mean}\left(\frac{BW}{BW_0}\right)^{0.5}\frac{\bar{S}}{\bar{N}} \qquad \text{Eqn. 1}$$

  - **noise_std**: SNR calculated using the assumption that the noise in the image is proportional to the S.D. of the signal in air.
  - **NEMA:** SNR calculated via subtraction method (requires 2 images to produce one SNR value)
- **Uniformity:** The Uniformity (U_{int}) is calculated for all combined element images using the method outlined in IPEM Report 112 and is referred to as the integral uniformity method. A low pass filter is applied to the combined element image and the "phantom mask" is applied so only voxels only within the phantom are considered. Uniformity is calculated using Eqn. 2, where S_{Max} is the maximum voxel intensity and S_{Min} is the minimum voxel intensity.

$$U_{int} = 1 - \frac{S_{Max} - S_{Min}}{S_{Max} + S_{Min}} \qquad \text{Eqn. 2}$$

- **Contrast:** The contrast (C) is calculated for both the suppressed and non suppressed T1w images using equation Eqn. 3, where $\overline{TM_1}$ is the average signal within the "TM_1 mask" (non-suppressed) and where $\overline{TM_2}$ is the average signal within the "TM_2 mask" (suppressed).

$$C = \overline{TM_1} - \overline{TM_2} \qquad \text{Eqn. 3}$$

- **Suppression Effectiveness:** The suppression effectiveness is calculated via three methods using the T1w images. The contrast ratio (CR) is defined as $CR = \frac{\overline{TM_1}}{\overline{TM_2}}$
  - **Ratio of contrast ratios:** $\frac{CR_{suppressed}}{CR_{non-suppressed}}$
  - **Ratio of contrasts:** $\frac{C_{suppressed}}{C_{non-suppressed}}$
  - **Scaled Ratio of contrasts**: $\frac{C_{suppressed}}{C_{non-suppressed}}\frac{\bar{S}_{non-suppressed}}{\bar{S}_{suppressed}}$

2.2.4 export_to_excel

If the user requested the results to be exported then the results produced by calculate_results are fed into export_to_excel (**data flow 6**). The results are all inputted into the spreadsheet specified by the user, with separate sheets for different sequence types, results types. There are also separate sheets for the group average results. For each repeat a new row is added (**data flow 7**) with the date and acquisition ID of the DICOM used to produce the result

For each sheet if there is already a row with the same date and acquisition ID of the analysed data the default is to not overwrite the previous analysis run. If ask_overwrite_analysis = True in the config file the User is asked if they want to overwrite the previous analysis, otherwise a message is displayed and the previous results are not overwritten.

2.2.5 produce_report

If the user requested a report to be produced then produce_report is called which produces a pdf report summarising results. produce_report requires the results from calculate_results, the sorted DICOMs to generate magnitude PNGs, paths to locate the results spreadsheet, baseline spreadsheet and baseline magnitude PNGs as well as generic PDF parameters (defined in the config file) such as the pdf_header_image path, pdf_text_sizes and glossary (**data flow 8**). An attempt is made to input SNR, uniformity, supression effectiveness and contrast results. In each case a table of results is produced comparing the results on the current analysis to the baseline results in the baseline spreadsheet (**data flow 9**). Graphs are also produced showing how each parameter changes over time. This information is drawn from the results spreadsheet (**data flow 10**). The graphs also display thresholds which are produced from information in the baseline spreadsheet (**data flow 9**). For each graph, a PNG is produced before it is inputted into the PDF (**data flow 11**).

Magnitude PNGs are also generated for the T2w images (see section 3) (**data flow 12**). These PNGs are inputted alongside Magnitude PNGs from baseline (**data flow 13**) in the appendix.

The appendix is produced containing magnitude images for each element on the day of testing at baseline.

An initial (draft) report is produced, which allows the user to view the report and the user is prompted (see Figure 8) to input a comment and outcome (Pass/Fail/Undetermined). Once this has been done a final report is produced with the comment and result (**data flow 14**).

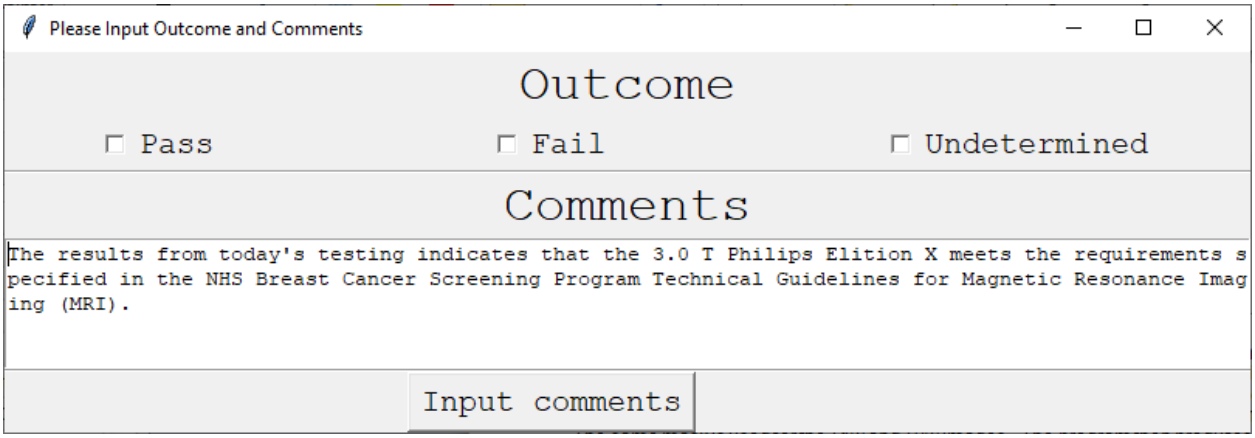


Figure 8 Tkinter window allowing the user to input a result outcome and comment into the PDF.

3 Version Control and Change History

Version	Date	Author	Section(s)	Principle Changes
1.0	21/05/2022	J. Harkin	All	Document Creation

Appendix 1: Example Config File Body Text

[user_input]
ask_overwrite_analysis = False

[default_paths]
default_search_path = S:/Radiology-Directorate/IRIS/Non-Ionising/MRI/Projects/NHSBSP_Analysis/DICOMS/to_analyse
default_archive_path = S:/Radiology-Directorate/IRIS/Non-Ionising/MRI/Projects/NHSBSP_Analysis/DICOMS/
default_results_path = S:/Radiology-Directorate/IRIS/Non-Ionising/MRI/Projects/NHSBSP_Analysis/Results/NHSBSP_Results.xlsx
default_baseline_path = S:/Radiology-Directorate/IRIS/Non-Ionising/MRI/Projects/NHSBSP_Analysis/Results/NHSBSP_Baseline.xlsx
default_report_path = S:/Radiology-Directorate/IRIS/Non-Ionising/MRI/Projects/NHSBSP_Analysis/Reports/

[sequence_names]
T2 = DelRec - SE_SNR
T1 = T1_GRE_NO_SPIR
T1_sup = T1_GRE_SPIR

[coil_spec]
Elements = 15
Lower_Threshold = 0.01
Upper_Threshold = 0.1

[sheet_names_to_report]
SNR = SNR_T2_noise_av
uniformity = GA_Uniformity_T2
suppression = GA_Suppression_T1w
contrast = GA_Contrast_T1w

[pdf_header_image]
file_path = S:/Radiology-Directorate/IRIS/Non-Ionising/MRI/Projects/NHSBSP_Analysis/Reports/NIR Logo.PNG

[pdf_text_sizes]
title_size = 24
heading_size = 16
body_txt_size = 10

[pdf_default_comment]
comment = Default PASS comment - The results from today's testing indicates that the 3.0 T Philips Elition X meets the requirements specified in the NHS Breast Cancer Screening Program Technical Guidelines for Magnetic Resonance Imaging (MRI).

[pdf_glossary]

SNR = (K_mean)(<TM>/<air>)(BW/BW0)^0.5. Where K_mean is a scale factor dependant on the number of elements, BW is the receive bandwidth of the acquired image, BW0 = 130 Hz/Px, <TM> is the average magnitude of pixels within the phantom mask and <air>is the average magnitude of pixels within the air mask.

Uniformity = The Uniformity (Uint) is calculated using the method outlined in IPEM Report 112 and is referred to as the integral uniformity method.

CE = Combined Element: These images are generated using a sum of squares combination of the individual element images.

IE = Individual Element: IE_1 indicates the element 1. Elements are numbered sequentially according to the DICOM Tag: 07A1,103E.

Contrast = <TM1> - <TM2>. Where <TM1> is the average magnitude of pixels within the TM1 mask and <TM2> is the average magnitude of pixels within the TM2 mask.

Scaled Contrast = The Contrast divided by <TM>

Contrast Ratio = <TM1>/<TM2>

Ratio of contrast ratios = The contrast ratio for the T1w suppressed image divided by the contrast ratio for the non suppressed image.

Ratio of contrasts = The contrast of the suppressed image divided by the contrast of the non suppressed image.

Scaled ratio of contrasts = The scaled contrast of the suppressed image divided by the scaled contrast of the non suppressed image.

[report_sections]

T2W SE Image Analysis = This section summarises the results of SNR and uniformity testing of the T2W images. SNR is reported for each element individually, and all elements combined. Uniformity is reported for the combined element (CE) image.

T1W GRE Image Analysis = This section summarises the results of the suppression effectiveness and contrast testing of the CE T1w images.

Appendix A - T2W SE Magnitude Images = This section displays the T2W magnitude images, for each element individually and all elements combined; on the testing date and at acceptance.