Realization of a framework for large scale virtual clinical studies in breast imaging

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Situation

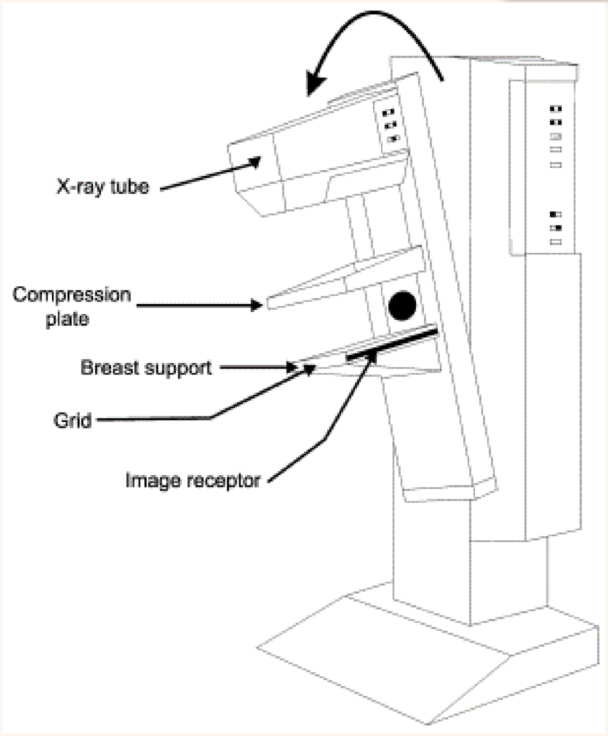


Figure 1: A mammography unit [3, p. 213]

Breast cancer is a common form of cancer that mainly affects women, and early detection is key to improving patients' prognoses and reducing mortality rates. **Mammography** can detect breast cancer in its early stages, when it is most treatable. This can lead to better outcomes for patients and can help reduce mortality rates [1]. During a mammogram, **ionizing radiation** is used. Therefore, it is important to **ensure the quality** of these interventions. To ensure quality, clinical trials are needed that identify the quality of the images and the influence of various scanning parameters of the mammography device on the image [2].

Over the past ten years, significant progress has been made in the use of **computer simulations** to design and improve medical imaging devices. These simulations, which are created using specialized software, allow researchers to **virtually test** and evaluate the performance of an existing or proposed device [4]. In 2011 the research group Medical Physics & Quality Control at the UZ Leuven developed a **simulation framework** in MATLAB. This tool allows to insert a simulated lesion in an image of a real patient [5].

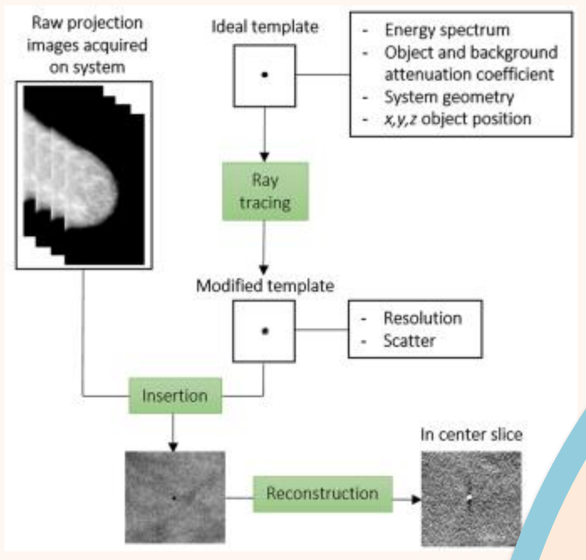


Figure 2: Diagram of the MATLAB simulation framework [5, p. 3]

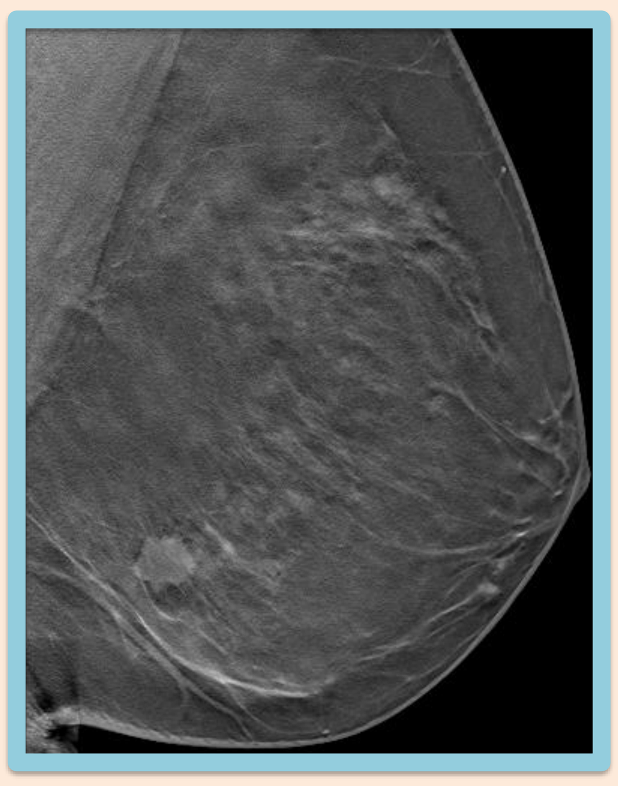
Problem & goal

Figure 3: Image of the simulation of a small aluminum sphere

Problem with current simulation framework:

- Not suitable for large-scale virtual clinical studies, making the simulation time for multiple simulations longer than needed.
- The user interface is not user-friendly.
- The code is spread across multiple files. This makes it difficult to understand the structure. That, combined with incomplete documentation, makes it very time-consuming for the user to understand and possibly modify the code.

Goal: The goal is to make a simulation tool in the Python environment that has the same functionality as the MATLAB simulation tool that is well structured and user-friendly. It also needs to be able to easily perform multiple simulations so that it can be used for large-scale virtual studies



Material and method

Method: The code was made in the Python environment Spyder by systematically programming each step of the pipeline. Validation was done by either comparing it to MATLAB simulation results or by visually checking the results. Besides validation the tool was also tested for its ability to simulate clinical cases.

Examples of validation:

Accuracy of simulated large area object:

- Aluminum sheet with dimensions 10 x 10 x 0.2 mm^3 is simulated and compared to the results in MATLAB.
- Parameters were compared like: SDNR and peak contrast. Also, the profile in the x-direction was compared.

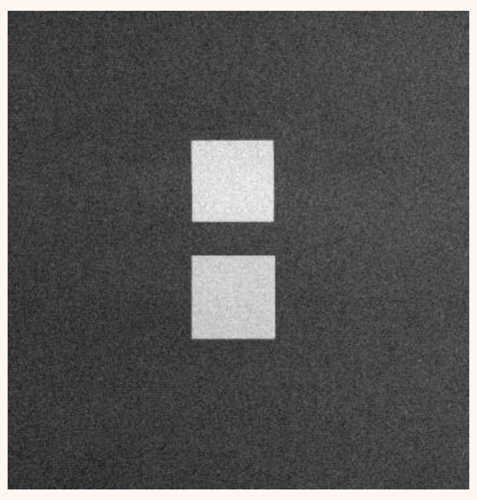


Figure 4: Image of the MATLAB and Python simulation of an aluminum sheet

Accuracy of simulated small high contrast object:

- Aluminum sphere with a radius of 0.5 mm.
- Results were compared to the MATLAB simulation.

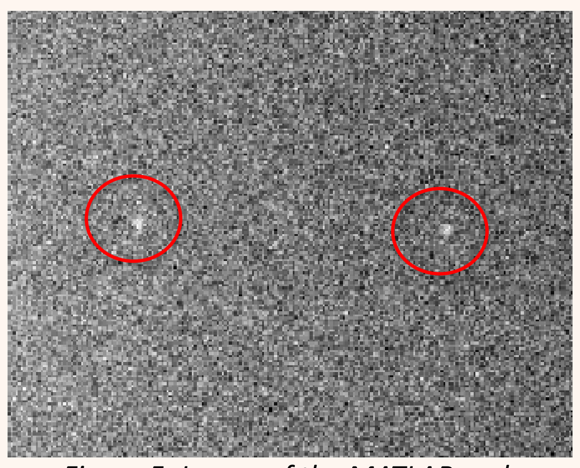


Figure 5: Image of the MATLAB and Python simulation of an aluminum sphere

Results and conclusion

Results:

- Resulting tool has full functionality of the MATLAB tool.
- Validation shows a general good correspondence between the simulations and real images with some bigger errors at certain cases
- Tool has the ability to mimic clinical cases by simulation.

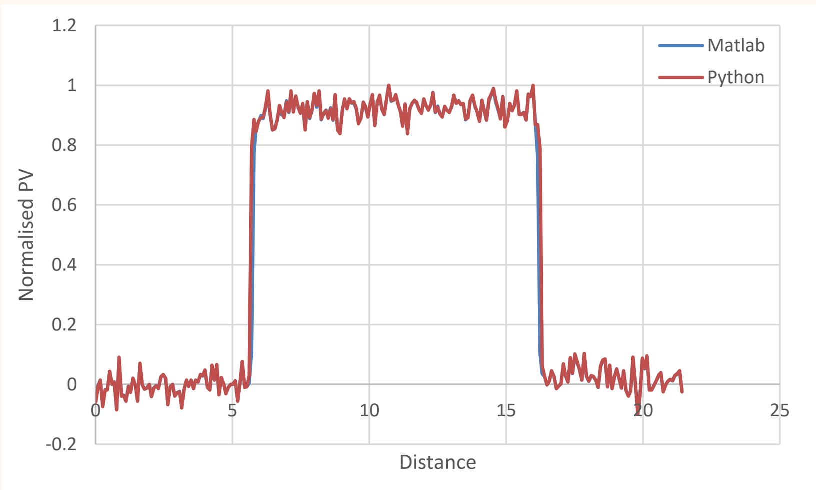


Figure 5: Comparison of the profiles from the MATLAB and Python simulation for aluminum sheet

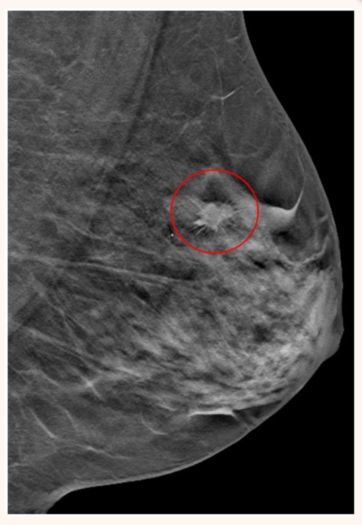


Figure 6: Outcome of a simulation of a clinical case where a lesion (red circle) is simulated on a real breast

Conclusion: The new tool can perform multiple simulation without input of the user meaning it can be used for large-scale clinical studies. The validation shows that the results of both the simulations match well. Further development should be made to correct minor errors.
The tool shows the ability to simulate clinical cases making it a viable option to be used in virtual clinical trials.

Supervisors / Co-supervisors / Advisors

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[1] "Bevolkingsonderzoek Borstkanker | Vlaanderen.be." https://www.vlaanderen.be/bevolkingsonderzoek-borstkanker (accessed Dec. 21, 2022).
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