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A scuola di astroparticelle

“Dalle astroparticelle alle nanotecnologie... a scuola di Fisica Moderna”

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Classe III ALM

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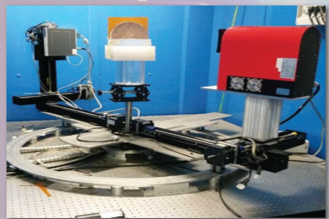
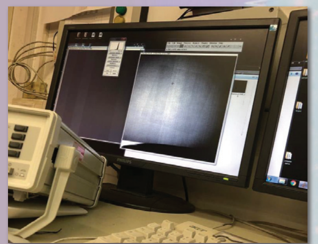
UNDERSTANDING X-RAY MAMMOGRAPHY: *MONTE CARLO SIMULATION*

Liceo Scientifico Matematico P.S. Mancini, 3ALM, Avellino, Italy

Purpose: The aim of this work is to understand the x-ray imaging. We simulated thanks to Montecarlo code some mammographic examinations.





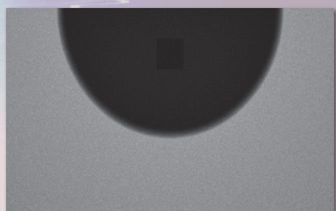
Materials and Methods: we used a GEANT4 based Monte Carlo code for simulating mammografic exams. We modelled a phantom of the female breast using a plexiglass cylinder with a semicircular section with a diameter of 16 cm and height 5 cm. The breast was included in two compression paddles made of PMMA. We also included a piece of copper. We simulated the X-ray source with monochromatic photons ranging between 40 and 80 kVp.

Simulation: In our case we made several attempts to achieve an increasingly precise image. So we initially positioned the aluminum phantom to simulate the tumor and did several analyzes:

1. Sequence of 50 images; we did not have a good result and we acquired a Dark, using a voltage of 60 KVp and a current of 500 microA
2. Sequence of 15 images; yet we have not had a good result without altering the values of current and voltage
3. As a last attempt we have increased by 20 images and we have achieved a better result.

We then decided to change the material and replace aluminum with copper. We also reduced the thickness of the Plexiglas to observe its effects, having a material three times more dense than aluminum. In fact with only 20 images it was possible to have an excellent image quality.

Results: With the simulation mammografic unit we were able to detect cylindrical lesions with diameters down to 2 mm. With the dose study we showed that the contrast to noise ratio (CNR) increases as the dose level increases; on the other hand the CNRD which takes into account also for the absorbed dose resulted constant for dose higher than 1 mGy. With the energy study we showed that the CNR has a maximum value for 40 kVp photon energy; the CNRD, instead, increases as the photon energy and it presents its maximum value at 80 kVp.



Conclusion: throught the use of a Monte Carlo code we have understood the fundamentals of the X-ray based medical imaging. In particoular we simulated mammografic exams for studying the influences of the radiation dose and the photon energy on the image quality. For this purpose we understood the effects of the dose on the biological tissue andthe fundamental parameters for a quantitative image analysi.

UNDERSTANDING X-RAY MAMMOGRAPHY:

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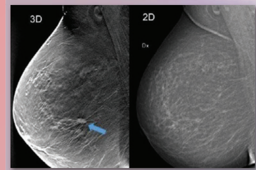
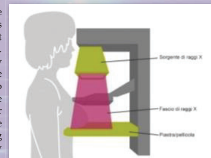


Mammography is a specific type of X-ray imaging that uses a low-dose radiology system specially designed to create detailed breast images, called mammograms.The mammograms are used or as a screening tool for the early detection of breast cancer in asymptomatic women and for the detection and diagnosis of breast cancer in women without signs or symptoms of breast cancer or for the detection and diagnosis of cancer in women with symptoms such as nodules, pain or nipple discharge.

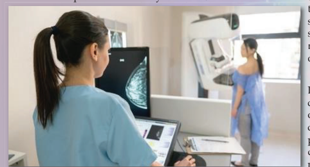
Digital mammography, also known as **full-field digital mammography**, uses electronic detectors that convert X-rays into electrical signals. Breast images can be viewed on a computer screen. Advanced developments in mammography allow considerable reductions in the required radiation dose. For example, digital mammography can reduce the dose by up to 50% compared to a conventional film mammography. New software is also available that can further reduce the dose up to a maximum of 30% while maintaining the same image quality.

Screening mammography

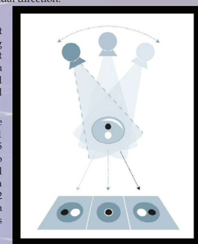
Breast cancer is the most common cancer in the world for women. The sooner breast cancer is detected, the better the possibilities for treatment and treatment with conservative breast therapy. Because mammography allows the early detection of breast cancer, many countries have established screening programs for women who have no or no sign of breast cancer. For routine breast screening, two images are acquired for each breast and a radiologist interprets the mammograms. The current screening mammography emits an extremely low radiation dose, so that the health risks due to mammographic screening are minimized and the benefit of the early detection of tumors is considered superior to these very low risks.

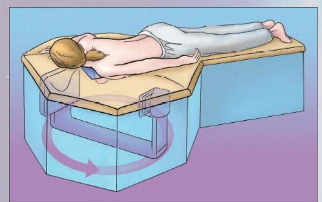


Digital breast tomosynthesis is a reduced scan angle tomographic technique. The DBT scanner includes an X-ray tube rotating around a horizontal axis that, in a certain range of angles, acquires a series of low-dose projections of the compressed breast. This tube can emit X-rays continuously or in step-and-shot mode, and move in such a way as to obtain a craniocaudal view, that is to say that the beam is located perpendicular to the compressed sinus, or mediolateral oblique, ie with the breast irradiated by a beam with a direction of 45 ° with respect to the craniocaudal direction.



During the examination, the patient can be positioned standing, sitting or lying down, with the breast compressed between a compression plate and the aforementioned detector: the three-dimensional nature of tomosynthesis, however, makes it necessary to have less compression of the breast, which involves greater comfort for the patient compared to the mammography examination. The devices on the market acquire between 11 and 50 projections, in a range of angles between 15 ° and 60 ° and in times that vary between 5 and 25 seconds. The flat panel digital detectors used for tomosynthesis are characterized, compared to mammography, by a reduced reading time (due to residual images in subsequent acquisitions), and minimal reduction of efficiency at low exposure; this allows the acquisition of numerous images in a scanning time of 10-20 seconds. However, the definition of the reconstructed tissue slice, typically 1-2 mm in the z direction (i.e. in the direction orthogonal to the detector), does not indicate the resolution in that direction, which instead is a function of the angular interval at which the tomography is performed .





Breast computed tomography (breast computed tomography, BCT) allows, at least in principle, to overcome the problem of DBT reconstruction artifacts, which was presented in the last paragraph (while introducing other types of artifacts), and allows to perform X-ray imaging of the breast without the need to compress the organ, with considerable reduction of the patient's discomfort during the examination. In the BCT the breast to be analyzed is inserted in a special opening: it is positioned in this way at the center of a rotation system of the imaging apparatus, which moves parallel to the sagittal plane and which provides, in diametrically opposite positions, a X-ray tube and a scanner. This configuration allows the breast to be irradiated, thus preventing exposure to x-rays of the tissues of the thoracic cavity; moreover, it also makes the exam much less annoying for the patient than for a mammogram, because the breast does not undergo the mechanical stress of the latter's characteristic breast compression. The geometry of the scanner, in theory, would allow the reconstruction of an image of the same size as the breast.

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