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Development of computational tools for construction of a continuous energy X-ray spectra catalogue for mammography simulation

Santos[a] L. C. S., Silva[b] J. F., Vieira[b,c] J.W., Lima[d] F. R. A., Oliveira[e] A. C. H., Oliveira[a] V. R. S.

[a]Universidade Federal de Pernambuco, 50670-901, Av. Prof. Moraes Rego, 1235, Recife/PE

larissa.css@outlook.com; victor.soliveira@ufpe.com

[b]Instituto Federal de Pernambuco, 50740-545, Av. Prof. Luiz Freire, 500, Recife/PE

jessicafelix1719@gmail.com

[c]Escola Politécnica de Pernambuco, 50720-001, R. Benfica, 455, Recife/PE

jose.wilson59@uol.com.br

[d]Centro Regional de Ciências Nucleares do Nordeste, 50740-545, Av. Professor Luiz Freire, 200, Recife/PE

falima@globo.com

[e]Faculdade Nova Esperança, 58067-698, Av. Frei Galvão, 12, João Pessoa/PB

oliveira_ach@yahoo.com

Introduction

Exposing individuals to ionizing radiation is unfeasible as a research method in terms of radiological protection standards [1]. Exposure Computational Models (ECMs) play an important role in simulating radiation transport and its interaction with matter. ECMs simulations are comprised of three basic components: a simulator algorithm with radioactive source properties, a Monte Carlo (MC) code for radiation transport simulation, and a computational phantom to represent the geometry under analysis [2]. Such advanced techniques have been used to accurately simulate medical procedures. This study aimed to construct a catalogue of X-ray energy spectra of mammography for use in various simulations. Additionally, an *in-house* software was developed in order to manage catalogue setting features.

Methodology

Data from output spectra used to construct the catalogue were primarily obtained in the online tool Simulation of X-Ray Spectra (SXRS), available at *https://www.oem-products.siemens-healthineers.com /x-ray-spectra-simulation*. SXRS enables spectra downloading and provides access to plenty of selection parameters, including anode material, tube voltage (ranging from 18 kV to 40 kV, at 1kV intervals), filter material, and filter thickness (table 1). Output data format acquired on spectra simulations need to be formatted in order to be read and interpreted by the MC code.

Table 1: *Anode material, filter material and filter thickness.*

Anode Material	Filter Material	Thickness (mm)
Molybdenum	Molybdenum	0,03
Molybdenum	Rhodium	0,025
Rhodium	Rhodium	0,025
Tungsten	Aluminium	0,5
Tungsten	Rhodium	0,05
Tungsten	Silver	0,05

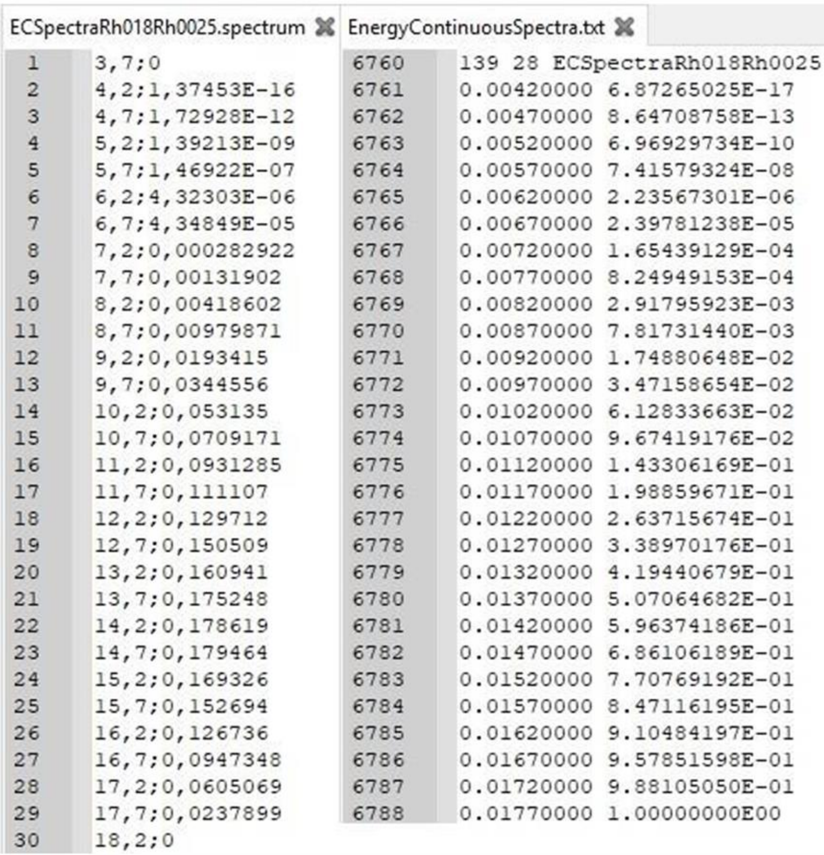
Source: the authors.

For this purpose, an algorithm was implemented in the MonteCarlo software and aided by Digital Image Processing (DIP) software [3].

Results

Figure 1 shows, partially, the image of the original spectrum file labeled by '*ECSpectraRh018Rh0025.spectrum*' (energy in KeV and the average number of photons per mm²) and the same data organized in the *EnergyContinuousSpectra.txt* file with discrete spectra catalogue (energy in MeV and the cumulative probability).

Figure 1: *Original spectra data and organized spectra data in EnergyContinuousSpectra.txt file.*



ECSpectraRh018Rh0025.spectrum

```
3,7;0
4,2;1,37453E-16
4,7;1,72928E-12
5,2;1,39213E-09
5,7;1,46922E-07
6,2;4,32303E-06
6,7;4,34849E-05
7,2;0,000282922
7,7;0,00131902
8,2;0,00418602
8,7;0,00979871
9,2;0,0193415
9,7;0,0344556
10,2;0,053135
10,7;0,0709171
11,2;0,0931285
11,7;0,111107
12,2;0,129712
12,7;0,150509
13,2;0,160941
13,7;0,175248
14,2;0,178619
14,7;0,179464
15,2;0,169326
15,7;0,152694
16,2;0,126736
16,7;0,0947348
17,2;0,0605069
17,7;0,0237899
18,2;0
```

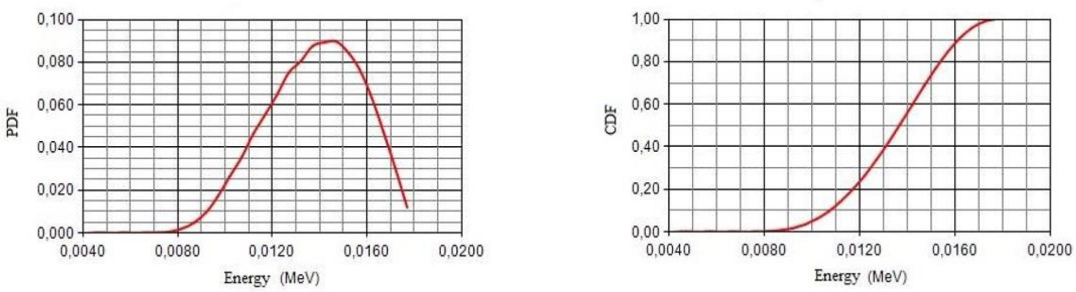
EnergyContinuousSpectra.txt

```
139 28 ECSpectraRh018Rh0025
0.00420000 6.87265025E-17
0.00470000 8.64708758E-13
0.00520000 6.96929734E-10
0.00570000 7.41579324E-08
0.00620000 2.23567301E-06
0.00670000 2.39781238E-05
0.00720000 1.65439129E-04
0.00770000 8.24949153E-04
0.00820000 2.91795923E-03
0.00870000 7.81731440E-03
0.00920000 1.74880648E-02
0.00970000 3.47158654E-02
0.01020000 6.12833663E-02
0.01070000 9.67419176E-02
0.01120000 1.43306169E-01
0.01170000 1.98859671E-01
0.01220000 2.63715674E-01
0.01270000 3.38970176E-01
0.01320000 4.19440679E-01
0.01370000 5.07064682E-01
0.01420000 5.96374186E-01
0.01470000 6.86106189E-01
0.01520000 7.70769192E-01
0.01570000 8.47116195E-01
0.01620000 9.10484197E-01
0.01670000 9.57851598E-01
0.01720000 9.88105050E-01
0.01770000 1.00000000E00
```

Source: the authors.

Figure 2 shows a spectrum curve (*ECSpectraRh018Rh0025.spectrum*), obtained by reading the *EnergyContinuousSpectra.txt* file in the DIP software. The following 18 kV spectrum was simulated with anode-filter combination of Rhodium-Rhodium and filter thickness of 0.025 mm. Both charts below describe, respectively, the probability density function (figure 2 *(a)*) and accumulated distribution function (figure 2 *(b)*) as a function of energy (MeV).

Figure 2: *Spectrum curve charts read in DIP.*
(a) Probability Density Function. (b) Cumulative Distribution Function.



(a) *(b)*

Source: the authors.

Conclusion

In-house softwares of the Numerical Dosimetry Research Group were used to organize and display continuous energy spectra, derived from mammography simulations, in a text file and visualize each spectrum as a curve. Regarding all simulated spectra, the catalogue was demonstrated to be extremely useful for coupling in ECMs and it will soon be used in dosimetric assessments.

References

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[3] VIEIRA, J. W.; LIMA, F. R. A. Um software para o processamento de imagens digitais usadas na construção de fantomas de voxels. Retrived from: <https://inis.iaea.org/collection/NCLCollectionStore/_Public/46/091/46091313.pdf>. Accessed May 23th, 2019.