//

DESCRIPTION OF THE SPECT BENCHMARK

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The gamma camera which is simulated in the benchmark is a virtual camera and does not correspond to any commercial system.
The camera is made of 4 heads at 90° each, each with:

- a 2 cm thick lead shielding
- a lead collimator (hole diameter: 0.3 cm, collimator thickness: 3 cm and septal thickness: 0.6 mm)
- a 1 cm thick NaI crystal
- a 2.5 cm thick backcompartment in perspex

The head of the camera (i.e. the scanner) is 7 cm in thickness, 21 cm in width and 30 cm in length.

A SPECT acquisition is simulated, using the SPECThead system.
The acquisition consists in 64 projections, i.e. 16 projections per head. The heads move along a circular orbit with a 7 cm radius of rotation and a speed of 0.15 degree per second.

The object under investigation is a cylindrical phantom (5 cm in diameter and 20 cm in length) filled with water and including a cylinder 2 cm in diameter and 5 cm long filled with Tc-99m (emission energy: 140 keV). The phantom lies on a table (0.6 cm deep, 8 cm wide and 34 cm long). During the “acquisition”, the table translates together with the phantom (which does not move with respect to the table), at 0.04 cm/s. Confinement is used to make the phantom move simultaneously with the table. Confinement is achieved by creating a volume (called movsource) with the same dimensions as the source and with a translation motion identical to that of the table and by confining the activity to this volume. The activity of the source is fixed to 30 kBq.

The detected events are recorded in the crystal volume. The Compton events are detected in the following volumes:

- phantom (phantom and movsource)
- collimator
- back-compartment
- shielding
- table

The physics processes are modelled using the low energy electromagnetic processes package. Rayleigh, photoelectric and Compton interactions are set on while the gamma conversion interactions are set off.

To speed the simulation up, thresholds are introduced. The X-rays are tracked until their energy fall under 20 keV. Secondary electrons are not tracked.

The digitizer processes the hits recorded by the sensitive detector.
The adder module transforms hits into pulses.

The blurring module simulates a Gaussian energy blurring of FWHM=10% at 140 keVLimited spatial resolution of photomultipliers and associated electronic was simulated using a Gaussian blur with standard deviation of 2 mm.

A thresholder and a upholder were used to consider only the particles detected with an energy between 20 and 190 keV.

16 runs of 37.5 seconds are performed, to simulate the 16 positions of the 4 gamma camera heads, yielding 64 projections.

//

HOW TO USE benchmark_spectra.c

//

1) Compile the program using:

```
gcc –o benchmark_spectra benchmark_spectra.c -lm
```

2) Run the program using:

```
./benchmark_spectra gateSingles.dat
```

where GateSingles.dat is the name of the file generated during the run of the benchmark.

Help regarding the program can be obtained using:

```
benchmark_spectra -h
```

3) The program is an interactive program and runs as follows:

The user is asked for the lower threshold of the energy spectrum to be created:

```
Enter the lower energy threshold (MeV)
0.02  //The user chooses 0.02 MeV
Lower energy threshold is 0.0200000 MeV
```

The user is asked for the upper threshold of the energy spectrum to be created:

```
Enter the upper energy threshold (MeV)
0.19 //The user chooses 0.19 MeV
Upper energy threshold is 0.1900000 MeV
```

The user is asked for the number of energy windows in which the energy range should be split:

```
Enter the number of energy windows
100 //The user chooses 100
Energy range will be divided into 100 energy windows
```

The user is asked for the number of scattering volumes for which the scatter spectrum should be created. The maximum number of scattering volumes is 10.

```
Enter the number of scattering volume (max is 10)
6 //The user chooses 6
6 scattering volumes will be considered
```

The user is asked for the first four letters of each scattering volume to be considered:

```
Enter the first four letters of the scattering volume number 1
shie //The user chooses shie for shielding
Enter the first four letters of the scattering volume number 2
coll //The user chooses coll for collimator
Enter the first four letters of the scattering volume number 3
comp //The user chooses comp for compartment
Enter the first four letters of the scattering volume number 4
tabl //The user chooses tabl for table
Enter the first four letters of the scattering volume number 5
```

```
movs //The user chooses movs for movsource
Enter the first four letters of the scattering volume number 6
Phan //The user chooses Phan for Phantom

The scattering volumes that will be considered are the following:
shie
coll
comp
tabl
movs
Phan

Beginning of processing

End of processing
```

The program lists the names of the files corresponding to each spectrum that has been created:

```
File fich_p corresponds to the primary spectrum
File fich_c corresponds to the photons which have scattered in the
crystal
File fich_t corresponds to the total spectrum
File fich_1 corresponds to the photons whose last scatter
interaction was in the shiel volume
File fich_2 corresponds to the photons whose last scatter
interaction was in the coll volume
File fich_3 corresponds to the photons whose last scatter
interaction was in the comp volume
File fich_4 corresponds to the photons whose last scatter
interaction was in the tabl volume
File fich_5 corresponds to the photons whose last scatter
interaction was in the movs volume
File fich_6 corresponds to the photons whose last scatter
interaction was in the Phan volume
File fich_o1 corresponds to 1st order scatter
File fich_o2 corresponds to 2nd scatter order
File fich_o3 corresponds to 3rd scatter order
File fich_o4 corresponds to 4rd scatter order
File fich_o5 corresponds to scatter orders greater than 4
```

The program lists the number of detected counts in each spectrum:

```
Number of counts for the total energy spectrum = 35852
Number of counts for the primary spectrum =11719
Number of counts for the total scatter spectrum =24133
Number of counts for the crystal scatter spectrum =2966
Number of counts for the shie scatter spectrum = 2
Number of counts for the coll scatter spectrum = 779
Number of counts for the comp scatter spectrum = 442
Number of counts for the tabl scatter spectrum = 1197
Number of counts for the movs scatter spectrum = 4902
Number of counts for the Phan scatter spectrum = 13844
Number of counts for the order1 scatter spectrum = 12713
Number of counts for the order2 scatter spectrum = 5532
Number of counts for the order3 scatter spectrum = 2846
Number of counts for the order4 scatter spectrum = 1511
Number of counts for scatter orders greater than 4 spectrum = 1531
```

The output files are ASCII files. Each file is made of one column and as many lines as the number of energy windows. A line represents the number of detected photons in an energy window.
The generated files can be easily imported in Excel to be processed.

///

HOW TO USE benchmark_projections.c

///

1) Compile the program using:

```
gcc –o benchmark_projections benchmark_ projections.c -lm
```

2) Run the program using:

```
benchmark_projections GateSingles.dat
```

where gateSingles.dat is the name of the file generated during the run of the benchmark.

Help regarding the program can be obtained using:

```
benchmark_projections -h
```

3) The program is an interactive program and runs as follows:
The user is asked for the dimension of the image to be created:

```
Enter the number of rows and columns of the images to be created
128  //The user wants images of size 128 x 128
Image size is 128 x 128
```

The user is asked for the lower energy threshold of the image to be created:

```
Enter the lower energy threshold (MeV)
0.02  //The user chooses 0.02 MeV
Lower energy threshold is 0.020000 MeV
```

The user is asked for the upper energy threshold of the energy spectrum to be created:

```
Enter the upper energy threshold (MeV)
0.19 //The user chooses 0.19 MeV
Upper energy threshold is 0.190000 MeV
```

The user is asked for the pixel size of the images to be created:

```
Enter the size of the pixels (mm)
0.904 //The user chooses 0.904 mm
Pixels are 0.904 mm x 0.904 mm
```

The number of projections is predefined and is 64.

```
Beginning of processing

End of processing
```

The program lists the number of detected counts in each spectrum:

```
Number of detected events in the image of primary and scattered
photons = 17606
Number of primary events in the image of primary photons = 5689
Number of scattered events  in the image of scattered photons = 11917
```

The program lists the names of the file corresponding to the images that has been created:

```
File Total corresponds to the image of primary and scattered photons
File Primary corresponds to the image of primary photons
File Scatter corresponds to the image of scattered photons
```

Output files are Interfile files without header (raw data) in integer coded on 4 bytes.

//

HOW TO USE benchSPECT.C

//

1) After processing successfully the SPECT benchmark, start root:

```
root
```

2) Run the root analysis program:

```
.x benchSPECT.C
```

3) As a result, it produces plots similar to those displayed in benchSPECT.gif and outputs similar to those stored in benchSPECT.log.