TOWARDS A STANDARDIZATION OF THE DESCRIPTION AND VALIDATION OF MONTE CARLO SIMULATION CODES IN SPECT AND PET

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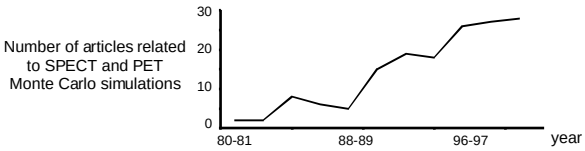
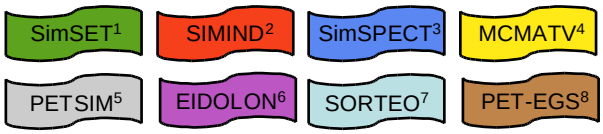
BACKGROUND

Monte Carlo simulations are increasingly used in SPECT and PET, for optimizing imaging protocols, studying quantification issues, assessing quantification protocols and even designing correction methods.



About 10 simulation codes dedicated to SPECT and/or PET simulations are currently available. However, there is no way to readily compare their features and performance.



Examples of well-known codes dedicated to SPECT and PET simulations

OBJECTIVES

1. To introduce a description profile for Monte Carlo SPECT and PET simulation codes by which code developers might specify their codes.

2. To propose validation procedures for Monte Carlo SPECT and PET simulation codes by which uniform and accurate specification of code performance could be accomplished.

METHODS

- Comprehensive review of the publications related to SPECT and PET Monte Carlo codes.
- Identification of the characteristics which differ from code to code and which should therefore be systematically specified.
- Definition of a **description profile** consisting of these features.
- For 7 simulation codes, attempt to fill in the description profile from published material only.
- Listing of the procedures and parameters used to validate Monte Carlo simulation codes in SPECT and PET.
- Derivation of a set of simulator **performance attributes** that best characterize the agreement between simulated and real data.
- For 7 simulation codes, attempt to specify the performance attributes solely from published material.

RESULTS

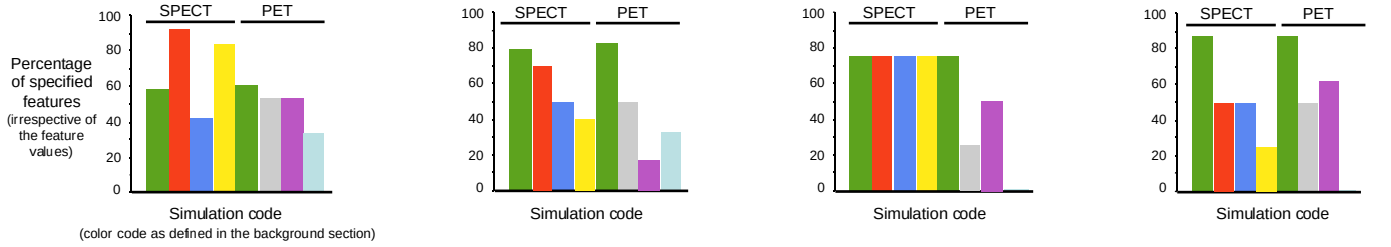
- The **description profile** consisted of 40 first-level features related to the:

Model **accuracy** (15 features)
e.g., random number generator, coherent scatter modeling, references of the cross-section tables, crystal interaction modeling.

Code **flexibility** (13 features)
e.g., type of source description, type of detectors (plane, ring), simulation of transmission studies, output data.

Code **efficiency** (4 features)
e.g., variance reduction techniques (forced detection, stratification, weight windows), parallelization facilities.

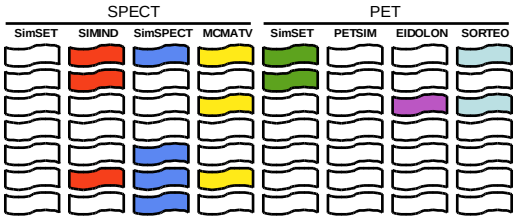
Ease of use (8 features)
e.g., language, supported platforms, user interface, availability, technical support, test data, documentation.



(color code as defined in the background section)

- 7 **performance attributes** were identified, each attribute including several sub-attributes and being given together with NEMA-like test conditions, test equipments, measurement procedures and reporting techniques.

Performance attributes	**Sub-attributes**
- Spatial resolution	centered in the FOV, off-centered, without and with scatter
- Local spectra	at different positions
- Scatter fractions	for different configurations
- Detector shielding	close and far from the end of the FOV
- Sensitivity	2D / 3D
- Image	simple objects, anthropomorphic phantoms
- Statistical properties of simulated data	without and with variance reduction techniques



colored flags indicate that published papers include validation data against real measurements regarding the attribute

DISCUSSION and CONCLUSION

- Simulation codes are currently not completely specified, which prevents from getting a precise picture of their potential.
- Current performance reports of simulation codes are incomplete and do not use common measurement procedures. This limits the sound use of the codes and makes it difficult to compare code performance.

Description profile and set of performance attributes are needed to uniformly characterize SPECT and PET simulation codes, hence help the potential user choose the code best suited to his specific application. We suggest definitions of description profile and performance attributes for the description and validation of simulation codes. These definitions might serve as a basis for a discussion between researchers involved in Monte Carlo simulations to agree on standardized procedures for code description and validation.

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