Online PET Reconstruction From List-Mode Data
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INTRODUCTION
This work proposes an alternative to ordered subsets to improve the convergence speed of list-mode expectation-maximization algorithms.

Instead of subdividing the input data into subsets, the stream of measured coincidence events is processed online and the image is directly updated. The Sliding Window Expectation-Maximization (SWEM) algorithm is an incremental estimation method that reconstructs explicitly a dynamic image.

STATIC PHANTOM EXPERIMENT

Sliding and Expanding Window
Graphical representation of the projection-based bookkeeping mechanism of the SWEM algorithm. The number of already processed pages is noted in front of each line. N is the number of events.

1. The data stream never ends but pages index the sub-space.
2. The image is updated incrementally for each new event.
3. Previous image updates of older events are removed.
4. Pages are circular, the window expands (i.e., page replacement).

The width of the sliding window increases progressively to balance smoothly between early estimation and global convergence behavior.

Nested Balls Phantom
The numerical phantom is defined by 4 spheres of various activity and size. A list-mode data of 9 million events was simulated by Monte-Carlo. Event by event (EBE) variants of list-mode OSEM and COSEM are special cases of SWEM. EBE-OSEM 1 page of 500,000 events and no window expansion (factor set to 1.0). EBE-COSEM 6 pages of 500,000 events such that the whole 8 million events are covered. SWEM 6 pages of 500,000 events and 10% of window expansion (factor set to 1.1).

Quantitative Analyses of Static Image Reconstructions
The contrast recovery coefficient and the normalized mean squared error (NMSE) from the objective image are plotted for various values of the window expansion factor between 1.0 and 1.2. The number of memory pages is fixed to 4 for SWEM. Using more pages increases further the performances but requires more memory resources. The visual contrast is defined as the ratio between the reconstructed mean activity in the small high activity ball and the mean activity in a reference region inside the background. With an appropriate window expansion factor, SWEM prevents overfilling the data, is faster than COSEM, and yields better image quality than OSEM.

DYNAMIC CARDIAC PERFUSION STUDY

MLEM Maximum Likelihood Expectation-Maximization

Batch EM Algorithm
For each image element
1. Expectation from all events compute the likelihood of the image element
2. Maximization multiply the image element to improve image likelihood

Online EM Algorithm
For each event
1. Expectation from the event, compute the likelihood of all image elements
2. Maximization increment all image elements to improve image likelihood


tube of response model
The tube of response model is more accurate. A fast implementation is 40% faster than incremental Saldon.

Cardiac Perfusion Protocol
A bolus of 511 labelled ammonia is injected intravenously and a list-mode is acquired during two minutes only. The tracer quickly enters the blood pool during the first few seconds and then passively diffuses into tissues. A dynamic image is reconstructed to capture the flow of tracer:

• T1K12P performs independent static image reconstructions from batches of data acquired during 10 (12 iterations).
• SWEM updates the image estimate for each event and enforces temporal coherence (single pass over the dataset).

Editorial note: This work presents a general online image reconstruction method for PET list-mode data. The online SWEM algorithm is based on event-by-event incremental image updates. SWEM improves the current image by exploring the statistical information of events, as soon as they are measured.

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