UCDAVIS HEALTH

Cloud-Based Serverless Computing Enables Accelerated Monte Carlo-Based Scatter Correction for PET

UCDAVIS EXPLORER MOLECULAR IMAGING CENTER

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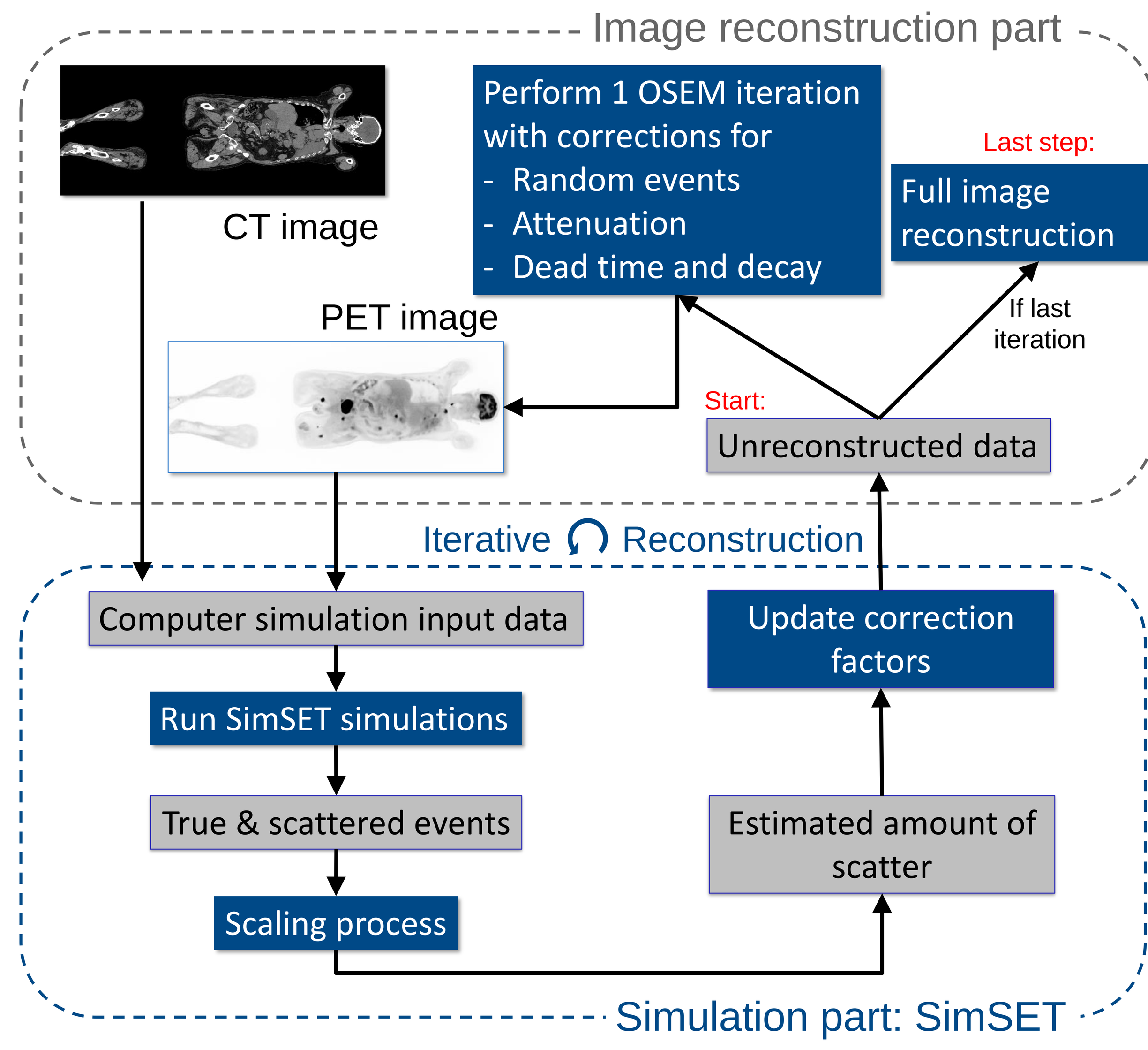
Introduction and Background

- **Importance of scatter correction (SC)**
  Essential component of PET image reconstruction to obtain quantitatively accurate images with high contrast
- **Total-body and long axial field-of-view PET**
  SC becomes more complex
  - Huge data sizes
  - More oblique lines of response with higher probability for multiple scatters
  - Variable coincidence time windows
- **Implementation: Monte Carlo-based approach**
  - Inherently includes multiple scatter
  - Separation of trues and scatters
  - Challenge: high computational expense
- **Overcoming computational burdens**
  Highly parallelized cloud-based computation

Scatter Correction for Total-Body PET

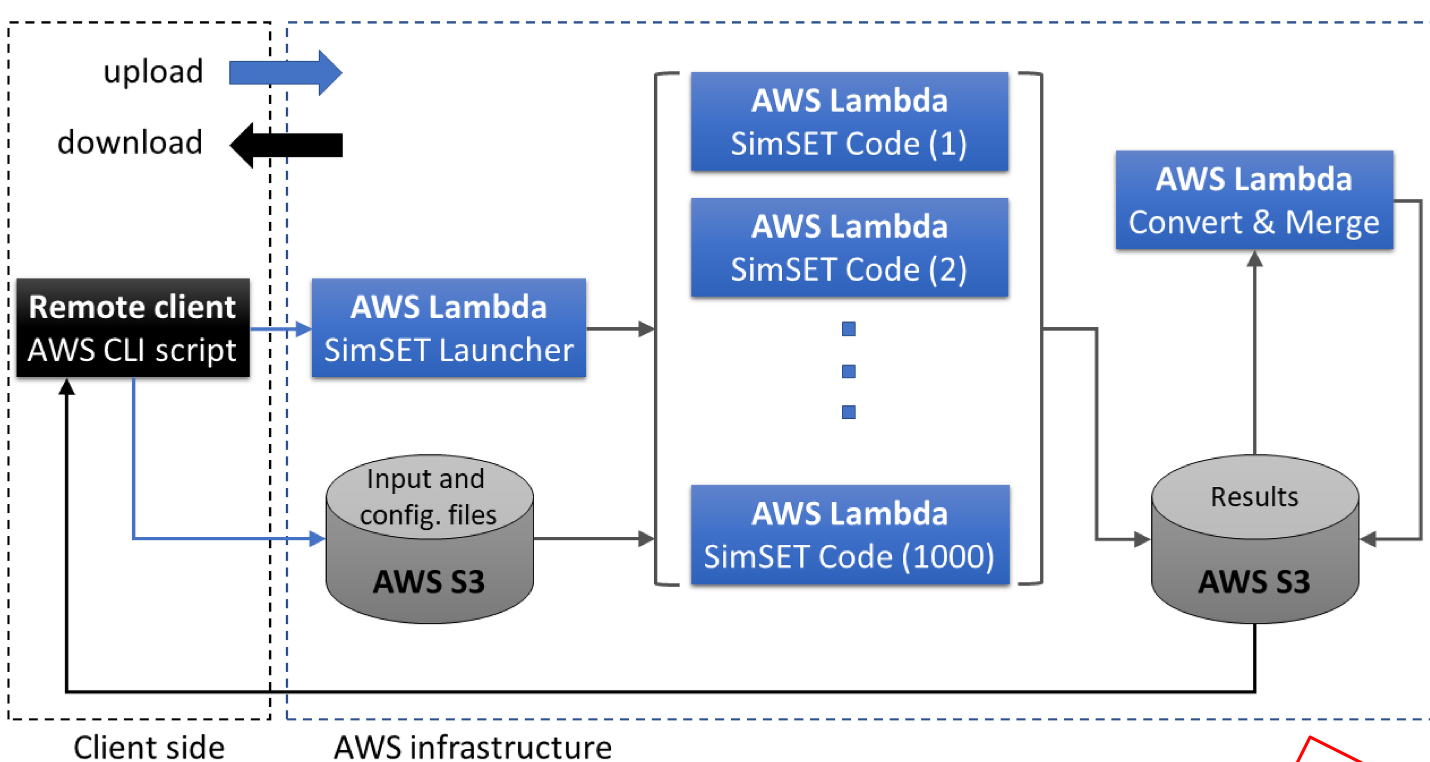
- **Monte Carlo-based scatter correction**
  - Utilizing the SimSET toolkit
  - SC performed between individual image reconstruction iterations
  - Using 2.5 billion simulated decays
- **Sinogram scaling**
  - Detector block-based sinograms
  - Scaling of (trues + scatters) to (prompts – randoms)
  - Calculation of SC terms for each list-mode event
- **Computational burden**
  ~1 hour (!) per iteration on local servers



Acceleration through Cloud-Based Computing

Manuscript in preparation

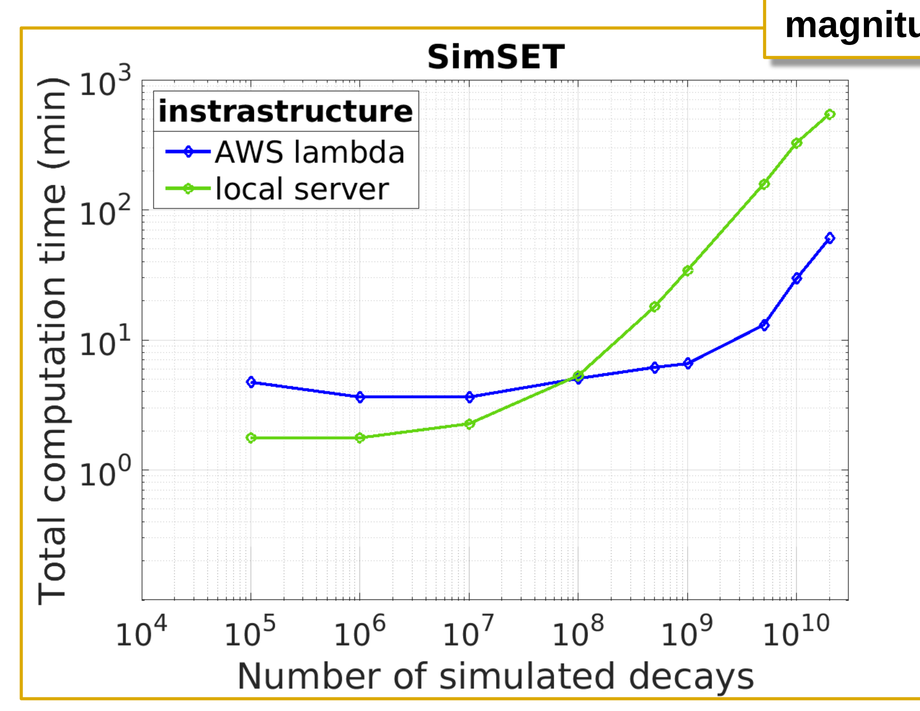
- **Amazon Web Services (AWS) Lambda**
  - Powerful serverless computing tool for distributed computation
  - Parallel execution of short-lived programs without managing large physical servers
- **SimSET on AWS**
  - Containerized application image with SimSET installed
  - Independent simulations on up to 1000 Lambda instances
  - Subsequent concatenation of all output files
  - File sizes: e.g., 100 million simulated coincidences result in ~1 GB of data.



- **Settings and constraints**
  - 10 GB per-instance memory
  - 10 GB temporary storage
  - 15 min max. execution time
  - Allows for up to $5 \cdot 10^6$ decays per Lambda
- **Run time measurements**
  - Up to $2 \cdot 10^{10}$ total decays
  - Comparison to local servers (44 CPU threads on Intel® Xeon® Gold 6126 CPUs at 2.6 GHz)

Results

Speed up by more than one order of magnitude

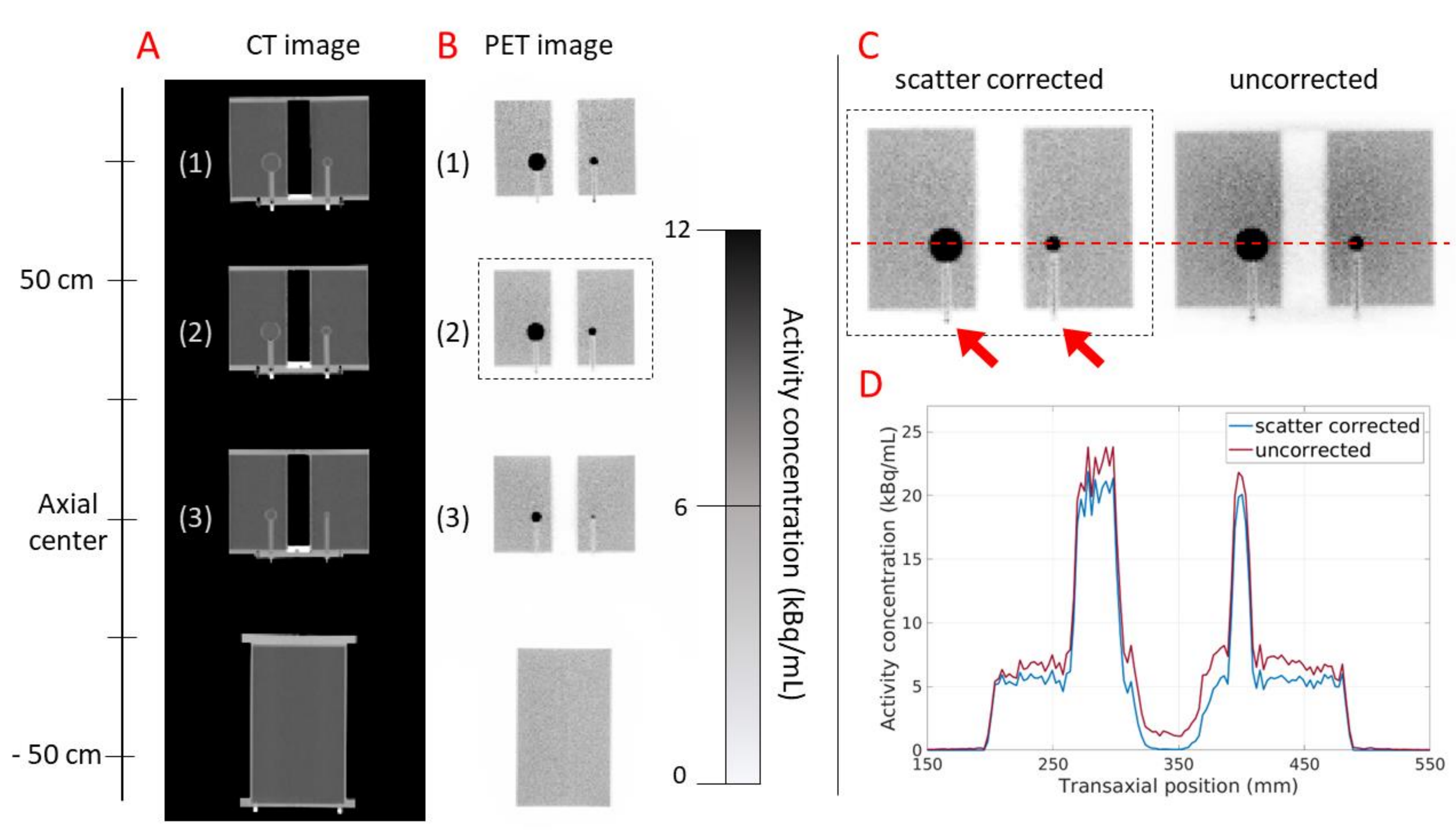


- **Performance: AWS ←→ local servers**
  - Above 10^8 decays, AWS Lambda outperforms local computation
  - Above $5 \cdot 10^9$ decays: sequential repetition needed due to 15-min maximum execution time constraint

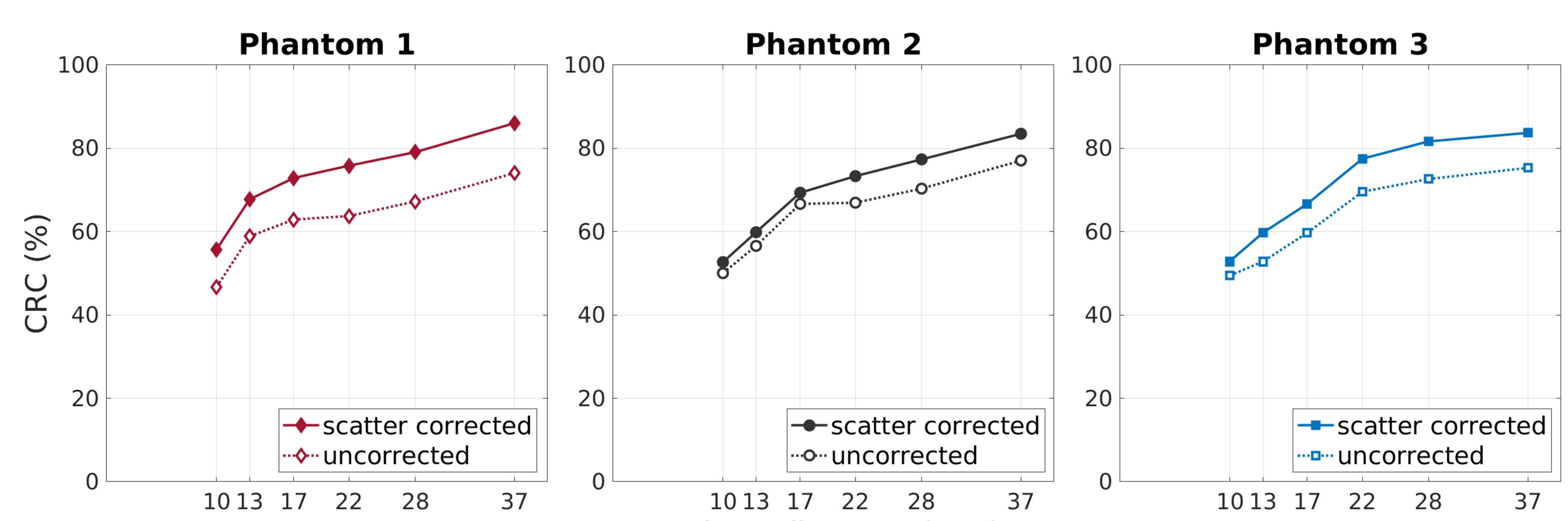
Demonstration of Scatter Correction

Manuscript under revision

- **20-min phantom study on uEXPLORER total-body PET/CT scanner**
  - 3 NEMA Image Quality phantoms + homogenous cylinder phantom
  - 4 iterations (OSEM), 13 subsets, 2.85 mm voxel size



- **Visual inspection**
  - Scatter removed from cold lung insert and plastic parts
  - Residual in spheres' stems visible
- **Line profiles**
  - No gradient in corrected image
  - Minimum activity concentration lower by 94.6% in corrected image
- **Contrast recovery coefficient**
  - Consistently greater compared to uncorrected images (see graphs)
- **Average bias on the background activity concentration**
  - With SC: -0.12 %
  - Without SC: +7.97 %
- **Mean residual lung error**
  - With SC: 1.60 %
  - Without SC: 14.45 %
- **Background variability**
  - On average 0.73% lower than on uncorrected images



Underlying In-House Image Reconstruction Framework

A vendor-independent open-source framework using C++ and MATLAB to facilitate complex research projects

1) Data selection, list-mode decoding and pre-calculation of correction factors

2) Setting length of single or multiple frames

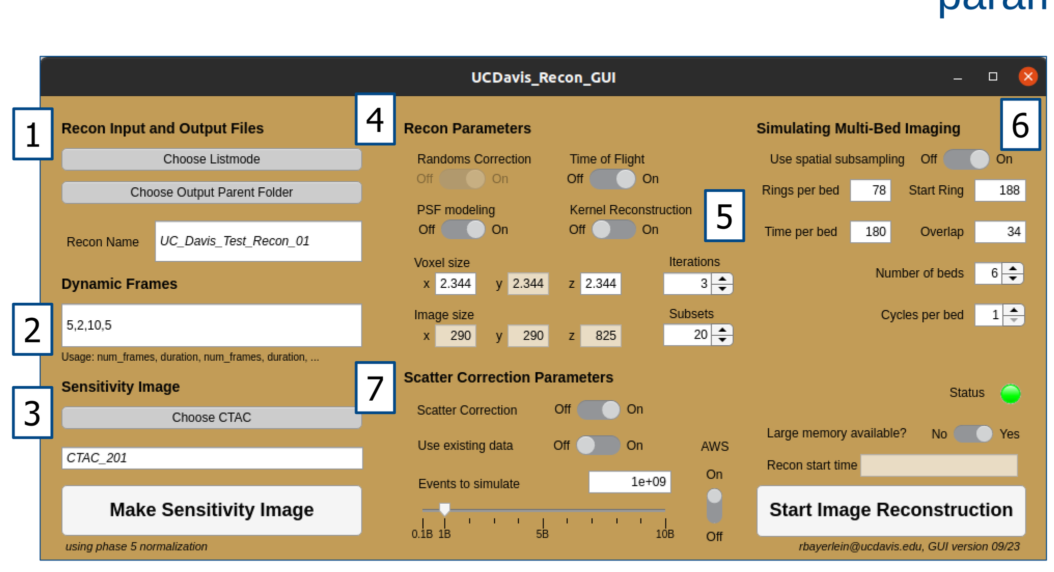
3) Sensitivity Image Generation Process

4) Selection of reconstruction parameters and voxel size

5) Performance of Kernel-based image recon-struction (new feature)

6) Simulation of conventional scanners from total-body PET data

7) Scatter correction (SC) with optional use of serverless cloud computing on AWS



Limitations and Discussion

- **Dependency on internet connection speed**
  Up to 10 GB of files to be downloaded depending on the number of simulated decays
- **Cost**
  Simulation of $2.5 \cdot 10^9$ decays costs about \$10
  → could be a solid alternative to on-site computing servers considering procurement overhead and maintenance costs
- **Limitation for dynamic imaging**
  Large number of individual scatter corrections required
  → time-advantage of cloud-based computation might vanish

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