Increasing the location rate of Positron Emission Particle Tracking (PEPT) measurements

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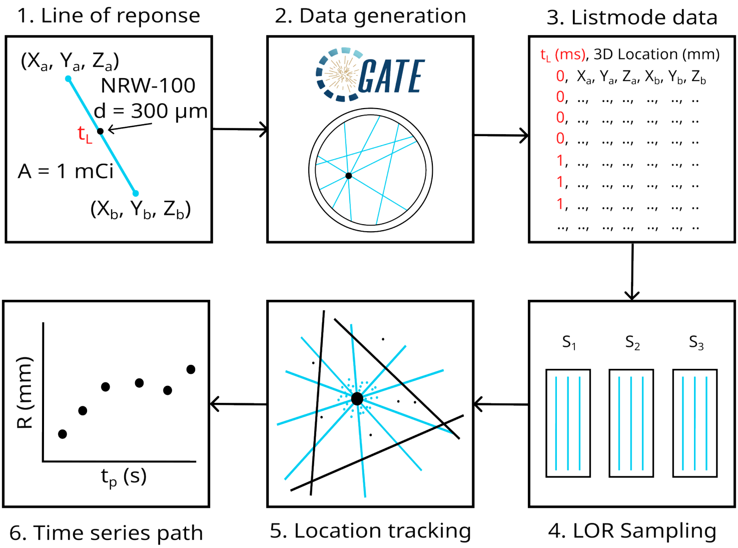
Overview of PEPT



See Parker et al.; Nicușan and Windows-Yule

Data generation

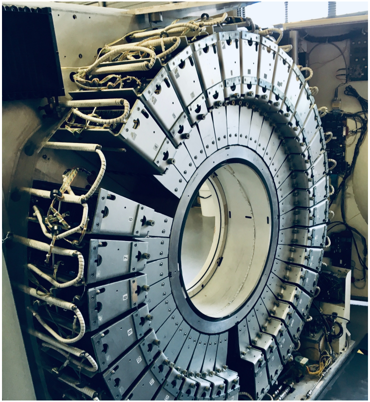


Figure 1: Siemens ECAT HR++ PET scanner at PEPT Cape Town.

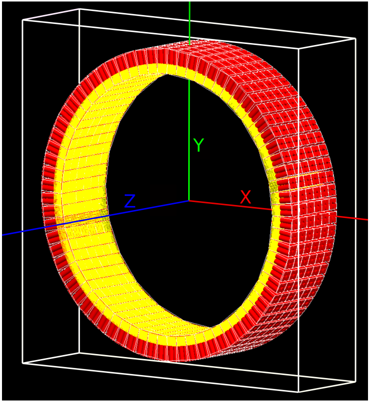


Figure 2: GATE simulation of the HR++ PET camera as seen in Figure 2.

See Perin et al.

The research problem

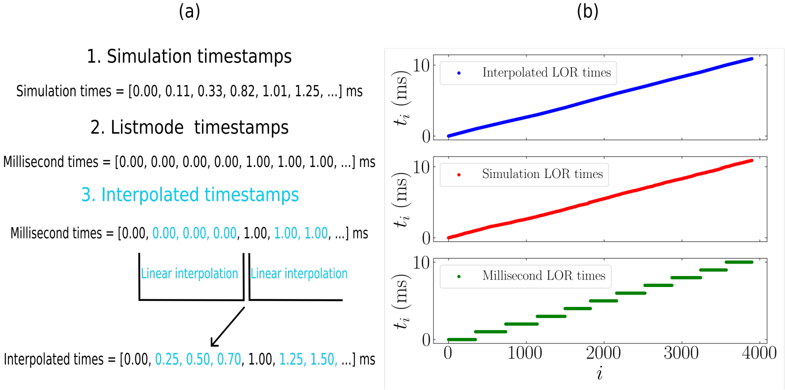


Figure 3: Illustration (a) shows the interpolation algorithm and (b) shows the timestamps of the simulation, millisecond and interpolation LORs.

Timestamp difference

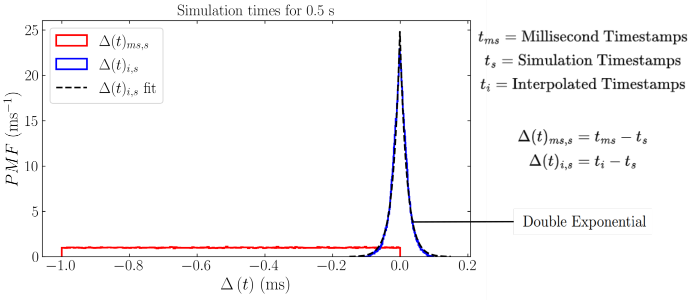


Figure 4: The temporal error, $\Delta(t)$, for both the millisecond and the interpolated timestamps.

- The following fit results are for $\Delta(t)_{i,s}$
- μ = (-7.3 $\pm$ 1.0)$\times 10^{-4}$ ms, β = 0.02014 $\pm$ 0.00014 ms
- Reduced $\chi^2 = 0.28$, $L = 377 \pm 19$ kHz

Random walk model

- The $\gamma = 0.0$ mm, $\sigma = 1.0$ mm and τ user defined.
- A moving average with a window size of 4 was applied.

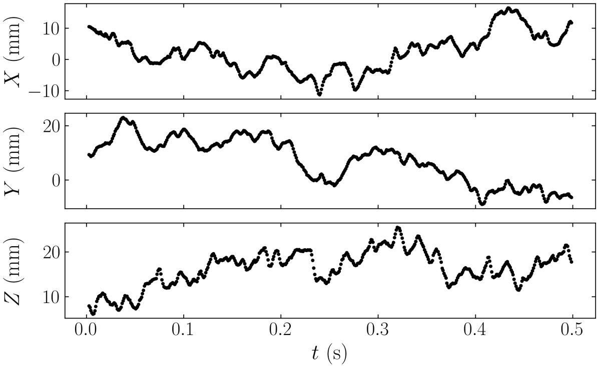


Figure 5: The X, Y and Z dimensions of the random walk model for 0.5 s .

Trajectory comparison

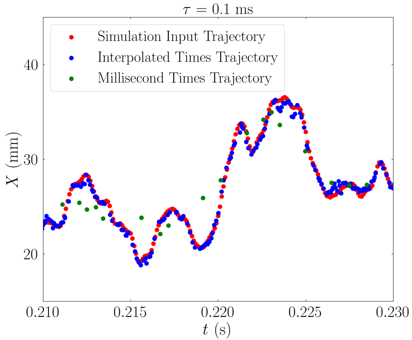


Figure 6: X dimension of path with $\tau = 0.1$ ms

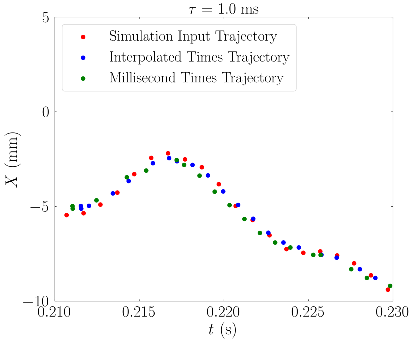


Figure 7: X dimension of path with $\tau = 1.0$ ms

Velocity distributions

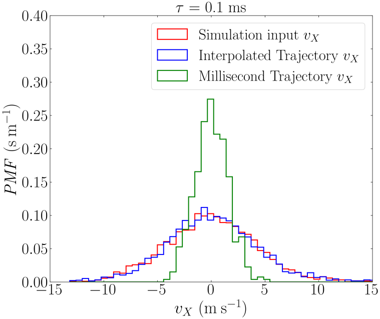


Figure 8: v_X distributions for $\tau = 0.1$ ms.

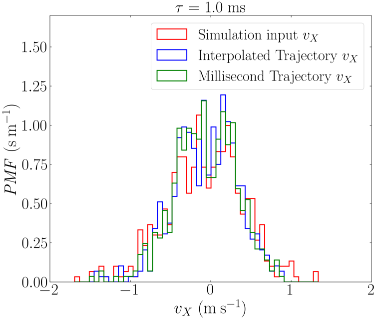


Figure 9: v_X distributions for $\tau = 1.0$ ms.

- Large maximum v_X for Figure 8 compared to Figure 9

Trajectory uncertainties

Trajectory uncertainty equation

$$\Delta(R) = \left[\sum_{j=0}^{n} |R_i(j) - R_t(j)|\right] / n$$

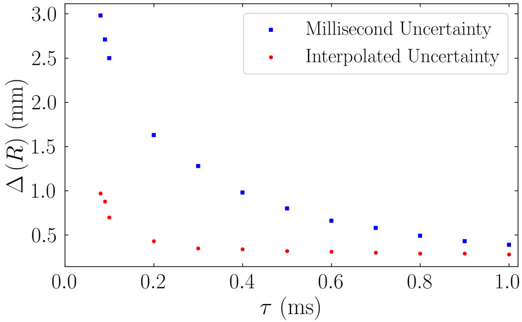


Figure 10: The uncertainty, $\Delta(R)$, as a function of time step, τ, for $\tau \in \{0.08, 1.00\}$ ms.

Similarity of velocity distributions

Jensen-Shannon distance (*JSD*)

A *JSD* from 0 to 1 shows similarity to dissimilarity.

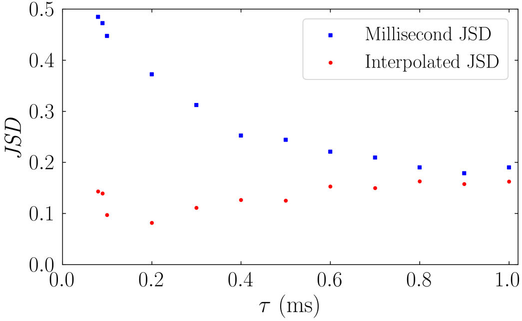
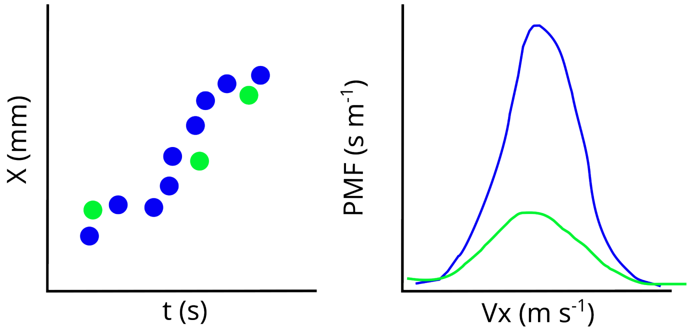


Figure 11: The *JSD* as a function of time step, τ, for $\tau \in \{0.08, 1.00\}$ ms.

Conclusion



- ↑ in temporal resolution ⇒ ↑ in location frequency
- ↓ of uncertainty in the trajectory
- This increases the ability of PEPT to track high speed tracers undergoing turbulent motion *e.g.* centrifuge pumps

References

Hampel, DM, et al., “SuperPEPT: A new tool for positron emission particle tracking; first results”. *Nuclear Instruments and Methods in Physics*, vol. 1028, 2022, p. 166254.

Nicușan, AL, and CRK Windows-Yule, “Positron emission particle tracking using machine learning”. *Review of Scientific Instruments*, vol. 91, no. 1, 2020, p. 013329.

Parker, DJ, et al., “Positron emission particle tracking-a technique for studying flow within engineering equipment”. *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment*, vol. 326, no. 3, 1993, pp. 592–607.

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Thank you!

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