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Considerations when interpolating discrete measurements of continuous functions: applications to particle tracking in physical systems

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Abstract content
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Geographical curves are so involved in their detail that their lengths are often infinite or more accurately, undefinable. B. B. Mandelbrot Science: 156, 1967, 636-638.

A wide range of techniques exist in order to measure the location(s) of particle(s) at discrete points along their trajectory. These techniques range from soft field optical techniques (e.g. high speed video, laser driven systems etc) into hard field tomography (e.g. x-ray, Positron Emission Particle Tracking (PEPT)). In all of these cases an image (or image analogue) is produced at a fixed time, usually as a local time average of system behaviour during an acquisition window. Images or their equivalent are repeatedly produced at a fixed rate defined by the hardware capability in many cases (optical, x-ray), or the emission rate of the measurement probe in other cases (emission tomography, PEPT).

Of fundamental importance to any of these sampling methods is the concept of the Nyquist criterion, i.e. the fact that a periodic function must be sampled at twice its frequency in order to be properly resolved by measurement. In the case of particle tracking it is then clear that for discrete measurements any phenomena occurring between samples goes unobserved. Simple linear interpolation (including cross-correlation) is often used to describe particle motion between sampled points along the particle trajectory, but this is an approximation at best, and may be an incorrect interpretation of the physical system.

In this paper we demonstrate the practical impact of Nyquist sampling upon the simple examples of measuring linear and circular motion. In these cases we demonstrate that the measured path length differs from the actual path length travelled by the particle. We propose a set of defined limits for measuring distance (and therefore velocity) and a standard for handling their uncertainties.

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Primary author: Dr LEADBEATER, Thomas (University of Cape Town)

Co-authors: Prof. BUFFLER, Andy (University of Cape Town); Dr COLE, Kathryn (University of Cape Town); Mr VAN HEERDEN, Michael (University of Cape Town)

Presenter: Dr LEADBEATER, Thomas (University of Cape Town)

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