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4D X-ray microtomography of vibrating multiscale structures: numerical optimisation and experimental validation

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In the last decade, some pioneer studies have been proposed to image the structural motions of biological oscillators using synchrotron X-ray tomography. The first advances have allowed visualising 3D low-frequency tissue motions, notably for lung and cardiac function measurement [1]. More recently, 3D images of fly muscles during wingbeat at 145 Hz were obtained [2]. However, breakthroughs are still expected in acquisition and reconstruction procedures to keep improving the spatio-temporal resolution, and study the mechanics of fast-vibrating multiscale structures. Thereby, this work aims at: (i) proposing a numerical tool to optimise scanning parameters for any multiscale oscillator; (ii) assessing its relevance by comparison with 4D X-ray data acquired at various time and spatial scales.

First, an optimisation procedure is proposed to minimise the blurring artefacts typically obtained when imaging a moving structure, which strongly depend on the couple formed by the speed of its periodic motion and the exposure time of the detector in use. Based on simulations conducted on a vibrating Shepp-Logan phantom, charts of ideal scanning parameters are computed.

Then, a custom vibro-mechanical set-up was designed to subject samples to a large range of vibrating loadings (up to 1500 Hz). Knowing the *a priori* optimal scanning parameters, 4D X-ray tomographies with retrospectively gated projections were then performed both with laboratory and synchrotron sources. Samples were made of soft silicone matrices reinforced with different fibrous architectures and were subjected to sinusoidal rigid body translation (from 1 to 400 Hz).

Finally, comparing real and virtual 4D data, the relevance of the methodology will be discussed according to spatial (macro/micro) and time scales (low/high frequency).

REFERENCES

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- [2] Walker *et al.*, *In Vivo Time-Resolved Microtomography Reveals the Mechanics of the Blowfly Flight Motor*, PLoS Biology, 12(3):e1001823, 2014.