Quantum technologies for classical navigators

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Although governed by different physical laws and occurring on quite different scales, quantum technologies for inertial and magnetic sensing and timekeeping adopt many mechanisms familiar in classical navigation. We explore these analogies to navigational techniques and instruments to illustrate some mechanisms of quantum technology and inspire new approaches [1].

The marine chronometers developed by John Harrison [2] allowed a ship's longitude to be found by comparing a clock, which had been set at the point of departure, with the local solar time determined by celestial observation. Atom interferometry may be used to determine velocities in the same manner, setting the phase of a quantum superposition using a beamsplitter pulse and later measuring it relative to the spatially-dependent phase of the recombiner field [3]. Two back-to-back measurements allow differential measurements that can reveal rotation, acceleration or gravity.

Atom interferometers frequently suffer from inhomogeneities in their light-atom interactions, which affect the fringe phase and visibility and blur the results for an atom ensemble. By tailoring the optical phase during the pulse, the result can be rendered at least partially immune to experimental variations, following the same principle that Zermelo adopted to optimize airship navigation [4] by finding a route whose duration varies least with small perturbations [5].

In *Puzzle-Math* [6], Gamow and Stern explained how, for randomly timed observations, the first elevator to reach a given floor in a building need not have equal likelihood of ascending and descending, even though the numbers of ascents and descents are equal. The the *VHF omni-directional radio range* (VOR) system used by airliners today follows this principle. With optical pulses in place of elevators, the same approach can provide a position-dependent optical trapping force in the absence of MOT fields, intensity gradients or other spatial inhomogeneities [7].

Other similarities range from GPS and optical lattices to magneto-optical trapping and Viking navigation, dark states and the gyrocompass.

Keywords: QUANTUM TECHNOLOGY, NAVIGATION, ATOM INTERFEROMETRY

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