A Novel Virtual Reality System for Spatial Navigation Experiments on Tethered Animals

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Introduction

- In spatial navigation experiments, virtual reality (VR) allows complete control of sensorimotor stimuli[1,2] (Fig. 1).
- FicTrac is a promising software for determining 2D fictive animal paths by computing the absolute orientation of a spherical trackball in a VR setup[3] (Fig. 4).
- Our goal was to eradicate the core inefficiencies in speed and accuracy of FicTrac and the hardware used for the VR setup.

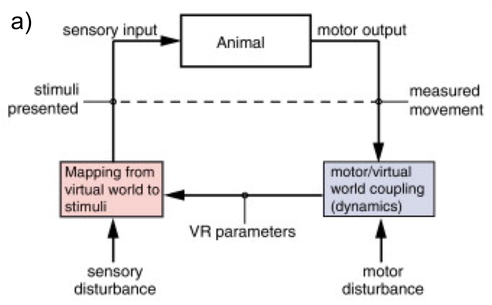

Figure 1: VR schematic[1]. (a) Mechanisms of VR. (b) Mechanisms of a common VR apparatus.

Methods

- **VR apparatus**: We rebuilt a VR apparatus, with an airflow cushioned support for the beach ball at the bottom, and ball bearings for stability from the sides (Fig. 3a). The valve of the beach ball was cut to increase uniformity. The beach ball was applied with a UV reflective coat to create patterns which the FicTrac algorithm could reliably track.
- **Ball tracking with FicTrac**: The small trackball (radius = 8 in.) was rotated once clockwise and counterclockwise about each of its three axes and angular displacement vs. time was plotted using MATLAB. The large trackball (radius = 12.8 in.) was rotated five times clockwise and counterclockwise about each axis and angular displacement vs. time was plotted using MATLAB (Fig. 6).

FicTrac setup and output

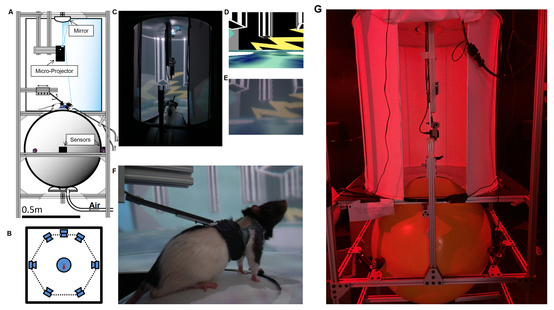

Figure 2: Diagram of the VR apparatus[4]. (a) Hardware used for projecting VR onto a screen. (b) Top-down view of surround sound speakers. (c) VR projector with tethered animal atop a trackball. (d) Image of VR. (e) Image of VR taken inside the apparatus from the point of view of the rat. (f) Tethered rat inside the apparatus. (g) Complete view of the apparatus.

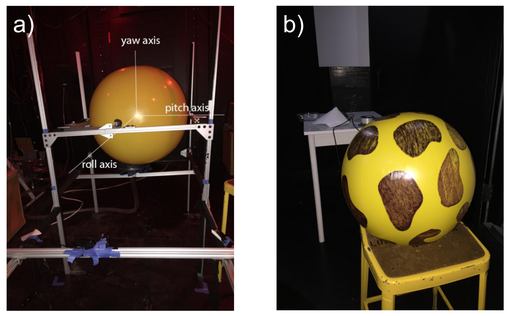

Figure 3: Setups used to test FicTrac's accuracy. (a) The rat will run atop the trackball, below a projector that displays VR. (b) A 15 FPS webcam was fixed atop the white table and the ball sat atop a makeshift stand to keep the ball in place while the experimenter rotated the ball with their hands.

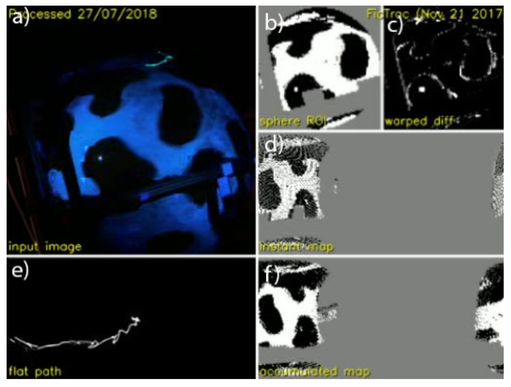

Figure 4: The console output of FicTrac. (a) The field of view (FOV) of the camera, displaying the estimated fictive path. (b) The binary representation of the trackball as seen through a mask image. (c) Disparity between two frames. (d) Instantaneous geographic projection of the input sphere ROI. (e) Fictive path of an animal walking on the trackball. (f) Concatenated geographic projection of the trackball's absolute orientation.

Algorithm

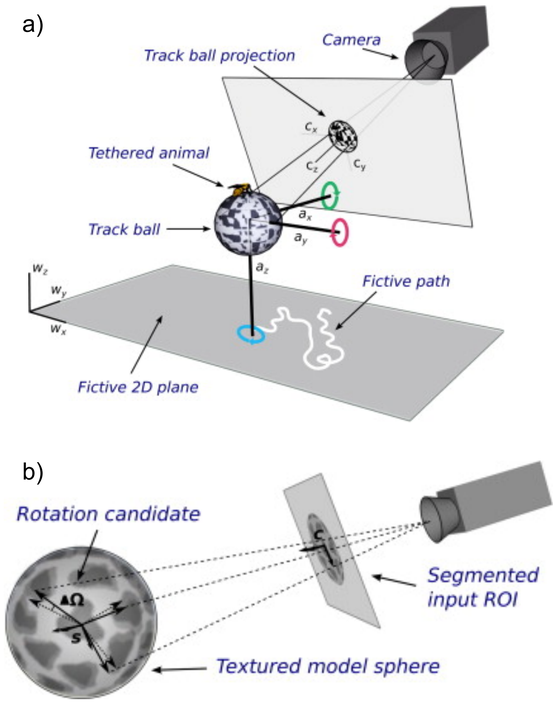

Figure 5: Pictorial representations of the core algorithms used[3]. (a) The camera coordinates are transformed into laboratory coordinates from which the fictive path is determined. (b) A simulated rotation candidate that FicTrac uses to map the absolute orientation of the trackball.

FicTrac accuracy and error

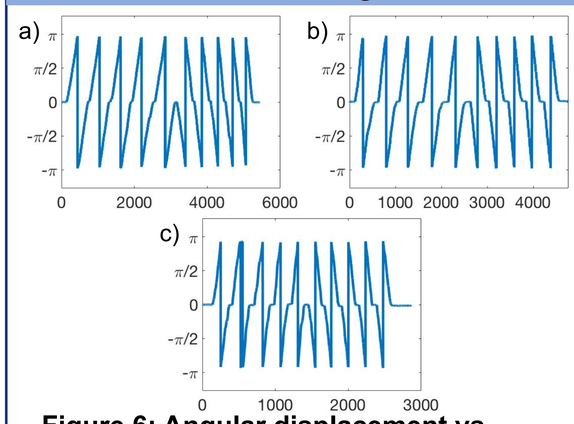

Figure 6: Angular displacement vs. frame of the large beach ball about each axis. (a) Pitch [y] axis. (b) Yaw [x] axis. (c) Roll [z] axis.

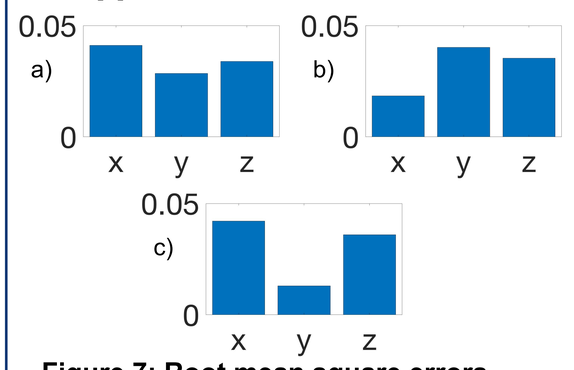

Figure 7: Root mean square errors (RMSEs) of rotations about each axis. (a) Pitch [y] axis. (b) Yaw [x] axis. (c) Roll [z] axis.

Results

- Blobs created by the UV-light paint effectively allow the FicTrac software to map the trackball's absolute orientation through the use of algorithms (Fig. 5).
- FicTrac accurately maps and tracks the changes in the small and large trackball orientations in real time (Fig. 6).
- The optical mouse-based approach has been shown to have a percent error of 2%, whereas FicTrac has a percent error of 0.3% (Fig. 7).

Discussion

- This new VR system is an experimental paradigm shift that will potentially improve the reliability of neuroelectrophysiological measurements.
- The next step is to test this setup in a spatial navigation experiment.

References

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