Magnetotaxis of Caenorhabditis elegans in Three-Dimensions

Christina Lee, Crystal Ma, Jenna Stelmar, Patricia Zhao, Joyce Liu, Joseph Thatcher, and Katsushi Arisaka

UCLA, *Elegant Mind Club* @ Department of Physics and Astronomy

http://www.elegantmind.org

UCLA Science Poster Day on May 24, 2016

ABSTRACT

- Past research by Vidal-Gadea et. al (2015) on magnetotaxis drew conclusions based on the relative terminal position of *C. elegans* rather than through a continuous analysis of their movement.
- This experiment will analyze the motor activity of *C. elegans* in response to artificial magnetic fields using a custom three-dimensional worm tracker application derived in MATLAB.
- In addition, the three-dimensional setup can be used to analyze the worm's free motion behavior, as well as the worm's behavior under various types of stimulation.

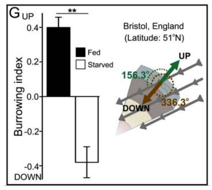


Figure 1. Vidal-Gadea et al. (2015) showed that *C. elegans* change the direction of their burrowing based on if they are well-fed or starved in 2D.

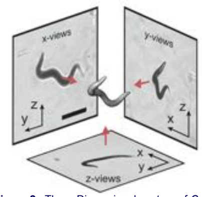


Figure 2. Three-Dimensional posture of *C. elegans*, which can be used to study the worm's burrowing migrations in a more natural 3D environment.

INTRODUCTION

The experiment by Vidal-Gadea et al. (2015) reported that starved *C. elegans* orient downwards with respect to the geomagnetic field vector during vertical burrowing migrations due to the AFD sensory neuron.

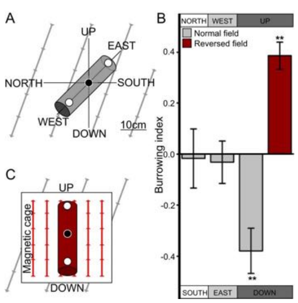


Figure 3 (to the right). The vertical burrowing migrations found by Vidal-Gadea et al. (2015).

OBJECTIVES

Our aim is to track the movement of *C. elegans* by employing a new, three-dimensional setup to mimic the organism's natural environment. By doing so, we hope to study the worm's burrowing behavior in response to magnetosensation.

HYPOTHESIS

C. elegans will exhibit a larger angle of vertical burrowing as a result of magnetosensation when exposed to an artificial magnetic field of greater intensity than the geomagnetic field (0.25 to 0.65 Gauss).

CONCEPTUAL DIAGRAM

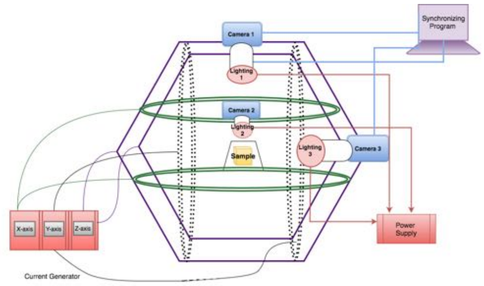
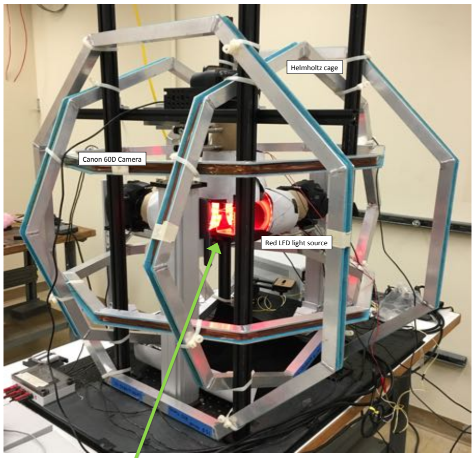


Figure 4. Diagram of experimental set-up, including Helmholtz cage, cameras, and light sources. There are three separate current generators for each axis and a synchronizing program used to start each camera at the the same time.

MATERIALS AND METHODS



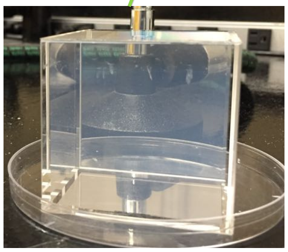


Figure 5 (above). A 5cm cuvette filled with 2% gelatin and 15-20 N2 WT strain *C. elegans* incubated at 20.4˚C.

Figure 6 (to the left). A 1 m^3 Helmholtz cage, capable of generating an artificial magnetic field in three dimensions, with three orthogonal Canon 60D cameras. Each camera fitted with a custom cone lined with red LED lights and are pointed towards the stage holding the 5cm cuvette.

- Recorded data in time-lapse format in 10 minutes trials.
- Each trial was repeated under various magnetic fields (0.365, 1, 3, 10 Gauss).

CALIBRATION DATA

- **Principle of Stimulation:** The artificial magnetic field is powered by a current moving through the x, y, and z axes.
- The **uniformity** of the magnetic field was measured via a Gaussmeter and was found to be ±.02 Gauss when measured across the 5cm^3 area.

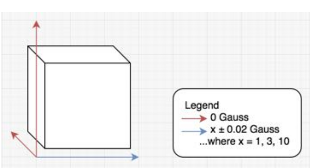


Figure 7. A depiction of the distribution of the magnetic field within the 5cm^3 sample.

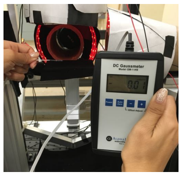


Figure 8. Measurement of the magnetic field intensity to prove uniformity throughout the sample. Data is displayed in table 1.

Uniformity of Magnetic Field					
1 Gauss					
Xi	Xf	Yi	Yf	Zi	Zf
1.00	1.02	0.02	0.03	0.15	0.14
3 Gauss					
Xi	Xf	Yi	Yf	Zi	Zf
2.98	3.00	0.16	0.17	0.24	0.26
10 Gauss					
Xi	Xf	Yi	Yf	Zi	Zf
10.10	10.09	0.10	0.08	0.01	0.02

Table 1. The distances between initial and final positions were equal to 6cm to account for the size of the cube. The magnetic field was measured in each direction for these distances in order to confirm the uniformity of the magnetic field throughout the setup.

RESULTS

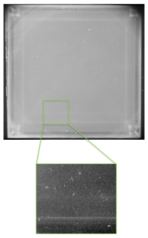


Figure 9. Raw data from top (XY) camera.

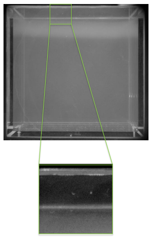


Figure 10. Raw data from left (XZ) side camera.

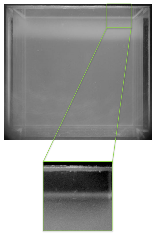


Figure 11. Raw data from right side (YZ) camera.

- Our preliminary data is exhibited above in Figures 9-11. The custom analysis program used to track *C. elegans* in three-dimensions is still under construction.
- Despite the limited amount of analysis, we were able to construct a new, three-dimensional setup that can be applied to a variety of other experiments.
- The depth of field was increased to provide a clear visual field throughout the 5cm^3 cube by drilling small 1mm holes into the camera lens covers to decrease the aperture.
- This was the first time that a sample has been observed using a large 5cm^3 gelatin cuvette, granting us an opportunity to view *C. elegans* in a more natural environment.

CONCLUSIONS

- The results of our experiment do not reveal a relationship between burrowing direction and the vertical magnetic field vector.
- Therefore, we cannot deduce a significant positive or negative response of *C.elegans* to the magnetic field as suggested by Vidal-Gadea et al. (2015).
- These results may differ from previous research due to our new setup that allowed us to observe the burrowing migrations of *C. elegans* in three-dimensions.
- Limitations:
  - Depth of field was not perfected, causing many of the worms to be out of focus.
  - Analysis software still being updated.

FUTURE EXPERIMENTS

- Small adjustments for the systems:
  - Use different camera lenses in order to attain the desired depth of field.
  - Use a smaller glass cuvette, such as a 4 cm^3 or 3 cm^3 cube to impose less demand on the depth of field.
- This system can be broadened to study phototactic, electrotactic, and thermotactic behavior of *C. elegans* in greater detail and allow greater extrapolation of experimental results.

REFERENCES

Kwon N., Pyo J., Lee S-J., Je JH (2013) 3-D Worm Tracker for Freely Moving *C. elegans*. PLoS ONE 8(2): e57484. doi:10.1371/journal.pone.0057484

Vidal-Gadea, A., Ward, K., Beron, C., Ghorashian, N., Gokce, S., Russell, J., … Pierce-Shimomura, J. (2015). Magnetosensitive neurons mediate geomagnetic orientation in *Caenorhabditis elegans*. *eLife*, *4*, e07493. doi: 10.7554/eLife.07493.

ACKNOWLEDGEMENTS

- A special thank you to Richa Raghute for preparing the bio sample, Javier Carmona for helping create the hardware setup, and Suying Jin for working on the analysis software.