The Design and Application of a Three-Dimensional Flying Prey Simulator

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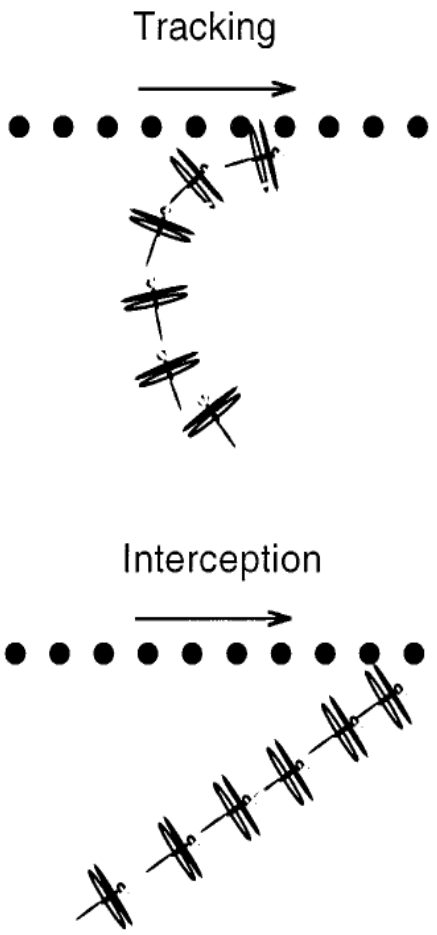
Objective

- Investigate the neuronal control of flying prey interception in dragonflies

  - Will be used to determine how dragonfly neurons encode information about object movement in three dimensions

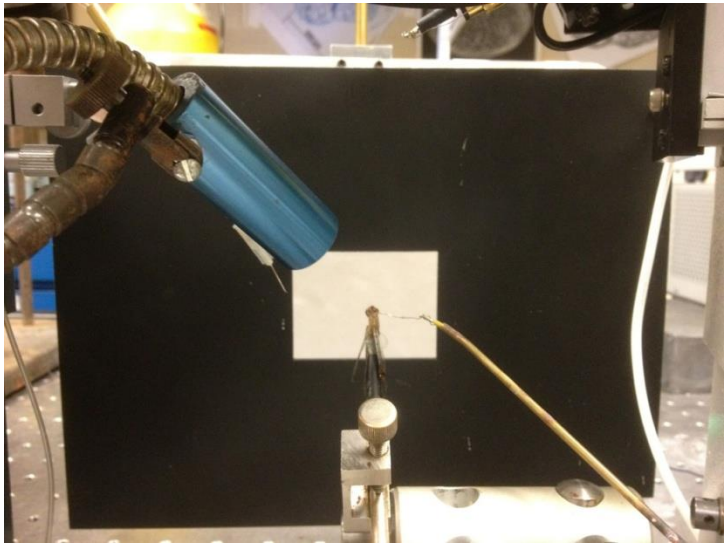
Introduction

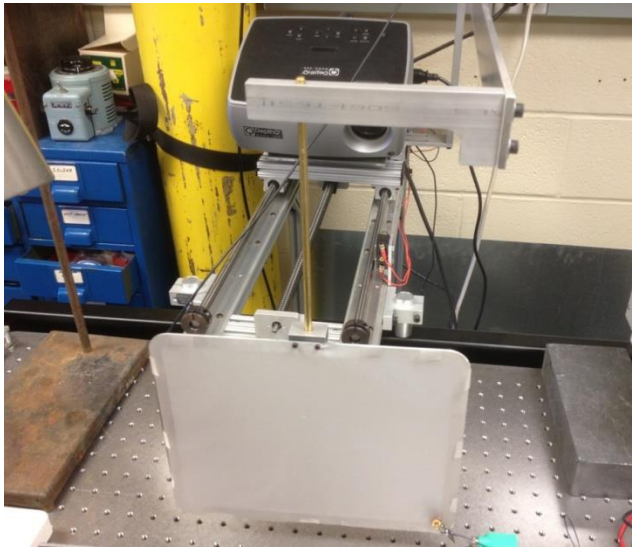
- Highly efficient aerial predators
- Requires rapid visual processing and information transmission
- Evolution of large neurons in the control pathway
- Target-selective descending neurons (TSDNs)



Motivation

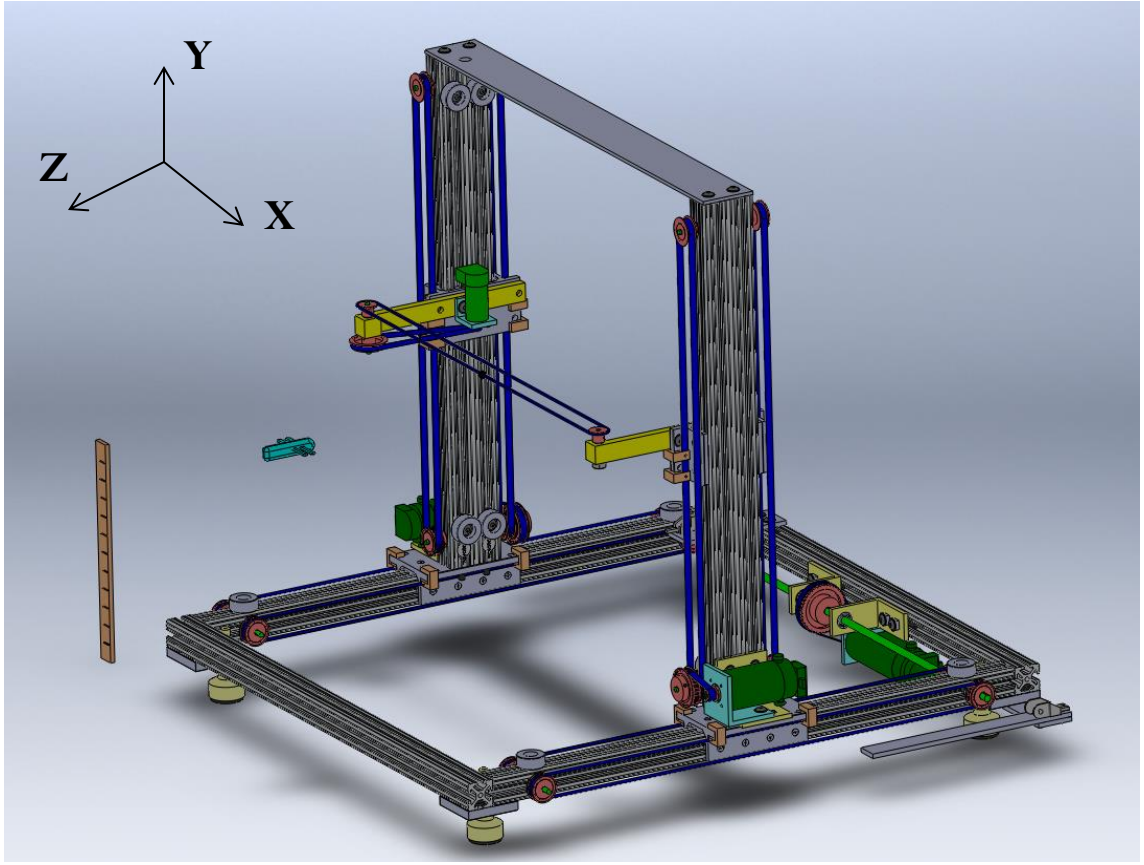
- Previously the dragonfly visual neurons have been mostly restricted to two dimensions
  - X direction (right-left) and Y direction (up-down)
- Flying insect prey pursued by dragonflies move in three dimensions and little is known about how the visual neurons encode the third (depth dimension)





Design Requirements

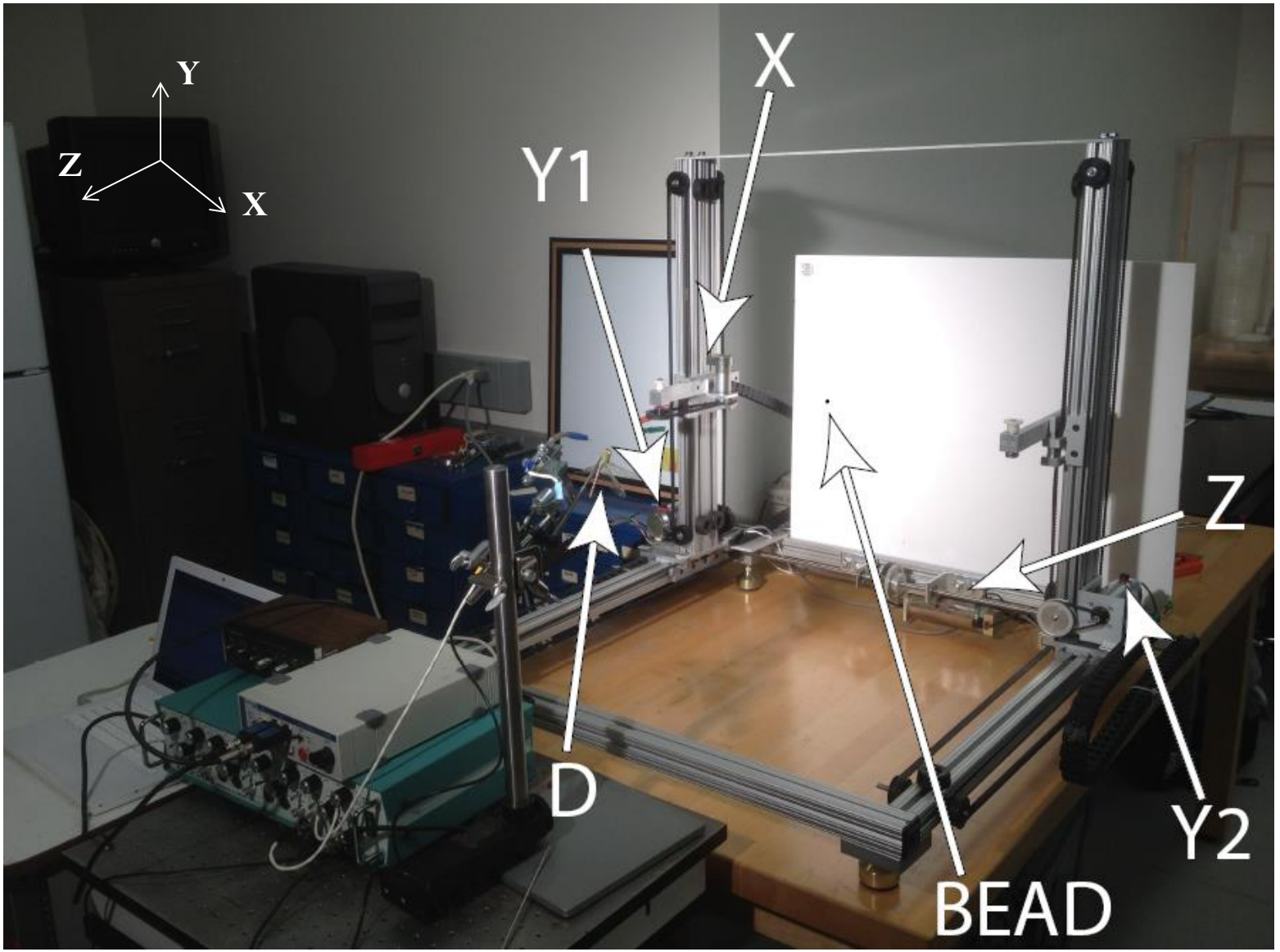
- Maximum speed of 1 m/s in all directions
- Motor rise time of less than 10 ms in all directions
- Interior volume of 0.1 m^3 in which the bead can move



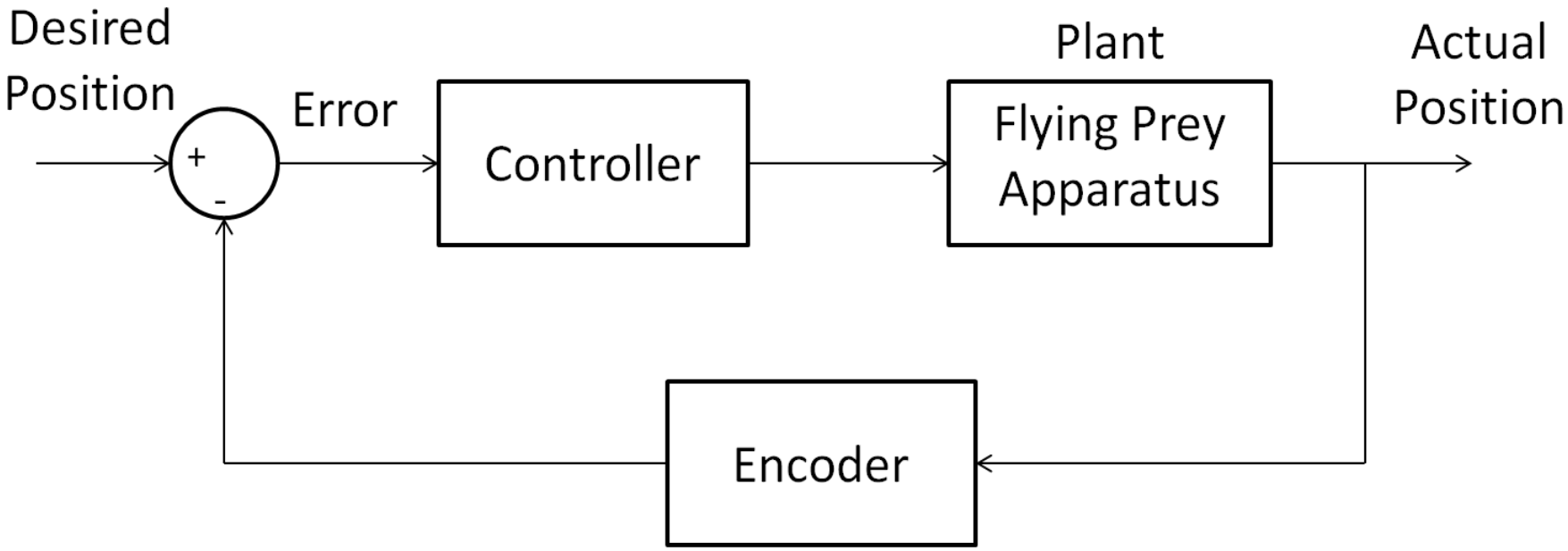
Methods

- Devise and construct the structural framework of the apparatus
- Achieve open loop control by implementing motors and encoders
- Obtain closed loop control through Simulink and Real Time Windows Target
- Run neurobiological experiments with live dragonflies

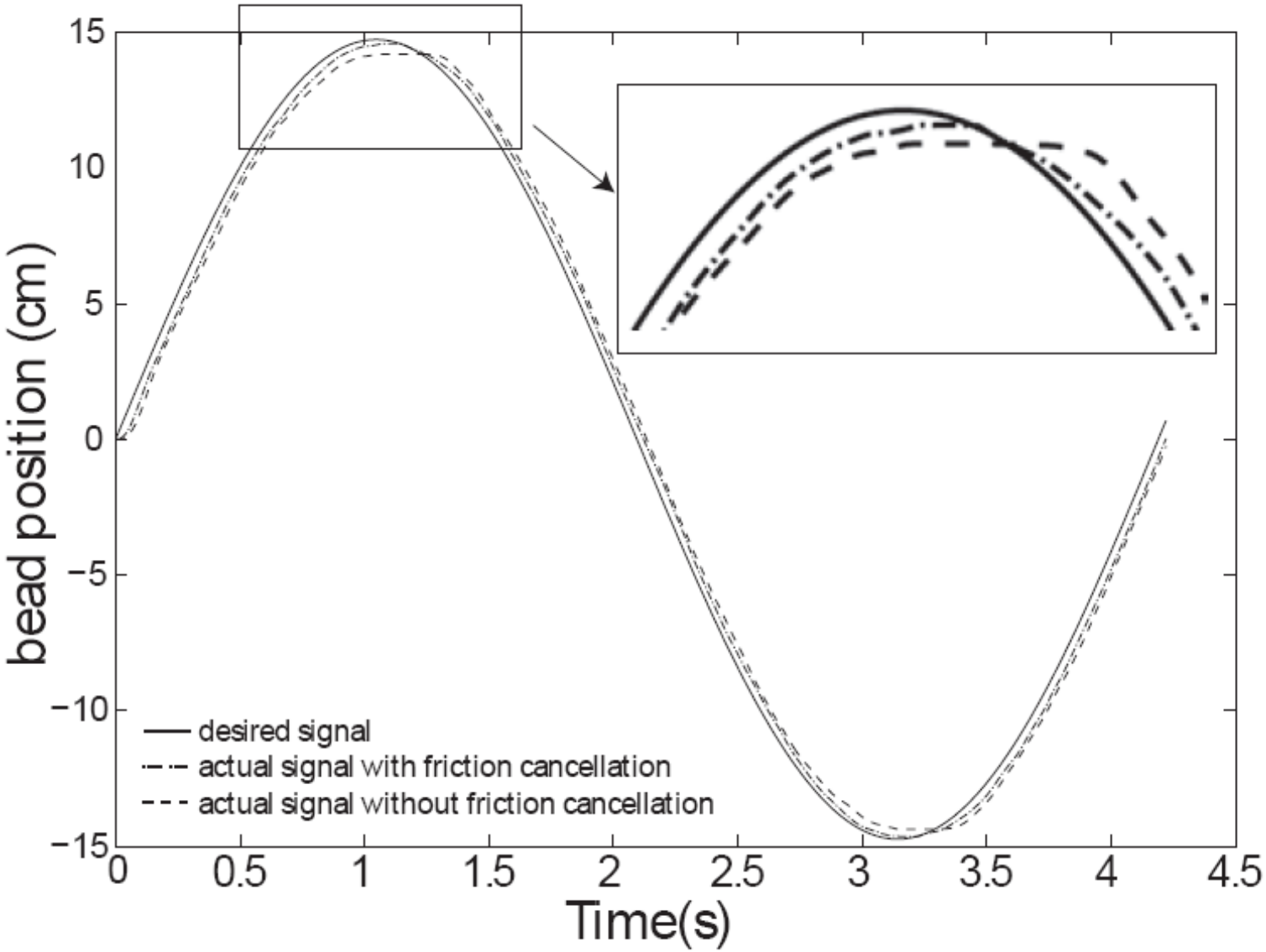
Flying Prey Simulator



Closed Loop System

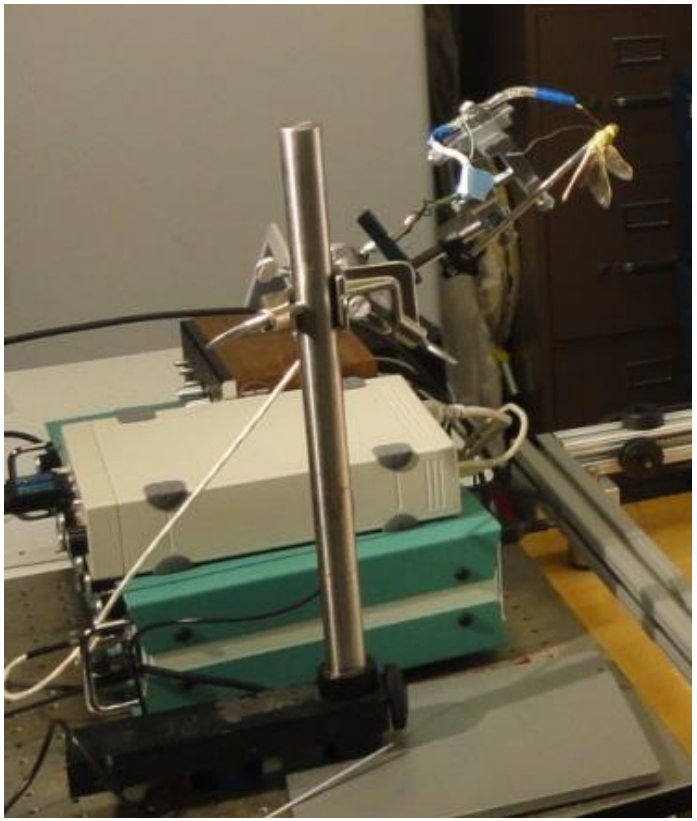


Sinusoidal Tracking Results



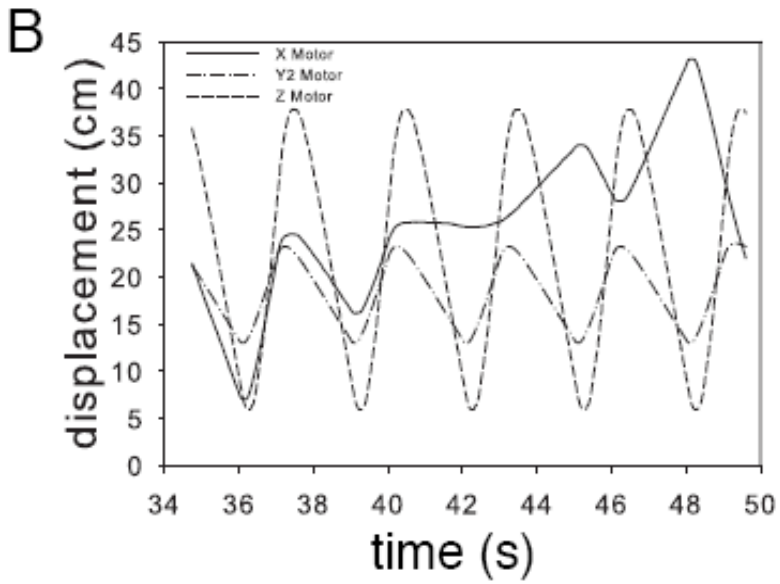
Dragonfly Test Setup

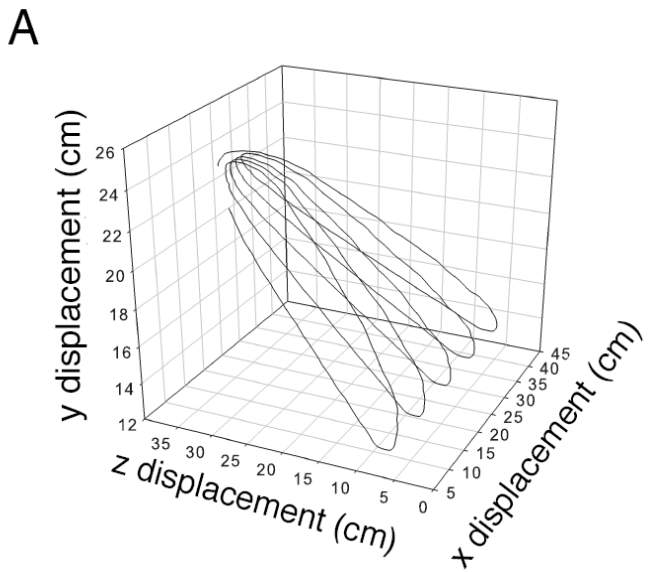
- Dragonfly (Anax Junius) was mounted with wax to a rigid bar
- Hook electrode fashioned from bare 100 μm silver wire
- Placed so the 3 mm bead was centered on the acute region of the dorsal compound eye

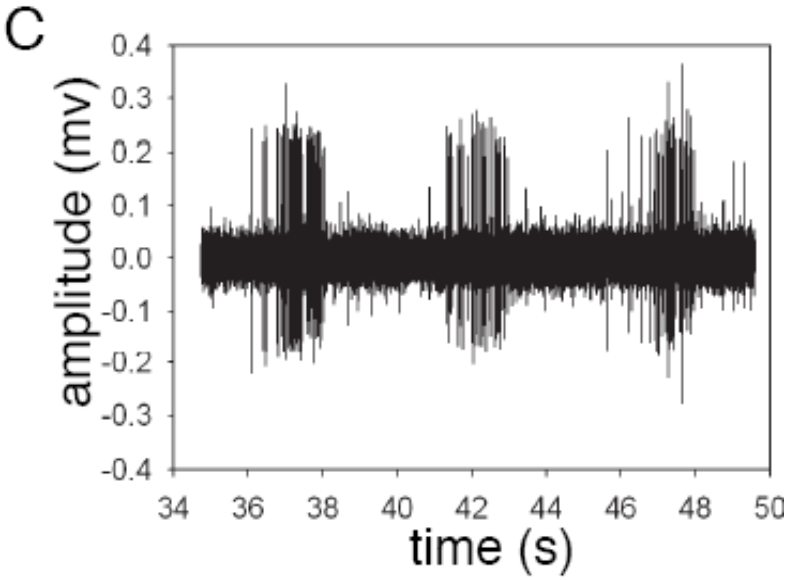


Dragonfly Testing Results

- Bead performed collision-like path to simulate a small insect flying toward the live dragonfly
- Bead trajectory formed shape of a pyramid with the pyramid's apex positioned at the head of the dragonfly







Conclusions

- Apparatus has a remarkable level of repeatability
- Device will help further our understanding of the information transmitted by TSDNs in the dragonfly
  - Little is known about the way in which information concerning the prey distance (Z dimension) is integrated into their responses

- Unraveling the neural basis of visually guided prey interception by dragonflies could reveal how a small group of neurons can drive a fast, complex, and highly reliable behavior such as the interception of flying insects

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