Miniature Implantable Computers for Functional Electrical Stimulation and Recording of Neuromuscular Activity

Jaideep Mavoori, Bjorn Millard, Jeff Longnion, Tom Daniel, Chris Diorio

University of Washington, Seattle.

Overview

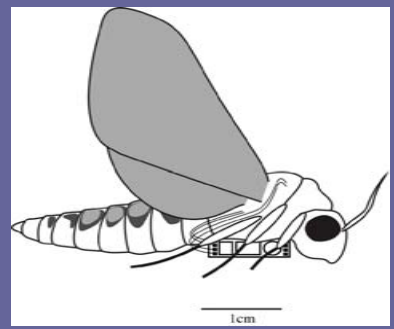
- Motivation
- Objectives
- Biological background
- Neurochip architecture
- Experiments on insect flight
- Summary and conclusions

Motivation

- Biological motor control and learning
- Neurophysiology of freely-behaving organisms
- Bio-computer interfaces
- Autonomous implantable computers

Objectives

Hawkmoth (*Manduca sexta*)



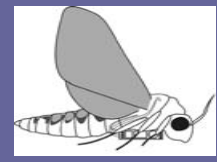
- insect flight
- insect intelligence
- flight control & design
- flight energetics

Background

Manduca tracking a robotic flower

- Nocturnal hover flyer
- Visually-guided tracking
- Can carry ~1g
- Use abdomen for center of gravity shifts

Background



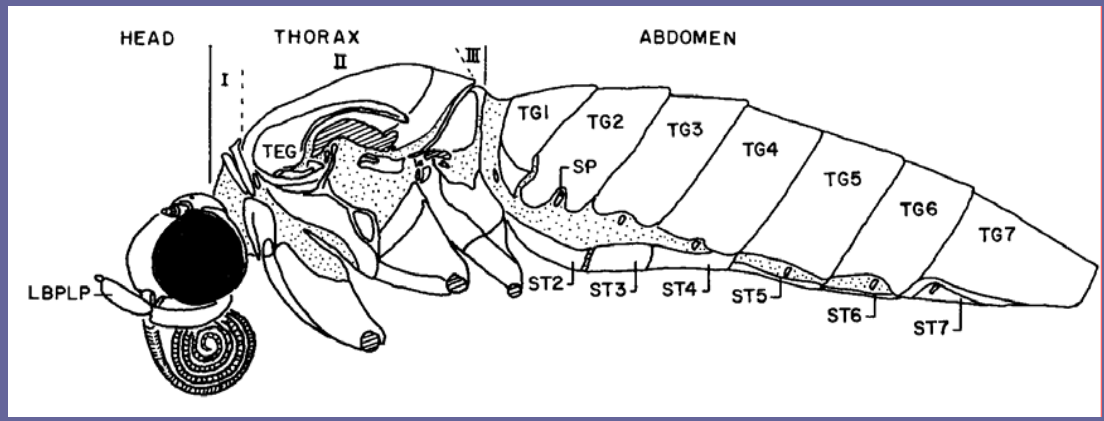
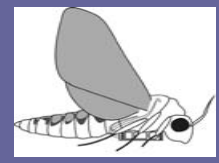


Figure from J.L. Eaton's "Lepidopteran Anatomy"

- Simple musculature
- Unmyelinated nerves allowing low-voltage stimulation

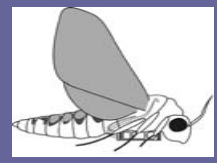
Abdominal Flexion
Constrained Flight

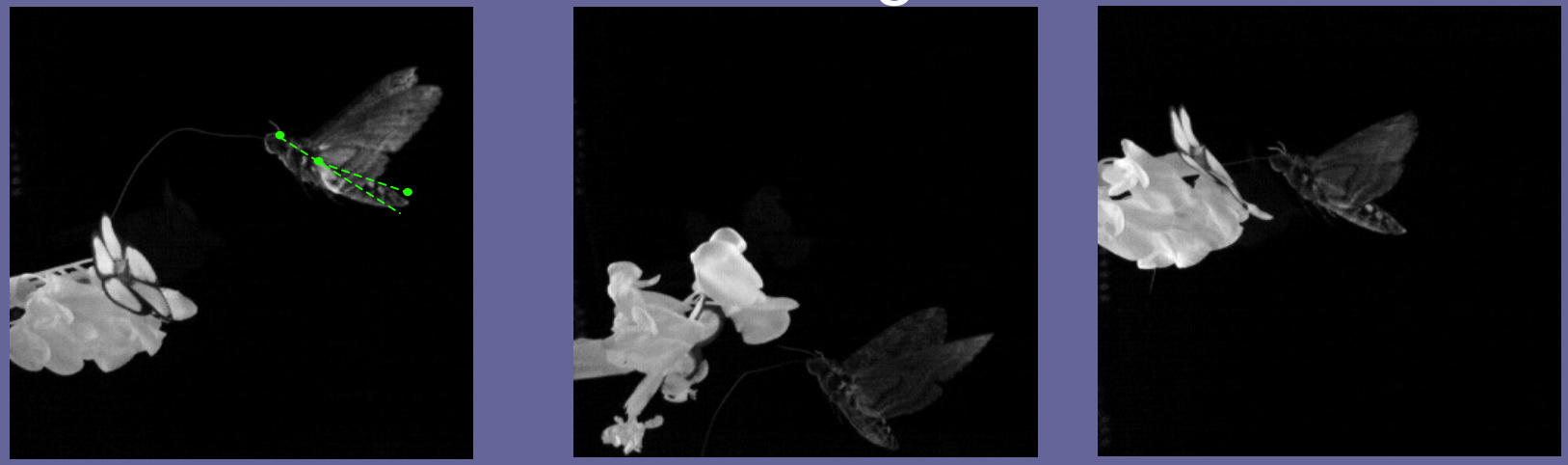


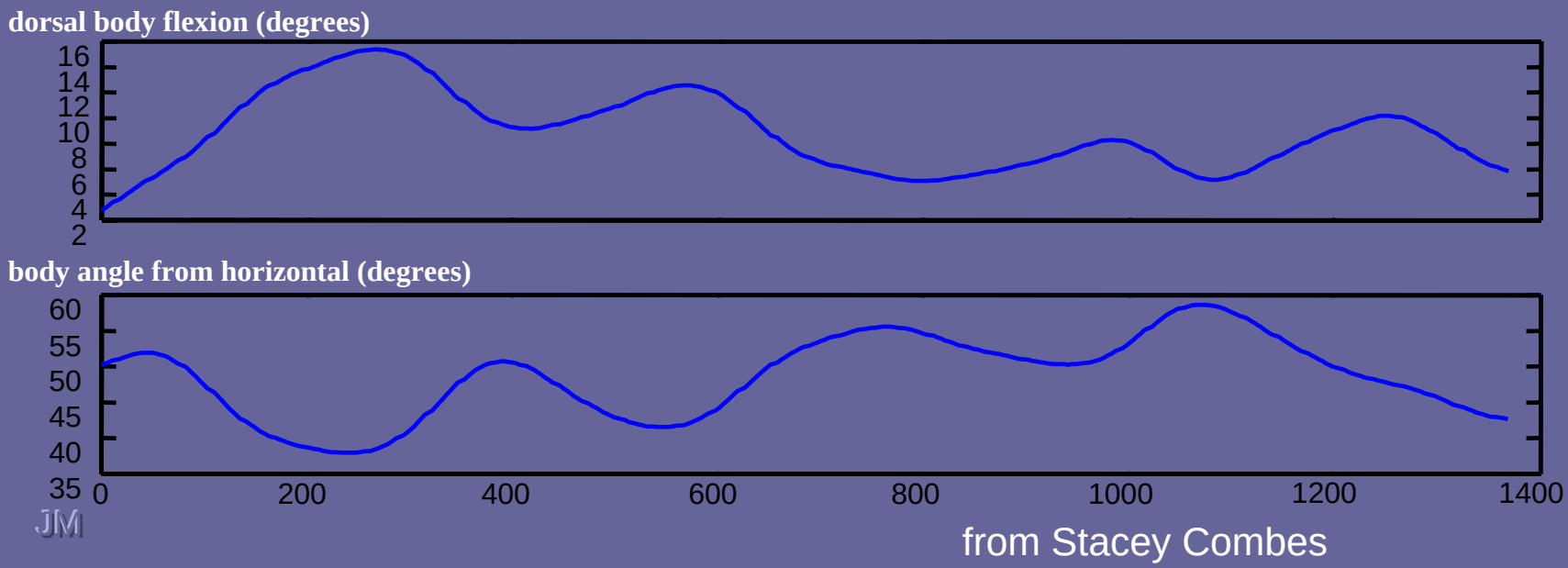
- Flexion and visual feedback
- Used during hover, forward-flight maneuvers
- And for predator avoidance

Abdominal Flexion

Free Flight



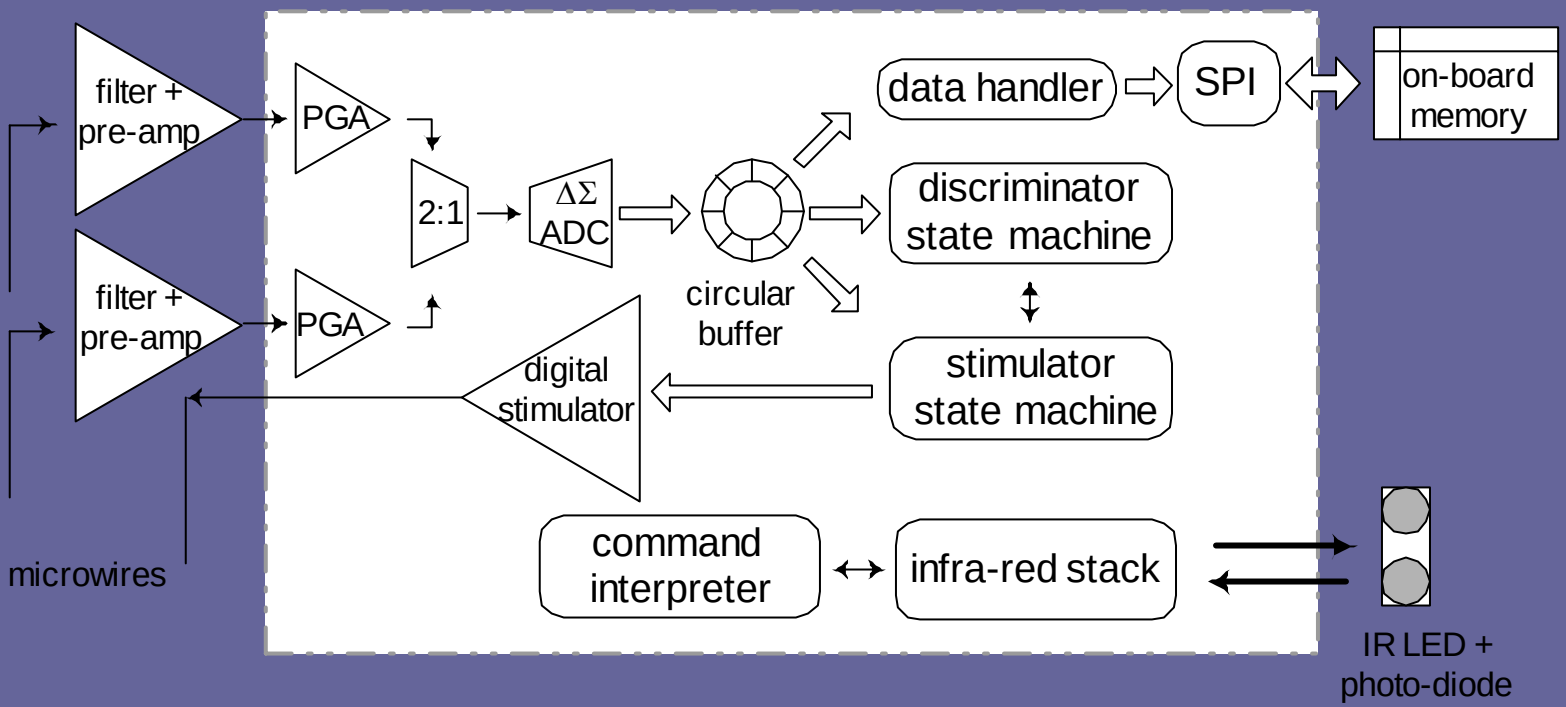




JM

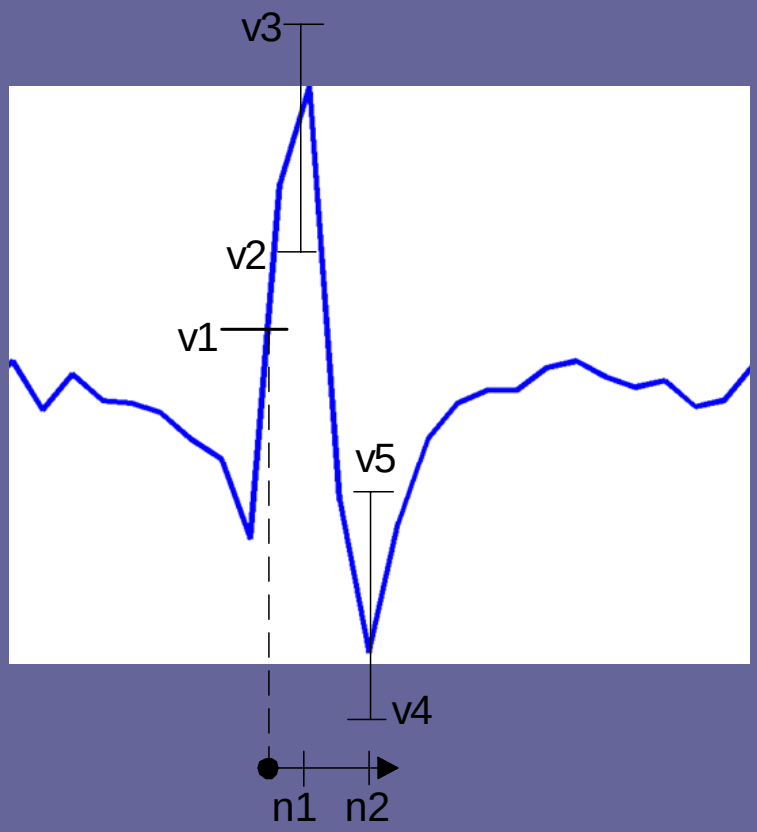
from Stacey Combes

Neurochip Architecture

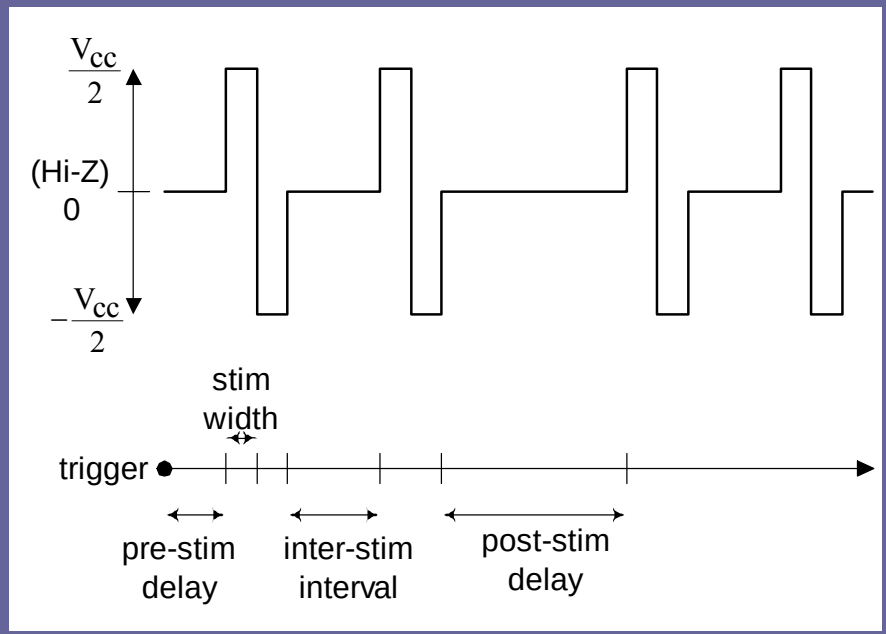


Neurochip Architecture

Dual time-amplitude discriminator



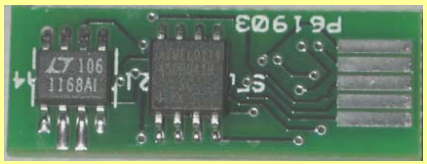
Biphasic digital stimulator



Neurochip Prototypes

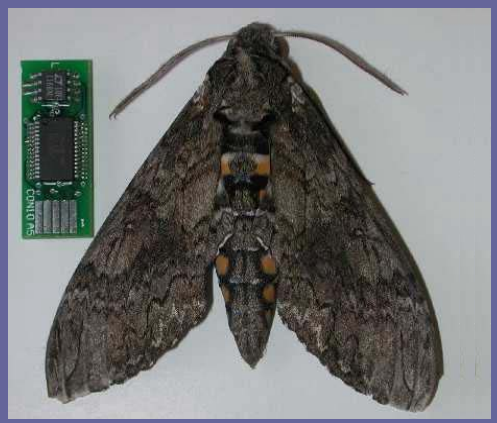
1st Generation

(top)

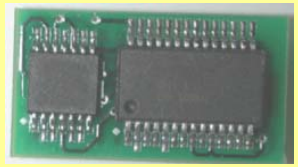


(bottom)

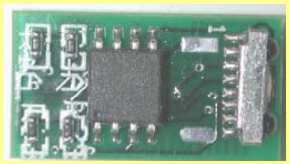
1cm x 3cm x 0.5cm
1.47g (without battery)



2nd Generation



(top)

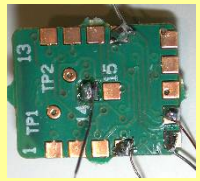


(bottom)

1cm x 1.9cm x 0.4cm
0.85g (without battery)

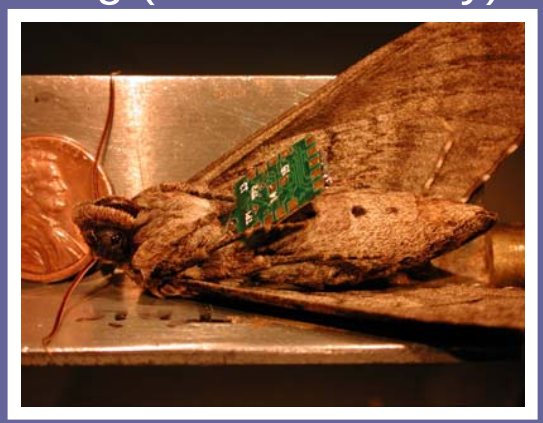
3rd Generation

(top)

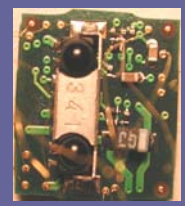


(bottom)

1cm x 1.25cm x 0.25cm
0.25g (without battery)



4th Generation

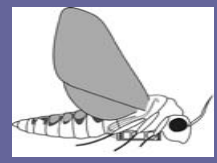


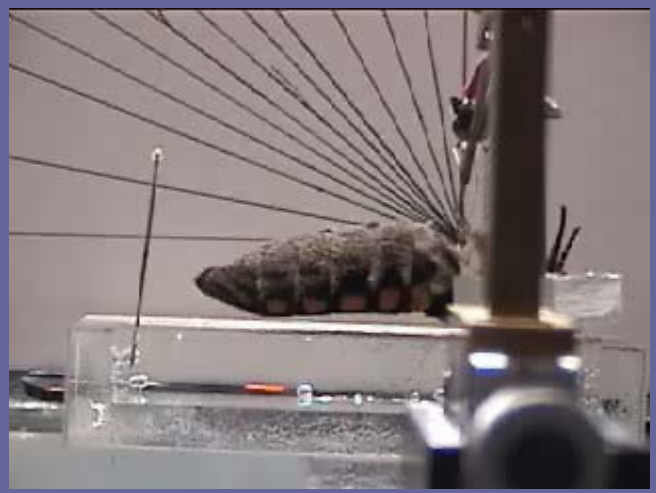
0.9cm x 1cm
0.6g

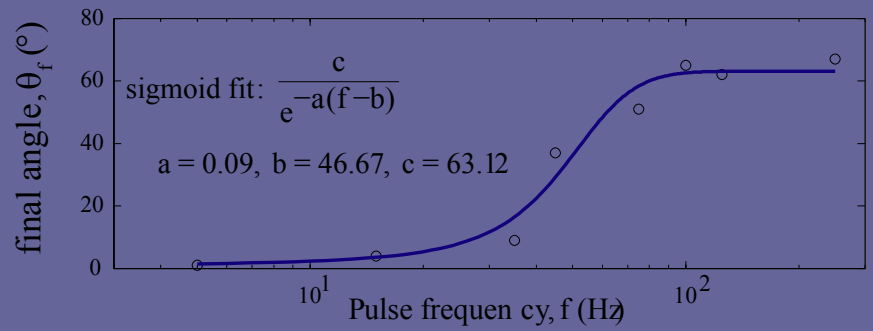
Neurochip Prototypes

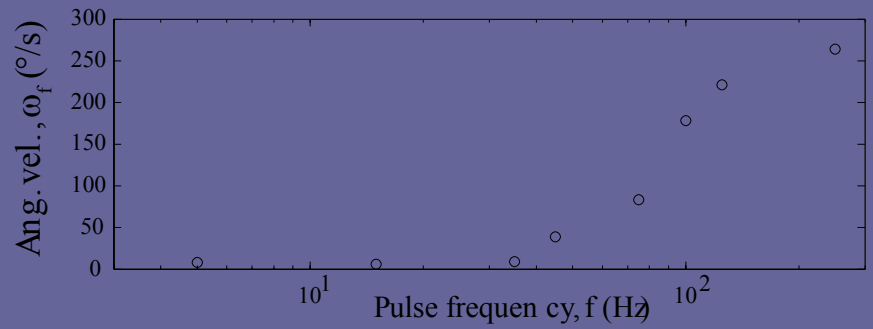
Neurochip Experiments

Abdominal flexion: Tuning curves









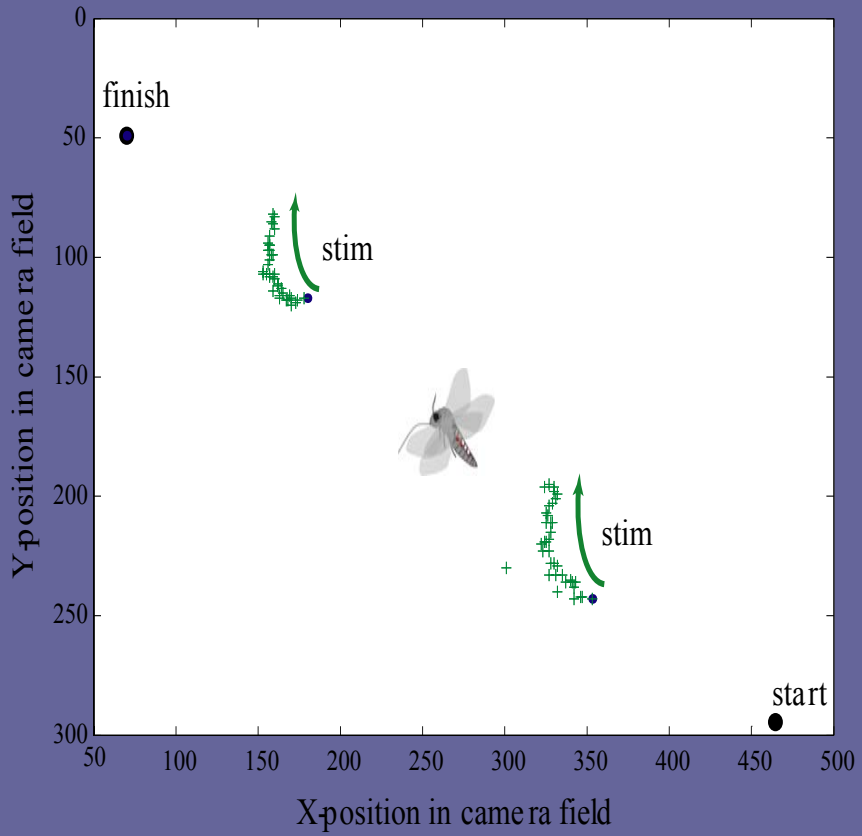
f = 35Hz

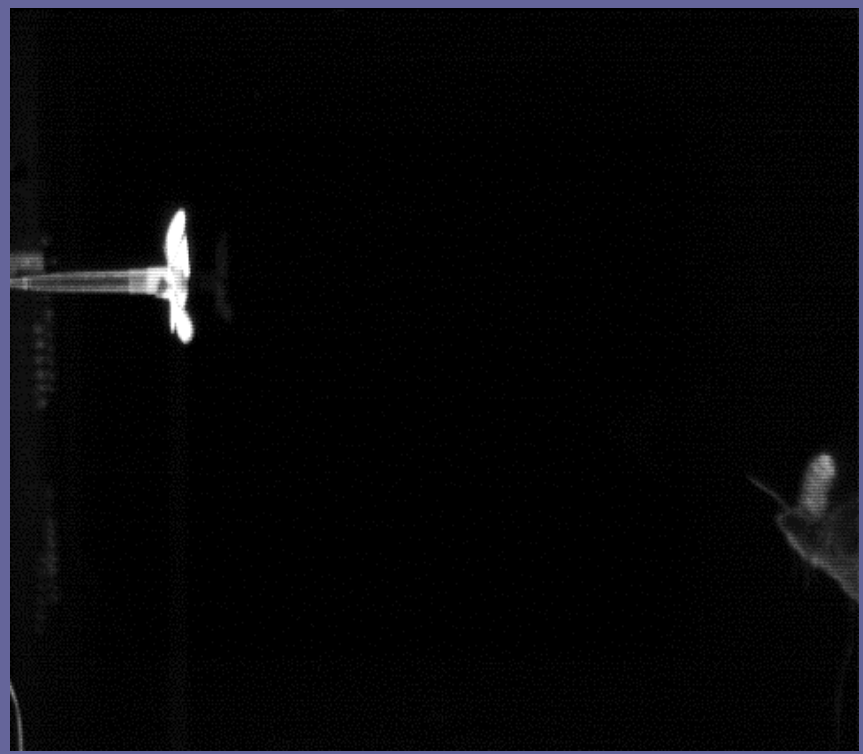
f = 45Hz

f = 75Hz

Neurochip Experiments

Stimuli: 1ms pulse @ 100Hz





JM

Summary

- Feasibility of miniature flight computers
- Tuning characteristics of abdominal flexion to pure digital stimulation
- In-flight stimulation to affect flight path deviations

Acknowledgements

- Office of Naval Research and
  The David and Lucile Packard Foundation
  for sponsoring this research
- Cypress Semiconductor for PSoC dice
- Collaborators in Daniel and Diorio labs