Vision Sensors for Entomologically-inspired Micro Aerial Vehicles

Dan Black, in collaboration with Professor Reid Harrison
Insect Inspired

- Two kinds of vehicles:
  - Micro Hovering Aerial Vehicles (MHAVs)
    - ~50cm diameter
    - Larger, but smarter
  - Micromechanical Flying Insects (MFIs)
    - Very small, ~.1g
    - Smaller, able to accomplish specific, simple tasks

- Both need to be autonomous
Motivation

- It’s really cool.
- Building Clearing (points of entry, mapping)
- Situation Assessment (earthquakes, terrorism, etc.)
- Data Acquisition – Perch and Move
- Anything else the Government can come up with.
Who’s involved?

- University of California
- California Institute of Technology
- Stanford University
- Boston University
- University of Utah
  - Vision Sensors
Autonomous

- Keeps itself upright
- Doesn’t wander
- Compensates for wind currents, etc.
  - So user doesn’t have to
- Doesn’t run into walls, other objects (obstacle avoidance)

- All of these will depend on vision sensors
Version One: both dumb and smart

- Integrate CMOS imager and “smart” imager
  - Smart pixels already developed by Harrison
    - Gives directional information in x and y directions
    - Output is a differential current, for easy adding
  - “Dumb” CMOS imager in center with smart pixels on the outside
“Smart” Pixel

- Photoreceptors
- Temporal bandpass filters
- Temporal lowpass filters
- Multipliers
- Opponent subtraction
“Smart” Pixel Details

Photoreceptor and Filtering

Low-Pass Filter (Phase Lag)

Multiplier
Combining Pixel Information

Spatial integration

Wide-field output
General Idea

Each pixel outputs both an x and y analog directional output.

These are combined for overall directional information.

CMOS Imager is a Separate System.
Testing

- Adjust design to output individual pixel information
- Develop Method of extracting this information
  - Microcontroller, external hardware
- Develop Matlab program for meaningful analysis
  - While waiting for chip to be fabricated
Integration

- Sensor must be integrated into MFI
  - Design with this in mind
  - Find out requirements, expected outputs

- Integration primarily at UC Berkeley
  - I will likely go there to help with integration
Communication Plan

- Meet with Dr. Harrison each week
  - Discuss Progress
  - Resolve Questions
  - More Often as necessary
- Presentations at milestones to Harrison and Grad Students
- Collaboration as needed with team members at other Universities
<table>
<thead>
<tr>
<th>Milestone</th>
<th>Y</th>
<th>WP or Proto</th>
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<tbody>
<tr>
<td>Design V1 chip with optical flow and CMOS imager</td>
<td>Y0.5</td>
<td>WP</td>
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<tr>
<td>Benchtop testing of V1 chip</td>
<td>Y1.0</td>
<td>proto</td>
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<tr>
<td>Flight testing of V1 chip (at Berkeley, data collection)</td>
<td>Y1.5</td>
<td>WP</td>
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<tr>
<td>Design of V2 sensor chip</td>
<td>Y1.5</td>
<td>WP</td>
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<tr>
<td>V2 sensor for integration with MFI</td>
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<td>proto</td>
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<tr>
<td>V3 sensor design with roll/ pitch/ yaw detection + ocelli</td>
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<td>Benchtop testing of V3 chip</td>
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<tr>
<td>V4 sensor design with collision avoidance</td>
<td>Y4.0</td>
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## Schedule Tasks

<table>
<thead>
<tr>
<th>Tasks</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
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<tbody>
<tr>
<td>Learn Lab Tools</td>
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<td>Research Previous Work</td>
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<td>Preliminary Design</td>
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<td>Design Simulation</td>
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<td>Determine Testing Strategy</td>
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<td>Design Modifications</td>
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<td>VLSI Layout</td>
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<td>Submit for Fabrication</td>
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<td>Implement Testing Strategy</td>
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<td>Documentation</td>
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*Note: Colors indicate the progress of each task across the months.*
Schedule Tasks (cont.)

<table>
<thead>
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<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
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<tbody>
<tr>
<td>Implement Testing Strategy</td>
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<tr>
<td>Develop Analysis Tools</td>
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<tr>
<td>Receive Fabricated Chip</td>
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<tr>
<td>Test Chip and Analyze Performance</td>
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<tr>
<td>Prepare for Thesis Presentation</td>
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<td>Present Senior Thesis</td>
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Risks, Difficulties

- $$$ - No grant, no project
  - Backup plan involves neural recording
- Low power, small area
  - Layout will be a challenge
- Testing will be tough
- Simultaneous data for collision, flow, rotation info
Questions?