Active sensing and its application to neuromorphic space imaging

Gregory Cohen – ICNS, WSU
Important Points

• The importance of active sensing
• The importance of prediction in neuromorphic systems
• Temporal resolution makes up for spatial resolution
• The importance of synchronization
• Biologically inspired - not biologically plausible
• Low-power, low-bandwidth sensing and computation
What is space situational awareness?
Space Situational Awareness

1957

Dr Stuart Grey
Low-Earth Orbit
Source: stuffin.space
Medium Earth Orbit
Source: stuffin.space
Geosynchronous Orbits
Source: stuffin.space
Neuromorphic Event-based Sensors

**Novel imaging paradigm**

- Independent and asynchronous pixels
- Logarithmic change detection gives very high dynamic range
- Frame-free imaging with no fixed integration times
- High-speed imaging (events have 1 µs resolution)
- Greatly reduces motion blur and saturation effects

**High-speed, low-power, low-bandwidth imaging**

**Requires a new approach to processing and computer vision**
Experimental Setup

<table>
<thead>
<tr>
<th>Telescope</th>
<th>Manufacturer and Model</th>
<th>Focal Length</th>
<th>f / ratio</th>
<th>Sensor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary telescope</td>
<td>Officina Stellare RH200</td>
<td>600 mm</td>
<td>f / 3</td>
<td>CCD Sensor</td>
</tr>
<tr>
<td>Secondary telescope</td>
<td>8” Meade LX200</td>
<td>2000mm</td>
<td>f / 10</td>
<td>ATIS Sensor</td>
</tr>
</tbody>
</table>
Imaging the Stars and Planets
Imaging the Stars and Planets
Low Earth Orbit Satellites (LEOs)
Siderally tracking the stars.
Tracking LEOs – Tracking SL8RB 21938
Low Earth Orbit Satellites (LEOs)

Siderally tracking the stars.

Event Frames

Visualization Surface

0.00 seconds. 2 events
ABS-6 GEO Synchronous Orbit Ground Truth
Geosynchronous Objects

Object: ABS-6 (25924) on 04/06/207

Sidereal tracking is used to visualize the GEO

Real-time Frames

Visualization Surface

0.00 seconds. 2 events
Real-time Detection of Daytime LEOs

[Graphs and charts related to ATIS and DAVIS Time surface plots are shown]
Atmospheric Effects? Jupiter from the DAVIS Camera

0.00 seconds, 2 events

0.00 seconds, 2 events
Atmospheric Effects?
Scintillation Effects?

No scintillation
No Noise

Scintillation
No Noise
Star Tracking with CCD Imaging
Star Mapping with an Event-based Sensor

- Time: 0.1 sec
- Memory surface $\tau = 0.5$ sec

- Index: 1.091 (Million Events)
- Inferred Memory Surface $\tau = 25$ sec Spatial Sigma = 3 pixels
Star Mapping with an Event-based Sensor

Comparison of the inferred star map and the ground truth from the CCD sensor
Seeing Through Gaps in Clouds
Seeing Through Gaps in Clouds
Active Sensing and Occlusion-invariant Sensing
Seeing through the bushes
Seeing through the bushes
Questions