First Annual Partners’ Meeting
Presentation
SmartCam – Computational Photometer

Arctic Domain Awareness Center (ADAC)
A DHS Center of Excellence

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Low-Cost Multi-Channel Imager
- Primary: Visible + IR for Multi-spectral Imaging
- Secondary: Two Channel Visible for Passive 3D Imaging

Smarter “Go-Pro Like” Instrument for Safety, Security, Resource Monitoring (DHS, USGS, …)
- Integrate Off-the-Shelf LWIR, Visible and LIDAR for Fusion
- Drop-in Place on UAV, Marine Vessel, Buoy, Port
- Smarter, Multi-Channel
- Potentially Wearable
- Power Efficient
- Intelligent Uplink

3D and Multi-Spectral Fusion using GP-GPU or FPGA Co-processing
Low-cost, software-defined, smart “Go-Pro” style device with visible and multi-spectral image fusion

- Efficient energy use with image analysis on the device itself
- Emphasis on software intelligence for automatic detection, tracking, and data fusion analysis

Examples

Visible image of a forest fire obscured by smoke (left), while a thermal satellite image indicates hot spots (right), leading to calculation of Normalized Burn Ratio (SWIR, NIR) [O’Connor, Exelis]. SmartCam on a UAV could provide higher resolution, real-time data for situational awareness.

Bergy bits may be difficult to detect with a search light (left) but could be automatically detected by SmartCam software with a thermal camera (right) using machine learning [FLIR].

Automatic hazard and threat identification and annotation from a car [nVidia PX] could be adapted by SmartCam for marine environments.
Multi-Spectral

- Real-Time Fusion of IR + Visible with FPGA/GPU Efficiency

- Threat assessment with Annotation

- Amount of hot Liquid detected and Quantified

- Behavior Modeling of Targets and Threats
  - Skeletal Transformation,
  - Posture, Threat Assessment
Machine Learning Intelligence

- Detection of Safety and Security Threats (Visual)
- Threat Assessment and Characterization
- Annotation and Fusion with Real-Time Digital Video
- E.g. Potentially Unsafe Approach at Ted Stevens

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LWIR Sensors

- **High Resolution** – **DRS Tamarisk** NTSC, 640x480, $6K OTS
- **Medium Resolution** – **SEEK Thermal XR**, USB 2, 206x156, $250 OTS
- **Low Resolution** – **ATOM80** USB 2, 80x60, $900 OTS, **FLIR LEPTON**, $180

Integrated with Ubuntu 12.04 LTS, V4L2 Connexant Decoder

False Coloring by SEEK AOS App, Not Yet Integrated

Fully Integrated with NVIDIA Jetson with visible 640x480 and OpenCV
Milestones Achieved

- Custom PCB Interface + System

- On hold due to OTS advances, focus on software and applications
- After proving feasibility may re-visit with industry partner to re-layout (Mentor, Intel, Altera support)
Configuration #1 - FPGA Acceleration

Thermal Map Threat Assessment

Dynamic Hazard Assessment

Cloud Analytics and Machine Learning

HD Camera #1 (NIR, Visible)

Vector Processing CVPU (Computer Vision Processing Unit) DE1-SoC

HD Camera #N (LWIR, UV)

USB 3.0, GigE Vision Host Channels

Mobile Sensor Network Processor

2D/3D Spatial Safety Assessment

Flash SD Card (local database)

HD Digital Camera Port (Snapshot history)

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Configuration #2 – GP-GPU Acceleration

Jetson Tegra X1
With GP-GPU Co-Processing

Dynamic Hazard Assessment

Cloud Analytics and Machine Learning

2D/3D Spatial Safety Assessment

Flash SD Card (local database)

HD Camera #1 (NIR, Visible)

Many multi-spectral focal planes ...

HD Camera #N (LWIR, UV)

Threat assessment With Annotation
Feasibility Testing in Marine Domain

- Basic Vessel Detection, Tracking, Identification
- At Ports Light Stations, and In Straits (E.g. Unimak Strait – Great Circle Route to Asia, Bering Strait)
- Big Data Analytics Combined with Sensor Networks (Potential To Enhance Situational Awareness)

- Marguerite Ace Leaves Long Beach
- HD visible imaging of departures
- And transits with ID
- LWIR night/fog detection and tracking
- Correlation to S-AIS and DBMS
- (Field Test – June 2015, Long Beach)
Ideas for Field Testing

- Monitor Unimak and Bering Strait (Visible, LWIR, [LIDAR])
  - Current Tracking is Voluntary S-AIS and VHF Radio Communications
  - Limited Communications and USCG Patrol in this Region

Unimak Pass is a 12 mile wide Transit for Majority of Great Circle Shipping Traffic Passing Through Arctic

Existing USCG Infrastructure Can Be Leveraged to Place a SmartCam

SmartCam System Could Be Used with LWIR + Visible Long-Range Optics And/Or Low-Cost LIDAR Sensors

Cross Check S-AIS with Secondary Record for Improved Domain Awareness

Research goal: Feasibility of vessel tracking, spotting, tracking, ID with more intelligence and lower cost than RADAR
Feasibility for SAR Ops / Port Security

- Add camera systems to Cutters (around, mast)
- Detect bodies in the water, Port trespassing, Complements Aircraft FLIR

**Surfers in the Water**
Hand-held, Cutter Mounted, Buoys
Complements Existing Helicopter and C130 FLIR
*(Field Test – June 2015, Malibu)*

**Trespassers at Night Shown on Jetty**
Hand-held, Port Drop-in-Place, Buoys
Complements Existing Security Off-Grid Installations
*(Field Test – June 2015, San Pedro)*
Accomplishments

Milestones Achieved

- Testing power consumption
  - Low power (0.6W) to normal (6W at 3000mAh → 2-3 hours); need sleep and wakeup with periodic sense if off the grid
  - Couple with hybrid power, OTS leveraging
- Testing LWIR range and Night/Fog Conditions
  - Can see vessels 2 to 13 kilometers with out with 25 degree field of view (25mm lens)
  - Can see vessels TBD miles with out with 9.6 degree field of view (65mm lens) – Next Planned Test
  - Can identify Vessels with HD Visible (200mm lens)
  - Visible + IR Fusion Feasibility Testing (Night, Day)

Anchored Vessels Over Night Waiting for Long Beach Port Access (Field Test – June 2015, San Pedro)
Anchor Points Shown on S-AIS in Excess Of 10 Km From Observing Point
Distance Feasibility Detail (Estimated)

- Range Estimated from S-AIS Data Corresponding to Observations for Anchor Locations and Geographic References

Estimated Using Google GIS and MarineTraffic S-AIS

Expect Significant Increase with 65mm LWIR Lens

Bluff & 40th St. in San Pedro, CA
Stakeholders Identified

- Port of Anchorage

- Black Bear Visits to Port of Anchorage & Government Hill

- Ports in General – Arctic, Off-Grid Monitoring Locations

- Exploration with USCG

- Potential non-DHS stakeholders (e.g. USGS, FWS)
Gaps and Lessons Learned

- More testing needed before application development
  - PTZ (Pan/Tilt/Zoom)
  - Scanning and Searching, Fusion, Power Efficiency
- Power issues for continuous operation off the grid
  - Solar Re-charge (Summer)
  - Ultra capacitor
  - Wind Re-charge (Winter)
  - Fuel Cell Operations (Winter)
- Keep close watch on commercial advances (Cost Savings, Performance Improvement – Faster than Moore’s Law!)
- Leverage Rapidly Decreasing Costs for NIR, LWIR, and Hyperspectral Detectors
- Verify Off-the-Shelf Product Claims with Feasibility Testing in Marine Environments
Next Steps

- Application development for specific scenarios (e.g. vessels)
- Field Testing with AeroVironment
- Publish Initial Results (Power, Feasibility) – SPIE Sensor Technology+Applications or Similar
- Leverage Military Spin-Out Technology
- Arctic Power
  - Fuel Cell Operation (Winter – 4380 hours)
    - H2 PEM
      - 12W PEM Fuel Cell
      - 552L H2 Supply \(\rightarrow\) 100 to 1000 hours operation
      - Methanol Reforming Fuel Cells, 50W Cell (Ultracell)
        - Methanol + Water, 2 weeks at peak output?
  - Battery and Solar Recharge
  - Super capacitors
    - Combine with batteries and/or fuel cell
  - Hybrid solution for different seasons could keep system running continuously
Couple with sensor networks

- SmartCam could be the infrastructure node that uplinks data from neighboring sensor nodes (moteinos)
- SmartCam processor capable of also processing sensor network data
- Opportunistic uplink to maritime vessels and UAVs or directly to the Cloud for situational awareness

More Testing in Port Environments in Anchorage and Long Beach

Work with USCG to Place in Existing Light Stations?