Designing Cameras to Detect the "Invisible": Handling Edge Cases Without Supervision

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Algolux – Robust Perception for All Conditions

- AI software company based in Montreal, with offices in Palo Alto and Munich
- 75+ employees primarily in Montreal with over 85% in R&D
- Significant industry and academic recognition

- Atlas Camera Optimization Suite
  Optimize accuracy for existing vision systems
  Up to 15% improvement

- Eos Embedded Perception
  Optimize accuracy for new vision systems
  Up to 3x improvement
Today’s Vision Systems Fail in Edge Cases
Typical Imaging Stack
Typical Imaging Stack

- ISP
  - Black Level
  - Bad Pixel Correction
  - Lens Correction
  - Denoise
  - Demosaic
  - Tone Mapping
  - Image Enhancing
  - Metering

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Typical Imaging Stack

Supervise to handle edge-cases
Today’s Best Practices

Best practice is to supervise to handle edge-cases

Differentiable!

Not Differentiable.

Not Differentiable.

Not Differentiable.
Jointly Learn Perception, Image Processing and Sensing

Differentiable !
Can be an Image

Differentiable !

Differentiable !
Algolux Eos
Embedded Perception Software
Simulates RGB to RAW for generic data
- Transforms arbitrary sensor raw to target raw
- Domain adaptation for clear well-illuminated images to suboptimal images
We leverage vast amounts of unlabeled data by intensive contrastive learning in the RAW domain.
We jointly train Monocular Depth Estimation and motion models from **unlabeled videos in RAW**

- Given an input frame $I_t$ and nearby frames $I_{t-1}$, $I_{t+1}$, a convolutional network produces a depth map from $I_t$, a second network estimates camera poses relative to $I_{t-1}$ and $I_{t+1}$.
- All losses defined in the RAW domain instead for post-ISP.
Perception Stack
Eos Perception Portfolio

Control | Decision & Control | Vehicle Actuators
Planning | Prediction | Trajectory Planning

Eos Perception

2D & 3D Detection | Object & Sensor Fusion | Multi-Object Tracking | Localization

Sensor Interface & Signal Processing

Eos Inference Engine

Sensor Suite & HD Map & CAN

Cameras | Gated Cameras | Lidars | Radars | IMU | GPS | HD Map | CAN

Target Compute Platform
Eos Perception Baseline Features

- Object Detection & Tracking
- Traffic Light Detection
- Lane Detection
- Freespace Detection (with Ego-Lane Extension)
- Reflection Removal & Obstruction Detection
- Online Calibration

Sensor Interface & Signal Processing

Eos Inference Engine
Eos L2+ Stack for Camera and Radar Perception

Control: Decision & Control, Vehicle Actuators
Planning: Prediction, Trajectory Planning

Detection: Object Detection, 2D & Mono 3D, Traffic Light, Traffic Sign, Lane, Freespace, Multimodal Obstacle Detection, Ground Plane Estimation, Radar Obstacle Detection, Obstruction Detection

Object & Radar Fusion: Camera, Radar

Multi-Object Tracking

Localization: Multimodal Odometry, Visual Odometry, Dead Reckoning

Sensor Diagnostics and Calibration

Sensor Abstraction Layer and Synchronization

Eos Inference Engine

Sensor Suite & HD Map & CAN: Cameras, Radars, IMU, GPS, CAN

Target Compute Platform

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### Eos L4 Stack for Multi-Sensor Fusion

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#### 2D & 3D Detection
- Obstacle Detection: Radar, Lidar, and Multimodal
- Traffic Lights and State
- Traffic Signs
- Ground Plane Estimation
- Lanes
- Free Space
- Obstruction Detection

#### Object & Sensor Fusion
- Camera
- Lidar
- Radar

#### Multi-Object Tracking
- Track to Track
- Multi-Sensor
- Mono-Sensor

#### Localization
- Multi-Sensor Fusion
- Visual SLAM
- HD Map
- RTK GNSS

#### Sensor Diagnostics and Calibration

#### Sensor Abstraction Layer and Synchronization

#### Eos Inference Engine

#### Sensor Suite & HD Map & CAN
- Cameras
- Gated Cameras
- Lidars
- Radars
- IMU
- GPS
- HD Map
- CAN

#### Target Compute Platform

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Evaluations
Qualitative Object Detection Examples

- **Dark Night**
- **Snow Fall**
- **Low Light & Glare from Dirty Windshield**
- **Foggy Night**
Best Performance in Harsh Conditions

**Training Data**
Algolux dataset with a mix of easy and challenging lighting and weather scenarios

**Validation/Test Data**
See Dataset specs later in the slides.
Eos Pedestrian Detection
Wide-Angle Low-Light
Eos Surround View
Wide-angle Rearview – Dusk / Mud
Eos Free Space Detection
Harsh Conditions
Eos Traffic Light State Detection
Evening Rainy Conditions
Eos vs. Tesla Autopilot

Eos is capable of performing more robust and stable frame by frame detections vs. Tesla camera/radar fusion + tracking system’s intermittent detections.
Eos vs. Tesla Autopilot
Eos vs. Nvidia Driveworks
Object Detection – AR 0231
Object Detection – Next-Gen Sensors AT820
Low-Contrast Measurements in Bad Weather
Eos vs. Nvidia Drivenet 2.2
Object Detection – Night and Snow
Eos vs. Nvidia Drivenet – Object Detection
Small Objects down to 10pix width

Clear Day

Night Conditions

Algolux Eos  Nvidia Drivenet

Algolux Eos  Nvidia Drivenet

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Key Takeaways

• Current vision systems are *designed* to fail in edge cases
• Domain adaptation and unsupervised end-to-end learning from RAW to detections is required to address robustness issues
• Significantly outperforms the industry for perception robustness and scalability

Resources

To learn more about Eos, visit [https://algolux.com/solutions/eos-embedded-perception/](https://algolux.com/solutions/eos-embedded-perception/)

To learn more about the research behind the technology, visit [https://algolux.com/research/](https://algolux.com/research/)
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