Safer and More Efficient Intersections with Computer Vision

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Cubic Transportation Systems // GRIDSMART
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Who is GRIDSMART?

GRIDSMART, acquired by Cubic in January 2019, operates in the Intelligent Transportation Systems (ITS) space.

Cubic Transportation Systems is the leading integrator of payment and information solutions and services for transit, with 35+ million passengers served by Cubic systems daily.


GRIDSMART products are in ~8,000 intersections and ~1,300 communities, including 49 U.S. states and 29 countries. GRIDSMART products impact the lives of ~80 million people per day.
What is the GRIDSMART System product?

GRIDSMART is a unique system for intersection actuation, traffic data collection, and situational awareness.

Why unique?
Principles, Technology, Vision

Principles:
Simple. Flexible. Transparent.

Vision:
Improve The Lives Of One Billion People

What is intersection actuation?
Lights change in response to cars, not just timing.
Intersections 101 (N. America)
Intersections 101: Basic definitions

The Box

Approaches

Stop-lines
Intersections 101: Detection areas

- **Stop-line Detection**
- **Advanced Detection**
Intersections 101: The cabinet
Intersections 101: How they work

The Controller changes the lights.

Controller → MMU

The "Malfunction Monitoring Unit" or "conflict monitor."

... 

Detectors

The GRIDSMART System serves as the Detection.

The traffic signal represents a Phase from the Controller that controls a Movement for vehicles or pedestrians.
In-ground detection comprises about 55% of the detection market, down from about 70% in 2008. There are also wireless in-ground sensors (magnetometers), e.g. PODs, which work on the same principles.
Other above-ground (directional) detection modalities include radar, traditional video, and thermal imaging. GRIDSMART was the world's first omnidirectional imaging system until copied by a competitor in ~2018.
Intersections 101: Inside the cabinet
How GRIDSMART Works
How GRIDSMART works

A fusion of low-level image processing and high-level computer vision.

• Background & foreground modeling
• Salient point detection & tracking (optical flow)
• 3D inference (approximate extrinsic calibration)
• Bayesian hypothesis tracking
• Domain knowledge
• All processed in fisheye directly
Showing greedy hypotheses. Note the bicyclist.
Bicycles: Safer & More Efficient
Bicycles: The Problem


\[ G_{min} + Y + R_{clr} \geq 6\text{sec} + \frac{(W + 6\text{ft})}{14.7\text{ft/sec}} \]

- That CA code was written to require bicycles be discriminated at the stop-lines or to require all signals be reprogrammed to provide bike clearances by default.

- There are both safety and efficiency problems with stop-line discrimination. GRIDSMART elected to not provide a solution, because we knew it was a stop-gap, unsafe, and suboptimal.

- The CA code changed (March 2018) to allow systems that provided adequate clearance, not requiring stop-line discrimination.

- GRIDSMART released its solution in 2019.
Bicycles: The GRIDSMART Solution

- Detect and track all moving objects.

- As those objects enter the box, continually apply a CNN image classifier.

- If object is possibly a Vulnerable Road User (VRU), activate output to controller. The controller will use that input to create short green extensions while a VRU is in the box.

- Continue to do inference until certainty, or object has left the box.

- We use Intel® Technologies' OpenVINO™ for inference on the CPU.
Single bicyclist example.
Multiple bicyclists, multiple directions.
Multiple VRUs, inference until certainty (black dot).
Why both safer & more efficient?

What if stop-line discrimination is not 100% accurate?

• A false positive means a long min green and a significant loss of efficiency.
• A false negative is dangerous because cyclist expects adequate clearance and is unaware they will not have it.

But in the box:

• A false positive triggers only a short extension. So inference in the box can err on the side of safety to dramatically reduce missed bikes while still being more efficient.
• Stop-line discrimination assume all bicyclists travel the same speed. Even if stop-line discrimination was 100% accurate, it still wastes green time.
CA MUTCD: 12.9 sec (95 ft)

Actual 1: 8.8 sec (-32%)

Actual 2: 4.8 sec (-63%)

Both on All Red!
Other Challenges
Challenges: Environmental. Expectations.

Need to operate at full functionality at 165F (74C) for 15 hours. Limited air flow.

Often near the ocean. Often near construction.

The industry generally expects of 7-10 year life cycle for the physical products as a minimum.
Challenges: Installation, environmental

Do not ignore the physical realities of the installation, whether in your control or not.

Fisheye is better when mounted higher. But long poles are (very) expensive to ship.

Camera is susceptible to lightning strikes. Grounding and accessible surge protection are important.

A simplified installation, means a better installation and better performance.
Challenges: Installation, environmental

Ethernet cables to camera are often run alongside high-power cables. (Not a good thing.)

Ethernet cables can only go so far without need repeaters.

LED luminaires emit strong, noisy EM fields.

Cameras need ~50W power. (Why?)
Challenges: Lighting

Single exposure.

Multi-frame HDR.
Challenges: Lighting

Direct sunlight. Requires ML approach to detect loss-of-visibility.

Shadows plus something else...
Challenges: Resolution (optics & pixels)

Optics: No Free Lunch

Small sedan footprint:
~40 pixels

Small sedan footprint:
~7,000 pixels
Closing Thoughts
Closing Thoughts

Control as many aspects of your product as you can. Account for the things you cannot control. Make it easier to get right. Then make it easier again to get right.

*How you do anything is how you do everything.*

I believe in tracking all objects, not just those that you classify first. (That might change in near future.)

How did this all get started? Founders were sitting at a red light with no cars coming the other way.