Implementing Embedded Vision: Designing Systems That See and Understand Their Environments

Developing Low-Cost, Low-Power, Small Vision Systems

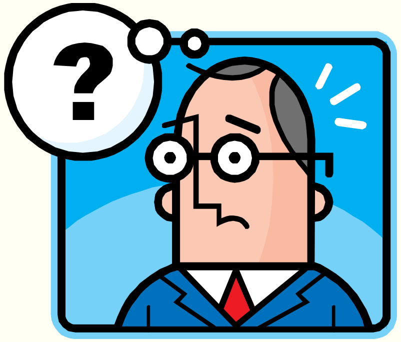
22 Mar 2013
Simon C. Morris, CogniVue Corporation

Cognivue — Innovating With Vision

embedded VISION ALLIANCE

Introduction

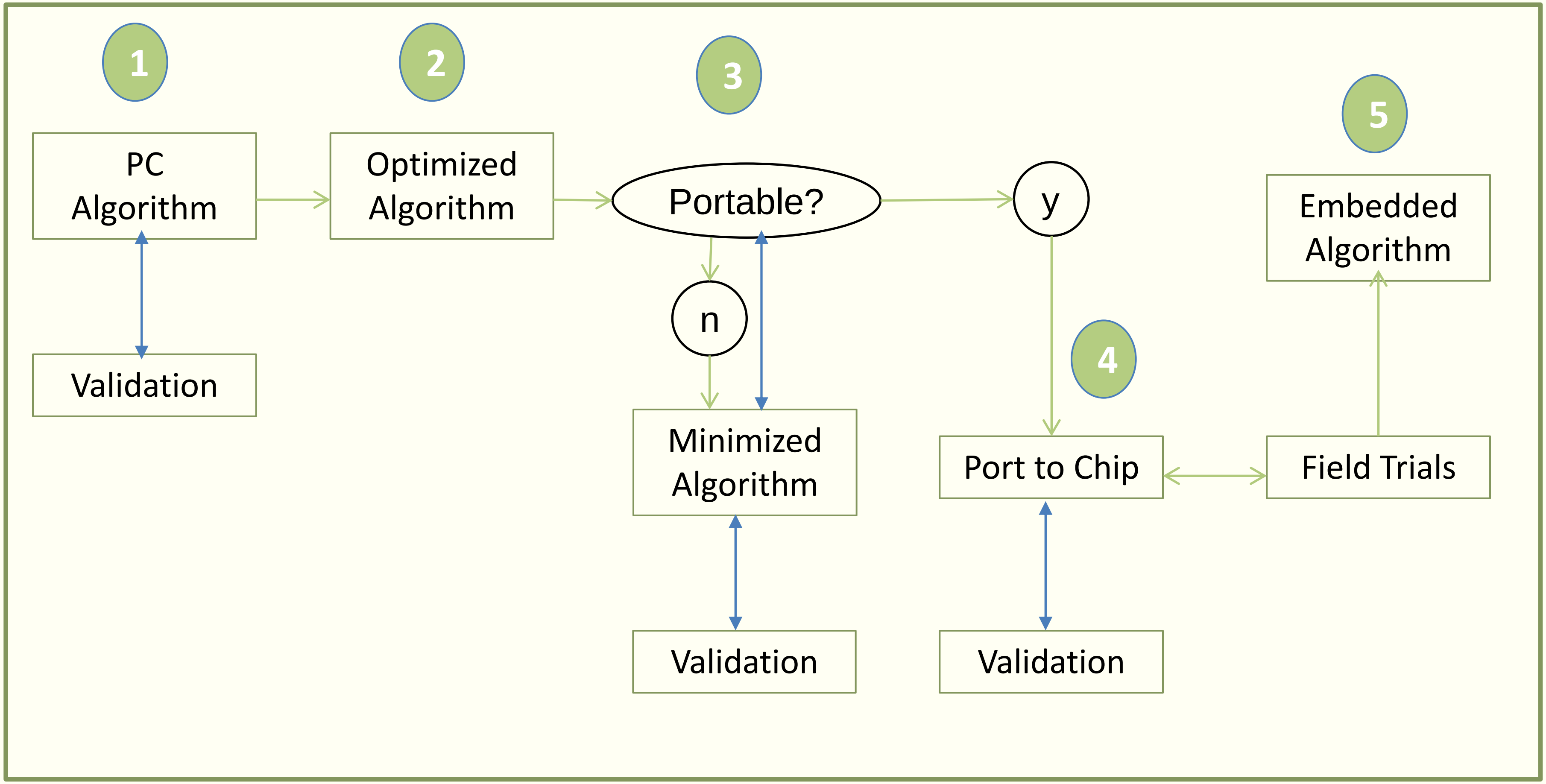
Who is this for?



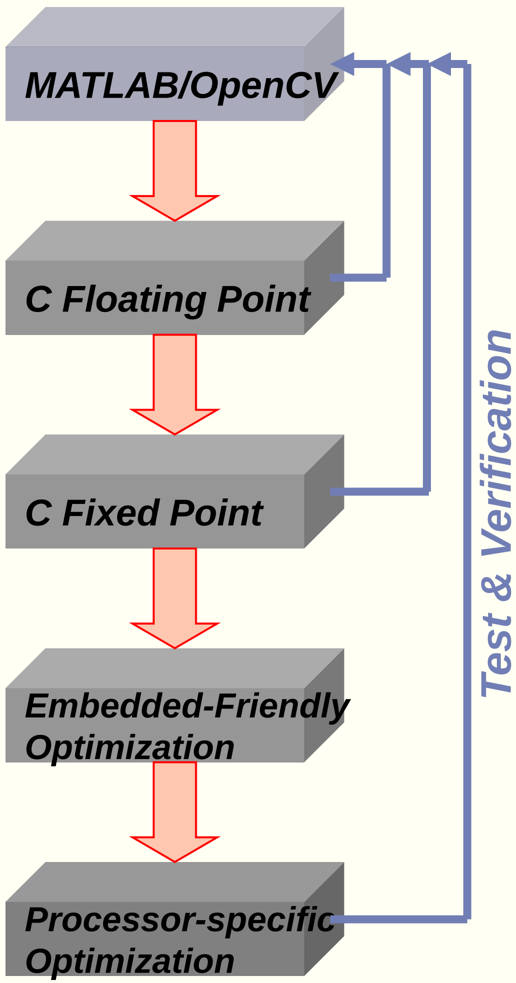
What will be covered?

What can I do with this?

Embedded Development



Typical Algorithm Optimization



C Floating Point

- Data dynamic range analysis

C Fixed point

- Understand & optimize the high level algorithm
- Data type optimization & error analysis
- Normalization & scaling
- Algorithm profiling

"Embedded Friendly" Optimization

- Inline functions
- Alignment of data
- Sequential memory references
- Optimization of mathematical operations
- Minimizing memory usage, reliance on large caches

Deeply Embedded Platform Specific Optimization

- Assembly code (RTL for FPGA)
- Parallel instructions
- Pipeline optimization
- Memory management & data storage
- Cache optimization

What the Customer Wanted

1. Better rear camera, attractive ASP, BoM < $35
2. De-warp 180 degree fish-eye, offer multi-view with overlay
3. Track the closest object, replicate ultra-sonic zones
4. Use a single VGA WDR sensor, 180 degree fish-eye lens
5. From boot-up to object detection in <500msec
6. Processing in the camera module

Algorithm Development

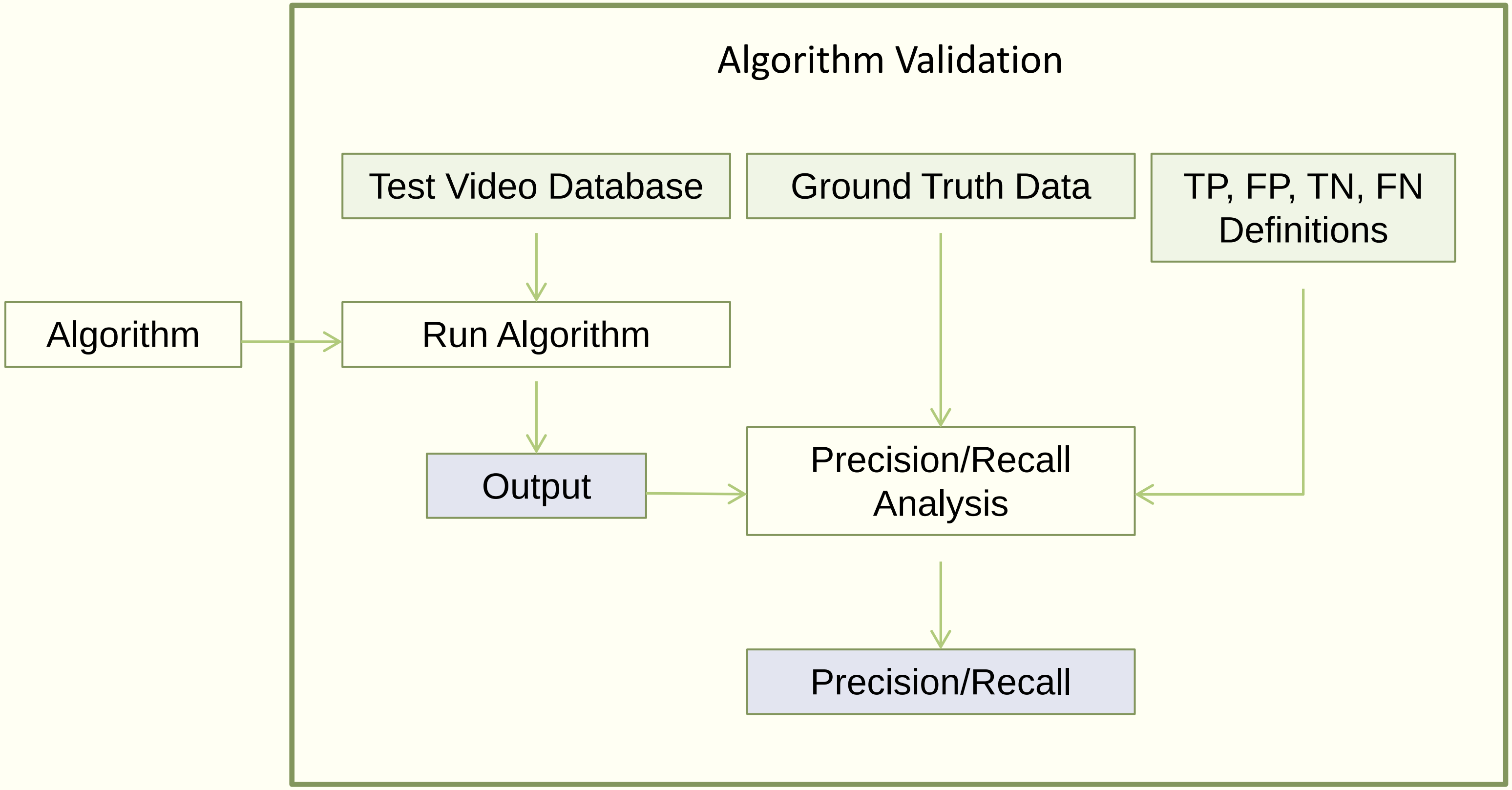
Research determined (started on PC with OpenCV):

- Need for 2 separate obstacle detectors (static, moving)
- Need for 3D reconstruction of the scene to calculate distance
- Do distortion correction, over-lay, object detection in real time

Embedded platform required

- Partition of image processing primitives – scalar and vector
- Simplifying data structures to remove unnecessary de-referencing, function calls, and virtual functions
- Replacing C++ STL objects (*vectors, lists, shared pointers*) used in OpenCV with simpler data structures
- Accounting for time dependencies of simultaneously running tasks

Algorithm Development



Validation and Testing

Significant time is needed to build video test data base, 100+ video scenarios. Three levels of testing needed:

1. Algorithm assessed by observing the detection and false detection rate over the entire video test database
2. Testing on the embedded platform
   - Check bit trueness with PC version. Helps to Isolate any problems in the porting.
   - Validate on the test database and compare performance with PC version.
3. Perform field trials

Hardware

Primary Challenge

- Module needed to be small - ~ 1 inch cube, fit typical installations
- Module is water tight seal, no internal/external airflow – chips overheat, vision processor needs to be <500mW
- Heat dissipation critical. Image sensor is sensitive to heat

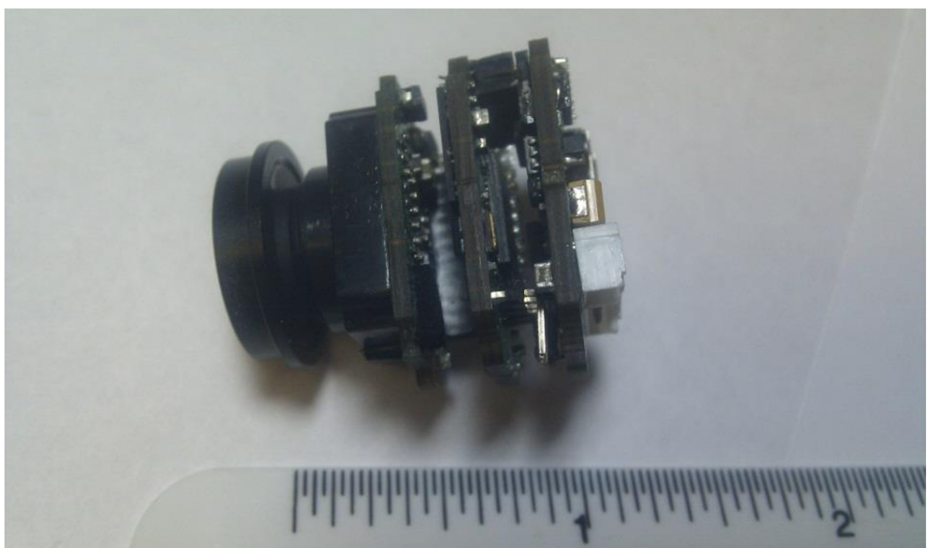
Solutions:

- Several small PCBs. The parts with the most heat kept furthest from sensor
- Metal casing and thermally conductive padding used to contact the case directly to sink heat to the case
- High efficiency DC-DC convertors used (90%+) to minimize heat dissipation in the power supplies. Passive LDO regulators only used with low in-out voltages for image sensor analog supplies

Result: Smart Rear Camera

Within a 1” cube, image cognition processor inside rear camera can do:

- Distortion correction and perspective view
- Feature detection, tracking and distance estimation
- Overlay of lines, text and NTSC/PAL analog video output



Lessons Learned and Applied

1. Programming guidelines:

- Programming guidelines for developers – reduces re-writes

2. Vision centric software framework:

- Algorithm development does not consider data movement
- Framework ensures data is available for processing
- Reduces pipeline stalls, cache misses

3. Specialized vision libraries:

- To speed porting on multi-core and vector processors create higher level complex processing “primitives” (specialized vision libraries)

Lessons Learned and Applied

4. Tool for camera calibration & LUT generation

- Task of generating LUTs for sensor/lens combo is tedious and time consuming

5. Need for comprehensive golden image test database

- Create in parallel with algorithm development, automate testing
- Determines if algorithm changes have impacted performance
- Validate the algorithm against test data base prior to porting
- Variability in the in-field environmental conditions will alter algorithm performance. Field trials must use the same test criteria

6. Plan to do several iterations

The Embedded Vision Alliance

Free Resources on Embedded Computer Vision

The **Embedded Vision Alliance** web site, at www.Embedded-Vision.com, covers embedded vision applications and technology, including interviews and demonstrations

Register on the Alliance web site for free access to:

• **The Embedded Vision Academy** - free in-depth tutorial articles, video "chalk talks," code examples, and discussion forums.

• **Embedded Vision Insights** - bimonthly newsletter with industry news and updates on new resources available on the Alliance website.

Embedded vision technology and services companies interested in becoming sponsoring members of the Alliance may contact info@Embedded-Vision.com

Embedded Vision Summit

A Free Educational Event for Engineers - San Jose, April 25th

Learn how to use the hottest new technology in the industry to create "machines that see"

- Technical presentations on sensors, processors, tools, and design techniques
- Keynote by Prof. Pieter Abbeel, UC Berkeley, a leader in developing machine intelligence
- Cool demonstrations and opportunities to meet with leading vision technology suppliers

Co-located with UBM Electronics' DESIGN West

- DESIGN West also includes the Embedded Systems Conference, Black Hat Summit, and exhibits

The Summit is free, but space is limited. To register to attend, go to www.embedded-vision.com/embedded-vision-summit

Thank-you

Merci, Danke Schon, Tack Sa Mycket,

ありがとう，Kam Sa Hum Ni Da，감사합니다,
Duo Xie, 谢谢

For more information:

www.cognivue.com