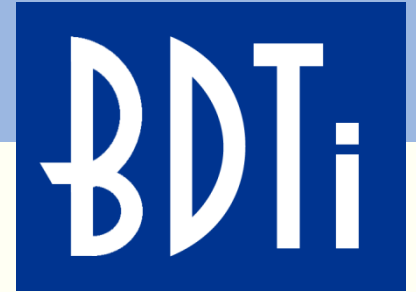*The most trusted source of analysis, advice, and engineering for embedded processing technology and applications*

Get up and Running Quickly With Embedded Vision Using OpenCV on Android
Eric Gregori

ESC–323

San Jose–April 24, 2013

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info@BDTI.com
http://www.BDTI.com

What is Computer Vision?

"Computer vision is the science and technology of **machines that see,** where 'see' means that the machine is able to **extract information from an image** that is necessary to solve some task."
   – Adapted from en.wikipedia.org/wiki/Computer_vision

Computer vision is distinct from other types of video and image processing: in involves **extracting meaning** from visual inputs.

"Half of the human brain is devoted directly or indirectly to vision."
   – Paraphrased from Prof. Mriganka Sur, MIT

Algorithms: The Heart of Computer Vision

In 2D computer vision, the **algorithm** converts a data set containing illumination data from a sensor (camera) into another data set containing a different type of data, usually reducing the amount of data in the process.

337K Bytes of Illumination data

Algorithm

1 Byte of dot count data
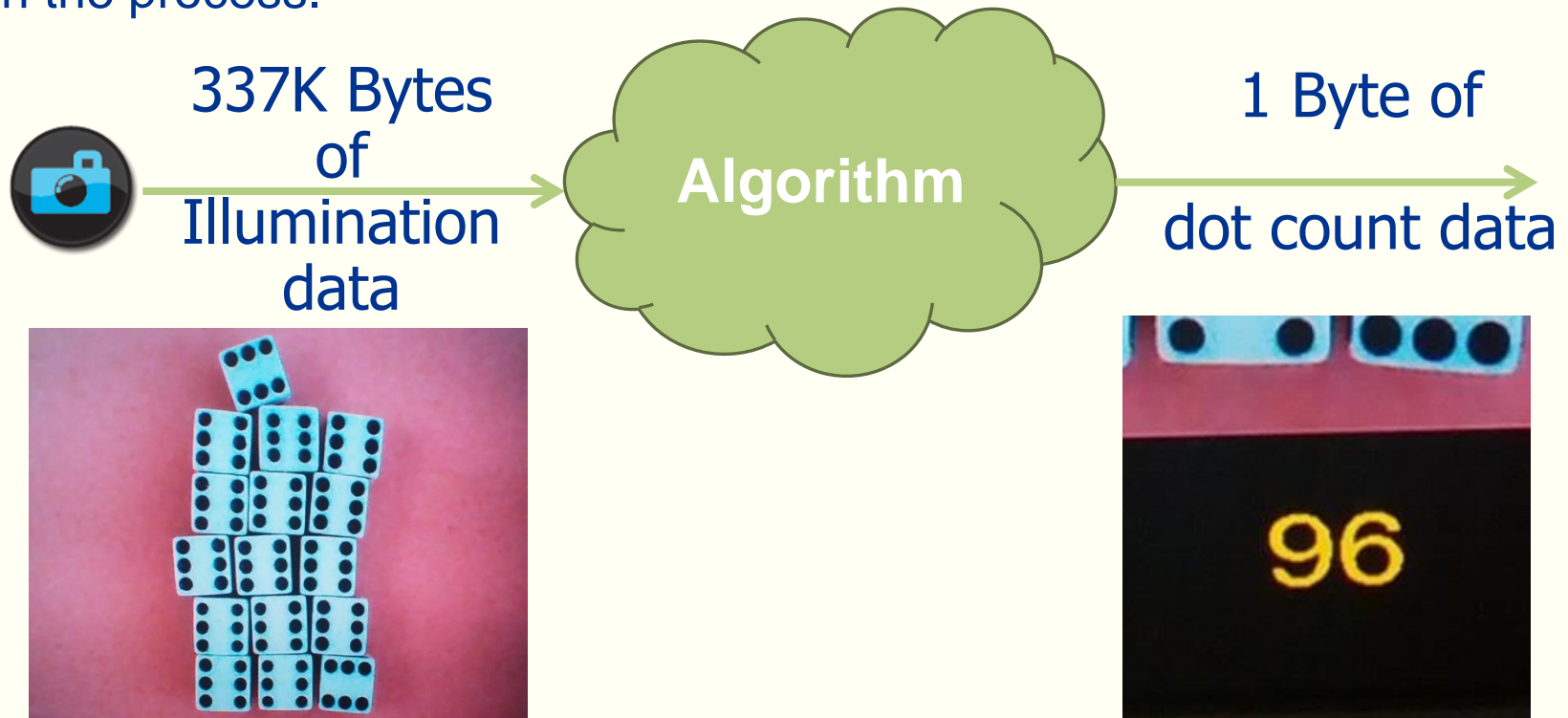
Welcome to the Era of *Embedded* Vision

Most computer vision algorithms require large numbers of CPU cycles to perform their data conversion.

For example: Converting a 720×480 grayscale image of dice at 30 frames per second into a single byte dot count requires over 44044 MIPS.

Not too long ago that type of performance was only available on desktop class systems.

BDTI Embedded Vision Engineering Services (1)

BDTI provides embedded vision engineering services for product development.

BDTI:

- Is highly trusted partner—consistently delivering projects right the first time, on time and on budget
- Has extensive, hands-on experience in Blackfin software development
- Knows vision applications, algorithms and tools, including OpenCV
- Has 20 years of experience developing highly optimized embedded code

BDTI Embedded Vision Engineering Services (2)

You can count on BDTI to be:

- Customer-focused—a reliable partner that works to fully understand your application, clarify your requirements and select the best approach
- Collaborative—BDTI will work with your engineering team, handling part of your project—or provide complete product development
- Practical—BDTI can work with your algorithms or create new algorithms to speed your product to market

Contact BDTI at info@BDTI.com or http://www.BDTI.com/Contact

What is OpenCV?

An open source library of over 500 functions

Over 2500 algorithms

An easy tool for experimenting with computer vision

C/C++/Python Java/Matlab

Windows/Linux/ Android/iPhone platforms

Over 6,000,000 downloads

OpenCV Overview:

Developer http://code.opencv.org; User: http://opencv.org > 2500 algorithms

Robot support

General Image Processing Functions

Image Pyramids

Segmentation

Geometric descriptors

Camera calibration, Stereo, 3D

Transforms

Features

Utilities and Data Structures

Tracking

Machine Learning:
• Detection,
• Recognition

Fitting

Matrix Math

Courtesy of Gary Bradski

OpenCV Represents almost 15 Years of Computer Vision Research and Application Development
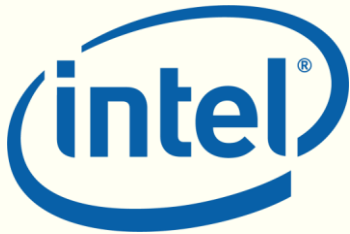
Courtesy of Gary Bradski

Recent Functionality in OpenCV

OpenCV 2.4.5 was released in April 2013 (just 2 weeks ago)

Major New Functionality

- Desktop Java support

- Face recognition (contributed by Philipp Wagner)

- FREAK keypoint descriptor (from EPFL lab)

- GMG background subtractor (contributed by A. B. Godbehere)

- Video stabilization module (by OpenCV NVIDIA team)

- Enhanced LogPolar transform

- OpenFABMAP image recognition algorithm (for image retrieval)

- Better solvePnP algorithms 2D points to 3D pose (implementations of EPFL algorithms)

New OpenCV4Android Functionality

- Front and back camera support

- Camera hardware control
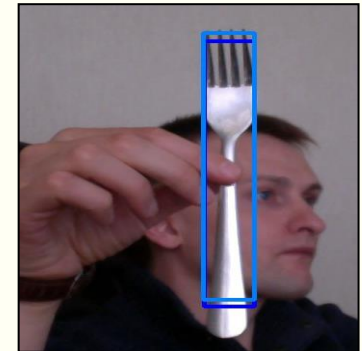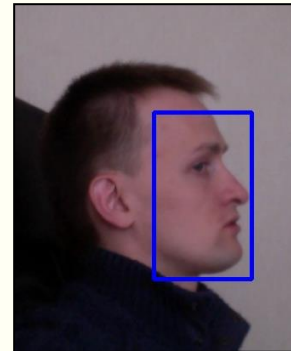
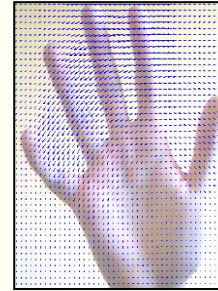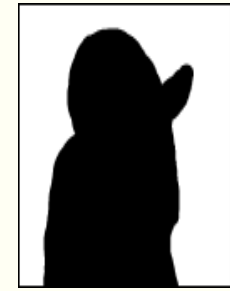Cascade: Side face, and silverware

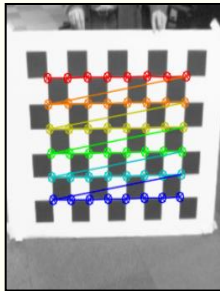# What Can OpenCV Do?

Image Processing
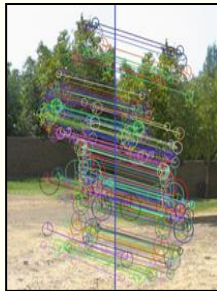
Transforms
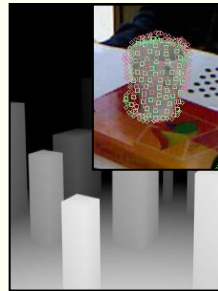
Fitting

Optical Flow Tracking

Segmentation

Calibration

Features VSLAM

Depth, Pose Normals, Planes, 3D Features

Object Recognition Machine Learning

Computational Photography

Courtesy of Gary Bradski

Where is OpenCV Used?

- Academic and industry research
- Security systems
- Google Maps, Streetview
- Image/video search and retrieval
- Structure from motion in movies
- Machine vision factory production inspection systems
- Automatic driver assistance systems
- Safety monitoring (dam sites, mines, swimming pools)
- Robotics
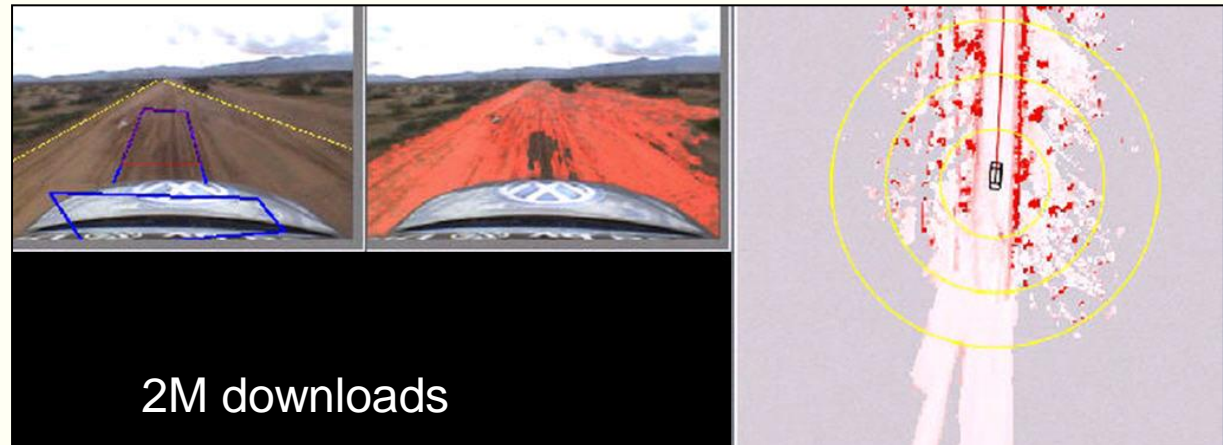
2M downloads

Courtesy of Gary Bradski

The New Face of OpenCV: OpenCV.org

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OPENCV
(OPEN SOURCE COMPUTER VISION)

OpenCV is released under a BSD license and hence it's free for both academic and commercial use. It has C++, C, Python and Java interfaces and supports Windows, Linux, Mac OS, iOS and Android. OpenCV was designed for computational efficiency and with a strong focus on real-time applications. Written in optimized C/C++, the library can take advantage of multi-core processing. Adopted all around the world, OpenCV has more than 47 thousand people of user community and estimated number of downloads exceeding 6 million. Usage ranges from interactive art, to mines inspection, stitching maps on the web or through advanced robotics.

QUICK LINKS:

Online documentation

User Q&A forum

Report a bug

Developers zone

Build farm

LATEST DOWNLOADS

11/04/2013
VERSION 2.4.5

OpenCV for Windows

OpenCV for Linux/Mac

OpenCV for Android

OpenCV for iOS

WHAT'S NEW

11/04/2013
OpenCV 2.4.5 is out!
If you completed with your April Fool jokes, it's a good time to meet OpenCV 2.4.5

27/03/2013
Image Debugger Plug-in for Visual Studio
Microsoft just released Image Watch, a free Visual Studio extension for

01/03/2013
OpenCV 2.4.4 is out!
On the first day of Spring the OpenCV Development Team released OpenCV 2.4.4. Big thanks to

15/02/2013
OpenCV now supports desktop Java
As of OpenCV 2.4.4, OpenCV supports desktop Java development using

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OpenCV in The Embedded Space

OpenCV has always been available to the embedded space under Linux

The library has been ported to: PowerPC, MIPS, Blackfin, Xscale and ARM
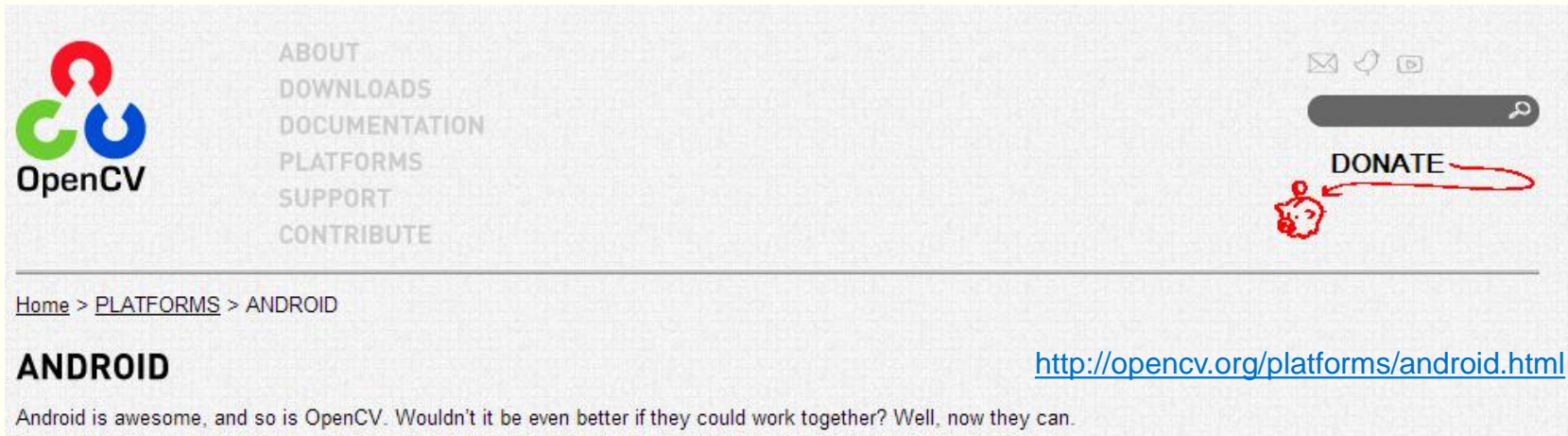
If it can run Linux, it can run OpenCV

http://whatnicklife.blogspot.com/2010/05/beagle-has-2-eyes-opencv-stereo-on.html

TI BeagleBoard

TI BeagleBone

Raspberry Pi (Broadcom)

Analog Devices Blackfin

Freescale i.MX

Android (Qualcomm, NVIDIA)

iOS

OpenCV4Android

Home > PLATFORMS > ANDROID

ANDROID

http://opencv.org/platforms/android.html

Android is awesome, and so is OpenCV. Wouldn't it be even better if they could work together? Well, now they can.

OpenCV 2.4 for Android:

- Native Android camera support
- Multithreading
- Java API
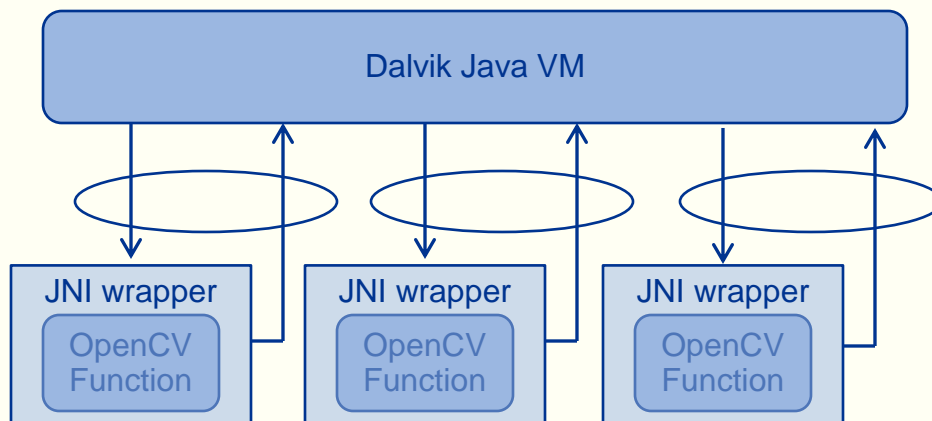- Tegra hardware optimizations
- OpenCV Manager

Courtesy of Gary Bradski

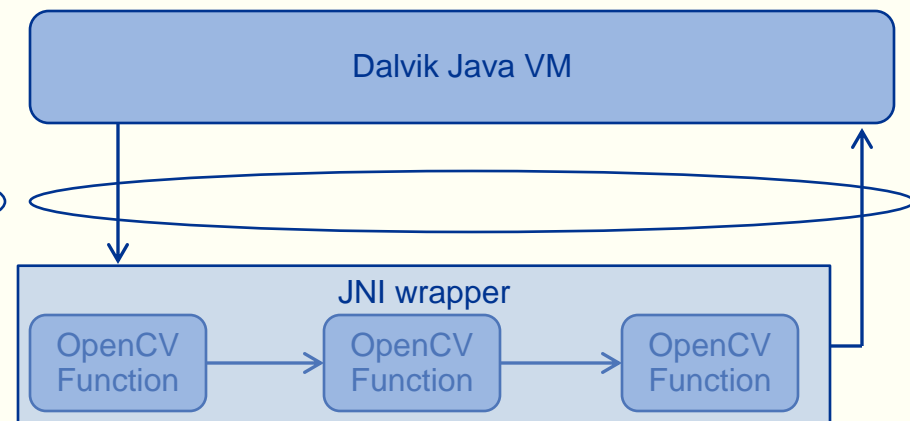# OpenCV4Android Development Java or C++ or Both

Java (basic)

- The Android way
- OpenCV Java API (wrappers)
- Computations are performed on a native level
- JNI call overhead
- Multiple JNI calls in pipeline

Native C++

- JNI—Java Native Interface
- Native C++ OpenCV API
- Fewer JNI calls, faster performance
- One JNI call for pipeline
- Easy port from Desktop

OpenCV Manager

- Android service targeted to manage OpenCV library binaries on end user devices

- Allows sharing the OpenCV dynamic libraries of different versions between applications on the same device

- Installed and updated from Google Play

- Guarantees usage of current/trusted OpenCV libraries

- Less memory usage
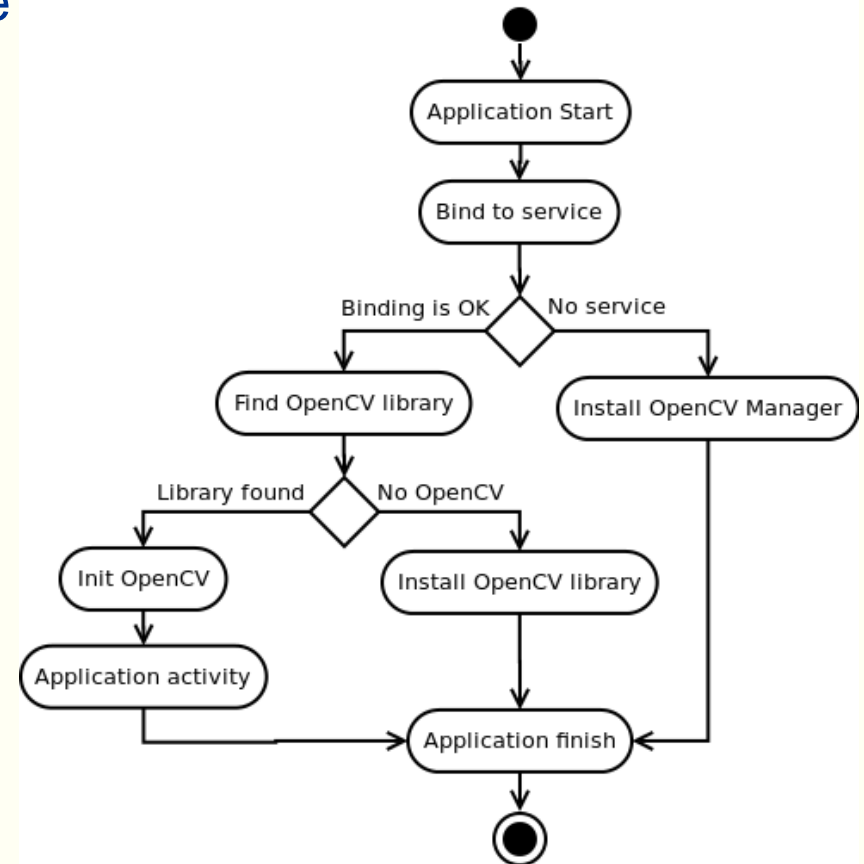
HOW TO BUILD EMBEDDED-VISION APPLICATIONS USING OPENCV ON ANDROID

Best-in-class On-line Documentation/Tutorials

[Developing OpenCV Applications Using the Java API](#)
[Developing OpenCV Applications Using the Native API (C++)](#)
[Building the Android OpenCV Libraries From Source](#)

Installing Android the Easy Way—TADP

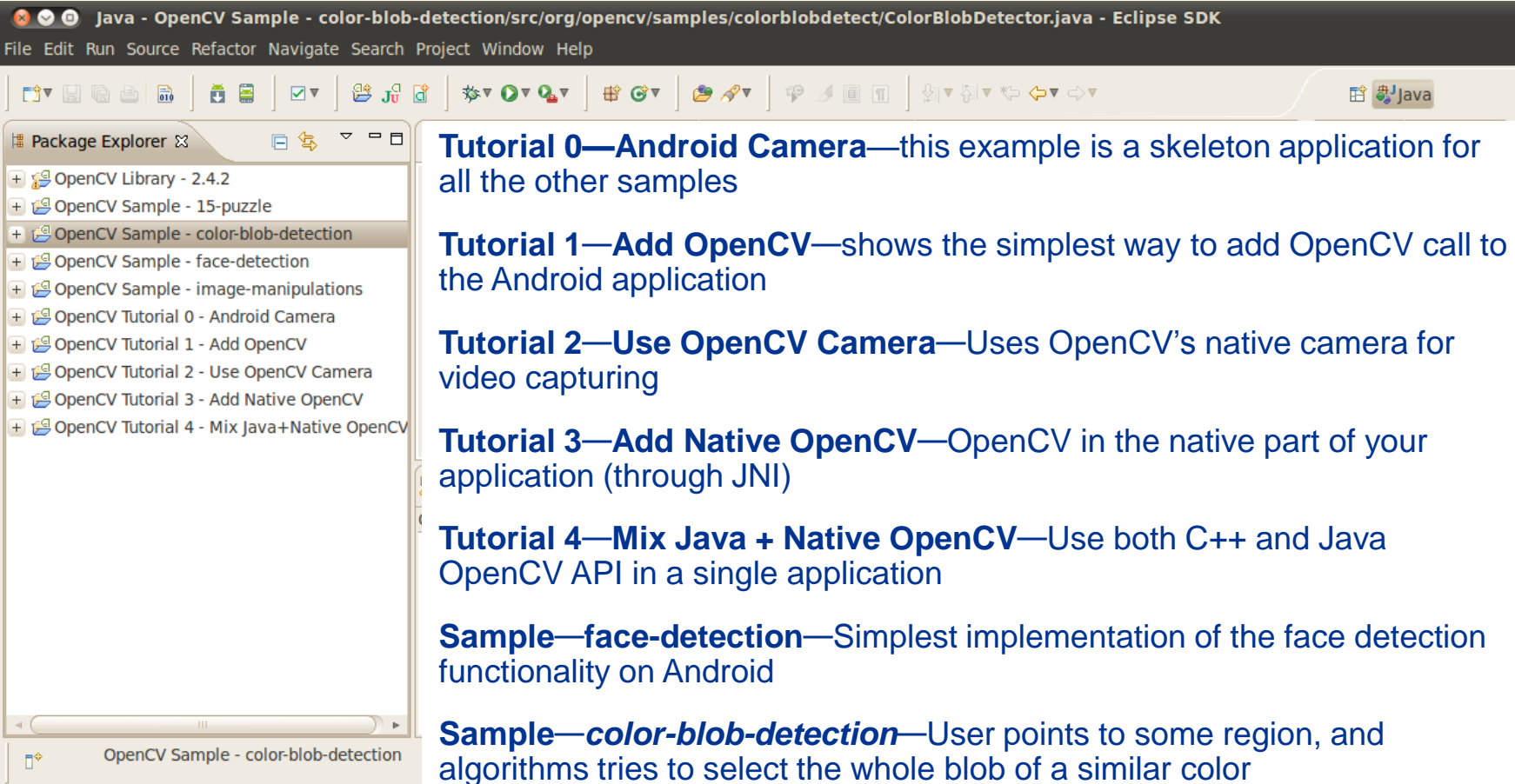## Tegra Android Development Pack

OVERVIEW

Setting up an Android development environment can be a complex and frustrating experience. NVIDIA simplifies this for all Android developers with a single installer that manages this complexity for you.

The **Tegra Android Development Pack 2.0** installs all software tools required to develop for Android on NVIDIA's Tegra platform. This suite of developer tools is targeted at Tegra devices, but will configure a development environment that will work with almost any Android device. This cure for the common cold is available on Windows, OSX, Ubuntu Linux 32-bit and Ubuntu Linux 64-bit.

- The Tegra Android Development Pack—TADP makes installing the Android development tools automatic

- TADP can be used even if you are building for an Android device that does NOT use a Tegra application processor

- TADP installers are available for:
  - Windows
  - OSX
  - Ubuntu 32bit —Requires Java
  - Ubuntu 64bit —Requires Java

- Development Tools Included:
  - Android SDK r21.0.1
  - Android APIs
  - Android NDK r8d
  - Google USB Driver
  - Android Support Library
  - JDK 6u24
  - Cygwin 1.7
  - Eclipse 4.2.1, CDT 8.1.1, ADT 21.0.1
  - Apache Ant 1.8.2
  - **OpenCV for Tegra 2.4.3.2**

Installed and Ready to Start Development

Tutorial 0—Android Camera—this example is a skeleton application for all the other samples

Tutorial 1—Add OpenCV—shows the simplest way to add OpenCV call to the Android application

Tutorial 2—Use OpenCV Camera—Uses OpenCV's native camera for video capturing

Tutorial 3—Add Native OpenCV—OpenCV in the native part of your application (through JNI)

Tutorial 4—Mix Java + Native OpenCV—Use both C++ and Java OpenCV API in a single application

Sample—face-detection—Simplest implementation of the face detection functionality on Android

Sample—*color-blob-detection*—User points to some region, and algorithms tries to select the whole blob of a similar color

SHOW DEMOS HERE

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FACE DETECTION
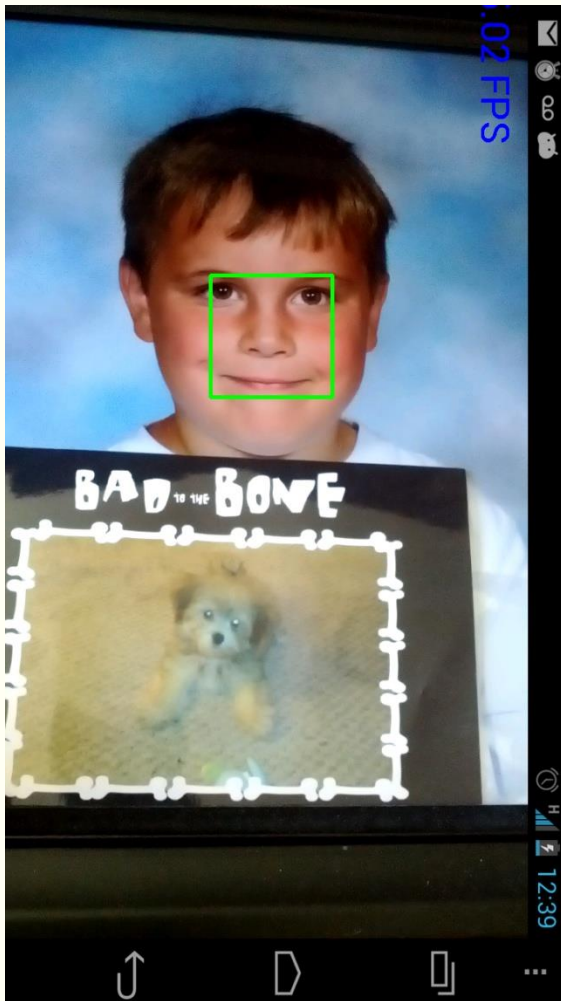
Face Detection

Face detection is one use of an algorithm that is trained to look for specific features, in a specific order.

Instead of being programed, this algorithm learns what an object looks like through training.

Training is done offline, and is accomplished by "showing" the learning algorithm both positive and negative images (images with a face and without a face).

Face Detection—Using Haar Features

Four distinct templates referred to as **Haar features**.

Templates can be processed faster then other techniques.

The template is laid over a portion of the image, and a weight is calculated based on the pixels under the template.

A

B

C

D
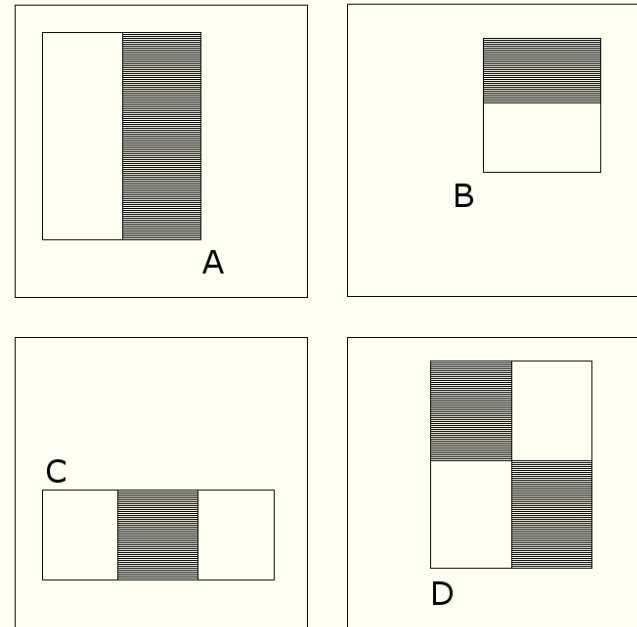
How does training work?

A face of 24×24 pixels can have 45,396 possible combinations/scales of the templates from the pervious slide.

The purpose of training is to reduce the 45,396 possible combinations down to a minimum number and an ideal order.
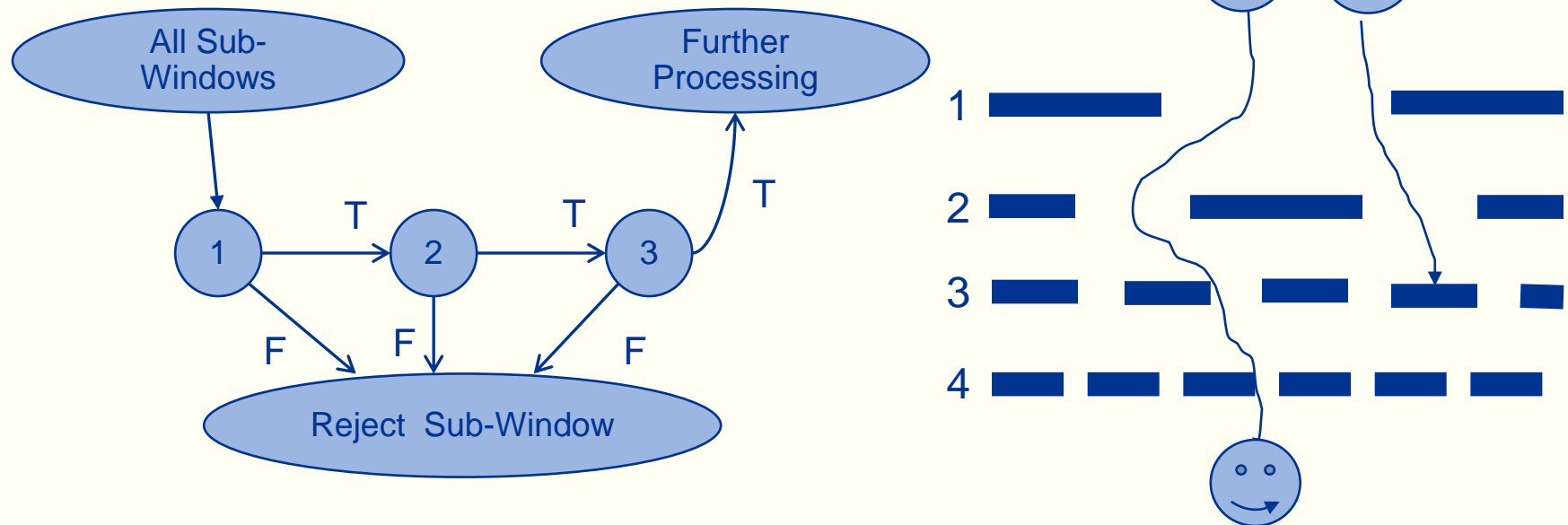
COLOR BLOB DETECTION / CONTOURS

Color Blob Tracking

A "color blob" is a group of adjacent pixels with a common color component.

Segmenting objects based on color is a very efficient method of separating foreground objects from background objects.
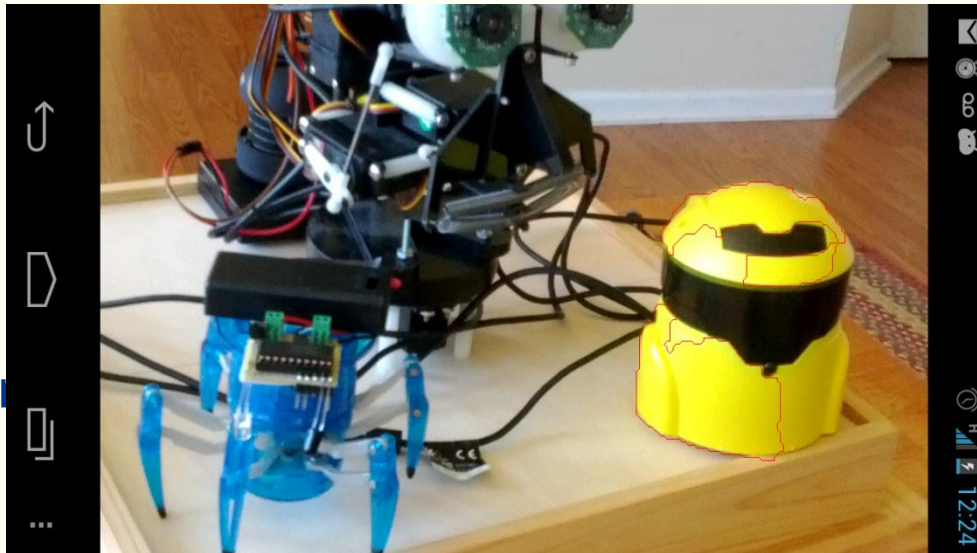
Works well if object of interest is a distinct color.

Problem: Camera "sees" color changes with lighting due to limited dynamic

Color Blob Tracking
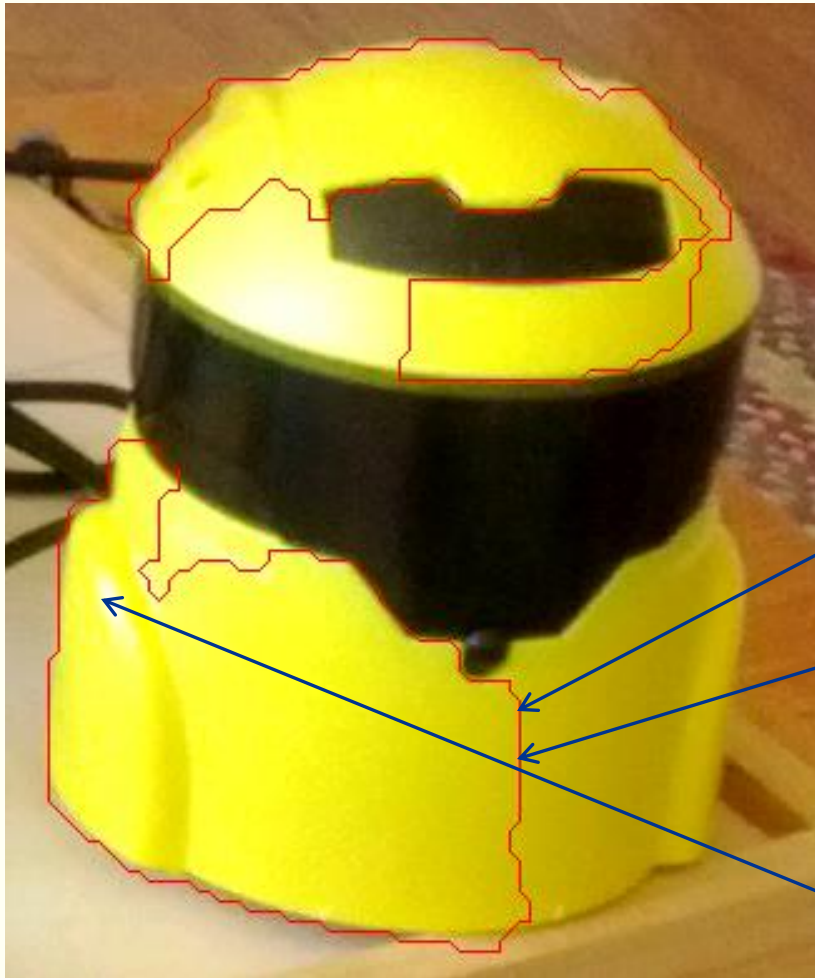
Contours are chains of similar connected features defining a line/curve in an image.

A contour associates many individual features into a single segment.

Many individual features (yellow pixels).

Single segment (defined by red line).

Contour only defines boundary, not content (not all pixels in segment are yellow).

THE FUTURE OF OPENCV

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OpenCV Helping Drive the New Khronos Standard: OpenVL

- Vision Hardware Acceleration Layer
  - Enable hardware vendors to implement accelerated imaging and vision algorithms

- OpenVL can be used by high-level libraries or applications directly
  - Primary focus on enabling real-time vision apps on mobile and embedded systems

- Future versions of OpenCV will leverage OpenVL

- Working group aiming for stable draft spec in 2012

Courtesy of Gary Bradski

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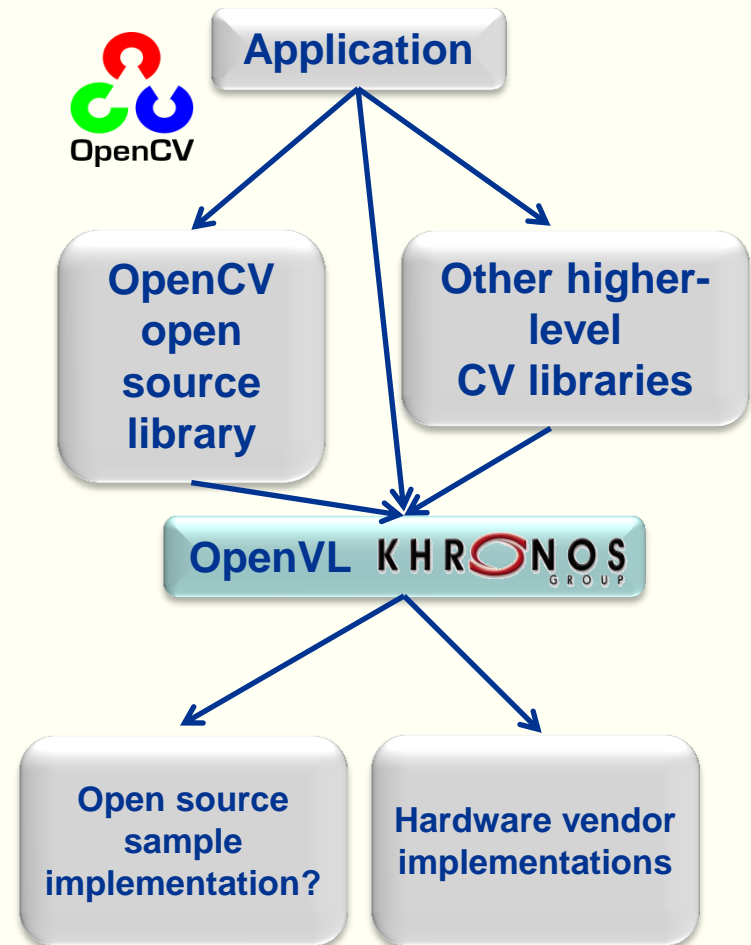
Coming Highlights in OpenCV

- Faster releases 4x-6x/year
- Cloud support (python on Amazon servers)
- Revamped mathematical framework for detectors and descriptors:
  - Faster and way more accurate
- Depth motion fusion
- Iris Recognition
- Transparent item ID
- ARM optimization(?)
- 3D model training
- 2D barcodes
- 2D line matching
- Parts from whole
- More modular
- More optimized

User: http://opencv.org   Developer: http://code.opencv.org

Courtesy of Gary Bradski

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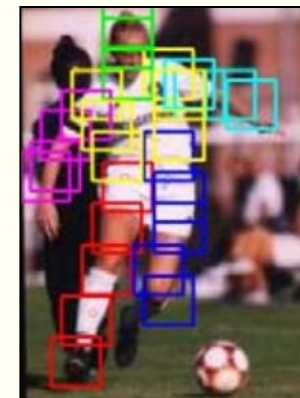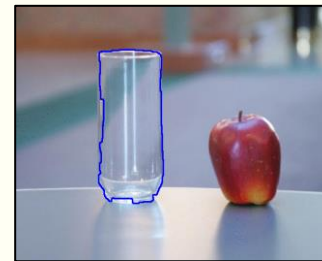
Summary

- Embedded vision enables systems to "see and understand" their environments, making them more intelligent and responsive

- OpenCV is a popular, free computer vision library supported by industry and academia. It supports over 2500 algorithms and has been downloaded over 5 million times

- With the help of NVIDIA, OpenCV has been ported to the Android operating system

- Using the Google Android tools and NVIDIA installer, developing OpenCV applications on Android is easy

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FOR EMBEDDED PROCESSING TECHNOLOGY

RESOURCES

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Selected Resources: The Embedded Vision Alliance

The Embedded Vision Alliance is an industry partnership to transform the electronics industry by inspiring and empowering engineers to design systems that see and understand

Free Resources from the Embedded Vision Alliance

The Embedded Vision Alliance web site, at www.Embedded-Vision.com provides free, high-quality technical educational resources for engineers

Register on the Alliance web site for free access to:

- The Embedded Vision Academy—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

Tomorrow: 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 DESIGN West at the San Jose Convention Center

The Summit is free, but space is limited and pre-registration is required

For details and to request a spot, see www.embeddedvisionsummit.com

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Useful OpenCV Links

- **Developer OpenCV Site:** http://code.opencv.org

- **User OpenCV Site:** http://opencv.org

- **User Group:**
  http://tech.groups.yahoo.com/group/OpenCV/join

- **Book on OpenCV:**

  - http://oreilly.com/catalog/9780596516130/

  - http://www.amazon.com/Learning-OpenCV-Computer-Vision-Library/dp/0596516134

  - **Code examples from the book:**
    http://examples.oreilly.com/9780596516130/

Version 2 of the book is coming July, 2013
For high level issues, partnering, financial contributions, consulting, contract services:
Contact: garybradski@gmail.com
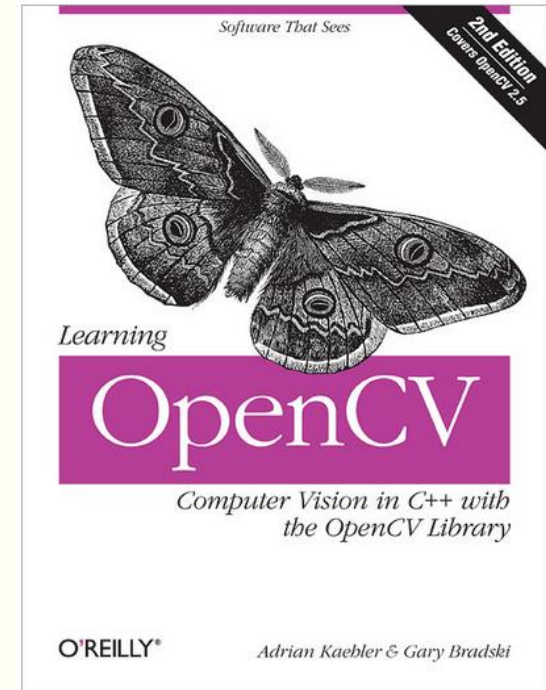
Version 2 available
July 2013

Additional Resources

BDTI's web site, www.BDTI.com, provides a variety of free information on processors used in vision applications.

BDTI's free "InsideDSP" email newsletter covers tools, chips, and other technologies for embedded vision and other DSP applications. Sign up at www.BDTI.com.