OpenCV

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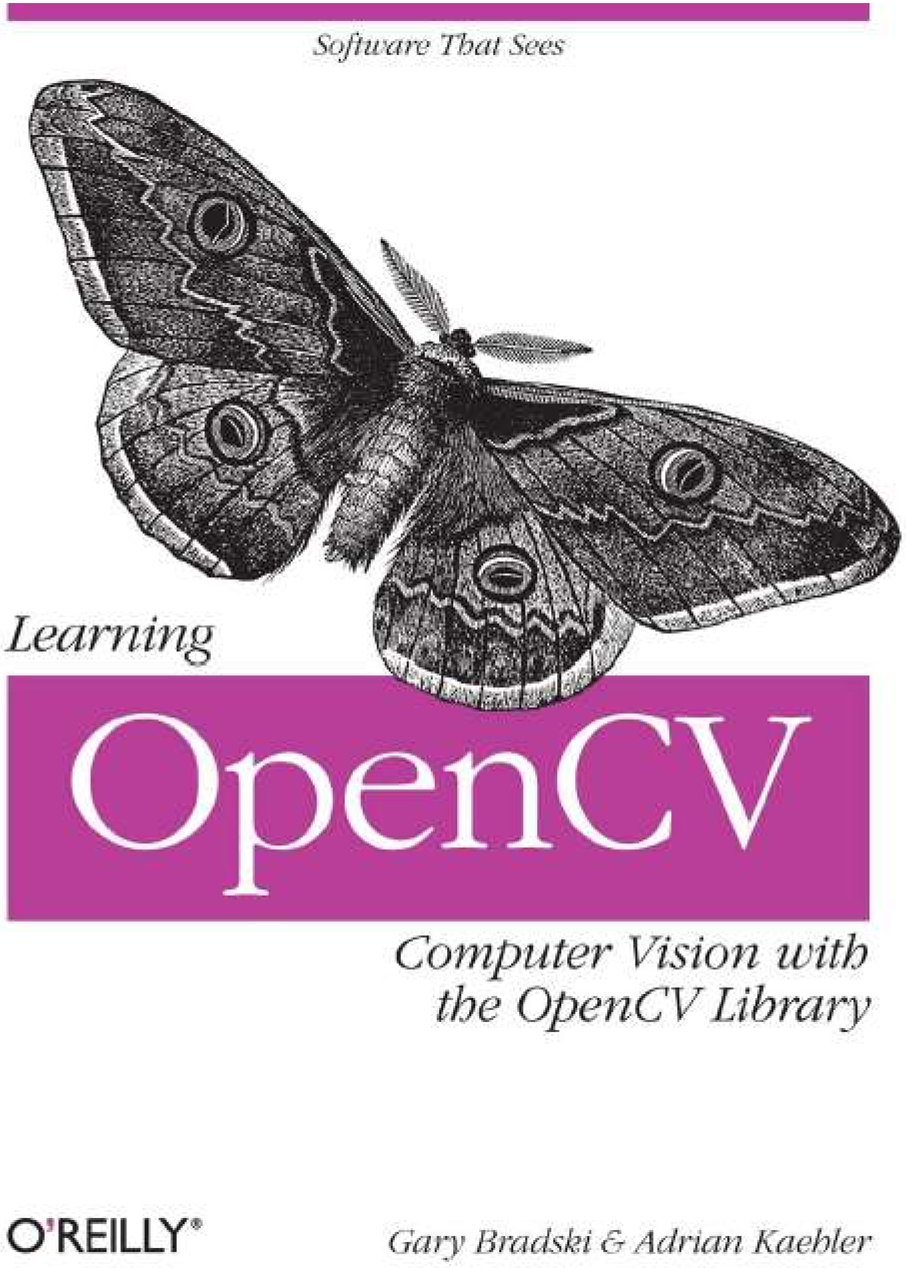


Software That Sees

Learning

OpenCV

Computer Vision with the OpenCV Library

O'REILLY®

Gary Bradski & Adrian Kaebler

Content (1/3)

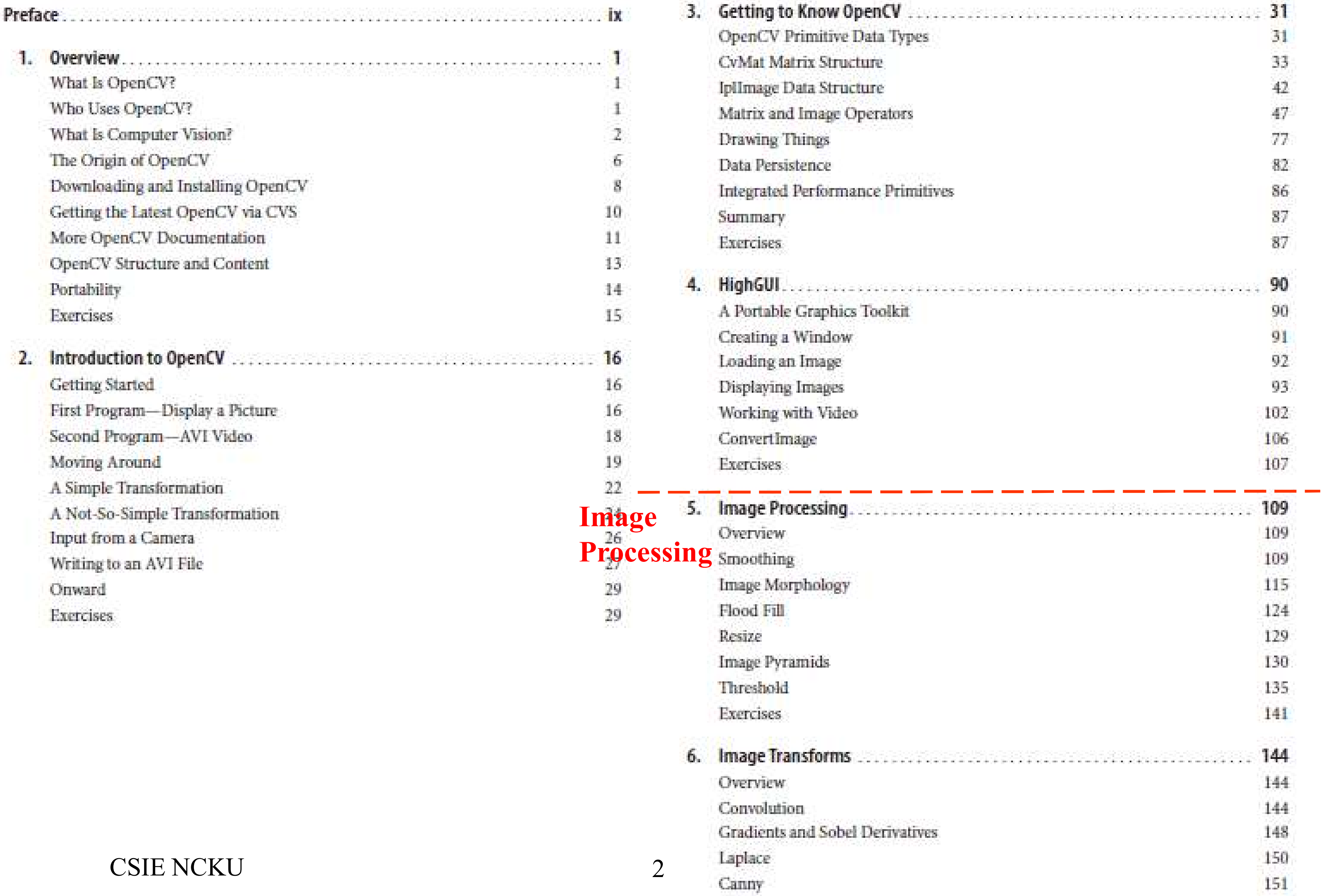
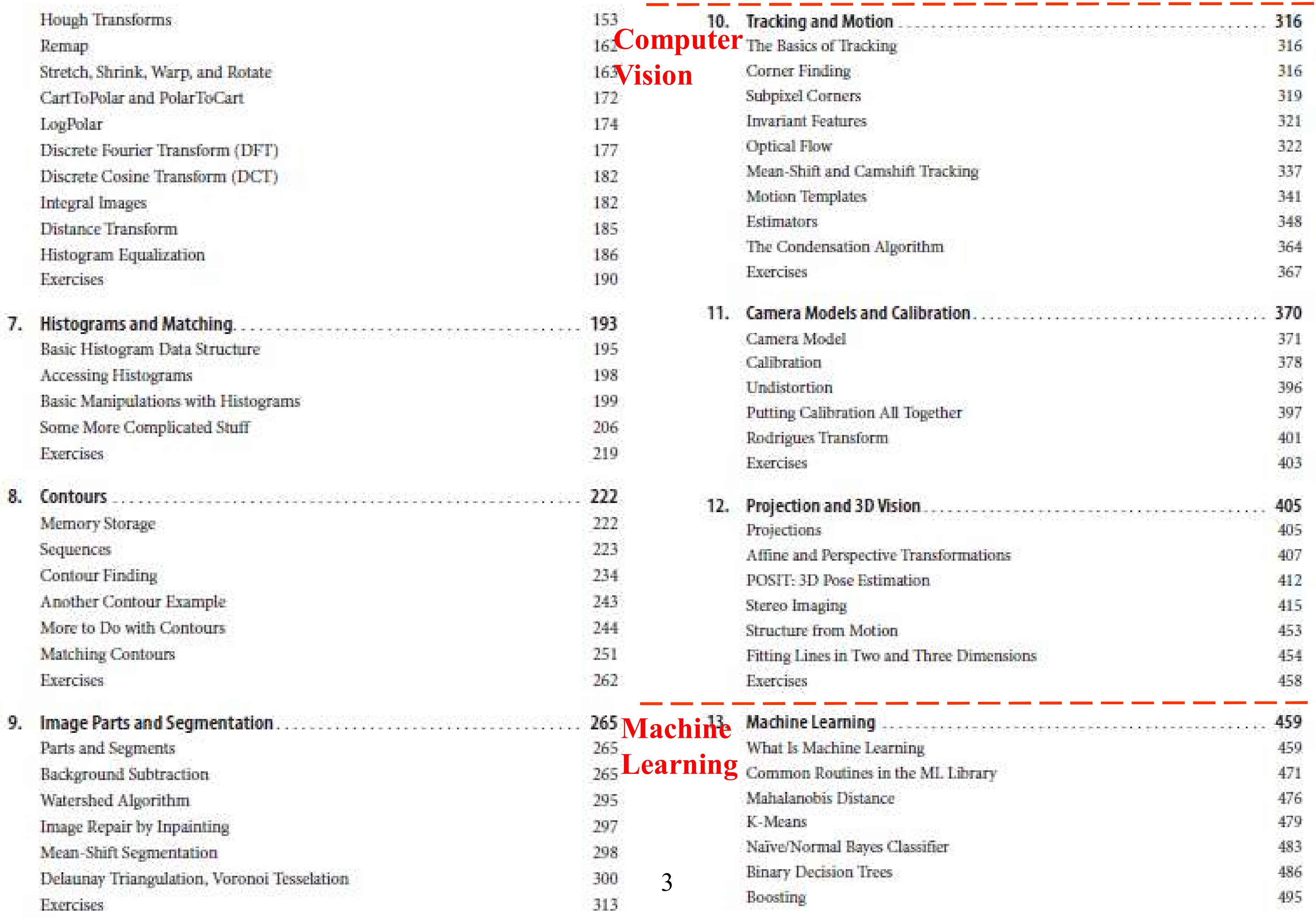


Image Processing

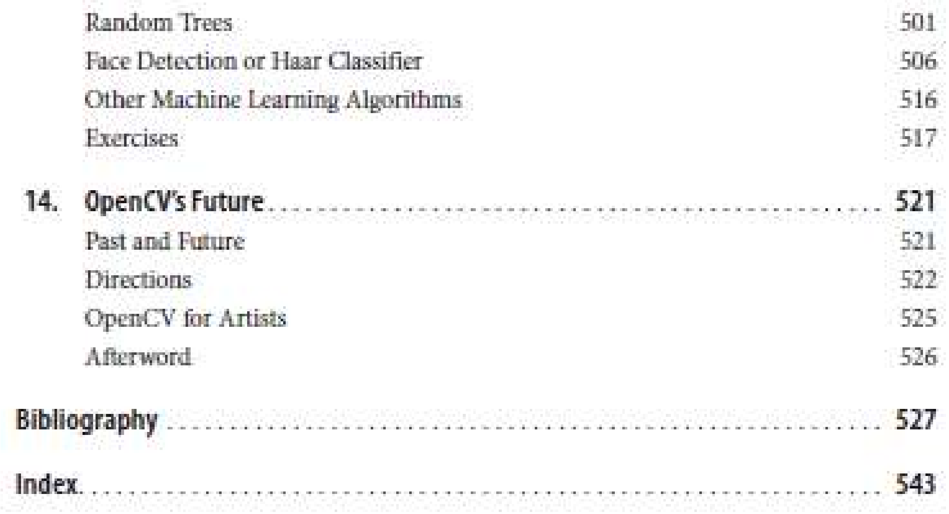
Content (2/3)



Computer Vision

Machine Learning

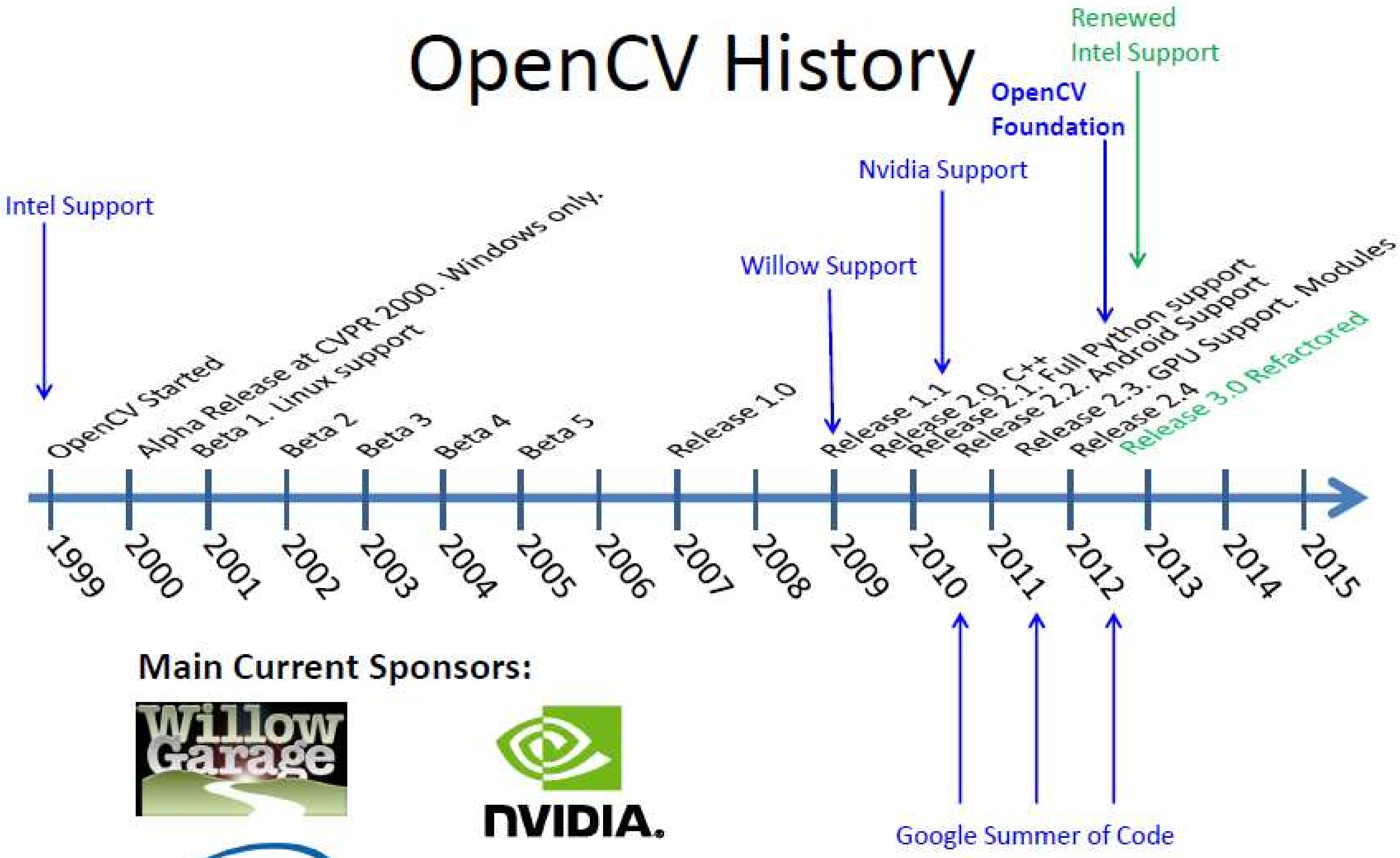
Content (3/3)



What is OpenCV

- **Open** Source **C**omputer **V**ision Library
- Routines focused on real time image processing and 2D + 3D computer vision.
  - **On Linux, Windows, Mac, Android and iOS**
  - **C++, C, Java, Matlab and Python interfaces**
- **Free** for commercial or research use in whole or in part.

OpenCV History



Main Current Sponsors:

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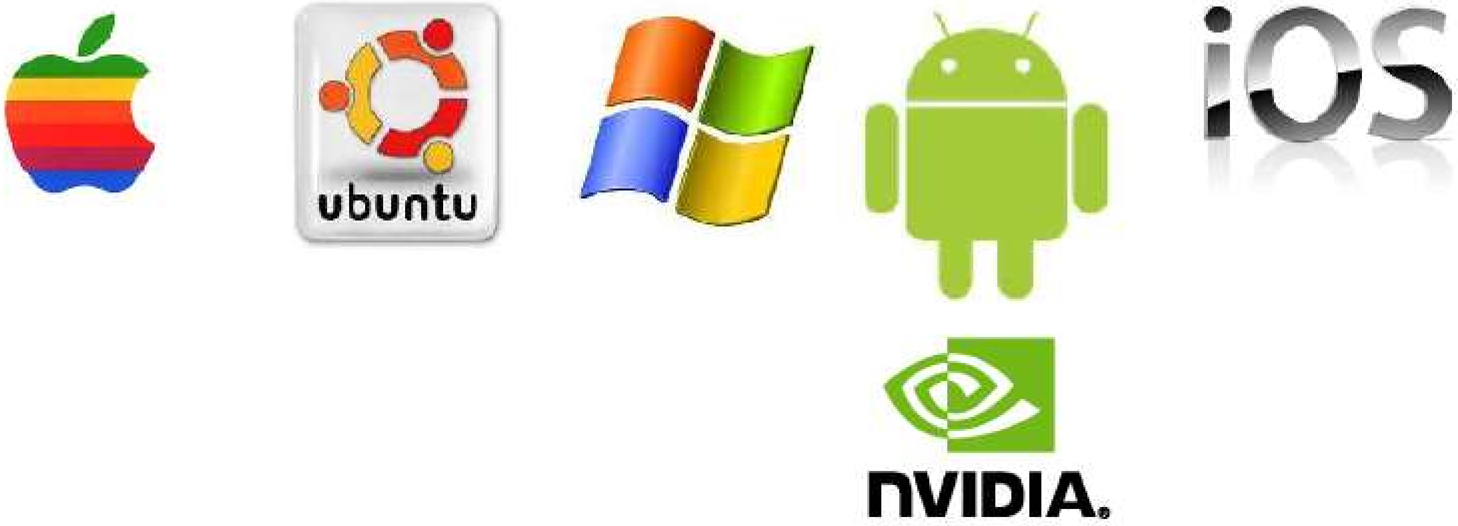
Environments, Platforms

- Languages:
  - C++, C#, Python, C, Java
- Platforms:



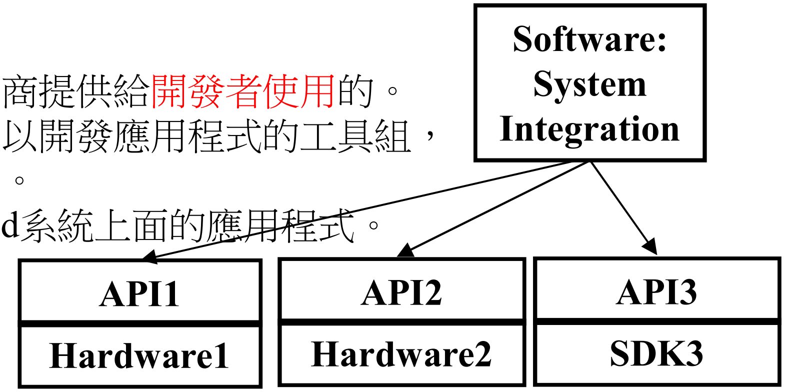
OpenCV Android Module

- OpenCV 2.4 for Android:
  - Native Android Camera Support
  - Multithreading
  - Java API (soon)
  - Tegra HW Optimizations (soon)

Wiki with the latest information:

http://blog.jyny.tw/2013/01/api-sdk.html

SDK Vs. API (1/2)



- **SDK (Software Development Kit)**
  翻譯成中文就是"軟體開發工具組"
  是用來幫一個 產品 或 平台 開發應用程式的工具組，由產品的廠商提供給開發者使用的。
  通常是 某一家廠商 針對某一 平台 或 系統 或 硬體 所發佈出來用以開發應用程式的工具組，
  在這個工具包裡面，可能包含了各式各樣的開發工具，模擬器等。
  例如：給 Android平台 使用的 Android SDK 就是用來開發 Android系統上面的應用程式。

- **API (Application Programming Interface)**
  翻譯成中文就是"應用程式介面"，其實這樣翻譯不太直觀。
  翻譯為介面，顧名思義就要溝通兩隻不同的東西用的，通常由一組函式所組成。
  在同一個平台下的兩個不同東西(程式 or 系統)，為了能取用對方的功能等等，
  所以一個 X程式 寫了一組函式，讓同一平台的其他程式取用 X程式 的功能，
  那組函式就可以說是那個 X程式 對外開放的 API。
  甚至是系統呼叫，
  因為作業系統的任務就是管理好電腦的各種資源，所以程式需要資源時必須跟作業系統溝通，申請使用某某功能等等，稱為系統呼叫(調用)。
  系統呼叫的時候也是取用OS作業系統提供的API。
  例如：我要在 自己的網頁 加入google map提供的功能，就使用"google map API“

- **通常SDK(開發者工具包) 裡也會帶有很多 API** ，用來調用一些系統平台程式提供的功能
  例如說：視窗顯示，圖形特效等等。
  以下舉一個實際例子來說明，調用系統程式功能的API 是怎麼一回事
  開發Windows應用程式的SDK(開發者工具包) 裡就包含 Win32 API
  說明： Win32 API 是一個函式庫，可以給 Windows應用程式 調用 Windows系統的功能

- 在PTT看到有人問了差異性，我的看法是
  SDK是用來開發某一個平台的程式的工具包 (J: Toolkit)，API 是讓同一平台下的程式取用它的功能的函式庫 (J: Library)。

http://blog.jyny.tw/2013/01/api-sdk.html

SDK Vs. API (2/2)

1. API 通常大家都不會弄錯，的確就是以功能為導向的"方法"或"函式"清單，看程式語言或平台而定(Methods, Functions...)，而每個 API 主要都是為了達成某特定功能所設計的。
   開發商可以為了不同平台，設計相同的 API 讓開發者使用，
   也可能會因應不同平台，製作不同的 API 讓開發者使用。

2. 當 API 數量夠多功能夠繁複並且可交互為用的時候，
   (例如為了達成某些功能，常需要同時引用某些 APIs 來完成)
   開發商就會為了開發便利，而預先撰寫好一些組合好 APIs 的 API供開發者使用，來統一有特定需求的開發者能有一致的開發與使用體驗，(例如讓使用“網路連線”的開發者不需自己處理網路的基礎溝通信息，與錯誤處理方式，使 API 在應用的時候有一定程度的便利性等)

   然後，也陸續發展出，甚至是設計不同平台開發環境所需的套件，測試、除錯工具，尤其針對不同平台，更是設計了對應的工具來協助開發、除錯；
   SDK 名詞之所以出現，儼然是為了匯整上述這些資源而誕生的，我想也可以說成是 API 的包含者(直接使用)與應用者(以便加速開發)，也因此可以說這兩個是屬於不同層級的東西...

以 Android 來說：
a. 我們要擁有 Android SDK 才能開發 Android 應用程式
(針對不同開發系統而不同 Linux, Windows)
b. Android SDK 裡的 APIs 統統都可以單獨使用，只不過你會發現他們都還有許多其他的應用，而且可能還比自己寫來得更有效率
c. Android SDK 跟開發環境整合後，除了提供程式碼語法錯誤檢查外，還提供模擬器平台讓我們不需要硬體就可以模擬測試
d. Android SDK 內有測試用的 APIs，來協助我們檢查記憶體用量、程式效能以及狀態顯現等功能 (當然它建議僅在測試除錯時才使用)

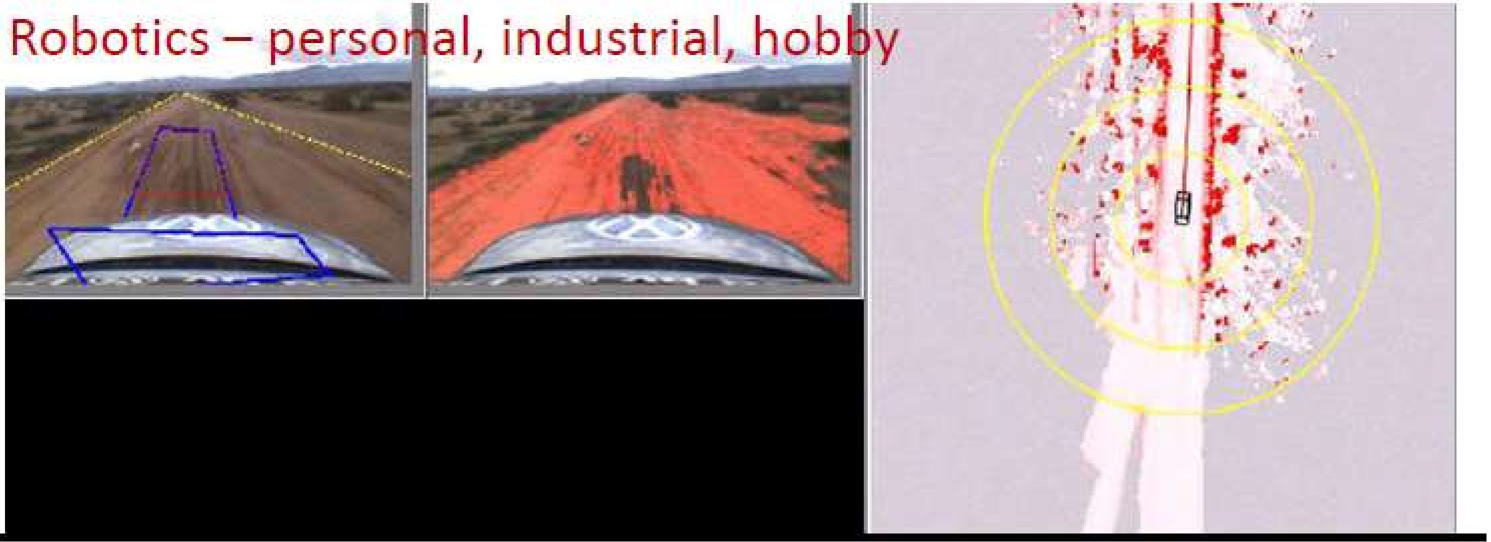
以 Facebook 來說：
a. 我們要下載 Facebook SDK 才能開發應用程式
(針對不同開發語言或平台而不同，PHP, JavaScript, Android, iOS)
b. Facebook 官網提供 SDK 詳細的 APIs 解說與使用方法、範例說明等
c. Facebook 官網提供 線上測試工具，測試某些API的指令與語法

以 Google Map API 來說：
網頁開發，只需使用 Google Map API 即可在網頁上開發、使用其功能(但是在 Android, iOS 上開發則另外需要 Google Map SDK 才行)

由此可知，我們可以清楚知道 API 與 SDK 的定義差別了！

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 – personal, industrial, hobby



OpenCV Foundation

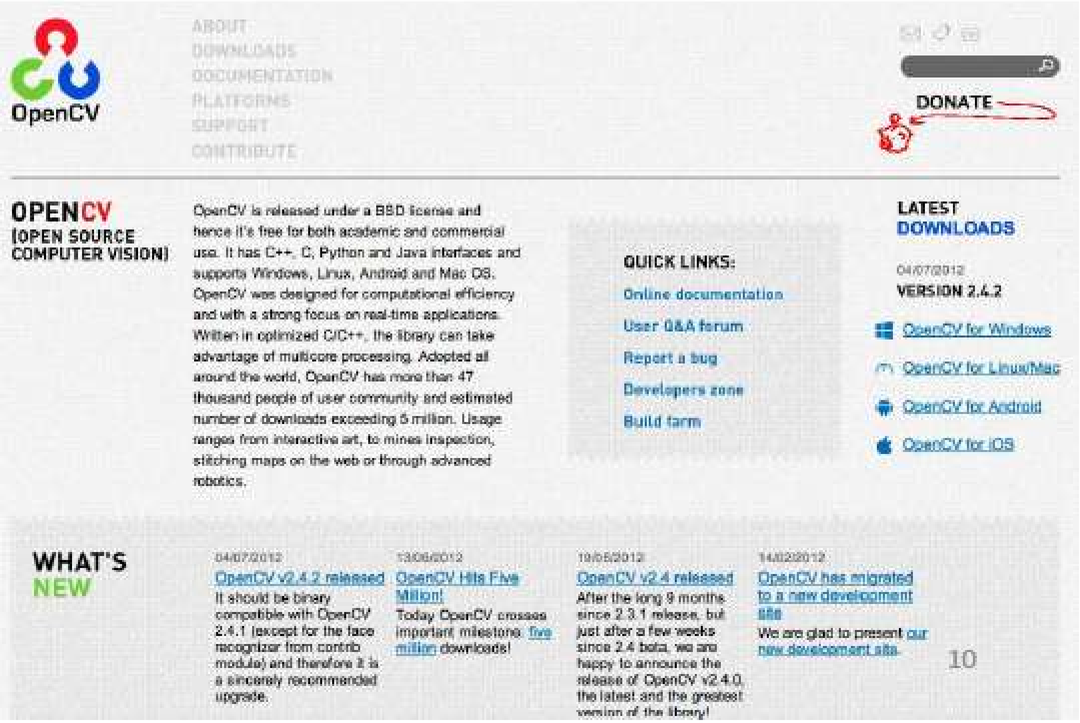
- Founded this July, 2012
- http://opencv.org (user site) Documentation: http://docs.opencv.org
- http://code.opencv.org (developer site)
- Contribute (via Credit, debit or paypal):
  - http://tinyurl.com/7eujyo2

For larger corporate support
And/or partnership, contact
Garybradski@gmail.com

Support levels:

- Diamond
- Platinum
- Gold
- Silver
- Bronze

Includes support, brainstorming and development sprints. Higher levels include strategic control.



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, Android and Mac OS. 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 multicore processing. Adopted all around the world, OpenCV has more than 47 thousand people of user community and estimated number of downloads exceeding 5 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

04/07/2012
VERSION 2.4.2

- OpenCV for Windows
- OpenCV for Linux/Mac
- OpenCV for Android
- OpenCV for iOS

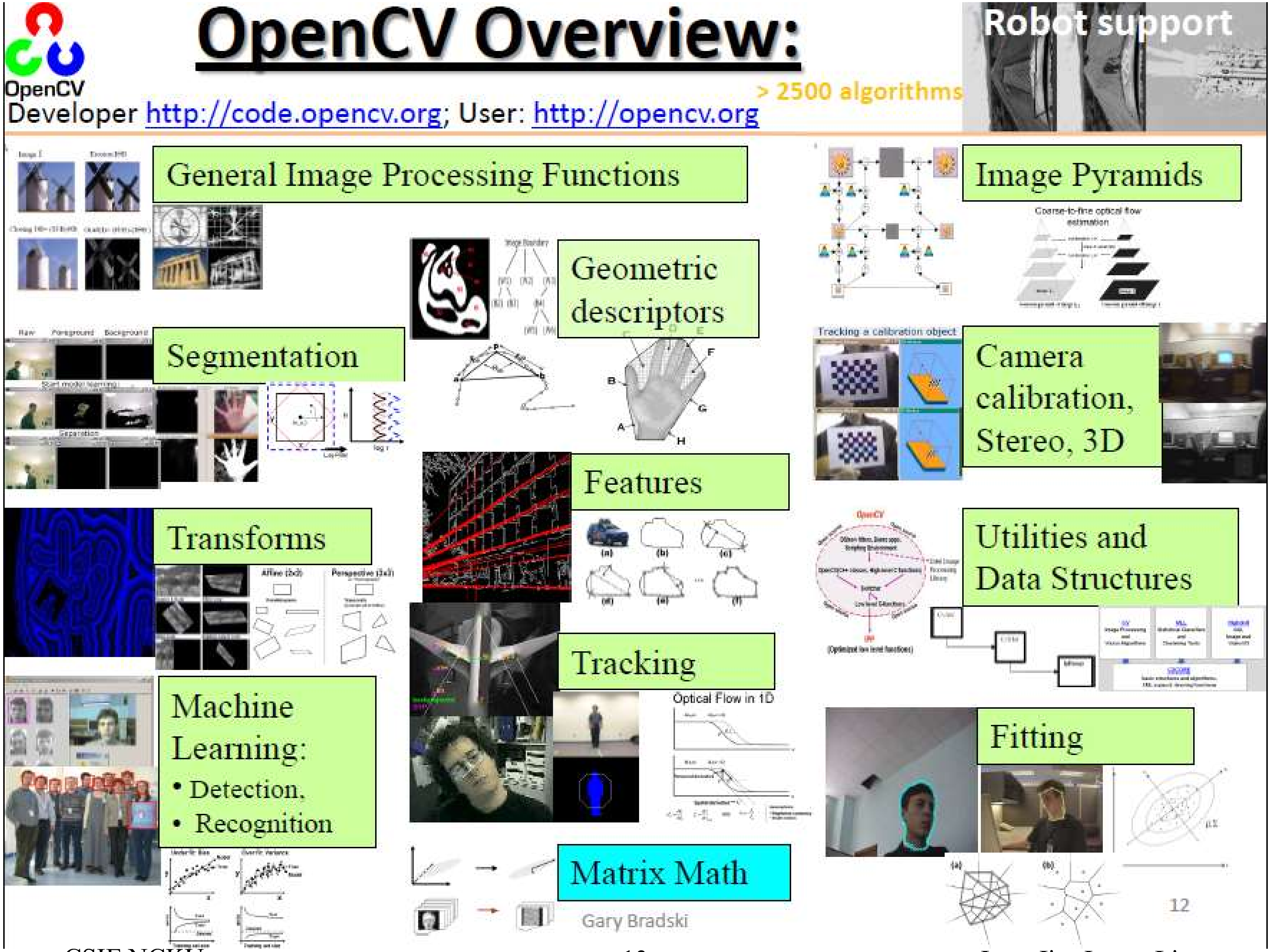
WHAT'S
NEW

04/07/2012
OpenCV v2.4.2 released
It should be binary compatible with OpenCV 2.4.1 (except for the face recognizer from contrib module) and therefore it is a sincerely recommended upgrade.

13/06/2012
OpenCV Hits Five Million!
Today OpenCV crosses important milestone: five million downloads!

19/05/2012
OpenCV v2.4 released
After the long 9 months since 2.3.1 release, but just after a few weeks since 2.4 beta, we are happy to announce the release of OpenCV v2.4.0, the latest and the greatest version of the library!

14/02/2012
OpenCV has migrated to a new development site
We are glad to present our new development site.



OpenCV Overview:

OpenCV

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

> 2500 algorithms

Robot support

General Image Processing Functions

Segmentation

Transforms

Machine Learning:

- Detection,
- Recognition

Geometric descriptors

Features

Tracking

Matrix Math

Image Pyramids

Camera calibration, Stereo, 3D

Utilities and Data Structures

Fitting

Gary Bradski

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Coarse-to-fine optical flow estimation
Tracking a calibration object
Optical Flow in 1D
Affine (2x3)
Perspective (3x3)
OpenCV

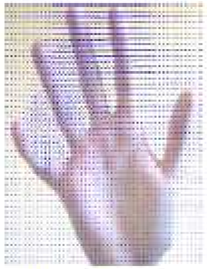
OpenCV Algorithm Modules Overview

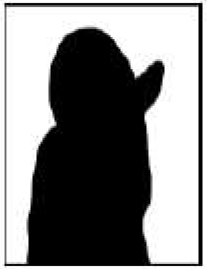
HighGUI:
I/O, Interface

Image Processing

Transforms

Fitting


Optical Flow
Tracking


Segmentation

Calibration

Features
VSLAM

Depth, Pose
Normals, Planes,
3D Features

Object recognition
Machine learning

Computational
Photography

CORE:
Data structures, Matrix math, Exceptions etc

Machine Learning Library (MLL)

<u>CLASSIFICATION / REGRESSION</u>

(new) Fast Approximate NN (FLANN)

(new) Extremely Random Trees

CART

Naïve Bayes

MLP (Back propagation)

Statistical Boosting, 4 flavors

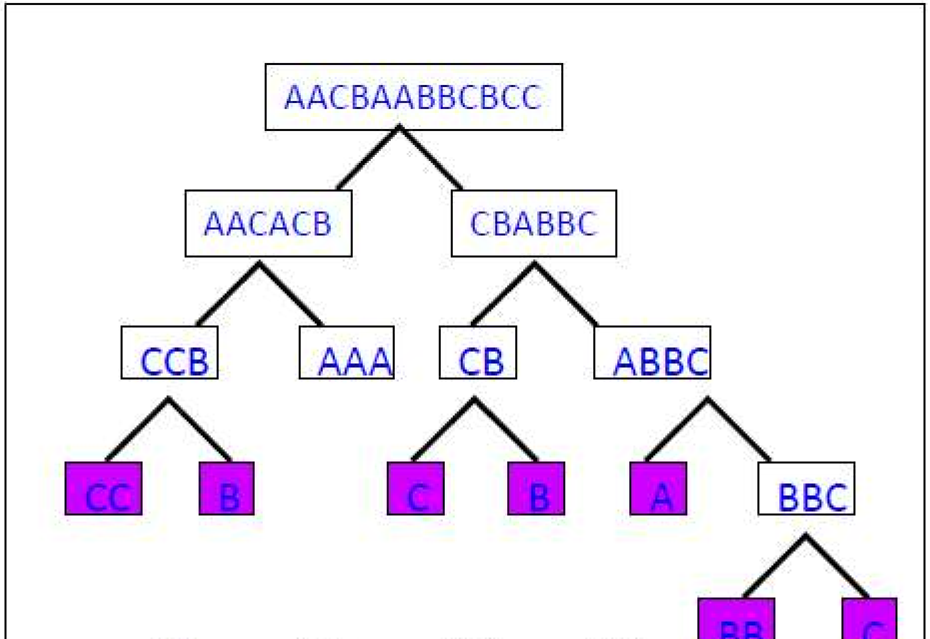
Random Forests

SVM

Face Detector

(Histogram matching)

(Correlation)

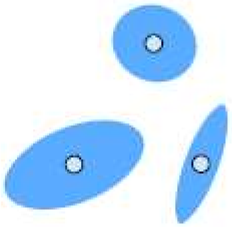


<u>CLUSTERING</u>

K-Means

EM

(Mahalanobis distance)



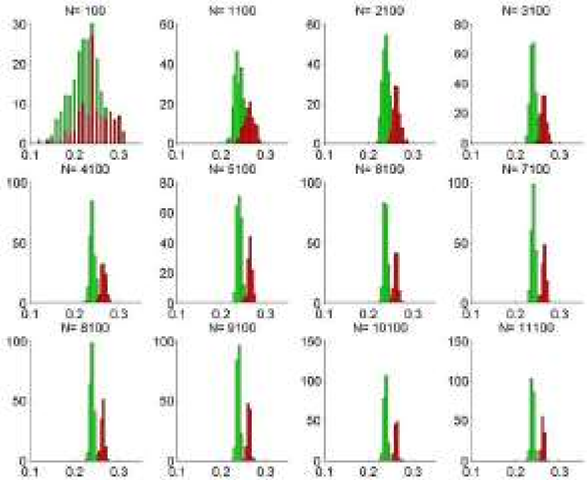
<u>TUNING/VALIDATION</u>

Cross validation

Bootstrapping

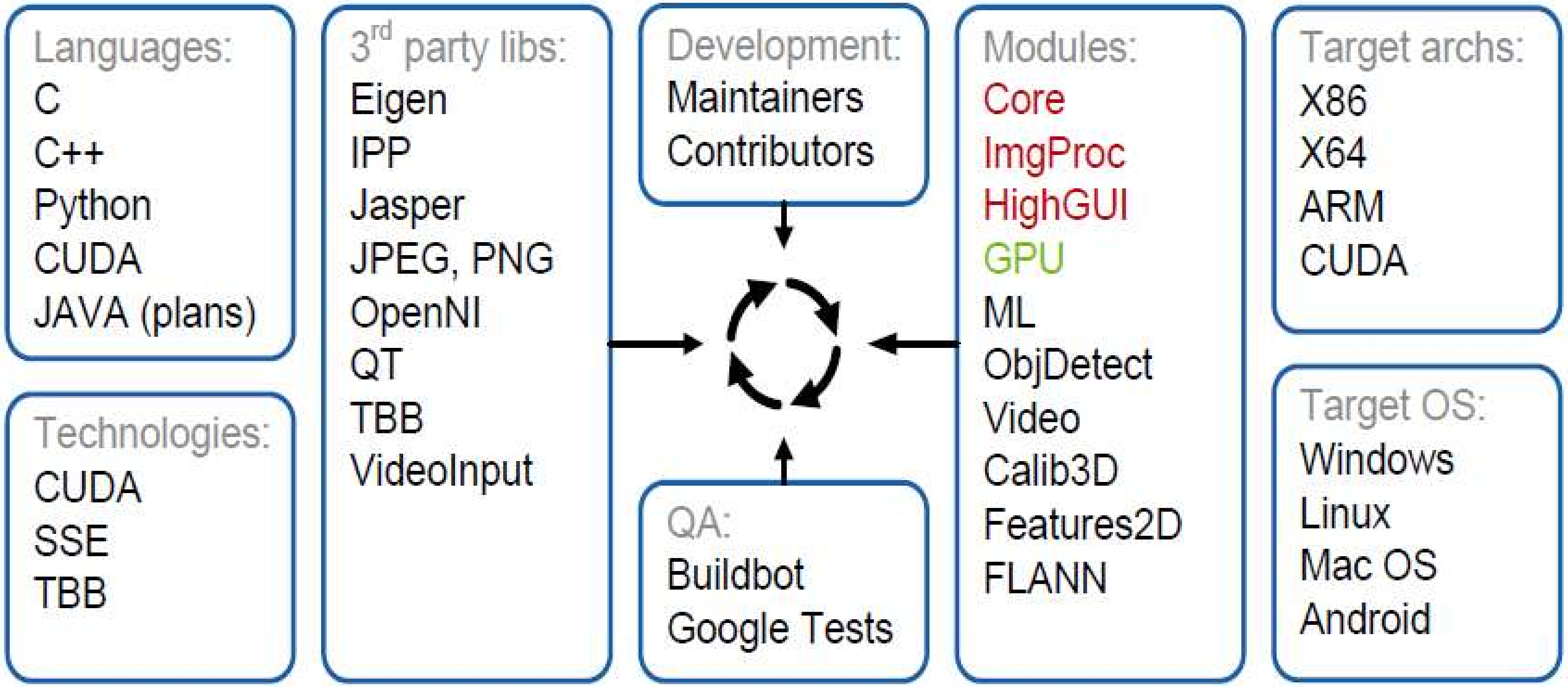
Variable importance

Sampling methods



http://opencv.org

OpenCV Architecture and Development



Languages:
C
C++
Python
CUDA
JAVA (plans)

Technologies:
CUDA
SSE
TBB

3rd party libs:
Eigen
IPP
Jasper
JPEG, PNG
OpenNI
QT
TBB
VideoInput

Development:
Maintainers
Contributors

QA:
Buildbot
Google Tests

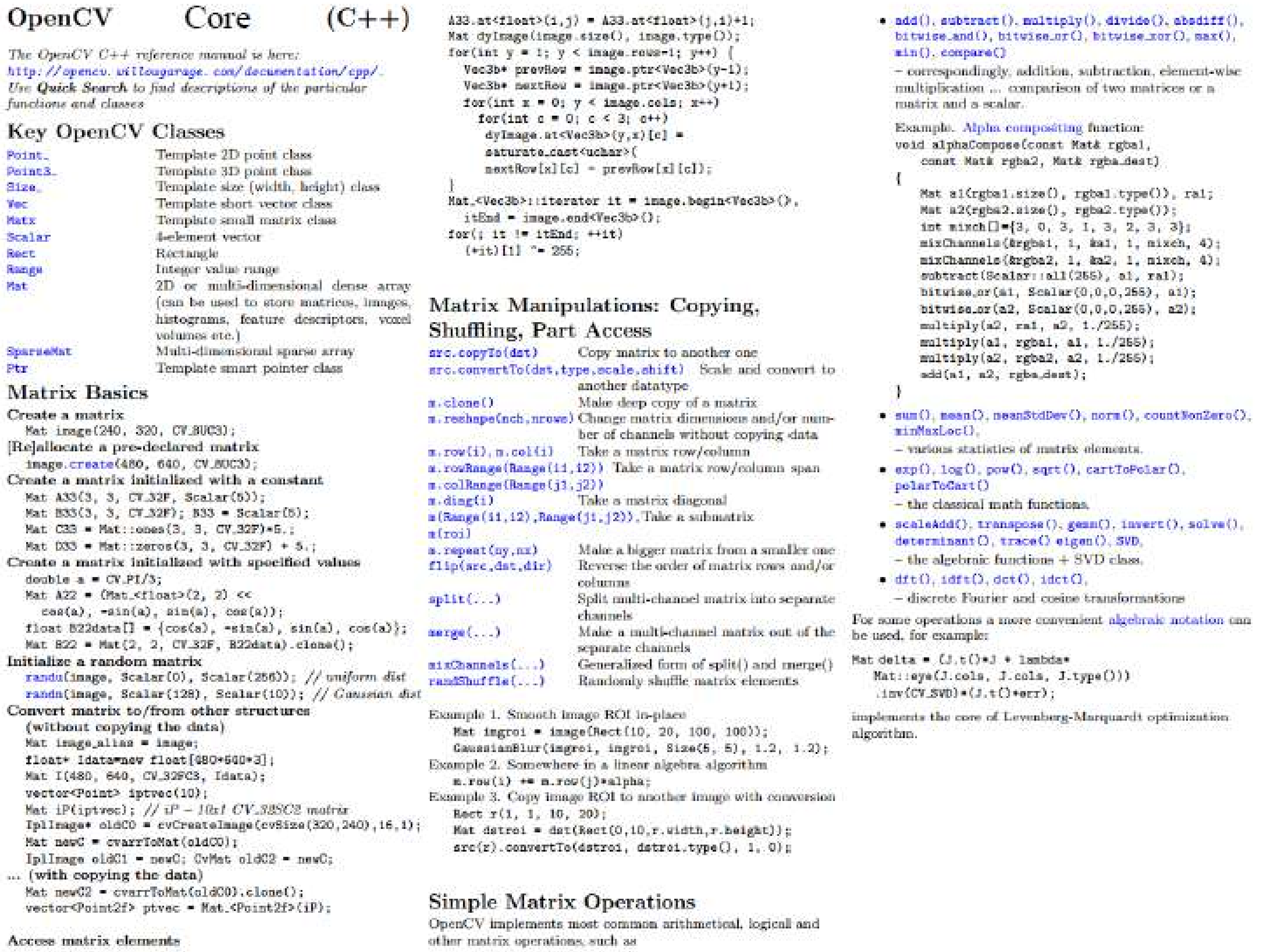
Modules:
Core
ImgProc
HighGUI
GPU
ML
ObjDetect
Video
Calib3D
Features2D
FLANN

Target archs:
X86
X64
ARM
CUDA

Target OS:
Windows
Linux
Mac OS
Android

CORE:
Data structures, Matrix math, Exceptions etc

OpenCV Modules: Core



OpenCV Core (C++)

The OpenCV C++ reference manual is here: *http://opencv.willowgarage.com/documentation/cpp/*. *Use* ***Quick Search*** *to find descriptions of the particular functions and classes*

Key OpenCV Classes

`Point_`	Template 2D point class
`Point3_`	Template 3D point class
`Size_`	Template size (width, height) class
`Vec`	Template short vector class
`Matx`	Template small matrix class
`Scalar`	4-element vector
`Rect`	Rectangle
`Range`	Integer value range
`Mat`	2D or multi-dimensional dense array (can be used to store matrices, images, histograms, feature descriptors, voxel volumes etc.)
`SparseMat`	Multi-dimensional sparse array
`Ptr`	Template smart pointer class

Matrix Basics

Create a matrix

```
  Mat image(240, 320, CV_8UC3);
```

[Re]allocate a pre-declared matrix

```
  image.create(480, 640, CV_8UC3);
```

Create a matrix initialized with a constant

```
  Mat A33(3, 3, CV_32F, Scalar(5));
  Mat B33(3, 3, CV_32F); B33 = Scalar(5);
  Mat C33 = Mat::ones(3, 3, CV_32F)*5.;
  Mat D33 = Mat::zeros(3, 3, CV_32F) + 5.;
```

Create a matrix initialized with specified values

```
  double a = CV_PI/3;
  Mat A22 = (Mat_<float>(2, 2) <<
    cos(a), -sin(a), sin(a), cos(a));
  float B22data[] = {cos(a), -sin(a), sin(a), cos(a)};
  Mat B22 = Mat(2, 2, CV_32F, B22data).clone();
```

Initialize a random matrix

```
  randu(image, Scalar(0), Scalar(256)); // uniform dist
  randn(image, Scalar(128), Scalar(10)); // Gaussian dist
```

Convert matrix to/from other structures

(without copying the data)

```
  Mat image_alias = image;
  float* Idata=new float[480*640*3];
  Mat I(480, 640, CV_32FC3, Idata);
  vector<Point> iptvec(10);
  Mat iP(iptvec); // iP - 10x1 CV_32SC2 matrix
  IplImage* oldC0 = cvCreateImage(cvSize(320,240),16,1);
  Mat newC = cvarrToMat(oldC0);
  IplImage oldC1 = newC; CvMat oldC2 = newC;
```

... (with copying the data)

```
  Mat newC2 = cvarrToMat(oldC0).clone();
  vector<Point2f> ptvec = Mat_<Point2f>(iP);
```

Access matrix elements

```
A33.at<float>(i,j) = A33.at<float>(j,i)+1;
Mat dyImage(image.size(), image.type());
for(int y = 1; y < image.rows-1; y++) {
  Vec3b* prevRow = image.ptr<Vec3b>(y-1);
  Vec3b* nextRow = image.ptr<Vec3b>(y+1);
  for(int x = 0; y < image.cols; x++)
    for(int c = 0; c < 3; c++)
     dyImage.at<Vec3b>(y,x)[c] =
     saturate_cast<uchar>(
     nextRow[x][c] - prevRow[x][c]);
}
Mat_<Vec3b>::iterator it = image.begin<Vec3b>(),
  itEnd = image.end<Vec3b>();
for(; it != itEnd; ++it)
  (*it)[1] ^= 255;
```

Matrix Manipulations: Copying, Shuffling, Part Access

`src.copyTo(dst)`	Copy matrix to another one
`src.convertTo(dst,type,scale,shift)`	Scale and convert to another datatype
`m.clone()`	Make deep copy of a matrix
`m.reshape(nch,nrows)`	Change matrix dimensions and/or number of channels without copying data
`m.row(i), m.col(i)`	Take a matrix row/column

`m.rowRange(Range(i1,i2))`
`m.colRange(Range(j1,j2))`
	Take a matrix row/column span

`m.diag(i)`	Take a matrix diagonal
`m(Range(i1,i2),Range(j1,j2))`, `m(roi)`	Take a submatrix
`m.repeat(ny,nx)`	Make a bigger matrix from a smaller one
`flip(src,dst,dir)`	Reverse the order of matrix rows and/or columns
`split(...)`	Split multi-channel matrix into separate channels
`merge(...)`	Make a multi-channel matrix out of the separate channels
`mixChannels(...)`	Generalized form of split() and merge()
`randShuffle(...)`	Randomly shuffle matrix elements

Example 1. Smooth image ROI in-place

```
  Mat imgroi = image(Rect(10, 20, 100, 100));
  GaussianBlur(imgroi, imgroi, Size(5, 5), 1.2, 1.2);
```

Example 2. Somewhere in a linear algebra algorithm

```
  m.row(i) += m.row(j)*alpha;
```

Example 3. Copy image ROI to another image with conversion

```
  Rect r(1, 1, 10, 20);
  Mat dstroi = dst(Rect(0,10,r.width,r.height));
  src(r).convertTo(dstroi, dstroi.type(), 1, 0);
```

Simple Matrix Operations

OpenCV implements most common arithmetical, logical and other matrix operations, such as

- `add()`, `subtract()`, `multiply()`, `divide()`, `absdiff()`, `bitwise_and()`, `bitwise_or()`, `bitwise_xor()`, `max()`, `min()`, `compare()`

  – correspondingly, addition, subtraction, element-wise multiplication ... comparison of two matrices or a matrix and a scalar.

  Example. Alpha compositing function:

  ```
  void alphaCompose(const Mat& rgba1,
      const Mat& rgba2, Mat& rgba_dest)
  {
      Mat a1(rgba1.size(), rgba1.type()), ra1;
      Mat a2(rgba2.size(), rgba2.type());
      int mixch[]={3, 0, 3, 1, 3, 2, 3, 3};
      mixChannels(&rgba1, 1, &a1, 1, mixch, 4);
      mixChannels(&rgba2, 1, &a2, 1, mixch, 4);
      subtract(Scalar::all(255), a1, ra1);
      bitwise_or(a1, Scalar(0,0,0,255), a1);
      bitwise_or(a2, Scalar(0,0,0,255), a2);
      multiply(a2, ra1, a2, 1./255);
      multiply(a1, rgba1, a1, 1./255);
      multiply(a2, rgba2, a2, 1./255);
      add(a1, a2, rgba_dest);
  }
  ```

- `sum()`, `mean()`, `meanStdDev()`, `norm()`, `countNonZero()`, `minMaxLoc()`,

  – various statistics of matrix elements.

- `exp()`, `log()`, `pow()`, `sqrt()`, `cartToPolar()`, `polarToCart()`

  – the classical math functions.

- `scaleAdd()`, `transpose()`, `gemm()`, `invert()`, `solve()`, `determinant()`, `trace()` `eigen()`, `SVD`,

  – the algebraic functions + SVD class.

- `dft()`, `idft()`, `dct()`, `idct()`,

  – discrete Fourier and cosine transformations

For some operations a more convenient algebraic notation can be used, for example:

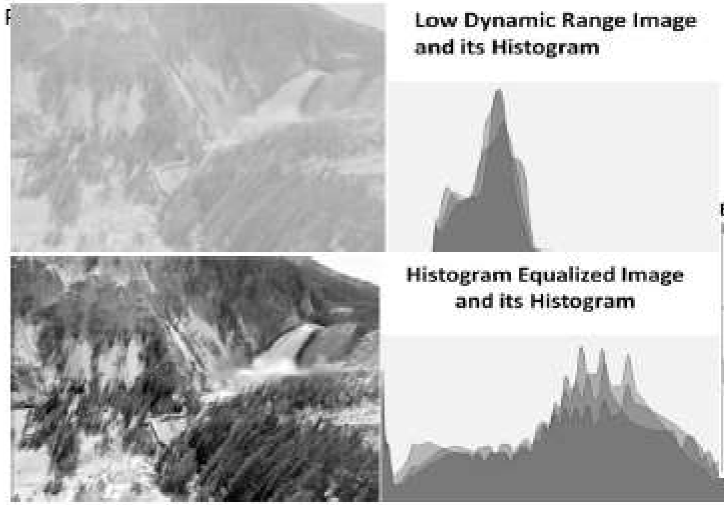
```
Mat delta = (J.t()*J + lambda*
   Mat::eye(J.cols, J.cols, J.type()))
   .inv(CV_SVD)*(J.t()*err);
```

implements the core of Levenberg-Marquardt optimization algorithm.

OpenCV Modules: Image Processing

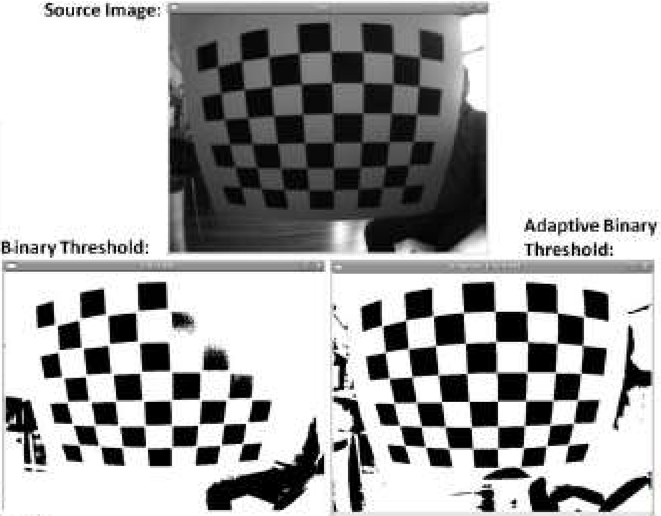
Image

F



Low Dynamic Range Image and its Histogram

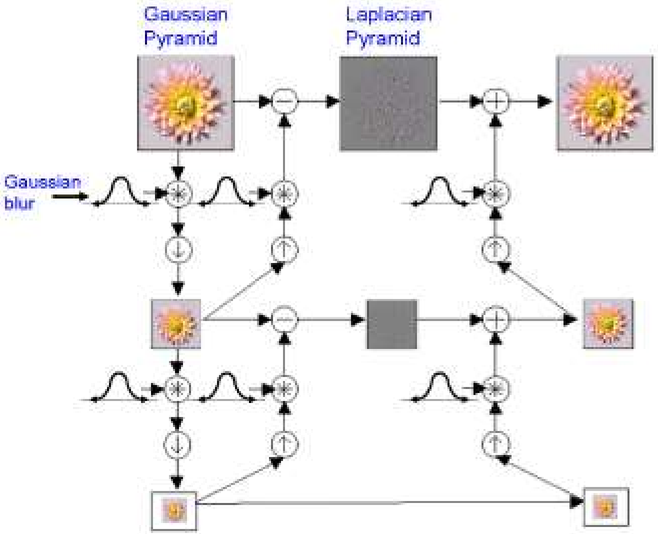
Histogram Equalized Image and its Histogram

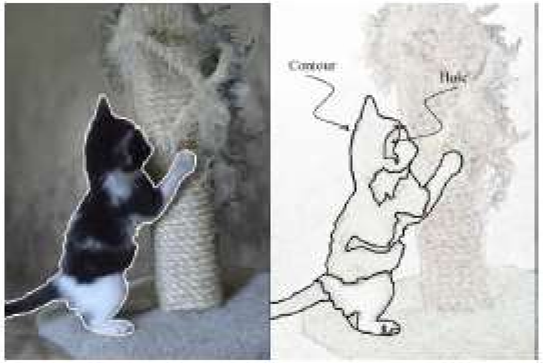


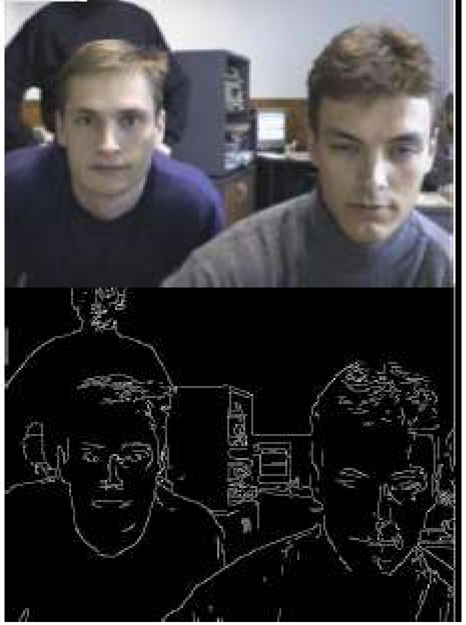
Source Image:

Binary Threshold:

Adaptive Binary Threshold:

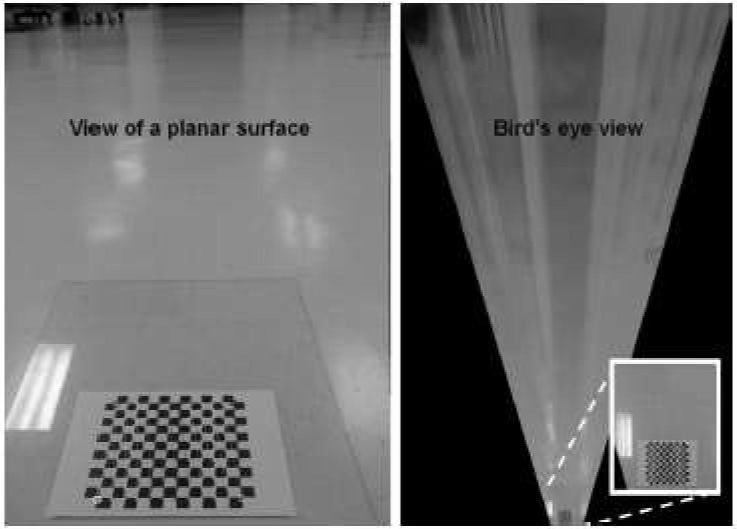


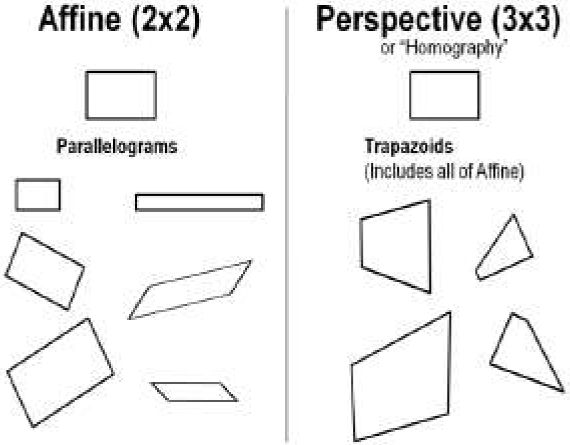




OpenCV Modules: Transforms

Transforms



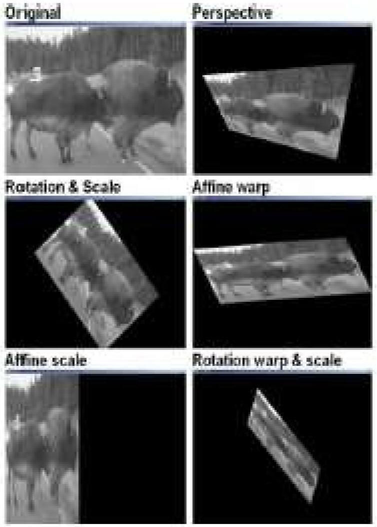


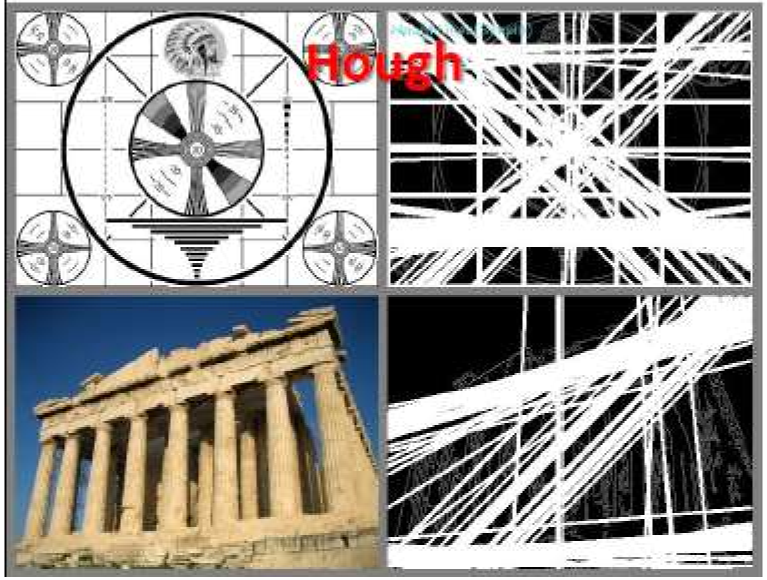
Affine (2x2)

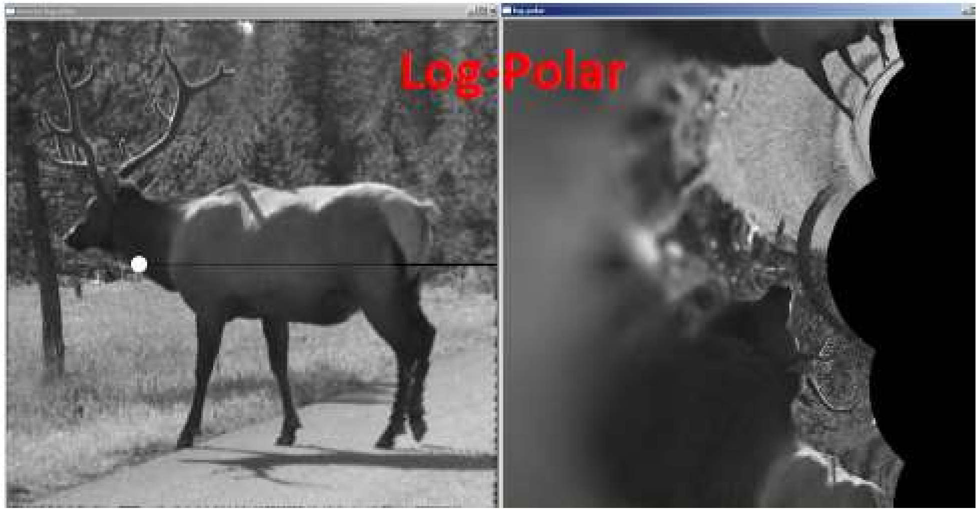
Parallelograms

Perspective (3x3)
or "Homography"

Trapazoids
(Includes all of Affine)

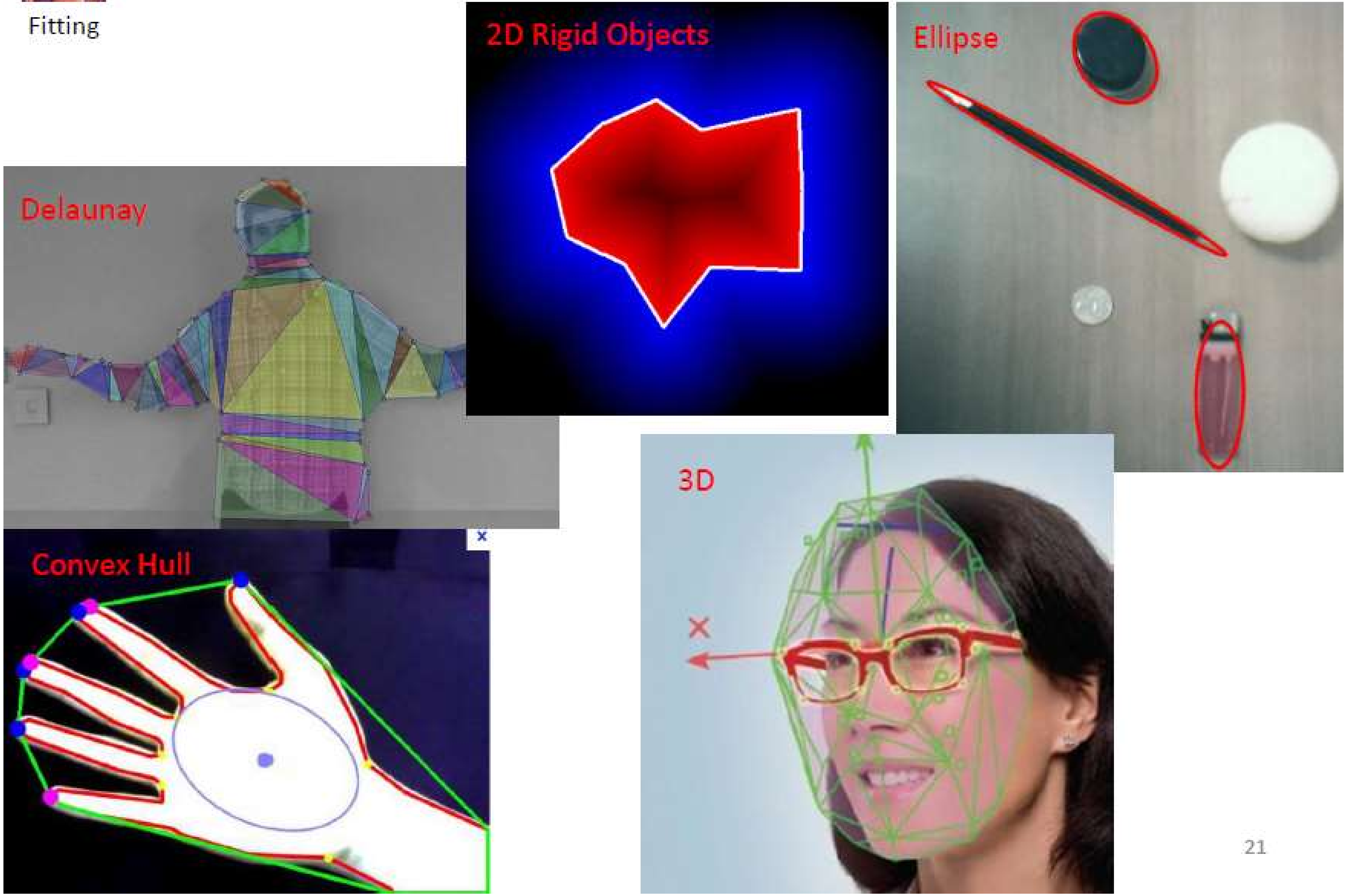






OpenCV Modules: Fitting

Fitting



Optical Flow Tracking

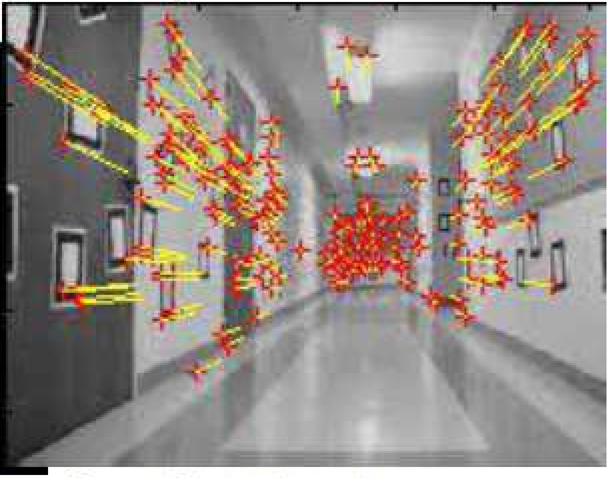
OpenCV Modules: Optic Flow, Track

http://www.youtube.com/watch?v=bWyBGmzfP-g

```
// opencv/samples/c/lkdemo.c
int main(…){
…
CvCapture* capture = <…> ?
    cvCaptureFromCAM(camera_id) :
    cvCaptureFromFile(path);
if( !capture ) return -1;
for(;;) {
  IplImage* frame=cvQueryFrame(capture);
  if(!frame) break;
  // … copy and process image
cvCalcOpticalFlowPyrLK( …)
  cvShowImage( “LkDemo”, result );
  c=cvWaitKey(30); // run at ~20-30fps speed
  if(c >= 0) {
      // process key
 }}
cvReleaseCapture(&capture
```

lkdemo.c, 190 lines

(needs camera to run)

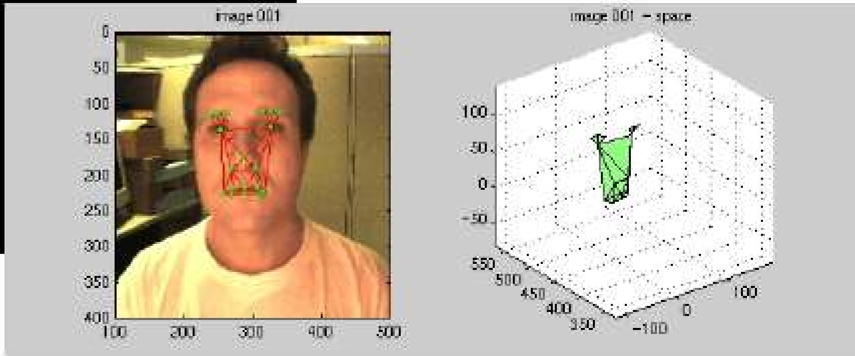


$$I(x+dx, y+dy, t+dt) = I(x, y, t);$$

$$-\partial I / \partial t = \partial I / \partial x \cdot (dx/dt) + \partial I / \partial y \cdot (dy/dt);$$

$$G \cdot \partial X = b,$$

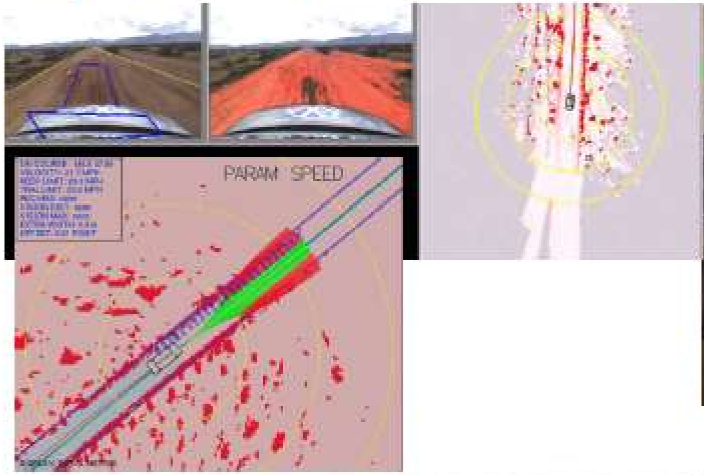
$$\partial X = (\partial x, \partial y), G = \sum \begin{bmatrix} I_x^2, & I_x I_y \\ I_x I_y, & I_y^2 \end{bmatrix}, b = \sum I_t \begin{bmatrix} I_x \\ I_y \end{bmatrix}$$

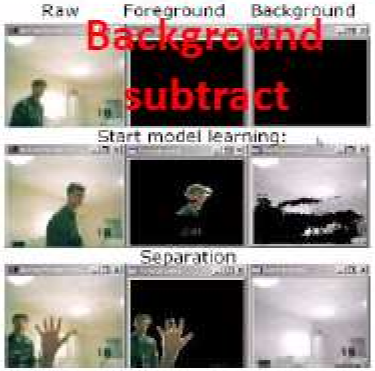


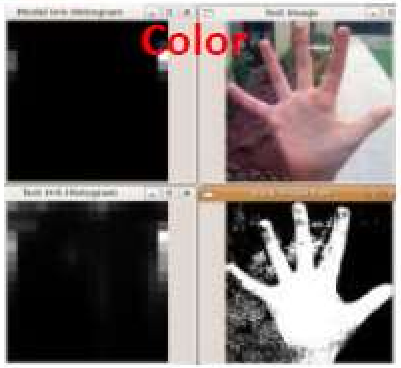
http://www.youtube.com/watch?v=1osj7kRgswk

OpenCV Modules: Segmentation

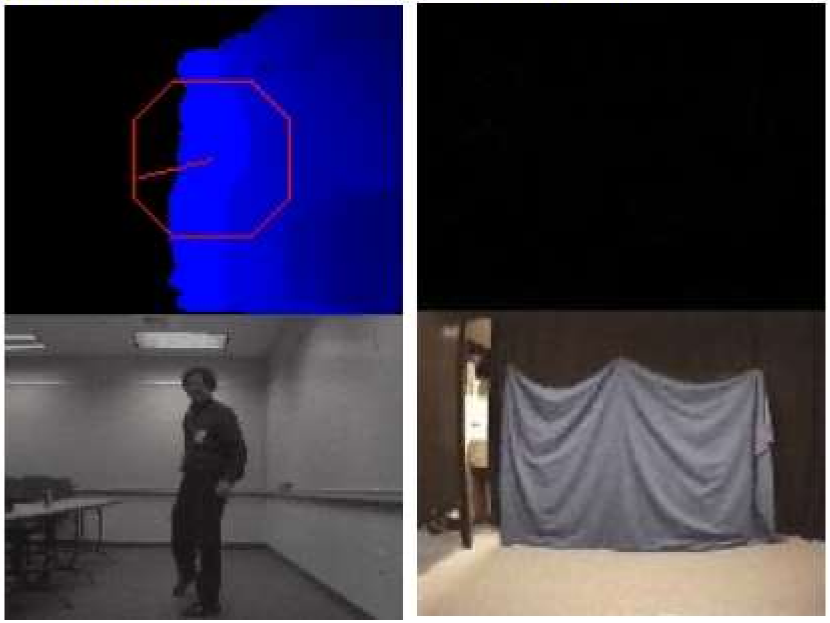
Segmentation







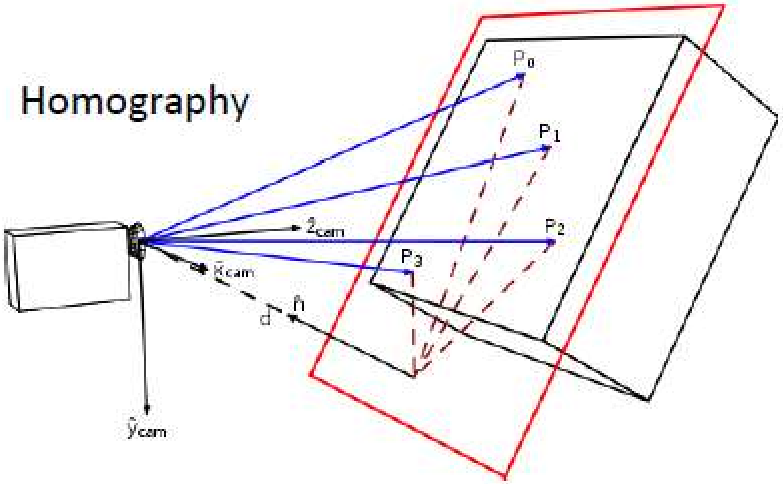
https://www.youtube.com/watch?v=OxmDonZja74
http://www.youtube.com/watch?v=Ktrjh5-KLKo

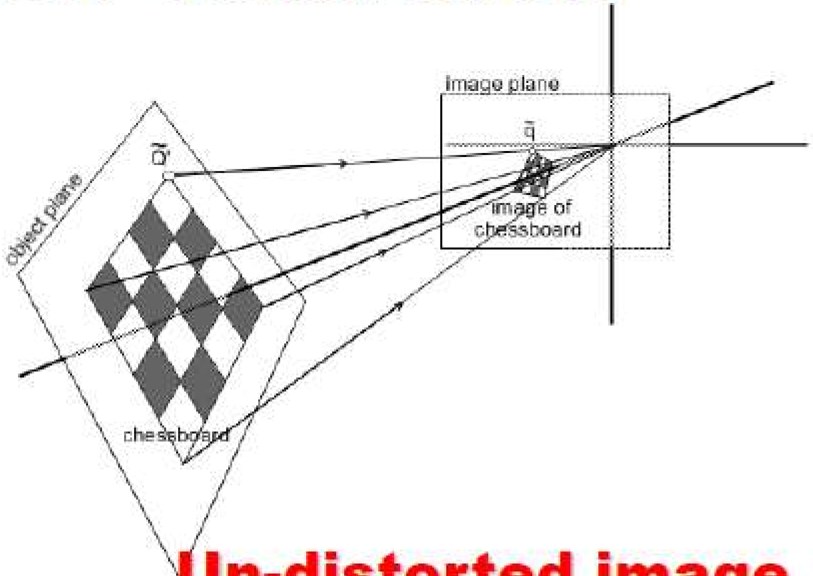


OpenCV Modules: Calibration

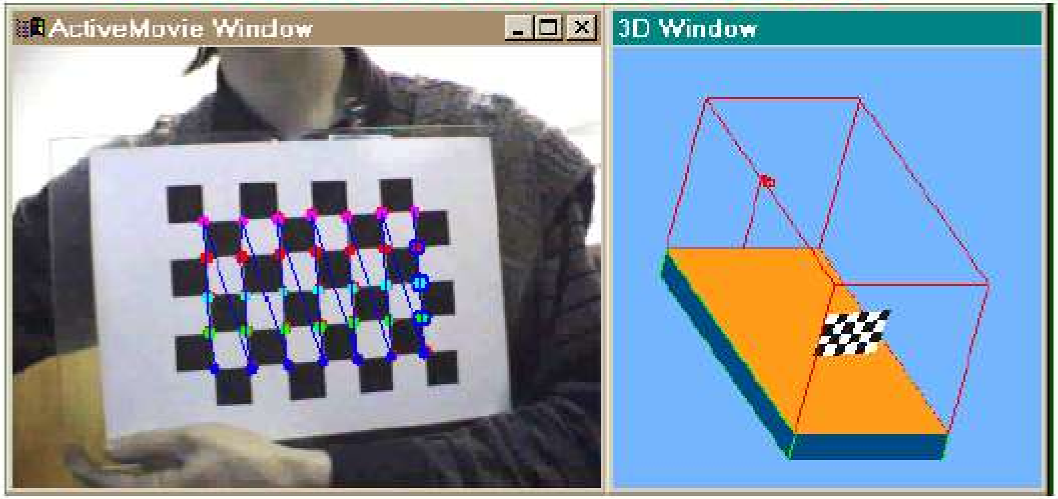
Calibration

Homography





3D view of checkerboard



Un-distorted image

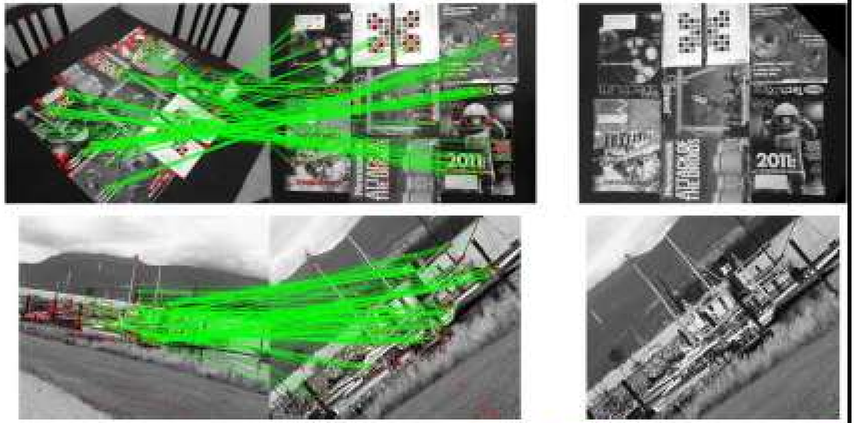
24

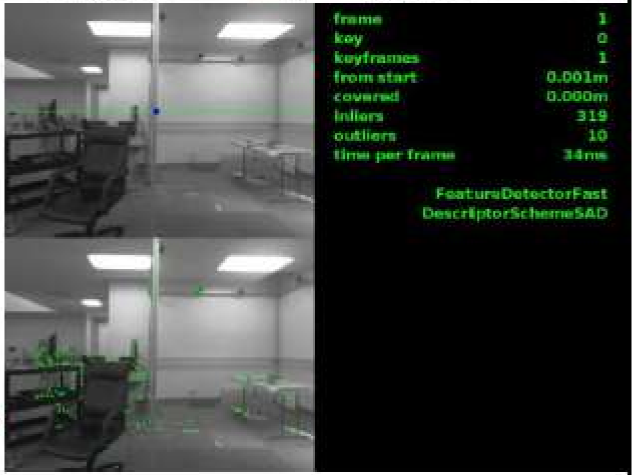
http://www.youtube.com/watch?v=DrXIQfQHFv0

http://www.youtube.com/watch?v=PuWQnCReIeE

OpenCV Modules: Features, VSLAM

Features
VSLAM





```
frame                       1
key                         0
keyframes                   1
from start             0.001m
covered                0.000m
inliers                   319
outliers                   10
time per frame           34ms

          FeatureDetectorFast
         DescriptorSchemeSAD
```

Read two input images:

```
Mat img1 = imread(argv[1], CV_LOAD_IMAGE_GRAYSCALE);
```

Detect keypoints in both images:

```
// detecting keypoints
FastFeatureDetector detector(15);
vector<KeyPoint> keypoints1;
detector.detect(img1, keypoints1);
```

Compute descriptors for each of the keypoints:

```
// computing descriptors
SurfDescriptorExtractor extractor;
Mat descriptors1;
extractor.compute(img1, keypoints1, descriptors1);
```

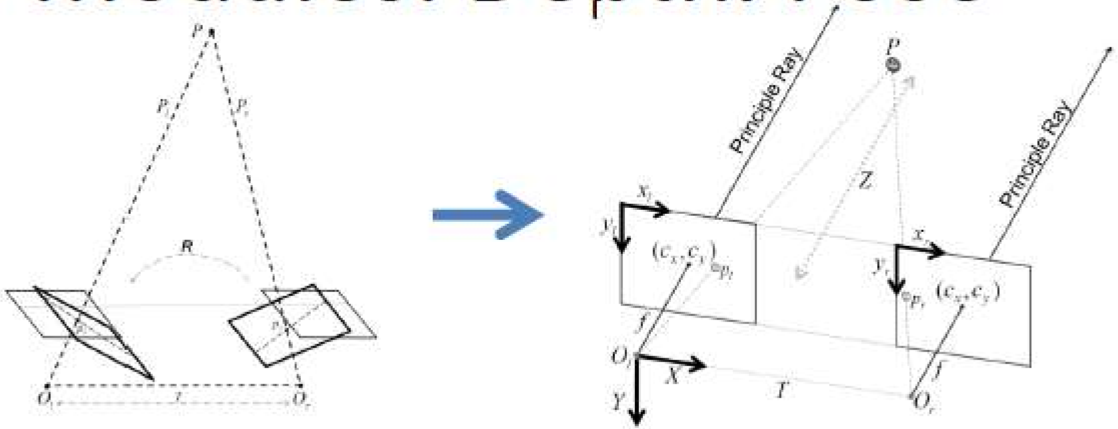
Now, find the closest matches between descriptors from the first image to the second:

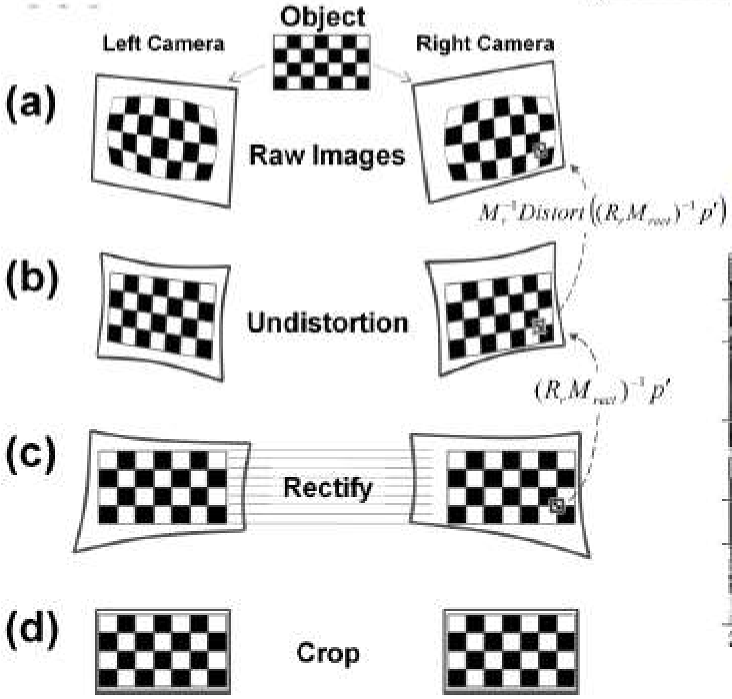
```
// matching descriptors
BruteForceMatcher<L2<float> > matcher;
vector<DMatch> matches;
matcher.match(descriptors1, descriptors2, matches);
```

Change one or both of these lines to switch detector and/or descriptor types

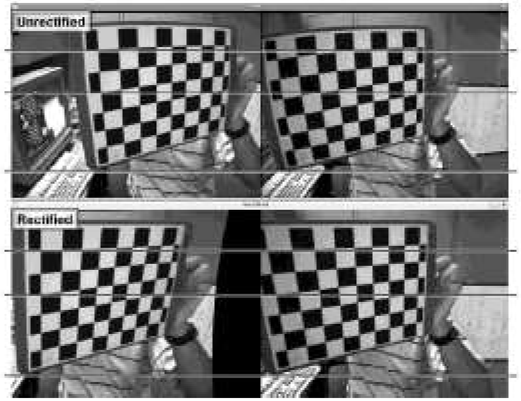
Depth, Pose
Normals, Planes,
3D Features

OpenCV Modules: Depth. Pose

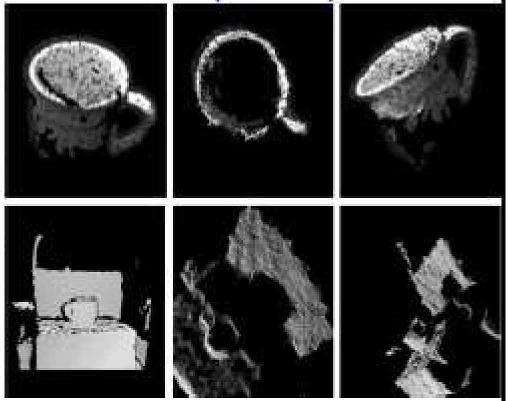




Left – right feature alignment:



Some examples of
3D stereo depth maps:



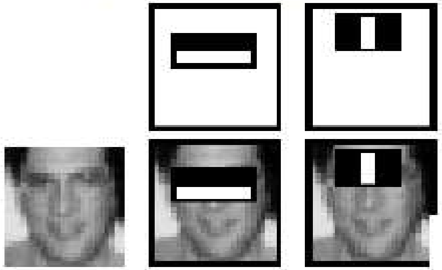
Object recognition
Machine learning

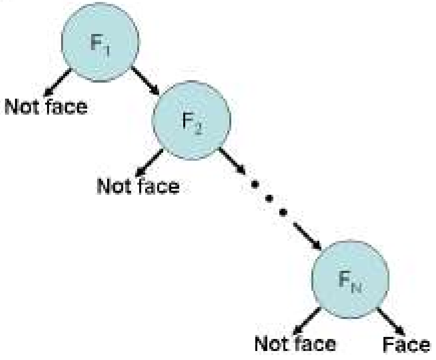
OpenCV Modules: Obj Rec/ML

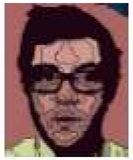
https://www.youtube.com/watch?v=_RF0VpR4xog

VSLAM

http://youtu.be/i1uUuWwbIcc

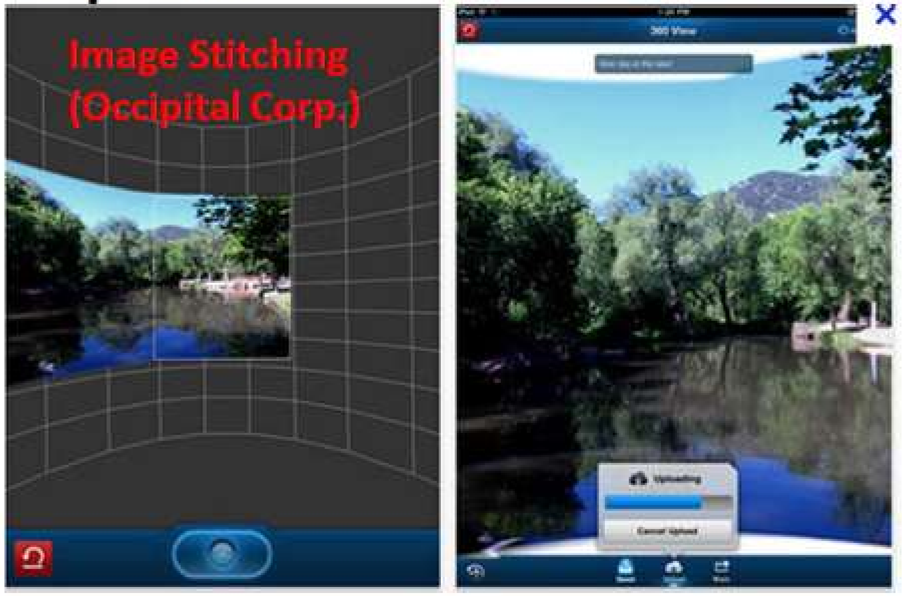


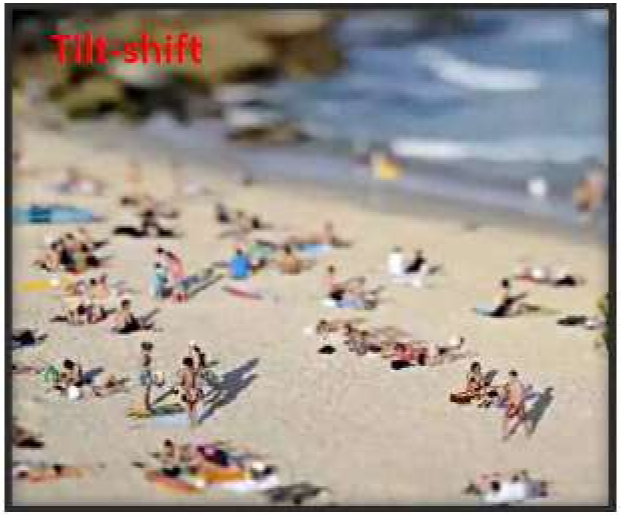


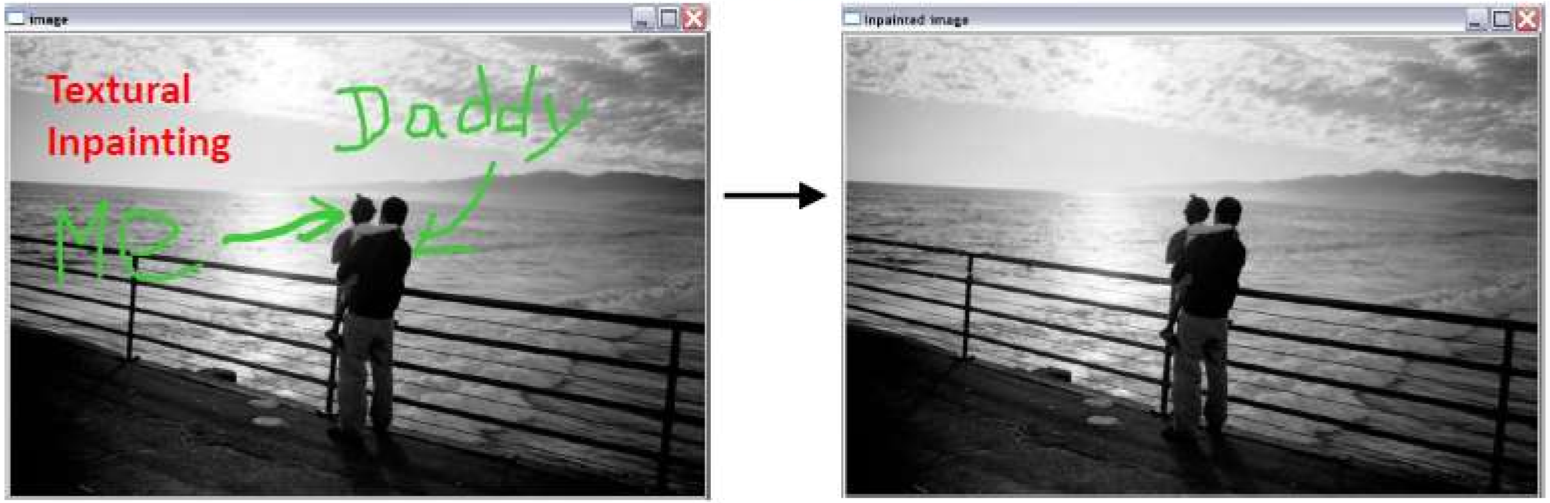


Computational Photography

OpenCV Modules: Comp Photog







OpenCV GPU Module:

- Image processing building blocks:

Color conversions

Geometrical transforms

Per-element operations

Integrals, reductions

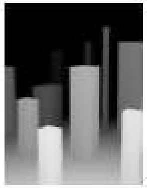
Template matching

Filtering engine

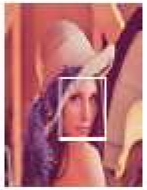
Feature detectors

- High-level algorithms:

Stereo matching



Face detection



Feature matching

OpenCV GPU Module Example

```
Mat frame;
VideoCapture capture(camera);
cv::HOGDescriptor hog;

hog.setSVMDetector(cv::HOGDescriptor
::
getDefaultPeopleDetectorector());

capture >> frame;




vector<Rect> found;
hog.detectMultiScale(frame, found,
    1.4,  Size(8, 8), Size(0, 0),
1.05, 8);
```

```
Mat frame;
VideoCapture capture(camera);
cv::gpu::HOGDescriptor hog;

hog.setSVMDetector(cv::HOGDescriptor
::
getDefaultPeopleDetectorector());

capture >> frame;

GpuMat gpu_frame;
gpu_frame.upload(frame);

vector<Rect> found;
hog.detectMultiScale(gpu_frame,
found,
    1.4, Size(8, 8), Size(0, 0),
1.05, 8);
```

- Designed very similar!

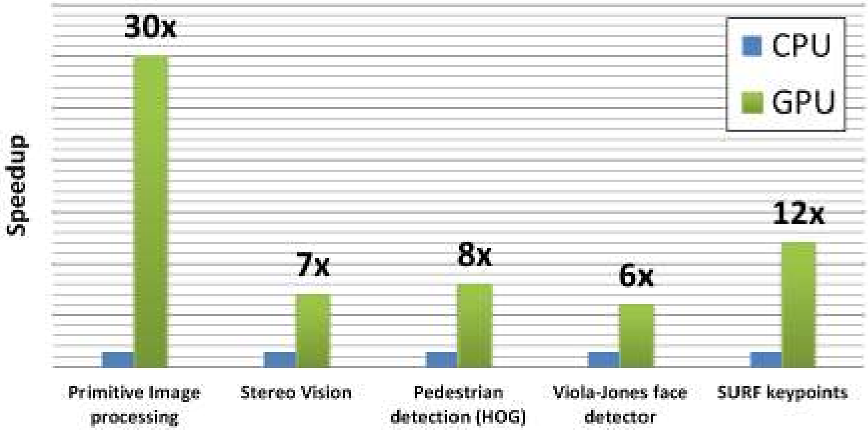
OpenCV GPU Module Performance

Tesla C2050 (Fermi) vs. Core i5-760 2.8GHz (4 cores, TBB, SSE)

- Average speedup for primitives: 33×
  - For "good" data (large images are better)
  - Without copying to GPU

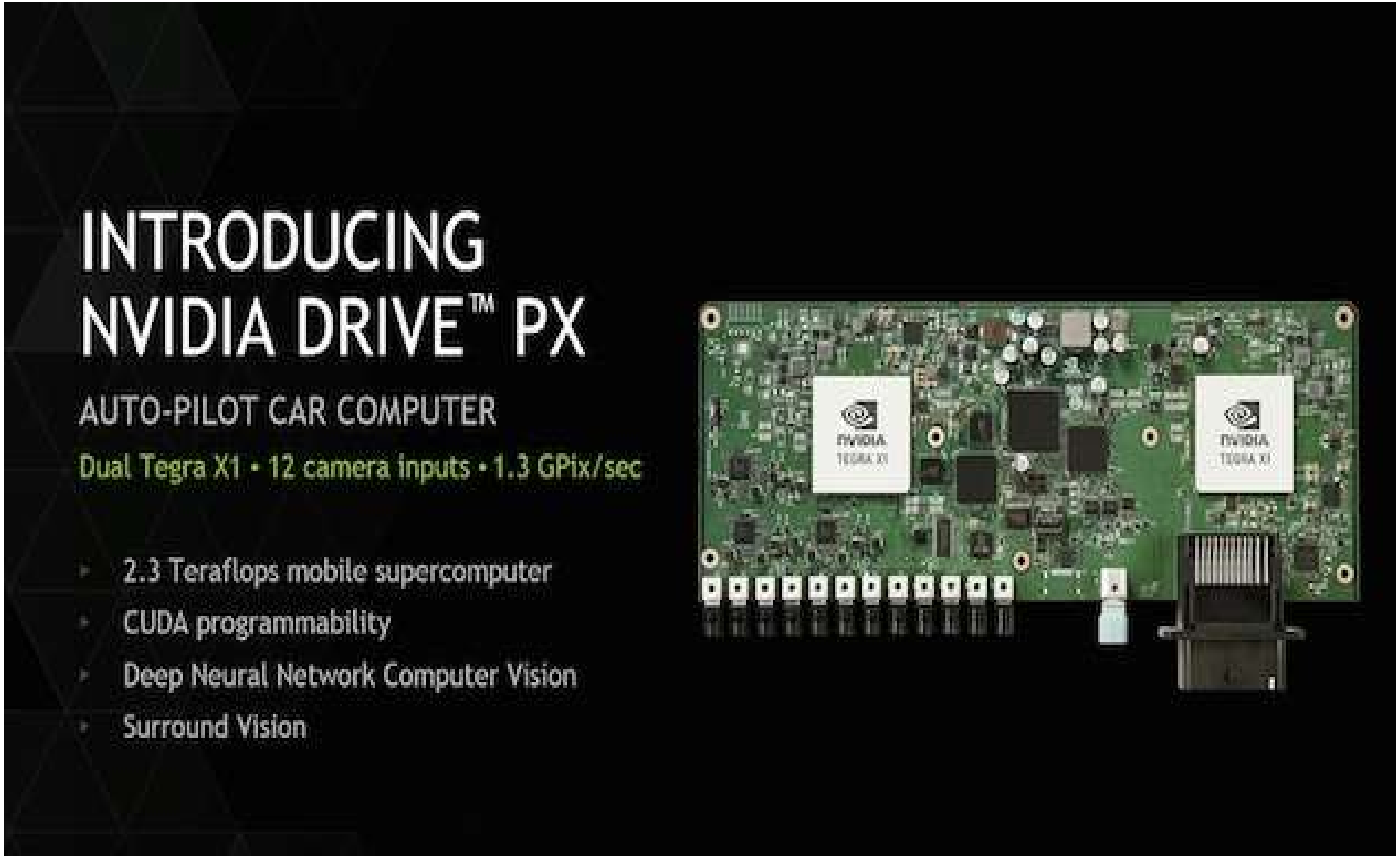
What can you get from your computer?

- opencv\samples\gpu\perfomance



7

OpenCV: Nvidia Drive PX –
Tegra + CUDA + Deep Learning



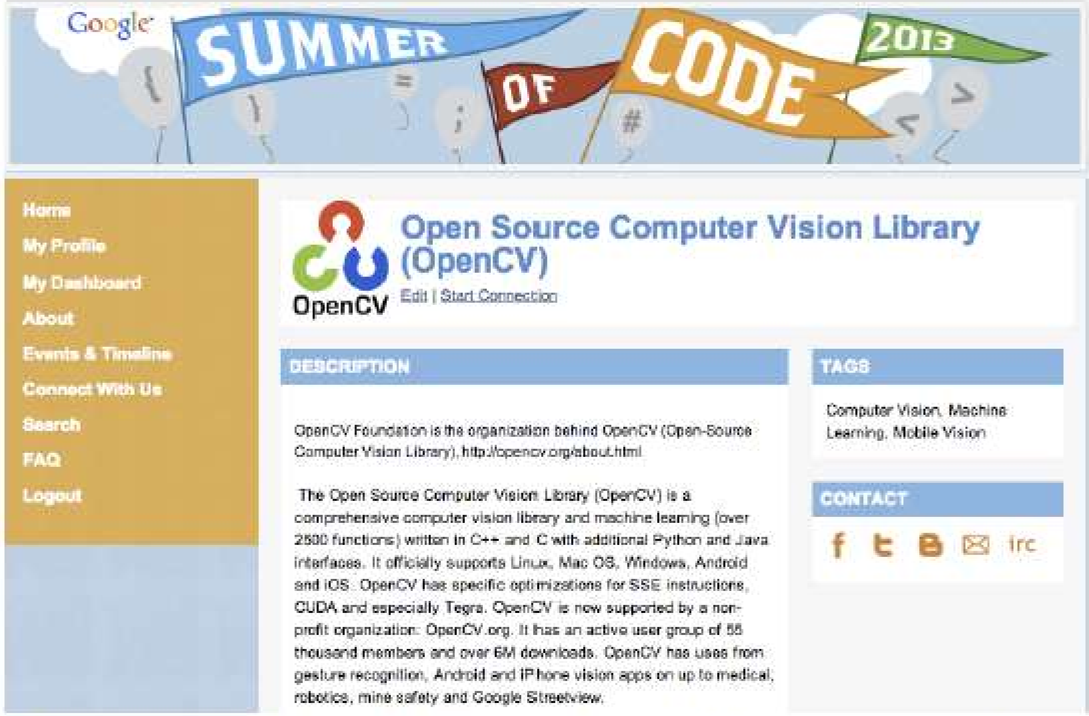
INTRODUCING
NVIDIA DRIVE™ PX

AUTO-PILOT CAR COMPUTER

Dual Tegra X1 • 12 camera inputs • 1.3 GPix/sec

- 2.3 Teraflops mobile supercomputer
- CUDA programmability
- Deep Neural Network Computer Vision
- Surround Vision

Google Summer of Code 2013



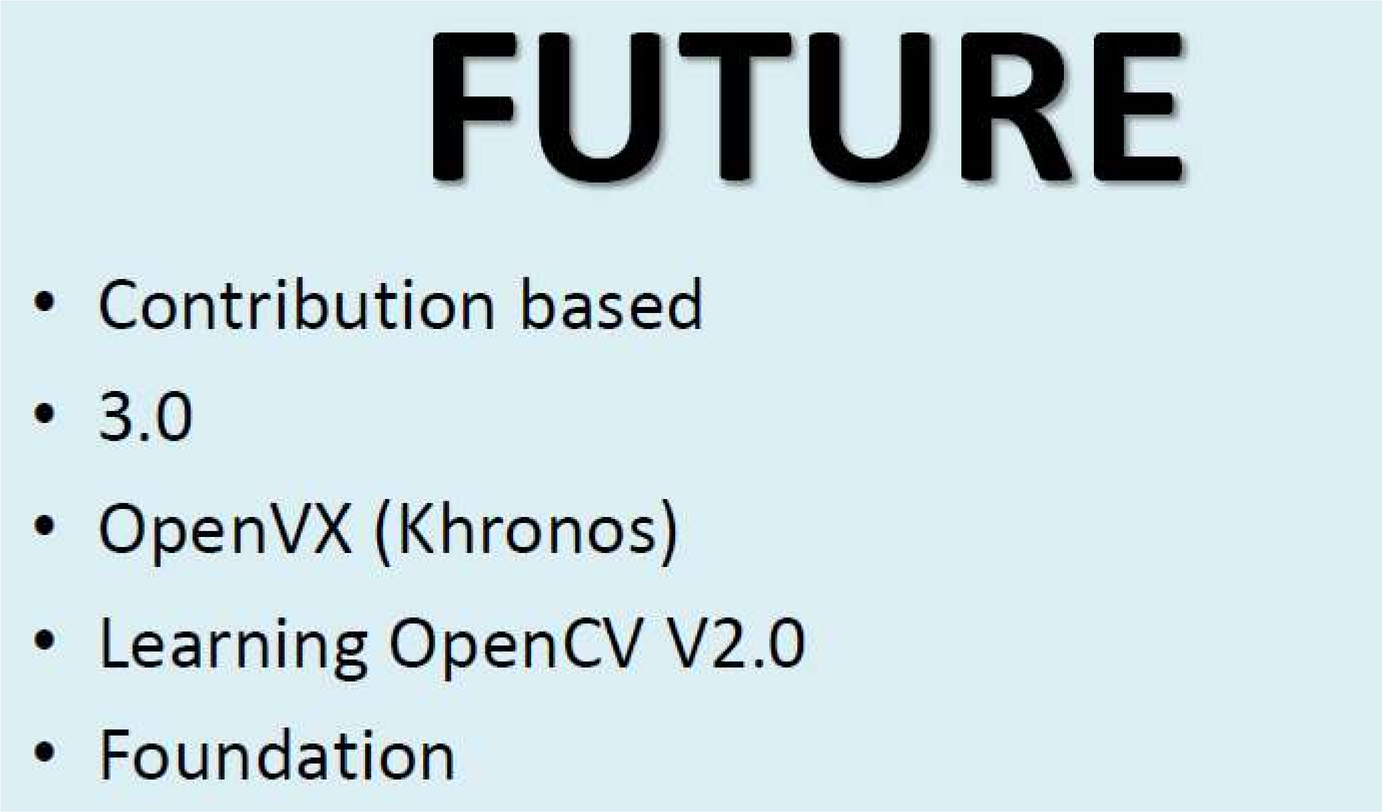
Open Source Computer Vision Library (OpenCV)

OpenCV Foundation is the organization behind OpenCV (Open-Source Computer Vision Library), http://opencv.org/about.html

The Open Source Computer Vision Library (OpenCV) is a comprehensive computer vision library and machine learning (over 2500 functions) written in C++ and C with additional Python and Java interfaces. It officially supports Linux, Mac OS, Windows, Android and iOS. OpenCV has specific optimizations for SSE instructions, CUDA and especially Tegra. OpenCV is new supported by a non-profit organization: OpenCV.org. It has an active user group of 55 thousand members and over 6M downloads. OpenCV has uses from gesture recognition, Android and IPhone vision apps on up to medical, robotics, mine safety and Google Streetview.

Computer Vision, Machine Learning, Mobile Vision

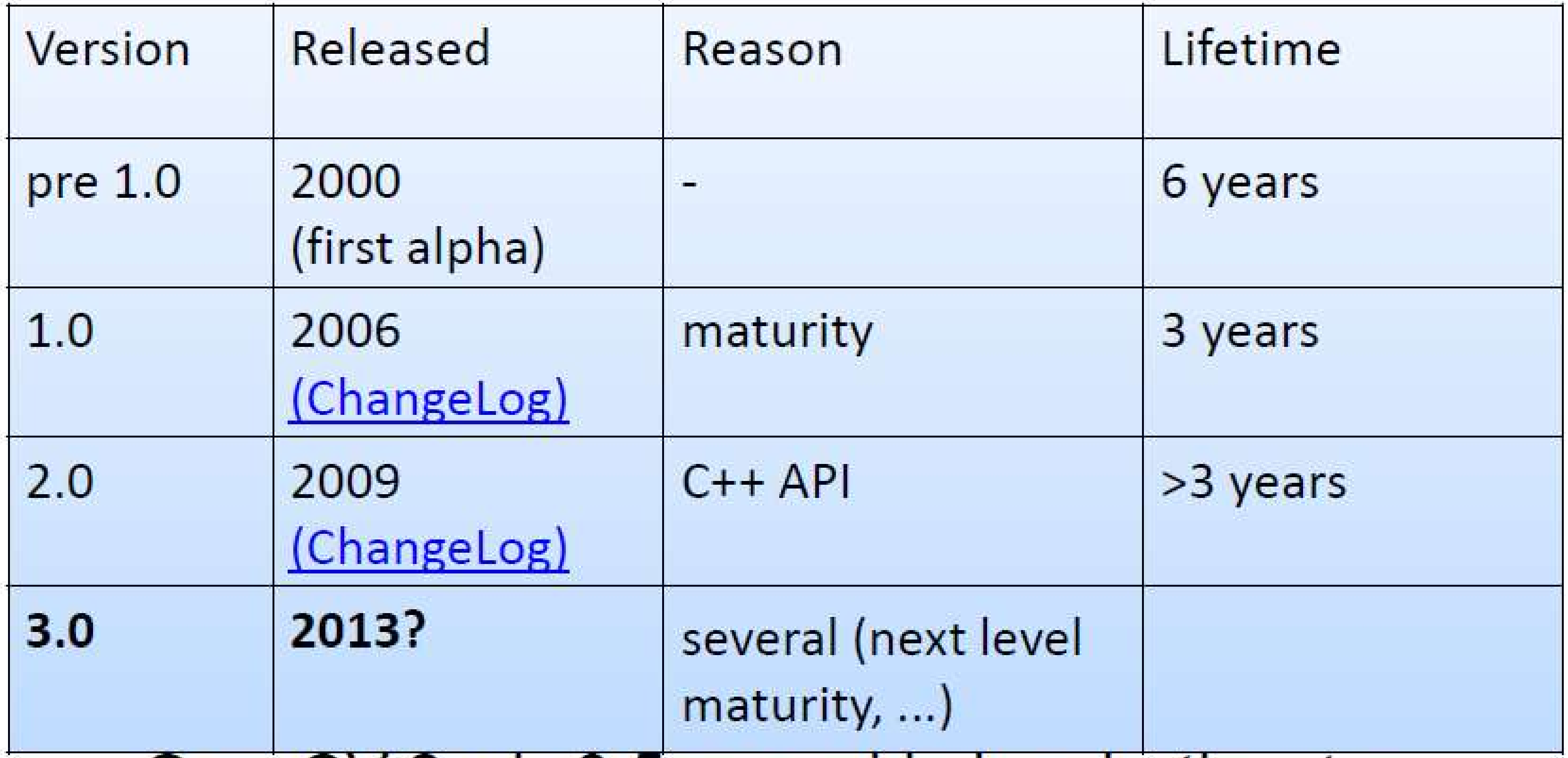
- Google Summer of Code Page: http://www.google-melange.com/gsoc/org/google/gsoc2013/opencv
- Our ideas page: http://code.opencv.org/projects/gsoc2013/wiki



FUTURE

- Contribution based
- 3.0
- OpenVX (Khronos)
- Learning OpenCV V2.0
- Foundation

OpenCV Timeline



Version	Released	Reason	Lifetime
pre 1.0	2000 (first alpha)	-	6 years
1.0	2006 (ChangeLog)	maturity	3 years
2.0	2009 (ChangeLog)	C++ API	>3 years
3.0	**2013?**	several (next level maturity, ...)	

OpenCV 2.x is 3.5-year old already, time to bump the version number!

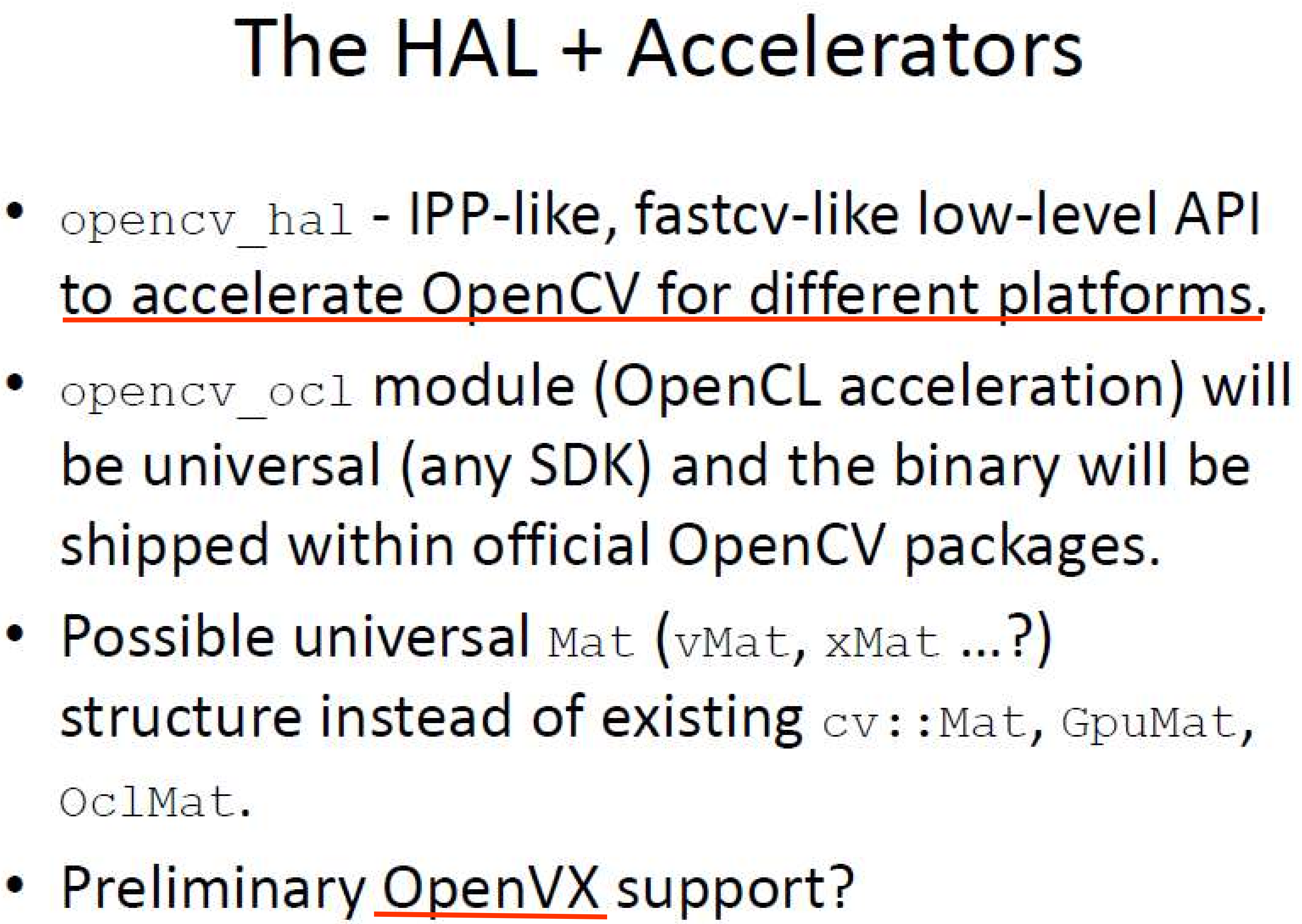
Dropping old skin

- OpenCV 1.x: C API
- OpenCV 2.x: new C++ API + fully supported C API. It's quite a burden!
- OpenCV 3.0:
  - refined C++ API + officially deprecated C API in a separate module(s)
  - no old-style Python bindings
  - cleaned documentation (just new-style API)
  - even a few wrong things from 2.x C++ API will be corrected or deprecated

  (*no way we could do that in 2.5!*)

Emphasis on binaries

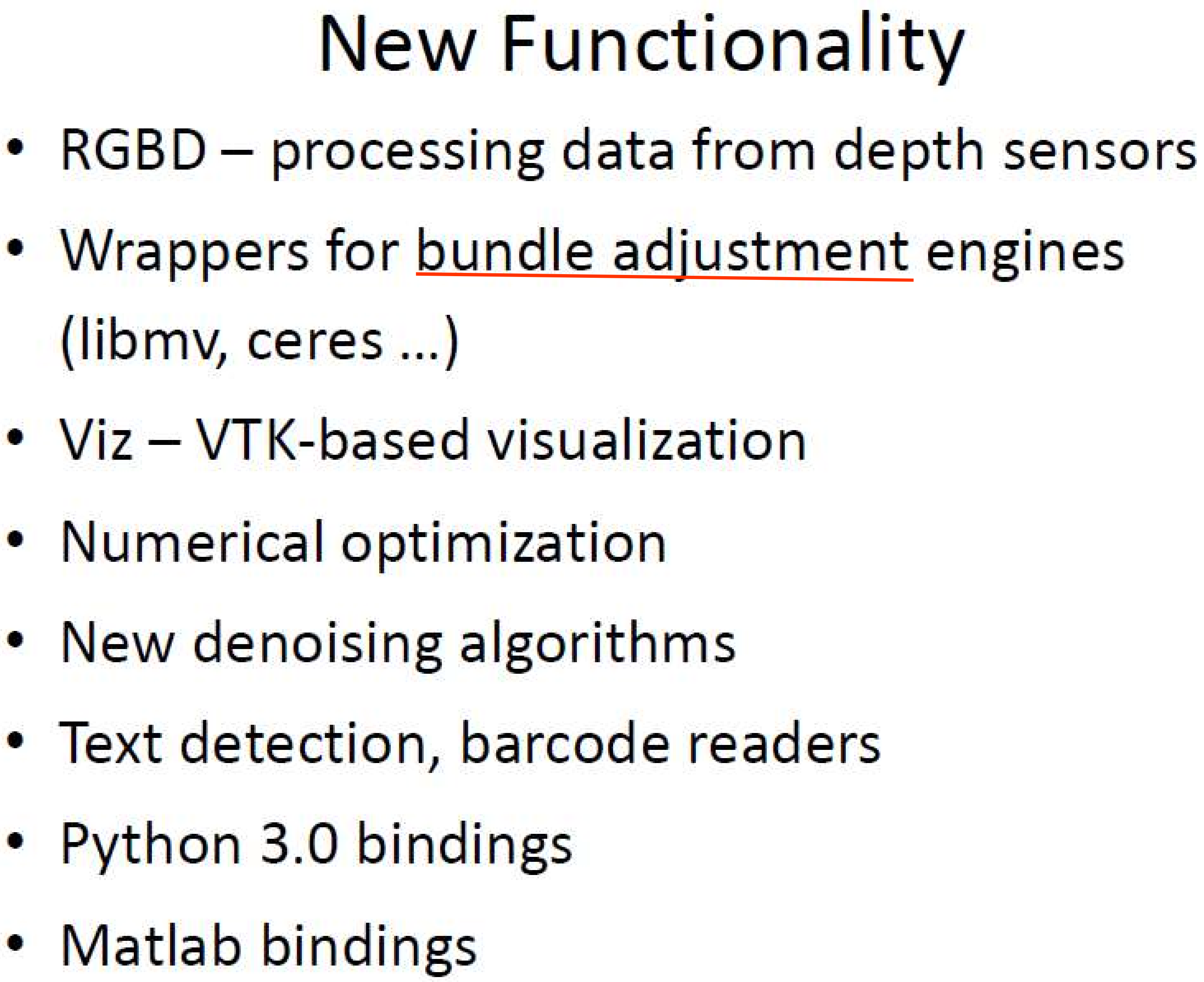
- For a long time OpenCV principles were:
  - Source-level compatibility
  - "Build it yourself!"
- Binary compatibility in 2.4.x
- In OpenCV 3.0 we continue the trend:
  - provide high-quality binary packages for each major platform => easier to maintain, more convenient for users
  - maintain binary compatibility for years!



The HAL + Accelerators

- `opencv_hal` - IPP-like, fastcv-like low-level API to accelerate OpenCV for different platforms.
- `opencv_ocl` module (OpenCL acceleration) will be universal (any SDK) and the binary will be shipped within official OpenCV packages.
- Possible universal `Mat` (`vMat`, `xMat` ...?) structure instead of existing `cv::Mat`, `GpuMat`, `OclMat`.
- Preliminary OpenVX support?

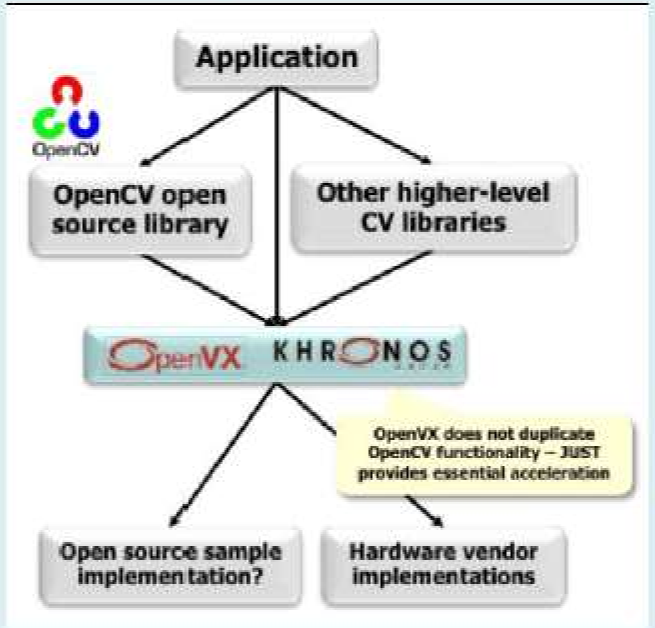
khronos 發表電腦視覺API 標準：**OpenVX**. 在2011 年的時候，Khronos 曾經發表過一個名為「Vision」的API 標準，希望可以為電腦視覺（Computer Vision）的處理、定義一套標準的介面，作為硬體加速的抽象層；當時，基本上只是剛開始的階段，並沒有完整的介面出來。2014年10月21日



New Functionality

- RGBD – processing data from depth sensors
- Wrappers for bundle adjustment engines (libmv, ceres …)
- Viz – VTK-based visualization
- Numerical optimization
- New denoising algorithms
- Text detection, barcode readers
- Python 3.0 bindings
- Matlab bindings

OpenVX (Khronos HAL)



Application

OpenCV open source library

Other higher-level CV libraries

OpenVX KHRONOS

OpenVX does not duplicate OpenCV functionality – JUST provides essential acceleration

Open source sample implementation?

Hardware vendor implementations

OpenVX

khronos 發表電腦視覺API 標準：**OpenVX**. 在2011 年的時候，Khronos 曾經發表過一個名為「Vision」的API 標準，希望可以為電腦視覺（Computer Vision）的處理、定義一套標準的介面，作為硬體加速的抽象層；當時，基本上只是剛開始的階段，並沒有完整的介面出來。2014年10月21日

- ❑ Khronos group - OpenVX:
  - Connecting software to silicon
  - OpenVX is an open, royalty-free standard for cross platform acceleration of computer vision applications.
  - It is designed by the Khronos Group to facilitate portable, optimized and power-efficient processing of methods for vision algorithms.
  - This is aimed for embedded and real-time programs within computer vision and related scenarios. It uses a connected graphics representation of operations.

OpenMP and OpenCL

1. OpenMP: Multi-Cores CPU, Multi-Core GPU, Multi-Core DSP

2. OpenCL: CPU + GPU, ARM + GPU

Computer Vision: Algorithms and Applications

R. Szeliski, *Computer Vision: Algorithms and Applications*, Springer, 2010.

ISBN-10: 1848829345 or ISBN-13: 978-1848829343

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National Cheng Kung University

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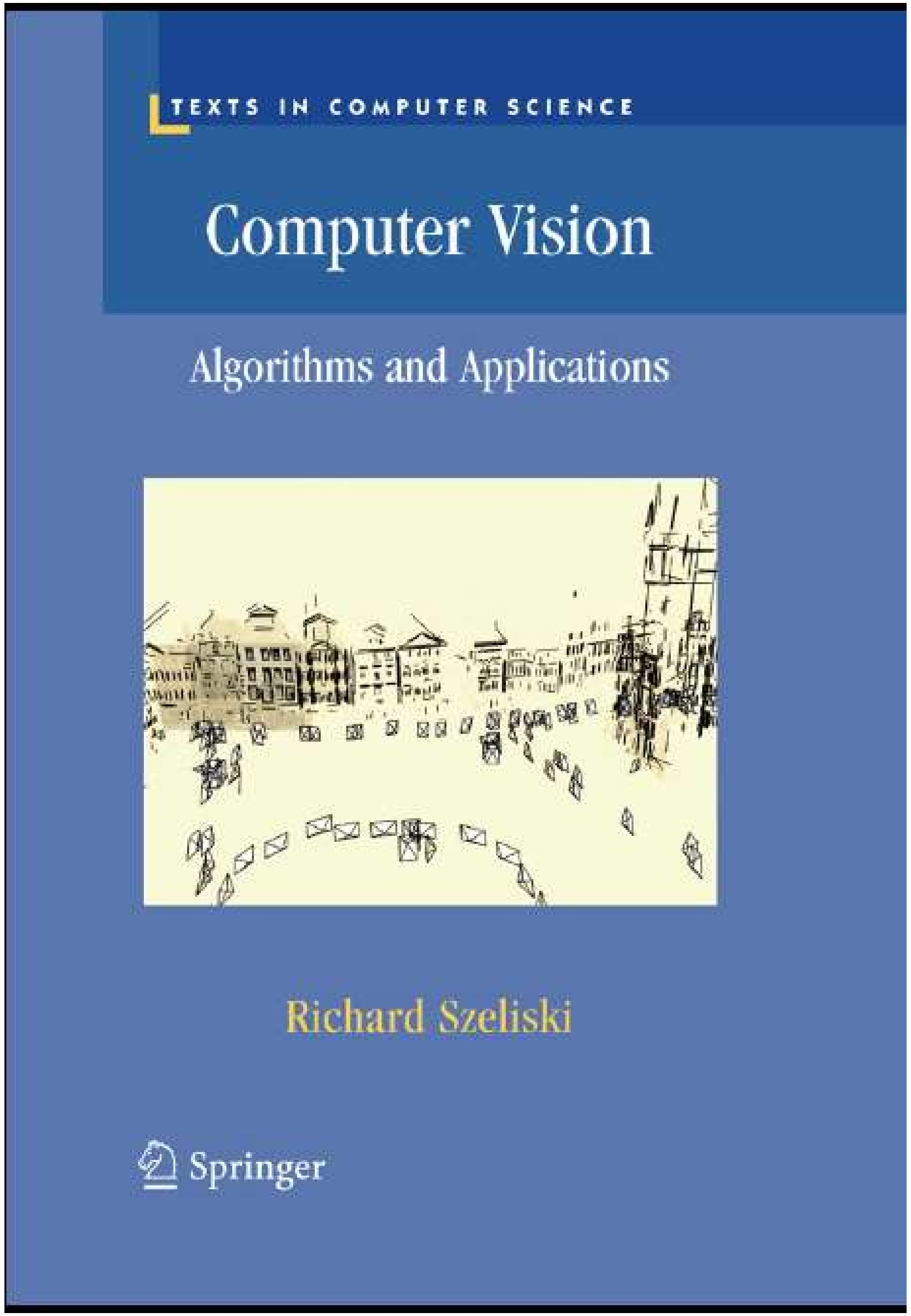
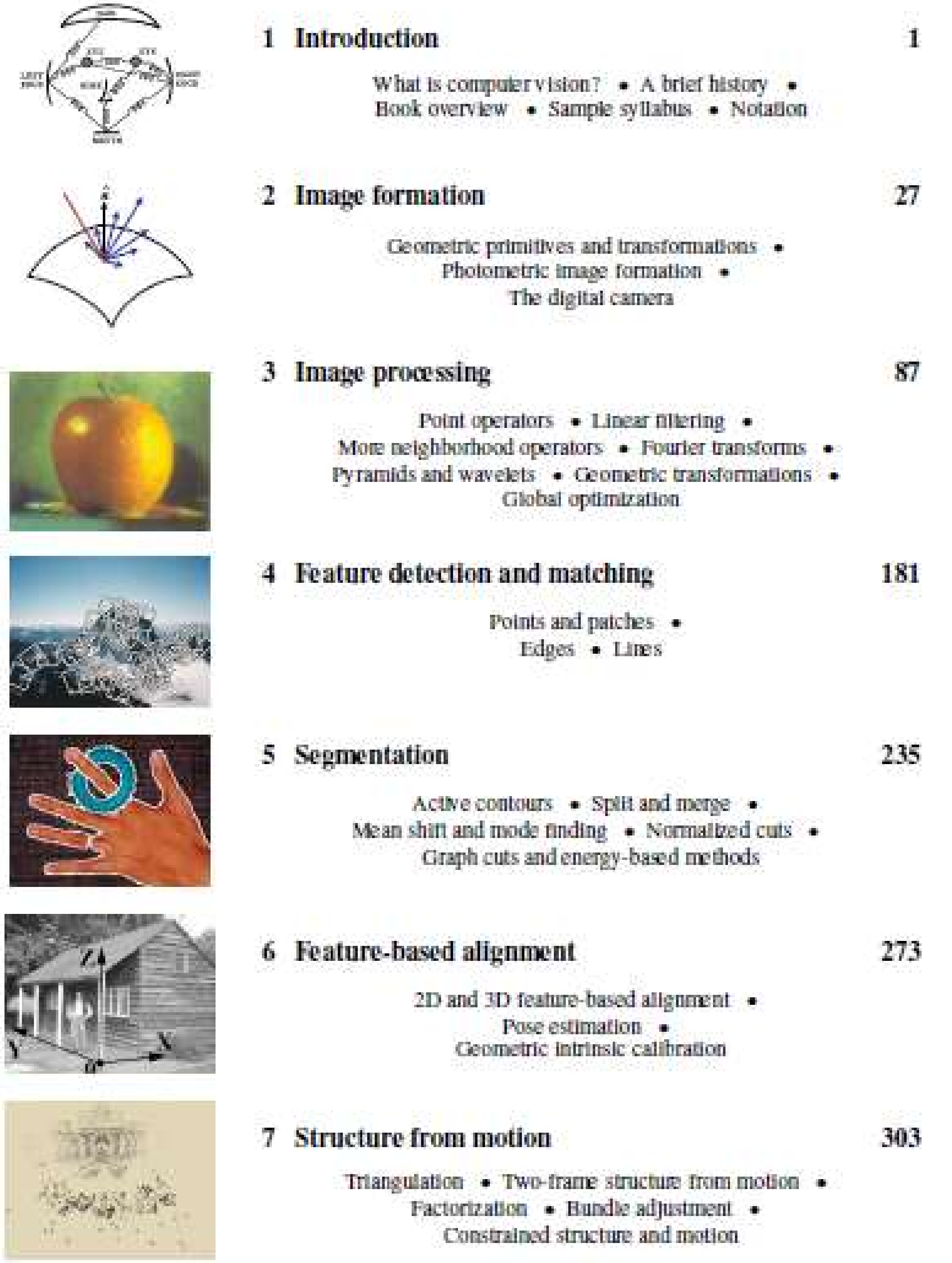
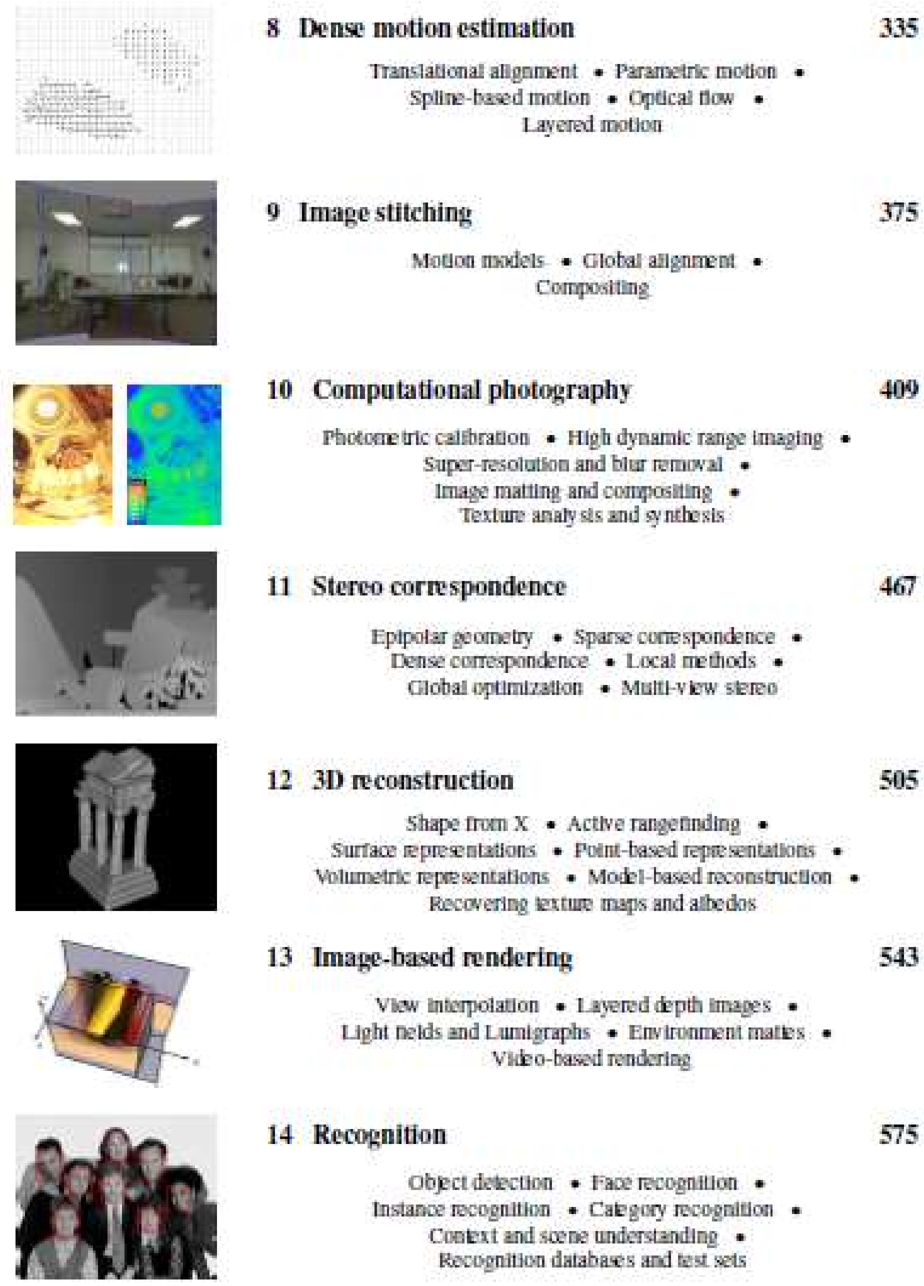
jjlien@csie.ncku.edu.tw
http://robotics.csie.ncku.edu.tw



Content (1/2)



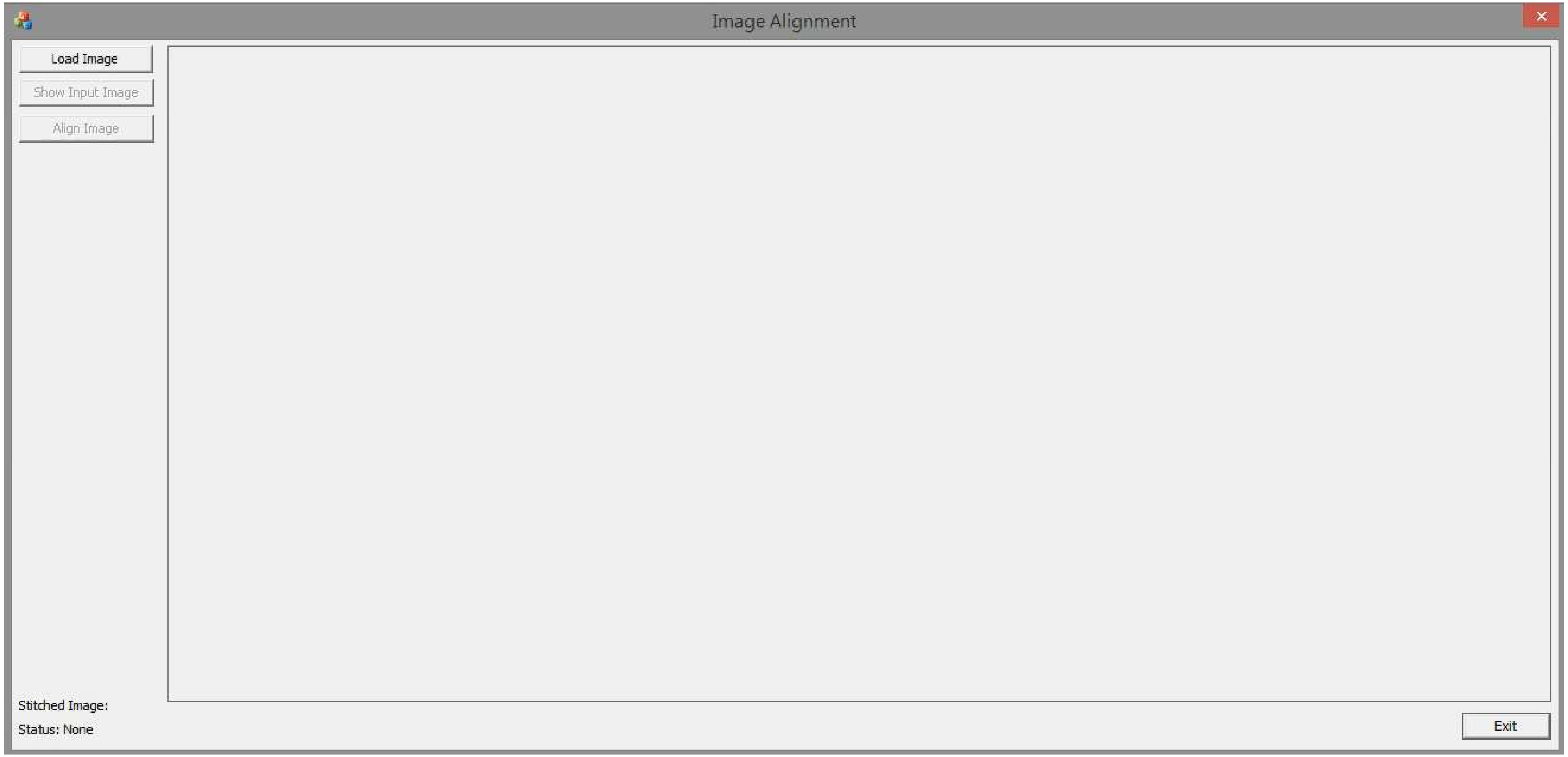
Content (2/2)



Slow Motion with Panorama (1/3)

[redacted]

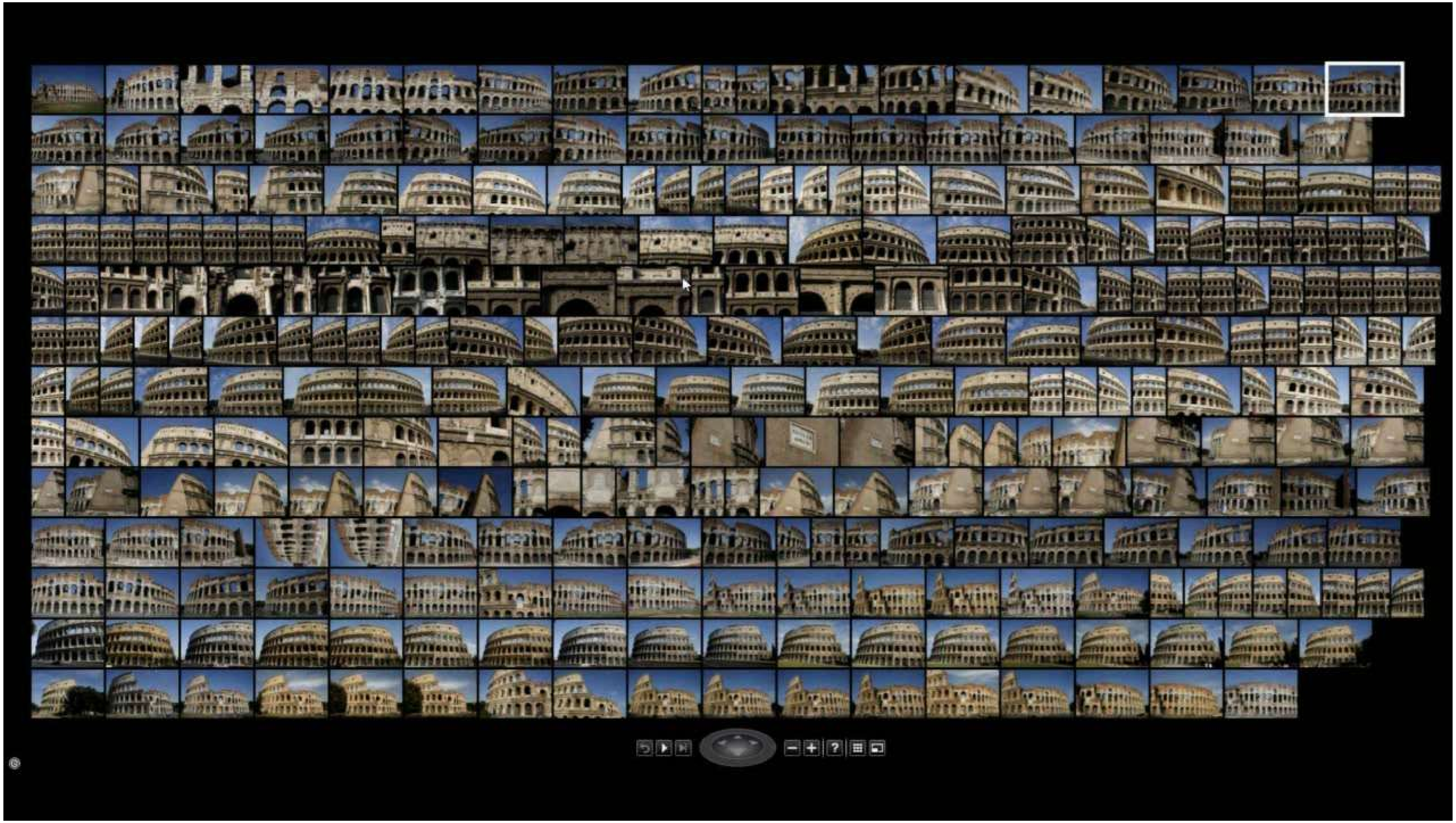
Panoramic Image Stitching with Local and Global Registration (2/3)



Stitched Image:

Status: None

Panoramic Image Stitching with Local and Global Registration (3/3)



References

1. G. Bradski and A. Kaebler, *Learning OpenCV, Computer Vision with the OpenCV Library*, O’Reilly, 2008. ISBN-10: 0596516134 or ISBN-13: 978-0596516130.
2. R. Szeliski, *Computer Vision: Algorithms and Applications*, Springer, 2010. ISBN-10: 1848829345 or ISBN-13: 978-1848829343.