Beginner’s Guide to Computer Vision

Jayneil Dalal¹  Sohil Patel²

¹Technical Writer/Embedded Linux Engineer
Intel
www.elinux.org/Jayneil_Dalal

²Computer Vision Engineer
Consultant

July 24, 2013
1. **Introduction**
   - Anatomy of the tutorial
   - Computer Vision (CV)

2. **Learning Computer Vision via OpenCV**
   - Basics
   - Implementing Computer Vision

3. **Going Beyond**
   - More OpenCV Codes
   - 3D
   - Thanks
About US

- We are open source advocates and evangelists.
- We have recently started a hackerspace in India “Jayso Labs” where students can work on a wide variety of open source hardware boards (Arduino, Beaglebone Black, Raspberry Pi, Papiloboard, Pandaboard, Arndaleboard etc.) for just $10.
  - www.jaysolabs.com
About US

- We are open source advocates and evangelists.
- We have recently started a hackerspace in India “Jayso Labs” where students can work on a wide variety of open source hardware boards (Arduino, Beaglebone Black, Raspberry Pi, Papilo board, Pandaboard, Arndaleboard etc.) for just $10.

  - www.jaysolabs.com
About US

- We are open source advocates and evangelists.
- We have recently started a hackerspace in India “Jayso Labs” where students can work on a wide variety of open source hardware boards (Arduino, Beaglebone Black, Raspberry Pi, Papiloboard, Pandaboard, Arndaleboard etc.) for just $10.
  - www.jaysolabs.com
Our Book

http://opencv.org/instant-opencv-starter.html
Introduction

- Anatomy of the tutorial
- Computer Vision (CV)

Learning Computer Vision via OpenCV

- Basics
- Implementing Computer Vision

Going Beyond

- More OpenCV Codes
- 3D
- Thanks
This tutorial is for beginners who have no prior experience to Computer Vision. Basic understanding of C/C++ is expected.

All the attendees will be given a DVD containing the following:

- Ubuntu image with OpenCV 2.4.3 pre-installed
- Virtual box application for Windows & Linux
- OpenCV tutorial codes

If you don’t have a DVD, you can download the tutorial material from the link below:

https://sourceforge.net/projects/oscon13cv/
This tutorial is for beginners who have no prior experience to Computer Vision. Basic understanding of C/C++ is expected.

All the attendees will be given a DVD containing the following

- Ubuntu image with OpenCV 2.4.3 pre-installed
- Virtual box application for Windows & Linux
- OpenCV tutorial codes

If you don't have a DVD, you can download the tutorial material from the link below:
https://sourceforge.net/projects/oscon13cv/
This tutorial is for beginners who have no prior experience to Computer Vision. Basic understanding of C/C++ is expected.

All the attendees will be given a DVD containing the following

- Ubuntu image with OpenCV 2.4.3 pre-installed
- Virtual box application for Windows & Linux
- OpenCV tutorial codes

If you don't have a DVD, you can download the tutorial material from the link below:
https://sourceforge.net/projects/oscon13cv/
This tutorial is for beginners who have no prior experience to Computer Vision. Basic understanding of C/C++ is expected.

All the attendees will be given a DVD containing the following:

- Ubuntu image with OpenCV 2.4.3 pre-installed
- Virtual box application for Windows & Linux
- OpenCV tutorial codes

If you don't have a DVD, you can download the tutorial material from the link below:
https://sourceforge.net/projects/oscon13cv/
Prerequisites

- This tutorial is for beginners who have no prior experience to Computer Vision. Basic understanding of C/C++ is expected.
- All the attendees will be given a DVD containing the following:
  - Ubuntu image with OpenCV 2.4.3 pre-installed
  - Virtual box application for Windows & Linux
  - OpenCV tutorial codes
- If you don't have a DVD, you can download the tutorial material from the link below:
  https://sourceforge.net/projects/oscon13cv/
Anatomy of the tutorial

Setup

- Please make sure that you have Visualization Technology (VT) enabled in your BIOS.
- Then install Virtual box on your machine if you don’t have it.
- Create a virtual instance using the Ubuntu image provided with at least 1 core, 1 GB RAM.
- Log into the live mode. DO NOT INSTALL UBUNTU!
- Username=Password=opencv
- Make sure that the Codelite IDE has been pre-configured with the tutorial codes.
**Setup**

- Please make sure that you have Visualization Technology (VT) enabled in your BIOS.
- Then install Virtual box on your machine if you don’t have it.
- Create a virtual instance using the Ubuntu image provided with at least 1 core, 1 GB RAM.
- Log into the live mode. DO NOT INSTALL UBUNTU!
- Username=Password=opencv
- Make sure that the Codelite IDE has been pre-configured with the tutorial codes.
Please make sure that you have Visualization Technology (VT) enabled in your BIOS.

Then install Virtual box on your machine if you don’t have it.

Create a virtual instance using the Ubuntu image provided with at least 1 core, 1 GB RAM.

Log into the live mode. DO NOT INSTALL UBUNTU!

Username=Password=opencv

Make sure that the Codelite IDE has been pre-configured with the tutorial codes.
Anatomy of the tutorial

Setup

- Please make sure that you have Visualization Technology (VT) enabled in your BIOS.
- Then install Virtual box on your machine if you don’t have it.
- Create a virtual instance using the Ubuntu image provided with at least 1 core, 1 GB RAM.
- Log into the live mode. DO NOT INSTALL UBUNTU!
  - Username=Password=opencv
- Make sure that the Codelite IDE has been pre-configured with the tutorial codes.
Setup

- Please make sure that you have Visualization Technology (VT) enabled in your BIOS.
- Then install Virtual box on your machine if you don’t have it.
- Create a virtual instance using the Ubuntu image provided with at least 1 core, 1 GB RAM.
- Log into the live mode. DO NOT INSTALL UBUNTU!
- Username=Password=opencv
- Make sure that the Codelite IDE has been pre-configured with the tutorial codes.
Please make sure that you have Visualization Technology (VT) enabled in your BIOS.

Then install Virtual box on your machine if you don’t have it.

Create a virtual instance using the Ubuntu image provided with at least 1 core, 1 GB RAM.

Log into the live mode. DO NOT INSTALL UBUNTU!

Username=Password=opencv

Make sure that the Codelite IDE has been pre-configured with the tutorial codes.
1 Introduction
   • Anatomy of the tutorial
   • Computer Vision (CV)

2 Learning Computer Vision via OpenCV
   • Basics
   • Implementing Computer Vision

3 Going Beyond
   • More OpenCV Codes
   • 3D
   • Thanks
What is it?

- It is a discipline of “teaching machines how to see”.
- Used in various industries - Biomedical, Robotics, Computers, Automotive, Aviation etc.
What is it?

- It is a discipline of “teaching machines how to see”.
- Used in various industries - Biomedical, Robotics, Computers, Automotive, Aviation etc.
Why learn Computer Vision?

- Solve some of the world’s most toughest problems.
- It’s cool and fun. Also one does not need a PhD to implement it.
Why learn Computer Vision?

- Solve some of the world’s most toughest problems.
- Its cool and fun. Also one does not need a PhD to implement it.
Applications of Computer Vision

- Motivation video
- Used in all the latest cars today to assist drivers.
- Used by a lot of companies like Facebook, Google etc. to identify people in their photos.
1 Introduction
   - Anatomy of the tutorial
   - Computer Vision (CV)

2 Learning Computer Vision via OpenCV
   - Basics
   - Implementing Computer Vision

3 Going Beyond
   - More OpenCV Codes
   - 3D
   - Thanks
What is an Image?
What is an Image?

- It is nothing but a collection of ones and zeros! That is how machines see them at least.
- It is made up of small constituent elements called ’picture elements’ a.k.a pixels as shown below.

Each pixel stores specific color information about the picture.

A 1920*1080 picture has 2073600 pixels. More pixels means clarity up to a certain point.

JPEG, PNG, BMP, GIF etc. - standardized means of organizing and storing images.
What is an Image?

- It is nothing but a collection of ones and zeros! That is how machines see them atleast.
- It is made up of small constituent elements called 'picture elements' a.k.a pixels as shown below

Each pixel stores specific color information about the picture.
- A 1920*1080 picture has 2073600 pixels. More pixels means clarity upto a certain point.
- JPEG, PNG, BMP, GIF etc. - standardized means of organizing and storing images.
What is an Image?

- It is nothing but a collection of ones and zeros! That is how machines see them at least.
- It is made up of small constituent elements called 'picture elements' a.k.a pixels as shown below.

Each pixel stores specific color information about the picture.
- A 1920*1080 picture has 2073600 pixels. More pixels means clarity up to a certain point.
- JPEG, PNG, BMP, GIF etc. - standardized means of organizing and storing images.
What is an Image?

- It is nothing but a collection of ones and zeros! That is how machines see them atleast.
- It is made up of small constituent elements called ‘picture elements’ a.k.a pixels as shown below.

![](image)

- Each pixel stores specific color information about the picture.
- A 1920*1080 picture has 2073600 pixels. More pixels means clarity upto a certain point.
- JPEG, PNG, BMP, GIF etc. - standardized means of organizing and storing images.
What is an Image?

- It is nothing but a collection of ones and zeros! That is how machines see them at least.
- It is made up of small constituent elements called 'picture elements' a.k.a pixels as shown below.

![Image example]

- Each pixel stores specific color information about the picture.
- A 1920*1080 picture has 2073600 pixels. More pixels means clarity up to a certain point.
- JPEG, PNG, BMP, GIF etc. - standardized means of organizing and storing images.
Color Models - RGB, HSV, CMYK.

- A mathematical method to describe colors as a tuple of numbers.
- Colors can be additive or subtractive.
### Terminologies

- **Saturation**: INCREASE = bright colors  
  DECREASE = grayish colors
- **Brightness**: LOW = DARK tones; HIGH = LIGHT tones
- **Contrast**: Difference between the dark and light spots in the image.
Terminologies

- **Saturation**: INCREASE = bright colors  DECREASE = grayish colors
- **Brightness**: LOW = DARK tones; HIGH = LIGHT tones
- **Contrast**: Difference between the dark and light spots in the image.
**Terminologies**

- **Saturation**: INCREASE=bright colors DECREASE=grayish colors
- **Brightness**: LOW=DARK tones; HIGH=LIGHT tones
- **Contrast**: Difference between the dark and light spots in the image.
1 Introduction
   • Anatomy of the tutorial
   • Computer Vision (CV)

2 Learning Computer Vision via OpenCV
   • Basics
   • Implementing Computer Vision

3 Going Beyond
   • More OpenCV Codes
   • 3D
   • Thanks
Why OpenCV

- World’s most popular open source computer vision library.
- Available under BSD license - great for making commercial applications!
- 500+ optimized algorithms for image and video analysis
- Cross platform- Mac OS, Windows, Android, iOS, Linux.
- C, C++, Python and Java interfaces
Why OpenCV

- World’s most popular open source computer vision library.
- Available under BSD license - great for making commercial applications!
  - 500+ optimized algorithms for image and video analysis
  - Cross platform- Mac OS, Windows, Android, iOS, Linux.
  - C, C++, Python and Java interfaces
Why OpenCV

- World’s most popular open source computer vision library.
- Available under BSD license - great for making commercial applications!
- 500+ optimized algorithms for image and video analysis
- Cross platform- Mac OS, Windows, Android, iOS, Linux.
- C, C++, Python and Java interfaces
Why OpenCV

- World’s most popular open source computer vision library.
- Available under BSD license - great for making commercial applications!
- 500+ optimized algorithms for image and video analysis
- Cross platform- Mac OS, Windows, Android, iOS, Linux.
- C, C++, Python and Java interfaces
Why OpenCV

- World’s most popular open source computer vision library.
- Available under BSD license - great for making commercial applications!
- 500+ optimized algorithms for image and video analysis
- Cross platform- Mac OS, Windows, Android, iOS, Linux.
- C, C++, Python and Java interfaces
Installing OpenCV

- Two approaches: install pre-compiled package or build it from source.
- For Ubuntu, all you need to do is type “sudo apt-get install libopencv-dev” in a terminal window.
- http://youtu.be/b3IQyhJXXK78
Installing OpenCV

- Two approaches: install pre-compiled package or build it from source.
- For Ubuntu, all you need to do is type “sudo apt-get install libopencv-dev” in a terminal window.

http://youtu.be/b3IQyhJXK78
Installing OpenCV

- Two approaches: install pre-compiled package or build it from source.
- For Ubuntu, all you need to do is type “sudo apt-get install libopencv-dev” in a terminal window.
- [http://youtu.be/b3IQyhJXXK78](http://youtu.be/b3IQyhJXXK78)
Resources

- Website: http://opencv.org/
- Official user group: http://tech.groups.yahoo.com/group/OpenCV/
- Tutorials
- Reference manual, user guide & cheatsheet available in OpenCV/doc folder.
Resources

- Website: http://opencv.org/
- Official user group: http://tech.groups.yahoo.com/group/OpenCV/
- Tutorials
- Reference manual, user guide & cheatsheet available in OpenCV/doc folder.
Resources

- Website: http://opencv.org/
- Official user group: http://tech.groups.yahoo.com/group/OpenCV/
- Tutorials
  - Reference manual, user guide & cheatsheet available in OpenCV/doc folder.
Resources

- Website: http://opencv.org/
- Official user group: http://tech.groups.yahoo.com/group/OpenCV/
- Tutorials
- Reference manual, user guide & cheatsheet available in OpenCV/doc folder.
Implementing Computer Vision

OpenCV Modules

- **Core**: compact module defining basic data structures, including the dense multidimensional array Mat and basic functions used by all other modules.
- **Imgproc**: an image processing module that includes linear and non-linear image filtering, geometrical image transformations (resize, affine and perspective warping, generic table-based remapping), color space conversion, histograms, and so on.
- **Video**: a video analysis module that includes motion estimation, background subtraction, and object tracking algorithms.
- **Calib3d**: basic multiple-view geometry algorithms, single and stereo camera calibration, object pose estimation, stereo correspondence algorithms, and elements of 3D reconstruction.
- **Features2d**: salient feature detectors, descriptors, and descriptor matchers.
- **Objdetect**: detection of objects and instances of the predefined classes (for example, faces, eyes, mugs, people, cars, and so on).
- **Highgui**: an easy-to-use interface to video capturing, image and video codecs, as well as simple UI capabilities.
- **Gpu**: GPU - accelerated algorithms from different OpenCV modules.
Up & Running

- Please run the “Hello World” program.
- Explanation
- Please run the “Modify Image” program.
- Explanation
- BREAK
Please run the “Hello World” program.

Explanation

Please run the “Modify Image” program.

Explanation

BREAK
Up & Running

- Please run the “Hello World” program.
- Explanation
- Please run the “Modify Image” program.
- Explanation
- BREAK
Up & Running

- Please run the “Hello World” program.
- Explanation
- Please run the “Modify Image” program.
- Explanation
- BREAK
Up & Running

- Please run the “Hello World” program.
- Explanation
- Please run the “Modify Image” program.
- Explanation
- BREAK
There are three types of Image:

- **RGB**: 3 channels, 0-255
  - Grayscale: 1 channel, 0[BLACK]-255[WHITE]
  - Black and White: 1 channel, 0 or 1
Types of Image

- There are three types of Image:
  - RGB: 3 channels, 0-255
  - Grayscale: 1 channel, 0[BLACK]-255[WHITE]
  - Black and White: 1 channel, 0 or 1
There are three types of Image:

- RGB: 3 channels, 0-255
- Grayscale: 1 channel, 0[BLACK]-255[WHITE]
- Black and White: 1 channel, 0 or 1
Implementing Computer Vision

RGB
Grayscale
Black and White
Data types in OpenCV

- 8-bit unsigned integer (uchar), CV_8U
- 8-bit signed integer (schar), CV_8S
- 16-bit unsigned integer (ushort), CV_16U
- 16-bit signed integer (short), CV_16S
- 32-bit signed integer (int), CV_32S
- 32-bit floating-point number (float), CV_32F
- 64-bit floating-point number (double), CV_64F
Image storage in OpenCV

- Mat - Primitive datatype in OpenCV to store images.

- More info here: 
  http://opencv.willowgarage.com/documentation/cpp/basic_structures.html#cv-mat-mat

- Image properties: height, width, depth, type, channels, pixels

- Please run the “Matrix Operation” program.

- Explanation
Mat - Primitive datatype in OpenCV to store images.

More info here:
http://opencv.willowgarage.com/documentation/cpp/basic_structures.html#cv-mat-mat

Image properties: height, width, depth, type, channels, pixels

Please run the “Matrix Operation” program.

Explanation
Image storage in OpenCV

- Mat - Primitive datatype in OpenCV to store images.
- More info here: http://opencv.willowgarage.com/documentation/cpp/basic_structures.html#cv-mat-mat
- Image properties: height, width, depth, type, channels, pixels
- Please run the “Matrix Operation” program.
Image storage in OpenCV

- Mat - Primitive datatype in OpenCV to store images.
- More info here: http://opencv.willowgarage.com/documentation/cpp/basic_structures.html#cv-mat-mat
- Image properties: height, width, depth, type, channels, pixels
- Please run the “Matrix Operation” program.
- Explanation
RGB Color model
Implementing Computer Vision

HSV Color model

![HSV Color Model Diagram](image-url)
Image Conversions

- RGB to Grayscale (reverse not possible!)
  - Grayscale to black and white.
  - Makes processing much easier.
  - Please run the Image Conversion code.
  - Explanation
Implementing Computer Vision

Image Conversions

- RGB to Grayscale (reverse not possible!)
- Grayscale to black and white.
  - Makes processing much easier.
  - Please run the Image Conversion code.
  - Explanation
Image Conversions

- RGB to Grayscale (reverse not possible!)
- Grayscale to black and white.
- Makes processing much easier.

Please run the Image Conversion code.

Explanation
Image Conversions

- RGB to Grayscale (reverse not possible!)
- Grayscale to black and white.
- Makes processing much easier.
- Please run the Image Conversion code.

Explanation
Image Conversions

- RGB to Grayscale (reverse not possible!)
- Grayscale to black and white.
- Makes processing much easier.
- Please run the Image Conversion code.
- Explanation
Pixel Manipulation

- Dealing with one/many pixel simultaneously.

- Please run the Pixel manipulation code.

- Explanation

- Classic example: Image Steganography

- Explanation
Pixel Manipulation

- Dealing with one/many pixel simultaneously.
- Please run the Pixel manipulation code.
  - Explanation
  - Classic example: Image Steganography
  - Explanation
Pixel Manipulation

- Dealing with one/many pixel simultaneously.
- Please run the Pixel manipulation code.
- Explanation
  - Classic example: Image Steganography
  - Explanation
Pixel Manipulation

- Dealing with one/many pixel simultaneously.
- Please run the Pixel manipulation code.
- Explanation
- Classic example: Image Steganography
- Explanation
Pixel Manipulation

- Dealing with one/many pixel simultaneously.
- Please run the Pixel manipulation code.
- Explanation
- Classic example: Image Steganography
- Explanation
Histogram

- It is a graph showing the number of pixels in an image at each different intensity value found in that image.
- Histograms are used to depict image statistics in an easily interpreted visual format.
**Histogram**

- It is a graph showing the number of pixels in an image at each different intensity value found in that image.
- Histograms are used to depict image statistics in an easily interpreted visual format.
Histogram

- It is a graph showing the number of pixels in an image at each different intensity value found in that image.
- Histograms are used to depict image statistics in an easily interpreted visual format.
Plotting your own Histogram

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>
Importance of Histogram

- It is used in many applications to improve the visual appearance of an image.
- Trivial image comparison.
Importance of Histogram

- It is used in many applications to improve the visual appearance of an image.
- Trivial image comparison.
Importance of Histogram

- It is used in many applications to improve the visual appearance of an image.
- Trivial image comparison.
Equalization

- It is a method that improves the contrast in an image, in order to stretch out the intensity range.
Equalization

- It is a method that improves the contrast in an image, in order to stretch out the intensity range.
Equalization

- It is a method that improves the contrast in an image, in order to stretch out the intensity range.
1 Introduction
- Anatomy of the tutorial
- Computer Vision (CV)

2 Learning Computer Vision via OpenCV
- Basics
- Implementing Computer Vision

3 Going Beyond
- More OpenCV Codes
- 3D
- Thanks
Changing the brightness/contrast of a given image
- Smoothening a given image
- Edge detection
- Please run all of the above codes.
- Explanation
Examples

- Changing the brightness/contrast of a given image
- Smoothening a given image
- Edge detection
- Please run all of the above codes.
- Explanation
Examples

- Changing the brightness/contrast of a given image
- Smoothening a given image
- Edge detection

Please run all of the above codes.

Explanation
Examples

- Changing the brightness/contrast of a given image
- Smoothening a given image
- Edge detection
- Please run all of the above codes.

Explanation
Examples

- Changing the brightness/contrast of a given image
- Smoothening a given image
- Edge detection
- Please run all of the above codes.
- Explanation
1 Introduction
   • Anatomy of the tutorial
   • Computer Vision (CV)

2 Learning Computer Vision via OpenCV
   • Basics
   • Implementing Computer Vision

3 Going Beyond
   • More OpenCV Codes
   • 3D
   • Thanks
3D Image Processing

- Z parameter - depth.
- 3D Cameras use either 'time of flight' or the structured light technology.
- Explanation
3D Image Processing

- Z parameter - depth.
- 3D Cameras use either 'time of flight' or the structured light technology.

Explanations
3D Image Processing

- Z parameter - depth.
- 3D Cameras use either 'time of flight' or the structured light technology.
- Explanation
Hardware Devices

- Microsoft Kinect
- Primesense
- Softkinetic
Hardware Devices

- Microsoft Kinect
- Primesense
- Softkinetic
Hardware Devices

- Microsoft Kinect

- Primesense

- Softkinetic
Software

- OpenNI library - world’s most popular open source 3D image processing library.
- Point Cloud Library (PCL)
Software

- OpenNI library - world’s most popular open source 3D image processing library.

- Point Cloud Library (PCL)
Potential Applications

- Terrain mapping
- Gaming
- Medical
Potential Applications

- Terrain mapping
- Gaming
- Medical
Potential Applications

- Terrain mapping
- Gaming
- Medical
Getting RGB data and depth map using Microsoft Kinect.
Hand Tracker
Skeleton Tracking
Kinect hacks on Pandaboard
Demos

- Getting RGB data and depth map using Microsoft Kinect.
- Hand Tracker
- Skeleton Tracking
- Kinect hacks on Pandaboard
Demos

- Getting RGB data and depth map using Microsoft Kinect.
- Hand Tracker
- Skeleton Tracking
- Kinect hacks on Pandaboard
Demos

- Getting RGB data and depth map using Microsoft Kinect.
- Hand Tracker
- Skeleton Tracking
- Kinect hacks on Pandaboard
1. Introduction
   - Anatomy of the tutorial
   - Computer Vision (CV)

2. Learning Computer Vision via OpenCV
   - Basics
   - Implementing Computer Vision

3. Going Beyond
   - More OpenCV Codes
   - 3D
   - Thanks
Thank you for attending our tutorial! :-)

- Jayneil: jayneil.dalal@gmail.com
- Sohil: sohilpatel4932@gmail.com
Thank you for attending our tutorial! :-) 

- Jayneil: jayneil.dalal@gmail.com 
- Sohil: sohilpatel4932@gmail.com
Thank you for attending our tutorial! :-)

- Jayneil: jayneil.dalal@gmail.com
- Sohil: sohilpatel4932@gmail.com
Thank you for attending our tutorial! :-) 

- Jayneil: jayneil.dalal@gmail.com
- Sohil: sohilpatel4932@gmail.com