

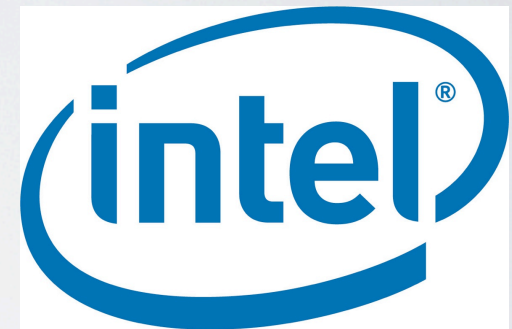


# Introduction to OpenCV

Marvin Smith

# Introduction

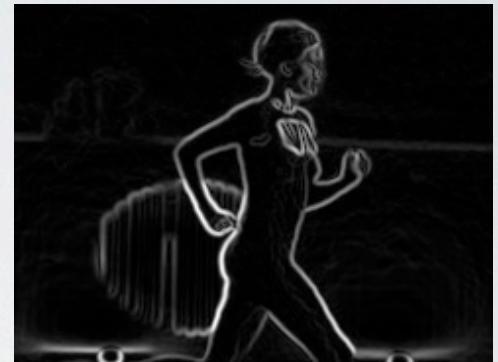
- OpenCV is an Image Processing library created by Intel and maintained by Willow Garage.
- Available for C, C++, and Python
- Newest update is version 2.2
- Open Source and free
- Easy to use and install





# Installation Instructions

- For Mac OS X. Simply install Mac Ports then type  
sudo port install opencv
- Do not use synaptic on Linux to install OpenCV.  
It is version 1.2.
- For Linux and Windows, follow the installation guide at  
<http://opencv.willowgarage.com/wiki/InstallGuide>
- Linux users can come to me for help. I have built it on  
Ubuntu dozens of times. I have built it successfully on  
Windows once.
- Make sure to read the beginning as it gives you  
precise commands to install ffmpeg, libavformat-dev,  
libswscale-dev, and other required libraries.
- Follow instructions exactly!!!!



# BASIC OPENCV STRUCTURES

- **Point, Point2f** - 2D Point
- **Size** - 2D size structure
- **Rect** - 2D rectangle object
- **RotatedRect** - Rect object with angle
- **Mat** - image object



# Point

- 2D Point Object

- int x, y;

- Functions

- Point.**dot**(<Point>) - computes dot product
  - Point.**inside**(<Rect>) - returns true if point is inside

- Math operators, you may use

- Point operator +

- Point operator +=

- Point operator -

- Point operator -=

- Point operator \*

- Point operator \*=

- bool operator ==

- bool operator != double norm

```
10 int main(int argc, char* argv[]){
11
12     Point a(1,1);
13     Point b(2,2);
14     Point c = a+b;
15
16     cout << c.x << ", " << c.y << endl;
17     c = a*2;
18     cout << c.x << ", " << c.y << endl;
19     cout << norm(b) << endl;
20
21     if(a==b)
22         cout << "A == B" << endl;
23     else
24         cout << "A != B" << endl;
25     if(b != c)
26         cout << "B != C" << endl;
27     else
28         cout << "B == C" << endl;
29     return 0;
30 }
```

```
Marvin-Smit
3, 3
2, 2
2.82843
A != B
B == C
Marvin-Smit
```

# Size

- 2D Size Structure
  - int width, height;
- Functions
  - Point.area() - returns (width \* height)

# RECT

- 2D Rectangle Structure
  - int x, y, width, height;
- Functions
  - Point.tl() - return top left point
  - Point.br() - return bottom right point



# cv::Mat

- The primary data structure in OpenCV is the Mat object. It stores images and their components.
- Main items
  - rows, cols - length and width(int)
  - channels - 1: grayscale, 3: BGR
  - depth: CV\_<depth>C<num chan>
- See the manuals for more information

```
int main(int argc, char* argv[]){  
    Mat image = imread(argv[1]);  
  
    cout << "Columns = " << image.cols << endl;  
    cout << "Rows    = " << image.rows << endl;  
    cout << "Type    = ";  
  
    if(image.type() == CV_8UC1) cout << "CV_8UC1" << endl;  
    else if(image.type() == CV_8UC3) cout << "CV_8UC3" << endl;  
    else if(image.type() == CV_32FC1) cout << "CV_32FC1" << endl;  
    else if(image.type() == CV_32FC3) cout << "CV_32FC3" << endl;  
    else cout << "Unknown" << endl;  
  
    return 0;  
}
```

```
Marvin-Smiths-MacBook-Pro:Documents marvin_smith1$ g++ mat.cpp `pkg-config  
Marvin-Smiths-MacBook-Pro:Documents marvin_smith1$ ./a.out photo.jpg  
Columns = 400  
Rows    = 300  
Type    = CV_8UC3  
Marvin-Smiths-MacBook-Pro:Documents marvin_smith1$
```

# cv::Mat

## • Functions

- Mat.**at**<datatype>(row, col)[channel] - returns pointer to image location
- Mat.**channels**() - returns the number of channels
- Mat.**clone**() - returns a deep copy of the image
- Mat.**create**( rows, cols, TYPE) - re-allocates new memory to matrix
- Mat.**cross**(<Mat>) - computes cross product of two matrices
- Mat.**depth**() - returns data type of matrix
- Mat.**dot**(<Mat>) - computes the dot product of two matrices



# cv::Mat

## • Functions

- `Mat(Range(xmin,xmax),Range(ymin,ymax))` - returns sub image
- `Mat.type()` - returns the TYPE of a matrix

## • Iterator Usage

- `Mat.begin()` - moves Mat iterator to beginning of image
- `Mat.end()` - moves Mat iterator to end of image

```
34 //Example of using iterators to invert an image|
35 MatConstIterator_<uchar> src_it = image.begin<uchar>();
36
37 MatConstIterator_<uchar> src_it end = image.end<uchar>();
38
39 MatIterator_<uchar> dst_it = ret.begin<uchar>();
40
41 for(; src it != src it end; src it++,dst it++){
42     pix = *src it;
43     *dst it = uchar(255) - pix;
44 }
```

# Image TYPES

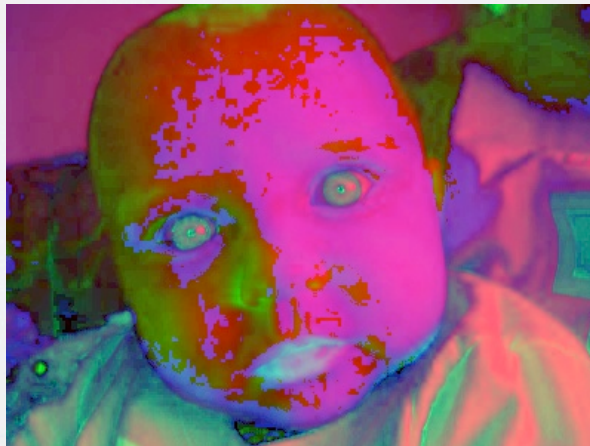
- The TYPE is a very important aspect of OpenCV
- Represented as `CV_<Datatype>C<# Channels>`
- Example Datatypes/ Depths

<b>OpenCV Tag</b>	<b>Representation</b>	<b>OpenCV Value</b>
CV_8U	8 bit unsigned integer	0
CV_8S	8 bit signed integer	1
CV_16U	16 bit unsigned integer	2
CV_16S	16 bit signed integer	3
CV_32S	32 bit signed integer	4
CV_32F	32 bit floating point number	5
CV_64F	64 bit floating point number	6



# Pixeltypes

- PixelTypes shows how the image is represented in data
  - BGR - The default color of imread(). Normal 3 channel color
  - HSV - Hue is color, Saturation is amount, Value is lightness. 3 channels
  - GRAYSCALE - Gray values, Single channel
- OpenCV requires that images be in BGR or Grayscale in order to be shown or saved. Otherwise, undesirable effects may



# HELLO WORLD

- Example Code

```
//Loads image and displays  
//call by ./a.out image.jpg  
//
```

```
#include <cv.h>  
#include <cvaux.h>  
#include <highgui.h>
```

```
using namespace cv;
```

```
int main(int argc, char* argv[ ]){  
    Mat image = imread(argv[1]);  
  
    namedWindow("Sample Window");  
    imshow("Sample Window",image);  
    waitKey(0);  
    return 0;  
}
```

**This program will load and show an image**





# Starting Out in OpenCV

- OpenCV uses the **cv** namespace.
- `cv::Mat` object replaces the original C standard **IplImage** and **CvMat** classes.
- All original functions and classes of the C standard OpenCV components in the Bradski book are still available and current. However you will need to read that book for it.
- **namedWindow** is used for viewing images. See my manual for instructions on calling it.
  - In general, default string as input with original image size set. Else, use string as input name and 0 for adjustable size.

# Image I/O

- OpenCV provides simple and useful ways to read and write images.
- Note that there are many extra options to these commands which are available on the wiki.
- `waitKey( int x )` has two main features.
  - if  $x > 0$ , then `waitKey` will wait  $x$  milliseconds
  - if  $x = 0$ , then `waitKey` will not move until key is pressed

## • Examples

```
//Read an image
```

```
Mat image = imread( <string>, <0 -gray, 1 -BGR>)
```

```
//Note 1 is default
```

```
//Write an image
```

```
imwrite( <string filename> , image );
```

```
//Create window for output
```

```
namedWindow( <window name> );
```

```
//Output image to window
```

```
imshow( <window name> , <image Mat to show> );
```

```
//pause program for input
```

```
key = waitKey( 0 );
```

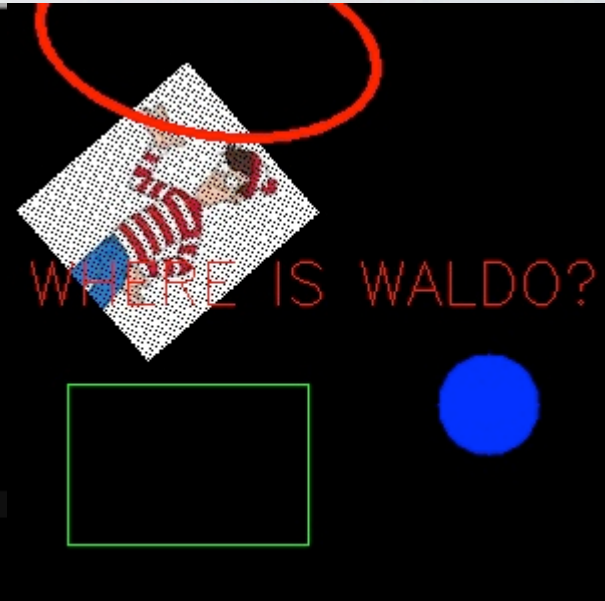


# DRAWING STUFF

- Sometimes it is necessary to draw stuff onto the image. Instead of using complicated functions, why not just call a simple function?
- Here are some simple examples...
- void **circle**(image, Point(x,y),int rad, CV\_BGR(b,g,r), int thickness=1)
- void **ellipse**(image, RotatedRect box, CV\_BGR(b,g,r), int thickness=1)
- void **line**(image, Point(x,y), Point(x,y), CV\_BGR(b,g,r), int thickness= 1)
- void **rectangle**(img, Point(x,y), Point(x,y), CV\_BGR(b,g,r), int thickness)
  - NOTE: negative thickness will fill in the rectangle
- MORE... [http://opencv.willowgarage.com/documentation/cpp/core\\_drawing\\_functions.html](http://opencv.willowgarage.com/documentation/cpp/core_drawing_functions.html)

# Drawing stuff

```
1 #include <cv.h>
2 #include <cvaux.h>
3 #include <highgui.h>
4
5 using namespace cv;
6
7 int main(int argc, char* argv[]){
8
9     Mat image(300,300,CV_8UC3);
10    Mat sub = imread(argv[1]);
11    float x,y;
12
13    //Project image onto new with 45deg rotation
14    for(int i=0;i<sub.rows;i++){
15        for(int j=0;j<sub.cols;j++){
16            x = (j+0)*cos(0.85398)-(i-0)*sin(0.85398);
17            y = (j+0)*sin(0.85398)+(i-0)*cos(0.85398);
18            if(x+90 >= 0 && y+30 >= 0 && x+90 < image.cols && y+30 < image.rows)
19                image.at<Vec3b>(y+30,x+90) = sub.at<Vec3b>(i,j);
20        }
21
22        //Draw an ellipse
23        RotatedRect rotrrect(Point(100,20),Size(90,170),101);
24        ellipse(image,rotrrect,Scalar(0,0,255),3);
25
26        //Draw a circle
27        circle(image,Point(240,200),25,Scalar(255,0,0,0),-1);
28
29        //Draw a box
30        rectangle(image,Point(30,190),Point(150,270),Scalar(0,255,0),1);
31
32        //Place Text
33        putText(image,"WHERE IS WALDO?",Point(10,150),FONT_HERSHEY_SIMPLEX,1,Scalar(0,0,255));
34
35        //Output
36        imwrite("image0.jpg",image);
37
38        return 0;
39    }
```



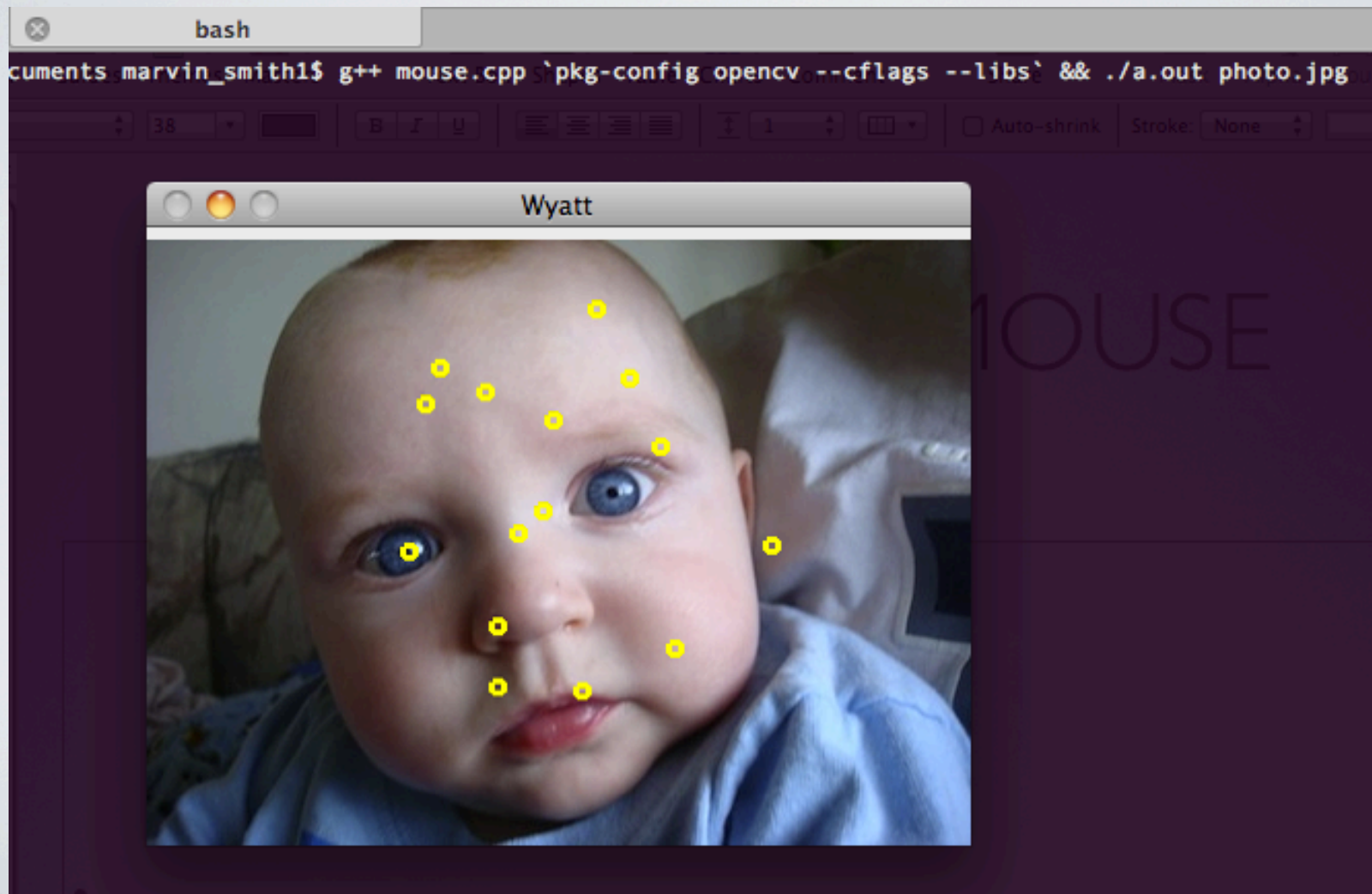


# Using the Mouse

- OpenCV allows you to use the mouse to interact with the screen. Note that this feature is from OpenCV 1.0 and is compatible with Mat objects.
- This program allows you to draw dots on the image.

```
7 struct OPTIONS{
8     OPTIONS(): X(-1),Y(-1),drawing_dot(false){}
9     int X;
10    int Y;
11    bool drawing_dot;
12 };
13 OPTIONS options;
14
15 void my_mouse_callback( int event, int x, int y, int flags, void* param ){
16     IplImage* image = (IplImage*) param;
17
18     switch( event ){
19
20         case CV_EVENT_LBUTTONDOWN:
21             options.X = x;
22             options.Y = y;
23             options.drawing_dot = true;
24             break;
25     }
26 }
27
28 int main(int argc, char* argv[]) {
29
30     IplImage* image = cvLoadImage(argv[1]);
31     Mat frame = imread(argv[1]);
32
33     namedWindow("Wyatt");
34     cvSetMouseCallback("Wyatt", my_mouse_callback, (void*) image);
35
36     //Take new points from user
37     while(cvWaitKey(15) != 27){
38         if( options.drawing_dot ){
39
40             circle(frame,Point(options.X,options.Y),3,CV_RGB(255,255,0),2);
41             options.drawing_dot = false;
42         }
43
44         imshow("Wyatt",frame);
45         waitKey(10);
46     }
47     cvReleaseImage(&image);
48
49     return 0;
}
```

# USING THE MOUSE





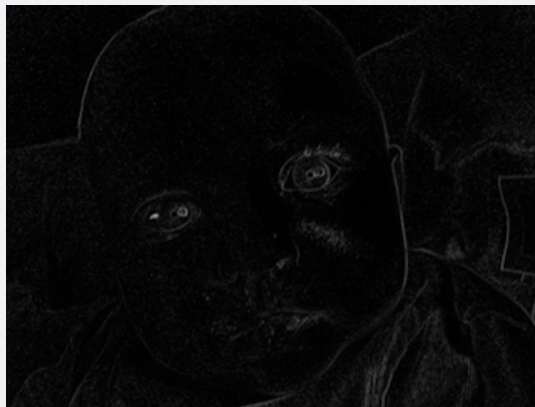
# Converting colorspace

- **cvtColor**( image, image, code)
  - Codes
    - CV\_<colorspace>2<colorspace>
  - Examples
    - **CV\_BGR2GRAY**
    - **CV\_BGR2HSV**
    - **CV\_BGR2LUV**

# Image Normalization

- **normalize**(imagein, imageout, low, high, method);
- Image normalization is the process of stretching the range of an image from [a, b] to [c, d].
- This is incredibly important for visualization because if the image is beyond [0,255] it will cause truncation or unsightly effects.

```
1 #include <cv.h>
2 #include <cvaux.h>
3 #include <highgui.h>
4
5 #include <iostream>
6
7 using namespace cv;
8 using namespace std;
9
10 int main(int argc, char* argv[]){
11
12     Mat image = imread(argv[1],0);
13     Mat data, dx, dy;
14     float pix;
15
16     imwrite("image_0.jpg",image);
17
18     image.convertTo(data,CV_32FC1);
19     data = data*4;
20
21     Sobel(data,dx,CV_32FC1,1,0);
22     Sobel(data,dy,CV_32FC1,0,1);
23
24     MatConstIterator_<float>dx_it    = dx.begin<float>();
25     MatConstIterator_<float>dx_it_end = dx.end<float>();
26     MatConstIterator_<float>dy_it    = dy.begin<float>();
27     MatIterator_<float> dst_it       = data.begin<float>();
28
29     for(; dx_it != dx_it_end; dst_it++,dx_it++,dy_it++){
30         *dst_it = sqrt(pow(*dx_it,2)+pow(*dy_it,2));
31     }
32
33     data.convertTo(image,CV_8UC1);
34     imwrite("image_1.jpg",image);
35
36     normalize(data,data,0,255,CV_MINMAX);
37     data.convertTo(image,CV_8UC1);
38     imwrite("image_2.jpg",image);
39
40     return 0;
41 }
```





# Thresholding

- `threshold( image, image, thresh, maxVal, CODE);`
- `CODE` - this is the method of thresholding. Different actions will be taken depending on this code.

- **THRESH\_BINARY**

$$\text{dst}(x, y) = \begin{cases} \text{maxVal} & \text{if } \text{src}(x, y) > \text{thresh} \\ 0 & \text{otherwise} \end{cases}$$

- **THRESH\_BINARY\_INV**

$$\text{dst}(x, y) = \begin{cases} 0 & \text{if } \text{src}(x, y) > \text{thresh} \\ \text{maxVal} & \text{otherwise} \end{cases}$$

- **THRESH\_TRUNC**

$$\text{dst}(x, y) = \begin{cases} \text{threshold} & \text{if } \text{src}(x, y) > \text{thresh} \\ \text{src}(x, y) & \text{otherwise} \end{cases}$$

- **THRESH\_TOZERO**

$$\text{dst}(x, y) = \begin{cases} \text{src}(x, y) & \text{if } \text{src}(x, y) > \text{thresh} \\ 0 & \text{otherwise} \end{cases}$$

- **THRESH\_TOZERO\_INV**

$$\text{dst}(x, y) = \begin{cases} 0 & \text{if } \text{src}(x, y) > \text{thresh} \\ \text{src}(x, y) & \text{otherwise} \end{cases}$$



# Edge Detection

- Sobel Edge Detection

`void cv::Sobel(image in, image out, CV_DEPTH, dx, dy);`

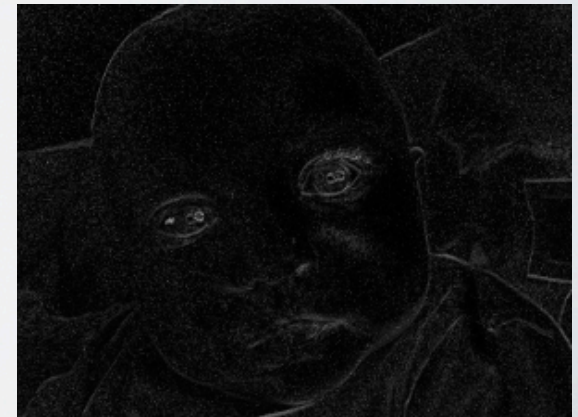
- Scharr Edge Detection

`void cv::Scharr(image in, image out, CV_DEPTH, dx, dy);`

- Laplacian Edge Detection

`void cv::Laplacian( image in, image out, CV_DEPTH);`

```
3 #include <cv.h>
4 #include <cvaux.h>
5 #include <highgui.h>
6
7 using namespace cv;
8
9 int main(){
10
11     Mat img = imread("photo.jpg",0);
12
13     imwrite("photo_gray.jpg",img);
14     Mat img_float;
15     img.convertTo(img_float,CV_32FC1);
16
17     Sobel(img_float,img_float,CV_32FC1,0,1);
18
19     Mat img_abs = abs(img_float);
20
21     normalize(img_float,img_float,0,255,CV_MINMAX);
22     normalize(img_abs ,img_abs ,0,255,CV_MINMAX);
23
24     img_float.convertTo(img,CV_8UC3);
25     imwrite("photo_float.jpg",img);
26     img_abs.convertTo(img,CV_8UC3);
27     imwrite("photo_abs.jpg",img);
28
29     return 0;
30 }
```

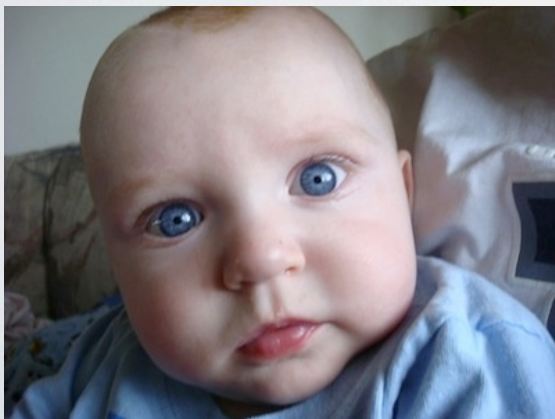




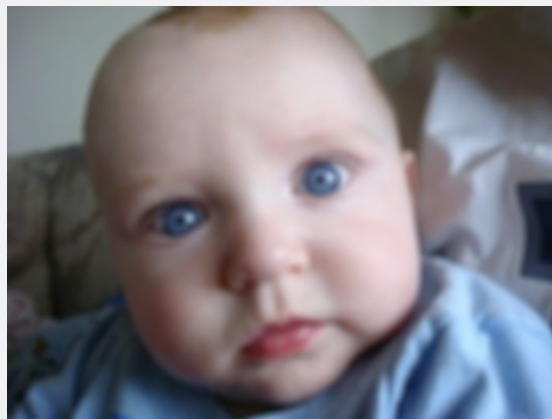
# Image Smoothing

- Image smoothing is used to reduce the sharpness of edges and detail in an image.
- OpenCV includes most of the commonly used methods.
- `void GaussianBlur(imagein, imageout, Size ksize, sig);`
  - *Note that there are more options, however this should keep things simple*
- `void medianBlur (imagein, imageout, Size ksize);`
- Other functions include generic convolution, separable convolution, dilate, and erode.

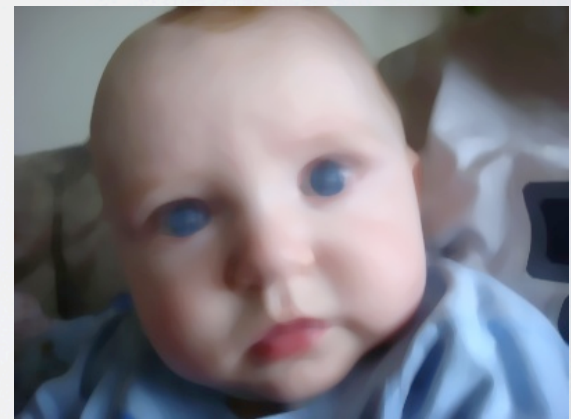
```
1 #include <cv.h>
2 #include <cvaux.h>
3 #include <highgui.h>
4
5 using namespace cv;
6
7 int main(int argc, char* argv[]){
8
9     Mat image = imread(argv[1],1);
10    Mat data1, data2;
11    imwrite("image0.jpg",image);
12
13    GaussianBlur(image,data1,Size(7,7),3);
14    medianBlur(image,data2,11);
15
16    imwrite("image1.jpg",data1);
17    imwrite("image2.jpg",data2);
18
19    return 0;
20 }
```



Original



Gaussian Blur



Median Blur

# STOP!

This is not relevant until the last part  
of the class.

## **Beware!**



# Linear Algebra

- OpenCV contains many useful and simple functions for applying linear algebra on images.
- Most major operators are allowed.
- operator `*` performs matrix multiplication, NOT elementwise multiplication.

## Operators

**given:** `Mat image;`

- **`image.inv()`**; //inverse
- **`image.t()`**; //transpose
- **`image.clone()`**; //creates deep copy
- **`image.diag(int d=0)`** //returns diagonal
- **`image.mul(mat, double)`**; //performs elementwise multiplication.
- **`image.cross(mat)`**; //performs cross product
- **`image.dot(mat)`**; //performs dot product
- **`image.eye()`**; //converts mat to identity matrix

# Singular Value Decomposition

## Example

given:

$$-11x + 2y = 0$$

$$2x + 3y = 7$$

$$2x - y = 5$$

- Singular Value Decomposition is a vital part of any computer vision based system. Luckily, OpenCV makes this a trivial task.
- To solve a least-squares problem, simply call the **solve** command.
- **bool solve(src1, src2, dst, int flags);**
- Usually, src1 is A, src2 is b, and dst is x. Remember flags is method...
- **DECOMP\_LU** - Fast but cannot solve over-determined systems.
- **DECOMP\_SVD** - SVD, can solve just about anything
- Others available, but stick to the basics...

```
//Main Driver
int main(){

    Mat data1(3,3,CV_32FC1);
    Mat data2(3,1,CV_32FC1);
    Mat results;

    //Matrix A
    data1.at<float>(0,0) = -11;
    data1.at<float>(0,1) = 2;
    data1.at<float>(1,0) = 2;
    data1.at<float>(1,1) = 3;
    data1.at<float>(2,0) = 2;
    data1.at<float>(2,1) = -1;

    //Matrix b
    data2.at<float>(0,0) = 0;
    data2.at<float>(1,0) = 7;
    data2.at<float>(2,0) = 5;

    solve(data1,data2,results,DECOMP_SVD);

    Print_Mat(results);

    return 0;
}
```



# SVD Results

- Using OpenCV

```
Marvin-Smiths-MacBook-Pro:Documents marvin_smith1$ g++ SVD.cpp `pkg-config opencv --libs --cflags`  
Marvin-Smiths-MacBook-Pro:Documents marvin_smith1$ ./a.out  
x = 0.421053  
y = 1.68421  
Marvin-Smiths-MacBook-Pro:Documents marvin_smith1$
```

- Using GNU Octave

```
octave:3> A = [-11 2; 2 3; 2 -1];  
octave:4> b = [0; 7; 5];  
octave:5>  
octave:5> A\b  
ans =  
  
    0.42105  
    1.68421  
octave:6>
```

# Principle Component Analysis

- Since you will need to learn this, I will include it. Although you will undoubtedly will have to create your own PCA program, OpenCV covers it very nicely.
- `PCA( Mat data, Mat mean, int FLAG, int numcomp=0)`
  - FLAG: `PCA_DATA_AS_ROW` / `PCA_DATA_AS_COL`
  - numcomp is the k value, 0 means all values retained
  - in general, just pass the vectors into data and the mean will be returned.
- `PCA.project( Mat vector)`
  - projects the vector into the built eigenspace and returns the result
- `PCA.backproject( Mat vector)`
  - reconstructs the vector from the principle component subspace



## Important Tips

- Remember that images are read from file as 8-bit unsigned integers. In order to do complicated math operations, convert to 32-bit floating point type. Then convert back to write to file.
- Always remember that rows is your y coordinate and that cols is your x coordinate. Size objects are called X,Y while images are referenced row, col. There are many subtle things that will ruin good code.