OpenCV 2.4 Cheat Sheet (C++)

The OpenCV C++ reference manual is here: `http://docs.opencv.org`. *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; x < 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.

Image Processsing

Filtering

filter2D()	Non-separable linear filter
sepFilter2D()	Separable linear filter
boxFilter(), GaussianBlur(), medianBlur(), bilateralFilter()	Smooth the image with one of the linear or non-linear filters
Sobel(), Scharr()	Compute the spatial image derivatives
Laplacian()	compute Laplacian: $\Delta I = \frac{\partial^2 I}{\partial x^2} + \frac{\partial^2 I}{\partial y^2}$
erode(), dilate()	Morphological operations

Example. Filter image in-place with a 3x3 high-pass kernel (preserve negative responses by shifting the result by 128):

```
filter2D(image, image, image.depth(), (Mat_<float>(3,3)<<
    -1, -1, -1, -1, 9, -1, -1, -1, -1), Point(1,1), 128);
```

Geometrical Transformations

resize()	Resize image
getRectSubPix()	Extract an image patch
warpAffine()	Warp image affinely
warpPerspective()	Warp image perspectively
remap()	Generic image warping
convertMaps()	Optimize maps for a faster remap() execution

Example. Decimate image by factor of $\sqrt{2}$:

```
Mat dst; resize(src, dst, Size(), 1./sqrt(2), 1./sqrt(2));
```

Various Image Transformations

cvtColor()	Convert image from one color space to another
threshold(), adaptivethreshold()	Convert grayscale image to binary image using a fixed or a variable threshold
floodFill()	Find a connected component using region growing algorithm
integral()	Compute integral image
distanceTransform()	build distance map or discrete Voronoi diagram for a binary image.
watershed(), grabCut()	marker-based image segmentation algorithms. See the samples watershed.cpp and grabcut.cpp.

Histograms

calcHist()	Compute image(s) histogram
calcBackProject()	Back-project the histogram
equalizeHist()	Normalize image brightness and contrast
compareHist()	Compare two histograms

Example. Compute Hue-Saturation histogram of an image:

```
Mat hsv, H;
cvtColor(image, hsv, CV_BGR2HSV);
int planes[]={0, 1}, hsize[] = {32, 32};
calcHist(&hsv, 1, planes, Mat(), H, 2, hsize, 0);
```

Contours

See contours2.cpp and squares.cpp samples on what are the contours and how to use them.

Data I/O

XML/YAML storages are collections (possibly nested) of scalar values, structures and heterogeneous lists.

Writing data to YAML (or XML)

```
// Type of the file is determined from the extension
FileStorage fs("test.yml", FileStorage::WRITE);
fs « "i" « 5 « "r" « 3.1 « "str" « "ABCDEFGH";
fs « "mtx" « Mat::eye(3,3,CV_32F);
fs « "mylist" « "[" « CV_PI « "1+1" «
   "{:" « "month" « 12 « "day" « 31 « "year"
   « 1969 « "}" « "]";
fs « "mystruct" « "{" « "x" « 1 « "y" « 2 «
   "width" « 100 « "height" « 200 « "lbp" « "[:";
const uchar arr[] = {0, 1, 1, 0, 1, 1, 0, 1};
fs.writeRaw("u", arr, (int)(sizeof(arr)/sizeof(arr[0])));
fs « "]" « "}";
```

Scalars (integers, floating-point numbers, text strings), matrices, STL vectors of scalars and some other types can be written to the file storages using « operator

Reading the data back

```
// Type of the file is determined from the content
FileStorage fs("test.yml", FileStorage::READ);
int i1 = (int)fs["i"]; double r1 = (double)fs["r"];
string str1 = (string)fs["str"];
Mat M; fs["mtx"] » M;
FileNode tl = fs["mylist"];
CV_Assert(tl.type() == FileNode::SEQ && tl.size() == 3);
double tl0 = (double)tl[0]; string tl1 = (string)tl[1];
int m = (int)tl[2]["month"], d = (int)tl[2]["day"];
int year = (int)tl[2]["year"];
FileNode tm = fs["mystruct"];
Rect r; r.x = (int)tm["x"], r.y = (int)tm["y"];
r.width = (int)tm["width"], r.height = (int)tm["height"];
int lbp_val = 0;
FileNodeIterator it = tm["lbp"].begin();
for(int k = 0; k < 8; k++, ++it)
   lbp_val |= ((int)*it) « k;
```

Scalars are read using the corresponding FileNode's cast operators. Matrices and some other types are read using » operator. Lists can be read using FileNodeIterator's.

Writing and reading raster images

```
imwrite("myimage.jpg", image);
Mat image_color_copy = imread("myimage.jpg", 1);
Mat image_grayscale_copy = imread("myimage.jpg", 0);
```

*The functions can read/write images in the following formats: **BMP (.bmp), JPEG (.jpg, .jpeg), TIFF (.tif, .tiff), PNG (.png), PBM/PGM/PPM (.p?m), Sun Raster (.sr), JPEG 2000 (.jp2)**. Every format supports 8-bit, 1- or 3-channel images. Some formats (PNG, JPEG 2000) support 16 bits per channel.*

Reading video from a file or from a camera

```
VideoCapture cap;
if(argc > 1) cap.open(string(argv[1])); else cap.open(0);
Mat frame; namedWindow("video", 1);
for(;;) {
   cap » frame; if(!frame.data) break;
   imshow("video", frame); if(waitKey(30) >= 0) break;
}
```

Simple GUI (highgui module)

namedWindow(winname,flags)	Create named highgui window
destroyWindow(winname)	Destroy the specified window
imshow(winname, mtx)	Show image in the window
waitKey(delay)	Wait for a key press during the specified time interval (or forever). Process events while waiting. *Do not forget to call this function several times a second in your code.*
createTrackbar(...)	Add trackbar (slider) to the specified window
setMouseCallback(...)	Set the callback on mouse clicks and movements in the specified window

See camshiftdemo.cpp and other OpenCV samples on how to use the GUI functions.

Camera Calibration, Pose Estimation and Depth Estimation

calibrateCamera()	Calibrate camera from several views of a calibration pattern.
findChessboardCorners()	Find feature points on the checkerboard calibration pattern.
solvePnP()	Find the object pose from the known projections of its feature points.
stereoCalibrate()	Calibrate stereo camera.
stereoRectify()	Compute the rectification transforms for a calibrated stereo camera.
initUndistortRectifyMap()	Compute rectification map (for remap()) for each stereo camera head.
StereoBM, StereoSGBM	The stereo correspondence engines to be run on rectified stereo pairs.
reprojectImageTo3D()	Convert disparity map to 3D point cloud.
findHomography()	Find best-fit perspective transformation between two 2D point sets.

To calibrate a camera, you can use calibration.cpp or stereo_calib.cpp samples. To get the disparity maps and the point clouds, use stereo_match.cpp sample.

Object Detection

matchTemplate	Compute proximity map for given template.
CascadeClassifier	Viola's Cascade of Boosted classifiers using Haar or LBP features. Suits for detecting faces, facial features and some other objects without diverse textures. See facedetect.cpp
HOGDescriptor	N. Dalal's object detector using Histogram-of-Oriented-Gradients (HOG) features. Suits for detecting people, cars and other objects with well-defined silhouettes. See peopledetect.cpp