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`