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|     Introduction to OpenCV
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>>> What is OpenCV?

* Open Source project on GitHub with >1M downloads per year.
  https://github.com/opencv/opencv

* The most popular computer vision library with 20 years of history

* Has modular structure: core, imgproc, calib3d, dnn, stiching, ...

* Written in C++ but has automatic wrappers in Python, Java, JavaScript, Matlab, GO, PHP

* Cross-platform and well optimized for R&D

>>> OpenCV basic structures

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* cv::Mat – images, masks, vector fields, complex values, any data

```
  cv::Mat mat(480, 640, CV_8UC3);
  int rows      = mat.rows;         // 480
  int cols      = mat.cols;         // 640
  int channels  = mat.channels();   // 3
  uint8_t* data = mat.data;
```

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* cv::Mat types: depth (CV_8U, CV_16F, CV_32F, CV_64F) + number of channels:

```
  CV_8U + C + 3 = CV_8UC3
```

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* std::cout << mat << std::endl;   - To print cv::Mat in console

>>> OpenCV basic structures

```
+-------------------------+-------------------------+-------------------------+
| * cv::Rect rect;        | * cv::Point point;      | * cv::Size size;        |
|   int x = rect.x;       |   int x = point.x;      |   int w = size.width;   |
|   int y = rect.y;       |   int y = point.y;      |   int h = size.height;  |
|   int w = rect.width;   |                         |                         |
|   int h = rect.height;  |                         |                         |
+-------------------------+-------------------------+-------------------------+
| * Region of interest (ROI)                          [1, 1, 1,  [1, 1, 1,  |
|   cv::Mat mat = cv::Mat::ones(5, 3, CV_8UC1);        1, 1, 1,   5, 5, 1,  |
|   std::cout << mat << std::endl;                     1, 1, 1,   5, 5, 1,  |
|                                                      1, 1, 1,   5, 5, 1,  |
|   cv::Mat roi = mat(cv::Rect(/*xywh*/ 0, 1, 2, 3));  1, 1, 1]   1, 1, 1]  |
|   roi.setTo(5);                                                           |
|   std::cout << mat << std::endl;                                          |
+---------------------------------------------------------------------------+
```

>>> IO

```
---- Read image from file ------------------------------------------------
cv::Mat image = cv::imread("C:\\Users\\dkurtaev\\Pictures\\example.jpg");

---- Read frames from a camera ---+---- Visualize an image ----------------
cv::Mat frame;                    | cv::namedWindow("My image", cv::WINDOW_NORMAL);
cv::VideoCapture cap(0);          | cv::imshow("My image", image);
cap >> frame;                     | cv::waitKey();
                                  |
---- Write image to the file -----+
cv::Mat mat(480, 640, CV_8UC3);   |
cv::randu(mat, 0, 255);           |
cv::imwrite("output.png", mat);   |
```

>>> Drawings

```
cv::rectangle(image,
              cv::Point(37, 357),       // left-top corner
              cv::Point(196, 408),      // right-bottom corner
              cv::Scalar(0, 255, 0));   // color (BGR)

cv::circle(image,
           cv::Point(37, 357),      // center
           15,                      // radius
           cv::Scalar(255, 0, 0),   // color (BGR)
           cv::FILLED);             // thickness

cv::putText(image, "Matreshka",
            cv::Point(0, 20),           // position
            cv::FONT_HERSHEY_SIMPLEX,   // font
            0.5,                        // scale
            cv::Scalar(0, 255, 255));   // color (BGR)
```

>>> Methods

* Image2Image

```
cv::Mat src, dst, mask;

cv::resize(src, dst, cv::Size(1280, 960));

cv::Canny(src, dst, /*threshold1*/ 100, /*threshold2*/ 200);

cv::inpaint(src, mask, dst, /*inpaintRadius*/ 3, cv::INPAINT_TELEA);

std::vector<cv::Mat> images;
cv::Ptr<Stitcher> stitcher = cv::Stitcher::create(cv::Sticher::PANORAMA);
stitcher->stitch(images, dst);
```

>>> Methods

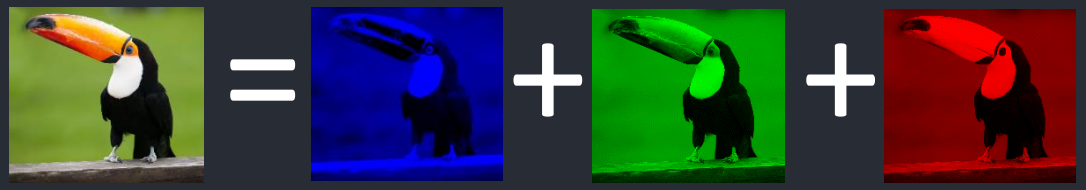
* Image2Data

```
  cv::Mat image;

  std::vector<std::vector<cv::Point> > contours;
  cv::findContours(image, contours, cv::RETR_EXTERNAL, cv::CHAIN_APPROX_SIMPLE);
-------------------------------------------------------------------------------
  std::vector<std::vector<cv::Point2f > > corners;
  std::vector<int> ids;
  auto dictionary = cv::aruco::getPredefinedDictionary(cv::aruco::DICT_6X6_250);

  cv::aruco::detectMarkers(image, dictionary, corners, ids);
```

>>> Image processing



```
cv::Mat src = cv::imread("example.jpg");  // src.data = BGRBGR...BGR
cv::Mat dst(src.size(), CV_8UC1);

for (int y = 0; y < src.rows; ++y) {
  for (int x = 0; x < src.cols; ++x) {
    cv::Vec3b bgr = src.at<cv::Vec3b>(y, x);
    uint8_t gray = (29 * bgr[0] + 150 * bgr[1] + 77 * bgr[2]) >> 8;
    dst.at<uint8_t>(y, x) = gray;
  }
}

cv::imshow("grayscale", dst);
cv::waitKey();
```

>>> Modules

* opencv

  core, imgcodecs, imgproc, videoio, highgui
  gapi
  photo, stitching
  features2d, calib3d
  flann, ml, dnn
  objdetect
  video

* opencv_contrib

  aruco, bgsegm, img_hash, optflow, quality, rgbd, and many more

>>> Installation (Windows)

* Go to https://github.com/opencv/opencv/releases and download "opencv-4.1.0-vc14_vc15.exe"
* Unpack the library (double click or [right mouse button] -> [app] -> [Extract])
  Structure:

```
|-- opencv
    |-- build
        |-- include
        |-- x64
            |-- vc14
                |-- bin & lib
            |-- vc15
                |-- bin & lib
    |-- sources
```

>>> Hello World! (Windows)

* Create project (Microsoft Visual Studio)
  * [File] -> [New] -> [Project] -> [Win32 Console Application]
  * Enable "Empty project" option. Switch to Release mode and x64 platform

* Add OpenCV dependency
  * [Project] -> [Properties] -> [C/C++] -> [General]
  * [Additional Include Directories]: set path to "opencv\build\include"
  * [Project] -> [Properties] -> [Liner] -> [General]
  * [Additional Library Directories]: set path to "opencv\build\x64\vc15\lib"
  * [Project] -> [Properties] -> [Liner] -> [Input]
  * [Additional Dependencies]: add "opencv_world410.lib"
  * Copy "opencv\build\x64\vc15\bin\opencv_world410.dll" to "project\x64\Release"

>>> Hello World! The simplest eyes detector

```cpp
#include <opencv2/opencv.hpp>

int main(int argc, char** argv) {
    cv::VideoCapture cap(0);
    cv::Mat frame, gray;
    while (cv::waitKey(1) < 0) {
        cap >> frame;
        if (frame.empty())
            break;

        cv::cvtColor(frame, gray, cv::COLOR_BGR2GRAY);

        double minVal;
        cv::Point minLoc;

        cv::minMaxLoc(gray, &minVal, 0, &minLoc);
        cv::circle(frame, minLoc, 10, cv::Scalar(0, 255, 0), cv::FILLED);

        // Exclude found point area from the search.
        cv::circle(gray, minLoc, 50, 255, cv::FILLED);

        cv::minMaxLoc(gray, &minVal, 0, &minLoc);
        cv::circle(frame, minLoc, 10, cv::Scalar(0, 255, 0), cv::FILLED);

        cv::imshow("frame", frame);
    }
    return 0;
}
```