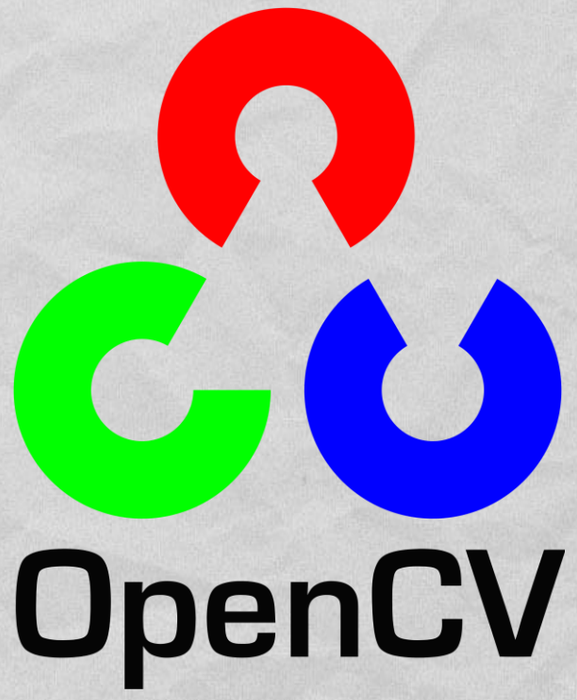
EMBEDDED SYSTEMS PROGRAMMING 2015-16

OpenCV

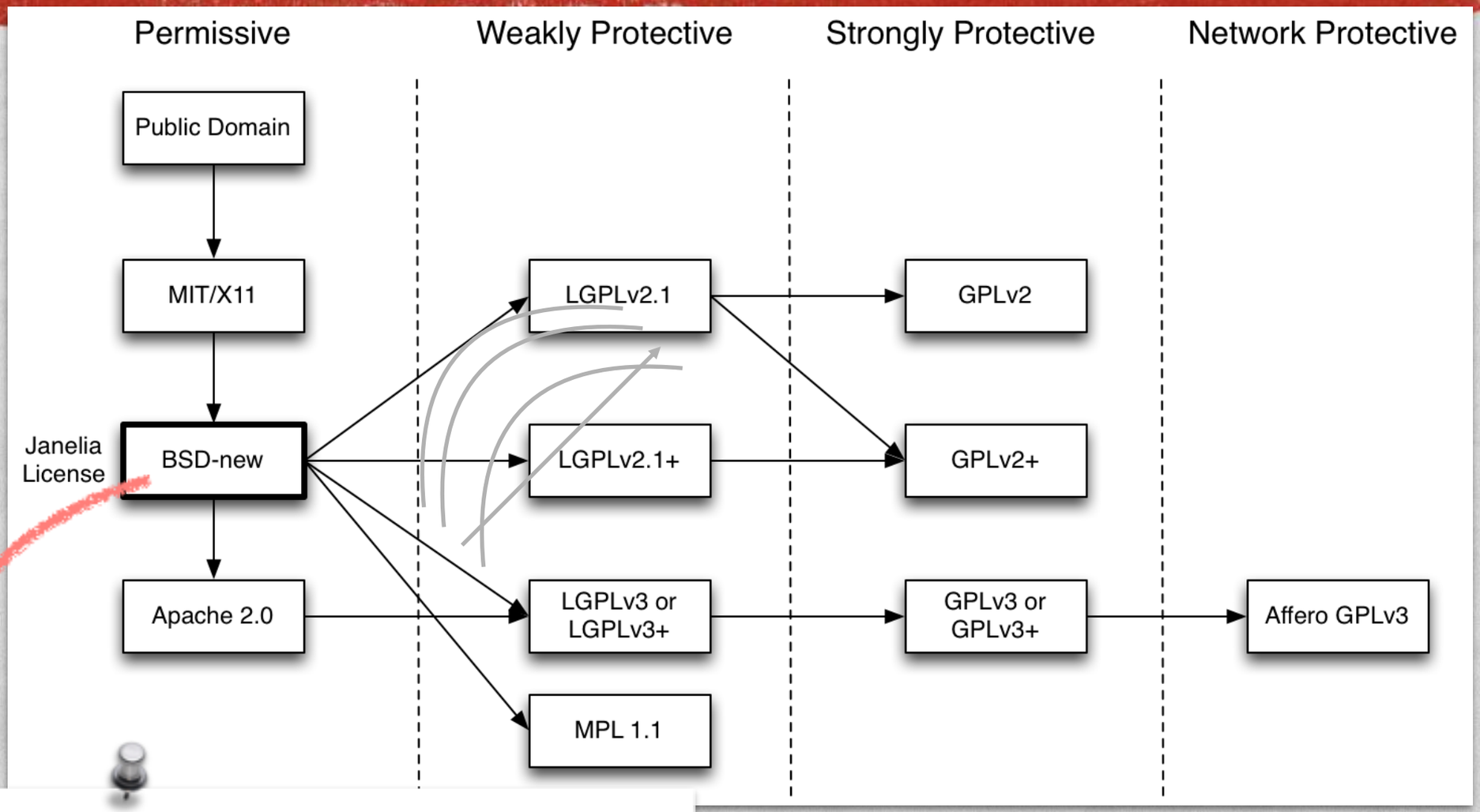
OPENCV 3.1

- "OpenCV" = "Open Computer Vision":
  library of computer vision algorithms,
  free and open source



- Cover machine learning as well
- Supports Windows, Mac OS, Linux,
  Android, iOS
- Written C++;
  additional interfaces for C, Python, Java, MATLAB

OPENCV: LICENSE (1/2)




```
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```

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OPENCV: APPLICATIONS

- Facial recognition
- Gesture recognition and human-computer interaction in general
- Augmented reality
- Motion tracking
- Mobile robotics

OPENCV: MODULES (1/5)

- **core**: contains all of the basic object types and their basic operations
- **imgproc**: basic transformations on images, filters and convolutional operators
- **highgui**: platform-independent GUI and media I/O functions to read/display images, or to get user input
- **video**: motion analysis and object tracking
- **calib3d**: camera calibration and 3D reconstruction

OPENCV: MODULES (2/5)

- **features2d**: algorithms for detecting, describing and matching keypoint features
- **objdetect**: algorithms for detecting specific objects (requires training)
- **ml**: algorithms for statistical classification, regression and clustering of data
- **flann**: clustering and search in multi-D spaces (mostly used by other OpenCV modules)

OPENCV: MODULES (3/5)

- **photo**: computational photography (inpainting, image denoising)
- **stitching**: image stitching pipeline
- **superres**: a few algorithms to enhance image resolution by exploiting the information in multiple frames
- **viz**: functions for 3D visualization

OPENCV: MODULES (4/5)

- **gpu**: CUDA-accelerated computer vision
- **ocl**: OpenCL-accelerated computer vision
- **contrib**: contributed/experimental functionality
- **nonfree**: non-free (e.g., patented) functionality
- **legacy**: deprecated functionality

OPENCV: MODULES (5/5)

- **imgcodecs**: image file reading and writing
- **videoio**: media I/O
- **videostab**: video stabilization
- **cuda*** (**cudaarithm**, **cudafilters**, **cudaimgproc**, …): further CUDA-accelerated functions

OPENCV: EXTRA MODULES (1/4)

- **aruco**: detection of ArUco fiducial markers
- **bgsegm**: improved background-foreground segmentation methods
- **bioinspired**: biologically inspired vision models and tools
- **ccalib**: custom calibration pattern for 3D reconstruction
- **cvv**: GUI for interactive visual debugging
- **datasets**: framework for manipulating datasets (loading data, evaluating different algorithms, etc.)

OPENCV: EXTRA MODULES (2/4)

- **dnn**: Deep Neural Network module
- **dpm**: object detection with Deformable Part-based Models
- **lsface**: face recognition algorithms
- **fuzzy**: image processing based on fuzzy mathematics
- **hdf**: Hierarchical Data Format I/O routines
- **line_descriptor**: binary descriptors for lines extracted from an image
- **matlab**: MATLAB bridge

OPENCV: EXTRA MODULES (3/4)

- **optflow**: optical flow algorithms
- **plot**: plot functions for matrix (`Mat`) data
- **reg**: image registration algorithms
- **rgbd**: RGB+Depth processing
- **saliency**: algorithms for the detection of salient objects
- **sfm**: Structure From Motion algoritms
- **stereo**: algorithms for computing stereo correspondence
- **structured_light**: structured light API

OPENCV: EXTRA MODULES (4/4)

- **surface_matching**: 3D object recognition
- **text**: text detection and recognition
- **tracking**: long-term object tracking API
- **xfeatures2d**: experimental and non-free 2D features
- **ximgproc**: additional image processing algorithms
- **xobjdetect**: additional object detection algorithms
- **xphoto**: additional photo processing algorithms

CORE

- **Data structures** (points, arrays, matrices…)
- **Operations on data structures**
  including DCT, DFT, sorting, PCA, SVD, eigenvalues, eigenvectors
- **Clustering, partitioning**
- **Drawing functions**
- **XML/YAML file storage**

COMMON DATA TYPES

- **`Point`**: 2-D point
- **`Point3`**: 3-D point
- **`Scalar`**: 4-element vector
- **`Mat`**: *n*-dimensional dense array
  (i.e., *n*-dimensional dense matrix)

- In C++ they are template classes,
  in Java elements are doubles

IMGPROC (1/3)

- **Image filtering**
  - Blur, smooth, noise reduction, erosion/dilation
  - Computing image derivatives, edge detection
  - Convolution with a kernel
- **Image transformations**
  - Affine transform, perspective transform, resize
  - Rectification, compensation of lens distortion
  - Linear-polar space conversion, color space conversion
  - Flood fill, thresholding, image segmentation

IMGPROC (2/3)

- Histograms
- Structural analysis and shape descriptors
  - Contours: detection, calculation of lengths and areas
  - Image moments
  - Approximation of a polygonal curve
  - Fit with a line, bounding box, convex hull, circle, ellipse

IMGPROC (3/3)

- **Motion analysis and object tracking**
  - Accumulation of images (with weights)
  - Phase correlation
- **Feature and object detection**
  - Corner detection
  - Edge detection
  - Detection of lines and circles
  - Detection of an arbitrary template

HIGHGUI

- **Reading/writing image and video files**
  Several image formats: BMP, DIB, JPG, J2K, PNG, TIFF, PBM, … Supported video codecs are platform-dependent.
  Images are read from / stored to matrices

- **Video capturing** from cameras

- **GUI functions for windows and mouse**

VIDEO

- **Optical flow**
- **Rigid transform estimation**
- **Motion estimation** of a given silhouette
- **Motion splitting** into separate independent motions
- **Background/foreground segmentation**

FEATURES2D

- **Common data structures**
  E.g., the `KeyPoint` class: models a salient point
- **Feature detection** (several algorithms)
- **Blob detection**

OBJDETECT

- **Haar feature-based cascade of boosted classifiers**
- **Discriminatively trained latent SVM**

- Both detectors require training
- Both must must be applied repeatedly to the image at different positions and scales

ML (1/3)

- **Normal Bayes classifier**
  Assumes that feature vectors from each class are normally distributed

- **K-nearest neighbors** (K-NN)
  Classification outcome is determined by analyzing *K* of the nearest neighbors of the sample

- **Support vector machine** (SVM)
  Both 2-class and *n*-class (*n*≥2) datasets are supported

ML (2/3)

- **Expectation maximization** (EM)
  Iterative algorithm for maximum-likelihood estimates

- **Neural network**
  Feed-forward multi-layer neural network.
  Three common activation functions are supported

- **Decision tree**
  Both ordered and categorical variables are possible

ML (3/3)

- **Random trees, extremely randomized trees**
  Ensemble classifiers based on decision trees

- **Boosting**
  ML technique to addresses misclassified instances with a multi-step training procedure

- **Gradient boosted trees**
  Classification algorithm based on decision trees and boosting. *n*-class ($n \geq 2$) datasets are supported

OPENCV 3.1 & ANDROID (1/2)

- Only a subset of modules mapped to Java packages: **calib3d, core, features2d, imgcodecs, imgproc, ml, objdetect, photo, video, videoio**
- Only a subset of algorithms/functions in such modules
- Additional **utils** package for data types conversion. Additional **android** package: more about it later
- Documentation is lacking. Official distribution and samples still target the Eclipse IDE

CORE CLASS

- Available only in Java
- Part of the `core` package
- Collects, as static members, a large set of C++ functions for the manipulation of `Mat`s

CORE CLASS: EXAMPLES

- Basic, **element-wise operations**
  (e.g., calculating the absolute value of all `Mat` elements)
- **Matrix operations**
  (calculating determinant, eingenvalues, PCA, SVD, …)
- **Operations on pairs of `Mats`** (e.g., adding)
- **Transforms** (e.g., DCT, DFT)
- **“Image” operations** (e.g., flip a matrix along a row/column)

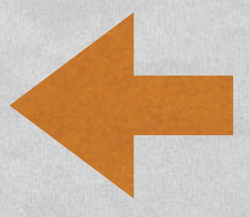
OPENCV 3.1 & ANDROID (2/2)

- **android** module
  - Interfaces and classes for initialization (more on initialization later)
  - Interfaces and classes to interact with the camera
  - `Utils` class for `mat` ↔ `Bitmap` conversion
  - `FpsMeter` class to calculate FPS and display result

- If the Java interface is limiting you, switch to the NDK and access the full-fledged OpenCV

ANDROID: INITIALIZATION

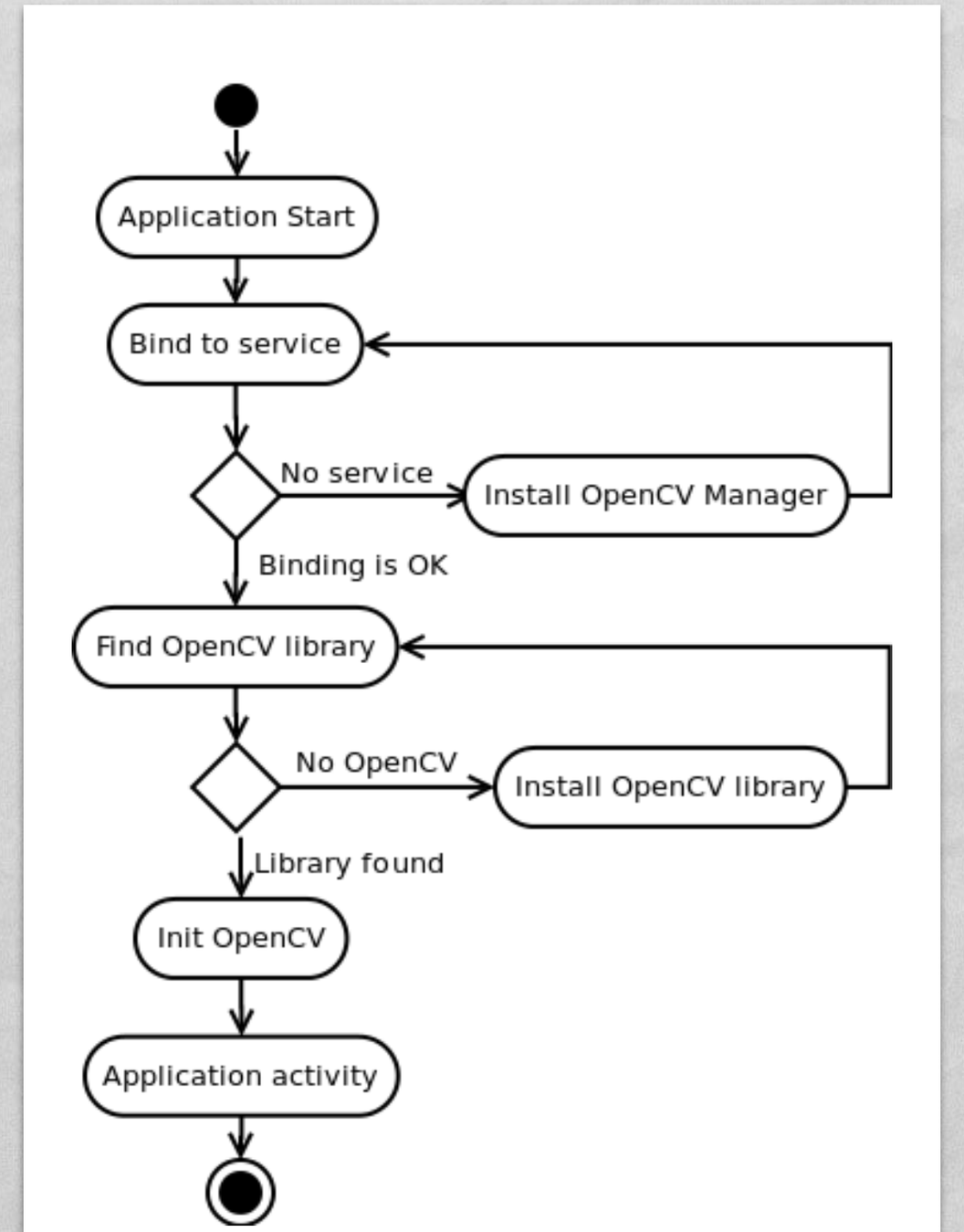
- **Static**: the app package contains all OpenCV binaries (actually, several copies of them: one for each supported platform)
  - Uses tens of MBs per app
  - App update required when a new OpenCV version is out
- **Dynamic**: OpenCV binaries contained in the auxiliary app **OpenCV Manager**



OPENCV MANAGER

- Contains all versions of OpenCV;
  automatic HW acceleration on supported platforms
- Supports both Java and native code
- Must be installed separately
- Available in the Play Store
  and in the OpenCV distribution package

INIT WITH OCV MANAGER



OPENCVLOADER CLASS

- Java class providing common initialization methods

- **`static boolean initDebug()`**
  Static initialization

- **`static boolean initAsync(String Version, Context AppContext, LoaderCallbackInterface Callback)`**
  Dynamic initialization with OpenCV version `version`. Returns true if initialization started successfully

LOADERCALLBACKINTERFACE

- Java interface that specifies how initialization must be managed

- **`void onManagerConnected(int status)`**
  Called after an attempt to connect to OpenCV Manager has been made. The initialization status can be `SUCCESS`, `INCOMPATIBLE_MANAGER_VERSION`, `INSTALL_CANCELED`, `MARKET_ERROR`, `INIT_FAILED`

- **`void onPackageInstall(InstallCallbackInterface Callback)`**
  Called when package installation is needed

BASELOADERCALLBACK CLASS

- Java class implementing `LoaderCallbackInterface`

- Designed to work inside an activity;
  use inside a service requires modifications

- Calls `Activity.finish()` method to exit in case of initialization failure

INIT: EXAMPLE (1/2)

```
public class MyActivity extends Activity implements LoaderCallbackInterface
{
private BaseLoaderCallback mOpenCVCallBack = new BaseLoaderCallback(this)
{
    @Override
    public void onManagerConnected(int status)
    {
        switch (status)
        {
         case LoaderCallbackInterface.SUCCESS:
         {
             Log.i(TAG, "OpenCV loaded successfully");
             // Create and set View
             mView = new puzzle15View(mAppContext);
             setContentView(mView);
          } break;
          default:
          {
             super.onManagerConnected(status);
          } break;
        }
    }
};
```

INIT: EXAMPLE (2/2)

```
/** Call on every application resume **/
@Override
protected void onResume()
{
    Log.i(TAG, "Called onResume");
    super.onResume();

    Log.i(TAG, "Trying to load OpenCV library");
    if (!OpenCVLoader.initAsync(OpenCVLoader.OPENCV_VERSION_2_4_6,
        this, mOpenCVCallBack))
    {
        Log.e(TAG, "Cannot connect to OpenCV Manager");
    }
}
```

REFERENCES

- OpenCV C++ API reference
- OpenCV Java API reference (includes Android-specific classes)
- Android Development with OpenCV
- OpenCV 2.4 cheat sheet (C++)

LAST MODIFIED: APRIL 29, 2016