OpenCV Java Tutorials Documentation

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CHAPTER 1

Installing OpenCV for Java

Introduction to OpenCV for Java.

As of OpenCV 2.4.4, OpenCV supports desktop Java development. This tutorial will help you install OpenCV on your desktop SO.

Install the latest Java version.

Download the latest Java JDK at the Oracle link. Now you should be able to install the last Java JDK by open the file just downloaded.

Install the latest Eclispe version.

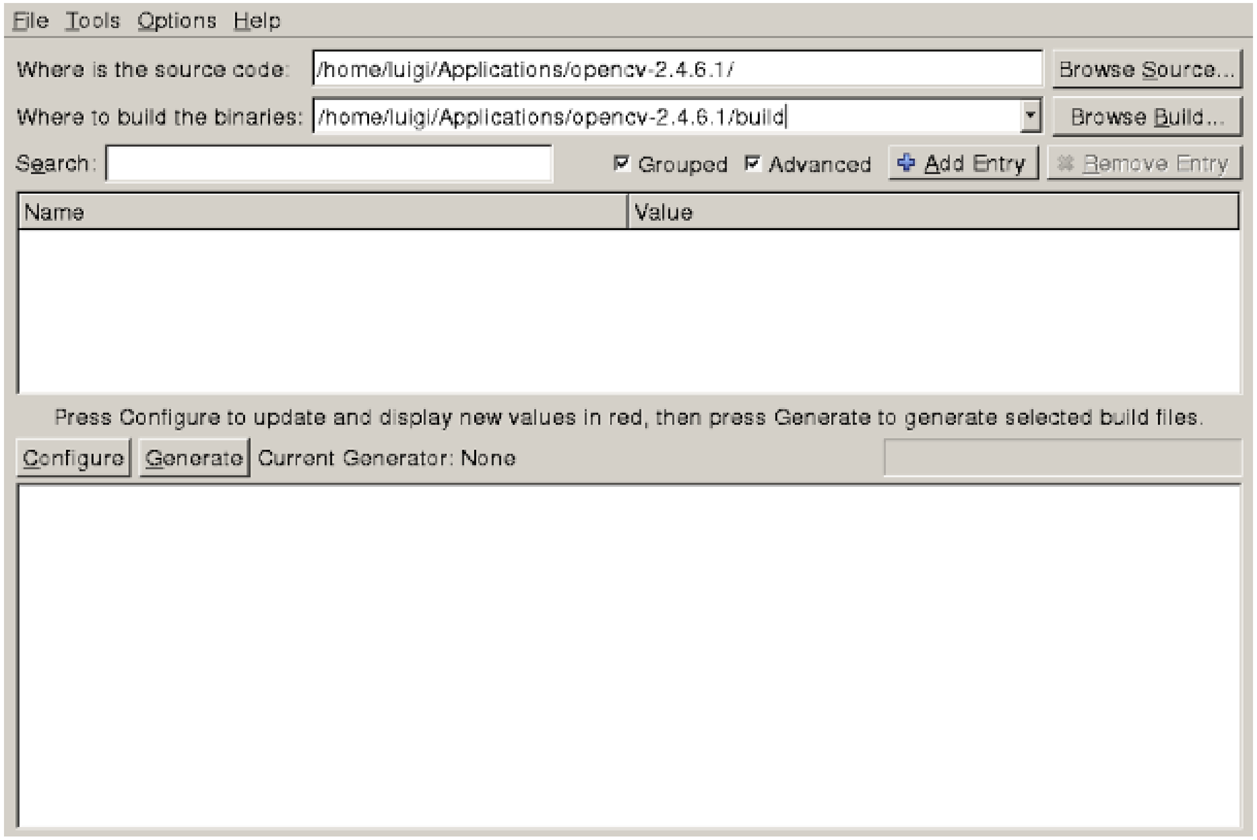
Download the latest Eclipse version at the Eclipse Download page choosing the `Eclipse IDE for Java Developers` version (suggested). Put the downloaded folder wherever you want to. You don't need to install anything.

Install Open CV 2.4.6 under Windows.

First of all you should download the OpenCV library (version 2.4.6) from here. Once you get the folder `opencv` put in wherever you prefer. Now the only two things you will need are: the `opencv-246.jar` file located at `\opencv\build\java` and the dll library located at `\opencv\build\java\x64` (for 64-bit systems) or `\opencv\build\java\x86` (for 32-bit systems). If not present create a `data` folder under `\opencv`.

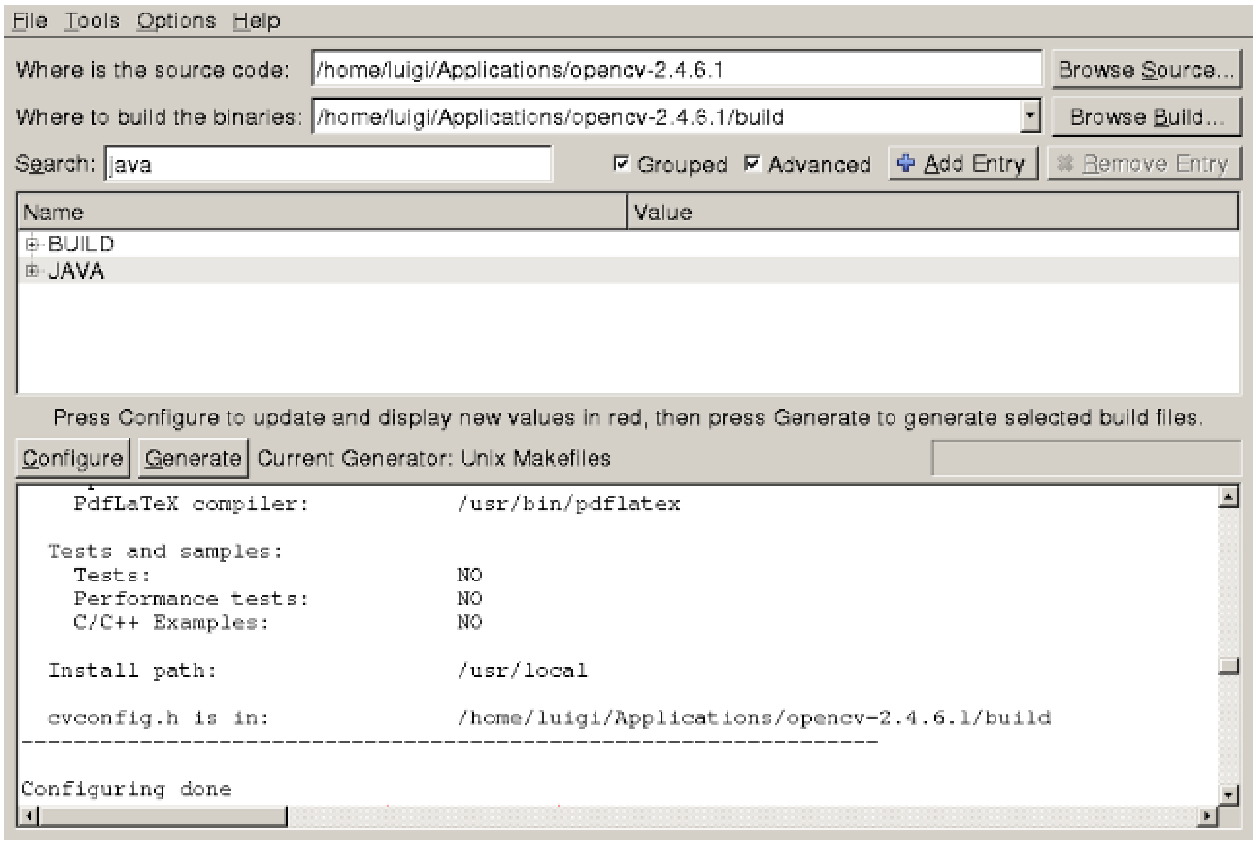
Install Open CV 2.4.6 under Linux or Mac.

The following instructions are useful if you wan to compile OpenCV under Windows. As first step, if you don't have these already, download and install CMake and Apache Ant. Extract the downloaded OpenCV file in a location of your choice and open CMake (cmake-gui). Put the location of the extracted OpenCV library in the `Where is the source code field` (e.g., /opencv2.4.6.1/) and put the destination directory of your build in the `Where to build the binaries` field (e.g., /opencv2.4.6.1/build), at last, check the `Grouped` and `Advanced` checkboxes.


Where is the source code: /home/luigi/Applications/opencv-2.4.6.1/
Where to build the binaries: /home/luigi/Applications/opencv-2.4.6.1/build
☑ Grouped ☑ Advanced
Press Configure to update and display new values in red, then press Generate to generate selected build files.
Current Generator: None

Now press `Configure` and use the default compilers for `Unix Makefiles`. In the `Ungrouped Entries` group, insert the path to the Apache Ant executable (e.g., `/apacheant1.9.2/bin/ant`). In the `BUILD` group, unselect: * `BUILD_PERF_TESTS`. * `BUILD_SHARED_LIBRARY` to make the Java bindings dynamic library all-sufficient. * `BUILD_TESTS`. * `BUILD_opencv_python`.

In the `CMAKE` group, set to `Debug` (or `Release`) the `CMAKE_BUILD_TYPE` In the `JAVA` group: insert the Java AWT include path (e.g., `/usr/lib/jvm/java7oracle/include/`) insert the Java include path (e.g., `/usr/lib/jvm/java7oracle/include/`) insert the alternative Java include path (e.g., `/usr/lib/jvm/java7oracle/include/linux`) Once we have pressed `Generate` twice the CMake window should appear with a white background. Now close CMake.



Where is the source code: /home/luigi/Applications/opencv-2.4.6.1

Where to build the binaries: /home/luigi/Applications/opencv-2.4.6.1/build

Search: java

Press Configure to update and display new values in red, then press Generate to generate selected build files.

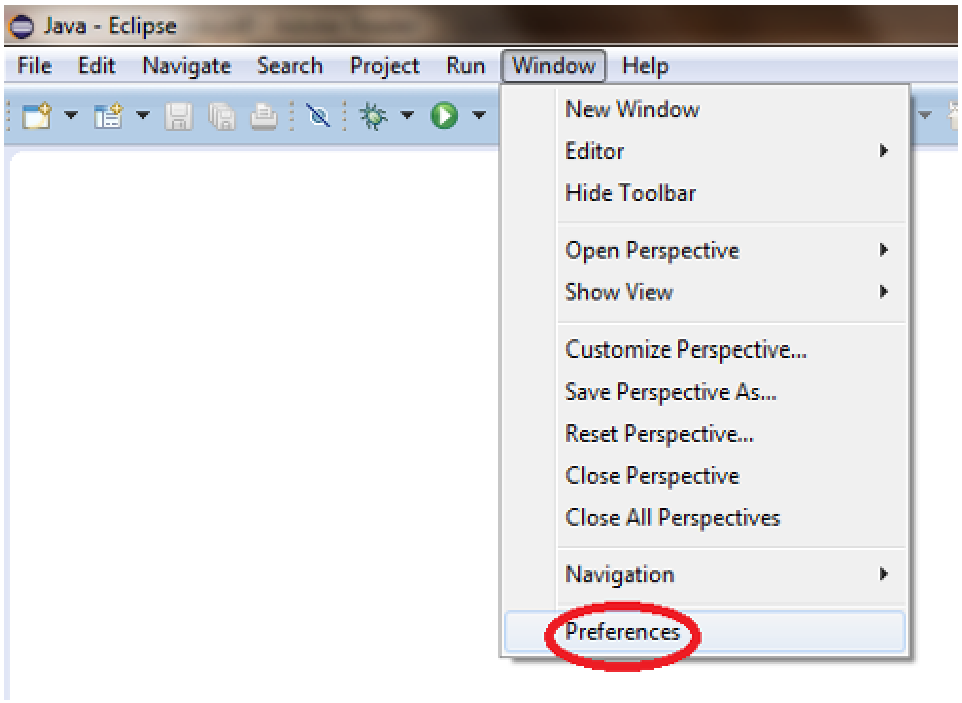
Current Generator: Unix Makefiles

```
    PdfLaTeX compiler:            /usr/bin/pdflatex

  Tests and samples:
    Tests:                        NO
    Performance tests:            NO
    C/C++ Examples:               NO

  Install path:                   /usr/local

  cvconfig.h is in:               /home/luigi/Applications/opencv-2.4.6.1/build
-----------------------------------------------------------------

Configuring done
```

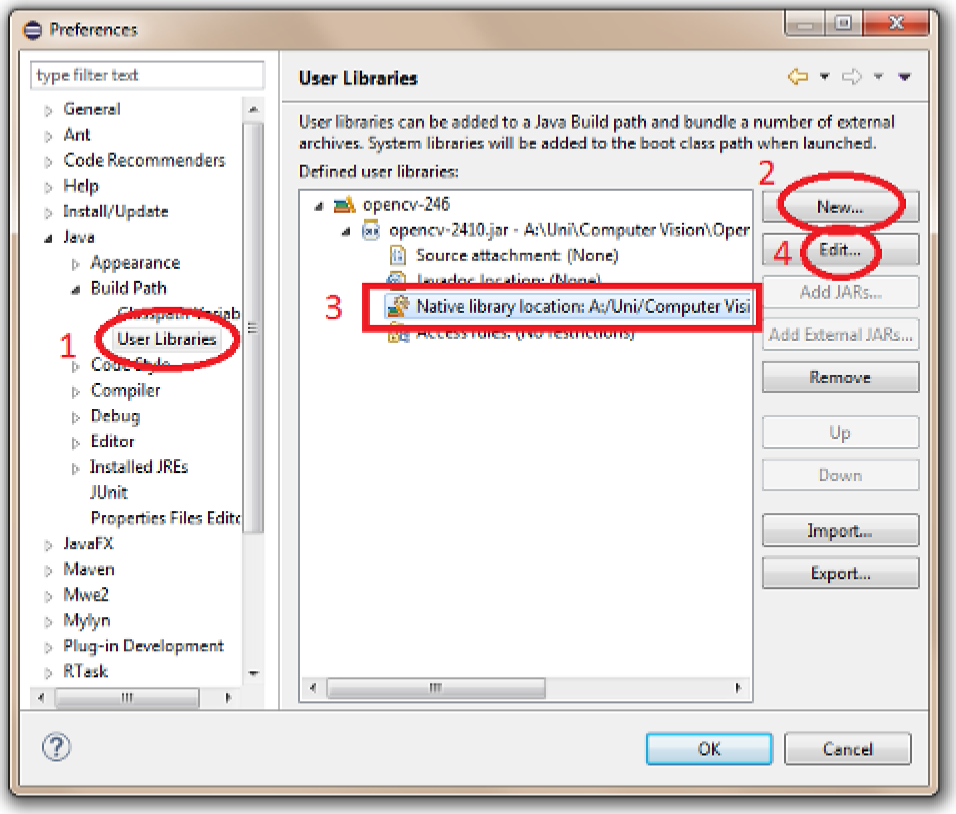
Now open the terminal , go to the `build` folder of OpenCV and build everything with the command: `make -j8` (wait for the process to be completed...). If everything went well you should have `opencv-246.jar` and `libopencv_java246.so` files in the `/opencv-2.4.6.1/build/bin` directory and the `data` folder in the `/opencv-2.4.6.1/` directory.

Set up OpenCV for Java in Eclipse

Open Eclipse and select a workspace of your choice. Create a User Library, ready to be used on all the next projects: go to `Window > Preferences...`.



From the menu navigate under `Java > Build Path > User Libraries` and choose `New...`. Enter a name for the library (e.g., opencv246) and select the newly created user library. Choose `Add External JARs...`, browse to select `opencv246.jar`. After adding the jar, extend it and select `Native library location` and press `Edit...`.



Select `External Folder...` and browse to select the folder containing the OpenCV libraries (e.g., `C:\opencv\build\java\x64` under Windows).

CHAPTER 2

First Java Application with OpenCV

Note: We assume that by now you have already read the previous tutorials. If not, please check previous tutorials at http://polito-java-opencv-tutorials.readthedocs.org/en/latest/index.html. You can also find the source code and resources at https://github.com/java-opencv/Polito-Java-OpenCV-Tutorials-Source-Code

Introduction to a OpenCV application with Java

This tutorial will guide you through the creation of a simple Java console application using the OpenCV library by mean of Eclipse.

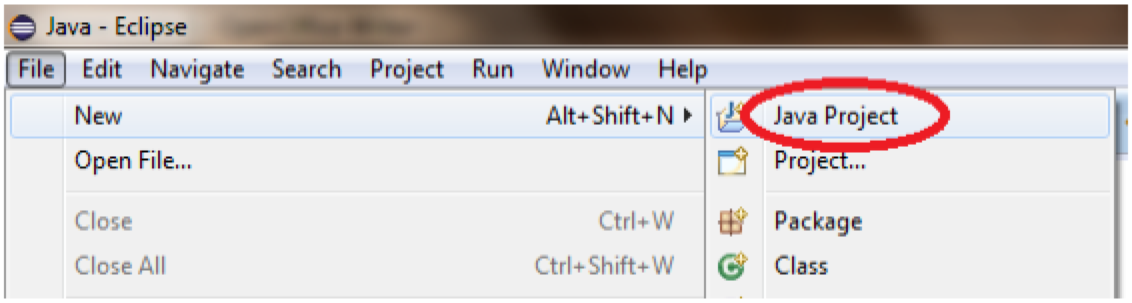
What we will do in this tutorial

In this guide, we will:

- Create a new Java Project
- Add a User Library to the project
- Build and Run the application

Create a New Project

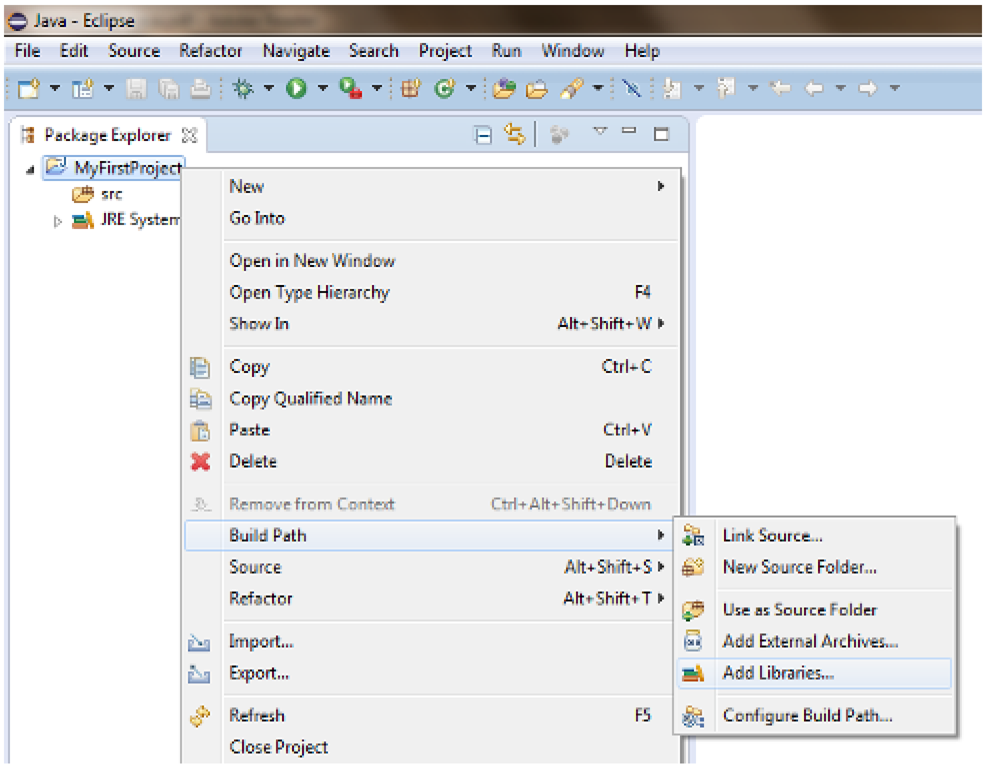
Open Eclipse and create a new Java project; open the `File` menu, go to `New` and click on `Java Project`.



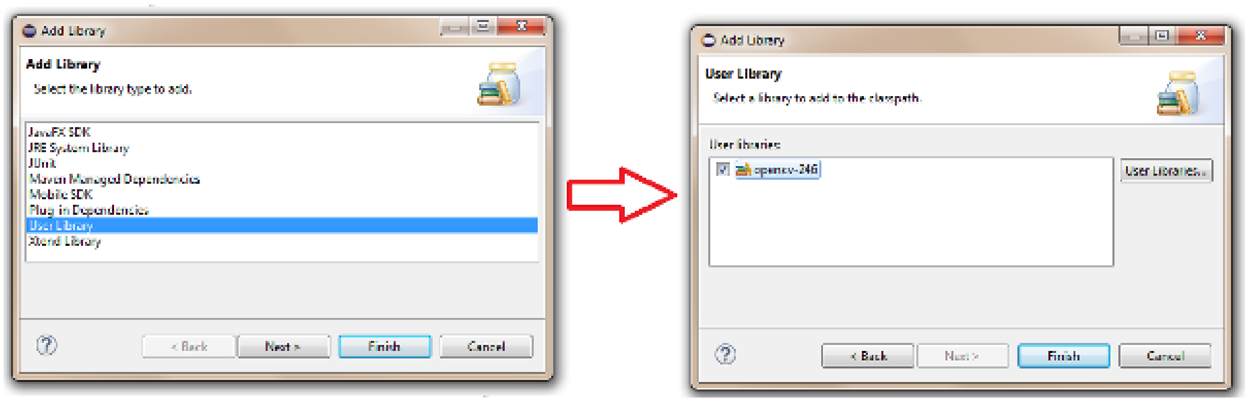
In the `New Java Project` dialog write the name of your project and click on `Finish`.

Add a User Library

If you followed the previous tutorial (`Installing OpenCV for Java`), you should already have the OpenCV library set in your workspace's user libraries, if not please check out the previous tutorial. Now you should be ready to add the library to your project. Inside Eclipse's `Package Explorer` just right-click on your project's folder and go to `Build Path --> Add Libraries...`.



Select `User Libraries` and click on `Next`, check the checkbox of the OpenCV library and click `Finish`.



Create a simple application

Now add a new Class to your project by right-clicking on your project's folder and go to `New --> Class`. Write a name of your choice for both the package and the class then click on `Finish`. Now we are ready to write the code of our first application. Let's start by define the `main` method:

```
public class MyFirstApp {
        public static void main(String[] args){
                System.loadLibrary(Core.NATIVE_LIBRARY_NAME);
                Mat mat = Mat.eye(3, 3, CvType.CV_8UC1);
                System.out.println("mat = " + mat.dump());
        }
}
```

First of all we need to load the Native Library previously set on our project.

```
System.loadLibrary(Core.NATIVE_LIBRARY_NAME);
```

Then we can define a new Mat.

Note: The class **Mat** represents an n-dimensional dense numerical single-channel or multi-channel array. It can be used to store real or complex-valued vectors and matrices, grayscale or color images, voxel volumes, vector fields, point clouds, tensors, histograms. For more details check out the OpenCV page.

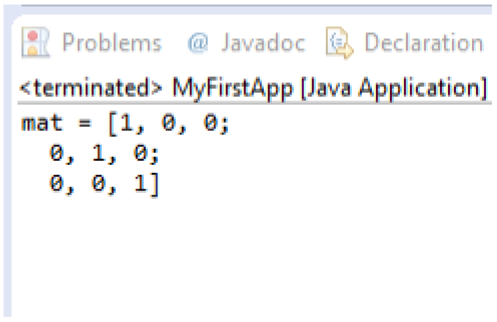
```
Mat mat = Mat.eye(3, 3, CvType.CV_8UC1);
```

The `Mat.eye` represents a identity matrix, we set the dimensions of it (3x3) and the type of its elements.

As you can notice, if you leave the code just like this, you will get some error; this is due to the fact that eclipse can't resolve some variables. You can locate your mouse cursor on the words that seem to be errors and wait for a dialog to pop up and click on the voice `Import...`. If you do that for all the variables we have added to the code the following rows:

```
import org.opencv.core.Core;
import org.opencv.core.CvType;
import org.opencv.core.Mat;
```

We can now try to build and run our application by clicking on the Run button. You should have the following output:



```
<terminated> MyFirstApp [Java Application]
mat = [1, 0, 0;
  0, 1, 0;
  0, 0, 1]
```

Here I put the whole source code:

```
package mypackage;

import org.opencv.core.Core;
import org.opencv.core.CvType;
import org.opencv.core.Mat;

public class MyFirstApp {
        public static void main(String[] args){
                System.loadLibrary(Core.NATIVE_LIBRARY_NAME);
                Mat mat = Mat.eye(3, 3, CvType.CV_8UC1);
                System.out.println("mat = " + mat.dump());
        }
}
```

CHAPTER 3

First JavaFX Application with OpenCV

Note: We assume that by now you have already read the previous tutorials. If not, please check previous tutorials at http://polito-java-opencv-tutorials.readthedocs.org/en/latest/index.html. You can also find the source code and resources at https://github.com/java-opencv/Polito-Java-OpenCV-Tutorials-Source-Code

Introduction to a OpenCV application with JavaFX

This tutorial will guide you through the creation of a simple JavaFX gui application using the OpenCV library by mean of Eclipse.

What we will do in this tutorial

In this guide, we will:

- Install the `e(fx)clipse` plugin and (optional) *Scene Builder*.
- Work with *Scene Builder*.
- Write and Run our application.

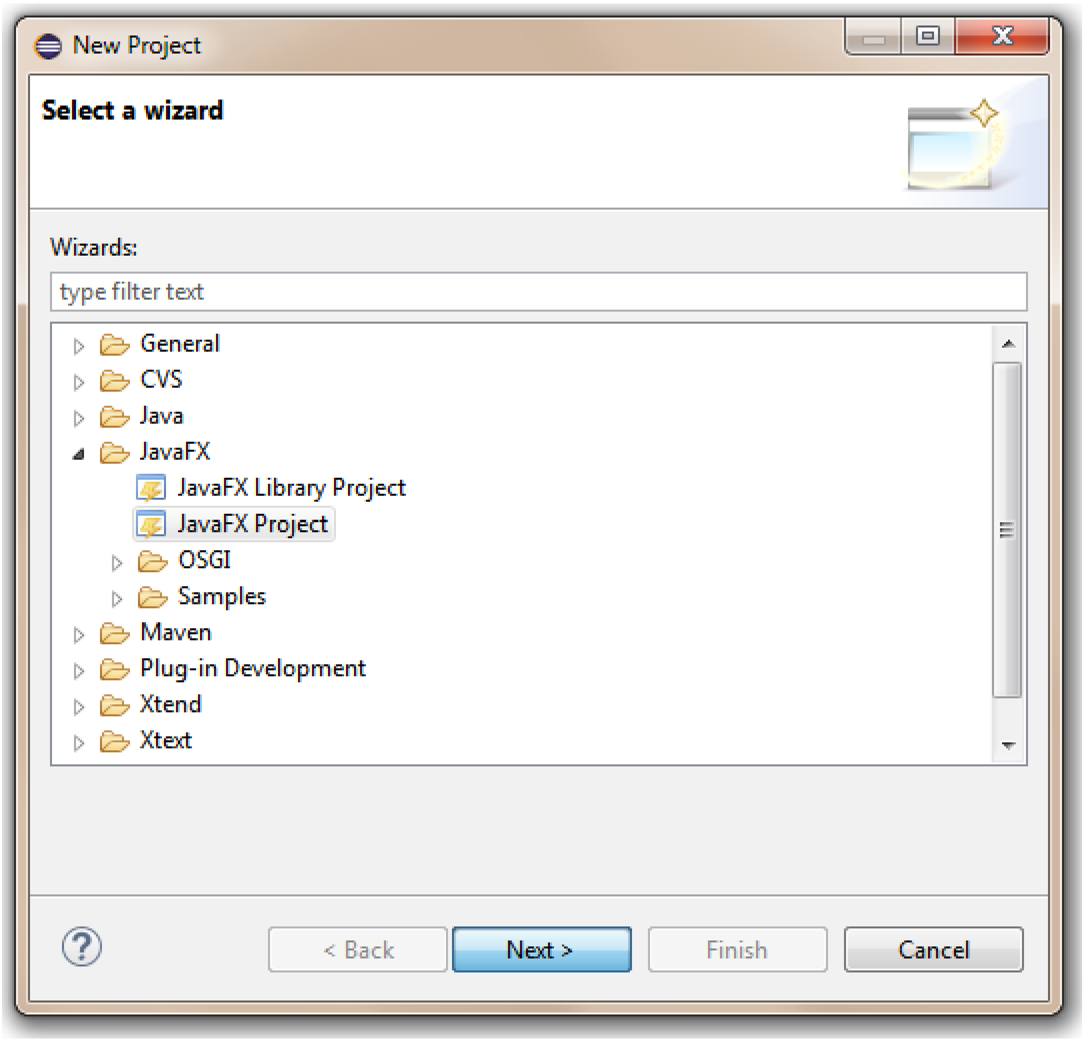
Our First Application in JavaFX

Our application is going to capture a video stream from our webcam and it will display it on our gui. We will create the gui with Scene Builder and it is going to have a button, which will allow us to stat and stop the stream and a simple image view container where we will put the stream frames.

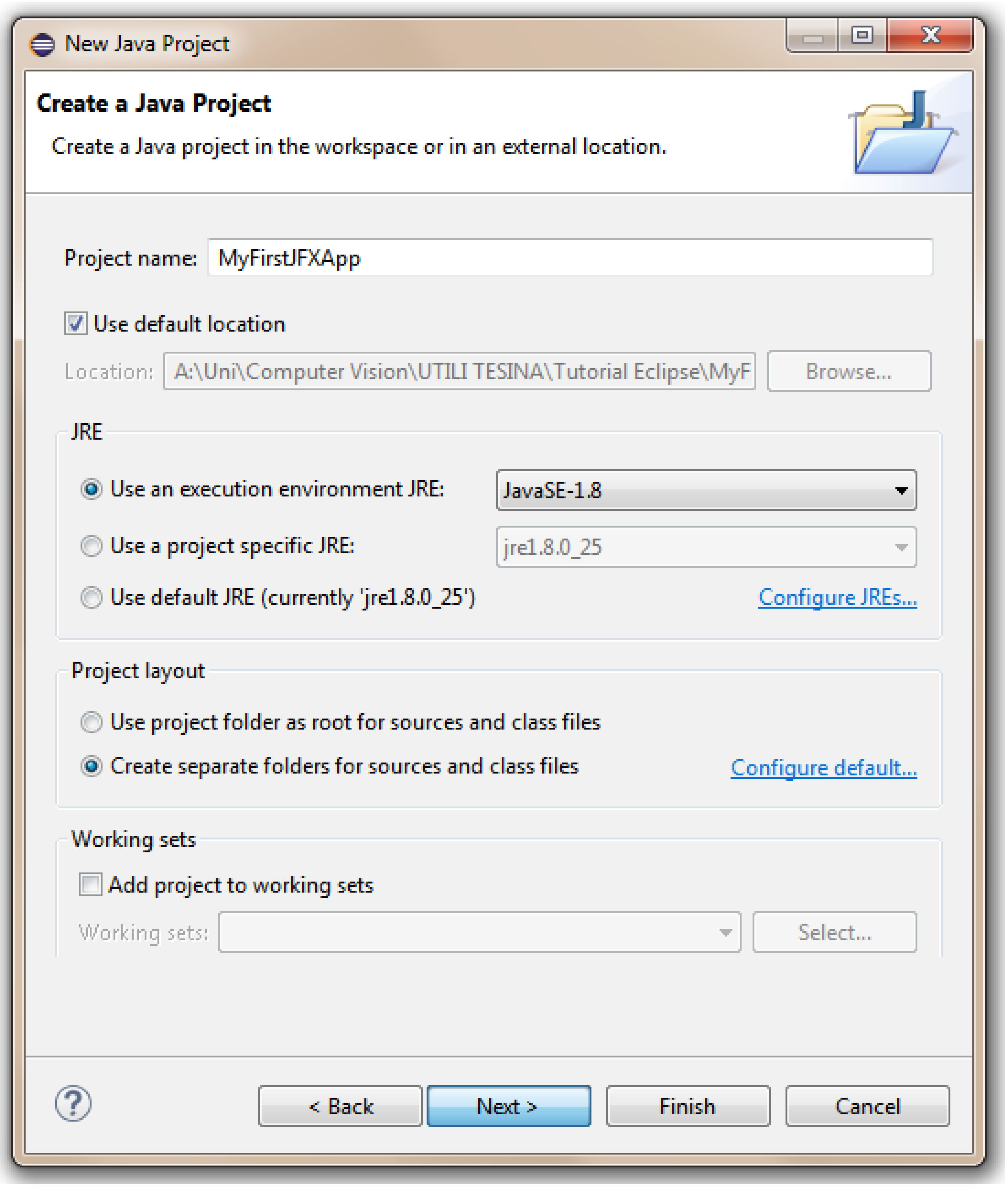
Installing e(fx)clipse plugin and Scene Builder

In Eclipse, install the `e(fx)clipse` plugin, by following the guide at http://www.eclipse.org/efxclipse/install.html#fortheambitious. If you choose not to install such a plugin, you have to create a traditional **Java project** and add `jfxrt.jar` (present in the JDK folder) to the `project/library`. Download and install the *JavaFX Scene Builder* from http://www.oracle.com/technetwork/java/javafx/tools/index.html.

Now you can create a new JavaFX project. `Go to File-->New-->Project...` and select `JavaFx project...`.



Choose a name for your project and click `Next`.


New Java Project

Create a Java Project

Create a Java project in the workspace or in an external location.

Project name: MyFirstJFXApp

[✓] Use default location

Location: A:\Uni\Computer Vision\UTILI TESINA\Tutorial Eclipse\MyF

JRE

(●) Use an execution environment JRE: JavaSE-1.8

( ) Use a project specific JRE: jre1.8.0_25

( ) Use default JRE (currently 'jre1.8.0_25')

Project layout

( ) Use project folder as root for sources and class files

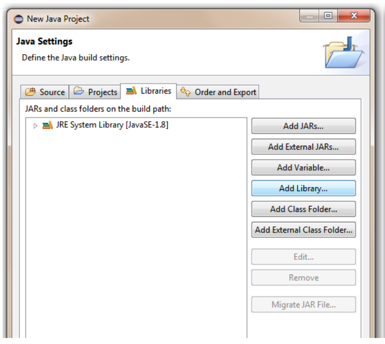
(●) Create separate folders for sources and class files

Working sets

[ ] Add project to working sets

Working sets:

Now add your OpenCV user library to your project and click `Next`.

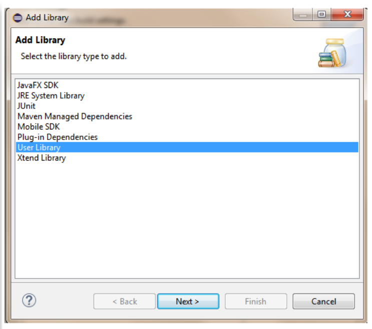

New Java Project

Java Settings

Define the Java build settings.

JARs and class folders on the build path:

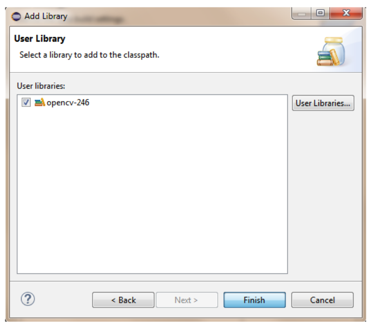
JRE System Library [JavaSE-1.8]


Add Library

Add Library

Select the library type to add.

JavaFX SDK
JRE System Library
JUnit
Maven Managed Dependencies
Mobile SDK
Plug-in Dependencies
User Library
Xtend Library


Add Library

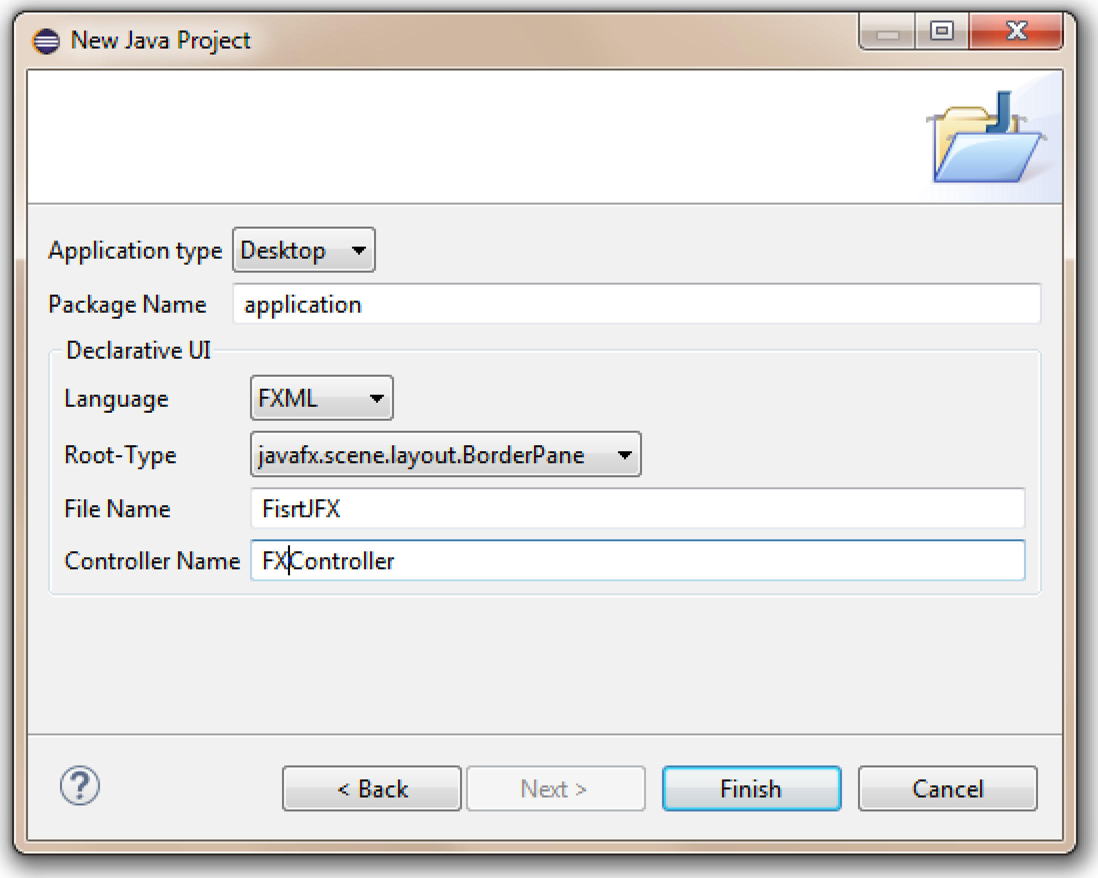
User Library

Select a library to add to the classpath.

User libraries:

[✓] opencv-246

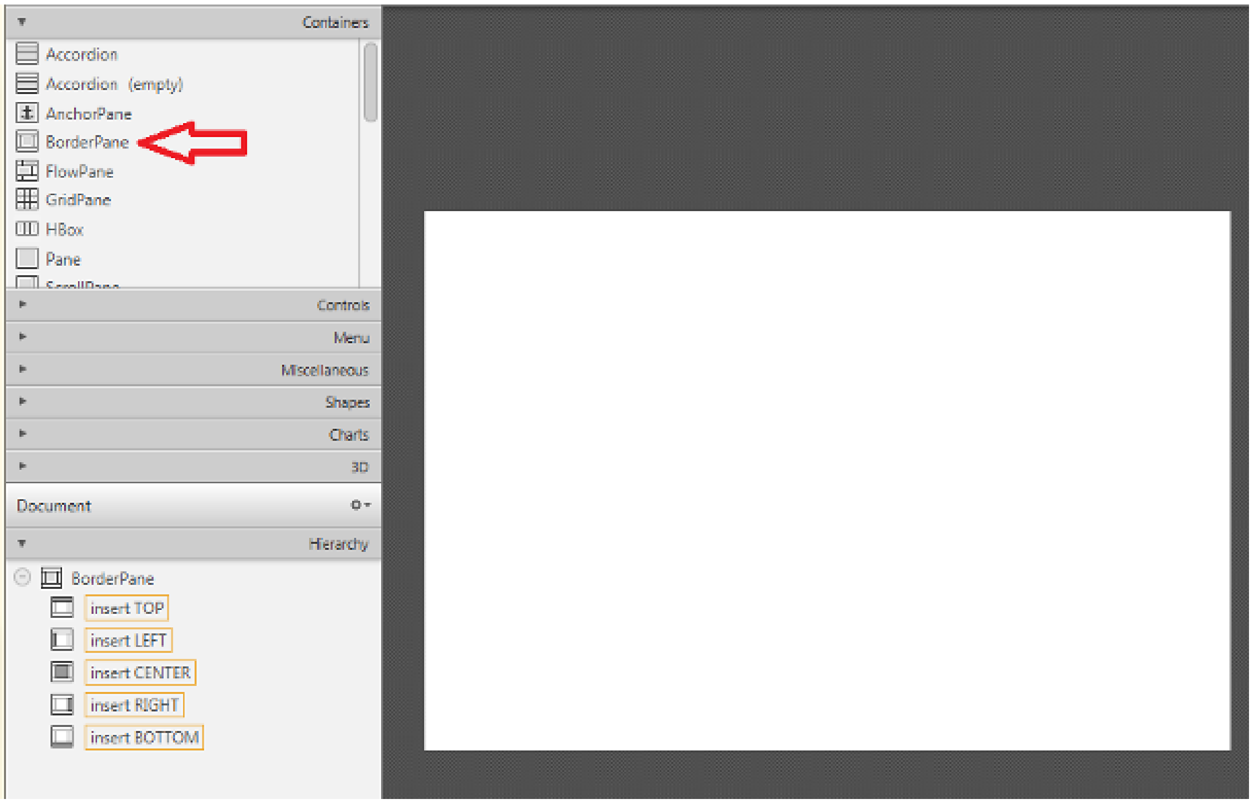
Choose a name for your package, *FXML file* and *Controller Class*. The *FXML file* will contain the description of your GUI in FXML language, the controller class will handle all the method and event which have to be called and managed when the user interacts with the GUI's components.



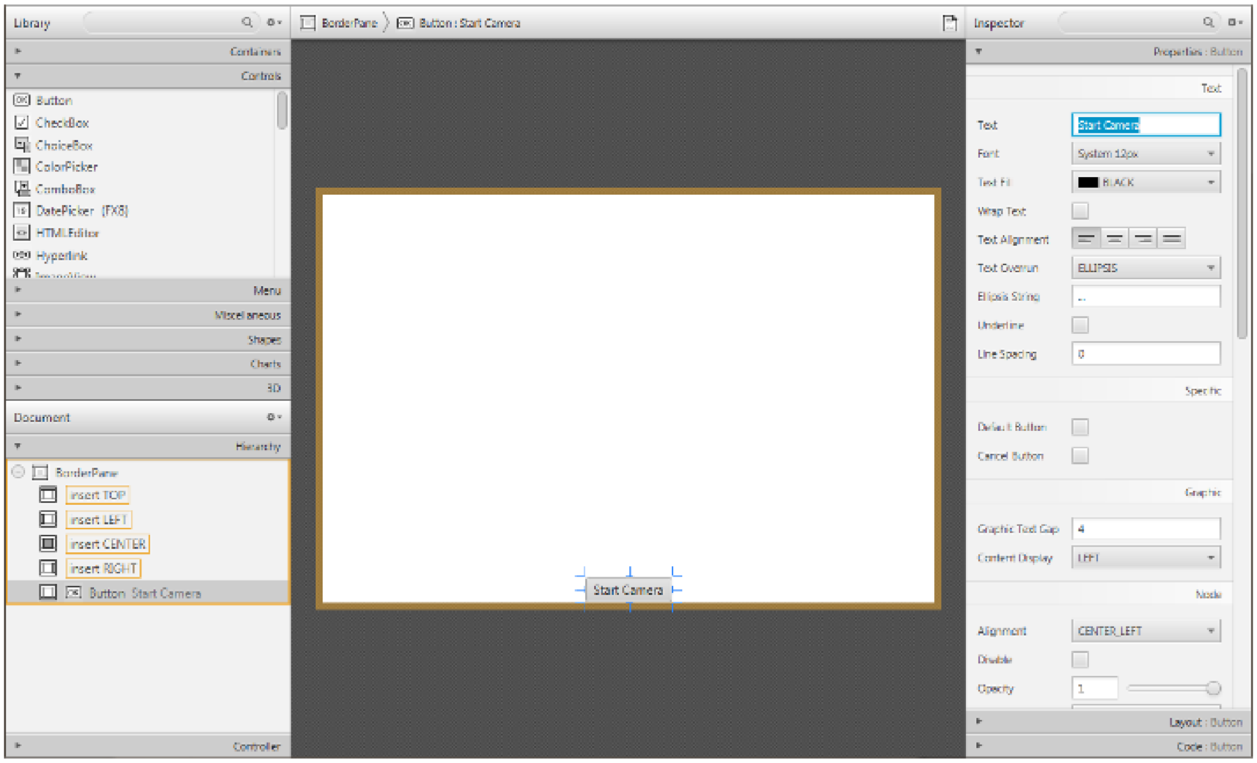
Application type: Desktop
Package Name: application
Declarative UI
Language: FXML
Root-Type: javafx.scene.layout.BorderPane
File Name: FisrtJFX
Controller Name: FXController

Working with Scene Builder

If you have installed *Scene Builder* you can now right click on your *FXML file* in Eclipse and select `Open with SceneBuilder`. *Scene Builder* can help construct you gui by interacting with a graphic interface; this allows you to see a real time preview of your window and modify your components and their position just by editing the graphic preview. Let's take a look at what I'm talking about. At fist the *FXML file* will have just an *AnchorPane*. An AnchorPane allows the edges of child nodes to be anchored to an offset from the anchorpane's edges. If the anchorpane has a border and/or padding set, the offsets will be measured from the inside edge of those insets. The anchorpane lays out each managed child regardless of the child's visible property value; unmanaged children are ignored for all layout calculations. You can go ahead and delete the anchorpane and add a *BorderPane* instaed. A BorderPane lays out children in top, left, right, bottom, and center positions.



You can add a BorderPane by dragging from the `Container` menu a borderpane and then drop it in the `Hierarchy` menu. Now we can add the button that will allow us to start and stop the stream. Take a button component from the `Controls` menu and drop it on the **BOTTOM** field of our BP. As we can see, on the right we will get three menus (Properties, Layout, Code) which are used to customize our selected component. For example we can change text of our button in "Start Camera" in the `Text` field under the `Properties` menu and the id of the button (e.g. "start_btn") in the `fx:id` field under the `Code` menu.



Text

Text: Start Camera
Font: System 12px
Text Fill: BLACK
Wrap Text
Text Alignment
Text Overrun: ELLIPSIS
Ellipsis String: ...
Underline
Line Spacing: 0

Specific

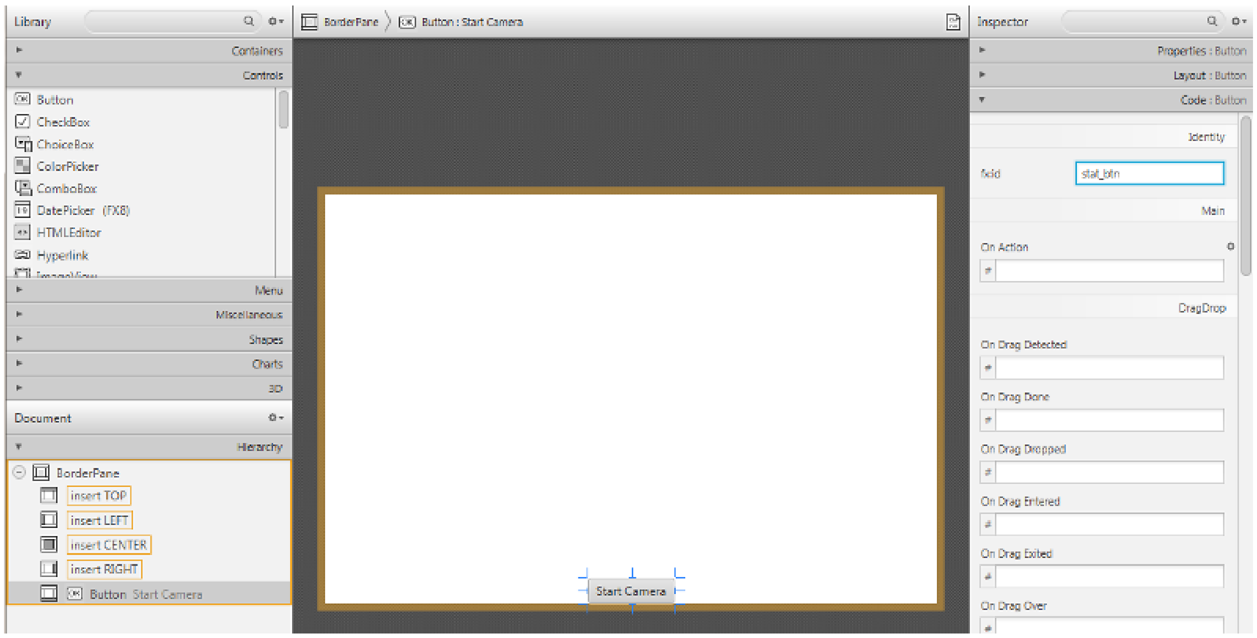
Default Button
Cancel Button

Graphic

Graphic Text Gap: 4
Content Display: LEFT

Node

Alignment: CENTER_LEFT
Disable
Opacity: 1



Identity

fx:id: start_btn

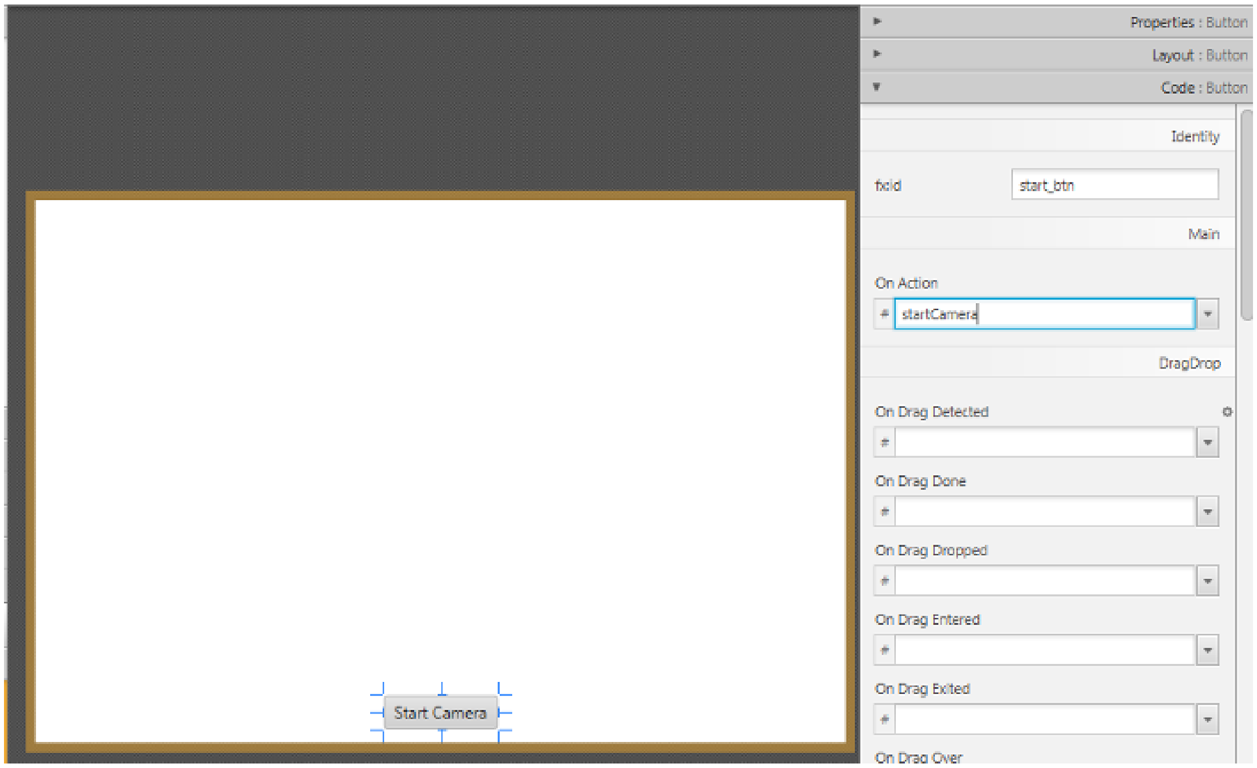
Main

On Action: #

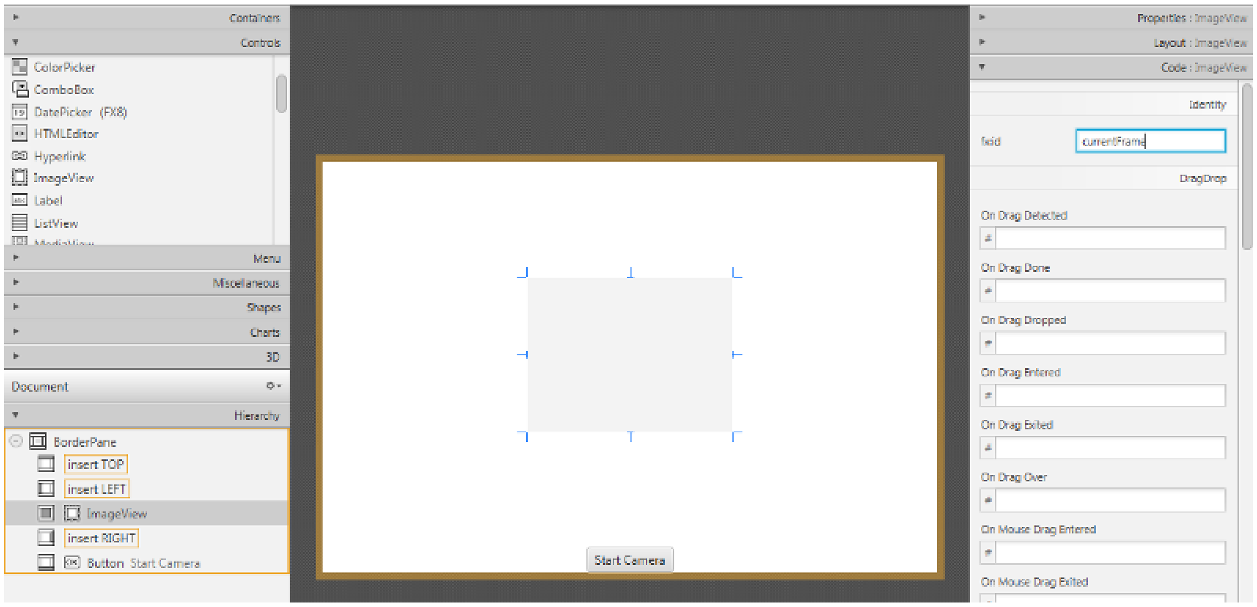
DragDrop

On Drag Detected: #
On Drag Done: #
On Drag Dropped: #
On Drag Entered: #
On Drag Exited: #
On Drag Over: #

We are going to need the id of the button later, in order to edit the button properties from our *Controller*'s methods. As you can see our button is too close to the edge of the windows, so we should add some bottom margin to it; to do so we can add this information in the `Layout` menu. In order to make the button work, we have to set the name of the method (e.g. "startCamera") that will execute the action we want to preform in the field `OnAction` under the `Code` menu.



Now, we shall add an *ImageView* component from the `Controls` menu into the **CENTER** field of our BP. Let's also edit the id of the image view (e.g. "currentFrame"), and add some margin to it.



Finally we have to tell which Controller class will mange the GUI, we can do so by adding our controller class name in the `Controller class` field under the `Controller` menu located in the bottom left corner of the window.

We just created our first GUI by using Scene Builder, if you save the file and return to Eclipse you will notice that some FXML code has been generated automatically.

Key concepts in JavaFX

The **Stage** is where the application will be displayed (e.g., a Windows' window). A **Scene** is one container of Nodes that compose one "page" of your application. A **Node** is an element in the Scene, with a visual appearance and an interactive behavior. Nodes may be hierarchically nested . In the *Main class* we have to pass to the *start* function our *primary stage*:

```
public void start(Stage primaryStage)
```

and load the fxml file that will populate our stage, the *root element* of the scene and the controller class:

```
FXMLLoader loader = new FXMLLoader(getClass().getResource("MyFirstJFX.fxml"));
BorderPane root = (BorderPane) loader.load();
FXController controller = loader.getController();
```

Managing GUI interactions with the Controller class

For our application we need to do basically two thing: control the button push and the refreshment of the image view. To do so we have to create a reference between the gui components and a variable used in our controller class:

```
@FXML
private Button start_btn;
@FXML
private ImageView currentFrame;
```

The `@FXML` tag means that we are linking our variable to an element of the fxml file and the value used to declare the variable has to equal to the id set for that specific element.

The `@FXML` tag is used with the same meaning for the Actions set under the Code menu in a specific element.

for:

```
<Button fx:id="start_btn" mnemonicParsing="false" onAction="#startCamera" text="Start␣
↪Camera" BorderPane.alignment="CENTER">
```

we set:

```
@FXML
protected void startCamera(ActionEvent event) { ...
```

Video Capturing

Essentially, all the functionalities required for video manipulation is integrated in the VideoCapture class.

```
private VideoCapture capture = new VideoCapture();
```

This on itself builds on the FFmpeg open source library. A video is composed of a succession of images, we refer to these in the literature as frames. In case of a video file there is a frame rate specifying just how long is between two frames. While for the video cameras usually there is a limit of just how many frames they can digitalize per second. In our case we set as frame rate 30 frames per sec. To do so we initialize a timer that will open a background task every *33 milliseconds*.

```
TimerTask frameGrabber = new TimerTask() { ... }
this.timer = new Timer();
this.timer.schedule(frameGrabber, 0, 33);
```

To check if the binding of the class to a video source was successful or not use the `isOpened` function:

```
if (this.capture.isOpened()){ ... }
```

Closing the video is automatic when the objects destructor is called. However, if you want to close it before this you need to call its release function.

```
this.capture.release();
```

The frames of the video are just simple images. Therefore, we just need to extract them from the VideoCapture object and put them inside a Mat one.

```
Mat frame = new Mat();
```

The video streams are sequential. You may get the frames one after another by the read or the overloaded >> operator.

```
this.capture.read(frame);
```

Now we are going to convert our image from *BGR* to *Grayscale* format. OpenCV has a really nice function to do this kind of transformations:

```
Imgproc.cvtColor(frame, frame, Imgproc.COLOR_BGR2GRAY);
```

As you can see, cvtColor takes as arguments:

- a source image (frame)
- a destination image (frame), in which we will save the converted image.
- an additional parameter that indicates what kind of transformation will be performed. In this case we usev `CV_BGR2GRAY` (because of `imread` has BGR default channel order in case of color images).

Now in order to put the captured frame into the ImageView we need to convert the Mat in a Image. We first create a buffer to store the Mat.

```
MatOfByte buffer = new MatOfByte();
```

Then we can put the frame into the buffer by using the `imencode` function:

```
Highgui.imencode(".png", frame, buffer);
```

This encodes an image into a memory buffer. The function compresses the image and stores it in the memory buffer that is resized to fit the result.

Note: `cvEncodeImage` returns single-row matrix of type `CV_8UC1` that contains encoded image as array of bytes.

It takes three parameters:

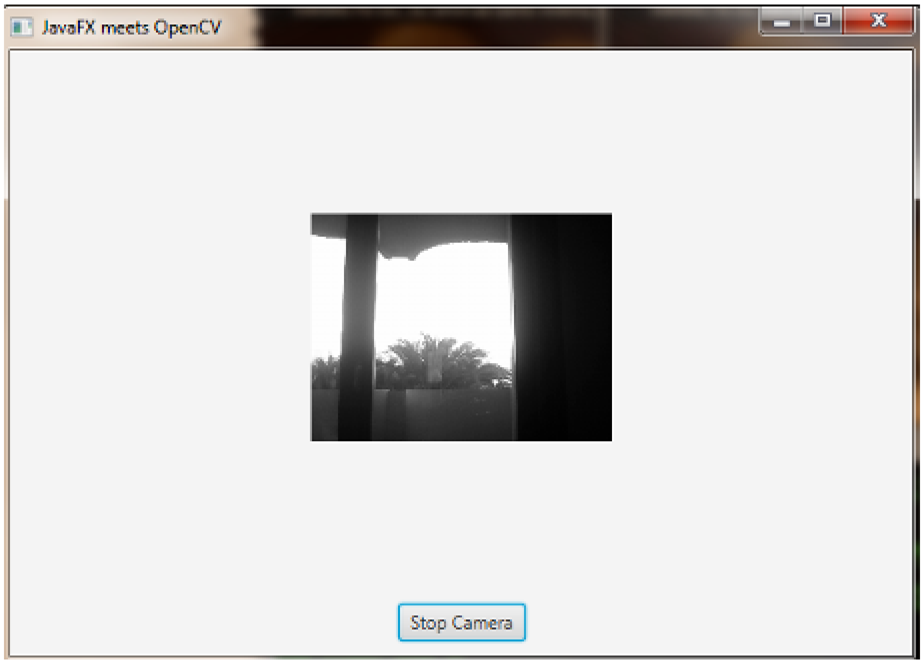
- (".png") File extension that defines the output format.
- (frame) Image to be written.
- (buffer) Output buffer resized to fit the compressed image.

Once we filled the buffer we have to stream it into an Image by using `ByteArrayInputStream`:

```
new Image(new ByteArrayInputStream(buffer.toArray()));
```

Now we can put the new image in the ImageView. With *Java 1.8* we cannot perform an update of a gui element in a thread that differs from the main thread; so we need to get the new frame in a second thread and refresh our ImageView in the main thread:

```
Image tmp = grabFrame();
Platform.runLater(new Runnable() {
        @Override public void run(){frameView.setImage(tmp);}
});
```



Source Code

- Main.java

```
public class Main extends Application {
        @Override
        public void start(Stage primaryStage) {
                try {
                        // load the FXML resource
                        FXMLLoader loader = new FXMLLoader(getClass().getResource(
↪"MyFirstJFX.fxml"));
                        // store the root element so that the controllers can use it
                        BorderPane root = (BorderPane) loader.load();
                        // create and style a scene
                        Scene scene = new Scene(root);
                        scene.getStylesheets().add(getClass().getResource(
↪"application.css").toExternalForm());
                        // create the stage with the given title and the previously␣
↪created scene
                        primaryStage.setTitle("JavaFX meets OpenCV");
                        primaryStage.setScene(scene);
                        // show the GUI
                        primaryStage.show();
                        // set a reference of this class for its controller
                        FXController controller = loader.getController();
                        controller.setRootElement(root);

                } catch(Exception e) {
                        e.printStackTrace();
                }
        }

        public static void main(String[] args) {
                // load the native OpenCV library
                System.loadLibrary(Core.NATIVE_LIBRARY_NAME);
                launch(args);
        }
}
```

- FXController.java

```
public class FXController {

    @FXML
    private Button start_btn;
    @FXML
    private ImageView currentFrame;

    private Pane rootElement;
    private Timer timer;
    private VideoCapture capture = new VideoCapture();

    @FXML
    protected void startCamera(ActionEvent event)
    {
            // check: the main class is accessible?
            if (this.rootElement != null)
            {
                    // get the ImageView object for showing the video stream
                    final ImageView frameView = currentFrame;
                    // check if the capture stream is opened
                    if (!this.capture.isOpened())
                    {
                            // start the video capture
                            this.capture.open(0);
                            // grab a frame every 33 ms (30 frames/sec)
                            TimerTask frameGrabber = new TimerTask() {
                                    @Override
                                    public void run()
                                    {
                                            Image tmp = grabFrame();
                                            Platform.runLater(new Runnable() {
                                                    @Override
                                        public void run()
                                                    {
                                                            frameView.setImage(tmp);
                                        }
                                            });
                                        }
                                };
                                this.timer = new Timer();
                                //set the timer scheduling, this allow you to perform␣
↪frameGrabber every 33ms;
                                this.timer.schedule(frameGrabber, 0, 33);
                                this.start_btn.setText("Stop Camera");
                        }
                        else
                        {
                                this.start_btn.setText("Start Camera");
                                // stop the timer
                                if (this.timer != null)
                                {
                                        this.timer.cancel();
                                        this.timer = null;
                                }
                                // release the camera
                                this.capture.release();
                                // clear the image container
                                frameView.setImage(null);
                        }
                }
        }

        private Image grabFrame()
        {
                //init
                Image imageToShow = null;
                Mat frame = new Mat();
                // check if the capture is open
                if (this.capture.isOpened())
                {
                        try
                        {
                                // read the current frame
                                this.capture.read(frame);
                                // if the frame is not empty, process it
                                if (!frame.empty())
                                {
                                        // convert the image to gray scale
                                        Imgproc.cvtColor(frame, frame, Imgproc.COLOR_
↪BGR2GRAY);
                                        // convert the Mat object (OpenCV) to Image␣
↪(JavaFX)

                                        imageToShow = mat2Image(frame);
                                }
                        }
                        catch (Exception e)
                        {
                                // log the error
                                System.err.println("ERROR: " + e.getMessage());
                        }
                }
                return imageToShow;
        }
```

```
    private Image mat2Image(Mat frame)
    {
            // create a temporary buffer
            MatOfByte buffer = new MatOfByte();
            // encode the frame in the buffer
            Highgui.imencode(".png", frame, buffer);
            // build and return an Image created from the image encoded in the buffer
            return new Image(new ByteArrayInputStream(buffer.toArray()));
    }

    public void setRootElement(Pane root)
    {
            this.rootElement = root;
    }

}
```

- MyFirstJFX.fxml

```
<?xml version="1.0" encoding="UTF-8"?>

<?import java.lang.*?>
<?import javafx.geometry.*?>
<?import javafx.scene.control.*?>
<?import javafx.scene.image.*?>
<?import javafx.scene.layout.*?>
<?import javafx.scene.layout.BorderPane?>
<?import javafx.scene.image.ImageView?>
<?import javafx.scene.layout.HBox?>
<?import javafx.scene.control.Button?>
<?import javafx.geometry.Insets?>

<BorderPane maxHeight="-Infinity" maxWidth="-Infinity" minHeight="-Infinity" minWidth=
↪"-Infinity" prefHeight="400.0" prefWidth="600.0" xmlns="http://javafx.com/javafx/8"␣
↪xmlns:fx="http://javafx.com/fxml/1" fx:controller="application.FXController">
   <bottom>
      <Button fx:id="start_btn" mnemonicParsing="false" onAction="#startCamera" text=
↪"Start Camera" BorderPane.alignment="CENTER">
         <BorderPane.margin>
            <Insets bottom="10.0" />
         </BorderPane.margin></Button>
   </bottom>
   <center>
      <ImageView fx:id="currentFrame" fitHeight="150.0" fitWidth="200.0" pickOnBounds=
↪"true" preserveRatio="true" BorderPane.alignment="CENTER">
         <BorderPane.margin>
            <Insets bottom="10.0" left="10.0" right="10.0" top="10.0" />
         </BorderPane.margin></ImageView>
   </center>
</BorderPane>
```

CHAPTER 4

OpenCV Basics

Note: We assume that by now you have already read the previous tutorials. If not, please check previous tutorials at http://polito-java-opencv-tutorials.readthedocs.org/en/latest/index.html. You can also find the source code and resources at https://github.com/java-opencv/Polito-Java-OpenCV-Tutorials-Source-Code

What we will do in this tutorial

In this guide, we will:

- Create a basic *checkbox* interaction to alter the color of the video stream.
- Add a basic *checkbox* interaction to "alpha over" a logo to the video stream.
- Display the video stream *histogram* (both one and three channels).

Getting started

For this tutorial we can create a new JavaFX project and build a scene as the one realized in the previous one. So we've got a window with a border pane in witch:

- in the **BOTTOM** we have a button inside a *HBox*:

```
<HBox alignment="CENTER" >
   <padding>
      <Insets top="25" right="25" bottom="25" left="25"/>
   </padding>
   <Button fx:id="button" alignment="center" text="Start camera" onAction="
↪#startCamera" />
</HBox>
```

- in the **CENTRE** we have a ImageView:

```
<ImageView fx:id="currentFrame" />
```

Color channel checkbox

Let's open our fxml file with Scene Builder and add to the **RIGHT** field of our BP a vertical box `VBox`. A VBox lays out its children in a single vertical column. If the VBox has a border and/or padding set, then the contents will be layed out within those insets. Also it will resize children (if resizable) to their preferred heights and uses its `fillWidth` property to determine whether to resize their widths to fill its own width or keep their widths to their preferred (fillWidth defaults to true). A `HBox` works just like a VBox but it lays out its children horizontally instead of vertically.

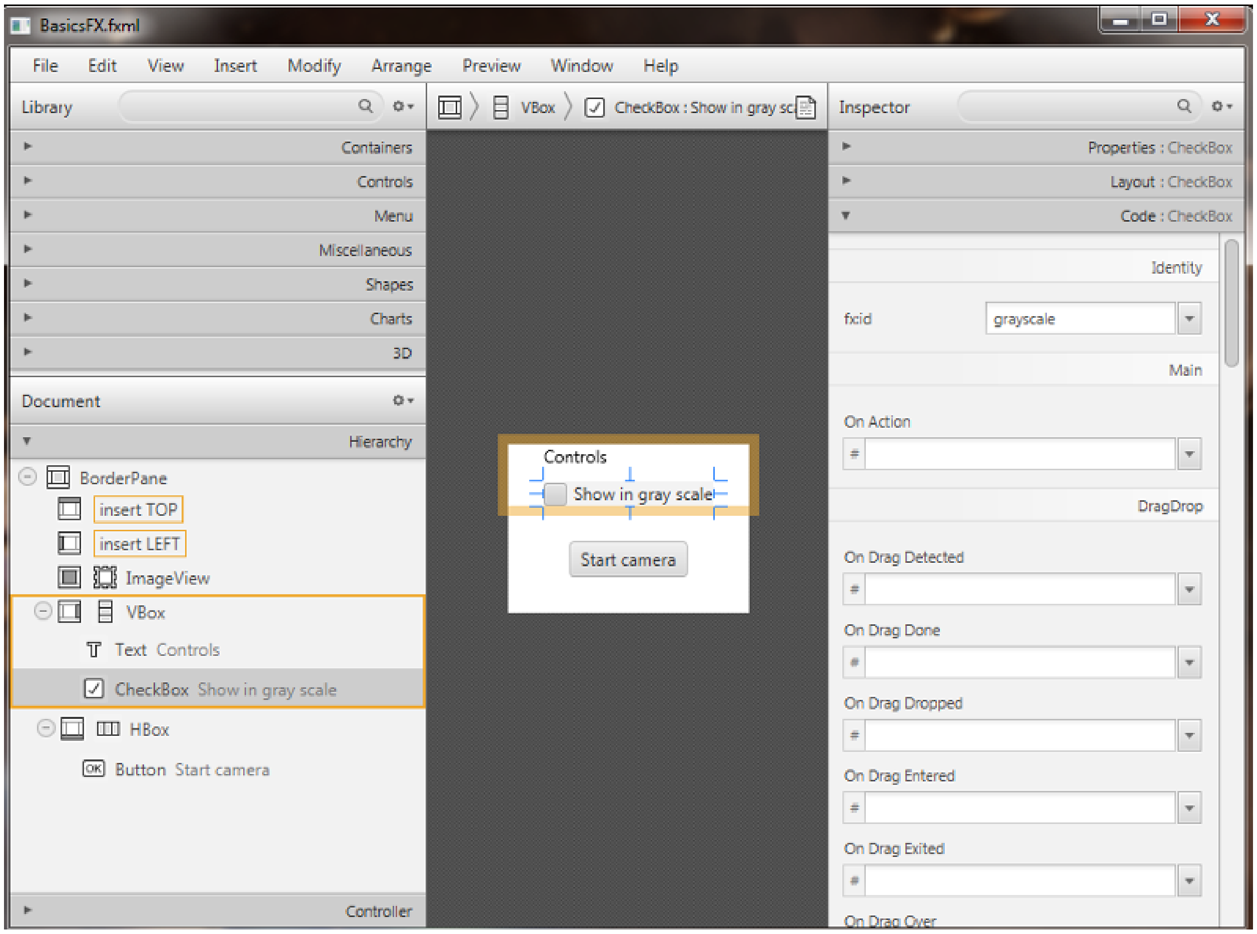
Now we can put inside the VBox a new checkbox, change its text to "Show in gray scale" and set a id (e.g. "grayscale").

```
<CheckBox fx:id="grayscale" text="Show in gray scale" />
```

Let's also add a title to this section by putting before our new checkbox, but still inside the VBox, a text and set its text as "Controls" (we can find the text element under the `Shapes` menu).

```
<Text text="Controls" />
```

In the Scene Builder we now have:



fx:id grayscale

The graphic interface is complete for the first task, now we need to work on the controller; in the previous tutorial we could control the number of channels displayed on screen with the line (98):

```
Imgproc.cvtColor(frame, frame, Imgproc.COLOR_BGR2GRAY);
```

In order to control this conversion with the check box, we have to link the check box with a FXML variable:

```
@FXML
private CheckBox grayscale;
```

Now we can implement the control by adding a simple if condition which will perform the conversion only if our check box is checked:

```
if (grayscale.isSelected()){
   Imgproc.cvtColor(frame, frame, Imgproc.COLOR_BGR2GRAY);
}
```

Load an Image and Add it to the Stream

The next step is to add another check box which, if checked, will trigger the display of an image over the camera stream. Let's start by adding the image to the project; create a new folder in the root directory of your project and put the image in there. In my project I have a `resources` folder with a `Poli.png` image. Go back to Eclipse and refresh your project (you should have the new folder in it). Let's open the fxml file with Scene Builder and add a new checkbox below the one that controls the stream colors; we have to set the text, the name of the method in the `OnAction` field and a id. In the code we will have for example:

```
<CheckBox fx:id="logoCheckBox" text="Show logo" onAction="#loadLogo" />
```

In the controller file we have to define a new variable associated with the checkbox, the method set on the `OnAction` field and adapt the code so that it will display the logo when the checkbox is checked and the stream is on. Variable:

```
@FXML
private CheckBox logoCheckBox;
```

`loadLogo` metheod: In this method we are going to load the image whenever the logoCheckBox id selected (checked). In order to load the image we have to use a basic OpenCV function: imread. It return a Mat and takes the path of the image and a flag (> 0 RGB image, =0 grayscale, <0 with the alpha channel).

```
@FXML
protected void loadLogo(){
    if (logoCheckBox.isSelected())
            this.logo = Highgui.imread("resources/Poli.png");
}
```

Adapt the code.

We are going to add some variants to the code in order to display our logo in a specific region of the stream. This means that for each frame capture, before the image could be converted into 1 or 3 channels, we have to set a **ROI** (region of interest) in which we want to place the logo. Usually a ROI of an Image is a portion of it, we can define the roi as a Rect object. Rect is a template class for 2D rectangles, described by the following parameters:

- Coordinates of the top-left corner. This is a default interpretation of Rect.x and Rect.y in OpenCV. Though, in your algorithms you may count x and y from the bottom-left corner.
- Rectangle width and height.

```
Rect roi = new Rect(frame.cols()-logo.cols(), frame.rows()-logo.rows(), logo.cols(),␣
↪logo.rows());
```

Then we have to take control of our Mat's ROI, by doing so we are able to "add" our logo in the disired area of the frame defined by the ROI.

```
Mat imageROI = frame.submat(roi);
```

We had to make this operation because we can only "add" Mats with the same sizes; but how can we "add" two Mat together? We have to keep in mind that our logo could have 4 channels (RGB + alpha). So we could use two functions: `addWeighted` or `copyTo`. The `addWeighted` function calculates the weighted sum of two arrays as follows:

dst(I)= saturate(src1(I) alpha + src2(I)* beta + gamma)*

where I is a multi-dimensional index of array elements. In case of multi-channel arrays, each channel is processed independently. The function can be replaced with a matrix expression:

*dst = src1*alpha + src2*beta + gamma*

Note: Saturation is not applied when the output array has the depth `CV_32S`. You may even get result of an incorrect sign in the case of overflow.

Parameters:

- **src1** first input array.
- **alpha** weight of the first array elements.
- **src2** second input array of the same size and channel number as src1.
- **beta** weight of the second array elements.
- **gamma** scalar added to each sum.
- **dst** output array that has the same size and number of channels as the input arrays.

So we'll have:

```
Core.addWeighted(imageROI, 1.0, logo, 0.7, 0.0, imageROI);
```

The second method (`copyTo`) simply copies a Mat into the other. We'll have:

```
Mat mask = logo.clone();
logo.copyTo(imageROI, mask);
```

Everything we have done so far to add the logo to the image has to perform only IF our checkbox is check and the image loading process has ended successfully. So we have to add an if condition:

```
if (logoCheckBox.isSelected() && this.logo != null)
{
    Rect roi = new Rect(frame.cols() - logo.cols(), frame.rows() - logo.rows(), logo.
↪cols(),logo.rows());
    Mat imageROI = frame.submat(roi);
    // add the logo: method #1

    Core.addWeighted(imageROI, 1.0, logo, 0.7, 0.0, imageROI);
    // add the logo: method #2
    // Mat mask = logo.clone();
    // logo.copyTo(imageROI, mask);
}
```

Calculate a Histogram

A histogram is a collected counts of data organized into a set of predefined bins. In our case the data represents the intensity of the pixel so it will have a range like (0, 256).

Since we know that the range of information value, we can segment our range in subparts (called bins); let's identify some parts

1. **dims**: The number of parameters you want to collect data of.
2. **bins**: It is the number of subdivisions in each dim. In our example, bins = 256
3. **range**: The limits for the values to be measured. In this case: range = [0,255]

Our last goal is to display the histogram of the video stream for either RGB or in grayscale. For this task we are going to define a method in our controller class that takes a Mat (our current frame) and a boolean that will flag if the frame is in RGB or in grayscale, for example:

First thing we need to do is to divide the frame into other *n* frames, where *n* represents the number of channels of which our frame is composed. To do so we need to use the `Core.split` function; it need a source Mat and a List<Mat> where to put the different channels. Obviously if the frame is in grayscale the list will have just one element.

Before we could calculate the histogram of each channel we have to prepare all the inputs that the `calcHist` function needs. The functions calcHist calculate the histogram of one or more arrays. The elements of a tuple used to increment a histogram bin are taken from the corresponding input arrays at the same location. Parameters:

- **images** Source arrays. They all should have the same depth, CV_8U or CV_32F, and the same size. Each of them can have an arbitrary number of channels.
- **channels** List of the dims channels used to compute the histogram. The first array channels are numerated from 0 to images[0].channels()-1, the second array channels are counted from images[0].channels() to images[0].channels() + images[1].channels()-1, and so on.
- **mask** Optional mask. If the matrix is not empty, it must be an 8-bit array of the same size as images[i]. The non-zero mask elements mark the array elements counted in the histogram.
- **hist** Output histogram, which is a dense or sparse dims -dimensional array.
- **histSize** Array of histogram sizes in each dimension.
- **ranges** Array of the dims arrays of the histogram bin boundaries in each dimension. When the histogram is uniform (uniform =true), then for each dimension i it is enough to specify the lower (inclusive) boundary L_0 of the 0-th histogram bin and the upper (exclusive) boundary U_(histSize[i]-1) for the last histogram bin histSize[i]-1. That is, in case of a uniform histogram each of ranges[i] is an array of 2 elements. When the histogram is not uniform (uniform=false), then each of ranges[i] contains histSize[i]+1 elements: L_0, U_0=L_1, U_1=L_2,..., U_(histSize[i]-2)=L_(histSize[i]-1), U_(histSize[i]-1). The array elements, that are not between L_0 and U_(histSize[i]-1), are not counted in the histogram.
- **accumulate** Accumulation flag. If it is set, the histogram is not cleared in the beginning when it is allocated. This feature enables you to compute a single histogram from several sets of arrays, or to update the histogram in time.

The image will be our frame, we don't need a mask and the last flag will be false; thus we need to define the channels, the hist, the `histSize` and the `ranges`:

In the RGB case we will need all of the hist defined, in the grayscale case instead we will use just the `hist_b` one. We are now ready to do the histogram calculation:

Where `gray` is the flag we passed to the `showHistogram` method.

Draw the Histogram

Next step is to draw the calculated histogram in our gui. Open the fxml file with Scene Builder and add an ImageView above the "Controls" text in the right of the BP and set its id:

```
<ImageView fx:id="histogram" />
```

Now back to the Controller class. Let's add a global variable to control the just added image view:

```
@FXML
private ImageView histogram;
```

and continue to write the `showHistogram` method. First thing first, let's create an image to display the histogram:

```
int hist_w = 150;
int hist_h = 150;
int bin_w = (int) Math.round(hist_w / histSize.get(0, 0)[0]);
Mat histImage = new Mat(hist_h, hist_w, CvType.CV_8UC3, new Scalar(0, 0, 0));
```

before drawing, we first normalize the histogram so its values fall in the range indicated by the parameters entered:

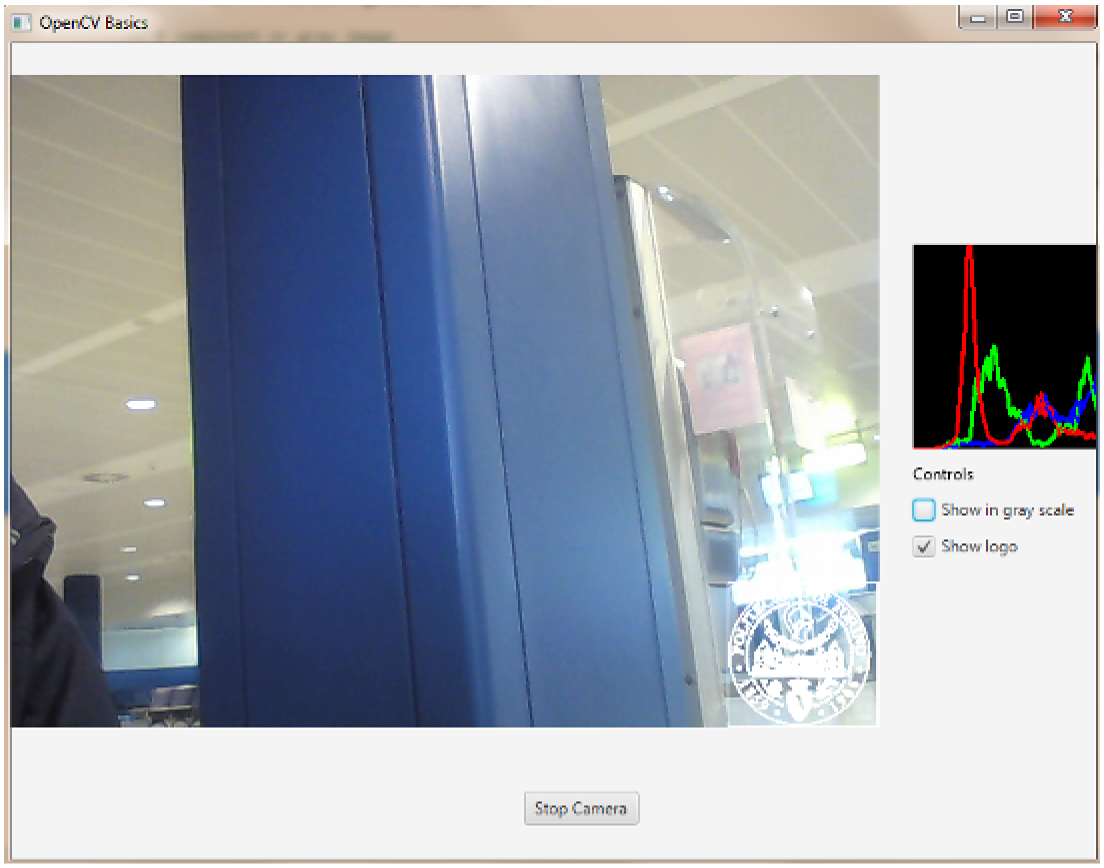
```
Core.normalize(hist_b, hist_b, 0, histImage.rows(), Core.NORM_MINMAX, -1, new Mat());
if (!gray){
   Core.normalize(hist_g, hist_g, 0, histImage.rows(), Core.NORM_MINMAX, -1, new␣
↪Mat());
   Core.normalize(hist_r, hist_r, 0, histImage.rows(), Core.NORM_MINMAX, -1, new␣
↪Mat());
}
```

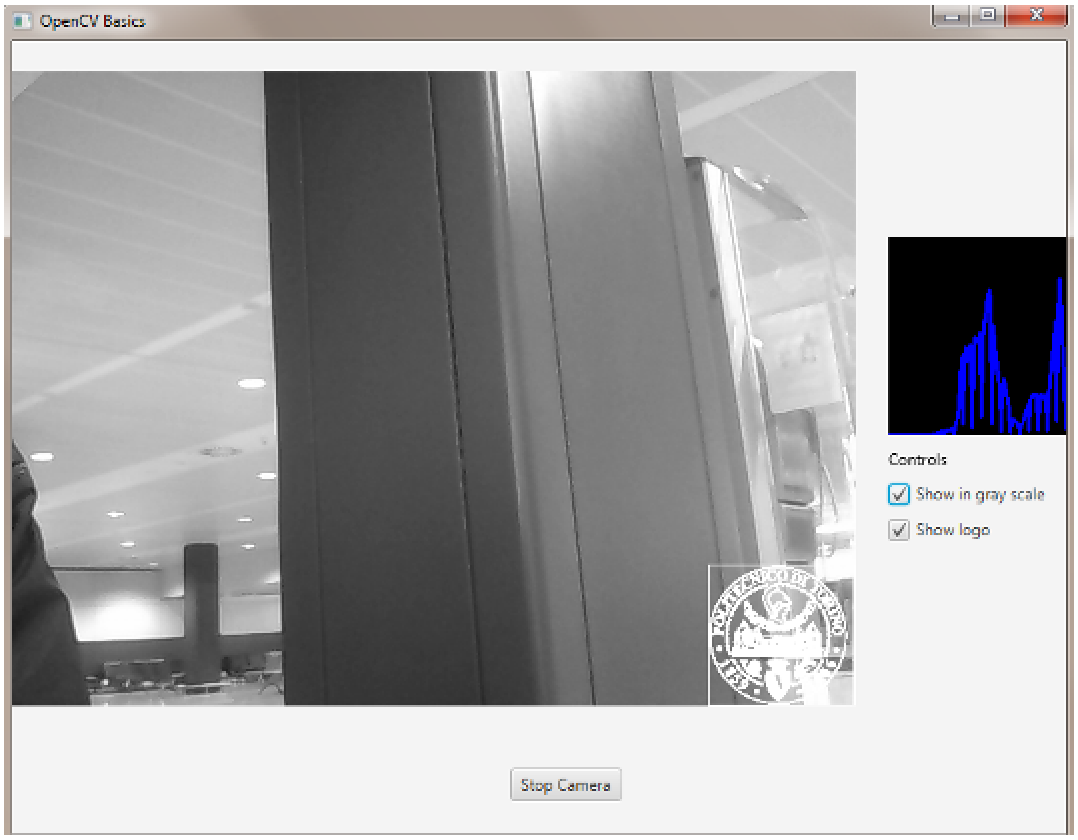
Now we can draw the histogram in our Mat:

```
for (int i = 1; i < histSize.get(0, 0)[0]; i++){
   Core.line(histImage, new Point(bin_w * (i - 1), hist_h - Math.round(hist_b.get(i -␣
↪1, 0)[0])), new Point(bin_w * (i), hist_h - Math.round(hist_b.get(i, 0)[0])), new␣
↪Scalar(255, 0, 0), 2, 8, 0);
   if (!gray){
      Core.line(histImage, new Point(bin_w * (i - 1), hist_h - Math.round(hist_g.
↪get(i - 1, 0)[0])),new Point(bin_w * (i), hist_h - Math.round(hist_g.get(i, 0)[0])),
↪ new Scalar(0, 255, 0), 2, 8, 0);
      Core.line(histImage, new Point(bin_w * (i - 1), hist_h - Math.round(hist_r.
↪get(i - 1, 0)[0])),Math.round(hist_r.get(i, 0)[0])), new Scalar(0, 0, 255), 2, 8,␣
↪0);
   }
}
```

Let's convert the obtained Mat to an Image with our method `mat2Image` and update the ImageView with the returned Image:

```
histo = mat2Image(histImage);
Platform.runLater(new Runnable() {
   @Override
   public void run() {
      histogram.setImage(histo);
   }
});
```


OpenCV Basics
Controls
Show in gray scale
Show logo
Stop Camera


OpenCV Basics
Controls
Show in gray scale
Show logo
Stop Camera

Source Code

- Basics.java

```
public class Basics extends Application {
    @Override
    public void start(Stage primaryStage) {
            try
            {
                    // load the FXML resource
                    FXMLLoader loader = new FXMLLoader(getClass().getResource(
↪"BasicsFX.fxml"));
                    // store the root element so that the controllers can use it
                    BorderPane rootElement = (BorderPane) loader.load();
                    // create and style a scene
                    Scene scene = new Scene(rootElement, 800, 600);
                    scene.getStylesheets().add(getClass().getResource("application.css
↪").toExternalForm());
                    // create the stage with the given title and the previously␣
↪created
                    // scene
                    primaryStage.setTitle("OpenCV Basics");
                    primaryStage.setScene(scene);
                    // show the GUI
                    primaryStage.show();

            }
            catch (Exception e)
            {
                    e.printStackTrace();
            }
    }

    public static void main(String[] args) {
            // load the native OpenCV library
            System.loadLibrary(Core.NATIVE_LIBRARY_NAME);

            launch(args);
    }
}
```

- BasicsController.java

```
public class BasicsController {
    // the FXML button
            @FXML
            private Button button;
            // the FXML grayscale checkbox
            @FXML
            private CheckBox grayscale;
            // the FXML logo checkbox
            @FXML
            private CheckBox logoCheckBox;
            // the FXML grayscale checkbox
            @FXML
            private ImageView histogram;
            // the FXML area for showing the current frame
            @FXML
```

```
        private ImageView currentFrame;

        // a timer for acquiring the video stream
        private Timer timer;
        // the OpenCV object that realizes the video capture
        private VideoCapture capture = new VideoCapture();
        // a flag to change the button behavior
        private boolean cameraActive = false;
        // the logo to be loaded
        private Mat logo;
        private Image i,histo;

        /**
         * The action triggered by pushing the button on the GUI
         */
        @FXML
        protected void startCamera()
        {
                if (!this.cameraActive)
                {
                        // start the video capture
                        this.capture.open(0);

                        // is the video stream available?
                        if (this.capture.isOpened())
                        {
                                this.cameraActive = true;

                                // grab a frame every 33 ms (30 frames/sec)
                                TimerTask frameGrabber = new TimerTask() {
                                        @Override
                                        public void run()
                                        {
                                                i = grabFrame();
                                                Platform.runLater(new Runnable() {
                                                        @Override
                                                        public void run() {
                                                                currentFrame.
↪setImage(i);

                                                        }
                                                });
                                        }
                                };
                                this.timer = new Timer();
                                this.timer.schedule(frameGrabber, 0, 33);

                                // update the button content
                                this.button.setText("Stop Camera");
                        }
                        else
                        {
                                // log the error
                                System.err.println("Impossible to open the camera␣
↪connection...");
                        }
                }
                else
                {
```

```
                                // the camera is not active at this point
                                this.cameraActive = false;
                                // update again the button content
                                this.button.setText("Start Camera");
                                // stop the timer
                                if (this.timer != null)
                                {
                                        this.timer.cancel();
                                        this.timer = null;
                                }
                                // release the camera
                                this.capture.release();
                                // clean the image area
                                Platform.runLater(new Runnable() {
                                        @Override
                                        public void run() {
                                                currentFrame.setImage(null);
                                        }
                                });
                        }
                }

                /**
                 * The action triggered by selecting/deselecting the logo checkbox
                 */
                @FXML
                protected void loadLogo()
                {
                        if (logoCheckBox.isSelected())
                        {
                                // read the logo only when the checkbox has been selected
                                this.logo = Highgui.imread("resources/Poli.png");
                        }
                }

                /**
                 * Get a frame from the opened video stream (if any)
                 *
                 * @return the {@link Image} to show
                 */
                private Image grabFrame()
                {
                        // init everything
                        Image imageToShow = null;
                        Mat frame = new Mat();

                        // check if the capture is open
                        if (this.capture.isOpened())
                        {
                                try
                                {
                                        // read the current frame
                                        this.capture.read(frame);

                                        // if the frame is not empty, process it
                                        if (!frame.empty())
                                        {
                                                // add a logo...
```

```
                                                        if (logoCheckBox.isSelected() && this.
↪logo != null)
                                                        {
                                                                Rect roi = new Rect(frame.cols() -
↪ logo.cols(), frame.rows() - logo.rows(), logo.cols(),logo.rows());
                                                                Mat imageROI = frame.submat(roi);
                                                                // add the logo: method #1
                                                                Core.addWeighted(imageROI, 1.0,␣
↪logo, 0.7, 0.0, imageROI);

                                                                // add the logo: method #2
                                                                // Mat mask = logo.clone();
                                                                // logo.copyTo(imageROI, mask);
                                                        }

                                                        // if the grayscale checkbox is selected,␣
↪convert the image
                                                        // (frame + logo) accordingly
                                                        if (grayscale.isSelected())
                                                        {
                                                                Imgproc.cvtColor(frame, frame,␣
↪Imgproc.COLOR_BGR2GRAY);
                                                        }

                                                        // show the histogram
                                                        this.showHistogram(frame, grayscale.
↪isSelected());

                                                        // convert the Mat object (OpenCV) to␣
↪Image (JavaFX)
                                                        imageToShow = mat2Image(frame);
                                                }

                                        }
                                        catch (Exception e)
                                        {
                                                // log the (full) error
                                                System.err.println("ERROR: " + e);
                                        }
                                }

                                return imageToShow;
                        }

                        /**
                         * Compute and show the histogram for the given {@link Mat} image
                         *
                         * @param frame
                         *            the {@link Mat} image for which compute the histogram
                         * @param gray
                         *            is a grayscale image?
                         */
                        private void showHistogram(Mat frame, boolean gray)
                        {
                                // split the frames in multiple images
                                List<Mat> images = new ArrayList<Mat>();
                                Core.split(frame, images);
```

```
                    // set the number of bins at 256
                    MatOfInt histSize = new MatOfInt(256);
                    // only one channel
                    MatOfInt channels = new MatOfInt(0);
                    // set the ranges
                    MatOfFloat histRange = new MatOfFloat(0, 256);

                    // compute the histograms for the B, G and R components
                    Mat hist_b = new Mat();
                    Mat hist_g = new Mat();
                    Mat hist_r = new Mat();

                    // B component or gray image
                    Imgproc.calcHist(images.subList(0, 1), channels, new Mat(), hist_
↪b, histSize, histRange, false);

                    // G and R components (if the image is not in gray scale)
                    if (!gray)
                    {
                            Imgproc.calcHist(images.subList(1, 2), channels, new␣
↪Mat(), hist_g, histSize, histRange, false);
                            Imgproc.calcHist(images.subList(2, 3), channels, new␣
↪Mat(), hist_r, histSize, histRange, false);
                    }

                    // draw the histogram
                    int hist_w = 150; // width of the histogram image
                    int hist_h = 150; // height of the histogram image
                    int bin_w = (int) Math.round(hist_w / histSize.get(0, 0)[0]);

                    Mat histImage = new Mat(hist_h, hist_w, CvType.CV_8UC3, new␣
↪Scalar(0, 0, 0));
                    // normalize the result to [0, histImage.rows()]
                    Core.normalize(hist_b, hist_b, 0, histImage.rows(), Core.NORM_
↪MINMAX, -1, new Mat());

                    // for G and R components
                    if (!gray)
                    {
                            Core.normalize(hist_g, hist_g, 0, histImage.rows(), Core.
↪NORM_MINMAX, -1, new Mat());
                            Core.normalize(hist_r, hist_r, 0, histImage.rows(), Core.
↪NORM_MINMAX, -1, new Mat());
                    }

                    // effectively draw the histogram(s)
                    for (int i = 1; i < histSize.get(0, 0)[0]; i++)
                    {
                            // B component or gray image
                            Core.line(histImage, new Point(bin_w * (i - 1), hist_h -␣
↪Math.round(hist_b.get(i - 1, 0)[0])), new Point(
                                            bin_w * (i), hist_h - Math.round(hist_b.
↪get(i, 0)[0])), new Scalar(255, 0, 0), 2, 8, 0);
                            // G and R components (if the image is not in gray scale)
                            if (!gray)
                            {
                                    Core.line(histImage, new Point(bin_w * (i - 1),␣
↪hist_h - Math.round(hist_g.get(i - 1, 0)[0])),
                                                    new Point(bin_w * (i), hist_h -␣
↪Math.round(hist_g.get(i, 0)[0])), new Scalar(0, 255, 0), 2, 8,
                                                    0);
                                    Core.line(histImage, new Point(bin_w * (i - 1),␣
↪hist_h - Math.round(hist_r.get(i - 1, 0)[0])),
                                                    new Point(bin_w * (i), hist_h -␣
↪Math.round(hist_r.get(i, 0)[0])), new Scalar(0, 0, 255), 2, 8,
                                                    0);
                            }
                    }

                    histo = mat2Image(histImage);

                    // display the whole
                    Platform.runLater(new Runnable() {
                            @Override
                public void run() {
                                    histogram.setImage(histo);
                    }
                            });

            }

            /**
             * Convert a Mat object (OpenCV) in the corresponding Image for JavaFX
             *
             * @param frame
             *            the {@link Mat} representing the current frame
             * @return the {@link Image} to show
             */
            private Image mat2Image(Mat frame)
            {
                    // create a temporary buffer
                    MatOfByte buffer = new MatOfByte();
                    // encode the frame in the buffer, according to the PNG format
                    Highgui.imencode(".png", frame, buffer);
                    // build and return an Image created from the image encoded in the
                    // buffer
                    return new Image(new ByteArrayInputStream(buffer.toArray()));
            }
}
```

- BasicsFX.fxml

```
<BorderPane xmlns:fx="http://javafx.com/fxml/1" fx:controller="application.
↪BasicsController">
        <center>
           <ImageView fx:id="currentFrame" />
   </center>
   <right>
      <VBox alignment="CENTER_LEFT" spacing="10">
         <padding>
            <Insets left="25" right="25"/>
         </padding>
         <ImageView fx:id="histogram" />
         <Text text="Controls" />
         <CheckBox fx:id="grayscale" text="Show in gray scale" />
         <CheckBox fx:id="logoCheckBox" text="Show logo" onAction="#loadLogo" />
      </VBox>
   </right>
   <bottom>
      <HBox alignment="CENTER" >
         <padding>
            <Insets top="25" right="25" bottom="25" left="25"/>
         </padding>
         <Button fx:id="button" alignment="center" text="Start camera" onAction="
↪#startCamera" />
      </HBox>
   </bottom>
</BorderPane>
```

CHAPTER 5

Camera Calibration

Note: We assume that by now you have already read the previous tutorials. If not, please check previous tutorials at http://polito-java-opencv-tutorials.readthedocs.org/en/latest/index.html. You can also find the source code and resources at https://github.com/java-opencv/Polito-Java-OpenCV-Tutorials-Source-Code

Goal

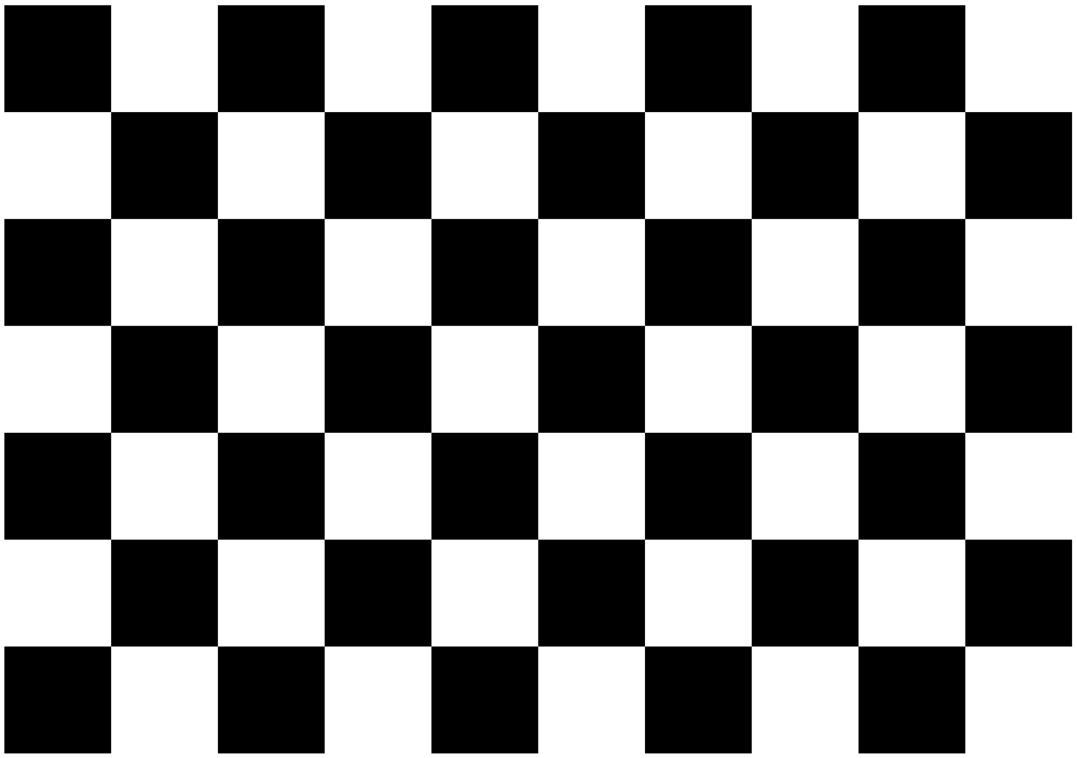
The goal of this tutorial is to learn how to calibrate a camera given a set of chessboard images.

What is the camera calibration?

The camera calibration is the process with which we can obtain the camera parameters such as intrinsic and extrinsic parameters, distortions and so on. The calibration of the camera is often necessary when the alignment between the lens and the optic sensors chip is not correct; the effect produced by this wrong alignment is usually more visible in low quality cameras.

Calibration Pattern

As we said earlier we are going to need some sort of pattern that the program can recognize in order to make the calibration work. The pattern that we are going to use is a chessboard image.



The reason why we use this image is because there are some OpenCV functions that can recognize this pattern and draw a scheme which highlights the intersections between each block. To make the calibration work you need to print the chessboard image and show it to the cam; it is important to maintain the sheet still, better if stick to a surface. In order to make a good calibration, we need to have about 20 samples of the pattern taken from different angles and distances.

What we will do in this tutorial

In this guide, we will:

- Create some TextEdit field to give some inputs to our program
- Recognize the pattern using some OpenCV functions
- Calibrate and show the video stream.

Getting Started

Create a new JavaFX project (e.g. "CameraCalibration") with the usual OpenCV user library. Open Scene Builder and add a Border Pane with:

- on **TOP** we need to have the possibility to set the number of samples for the calibration, the number of horizontal corners we have in the test image, the number of vertical corners we have in the test image and a button to update this data. To make things cleaner let's put all these elements inside a HBox.

```
<HBox alignment="CENTER" spacing="10">
```

Let's also add some labels before each text fields. Each text field is going to need an id, and let's put a standard value for them already.

```
<Label text="Boards #" />
<TextField fx:id="numBoards" text="20" maxWidth="50" />
<Label text="Horizontal corners #" />
<TextField fx:id="numHorCorners" text="9" maxWidth="50" />
<Label text="Vertical corners #" />
<TextField fx:id="numVertCorners" text="6" maxWidth="50" />
```

For the button instead, set the id and a method for the onAction field:

```
<Button fx:id="applyButton" alignment="center" text="Apply" onAction="#updateSettings
↪" />
```

- on the **LEFT** add an ImageView inside a VBox for the normal cam stream; set an id for it.

```
<ImageView fx:id="originalFrame" />
```

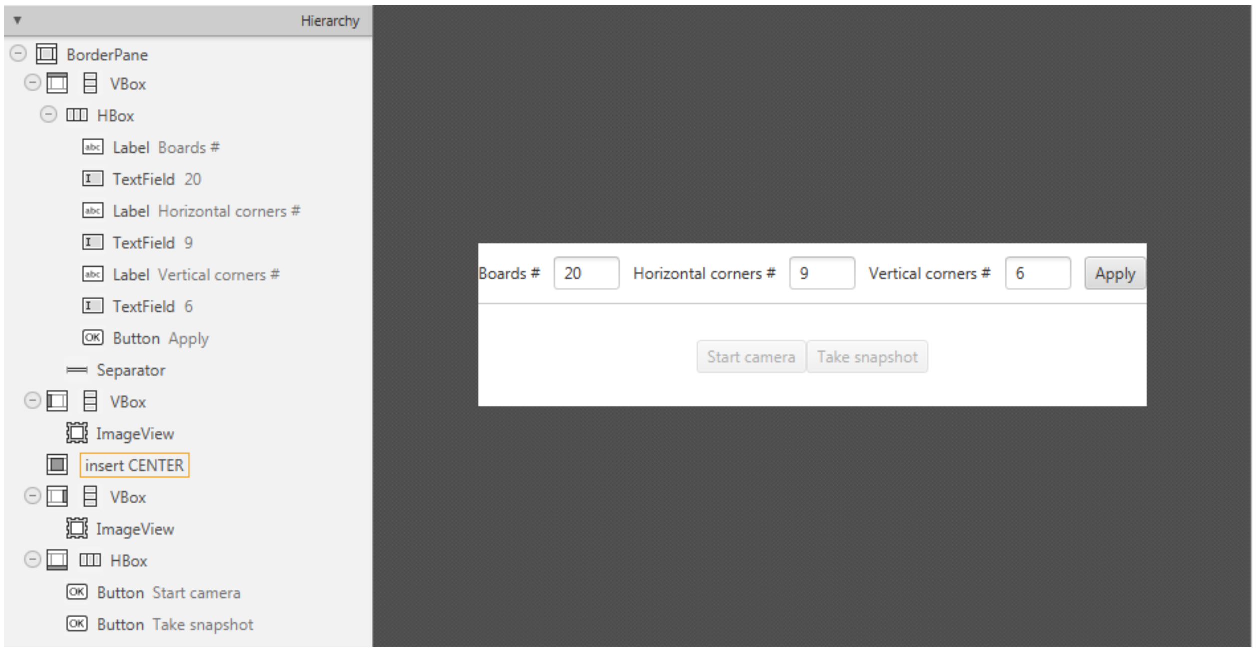
- on the **RIGHT** add an ImageView inside a VBox for the calibrated cam stream; set an id for it.

```
<ImageView fx:id="originalFrame" />
```

- in the **BOTTOM** add a start/stop cam stream button and a snapshot button inside a HBox; set an id and a action method for each one.

```
<Button fx:id="cameraButton" alignment="center" text="Start camera" onAction="
↪#startCamera" disable="true" />
<Button fx:id="snapshotButton" alignment="center" text="Take snapshot" onAction="
↪#takeSnapshot" disable="true" />
```

Your GUI will look something like this:



Pattern Recognition

The calibration process consists on showing to the cam the chessboard pattern from different angles, depth and points of view. For each recognized pattern we need to track:

- some reference system's 3D point where the chessboard is located (let's assume that the Z axe is always 0):

```
for (int j = 0; j < numSquares; j++)
   obj.push_back(new MatOfPoint3f(new Point3(j / this.numCornersHor, j %␣
↪this.numCornersVer, 0.0f)));
```

- the image's 2D points (operation made by OpenCV with findChessboardCorners):

```
boolean found = Calib3d.findChessboardCorners(grayImage, boardSize,␣
↪imageCorners, Calib3d.CALIB_CB_ADAPTIVE_THRESH + Calib3d.CALIB_CB_
↪NORMALIZE_IMAGE + Calib3d.CALIB_CB_FAST_CHECK);
```

The `findChessboardCorners` function attempts to determine whether the input image is a view of the chessboard pattern and locate the internal chessboard corners. Its parameters are:

- **image** Source chessboard view. It must be an 8-bit grayscale or color image.
- **patternSize** Number of inner corners per a chessboard row and column
- **corners** Output array of detected corners.
- **flags Various operation flags that can be zero or a combination of the following values:**
  - `CV_CALIB_CB_ADAPTIVE_THRESH` Use adaptive thresholding to convert the image to black and white, rather than a fixed threshold level (computed from the average image brightness).
  - `CV_CALIB_CB_NORMALIZE_IMAGE` Normalize the image gamma with "equalizeHist" before applying fixed or adaptive thresholding.
  - `CV_CALIB_CB_FILTER_QUADS` Use additional criteria (like contour area, perimeter, square-like shape) to filter out false quads extracted at the contour retrieval stage.
  - `CALIB_CB_FAST_CHECK` Run a fast check on the image that looks for chessboard corners, and shortcut the call if none is found. This can drastically speed up the call in the degenerate condition when no chessboard is observed.

Warning: Before doing the `findChessboardCorners` convert the image to gayscale and save the board size into a Size variable:

```
Imgproc.cvtColor(frame, grayImage, Imgproc.COLOR_BGR2GRAY);
Size boardSize = new Size(this.numCornersHor, this.numCornersVer);
```

If the recognition went well `found` should be `true`.

For square images the positions of the corners are only approximate. We may improve this by calling the `cornerSubPix` function. It will produce better calibration result.

```
TermCriteria term = new TermCriteria(TermCriteria.EPS | TermCriteria.MAX_ITER, 30, 0.
↪1);
Imgproc.cornerSubPix(grayImage, imageCorners, new Size(11, 11), new Size(-1, -1),␣
↪term);
```

We can now highlight the found points on stream:

```
Calib3d.drawChessboardCorners(frame, boardSize, imageCorners, found);
```

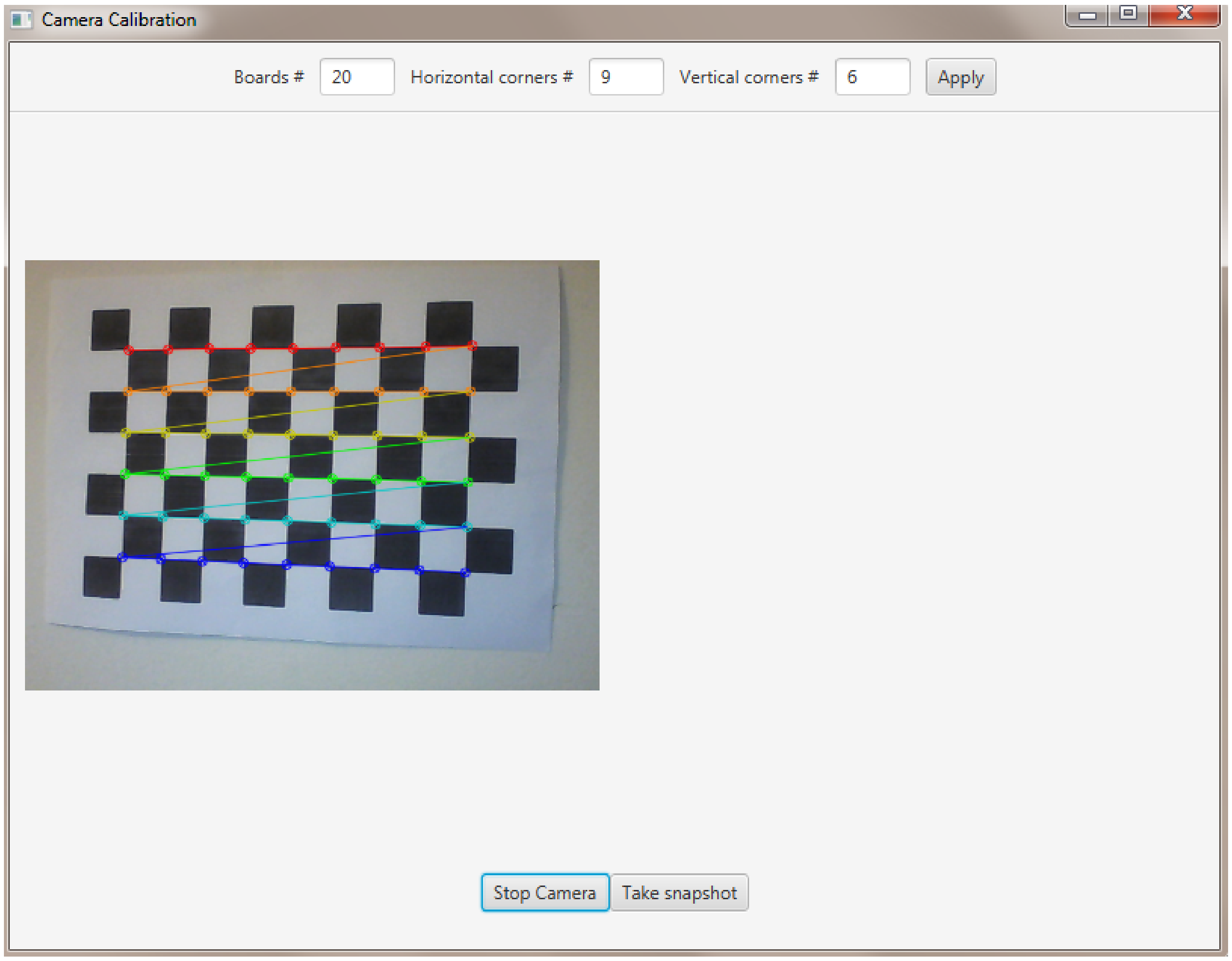
The function draws individual chessboard corners detected either as red circles if the board was not found, or as colored corners connected with lines if the board was found.

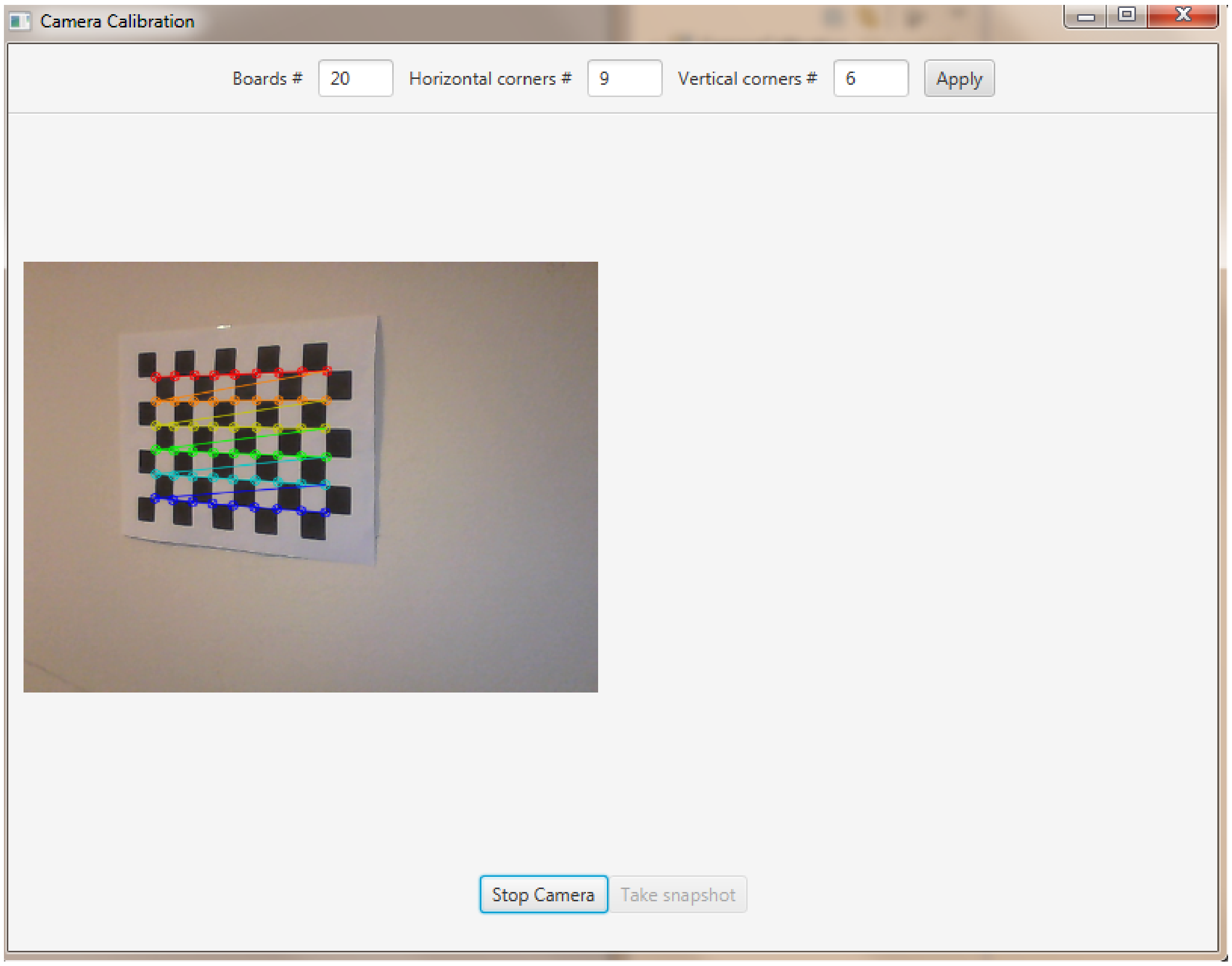
Its parameters are:

- **image** Destination image. It must be an 8-bit color image.
- **patternSize** Number of inner corners per a chessboard row and column.
- **corners** Array of detected corners, the output of findChessboardCorners.
- **patternWasFound** Parameter indicating whether the complete board was found or not. The return value of `findChessboardCorners` should be passed here.

Now we can activate the Snapshot button to save the data.

```
this.snapshotButton.setDisable(false);
```





We should take the set number of "snapshots" from different angles and depth, in order to make the calibration.

Note: We don't actually save the image but just the data we need.

Saving Data

By clicking on the snapshot button we cal the `takeSnapshot` method. Here we need to save the data (2D and 3D points) if we did not make enough sample:

```
this.imagePoints.add(imageCorners);
this.objectPoints.add(obj);
this.successes++;
```

Otherwise we can calibrate the camera.

Camera Calibration

For the camera calibration we should create initiate some needed variable and then call the actual calibration function:

```
List<Mat> rvecs = new ArrayList<>();
List<Mat> tvecs = new ArrayList<>();
intrinsic.put(0, 0, 1);
intrinsic.put(1, 1, 1);

Calib3d.calibrateCamera(objectPoints, imagePoints, savedImage.size(), intrinsic,␣
↪distCoeffs, rvecs, tvecs);
```

The `calibrateCamera` function estimates the intrinsic camera parameters and extrinsic parameters for each of the views. The algorithm is based on [Zhang2000] and [BouguetMCT]. The coordinates of 3D object points and their corresponding 2D projections in each view must be specified. Its parameters are:

- **objectPoints** In the new interface it is a vector of vectors of calibration pattern points in the calibration pattern coordinate space. The outer vector contains as many elements as the number of the pattern views. The points are 3D, but since they are in a pattern coordinate system, then, if the rig is planar, it may make sense to put the model to a XY coordinate plane so that Z-coordinate of each input object point is 0.
- **imagePoints** It is a vector of vectors of the projections of calibration pattern points.
- **imageSize** Size of the image used only to initialize the intrinsic camera matrix.
- **cameraMatrix** Output 3x3 floating-point camera matrix *A* = |*fx 0 cx*| |*0 fy cy*| |*0 0 1*|. If `CV_CALIB_USE_INTRINSIC_GUESS` and/or `CV_CALIB_FIX_ASPECT_RATIO` are specified, some or all of *fx*, *fy*, *cx*, *cy* must be initialized before calling the function.
- **distCoeffs** Output vector of distortion coefficients of 4, 5, or 8 elements.
- **rvecs** Output vector of rotation vectors estimated for each pattern view. That is, each k-th rotation vector together with the corresponding k-th translation vector.
- **tvecs** Output vector of translation vectors estimated for each pattern view.

We ran calibration and got camera's matrix with the distortion coefficients we may want to correct the image using `undistort` function:

```
if (this.isCalibrated)
{
    // prepare the undistored image
    Mat undistored = new Mat();
    Imgproc.undistort(frame, undistored, intrinsic, distCoeffs);
    undistoredImage = mat2Image(undistored);
}
```

The `undistort` function transforms an image to compensate radial and tangential lens distortion.

Source Code

- CameraCalibration.java

```
public class CameraCalibration extends Application {
    @Override
    public void start(Stage primaryStage) {
            try {
                    // load the FXML resource
                    FXMLLoader loader = new FXMLLoader(getClass().getResource("CC_FX.
↪fxml"));
                    // store the root element so that the controllers can use it
                    BorderPane rootElement = (BorderPane) loader.load();
```

```
                        // set a whitesmoke background
                        rootElement.setStyle("-fx-background-color: whitesmoke;");
                        // create and style a scene
                        Scene scene = new Scene(rootElement, 800, 600);
                        scene.getStylesheets().add(getClass().getResource("application.css
↪").toExternalForm());
                        // create the stage with the given title and the previously␣
↪created
                        // scene
                        primaryStage.setTitle("Camera Calibration");
                        primaryStage.setScene(scene);
                        // init the controller variables
                        CC_Controller controller = loader.getController();
                        controller.init();
                        // show the GUI
                        primaryStage.show();
                } catch(Exception e) {
                        e.printStackTrace();
                }
        }

        public static void main(String[] args) {
                // load the native OpenCV library
                System.loadLibrary(Core.NATIVE_LIBRARY_NAME);

                launch(args);
        }
}
```

- CC_Controller.java

```
public class CC_Controller {
    // FXML buttons
            @FXML
            private Button cameraButton;
            @FXML
            private Button applyButton;
            @FXML
            private Button snapshotButton;
            // the FXML area for showing the current frame (before calibration)
            @FXML
            private ImageView originalFrame;
            // the FXML area for showing the current frame (after calibration)
            @FXML
            private ImageView calibratedFrame;
            // info related to the calibration process
            @FXML
            private TextField numBoards;
            @FXML
            private TextField numHorCorners;
            @FXML
            private TextField numVertCorners;

            // a timer for acquiring the video stream
            private Timer timer;
            // the OpenCV object that performs the video capture
            private VideoCapture capture;
            // a flag to change the button behavior
```

```
	private boolean cameraActive;
	// the saved chessboard image
	private Mat savedImage;
	// the calibrated camera frame
	private Image undistoredImage,CamStream;
	// various variables needed for the calibration
	private List<Mat> imagePoints;
	private List<Mat> objectPoints;
	private MatOfPoint3f obj;
	private MatOfPoint2f imageCorners;
	private int boardsNumber;
	private int numCornersHor;
	private int numCornersVer;
	private int successes;
	private Mat intrinsic;
	private Mat distCoeffs;
	private boolean isCalibrated;

	/**
	 * Init all the (global) variables needed in the controller
	 */
	protected void init()
	{
		this.capture = new VideoCapture();
		this.cameraActive = false;
		this.obj = new MatOfPoint3f();
		this.imageCorners = new MatOfPoint2f();
		this.savedImage = new Mat();
		this.undistoredImage = null;
		this.imagePoints = new ArrayList<>();
		this.objectPoints = new ArrayList<>();
		this.intrinsic = new Mat(3, 3, CvType.CV_32FC1);
		this.distCoeffs = new Mat();
		this.successes = 0;
		this.isCalibrated = false;
	}

	/**
	 * Store all the chessboard properties, update the UI and prepare other
	 * needed variables
	 */
	@FXML
	protected void updateSettings()
	{
		this.boardsNumber = Integer.parseInt(this.numBoards.getText());
		this.numCornersHor = Integer.parseInt(this.numHorCorners.
↪getText());
		this.numCornersVer = Integer.parseInt(this.numVertCorners.
↪getText());
		int numSquares = this.numCornersHor * this.numCornersVer;
		for (int j = 0; j < numSquares; j++)
			obj.push_back(new MatOfPoint3f(new Point3(j / this.
↪numCornersHor, j % this.numCornersVer, 0.0f)));
		this.cameraButton.setDisable(false);
	}

	/**
	 * The action triggered by pushing the button on the GUI
```

```
         */
        @FXML
        protected void startCamera()
        {
                if (!this.cameraActive)
                {
                        // start the video capture
                        this.capture.open(0);

                        // is the video stream available?
                        if (this.capture.isOpened())
                        {
                                this.cameraActive = true;

                                // grab a frame every 33 ms (30 frames/sec)
                                TimerTask frameGrabber = new TimerTask() {
                                        @Override
                                        public void run()
                                        {
                                                CamStream=grabFrame();
                                                // show the original frames
                                                Platform.runLater(new Runnable() {
                                                        @Override
                                                    public void run() {
                                                                originalFrame.
↪setImage(CamStream);
                                                                // set fixed width
                                                                originalFrame.
↪setFitWidth(380);
                                                                // preserve image␣
↪ratio
                                                                originalFrame.
↪setPreserveRatio(true);
                                                                // show the␣
↪original frames
                                                                calibratedFrame.
↪setImage(undistoredImage);
                                                                // set fixed width
                                                                calibratedFrame.
↪setFitWidth(380);
                                                                // preserve image␣
↪ratio
                                                                calibratedFrame.
↪setPreserveRatio(true);
                                                }
                                                        });

                                        }
                                };
                                this.timer = new Timer();
                                this.timer.schedule(frameGrabber, 0, 33);

                                // update the button content
                                this.cameraButton.setText("Stop Camera");
                        }
                        else
                        {
                                // log the error
```

```
                                        System.err.println("Impossible to open the camera␣
↪connection...");
                                }
                        }
                        else
                        {
                                // the camera is not active at this point
                                this.cameraActive = false;
                                // update again the button content
                                this.cameraButton.setText("Start Camera");
                                // stop the timer
                                if (this.timer != null)
                                {
                                        this.timer.cancel();
                                        this.timer = null;
                                }
                                // release the camera
                                this.capture.release();
                                // clean the image areas
                                originalFrame.setImage(null);
                                calibratedFrame.setImage(null);
                        }
                }

                /**
                 * Get a frame from the opened video stream (if any)
                 *
                 * @return the {@link Image} to show
                 */
                private Image grabFrame()
                {
                        // init everything
                        Image imageToShow = null;
                        Mat frame = new Mat();

                        // check if the capture is open
                        if (this.capture.isOpened())
                        {
                                try
                                {
                                        // read the current frame
                                        this.capture.read(frame);

                                        // if the frame is not empty, process it
                                        if (!frame.empty())
                                        {
                                                // show the chessboard pattern
                                                this.findAndDrawPoints(frame);

                                                if (this.isCalibrated)
                                                {
                                                        // prepare the undistored image
                                                        Mat undistored = new Mat();
                                                        Imgproc.undistort(frame,␣
↪undistored, intrinsic, distCoeffs);
                                                        undistoredImage =␣
↪mat2Image(undistored);
                                                }
```

```
                                                        // convert the Mat object (OpenCV) to␣
↪Image (JavaFX)
                                                        imageToShow = mat2Image(frame);
                                                }

                                        }
                                        catch (Exception e)
                                        {
                                                // log the (full) error
                                                System.err.print("ERROR");
                                                e.printStackTrace();
                                        }
                                }

                                return imageToShow;
                        }

                        /**
                         * Take a snapshot to be used for the calibration process
                         */
                        @FXML
                        protected void takeSnapshot()
                        {
                                if (this.successes < this.boardsNumber)
                                {
                                        // save all the needed values
                                        this.imagePoints.add(imageCorners);
                                        this.objectPoints.add(obj);
                                        this.successes++;
                                }

                                // reach the correct number of images needed for the calibration
                                if (this.successes == this.boardsNumber)
                                {
                                        this.calibrateCamera();
                                }
                        }

                        /**
                         * Find and draws the points needed for the calibration on the chessboard
                         *
                         * @param frame
                         *            the current frame
                         * @return the current number of successfully identified chessboards as an
                         *         int
                         */
                        private void findAndDrawPoints(Mat frame)
                        {
                                // init
                                Mat grayImage = new Mat();

                                // I would perform this operation only before starting the␣
↪calibration
                                // process
                                if (this.successes < this.boardsNumber)
                                {
                                        // convert the frame in gray scale
                                        Imgproc.cvtColor(frame, grayImage, Imgproc.COLOR_
            ↪BGR2GRAY);
                                        // the size of the chessboard
                                        Size boardSize = new Size(this.numCornersHor, this.
            ↪numCornersVer);
                                        // look for the inner chessboard corners
                                        boolean found = Calib3d.findChessboardCorners(grayImage,␣
            ↪boardSize, imageCorners,
                                                        Calib3d.CALIB_CB_ADAPTIVE_THRESH +␣
            ↪Calib3d.CALIB_CB_NORMALIZE_IMAGE + Calib3d.CALIB_CB_FAST_CHECK);
                                        // all the required corners have been found...
                                        if (found)
                                        {
                                                // optimization
                                                TermCriteria term = new TermCriteria(TermCriteria.
            ↪EPS | TermCriteria.MAX_ITER, 30, 0.1);
                                                Imgproc.cornerSubPix(grayImage, imageCorners, new␣
            ↪Size(11, 11), new Size(-1, -1), term);
                                                // save the current frame for further elaborations
                                                grayImage.copyTo(this.savedImage);
                                                // show the chessboard inner corners on screen
                                                Calib3d.drawChessboardCorners(frame, boardSize,␣
            ↪imageCorners, found);

                                                // enable the option for taking a snapshot
                                                this.snapshotButton.setDisable(false);
                                        }
                                        else
                                        {
                                                this.snapshotButton.setDisable(true);
                                        }
                                }
                        }

                        /**
                         * The effective camera calibration, to be performed once in the program
                         * execution
                         */
                        private void calibrateCamera()
                        {
                                // init needed variables according to OpenCV docs
                                List<Mat> rvecs = new ArrayList<>();
                                List<Mat> tvecs = new ArrayList<>();
                                intrinsic.put(0, 0, 1);
                                intrinsic.put(1, 1, 1);
                                // calibrate!
                                Calib3d.calibrateCamera(objectPoints, imagePoints, savedImage.
            ↪size(), intrinsic, distCoeffs, rvecs, tvecs);
                                this.isCalibrated = true;

                                // you cannot take other snapshot, at this point...
                                this.snapshotButton.setDisable(true);
                        }

                        /**
                         * Convert a Mat object (OpenCV) in the corresponding Image for JavaFX
                         *
                         * @param frame
```

```
             *             the {@link Mat} representing the current frame
             * @return the {@link Image} to show
             */
            private Image mat2Image(Mat frame)
            {
                    // create a temporary buffer
                    MatOfByte buffer = new MatOfByte();
                    // encode the frame in the buffer, according to the PNG format
                    Highgui.imencode(".png", frame, buffer);
                    // build and return an Image created from the image encoded in the
                    // buffer
                    return new Image(new ByteArrayInputStream(buffer.toArray()));
            }
}
```

- CC_FX.fxml

```
<BorderPane xmlns:fx="http://javafx.com/fxml/1" fx:controller="application.CC_
↪Controller">
    <top>
            <VBox>
                    <HBox alignment="CENTER" spacing="10">
                            <padding>
                                    <Insets top="10" bottom="10" />
                            </padding>
                            <Label text="Boards #" />
                            <TextField fx:id="numBoards" text="20" maxWidth="50" />
                            <Label text="Horizontal corners #" />
                            <TextField fx:id="numHorCorners" text="9" maxWidth="50" />
                            <Label text="Vertical corners #" />
                            <TextField fx:id="numVertCorners" text="6" maxWidth="50" /
↪>
                            <Button fx:id="applyButton" alignment="center" text="Apply
↪" onAction="#updateSettings" />
                    </HBox>
                    <Separator />
            </VBox>
    </top>
    <left>
            <VBox alignment="CENTER">
                    <padding>
                            <Insets right="10" left="10" />
                    </padding>
                    <ImageView fx:id="originalFrame" />
            </VBox>
    </left>
    <right>
            <VBox alignment="CENTER">
                    <padding>
                            <Insets right="10" left="10" />
                    </padding>
                    <ImageView fx:id="calibratedFrame" />
            </VBox>
    </right>
    <bottom>
            <HBox alignment="CENTER">
                    <padding>
                            <Insets top="25" right="25" bottom="25" left="25" />
                    </padding>
                    <Button fx:id="cameraButton" alignment="center" text="Start camera
↪" onAction="#startCamera" disable="true" />
                    <Button fx:id="snapshotButton" alignment="center" text="Take␣
↪snapshot" onAction="#takeSnapshot" disable="true" />
            </HBox>
    </bottom>
</BorderPane>
```

CHAPTER 6

Fourier Transform

Note: We assume that by now you have already read the previous tutorials. If not, please check previous tutorials at http://polito-java-opencv-tutorials.readthedocs.org/en/latest/index.html. You can also find the source code and resources at https://github.com/java-opencv/Polito-Java-OpenCV-Tutorials-Source-Code

Goal

In this tutorial we are going to create a JavaFX application where we can load a picture from our file system and apply to it the *DFT* and the *inverse DFT*.

What is the Fourier Transform?

The Fourier Transform will decompose an image into its sinus and cosines components. In other words, it will transform an image from its spatial domain to its frequency domain. The result of the transformation is complex numbers. Displaying this is possible either via a real image and a complex image or via a magnitude and a phase image. However, throughout the image processing algorithms only the magnitude image is interesting as this contains all the information we need about the images geometric structure. For this tutorial we are going to use basic gray scale image, whose values usually are between zero and 255. Therefore the Fourier Transform too needs to be of a discrete type resulting in a Discrete Fourier Transform (DFT). The DFT is the sampled Fourier Transform and therefore does not contain all frequencies forming an image, but only a set of samples which is large enough to fully describe the spatial domain image. The number of frequencies corresponds to the number of pixels in the spatial domain image, i.e. the image in the spatial and Fourier domain are of the same size.

What we will do in this tutorial

In this guide, we will:

- Load an image from a *file chooser*.
- Apply the *DFT* to the loaded image and show it.
- Apply the *iDFT* to the transformed image and show it.

Getting Started

Let's create a new JavaFX project. In Scene Builder set the windows element so that we have a Border Pane with:

- on the **LEFT** an ImageView to show the loaded picture:

```
<ImageView fx:id="originalImage" />
```

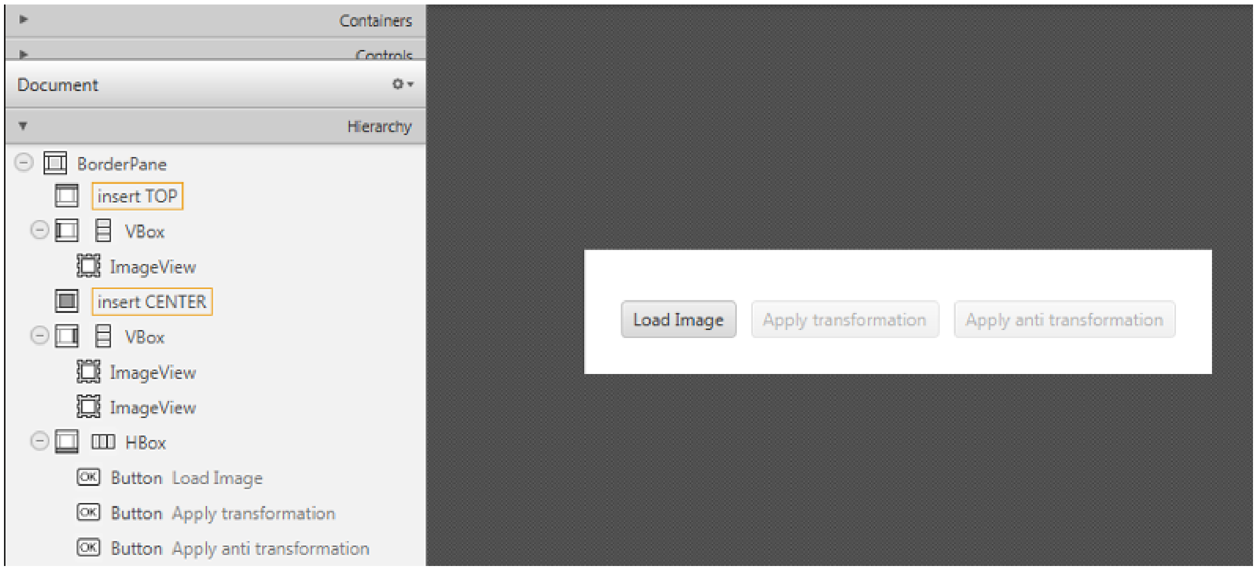
- on the **RIGHT** two ImageViews one over the other to display the DFT and the iDFT;

```
<ImageView fx:id="transformedImage" />
<ImageView fx:id="antitransformedImage" />
```

- on the **BOTTOM** three buttons, the first one to load the picture, the second one to apply the DFT and show it, and the last one to apply the anti-transform and show it.

```
<Button alignment="center" text="Load Image" onAction="#loadImage"/>
<Button fx:id="transformButton" alignment="center" text="Apply transformation"␣
↪onAction="#transformImage" disable="true" />
<Button fx:id="antitransformButton" alignment="center" text="Apply anti transformation
↪" onAction="#antitransformImage" disable="true" />
```

The gui will look something like this one:



Load the file

First of all you need to add to your project a folder `resources` with two files in it. One of them is a sine function and the other one is a circular aperture. In the Controller file, in order to load the image to our program, we are going to use a *filechooser*:

```
private FileChooser fileChooser;
```

When we click the load button we have to set the initial directory of the FC and open the dialog. The FC will return the selected file:

```
File file = new File("./resources/");
this.fileChooser.setInitialDirectory(file);
file = this.fileChooser.showOpenDialog(this.main.getStage());
```

Once we've loaded the file we have to make sure that it's going to be in grayscale and display the image into the image view:

```
this.image = Highgui.imread(file.getAbsolutePath(), Highgui.CV_LOAD_IMAGE_GRAYSCALE);
this.originalImage.setImage(this.mat2Image(this.image));
```

Applying the DFT

First of all expand the image to an optimal size. The performance of a DFT is dependent of the image size. It tends to be the fastest for image sizes that are multiple of the numbers two, three and five. Therefore, to achieve maximal performance it is generally a good idea to pad border values to the image to get a size with such traits. The `getOptimalDFTSize()` returns this optimal size and we can use the `copyMakeBorder()` function to expand the borders of an image:

```
int addPixelRows = Core.getOptimalDFTSize(image.rows());
int addPixelCols = Core.getOptimalDFTSize(image.cols());
Imgproc.copyMakeBorder(image, padded, 0, addPixelRows - image.rows(), 0, addPixelCols␣
↪- image.cols(),Imgproc.BORDER_CONSTANT, Scalar.all(0));
```

The appended pixels are initialized with zero.

The result of the DFT is complex so we have to make place for both the complex and the real values. We store these usually at least in a float format. Therefore we'll convert our input image to this type and expand it with another channel to hold the complex values:

```
padded.convertTo(padded, CvType.CV_32F);
this.planes.add(padded);
this.planes.add(Mat.zeros(padded.size(), CvType.CV_32F));
Core.merge(this.planes, this.complexImage);
```

Now we can apply the DFT and then get the real and the imaginary part from the complex image:

```
Core.dft(this.complexImage, this.complexImage);
Core.split(complexImage, newPlanes);
Core.magnitude(newPlanes.get(0), newPlanes.get(1), mag);
```

Unfortunately the dynamic range of the Fourier coefficients is too large to be displayed on the screen. To use the gray scale values to for visualization we can transform our linear scale to a logarithmic one:

```
Core.add(mag, Scalar.all(1), mag);
Core.log(mag, mag);
```

Remember, that at the first step, we expanded the image? Well, it's time to throw away the newly introduced values. For visualization purposes we may also rearrange the quadrants of the result, so that the origin (zero, zero) corresponds with the image center:

```
image = image.submat(new Rect(0, 0, image.cols() & -2, image.rows() & -2));
int cx = image.cols() / 2;
int cy = image.rows() / 2;

Mat q0 = new Mat(image, new Rect(0, 0, cx, cy));
Mat q1 = new Mat(image, new Rect(cx, 0, cx, cy));
Mat q2 = new Mat(image, new Rect(0, cy, cx, cy));
Mat q3 = new Mat(image, new Rect(cx, cy, cx, cy));

Mat tmp = new Mat();
q0.copyTo(tmp);
q3.copyTo(q0);
tmp.copyTo(q3);

q1.copyTo(tmp);
q2.copyTo(q1);
tmp.copyTo(q2);
```

Now we have to normalize our values by using the `normalize()` function in order to transform the matrix with float values into a viewable image form:

```
Core.normalize(mag, mag, 0, 255, Core.NORM_MINMAX);
```

The last step is to show the magnitude image in the ImageView:

```
this.transformedImage.setImage(this.mat2Image(magnitude));
```

Applying the iDFT

To apply the inverse DFT we simply use the `idft()` function, extract the real values from the complex image with the `split()` function, and normalize the result with `normalize()`:

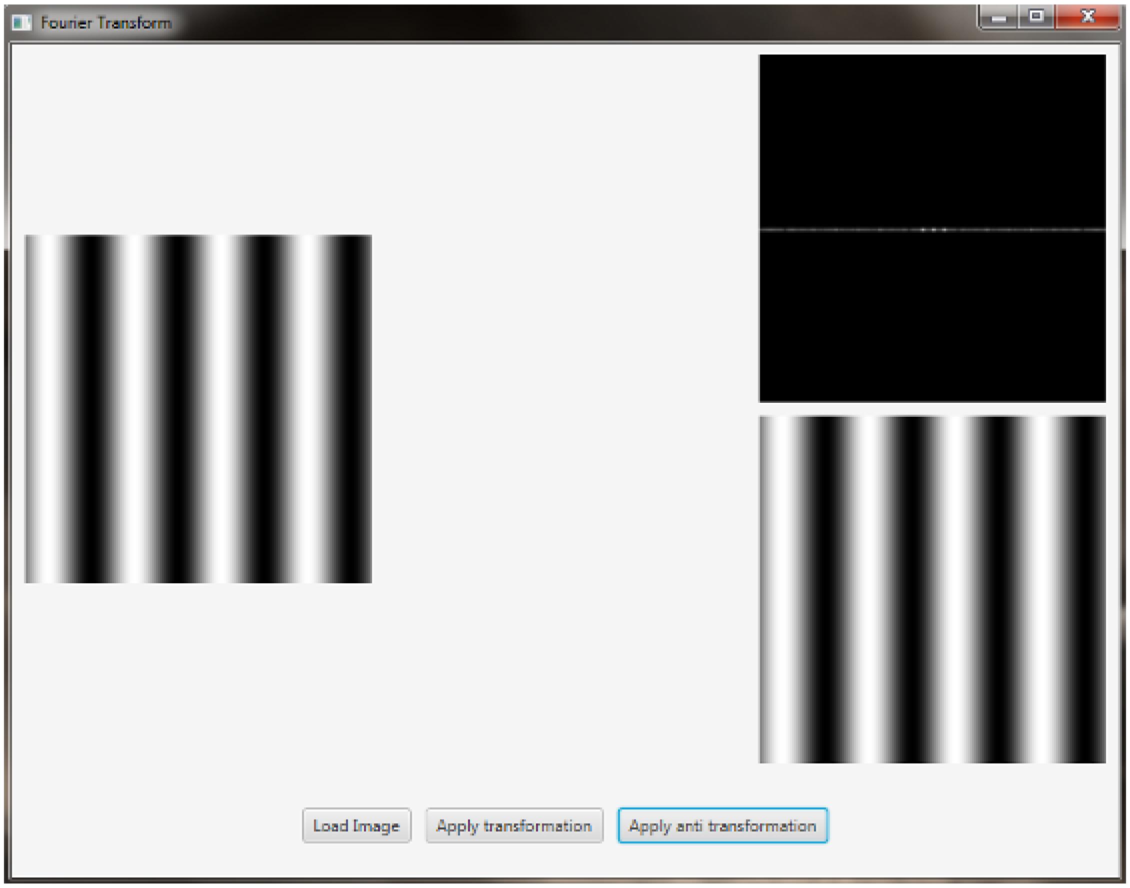
```
Core.idft(this.complexImage, this.complexImage);
Mat restoredImage = new Mat();
Core.split(this.complexImage, this.planes);
Core.normalize(this.planes.get(0), restoredImage, 0, 255, Core.NORM_MINMAX);
```

Finally we can show the result on the proper ImageView:

```
this.antitransformedImage.setImage(this.mat2Image(restoredImage));
```

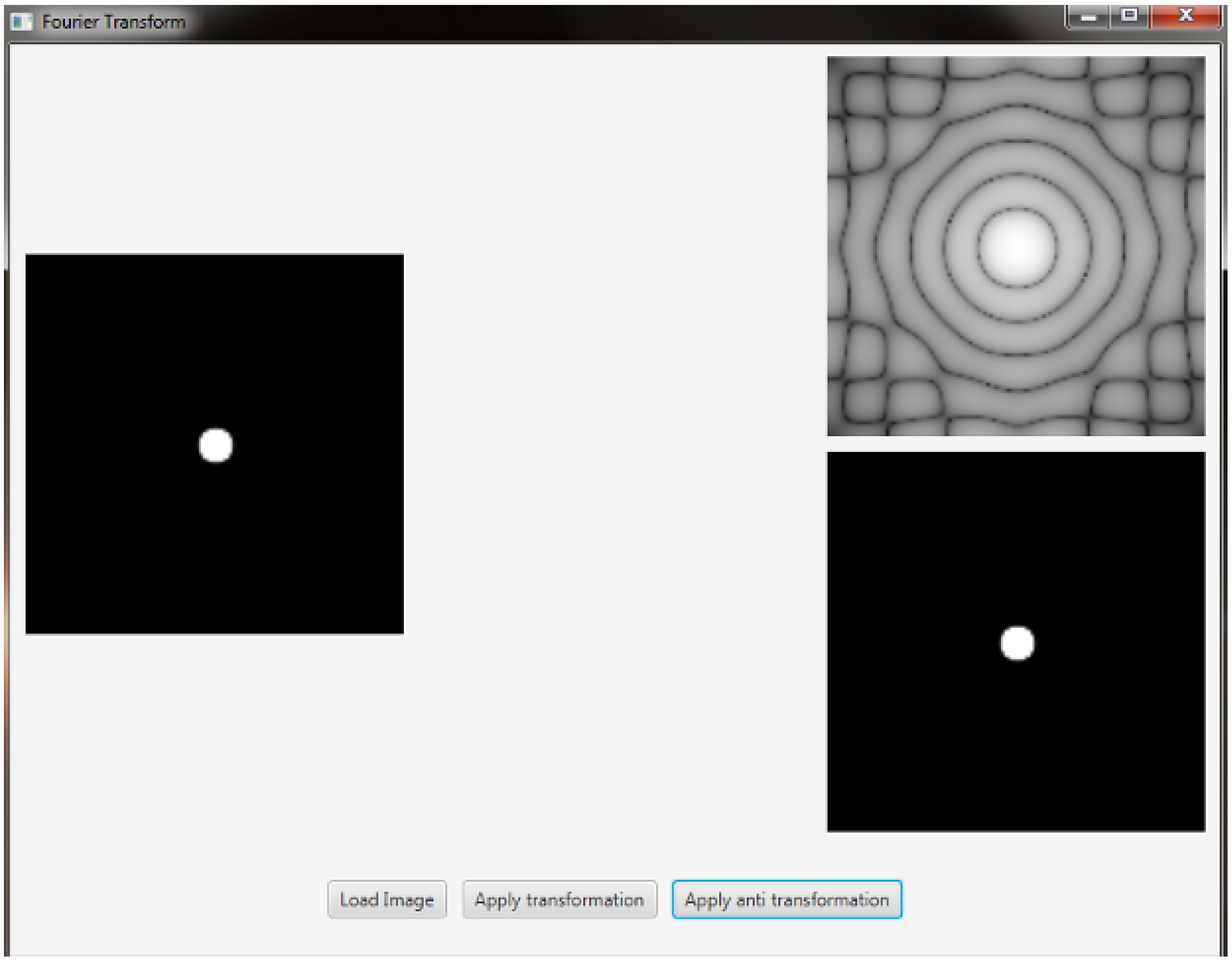
Analyzing the results

- *sinfunction.png*



The image is a horizontal sine of 4 cycles. Notice that the DFT just has a single component, represented by 2 bright spots symmetrically placed about the center of the DFT image. The center of the image is the origin of the frequency coordinate system. The x-axis runs left to right through the center and represents the horizontal component of frequency. The y-axis runs bottom to top through the center and represents the vertical component of frequency. There is a dot at the center that represents the (0,0) frequency term or average value of the image. Images usually have a large average value (like 128) and lots of low frequency information so FT images usually have a bright blob of components near the center. High frequencies in the horizontal direction will cause bright dots away from the center in the horizontal direction.

- *circle.png*



In this case we have a circular aperture, and what is the Fourier transform of a circular aperture? The diffraction disk and rings. A large aperture produces a compact transform, instead a small one produces a larger Airy pattern; thus the disk is greater if aperture is smaller; according to Fourier properties, from the center to the middle of the first dark ring the distance is *(1.22 x N) / d*; in this case N is the size of the image, and d is the diameter of the circle. An *Airy disk* is the bright center of the diffraction pattern created from a circular aperture ideal optical system; nearly half of the light is contained in a diameter of *1.02 x lamba x f_number*.

Source Code

- FourierTransform.java

```
public class FourierTransform extends Application {
    // the main stage
    private Stage primaryStage;

    @Override
    public void start(Stage primaryStage) {
            try
            {
                    // load the FXML resource
                    FXMLLoader loader = new FXMLLoader(getClass().getResource("FT_FX.
↪fxml"));
```

```
                    BorderPane root = (BorderPane) loader.load();
                    // set a whitesmoke background
                    root.setStyle("-fx-background-color: whitesmoke;");
                    Scene scene = new Scene(root, 800, 600);
                    scene.getStylesheets().add(getClass().getResource("application.css
↪").toExternalForm());
                    // create the stage with the given title and the previously␣
↪created scene
                    this.primaryStage = primaryStage;
                    this.primaryStage.setTitle("Fourier Transform");
                    this.primaryStage.setScene(scene);
                    this.primaryStage.show();

                    // init the controller
                    FT_Controller controller = loader.getController();
                    controller.setMainApp(this);
                    controller.init();
            }
            catch(Exception e) {
                    e.printStackTrace();
            }
    }

    /**
     * Get the main stage
     *
     * @return the stage
     */
    protected Stage getStage()
    {
            return this.primaryStage;
    }

    public static void main(String[] args) {
            // load the native OpenCV library
            System.loadLibrary(Core.NATIVE_LIBRARY_NAME);

            launch(args);
    }
}
```

- FT_Controller.java

```
public class FT_Controller {
            // images to show in the view
            @FXML
            private ImageView originalImage;
            @FXML
            private ImageView transformedImage;
            @FXML
            private ImageView antitransformedImage;
            // a FXML button for performing the transformation
            @FXML
            private Button transformButton;
            // a FXML button for performing the antitransformation
            @FXML
            private Button antitransformButton;
            // the main app
            private FourierTransform main;
            // the JavaFX file chooser
            private FileChooser fileChooser;
            // support variables
            private Mat image;
            private List<Mat> planes;
            // the final complex image
            private Mat complexImage;

            /**
             * Init the needed variables
             */
            protected void init()
            {
                    this.fileChooser = new FileChooser();
                    this.image = new Mat();
                    this.planes = new ArrayList<>();
                    this.complexImage = new Mat();
            }

            /**
             * Load an image from disk
             */
            @FXML
            protected void loadImage()
            {
                    // show the open dialog window
                    File file = new File("./resources/");
                    this.fileChooser.setInitialDirectory(file);
                    file = this.fileChooser.showOpenDialog(this.main.getStage());
                    if (file != null)
                    {
                            // read the image in gray scale
                            this.image = Highgui.imread(file.getAbsolutePath(),␣
↪Highgui.CV_LOAD_IMAGE_GRAYSCALE);
                            // show the image
                            this.originalImage.setImage(this.mat2Image(this.image));
                            // set a fixed width
                            this.originalImage.setFitWidth(250);
                            // preserve image ratio
                            this.originalImage.setPreserveRatio(true);
                            // update the UI
                            this.transformButton.setDisable(false);
                            // empty the image planes if it is not the first image to␣
↪be loaded
                            if (!this.planes.isEmpty())
                                    this.planes.clear();
                    }
            }

            /**
             * The action triggered by pushing the button for apply the dft to the
             * loaded image
             */
            @FXML
            protected void transformImage()
            {
```

```
                        // optimize the dimension of the loaded image
                        Mat padded = this.optimizeImageDim(this.image);
                        padded.convertTo(padded, CvType.CV_32F);
                        // prepare the image planes to obtain the complex image
                        this.planes.add(padded);
                        this.planes.add(Mat.zeros(padded.size(), CvType.CV_32F));
                        // prepare a complex image for performing the dft
                        Core.merge(this.planes, this.complexImage);

                        // dft
                        Core.dft(this.complexImage, this.complexImage);

                        // optimize the image resulting from the dft operation
                        Mat magnitude = this.createOptimizedMagnitude(this.complexImage);

                        // show the result of the transformation as an image
                        this.transformedImage.setImage(this.mat2Image(magnitude));
                        // set a fixed width
                        this.transformedImage.setFitWidth(250);
                        // preserve image ratio
                        this.transformedImage.setPreserveRatio(true);

                        // enable the button for perform the antitransformation
                        this.antitransformButton.setDisable(false);
                }

                /**
                 * Optimize the image dimensions
                 *
                 * @param image
                 *            the {@link Mat} to optimize
                 * @return the image whose dimensions have been optimized
                 */
                private Mat optimizeImageDim(Mat image)
                {
                        // init
                        Mat padded = new Mat();
                        // get the optimal rows size for dft
                        int addPixelRows = Core.getOptimalDFTSize(image.rows());
                        // get the optimal cols size for dft
                        int addPixelCols = Core.getOptimalDFTSize(image.cols());
                        // apply the optimal cols and rows size to the image
                        Imgproc.copyMakeBorder(image, padded, 0, addPixelRows - image.
↪rows(), 0, addPixelCols - image.cols(),Imgproc.BORDER_CONSTANT, Scalar.all(0));

                        return padded;
                }

                /**
                 * Optimize the magnitude of the complex image obtained from the DFT, to
                 * improve its visualization
                 *
                 * @param complexImage
                 *            the complex image obtained from the DFT
                 * @return the optimized image
                 */
                private Mat createOptimizedMagnitude(Mat complexImage)
                {
```

```
                // init
                List<Mat> newPlanes = new ArrayList<>();
                Mat mag = new Mat();
                // split the comples image in two planes
                Core.split(complexImage, newPlanes);
                // compute the magnitude
                Core.magnitude(newPlanes.get(0), newPlanes.get(1), mag);

                // move to a logarithmic scale
                Core.add(mag, Scalar.all(1), mag);
                Core.log(mag, mag);
                // optionally reorder the 4 quadrants of the magnitude image
                this.shiftDFT(mag);
                // normalize the magnitude image for the visualization since both␣
↪JavaFX
                // and OpenCV need images with value between 0 and 255
                Core.normalize(mag, mag, 0, 255, Core.NORM_MINMAX);

                // you can also write on disk the resulting image...
                // Highgui.imwrite("../magnitude.png", mag);

                return mag;
        }

        /**
         * Reorder the 4 quadrants of the image representing the magnitude, after
         * the DFT
         *
         * @param image
         *            the {@link Mat} object whose quadrants are to reorder
         */
        private void shiftDFT(Mat image)
        {
                image = image.submat(new Rect(0, 0, image.cols() & -2, image.
↪rows() & -2));
                int cx = image.cols() / 2;
                int cy = image.rows() / 2;

                Mat q0 = new Mat(image, new Rect(0, 0, cx, cy));
                Mat q1 = new Mat(image, new Rect(cx, 0, cx, cy));
                Mat q2 = new Mat(image, new Rect(0, cy, cx, cy));
                Mat q3 = new Mat(image, new Rect(cx, cy, cx, cy));

                Mat tmp = new Mat();
                q0.copyTo(tmp);
                q3.copyTo(q0);
                tmp.copyTo(q3);

                q1.copyTo(tmp);
                q2.copyTo(q1);
                tmp.copyTo(q2);
        }

        /**
         * The action triggered by pushing the button for apply the inverse dft to
         * the loaded image
         */
        @FXML
```

```
		protected void antitransformImage()
		{
			Core.idft(this.complexImage, this.complexImage);
			
			Mat restoredImage = new Mat();
			Core.split(this.complexImage, this.planes);
			Core.normalize(this.planes.get(0), restoredImage, 0, 255, Core.
↪NORM_MINMAX);
			
			this.antitransformedImage.setImage(this.mat2Image(restoredImage));
			// set a fixed width
			this.antitransformedImage.setFitWidth(250);
			// preserve image ratio
			this.antitransformedImage.setPreserveRatio(true);
		}
		
		/**
		 * Set the main app (needed for the FileChooser modal window)
		 * 
		 * @param mainApp
		 *            the main app
		 */
		public void setMainApp(FourierTransform mainApp)
		{
			this.main = mainApp;
		}
		
		/**
		 * Convert a Mat object (OpenCV) in the corresponding Image for JavaFX
		 * 
		 * @param frame
		 *            the {@link Mat} representing the current frame
		 * @return the {@link Image} to show
		 */
		private Image mat2Image(Mat frame)
		{
			// create a temporary buffer
			MatOfByte buffer = new MatOfByte();
			// encode the frame in the buffer, according to the PNG format
			Highgui.imencode(".png", frame, buffer);
			// build and return an Image created from the image encoded in the
			// buffer
			return new Image(new ByteArrayInputStream(buffer.toArray()));
		}
}
```

- FT_FX.fxml

```
<BorderPane xmlns:fx="http://javafx.com/fxml/1" fx:controller="application.FT_
↪Controller">
    <left>
        <VBox alignment="CENTER">
            <padding>
                <Insets right="10" left="10" />
            </padding>
            <ImageView fx:id="originalImage" />
        </VBox>
    </left>
    <right>
            <VBox alignment="CENTER" spacing="10">
                    <padding>
                            <Insets right="10" left="10" />
                    </padding>
                    <ImageView fx:id="transformedImage" />
                    <ImageView fx:id="antitransformedImage" />
            </VBox>
    </right>
    <bottom>
            <HBox alignment="CENTER" spacing="10">
                    <padding>
                            <Insets top="25" right="25" bottom="25" left="25" />
                    </padding>
                    <Button alignment="center" text="Load Image" onAction="#loadImage
↪"/>
                    <Button fx:id="transformButton" alignment="center" text="Apply␣
↪transformation" onAction="#transformImage" disable="true" />
                    <Button fx:id="antitransformButton" alignment="center" text=
↪"Apply anti transformation" onAction="#antitransformImage" disable="true" />
            </HBox>
    </bottom>
</BorderPane>
```

CHAPTER 7

Image Segmentation

Note: We assume that by now you have already read the previous tutorials. If not, please check previous tutorials at http://polito-java-opencv-tutorials.readthedocs.org/en/latest/index.html. You can also find the source code and resources at https://github.com/java-opencv/Polito-Java-OpenCV-Tutorials-Source-Code

Goal

In this tutorial we are going to create a JavaFX application where we can decide to apply to video stream captured from our web cam either a *Canny edge detector* or a Background removal using the two basic morphological operations: *dilatation* and *erosion*.

Canny edge detector

The **Canny edge detector** is an edge detection operator that uses a multi-stage algorithm to detect a wide range of edges in images. It was developed by John F. Canny in 1986.

Canny edge detection is a four step process:

1. A Gaussian blur is applied to clear any speckles and free the image of noise.
2. A gradient operator is applied for obtaining the gradients' intensity and direction.
3. Non-maximum suppression determines if the pixel is a better candidate for an edge than its neighbors.
4. Hysteresis thresholding finds where edges begin and end.

The Canny algorithm contains a number of adjustable parameters, which can affect the computation time and effectiveness of t

- The size of the Gaussian filter: the smoothing filter used in the first stage directly affects the results of the Canny algorithm. Smaller filters cause less blurring, and allow detection of small, sharp lines. A larger filter causes more blurring, smearing out the value of a given pixel over a larger area of the image.
- Thresholds: A threshold set too high can miss important information. On the other hand, a threshold set too low will falsely identify irrelevant information (such as noise) as important. It is difficult to give a generic threshold that works well on all images. No tried and tested approach to this problem yet exists.

For our purpose we are going to set the filter size to 3 and the threshold editable by a Slider.

Dilatation and Erosion

Dilation and erosion are the most basic morphological operations. Dilation adds pixels to the boundaries of objects in an image, while erosion removes pixels on object boundaries. The number of pixels added or removed from the objects in an image depends on the size and shape of the structuring element used to process the image. In the morphological dilation and erosion operations, the state of any given pixel in the output image is determined by applying a rule to the corresponding pixel and its neighbors in the input image. The rule used to process the pixels defines the operation as a dilation or an erosion.

Dilatation: the value of the output pixel is the maximum value of all the pixels in the input pixel's neighborhood. In a binary image, if any of the pixels is set to the value 1, the output pixel is set to 1.

Erosion: the value of the output pixel is the minimum value of all the pixels in the input pixel's neighborhood. In a binary image, if any of the pixels is set to 0, the output pixel is set to 0.

What we will do in this tutorial

In this guide, we will:

- Add a checkbox and a *Slider* to select and control the Canny edge detector.
- Use the Canny edge function provided by OpenCV.
- Use the Dilatation and erosion functions provided by OpenCV.
- Create a background removal function.

Getting Started

Let's create a new JavaFX project. In Scene Builder set the windows element so that we have a Border Pane with:

- on **TOP** a VBox containing two HBox, each one followed by a separator.
- In the first HBox we are goning to need a checkbox and a *slider*, the first one is to select the Canny e.d. mode and the second one is going to be used to control the value of the threshold to be passed to the Canny e.d. function.

```
<CheckBox fx:id="canny" onAction="#cannySelected" text="Edge detection"/>
<Label text="Canny Threshold" />
<Slider fx:id="threshold" disable="true" />
```

- In the second HBox we need two checkboxes, the first one to select the Backgrond removal mode and the second one to say if we want to invert the algorithm (a sort of "foreground removal").

```
<CheckBox fx:id="dilateErode" onAction="#dilateErodeSelected" text=
↪"Background removal"/>
<CheckBox fx:id="inverse" text="Invert" disable="true"/>
```

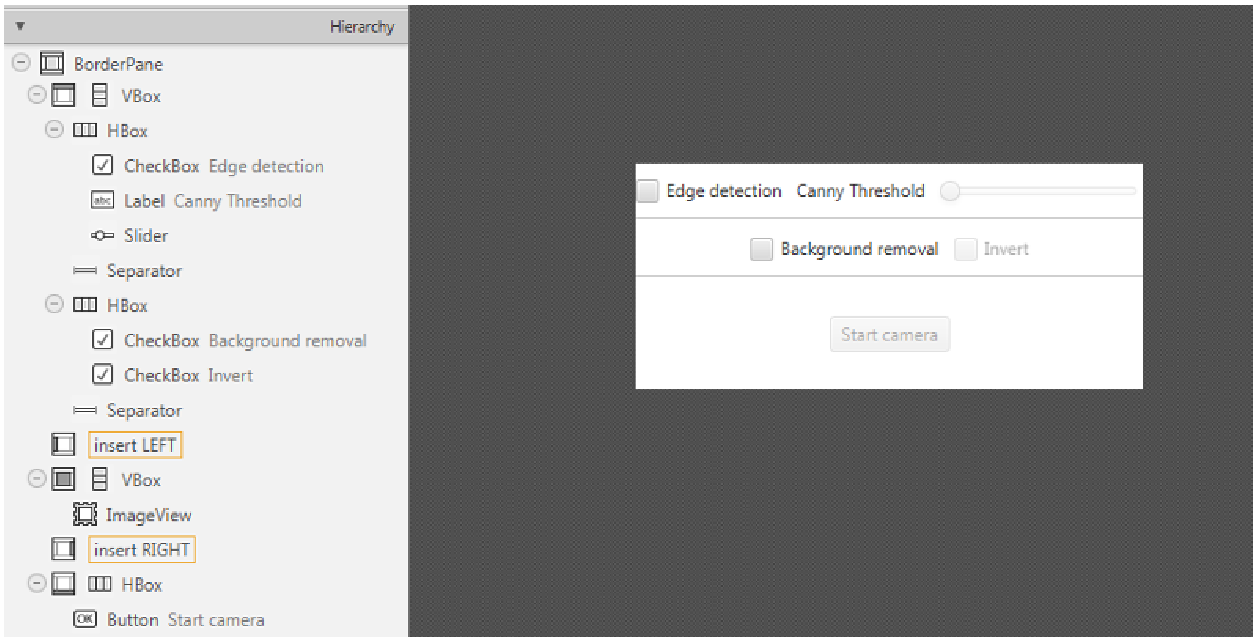
- in the **CENTRE** we are going to put an ImageView for the web cam stream.

```
<ImageView fx:id="originalFrame" />
```

- on the **BOTTOM** we can add the usual button to start/stop the stream

```
<Button fx:id="cameraButton" alignment="center" text="Start camera" onAction="
↪#startCamera" disable="true" />
```

The gui will look something like this one:



Using the Canny edge detection

If we selected the Canny checkbox we can perform the method `doCanny`.

```
if (this.canny.isSelected()){
    frame = this.doCanny(frame);
}
```

`doCanny` is a method that we define to execute the edge detection. First, we convert the image into a grayscale one and blur it with a filter of kernel size 3:

```
Imgproc.cvtColor(frame, grayImage, Imgproc.COLOR_BGR2GRAY);
Imgproc.blur(grayImage, detectedEdges, new Size(3, 3));
```

Second, we apply the OpenCV function Canny:

```
Imgproc.Canny(detectedEdges, detectedEdges, this.threshold.getValue(), this.threshold.
↪getValue() * 3, 3, false);
```

where the arguments are:

- `detectedEdges`: Source image, grayscale
- `detectedEdges`: Output of the detector (can be the same as the input)
- `this.threshold.getValue()`: The value entered by the user moving the Slider
- `this.threshold.getValue() * 3`: Set in the program as three times the lower threshold (following Canny's recommendation)
- `3`: The size of the Sobel kernel to be used internally
- `false`: a flag, indicating whether to use a more accurate calculation of the magnitude gradient.

Then we fill a dest image with zeros (meaning the image is completely black).

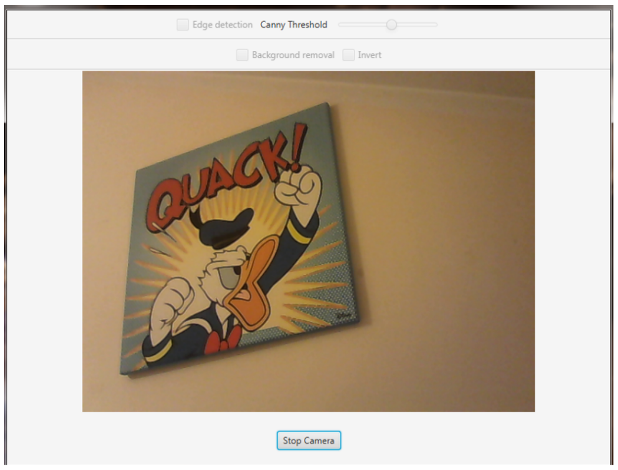
```
Mat dest = new Mat();
Core.add(dest, Scalar.all(0), dest);
```

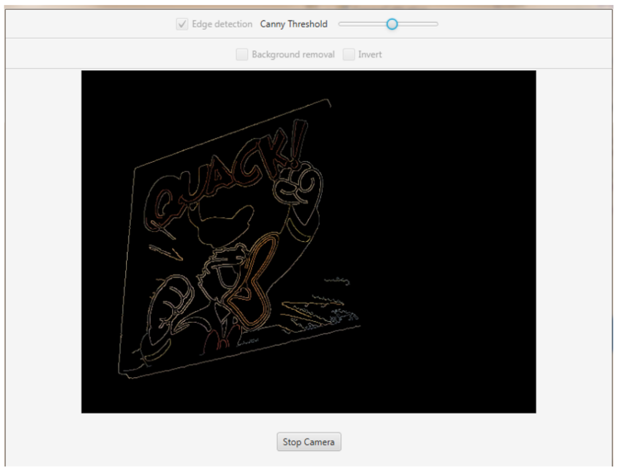
Finally, we will use the function copyTo to map only the areas of the image that are identified as edges (on a black background).

```
frame.copyTo(dest, detectedEdges);
```

`copyTo` copies the src image onto `dest`. However, it will only copy the pixels in the locations where they have non-zero values.

Canny Result





Using the Background Removal

If we seletced the background removal checkbox we can perform the method `doBackgroundRemoval`

```
else if (this.dilateErode.isSelected())
{
    frame = this.doBackgroundRemoval(frame);
}
```

doBackgroundRemoval is a method that we define to execute the background removal.

Fisrt we need to convert the current frame in HVS:

```
hsvImg.create(frame.size(), CvType.CV_8U);
Imgproc.cvtColor(frame, hsvImg, Imgproc.COLOR_BGR2HSV);
Now let's split the three channels of the image:
Core.split(hsvImg, hsvPlanes);
```

Calculate the Hue component mean value:

```
Imgproc.calcHist(hue, new MatOfInt(0), new Mat(), hist_hue, histSize, new␣
↪MatOfFloat(0, 179));
for (int h = 0; h < 180; h++)
    average += (hist_hue.get(h, 0)[0] * h);
average = average / hsvImg.size().height / hsvImg.size().width;
```

If the background is uniform and fills most of the frame, its value should be close to mean just calculated. Then we can use the mean as the threshold to separate the background from the foreground, depending on the invert chackbox we need to perform a back(fore)ground removal:

```
 if (this.inverse.isSelected())
     Imgproc.threshold(hsvPlanes.get(0), thresholdImg, threshValue, 179.0, Imgproc.
↪THRESH_BINARY_INV);
else
     Imgproc.threshold(hsvPlanes.get(0), thresholdImg, threshValue, 179.0, Imgproc.
↪THRESH_BINARY);
```

Now we apply a low pass filter (blur) with a 5x5 kernel mask to enhance the result:

```
Imgproc.blur(thresholdImg, thresholdImg, new Size(5, 5));
```

Finally apply the *dilatation* then the *erosion* (**closing**) to the image:

```
Imgproc.dilate(thresholdImg, thresholdImg, new Mat(), new Point(-1, 1), 6);
Imgproc.erode(thresholdImg, thresholdImg, new Mat(), new Point(-1, 1), 6);
```

The functions take these parameters:

- thresholdImg input image;
- thresholdImg output image of the same size and type as thresholdImg;
- new Mat() a kernel;
- new Point(-1, 1) position of the anchor within the element; default value (-1, 1) means that the anchor is at the element center.
- 6 number of times the operation is applied.

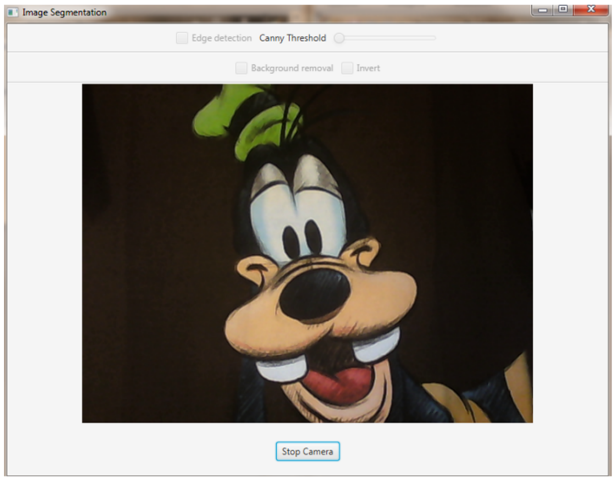
After the closing we need to do a new binary threshold:

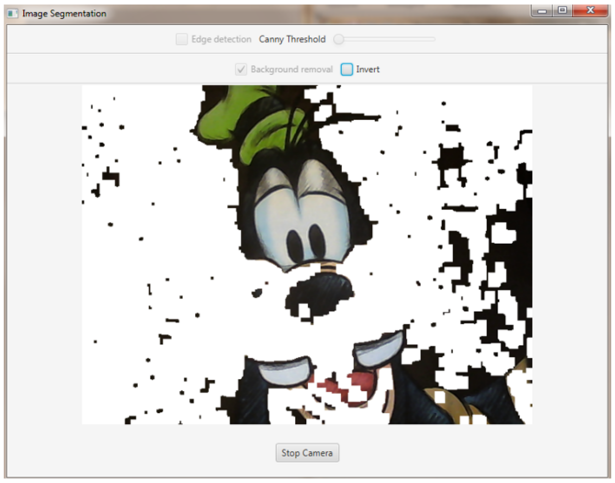
```
Imgproc.threshold(thresholdImg, thresholdImg, threshValue, 179.0, Imgproc.THRESH_
↪BINARY);
```

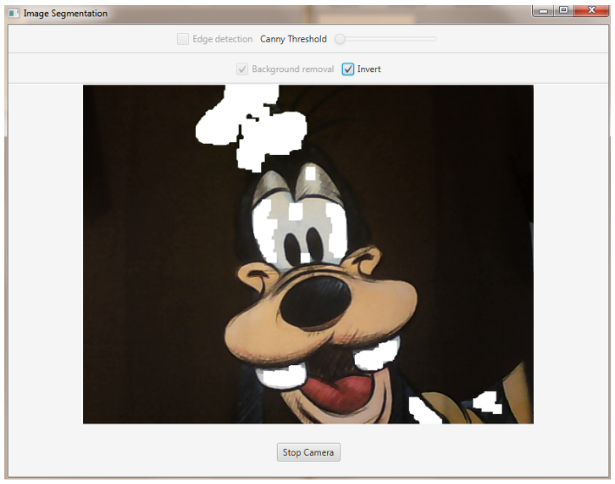
At last, we can apply the image we've just obtained as a mask to the original frame:

```
Mat foreground = new Mat(frame.size(), CvType.CV_8UC3, new Scalar(255, 255, 255));
frame.copyTo(foreground, thresholdImg);
```

Background Removal Result







Source Code

- ImageSegmentation.java

```
public class ImageSegmentation extends Application {
    @Override
    public void start(Stage primaryStage)
    {
            try
            {
                    // load the FXML resource
                    BorderPane root = (BorderPane) FXMLLoader.load(getClass().
↪getResource("IS_FX.fxml"));
                    // set a whitesmoke background
                    root.setStyle("-fx-background-color: whitesmoke;");
                    // create and style a scene
                    Scene scene = new Scene(root, 800, 600);
                    scene.getStylesheets().add(getClass().getResource("application.css
↪").toExternalForm());
```

```
                        // create the stage with the given title and the previously␣
↪created
                        // scene
                        primaryStage.setTitle("Image Segmentation");
                        primaryStage.setScene(scene);
                        // show the GUI
                        primaryStage.show();
                }
                catch (Exception e)
                {
                        e.printStackTrace();
                }
        }

        public static void main(String[] args)
        {
                // load the native OpenCV library
                System.loadLibrary(Core.NATIVE_LIBRARY_NAME);

                launch(args);
        }
}
```

- IS_Controller.java

```
public class IS_Controller {

        // FXML buttons
        @FXML
        private Button cameraButton;
        // the FXML area for showing the current frame
        @FXML
        private ImageView originalFrame;
        // checkbox for enabling/disabling Canny
        @FXML
        private CheckBox canny;
        // canny threshold value
        @FXML
        private Slider threshold;
        // checkbox for enabling/disabling background removal
        @FXML
        private CheckBox dilateErode;
        // inverse the threshold value for background removal
        @FXML
        private CheckBox inverse;

        // a timer for acquiring the video stream
        private Timer timer;
        // the OpenCV object that performs the video capture
        private VideoCapture capture = new VideoCapture();
        // a flag to change the button behavior
        private boolean cameraActive;
        private Image CamStream;

        /**
         * The action triggered by pushing the button on the GUI
         */
        @FXML
```

```
    protected void startCamera()
    {
            if (!this.cameraActive)
            {
                    // disable setting checkboxes
                    this.canny.setDisable(true);
                    this.dilateErode.setDisable(true);

                    // start the video capture
                    this.capture.open(0);

                    // is the video stream available?
                    if (this.capture.isOpened())
                    {
                            this.cameraActive = true;

                            // grab a frame every 33 ms (30 frames/sec)
                            TimerTask frameGrabber = new TimerTask() {
                                    @Override
                                    public void run()
                                    {
                                            CamStream = grabFrame();
                                            Platform.runLater(new Runnable() {
                                                    @Override
                                                    public void run() {

                                                            // show the original␣
↪frames
                                                            originalFrame.
↪setImage(CamStream);
                                                            // set fixed width
                                                            originalFrame.
↪setFitWidth(600);
                                                            // preserve image ratio
                                                            originalFrame.
↪setPreserveRatio(true);

                                                    }
                                            });
                                    }
                            };
                            this.timer = new Timer();
                            this.timer.schedule(frameGrabber, 0, 33);

                            // update the button content
                            this.cameraButton.setText("Stop Camera");
                    }
                    else
                    {
                            // log the error
                            System.err.println("Failed to open the camera connection..
↪.");
                    }
            }
            else
            {
                    // the camera is not active at this point
                    this.cameraActive = false;
```

```
                        // update again the button content
                        this.cameraButton.setText("Start Camera");
                        // enable setting checkboxes
                        this.canny.setDisable(false);
                        this.dilateErode.setDisable(false);

                        // stop the timer
                        if (this.timer != null)
                        {
                                this.timer.cancel();
                                this.timer = null;
                        }
                        // release the camera
                        this.capture.release();
                        // clean the image area
                        originalFrame.setImage(null);
                }
        }

        /**
         * Get a frame from the opened video stream (if any)
         *
         * @return the {@link Image} to show
         */
        private Image grabFrame()
        {
                // init everything
                Image imageToShow = null;
                Mat frame = new Mat();

                // check if the capture is open
                if (this.capture.isOpened())
                {
                        try
                        {
                                // read the current frame
                                this.capture.read(frame);

                                // if the frame is not empty, process it
                                if (!frame.empty())
                                {
                                        // handle edge detection
                                        if (this.canny.isSelected())
                                        {
                                                frame = this.doCanny(frame);
                                        }
                                        // foreground detection
                                        else if (this.dilateErode.isSelected())
                                        {
                                                frame = this.doBackgroundRemoval(frame);
                                        }

                                        // convert the Mat object (OpenCV) to Image␣
↪(JavaFX)
                                        imageToShow = mat2Image(frame);
                                }

                        }
```

```
                    catch (Exception e)
                    {
                            // log the (full) error
                            System.err.print("ERROR");
                            e.printStackTrace();
                    }
            }

            return imageToShow;
    }

    /**
     * Perform the operations needed for removing a uniform background
     *
     * @param frame
     *            the current frame
     * @return an image with only foreground objects
     */
    private Mat doBackgroundRemoval(Mat frame)
    {
            // init
            Mat hsvImg = new Mat();
            List<Mat> hsvPlanes = new ArrayList<>();
            Mat thresholdImg = new Mat();

            // threshold the image with the histogram average value
            hsvImg.create(frame.size(), CvType.CV_8U);
            Imgproc.cvtColor(frame, hsvImg, Imgproc.COLOR_BGR2HSV);
            Core.split(hsvImg, hsvPlanes);

            double threshValue = this.getHistAverage(hsvImg, hsvPlanes.get(0));

            if (this.inverse.isSelected())
                    Imgproc.threshold(hsvPlanes.get(0), thresholdImg, threshValue,␣
↪179.0, Imgproc.THRESH_BINARY_INV);
            else
                    Imgproc.threshold(hsvPlanes.get(0), thresholdImg, threshValue,␣
↪179.0, Imgproc.THRESH_BINARY);

            Imgproc.blur(thresholdImg, thresholdImg, new Size(5, 5));

            // dilate to fill gaps, erode to smooth edges
            Imgproc.dilate(thresholdImg, thresholdImg, new Mat(), new Point(-1, 1),␣
↪6);
            Imgproc.erode(thresholdImg, thresholdImg, new Mat(), new Point(-1, 1), 6);

            Imgproc.threshold(thresholdImg, thresholdImg, threshValue, 179.0, Imgproc.
↪THRESH_BINARY);

            // create the new image
            Mat foreground = new Mat(frame.size(), CvType.CV_8UC3, new Scalar(255,␣
↪255, 255));
            frame.copyTo(foreground, thresholdImg);

            return foreground;
    }

    /**
```

```
	 * Get the average value of the histogram representing the image Hue
	 * component
	 *
	 * @param hsvImg
	 *            the current frame in HSV
	 * @param hueValues
	 *            the Hue component of the current frame
	 * @return the average value
	 */
	private double getHistAverage(Mat hsvImg, Mat hueValues)
	{
		// init
		double average = 0.0;
		Mat hist_hue = new Mat();
		MatOfInt histSize = new MatOfInt(180);
		List<Mat> hue = new ArrayList<>();
		hue.add(hueValues);

		// compute the histogram
		Imgproc.calcHist(hue, new MatOfInt(0), new Mat(), hist_hue, histSize, new␣
↪MatOfFloat(0, 179));

		// get the average for each bin
		for (int h = 0; h < 180; h++)
		{
			average += (hist_hue.get(h, 0)[0] * h);
		}

		return average = average / hsvImg.size().height / hsvImg.size().width;
	}

	/**
	 * Apply Canny
	 *
	 * @param frame
	 *            the current frame
	 * @return an image elaborated with Canny
	 */
	private Mat doCanny(Mat frame)
	{
		// init
		Mat grayImage = new Mat();
		Mat detectedEdges = new Mat();

		// convert to grayscale
		Imgproc.cvtColor(frame, grayImage, Imgproc.COLOR_BGR2GRAY);

		// reduce noise with a 3x3 kernel
		Imgproc.blur(grayImage, detectedEdges, new Size(3, 3));

		// canny detector, with ratio of lower:upper threshold of 3:1
		Imgproc.Canny(detectedEdges, detectedEdges, this.threshold.getValue(),␣
↪this.threshold.getValue() * 3, 3, false);

		// using Canny's output as a mask, display the result
		Mat dest = new Mat();
		Core.add(dest, Scalar.all(0), dest);
		frame.copyTo(dest, detectedEdges);
```

```
                return dest;
        }

        /**
         * Action triggered when the Canny checkbox is selected
         *
         */
        @FXML
        protected void cannySelected()
        {
                // check whether the other checkbox is selected and deselect it
                if (this.dilateErode.isSelected())
                {
                        this.dilateErode.setSelected(false);
                        this.inverse.setDisable(true);
                }

                // enable the threshold slider
                if (this.canny.isSelected())
                        this.threshold.setDisable(false);
                else
                        this.threshold.setDisable(true);

                // now the capture can start
                this.cameraButton.setDisable(false);
        }

        /**
         * Action triggered when the "background removal" checkbox is selected
         */
        @FXML
        protected void dilateErodeSelected()
        {
                // check whether the canny checkbox is selected, deselect it and disable
                // its slider
                if (this.canny.isSelected())
                {
                        this.canny.setSelected(false);
                        this.threshold.setDisable(true);
                }

                if(this.dilateErode.isSelected())
                        this.inverse.setDisable(false);
                else
                        this.inverse.setDisable(true);

                // now the capture can start
                this.cameraButton.setDisable(false);
        }

        /**
         * Convert a Mat object (OpenCV) in the corresponding Image for JavaFX
         *
         * @param frame
         *            the {@link Mat} representing the current frame
         * @return the {@link Image} to show
         */
```

```
    private Image mat2Image(Mat frame)
    {
            // create a temporary buffer
            MatOfByte buffer = new MatOfByte();
            // encode the frame in the buffer, according to the PNG format
            Highgui.imencode(".png", frame, buffer);
            // build and return an Image created from the image encoded in the
            // buffer
            return new Image(new ByteArrayInputStream(buffer.toArray()));
    }

}
```

- IS_FX.fxml

```
<BorderPane xmlns:fx="http://javafx.com/fxml/1" fx:controller="application.IS_
↪Controller">
    <top>
            <VBox>
                    <HBox alignment="CENTER" spacing="10">
                            <padding>
                                    <Insets top="10" bottom="10" />
                            </padding>
                            <CheckBox fx:id="canny" onAction="#cannySelected" text=
↪"Edge detection"/>
                            <Label text="Canny Threshold" />
                            <Slider fx:id="threshold" disable="true" />
                    </HBox>
                    <Separator />
                    <HBox alignment="CENTER" spacing="10">
                            <padding>
                                    <Insets top="10" bottom="10" />
                            </padding>
                            <CheckBox fx:id="dilateErode" onAction="
↪#dilateErodeSelected" text="Background removal"/>
                            <CheckBox fx:id="inverse" text="Invert" disable="true"/>
                    </HBox>
                    <Separator />
            </VBox>
    </top>
    <center>
            <VBox alignment="CENTER">
                    <padding>
                            <Insets right="10" left="10" />
                    </padding>
                    <ImageView fx:id="originalFrame" />
            </VBox>
    </center>
    <bottom>
            <HBox alignment="CENTER">
                    <padding>
                            <Insets top="25" right="25" bottom="25" left="25" />
                    </padding>
                    <Button fx:id="cameraButton" alignment="center" text="Start camera
↪" onAction="#startCamera" disable="true" />
            </HBox>
    </bottom>
</BorderPane>
```

CHAPTER 8

Face Recognition and Tracking

Note: We assume that by now you have already read the previous tutorials. If not, please check previous tutorials at http://polito-java-opencv-tutorials.readthedocs.org/en/latest/index.html. You can also find the source code and resources at https://github.com/java-opencv/Polito-Java-OpenCV-Tutorials-Source-Code

Goal

In this tutorial we are going to use well-known classifiers that have been already trained and distributed by OpenCV in order to detect and track a moving face into a video stream.

Cascade Classifiers

The object recognition process (in our case, faces) is usually efficient if it is based on the features take-over which include additional information about the object class to be taken-over. In this tutorial we are going to use the *Haar-like features* and the *Local Binary Patterns* (LBP) in order to encode the contrasts highlighted by the human face and its spatial relations with the other objects present in the picture. Usually these features are extracted using a *Cascade Classifier* which has to be trained in order to recognize with precision different objects: the faces' classification is going to be much different from the car's classification.

What we will do in this tutorial

In this guide, we will:

- Insert a checkbox to select the Haar Classifier, detect and track a face, and draw a green rectangle around the detected face.

- Inesrt a checkbox to select the LBP Classifier, detect and track a face, and draw a green rectangle around the detected face.

Getting Started

Let's create a new JavaFX project. In Scene Builder set the windows element so that we have a Border Pane with:

- on TOP a VBox a HBox and a separator. In the HBox we are goning to need two checkboxes, the first one is to select the Haar Classifier and the second one is to select the LBP Classifier.

```
<CheckBox fx:id="haarClassifier" onAction="#haarSelected" text="Haar␣
↪Classifier"/>
<CheckBox fx:id="lbpClassifier" onAction="#lbpSelected" text="LBP␣
↪Classifier"/>
```

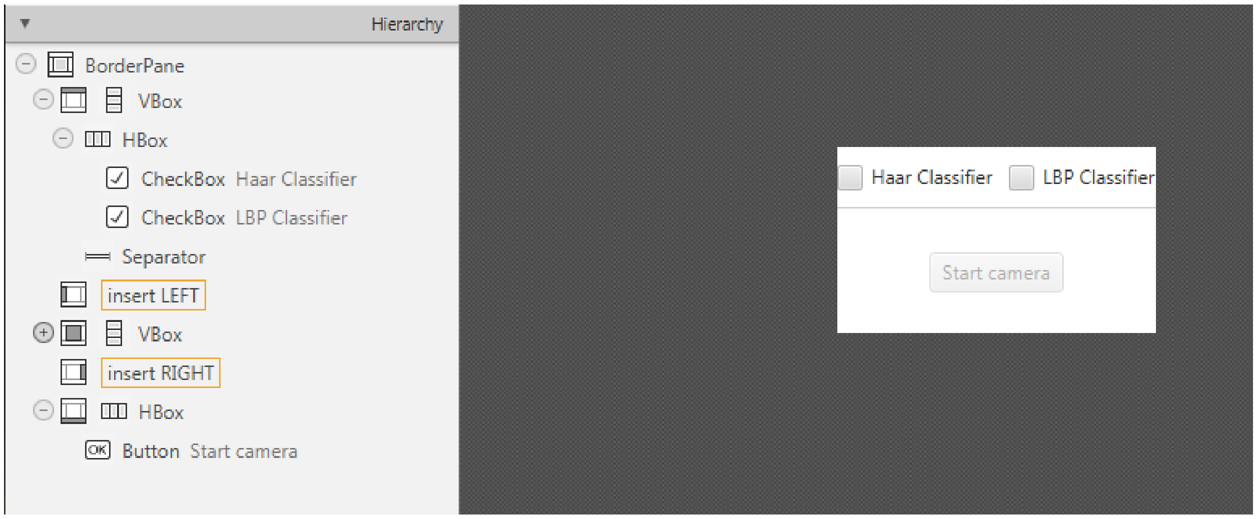
- in the CENTRE we are going to put an ImageView for the web cam stream.

```
<ImageView fx:id="originalFrame" />
```

- on the BOTTOM we can add the usual button to start/stop the stream

```
<Button fx:id="cameraButton" alignment="center" text="Start camera"␣
↪onAction="#startCamera" disable="true" />
```

The gui will look something like this one:



Loading the Classifiers

First of all we need to add a folder `resource` to our project and put the classifiers in it. In order to use the classifiers we need to load them from the resource folder, so every time that we check one of the two checkboxes we will load the correct classifier. To do so, let's implement the `OnAction` methods we already declared before:

- **`haarSelected`** inside this method we are going to load the disired Haar Classifier (e.g. `haarcascade_frontalface.xml`) as follows:

```
this.checkboxSelection("resources/lbpcascades/lbpcascade_frontalface_alt.xml
↪");
...
private void checkboxSelection(String... classifierPath)
{
        // load the classifier(s)
        for (String xmlClassifier : classifierPath)
        {
                this.faceCascade.load(xmlClassifier);
        }

        // now the capture can start
        this.cameraButton.setDisable(false);
}
```

- `lbpSelected` for the LPB we can use the same method and change the path of the classifier to be loaded:

```
this.checkboxSelection("resources/lbpcascades/lbpcascade_frontalface.xml");
```

Detection and Tracking

Once we've loaded the classifiers we are ready to start the detection; we are going to implement the detection in the `detectAndDisplay` method. First of all we need to convert the frame in grayscale and equalize the histogram to improve the results:

```
Imgproc.cvtColor(frame, grayFrame, Imgproc.COLOR_BGR2GRAY);
Imgproc.equalizeHist(grayFrame, grayFrame);
```

Then we have to set the minimum size of the face to be detected (this required is need in the actual detection function). Let's set the minimum size as the 20% of the frame hieght:

```
if (this.absoluteFaceSize == 0)
{
    int height = grayFrame.rows();
    if (Math.round(height * 0.2f) > 0)
    {
            this.absoluteFaceSize = Math.round(height * 0.2f);
    }
}
```

Now we can start the detection:

```
this.faceCascade.detectMultiScale(grayFrame, faces, 1.1, 2, 0 | Objdetect.CASCADE_
↪SCALE_IMAGE, new Size(this.absoluteFaceSize, this.absoluteFaceSize), new Size());
```

The `detectMultiScale` function detects objects of different sizes in the input image. The detected objects are returned as a list of rectangles. The parameters are:

- **image** Matrix of the type CV_8U containing an image where objects are detected.
- **objects** Vector of rectangles where each rectangle contains the detected object.
- **scaleFactor** Parameter specifying how much the image size is reduced at each image scale.
- **minNeighbors** Parameter specifying how many neighbors each candidate rectangle should have to retain it.

- **flags** Parameter with the same meaning for an old cascade as in the function cvHaarDetectObjects. It is not used for a new cascade.
- **minSize** Minimum possible object size. Objects smaller than that are ignored.
- **maxSize** Maximum possible object size. Objects larger than that are ignored.

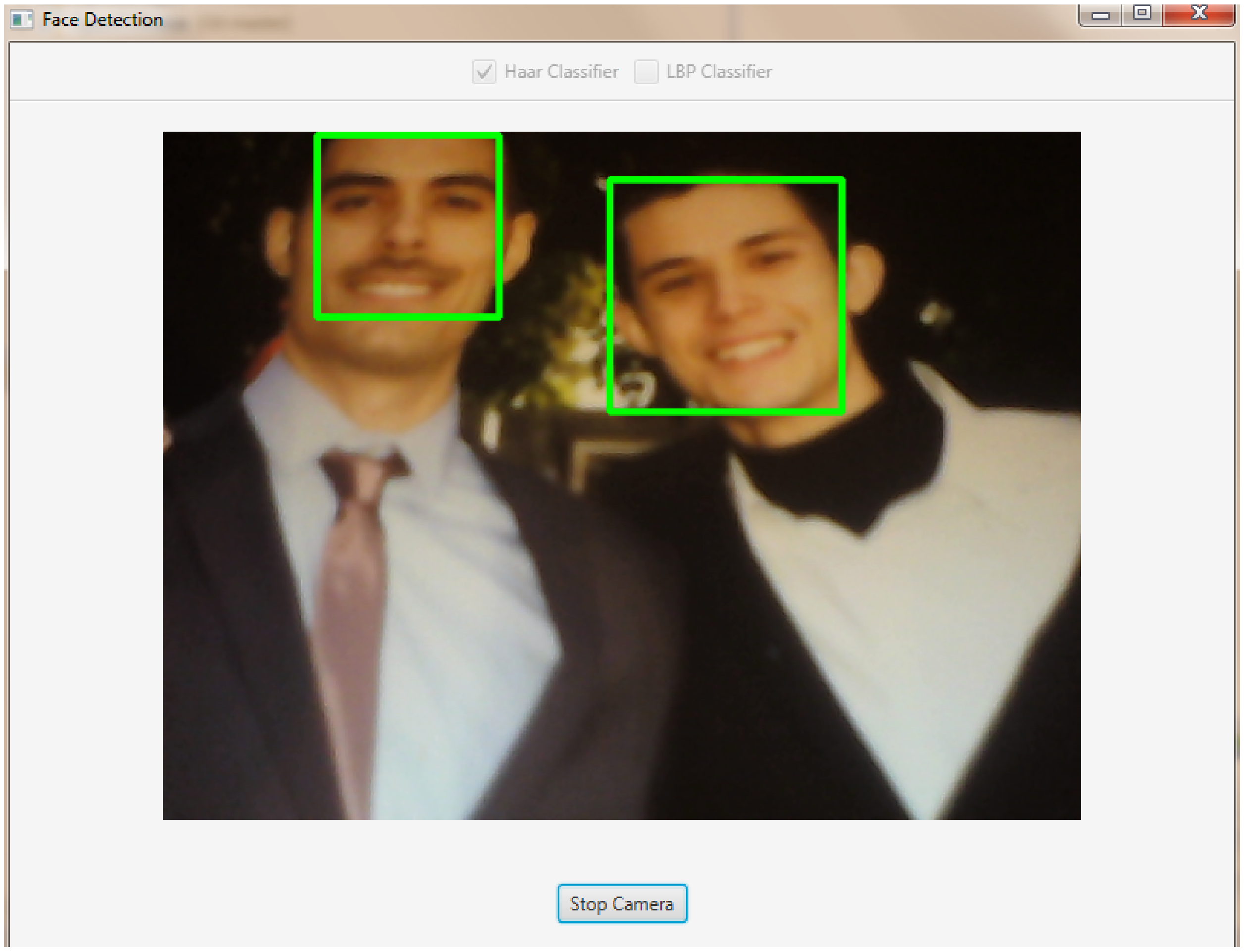
So the result of the detection is going to be in the **objects** parameter or in our case `faces`.

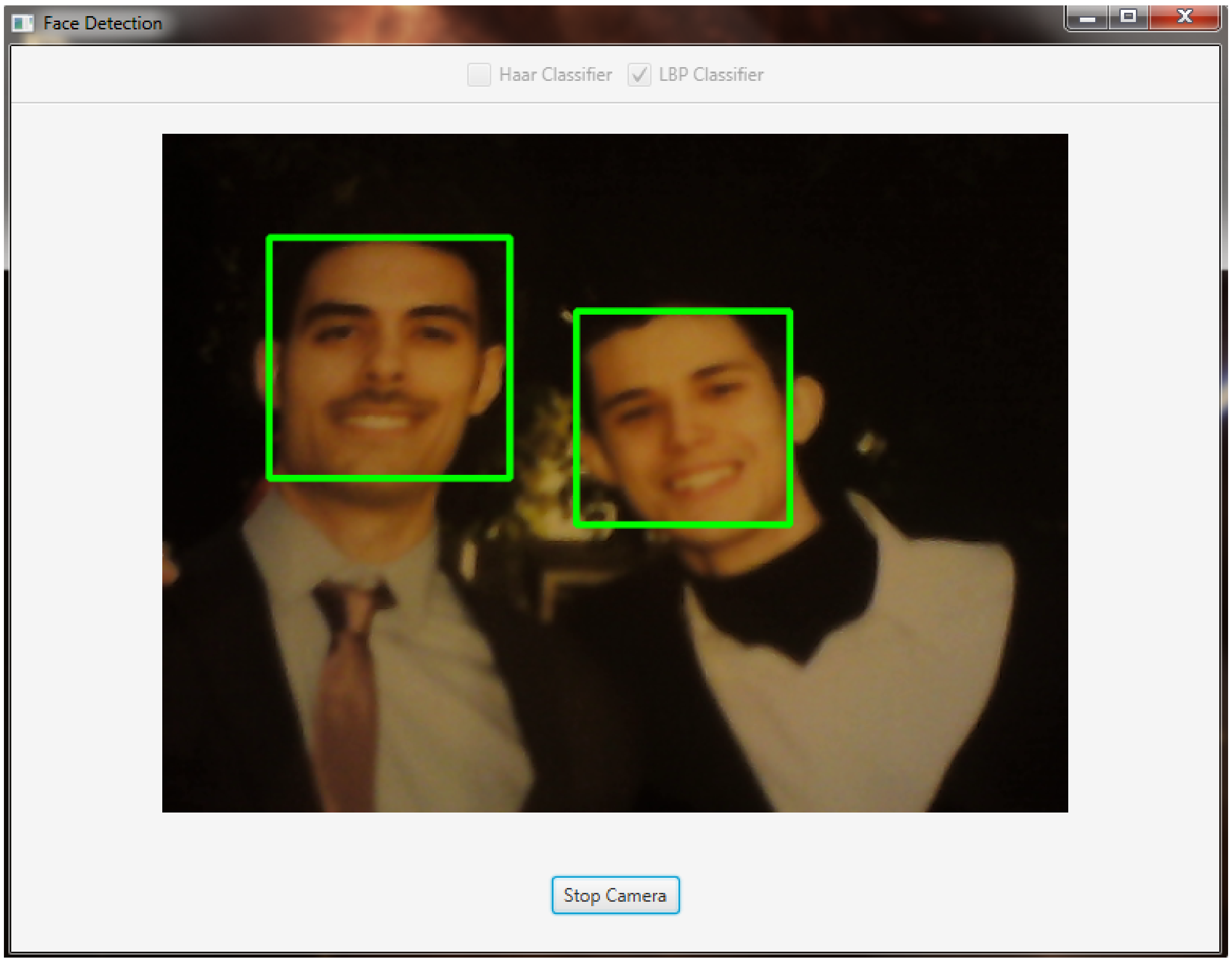
Let's put this result in an array of Rects and draw them on the frame, by doing so we can display the detected face are:

```
Rect[] facesArray = faces.toArray();
for (int i = 0; i < facesArray.length; i++)
    Core.rectangle(frame, facesArray[i].tl(), facesArray[i].br(), new Scalar(0, 255,␣
↪0, 255), 3);
```

As you can see we selected the color green with a trasparent background: `Scalar(0, 255, 0, 255)`. `.tl()` and `.br()` stand for *top-left* and *bottom-right* and they represents the two opposite vertexes. The last parameter just set the thickness of the rectangle's border.

The tracking part can be implemented by calling the `detectAndDisplay` method for each frame.





Source Code

- FaceDetection.java

```
public class FaceDetection extends Application {
    @Override
    public void start(Stage primaryStage)
    {
            try
            {
                   // load the FXML resource
                   FXMLLoader loader = new FXMLLoader(getClass().getResource("FD_FX.
↪fxml"));
                   BorderPane root = (BorderPane) loader.load();
                   // set a whitesmoke background
                   root.setStyle("-fx-background-color: whitesmoke;");
                   // create and style a scene
                   Scene scene = new Scene(root, 800, 600);
                   scene.getStylesheets().add(getClass().getResource("application.css
↪").toExternalForm());
                   // create the stage with the given title and the previously␣
↪created
```

```
                        // scene
                        primaryStage.setTitle("Face Detection");
                        primaryStage.setScene(scene);
                        // show the GUI
                        primaryStage.show();

                        // init the controller
                        FD_Controller controller = loader.getController();
                        controller.init();
                }
                catch (Exception e)
                {
                        e.printStackTrace();
                }
        }

        public static void main(String[] args)
        {
                // load the native OpenCV library
                System.loadLibrary(Core.NATIVE_LIBRARY_NAME);

                launch(args);
        }
}
```

- *FD_Controller.java <https://github.com/java-opencv/Polito-Java-OpenCV-Tutorials-Source-Code/blob/master/Face%20Detection/src/application/FD_Controller.java>*

```
public class FD_Controller {
    // FXML buttons
    @FXML
    private Button cameraButton;
    // the FXML area for showing the current frame
    @FXML
    private ImageView originalFrame;
    // checkbox for selecting the Haar Classifier
    @FXML
    private CheckBox haarClassifier;
    // checkbox for selecting the LBP Classifier
    @FXML
    private CheckBox lbpClassifier;

    // a timer for acquiring the video stream
    private Timer timer;
    // the OpenCV object that performs the video capture
    private VideoCapture capture;
    // a flag to change the button behavior
    private boolean cameraActive;
    // the face cascade classifier object
    private CascadeClassifier faceCascade;
    // minimum face size
    private int absoluteFaceSize;
    private Image CamStream;

    /**
     * Init the controller variables
     */
    protected void init()
    {
            this.capture = new VideoCapture();
            this.faceCascade = new CascadeClassifier();
            this.absoluteFaceSize = 0;
    }

    /**
     * The action triggered by pushing the button on the GUI
     */
    @FXML
    protected void startCamera()
    {
            if (!this.cameraActive)
            {
                    // disable setting checkboxes
                    this.haarClassifier.setDisable(true);
                    this.lbpClassifier.setDisable(true);

                    // start the video capture
                    this.capture.open(0);

                    // is the video stream available?
                    if (this.capture.isOpened())
                    {
                            this.cameraActive = true;

                            // grab a frame every 33 ms (30 frames/sec)
                            TimerTask frameGrabber = new TimerTask() {
                                    @Override
                                    public void run()
                                    {
                                            CamStream = grabFrame();
                                            Platform.runLater(new Runnable() {
                                                    @Override
                                        public void run() {
                                                                    // show the original␣
↪frames
                                                                    originalFrame.
↪setImage(CamStream);
                                                                    // set fixed width
                                                                    originalFrame.
↪setFitWidth(600);
                                                                    // preserve image ratio
                                                                    originalFrame.
↪setPreserveRatio(true);

                                            }
                                                    });
                                    }
                            };
                            this.timer = new Timer();
                            this.timer.schedule(frameGrabber, 0, 33);

                            // update the button content
                            this.cameraButton.setText("Stop Camera");
                    }
                    else
```

```
                        {
                                // log the error
                                System.err.println("Failed to open the camera connection..
↪.");
                        }
                }
                else
                {
                        // the camera is not active at this point
                        this.cameraActive = false;
                        // update again the button content
                        this.cameraButton.setText("Start Camera");
                        // enable setting checkboxes
                        this.haarClassifier.setDisable(false);
                        this.lbpClassifier.setDisable(false);

                        // stop the timer
                        if (this.timer != null)
                        {
                                this.timer.cancel();
                                this.timer = null;
                        }
                        // release the camera
                        this.capture.release();
                        // clean the image area
                        originalFrame.setImage(null);
                }
        }

        /**
         * Get a frame from the opened video stream (if any)
         *
         * @return the {@link Image} to show
         */
        private Image grabFrame()
        {
                // init everything
                Image imageToShow = null;
                Mat frame = new Mat();

                // check if the capture is open
                if (this.capture.isOpened())
                {
                        try
                        {
                                // read the current frame
                                this.capture.read(frame);

                                // if the frame is not empty, process it
                                if (!frame.empty())
                                {
                                        // face detection
                                        this.detectAndDisplay(frame);

                                        // convert the Mat object (OpenCV) to Image␣
↪(JavaFX)
                                        imageToShow = mat2Image(frame);
                                }
                        }
                        catch (Exception e)
                        {
                                // log the (full) error
                                System.err.print("ERROR");
                                e.printStackTrace();
                        }
                }

                return imageToShow;
        }

        /**
         * Perform face detection and show a rectangle around the detected face.
         *
         * @param frame
         *            the current frame
         */
        private void detectAndDisplay(Mat frame)
        {
                // init
                MatOfRect faces = new MatOfRect();
                Mat grayFrame = new Mat();

                // convert the frame in gray scale
                Imgproc.cvtColor(frame, grayFrame, Imgproc.COLOR_BGR2GRAY);
                // equalize the frame histogram to improve the result
                Imgproc.equalizeHist(grayFrame, grayFrame);

                // compute minimum face size (20% of the frame height)
                if (this.absoluteFaceSize == 0)
                {
                        int height = grayFrame.rows();
                        if (Math.round(height * 0.2f) > 0)
                        {
                                this.absoluteFaceSize = Math.round(height * 0.2f);
                        }
                }

                // detect faces
                this.faceCascade.detectMultiScale(grayFrame, faces, 1.1, 2, 0 | Objdetect.
    ↪CASCADE_SCALE_IMAGE, new Size(
                                this.absoluteFaceSize, this.absoluteFaceSize), new␣
    ↪Size());

                // each rectangle in faces is a face
                Rect[] facesArray = faces.toArray();
                for (int i = 0; i < facesArray.length; i++)
                        Core.rectangle(frame, facesArray[i].tl(), facesArray[i].br(), new␣
    ↪Scalar(0, 255, 0, 255), 3);

        }

        /**
         * When the Haar checkbox is selected, deselect the other one and load the
         * proper XML classifier
         *
```

```
	 */
	@FXML
	protected void haarSelected()
	{
		// check whether the lpb checkbox is selected and deselect it
		if (this.lbpClassifier.isSelected())
			this.lbpClassifier.setSelected(false);

		this.checkboxSelection("resources/haarcascades/haarcascade_frontalface_
↪alt.xml");
	}

	/**
	 *
	 When the LBP checkbox is selected, deselect the other one and load the
	 * proper XML classifier
	 */
	@FXML
	protected void lbpSelected()
	{
		// check whether the haar checkbox is selected and deselect it
		if (this.haarClassifier.isSelected())
			this.haarClassifier.setSelected(false);

		this.checkboxSelection("resources/lbpcascades/lbpcascade_frontalface.xml
↪");
	}

	/**
	 * Common operation for both checkbox selections
	 *
	 * @param classifierPath
	 *            the absolute path where the XML file representing a training
	 *            set for a classifier is present
	 */
	private void checkboxSelection(String... classifierPath)
	{
		// load the classifier(s)
		for (String xmlClassifier : classifierPath)
		{
			this.faceCascade.load(xmlClassifier);
		}

		// now the capture can start
		this.cameraButton.setDisable(false);
	}

	/**
	 * Convert a Mat object (OpenCV) in the corresponding Image for JavaFX
	 *
	 * @param frame
	 *            the {@link Mat} representing the current frame
	 * @return the {@link Image} to show
	 */
	private Image mat2Image(Mat frame)
	{
		// create a temporary buffer
		MatOfByte buffer = new MatOfByte();
```

```
            // encode the frame in the buffer, according to the PNG format
            Highgui.imencode(".png", frame, buffer);
            // build and return an Image created from the image encoded in the
            // buffer
            return new Image(new ByteArrayInputStream(buffer.toArray()));
    }
}
```

- FD_FX.fxml

```
<BorderPane xmlns:fx="http://javafx.com/fxml/1" fx:controller="application.FD_
↪Controller">
    <top>
            <VBox>
                    <HBox alignment="CENTER" spacing="10">
                            <padding>
                                    <Insets top="10" bottom="10" />
                            </padding>
                            <CheckBox fx:id="haarClassifier" onAction="#haarSelected"␣
↪text="Haar Classifier"/>
                            <CheckBox fx:id="lbpClassifier" onAction="#lbpSelected"␣
↪text="LBP Classifier"/>
                    </HBox>
                    <Separator />
            </VBox>
    </top>
    <center>
            <VBox alignment="CENTER">
                    <padding>
                            <Insets right="10" left="10" />
                    </padding>
                    <ImageView fx:id="originalFrame" />
            </VBox>
    </center>
    <bottom>
            <HBox alignment="CENTER">
                    <padding>
                            <Insets top="25" right="25" bottom="25" left="25" />
                    </padding>
                    <Button fx:id="cameraButton" alignment="center" text="Start camera
↪" onAction="#startCamera" disable="true" />
            </HBox>
    </bottom>
</BorderPane>
```

CHAPTER 9

Indices and tables

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