Writing ImageJ Plugins—A Tutorial

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Contents

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Version 1.71

1 Getting Started

1.1 About ImageJ[1]

ImageJ is a public domain Java image processing program inspired by NIH Image for the Macintosh. It runs, either as an online applet or as a downloadable application, on any computer with a Java 1.1 or later virtual machine. Downloadable distributions are available for Windows, Mac OS, Mac OS X and Linux.

It can display, edit, analyze, process, save and print 8-bit, 16-bit and 32-bit images. It can read many image formats including TIFF, GIF, JPEG, BMP, DICOM, FITS and "raw". It supports "stacks", a series of images that share a single window. It is multithreaded, so time-consuming operations such as image file reading can be performed in parallel with other operations.

It can calculate area and pixel value statistics of user-defined selections. It can measure distances and angles. It can create density histograms and line profile plots. It supports standard image processing functions such as contrast manipulation, sharpening, smoothing, edge detection and median filtering.

It does geometric transformations such as scaling, rotation and flips. Image can be zoomed up to 32:1 and down to 1:32. All analysis and processing functions are available at any magnification factor. The program supports any number of windows (images) simultaneously, limited only by available memory.

Spatial calibration is available to provide real world dimensional measurements in units such as millimeters. Density or gray scale calibration is also available.

ImageJ was designed with an open architecture that provides extensibility via Java plugins. Custom acquisition, analysis and processing plugins can be developed using ImageJ's built in editor and Java compiler. User-written plugins make it possible to solve almost any image processing or analysis problem.

ImageJ is being developed on Mac OS X using its built in editor and Java compiler, plus the BBEdit editor and the Ant build tool. The source code is freely available. The author, Wayne Rasband (wayne@codon.nih.gov), is at the Research Services Branch, National Institute of Mental Health, Bethesda, Maryland, USA.

1.2 About this Tutorial

This tutorial is an introduction to writing plugins for ImageJ. It discusses the concept of plugins in ImageJ and its onboard tools for plugin development. It starts with the discussion of the code skeleton of a new plugin and the sample plugins that are part of the ImageJ distribution, and covers those parts of the ImageJ API, which are essential for writing plugins, with a special focus on the image representation. A reference of the most important classes, methods and constants is provided and some more advanced topics are discussed.

In order to use this tutorial, a basic knowledge of the Java programming language is required. (Resources for Java beginners can be found in section 10.4). You should also try to get familiar with the use of ImageJ before you start writing plugins. The ImageJ documentation can be found at http://rsb.info.nih.gov/ij/docs, including links to further documentation resources.

[1]Description taken from http://rsb.info.nih.gov/ij/docs/intro.html

1.3 Setting up your Environment

For running ImageJ you need the ImageJ class and configuration files, a Java Runtime Environment (JRE) and—for compiling your own plugins—a Java compiler with the required libraries, as for example included in the Java 2 SDK Standard Edition (J2SE) from Sun Microsystems. Depending on the ImageJ distribution you are using, some or all of this may already be included.

1.3.1 Installing ImageJ

The latest distribution of ImageJ can be downloaded from http://rsb.info.nih.gov/ij/download.html.

In the following the installation of ImageJ will be described briefly for different operating systems. More detailed and up-to-date installation instructions can be found at http://rsb.info.nih.gov/ij/docs/install.

If you already have a JRE (and a Java compiler) installed on your computer and you are familiar with Java, you just need to download the ImageJ class and configuration files which are available as a ZIP archive. To run ImageJ, add `ij.jar` to your classpath and execute class `ij.ImageJ`. This also works for all operating systems for which there is no specific ImageJ distribution but for which a Java runtime environment is available.

Windows

The Windows version is available with installer, both with and without a Java Runtime Environment (JRE).

Mac OS

To run ImageJ on Mac OS you need the Macintosh Runtime for Java (MRJ). It can be downloaded from http://www.apple.com/java. MRJ requires Mac OS 8.1 or later. MRJ is preinstalled on new Macs. Installation instructions can be found on the MRJ download page.

The ImageJ distribution is a self-extracting archive (If it does not expand automatically after downloading, use e. g. StuffIt Expander). Double-click the “ImageJ” icon in the newly created folder to run it.

Mac OS X

Download the Mac OS X `tar.gz` file and double-click it to expand. Double-click the “ImageJ” icon to run ImageJ.

Linux x86

Download the Linux x86 `tar.gz` file, which contains Sun’s Java Runtime Environment, and extract it using e. g.

```
tar xvzf ij136-x86.tar.gz
```

and execute the `run` script in the ImageJ directory.

1.3.2 Installing the Java Compiler

Installing a Java compiler is only necessary if it is not included in the ImageJ distribution or provided by the operating system. In any case (also if you are using an operating system which is not mentioned here but for which a Java compiler is available) you can use a Java compiler of your choice to compile your plugins (e.g. J2SE SDK from Sun Microsystems, which you can download from http://www.javasoft.com).

Details on compiling plugins can be found in Section 2.10.

Windows

The ImageJ distribution for Windows includes a Java compiler which allows you to compile plugins inside ImageJ.

Mac OS

In addition to the MRJ you need the MRJ SDK. It can be downloaded from http://developer.apple.com/java. Run the installer you have downloaded. After the installation it is possible to compile plugins inside ImageJ.

Mac OS X

A Java compiler is included in Mac OS X Java, so you can compile plugins inside ImageJ.

Linux

The ImageJ distribution for Linux includes a Java compiler which allows you to compile plugins inside ImageJ.

1.4 Updating ImageJ

You can update ImageJ by replacing the ImageJ JAR file (`ij.jar`). The latest version is available at http://rsb.info.nih.gov/ij/upgrade. Just replace your existing `ij.jar` file with the one you downlaoded. The `ij.jar` file can be found directly in your ImageJ folder.

Note: The ImageJ JAR file also contains the configuration file `IJProps.txt`. If you want to save your settings, extract the file from your old `ij.jar` and replace it in the new one. You can edit JAR files with most ZIP utilities (e. g. WinZip).

2 The Plugin Concept of ImageJ

2.1 Macros vs. Plugins

The functions provided by ImageJ's built-in commands can be extended by user-written code in the form of macros and plugins. These two options differ in their complexity and capabilities.

Macros are an easy way to execute a series of ImageJ commands. The simplest way to create a macro is to call using "Plugins/Macros/Record" and execute the commands to be recorded. The macro code can be modified in the built-in editor. The ImageJ macro language contains a set of control structures, operators and built-in functions and can be used to call built-in commands and macros. A reference of the macro language can be found at http://rsb.info.nih.gov/ij/developer/macro/macros.html.

Plugins are a much more powerful concept than macros and most of ImageJ's built-in menu commands are in fact implemented as plugins. Plugins are implemented as Java classes, which means that you can use all features of the Java language, access the full ImageJ API and use all standard and third-party Java APIs in a plugin. This opens a wide range of possibilities of what can be done in a plugin. The most common uses of plugins are filters performing some analysis or processing on an image or image stack and I/O plugins for reading/writing not natively supported formats from/to file or other devices. But as you can see when looking at the plugins listed on the ImageJ plugins page (cf. Section 10.2), there are many other things you can do with plugins, such as rendering graphics or creating extensions of the ImageJ graphical user interface.

2.2 Plugins Folder—Installing Plugins

ImageJ user plugins have to be located in a folder called `plugins`, which is a subfolder of the ImageJ folder. But only class files in the `plugins` folder with at least one underscore in their name appear automatically in the "Plugins" menu. Since version 1.20 it is also possible to create subfolders of the `plugins` folder and place plugin files there. The subfolders are displayed as submenus of ImageJ's "Plugins" menu.

To install a plugin (e.g. one you have downloaded from the ImageJ plugins page) copy the `.class` file into the `plugins` folder or one of its subfolders. The plugin will appear in the plugin menu (or one of its submenus) the next time you start ImageJ. You can add it to a menu and assign a shortcut to it using the "Plugins/ Shortcut/ Install plugin..." menu. In this case, the plugin will appear in the menu without restarting ImageJ.

Alternatively, if you have the source code of a plugin, you can compile and run it from within ImageJ. More about compiling and running plugins can be found in Section 2.10.

You can specify the plugins directory using the `plugins.dir` property. This can be done by adding an argument like `-Dplugins.dir=c:\plugindirectory` to the commandline calling ImageJ. Depending on the type of installation you are using, this modification is made in the run script, the ImageJ.cfg file or the shortcut calling ImageJ.

2.3 Integrating Plugins into the ImageJ GUI

Like commands, plugins can be accessed via hot-keys. You can create a new hot-key by selecting "Create Shortcut" from the menu "Plugins / Shortcuts".

A string with arguments can be passed to a plugin. Installing a plugin using the menu command "Plugins / Shortcuts / Install Plugin ..." places the plugin into a selected menu, assigns a hot-key and passes an argument.
"Plugins / Shortcuts / Remove ..." removes a plugin from the menu.

2.4 Developing Plugins inside ImageJ

ImageJ provides an integrated editor for macros and plugins, which can not only be used to modify and edit code, but also to compile and run plugins.

The "Plugins / New ..." command displays a dialog that lets the user specify a name for the new plugin and select to create a new macro or one of three types of plugins. The types of plugins and the code that is created for a new plugin are discussed below.

The "Plugins / Edit ..." command displays a file open dialog and opens the selected plugin in a text editor.

2.5 Types of Plugins

There are basically two types of plugins: those that do not require an image as input (implementing the interface `PlugIn`) and plugin filters, that require an image as input (implementing the interface `PlugInFilter`). A `PlugInFrame` is a plugin that runs in its own window.

2.6 Interfaces

2.6.1 PlugIn

This interface has just one method:

`void run(java.lang.String arg)`
: This method runs the plugin, what you implement here is what the plugin actually does. `arg` is a string passed as an argument to the plugin, and it can also be an empty string. You can install plugins more than once, so that each of the commands can call the same plugin class with a different argument.

2.6.2 PlugInFilter

This interface also has a method

`void run(ImageProcessor ip)`
: This method runs the plugin, what you implement here is what the plugin actually does. It takes the image processor it works on as an argument. The processor can be modified directly or a new processor and a new image can be based on its data, so that the original image is left unchanged. The original image is locked while the plugin is running. In contrast to the `PlugIn` interface the `run` method does not take a string argument. The argument can be passed using

`int setup(java.lang.String arg, ImagePlus imp)`
: This method sets up the plugin filter for use. The `arg` string has the same function as in the `run` method of the `PlugIn` interface. You do not have to care for the argument `imp`—this is handled by ImageJ and the currently active image is passed. The `setup` method returns a flag word that represents the filters capabilities (i.e. which types of images it can handle).

2.7 PlugInFrame

A `PlugInFrame` is a subclass of an AWT frame that implements the `PlugIn` interface. Your plugin will be implemented as a subclass of `PlugInFrame`.
There is one constructor for a `PlugInFrame`. It receives the title of the window as argument:

`PlugInFrame(java.lang.String title)`
: As this class is a plugin, the method

`void run(java.lang.String arg)`
: declared in the `PlugIn` interface is implemented and can be overwritten by your plugin's `run` method.

Of course all methods declared in `java.awt.Frame` and its superclasses can be overwritten. For details consult the Java AWT API documentation.

2.8 The Code in a New Plugin

After creating a new plugin, a code skeleton for the new plugin is created. For all types of plugins, a list of import statements for the packages of the ImageJ API are created:

```
import ij.*;
import ij.process.*;
import ij.gui.*;
import java.awt.*;
import ij.plugin.*;
```

The packages of the ImageJ API are discussed in Section 3. Depending on the type of plugin, the package in the last import statement is `ij.plugin.*`, `ij.plugin.filter.*` or `ij.plugin.frame.*`.

2.8.1 PlugIn

For each plugin a new class is created, which implements the interface of the respective plugin type:

```
public class My_Plugin implements PlugIn {
    // ...
}
```

A plugin of type `PlugIn` only has a `run` method

```
    public void run(String arg) {
        IJ.showMessage("My_Plugin","Hello world!");
    }
```

In this sample code, a utility method is called, which displays a message box.

2.8.2 PlugInFilter

Similarly, a filter plugin implements the appropriate interface:

```
public class My_Filter_Plugin implements PlugInFilter {
    ImagePlus imp;

    // ...
}
```

In addition, the plugin declares an instance variable, which will hold the image on which the filter plugin works. The `setup` method is called when the plugin is instantiated. An argument string and an image are passed:

```
    public int setup(String arg, ImagePlus imp) {
        this.imp = imp;
        return DOES_ALL;
    }
```

In the method's code, the image argument is stored in the instance variable, and the capability flag of the filter plugin is returned. The following capability flags are defined in `PlugInFilter`:

`static int DOES_16` The plugin filter handles 16 bit grayscale images.

`static int DOES_32` The plugin filter handles 32 bit floating point grayscale images.

`static int DOES_8C` The plugin filter handles 8 bit color images.

`static int DOES_8G` The plugin filter handles 8 bit grayscale images.

`static int DOES_ALL` The plugin filter handles all types of images.

`static int DOES_RGB` The plugin filter handles RGB images.

`static int DOES_STACKS` The plugin filter supports stacks, ImageJ will call it for each slice in a stack.

`static int DONE` If the setup method returns `DONE` the `run` method will not be called.

`static int NO_CHANGES` The plugin filter does not change the pixel data.

`static int NO_IMAGE_REQUIRED` The plugin filter does not require an image to be open.

`static int NO_UNDO` The plugin filter does not support undo.

`static int ROI_REQUIRED` The plugin filter requires a region of interest (ROI).

`static int STACK_REQUIRED` The plugin filter requires a stack.

`static int SUPPORTS_MASKING` Plugin filters always work on the bounding rectangle of the ROI. If this flag is set and there is a non-rectangular ROI, ImageJ will restore the pixels that are inside the bounding rectangle but outside the ROI.

The `run` method receives the image processor (cf. Section 4.3) of the image and performs the actual function of the plugin:

```
    public void run(ImageProcessor ip) {
        ip.invert();
        imp.updateAndDraw();
        IJ.wait(500);
        ip.invert();
        imp.updateAndDraw();
    }
```

The example code inverts the image, updates the display, waits for a half second, and again inverts the image and updates the display.

2.8.3 PlugInFrame

The frame plugin extends the `PlugInFrame` class, which implements the `PlugIn` interface:

```
public class My_Plugin_Frame extends PlugInFrame {
    // ...
}
```

A `PlugInFrame` is derived from a Java AWT window. In the sample code the constructor for the class is implemented:

```
    public My_Plugin_Frame() {
        super("Plugin_Frame");
        TextArea ta = new TextArea(15, 50);
        add(ta);
        pack();
        GUI.center(this);
        show();
    }
```

First, the constructor of the base class is called with the title of the window as argument. Then a text area is created and added to the window, and the window is displayed.

2.9 A Sample Plugin (Example)

After looking at the code skeletons created for new plugins, we analyze the code of one of the sample plugins that come with ImageJ. You can find them in the plugins folder after installing ImageJ. `Inverter_` is a plugin that inverts 8 bit grayscale images.

Here we import the necessary packages, `ij` for the basic ImageJ classes, `ij.process` for image processors and the interface `ij.plugin.filter.PlugInFilter` is the interface we have to implement for a plugin filter.

```
import ij.*;
import ij.plugin.filter.PlugInFilter;
import ij.process.*;
import java.awt.*;
```

Note: Do not use a `package` statement inside plugin classes—they have to be in the default package!
The name of this plugin has the necessary underscore appended. It needs an image as input, so it has to implement `PlugInFilter`:

```
public class Inverter_ implements PlugInFilter {
```

What comes next is the method for setting up the plugin. For the case that we get "about" as argument, we call the method `showAbout` that displays an about dialog. In that case we return `DONE` because we do not want the `run` method to be called. In any other case we return the capability flags for this plugin: It works on 8 bit grayscale images, also on stacks and in the case that there is a ROI (region of interest) defined the plugin will just work on the masked region (ROI).

```
    public int setup(String arg, ImagePlus imp) {
        if (arg.equals("about")) {
            showAbout();
            return DONE;
        }
        return DOES_8G+DOES_STACKS+SUPPORTS_MASKING;
    }
```

The `run` method implements the actual function of the plugin. We get the processor of the original image. Then we get the image as an array of pixels from the processor—as it is a 8 bit grayscale image (= 256 possible values) we can use a `byte` array. Note that the pixel array is one-dimensional, containing one scan line after the other. Then we read the width of the image (because we need to know the length of a scan line) and the bounding rectangle of the ROI.

```
    public void run(ImageProcessor ip) {
        byte[] pixels = (byte[])ip.getPixels();
        int width = ip.getWidth();
        Rectangle r = ip.getRoi();
```

We now declare two variables to avoid calculating the position in the one dimensional image array every time. In the outer loop we go from the first line of the ROI to its last line. We calculate the offset (= position of the first pixel of the current scan line) and go in the inner loop from the left most pixel of the ROI to its right most pixel. We assign the current position to `i` and invert the pixel value by subtracting its value from 255.

```
        int offset, i;
        for (int y=r.y; y<(r.y+r.height); y++) {
            offset = y*width;
            for (int x=r.x; x<(r.x+r.width); x++) {
                i = offset + x;
                pixels[i] = (byte)(255-pixels[i]);
            }
        }
    }
```

`showAbout` uses the static method `showMessage` from class `IJ` to display a text in a message box. The first parameter specifies its title, the second the message text.

```
    void showAbout() {
        IJ.showMessage("About Inverter_...",
        "This sample plugin filter inverts 8-bit images. Look\n" +
        "at the 'Inverter_.java' source file to see how easy it is\n" +
        "in ImageJ to process non-rectangular ROIs, to process\n" +
        "all the slices in a stack, and to display an About box."
        );
    }
}
```

2.10 Compiling and Running Plugins

Now that we have looked at one of the sample plugins we want to compile and run it.

If the Java runtime environment you are using includes a Java compiler you can compile and run plugins inside ImageJ. There are basically two ways:

- Using the menu “Plugins / Compile and run...”, which opens a file dialog which lets you select a `.java` file which will be compiled into a class file and executed as plugin.
- Using “File / Compile and run...” in the built-in plugin editor which will compile and run the code in the editor window.

If your plugin requires other libraries (JARs) than ImageJ and the standard Java libraries, you have to make sure that they can be found by the Java compiler. The simplest way is to put them into the `ImageJ/jre/lib/ext` directory of your ImageJ installation (or to `/Library/Java/Extensions` on Mac OS X). If you are using another Java compiler, make sure that the libraries are included in the classpath by adding them to the list of libraries of the `-cp` command line option of the compiler.

3 ImageJ Class Structure

This section contains a brief overview of the class structure of ImageJ. It is by far not complete, just the most important classes for plugin programming are listed and briefly described. A UML class diagram is available at http://rsb.info.nih.gov/ij/developer/diagram.html.

`ij`

- `ImageJApplet`
  ImageJ can be run as applet or as application. This is the applet class of ImageJ. The advantage of running ImageJ as applet is that it can be run (remotely) inside a browser, the biggest disadvantage is the limited access to files on disk because of the Java applet security concept, if the applet is not signed. See also http://rsb.info.nih.gov/ij/applet/.
- `ImageJ`
  The main class of the ImageJ application. This class contains the program's main entry point, and the ImageJ main window.
- `Executer`
  A class for executing menu commands in separate threads (without blocking the rest of the program).
- `IJ`
  A class containing many utility methods (discussed in Section 5).
- `ImagePlus`
  The representation of an image in ImageJ, which is based on the `ImageProcessor` class (see Section 4).
- `ImageStack`
  An `ImageStack` is an expandable array of images (see Section 4).
- `WindowManager`
  This class manages the list of open windows.

`ij.gui`

- `ProgressBar`
  A bar in the ImageJ main window that informs graphically about the progress of a running operation.
- `GenericDialog`
  A modal dialog that can be customized and called on the fly, e.g. for getting user input before running a plugin (see Section 6).
- `HTMLDialog`
  A modal dialog that displays formatted HTML text.
- `MessageDialog`
  A modal dialog that displays an information message.
- `YesNoCancelDialog`
  A modal dialog with a message and "Yes", "No" and "Cancel" buttons.
- `SaveChangesDialog`
  A modal dialog with a message and "Don't Save", "Cancel" and "Save" buttons.

`NewImage`
: A class for creating a new image of a certain type from scratch.

`Roi`
: A class representing a region of interest of an image. If supported by a plugin, it can process just the ROI and not the whole image. There are several subclasses for specific types of ROIs, which are discussed in 4.5.

`ImageCanvas`
: A canvas derived from `java.awt.Canvas` on which an image is painted (see Section 6).

`ImageWindow`
: A frame derived from `java.awt.Frame` that displays an image (see Section 6).

`StackWindow`
: An `ImageWindow` designed for displaying stacks (see Section 6).

`HistogramWindow`
: An `ImageWindow` designed for displaying histograms (see Section 6).

`PlotWindow`
: An `ImageWindow` designed for displaying plots (see Section 6).

`ij.io`

This package contains classes for reading/decoding and writing/encoding image files.

`ij.macro`

The package implements the parser for the macro language and the built-in macro functions.

`ij.measure`

Contains classes for measurements.

`ij.plugin`

Most ImageJ menu commands are implemented as plugins and can therefore be found in the classes of `ij.plugin` and its subpackages.

`PlugIn`
: This interface has to be implemented by plugins, that do not require an image as input (see Section 2).

`Converter`
: Implements a method for conveniently converting an `ImagePlus` from one type to another (see Section 4.8)

`ij.plugin.filter`

`PlugInFilter`
: This interface has to be implemented by plugins, that require an image as input (see Section 2).

`ij.plugin.frame`

`PlugInFrame`
: A window class that can be subclassed by a plugin (see Section 2).

`ij.process`

`ImageConverter`
: A class that contains methods for converting images from one image type to another.

`ImageProcessor`
: An abstract superclass of the image processors for certain image types. An image processor provides methods for actually working on the image data (see Section 4).

`StackConverter`
: A class for converting stacks from one image type to another.

`StackProcessor`
: A class for processing image stacks.

4 Image Representation in ImageJ

When we looked at the sample plugin in Section 2.9 we saw that images are represented by `ImagePlus` and `ImageProcessor` objects in ImageJ. In this section we take a closer look at the way images are handled by ImageJ. Methods that are not discussed in the text but are of some importance for writing plugins can be found in the reference in Section 4.12.

4.1 Types of Images

Images are large arrays of pixel values. But it is important to know how these pixel values must be interpreted. This is specified by the type of the image. ImageJ knows five image types:

8 bit grayscale images can display 256 grayscales, a pixel is represented by a `byte` variable.

8 bit color images can display 256 colors that are specified in a lookup table (LUT), a pixel is represented by a `byte` variable.

16 bit grayscale images can display 65, 536 grayscales, a pixel is represented by a `short` variable.

RGB color images can display 256 values per channel, a pixel is represented by an `int` variable.

32 bit images are floating point grayscale images, a pixel is represented by a `float` variable.

For information about conversion between different image types, see Section 4.8. D. Sage and M. Unser (Biomedical Imaging Group, Swiss Federal Institute of Technology Lausanne) contributed a package called `ImageAccess`, which unifies access to images regardless of data types.[2]

[2]More information can be found at http://bigwww.epfl.ch/teaching/iplabsite/.

4.2 Images

An `ImagePlus` is an object that represents an image. It is based on an `ImageProcessor`, a class that holds the pixel array and does the actual work on the image. The type of the `ImageProcessor` used depends on the type of the image. The image types are represented by constants declared in `ImagePlus`:

`COLOR_256` A 8 bit color image with a look-up table.

`COLOR_RGB` A RGB color image.

`GRAY16` A 16 bit grayscale image.

`GRAY32` A 32 bit floating point grayscale image.

`GRAY8` A 8 bit grayscale image.

ImageJ displays images using a class called `ImageWindow`. It handles repainting, zooming, changing masks etc.
To construct an `ImagePlus` use one of the following constructors:

`ImagePlus()`

Default constructor, creates a new empty `ImagePlus` and does no initialization.

`ImagePlus(java.lang.String pathOrURL)`

Constructs a new `ImagePlus`, loading the Image from the path or URL specified.

`ImagePlus(java.lang.String title, java.awt.Image img)`

Constructs a new `ImagePlus` based on a Java AWT image. The first argument is the title of the `ImageWindow` that displays the image.

`ImagePlus(java.lang.String title, ImageProcessor ip)`

Constructs a new `ImagePlus` that uses the specified `ImageProcessor`. The first argument is the title of the `ImageWindow` that displays the image.

`ImagePlus(java.lang.String title, ImageStack stack)`

Constructs a new `ImagePlus` from an `ImageStack`. The first argument is the title of the `ImageWindow` that displays the image.

The type of an `ImagePlus` can be retrieved using

`int getType()`

Similar methods exist for getting the image dimension, the title (i.e. name of the `ImageWindow` that displays this image), the AWT image that represents the `ImagePlus` and the file information:

```
int getHeight()
int getWidth()
java.lang.String getTitle()
java.awt.Image getImage()
ij.io.FileInfo getFileInfo()
```

The AWT image on which the `ImagePlus` is based and the image's title title can be set using

```
void setImage(java.awt.Image img)
void setTitle(java.lang.String title)
```

An `ImagePlus` can have a list of additional properties that can be defined by the user. They are indexed using a string and can be any type of object. These properties can be read and set using the methods:

`java.util.Properties getProperties()`
: Returns this image's Properties.

`java.lang.Object getProperty(java.lang.String key)`
: Returns the property associated with `key`.

`void setProperty(java.lang.String key, java.lang.Object value)`
: Adds a key-value pair to this image's properties.

4.3 Processors

Each image is based on an image processor. The type of the processor depends on the type of the image. You can get and set the image processor using these two methods of an `ImagePlus`:

`ImageProcessor getProcessor()`
: Returns a reference to the image's `ImageProcessor`.

`void setProcessor(java.lang.String title, ImageProcessor ip)`
: Sets the image processor to the one specified.

When working with plugin filters you do not have to care about retrieving the processor from the `ImagePlus`, it is passed as argument to the `run` method.
`ImageProcessor` is an abstract class. Depending on the type of the image we use a subclass of `ImageProcessor`. There are five of them:

`ByteProcessor`
: Used for 8 bit grayscale and color images. It has a subclass called `BinaryProcessor` for grayscale images that only contain the pixel values 0 and 255.

`ShortProcessor`
: Used for 16 bit grayscale images.

`ColorProcessor`
: Used for 32 bit integer images (RGB with 8 bit per channel).

`FloatProcessor`
: Used for 32 bit floating point images.

4.4 Accessing Pixel Values

To work with the image we need access to its pixels. We know how to get the image's `ImageProcessor`. Retrieving the pixel values can be done by using an `ImageProcessor`'s

`java.lang.Object getPixels()`
: method. It returns a reference to this image's pixel array.

As the type of the array returned depends on the image type we need to cast this array to the appropriate type when we get it:

```
int[] pixels = (int[]) myProcessor.getPixels()
```

This example would work for an RGB image. As you have noticed we get back a one-dimensional array. It contains the image scanline by scanline. To convert a position in this array to a (x,y) coordinate in an image, we need at least the width of a scanline.
The width and height of an `ImageProcessor` can be retrieved using these methods:

`int getHeight()`

`int getWidth()`

Now we have everything to iterate through the pixel array. As you have seen in the sample plugin code this can be done using two nested loops.

Some cases need a bit more explanation: Reading pixels from `ByteProcessor`, `ShortProcessor` and from `ColorProcessor`.

Java's `byte` data type is signed and has values ranging from −128 to 127, while we would expect a 8 bit grayscale image to have values from 0 to 255. If we cast a `byte` variable to another type we have to make sure, that the sign bit is eliminated. This can be done using a binary AND operation (&):

```
int pix = pixels[i] & 0xff;
...
pixels[i] = (byte) pix;
```

It's the same with Java's `short` data type, which is also signed and has values ranging from −32,768 to 32,767, while we would expect a 16 bit grayscale image to have values from 0 to 65,535. If we cast a `short` variable to another type we have to make sure that the sign bit is eliminated. This can again be done using a binary AND operation:

```
int pix = pixels[i] & 0xffff;
...
pixels[i] = (short) pix;
```

`ColorProcessor`s return the pixel array as an `int[]`. The values of the three color components are packed into one `int` variable. They can be accessed as follows:

```
int red   = (int)(pixels[i] & 0xff0000)>>16;
int green = (int)(pixels[i] & 0x00ff00)>>8;
int blue  = (int)(pixels[i] & 0x0000ff);
...
pixels[i] = ((red & 0xff)<<16)+((green & 0xff)<<8) + (blue & 0xff);
```

The pixel array you work on is a reference to the `ImageProcessor`'s pixel array. So any modifications effect the `ImageProcessor` immediately. However, if you want the `ImageProcessor` to use another (perhaps newly created) array, you can do this using

`void setPixels(java.lang.Object pixels)`

You do not always have to retrieve or set the whole pixel array. `ImageProcessor` offers some other methods for retrieving or setting pixel values:

`int getPixel(int x, int y)`
: Returns the value of the specified pixel.

`void putPixel(int x, int y, int value)`
: Sets the pixel at (x,y) to the specified value.

`float getPixelValue(int x, int y)`
: Returns the value of the specified pixel.

`int[] getPixel(int x, int y, int[] iArray)`
: Returns the samples of the specified pixel as a one-element (grayscale) or three-element (RGB) array. Optionally, a preallocated array `iArray` can be passed to receive the pixel values.

`void getColumn(int x, int y, int[] data, int length)`
: Returns the pixels down the column starting at (x, y) in `data`.

`void putColumn(int x, int y, int[] data, int length)`
: Inserts the pixels contained in `data` into a column starting at (x, y).

`void getRow(int x, int y, int[] data, int length)`
: Returns the pixels along the horizontal line starting at (x,y) in `data`.

`void putRow(int x, int y, int[] data, int length)`
: Inserts the pixels contained in `data` into a horizontal line starting at (x,y).

`double[] getLine(int x1, int y1, int x2, int y2)`
: Returns the pixels along the line with start point (`x1`,`y1`) and end point (`x2`,`y2`).

The method

`int[] getPixel(int x, int y)`
: of `ImagePlus` returns the pixel value at (`x`,`y`) as a four element array.

All these methods should only be used if you intend to modify just a few pixels. If you want to modify large parts of the image it is faster to work with the pixel array.

4.5 Regions of Interest

A plugin filter does not always have to work on the whole image. ImageJ supports regions of interest (ROI) which can be rectangular, oval, polygonal, freeform or text selections of regions of the image.
The bounding rectangle of the current ROI can be retrieved from the `ImageProcessor` using

`java.awt.Rectangle getRoi()`
: This makes it possible to just handle the pixels that are inside this rectangle.

The method

`ImageProcessor getMask()`
: returns a mask image for non-rectangular ROIs.

ROIs can be set on the `ImageProcessor` using

`void setRoi(int x, int y, int rwidth, int rheight)`
: This sets the ROI to the rectangle starting at (x,y) with specified width and height.

`void setRoi(java.awt.Rectangle r)`
: Defines a rectangular selection.

`void setRoi(java.awt.Polygon r)`
: Defines a polygonal selection.

The methods listed above are also available on the `ImagePlus` object, which has in addition the method

`Roi getRoi()`

Returns a ROI object representing the current selection.

The classes representing the different types of ROIs can be found in `ij.gui`. These classes are:

- `Line`
- `OvalROI`
- `PolygonRoi`, with subclasses `FreehandRoi` and `PointRoi`
- `ShapeRoi`
- `TextRoi`

4.6 Creating New Images

In many cases it will make sense that a plugin does not modify the original image, but creates a new image that contains the modifications.
`ImagePlus`' method

`ImagePlus createImagePlus()`

returns a new `ImagePlus` with this `ImagePlus`' attributes, but no image.
A similar function is provided by `ImageProcessor`'s

`ImageProcessor createProcessor(int width, int height)`

which returns a new, blank processor with specified width and height which can be used to create a new `ImagePlus` using the constructor

`ImagePlus(java.lang.String title, ImageProcessor ip)`

The class `NewImage` offers some useful static methods for creating a new `ImagePlus` of a certain type.

`static ImagePlus createByteImage(java.lang.String title, int width, int height, int slices, int options)`

Creates a new 8 bit grayscale or color image with the specified title, width and height and number of slices. `options` is one of the constants listed below (e.g. to determine the initial filling mode of the image).

`static ImagePlus createFloatImage(java.lang.String title, int width, int height, int slices, int options)`

Creates a new 32 bit floating point image with the specified title, width and height and number of slices. `options` is one of the constants listed below (e.g. to determine the initial filling mode of the image).

`static ImagePlus createRGBImage(java.lang.String title, int width, int height, int slices, int options)`

Creates a new RGB image with the specified title, width and height and number of slices. `options` is one of the constants listed below that (e.g. to determine the initial filling mode of the image).

`static ImagePlus createShortImage(java.lang.String title, int width, int height, int slices, int options)`

Creates a new 16 bit grayscale image with the specified title, width and height and number of slices. `options` is one of the constants listed below (e.g. to determine the initial filling mode of the image).

`static ImagePlus createImage(java.lang.String title, int width, int height, int nSlices, int bitDepth, int options)`
: Creates a new image with the specified title, width and height and number of slices. `bitDepth` specifies the number of bits per pixel of the new image. `options` is one of the constants listed below (e.g. to determine the initial filling mode of the image).

These are the possible values for the `options` argument defined in class `NewImage`:

`FILL_BLACK` Fills the image with black color.

`FILL_WHITE` Fills the image with white color

`FILL_RAMP` Fills the image with a horizontal grayscale ramp.

There are two methods to copy pixel values between different `ImageProcessors`:

`void insert(ImageProcessor ip, int xloc, int yloc)`
: Inserts the image contained in `ip` at (`xloc`, `yloc`).

`void copyBits(ImageProcessor ip, int xloc, int yloc, int mode)`
: Copies the image represented by `ip` to `xloc`, `yloc` using the specified blitting mode.

The blitting mode is one of the following constants defined in the interface `Blitter`:

`ADD` destination = destination+source

`AND` destination = destination AND source

`AVERAGE` destination = (destination+source)/2

`COPY` destination = source

`COPY_INVERTED` destination = 255−source

`COPY_TRANSPARENT` White pixels are assumed as transparent.

`DIFFERENCE` destination = |destination−source|

`DIVIDE` destination = destination/source

`MAX` destination = maximum(destination,source)

`MIN` destination = minimum(destination,source)

`MULTIPLY` destination = destination ∗ source

`OR` destination = destination OR source

`SUBTRACT` destination = destination−source

`XOR` destination = destination XOR source

If you need a Java AWT image, you can retrieve it from the `ImageProcessor` using

`java.awt.Image createImage()`

4.7 Displaying Images

Now that we can modify images we need to know how the changes can be made visible. ImageJ uses a class called `ImageWindow` to display `ImagePlus` images. `ImagePlus` contains everything that is necessary for updating or showing newly created images.

`void draw()`
: Displays the image.

`void draw(int x, int y, int width, int height)`
: Displays the image and draws the ROI outline using a clipping rectangle.

`void updateAndDraw()`
: Updates the image from the pixel data in its associated `ImageProcessor` and displays it.

`void updateAndRepaintWindow()`
: Calls `updateAndDraw` to update from the pixel data and draw the image. The method also repaints the image window to force the information displayed above the image (dimension, type, size) to be updated.

`void show()`
: Opens a window to display the image and clears the status bar.

`void show(java.lang.String statusMessage)`
: Opens a window to display the image and displays `statusMessage` in the status bar.

`void hide()`
: Closes the window, if any, that is displaying the image.

4.8 Image Type Conversion

The simplest way to convert an image from one type to another is to use the conversion methods of the image's `ImageProcessor`.

`ImageProcessor convertToByte(boolean doScaling)`
: Converts the processor to a `ByteProcessor` (8 bit grayscale). If `doScaling` is set, the pixel values are scaled to the range $0 - 255$, otherwise the values are clipped.

`ImageProcessor convertToFloat()`
: Converts the processor to a `FloatProcessor` (32 bit grayscale). If a calibration table has been set, the calibration function is used.

`ImageProcessor convertToRGB()`
: Converts the processor to a `ColorProcessor` (RGB image).

`ImageProcessor convertToShort(boolean doScaling)`
: Converts the processor to a `ShortProcessor` (16 bit grayscale). If `doScaling` is set, the pixel values are scaled to the range $0 - 65,536$, otherwise the values are clipped.

`void threshold(int level)`
: Converts 8 and 16bit images grayscale to binary images using the specified threshold level. `autoThreshold()` determines the level automatically and then performs thresholding. On RGB images, thresholding is performed separately on each channel. Note that the thresholding methods work in place and do not return a new `ImageProcessor`.

The class `ImageConverter` in `ij.process` provides a number of methods for image type conversion, also methods for converting RGB and HSB to stacks and vice versa. They can be accessed either directly or by using the plugin class `ij.plugin.Converter` as a convenient interface.
An instance of the converter can be constructed using

`Converter()`

and works on the current image.
The only method of this class is

`public void convert(java.lang.String item)`
: where `item` is a string specifying the destination type. It can have one of the values "8-bit", "16-bit", "32-bit", "8-bit Color", "RGB Color", "RGB Stack" and "HSB Stack".

Similarly, an `ImageConverter` instance can be created using

`ImageConverter(ImagePlus imp)`

The methods for conversion are:

`public void convertToGray8()`
: Converts the `ImagePlus` to 8 bit grayscale.

`public void convertToGray16()`
: Converts the `ImagePlus` to 16 bit grayscale.

`public void convertToGray32()`
: Converts the `ImagePlus` to 32 bit grayscale.

`public void convertToRGB()`
: Converts the `ImagePlus` to RGB.

`public void convertToRGBStack()`
: Converts an RGB image to an RGB stack (i. e. a stack with 3 slices representing red, green and blue channel).

`public void convertToHSB()`
: Converts an RGB image to a HSB stack (i. e. a stack with 3 slices representing hue, saturation and brightness channel).

`public void convertRGBStackToRGB()`
: Converts a 2 or 3 slice 8-bit stack to RGB.

`public void convertHSBToRGB()`
: Converts a 3-slice (hue, saturation, brightness) 8-bit stack to RGB.

`public void convertRGBtoIndexedColor(int nColors)`
: Converts an RGB image to 8-bits indexed color. `nColors` must be greater than 1 and less than or equal to 256.

To scale to 0−255 when converting `short` or `float` images to `byte` images and to 0−65535 when converting `float` to `short` images set scaling `true` using

`public static void setDoScaling(boolean scaleConversions)`

`public static boolean getDoScaling()`
returns `true` if scaling is enabled.

`ImageConverter` does not convert stacks, you can use `StackConverter` for this purpose. An instance of this class can be created using

`StackConverter(ImagePlus img)`
It has the following methods:

`void convertToGray8()`
Converts this stack to 8-bit grayscale.

`void convertToGray16()`
Converts this stack to 16-bit grayscale.

`void convertToGray32()`
Converts this stack to 32-bit (float) grayscale.

`void convertToRGB()`
Converts the stack to RGB.

`void convertToIndexedColor(int nColors)`
Converts the stack to 8-bits indexed color. `nColors` must be greater than 1 and less than or equal to 256.

4.9 ColorInverter PlugIn (Example)

With the knowledge of the previous sections we can write our first own plugin. We will modify the `Inverter_` plugin so that it handles RGB images. It will invert the colors of the pixels of the original image's ROI and display the result in a new window.

As mentioned before, we start from the existing plugin `Inverter_`. First of all we modify the class name.

```
import ij.*;
import ij.gui.*;
import ij.process.*;
import ij.plugin.filter.PlugInFilter;
import java.awt.*;

public class ColorInverter_ implements PlugInFilter {
    ...
```

Don't forget to rename the file to `ColorInverter_.java`, otherwise you won't be able to compile it!

We want to handle RGB files, we do not want to apply it to stacks, we want to support non-rectangular ROIs and because we display the results in a new image we do not modify the original, so we change the capabilities returned by the setup method to `DOES_RGB + SUPPORTS_MASKING + NO_CHANGES`.

```
    public int setup(String arg, ImagePlus imp) {
        if (arg.equals("about")) {
            showAbout();
            return DONE;
        }
        return DOES_RGB+SUPPORTS_MASKING+NO_CHANGES;
    }
```

The `run` method will do the actual work.

```
    public void run(ImageProcessor ip) {
```

First we save the dimension and the ROI of the original image to local variables.

```
        int w = ip.getWidth();
        int h = ip.getHeight();
        Rectangle roi = ip.getRoi();
```

We want to have the result written to a new image, so we create a new RGB image of the same size, with one slice and initially black and get the new image's processor.

```
        ImagePlus inverted = NewImage.createRGBImage("Inverted image", w, h,
                                                  1, NewImage.FILL_BLACK);
        ImageProcessor inv_ip = inverted.getProcessor();
```

Then we copy the image from the original `ImageProcessor` to (0,0) in the new image, using `COPY` blitting mode (this mode just overwrites the pixels in the destination processor). We then get the pixel array of the new image (which is of course identical to the old one). It's a RGB image, so we get an `int` array.

```
        inv_ip.copyBits(ip,0,0,Blitter.COPY);
        int[] pixels = (int[]) inv_ip.getPixels();
```

We now go through the bounding rectangle of the ROI with two nested loops. The outer one runs through the lines in the ROI, the inner one through the columns in each line. The offset in the one-dimensional array is the start of the current line (= width of the image × number of scanlines).

```
        for (int i=roi.y; i<roi.y+roi.height; i++) {
            int offset =i*w;
            for (int j=roi.x; j<roi.x+roi.width; j++) {
```

In the inner loop we calculate the position of the current pixel in the one-dimensional array (we save it in a variable because we need it twice). We then get the value of the current pixel. Note that we can access the pixel array of the new image, as it contains a copy of the old one.

```
                int pos = offset+j;
                int c = pixels[pos];
```

We extract the three color components as described above.

```
                int r = (c & 0xff0000)>>16;
                int g = (c & 0x00ff00)>>8;
                int b = (c & 0x0000ff);
```

We invert each component by subtracting it's value from 255. Then we pack the modified color components into an integer again.

```
                r=255-r;
                g=255-g;
                b=255-b;
                pixels[pos] = ((r & 0xff) << 16) +
                              ((g & 0xff) << 8) +
                               (b & 0xff);
            }
        }
```

We have now done all necessary modifications to the pixel array. Our image is still not visible, so we call `show` to open an `ImageWindow` that displays it. Then we call `updateAndDraw` to force the pixel array to be read and the image to be updated.

```
        inverted.show();
        inverted.updateAndDraw();
    }
}
```

4.10 Stacks

ImageJ supports expandable arrays of images called image stacks, that consist of images (slices) of the same size. In a plugin filter you can access the currently open stack by retrieving it from the current `ImagePlus` using

`ImageStack getStack()`

ImagePlus also offers a method for creating a new stack:

`ImageStack createEmptyStack()`
: Returns an empty image stack that has the same width, height and color table as this image.

Alternatively you can create an `ImageStack` using one of these constructors:

`ImageStack(int width, int height)`
: Creates a new, empty image stack with specified height and width.

`ImageStack(int width, int height, java.awt.image.ColorModel cm)`
: Creates a new, empty image stack with specified height, width and color model.

To set the newly created stack as the stack of an `ImagePlus` use its method

`void setStack(java.lang.String title, ImageStack stack)`

The number of slices of a stack can be retrieved using the method

`int getSize()`

of class `ImageStack` or with the methods `int getStackSize()`

`int getImageStackSize()`

of class `ImagePlus`.
The currently displayed slice of an `ImagePlus` can be retrieved and set using

`int getCurrentSlice()`

`void setSlice(int index)`

A stack offers several methods for retrieving and setting its properties:

`int getHeight()`
: Returns the height of the stack.

`int getWidth()`
: Returns the width of the stack.

`java.lang.Object getPixels(int n)`
: Returns the pixel array of the specified slice, where `n` is a number from 1 to the number of slices. See also Section 4.4.

`void setPixels(java.lang.Object pixels, int n)`
: Assigns a pixel array to the specified slice, where `n` is a number from 1 to the number of slices. See also Section 4.4.

`ImageProcessor getProcessor(int n)`
: Returns an `ImageProcessor` for the specified slice, where `n` is a number from 1 to the number of slices. See also Section 4.3.

`java.lang.String getSliceLabel(int n)`
: Returns the label of the specified slice, where `n` is a number from 1 to the number of slices.

`void setSliceLabel(java.lang.String label, int n)`
: Sets the label of the specified slice, where `n` is a number from 1 to the number of slices.

`java.awt.Rectangle getRoi()`
: Returns the bounding rectangle of the stack's ROI. For more information on ROIs, see Section 4.5.

`void setRoi(java.awt.Rectangle roi)`
: Sets the stacks ROI to the specified rectangle. For more information on ROIs, see Section 4.5.

Slices can be added to and removed from the `ImageStack` using these methods:

`void addSlice(java.lang.String sliceLabel, ImageProcessor ip)`
: Adds the image represented by `ip` to the end of the stack.

`void addSlice(java.lang.String sliceLabel, ImageProcessor ip, int n)`
: Adds the image represented by `ip` to the stack following slice `n`.

`void addSlice(java.lang.String sliceLabel, java.lang.Object pixels)`
: Adds an image represented by its pixel array to the end of the stack.

`void deleteLastSlice()`
: Deletes the last slice in the stack.

```
void deleteSlice(int n)
```
Deletes the specified slice, where `n` is in the range 1...number of slices.

4.11 StackAverage PlugIn (Example)

This example shows how to handle stacks. It calculates the average values of pixels located at the same position in each slice of the stack and adds a slice showing the average values to the end of the stack.

First of all, we import the necessary packages. We want to work on the current stack so we need to implement `PlugInFilter`.

```
import ij.*;
import ij.plugin.filter.PlugInFilter;
import ij.process.*;

public class StackAverage_ implements PlugInFilter {
```

We define the stack as instance variable because we will retrieve it in `setup` and use it in `run`.

```
    protected ImageStack stack;
```

In this method we get the stack from the current image and return the plugin's capabilities—in this case we indicate that it handles 8 bit grayscale images and requires a stack as input.

```
    public int setup(String arg, ImagePlus imp) {
        stack = imp.getStack();
        return DOES_8G + STACK_REQUIRED;
    }
```

In the `run` method we declare a `byte` array that will hold the pixels of the current slice. Then we get width and height of the stack and calculate the length of the pixel array of each slice as the product of width and height. `sum` is the array to hold the summed pixel values.

```
    public void run(ImageProcessor ip) {
        byte[] pixels;
        int dimension = stack.getWidth()*stack.getHeight();
        int[] sum = new int[dimension];
```

In the outer loop we iterate through the slices of the stack and get the pixel array from each slice. In the inner loop we go through the pixel array of the current slice and add the pixel value to the corresponding pixel in the `sum` array.

```
        for (int i=1;i<=stack.getSize();i++) {
            pixels = (byte[]) stack.getPixels(i);
            for (int j=0;j<dimension;j++) {
                sum[j] += pixels[j] & 0xff;
            }
        }
```

We have now gone through the whole stack. The image containing the averages will be a 8 bit grayscale image again, so we create a `byte` array for it. Then we iterate through the pixels in the `sum` array and divide each of them through the number of slices to get pixel values in the range 0 . . . 255.

```
        byte[] average = new byte[dimension];
        for (int j=0;j<dimension;j++) {
            average[j] = (byte) ((sum[j]/stack.getSize()) & 0xff);
        }
```

Finally we add a new slice to the stack. It is called "Average" and represented by the pixel array that contains the average values.

```
        stack.addSlice("Average",average);
    }
```

4.12 Additional Reference

This reference is thought as a supplement to the concepts presented in this section. It is not complete—it just covers what you will normally need for writing plugins. For a complete reference see the API documentation and the source code (see Section 10.1 for the pointers to further documentation).

4.12.1 ImagePlus

Windows

`void setWindow(ImageWindow win)`
: Sets the window that displays the image.

`ImageWindow getWindow()`
: Gets the window that is used to display the image.

`void mouseMoved(int x, int y)`
: Displays the cursor coordinates and pixel value in the status bar.

Multithreading

`boolean lock()`
: Locks the image so that it cannot be accessed by another thread.

`boolean lockSilently()`
: Similar to lock, but doesn't beep and display an error message if the attempt to lock the image fails.

`void unlock()`
: Unlocks the image.

Lookup Tables

`LookUpTable createLut()`
: Creates a `LookUpTable` based on the image.

Statistics

`ij.process.ImageStatistics getStatistics()`
: Returns an `ImageStatistics` object generated using the standard measurement options (area, mean, mode, min and max).

`ij.process.ImageStatistics getStatistics(int mOptions)`
: Returns an `ImageStatistics` object generated using the specified measurement options.

`ij.process.ImageStatistics getStatistics(int mOptions, int nBins)`
: Returns an `ImageStatistics` object generated using the specified measurement options and number of histogram bins.

Calibration

`void setCalibration(ij.measure.Calibration cal)`
: Sets this image's calibration.

`void setGlobalCalibration(ij.measure.Calibration global)`
: Sets the system-wide calibration.

`ij.measure.Calibration getCalibration()`
: Returns this image's calibration.

`void copyScale(ImagePlus imp)`
: Copies the calibration from the specified image.

4.12.2 ImageProcessor

Geometric Transforms

`void flipHorizontal()`
: Flips the image horizontally.

`void flipVertical()`
: Flips the image vertically.

`void rotate(double angle)`
: Rotates the image `angle` degrees clockwise.

`void scale(double xScale, double yScale)`
: Scales the image by the specified factors.

`ImageProcessor crop()`
: Crops the image to the bounding rectangle of the current ROI. Returns a new image processor that represents the cropped image.

`ImageProcessor resize(int dstWidth, int dstHeight)`
: Resizes the image to the specified destination size. Returns a new image processor that represents the resized image.

`ImageProcessor rotateLeft()`
: Rotates the image 90 degrees counter-clockwise. Returns a new image processor that represents the rotated image.

`ImageProcessor rotateRight()`
: Rotates the image 90 degrees clockwise. Returns a new image processor that represents the rotated image.

`void setInterpolate(boolean interpolate)`
: Setting `interpolate` to `true` causes `scale()`, `resize()` and `rotate()` to do bilinear interpolation, otherwise nearest-neighbor interpolation is used.

Filters

`void convolve3x3(int[] kernel)`
: Convolves the image with the specified 3×3 convolution matrix.

`void convolve(float[] kernel, int kernelWidth, int kernelHeight)`
: Convolves the image with the specified convolution `kernelWidth`×`kernelHeight` matrix.

`void sharpen()`
: Sharpens the image using a 3×3 convolution kernel.

`void smooth()`
: Replaces each pixel with the 3×3 neighborhood mean.

`void noise(double range)`
: Adds random noise (random numbers within range) to the image.

`void filter(int type)`
: A 3×3 filter operation, the argument defines the filter type.

`void dilate()`
: Dilates the image using a 3×3 minimum filter.

`void erode()`
: Erodes the image using a 3×3 maximum filter.

`void findEdges()`
: Finds edges using a Sobel operator.

`void medianFilter()`
: A 3×3 median filter.

`void gamma(double value)`
: A gamma correction.

`void invert()`
: Inverts an image.

`void add(int value)`
: Adds the argument to each pixel value.

`void add(double value)`
: Adds the argument to each pixel value.

`void multiply(double value)`
: Multiplies each pixel value with the argument.

`void sqr()`
: Squares each pixel value.

`void sqrt()`
: Calculates the square root of each pixel value.

`void and(int value)`
: Binary AND of each pixel value with the argument.

`void or(int value)`
: Binary OR of each pixel value with the argument.

`void xor(int value)`
: Binary exclusive OR of each pixel value with the argument.

`void log()`
: Calculates pixel values on a logarithmic scale.

Drawing

`void setColor(java.awt.Color color)`
: Sets the foreground color. This will set the default fill/draw value to the pixel value that represents this color.

`void setValue(double value)`
: Sets the default fill/draw value.

`void setLineWidth(int width)`
: Sets the line width.

`void moveTo(int x, int y)`
: Sets the current drawing location to `(x,y)`.

`void lineTo(int x2, int y2)`
: Draws a line from the current drawing location to `(x2,y2)`.

`void drawPixel(int x, int y)`
: Sets the pixel at `(x,y)` to the current drawing color.

`void drawDot(int xcenter, int ycenter)`
: Draws a dot using the current line width and color.

`void drawDot2(int x, int y)`
: Draws a 2×2 dot in the current color.

`void drawPolygon(java.awt.Polygon p)`
: Draws the specified polygon.

`void drawRect(int x, int y, int width, int height)`
: Draws the specified rectangle.

`void fill()`
: Fills the current rectangular ROI with the current drawing color.

`void fillPolygon(java.awt.Polygon p)`
: Fills the specified polygon with the current drawing color.

`void fill(int[] mask)`
: Fills pixels that are within the current ROI and part of the mask (i. e. pixels that have value 0 (= black) in the mask array).

`void drawString(java.lang.String s)`
: Draws the string `s` at the current location with the current color.

`int getStringWidth(java.lang.String s)`
: Returns the width of the specified string in pixels.

Colors

`int getBestIndex(java.awt.Color c)`
: Returns the LUT index that matches the specified color best.

`java.awt.image.ColorModel getColorModel()`
: Returns this processor's color model.

`void invertLut()`
: Inverts the values in the lookup table.

Minimum, Maximum and Threshold

`double getMin()`
: Returns the smallest displayed pixel value.

`double getMax()`
: Returns the largest displayed pixel value.

`void setMinAndMax(double min, double max)`
: Maps the pixels in this image from `min`...`max` to the value range of this type of image.

`void resetMinAndMax()`
: For short and float images, recalculates the minimum and maximum image values needed to correctly display the image (i. e. maps the color values to the 255 displayable grayscales.

`void autoThreshold()`
: Calculates the auto threshold of an image and applies it.

`double getMinThreshold()`
: Returns the minimum threshold.

`double getMaxThreshold()`
: Returns the maximum threshold.

`void setThreshold(double minThreshold, double maxThreshold, int lutUpdate)`
: Sets the minimum and maximum threshold levels, the third parameters specifies if the lookup table will be recalculated.

Histograms

`int[] getHistogram()`
: Returns the histogram of the image. This method will return a luminosity histogram for RGB images and `null` for floating point images.

`int getHistogramSize()`
: The size of the histogram is 256 for 8 bit and RGB images and max-min+1 for 16 bit integer images.

Snapshots (Undo)

`void snapshot()`
: Saves the current state of the processor as snapshot.

`java.lang.Object getPixelsCopy()`
: Returns a reference to this image's snapshot (undo) array, i. e. the pixel array before the last modification.

`void reset()`
: Resets the processor to the state saved in the snapshot.

`void reset(int[] mask)`
: Resets the processor to the state saved in the snapshot, excluding pixels that are part of mask.

4.12.3 Stacks

Accessing Images

`java.lang.Object[] getImageArray()`
: Returns the stack as an array of `ImagePlus` objects.

`java.lang.Object getPixels(int n)`
: Returns the pixel array for the specified slice ($1 <= n <= nr\_slices$).

Color

`boolean isHSB()`
: Returns `true`, if this is a 3-slice HSB stack.

`boolean isRGB()`
: Returns `true`, if this is a 3-slice RGB stack.

`java.awt.image.ColorModel getColorModel()`
: Returns the stack's color model.

`void setColorModel(java.awt.image.ColorModel cm)`
: Assigns a new color model to the stack.

5 ImageJ's Utility Methods

The ImageJ API contains a class called `IJ` that contains some very useful static methods.

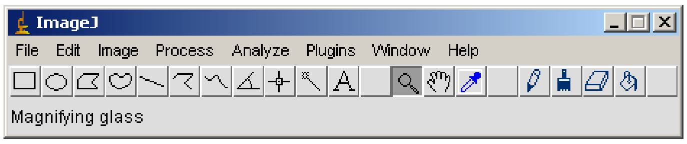


Figure 1: The ImageJ main window and its components: Menu bar, tool bar and status bar.

5.1 (Error) Messages

It is often necessary that a plugin displays a message—be it an error message or any other information. To display an error message use

`static void error(java.lang.String msg)`
: It displays a message in a dialog box entitled “Error”. To display an error message with a custom title use

`static void error(java.lang.String title, java.lang.String msg)`

`static void showMessage(java.lang.String msg)`
: displays a message in a dialog box entitled “Message”. To specify the title of the message box use

`static void showMessage(java.lang.String title, java.lang.String msg)`

All these methods display modal message boxes with just an ”OK” button. If you want to let the user choose whether to cancel the plugin or to let it continue, use

`static boolean showMessageWithCancel(java.lang.String title, java.lang.String msg)`
: This method returns `false` if the user clicks cancel and `true` otherwise.

There are also some predefined messages:

`static void noImage()`
: Displays a “no images are open” dialog box.

`static void outOfMemory(java.lang.String name)`
: Displays an “out of memory” message in the ImageJ window.

`static boolean versionLessThan(java.lang.String version)`
: Displays an error message and returns false if the ImageJ version is less than the one specified.

5.2 ImageJ Window, Status Bar and Progress Bar

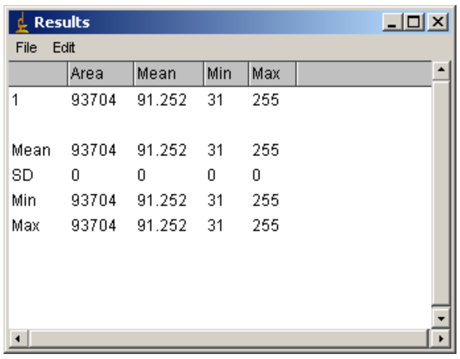
The ImageJ main window and its components are shown in Figure 1.

5.2.1 Displaying Text

To display a line of text in the results window (Figure 2) use

`static void write(java.lang.String s)`
: It is possible to use the results window’s text panel as a table (e. g. for displaying statistics, measurements, etc.). In that case ImageJ lets you set the headings of the columns using

`static void setColumnHeadings(java.lang.String headings)`
: Note that this method clears the entire text panel.



	Area	Mean	Min	Max
1	93704	91.252	31	255
Mean	93704	91.252	31	255
SD	0	0	0	0
Min	93704	91.252	31	255
Max	93704	91.252	31	255

Figure 2: The ImageJ results window displays messages, measurements, etc. It opens automatically, when text is written to it.

`static boolean isResultsWindow()`
: can be used to check whether the results window is open.

`static void log(java.lang.String s)`
: displays a line of text in the log window. To temporarily redirect the output of `IJ.error()` and `IJ.showMessage()` to the log window, call

`static void redirectErrorMessages()`

You will often want to displays numbers, which you can format for output using

`static java.lang.String d2s(double n)`
: Converts a number to a formatted string using two digits to the right of the decimal point.

`static java.lang.String d2s(double n, int precision)`
: Converts a number to a rounded formatted string.

5.2.2 Status Bar

Text can also be displayed in the status bar at the bottom of the main window using the method

`static void showStatus(java.lang.String s)`

It can be useful to display the time that was needed for an operation:

`static void showTime(ImagePlus imp, long start, java.lang.String str)`
: will display the string argument you specify, followed by the time elapsed since the specified start value and the rate of processed pixels per second.

5.2.3 Progress Bar

The progress of the current operation can be visualized using ImageJ's progress bar.

`static void showProgress(double progress)`
: updates the position of the progress bar to the specified value (in the range from 0.0 to 1.0).

`static void showProgress(int currentIndex, int finalIndex)`
: updates the position of the progress bar by setting the bar length to $(currentIndex/finalIndex) * total - length$.

5.3 User input

Often user input (e. g. a parameter) is required in a plugin. ImageJ offers two simple methods for that purpose.

`static double getNumber(java.lang.String prompt, double defaultNumber)`
: Allows the user to enter a number in a dialog box.

`static java.lang.String getString(java.lang.String prompt, java.lang.String defaultString)`
: Allows the user to enter a string in a dialog box.

A way to build more sophisticated dialogs is presented in Section 6.1, accessing mouse and keyboard events is discussed in Section 6.6.

5.4 Calling Menu Commands, Macros and Plugins

You can access all menu commands from a plugin. There are two different methods:

`static void doCommand(java.lang.String command)`
: Starts executing a menu command in a separate thread and returns immediately. Executing the command in a separate thread means that the program will not wait until the command is executed, it will immediately proceed. This has the advantage that the program is not blocked while the command is running.

`static void run(java.lang.String command)`
: Runs a menu command in the current thread, the program will continue after the command has finished. To additionally pass options to the command, use.

`static void run(java.lang.String command, java.lang.String options)`

There are also two methods to run macros, one with arguments and one without:

`static java.lang.String runMacro(java.lang.String macro)`

`static java.lang.String runMacro(java.lang.String macro, java.lang.String arg)`

To run a macro by specifiying its file name, use

`static java.lang.String runMacroFile(java.lang.String name, java.lang.String arg)`

Like macros you can also run other plugins.

`static java.lang.Object runPlugIn(java.lang.String className, java.lang.String arg)`
: Runs the plugin specified by its class name and initializes it with the specified argument.

5.5 MessageTest PlugIn (Example)

We will now look at a plugin that uses some of the utility methods presented in this chapter. This time, we do not need an image, so we implement the interface `PlugIn`. We also have to import the package `ij` as we need the class `IJ` from there.

```
import ij.*;
import ij.plugin.PlugIn;

public class Message_Test implements PlugIn {
```

All we have to implement is the `run` method. We do not need the argument, so we ignore it. First of all we display a string in the status bar that informs the user that the plugin was started. Then we set the progress bar to 0% and show an error message.

```
    public void run(String arg) {
        IJ.showStatus("Plugin Message Test started.");
        IJ.showProgress(0.0);
        IJ.error("I need user input!");
```

We want the user to input a string and set the progress bar to 50% after that. Then we write a message into the main window saying that we were going to start the sample plugin `Red And Blue` (this is one of the plugins that come with ImageJ and displays a new image with a red/blue gradient) and run the plugin. Finally we set the progress bar to 100% and show a custom message box.

```
        String name = IJ.getString("Please enter your name: ","I.J. User");
        IJ.showProgress(0.5);
        IJ.write("Starting sample plugin Red And Blue ... ");
        IJ.runPlugIn("Red_And_Blue","");
        IJ.showProgress(1.0);
        IJ.showMessage("Finished.",name+", thank you for running this plugin");
    }
}
```

5.6 More Utilities

Images

`static ImagePlus createImage(java.lang.String title, java.lang.String type, int width, int height, int depth)`
: Creates a new image with the specified title, width and height and number of slices. `bitDepth` specifies the type of image to be created and is one of `GRAY8`, `GRAY16`, `GRAY32`, `RGB`. `options` is one of the constants listed in Section 4.6.

`static ImagePlus getImage()`
: Returns the active image.

Keyboard & Sound

`static void beep()`
: Emits an audio beep.

`static boolean altKeyDown()`
: Returns `true` if the Alt key is down.

`static boolean spaceBarDown()`
: Returns `true` if the space bar is down.

Accessing GUI Elements

`static ImageJ getInstance()`
: Returns a reference to the "ImageJ" frame.

`static java.applet.Applet getApplet()`
: Returns the applet that created this ImageJ or `null` if running as an application.

`static TextPanel getTextPanel()`
: Returns a reference to the text panel in ImageJ's results window.

System

`static boolean isMacintosh(), static boolean isMacOSX(), static boolean isWindows()`
: Returns `true` if the machine on which ImageJ is running is the specified platform.

`static boolean isJava14(), static boolean isJava2()`
: Returns true if ImageJ is running on a JVM greater or equal to 1.4 or on a Java 2 JVM respectively.

`static void wait(int msecs)`
: Delays `msecs` milliseconds.

`static java.lang.String freeMemory()`
: Returns the amount of free memory in kByte as string.

`static long currentMemory()`
: Returns the amount of memory currently used by ImageJ

6 Windows

By default, plugins work with `ImagePlus` objects displayed in `ImageWindows`. They can output information to the ImageJ window but they cannot control a window. Sometimes this can be necessary, especially for getting user input.

One option is to create a plugin, that has its own window. This can be done using the `PlugInFrame` class, that has been discussed in 2.5.

6.1 GenericDialog

In Section 5.3 we saw a very simple way of getting user input. If you need more user input than just one string or number, `GenericDialog` helps you build a *modal* AWT dialog, i. e. the programs only proceeds after the user has answered the dialog. The `GenericDialog` can be built on the fly and you don't have to care about event handling.
There are two constructors:

`GenericDialog(java.lang.String title)`
: Creates a new `GenericDialog` with the specified title.

`GenericDialog(java.lang.String title, java.awt.Frame parent)`
: Creates a new `GenericDialog` using the specified title and parent frame (e. g. your plugin class, which is derived from `PlugInFrame`). The ImageJ frame can be retrieved using `IJ.getInstance()`.

The dialog can be displayed using

`void showDialog()`

6.1.1 Adding controls

`GenericDialog` offers several methods for adding standard controls to the dialog:

`void addCheckbox(java.lang.String label, boolean defaultValue)`
: Adds a checkbox with the specified label and default value.

`public void addCheckboxGroup(int rows, int columns, java.lang.String[] labels, boolean[] defaultValues)`
: Adds a group of checkboxes using a grid layout with the specified number of rows and columns. The arrays contain the labels and the default values of the checkboxes.

`void addChoice(java.lang.String label, java.lang.String[] items, java.lang.String defaultItem)`
: Adds a drop down list (popup menu) with the specified label, items and default value.

`void addMessage(java.lang.String text)`
: Adds a message consisting of one or more lines of text.

`void addNumericField(java.lang.String label, double defaultValue, int digits)`
: Adds a numeric field with the specified label, default value and number of digits.

`void addNumericField(java.lang.String label, double defaultValue, int digits, int columns, java.lang.String units)`
: Adds a numeric field and additionally specifies the width of the field and displays the `units` string to the right of the field.

`void addSlider(java.lang.String label, double minValue, double maxValue, double defaultValue)`
: Adds a slider with the specified label, minimum, maximum and default values.

`void addStringField(java.lang.String label, java.lang.String defaultText)`
: Adds a 8 column text field with the specified label and default value.

`void addStringField(java.lang.String label,java.lang.String defaultText, int columns)`
: Adds a text field with the specified label, default value and number of columns.

`void addTextAreas(java.lang.String text1, java.lang.String text2, int rows, int columns)`
: Adds one or two text areas (side by side) with the specified initial contents and number of rows and columns. If `text2` is `null`, the second text area will not be displayed.

6.1.2 Getting Values From Controls

After the user has closed the dialog window, you can access the values of the controls with the methods listed here. There are two groups of methods for this purpose: One iterates through the controls of the same type and returns the value of the next control of this type in the order in which they were added to the dialog:

`boolean getNextBoolean()`

Returns the state of the next checkbox.

`java.lang.String getNextChoice()`

Returns the selected item in the next drop down list (popup menu).

`int getNextChoiceIndex()`

Returns the index of the selected item in the next drop down list (popup menu).

`double getNextNumber()`

Returns the contents of the next numeric field.

`java.lang.String getNextString()`

Returns the contents of the next text field.

`java.lang.String getNextText()`

Returns the contents of the next text area.

The other group of methods returns the list of controls for each type:

`java.util.Vector getCheckboxes()`

`java.util.Vector getChoices()`

`java.util.Vector getNumericFields()`

`java.util.Vector getSliders()`

`java.util.Vector getStringFields()`

The method

`boolean wasCanceled()`

returns `true`, if the user closed the dialog using the “Cancel” button, and `false`, if the user clicked the “OK” button.

If the dialog contains numeric fields, use

`boolean invalidNumber()`

to check if the values in the numeric fields are valid numbers. This method returns `true` if at least one numeric field does not contain a valid number.

`java.lang.String getErrorMessage()`

returns an error message if `getNextNumber()` was unable to convert a string into a number, otherwise, returns `null`.

`GenericDialog` extends `java.awt.Dialog`, so you can use any method of `java.awt.Dialog` or one of its superclasses. For more information consult the Java AWT documentation.

6.2 FrameDemo PlugIn (Example)

This demo shows the usage of `GenericDialog` and `PlugInFrame`. It displays a dialog that lets the user specify the width and height of the `PlugInFrame` that will be displayed after closing the dialog.

We import the `ij` and `ij.process` package, the `ij.gui` package, where `GenericDialog` is located and the classes `PlugInFrame` and AWT label.

```
import ij.*;
import ij.gui.*;
import ij.plugin.frame.PlugInFrame;
import java.awt.Label;
```

Our plugin is a subclass of `PlugInFrame` which implements the `PlugIn` interface, so we don't have to implement an interface here.

```
public class FrameDemo_ extends PlugInFrame {
```

We overwrite the default constructor of the new class. If we wouldn't do that, the superclass' default constructor `PlugInFrame()` would be called, which does not exist. So we have to call the superclass' constructor and specify a title for the new frame.

```
    public FrameDemo_() {
        super("FrameDemo");
    }
```

In the `run` method we create a `GenericDialog` with the title "FrameDemo settings". Then we add two 3 digit numeric fields with a default value of 200.

```
    public void run(String arg) {
        GenericDialog gd = new GenericDialog("FrameDemo settings");
        gd.addNumericField("Frame width:",200.0,3);
        gd.addNumericField("Frame height:",200.0,3);
```

We display the dialog. As it is modal, the program is stopped until the user closes the dialog. If the user clicks "Cancel'" we display an error message and leave the `run` method.

```
        gd.showDialog();
        if (gd.wasCanceled()) {
            IJ.error("PlugIn canceled!");
            return;
        }
```

Here we get the values of the numeric fields with two calls of `getNextNumber()`. We set the size of the `FrameDemo` window to these values and add a centered AWT label with the text "PlugInFrame demo". Finally we show the frame.

```
        this.setSize((int) gd.getNextNumber(),(int) gd.getNextNumber());
        this.add(new Label("PlugInFrame demo",Label.CENTER));
        this.show();
    }
}
```

6.3 ImageWindow

An `ImageWindow` is a frame (derived from `java.awt.Frame`) that displays an `ImagePlus`. The frame contains an `ImageCanvas` on which the image is painted and a line of information text on top. Each `ImagePlus` is associated with an `ImageWindow`, which is created when the image's `show()` method is called for the first time. `ImageWindows` can also be created using one of the constructors:

`ImageWindow(ImagePlus imp)`
: Creates a new `ImageWindow` that contains the specified image.

`ImageWindow(ImagePlus imp, ImageCanvas ic)`
: Creates a new `ImageWindow` that contains the specified image which will be painted on the specified canvas.

`ImageJ` maintains the list of open windows using the `WindowManager` class. When the constructor of `ImageWindow` is called, the window is added to the list of open windows.

`boolean close()`
: Closes the window and removes it from the list. If the image has been changed, this method will ask the user whether the image displayed in this window shall be saved. If the user wants to save the image the method returns `false`. Otherwise it returns `true` and the image is deleted.

`boolean isClosed()`
: Returns `true` if `close()` has already been called, `false` otherwise.

The image displayed in an `ImageWindow` and the canvas on which the image is drawn can be accessed using

`ImagePlus getImagePlus()`

`ImageCanvas getCanvas()`

`ImageWindow` provides methods for the cut, copy and paste command:

`void copy(boolean cut)`
: Copies the current ROI (which has to be rectangular) to the clipboard. If the argument cut is `true` the ROI is cut and not copied.

`void paste()`
: Pastes the content of the clipboard into the current image. The content of the clipboard may not be larger than the current image and must be the same type.

Like an `ImagePlus` an `ImageWindow` has a method

`void mouseMoved(int x, int y)`
: This method displays the specified coordinates and the pixel value of the image in this window in the status bar of the ImageJ window.

`ImageWindow` has also a useful public boolean variable called `running`, which is set to `false` if the user presses escape or closes the window. This can be used in a plugin like shown in the following fragment to give the user a possibility to interrupt a plugin.

```
...
win.running = true;
while (win.running) {
    // do computation
}
```

The variable `running2` has a similar function as `running`, but is also set to `false` if the user clicks in the image window.

6.4 ImageCanvas

Each `ImageWindow` has an `ImageCanvas` on which the image is drawn. This is a subclass of `java.awt.Canvas` and also implements a `MouseListener` and a `MouseMotionListener` (for more information see the Java API documentation, package `java.awt.event`). It can therefore be useful for event handling, e. g. by subclassing it. Additionally it can be used to get information on how the image is displayed and to modify this. Some useful methods of `ImageCanvas` are listed here:

`java.awt.Point getCursorLoc()`
: Returns the current cursor location.

`double getMagnification()`
: Returns the current magnification factor of the image.

`void setMagnification(double magnification)`
: Sets new magnification factor for image.

`java.awt.Rectangle getSrcRect()`
: The surrounding rectangle of the image with current magnification.

`int offScreenX(int x)`
: Converts a screen x-coordinate to an offscreen x-coordinate.

`int offScreenY(int y)`
: Converts a screen y-coordinate to an offscreen y-coordinate.

`int screenX(int x)`
: Converts an offscreen x-coordinate to a screen x-coordinate.

`int screenY(int y)`
: Converts an offscreen y-coordinate to a screen y-coordinate.

`void setCursor(int x, int y)`
: Sets the cursor based on the current tool and cursor location.

`void setImageUpdated()`
: `ImagePlus.updateAndDraw` calls this method to get the `paint` method to update the image from the `ImageProcessor`.

`void zoomIn(int x, int y)`
: Zooms in by making the window bigger.

`void zoomOut(int x, int y)`
: Zooms out by making `srcRect` bigger.

6.5 Subclasses of ImageWindow

6.5.1 StackWindow

A `StackWindow` is a frame for displaying `ImageStacks`. It is derived from `ImageWindow` and has a horizontal scrollbar to navigate within the stack.

`void showSlice(int index)`
: Displays the specified slice and updates the stack's scrollbar.

`void updateSliceSelector()`
: Updates the stack's scrollbar.

6.5.2 Histogram Window

`HistogramWindow` is a subclass of `ImageWindow` designed to display histograms. There are two constructors:

`HistogramWindow(ImagePlus imp)`
: Displays a histogram (256 bins) of the specified image. The window has the title "Histogram".

`HistogramWindow(java.lang.String title, ImagePlus imp, int bins)`
: Displays a histogram of the image, using the specified title and number of bins.

`void showHistogram(ImagePlus imp, int bins)`
: Displays the histogram of the image using the specified number of bins in the `HistogramWindow`.

6.5.3 PlotWindow

This is a subclass of `ImageWindow` designed for displaying plots in a (x, y)-plane

`PlotWindow(java.lang.String title, java.lang.String xLabel, java.lang.String yLabel, double[] xValues, double[] yValues)`
: Constructs a new plot window with specified title, labels for x- and y- axis and adds points with specified (x,y)-coordinates.

`void addLabel(double x, double y, java.lang.String label)`
: Adds a new label with the specified text at position (x,y).

`void addPoints(double[] x, double[] y, int shape)`
: This methods adds points with specified (x, y) coordinates to the plot. The number of points is given by the length of the array. The argument shape determines the shape of a point. Currently only circles are supported, which is specified by passing the constant `PlotWindow.CIRCLE`.

`void setLimits(double xMin, double xMax, double yMin, double yMax)`
: Sets the limits of the plotting plane.

6.6 Event Handling (Example)

`ImageWindow` and `ImageCanvas` are derived from the AWT classes `Frame` and `Canvas` and therefore support event handling. This is especially useful to get user input via mouse and keyboard events.

Event handling in Java AWT is based on interfaces called listeners. There is a listener interface for each type of event. A class implementing a listener interface is able to react on a certain type of event. The class can be added to a component's list of listeners and will be notified when an event that it can handle occurs.

A plugin that has to react on a certain type of event can implement the appropriate interface. It can access the window of the image it works on and the canvas on which the image is painted. So it can be added as a listener to these components.

For example, we want to write a plugin that reacts to mouse clicks on the image it works on. The listener interfaces are defined in `java.awt.event`, so we import this package.

```
    import ij.*;
    import ij.plugin.filter.PlugInFilter;
    import ij.process.*; import ij.gui.*;
    import java.awt.event.*;
```

The plugin has to implement the appropriate interface:

```
public class Mouse_Listener implements PlugInFilter, MouseListener {
    ...
```

We have to access the image and the canvas in more than one method, so we declare them as instance variables:

```
    ImagePlus img;
    ImageCanvas canvas;
```

In the `setup` method we have access to the `ImagePlus` so we save it to the instance variable. We also set the plugin's capabilities.

```
    public int setup(String arg, ImagePlus img) {
        this.img = img;
        return DOES_ALL+NO_CHANGES;
    }
```

In the `run` method we get the `ImageWindow` that displays the image and the canvas on which it is drawn. We want the plugin to be notified when the user clicks on the canvas so we add the plugin to the canvas' `MouseListeners`.

```
    public void run(ImageProcessor ip) {
        ImageWindow win = img.getWindow();
        canvas = win.getCanvas();
        canvas.addMouseListener(this);
    }
```

To implement the interface we have to implement the five methods it declares. We only want to react on clicks so we can leave the others empty. We get the coordinates of the point of the mouse click from the event object that is passed to the method. The image could be scaled in the window so we use the `offScreenX()` and `offScreenY()` method of `ImageCanvas` to receive the true coordinates.

```
    public void mouseClicked(MouseEvent e) {
        int x = e.getX();
        int y = e.getY();
        int offscreenX = canvas.offScreenX(x);
        int offscreenY = canvas.offScreenY(y);
        IJ.write("mousePressed: "+offscreenX+","+offscreenY);
    }

    public void mousePressed(MouseEvent e) {}

    public void mouseReleased(MouseEvent e) {}

    public void mouseEntered(MouseEvent e) {}

    public void mouseExited(MouseEvent e) {}
```

A more advanced mouse listener (which avoids assigning the listener to the same image twice) and a similar example that reacts on keyboard events can be found at the ImageJ plugins page (cf. Section 10).

Like mouse and key listeners a plugin can implement any event listener, e. g. a mouse motion listener. For adding a mouse motion listener, the following changes of the mouse listener plugin are necessary:
The class has to implement the event listener interface:

```
    public class Mouse_Listener implements PlugInFilter, MouseListener,
                                           MouseMotionListener {
```

In the `setup` method, we add the plugin as listener to the image canvas.

```
        canvas.addMouseMotionListener(this);
```

Of course we have to implement the methods defined in the interface:

```
    public void mouseDragged(MouseEvent e) {
        IJ.write("mouse dragged: "+e.getX()+","+e.getY());
    }

    public void mouseMoved(MouseEvent e) {
        IJ.write("mouse moved: "+e.getX()+","+e.getY());
    }
```

For details about listener interfaces, their methods and the events passed please see the Java AWT documentation.

7 Advanced Topics

7.1 Importing/Exporting Movies

Because of its capability to handle image stacks ImageJ can be used to process movies. Import and export plugins for a number of common movie formats are available, for example based on QuickTime (http://www.apple.com/quicktime/download) or Java Media Framework (http://java.sun.com/products/java-media/jmf/). The plugins can be found at the ImageJ plugins page listed in Section 10.2.

For all movie plugins it is recommended to increase the amount of available memory of the JVM used for running ImageJ (cf. Section 8).

7.2 Writing I/O plugins

7.2.1 Overview

Plugins cannot only be used to implement new processing functionality, but also to support reading and writing file formats which are not natively supported by ImageJ. The basic approach is quite simple and the ImageJ API offers all of the required functionality.
To read an image file

- Display a file open dialog using the `ij.io.OpenDialog` class and get the file path and name selected by the user.
- Read the image metadata (size, pixel type, etc.) and data from the file. If a Java library is available for this file format, consider using it for this step.
- Create a new `ImagePlus` and display it by calling `show`.

To write an image file

- Display a file save dialog using the `ij.io.SaveDialog` class and get the file path and name selected by the user.
- Write the image metadata (size, pixel type, etc.) and data to the file. If a Java library is available for this file format, consider using it for this step.

7.2.2 Simple_ASCII_Reader (Example)

To demonstrate the approach for writing I/O plugins, we are going to implement a reader and a writer plugin for a very simple image format. The format is a simple ASCII file. Each line contains the pixels of one line of the image, the pixels are separated by a space and the values are from 0 to 255, i.e. a 8 bit grayscale image can be stored with this file format. A sample image in this format, which contains a logarithmic gradient from left to right, looks as follows:

```
0 1 3 7 15 31 63 127 255
0 1 3 7 15 31 63 127 255
0 1 3 7 15 31 63 127 255
0 1 3 7 15 31 63 127 255
0 1 3 7 15 31 63 127 255
0 1 3 7 15 31 63 127 255
0 1 3 7 15 31 63 127 255
0 1 3 7 15 31 63 127 255
0 1 3 7 15 31 63 127 255
```

The reader plugin does not need an image as input, so we implement the `PlugIn` interface, and we keep an `ImagePlus` as instance variable that will hold the image we read from file:

```
import java.io.*;
import ij.*;
import ij.io.*;
import ij.gui.*;
import ij.plugin.*;
import ij.process.*;
import java.util.*;

public class Simple_ASCII_Reader implements PlugIn {

  ImagePlus img;

  public Simple_ASCII_Reader() {
    img = null;
  }
```

The `run` method displays a file open dialog and gets the directory and file name the user has selected. In the case that the user has not selected a file (i.e. cancelled), we return. Otherwise we call the `read` method of our plugin (see below) and – in the case that a non-null image is returned – show the new image.

```
  public void run(String arg) {
    OpenDialog od = new OpenDialog("Open image ...", arg);
    String directory = od.getDirectory();
    String fileName = od.getFileName();
    if (fileName==null) return;

    read(directory,fileName);

    if (img==null) return;
    img.show();
  }
```

The actual functionality for reading the file is implemented in the `read` method of our plugin. It makes use of a utility method called `getLineAsArray`, that takes one line of file, tokenizes it and returns the values as a `short` array (as the values in the file are unsigned and thus outside the `byte` value range):

```
  protected short[] getLineAsArray(String line) {
    StringTokenizer tokenizer = new StringTokenizer(line," ");
    int size = tokenizer.countTokens();
    short[] values = new short[size];

    int i = 0;
    while (tokenizer.hasMoreTokens()) {
      String token = tokenizer.nextToken();
      values[i] = (new Short(token)).shortValue();
      i++;
    }
    return values;

  }
```

Now we can look at the `read` method. It opens a `BufferedReader`, and reads the lines of the file into a vector.

```
  protected void read(String dir, String filename)
  {
    try {
      BufferedReader br = new BufferedReader(new FileReader(dir+filename));
      Vector lines = new Vector();

      String line = br.readLine();
      while (line!=null) {
        lines.add(line);
        line = br.readLine();
      }
```

Then we have to determine the metadata of our image, in order to know how we have to create the new `ImagePlus`. In most real file formats you will find this information in some header structure of the image file. We know that our simple ASCII format represents a 8 bit graycale image with one slice, so we just need to get the width and height of the image. The height is the number of lines we have read and the width is the number of values in the first line. Then we can create the new image and get its pixel array.

```
      int height = lines.size();
      int width = getLineAsArray((String)lines.elementAt(0)).length;

      img = NewImage.createByteImage(filename, width, height, 1, NewImage.FILL_BLACK);
      byte[] pixels = (byte[]) img.getProcessor().getPixels();
```

Then we can iterate through the lines we have read, and copy the pixels from the array of each line to the pixel array of the image (converting them to `byte`). The rest of the code is just for exception handling (e.g. in the case that reading from the file fails).

```
      for (int i=0;i<height;i++) {
        short [] values = getLineAsArray((String)lines.elementAt(i));
        int offset = i*width;
        for (int j=0;j<width;j++) {
          pixels[offset+j] = (byte) values[j];
        }
      }
    }
    catch (Exception e) {
      IJ.error("Simple ASCII Reader", e.getMessage());
      return;
    }
  }
```

7.2.3 Simple_ASCII_Writer (Example)

Now we are going to implement a writer plugin for the same simple ASCII format. Clearly the writer needs an image as input, so we need to implement the interface `PlugInFilter`. We keep the image and its processor as instance variables and return from the `setup` method that we can handle 8 bit grayscale images.

```
public class Simple_ASCII_Writer implements PlugInFilter {
  ImagePlus img;
  ImageProcessor ip;

  public Simple_ASCII_Writer() {
    img = null;
    ip = null;
  }

  public int setup(String arg, ImagePlus imp) {
      img = imp;
      return DOES_8G;
    }
```

The `run` method displays a file save dialog, and – in case the user did not cancel – calls the `write` method of our plugin, which does the actual work.

```
  public void run(ImageProcessor ip) {
    SaveDialog sd = new SaveDialog("Save image ...", "image",".txt");
    String directory = sd.getDirectory();
    String fileName = sd.getFileName();
    if (fileName==null) return;
    IJ.showStatus("Saving: " + directory + fileName);
    this.ip = ip;
    write(directory, fileName);
  }
```

The `write` method opens a `BufferedWriter` and gets the pixel array of the image.

```
  protected void write(String dir, String filename)
  {
    try {
      BufferedWriter bw = new BufferedWriter(new FileWriter(dir+filename));
      byte[] pixels = (byte[])ip.getPixels();
```

Then we iterate through the pixel array and write the values to the file. We need to convert the numeric values to strings and write a space (except for the last one). Similarly, we write a line feed after each of the lines, except for the last one.

```
      int offset, pos;

      for (int j=0;j<img.getHeight();j++) {
        offset = j*img.getWidth();
        for (int i=0;i<img.getWidth();i++) {
          pos = offset = i;
          bw.write(new Integer(pixels[pos] & 0xff).toString());
          if (i<img.getWidth()-1) bw.write(" ");
        }
        if (j<img.getHeight()-1) bw.write("\n");
      }
```

The rest of the code just closes the writer and does the exception handling.

```
      bw.close();
    } catch (Exception e) {
      IJ.error("Simple ASCII Writer", e.getMessage());
      return;
    }
  }
```

Of course it would be possible to combine both plugins into one (using the `PlugInFilter` interface), using the argument to determine whether the plugin should read an image or write the currently active one.

7.2.4 Related issues

When reading/writing image files with 16bit or 32bit values, be aware of the fact that the native byte order of your machine might be different than that of the Java virtual machine. The byte order of the Java VM is most significant bit first ("big-endian"), while for example Intel processors use least significant bit first ("litte-endian"). The *ByteSwapper* plugin (available on the ImageJ plugins page) can be used to change the byte order in this case.

Another interesting plugin in this context is *HandleExtraFileTypes*, which can be used to access own reader plugins via the "File/Open" menu. ImageJ calls this plugin if a file to be opened is not recognized as one of the natively supported formats. A number of reader plugins are already included in *HandleExtraFileTypes* and you can easily add further ones.

You can use the same basic approach for device I/O (e.g. reading data using capture boards). In this case you will most likely need a Java library for accessing the hardware or you have to interface a native C library using Java Native Interface (JNI).

7.3 Using the ImageJ Library outside ImageJ

The ImageJ classes form an image processing library which can be used in other Java applications and applets and also on the server side in servlets or Java Server Pages (JSP). The following section outlines the use of the ImageJ library in such projects.

7.3.1 Why use the ImageJ library in your Java project?

Java 1.1.

Java 2 introduced many improvements concerning image processing with Java. But many users still use browsers that only have a Java 1.1 virtual machine and only a minority uses

Sun's Java plugin. Java 2 support may also be not available on less widespread platforms. ImageJ still supports Java 1.1 and is therefore a good choice especially for applets.

ImagePlus as internal image format.

You will probably need an internal image representation format for your application. It is convenient to use `ImagePlus` and `ImageProcessor` for this purpose, as a lot of basic functionality (reading/writing pixel values, scaling, etc.) is already available.

Plugins and Macros.

If you decide to use `ImagePlus` as your internal image format you can also use all plugins and macros from the ImageJ distribution as well as all other ImageJ plugins.

File I/O.

You can use the ImageJ file input/output plugins for reading and writing files in a variety of formats.

Of course there are some other useful Java based imaging toolkits and libraries besides ImageJ. The ImageJ links page at http://rsb.info.nih.gov/ij/links.html lists some of them.

7.3.2 Applications and Applets

To use the ImageJ library in your Java application, just import the necessary ImageJ packages (e. g. `ij.process`) in your classes. To compile and run your application you have to add `ij.jar` (if it's not in the application directory you also have to specify the path) to the classpath. In an application, you could also use dynamic class loading as it is implemented in ImageJ for accessing user plugins.

Using the ImageJ library in an applet is quite similar: include the import statement in your classes and add `ij.jar` to the classpath for compiling the applet. The Java security model requires all libraries used by an unsigned applet to be located on the same host and you have to include `ij.jar` in the archive list of the applet.

Assume your applet's code is located in `myapplet.jar`, the applet class is `MyApplet.class`, it uses the ImageJ library and both JAR files are located in the same directory as the HTML file that embeds the applet. The applet tag in the HTML page would look like

```
<APPLET CODE="MyApplet.class" ARCHIVE="myapplet.jar, ij.jar"
        WIDTH=400 HEIGHT=400>
</APPLET>
```

7.3.3 Servlets and JSP

Web applications often require modifying or generating images on the fly, e.g. for creating thumbnail images. In Java based server side solutions the ImageJ library can be used for image processing very easily. An example of a servlet that creates an image on the fly is available at http://rsb.info.nih.gov:8080/index.html.

The example discussed in the following reads an image using the ImageJ API, encodes the image as a JPEG image to display it in a web browser. If you are using servlets, just add the appropriate `import` statement for an ImageJ package to your servlet and include `ij.jar` in the classpath. In JSP applications, ImageJ can either be used "behind the curtain" inside Java Beans (where you just import it as in any other kind of Java class) or directly in a JSP page using e. g.

```
<\%\@ page import="ij.process.*" \%>
```

As display format you often have only the choice between JPEG, GIF or PNG in web applications. The output will not be written to a file but to the response stream of the servlet/JSP. You can use ImageJ's file encoders for this purpose or use e. g. Sun's JPEG encoder. The following servlet sample code illustrates how to load a file (in any format that can be read by ImageJ) and send it as a JPEG stream to the user's browser. The name of the image will be specified as parameter image of a GET request. A call of the servlet could look like

```
http://www.myserver.com/servlet/ShowImage?image=/images/picture.tif
```

We assume in this example that the image loaded is a RGB color image. Here is the complete code (requires Java 2):

First we import the servlet packages, the AWT image subpackage, the required ImageJ packages and the Sun JPEG encoder:

```
import javax.servlet.*;
import javax.servlet.http.*;
import java.io.*;
import java.awt.image.*;
import ij.*;
import ij.io.*;
import ij.process.*;
import com.sun.image.codec.jpeg.*;

public class ShowImage extends HttpServlet
```

We implement the method for handling a GET request, which gets the HTTP request and response as parameters. First we read the parameter containing the image URL from the request and open the ImageJ using ImageJ's Opener. As we assumed to open a color image, we can now get its `ColorProcessor`, create a new `BufferedImage` and store the image's pixel array in it.

```
public void doGet (HttpServletRequest request,
                   HttpServletResponse response)
                             throws ServletException, IOException {

        String inputURL=request.getParameter("image");
        Opener opener = new Opener();
        ImagePlus image = opener.openURL(inputURL);

        ColorProcessor cp = (ColorProcessor) image.getProcessor();
        int[] pixels = (int[]) cp.getPixels();
        BufferedImage bimg = new BufferedImage(cp.getWidth(),
                             cp.getHeight(), BufferedImage.TYPE_INT_RGB);
        bimg.setRGB(0,0,cp.getWidth(),cp.getHeight(),
                             pixels,0,cp.getWidth());
```

As we want to return a JPEG image, we set the appropriate MIME type for the HTTP response. We get the response's binary output stream and open a JPEG encoder on it. To get best quality, we disable subsampling and set the JPEG quality parameters to the maximum. Finally we encode the image with the specified parameters and clean up by flushing and closing the output stream.

```
        response.setContentType("image/jpeg");

        OutputStream outstr = response.getOutputStream();
        JPEGImageEncoder jie = JPEGCodec.createJPEGEncoder(outstr);

        JPEGEncodeParam jep = jie.getDefaultJPEGEncodeParam(bimg);
        jep.setQuality(1.0f,false);
        jep.setHorizontalSubsampling(0,1);
        jep.setHorizontalSubsampling(1,1);
        jep.setHorizontalSubsampling(2,1);
        jep.setVerticalSubsampling(0,1);
        jep.setVerticalSubsampling(1,1);
        jep.setVerticalSubsampling(2,1);
        jie.encode(bimg,jep);
        outstr.flush();
        outstr.close();
    }
}
```

A big advantage of JSP is the separation of implementation (which can be wrapped into Java Beans) and the page layout. A sample code that shows how a JSP based image processing system could look like, can be downloaded from http://www.fh-hagenberg.at/mtd/depot/imaging/imagej. It consists of a Java Bean that wraps the whole ImageJ functionality and also supports dynamic loading of user plugins (although plugins must not require user input except for the argument string).

8 Troubleshooting

8.1 ImageJ runs out of memory.

This can be solved by making more memory available to the Java Runtime Environment. As virtual memory is significantly slower than real RAM, you should try to assign not more than 2/3 of your real RAM to the Java virtual machine.

If you are using Mac OS X or a Windows version installed with the installer, you can set the maximum memory using the "Edit/Options/Memory" menu command. The changes will take effect after you restart ImageJ.

Otherwise change the `-mx` option passed to the Java virtual machine, e.g. `-xm256m` to set the memory to 256MB. The operating system specific instructions for setting the memory size can be found at http://rsb.info.nih.gov/ij/install.

8.2 A plugin is not displayed in ImageJ's plugins menu.

This may have several reasons:

- The plugins name does not contain an underscore.

- The plugin may not be in the plugin directory or one of its subdirectories.
- If you did not compile the plugin inside ImageJ, make sure that the compilation was successful and a class file has been created.

8.3 When you call the "Plugins/Compile and Run ..." menu, you get the message: "This JVM appears not to include the javac compiler. [...]"

If you are using Mac OS, you need the MRJ SDK in addition to the MRJ (Macintosh Runtime for Java).
If you experience this problem when using the Windows or Linux distribution including a Java compiler, make sure

- that the tools library (`tools11.jar` if you are using JRE/JDK 1.1, `tools.jar` if you are using Java 2 (JRE/JDK 1.2 or higher)) is in the classpath, and
- that you are using the right Java environment if you have more than one installed. Specify the path to the Java Virtual Machine you want to use explicitly.

8.4 ImageJ throws an exception when you use it in a web application running on a Unix/Linux server.

Many ImageJ classes are based on Java AWT. But the initialization of AWT will fail—usually during initializing the default ttolkit, which is required for loading images via AWT—on "headless" servers, i. e. servers with no Xserver installed. With JDK 1.4 or later, you can use the headless option

```
java -cp ij.jar;. -Djava.awt.headless=true ij.ImageJ
```

9 Frequently Asked Questions

9.1 How to change the URL for the sample images (menu "File/Open Samples") in order to access local copies of the files?

The URL is set using the `images.location` value in the file `IJ_Props.txt` which is located in `ij.jar`. The URL must include a trailing /.

You can edit `ij.jar` with a program that reads ZIP files. Some of them (e. g. WinZip) support editing a file from the archive directly and will update the archive after closing the modified file. Otherwise it is necessary to extract `IJ_Props.txt` from the archive and add it again after editing.
Example:

```
images.location=http://www.mymirror.com/ij/images/
```

9.2 How to include user plugins when running ImageJ as applet?

When running ImageJ as an unsigned applet, the class loader that loads user plugins will not work as the plugins folder is not in the code base. Add a package statement such as package `ij.plugins` to the plugin code and insert the compiled class into `ij.jar` (be sure to include it into the right folder). To make the plugin appear in the plugins menu add a line like

```
plug-in08="Plugin",ij.plugin.Plugin_
```

to the plugins section in `IJ_Props.txt`, which is also located in `ij.jar`.

You can edit `ij.jar` with a program that reads ZIP files. Some of them (e. g. WinZip) support editing a file from the archive directly and will update the archive after closing the modified file. Otherwise it is necessary to extract `IJ_Props.txt` from the archive and add it again after editing.

10 Further Resources

10.1 API Documentation, Source Code

The ImageJ API documentation is available online at
http://rsb.info.nih.gov/ij/developer/api/.

The browsable source code is available at http://rsb.info.nih.gov/ij/developer/source.
API documentation and source code are available for download at
http://rsb.info.nih.gov/ij/download.html.

10.2 Plugins Page

Many ImageJ plugins (with source code) are available at
http://rsb.info.nih.gov/ij/plugins.

10.3 ImageJ Mailing List

For questions concerning ImageJ that are not answered by the documentation consult the ImageJ mailing list.
A complete archive can be found at http://list.nih.gov/archives/imagej.html.
For information about subscribing see http://rsb.info.nih.gov/ij/list.html.

10.4 Java Resources

10.4.1 Online Resources

Java API documentation and many tutorials are available from Sun Microsystems at
http://java.sun.com/. Other online Java resources are:

- A comprehensive collection of Java resources (books, tutorials, FAQs, tools):
  http://www.apl.jhu.edu/~hall/java.
- O'Reilly Java Center: http://java.oreilly.com
- JavaWorld: http://www.javaworld.com
- DocJava: http://www.DocJava.com
- java.net: http://www.java.net
- Café au Lait: http://www.ibiblio.org/javafaq

10.4.2 Books

Java in a Nutshell
by David Flanagan
1252 pages, 5th edition (March 2005)
O'Reilly & Associates
ISBN: 0-596-00773-6

Java Examples in a Nutshell
by David Flanagan
720 pages, 3rd edition (January 2004)
O'Reilly & Associates
ISBN: 0-596-00620-9

Learning Java
by Patrick Niemeyer and Jonathan Knudsen
724 pages, 1st edition (May 2000)
O'Reilly & Associates
ISBN: 1-56592-718-4

The Sun Java Series
Detailed information can be found at http://java.sun.com/docs/books.

10.5 Image Processing Resources

Image Processing–An Introduction with Java and ImageJ
(Digitale Bildverarbeitung–Eine Einführung mit Java und ImageJ)
by Wilhelm Burger and Mark J. Burge
2nd revised edition 2006 (in German, the English edition is scheduled to appear in autumn 2006)
Springer-Verlag
ISBN 3-540-30940-3
This introductory textbook covers fundamental techniques in image processing in a practical, understandable fashion, without neglecting important formal precision and algorithmic details. Based on the freely available image processing software ImageJ, the book tries to smooth the path between initial ideas, mathematical specification, and practical implementation.