# 1. Basic operations. Color modes and geometrical transformations

## Exercises

1. Open a file *Lawn.jpg*. Get the following information about the image: filesize (in bytes), size (in pixels), color mode and number of bits per pixel. Convert the image into grayscale mode and save using the same filetype but a different name. Compare size of files for the two images. Explain the difference.
2. Open a file *Norway.tif*. Save it using JPEG type with quality levels: 25%, 50%, 75% and 100% (use *Edit–Options–Input/Output* to change the level). Compare filesize and quality of the original file and all JPEG files, write your conclusions. Which one is most optimal? Why?
3. Open a file *Norway.jpg*. Change the color mode to indexed colors (*8-bit Color*) using 4, 16, 64, 128 and 256 colors. Compare the quality of images and explain the difference.
4. Open a file *Lawn.jpg*. Split color channels into separate grayscale images and compare them with the original image. If you don't know a priory which one represents a red channel how can you recognize it among the grayscale images? Using *Lookup tables* show the channels by their colors (red, blue and green).
5. Open a file *Bloodsmear.jpg*. Make a duplicate and convert it into grayscale mode. For the original color image split color channels into separate images. Compare them with the grayscale image and write your conclusions. Merge color channels switching Red and Blue channels. Comment changes.
6. Open a sample image *T1 Head*. Using *Image–Stacks* submenus try the following options: split the stack to separate images, close images 120–129 and merge the rest back to stack. For slices from 20 to 50 make a montage image with following settings: scale factor – 1.0, cols – 5, rows – 6. Close all windows and reopen the sample image. Make 3D Project. Then try *Orthogonal Views* options and animation. No report for this task is needed.
7. Open a file *Flowers.jpg*. Crop it leaving only half of the left flower (including petal tips). Resize the cropped image (x5) using three different interpolation methods. Compare the resulting images and make conclusions.
8. There is an image of a toy truck in the file *Truck.jpg*. It is known that AB = 15 cm. Estimate the thickness of the truck bed (white) and distance DE in cm. What can you say about the accuracy of the results?

## 2. Image preprocessing. Pointwise operations and filtering

### Exercises

1. Open an image from file *Woman.jpg*. What can you say about the image quality? Plot an intensity histogram for this image and comment it. Make a standard contrast stretching for the image and compare images and their histograms. Explain changes and make your comments. Try contrast stretching with different stretch limits (saturated pixels), find the best solution, show and comment it.
2. Open an image from file *Moon.jpg*. Make histogram equalization and compare images and their histograms before and after equalization. Explain changes and show how these two plots should look after "ideal" equalization.
3. Apply gamma correction to images *Gradient.jpg* and *Another woman.jpg* with exponents $\gamma = 2$, 0.6, 0.4 and 0.25. Compare the results and make conclusions.
4. Open a sample image *Dot Blot*. Duplicate the image and apply *Process–Find Edges* operation to the copy. Subtract image with edges from the original image and comment the result. Try different mathematical and logical operations to get an image with high contrast between background and objects.
5. Open photos of a watch, taken at two different times – *Watch 1.jpg* and *Watch 2.jpg*. Use subtraction, division and XOR operations to underline the changes between these images. Compare and comment the results.
6. Do the same operations as in the previous task but with images *Watch 1 BW.jpg* and *Watch 2 BW.jpg*. Compare the results with previous and make conclusions.
7. Generate bit planes pictures (use AND operation with different binary constants and *Image–Adjust–Threshold*) for image *Woman.jpg*. Comment the result. Apply *Enhance contrast* operation to the original image and make the bit planes pictures again. Compare the results and write conclusions.
8. Open images from files *Noisy Lena.jpg*, *Bri.jpg* and *Statue.jpg*. Filter the images by applying mean and Gaussian filters with kernel size 3x3, 5x5, and 7x7 (so you will get 18 new images). Compare the results and make conclusions.
9. Apply median filter with different kernel size (3x3, 5x5, and 7x7) to the same images and compare the results. What filter is better for a specific image? Why?
10. Create several filters for sharpen image and finding edges. Apply these filters to the images from files *Bri.jpg*, *Bird.jpg* and *Noisy Lena.jpg*. Show the results and make conclusions. Do these images need any preprocessing and why?

## 3. Segmentation and edge detection

### Exercises

1. Load and look at the images from the files *Blobs.jpg*, *Bloodsmear.jpg*, *Noisy Lena.jpg* and *Truck.jpg*. Plot an intensity histogram for the images. What do you think about using thresholding procedure for segmentation of the images? What threshold you would use in each of the case? Describe results you expect to get. Apply manual thresholding (*Image–Adjust–Threshold*) with chosen threshold values, save and comment the results. Do they meet your expectations? Try different threshold positions to get the best result for each image.
2. Apply default automatic thresholding (*Process–Binary–Make Binary*) to the same images. Compare threshold values and results with obtained manually and make your comments.
3. Install plug-in *Auto Threshold*. Open the same images from previous tasks and apply the following methods: *Default*, *Triangle*, *Isodata* and *Outsu* (use *Image–Adjust–Auto Threshold*) and compare the results and threshold values. Comment the results.
4. Load an image from file *Truck.jpg*. Find and show horizontal and vertical gradients and the gradient modulus of the image using Prewitt and Sobel filters (use *Process–Filters–Convolve*). Compare the results.
5. Repeat the last procedure for an image from file *Noisy Lena.jpg*. Are you satisfied with result now? Why? Suggest a couple of solutions to improve the result and try them. Choose the best solution and explain your choice.
6. Install plug-in *FeatureJ* (you will find all available operations in *Plugins–FeatureJ*). Load images from the files *Blobs.jpg*, *Noisy Lena.jpg* and *Bloodsmear.jpg*. Using option *FJ Laplacian* compute Laplacian for these images with and without zero-crossing detection. Compare and comment all results.
7. For the same images apply *FJ Edges* (Canny edge detector) with different smoothing scale and default threshold values. Compare and comment the results.

# 4. Morphology based operations

## Exercises

1. Install the Morphology plug-in.
2. Open an image from file *Morph.jpg*. Apply the basic morphology operations (*dilation*, *erosion*, *opening* and *closing*) to the image using different radius of structure element (in *ImageJ* — different number of iterations, try from 1 to 5, for instance). Show results as a table with images and comment them.
3. Find the best combination of basic morphological operations to improve the quality of fingerprint image from file *Fingerprint.jpg*. Explain why the found combination is the best.
4. Load an image from file *Blobs.jpg*. Find a sequence of *ImageJ* operations that removes a background (makes it white), and all particles touching the image border and keeps the original particles' intensity and texture (check *Blobs 2.jpg* to see how it should be) for the rest.
5. Find a sequence of morphological and logical operations that keeps only objects with holes on an image from *Boltsandnuts.jpg* and removes the rest. Then find a sequence that does vice versa.
6. For the thresholded image from *Blobs.jpg* get a distance map and result of watershed segmentation for original and inverted versions. Compare and explain the difference if any.
7. Using only morphological (plus arithmetic/logic if needed) operations and *Analyze–Histogram* option calculate number of particles in image *Blobs.jpg* that do not touch image border and bigger than 2 pixels in diameter. Proof (by showing some image) that your result is correct.

# 5. Image analysis basics

## Exercises

1. Apply *Analyze Particles* option to thresholded image from *Blobs.jpg* keeping out particles that touching borders. Show outlines of particles and distribution of the particles area (as a histogram). Compare the number of particles you obtained with the number you have got in previous exercise. Are they different? Why?
2. Find a sequence of operations that gives you a number of particles and histogram of distribution of their size for an image from file *Pellets.jpg*. Apply the found procedure to images from folder *Pellets*. Think about how to check the accuracy of the result obtained.
3. File *Ecoli 1.jpg* contains fluorescent images of *E. coli* bacterial cells with visualized RNA. The bar denotes 2 microns. Find a sequence of operations that will calculate table of length of the cells on the image. Apply the procedure to image from file *Ecoli 2.jpg*. Evaluate the accuracy of results.
4. There is an MRI of Homer Simpson's brain in *Simpson MRI.jpg*. Find a ratio between volume of his brain and volume of his braincase. Describe and comment your solution. Is it possible to avoid manual operations (selections or measurements made by hand)?
5. Folder *Textures* contains images of four textures — bark, grass, pigskin and sand. Calculate statistics of intensity distribution (mean, median, standard deviation, skewness and kurtosis) for all images and find two that separate different textures best. Use Excel (or any other graph tool) scatter plot for the last step.
6. Folder *Watches* contains images of the same watch but at different time. Find a procedure that will calculate time (hours, minutes and seconds) by analyzing these images.

## 6. Advanced ImageJ

1. Write a macro that switches red and blue channels for color images.
2. Write a macro that counts a number of pellets (see task 2 from the previous exercise). Create a toolset for this and previous macro.
3. Find, install and test plug-in that calculates intensity distribution statistics for all images from a specific folder.
4. Find, install and test plug-in for image segmentation by active contours. Try it on several images and report on testing.