Computer Graphics ex1

The Interdisciplinary Center - Spring 2019

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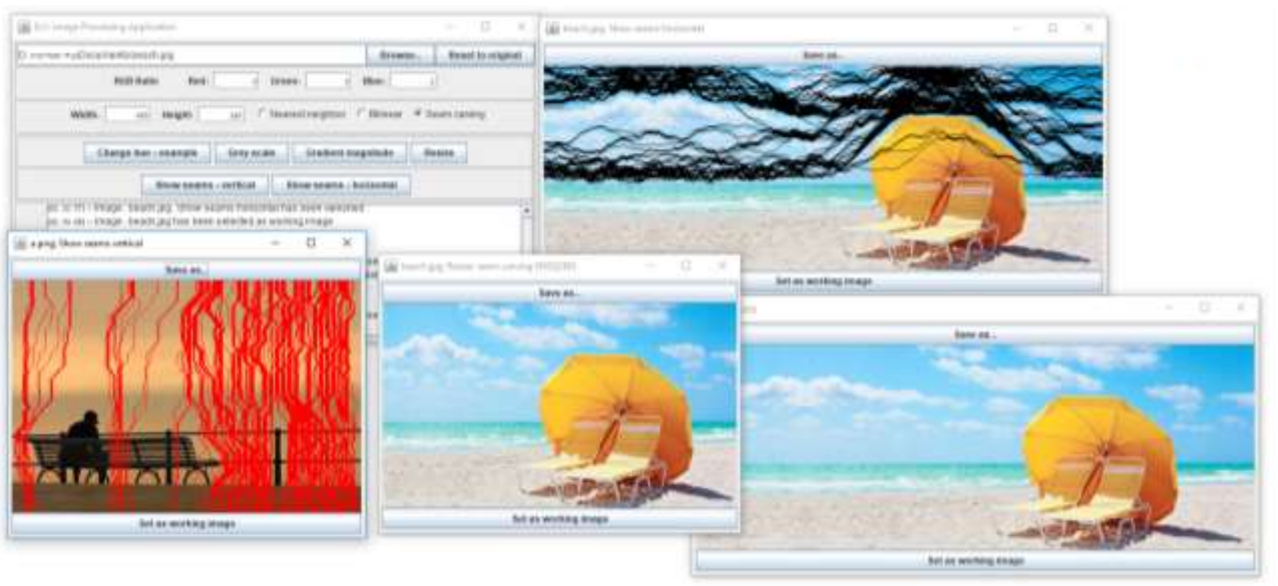
Image Processing and Seam Carving



In this exercise you will implement and explore image resizing using the seam carving algorithm, along with other basic image processing operations.

To illustrate the different operations you are provided with an example working java application that illustrates these operations:

- Changing the image's hue – already implemented as an example.
- Conversion into grayscale.
- Resizing an image using two methods:
  - Nearest neighbor.
  - Seam carving.

You are also provided with partial code, which you will need to complete to achieve an application that is similar to the given one.

What you should do

1. Install java (jdk) 11, see installation instruction in the following link.
2. Run the provided jar, which is a binary similar to what you are going to implement, and play around.
   If double click doesn't work, you can run the next command line:
   ```
   java -jar SeamCarving.jar
   ```
3. Read the partial code given in the src directory for this exercise. Understand what each class does and how.
4. You can use any kind of java IDE, but we will check your solution with eclipse, make sure it works in eclipse before you submit.
5. Your responsibility is to fill in the missing pieces according to the functionality described below. **Implement** all TODO's in the code (search for the string "TODO" and replace it with your code). The final result should behave the same as the provided jar.
6. Submit your implementation in a zip file according to the submission guidelines below.

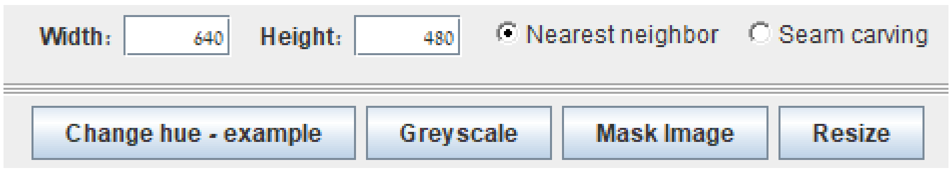
More specifically

- **Change hue – example:** This function is already implemented, explore its code and learn how to use the framework.
- **Greyscale:** Convert the image into grayscale, using the RGB weights that was entered in the application main window:

  RGB Ratio Red: 1 Green: 1 Blue: 1

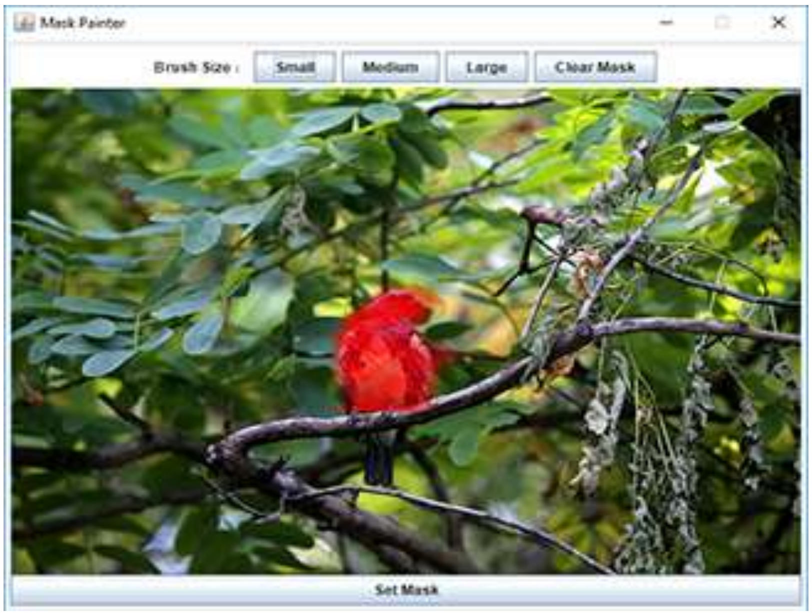
  You can change those values to get different results. (Each value should be an integer $\in [0,100]$ and the total amount should be greater than zero).
  Use the next formula to calculate the grey scaled image:

  ```
  for each pixel p ∈ input image do:
      greyColor = $\frac{p.red \times weights.red + p.green \times weights.green + p.blue \times weights.blue}{weights.red + weights.green + weights.blue}$
      set the greyColor as the output image's pixel.
  ```
- **Resize:** By clicking the "Resize" button, an invocation of the selected method will be performed.

  
  Width: 640 Height: 480 [✓ Nearest neighbor] Seam carving

  The methods are:
  - Nearest neighbor: Each new sized image pixel's color will be taken from the nearest appropriate pixel in the original image. Each image has different dimensions.
  - Seam carving: *general*
    - Use the forward energy formulation.
    - You need to make sure you take into account the input mask, meaning, you need to avoid regions that were masked by the user.

For example, given the following mask:



Then you need to make sure you avoid seams that pass through the red-highlighted region. You can use different brush size in-order to draw on the image. Remember to press **Set Mask** in order to apply the mask to the input image.

- You should implement only vertical seam carving (changing the image width). Horizontal seam carving will be implemented automatically by rotating the image first, then using the vertical seam carving, and finally, rotating the image back (these steps are already implemented in the partial code).
- You should implement both image reducing and image increasing.
- The code shouldn't run much slower than the supplied jar example.

Seam carving - algorithm

- Assume you need k seams
- For each seam
    - Calculate the costs matrix. Remember the formula from class:

$$M_{y,x} = pixelEnergy(y,x) + \min \begin{cases} M_{y-1,x-1} + C_L(y,x) \\ M_{y-1,x} + C_V(y,x) \\ M_{y-1,x+1} + C_R(y,x) \end{cases}$$

    - The pixel energy should be the gradient magnitude. Use forward difference for calculating the derivative at a certain pixel. If this is not possible, that is, the pixel is at the right/bottom borders of the image, then use backward difference for calculating the derivative in the corresponding direction (See slide 90 in the first lecture and use $\Delta x = 1$ or $\Delta y = 1$). **DON'T FORGET:** THE MAGNITUTED IS AN ABSOLUTE VALUE!
    - The pixel energy should be very large if the pixel is part of the "forbidden" region as specified by the input mask. You must do so by adding

`Integer.MAX_VALUE` to the energy matrix at **the marked pixels only (pixels in which the mask entry is TRUE)**.

  - Use dynamic programming to find the optimal seam. First find the smallest cost in the bottom row, then, travel back to the top along the path of minimal costs (invert the formula above).
  - Store the path of each seam in an appropriate data structure.
  - Remove the seam.

- In order to reduce the image's width by k, remove all the seams (paths) that you have stored in your data structure (make the appropriate modification to the image mask as well, that is, also remove these seams from the input mask - see getMaskAfterSeamCarving() in the source code SeamCarver.java).
- In order to increase the image's width by k, duplicate all the seams (paths) that you have stored in your data structure (do so to the image mask as well).

Notes:

- Note the coordinates of the paths; you should make an appropriate transformation. Think how.
- The costs matrix may contain very large values.
  Remember that: `Integer.MAX_VALUE+1` is **negative**. You're advised to use matrix of `long` values.
- We will check your work manually; your results should look similar to ours (not identical, but close enough).

General Tips

- A gray color g can be coded as: `new Color(g, g, g).getRGB();`
- **Make sure** you work properly when accessing 2D Arrays and Images. As said in class, the indexing is different for each data structure.
- When you remove a seam, all pixels to the right of it are shifted left by one. You will have to remember their original position. Use a helper array for that, e.g. an array with the size of the image, with the original column indices in each row:

$$\begin{array}{ccccccc} 0 & 1 & \mathbf{2} & \underline{3} & 4 & 5 & 6 \\ 0 & 1 & 2 & \mathbf{3} & \underline{4} & 5 & 6 \\ 0 & 1 & 2 & \mathbf{3} & \underline{4} & 5 & 6 \end{array}$$

becomes

$$\begin{array}{cccccc} 0 & 1 & \underline{3} & 4 & 5 & 6 \\ 0 & 1 & 2 & \underline{4} & 5 & 6 \\ 0 & 1 & 2 & \underline{4} & 5 & 6 \end{array}$$

- At the sides (left/right), you don’t have all three options for the costs. What you should do, is using the options you can.
  For example, at a leftmost pixel ($x = 0$), the cost would be:

$$M_{y,0} = pixelEnergy(y,x) + \min \begin{cases} M_{y-1,0} + C_V(y,0) \\ M_{y-1,1} + C_R(y,0) \end{cases}$$

The case of the rightmost pixels is equivalent.

- At the top row ($y = 0$), the cost would be:

$$M_{0,x} = pixelEnergy(0, x)$$

- To print numbers to the console with a constant width, you can use:
`System.out.format("%3d ", num);`
- Explore the given code, learn how it works.
- Java 11 supports functional programming paradigm (lambda expressions, method references, etc.). You're encouraged to use it in your code.

Bonus

These things can give you extra points, but you're on your own here. We won't answer questions regarding the bonus points.

1. (5pt) Implement the functionality of "Show seams" buttons.

Note that the implementation of bonus items has to be documented in an accompanying `readme.txt` file. **Undocumented items won't be graded.**

Submission Guidelines

Submit the "src" folder with all the java source files, **including** the files you didn't change.
REMEMBER: If you want the bonus, then also add the readme.txt file.
Your zip file should have the following name:
`<Ex##> <FirstName1> <FamilyName1> <ID1> <FirstName2> <FamilyName2> <ID2>`
For example: `Ex01 Bart Cohen-Simpson 34567890 Darth Vader-Levi 12345678`
Upload the file to the Moodle site.

Appendix I – Code

The source consists of the following classes:

`Main` – The entry point to the program. It is fully implemented.

`MenuWindow` – A class that represents the app's main window. It is fully implemented.

`ImageWindow` – A window that displays an image and allows you to save it as a PNG file. It is fully implemented.

MaskPainterWindow - An implementation of the mask painter window. This window allows to draw a mask on the input image.

`Logger` – An interface providing the log method(s), to print messages to the log field in the app's main window.

`FunctioalForEachLoops` – An abstract class that provides a convenient way of iterating over 2D arrays (also 1D arrays). It is fully implemented.

`RGBWeights` – A class that represents the weight of each color channel.

`ImageProcessor` extends **`FunctioalForEachLoops`** – A class that has some image processing methods:

> `logger` – A Logger type field that prints messages to the log field in the app's main window. You can use it the way you want.
>
> `changeHue()` – This is already implemented as an example. Test the implementation.
>
> `greyscale()` - Makes an image greyscale. You should implement this. The rgbWeights field should affect the result.
>
> `nearestNeighbor()` – Resize the image by using the nearest neighbor interpolation. You should implement this.

`SeamsCarver` extends **`ImageProcessor`** – A class that does seam carving. The rgbWeights field should affect the results.

> `constructor` – Initializes some necessary fields. Not fully implemented. You are required to continue its implementation; initialize some additional fields, run preliminary computations such as: finding the k most minimal seams, storing their paths etc.
>
> `increaseImageWidth()` - Increases the image's width. You should implement this.
>
> `reduceImageWidth()` - Reduces the image's width. You should implement this.
>
> `getMaskAfterSeamCarving()` - Return the image mask after seam carving is applied on the image. The new returned mask, should contain the original values of the remaining pixels in case seam removal was applied. If pixels were replicated due to seam insertion, then you need to replicate the mask values of the replicated pixels as well.
>
> `showSeams(int seamColorRGB)` - Colors the seams pending for removal/duplication in the given argument. You should implement this as a bonus.

Good Luck!