LEHRSTUHL FÜR
MUSTER-
ERKENNUNG

Preprocessing/Image Undistortion

Frank Schebesch, Tobias Würfl, Matthias Utzschneider,
Yixing Huang, Asmaa Khdeir, Houman Mirzaalian

Exercise Sheet 2

4   Preprocessing

(i) Shortly explain the term "preprocessing".

(ii) Artifacts are often encountered in medical imaging, and might obscure or simulate pathologies. There are many types of image artifacts, name at least three types of image artifacts **and** their origins.

(iii) Explain interpolation and regression and the difference of both in your own words.

(iv) An undistorted image $\mathbf{I}_1$ has to be generated from a distorted image $\mathbf{I}_0$. Describe the interpolation problems associated with the mapping from the distorted image to the undistorted image. What are the disadvantages of using the points of $\mathbf{I}_0$ for sampling to generate $\mathbf{I}_1$? Outline a good solution and a solution fixing the associated problems directly.

$\boxed{1+1.5+1.5+2}$

5   Polynomial Mappings

A parametric mapping for the distortion correction of a distorted image can be estimated by bivariate polynomials, i.e. $X(x', y')$ for the mapped x-coordinate of a point, in which (x', y') is a point in the undistorted image:

$$x = X(x', y') = \sum_{i=0}^{d} \sum_{j=0}^{d-i} u_{i,j} x'^i y'^j.$$
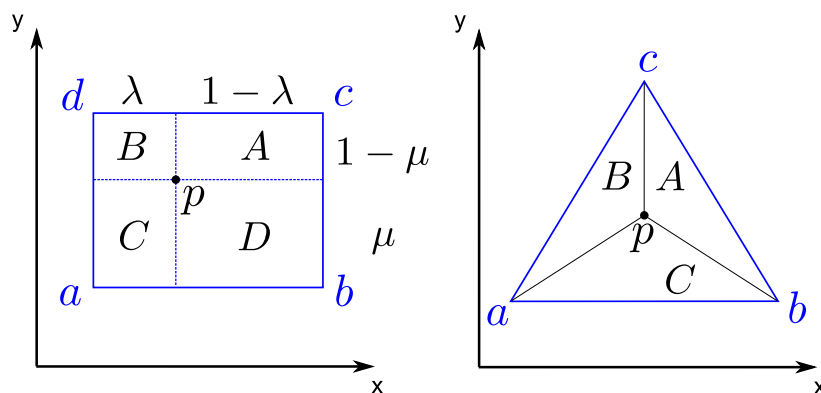
(i) How many multiplications does a naive evaluation of this polynomial take?

(ii) How can the number of multiplications for the evaluation be efficiently reduced and how many multiplications are necessary to evaluate the polynomial after the reduction?

(iii) Use the Horner scheme to evaluate the polynomial for $d = 2$.

(iv) Given six calibration points from the undistorted image, i.e., (x'_1, y'_1), (x'_2, y'_2), (x'_3, y'_3), (x'_4, y'_4), (x'_5, y'_5), (x'_6, y'_6), and $d = 2$, write the measurement matrix $\mathbf{A}$. How would you call this matrix in 1D?

(v) Have a look at the diagrams. What is the value at $p = (3, 5)$ when the corner nodes of the rectangle in the left diagram are $(2, 4)$, $(6, 4)$, $(6, 7)$, $(2, 7)$, and $a = 2$, $b = 5$, $c = 3$, $d = -1$?

(vi) Looking at the process of how you computed the last value, can you also compute the value at $p = (3, 2.464)$ in the right diagram with the corner nodes $(1, 1)$, $(5, 1)$, $(3, 4.464)$, and $a = 100$, $b = 250$, and $c = 250$.

$$\boxed{1+1+1+1+1+1}$$

6   Image Undistortion – Programming Exercise

Have a look at the code file *exercise2.java*. First, search for the main method and see what is happening there. Go through the code of `generateDistortedImage()` to understand how the distorted test images for this exercise are artificially created.

Your task is to undo this distortion by implementing the method `doImageUndistortion()` using the polynomial undistortion approach which you have seen in the lecture.

1. In real world we would know the relation between the undistorted and the distorted image by point correspondences of a calibration pattern. However, in this example we use the artificial distortion field.

   Therefore, we assume lattice points distributed over the whole image domain, e.g. a 8×8 lattice. For these 64 positions we know the relation between the undistorted (Xu,Yu) and the distorted image (Xd,Yd).

Set the number of lattice points and sample the undistorted and distorted image at those positions.

Attention: We want to **sample the distorted image** to get the corrected image. When creating the distortion field the ideal image was sampled to get the distorted one. Check the direction of the distortion regarding the undistorted and distorted image!

2. The distortion correction is described in the slide set for unit 11. d is the polynomial's degree. What is the maximum number for d w.r.t. the given number of sampling points?

3. Build the matrix $\mathbf{A}$ where the number of rows is the number of correspondences, and the number of columns is the number of coefficients (see "Gaußsche Summenformel").

4. Compute the pseudoinverse $\mathbf{A}^{\dagger}$ and use it to estimate the coefficients $u_{i,j}$ and $v_{i,j}$.

5. Compute the sampling grid for an undistorted image and resample the distorted image to obtain the undistorted image using bilinear interpolation. Show the result.
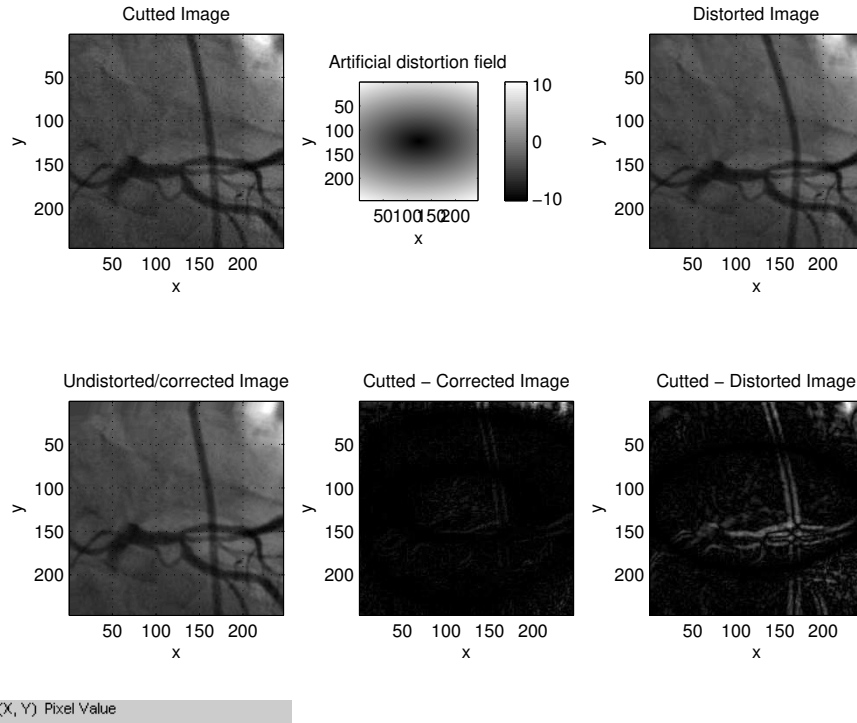
$$\boxed{2+1+0.5+1.5+1}$$

Figure 1: Original image, artificial distortion field and image undistortion result.