Photogrammetric Computer Vision

Final Exercise

Winter semester 21/22

(Course materials for internal use only!)

Computer Vision in Engineering – Prof. Dr. Rodehorst
M.Sc. Christian Benz
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Agenda

Topics:

Assignment 1.	Points and lines in the plane, first steps in MATLAB / Octave
Assignment 2.	Projective transformation (Homography)
Assignment 3.	Camera calibration using direct linear transformation (DLT)
Assignment 4.	Orientation of an image pair
Assignment 5.	Projective and direct Euclidean reconstruction
Assignment 6.	Stereo image matching
Final Project. *	**Least Squares Correlation**

***Depending on the regulations of your study program, this project might be optional for you!**

If you are not sure about the exact requirements for your study program,
please consult with a representative of the Academic Affairs Office in charge!

Agenda

	Beginning:	Submission deadline:
Assignment 1.	~~18.10.21~~	~~31.10.21~~
Assignment 2.	~~01.11.21~~	~~14.11.21~~
Assignment 3.	~~15.11.21~~	~~28.11.21~~
Assignment 4.	~~29.11.21~~	~~12.12.21~~
Assignment 5.	~~13.12.21~~	~~09.01.22~~
Assignment 6.	~~10.01.22~~	~~23.01.22~~
Final Project. *	**24.01.22**	**13.03.22**

***Depending on the regulations of your study program, this project might be optional for you!**

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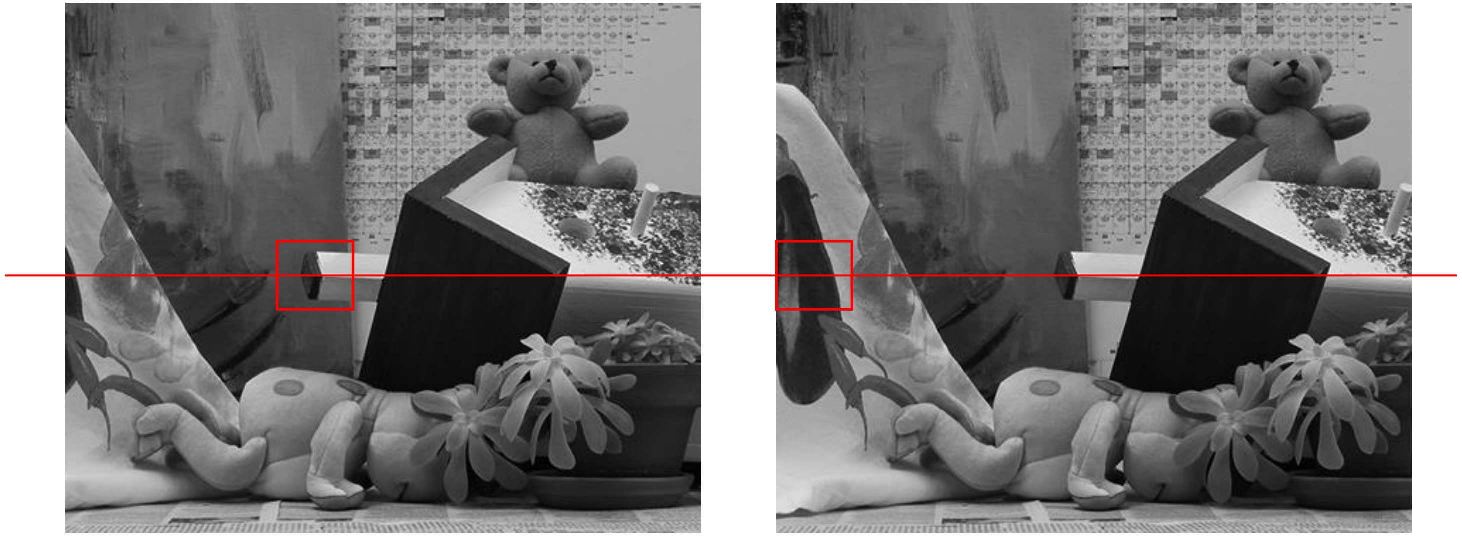
Assignment 6 – sample solution

Assignment 6: *Stereo image matching using* ***normalized cross-correlation***

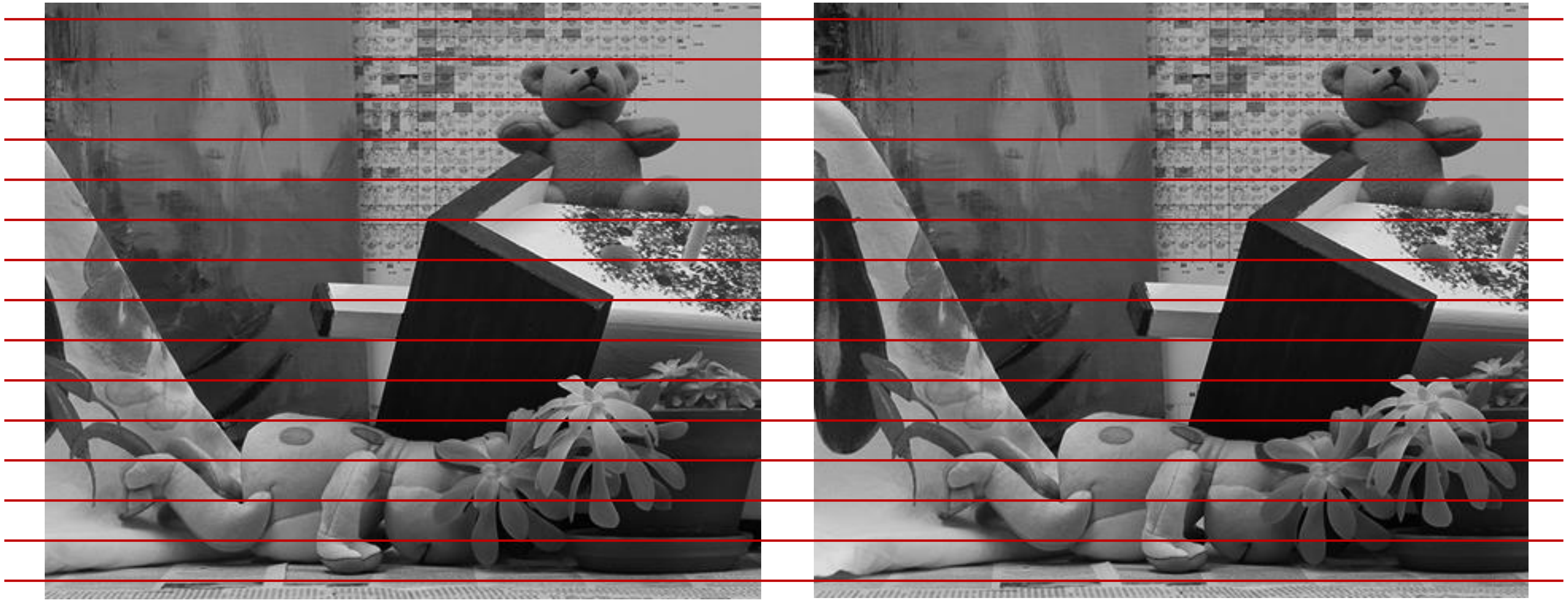


$$\rho_{NCC}(a,b) = \frac{\sigma_{ab}}{\sqrt{\sigma_a^2 \cdot \sigma_b^2}}$$

$$= \frac{\frac{1}{n^2}\left(\sum_{i,j=1}^{n} a(i,j)\cdot b(i,j)\right) - \bar{a}\cdot\bar{b}}{\sqrt{\left(\frac{1}{n^2}\left(\sum_{i,j=1}^{n} a(i,j)^2\right)-\bar{a}^2\right)\cdot\left(\frac{1}{n^2}\left(\sum_{i,j=1}^{n} b(i,j)^2\right)-\bar{b}^2\right)}}$$

Assignment 6: *Stereo image matching using* ***normalized cross-correlation***

horizontal scanlines = **epipolar lines**



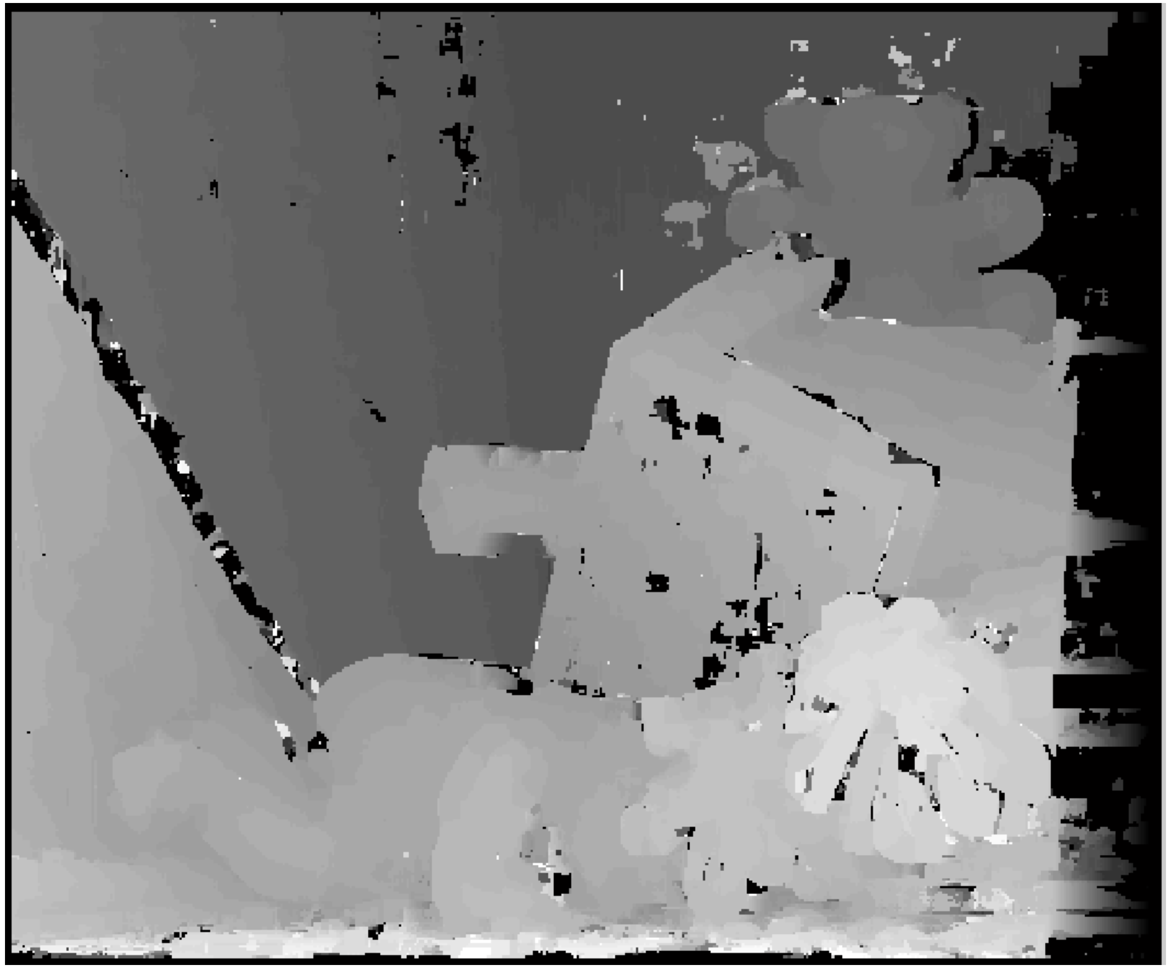
Reference image → left

Search image → right

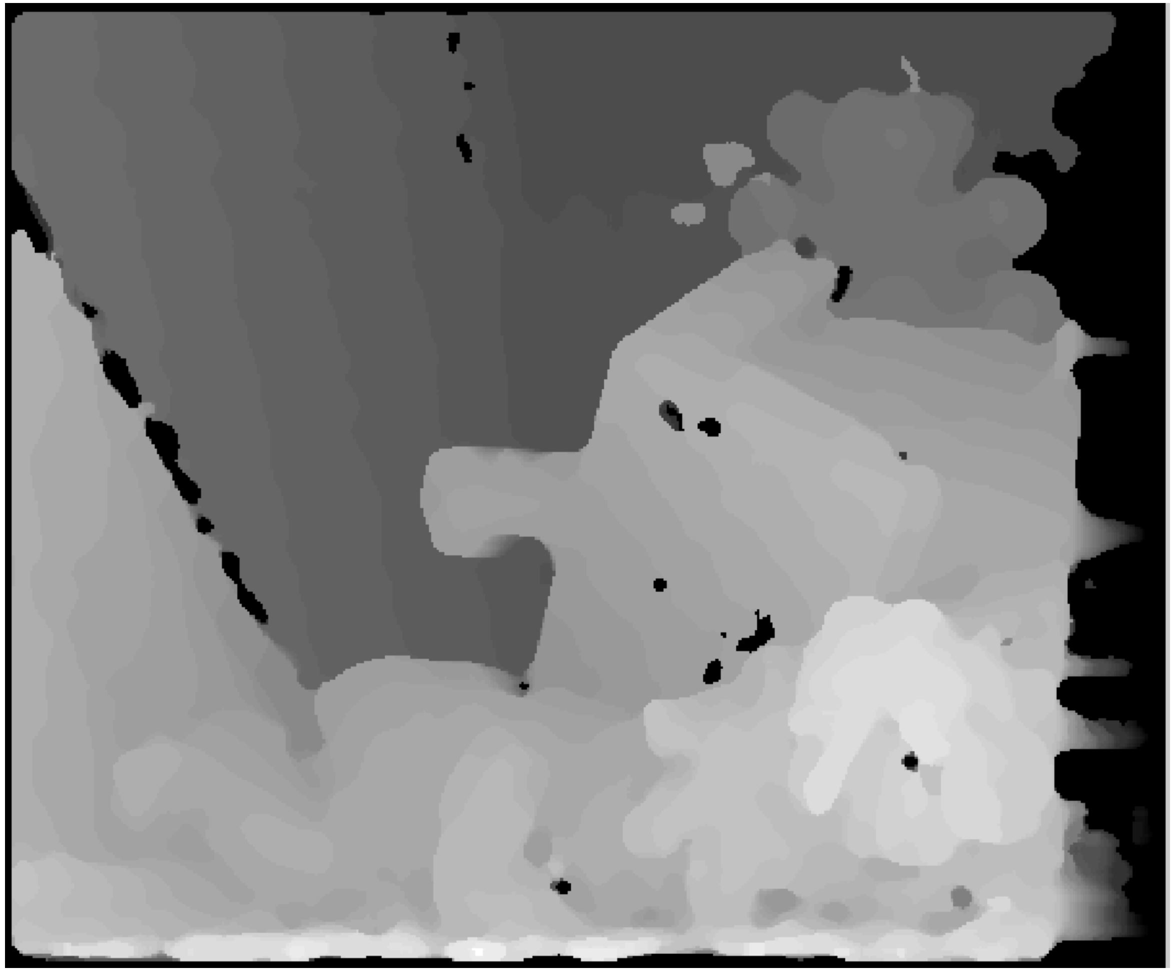
$$\rho_{NCC}(a,b) = \frac{\sigma_{ab}}{\sqrt{\sigma_a^2 \cdot \sigma_b^2}}$$

$$= \frac{\frac{1}{n^2}\left(\sum_{i,j=1}^{n} a(i,j)\cdot b(i,j)\right) - \bar{a}\cdot\bar{b}}{\sqrt{\left(\frac{1}{n^2}\left(\sum_{i,j=1}^{n} a(i,j)^2\right) - \bar{a}^2\right)\cdot\left(\frac{1}{n^2}\left(\sum_{i,j=1}^{n} b(i,j)^2\right) - \bar{b}^2\right)}}$$

Assignment 6: Sample results



Disparity Map



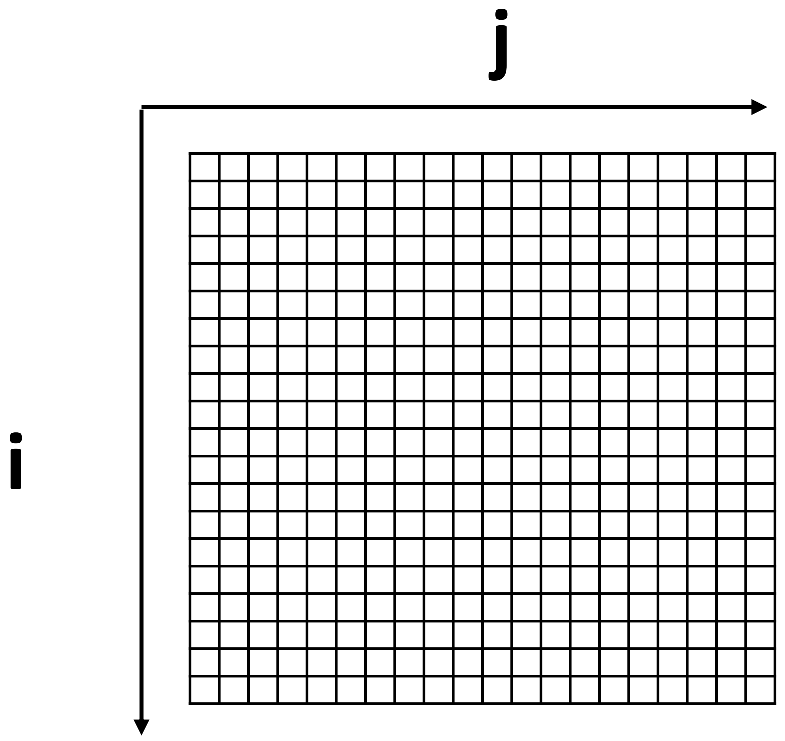
Smoothed Disparity Map

Sample code: Part 1

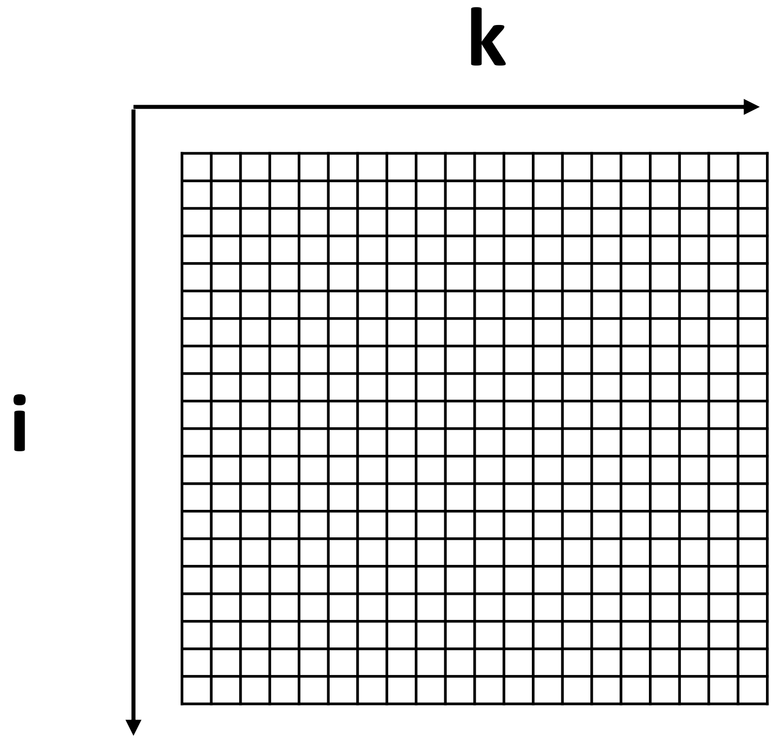
```
function exercise6
%        =========
r = 2;                                            % Image window radius (1...)
thres = 0.5;                               % Threshold for correlation (-1..1)
dmin = 10; dmax = 50;                          % Minimum and maximum disparity
left  = double(imread('left.png'));                % Read stereo normal images
right = double(imread('right.png'));
[h, w] = size(left);                             % Left image is the reference
D = zeros(h, w);                                    % Initialize disparity map

[lm, lms] = precalc(left, r);                     % Pre-calculate the mean and
[rm, rms] = precalc(right, r);                           % the mean of squares
...
```

```
function [m, ms] = precalc(img, r)           % Acceleration by pre-calculation
%        =========================
[h, w] = size(img);                                               % Image size
m  = zeros(h, w);                                 % Initialize result matrices
ms = zeros(h, w);
for i = 1+r : h-r                                % For each row i and column j
    for j = 1+r : w-r                        % with a distance r to the border
        A = img(i-r : i+r, j-r : j+r);              % Define an image window A
        m(i, j)  = mean2(A);                                       % Mean of A
        ms(i, j) = mean2(A.*A);                              % Mean of squares
    end
end
```

Assignment 6: *Stereo image matching using* ***normalized cross-correlation***



Reference image
→ left



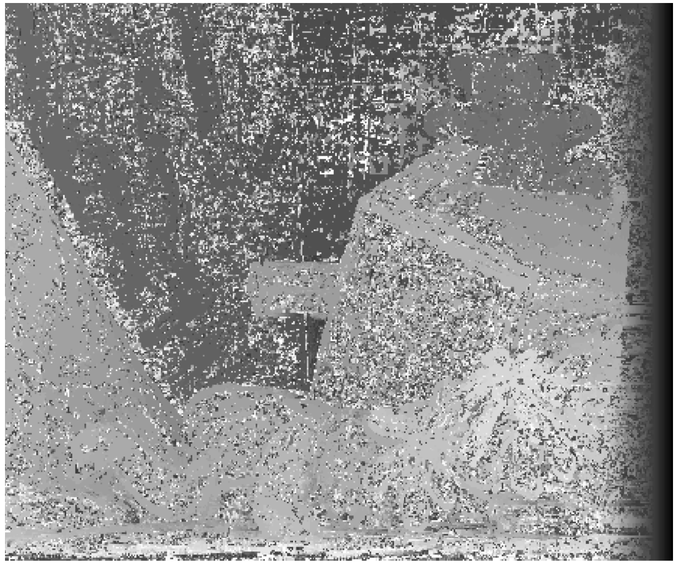
Search image
→ right

Sample code: Part 2

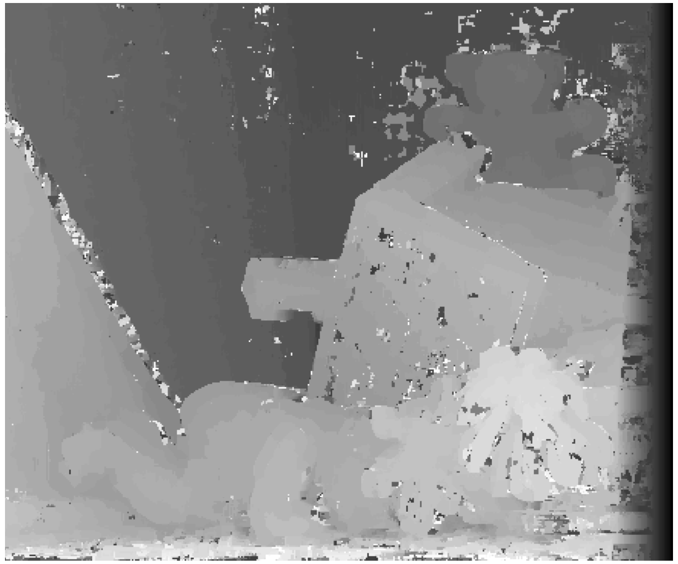
```
function exercise6
%        =========
…
for i = 1+r : h-r               % For each row i and column j of the reference
    for j = 1+r : w-r                  % image in a distance r from the border
        cmax = thres;
        start = max(j-dmax, r+1);                      % Crop the search space
        stop  = max(j-dmin, r+1);
        A = left(i-r : i+r, j-r : j+r);            % Define reference window A
        vl = lms(i, j) - lm(i, j)^2;                           % Variance of A
        if vl > 0                                      % If A contains texture
            for k = start : stop
                B = right(i-r : i+r, k-r : k+r);             % Search window B
                vr = rms(i, k) - rm(i, k)^2;                   % Variance of B
                if vr > 0                % If B contains texture calculate NCC
                    cc = (mean2(A.*B) - lm(i, j) * rm(i, k)) / sqrt(vl * vr);
                    if cc > cmax            % Maximize correlation coefficient
                        cmax = cc;                        % Winner takes all
                        D(i, j) = j - k;             % Store column difference
                    end
                end
            end
        end
    end
end
figure(2); imshow(D, []);              % Show disparities as gray value image
```

Assignment 6: Window size influence

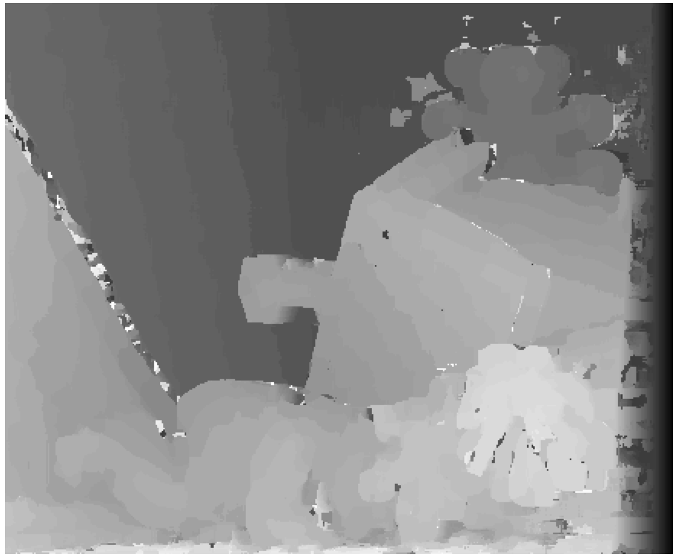
$d_{min} = 12,$
$d_{max} = 50$



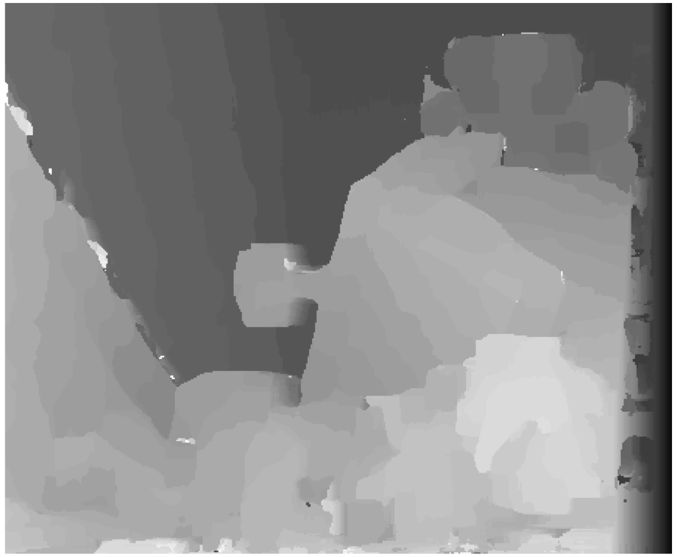
$r = 1$



$r = 3$

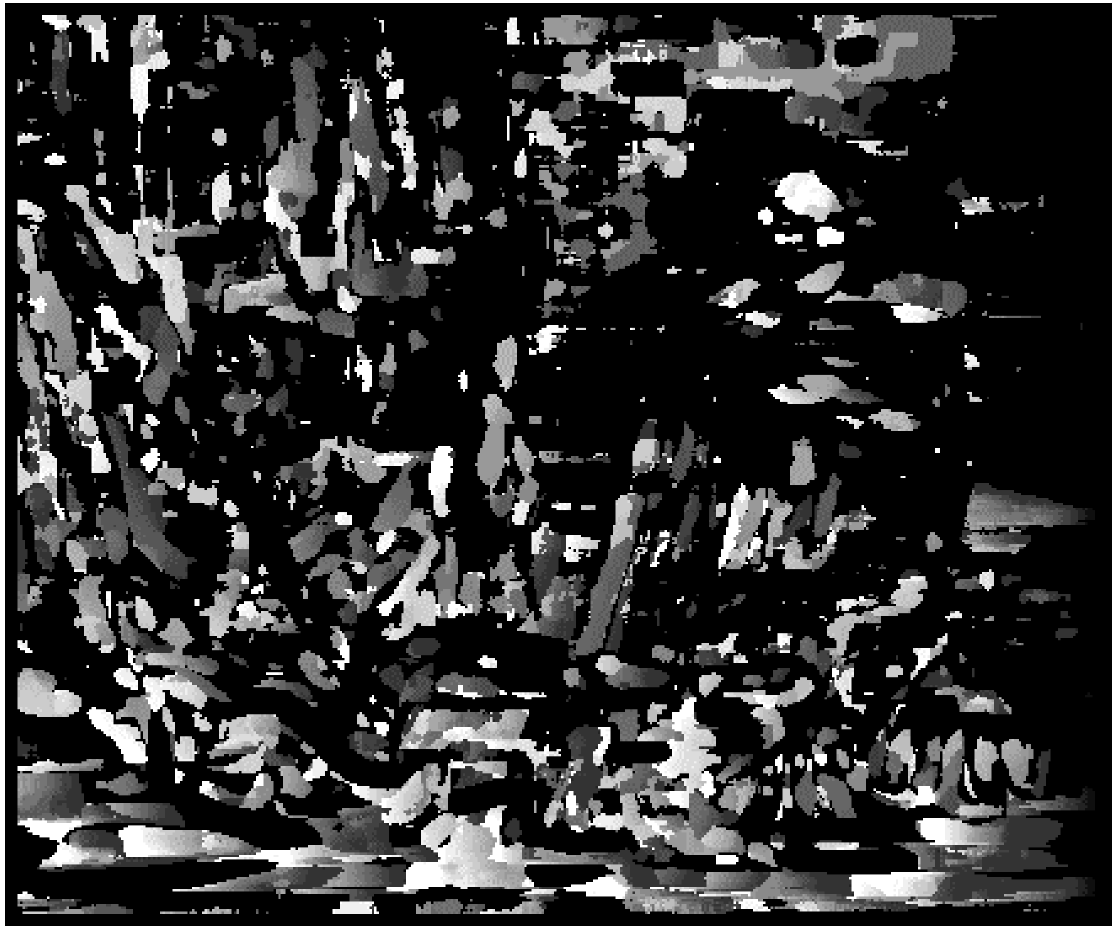


$r = 5$



$r = 10$

Assignment 6: Result for swapped images



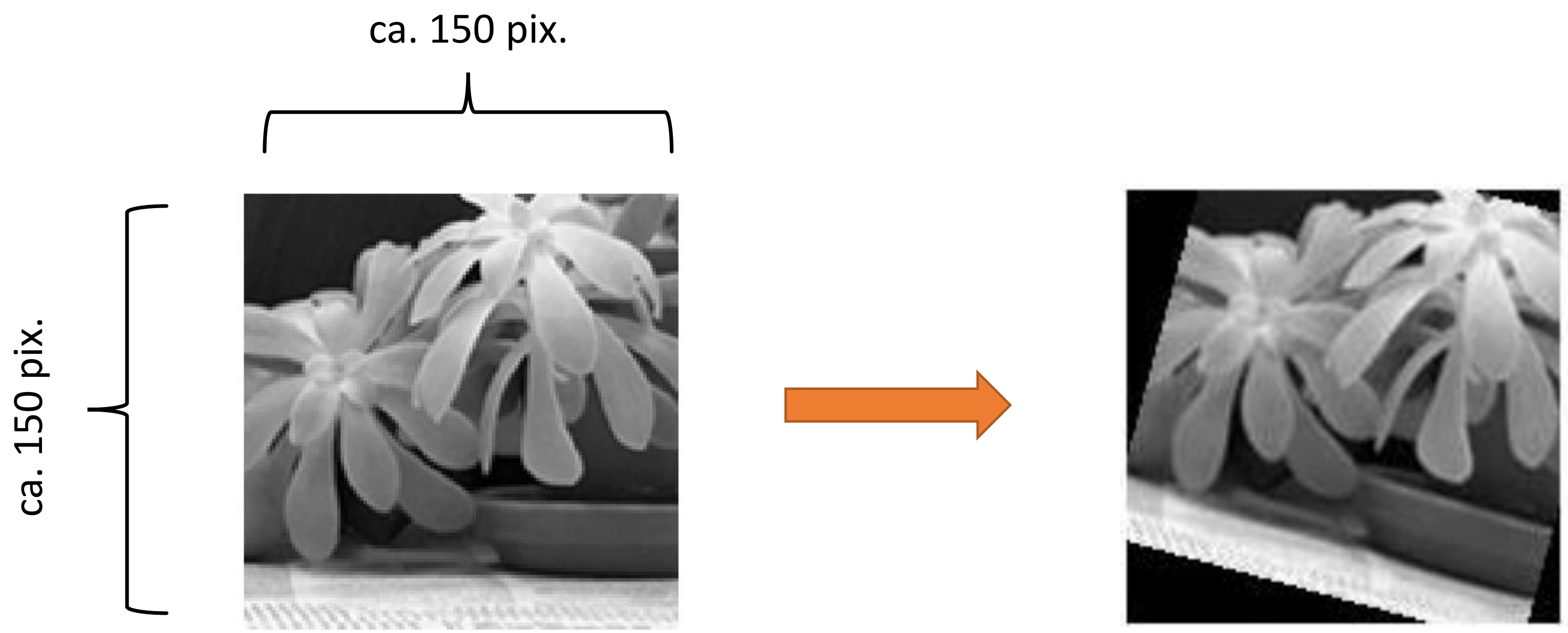
Final Project

- Work in small groups up to 3 people
- Submit solution via Moodle
- Each member of the group needs to submit

  the exact(!) same, final group solution

  → enter full information about group members in your documentation
- Topic: Least Squares Correlation
- Submission deadline: **13.03.2022, 13:30**

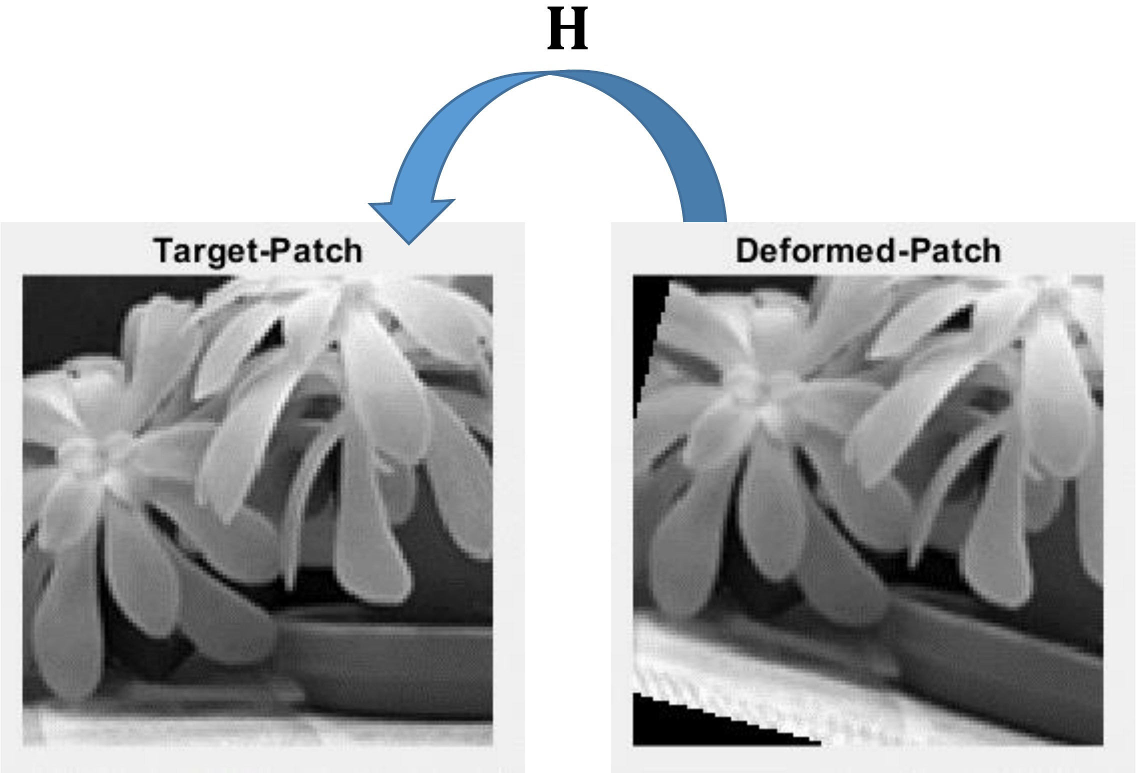
Final Project: Least Squares Correlation



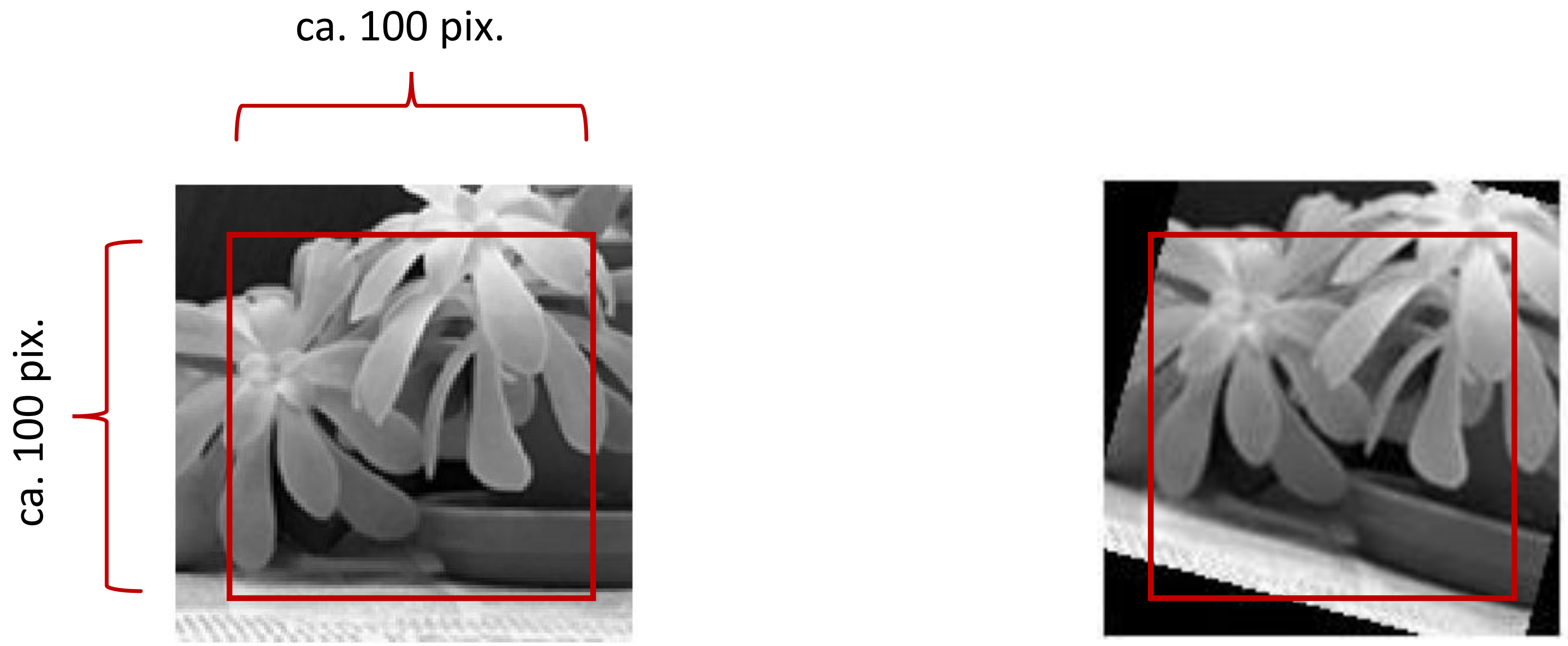
ca. 150 pix.

ca. 150 pix.

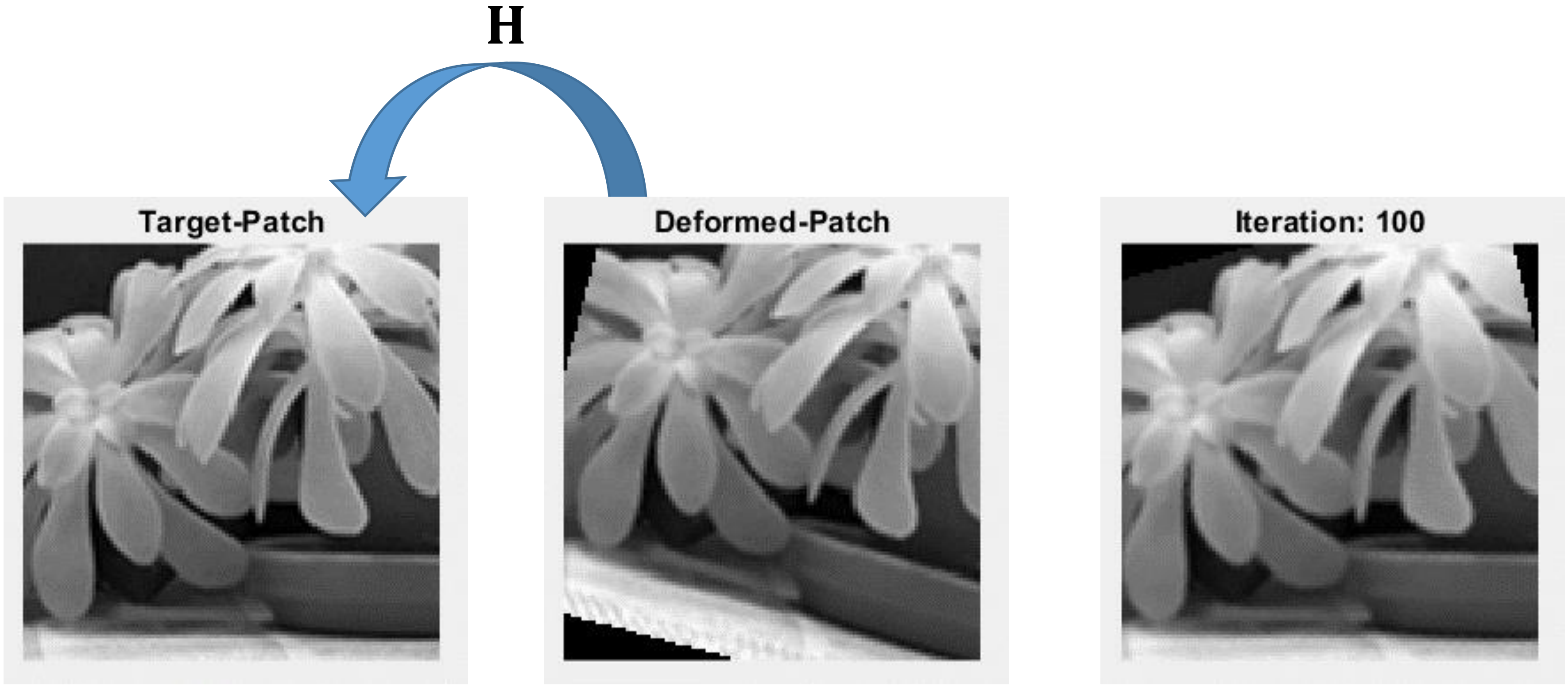
Final Project: Least Squares Correlation



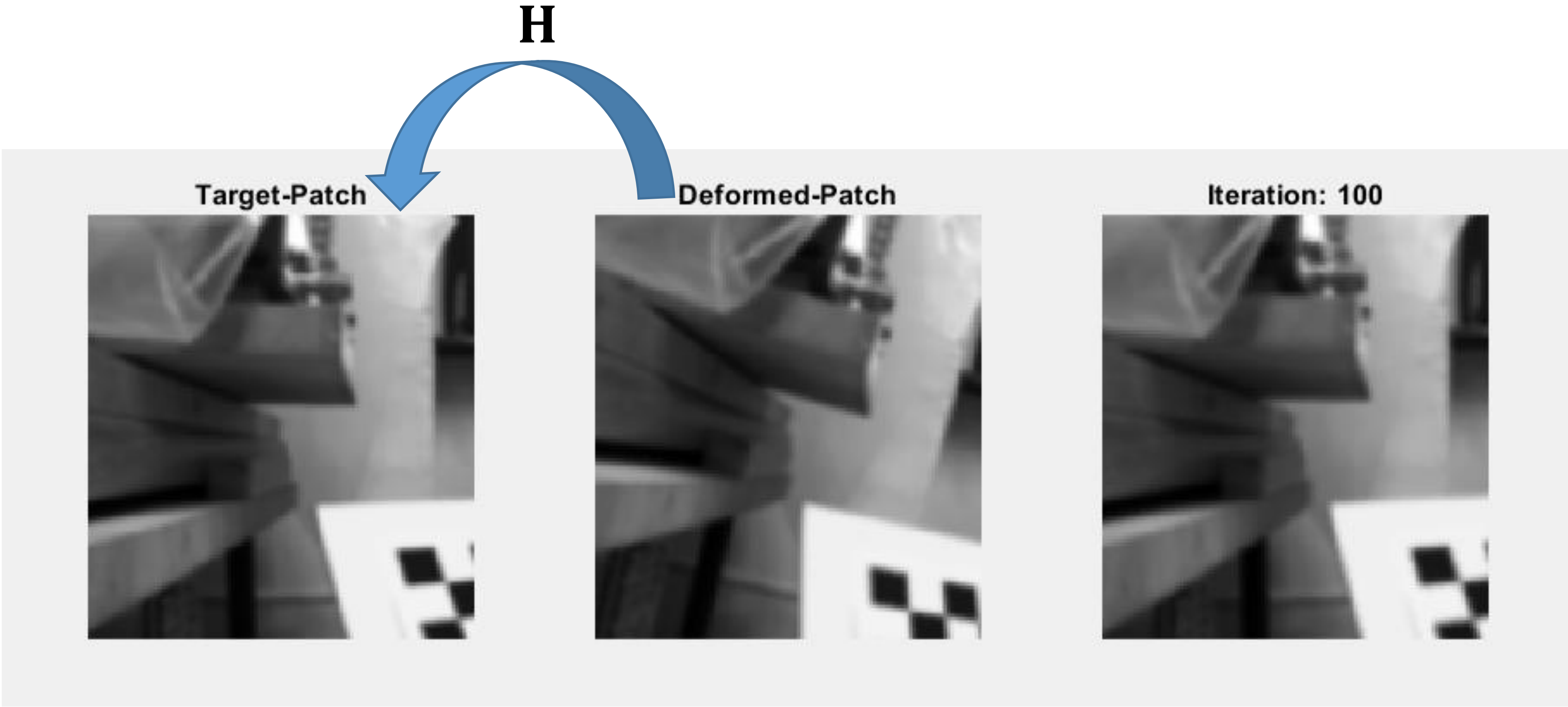
Final Project: Least Squares Correlation



Final Project: Least Squares Correlation



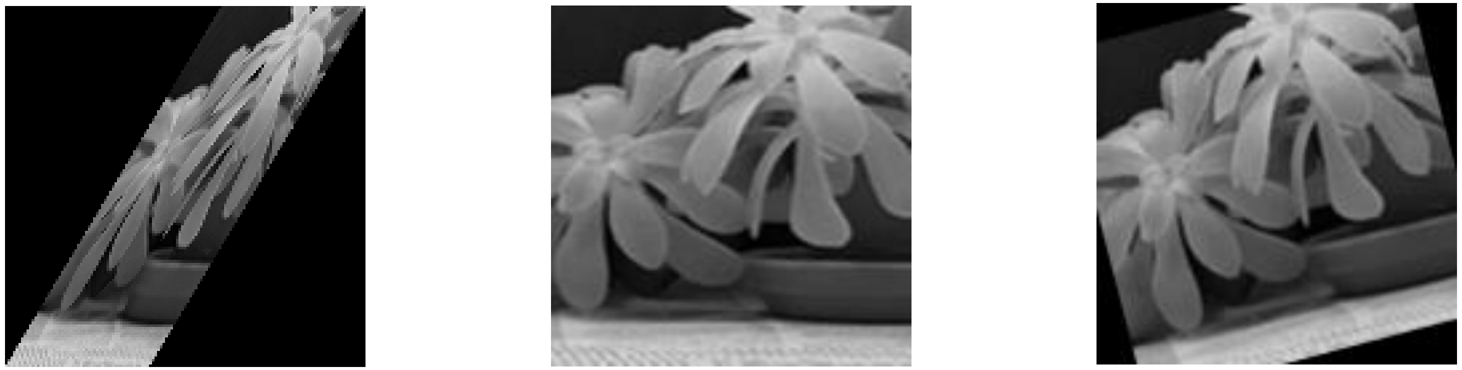
Final Project: Least Squares Correlation



Final Project: Least Squares Correlation

target image

differently distorted source images



shear

scale

rotation