Data level fusion

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Introduction

The algorithms implemented here fall into two main categories: filtering and upsampling, There's a special kind of focus on the bilateral methodology.

The following algorithms were implemented in this project:

1. Bilateral filtering
2. Median bilateral filtering
3. Guided bilateral filtering
4. Naive bilateral upsampling
5. Iterative bilateral upsampling

Bilateral filtering is a special non-linear method to reduce noise but still keep edges in the input image by using weighted average of the pixels in a nearby window. Guided bilateral filtering has two inputs: the normal image and the guide. The guide can be a modified version of the input image (in this case the median blur was applied to it) or the input image itself (in this case the process is equivalent to regular bilateral filtering). The guidance images is used as an unbiased, local approximation to the input image where the weights for bilateral filtering come from.

Median filtering is also a non-linear filtering technique, that caluclates the median of the neighboring pixels to calculate the value for the currently processed pixel.

Upsampling is a type of resampling algorithm, where the aim is to return an image of higher definition than the one passed as an input. Any filter that can be used for filtering can also be used for upsampling, hence bilateral upsampling is also possible. This is done by first taking a local window of pixels, reconstructing an image between the values, and taking a more dense measure of samples from the reconstructed space. In this project a guided upsampling algorithm was implemented in order to be able to upscale a depth image. The guide image is a high-definition RGB image from the same angle as the lower definition depth image.The depth image was then reconstructed into a 3D point cloud, and the point cloud was reconstructed into an oriented point cloud by approximating the surface normals for each 3-set of points.

During running the algorithms the following metrics were evaluated:

1. SSD/MSE
2. SSIM
3. NCC

The task also involved optimalization as well. The methodology was a grid search for the filter's kernel size and the Gaussian distribution's variance parameter. The parameters tried for the grid search were as follows:

1. Window size: $[3, 5, 7, 11]$
2. Variance: $[3, 5, 7, 11]$

Results

Bilateral filtering

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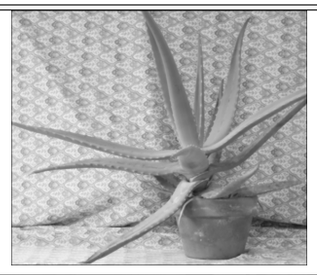
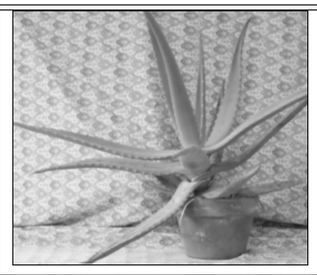
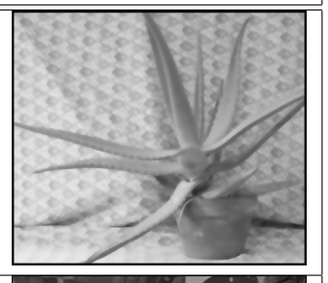
aloe				
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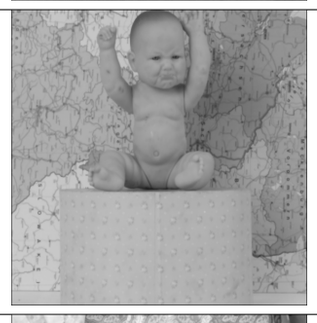
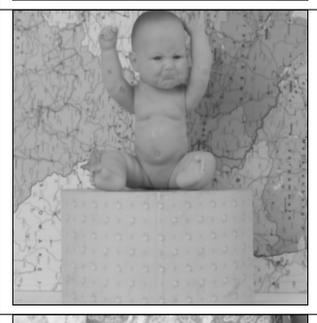
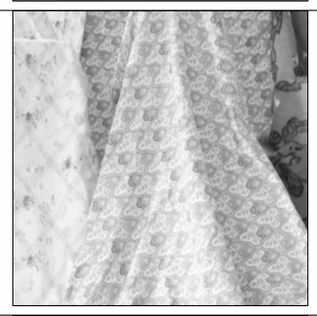
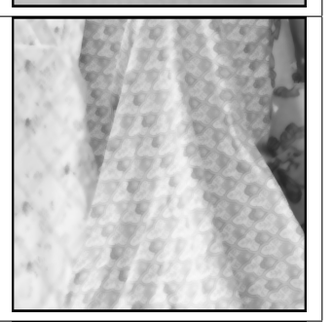
baby				
cloth				
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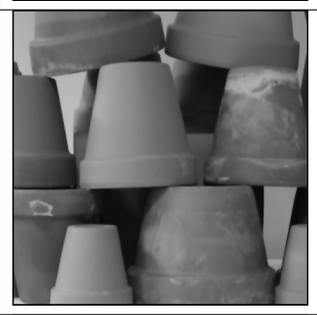
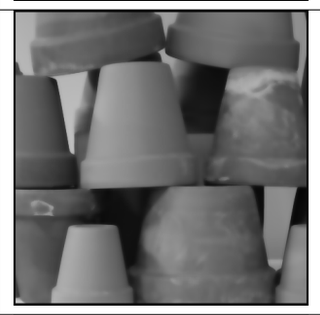
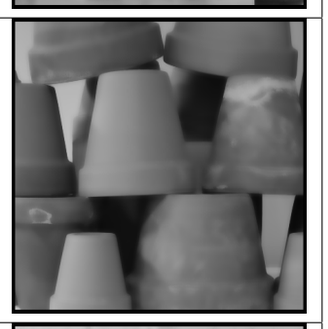
flowerpots				
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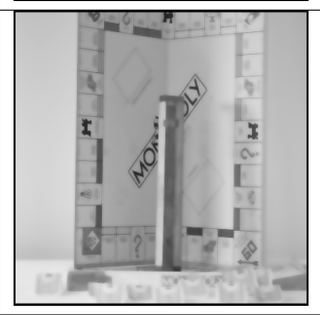
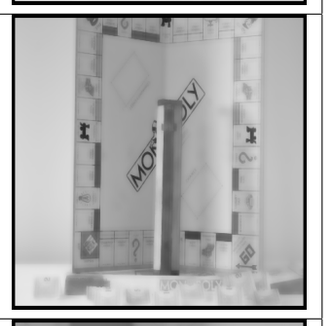
monopoly				
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Median bilateral filtering

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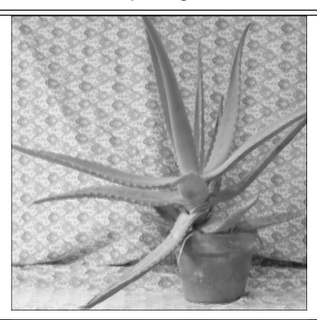
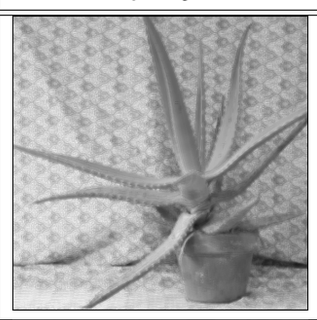
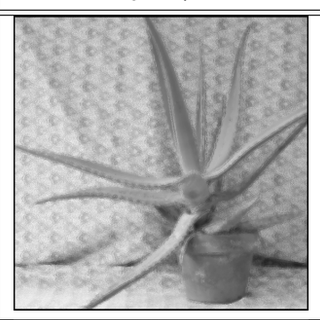
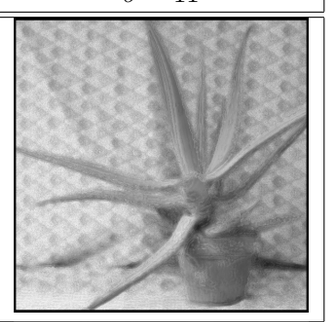
aloe				
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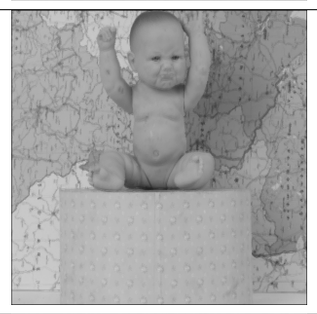
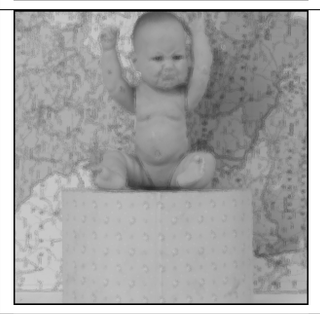
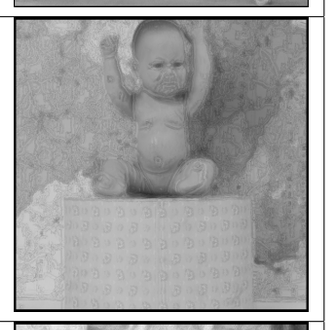
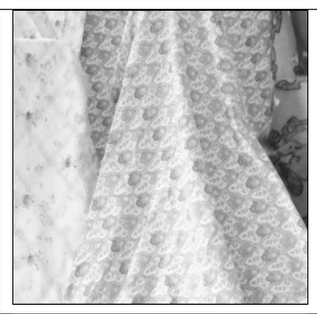
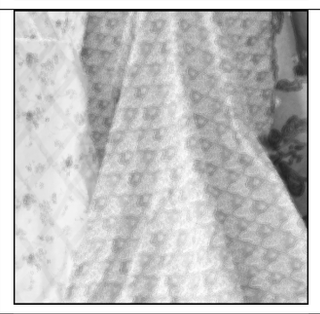
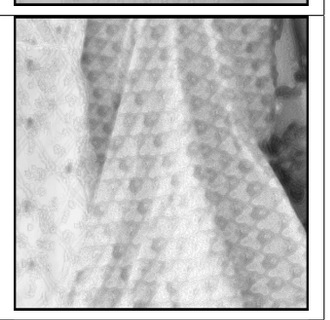
baby				
cloth				
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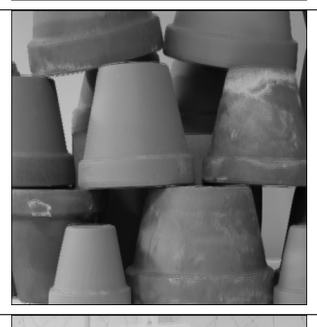
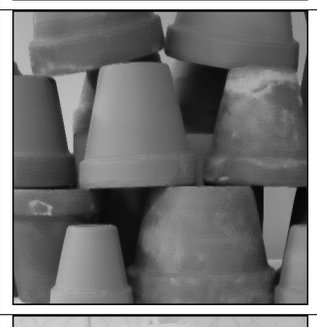
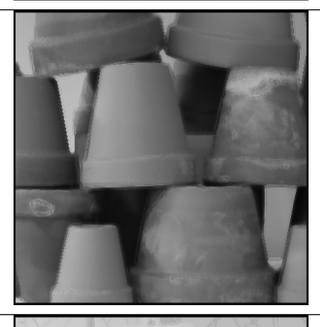
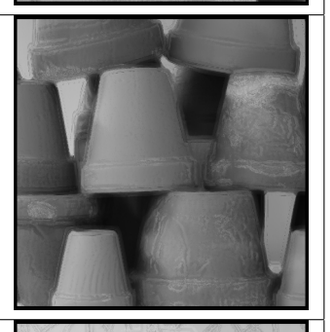
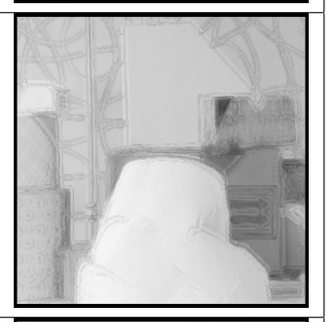
flowerpots				
lampshade				
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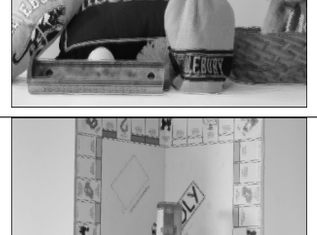
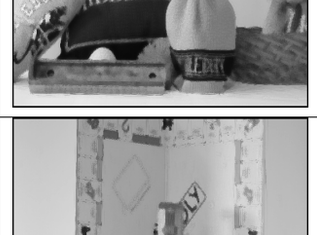
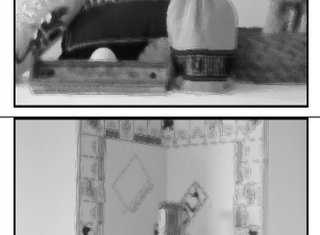
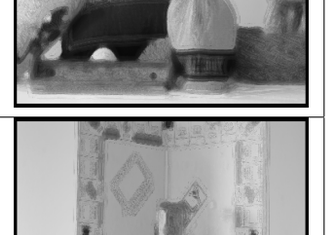
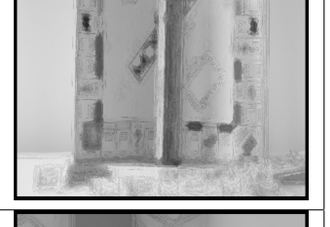
monopoly				
plastic				
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wood				

Guided bilateral filtering

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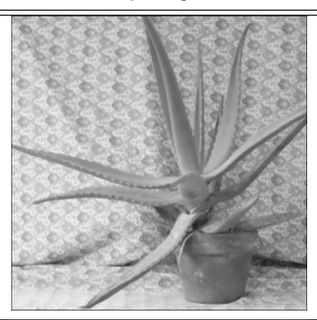
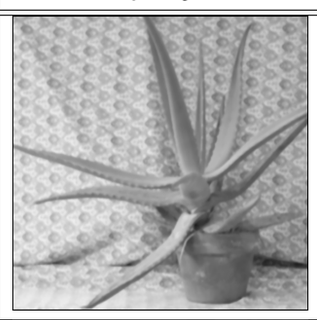
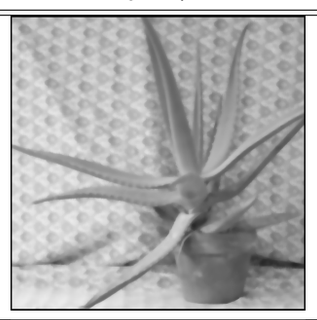
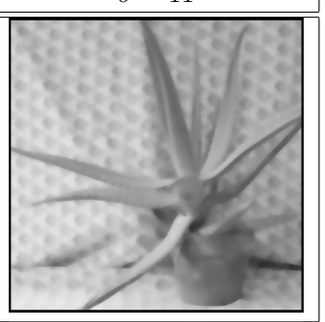
aloe				
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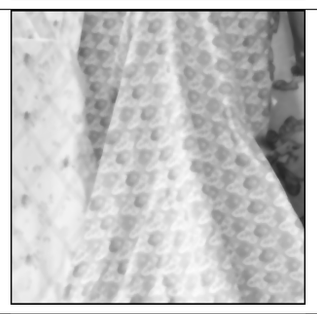
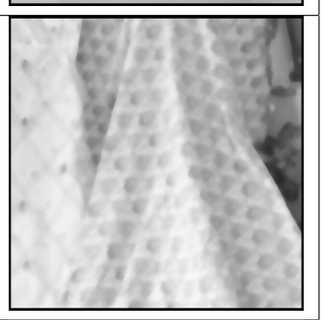
cloth				
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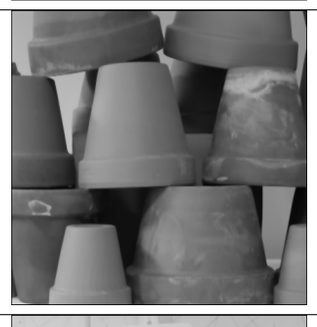
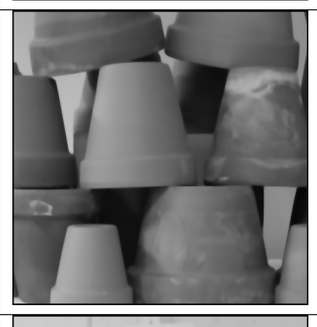
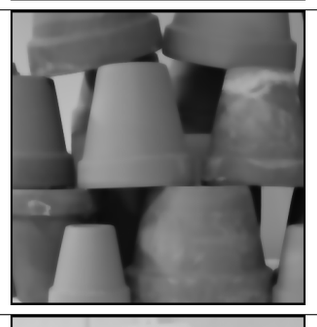
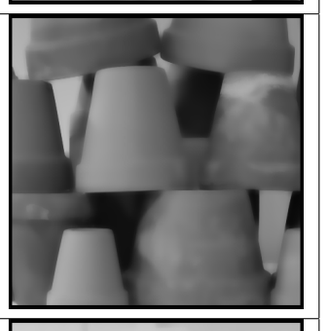
flowerpots				
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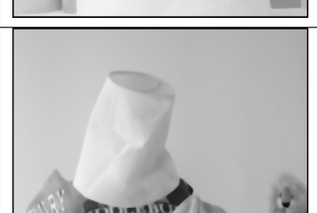
midd				
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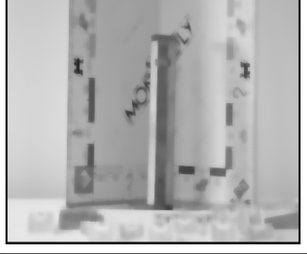
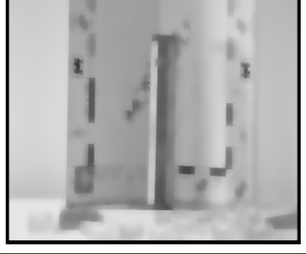
plastic				
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Naive upsampling

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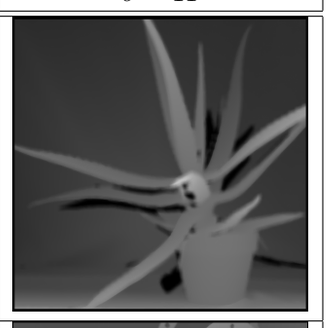
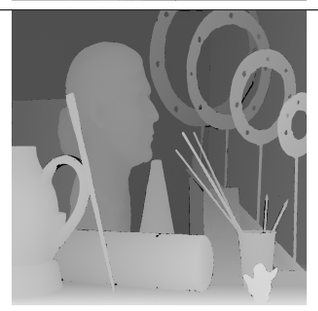
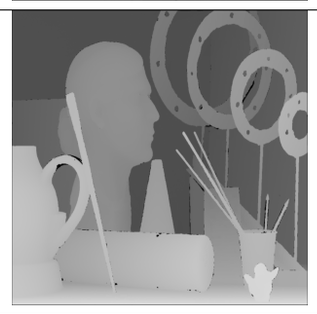
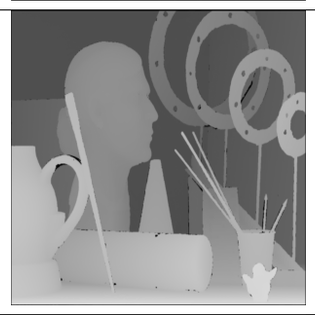
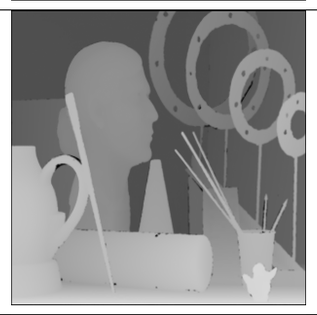
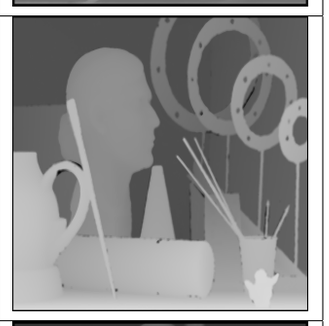
aloe					
art					
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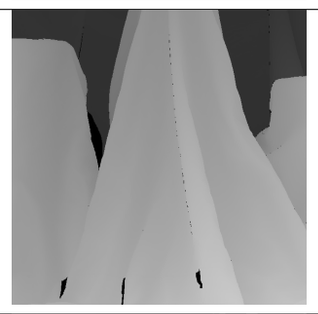
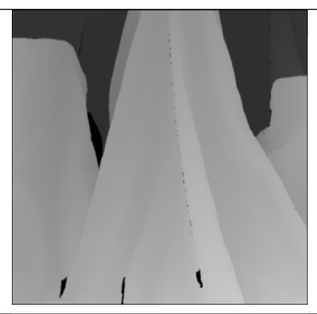
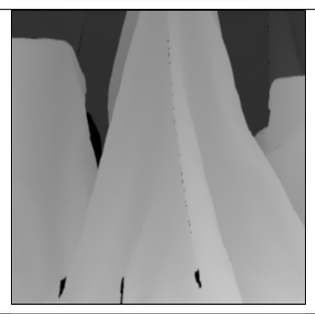
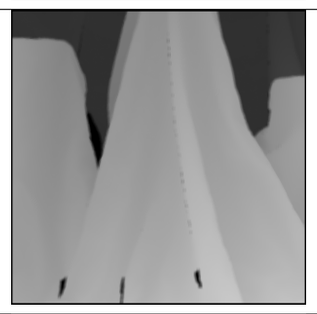
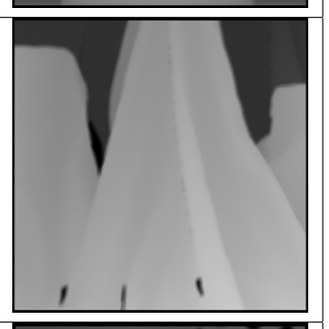
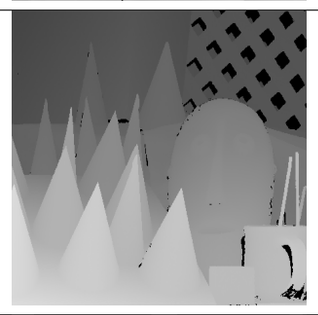
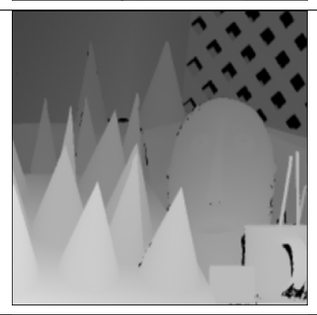
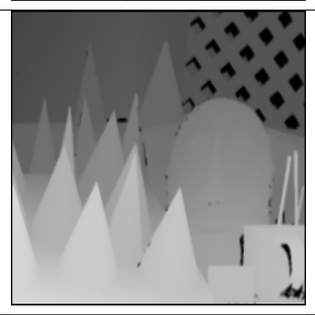
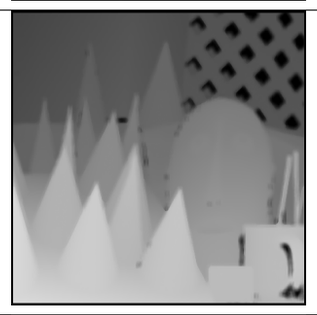
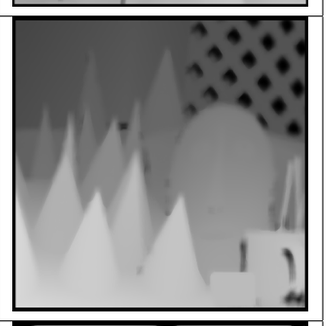
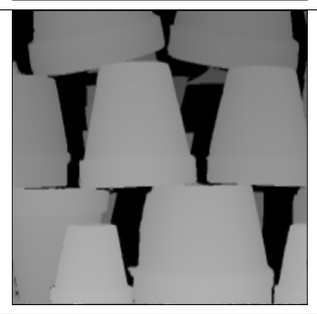
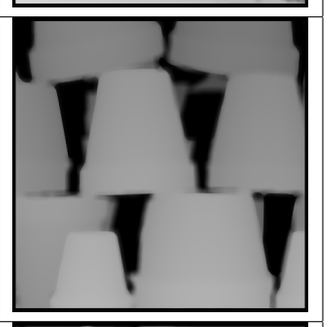
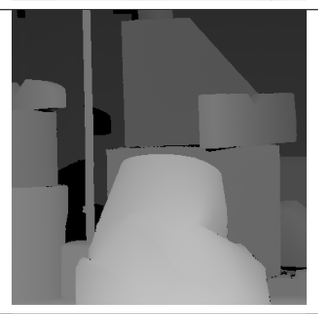
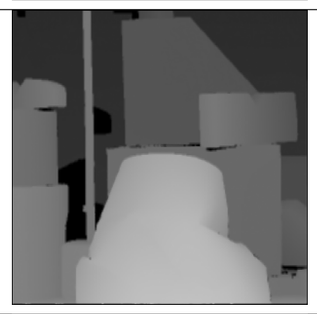
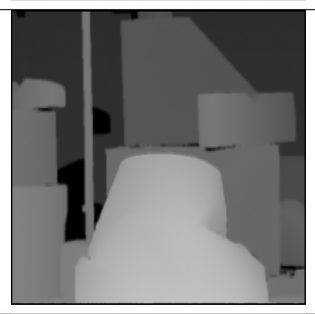
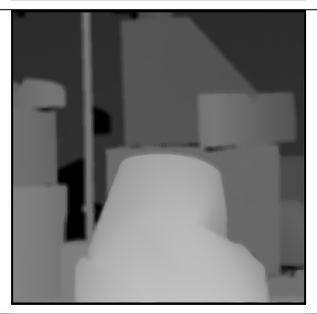
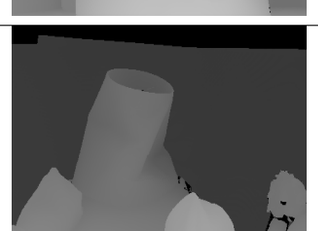
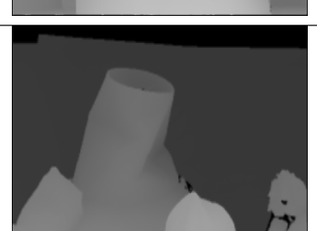
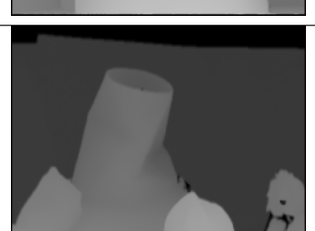
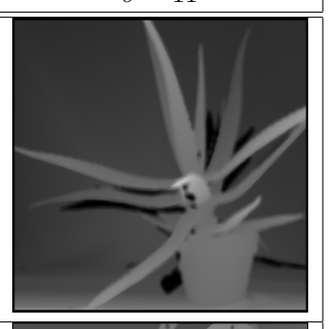
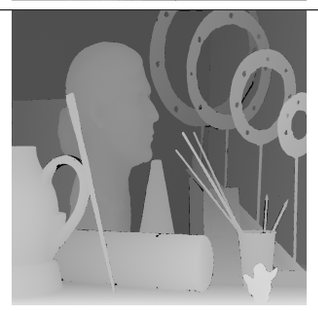
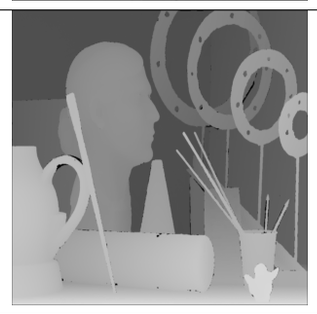
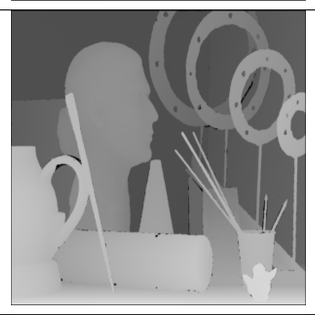
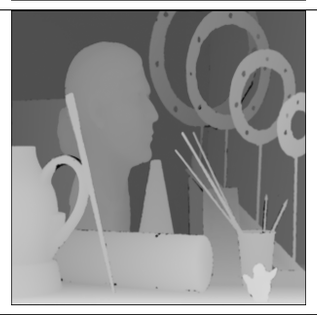
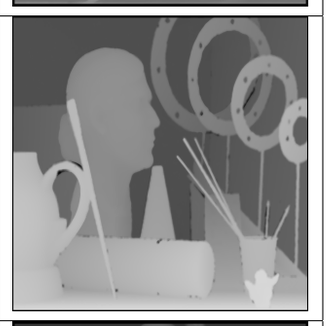
cloth					
cones					
flowerpots					
lampshade					
midd					
monopoly					
plastic					
rocks					
wood					

Iterative upsampling

	GT	$\sigma = 3$	$\sigma = 5$	$\sigma = 7$	$\sigma = 11$
aloe					
art					
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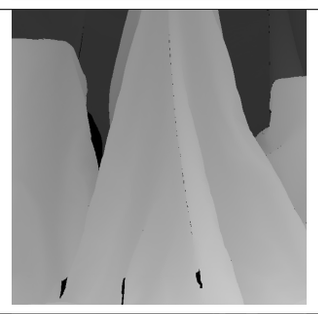
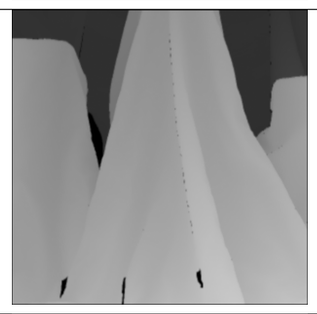
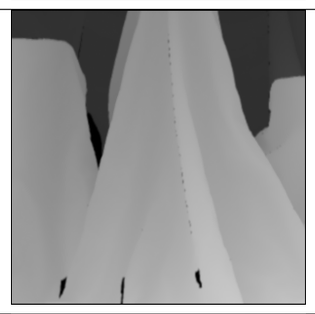
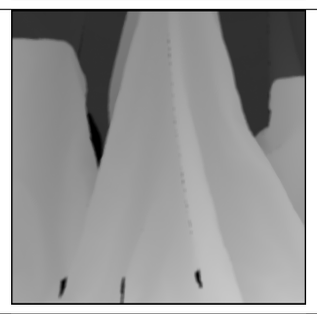
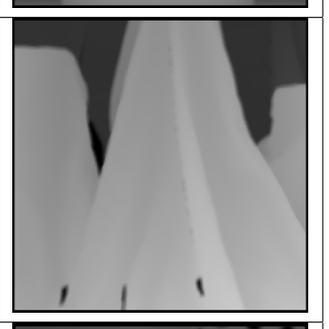
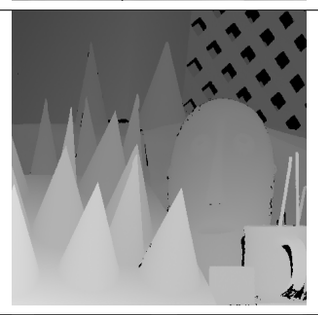
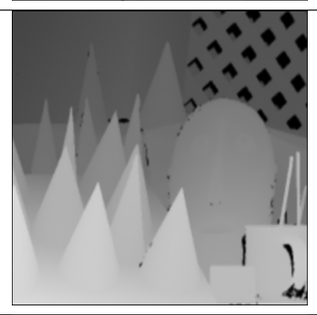
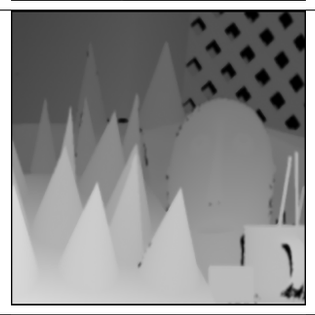
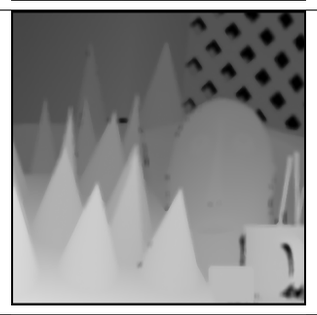
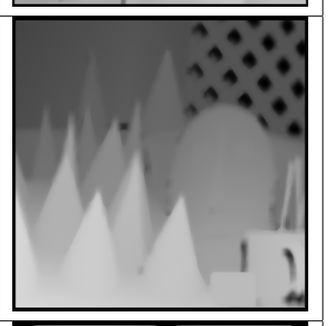
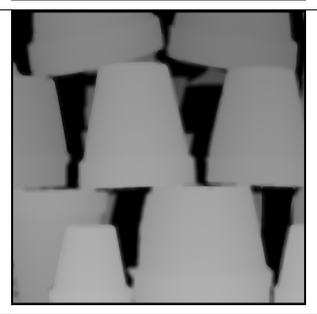
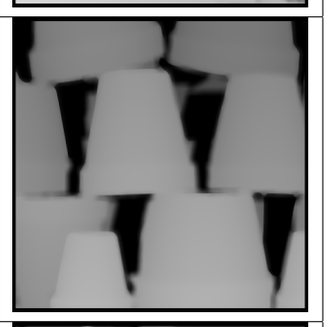
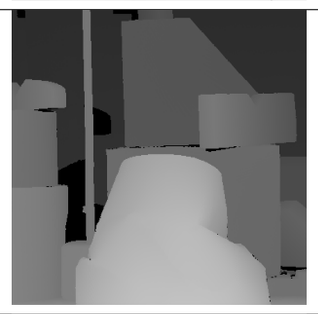
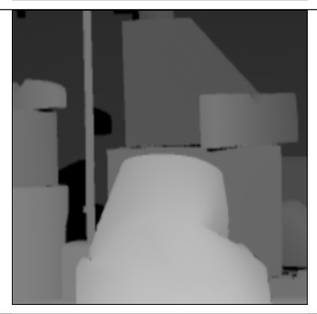
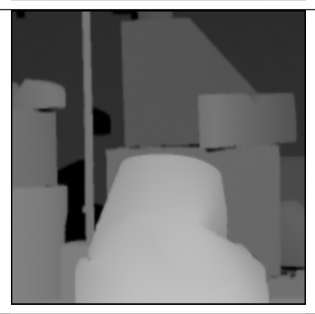
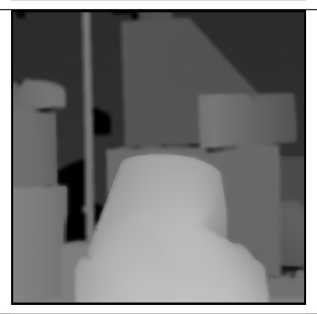
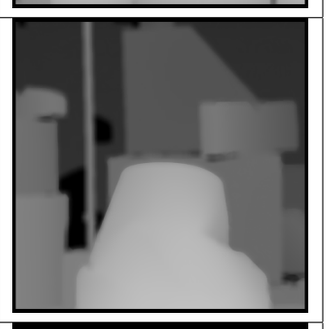
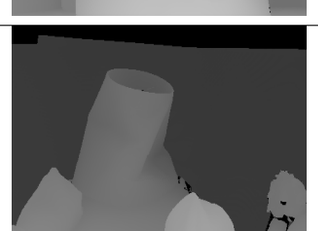
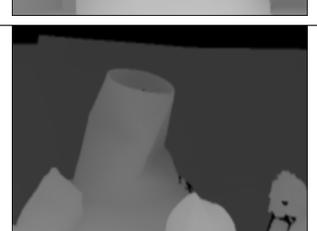
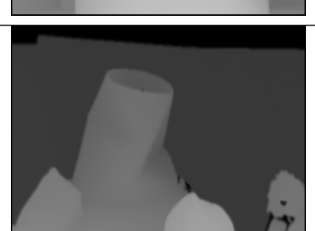
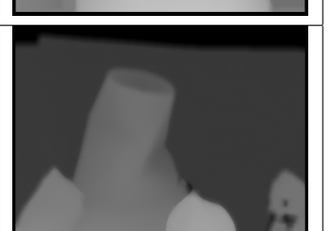
cloth					
cones					
flowerpots					
lampshade					
midd					
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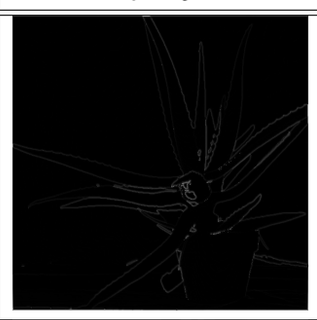
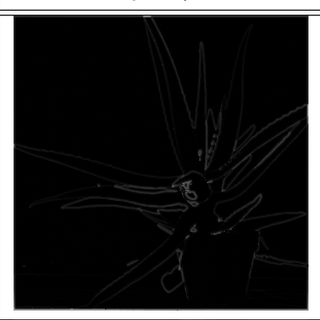
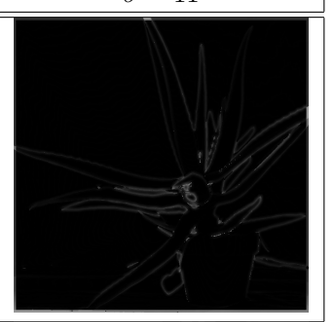
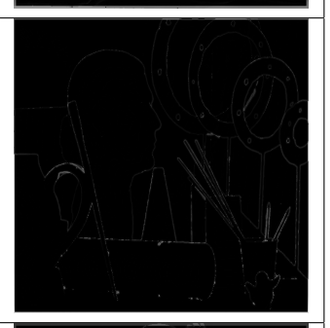
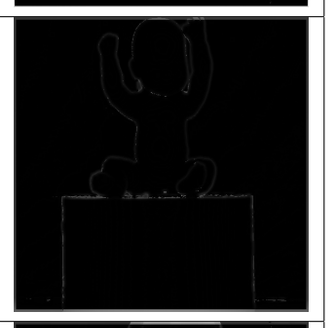
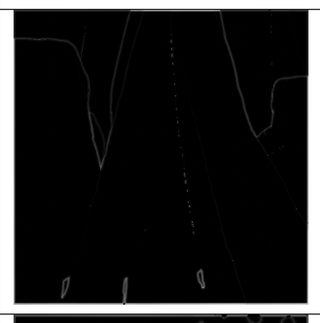
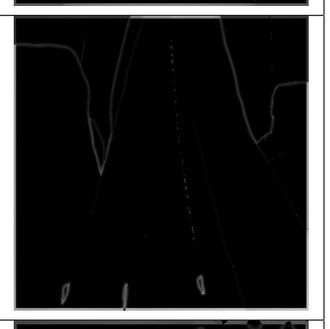
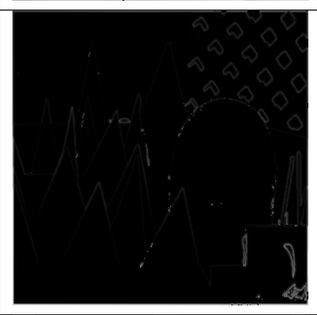
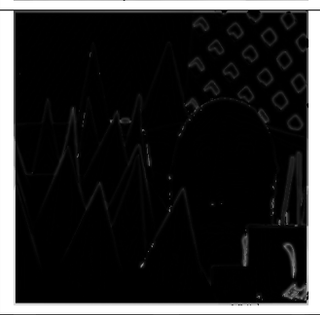
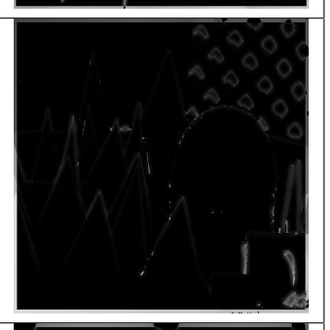
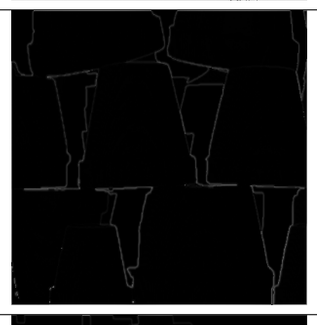
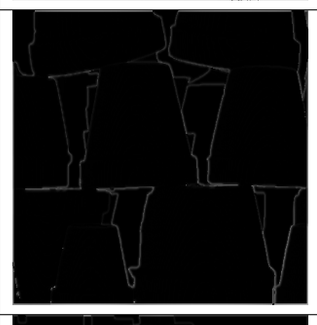
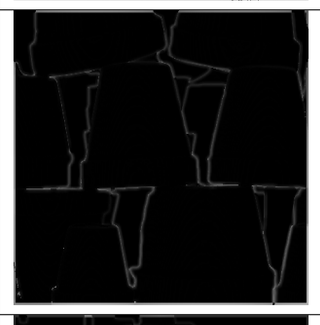
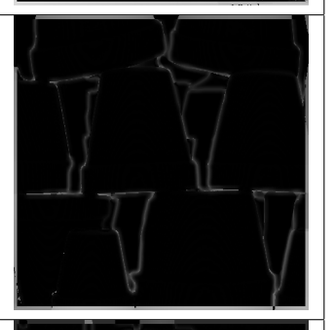
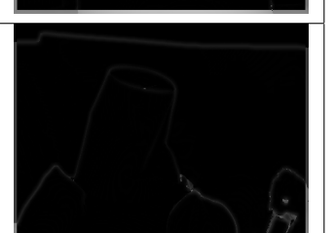
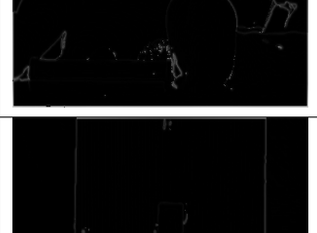
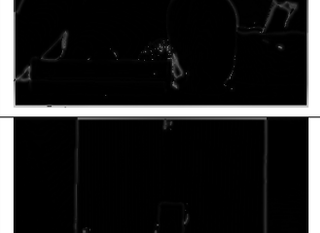
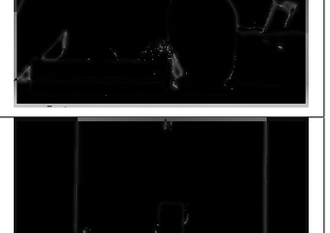
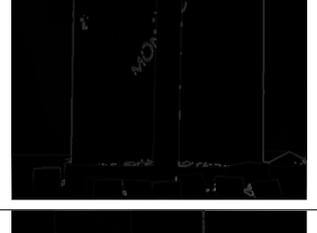
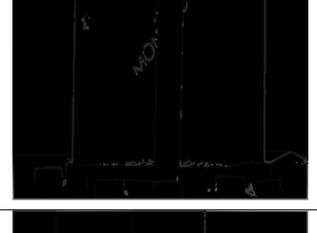
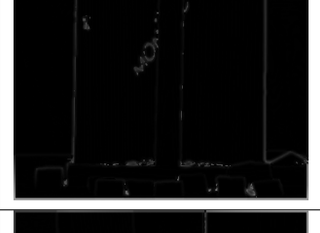
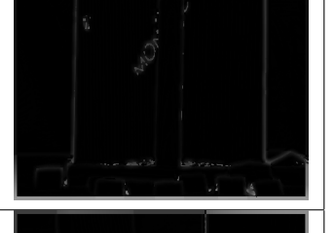
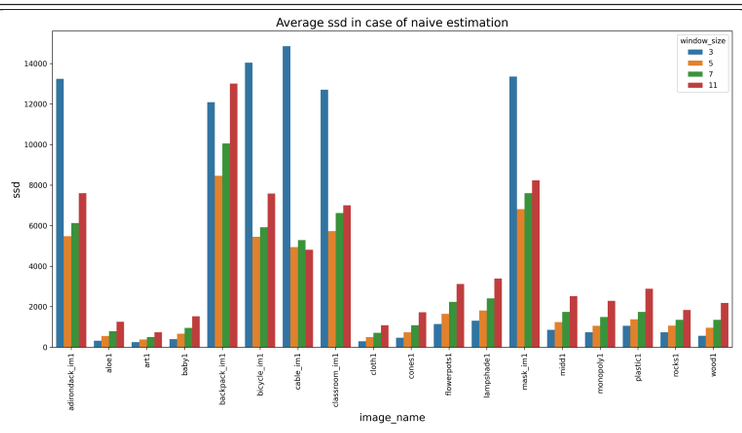
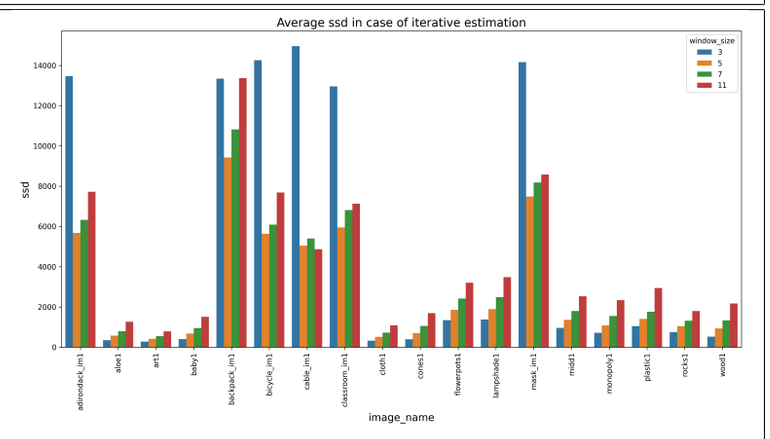
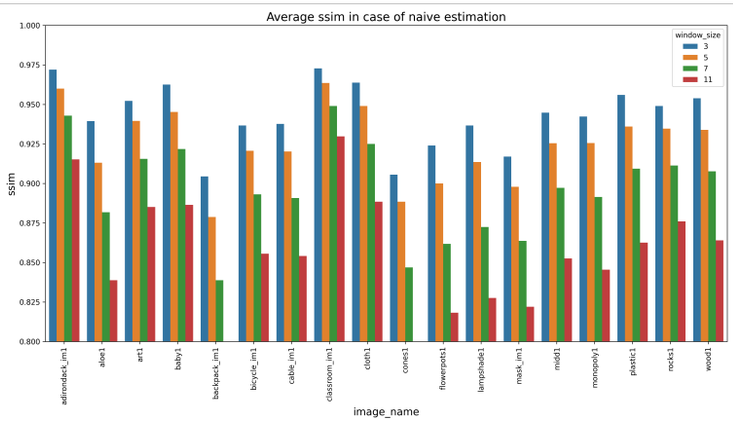
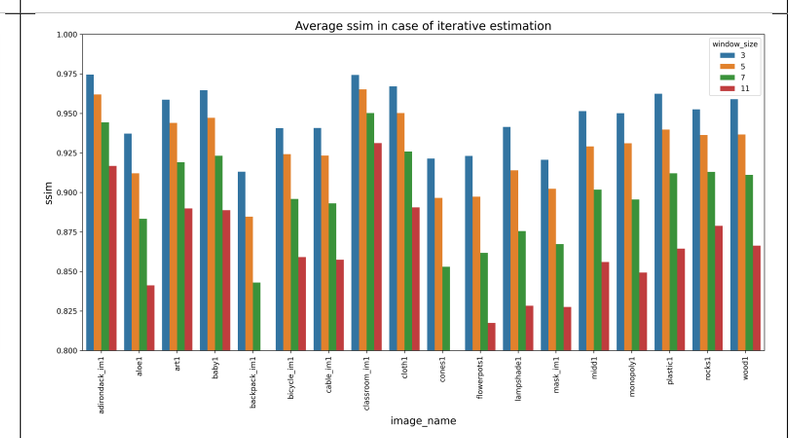
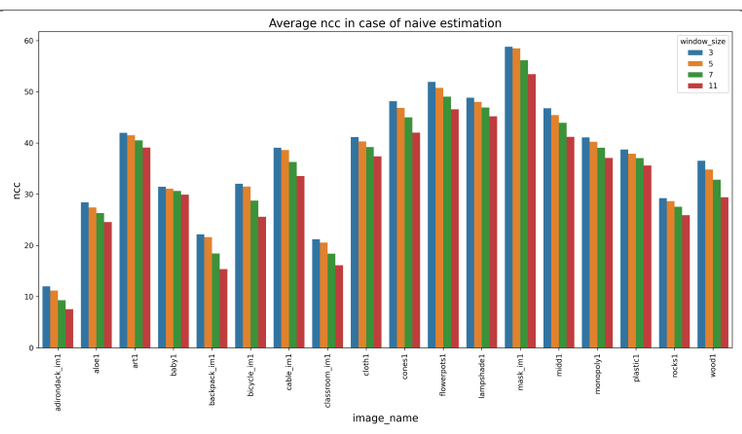
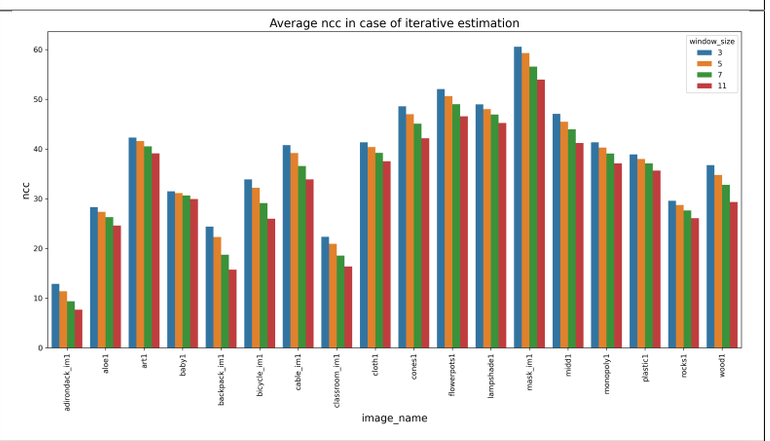
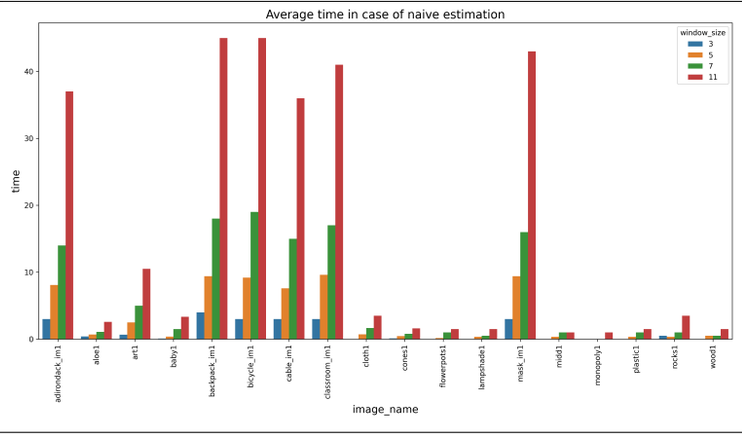
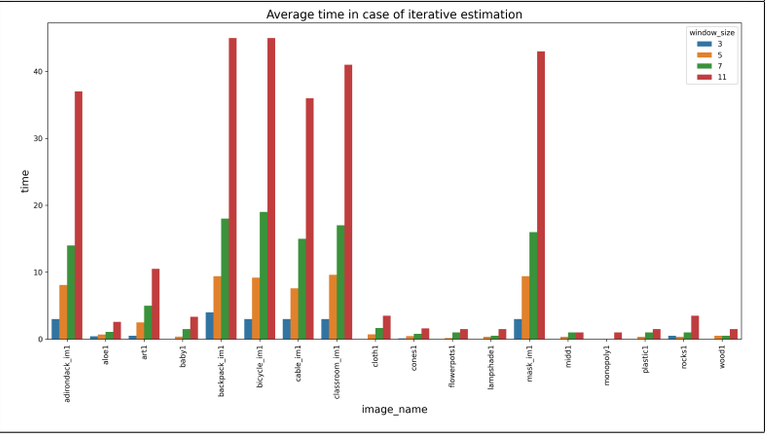
plastic					
rocks					
wood					

Difference images

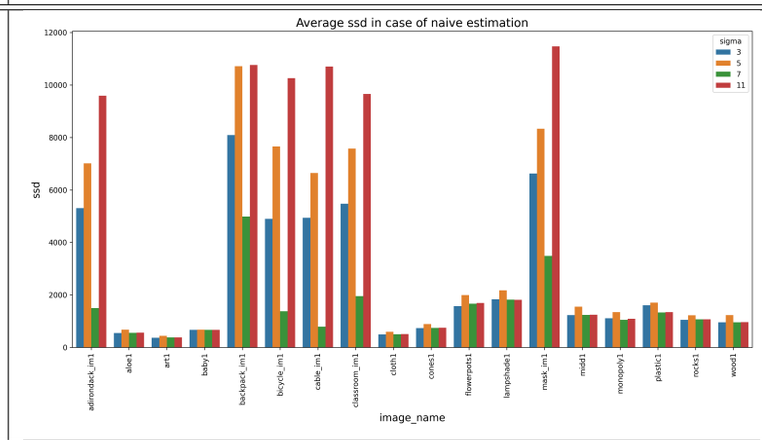
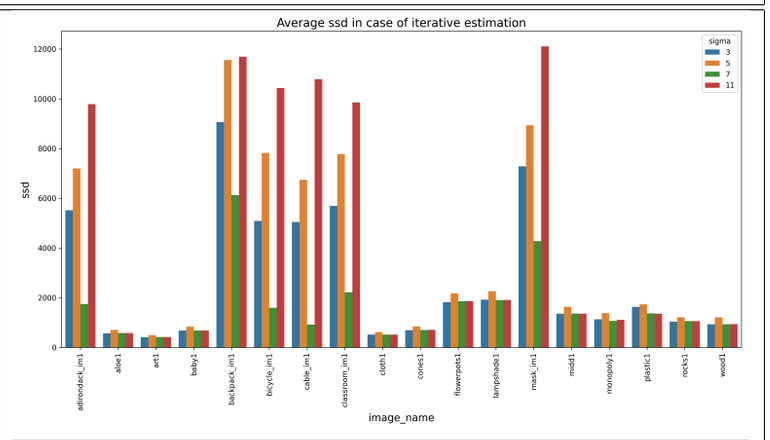
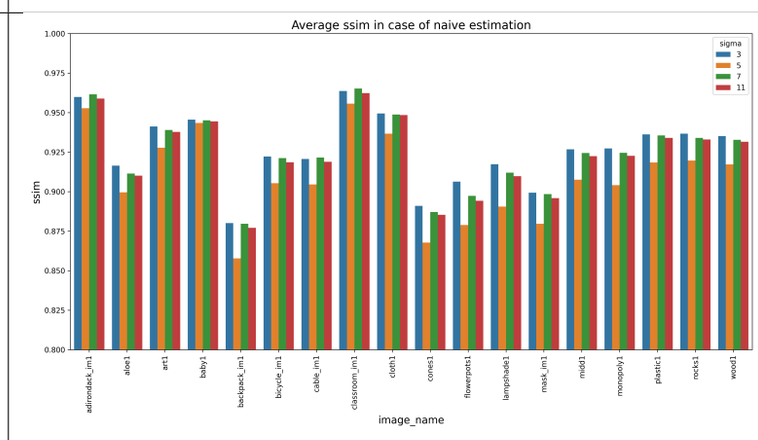
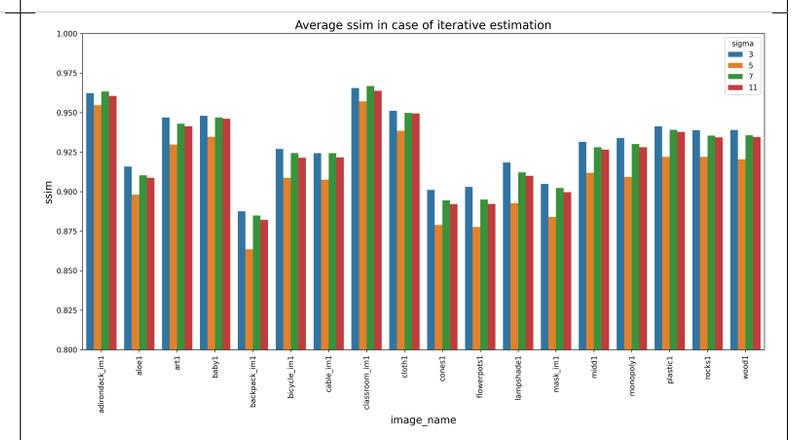
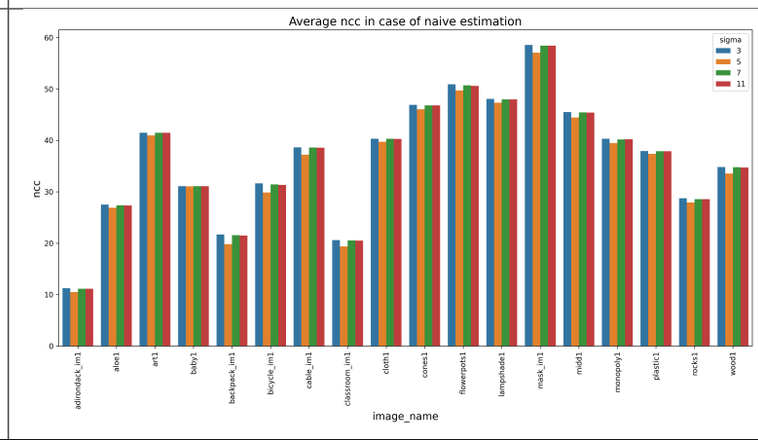
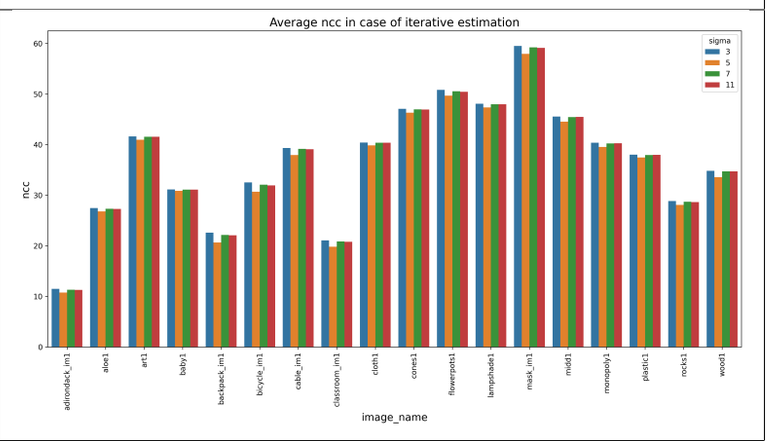
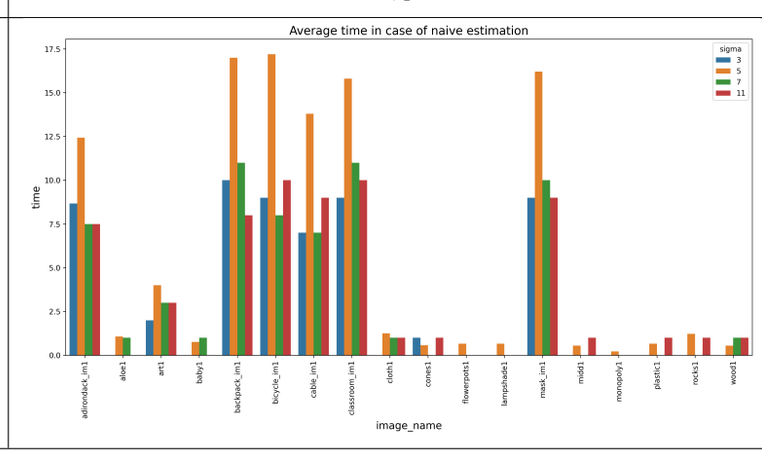
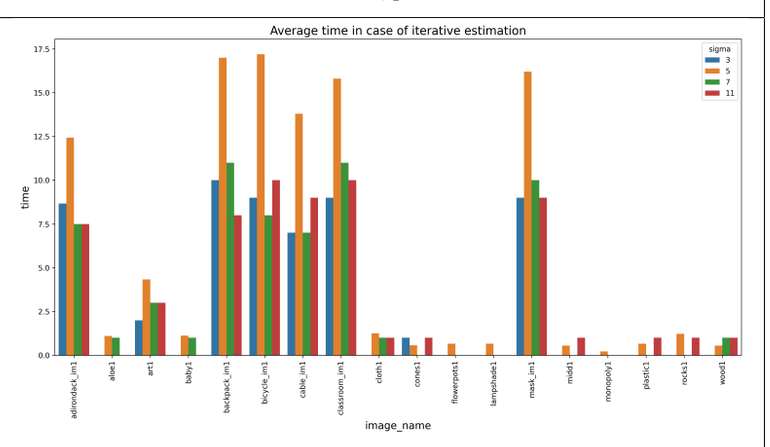
	$\sigma = 3$	$\sigma = 5$	$\sigma = 7$	$\sigma = 11$
aloe				
art				
baby				
cloth				
cones				
flowerpots				
lampshade				
midd				
monopoly				
plastic				
rocks				
wood				

Statistics

With respect to window size

	Naive	Iterative
SSD		
SSIM		
NCC		
Time		

With respect to Gaussian sigma

	Naive	Iterative
SSD		
SSIM		
NCC		
Time		

Optimalization results

With respect to window size

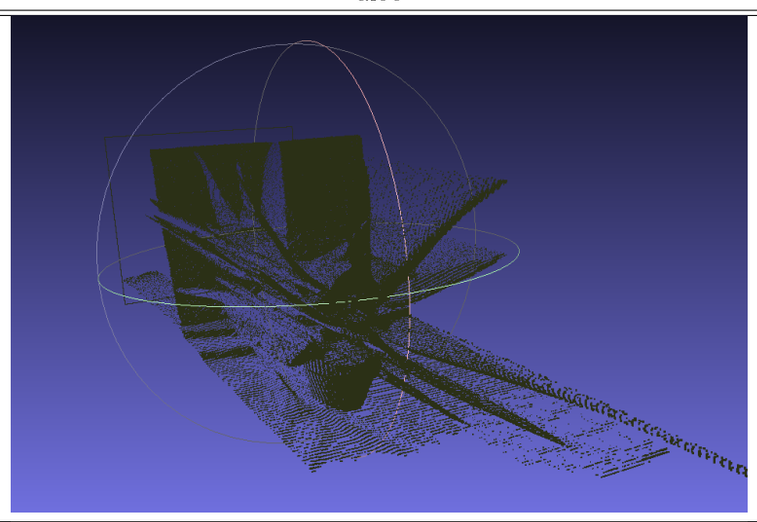
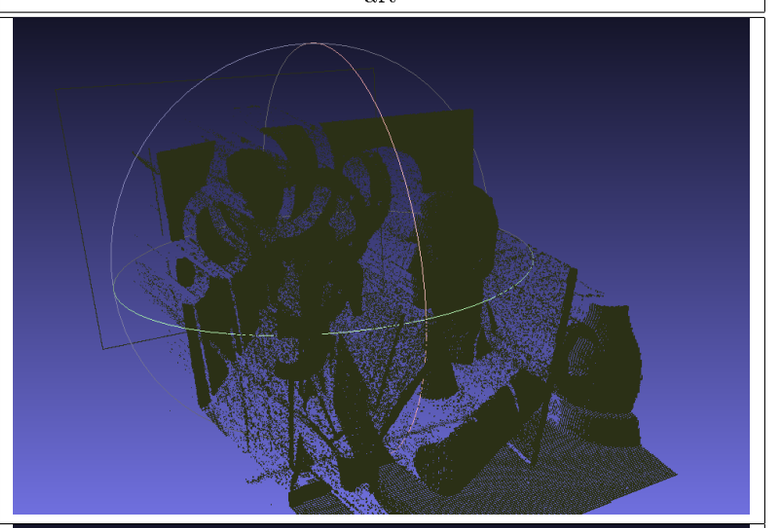
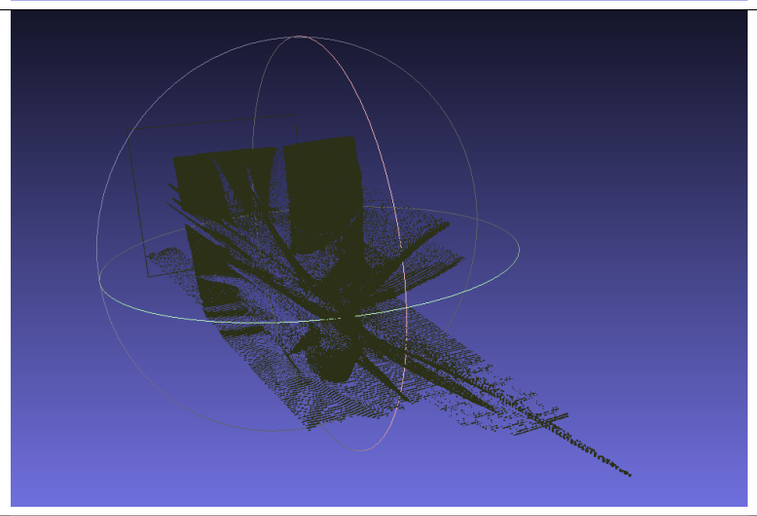
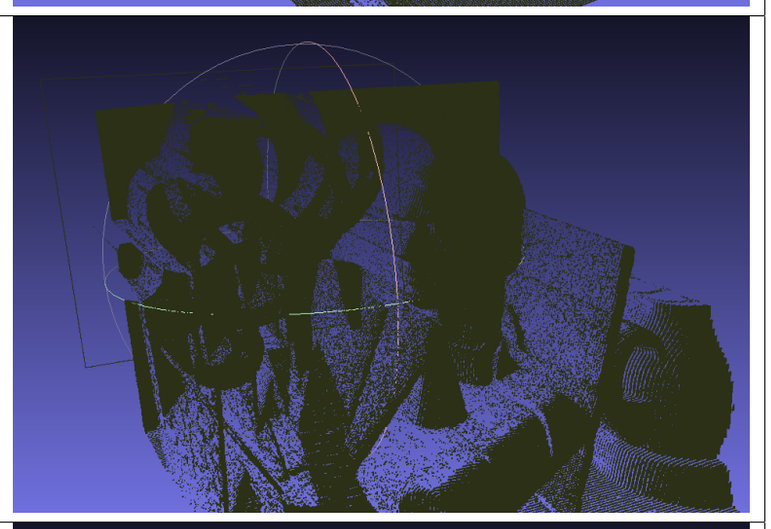
image name	window size	ssim	method
adirondack_im1	5	0.974548	iterative
aloe1	5	0.935097	iterative
art1	5	0.958625	iterative
baby1	5	0.964721	iterative
backpack_im1	5	0.913094	iterative
bicycle_im1	5	0.940653	iterative
cable_im1	5	0.940813	iterative
classroom_im1	5	0.974389	iterative
cloth1	5	0.967059	iterative
cones1	5	0.921442	iterative
flowerpots1	3	0.923997	naive
lampshade1	5	0.941437	iterative
mask_im1	5	0.920619	iterative
midd1	5	0.951395	iterative
monopoly1	5	0.950092	iterative
plastic1	5	0.962467	iterative
rocks1	5	0.952515	iterative
wood1	5	0.95896	iterative

With respect to Gaussian sigma

image name	sigma	ssim	method
adirondack_im1	5	0.963381	iterative
aloe1	3	0.916486	naive
art1	5	0.94687	iterative
baby1	5	0.94797	iterative
backpack_im1	5	0.887517	iterative
bicycle_im1	5	0.92702	iterative
cable_im1	5	0.924368	iterative
classroom_im1	5	0.966815	iterative
cloth1	5	0.951107	iterative
cones1	5	0.901072	iterative
flowerpots1	3	0.90637	naive
lampshade1	5	0.918461	iterative
mask_im1	5	0.904908	iterative
midd1	5	0.931419	iterative
monopoly1	5	0.933909	iterative
plastic1	5	0.941356	iterative
rocks1	5	0.938945	iterative
wood1	5	0.938993	iterative

Point clouds

Please note that for the oriented point clouds only ~20k points were kept from the original point cloud. Hence the distance between the points has increased.

	aloe	art
Naive		
Iterative		
Oriented