Restoration of blurred noisy images

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Courses: Optimization Methods, NLA

Project Proposal

Task

Given the observed blurry noisy image and blur matrix restore the initial image

Applications

- Micro science
- Security
- Photography industry
- Computer vision

Problem Statement

Notation

Let $z : 3 \times N^2$ be vector-reshaped observed image,
A - blur matrix, σ - derivation of additional noise,
$y : 3 \times N^2$ - initial image we are trying to restore,
$p(y)$ - penalty ('l1' and 'l2' are considered), τ - penalty parameter.

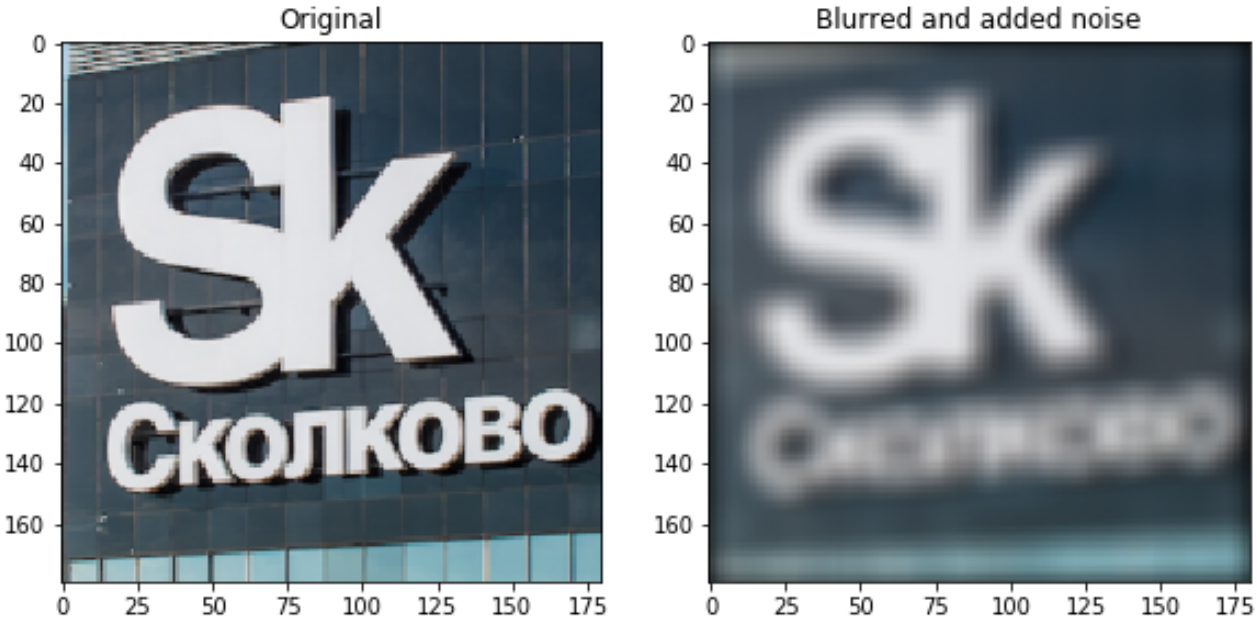
Formulation

$$\hat{y} = \underset{y \in \mathbb{R}^{n^2}}{\arg\min} \left(\frac{1}{2\sigma} ||z - Ay||_2^2 + \tau p(y) \right), \tag{1}$$

$$0 \leq \hat{y}_{ij} \leq 1, \forall i, j \tag{2}$$

Preparing Data

- Google photo
- Take gaussian filter
- Create kernel
- Reduce convolution to matvec operation
- Add some noise



Implemented Methods

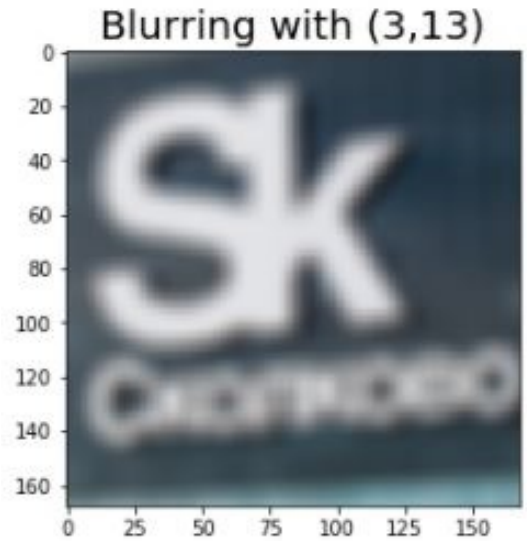
- CVXPY: Gurobi solver
- Projected Gradient Descent, Fast Gradient
- Proximal Gradient Method
- Newton method

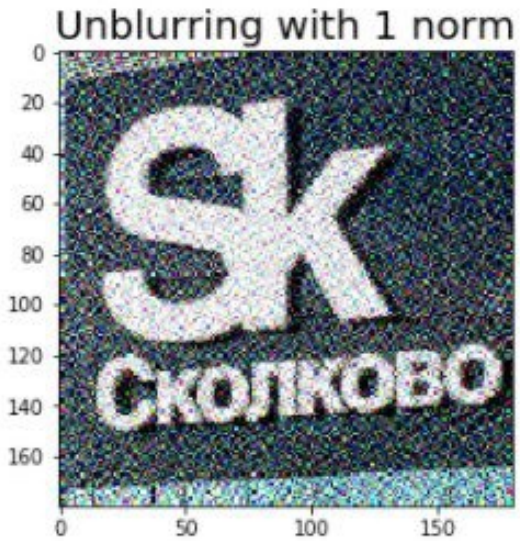
Variations

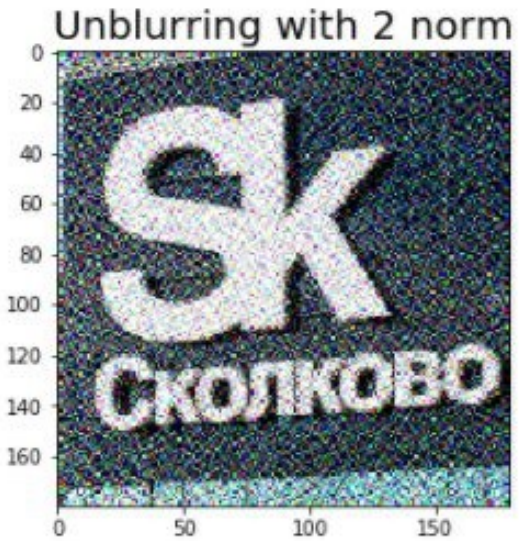
- Regularizations
- Kernels
- Initializations

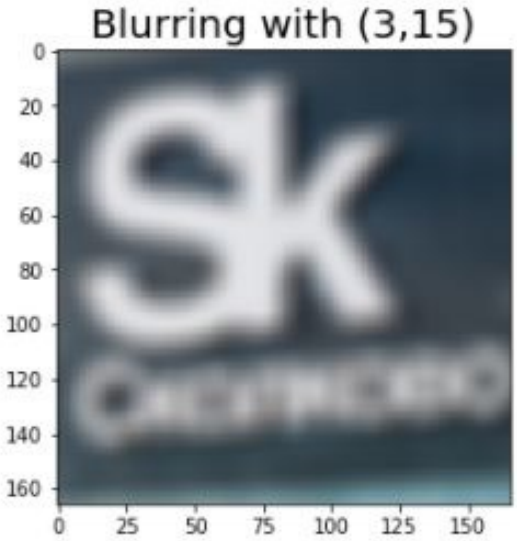
CVXPY. Various Kernels

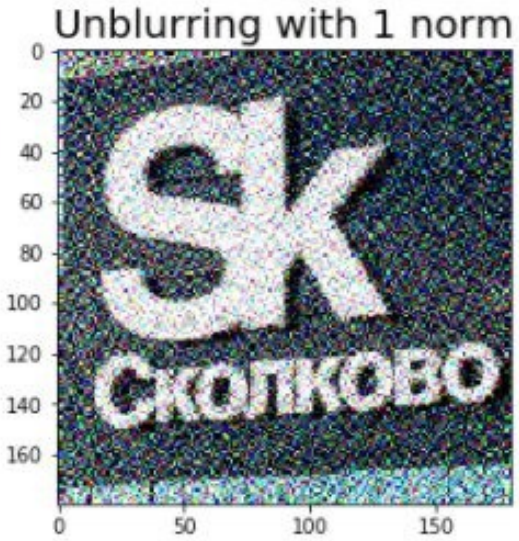
CVXPY. Various Kernels

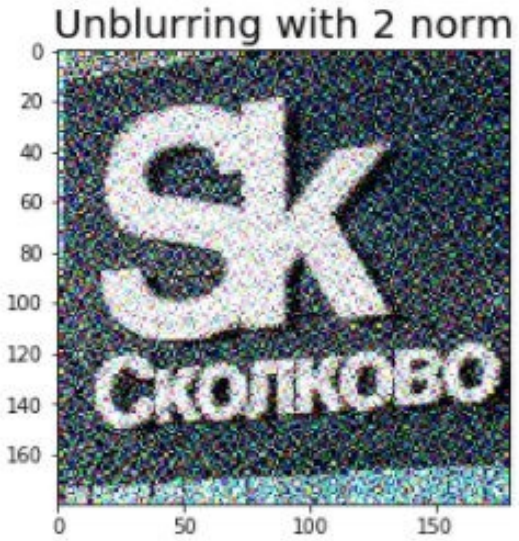




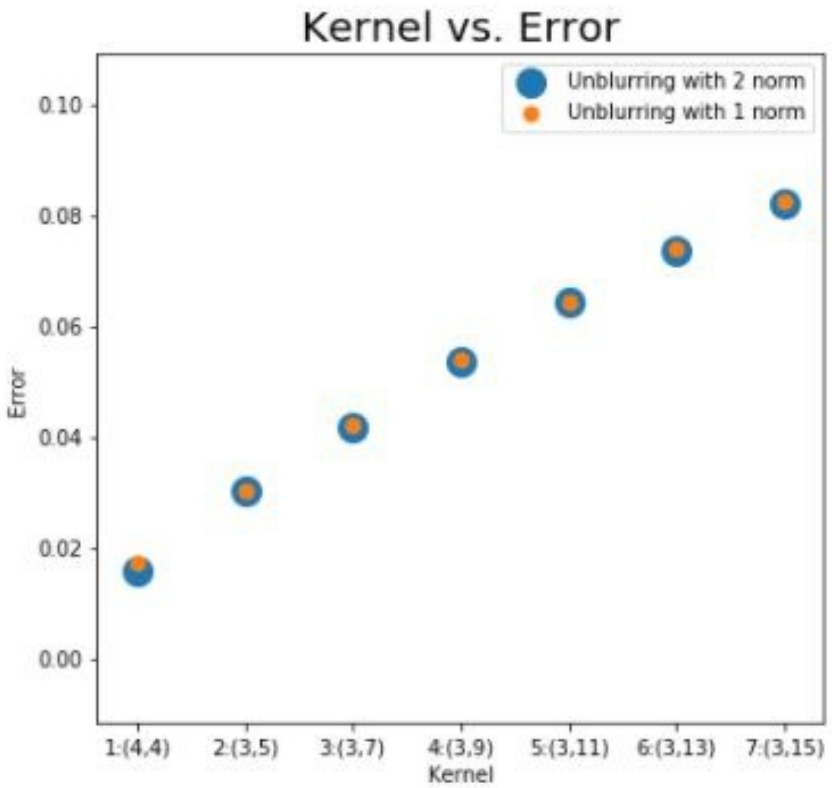


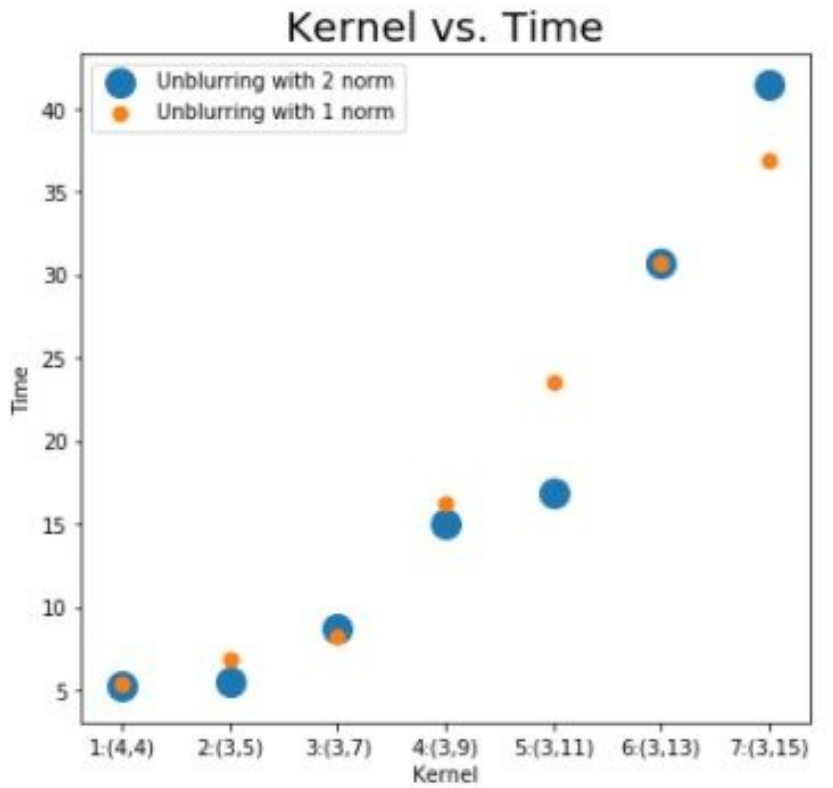




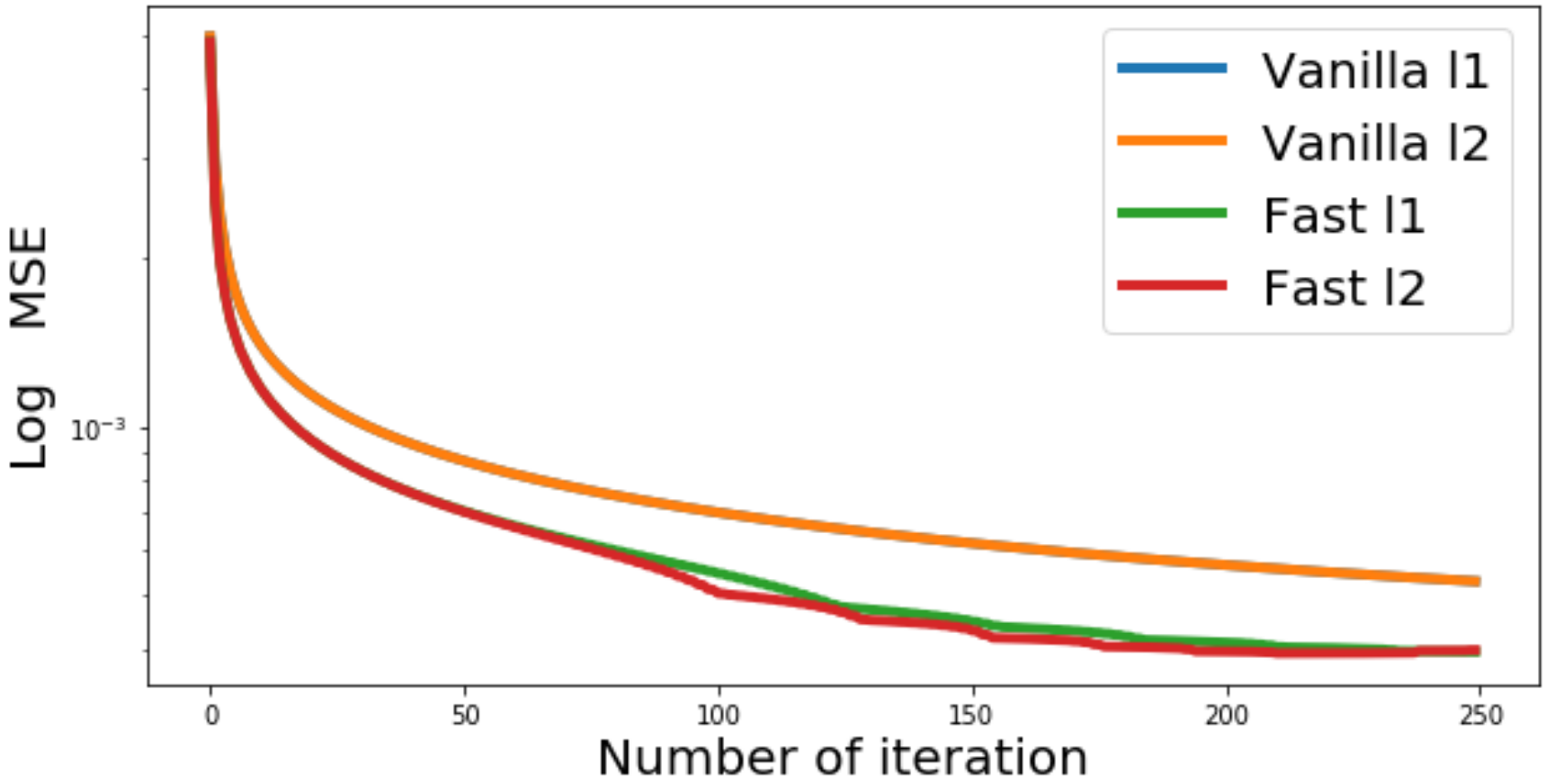


CVXPY. Comparison





Gradient Descent. Vanilla and Fast



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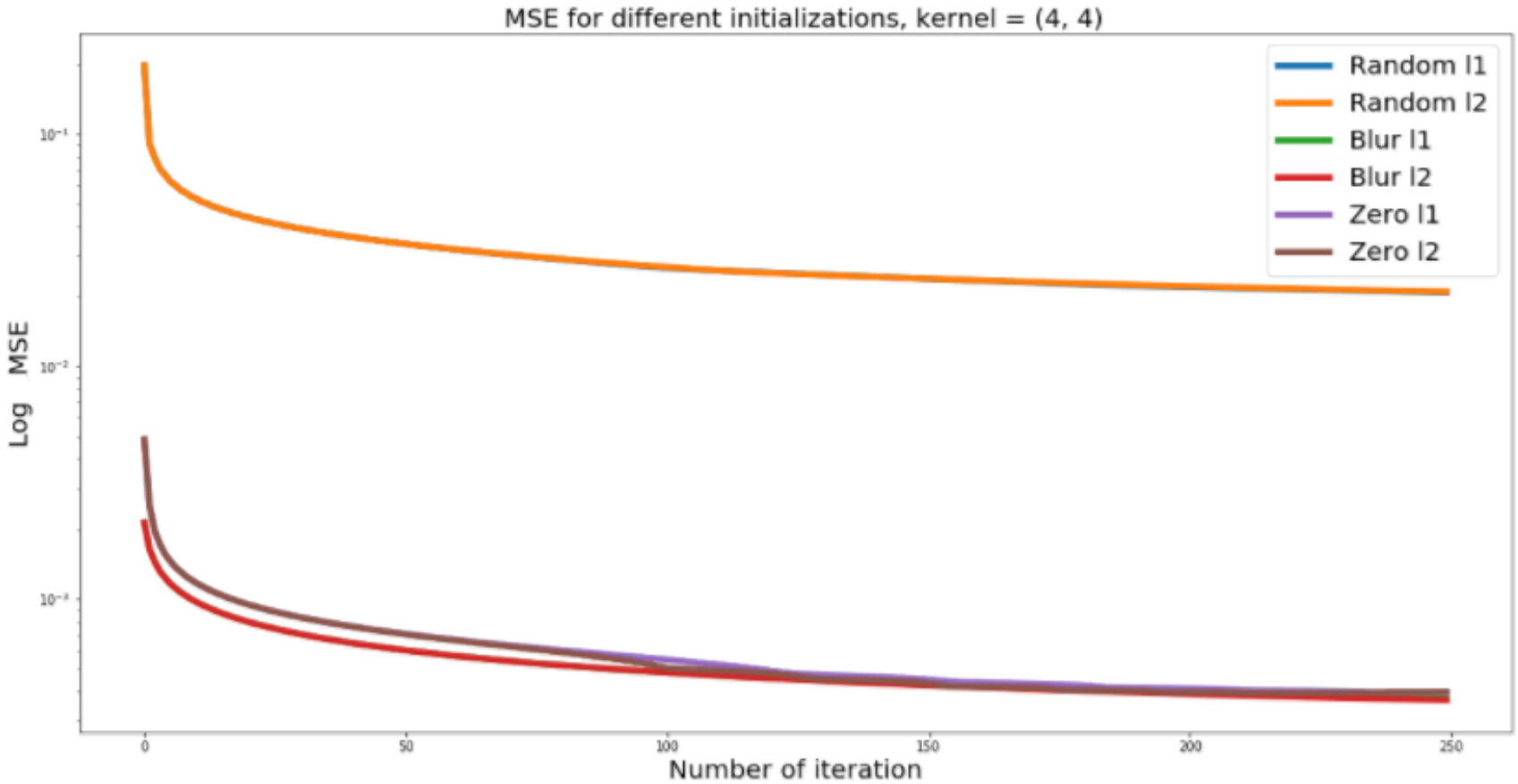
Fast Gradient. Different initializations



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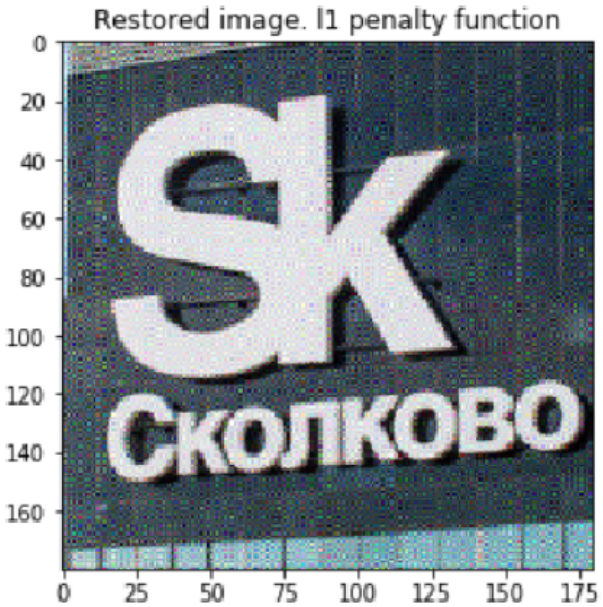
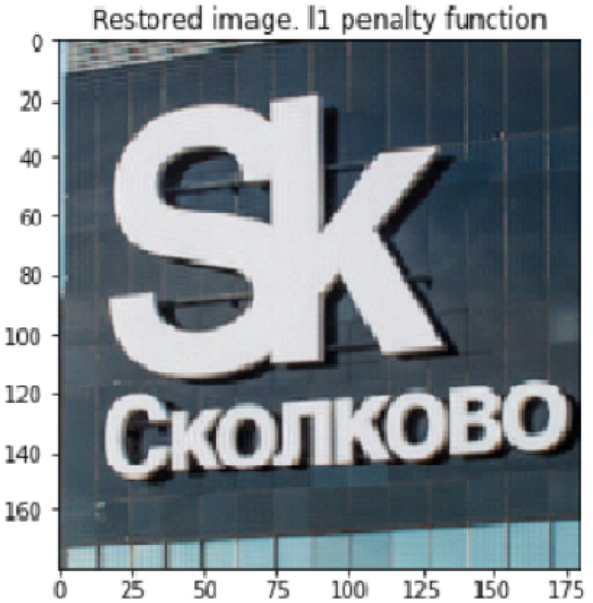
Fast Gradient. Different initializations





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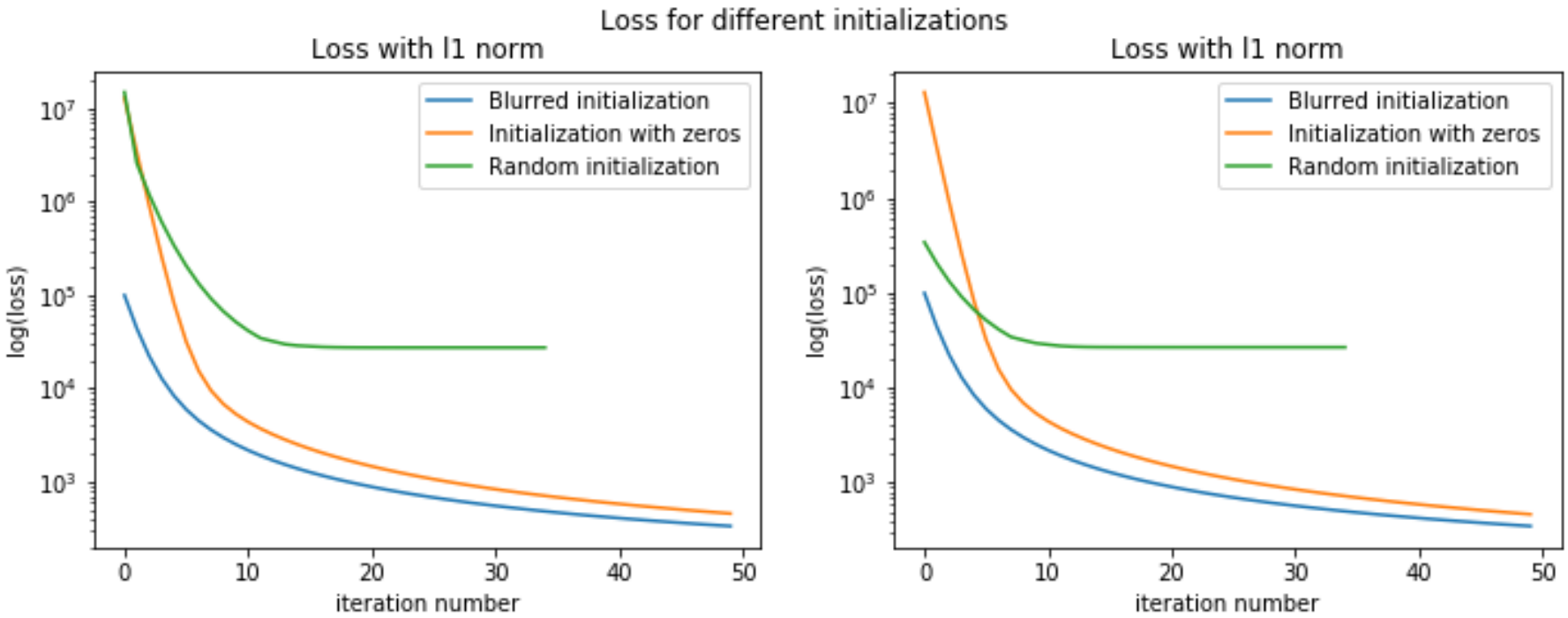
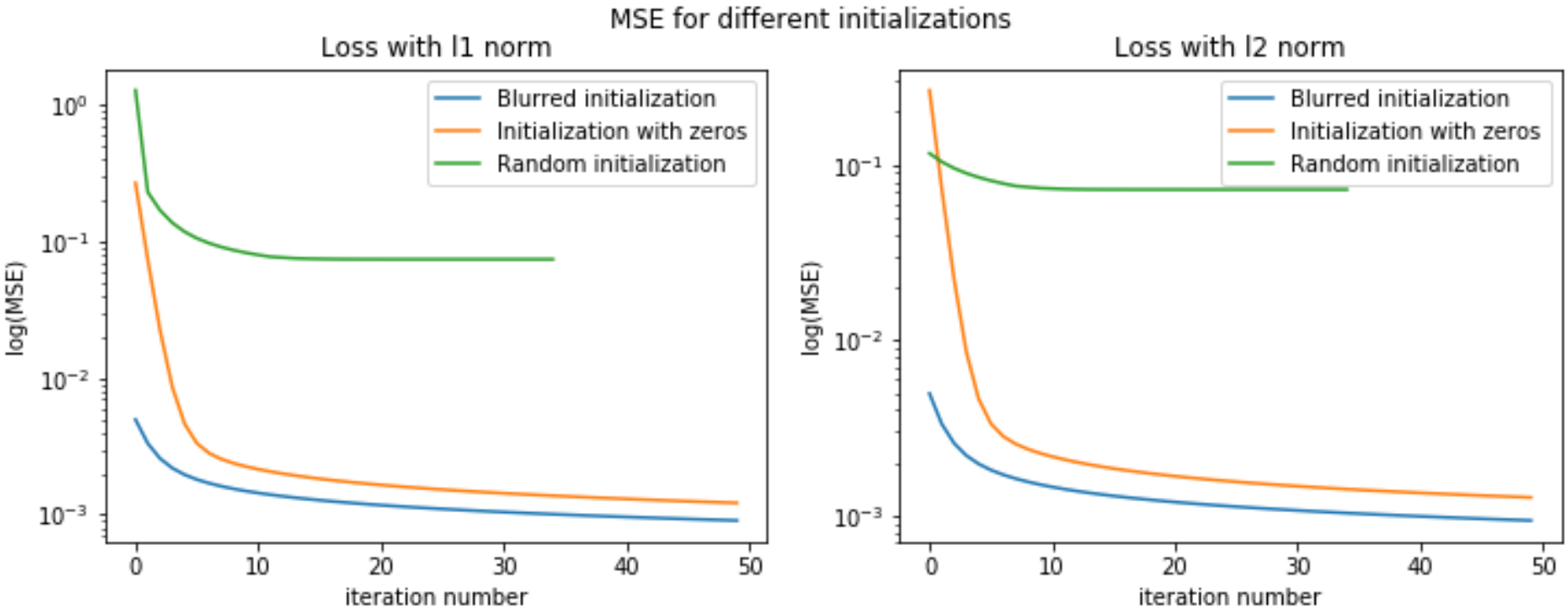
Comparison of two kernel's results

Proximal Gradient. Comparison for different initialization



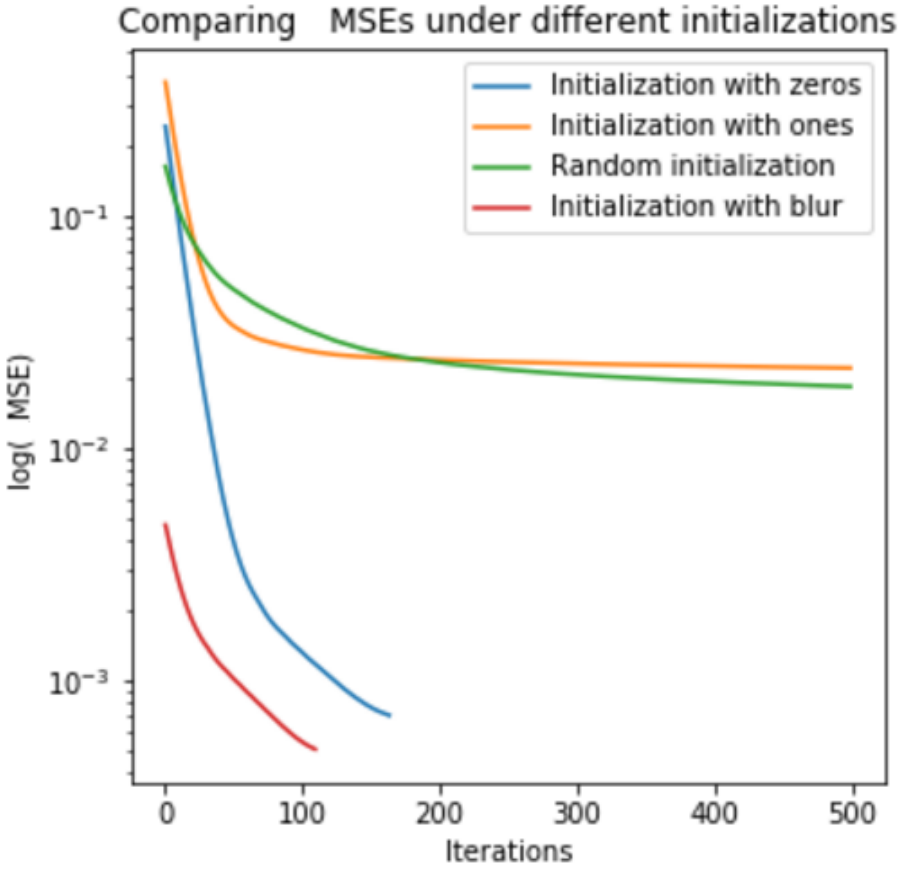
Proximal Gradient. Comparison for different initialization

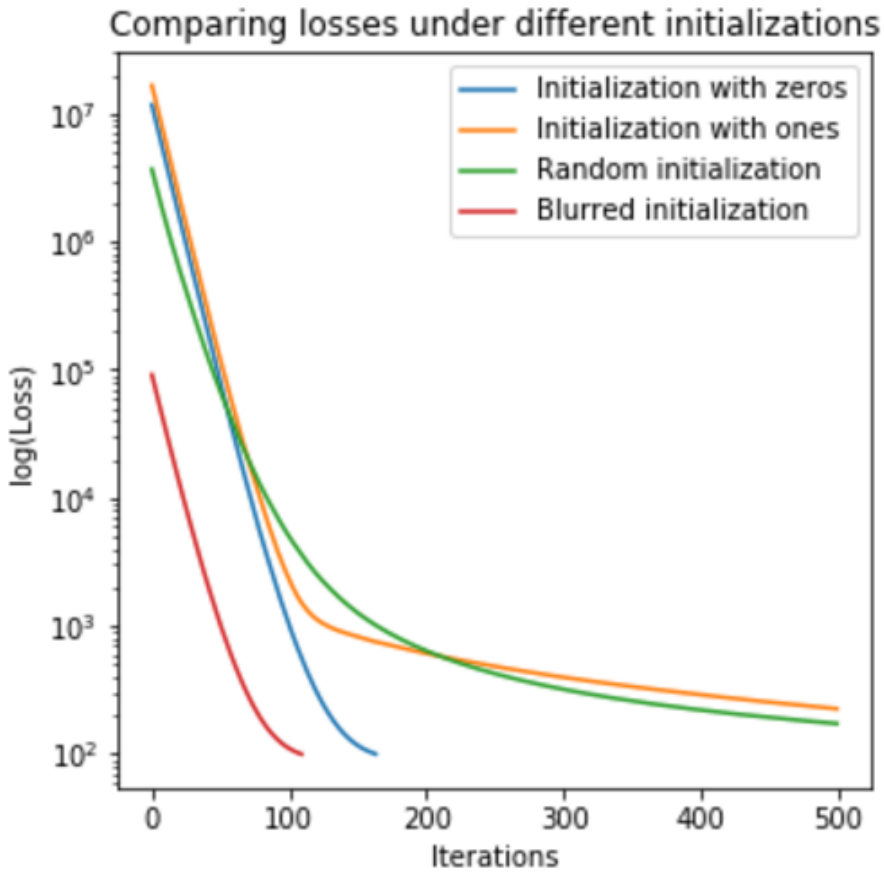


Proximal Gradient. Kernel = (4, 4)

Proximal Gradient. Kernel = (3, 15)

Newton Method. Different initializations





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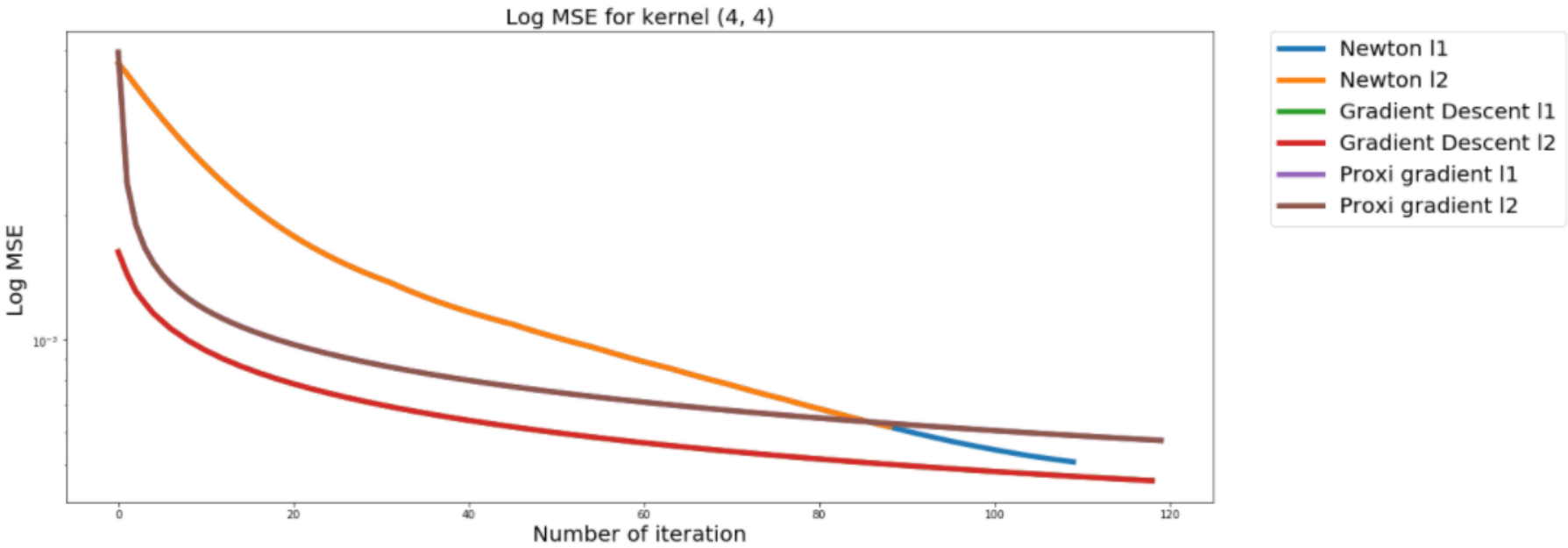
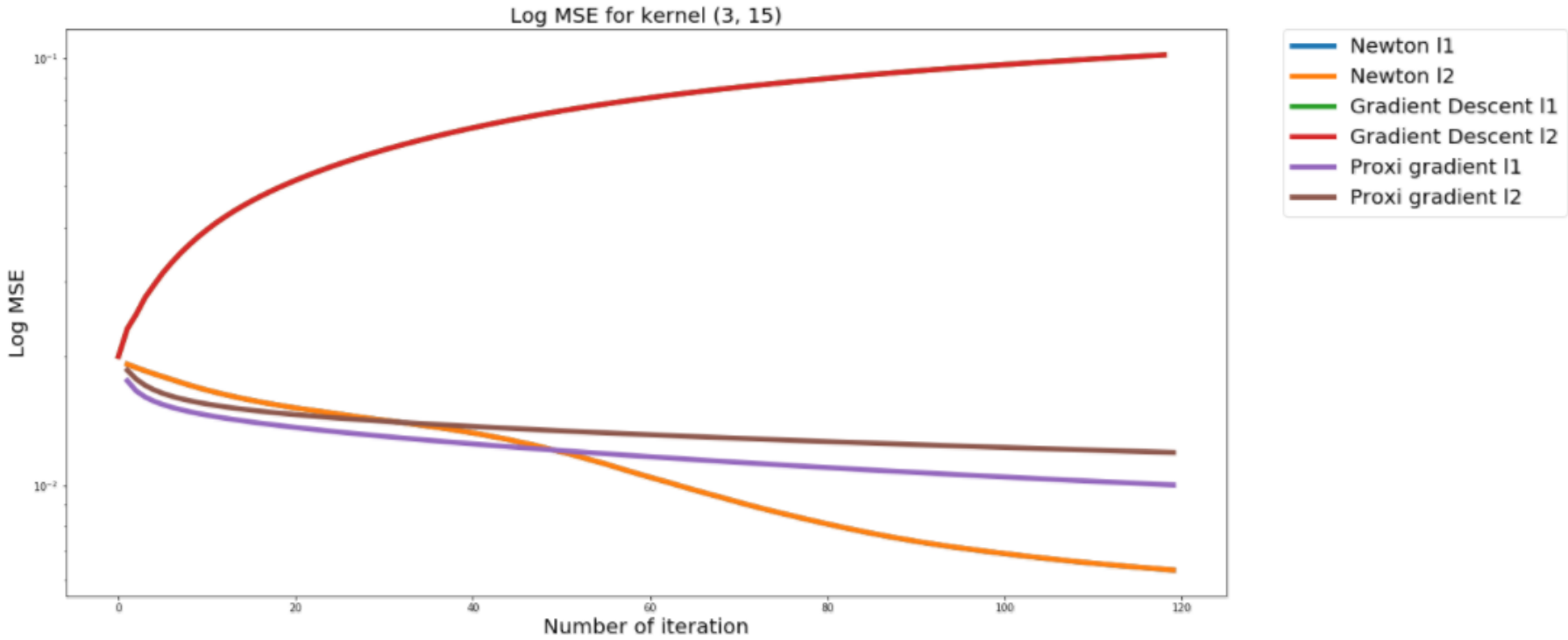
Newton Method. Kernel = (4, 4)

Newton Method. Kernel = (3, 15)

MSE Rate. Kernel = (4, 4)



MSE Rate. Kernel = (3, 15)



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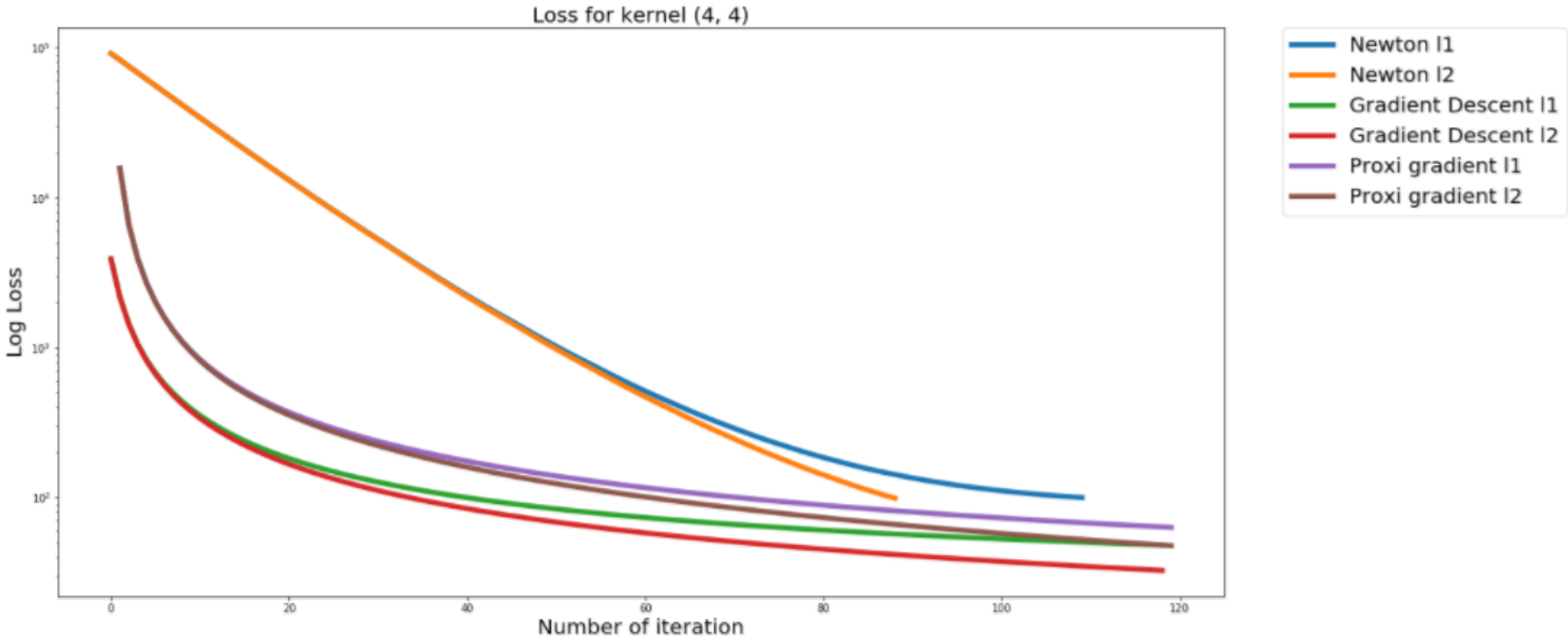
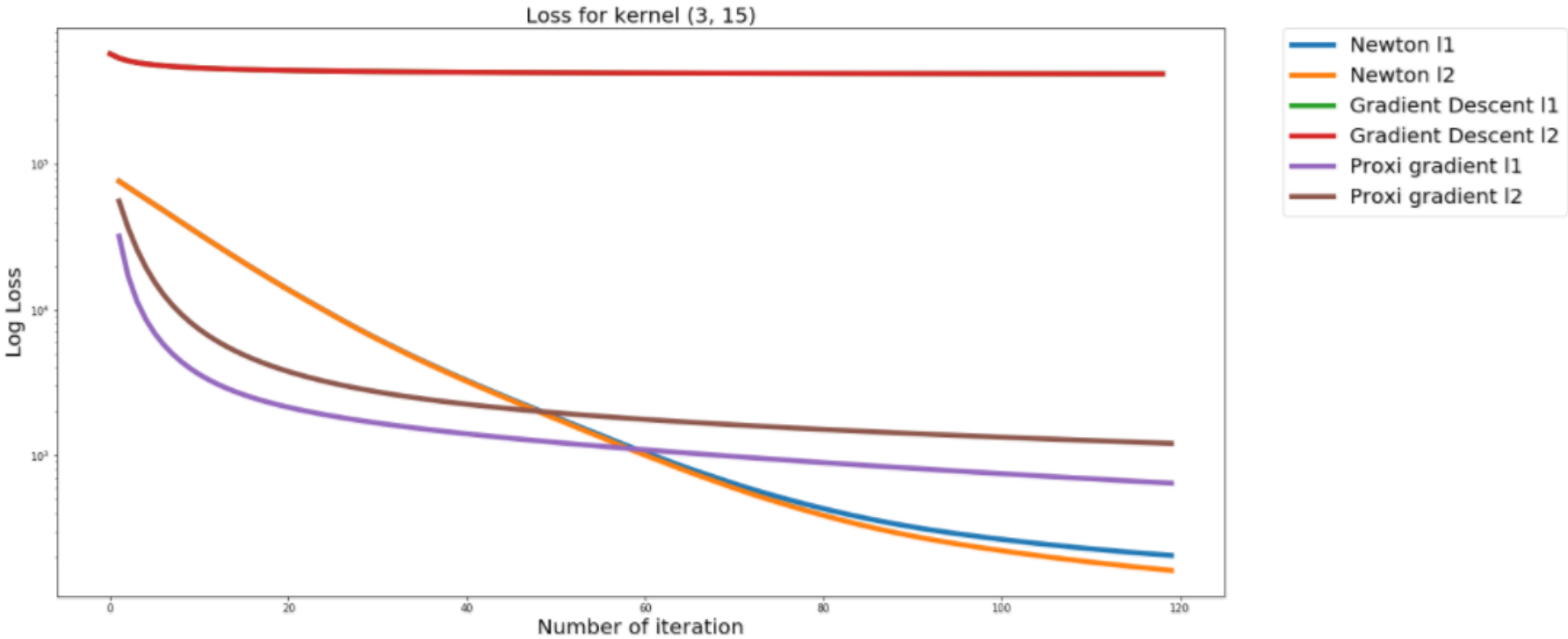
Loss Rate, Kernel = (4, 4)



Loss Rate, Kernel = (3, 15)



Conclusions

- Problem formulated
- Different approaches for solving were studied
- Data prepared
- Software developed, variations considered
- Results compared
- Team work appreciated

Our Team

Ekaterina Chuikova
data preparing
cvxpy

Daria Fokina
data preparing
proxi gradient

Anastasia Belozerova
projected and fast gradient
presentation

Fedor Streltsov
Newton method

Related Works

- A. Danielyan, V. Katkovnik, K. Egiazarian, BM3D frames and variational image deblurring, 2011.
- N. P. Galatsanos, A.K. Katsaggelos, Methods for choosing the regularization parameter and estimating the noise variance in image restoration and their relation, 1992.
- Lu Yuan, Jian Sun, Long Quan, Heung-Yeung Shum, Progressive Inter-scale and Intra-scale Non-blind Image Deconvolution.