

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.

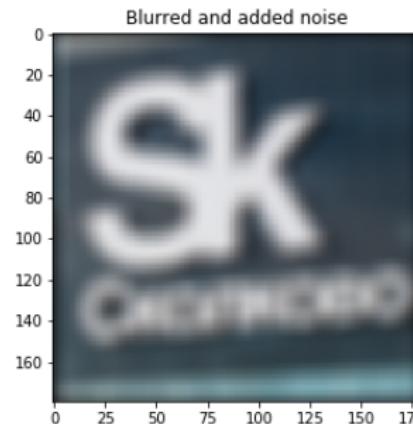
Formulation

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

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

Preparing Data

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



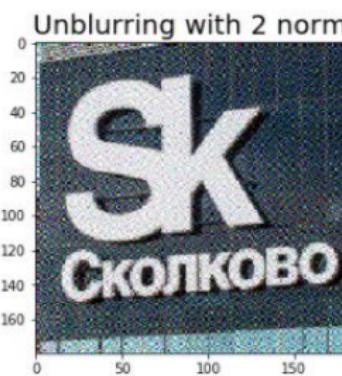
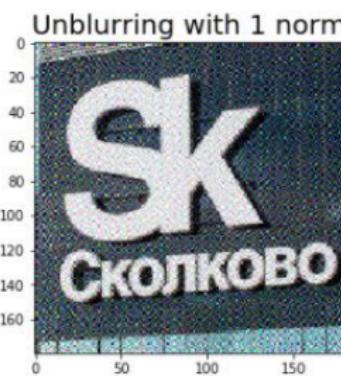
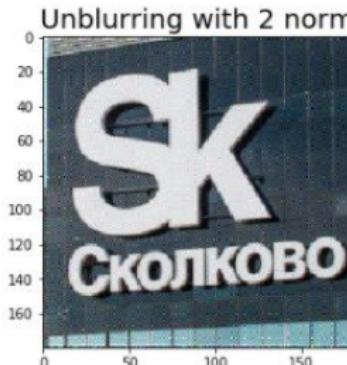
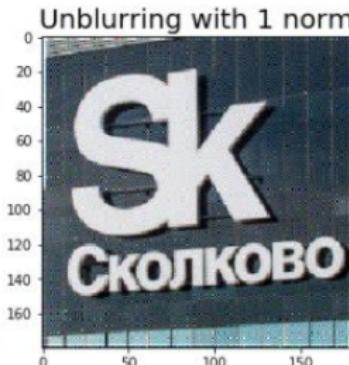
Implemented Methods

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

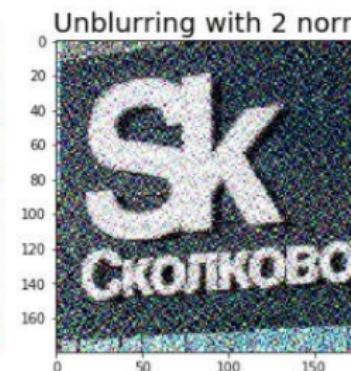
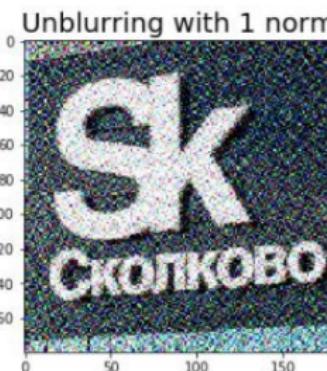
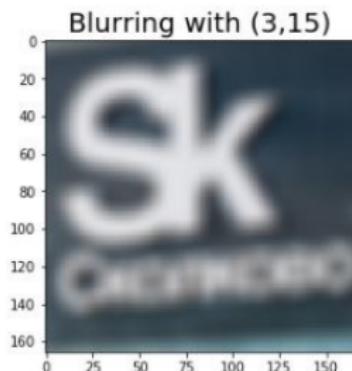
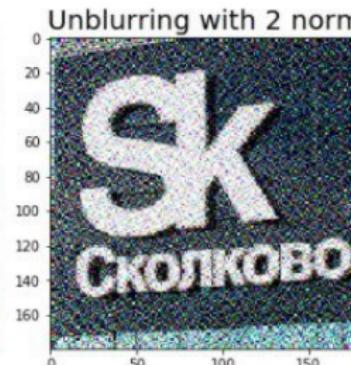
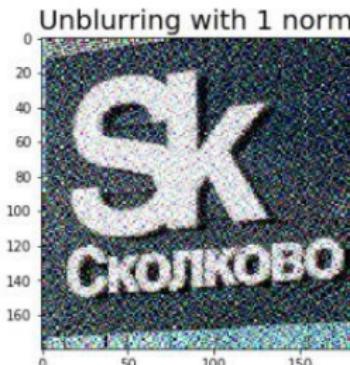
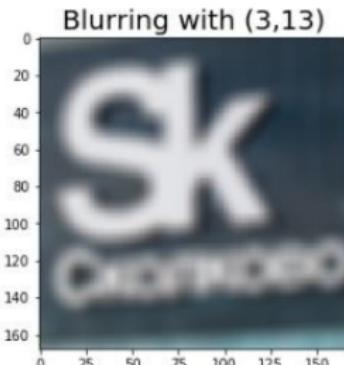
Variations

- Regularizations
- Kernels
- Initializations

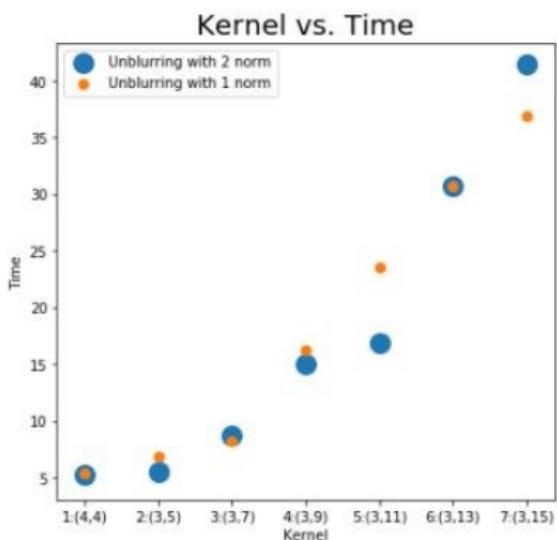
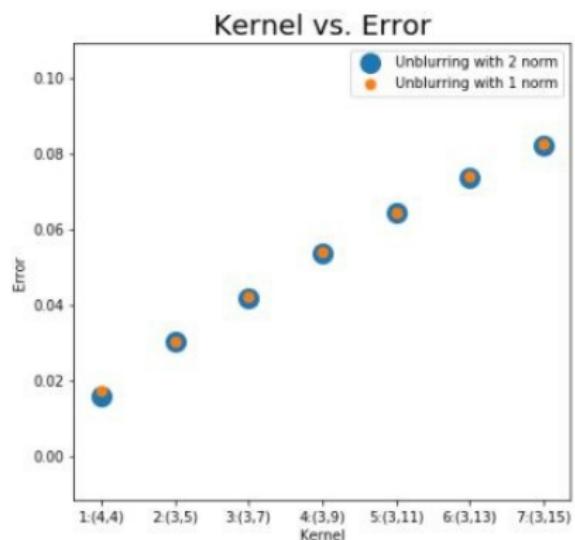
CVXPY. Various Kernels



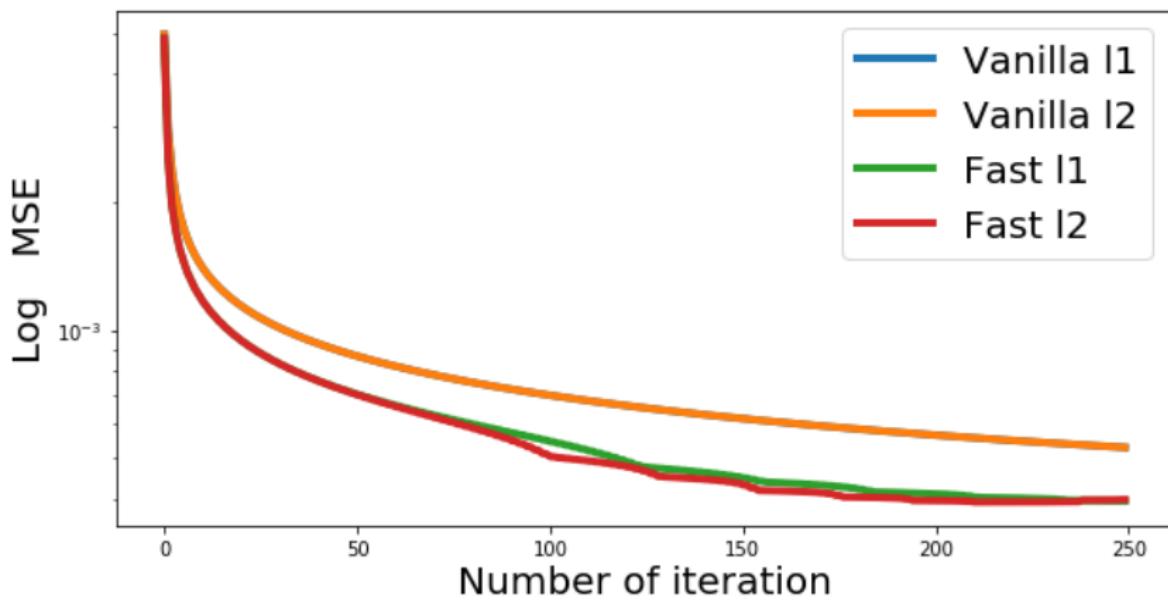
CVXPY. Various Kernels



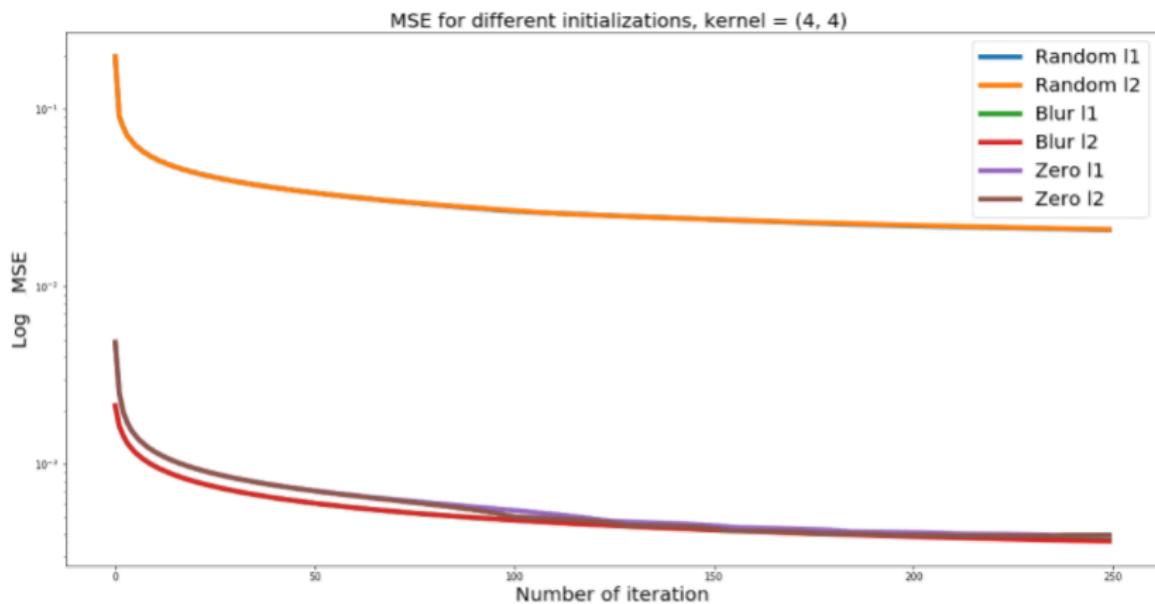
CVXPY. Comparison



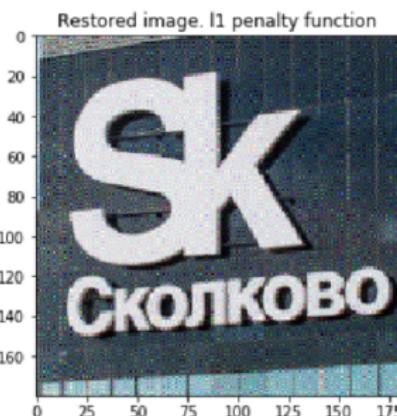
Gradient Descent. Vanilla and Fast



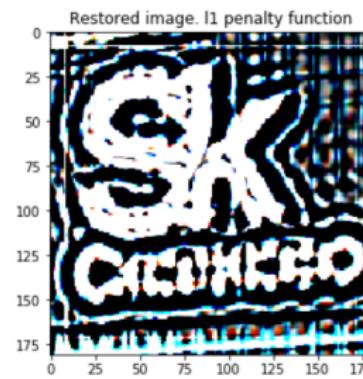
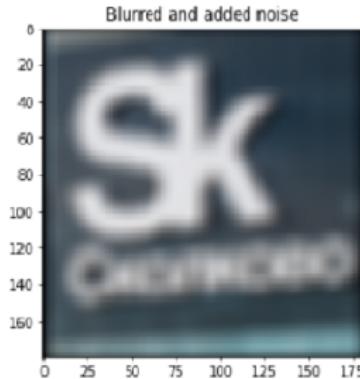
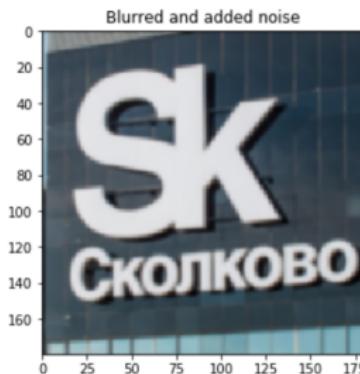
Fast Gradient. Different initializations



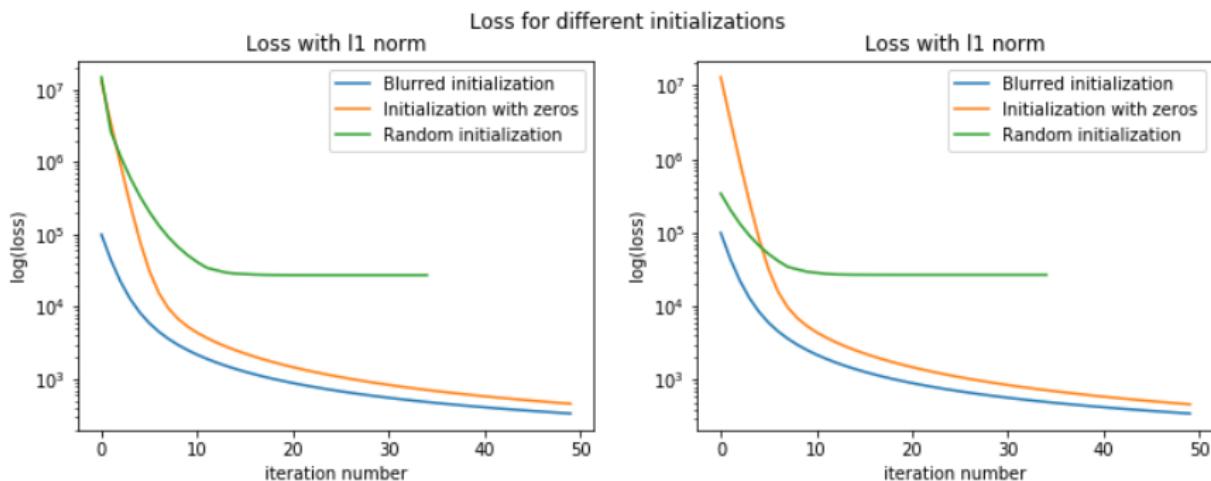
Fast Gradient. Different initializations



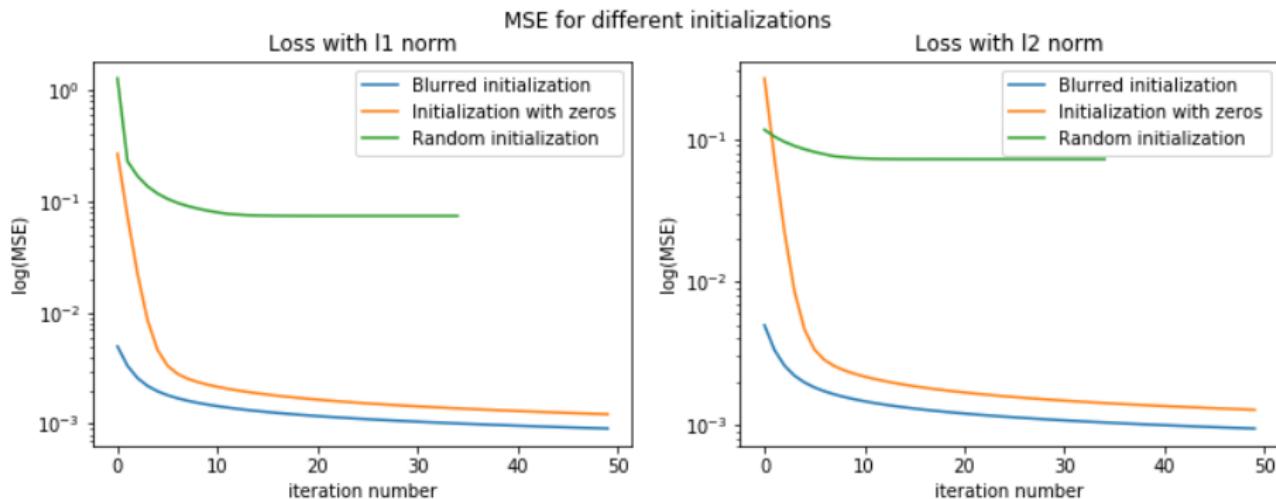
Comparison of two kernel's results



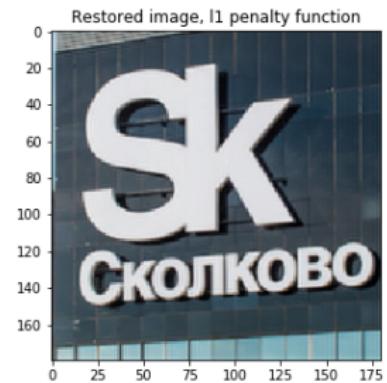
Proximal Gradient. Comparison for different initialization



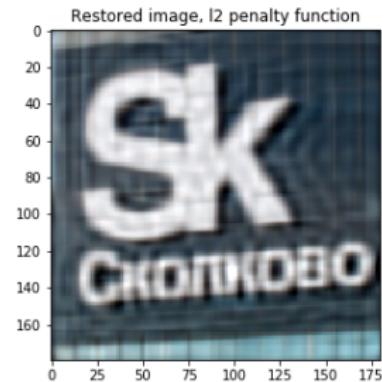
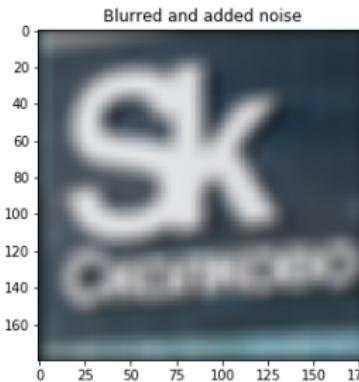
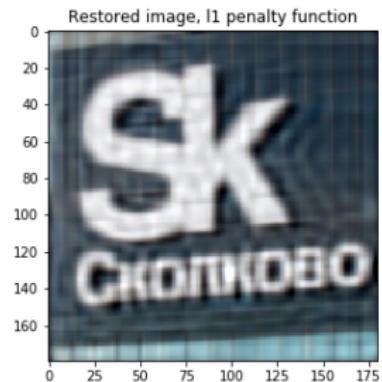
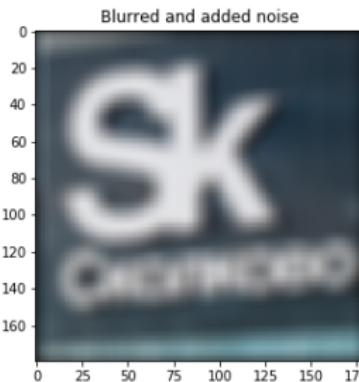
Proximal Gradient. Comparison for different initialization



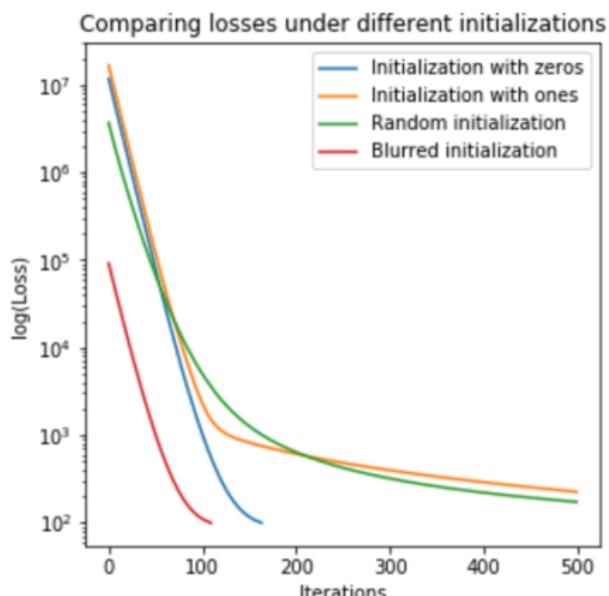
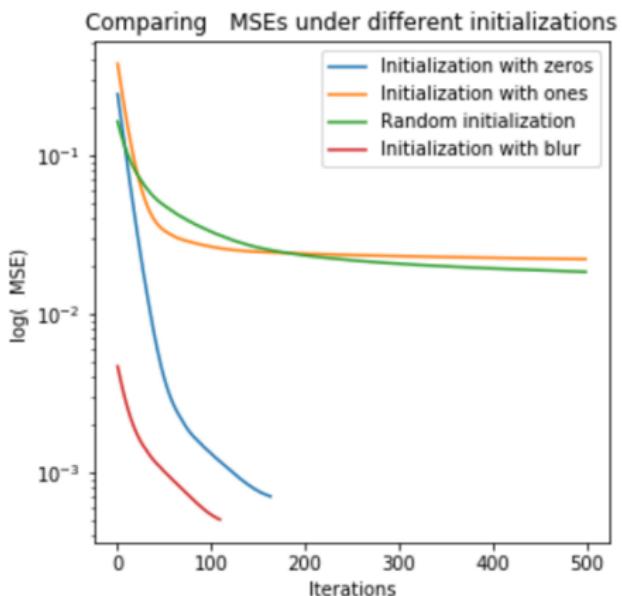
Proximal Gradient. Kernel = (4, 4)



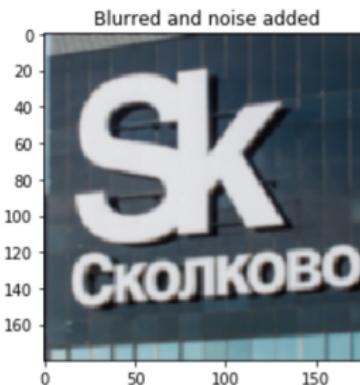
Proximal Gradient. Kernel = (3, 15)



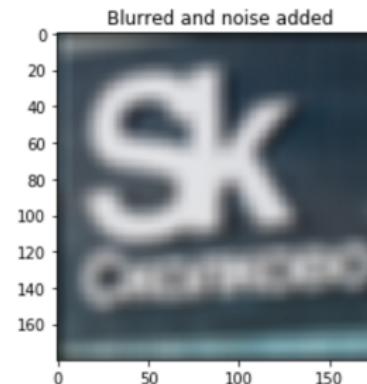
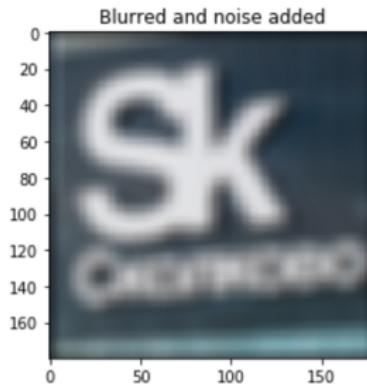
Newton Method. Different initializations



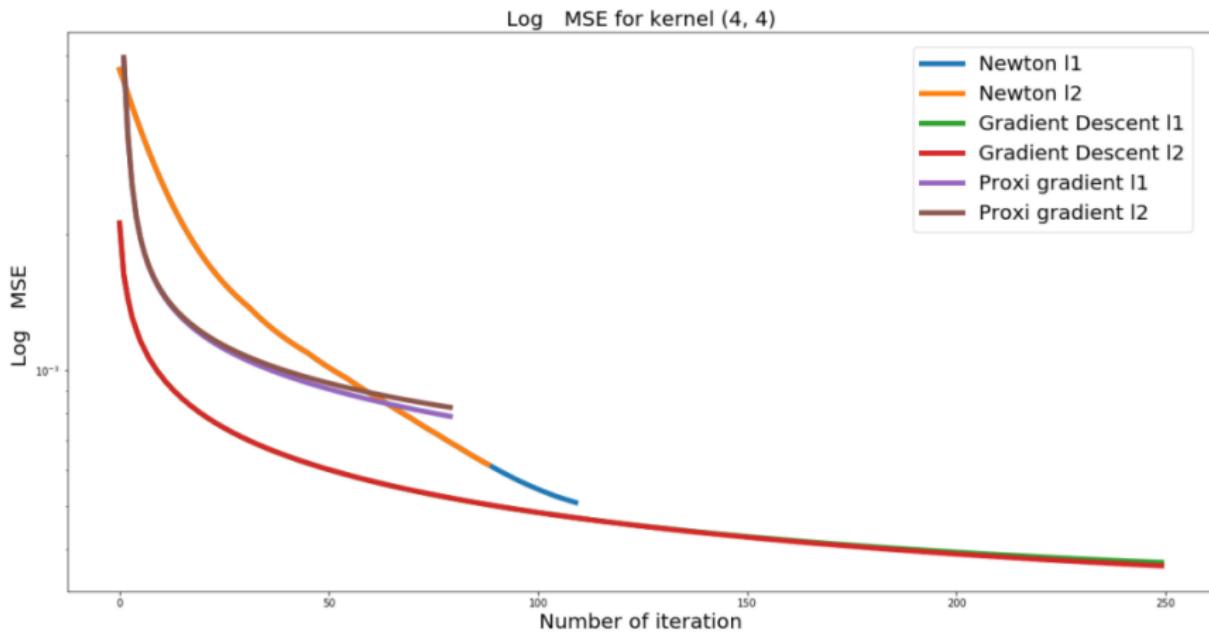
Newton Method. Kernel = (4, 4)



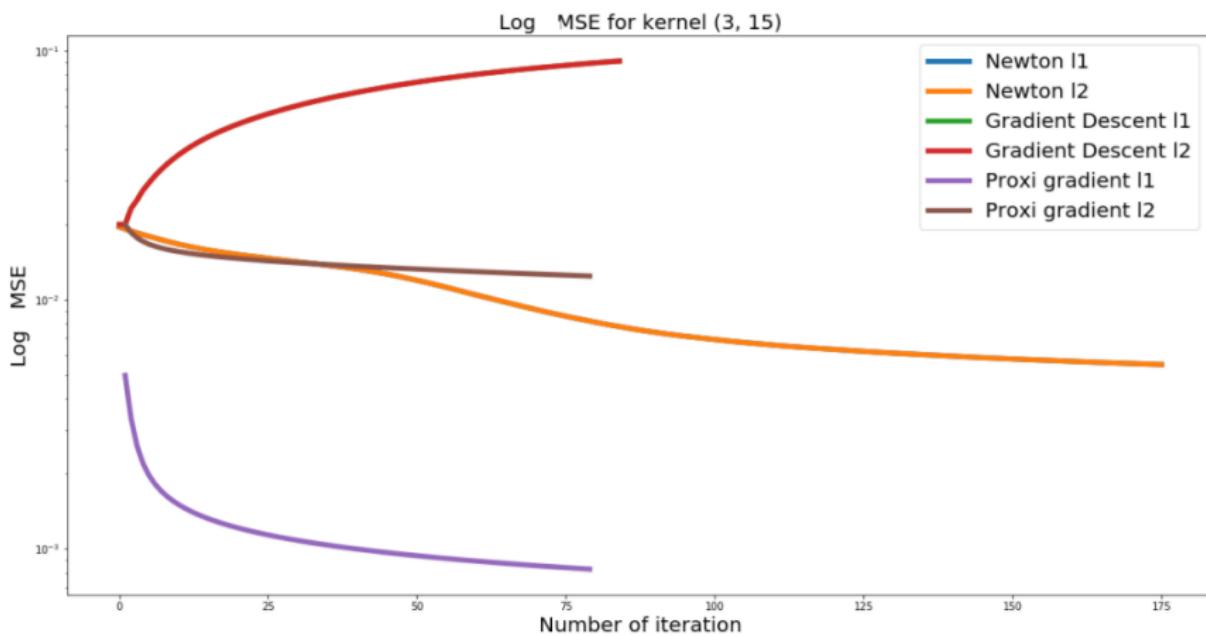
Newton Method. Kernel = (3, 15)



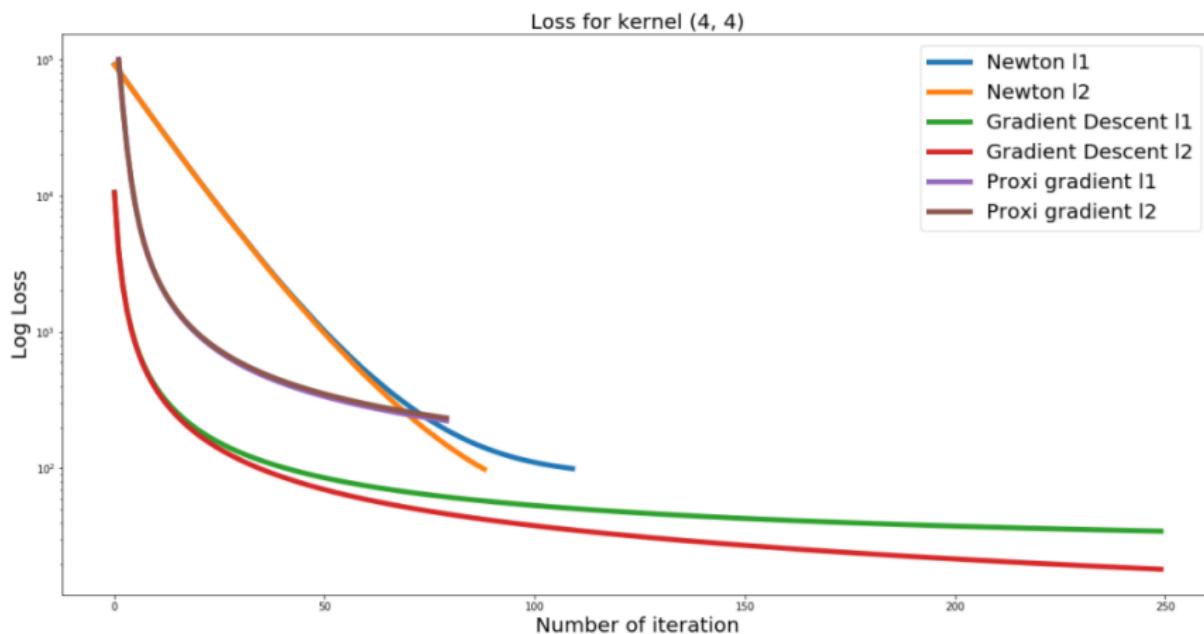
MSE Rate. Kernel = (4, 4)



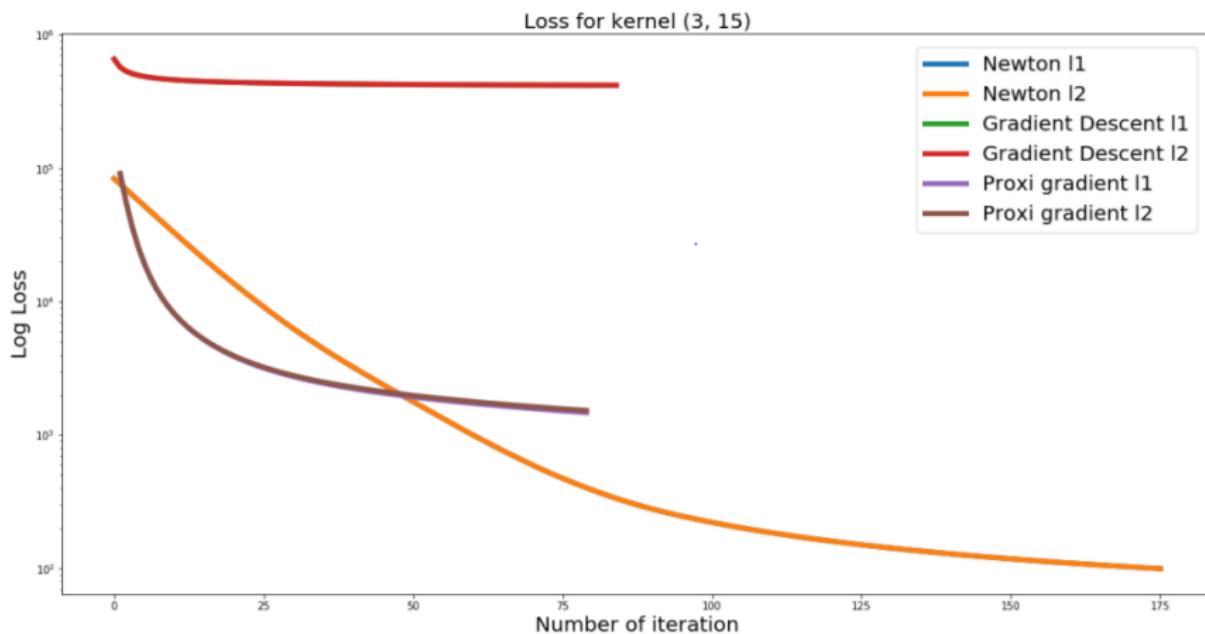
MSE Rate. Kernel = (3, 15)



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
prox 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.