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Jury Member Report – Doctor of Philosophy thesis.

Name of Candidate: Dmitry Ulyanov

PhD Program: Computational and Data Science and Engineering

Title of Thesis: Image Generation with Convolutional Neural Networks

Supervisor: Prof. Victor Lempitsky

Co-advisor: Prof. Andrea Vedaldi, University of Oxford

Date of Thesis Defense: 11 December 2019

Name of the Reviewer: Professor Andrzej Cichocki

I confirm the absence of any conflict of interest (Alternatively, Reviewer can formulate a possible conflict)	**Signature:**  **Date: 05-11-2019**

The purpose of this report is to obtain an independent review from the members of PhD defense Jury before the thesis defense. The members of PhD defense Jury are asked to submit signed copy of the report at least 30 days prior the thesis defense. The Reviewers are asked to bring a copy of the completed report to the thesis defense and to discuss the contents of each report with each other before the thesis defense.

If the reviewers have any queries about the thesis which they wish to raise in advance, please contact the Chair of the Jury.

Reviewer's Report

Reviewers report should contain the following items:

- Brief evaluation of the thesis quality and overall structure of the dissertation.
- The relevance of the topic of dissertation work to its actual content
- The relevance of the methods used in the dissertation
- The scientific significance of the results obtained and their compliance with the international level and current state of the art
- The relevance of the obtained results to applications (if applicable)
- The quality of publications

The summary of issues to be addressed before/during the thesis defense

The PhD Thesis of Mr. Dmitry Ulyanov is devoted to applications of deep convolutive neural networks for generation problems. Particular interest of the Author of this thesis are natural image generation tasks, especially style transfer, image super-resolution, inpainting, denoising, image enhancement. Particularly, he investigated how to you use efficiently deep neural networks for such tasks.

One of the challenging problems investigated carefully by the Author is how to combine a pair of different images to achieve a specific style and feel of the first image and content from the second image. Another problem considered in this thesis how we can one generate many examples or representations from the same single texture. Texture synthesis is not completely new problem since has been already extensively used by game developers and designers. Another important problem investigated by the Author is an image prior, i.e., how can we describe a set of natural images and define a prior toward this set to use in image generation tasks?

Neural networks have already found wide spectrum of practical applications for classification, recognition, clustering, anomaly detection, prediction but the use of deep neural networks for generation problems have been not yet fully explored, so the topic of research presented in this thesis is important and promising.

The Author verified and validated his scientific hypotheses by conducting extensive computer experiments and compared his algorithms with the state-of-the-art methods (in the time of when publications was submitted). Unfortunately, the Author not compared in his PhD thesis his methods with very recent algorithms published in 2019 and partially in 2018. He used the most common datasets and benchmarks for each task he considered. Moreover, he provided very useful codes for almost every paper he published on Github. The codes were professionally written in Python and Lua.

Mr. Ulyanov published 4 high quality and influential papers as the leading co-author, in the top A* conferences: CVPR (2), ICML, AAAI. Moreover, he is one of the coauthors of two additional papers published in ECCV (2018) and CVPR (2019).

The main contribution of the Author is that he developed and used a reparametrization methods in his excellent publications. First of all, he developed a feed-forward approach for style transfer in replace of optimization-based approach of Gatys *et al.* His method is 500 times faster than other existing methods. The main idea was to employ deep neural networks to approximate local minima of some specific energy functions instead of performing search of local minima every time to generate an image. He exploited a similar idea for “Deep Image Prior”, i.e., he used specific convolutive neural networks to parametrize a single image and show by simulation experiments that this reparametrization can serve as some image prior.

Critical comments: Although the thesis is very high quality and publications have high impact, I would like to indicate for some minor weakness of this PhD thesis. All chapters are to some extend just copies of the published papers. I expected that the Author make in the thesis more

comparative analysis i.e., compare his results with very recent related publication published in 2018-2019. Furthermore, in the Bibliography I could not find references to many very related papers published in 2019. So it would be great if the Author could add closely related references published recently. The paper about "Deep Image Prior" has achieved quite high citation rate (cited more than 290 times) and it has high impact for scientific community working in computer vision but this work lacks deep theoretical justification. It would be quite interesting in the future to explore practical aspect and potential applications of Deep Image Prior and how it can be used, for example, for neural network architecture search. Moreover, the Author compare most of his algorithm only in qualitative way (just by visualization of large number of images) without providing any quantitative measure or indexes. This problem is very challenging and could be topic in future research.

Summarizing, in my opinion the main achievement of the Author of the thesis are as follows

- Development of concept Deep Image Prior framework for single image denoising, super-resolution or inpainting (matrix, tensor completion). The author demonstrated that the structure of the neural network itself can work as a strong regularization (prior) for wide class of images (His related paper is cited already almost 300 times).
- Development of much faster method for image style transfer and texture synthesis.
- Proposing so called "Instance normalization" module, which is now widely adopted by the computer vision community and often used in generative models. His paper about this topic achieved already more than 500 citations.
- Development of a such GAN formulation that enables backward mapping. In fact this backward mapping can be combined with the discriminator network. Moreover, the author contributed to the development of a discriminator for GAN framework, based on perceptual features and to novel framework for realistic rendering of human avatars that combines neural rendering with classical rendering techniques.

Provisional Recommendation

X☐ *I recommend that the candidate should defend the thesis by means of a formal thesis defense*

☐ *I recommend that the candidate should defend the thesis by means of a formal thesis defense only after appropriate changes would be introduced in candidate's thesis according to the recommendations of the present report*

☐ *The thesis is not acceptable and I recommend that the candidate be exempt from the formal thesis defense*