

## **REVIEW**

on the dissertation work of

Xu Jiashu

on the topic “Research and Development of Self-Supervised Visual Feature Learning  
Based on Neural Networks”,

submitted for the degree of Doctor of Philosophy  
in the field of knowledge 12 Information Technologies  
within the specialty 121 Software Engineering

### **Relevance of the dissertation topic.**

The relevance of the dissertation topic is determined by the rapid expansion of the application fields of software systems based on artificial intelligence algorithms. This requires, among other matters, the creation of new models and algorithms for their training. In particular, the most relevant is the task of developing and implementing self-learning algorithms that do not require prior data labelling. The need for self-learning algorithms is explained by the fact that the annotation process is time-consuming and requires the involvement of experts, especially when it comes to the application of artificial intelligence in fields such as medicine. Modern training methods based on deep learning often encounter challenges in using extensive and unlabeled datasets, making the search for effective alternatives, such as self-learning algorithms, extremely important. Applying unsupervised learning techniques provides significant advantages, as it ultimately simplifies the processes of creating new software based on artificial intelligence methods. Therefore, the scientific task of developing new theoretical and practical approaches to self-supervised visual feature learning based on neural networks, which is addressed in the dissertation, is relevant.

### **Evaluation of the justification of the dissertation’s scientific results, their reliability, and novelty.**

The scientific novelty of the dissertation research results lies in the following.

1. For the first time, a self-learning method based on the mixing function (Mixup Feature) was proposed, which, due to the preliminary study of visual representations by predicting mixed features of masked images, which serve as substitutes for high-level semantic information, enables improving the performance of the model as a whole.
2. For the first time, a model of a masked autoencoder for self-learning with noise reduction and self-distillation functions is presented, which, due to a masked autoencoder and a teacher network, provides the reconstruction of corrupted image segments afflicted with random Gaussian noise.
3. For the first time, a model is proposed that, due to combining losses at the pixel level and feature level, enables the extraction of deep semantic characteristics of

the image, which complements the existing masked image modeling techniques, and increases the stability of self-learning models when working with unbalanced data sets.

The proposed method and models are new and different from known analogues; their application makes it possible to increase the efficiency of software systems based on artificial intelligence methods. To validate the reliability of the obtained results, the candidate has conducted an experimental part of his research, which confirmed the effectiveness of the proposed approach to creating a new self-supervised learning methodology. So, the dissertation work is characterized by scientific novelty and reasonableness.

The scientific research was conducted by the candidate at the Department of Computer Engineering of the National Technical University of Ukraine “Igor Sikorsky Kyiv Polytechnic Institute” within the framework of the scientific and development project “Artificial Intelligence Platform for Remote Automated Detection and Diagnosis of Human Diseases” (registration number: 2020.01/0490) under the supervision of the Head of the Department of Computer Engineering, Doctor of Technical Sciences, Professor Sergii Stirenko.

Thus, the scientific task set in the dissertation of researching, developing, and implementing self-supervised learning algorithms, which are part of the unsupervised learning methodology, has been fully accomplished. The candidate has fully mastered the methodology of scientific research.

### **Evaluation of the content of the dissertation, its completeness, and adherence to the principles of academic integrity.**

The content of Xu Jiashu’s dissertation work fully meets the Higher Education Standard for the specialty 121 Software Engineering and research directions according to the educational program “Software Engineering”.

The dissertation is a completed scientific work and demonstrates the presence of the candidate’s personal contribution to the scientific field of software engineering.

After reviewing the similarity report based on the examination of the dissertation work for textual matches, it can be concluded that Xu Jiashu’s dissertation is the result of the candidate’s independent research and does not contain elements of falsification, compilation, fabrication, plagiarism, or borrowing. The ideas, results, and texts of other authors used are properly cited with references to the relevant source.

### **Language and Style of Presentation of Results.**

The dissertation is written in English. The work is logically and coherently structured; its presentation meets the requirements set for such works. The text of the dissertation does not contain contradictions or unverified regularities. The level of

preparation of the dissertation demonstrates that the candidate correctly utilizes contemporary scientific methodology.

It comprises an introduction, four chapters, conclusions, a reference, and appendices. The total length of the dissertation is 168 pages.

In the introduction, the relevance of the dissertation's topic is demonstrated, and the objective, research tasks, and main propositions to be defended are formulated.

The first chapter presents a thorough analysis of known approaches to self-supervised visual feature learning. Conclusions are made regarding the possibility of refining these approaches to develop a more advanced self-supervised methodology.

In the second chapter, the possibilities of using masked images created using the Sobel operator, Histogram of Oriented Gradients (HOG), and Local Binary Patterns (LBP) visual descriptors are examined. The extraction of semantically significant visual features from images is discussed in detail. The Visual Transformer (ViT) is convincingly selected as the backbone for implementing the self-supervised learning method. The Masked AutoEncoder (MAE) is analyzed and chosen as well. As a result of the theoretical research presented in this chapter, two algorithms are proposed: a self-supervised algorithm based on the Mixup Feature function and a masked autoencoder algorithm for self-supervised with noise suppression and self-distillation features (Denoising Distillation Masked Autoencoder), which form the main scientific novelty of the dissertation work.

In the third chapter, the core of the experimental study is presented, with the objective of validating the correctness of the algorithms proposed in the second chapter. The datasets, curated for the training of corresponding models, are scrutinized in detail. The selection of hyperparameters, particularly the mixup hyperparameter  $\lambda$ , is analyzed and substantiated. A comparative evaluation of the proposed algorithms against established counterparts has been conducted.

In the fourth chapter, the application of the proposed algorithms for the analysis of medical images is discussed. The datasets used for training include sets of lung computer tomography images. The obtained results are presented in numerous graphs and tables. A substantiated conclusion has been drawn about the efficiency of the proposed self-learning methodology for its application in the development of medical software systems.

The conclusions summarize the main theoretical and practical outcomes of the research.

The dissertation is formatted in accordance with the requirements of the Order of the Ministry of Education and Science of Ukraine dated January 12, 2017, No. 40 "On Approval of the Requirements for Dissertation Formatting".

### **Publication of the results of the dissertation work.**

The scientific results of the dissertation are presented in 4 scientific publications by the candidate, including: 4 articles in periodic scientific journals indexed in the Web of Science Core Collection and/or Scopus databases, of which 1 article is in a journal ranked in the first quartile (Q1) according to the SCImago Journal and Country Rank or Journal Citation Reports classification.

Additionally, the results of the dissertation were presented at 3 scientific professional conferences.

The candidate's publications on the topic of the dissertation research are of a high scientific standard. All publications adhere to the principles of academic integrity.

The characterization of the candidate's personal contribution in scientific works published with co-authors and credited for the dissertation topic:

#### Articles in periodic scientific publications indexed in the Web of Science Core Collection and/or Scopus databases

1. Jiashu Xu and Sergii Stirenko (2023), "Mixup Feature: A Pretext Task Self-Supervised Learning Method for Enhanced Visual Feature Learning", in IEEE Access, vol. 11, pp. 82400-82409, IEEE, ISSN: 2169-3536, DOI: 10.1109/ACCESS.2023.3301561 (Scopus Q1, WoS Q2).

The candidate has proposed an approach to self-supervised feature learning.

2. Jiashu Xu, Sergii Stirenko (2023), "Denoising Self-Distillation Masked Autoencoder for Self-Supervised Learning", International Journal of Image, Graphics and Signal Processing (IJIGSP), Vol.15, No.5, pp. 29-38. MECS Press, ISSN:2074-9074, DOI:10.5815/ijigsp.2023.05.03 (Scopus).

The candidate has proposed a self-supervised learning method utilizing noise suppression.

3. Jiashu Xu, Sergii Stirenko (2022), "Self-Supervised Model Based on Masked Autoencoders Advance CT Scans Classification", International Journal of Image, Graphics and Signal Processing (IJIGSP), Vol.14, No.5, pp. 1-9. MECS Press, ISSN:2074-9074, DOI:10.5815/ijigsp.2022.05.01 (Scopus).

The candidate has proposed a self-supervised model that uses masked autoencoders for the classification of computer tomography images.

4. Jiashu Xu (2021), "A review of self-supervised learning methods in the field of medical image analysis", International Journal of Image, Graphics and Signal Processing (IJIGSP) 13, no. 4: 33-46. MECS Press, ISSN:2074-9074, 10.5815/ijigsp.2021.04.03 (Scopus).

The candidate has analyzed known unsupervised learning algorithms and their applicability for the analysis of medical images.

## Papers of scientific conferences

5. Yahu Yang, Hu Zhang, Jiashu Xu, Shenmin Song (2023), “MATEKG: A Large-scale Multi-class Equipment Knowledge Graph for Military Auxiliary Tasks”, 2023 IEEE 6th International Conference on Information Systems and Computer Aided Education (ICISCAE), Dalian, China. (Scopus).

The candidate has proposed a knowledge graph and its implementation.

6. Yang, Ya-Hu, Jiashu Xu, Yuri Gordienko, Sergii Stirenko (2021), “Abnormal Interference Recognition Based on Rolling Prediction Average Algorithm”, Advances in Computer Science for Engineering and Education III. ICCSEEA 2020. Advances in Intelligent Systems and Computing, vol 1247. Springer, Cham. [https://doi.org/10.1007/978-3-030-55506-1\\_28](https://doi.org/10.1007/978-3-030-55506-1_28) (Scopus).

The candidate has proposed a method for detecting anomalous obstructions.

7. Jiashu Xu, Sergii Stirenko (2020), “Facial Expression Recognition System Based on GAN Network Data Augmentation”, The International Conference on Security, Fault Tolerance, Intelligence 2020, pp. 144-149.

The candidate has proposed a facial expression recognition system.

Thus, the scientific results described in the dissertation are fully reflected in the candidate's scientific publications.

### **Shortcomings and comments to the dissertation work.**

1. Although the dissertation directly relates to the creation of cutting-edge software systems based on artificial intelligence, the candidate has insufficiently detailed the process of developing new software, which implements the proposed self-supervised learning methodology, in the dissertation text.
2. It would be advisable to include information regarding the software methods of implementing the proposed and experimentally tested models in the dissertation text.
3. The program code provided in the appendix is not sufficiently detailed in the main text of the dissertation.
4. While the dissertation focuses primarily on the application of the developed method and models for the analysis of medical images, the results obtained by the candidate could also be applied in fields beyond medicine. Therefore, it would be appropriate to consider also other examples and provide corresponding experimental results.
5. Figure 4.8, which demonstrates the experimental results for the CNN model on unbalanced data, is split into two parts between pages 111 and 112, complicating its analysis.



In my opinion, the expressed shortcomings and comments are not decisive and do not diminish the overall scientific novelty and practical significance of the results and do not affect the positive evaluation of the dissertation work.

### **Conclusion about the dissertation work.**

I consider that the dissertation work of the candidate for the Doctor of Philosophy degree, Xu Jiashu, on the topic “Research and Development of Self-Supervised Visual Feature Learning Based on Neural Networks” is conducted at a high scientific level, does not violate the principles of academic integrity, and is completed scientific research. The collective theoretical and practical results solve a scientific task of significant importance for the field of information technologies. The dissertation work, in terms of relevance, practical value, and scientific novelty, fully meets the requirements of the current legislation of Ukraine as provided in paragraphs 6 – 9 of the “Procedure for awarding the degree of Doctor of Philosophy and cancellation of the decision of a one-time specialized academic council of a higher education institution, scientific institution on awarding the degree of Doctor of Philosophy”, approved by the Resolution of the Cabinet of Ministers of Ukraine dated January 12, 2022, No. 44.

The candidate Xu Jiashu deserves to be awarded the degree of Doctor of Philosophy in the field of knowledge 12 Information Technologies within the specialty 121 Software Engineering.

### **Reviewer:**

Head of the Department of Computer Systems Software, National Technical University of Ukraine “Igor Sikorsky Kyiv Polytechnic Institute”,  
Doctor of Technical Sciences,  
Associate Professor.

12 February 2024

Yevgeniya SULEMA

