Video Processing and Understanding Lab

Universidad Autónoma de Madrid

SI1/PJI/2019-00414 AISEEME (2020-2022)

Aiding diagnosis by self-supervised deep learning from unlabeled medical imaging

D5 v3

Results Report

Video Processing and Understanding Lab

Escuela Politécnica Superior

Universidad Autónoma de Madrid

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HISTORY

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1.0	01/03/2021	Pablo Carballeira López	First version
2.0	01/03/2022	Pablo Carballeira López	Second version
3.0	12/12/2022	Pablo Carballeira López	Third version

CONTENTS:

1. Introduction

This *report* summarizes the results obtained within the AISEEME project. The results and deliverables referenced here are available in the project website (http://www-vpu.eps.uam.es/projects/aiseeme/).

2. Publications

2.1. Journals

[1] Kirill Sirotkin, Marcos Escudero-Viñolo, Pablo Carballeira, Juan Carlos San Miguel, "Improved skin lesion recognition by a Self-Supervised Curricular Deep Learning approach", submitted to IEEE Journal of Biomedical and Health Informatics. Preprint available at: https://arxiv.org/abs/2112.12086)

2.2. Book Chapters

2.3. Conferences

[2] Kirill Sirotkin, Pablo Carballeira, Marcos Escudero-Viñolo, "A study on the distribution of social biases in self-supervised learning visual models", Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR), 2022, pp. 10442-10451. (https://openaccess.thecvf.com/content/CVPR2022/html/Sirotkin_A_Study_on_the_Distribution_of_Social_Biases_in_Self-Supervised_CVPR_2022_paper.html)

[3] Marcos Escudero-Viñolo, Alejandro López-Cifuentes, "CCL: Class-wise Curriculum Learning for class imbalance problems," CCL: Proceedings of the IEEE International Conference on Image Processing (ICIP), 2022, pp. 1476-1480.

2.4. PhD Thesis

2.5. Master Thesis

[4] Self-supervised Deep Learning for Image Classification, Zahid Hassan Tushar (advisors: Marcos Escudero Viñolo and Pablo Carballeira López), Trabajo Fin de Máster (Master Thesis), Máster Universitario en Image Processing and Computer Vision, Univ. Autónoma de Madrid, Jul. 2021

[5] Self-Supervised Curricular Learning For Chest X-Ray Image Classification, Iván de Andrés Tamé, (advisor: Pablo Carballeira López), Trabajo Fin de Máster (Master Thesis), Máster Universitario en Deep Learning for Audio and Video Signal Processing, Univ. Autónoma de Madrid, Jul. 2022.

[6] Learning supervised by synthetic data for Chest X-ray images, Eric Morales Agostinho, (advisor: Juan Carlos San Miguel Avedillo), Trabajo Fin de Máster (Master Thesis), Máster Universitario en Deep Learning for Audio and Video Signal Processing, Univ. Autónoma de Madrid, Sep. 2022.

2.6. Graduate Thesis

[7] Aprendizaje auto supervisado para reconocimiento de objetos, Alejandro Camacho Valladares (advisor: Marcos Escudero Viñolo), Trabajo Fin de Grado (Graduate Thesis), Grado en Ingeniería de Tecnologías y Servicios de Telecomunicación, Univ. Autónoma de Madrid, Jun. 2020.

[8] Detección precoz de cáncer de piel en imágenes basado en redes convolucionales, Francisco Javier Martín Ameneiro (advisor: Juan Carlos San Miguel Avedillo), Trabajo Fin de Grado (Graduate Thesis), Grado en Ingeniería de Tecnologías y Servicios de Telecomunicación, Univ. Autónoma de Madrid, Jun. 2020.

[9] Análisis de la evolución, en número y tamaño, de lesiones de piel en zonas amplias del cuerpo, Juan Antonio Álvarez Castillo (advisor: Jesús Bescós Cano), Trabajo Fin de Grado (Graduate Thesis), Grado en Ingeniería de Tecnologías y Servicios de Telecomunicación, Univ. Autónoma de Madrid, Jun. 2020.

[10] Detección de lesiones cutáneas en imágenes basado en redes generativas adversarias, Nicolás Alexander Wolyniec Rojas, (advisor: Juan Carlos San Miguel Avedillo), Trabajo Fin de Grado (Graduate Thesis), Grado en Ingeniería Informática, Univ. Autónoma de Madrid, Jul. 2020.

[11] Aplicación para el análisis de la evolución de lesiones de piel en zonas amplias del cuerpo, Daniel Armengod, (advisor: Jesús Bescós Cano), Trabajo Fin de Grado (Graduate Thesis), Grado en Ingeniería de Tecnologías y Servicios de Telecomunicación, Univ. Autónoma de Madrid, Jul. 2021.

[12] Análisis comparativo de aproximaciones basadas en Deep Learning en la competición "SIIM-ISIC Melanoma Classification 2020", Beatriz López Lozano, (advisor: Juan Carlos San Miguel Avedillo), Trabajo Fin de Grado (Graduate Thesis), Grado en Ingeniería Informática, Univ. Autónoma de Madrid, Feb. 2022.

[13] Análisis de la influencia del volumen de datos en el rendimiento de técnicas de aprendizaje autosupervisado para clasificación de imagen dermatoscópica, Álvaro Rojo Torío, (advisor: Pablo Carballeira López), Trabajo Fin de Grado (Graduate Thesis), Grado en Ingeniería de Tecnologías y Servicios de Telecomunicación, Univ. Autónoma de Madrid, Jul. 2022.

[14] Aprendizaje Auto-Supervisado para Dominios No Convencionales, María de la Torriente Gómez, (advisor: Marcos Escudero Viñolo), Trabajo Fin de Grado (Graduate Thesis), Grado en Ingeniería de Tecnologías y Servicios de Telecomunicación, Univ. Autónoma de Madrid, Jul. 2022.

3. Project Documents

3.1. Published Deliverables

3.1.1. D1.1 "System Infrastructure" (version 1: Jan 2021, version 2: Jan 2022, version 3: Aug. 2022)

This deliverable describes the activities related to the maintenance and update of the data processing infrastructure available at VPULab for the development of the tasks within the AISEEME project.

3.1.2. D1.2 "Evaluation datasets" (Jan. 2021)

This deliverable describes the work related to task T.1.2 "Collection and generation of datasets": the aim of this task is to support to other tasks by generating train and test data and associated evaluation methodologies. It includes the selection of appropriate datasets (images and associated ground-truth) and their generation if required.

3.1.3. D2 "Enabling technologies: algorithms and findings" (Mar 2022)

This deliverable describes the work related to tasks T2.1: "Self-supervised frameworks and pretext tasks", T2.2: "Skin lesion assessment" and T2.3: "Lung nodule malignancy evaluation". The aim of T2.1 is to compare state-of-the-art SSL approaches, exploring the influence of the CNN architecture, the pretext task, and the training schedule. The aim of tasks T2.2 and T2.3 is to compare deep learning state-of-the-art approaches to skin lesion assessment and lung nodule malignancy evaluation.

3.1.4. D3 "Design of a curriculum-based multi-task self-supervised learning regime" (Aug 2022)

This deliverable describes the work related to tasks T3.1: "Empirical definition and completion of a pretext task curriculum", T3.2: "Evaluation of the impact of the architecture and training schedule", and T3.3: "Self-paced multi-task self-supervision". The aim of tasks T3.1 and T3.2 is to define pretext tasks orderings (curricula) and evaluate the dependencies between the task curriculum and the training framework. Task 3.3 aims to define a learning framework that permits to automatically define a pretext task curriculum for a given target task.

3.1.5. D4 "Multi-task SSL framework for applications in medical imaging" (Dec 2022)

This deliverable describes the work related to tasks T4.1: "Multi-task SSL approaches for skin lesion assessment" and T4.2: "Multi-task SSL approaches for lung nodule malignancy detection". The aim of tis tasks is to evaluate multi-task SSL frameworks on the assessment of skin lesions and lung nodule malignancy.

4. Public Resources

4.1. Software

- SB-SSL: Source code for the paper: Kirill Sirotkin, Pablo Carballeira, Marcos Escudero-Viñolo, "A study on the distribution of social biases in self-supervised learning visual models", Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR), 2022, pp. 10442-10451. https://github.com/vpulab/SB-SSL
- CCL: Source code for the paper: Marcos Escudero-Viñolo, Alejandro López-Cifuentes, "CCL: Class-wise Curriculum Learning for class imbalance problems," CCL: Proceedings of the IEEE International Conference on Image Processing (ICIP), 2022, pp. 1476-1480. https://github.com/vpulab/CCL

5. Main Achievements of the Project

5.1. Main achievements during months 1 to 12

5.1.1. WP1: Infrastructure and datasets

- T1.1: Infrastructure update and maintenance (Deliverable D1.1)
  - Acquisition and configuration of new hardware for GPU-based processing of visual data
- T1.2: Collection and generation of datasets (Deliverable D1.2)
  - Collection of generic wide-range and narrow-domain image classification datasets
  - Collection of skin lesion and lung malignancy assessment datasets
  - Collection of additional X-Ray and COVID-19 datasets
  - Post-processing of three-dimensional lung CT scans

5.1.2. WP2: Enabling technologies

- T2.1: Self-supervised frameworks and pretext tasks (Deliverable D2)
  - Set up of an open-source self-supervised learning framework
  - Initial analysis of self-supervised model representations for an automatic definition of a pretext task curriculum
- T2.2: Skin lesion assessment (Deliverable D2)
  - Evaluation of state-of-the-art methods on the ISIC-17 and ISIC-19 skin lesion datasets
- T2.3: Lung nodule malignancy evaluation (Deliverable D2)
  - Preliminary evaluation of suitable reference benchmarks

5.1.3. WP3: Curriculum-based multi-task self-supervised learning

- T3.1: Empirical definition and completion of a pretext task curriculum (Deliverable D3)
  - Exploratory experiments on the transferability of features learned by SSL methods to different image datasets
- T3.2: Evaluation of the impact of the architecture and training schedule (Deliverable D3)
  - Preliminary experiments on the effect dataset size and CNN extraction layer
- T3.3: Self-paced multi-task self-supervision (Deliverable D3)
  - No relevant activity on this task during this period

5.1.4. WP4: Use cases in medical imaging

- T4.1: Multi-task SSL approaches for skin lesion assessment (Deliverable D4)
  - No relevant activity on this task during this period
- T4.2: Multi-task SSL approaches for lung nodule malignancy detection (Deliverable D4)
  - No relevant activity on this task during this period

5.1.5. WP5: Management and dissemination

- T5.1: Management
  - Relevant workplan and budget adjustments performed due to the COVID-19 pandemic
  - Ethical committee approval for a collaborative project with Puerta de Hierro hospital
- T5.2: Dissemination
  - Publication of four Bachelor Thesis.

5.2. Main achievements during months 13 to 24

5.2.1. WP1: Infrastructure and datasets

- T1.1: Infrastructure update and maintenance (Deliverable D1.1)
  - Acquisition and installation of one additional GPU for the VPULab processing network
  - Initiated the deployment of cluster management software to maximize the usage of the computing resources of the VPULab processing network.
- T1.2: Collection and generation of datasets (Deliverable D1.2)
  - Collection of new datasets for: bias identification in SSL methods, skin lesion provided by project observer, Chest X-Ray for pneumonia recognition, and eye fundus.

5.2.2. WP2: Enabling technologies

- T2.1: Self-supervised frameworks and pretext tasks (Deliverable D2)
  - Study on the distribution of social biases in self-supervised learning visual models
- T2.2: Skin lesion assessment (Deliverable D2)
  - Completed the evaluation of state-of-the-art methods for skin lesion assessment.
- T2.3: Lung nodule malignancy evaluation (Deliverable D2)
  - Evaluated the state-of-the-art approach for pneumonia detection and COVID-origin assessment

5.2.3. WP3: Curriculum-based multi-task self-supervised learning

- T3.1: Empirical definition and completion of a pretext task curriculum (Deliverable D3)
  - Design and implementation of a framework to train visual models based on CNN architectures using a sequence of different SSL pretext tasks.
- T3.2: Evaluation of the impact of the architecture and training schedule (Deliverable D3)
  - Initiated the evaluation of learning-rate optimization in the training scheme of T3.1
- T3.3: Self-paced multi-task self-supervision (Deliverable D3)
  - Initiated the comparative analysis of internal representations learned by SSL methods

5.2.4. WP4: Use cases in medical imaging

- T4.1: Multi-task SSL approaches for skin lesion assessment (Deliverable D4)
  - Evaluation of the performance of the training scheme in T3.1 in skin lesion assessment.
- T4.2: Multi-task SSL approaches for lung nodule malignancy detection (Deliverable D4)
  - No relevant activity on this task during this period

5.2.5. WP5: Management and dissemination

- T5.1: Management
  - Two support technicians have been hired to support the research activities of the project.
- T5.2: Dissemination
  - Paper submitted to IEEE Journal of Biomedical and Health Informatics JBHI. The preprint is available in ArXiv.
  - Paper submitted to IEEE/CVF Conference on Computer Vision and Pattern Recognition.

5.3. Main achievements during months 25 to 33

5.3.1. WP1: Infrastructure and datasets

- T1.1: Infrastructure update and maintenance (Deliverable D1.1)
  - Acquisition and installation of 6 hard drives totaling 12TB of storage in the processing network of the VPULab.
- T1.2: Collection and generation of datasets (Deliverable D1.2)
  - Collection of new datasets for pathology recognition in Chest X-Ray images.

5.3.2. WP2: Enabling technologies

- T2.1: Self-supervised frameworks and pretext tasks (Deliverable D2)
  - No relevant activity on this task during this period.
- T2.2: Skin lesion assessment (Deliverable D2)
  - No relevant activity on this task during this period.
- T2.3: Lung nodule malignancy evaluation (Deliverable D2)
  - Updated state-of-the-art approaches for pneumonia recognition in CXR images of COVID patients, and state-of-the-art approaches for synthetic CXR image generation.

5.3.3. WP3: Curriculum-based multi-task self-supervised learning

- T3.1: Empirical definition and completion of a pretext task curriculum (Deliverable D3)
  - No relevant activity on this task during this period
- T3.2: Evaluation of the impact of the architecture and training schedule (Deliverable D3)
  - Analysis of the impact of dataset size in the performance of curriculum-based multi-task self-supervised learning regimes.

  - Improved method for automatic learning-rate and batch-size selection by evaluation of early-stopping training results.
- T3.3: Self-paced multi-task self-supervision (Deliverable D3)
  - Integration of a method for automatic learning-rate and batch-size selection by evaluation of early-stopping training results.
  - Integration of knowledge-distillation strategies for performance improvement in curriculum-based multi-task self-supervised learning regimes.
  - Extension of the comparative analysis of internal representations learned by different SSL methods

5.3.4. WP4: Use cases in medical imaging

- T4.1: Multi-task SSL approaches for skin lesion assessment (Deliverable D4)
  - Improvement of the performance of skin lesion assessment by optimum hyperparameter selection (integration of the developments in T3.2)
- T4.2: Multi-task SSL approaches for lung nodule malignancy detection (Deliverable D4)
  - Evaluation of the performance of the training scheme designed in T3.1 in the pneumonia recognition for CXR images.
  - Creation of synthetic CXR dataset and analysis of its influence in the training of deep learning models for pathology recognition in CXR images.

5.3.5. WP5: Management and dissemination

- T5.1: Management
  - Two support technicians have been hired to support the activities in T4.2.
- T5.2: Dissemination
  - Paper accepted and presented in the IEEE/CVF Conference on Computer Vision and Pattern Recognition 2022 Main Conference.
  - Paper accepted and presented at IEEE International Conference on Image Processing.