UNIVERSIDADE DA CORUÑA USC UNIVERSIDADE DE SANTIAGO DE COMPOSTELA Universidade Vigo

# Deep Learning (Master's degree in AI)

# Practice 3.1 - GANs (2022-2023)

**INSTRUCTIONS:**

- **Deadline:** May 19, 16:00.
- **Objectives**
  The goal of this laboratory is to investigate Generative Adversarial Networks (GANs) and compare them against Variational Autoencoders (VAEs).
- **Dataset**
  We will use the *celebA Dataset*, which contains $> 2 \times 10^5$ of faces. The dataset is available from: `https://www.kaggle.com/datasets/jessicali9530/celeba-dataset`.
- **Tasks**

  1. **Preliminary Research:** Begin by reviewing the fundamental concepts of Variational Autoencoders (VAEs), including their architecture and application as generative models. Similarly, study the basics of Generative Adversarial Networks (GANs), specifically focusing on Wasserstein GAN with Gradient Penalty (WGAN-GP) and the Deep Convolutional GANs (DCGANs). Familiarize yourself with their architecture and core components, such as the overall loss function of the generator and discriminator.
  2. **Data Preprocessing:** Download the CelebA dataset and perform any necessary preprocessing steps, such as normalization and resizing, to ensure the data is suitable for training GANs and VAEs.
  3. **Training Comparisons and Evaluations:**
     *a*) Train the VAE and WGAN-GP models on the CelebA dataset starting with the parameters provided in the lab notebooks. Experiment with hyperparameters of the models to obtain the best results. Utilize the provided notebook to incorporate code and calculations required for obtaining the Fréchet Inception Distance (FID) for generated samples at various points during the training process.
     *b*) Experiment with modifying the parameters and/or architectures to enhance the performance of each network. Implement at least one change in the GAN architecture as suggested during the lecture, such as adding more convolutional layers, incorporating a residual connection, or employing dilated convolutions. Provide a clear explanation of how these modifications influence the training process.

4. **Exploring the Latent Space:** Evaluate the results by examining the images generated by the VAE and GAN architectures. Experiment with interpolation of points in the latent space that correspond to real images, and observe the images produced from this interpolation. Additionally, generate and analyze some random images to further understand the capabilities of the trained models.
5. **Comparative Analysis and Reporting:** Compare the performance of GANs and VAEs in a comprehensive lab report that details your investigation of the strengths and weaknesses of each architecture. Present your results and provide a clear description of your findings. Discuss any general observations or insights you've gained regarding the training process for both GANs and VAEs.

- **Submission**
  - Training GANs is computationally intensive. For this lab practice, you can reduce the size of the image considerably to obtain results.
  - The exercises will be developed using Jupyter Notebooks.
  - Create a notebook for each task above mentioned and put them together in a ZIP file for submission.
  - **Each notebook should include**:
    - The practice can be carried out alone or in pairs, so the first cell of the notebook must be the full names of the authors.
    - The code for each of the models developed should be included and it should be a complete ML process: data loading and manipulation, network creation, training and results.
    - The notebook will be saved with the results of its execution included.
    - The code shall be accompanied by cells with an explanatory report containing a description of the process followed, detailing the problems encountered and justifying the decisions taken. It should also include a section on results and discussion of them.
  - **Submission process**
    - The exercises will be submitted using the virtual campus of each university:
      - Universidade da Coruña: `https://campusvirtual.udc.gal/`
      - Universidade de Vigo: `https://moovi.uvigo.gal/`
      - Universidade de Santiago de Compostela: `https://cv.usc.es/`
    - Each member of the practice group must submit the notebook in their corresponding Moodle task.
    - There is a strict deadline for each assignment. Past due submissions will be rejected.

- **Evaluation criteria**
  - Correct implementation of VAE and GAN architectures
  - Appropriate data preprocessing and training techniques
  - Evaluation and comparison of VAE and GAN performance
  - Quality and clarity of the report or presentation