Advanced Course on Deep Learning and Geophysical Dynamics.

November-December 2021

Advanced Course on Deep Learning and Geophysical Dynamics.

First edition of the course in the framework of AI Chairs OceaniX, DL4CLIM, ANITI-DAML and AI4Child (Prof. R. Fablet, P. Gallinari, S. Gratton and F. Rousseau) and LEFE-MANU program.

General objectives:

- Theoretical aspects of deep learning and its application to geophysical dynamics, especially regarding the exploitation of physical priors.

- Practice-oriented training for the implementation of deep learning schemes for geophysical dynamics

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PROJET FINANCÉ PAR L'ANR - PROJECT FUNDED BY THE ANR - ANR

ISblue

IMT Atlantique
Bretagne-Pays de la Loire
École Mines-Télécom

Practical information

All information available on discord server DLGD2021. Invitation link: https://discord.gg/KnjNFc2f

Remote participation through the following zoom link: https://imt-atlantique.zoom.us/j/98658614714?pwd=SGwrazVDWVNNeEc4dlZ3aFJpdW9UUT09

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On-site participation:

- PNBI, 2nd floor, conference room on Nov. 16, Nov. 23, Nov. 30 and Dec. 7
- IMT Atlantique, morning lecture (room B01-10), project session (room B01-14)

Organization of the course: Lectures

November 9. 9h30-12h30

Introduction to Deep Learning and Differentiable Physics

F. Rousseau

November 16. 9h30-12h30

Deep Learning and Optimisation

L. Drumetz

S. Gratton

November 23. 14h30-17h30

Deep Learning and Generative Models

P. Gallinari

November 30. 9h30-12h30

Deep Learning and Dynamical Systems

S. Ouala

December 7. 9h30-12h30

Deep Learning and Inverse Problems

R. Fablet

Project Sessions

All resources available at https://github.com/CIA-Oceanix/DLGD2021

Organization of the course: Project Sessions

Nov. 9. 14h00-17h00

Introduction to Pytorch and Pytorch Lightning + Session #1

Q. Febvre

Nov. 16. 14h00-17h00 **Session #2**

Nov. 23. 9h30-17h30 **Session #3**

Nov. 30. 14h00-17h00 **Session #4**

Dec. 7. 14h00-17h00 **Session #5**

Theme #1: Interpolation

M. Beauchamp

Theme #2: Forecasting

S. Ouala

S. Benaïchouche

Theme #3: Data Assimilation

M. Beauchamp

Q. Febvre

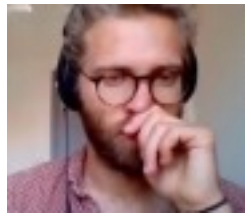
Theme #4: Neural closures

S. Ouala

Theme #5: Segmentation

A. Colin

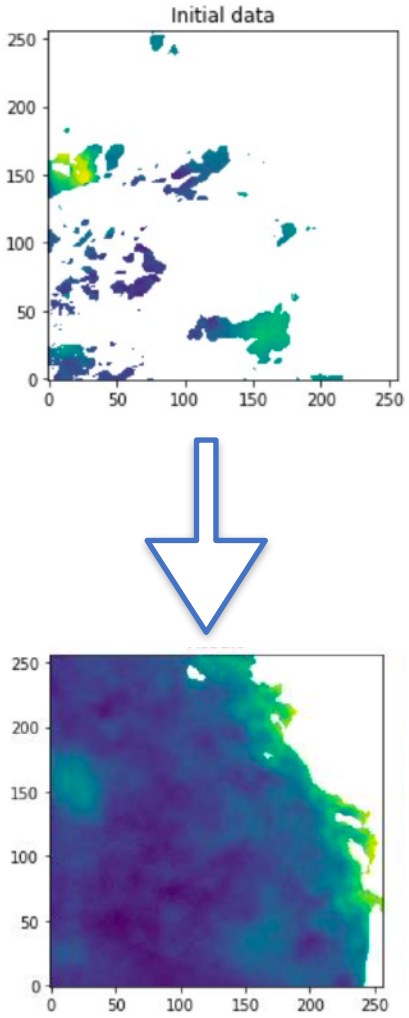
Theme #6: GAN & trajectories

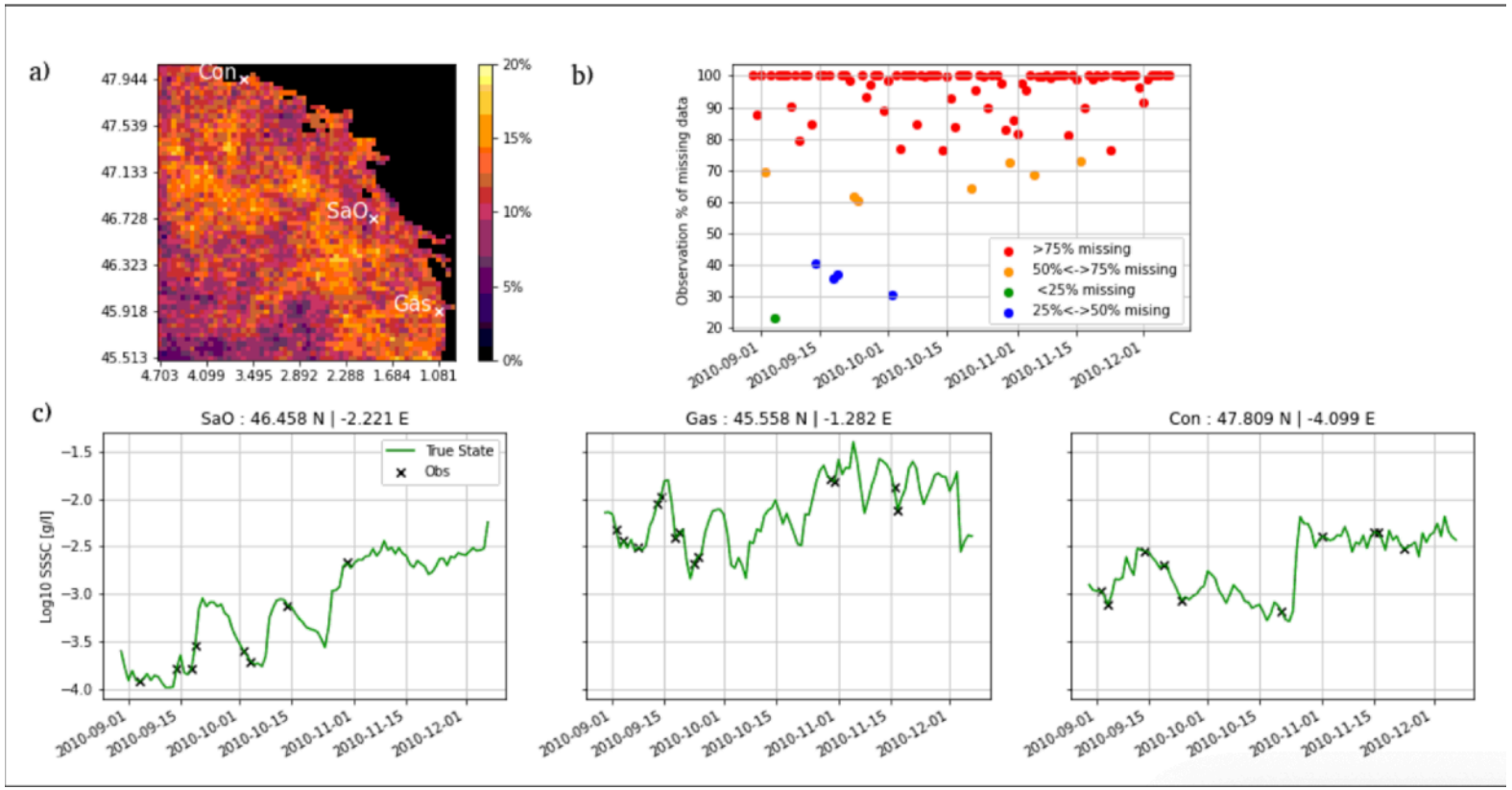


A. Roy

Project theme #1: space-time interpolation

Proposed case-study on satellite-derived sea surface suspended sediments





Supporting paper: https://www.mdpi.com/2072-4292/13/17/3537#

Project theme #2: short-term forecasting

Proposed case-study on wind short-term forecasting (Meteonet challenge/dataset)

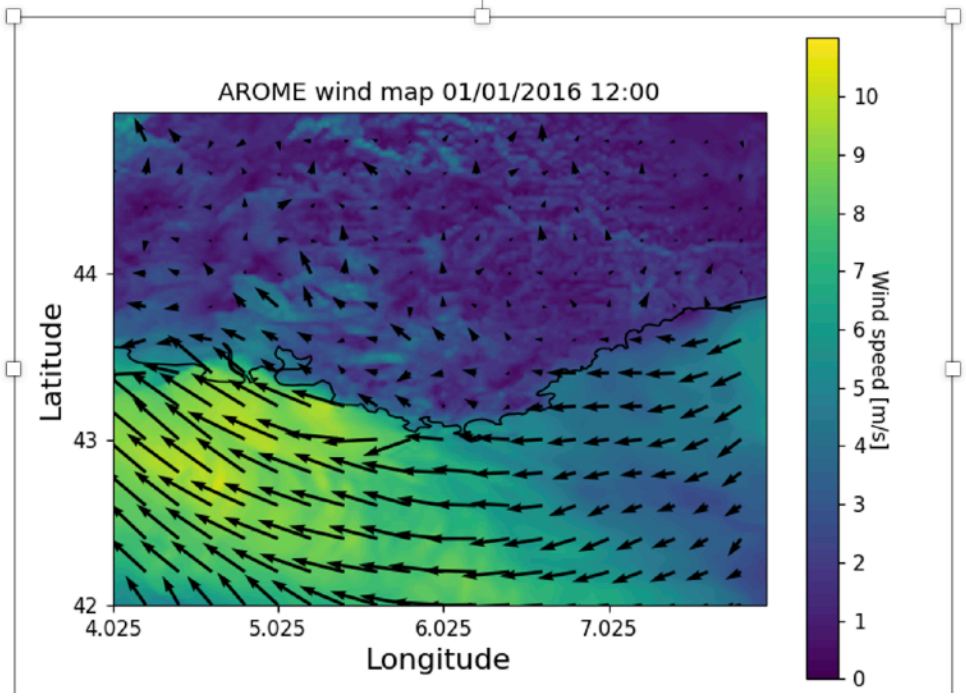
Time series forecasting :
- Using past data
- Using ground stations data
- 2D models, radar data

→ Wind power production and O&M

Input	Reference methods	Output
• Ground stations • NWP data • Radar / Satellite	LSTM RNN …	• Wind time series t + 6min → t + 6h

A Review On The Hybrid Approaches For Wind Speed Forecasting – Vidya et. al. 2019

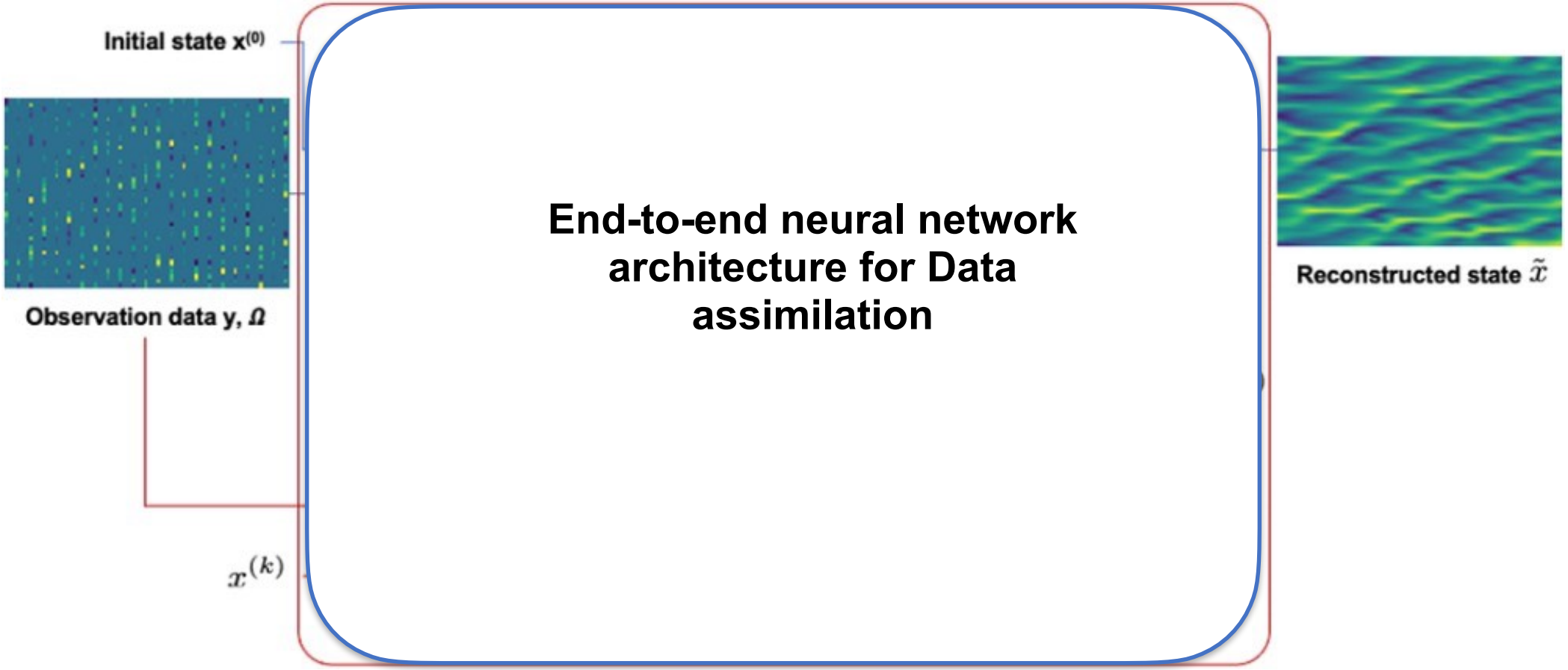
How to complement Numerical Weather Prediction models on short time scale using Deep Learning ?



Other possible “toy” case-studies using chaotic systems (eg, Lorenz systems)

Project theme #3: Data Assimilation

Proposed case-study on Lorenz-63/Lorenz-96 systems with partial observations



https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2021MS002572

Project theme #4: Neural closures

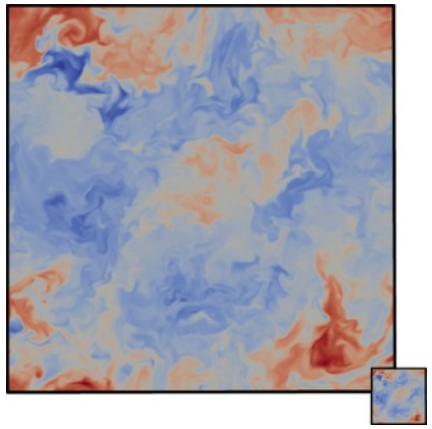
Proposed case-study on 3D turbulence and Burger's equation

Take a high resolution state y and its approximated state x,

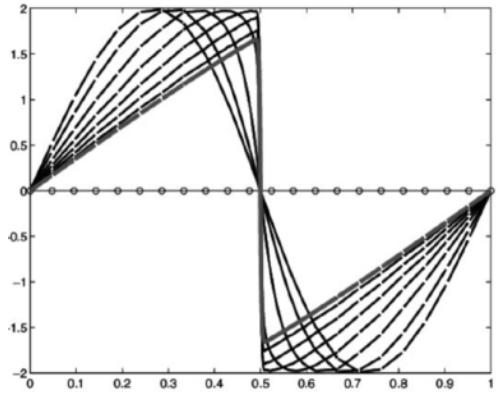
$$\partial_t y = \mathcal{H}_{\mathcal{F}}[y], \qquad y \in \Omega$$
$$\partial_t x + R = \mathcal{H}_{\mathcal{R}}[x], \qquad x \in \omega$$

where $\mathcal{H}_{\mathcal{R}}[x]$ and R are much faster to compute than $\mathcal{H}_{\mathcal{F}}[y]$.

3D turbulence (Non-differentiable forward model)



1D Burger equation (Differentiable forward model)



Project theme #5: segmentation

Proposed case-study on cloud cover nowcasting (Meteonet challenge/dataset)

Cloud cover nowcasting

- Satellite cloud index
- Radar data
- Infrared
- Water vapor
- Visible

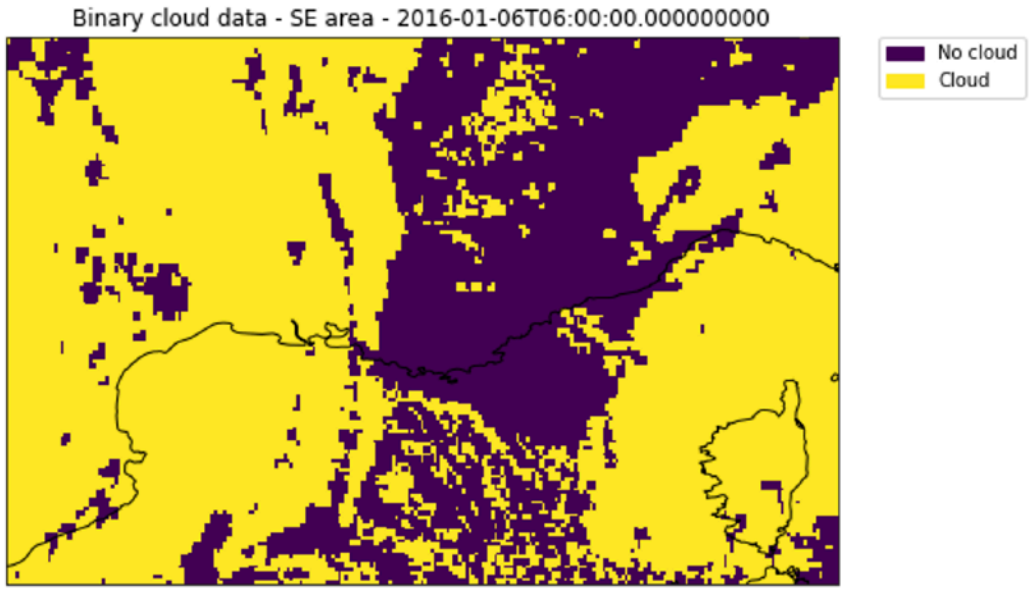
→

- Satellites line of sight
- Solar power prouction

How to use satelite products for cloud nowcasting ? Can it beat NWP model ?

Input	Reference methods	Output
• Satellite cloud index • (Satellite water column • Satellite visible • Satellite IR • Radar)	CNN U-Net	• Spatio-temporal cloud coverage

Cloud Cover Nowcasting with Deep Learning – Berthomier et. Al. arXiv 2020



Supporting paper: https://arxiv.org/abs/2009.11577

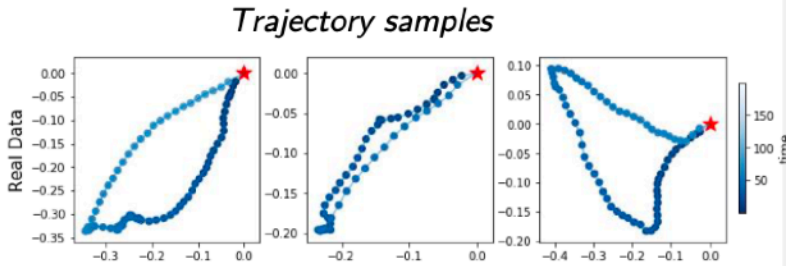
Project theme #5: Trajectory and GANs

Proposed case-study on seabird trajectories

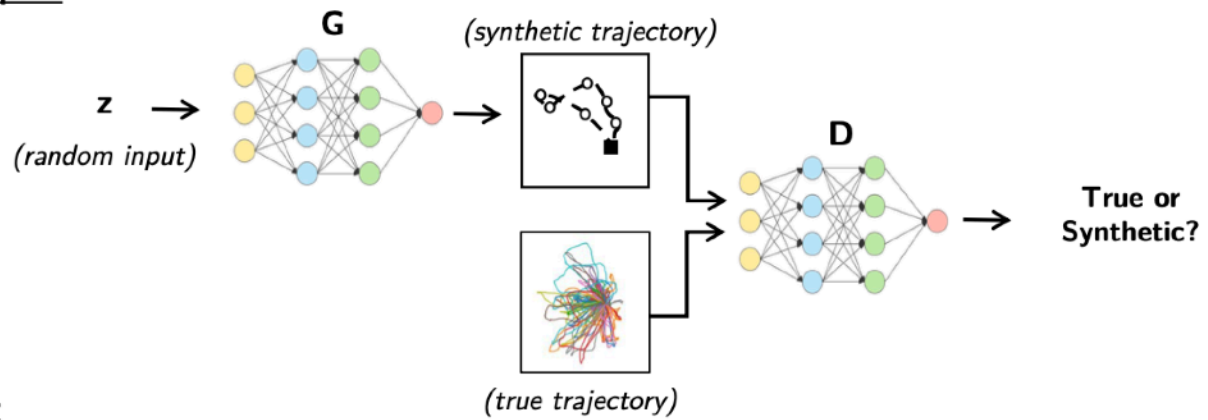
→ Dataset example :

158 foraging trips of 3 seabird species

Species	Country	Nb of trips
Sula sula	Brazil	30
Sula dactylatra	Brazil	50
Sula variegata	Peru	78



→ GAN example:



→ References:

https://github.com/AmedeeRoy/BirdGAN

https://www.biorxiv.org/content/10.1101/2021.09.27.461940v1.full.pdf

Organization of the course: Project Sessions
Proposed workplan

Sessions #1-2

- **Selection of the project theme for each group**
- **Discovery of the dataset/case-studies**
- **Problem Statement:**
  - **Which problem/ inputs/outputs ?**
  - Which training / validation / test dataset ?
  - Which training criterion / scheme ?
  - Which performance metrics ?
  - Selection of three approaches / models for inter-comparison purposes

- **Deliverable:** 2-to-4-slide presentation (Nov. 17), to be posted on discord

Sessions #3-4

- **Implementation and evaluation of the considered approaches**

- **Tentative workplan:**
  - **First approach/baseline:** Nov. 23
  - **Refinement and other approaches:** Nov. 30

- **Deliverable:** updated presentation with baseline approach (Nov. 23)

Sessions #5

- **Synthesis**
- **Short presentation (~ 10',** (virtual) poster session**)**
- **Deliverable:** notebooks or a git repo (better)