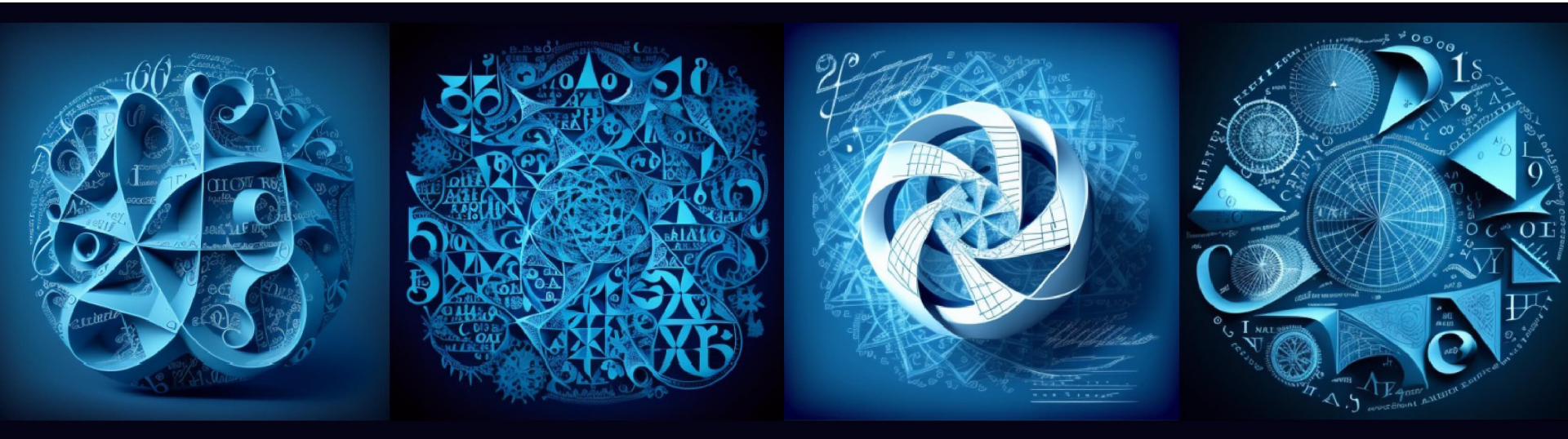
Welcome to ECE 594n

Equivariant, Geometric and Topological Deep Learning

Nina Miolane, Assistant Professor @ Geometric Intelligence Lab



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Equivariant, Geometric and Topological Deep Learning

An approach reminiscent of the most transformative discoveries of the history of science.

Let’s have a look at one of the oldest sciences: Physics.

Geometry: The Key To General Relativity

Topology: The Key to Quantum Computing?

JULY 20, 2017 | 10 MIN READ

The Strange Topology That Is Reshaping Physics

Topological effects might be hiding inside perfectly ordinary materials, waiting to reveal bizarre new particles or bolster quantum computing

BY DAVIDE CASTELVECCHI & NATURE MAGAZINE

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NEWS | 09 May 2023

Physicists create long-sought topological quantum states

Exotic particles called nonabelions could fix quantum computers' error problem.

Equivariance: The Key To Grand Unifications

$\mathbb{R}^4$: space time

$\mathbb{C}^3$: quark colors

$F(\mathbb{R}^4, \mathbb{C}^3)$:
fields of relativistic quarks

Lorentz group $SO(3,1)$ action

Color group $SU(3)$ action

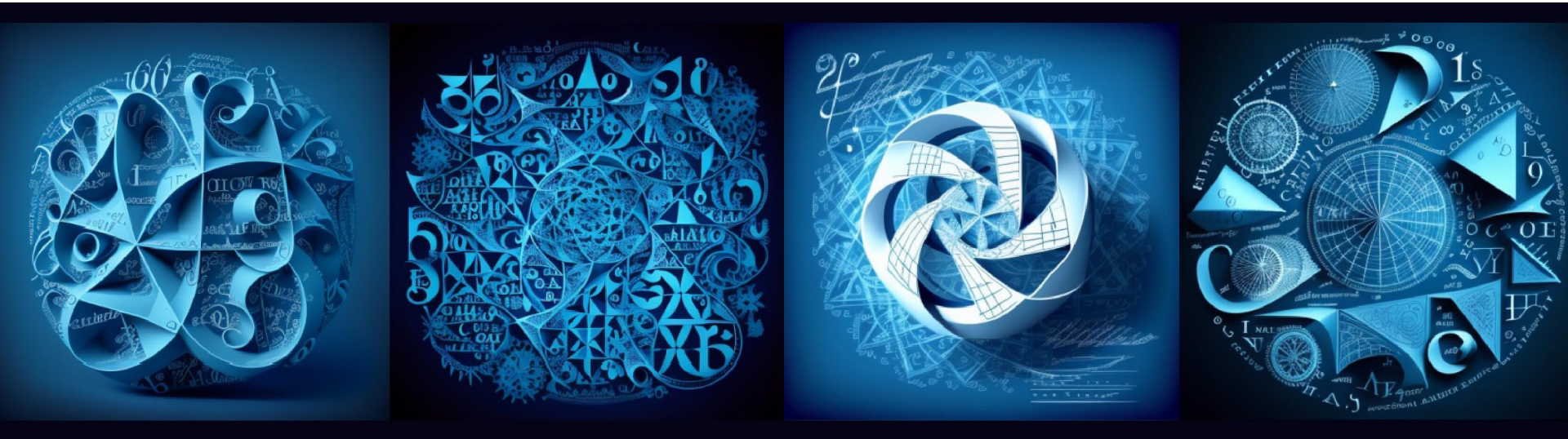
Two group actions: G_A $F(A, B)$ G_B

Scientists have successfully leveraged concepts of:

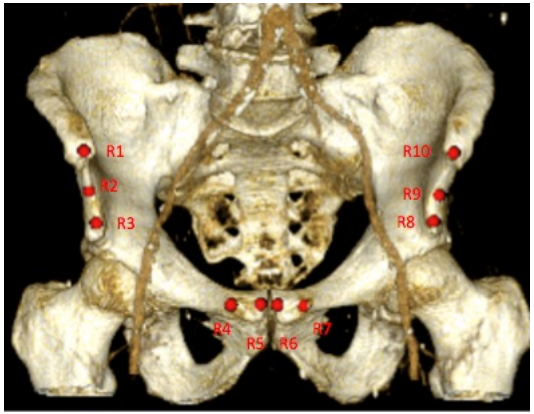
- Geometry
- Topology
- Equivariance

To explain the most intricate natural phenomena.

Can we use similar concepts to understand and build AI?



The data has an air of "déjà vu"



labels of landmarks

$\{1, .., K\}$

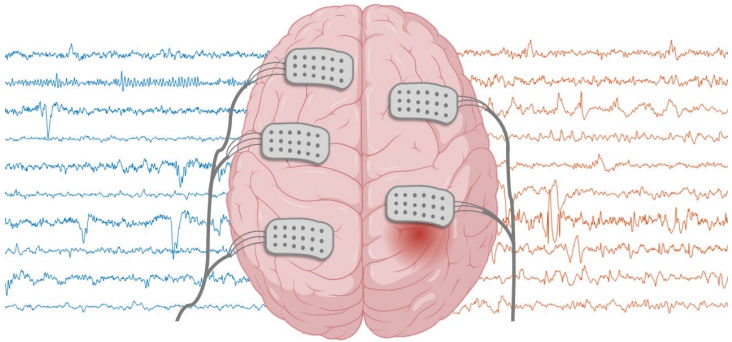
$F(\{1, \dots, K\}, \mathbb{R}^3)$:
anatomical landmarks

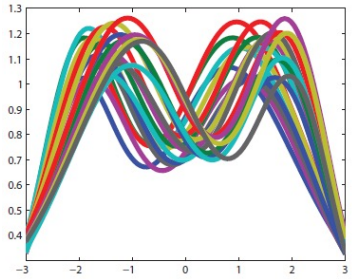
$\mathbb{R}^3$

$SE(3)$-action.

permutations
group action

The data has an air of “déjà vu”





Translations

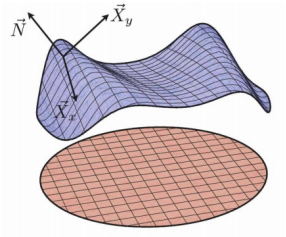
[0,1]

$F([0,1], \mathbb{R})$:
1-D signals

$\mathbb{R}$

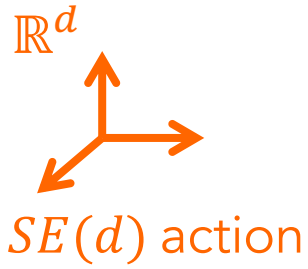
Scalings

The data has an air of "déjà vu"



$\boldsymbol{M}$

Imm(M, $\mathbb{R}^{\boldsymbol{d}}$):
shape spaces



Change of variables

The Erlangen Program

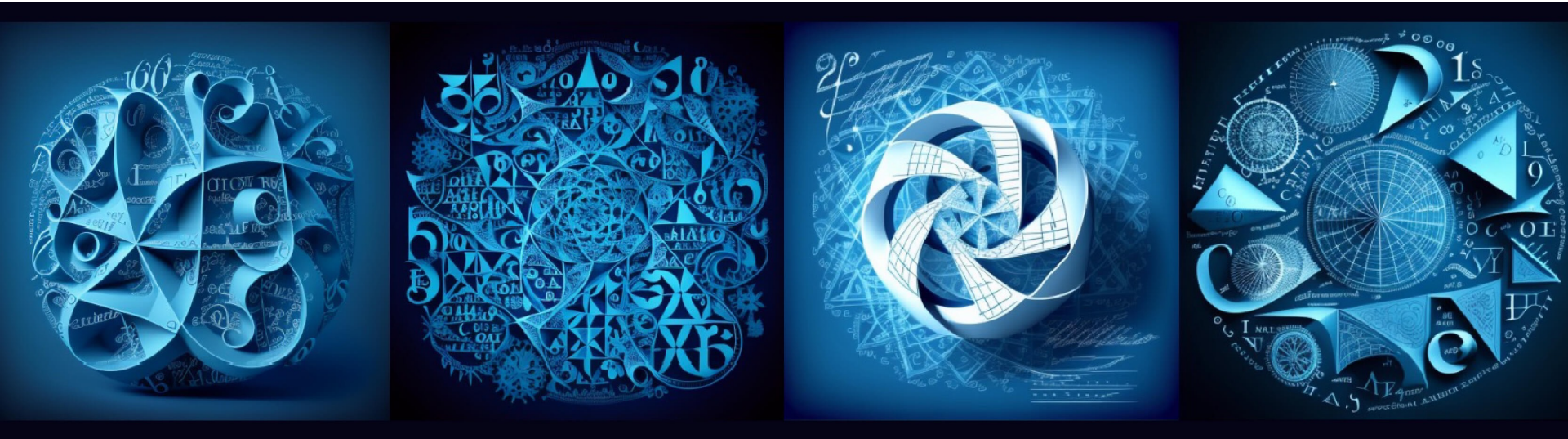
https://www.youtube.com/watch?v=w6Pw4MOzMuo&list=PPSV&t=27s

We need some form of unification in the spirit of the Erlangen program, to really understand deep learning and AI.

With two main goals:

1. Give a single framework to understand current neural networks.
2. Get intuition on how to build future deep learning models.

The goal of this class is to read, understand and apply cutting-edge research in equivariant, geometric, and topological deep learning.



Syllabus

You will:
-Get an understanding of the Erlangen program for deep learning.
-Become skilled in reading cutting-edge deep learning papers.
-Learn how to implement these methods.

Requirements:
Understanding of Deep Learning, Proficiency in Python.

Classes

- Mondays, Wednesdays 12:00 – 1:00 PM in PHELP 1431
- Slides: ECE 594n's GitHub:

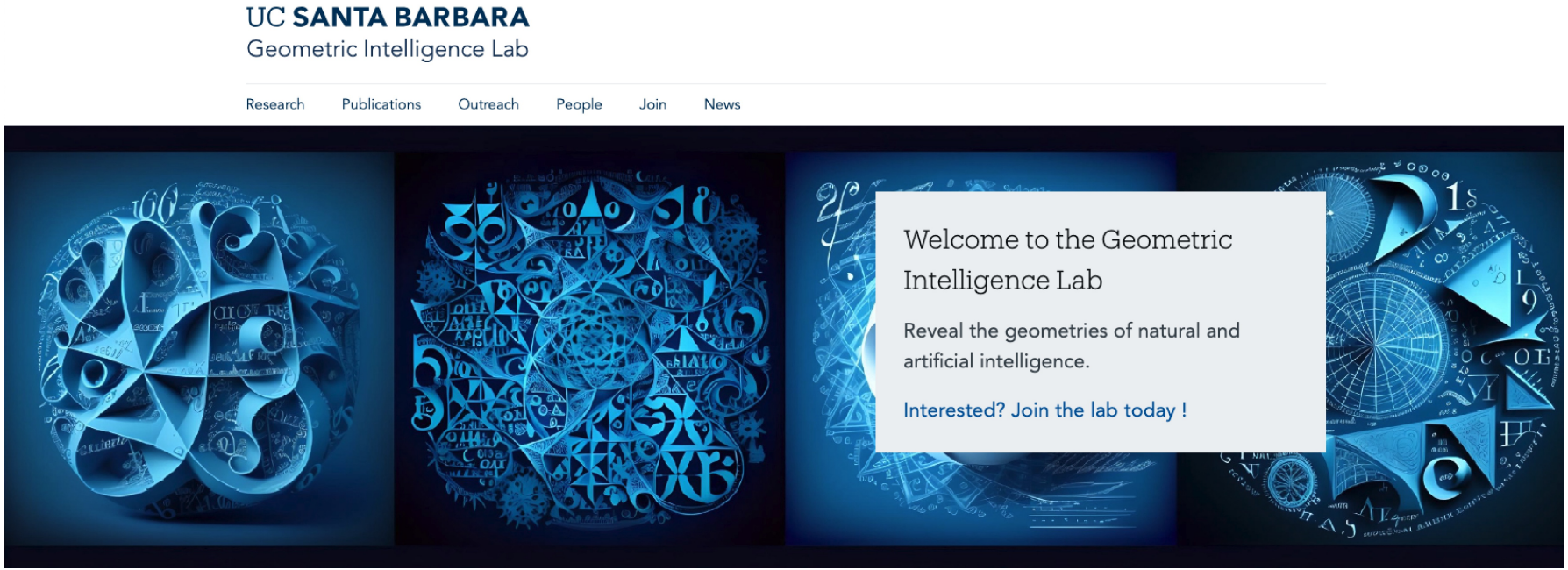
https://github.com/geometric-intelligence/ece594n.

Notes:

- Do not enroll in other courses whose schedule is conflicting with this class.
- If you cannot attend all lectures, please drop this class.

Instructor: Nina Miolane (me)

- Office Hours: Mondays 1:00 – 1:50 in class.



Slack

- Join the class Slack workspace via this link using your ucsb email address

https://join.slack.com/t/slack-uec3482/shared_invite/zt-2a6b9zrsy-mRWyuEYjccMESU4cSHZJyA

- Slack is our preferred communication channel.
- Avoid emails if possible, write on Slack.

Python and Jupyter Notebooks

We will use:

- Python version 3.8 or higher as our programming language,
- Jupyter notebooks to run Python interactively in a web browser.

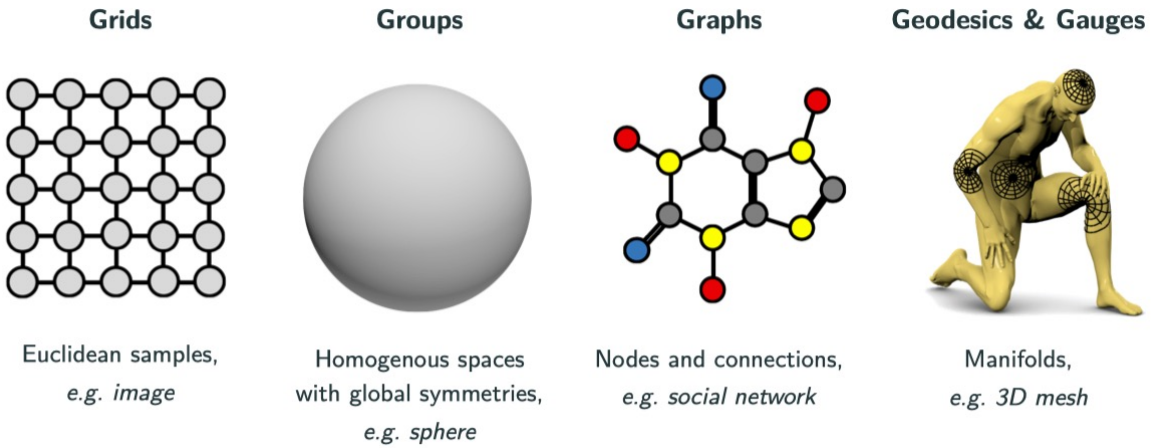
- You should download Anaconda which will install everything you need to run Python 3.8+ and Jupyter notebooks:
- Anaconda: https://www.anaconda.com/download

- Then: `conda env create -f environmnent.yml`.

Textbook

Bronstein et al. Geometric Deep Learning: Grids, Groups, Graphs, Geodesics, and Gauges (2021).

https://arxiv.org/abs/2104.13478



Outline

Literature:

- Symmetries
- Point Clouds and Meshes
- Graph And Topological Domains
- Transformers and Attention-Based Models

Applications:

- Projects

Grading

- HW Paper:
  - Present a paper in class. Code it. 50%.
- HW Project:
  - Analyze data with Equivariant, Geometric or Topological Deep Learning. 30%.
- Participation in class: 20%

HW Papers

- Individual.
- Details on the README:

https://github.com/geometric-intelligence/ece594n/tree/main/hw_papers

HW Project

- By team of 3-4.
- Details on the README:

https://github.com/geometric-intelligence/ece594n/tree/main/hw_projects

Questions?

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