



# Cohere For AI

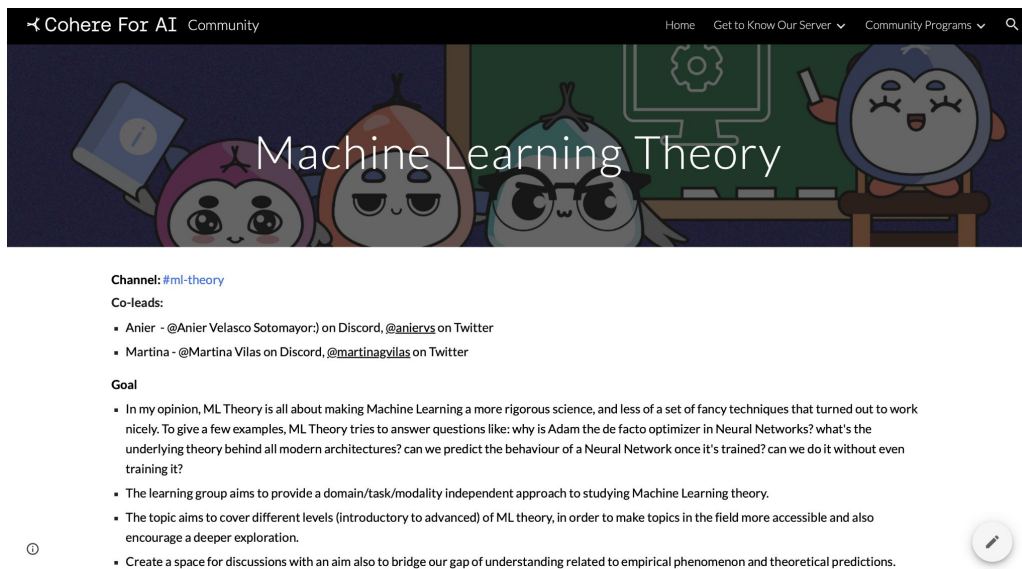
Exploring the unknown, together



# Geometric Deep Learning Cohort

# ML Theory resources (+recordings)

<https://sites.google.com/cohere.com/c4ai-community/community-programs/ml-theory>

The screenshot shows the 'Machine Learning Theory' community page on the Cohere For AI website. The header includes the Cohere For AI logo and navigation links for Home, Get to Know Our Server, and Community Programs. The main banner features a dark background with several cute, stylized characters and the text 'Machine Learning Theory'. Below the banner, the page lists the channel as #ml-theory, identifies co-leads Anier and Martina with their social media handles, and outlines the goal of the community: to make machine learning theory more rigorous and accessible through discussions and recordings.

✈ Cohere For AI Community

Home Get to Know Our Server Community Programs

## Machine Learning Theory

Channel: [#ml-theory](#)

Co-leads:

- Anier - [@Anier Velasco Sotomayor](#) on Discord, [@anierys](#) on Twitter
- Martina - [@Martina Vilas](#) on Discord, [@martinagvilas](#) on Twitter

Goal

- In my opinion, ML Theory is all about making Machine Learning a more rigorous science, and less of a set of fancy techniques that turned out to work nicely. To give a few examples, ML Theory tries to answer questions like: why is Adam the de facto optimizer in Neural Networks? what's the underlying theory behind all modern architectures? can we predict the behaviour of a Neural Network once it's trained? can we do it without even training it?
- The learning group aims to provide a domain/task/modality independent approach to studying Machine Learning theory.
- The topic aims to cover different levels (introductory to advanced) of ML theory, in order to make topics in the field more accessible and also encourage a deeper exploration.
- Create a space for discussions with an aim also to bridge our gap of understanding related to empirical phenomenon and theoretical predictions.



# What's ML Theory?

1. Making Machine Learning a rigorous science.
2. Understanding reasons behind a particular architecture.
3. Discovering and explaining the behaviour of models.
4. Designing the best (with guarantees) algorithm for training the network.

Statistical Physics

Mechanistic Interpretability

Modern Geometry

Abstract Algebra

Complexity Theory



# ML Theory Leads

Martina Vilas

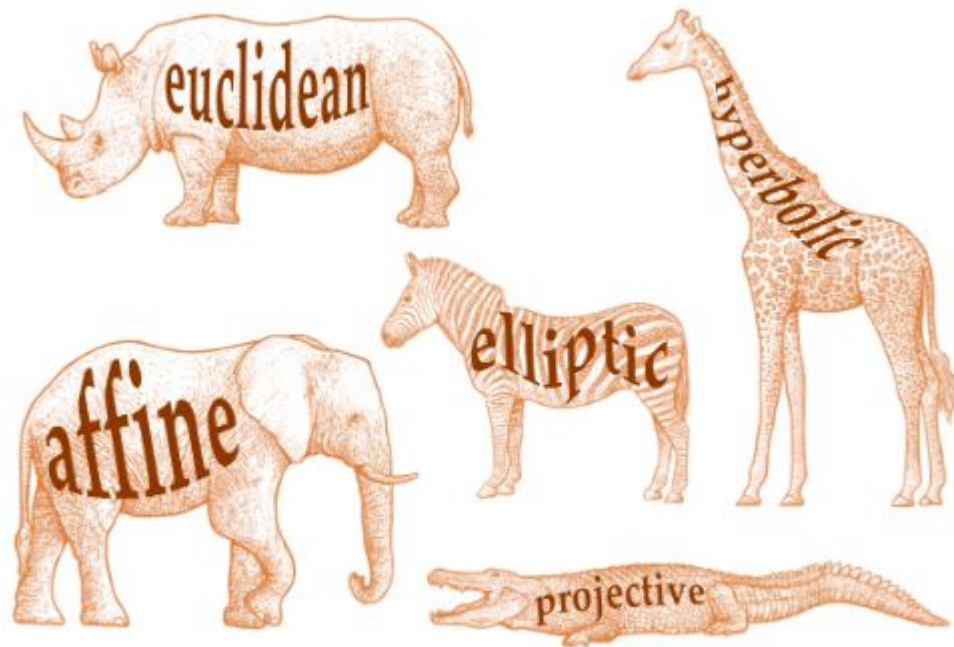


Anier Velasco



# The need for unification

# Zoo of geometries (XIX century)



## Zoo of geometries (XIX century)

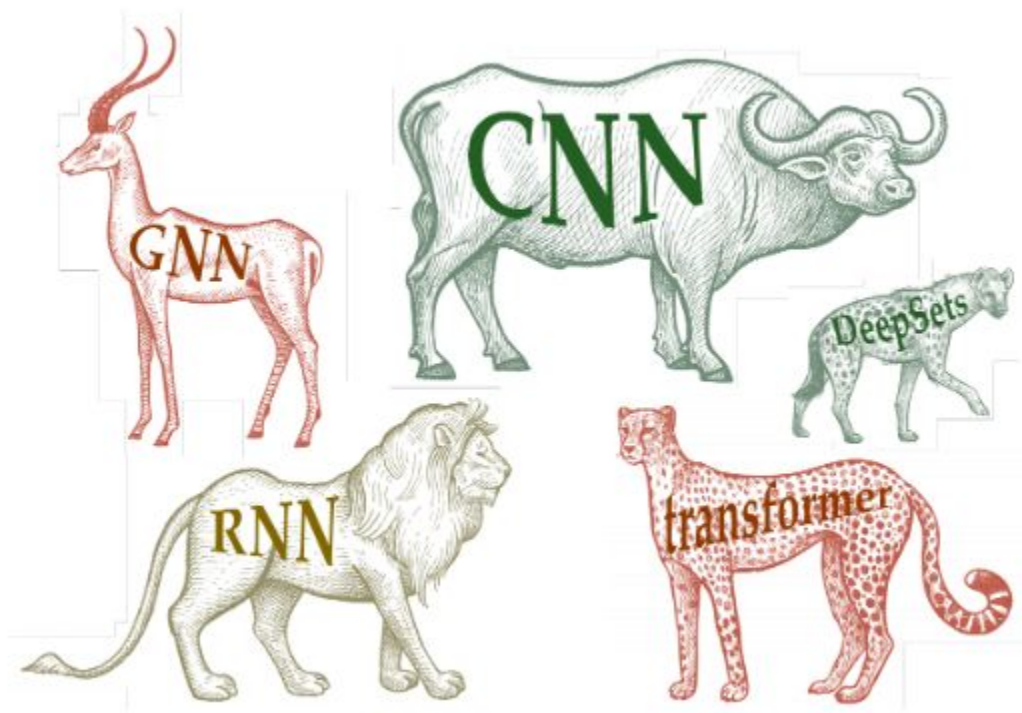


Unifying geometries through  
**symmetries**

Formalized through **group  
theory**



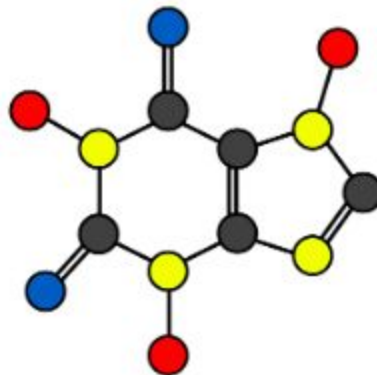
# Zoo of DL architectures (late 2010s)



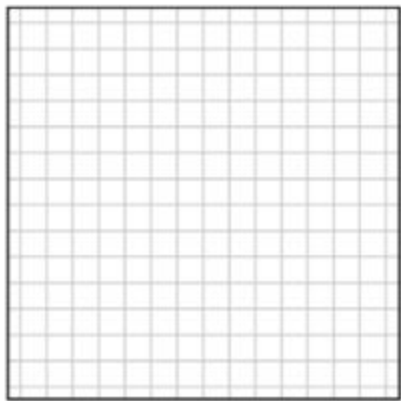
## Convolutional Neural Network



## Graph Neural Network

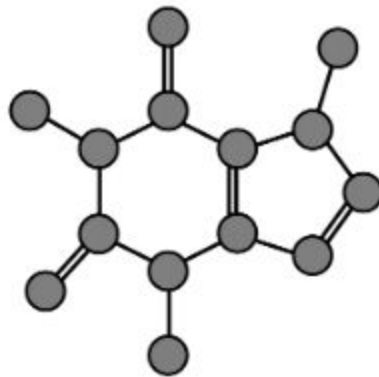


## Convolutional Neural Network



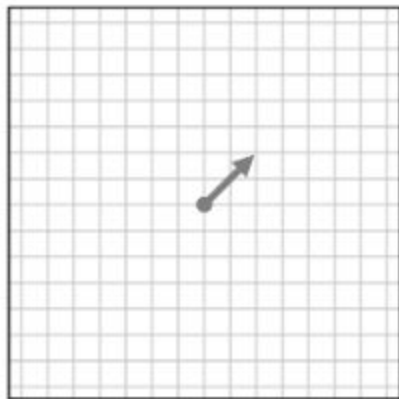
Underlying domain:  
grid

## Graph Neural Network



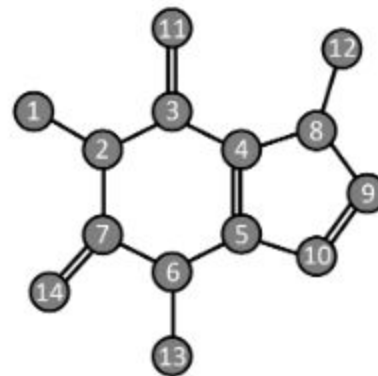
Underlying domain:  
graph

## Convolutional Neural Network



Symmetry:  
Translation

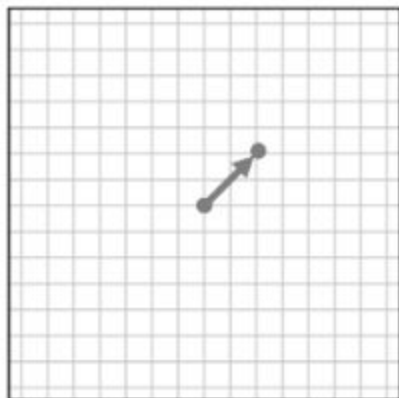
## Graph Neural Network



Symmetry:  
Permutation

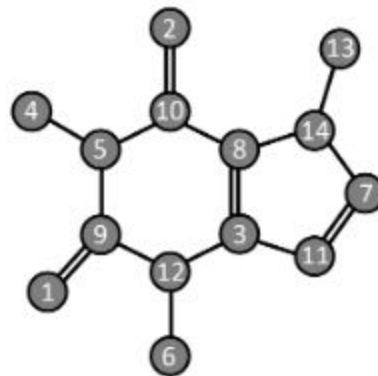


## Convolutional Neural Network



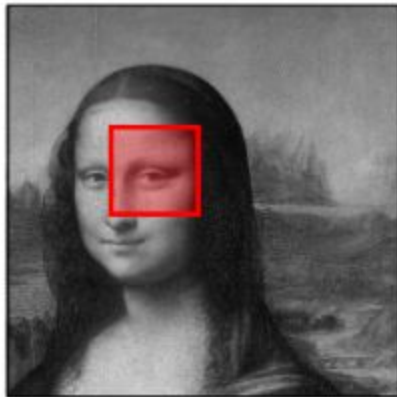
Symmetry:  
Translation

## Graph Neural Network



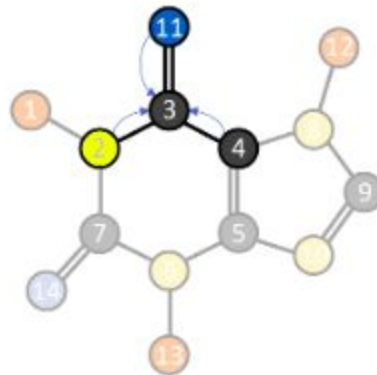
Symmetry:  
Permutation

## Convolutional Neural Network



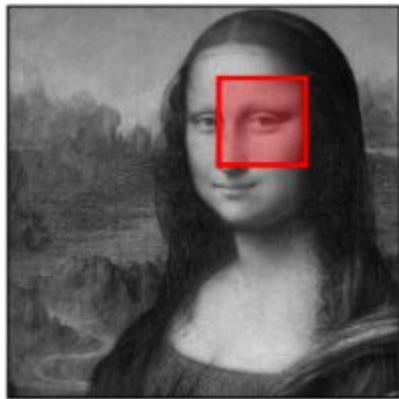
Convolution:  
translation equivariant

## Graph Neural Network



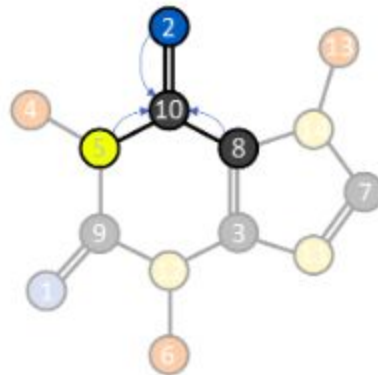
Message passing:  
permutation equivariant

## Convolutional Neural Network



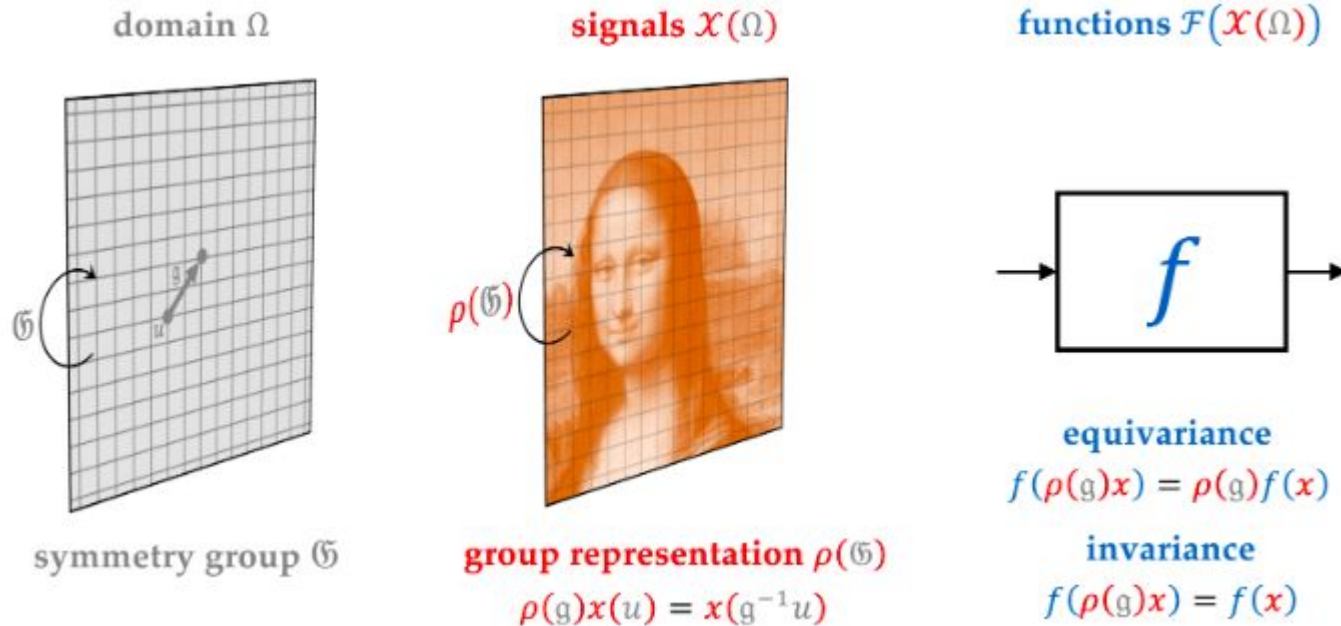
Convolution:  
translation equivariant

## Graph Neural Network



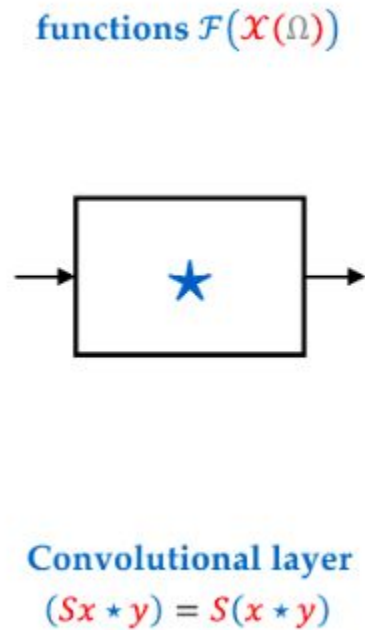
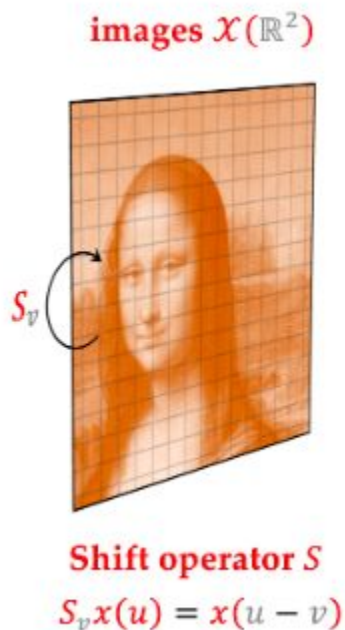
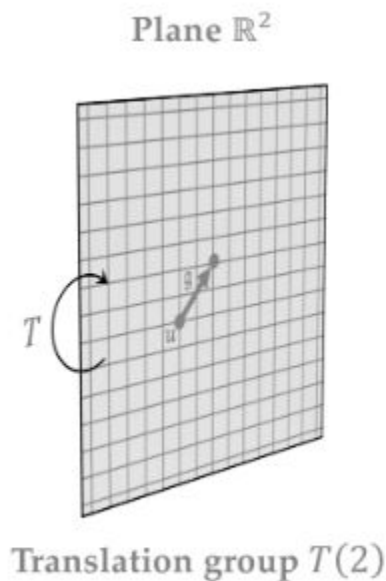
Message passing:  
permutation equivariant

# Geometric Deep Learning Blueprint



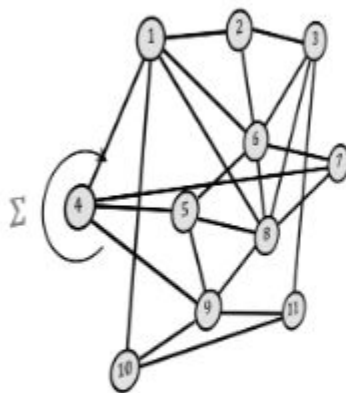


# Example: Convolutional Neural Networks



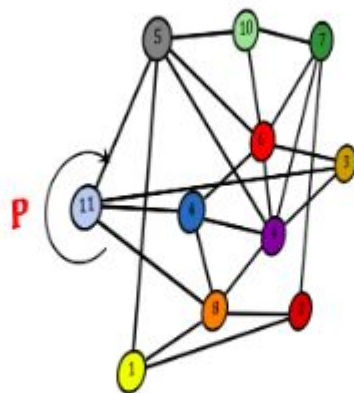
# Example: Graph Neural Networks

Graph  $G = (V, E)$



Permutation group  $\Sigma_n$

Node features  $\mathcal{X}(G)$



Permutation matrix  $P$

$$PX = (x_{\pi^{-1}(i),j})$$

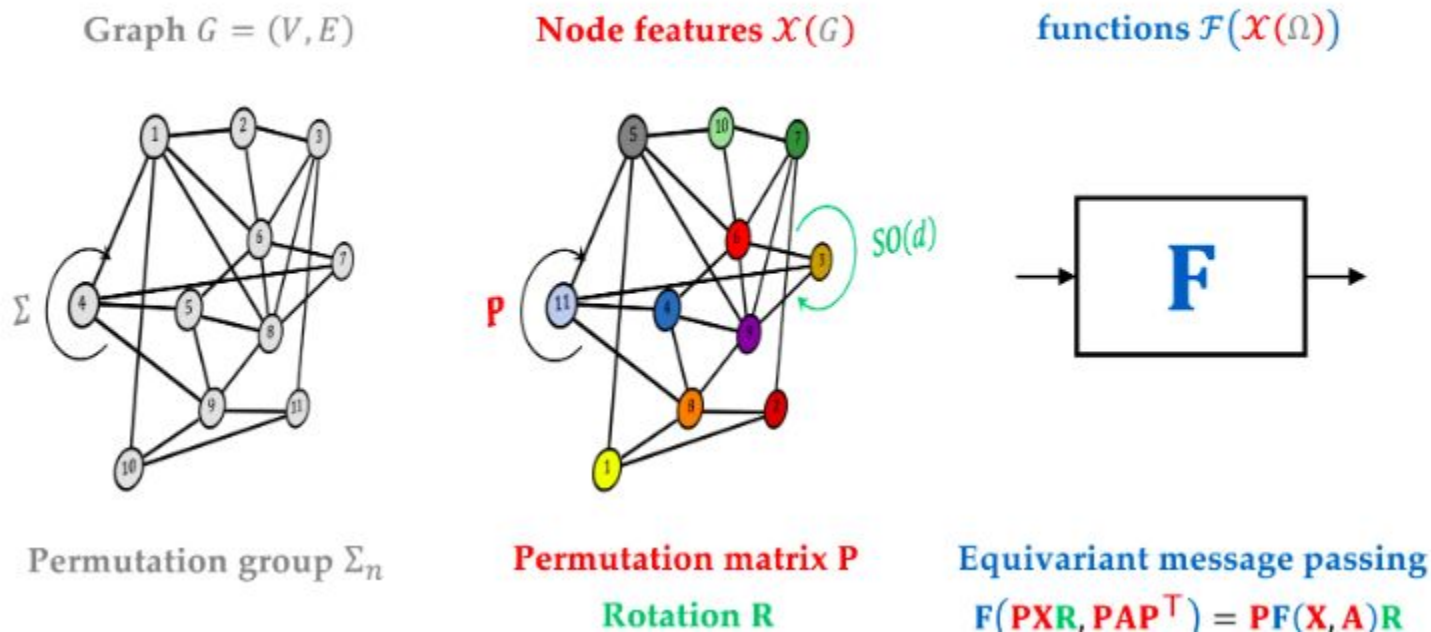
functions  $\mathcal{F}(\mathcal{X}(\Omega))$



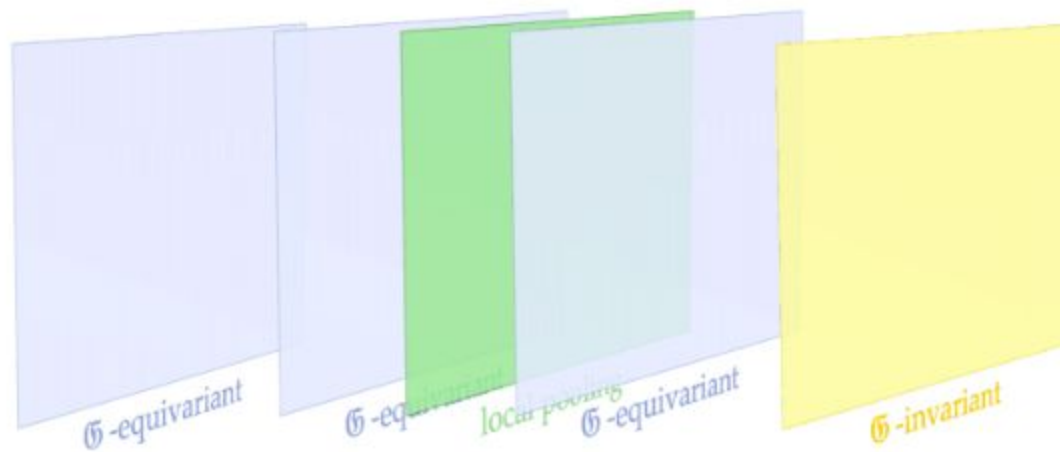
Message passing

$$F(PX, PAP^T) = PF(X, A)$$

# Example: Equivariant Graph NN

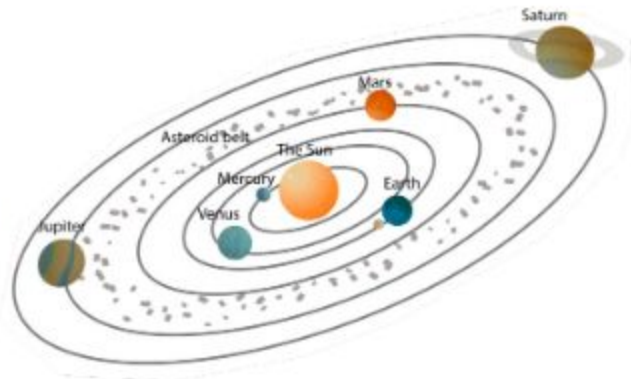
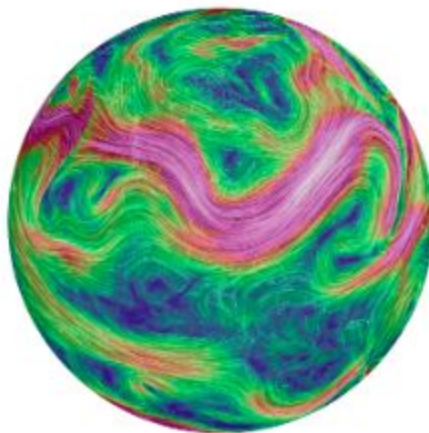
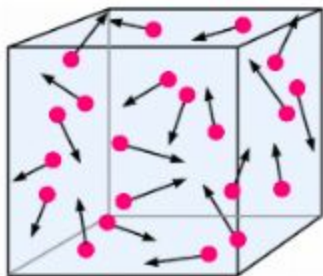


# Geometric Deep Learning Blueprint

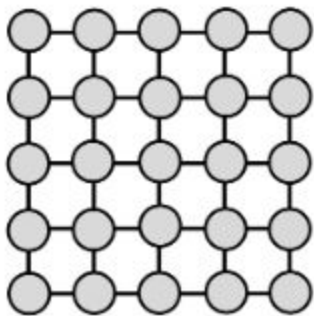




# Scale Separation



# The “5G” of Geometric Deep Learning



**Grids**



**Groups**

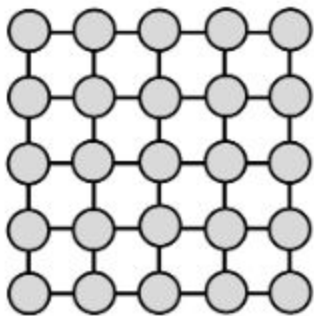


**Graphs**



**Geometric Graphs  
& Gauges**

# The “5G” of Geometric Deep Learning



**Images &  
Sequences**



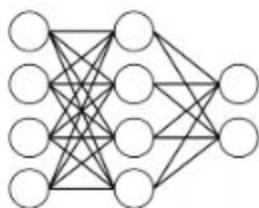
**Homogeneous  
spaces**



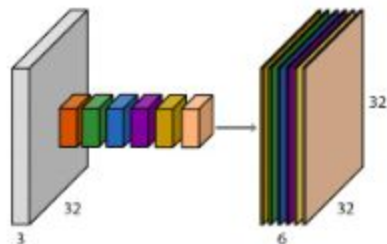
**Graphs & Sets**



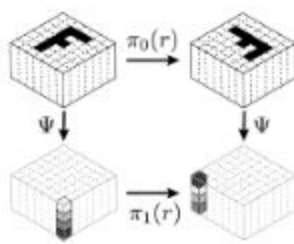
**Manifolds, Meshes &  
Geometric graphs**



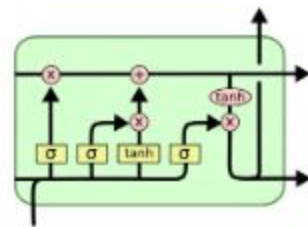
**Perceptrons**  
Function regularity



**CNNs**  
Translation



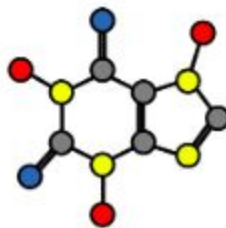
**Group-CNNs**  
Translation+Rotation,  
Global groups



**LSTMs**  
Time warping



**DeepSets / Transformers**  
Permutation



**GNNs**  
Permutation



**Intrinsic CNNs**  
Isometry / Gauge choice

# Schedule (weekly Sept.26th-Nov.28th)

**01**

Intro

**04**

Scale separation. GDL  
blueprint.

**02**

High dimensional  
learning

**05**

Graphs and Sets.  
(GNNs).

**03**

Invariance.  
Equivariance.

**05**

Practice on GNNs.



# Schedule

**06**

Grids. (CNNs).

**08**

Manifolds.

**07**

Groups. (Group  
Equivariant NNs).

**09**

Applications. SOTA.  
Critiques.

**07**

Practice on Group  
Equivariant NNs.

**10**

Closing

## Resources

[www.geometricdeeplearning.com](http://www.geometricdeeplearning.com)

# Resources

[https://maurice-weiler.gitlab.io/cnn\\_book/EquivariantAndCoordinateIndependentCNNs.pdf](https://maurice-weiler.gitlab.io/cnn_book/EquivariantAndCoordinateIndependentCNNs.pdf)

[https://www.cs.mcgill.ca/~wlh/grl\\_book/files/GRL\\_Book.pdf](https://www.cs.mcgill.ca/~wlh/grl_book/files/GRL_Book.pdf)

# Acknowledgements



**Michael Bronstein**  
Oxford / Twitter



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NYU



**Taco Cohen**  
Qualcomm



**Petar Veličković**  
DeepMind

# Prerequisites

- Fundamentals of Deep Learning
- Fundamentals of 1st year university math
  - Linear Algebra
  - Calculus
  - Maybe some statistics?
- Some DL framework (Pytorch, Jax)
- Basic abstract algebra and geometry is a plus.



# Questions?