

**Course #3:**

**Auto-encoders**

## Roadmap

- Recap from course #2
- Auto-encoders
- PyTorch Lightning

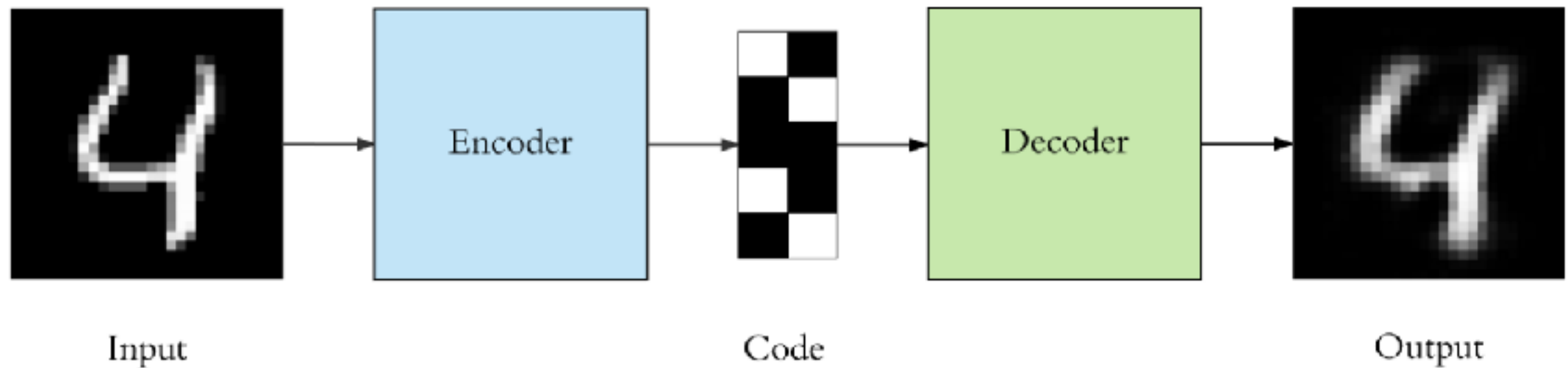
# Lecture. #2

## Things to know

- Convolution layers
- Pooling layers
- Activation layers
- Dropout layers
- Padding and stride
- Fine-tuning
- Over-fitting
- Data augmentation
-

# Auto-encoders

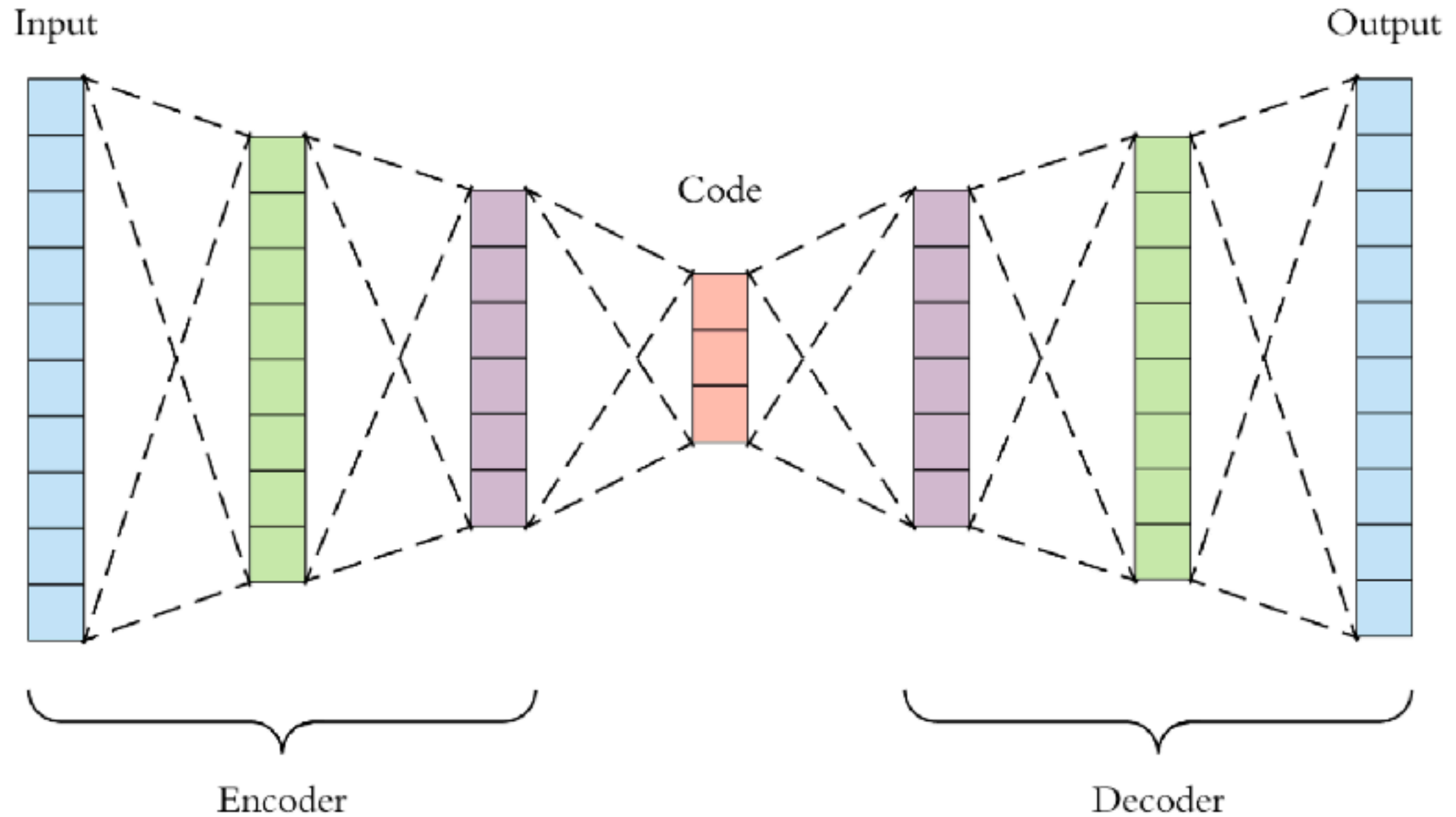
# Auto-encoders



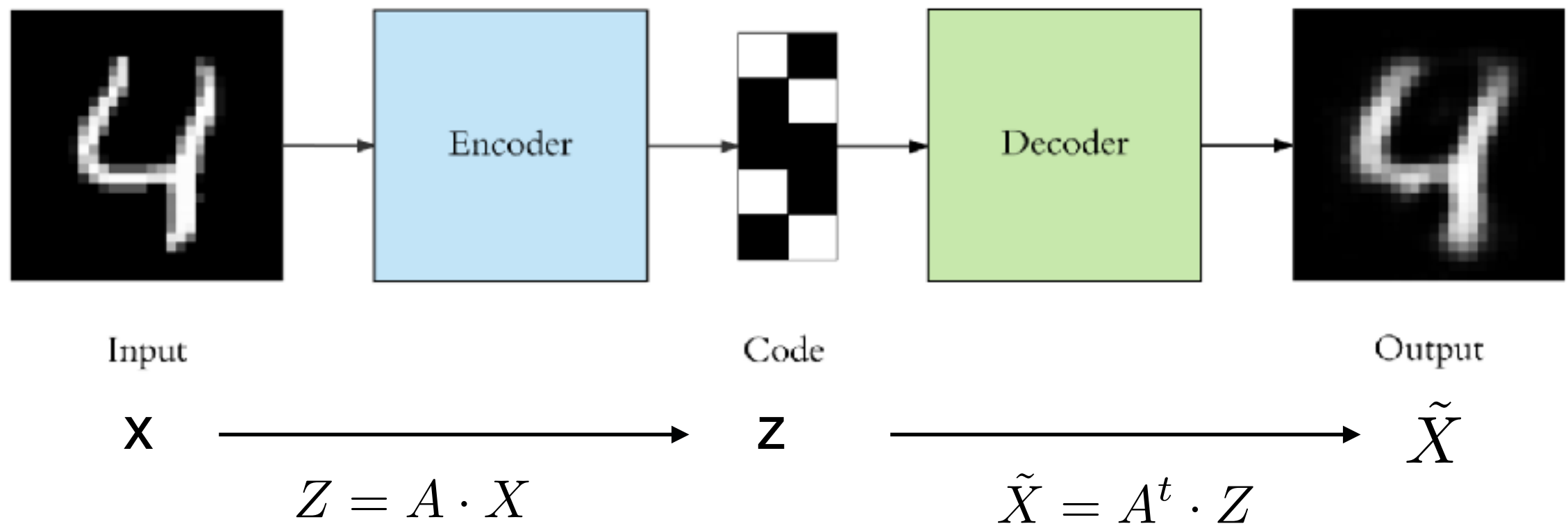
Output with the same shape as the input

Application ?

# Dense auto-encoders



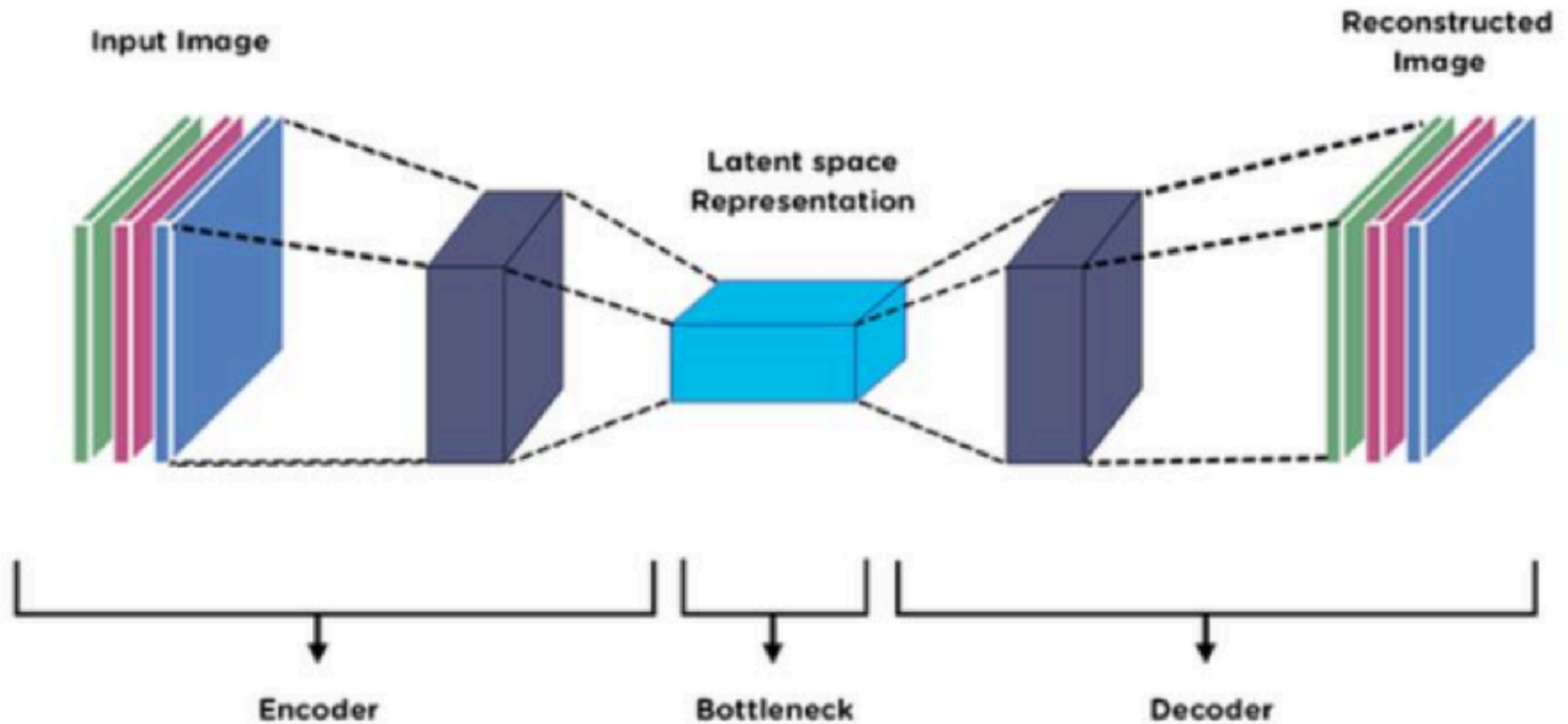
# PCA/EOF



PCA as a linear auto-encoder architecture.

Which additional constraint ?

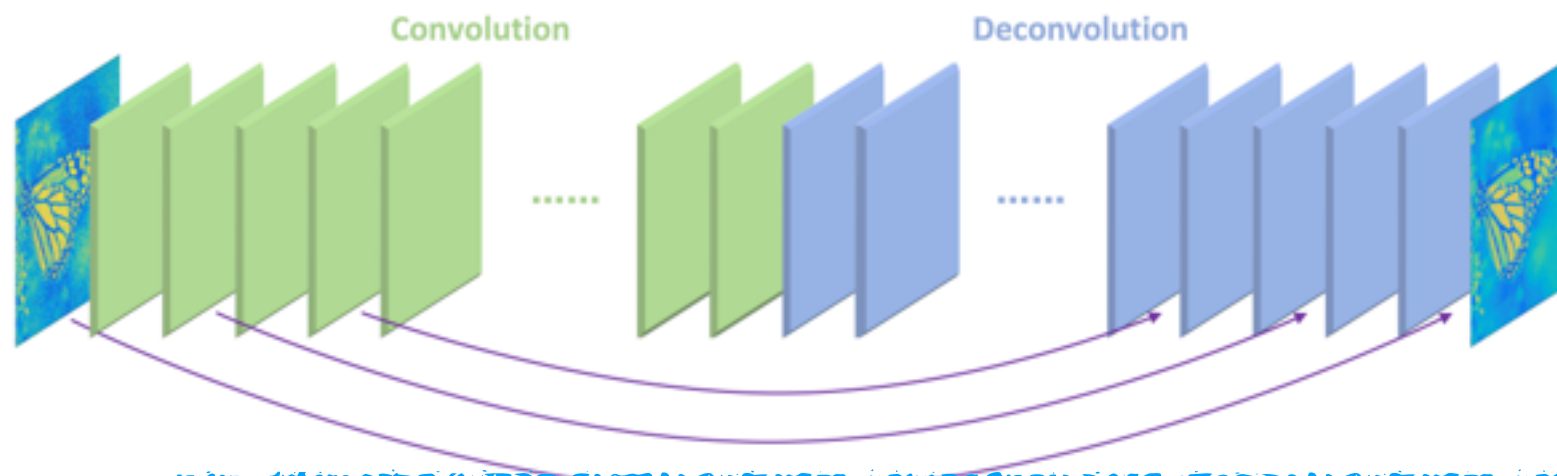
# Convolutional auto-encoders



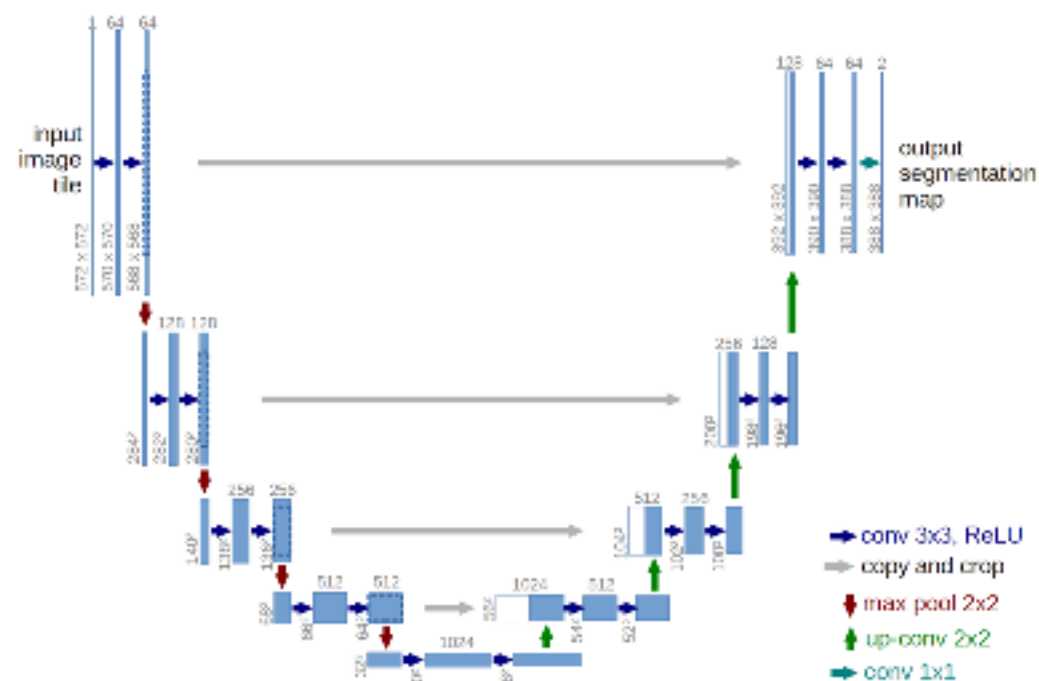


# Convolutional AE Zoo

Many applications do not require a low-dimensional representation  
(e.g., denoising, interpolation, super-resolution,...)



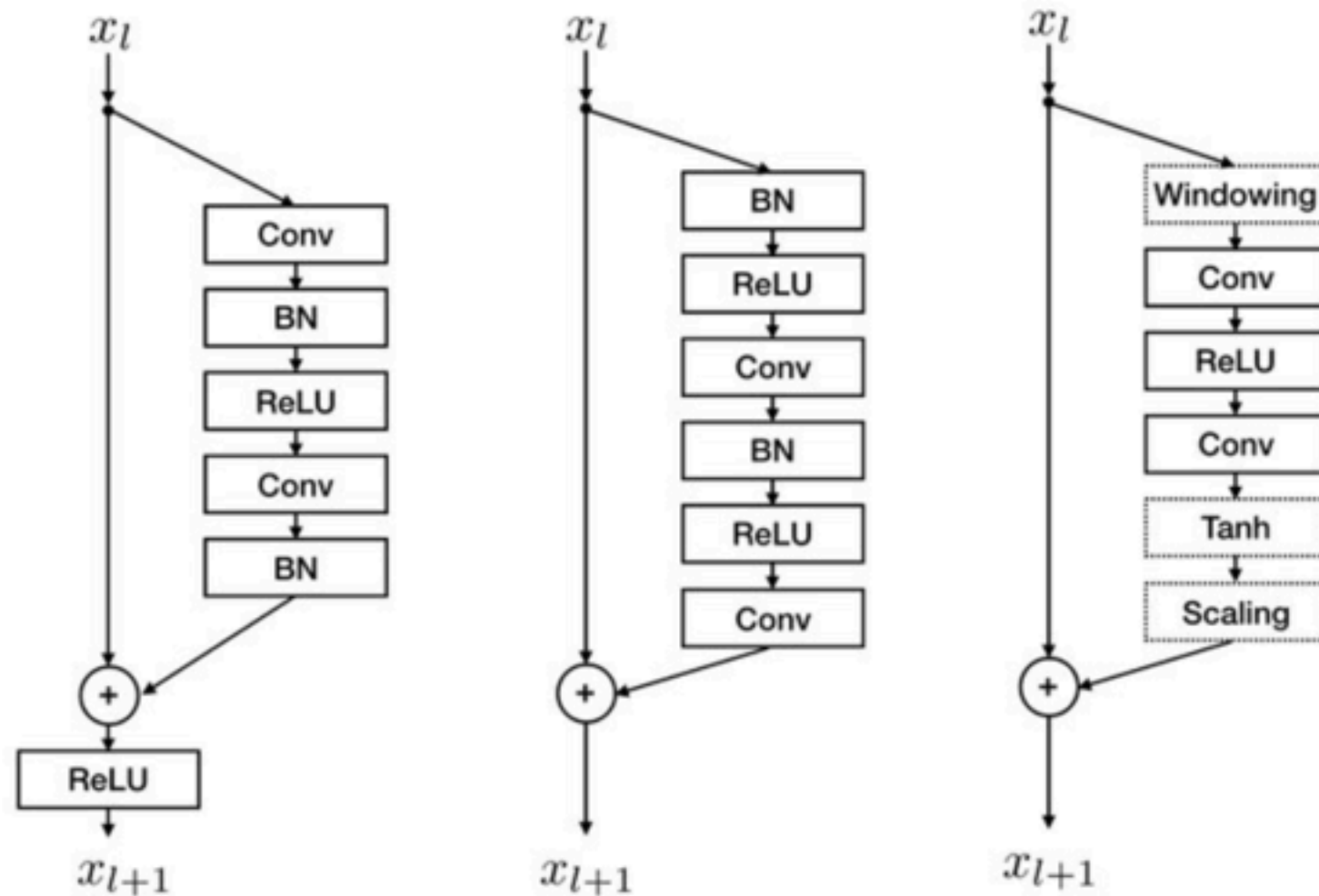
<https://arxiv.org/pdf/1606.08921.pdf>



UNet

Ronneberger  
et al., 2015

# Convolutional AE Zoo



Residual Block  
(ResNet)

Rousseau et al.,  
2019

Often used to address vanishing gradients (“very” deep networks)

# Auto-encoders for image denoising and image generation

Pytorch version

[https://github.com/CIA-Oceanix/DLOA2023/blob/main/lectures/notebooks/notebook\\_MNIST\\_AutoEncoder\\_students.ipynb](https://github.com/CIA-Oceanix/DLOA2023/blob/main/lectures/notebooks/notebook_MNIST_AutoEncoder_students.ipynb)

Lightning version

[https://github.com/CIA-Oceanix/DLOA2023/blob/main/lectures/notebooks/notebook\\_PytorchLightning\\_MNIST\\_AutoEncoder\\_students.ipynb](https://github.com/CIA-Oceanix/DLOA2023/blob/main/lectures/notebooks/notebook_PytorchLightning_MNIST_AutoEncoder_students.ipynb)

Question 1. Fill in the architecture of the dense encoder module to train a dense auto-encoder

Question 2. Add dropout layers in the convolutional encoder and decoder

Question 3. Modify the code to test a linear auto-encoder (cf. AE and PCA)

# PyTorch Lightning

# ConvAE & Ocean Dynamics

**JAMES** | Journal of Advances in Modeling Earth Systems

RESEARCH ARTICLE  
10.1029/2018MS001472

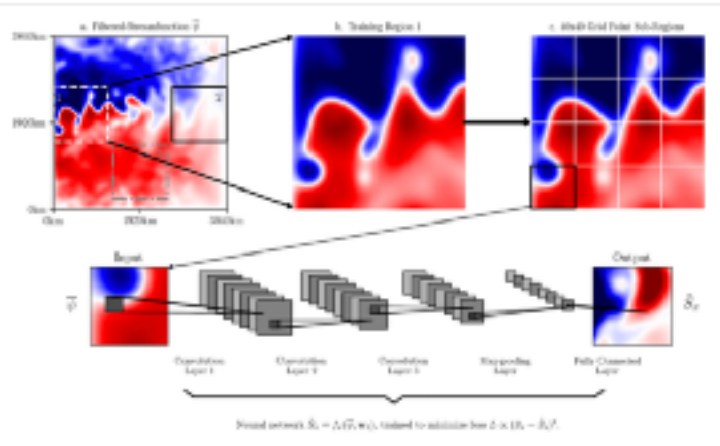
**Applications of Deep Learning to Ocean Data Inference and Subgrid Parameterization**

Thomas Bolton<sup>1</sup> and Laure Zanna<sup>1</sup>

<sup>1</sup>Department of Physics, University of Oxford, Oxford, UK

**Key Points:**

- We successfully use convolutional neural networks to predict unresolved turbulent processes and subsurface velocities
- The neural networks generalize to



<https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1029/2018MS001472>

## Super-Resolving Ocean Dynamics from Space with Computer Vision Algorithms

by Bruno Buongiorno Nardelli<sup>1,\*</sup>, Davide Cavallero<sup>2</sup>, Elodie Charles<sup>3</sup> and Daniele Ciani<sup>2</sup>

<sup>1</sup> Consiglio Nazionale delle Ricerche, Istituto di Scienze Marine (CNR-ISMAR), 80133 Naples, Italy  
<sup>2</sup> Consiglio Nazionale delle Ricerche, Istituto di Scienze Marine (CNR-ISMAR), 80133 Naples, Italy  
<sup>3</sup> Collecte Localisation France  
<sup>\*</sup> Author to whom correspondence should be addressed

Remote Sens. 2022, 14, 1159

## JAMES | Journal of Advances in Modeling Earth Systems

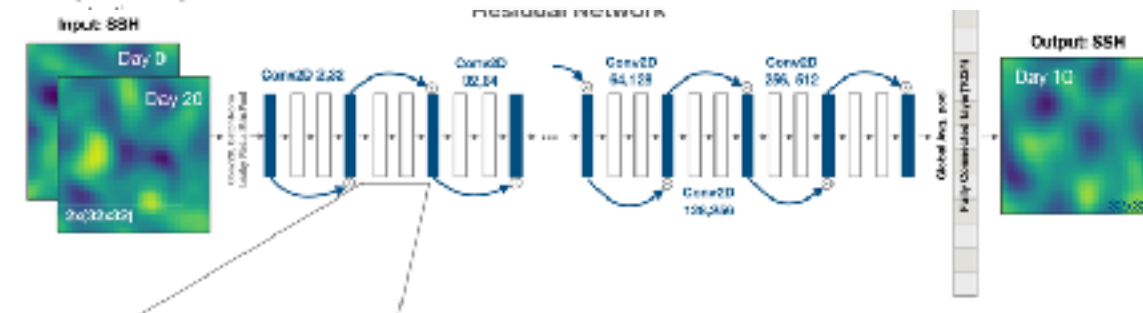
### RESEARCH ARTICLE

10.1029/2019MS001965

### A Deep Learning Approach to Spatiotemporal Sea Surface Height Interpolation and Estimation of Deep Currents in Geostrophic Ocean Turbulence

Georgy E. Manucharyan<sup>1</sup>, Lia Siegelman<sup>2</sup>, and Patrice Klein<sup>3,4</sup>

<sup>1</sup>School of Oceanography, University of Washington, Seattle, WA, USA, <sup>2</sup>The Population Laboratory, California Institute of Technology, Pasadena, CA, USA, <sup>3</sup>Laboratoire du Météorologie Dynamique, Ecole Normale Supérieure, CNRS, Paris, France, <sup>4</sup>Laboratoire d'Océanographie Physique et Spatiale, IFREMER, CNRS, Brest, France



<https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1029/2019MS001965>

## DINCAE 2.0: multivariate convolutional neural network with error estimates to reconstruct sea surface temperature satellite and altimetry observations

Alexander Barth<sup>1</sup>, Aida Alvera-Azcárate<sup>1</sup>, Charles Troupin<sup>1</sup>, and Jean-Marie Beckers<sup>1</sup>

GHEF, University of Liège, Liège, Belgium

Received: 18 Oct 2021 – Discussion started: 15 Nov 2021 – Revised: 10 Feb 2022 – Accepted: 17 Feb 2022 – Published: 15 Mar 2022

<https://gmd.copernicus.org/articles/15/2183/2022/>

# ConvAE & Ocean Dynamics

## Literature review

### Considered papers:

Topic#1 <https://gmd.copernicus.org/articles/15/2183/2022/>

Topic#2 <https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1029/2018MS001472>

Topic#3 <https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1029/2019MS001965>

Topic#4 <https://arxiv.org/abs/2010.04663>

### Questions:

- Which problem ?
- Which convolutional architecture ?
- Comments ?

# ConvAE architectures for Ocean Dynamics ?

# Lecture. #3

## Things to know (AE)

- Auto-encoder
- Latent variable
- UNet
- ResNet