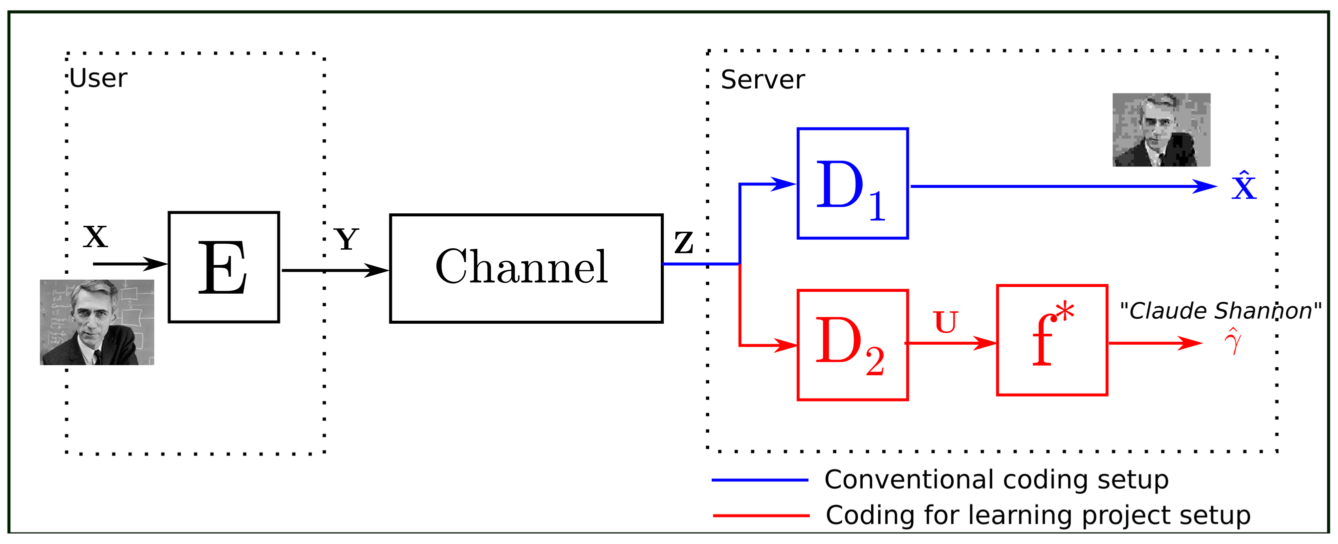
CoLearn

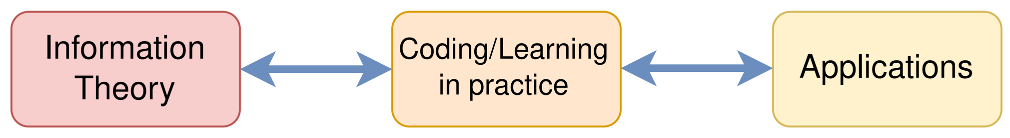
Coding for Learning

1. Project scientific objectives

Context: Huge mass of data (images, video, etc.) need to be sorted, processed, stored, recommended to users, etc.



- **Objective**: **Learning and data reconstruction over coded data**
- Key questions:
  - Is there a tradeoff between the data reconstruction and learning objectives?
  - Can one perform learning without prior decoding?
  - Does the source-channel separation principle still hold?
- Approach:



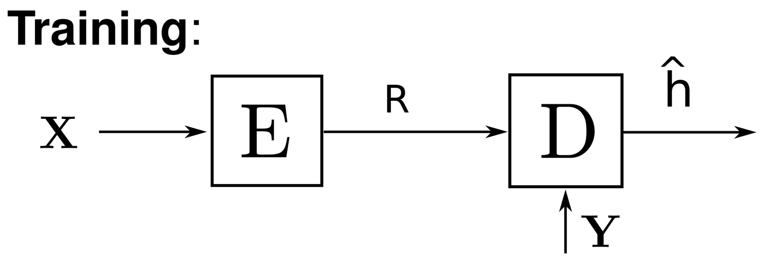
2. Information-Theoretic bounds for Regression over coded data

Problem addressed:

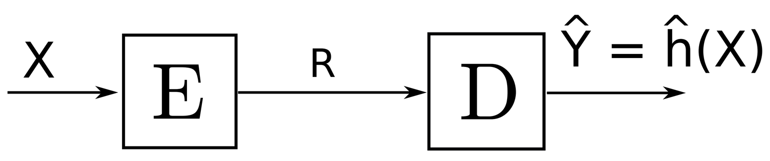
- Few is know about IT limits of communication-for-learning schemes
- We consider **regression** as a first yet simple learning problem:

$$Y = h(X) + \epsilon, \quad L(\hat{h}) = E[(Y - \hat{h}(X))^2]$$

Training:



Inference:

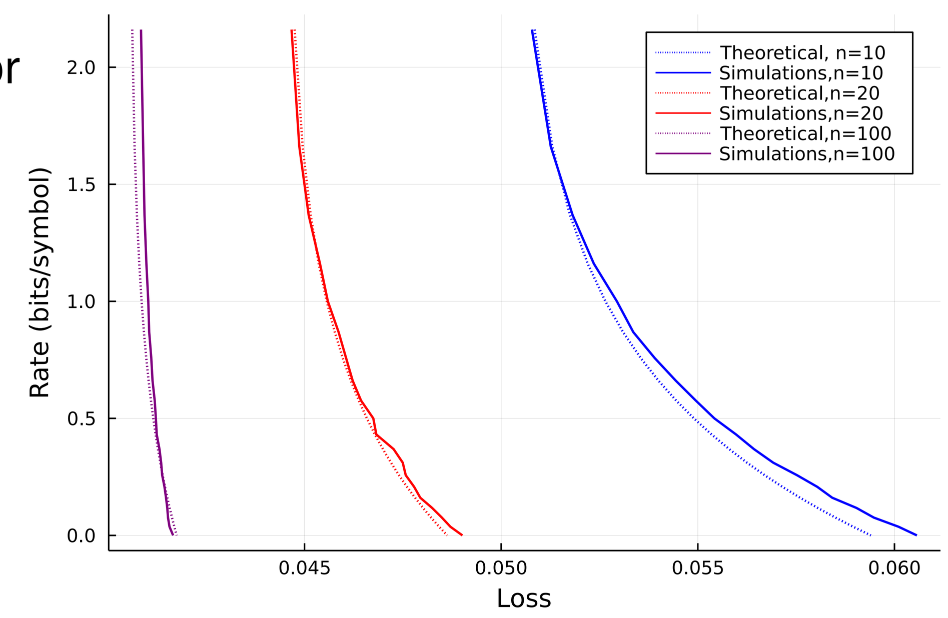


Results for linear regression: $Y = \beta_0 + \beta_1 X + \epsilon$, $\epsilon \sim \mathcal{N}(0, \sigma^2)$

Rate-Loss function $R(L)$ for training:

$$R = \frac{1}{2}\log_2\left(\frac{\sigma^2}{D}\right)$$

$$L = \sigma^2\left(1 - \frac{2}{n}\right) + \frac{2}{n}D$$



- The Rate and Loss depend on D, the Loss depends on n

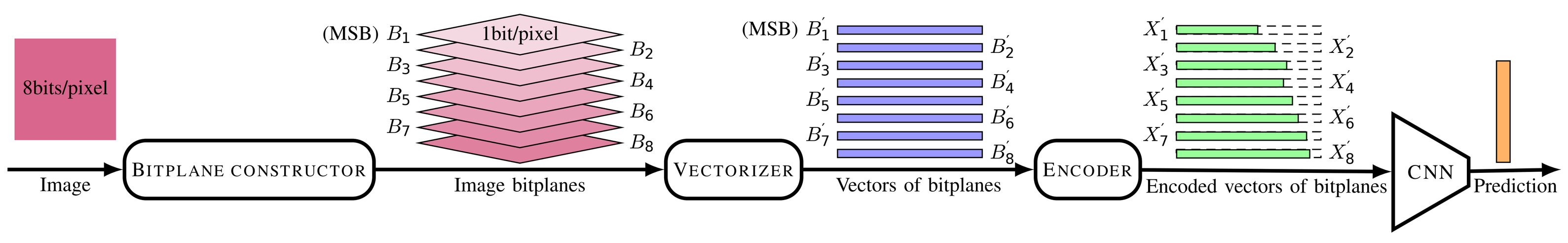
Insights and perspectives:

- To derive $R(L)$, we considered **partial reconstruction** before learning
- We should derive **finite-length** rate-loss functions
- The existence of a tradeoff between data reconstruction and learning most probably **depends on the learning problem**
- We aim to consider more complex regression and learning problems

3. Learning from Entropy-Coded Images with CNN

Problem addressed:

- Decoding before learning is very complex (processing, memory)
- Entropy-coding breaks the data structure
- Can we do learning without any prior decoding? **No? Let's try!**
- We consider **image classification** as a first yet simple learning problem



Results:

- We considered CNN architectures designed for 1D data
- Input data: entropy-coded grayscales images

		Coding Type		
Dataset	Network	None	Huffman	Arithmetic
MNIST	UVGG11	0.98911 ± 0.00162	0.83234 ± 0.01435	0.63130± 0.00736
	RESNET18	0.98753 ± 0.00080	0.74503 ± 0.00662	0.59498± 0.00737
Fashion-MNIST	UVGG11	0.90189 ± 0.00564	0.76347 ± 0.00712	0.68987± 0.00609
	RESNET18	0.84972 ± 0.00666	0.68620 ± 0.01145	0.61162± 0.00844
YCIFAR-10	UVGG11	0.56573 ± 0.00697	0.36062 ± 0.00462	0.29762± 0.00473
	RESNET18	0.38368 ± 0.00374	0.25913 ± 0.01172	0.24325± 0.00676

- The accuracy is much better than when considering random guessing
- Huffman coding allows for better accuracy than arithmetic coding

Insights and perspectives:

- Can one adapt the learning algorithm to take into account entropy-coding?
- Determine which entropy-coding techniques are **more suitable** for learning
- Determine **characteristics** an entropy-coding method allowing for learning should satisfy
- Consider the full coding chain (transform, quantization, etc.)

4. Perspectives

- Classify learning applications depending on whether there is a tradeoff between data reconstruction and learning
- Investigate learning without decoding both from fundamental and practical point of views
- Consider more complex learning problems and communication conditions related to the project applications (video coding, submarine communications)
- Investigate connections with the field of computation over coded data