# DATA LAB

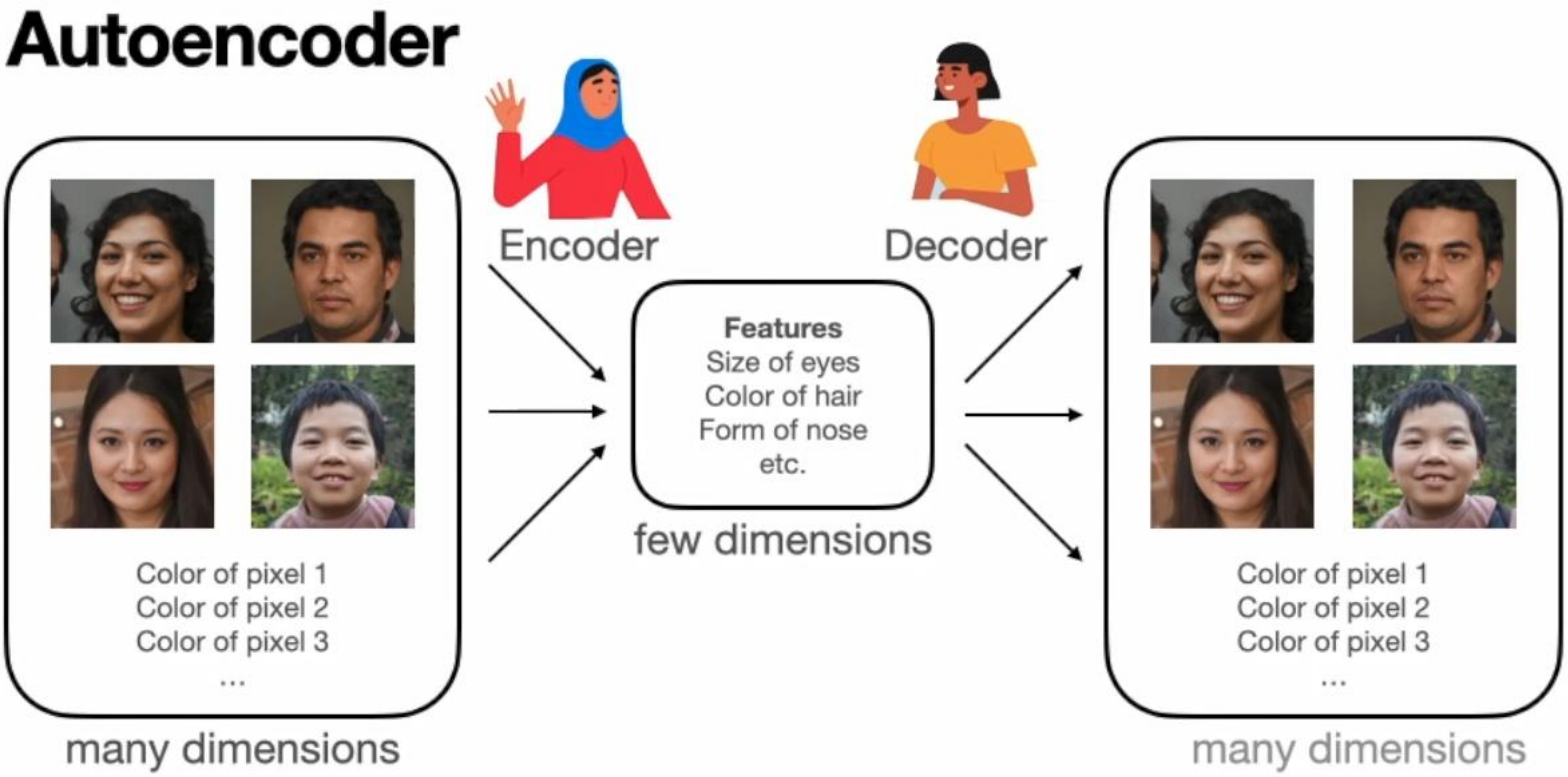
## GUARDA AVANTI

**Big Data,** nuove competenze
per nuove professioni.

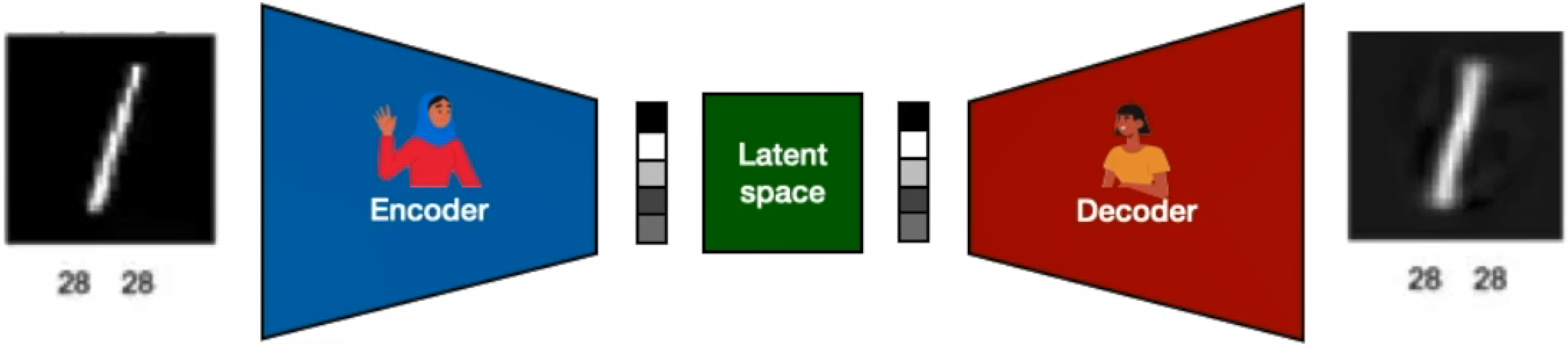
"Anticipare la crescita con le nuove competenze sui Big Data - Edizione 3" Operazione Rif. PA 2021-16029/RER approvata con DGR n° 927 del 21 giugno 2021 e co-finanziata dal Fondo Sociale Europeo PO 2014-2020 Regione Emilia-Romagna

# Deep Learning

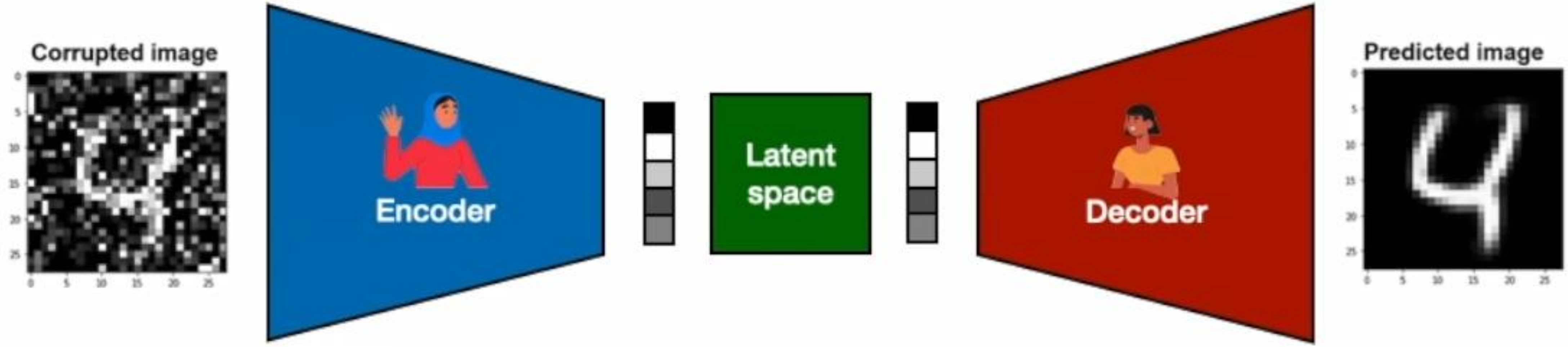
# AUTOENCODER
# VARIATIONAL AUTO ENCODER


Autoencoder
Encoder
Decoder
Features
Size of eyes
Color of hair
Form of nose
etc.
few dimensions
Color of pixel 1
Color of pixel 2
Color of pixel 3
...
many dimensions
Color of pixel 1
Color of pixel 2
Color of pixel 3
...
many dimensions

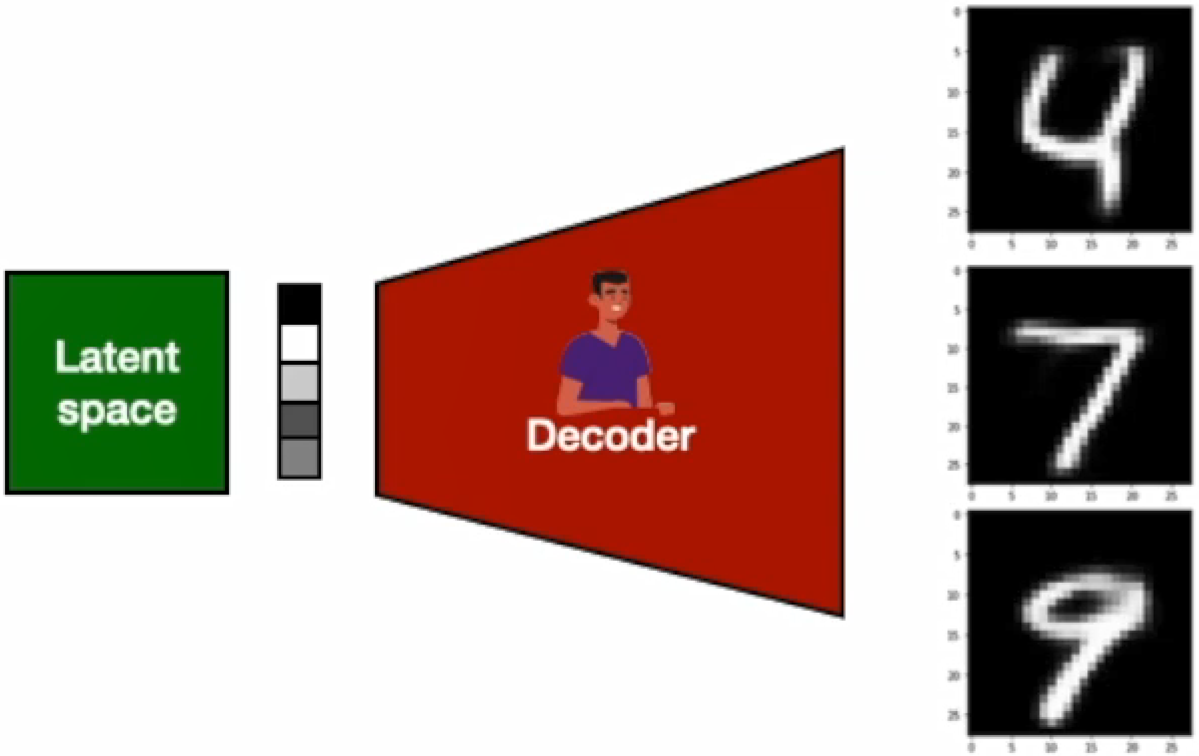
# Autoencoders



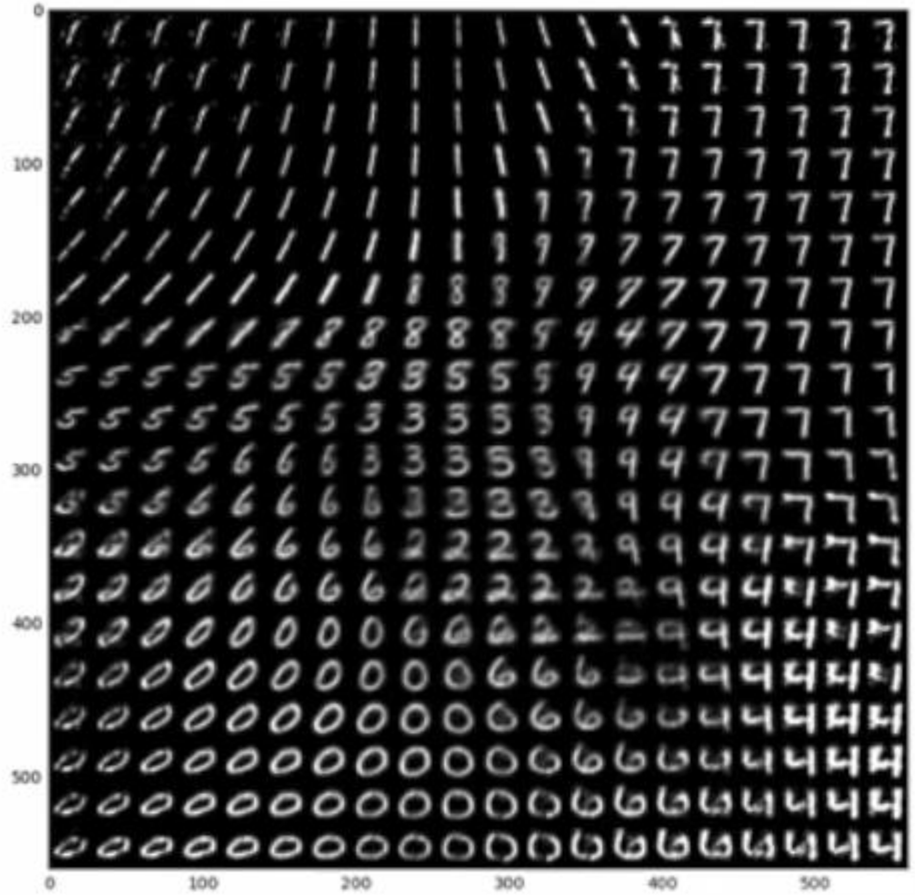
# Denoising autoencoders

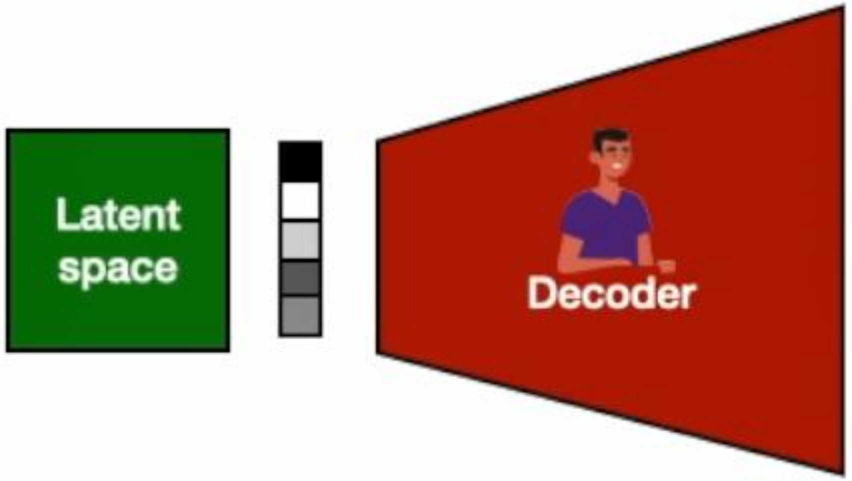


# Variational autoencoders



# Latent space

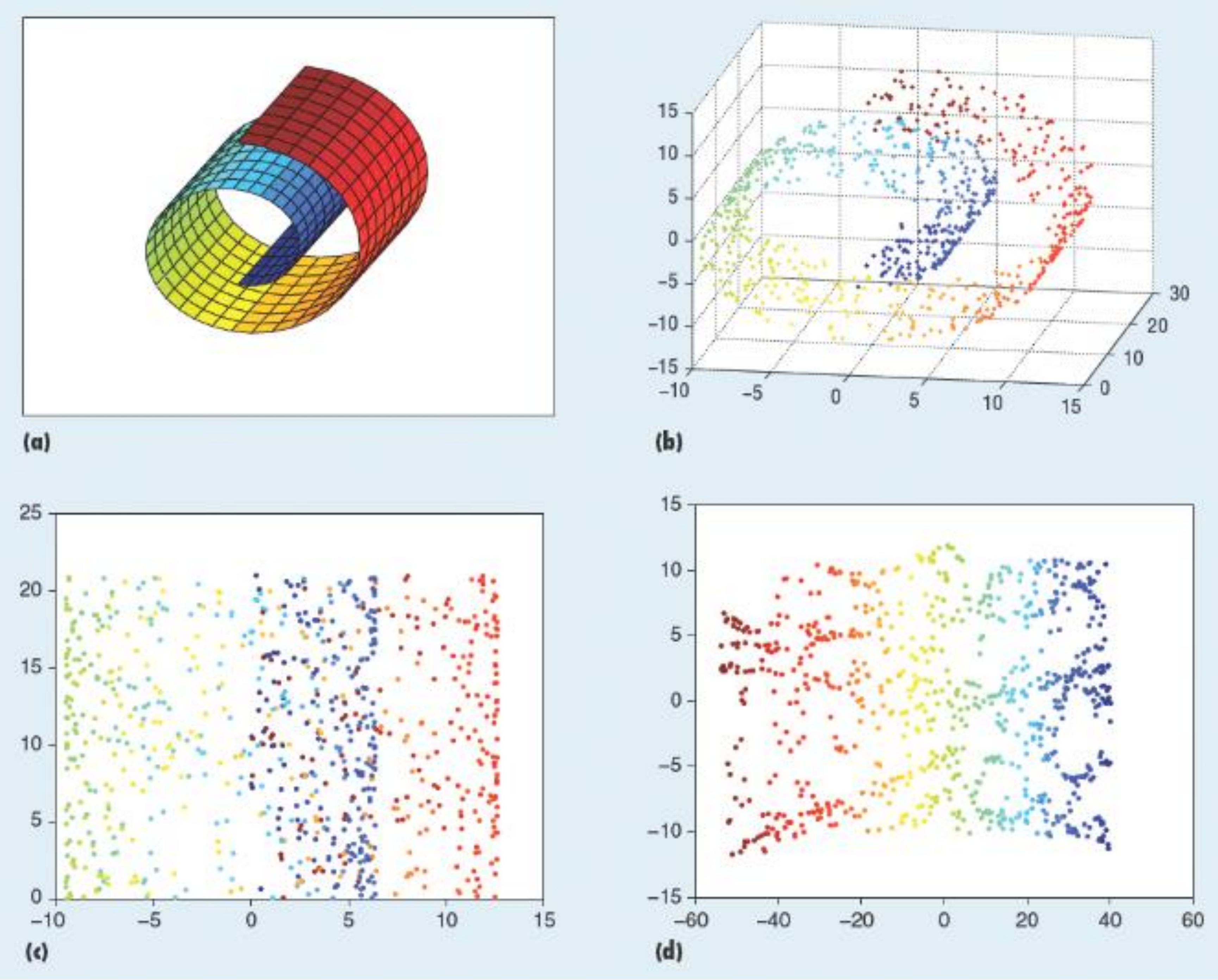




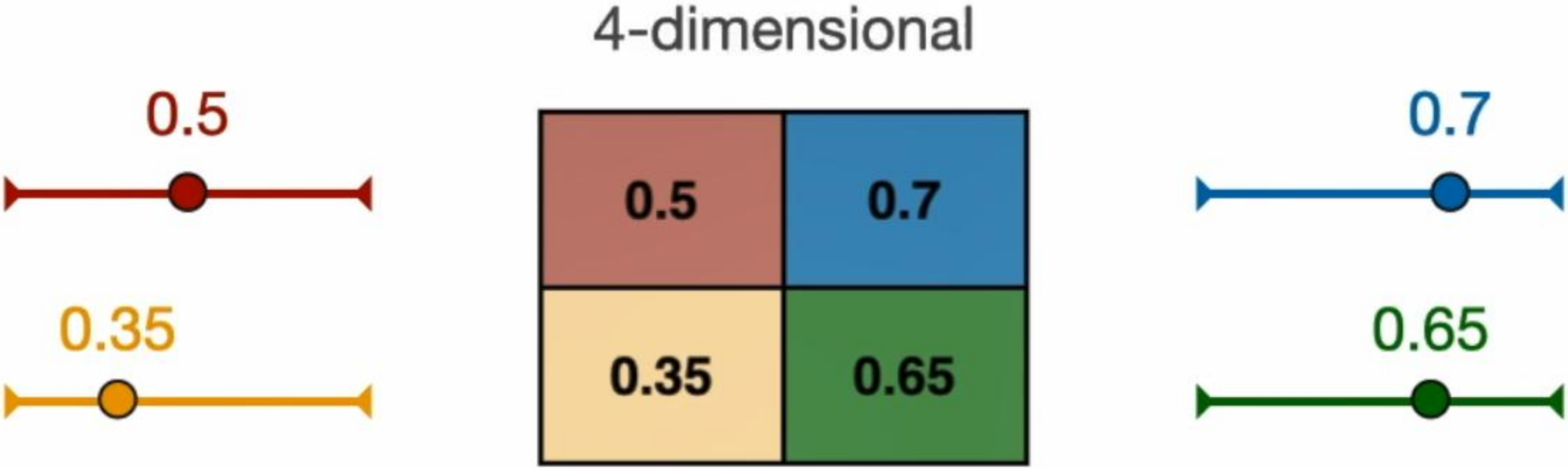

# Images generated by a VAE

Source: Tom White

# Dimensionality reduction


(a)
(b)
15
10
5
0
−5
−10
−15
−10
−5
0
5
10
15
30
20
10
0
(c)
25
20
15
10
5
0
−10
−5
0
5
10
15
(d)
15
10
5
0
−5
−10
−15
−60
−40
−20
0
20
40
60

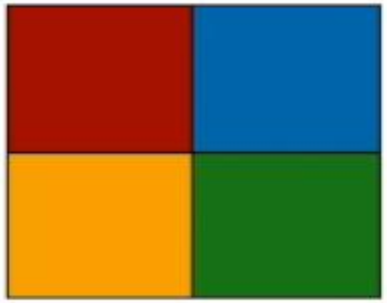
# Dataset of images

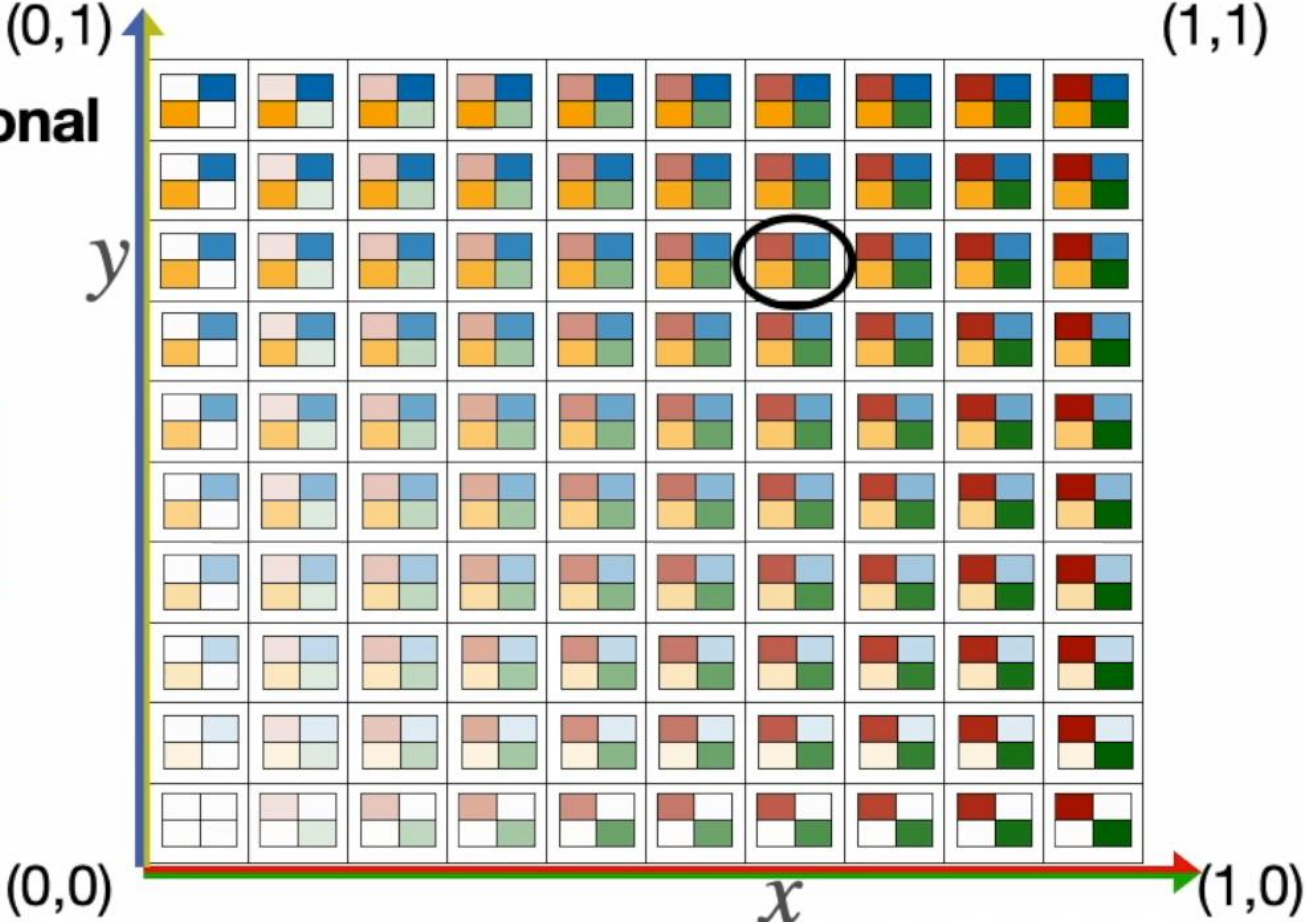


# Dataset of images

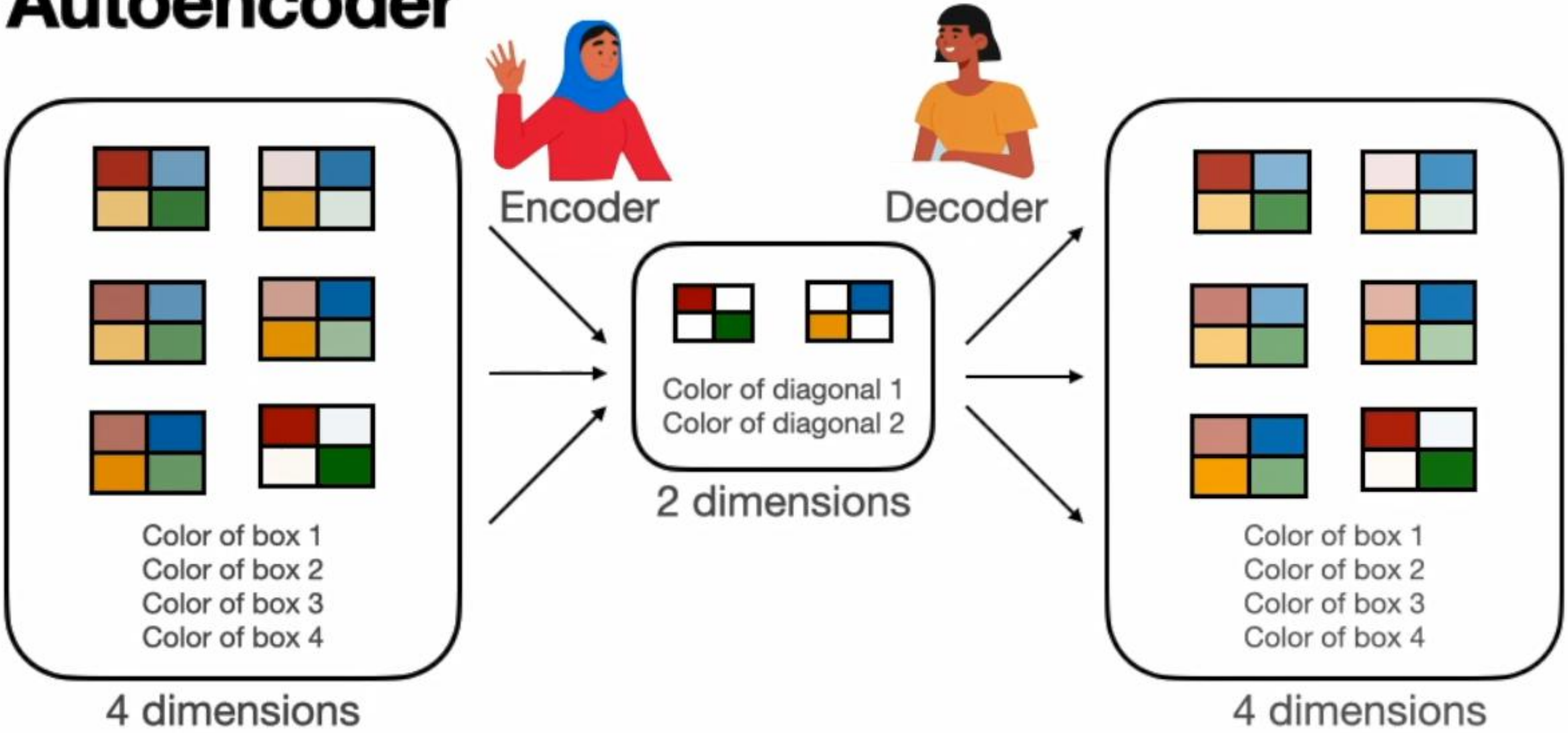
## 2-dimensional

**2-dimensional dataset**

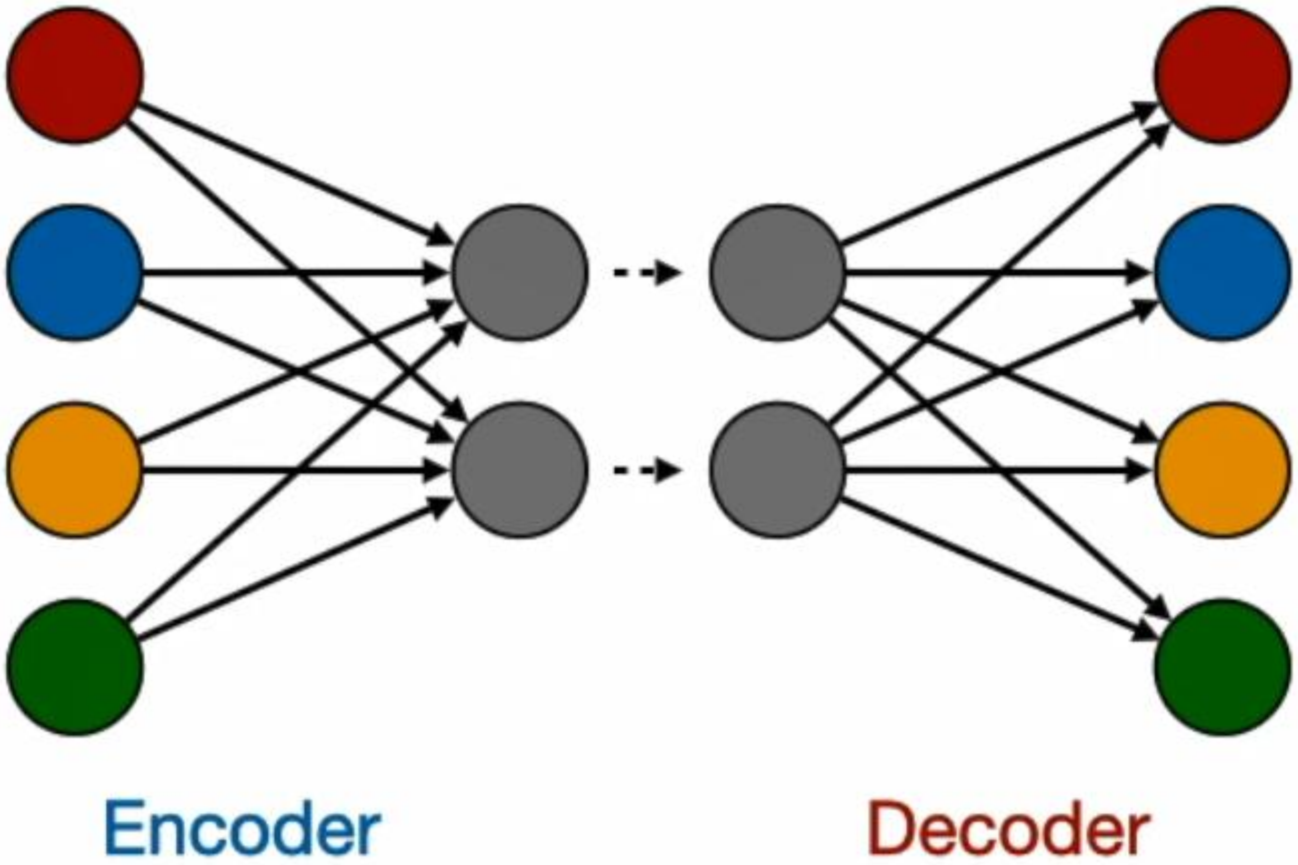




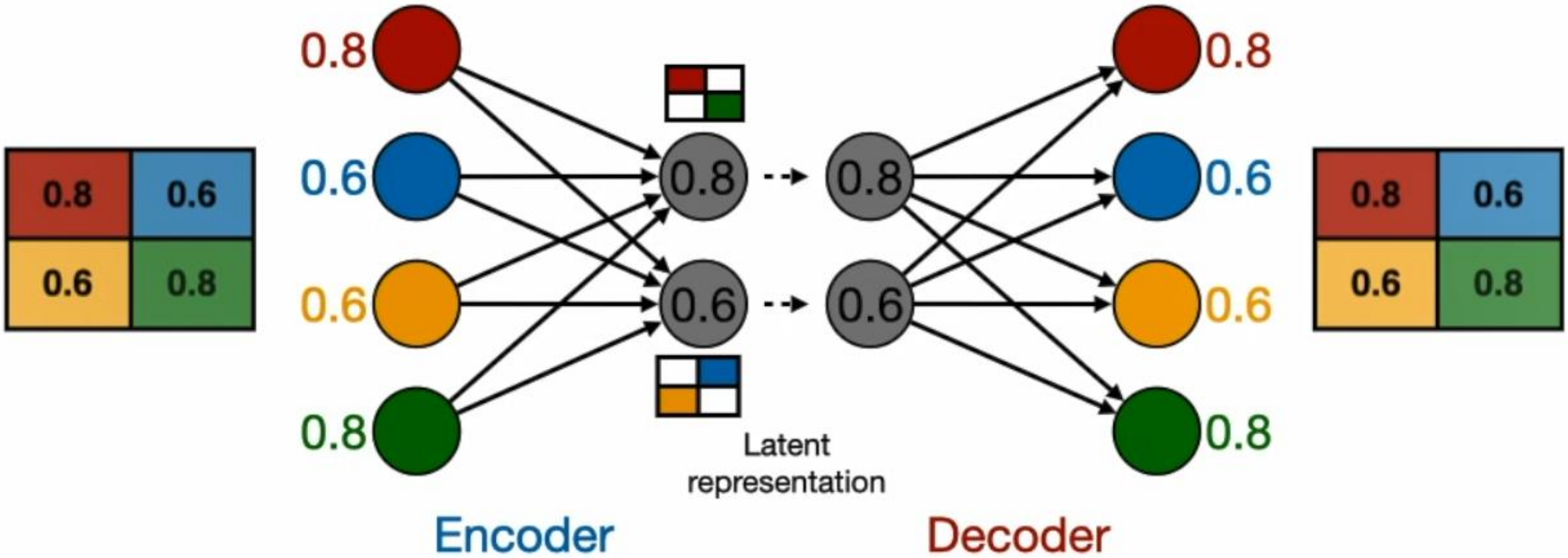
# Autoencoder



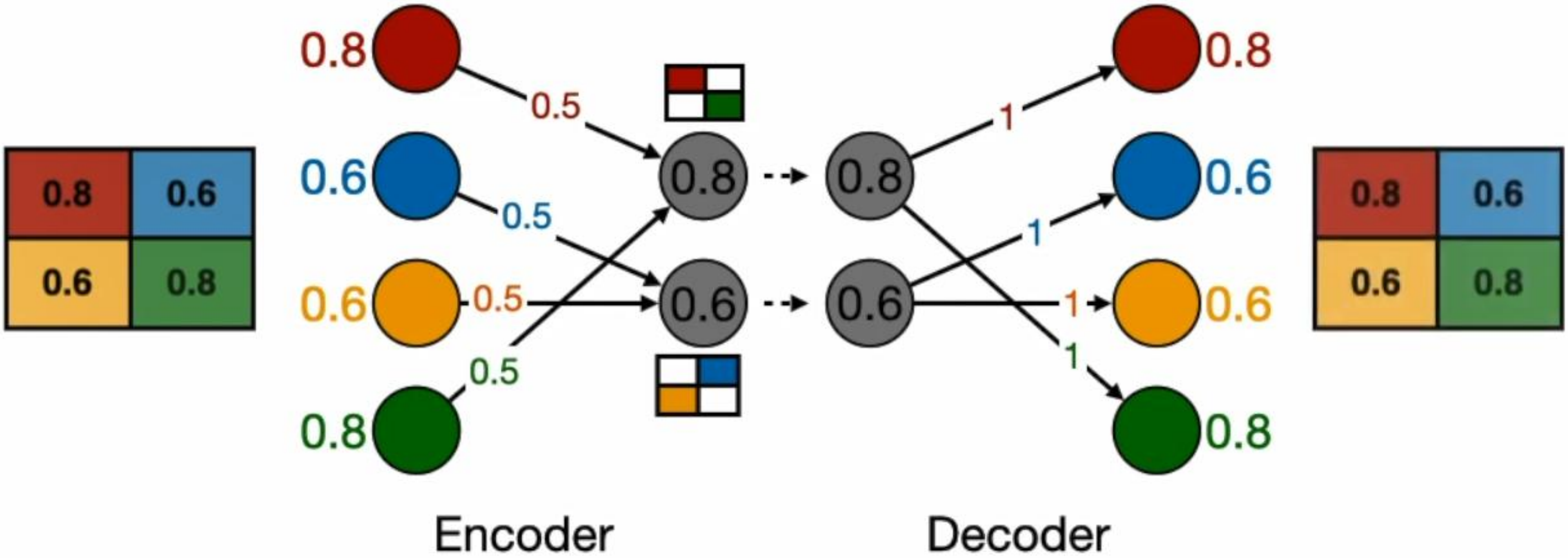
# Autoencoder



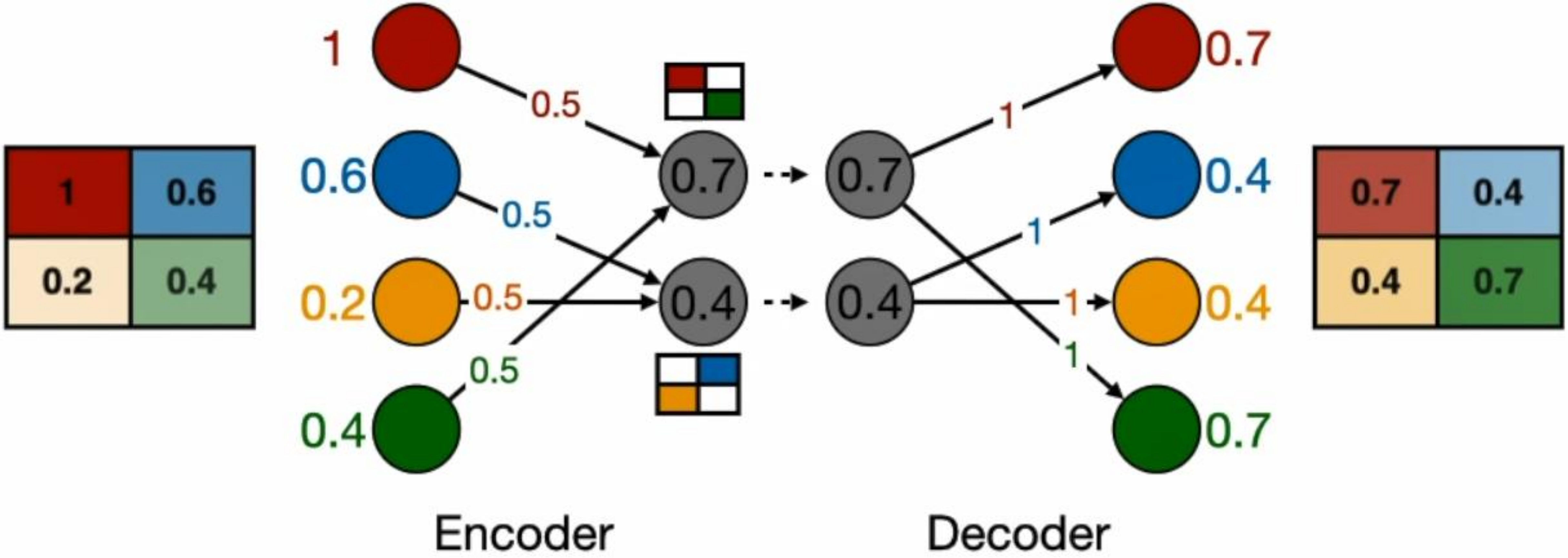
# Autoencoder



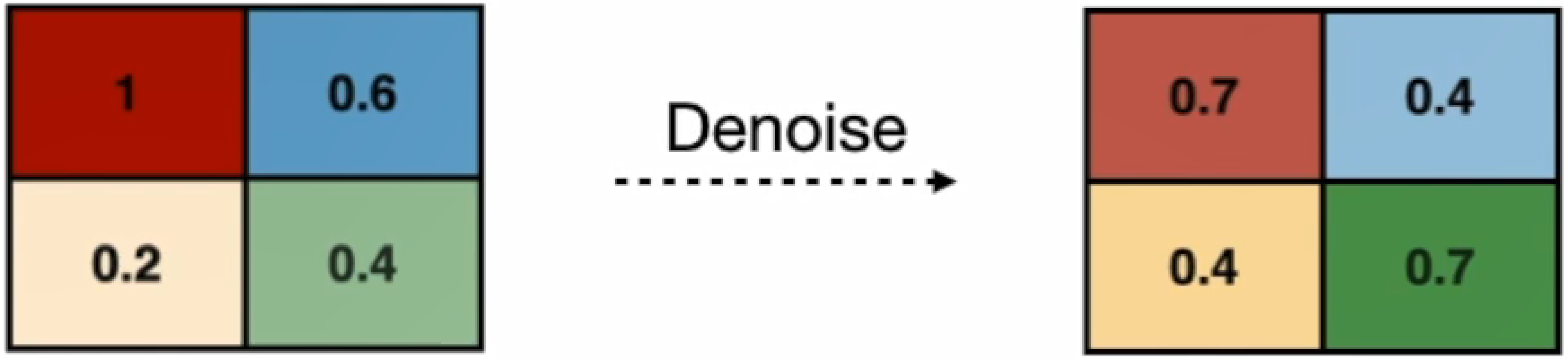
# Autoencoder



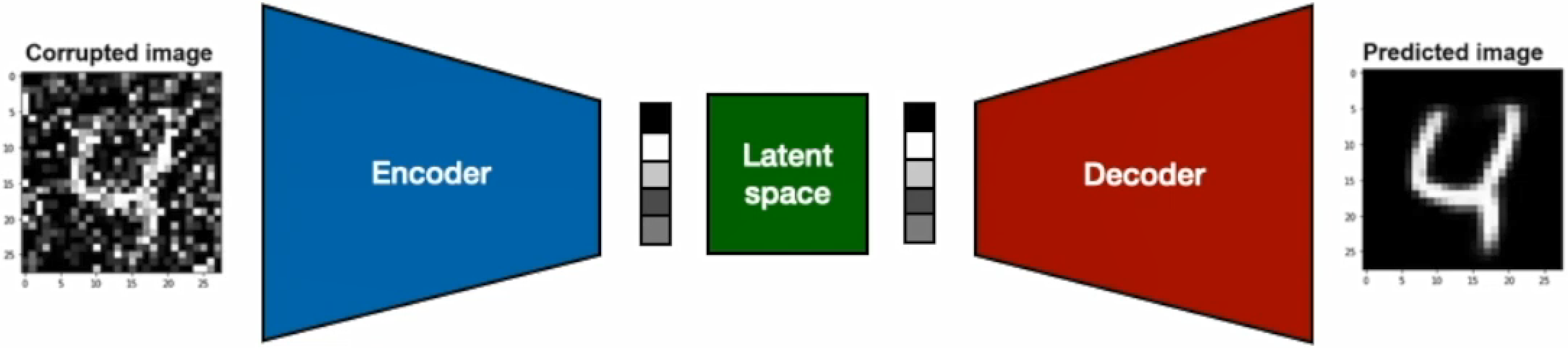
# Denoising autoencoder



# Correct noise

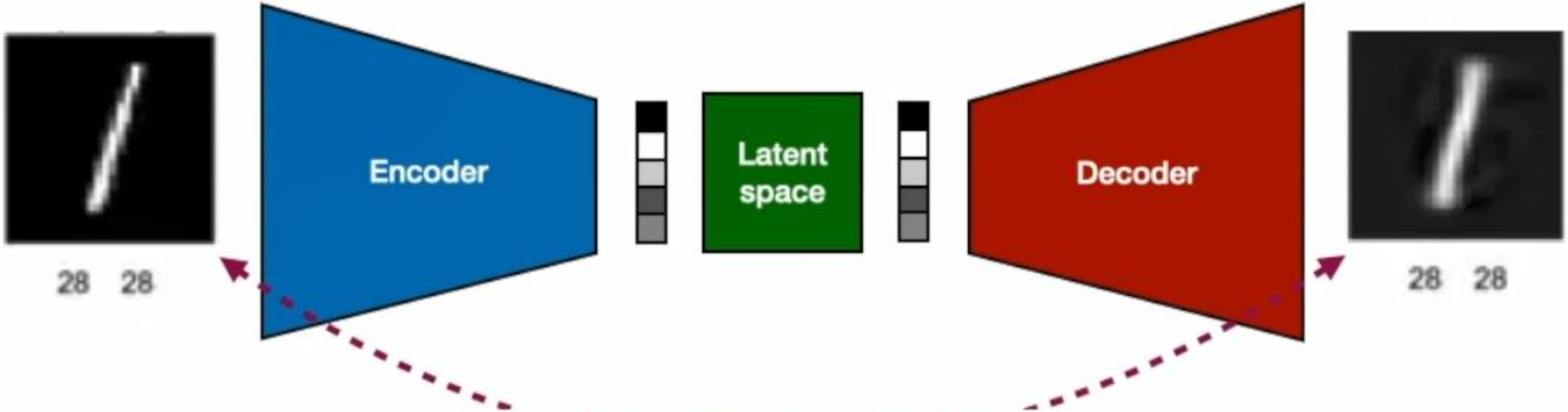


# Denoising autoencoders



# Training autoencoders

Initialize encoder and decoder
with random weights




Error: reconstruction loss

Do backpropagation
and update weights

# Reconstruction loss (Mean squared error)

$x$

| | |
|---|---|
| 0.6 | 0.4 |
| 0.4 | 0.6 |

$y$

| | |
|---|---|
| 0.65 | 0.42 |
| 0.36 | 0.59 |

$$MSE(x, y) = \sum_i (x_i - y_i)^2$$

$$(0.6 - 0.65)^2 + (0.4 - 0.42)^2 + (0.4 - 0.36)^2 + (0.6 - 0.59)^2$$

$$= 0.0046$$

$x$

| | |
|---|---|
| 0.6 | 0.4 |
| 0.4 | 0.6 |

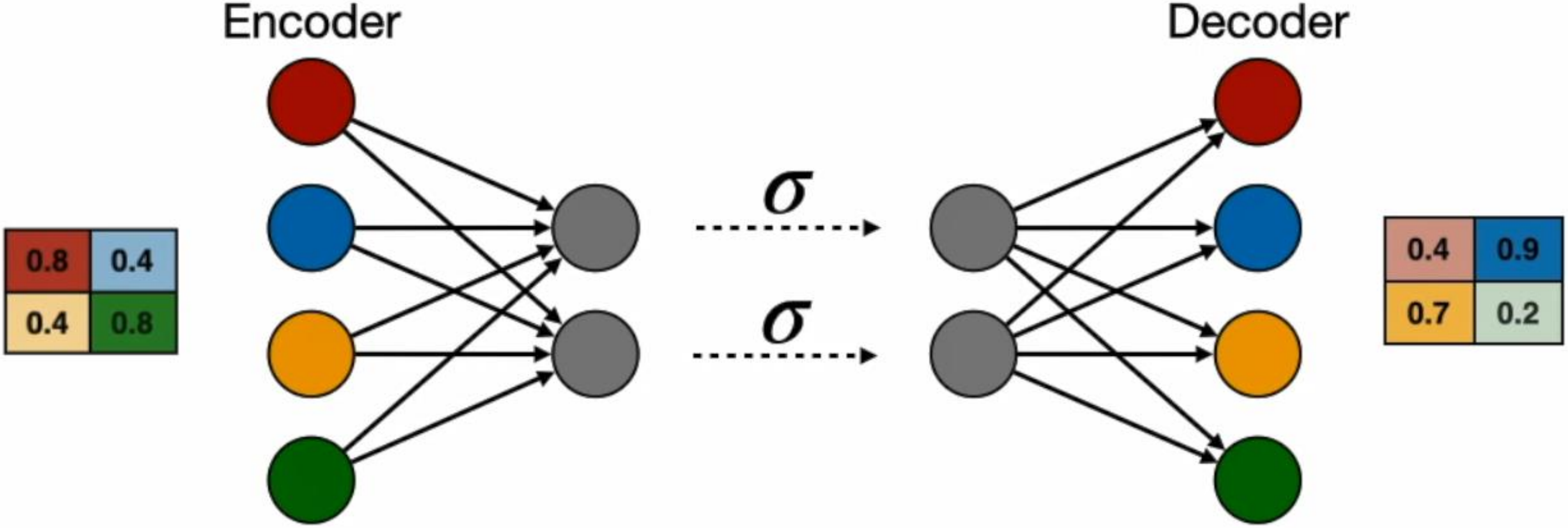
$y$

| | |
|---|---|
| 0.1 | 0.9 |
| 0.85 | 0.2 |

$$(0.6 - 0.1)^2 + (0.4 - 0.9)^2 + (0.4 - 0.85)^2 + (0.6 - 0.2)^2$$

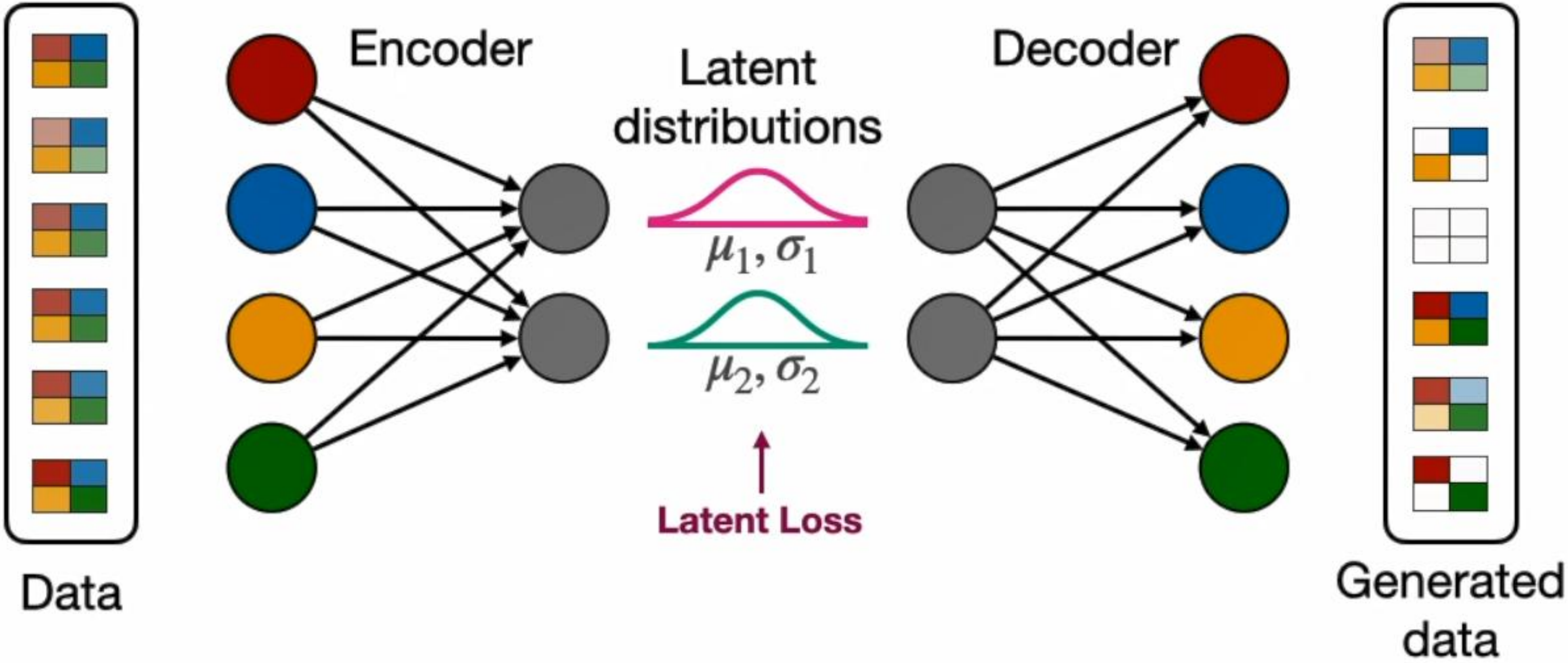
$$= 0.8625$$

# Training an variational autoencoder

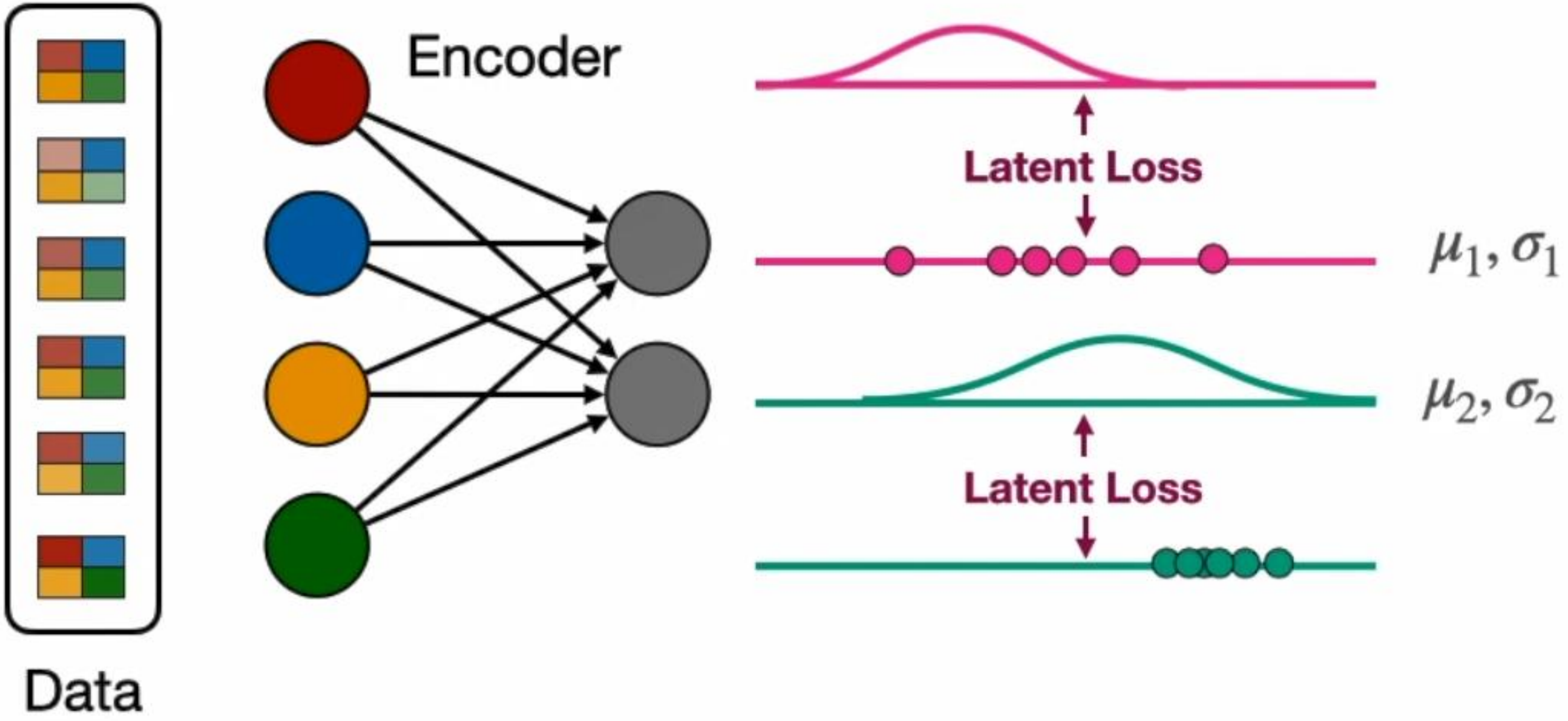



Recostruction loss

# Training a variational auto encoder



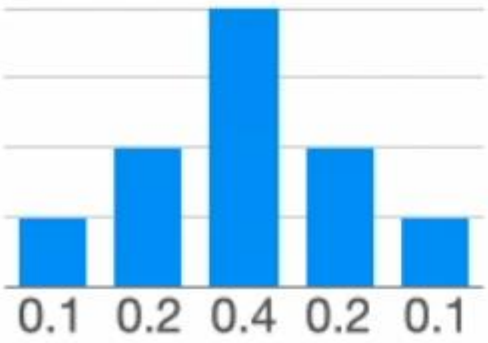
# Training a variational auto encoder



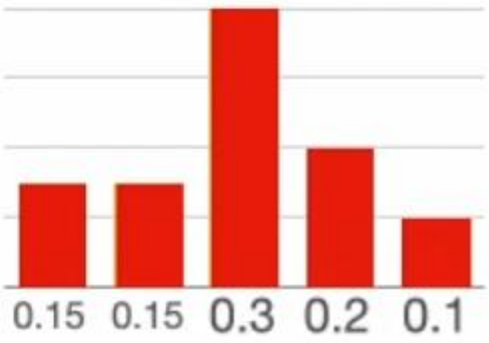
# Latent loss (KL-divergence)

$$KL(p, q) = \sum_i p_i \ln\left(\frac{p_i}{q_i}\right)$$

$p$



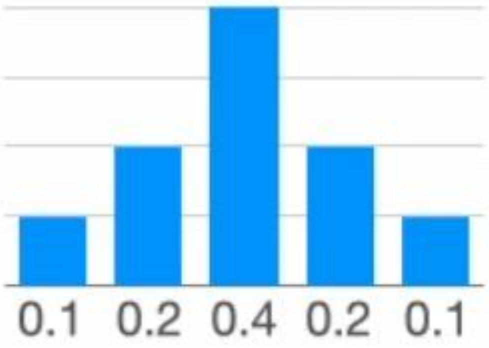

$q$



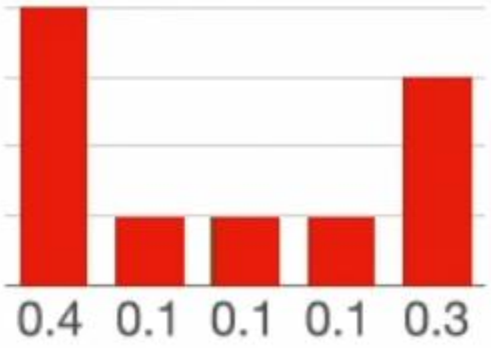

$$0.1 \ln \frac{0.1}{0.15} + 0.2 \ln \frac{0.2}{0.15} + 0.4 \ln \frac{0.4}{0.4} + 0.2 \ln \frac{0.2}{0.2} + 0.1 \ln \frac{0.1}{0.1}$$

$$= 0.132$$

$p$



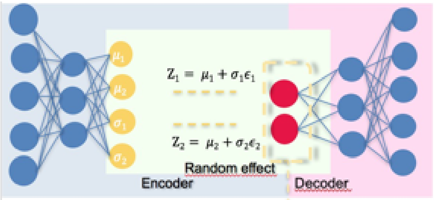

$q$



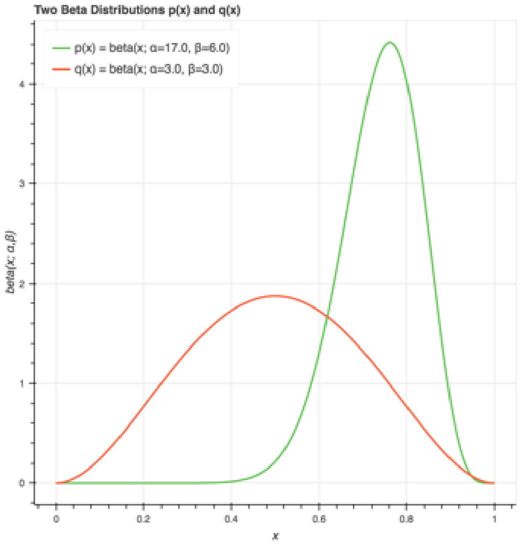

$$0.1 \ln \frac{0.1}{0.4} + 0.2 \ln \frac{0.2}{0.1} + 0.4 \ln \frac{0.4}{0.1} + 0.2 \ln \frac{0.2}{0.1} + 0.1 \ln \frac{0.1}{0.3}$$

$$= 0.583$$

- Force ordering in latent space




- During training, you are minimising some loss function




- For regression (normal AE): MSE(*output* - *input*)

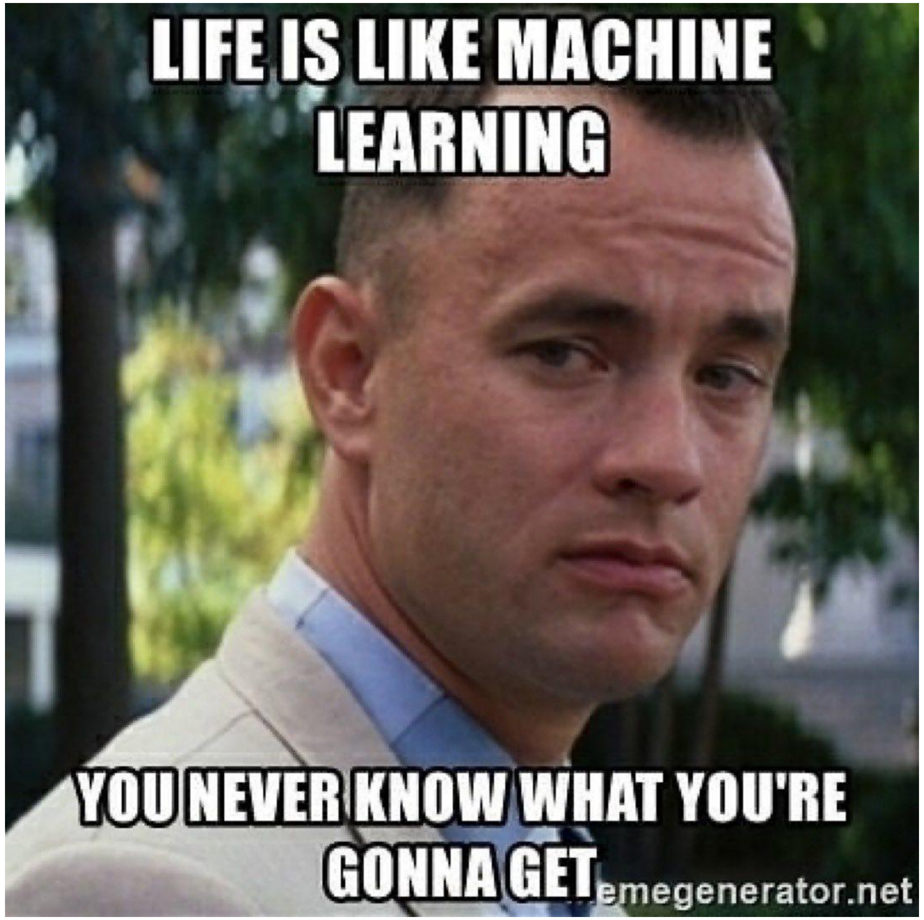
- Add KL-divergence term: $\Sigma_i \, \mathrm{KL}(\mathcal{N}(\mu_i, \sigma_i), \mathcal{N}(0,1)) := \mathrm{KL}(\mu,\sigma)$

- So $\mathcal{L}$ = MSE(*output* - *input*) + KL($\mu,\sigma$)

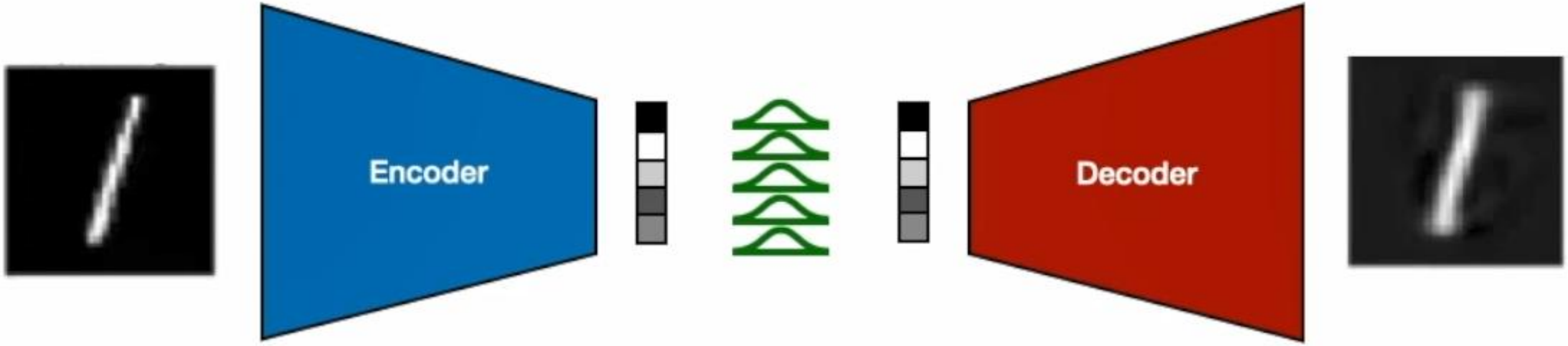
- The KL divergence punishes latent space values far away from the center

- Also, every point has a variance that is pushed to 1

- Balance MSE and KL —> group similar structures around the center



# Training a variational auto encoder



Gli autoencoder e i variational autoencoder (VAE) sono entrambi modelli di AI generativa per la compressione e la decompressione delle informazioni. Tuttavia, la principale differenza tra loro riguarda la modalità in cui trattano lo spazio latente, ovvero lo spazio di rappresentazione compresso delle informazioni.

Gli autoencoder tradizionali cercano di apprendere una rappresentazione compatta dei dati di input riducendoli in uno spazio latente tramite una funzione di codifica. Questo spazio latente viene poi utilizzato per decodificare una rappresentazione approssimata dei dati originali. Tuttavia, questo spazio latente non ha alcuna struttura specifica e le nuove rappresentazioni generate potrebbero non avere un significato coerente.

I VAE, d'altra parte, introducono una differenza chiave aggiungendo una componente di stocasticità allo spazio latente. Questo significa che invece di produrre un punto fisso nello spazio latente, il VAE produce una distribuzione di probabilità nello spazio latente. Questo permette al VAE di generare nuove immagini campionando casualmente punti nello spazio latente e decodificandoli, producendo così una varietà di immagini realistiche.

In sostanza, l'introduzione della componente stocastica nel VAE permette al modello di generare nuove immagini campionando da una distribuzione nello spazio latente, mentre negli autoencoder tradizionali non c'è questa possibilità poiché non c'è una struttura stocastica nello spazio latente.

That's all Folks!