Applied Machine Learning

Autoencoders

Autoencoders

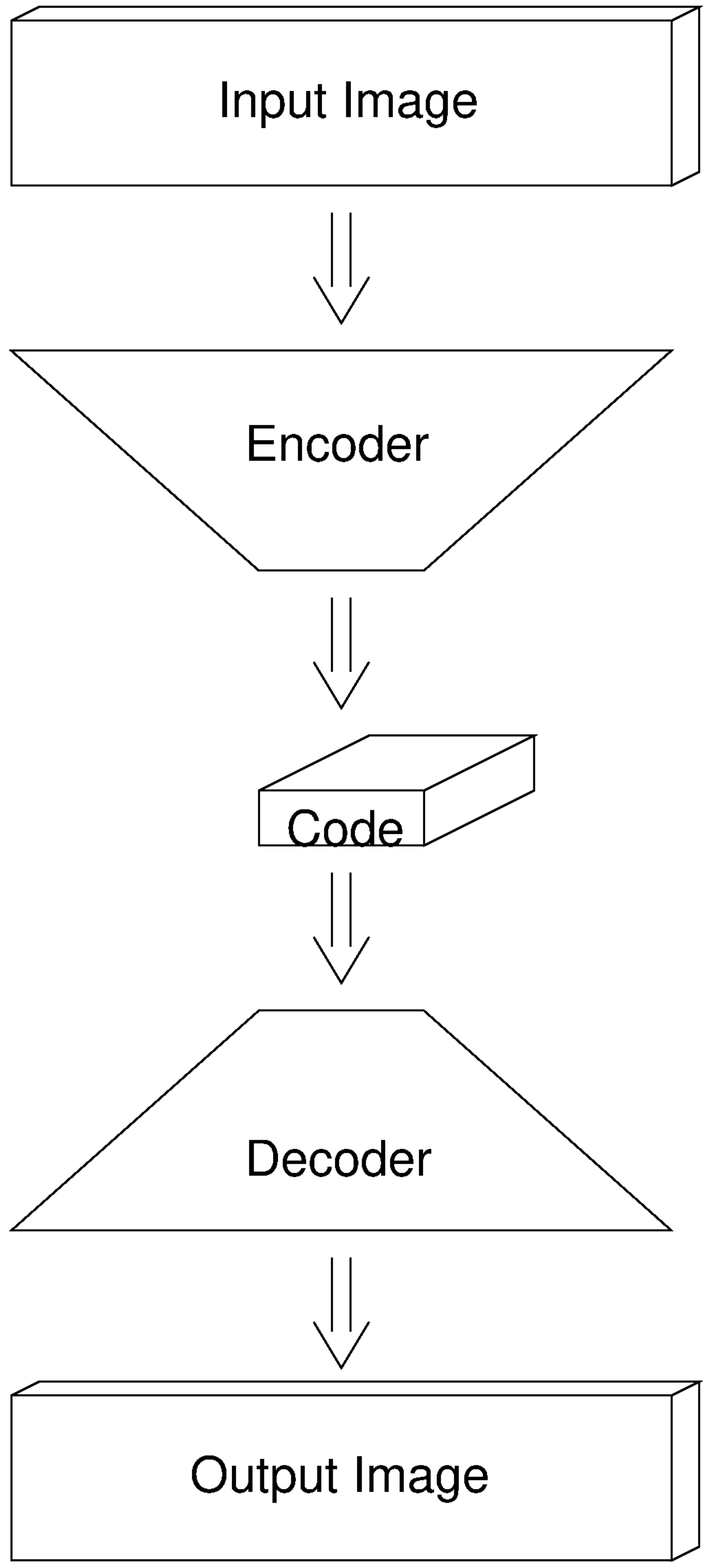
- Structure of autoencoders
- deconvolutional layers
- unpooling layers
- sigmoid layers
- cost function for training autoencoders

Encoders and Decoders

- Encoder
    - Input: high-dimensional data item
    - Output: low-dimensional representation of data item that preserves relevant information
    - CNNs layers as encoders
        - Map pixels to classes
- Decoder
    - Input: low-dimensional representation of data item
    - Output: original high-dimensional data item
    - NN layers as decoders
        - learn reverse mapping to predict original item

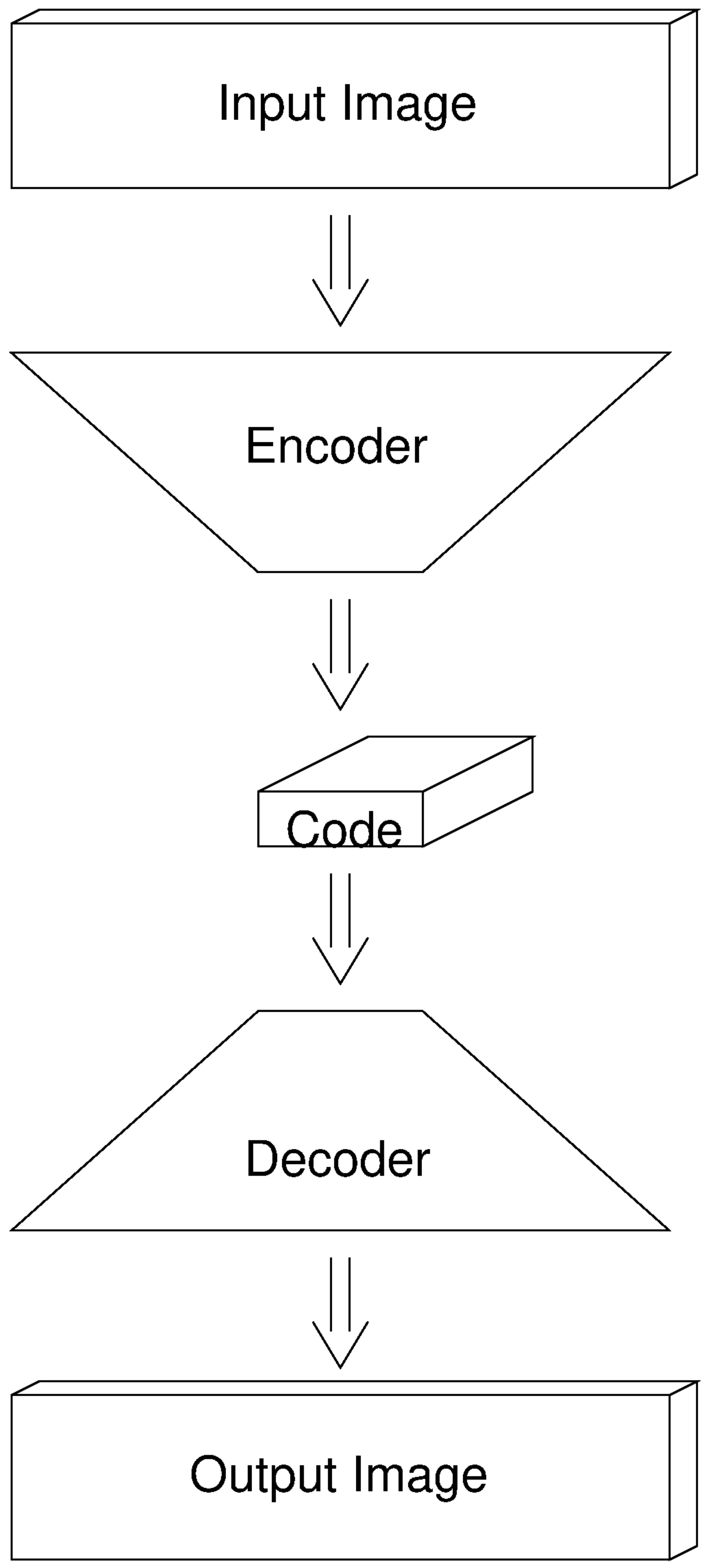
Autoencoders

- Pair of encoder and decoder that are trained together
  - Encoder: $\mathscr{E}$
    - maps item $\mathbf{x}_i$ into code $\mathbf{z}$
    - $\mathbf{z} = \mathscr{E}(\mathbf{x}_i)$
  - Decoder: $\mathscr{D}$
    - reconstructs item $\mathbf{x}_o$ from from code $\mathbf{z}$
    - $\mathbf{x}_o = \mathscr{D}(\mathbf{z})$
  - Training goal: output similar to input
    - $\mathbf{x}_o \approx \mathbf{x}_i$



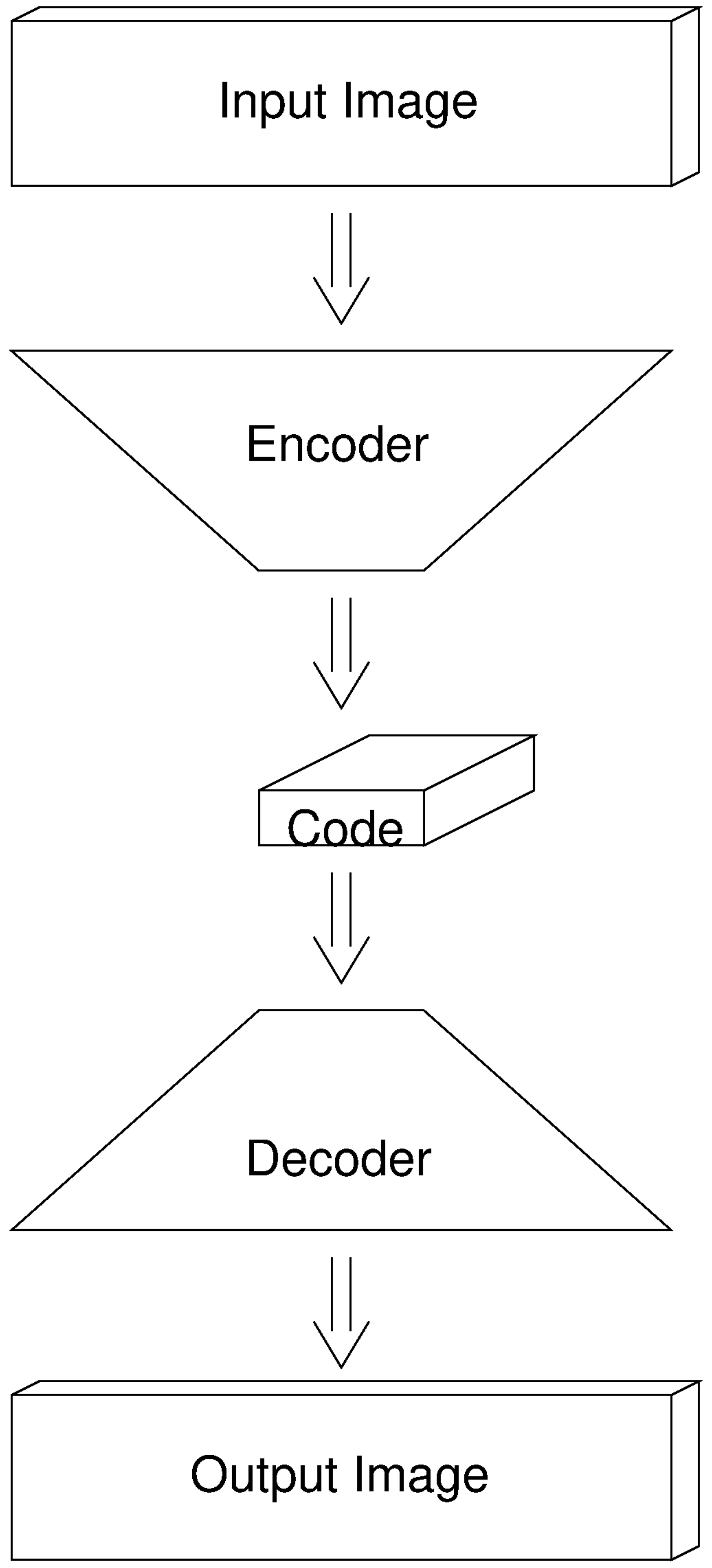
Autoencoders

- Encoder: $\mathscr{E}$ $\qquad$ $\mathbf{z} = \mathscr{E}(\mathbf{x}_i)$
- Decoder: $\mathscr{D}$ $\qquad$ $\mathbf{x}_o = \mathscr{D}(\mathbf{z})$
- Training goal: $\qquad$ $\mathbf{x}_o \approx \mathbf{x}_i$
- Some Applications:
  - Unsupervised feature learning
    - $\mathbf{z}$: feature set, $\mathbf{x}_o$: validation
  - Clustering
    - $\mathbf{z}$: cluster distribution, $\mathbf{x}_o$: validation
  - Image Generation
    - $\mathbf{z}$: image distributions, $\mathbf{x}_o$: reconstructed images



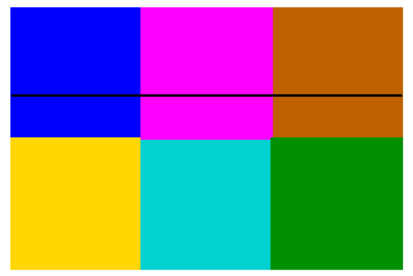
Autoencoder for Images

- Input: Image I_i with dimensions $i_u \times i_v \times 1$
- Encoder layers
  - convolutional + pooling layers
    - stride length $s > 1$
    - parameters: θ_e
  - Output code: Feature map $Z_i = \mathscr{E}(I_i, \theta_e)$
    - Dimensions $z_u \times z_v \times l$
    - Usually smaller than input $z_u \times z_v \ll i_u \times i_v$
- Decoder layers mirror structure of the encoder layers
  - deconvolutional layer mirrors convolutional layer
  - unpooling layer mirrors pooling layer



Deconvolutional Layer

- Deconvolutional or transposed convolutional layer
    - Complementary to convolutional layer
    - Increases spatial dimensionality of input
    - input dimensions: $u \times v \times 1$
- Output feature map
    - Stride length: s
    - dimensions:
      $[u + u * (s - 1)] \times [v + v * (s - 1)] \times 1$
    - Kernel dimensions: $[2 * k + 1] \times [2 * k + 1]$



Unpooling Layer

- Unpooling Layer
  - Complementary to function applied at the pooling layer
  - same patch size p as in the mirrored pooling layer
- Output feature map with one patch per input pixel initialized with 0s
  - average unpooling
    - copy input pixel value to all pixels in the output patch
  - maximum pooling:
    - Modification to mirrored pooling layer
      - max-pooling map
      - map with location of source max pixel
    - copy input pixel value to output patch at the same location of max pixel at mirrored pooling layer

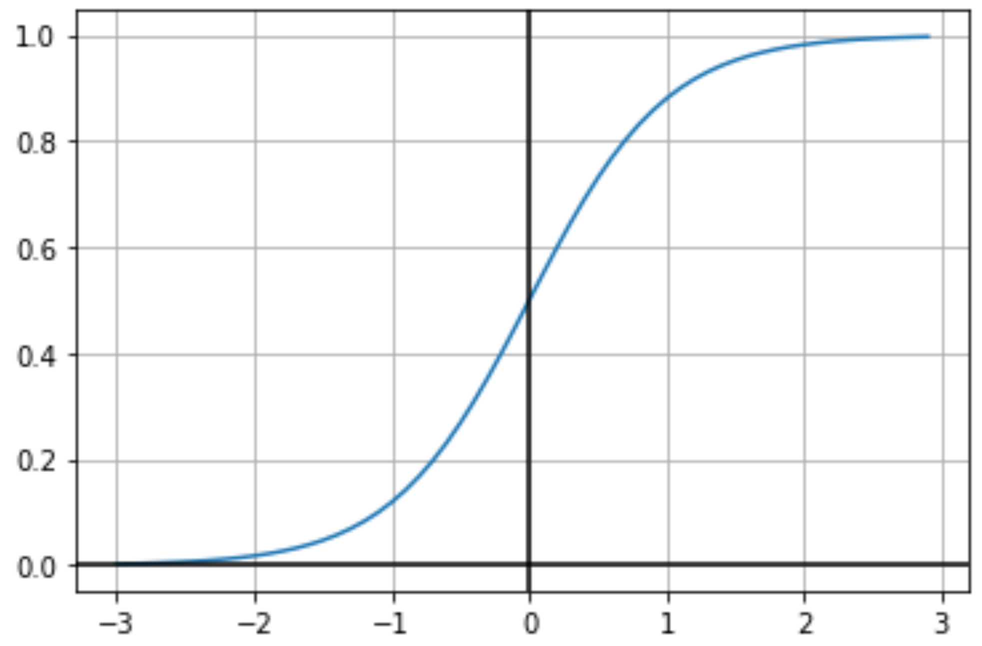
Avg.

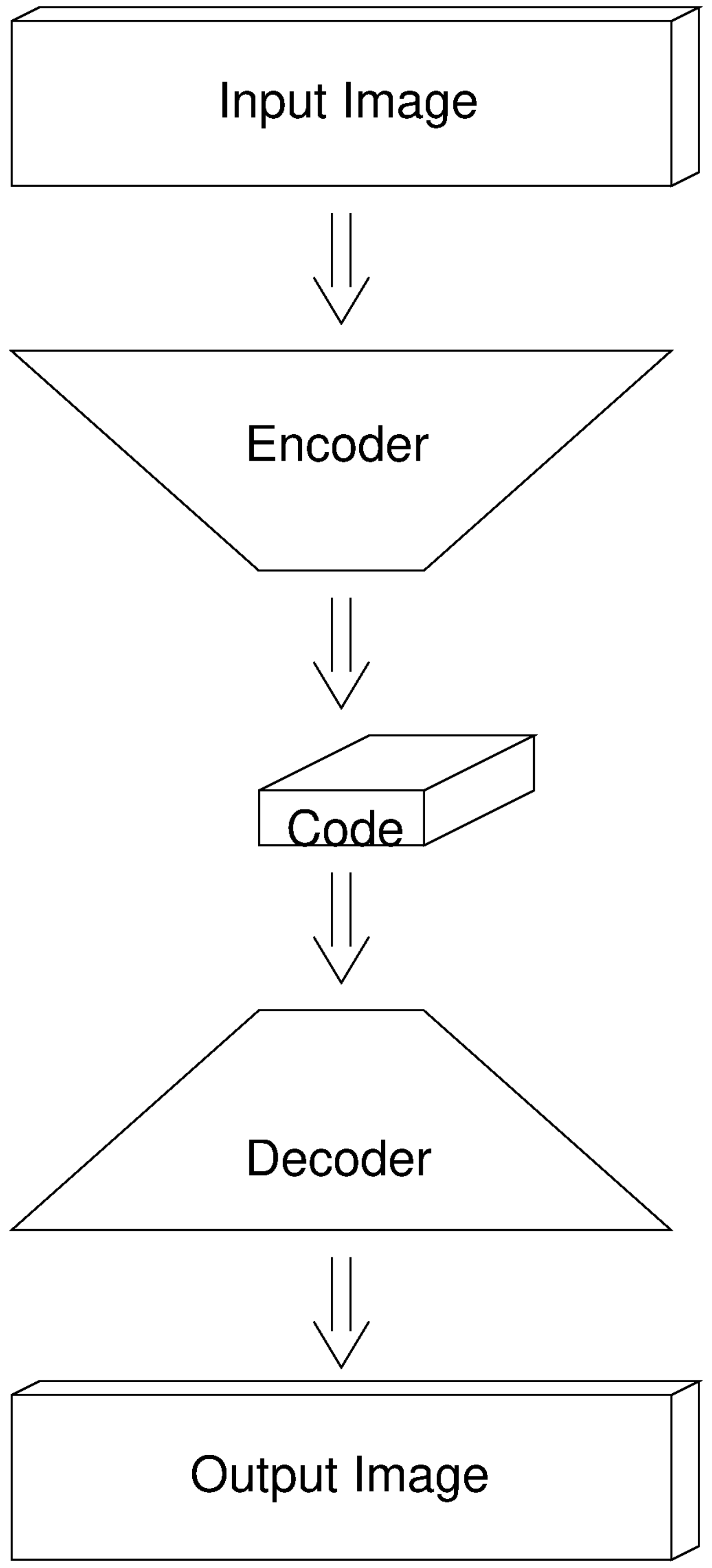
2	0.5
1.5	0

2	2	0.5	0.5
2	2	0.5	0.5
1.5	1.5	0	0
1.5	1.5	0	0

Sigmoid Layer

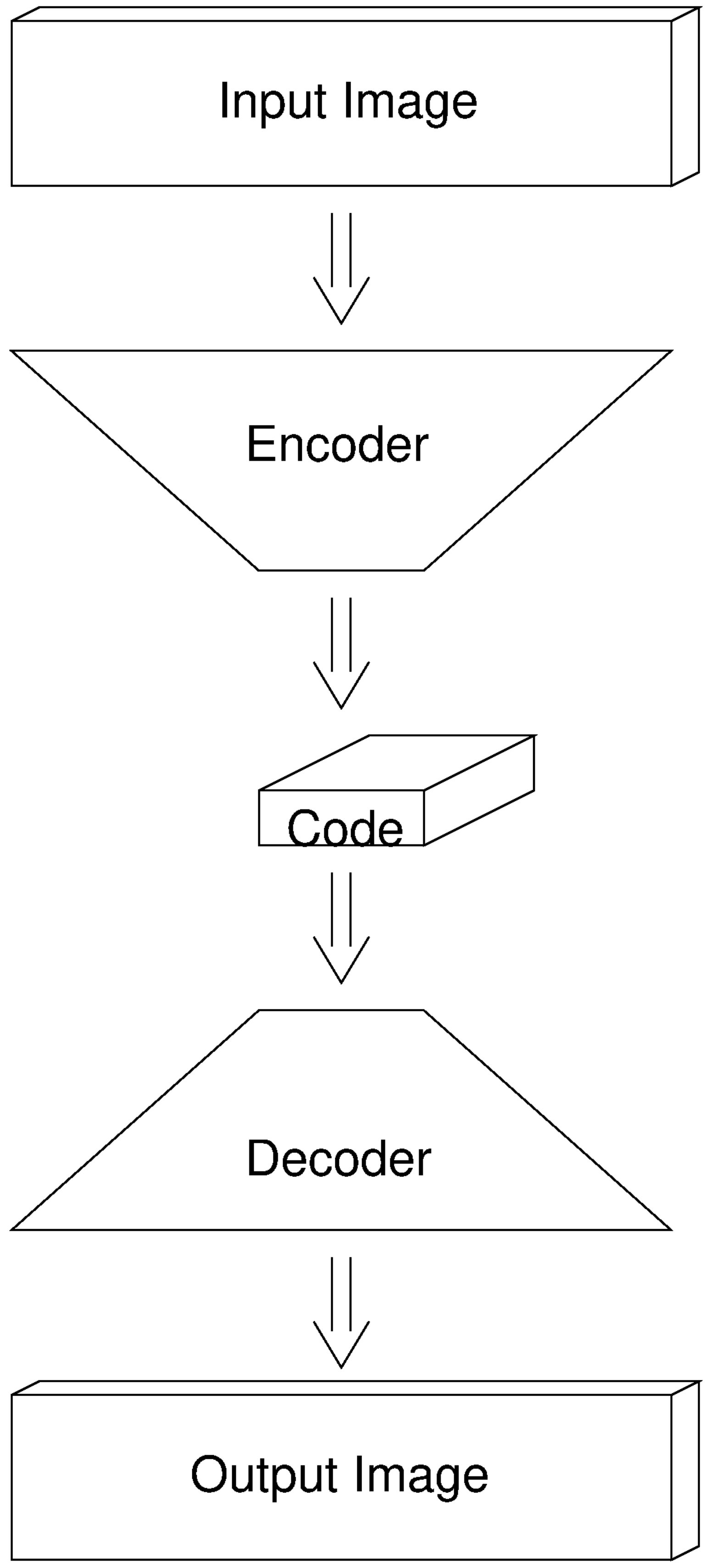
- Output decoder layer
  - Image
  - non-linear
    - sigmoid: $s(x) = \dfrac{1}{1 + e^{-x}}$
      - output range: [0-1]
      - can be mapped to [0-255]
- if needed, preprocess inputs to the encoder to be in range [0-1]





Training Autoencoder

- Input: image I_i
- Encoder
  - parameters θ_e
  - Output: Feature map $Z_i = \mathscr{E}(I_i, \theta_e)$
- Decoder
  - parameters θ_d
  - Output: image $\mathscr{D}(Z_i, \theta_d)$
- Cost function: $\|\mathscr{D}(Z_i, \theta_d) - I_i\|^2$
  - susceptible to small changes in images in training set



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