Convolutional Neural Nets

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Questionnaire

- Please go to Ilias
- Open the questionnaire ‚NN Basics'
- Note that the questionnaire is anonymous, meaning we only receive the final statistics and responses, not the identities of the individuals who submitted them.

Outline

- Motivation
- Convolutional Neural Nets (CNN)
- Training
- Applications

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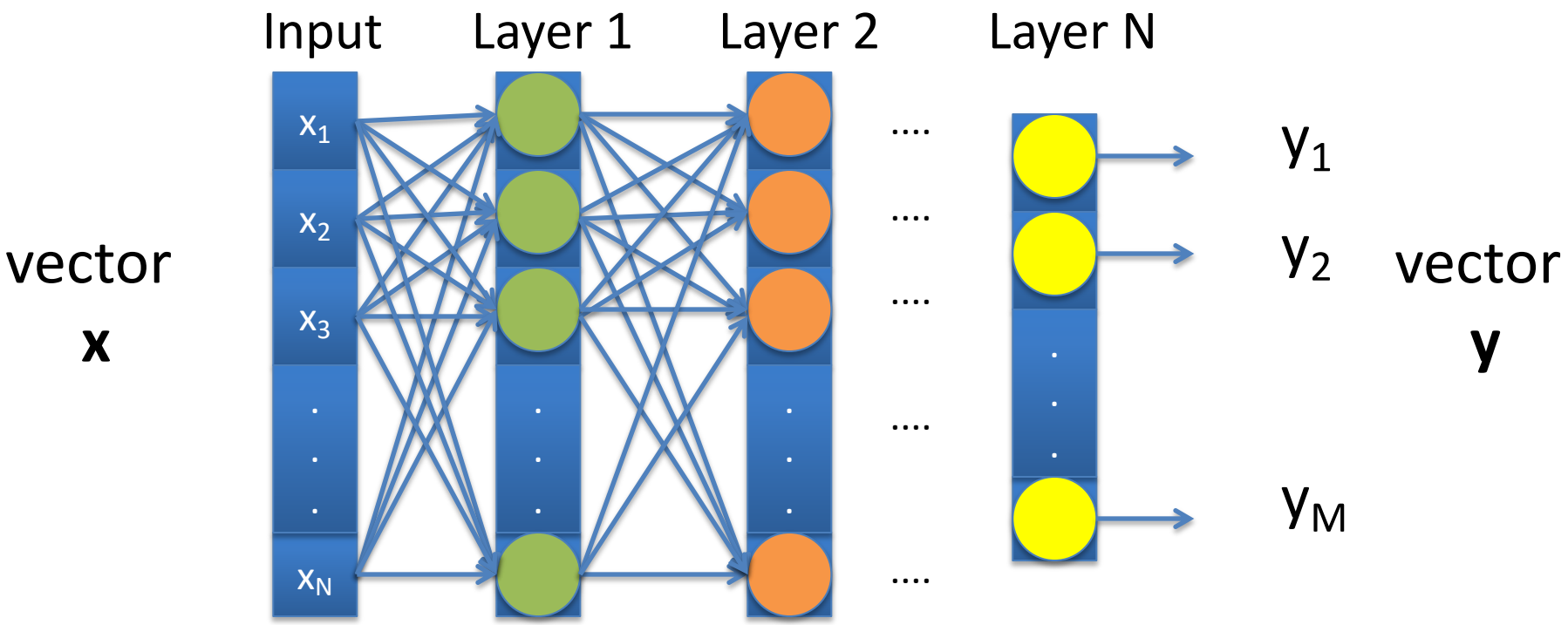
Feed-forward Neural Nets



Challenges

- Challenge 1: What if the input is a matrix?

0	1	0	0	1
2	3	3	3	4
4	0	1	0	1
3	4	2	3	3

Challenges

- Challenge 1: What if the input is a matrix?

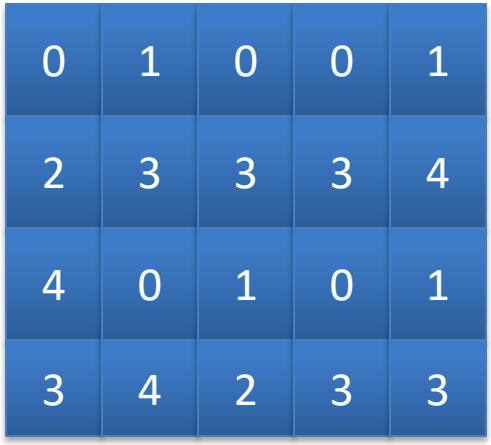
0	1	0	0	1
2	3	3	3	4
4	0	1	0	1
3	4	2	3	3

0
2
4
3
1
3
0
4

…

Challenges

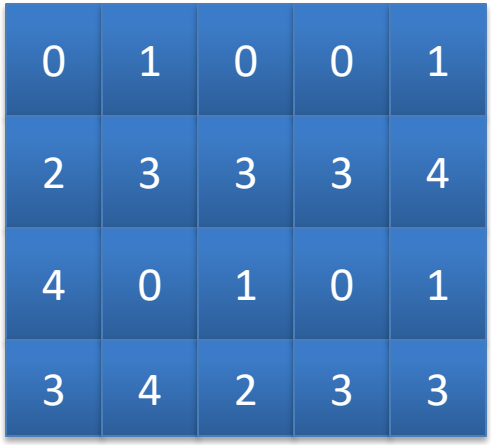
- Challenge 1: What if the input is a matrix?



- #parameters ↗

Challenges

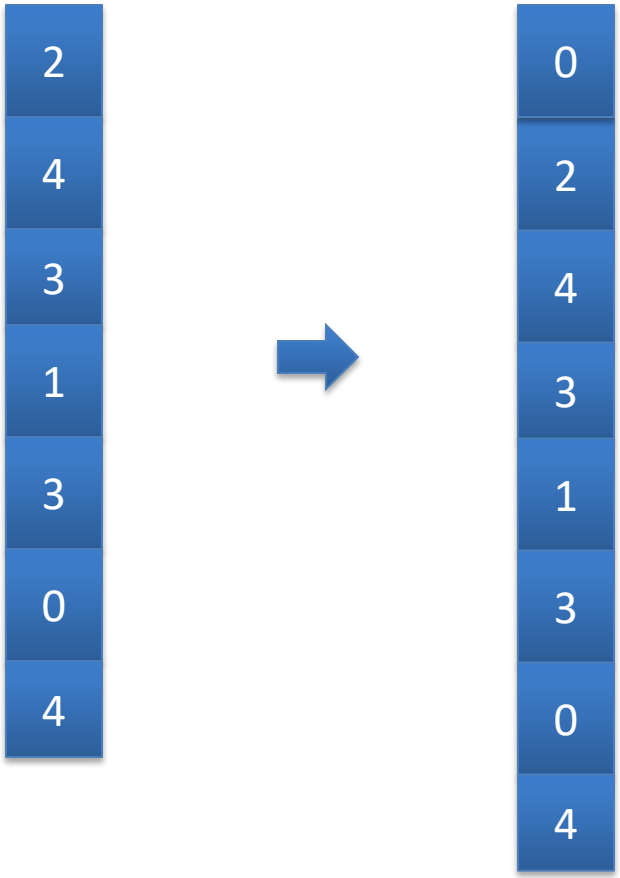
- Challenge 1: What if the input is a matrix?



- Don‘t want to blow up the number of parameters
  - If possible, reduce the number of parameters

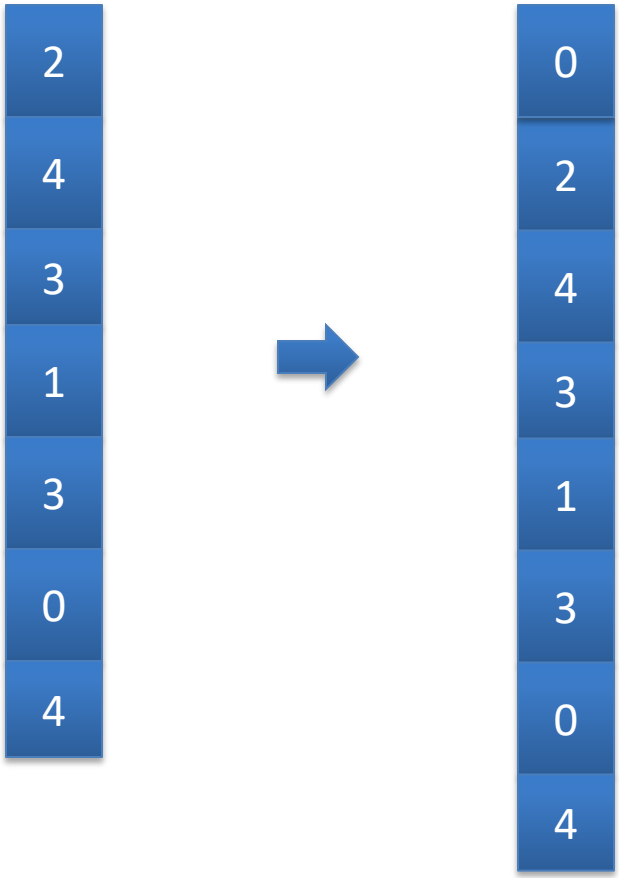
Challenges

- Challenge 2: What if the input is shifted?



Challenges

- Challenge 2: What if the input is shifted?

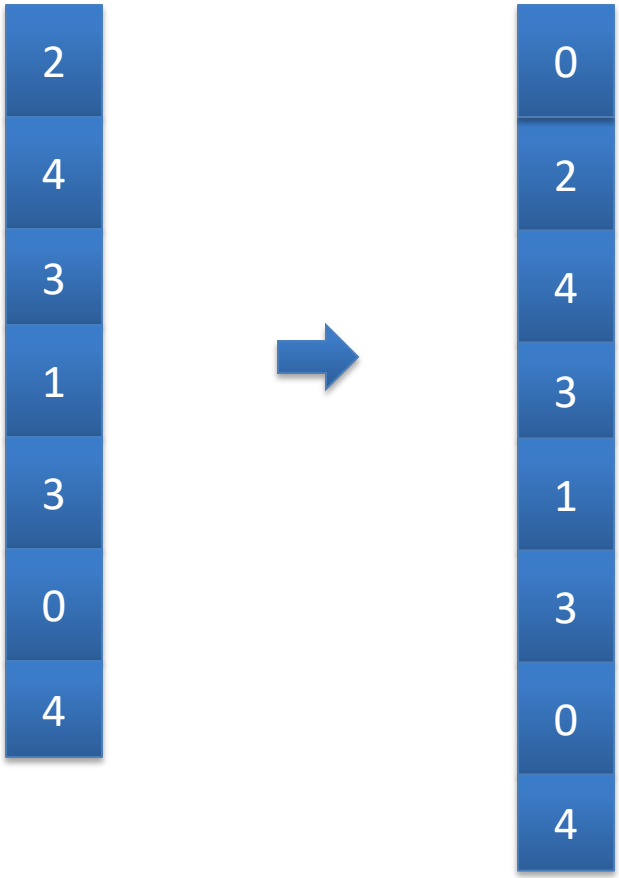


Real-world example 1:

- Language processing:
  - Input 1: „I am happy today“
  - Input 2: „Today I am happy“

Challenges

- Challenge 2: What if the input is shifted?

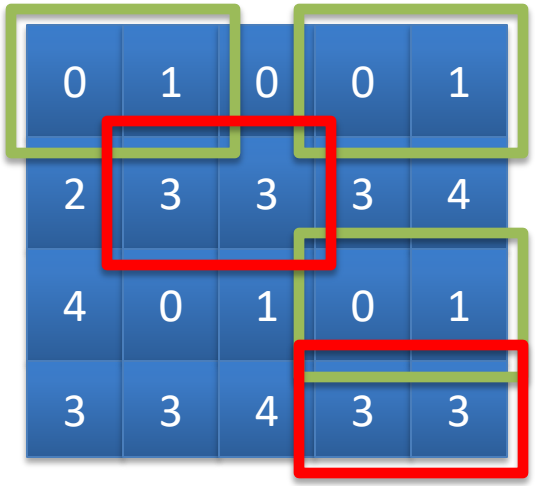


Real-world example 2:

- Computer vision:

Challenges

- Challenge 2: What if the input is shifted?



- Wish to recognize patterns
  - Position independent

Convolutional neural nets

- Proposed by LeCun et al. 1990
  - Hand-written digit recognition with a back-propagation network
- One version of this network was proposed by Waibel in 1989
  - Phoneme recognition using time-delay neural networks
- Image recognition with Convolution Neural Nets has won all the competitions
- Also used in speech recognition and natural language processing

Convolutional neural nets

- The first CNN which won the ImageNet Large Scale Visuale Recognition Challenge (ILSVRC) 2012

Model	Top-1 (%)	Top-5 (%)
Sparse Coding	47.1	28.2
SIFT + FVs	45.7	25.7
CNN	37.5	17.0

Results on ILSVRC-2010 test data

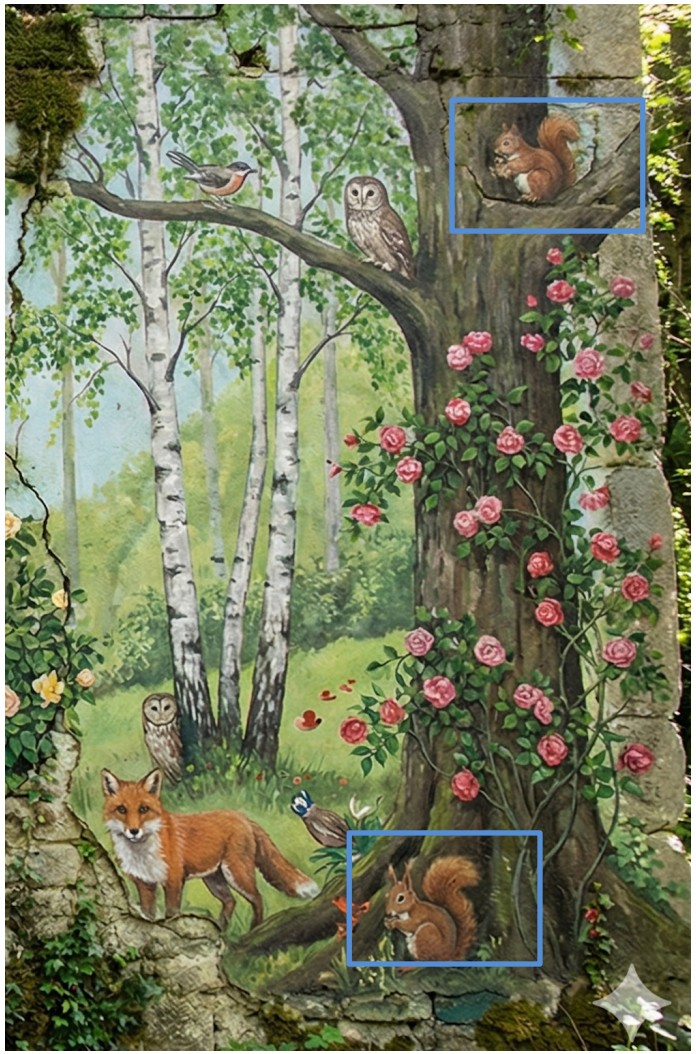
Model	Top-5 (%)
Sparse Coding	26.2
5 CNNs	16.4
7 CNNs	15.3

Results on ILSVRC-2012 test data

- *Krizhevsky, A., Sutskever, I., Hinton, G.: Imagenet classification with deep convolutional neural networks. In: NIPS (2012)*

Getting the Intuition

Getting the Intuition



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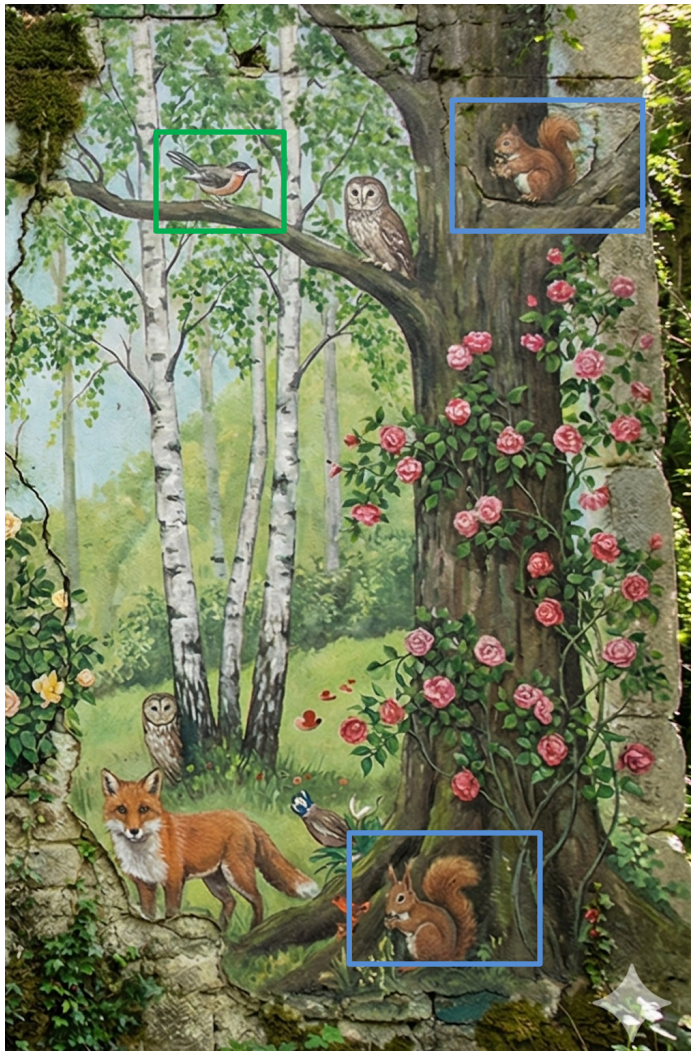

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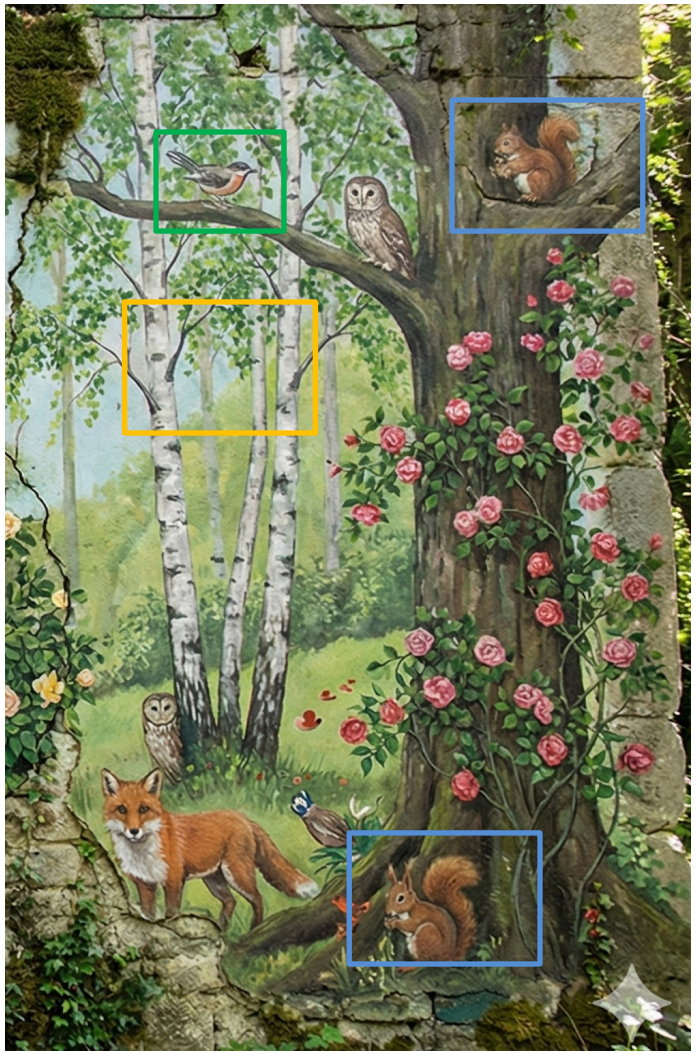

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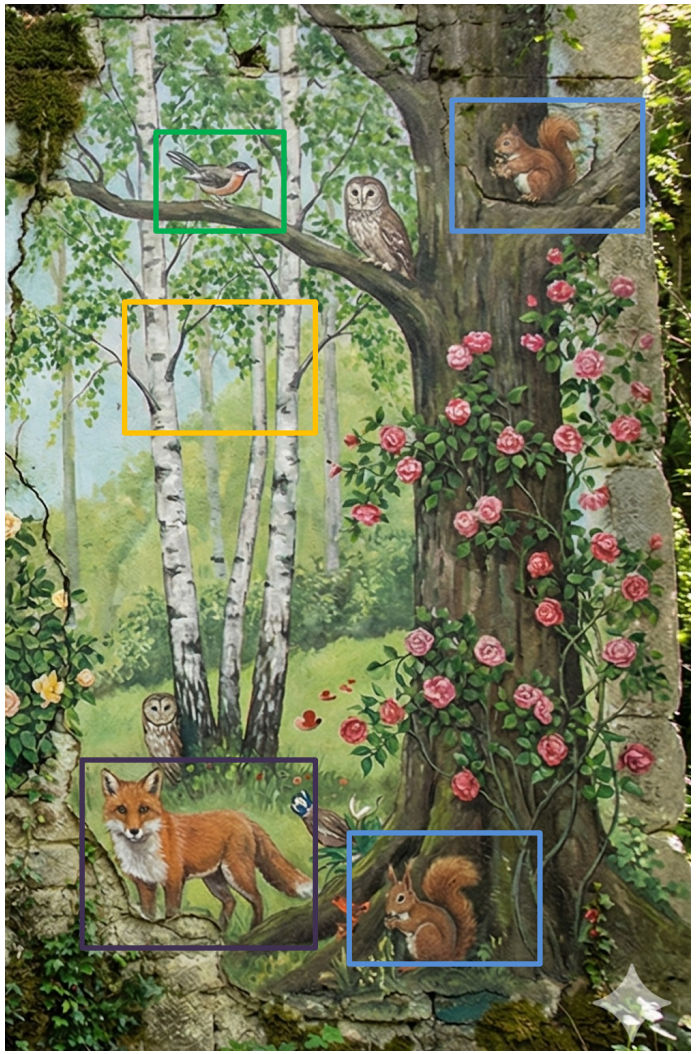

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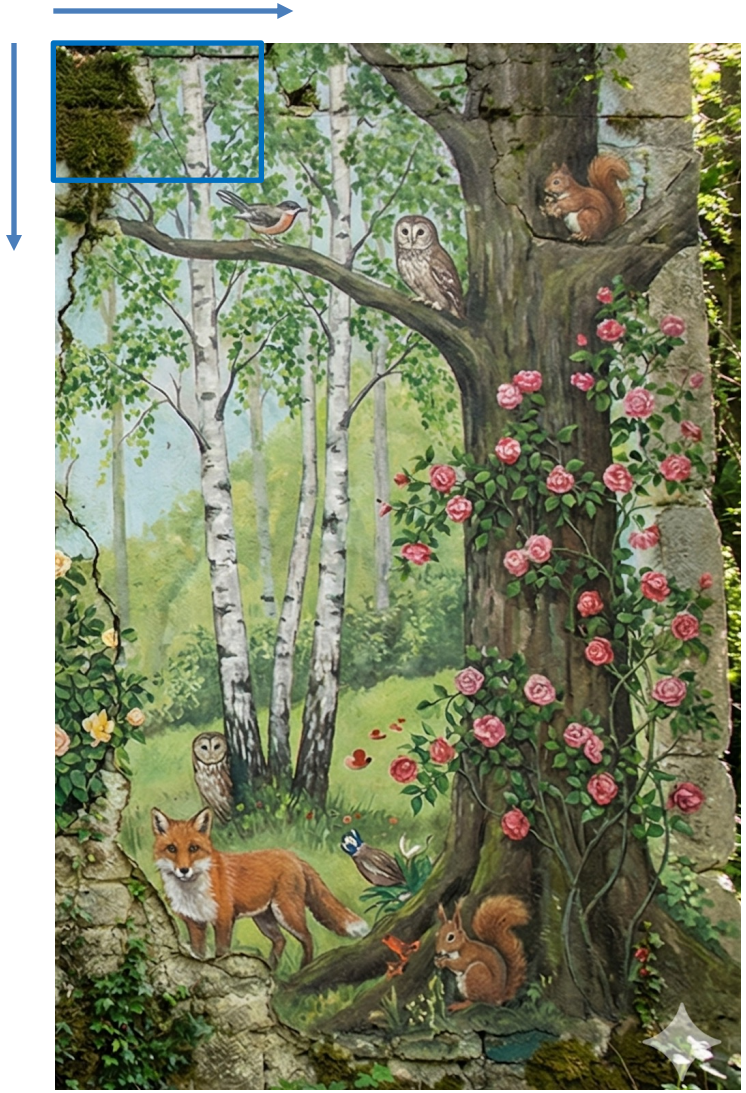

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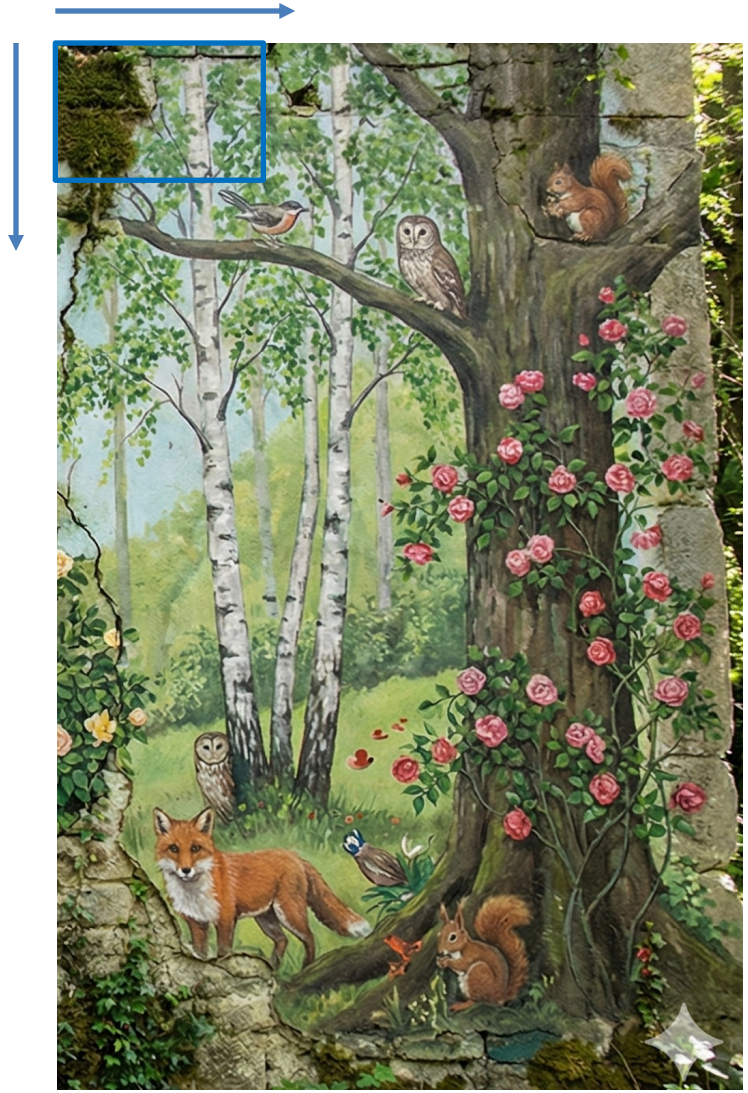
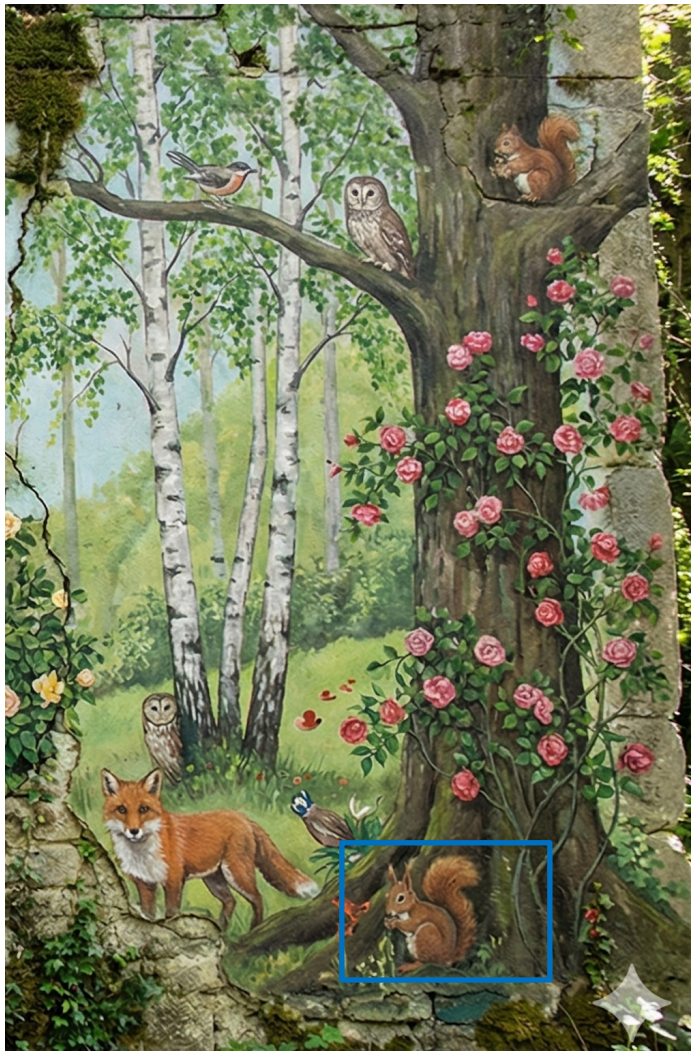


No squirrel found!

Getting the Intuition

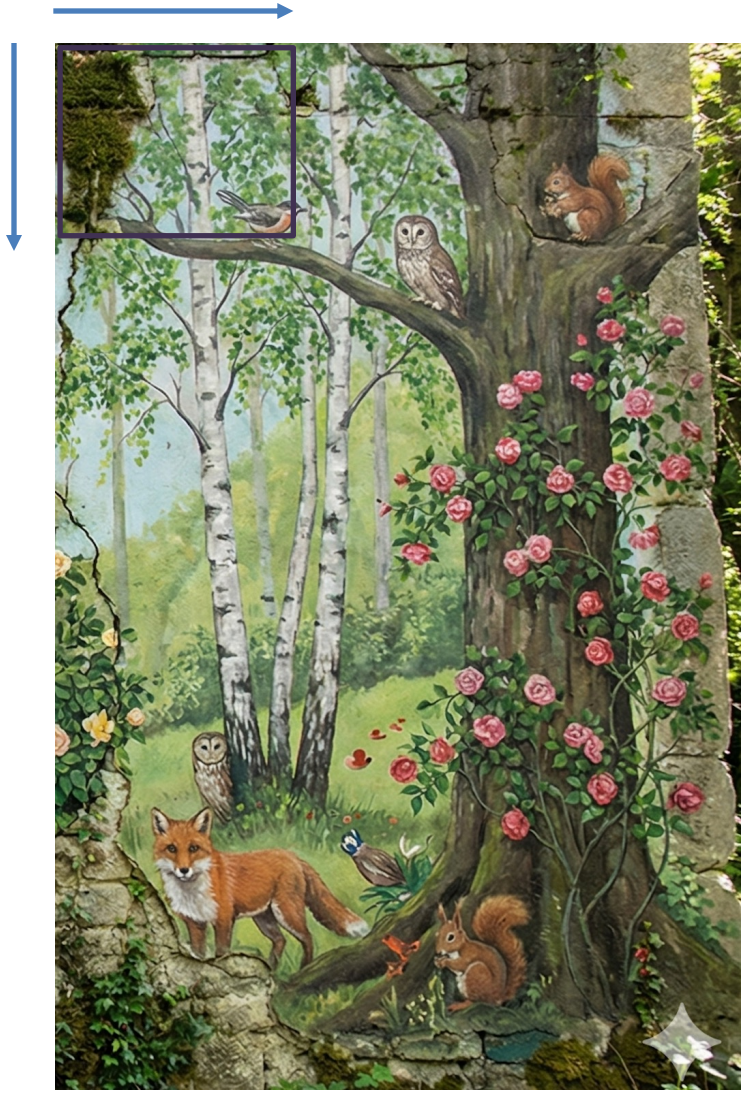
Squirrel found!

Getting the Intuition



Squirrel found!

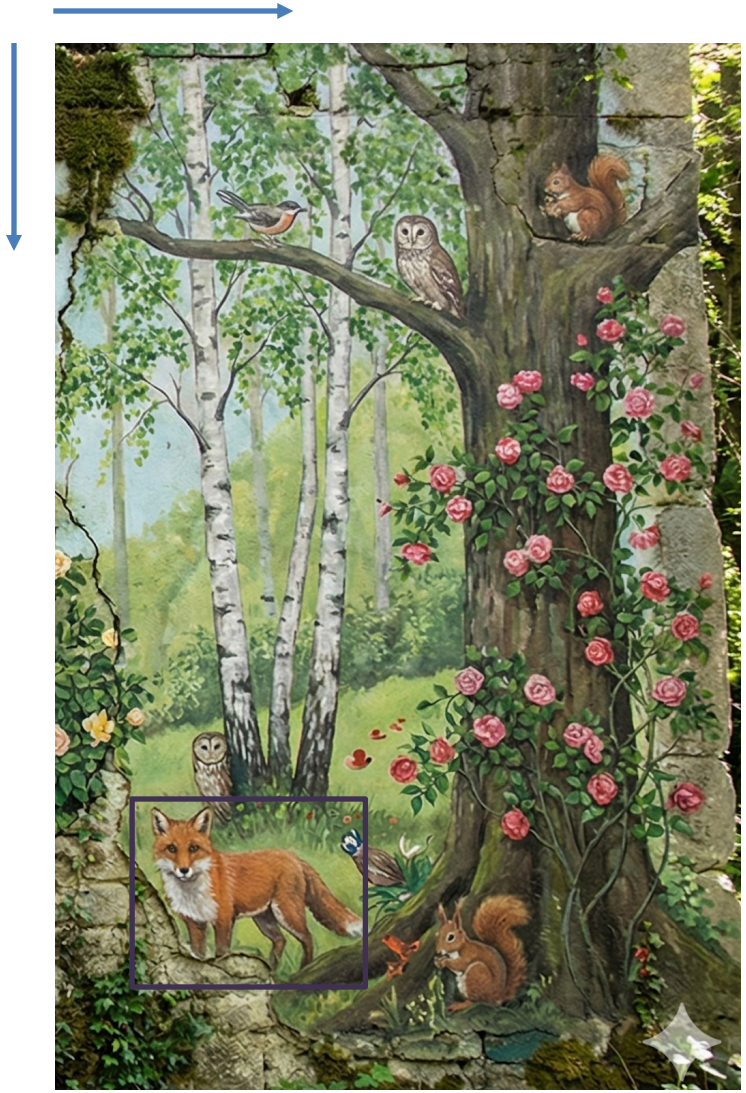
Getting the Intuition



Getting the Intuition

No fox found!

Getting the Intuition



Fox found!

Getting the Intuition

- After the scanning process, we find information:

[No squirrel found, no squirrel found, … **squirrel found**, no squirrel found, …., **squirrel found**, ….]

Filtering out irrelevant information

[squirrel found, squirrel found]

Getting the Intuition

- After the scanning process, we find information:

[No fox found, no squirrel found, … **fox found**, ….]

Filtering out irrelevant information

[fox found]

Getting the Intuition

- After filtering, we merge relevant information

[squirrel found, squirrel found]

[fox found]

Getting the Intuition

- After filtering, we merge relevant information

[**squirrel found, squirrel found**]

[**fox found**]

Decision

Nature scene

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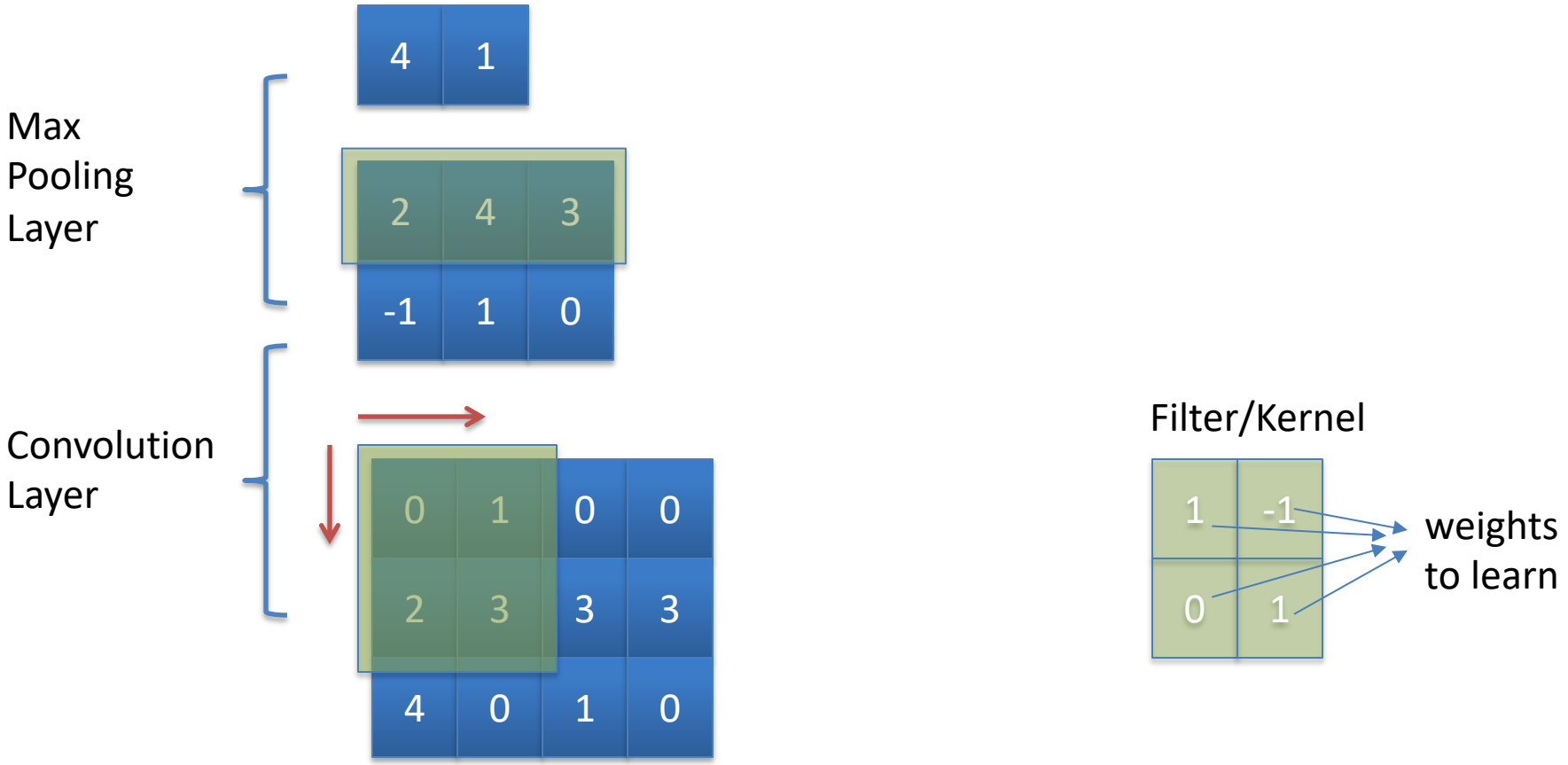
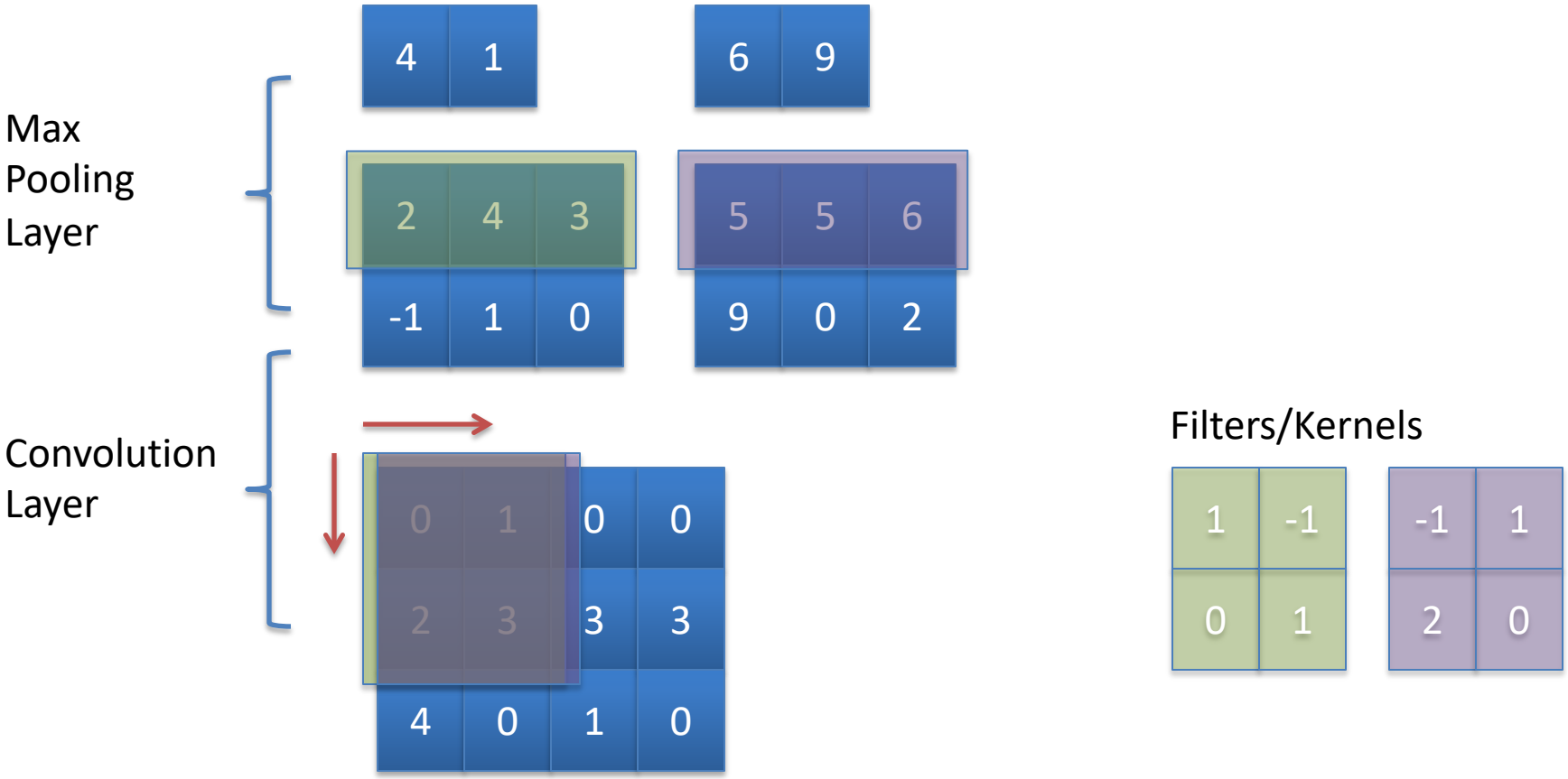
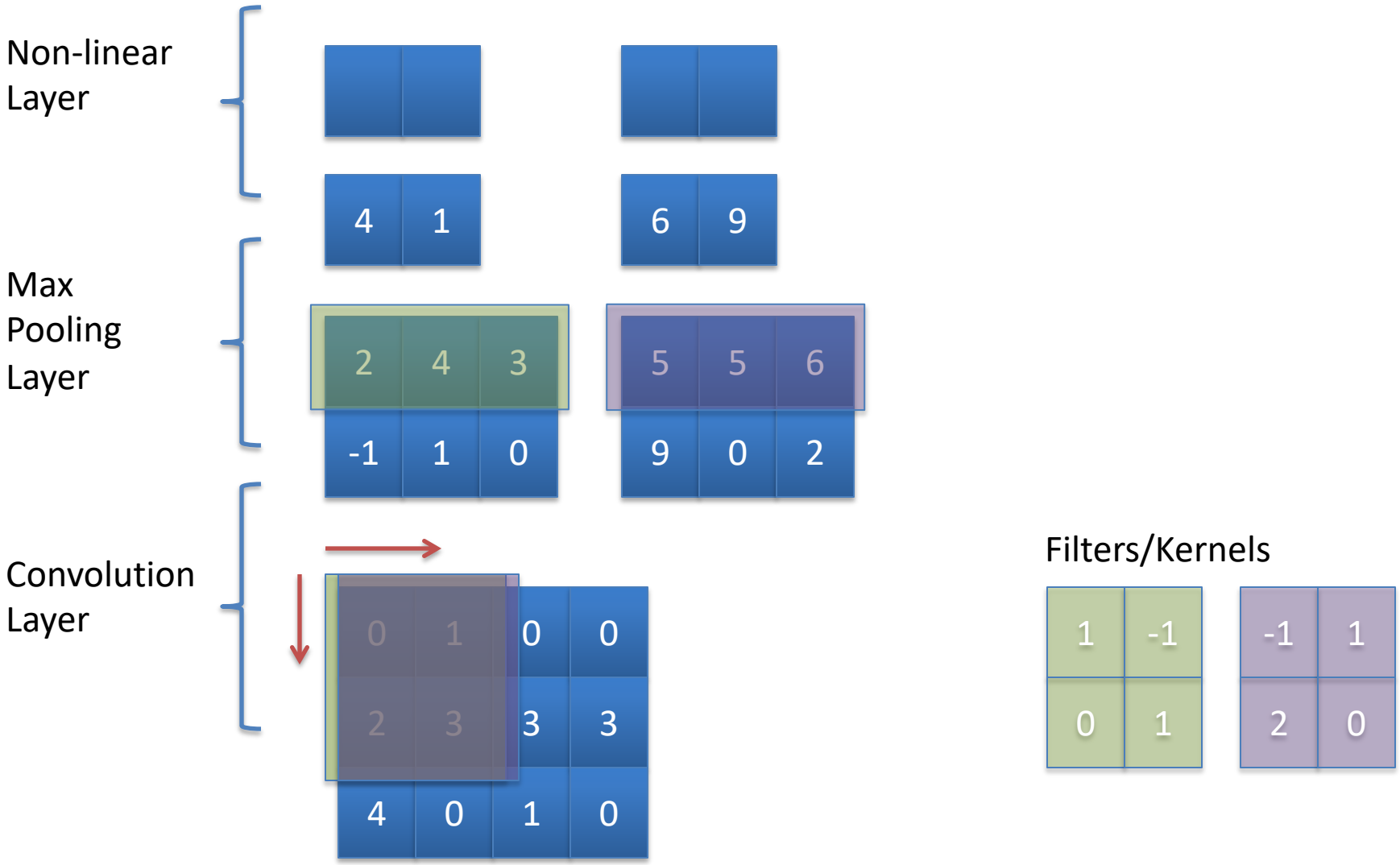
Convolutional Neural Nets



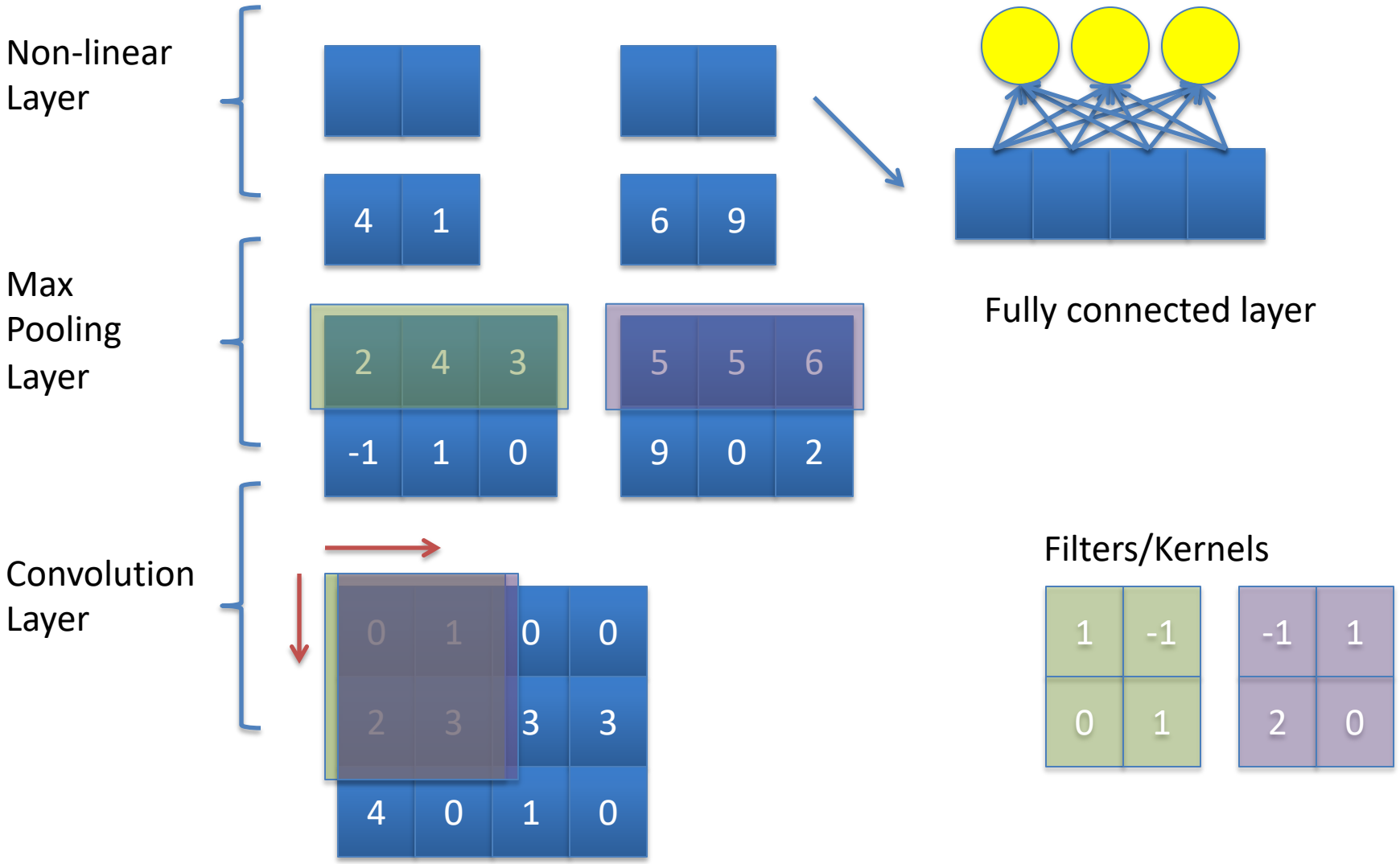
Convolutional Neural Nets



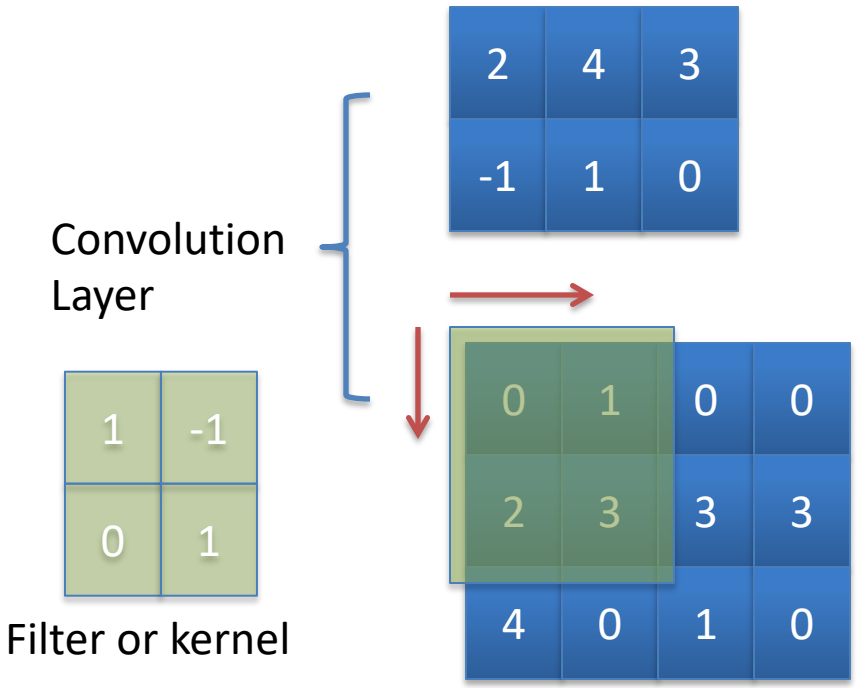
Convolutional Neural Nets



Convolutional Neural Nets



Convolution Layer

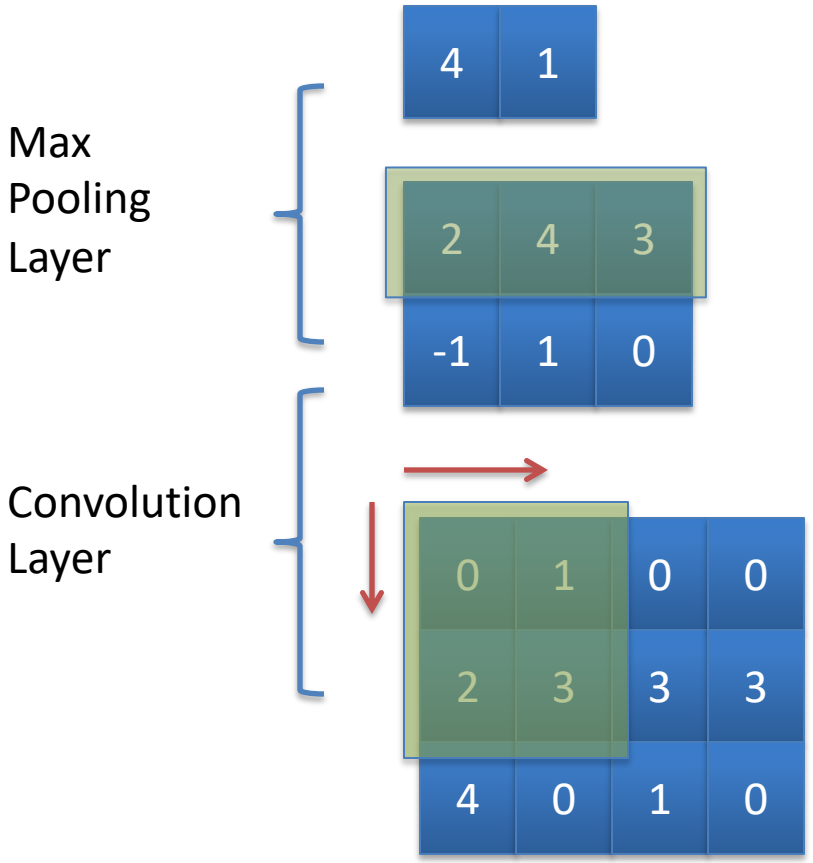


- Learn filters (each is a *mxn* window with weights)
- Shift this window through the input
- Shift called ‚stride' e.g. = 1
- Apply the convolution:

$$f^{l}_{hw} = \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} w^{l}_{ij} f^{l-1}_{h+i,w+j}$$

- Intuition:
  - Learn local features which are important for classification
  - Position independent

(Max) Pooling Layer



- Define a window size (*mxn*)
- Shift this window through the input
- Shift called ‚stride‘, e.g. 1
- Get the max value:

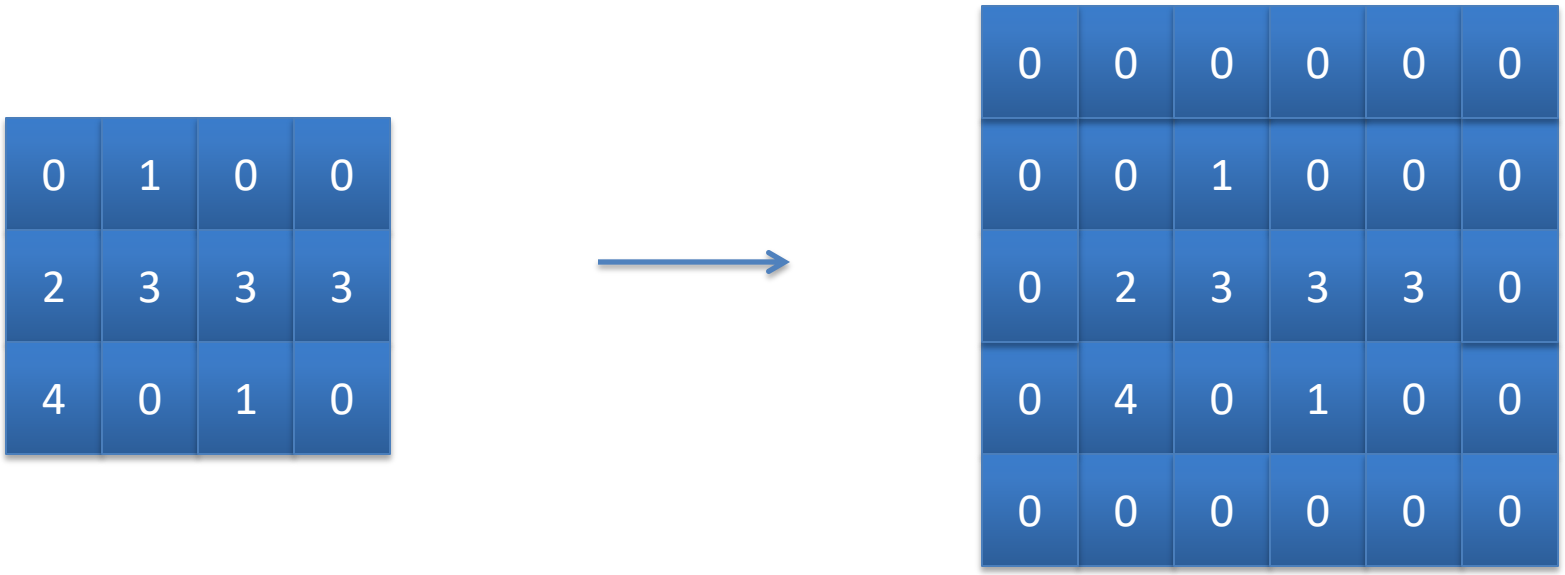
$$f_{hw}^{l+1} = \max_{0<i<m,0<j<n} \{ f_{h+i,w+j}^{l} \}$$

- Intuition:
  - The network should learn to pickup the most important information for further classification

CNN Hyper-parameters

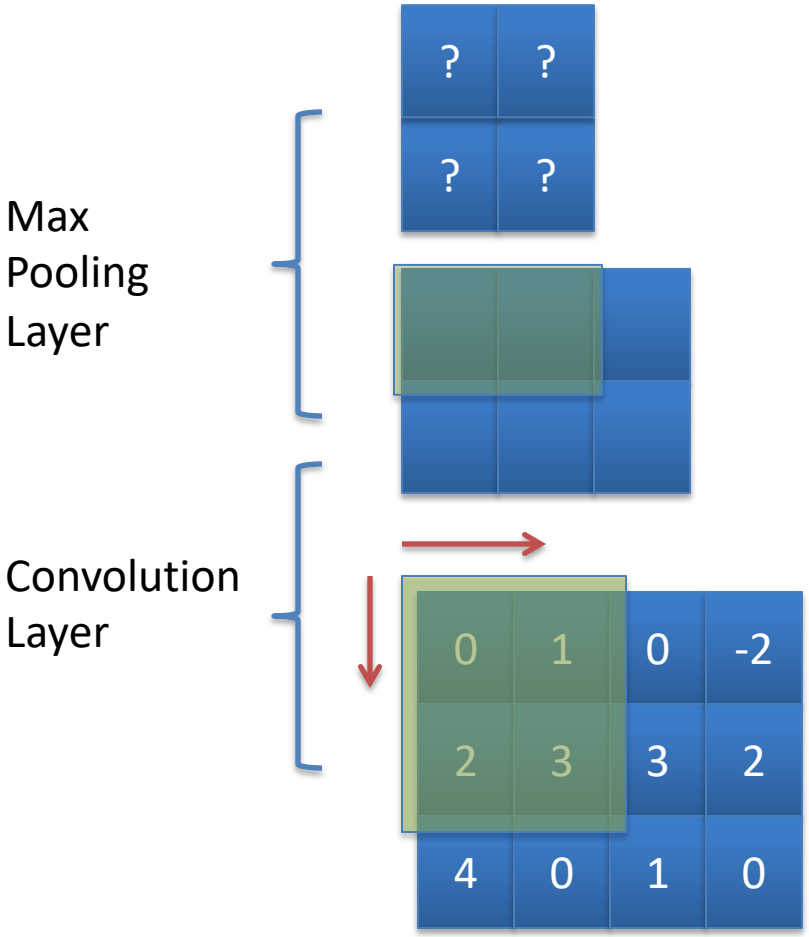
- Convolution Layer:
  - Number of filters
  - Filter size: height and width
  - Stride
- Max pooling layer
  - Pooling size: height and width
  - Stride

Zero Padding



- Motivation:
  - The filters are not well defined for data input which are near the borders → zero padding will help
  - Zero padding size is also one of the hyper-parameters

Example



- Compute the output of the network after applying the convolution and max pooling layer
- b = 0
  stride = (1,1)

-1	1
2	-2

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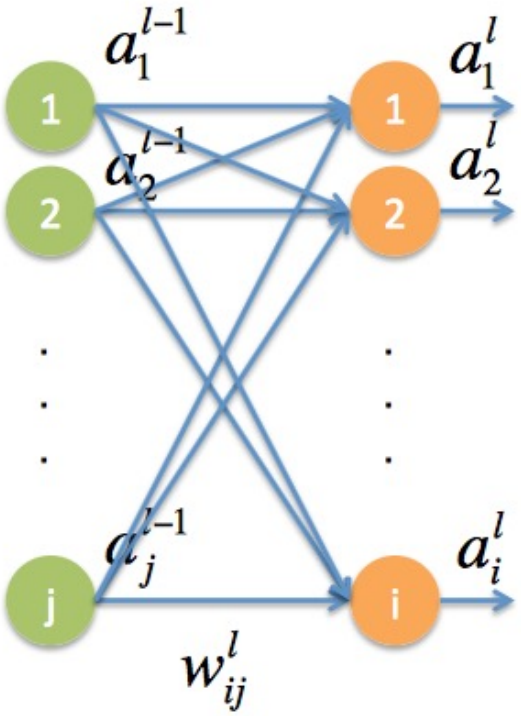
CNN Training with Gradient Descent

- Almost the same as the training for MLP
- Backprogation can be applied
- New things are:
  - Gradient for the convolution layer
  - Gradient for the max pooling layer

Recap: Backpropagation



$$\frac{\partial C}{\partial w_{ij}^l} = \frac{\partial z_i^l}{\partial w_{ij}^l} \frac{\partial C}{\partial z_i^l}$$

$$\begin{cases} a_j^{l-1} & l > 1 \\ x_j & l = 1 \end{cases}$$

$$\delta_i^l$$

Forward pass

$$z^l = W^l a^{l-1} + b^l$$

$$a^l = \sigma(z^l)$$

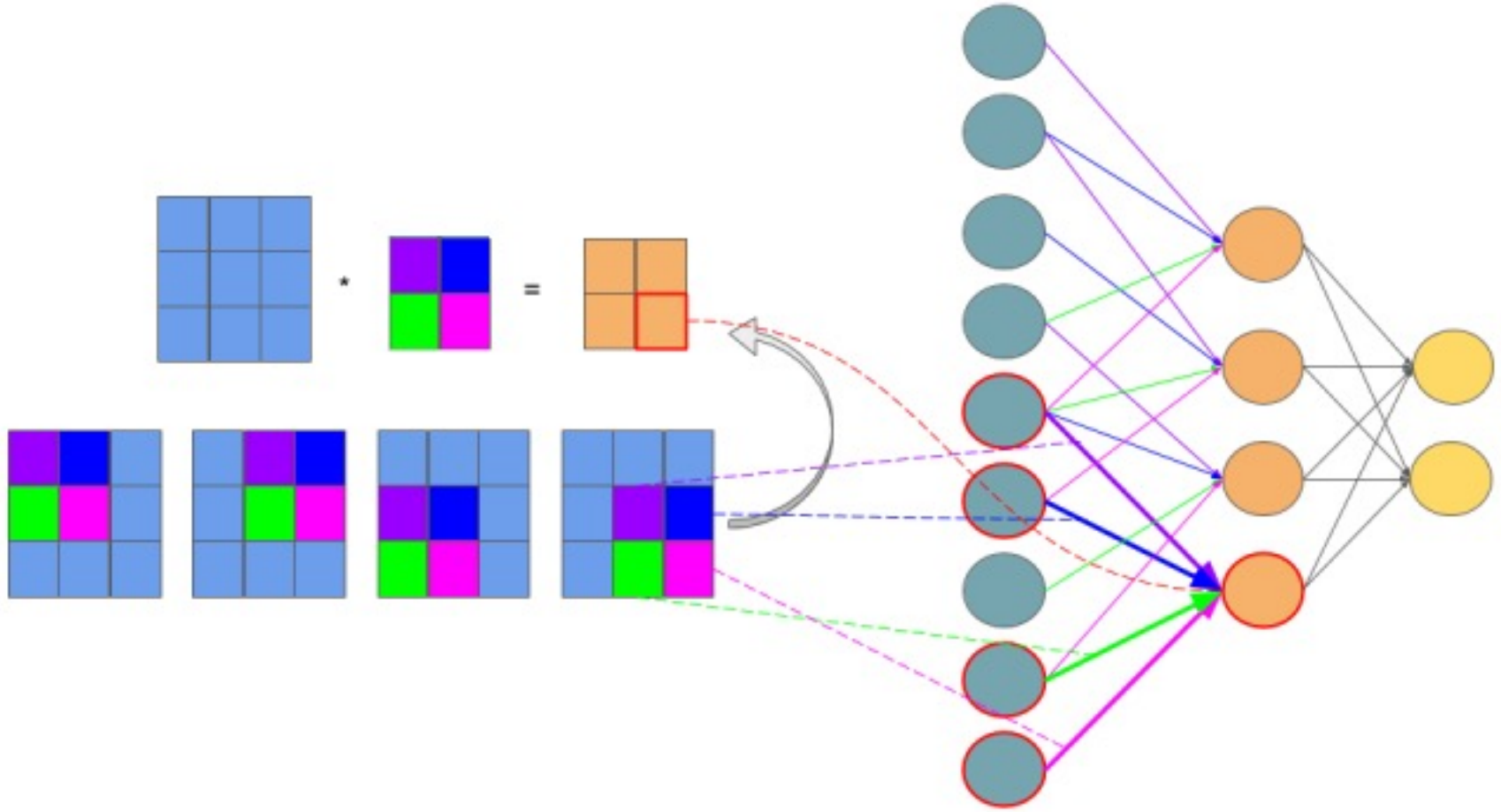
Backward pass

$$\delta^L = \sigma'(z^L)\nabla C(y)$$

$$\delta^l = \sigma'(z^l)(W^{l+1})^T \delta^{l+1}$$

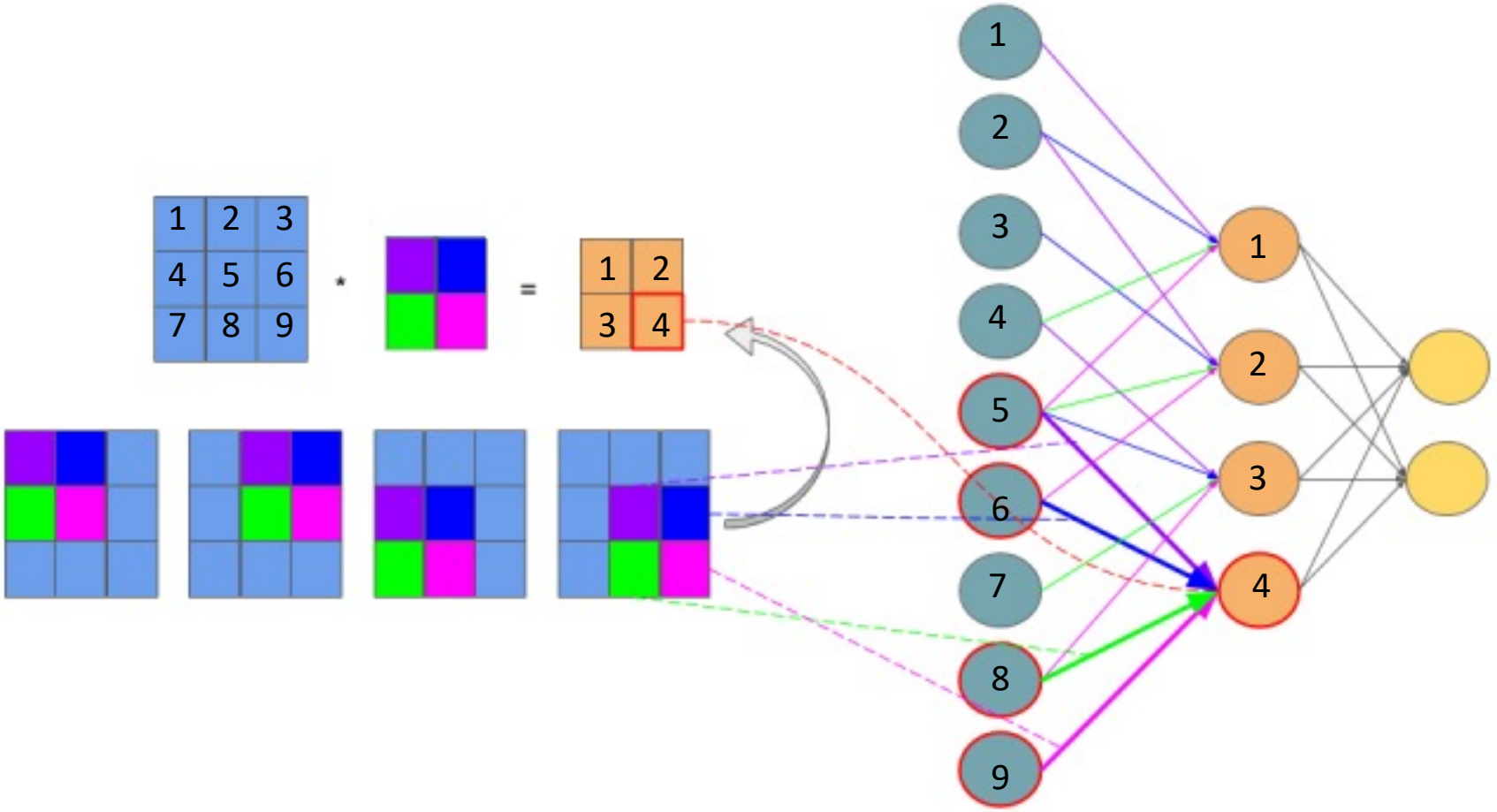
.....

Alternative CNN representation



https://grzegorzgwardys.wordpress.com/2016/04/22/8/
(slightly adapted)

Alternative CNN representation



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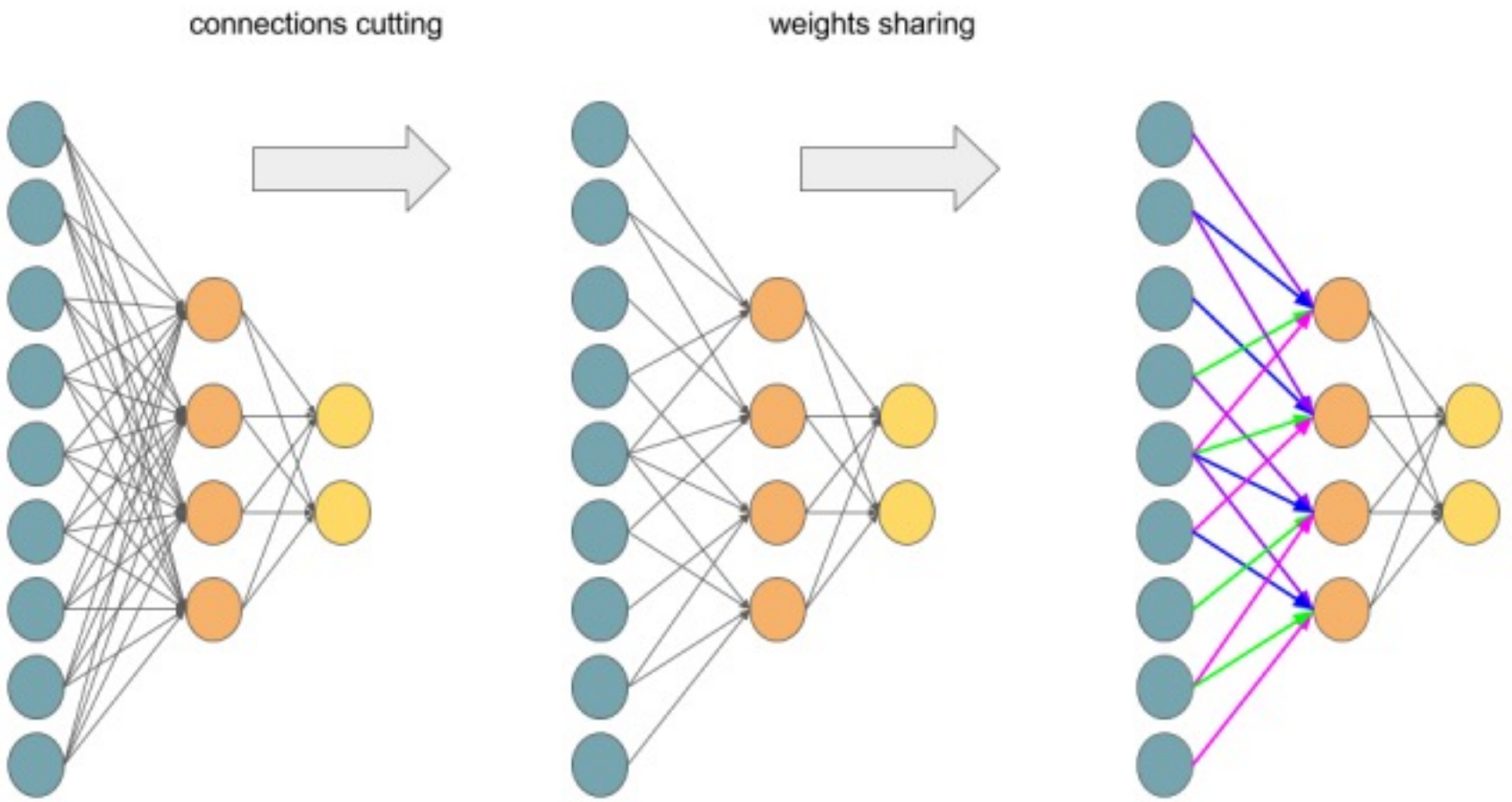

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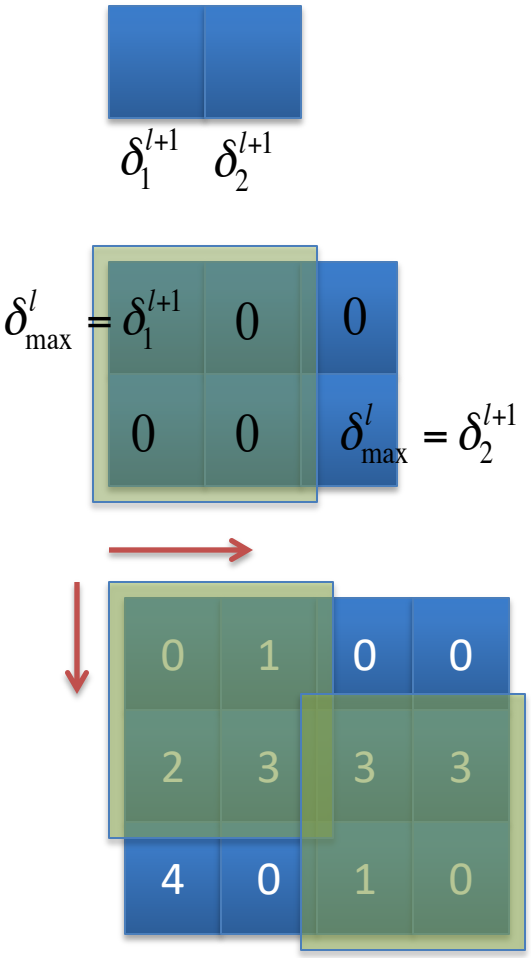
Gradient Computation for CNN



- Gradient of the convolution is a sum over all gradients of the shared parameters
- Gradient of the max pooling layer depends on the indices of the largest value
  - Need to store the indices of the largest value

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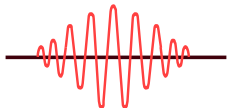
CNN for Speech Emotion Recognition [Neumann, Vu, 2017]

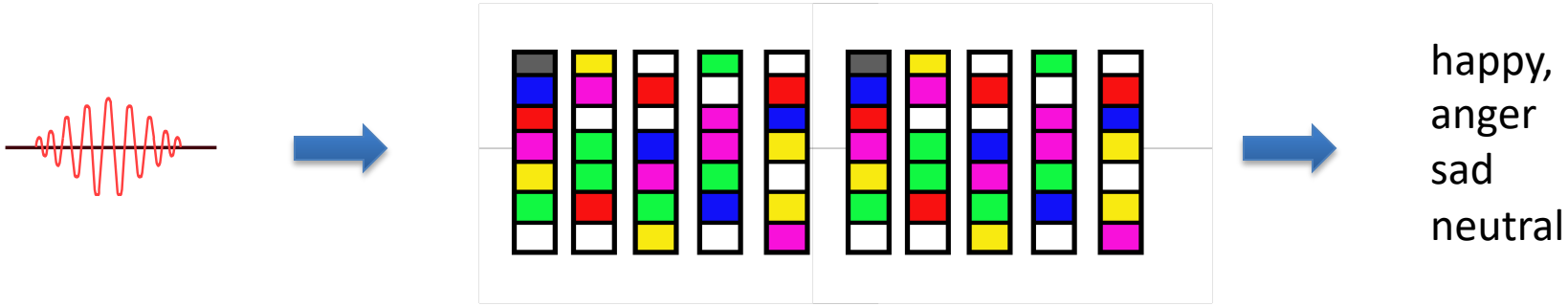
- Extract emotion from speech



Which emotion? (happy, anger, sad or neutral)

CNN for Speech Emotion Recognition [Neumann, Vu, 2017]

- Extract emotion from speech



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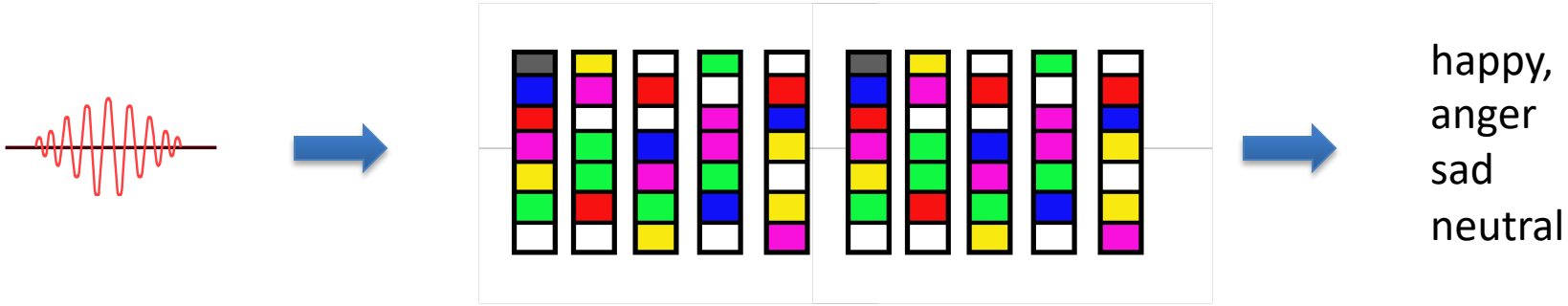


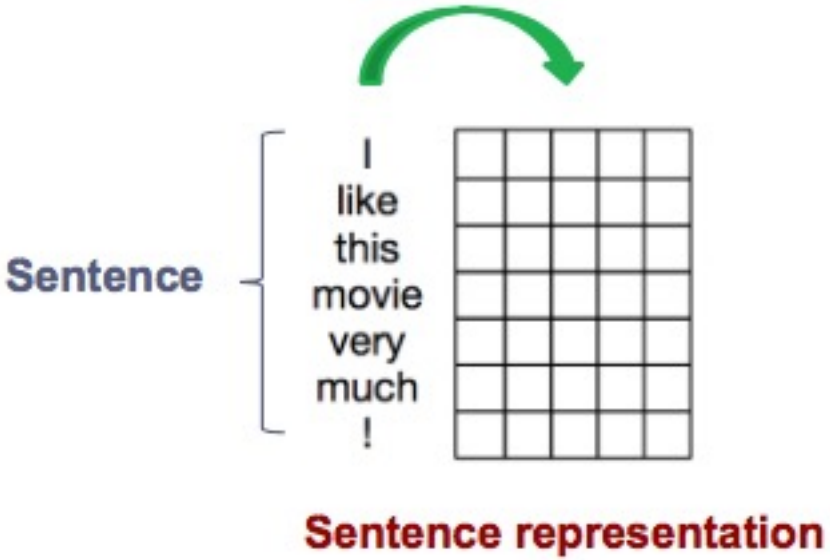
Features (dim.)	Average	Min	Max
logMel (26)	**61.71**	60.40	**62.66**
MFCC (13)	61.31	**60.85**	61.35
eGeMAPS (25)	60.25	59.41	60.94
Prosody (7)	56.34	55.82	57.57

CNN for Natural Language Processing

- Mostly used for sentence modelling
  - Kalchbrenner et al 2014
  - Kim, 2014
  - Etc.
- If the input is a sentence, where can we get the image for CNN?

CNN for Natural Language Processing

- If the input is a sentence, where can we get the image for CNN?
  - Word representations (word vectors / word embeddings): a word can be represented as a vector



Word → Vector

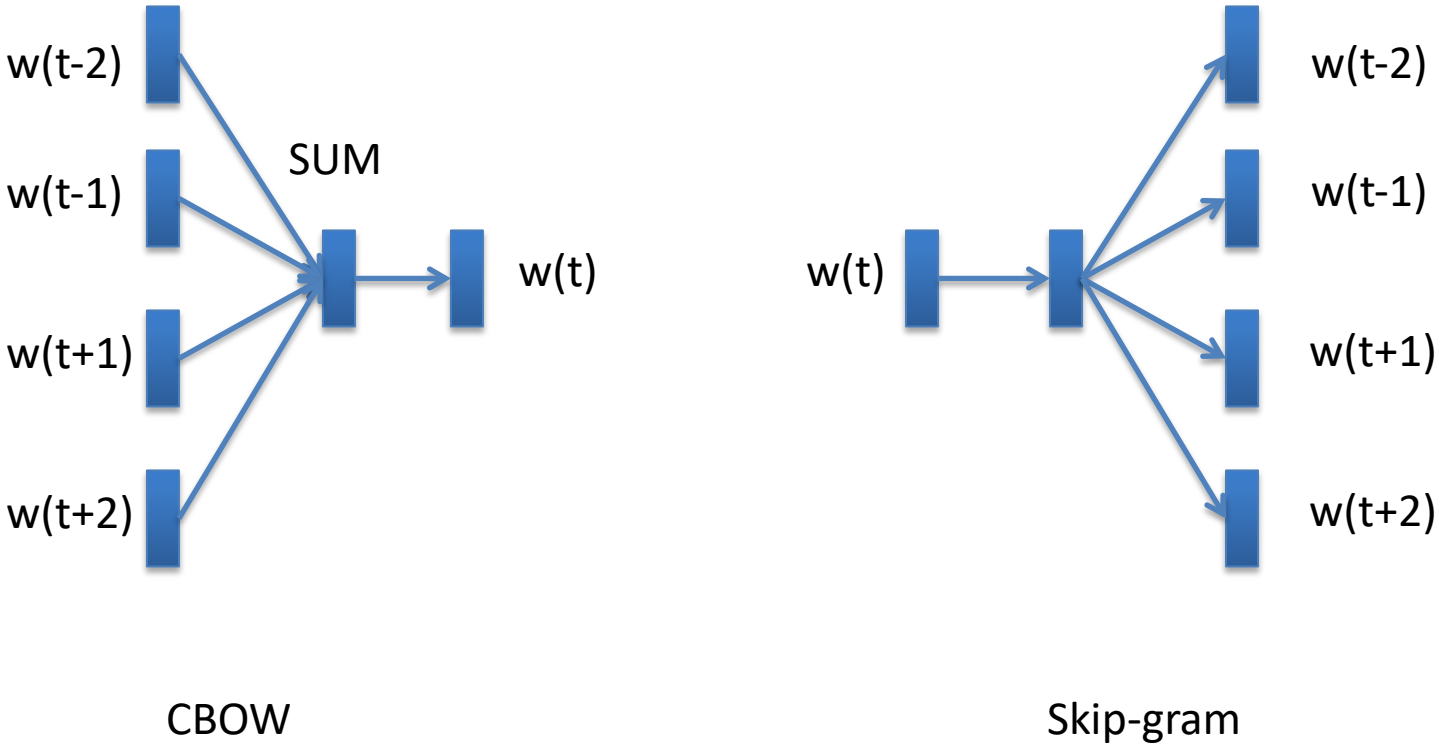
- 1 hot vector (1-of-N)
  - Define a lexicon = [cool, bad, great, very, not]
  - ‚cool‘ = [1, 0, 0, 0, 0]
  - ‚great‘ = [0, 0, 1, 0, 0]
  - ‚not‘ = [0, 0, 0, 0, 1]
  - ‚cooool‘ = [0, 0, 0, 0, 0]
- Properties:
  - Word vector has a dimension of the lexicon size
  - Each dimension corresponds to a word in the lexicon

Word → Vector

- 1 hot vector (1-of-N) with word hashing
- The idea is to have a lexicon with n-gram characters
  - Lexicon = [‚am_‘, ... ‚coo‘, ‚col‘, ...‘ool‘, ‚ooo‘, ...]
  - ‚cool‘ = [0, ..., 1, 0, ..., 1, ..., 0, 0, ...]
  - ‚coool‘ = [0, ..., 1, 0, ..., 1, ..., 0, 1, ...]
- It captures some relations between words
- It‘s quite useful
  - if there are a lot of OOV words
  - for morphological rich languages

Word Embeddings

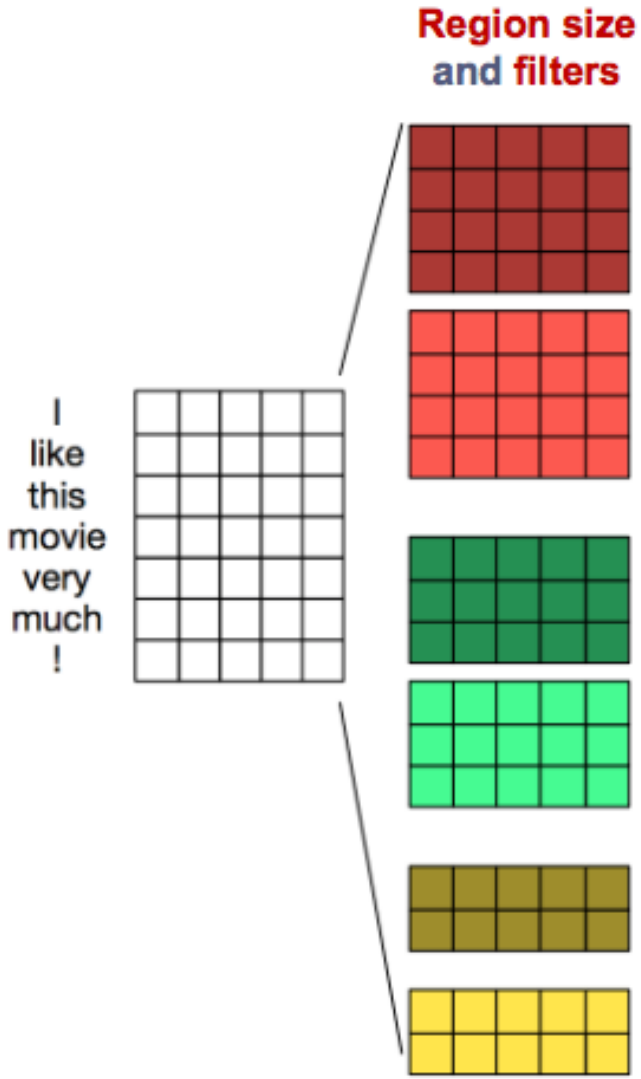
- Another way was proposed by T. Mikolov 2013
- https://code.google.com/p/word2vec/



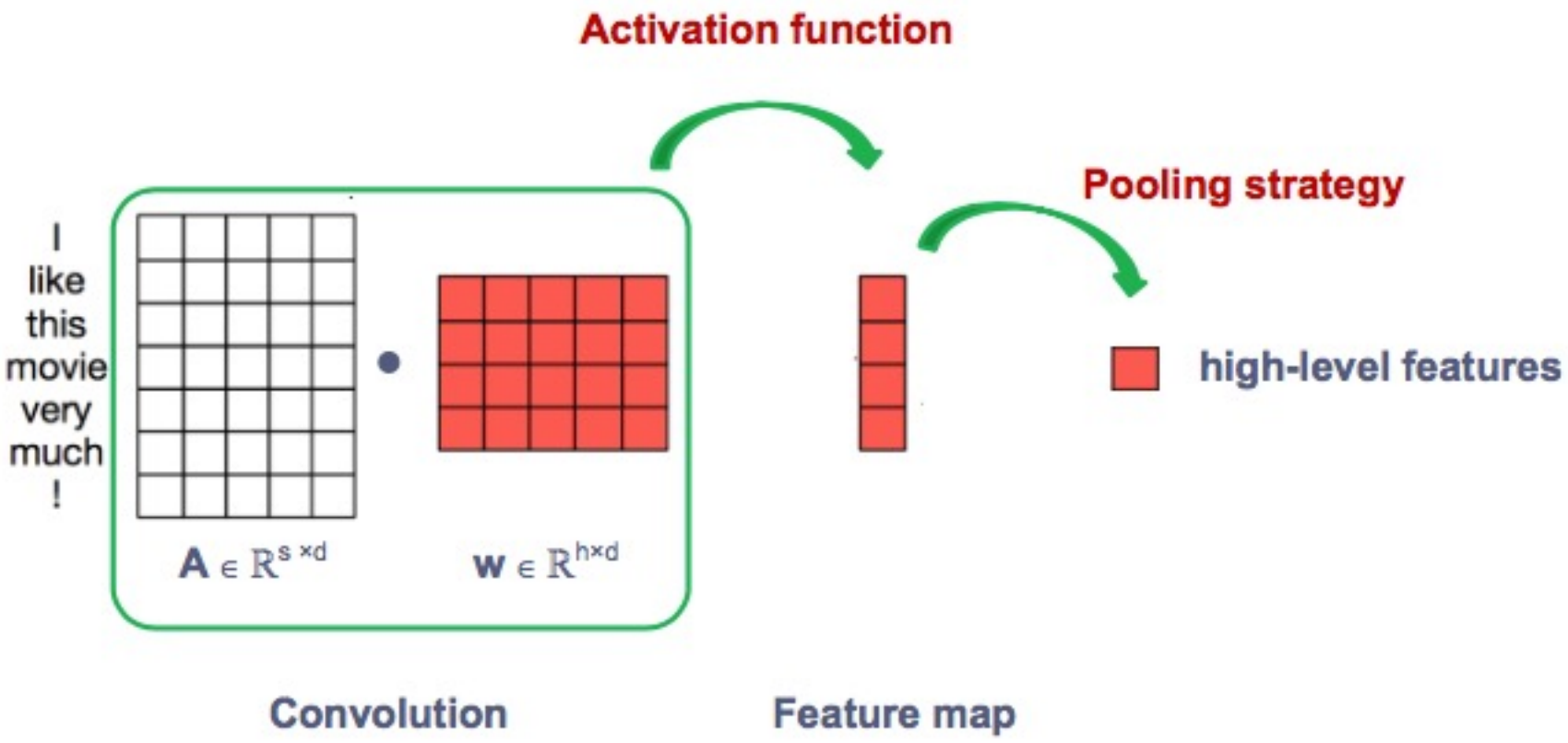
Word Embeddings

- Linear relations between words:
  - v(king) – v(queen) ≈ v(man) – v(woman)
  - v(japan) – v(tokio) ≈ v(germany) – v(berlin)
  - v(italy) – v(wine) ≈ v(germany) – v(?)
  - v(japan) – v(sushi) ≈ v(germany) – v(?)
- It can be used to solve analogy tasks
  - Rome : Italy ≈ Berlin : ?
  - Compute v(Berlin) – v(Rome) + v(Italy)
  - Find the closest vector

CNN for Natural Language Processing



CNN for Natural Language Processing



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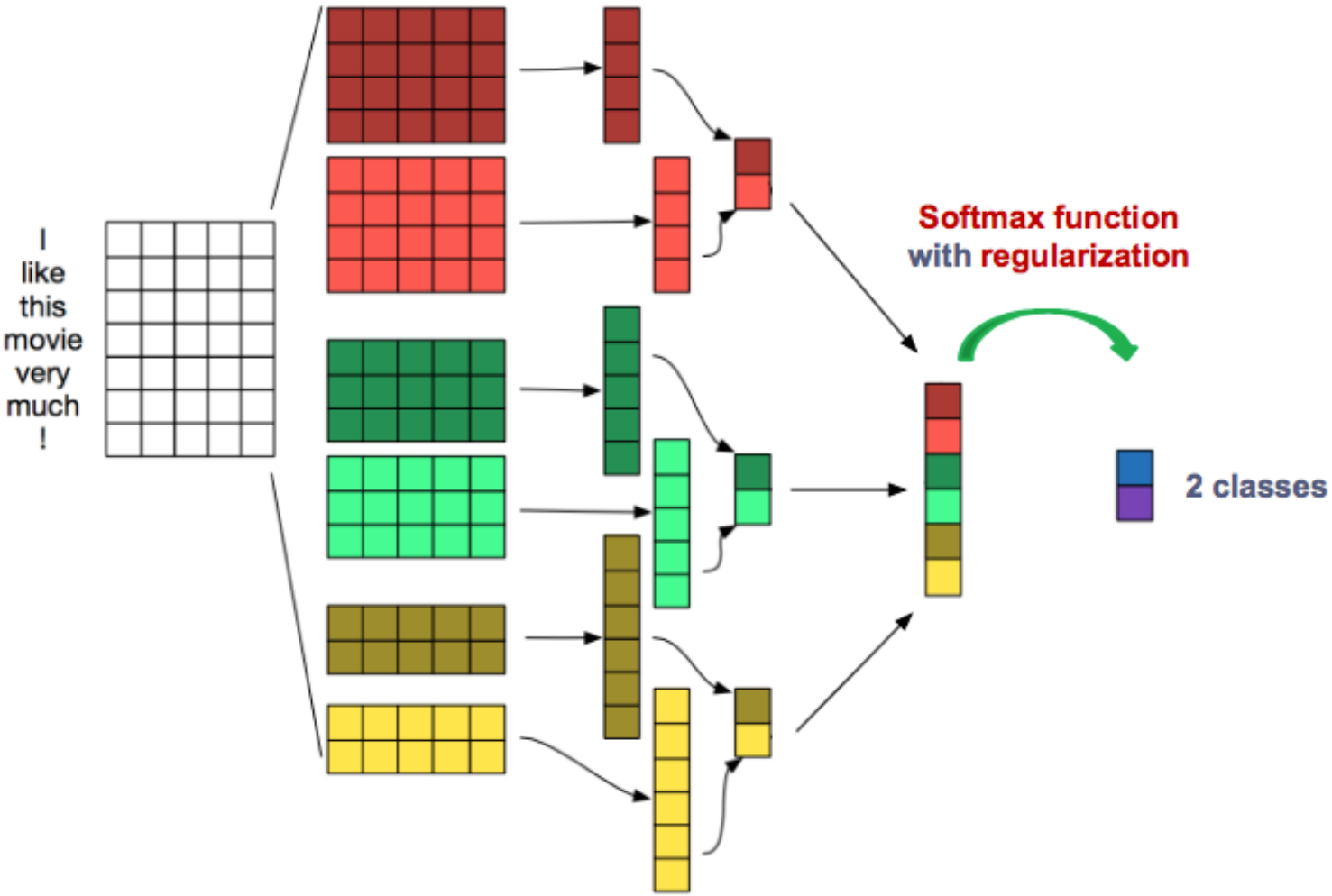
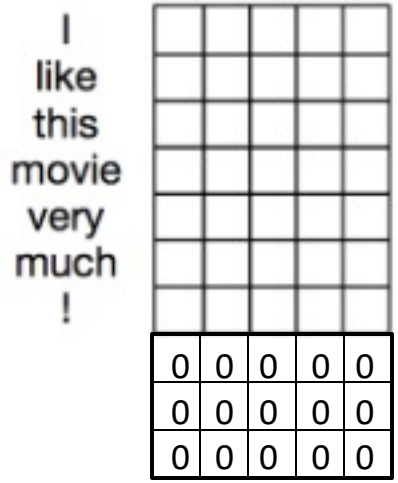


CNN for Natural Language Processing

- What if the sentences have different length?

CNN for Natural Language Processing

- What if the sentences have different length?
  - Define a max sentence length
  - Pad the sentence with zero vectos or cut the sentence to the max sentence length
  - E.g. with a max sentence length of 10
    - ‚I like this movie very much!‘ can be represented as follows



Thanks for listening!