02 | Building Blocks of Deep Learning

Microsoft

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Background for Deep Learning

- Review of multi-class distributions
- Tensors for deep learning
- Basics of image data
- Introduction to Keras

Review of Binary Classification

Bernoulli distribution for probability of success

Observation: ν = 1:

$$p(\nu = 1) = \Theta$$

$$\textit{where}$$

$$\nu = \textit{an observation}$$

$$\Theta = \textit{probability parameter}$$

Review of Binary Classification

We extend the Bernoulli distribution for multiple trials with the **Binomial distribution** for k successes in n trials:

$$p(\nu = k \mid \Theta) = \binom{n}{k} \Theta^k (1 - \Theta)^{n-k}$$

Were the Binomial coefficient, pronounced n choose k is:

$$\binom{n}{k}$$

Review of Binary Classification

How do perform classification with the Bernoulli distribution?

Use the **logistic** or **sigmoid** function

$$\sigma(x) = \frac{L}{1 + e^{-k(x_0 - x)}}$$

$$where$$

$$L = max\ value$$

$$k = slope$$

$$x_0 = sigmoid\ midpoint$$

Review of Binary Classification

Simplify the logistic function if k = 1, L = 1 and x_o = 0:

$$\sigma(x) = \frac{1}{1 + e^{-x}} = \frac{e^x}{1 + e^x}$$

Classification with the Categorical Distribution

- What are the distribution for multi-class problem?
- Use the **Categorical distribution** with probability mass function:

$$p(x = i \mid \boldsymbol{\theta}) = \theta_i$$

Where:

$$\boldsymbol{\theta} = (\theta_1, \ldots, \theta_k)$$

And:

$$\sum_{i=1}^{k} \theta_i = 1.0$$

Classification with the Categorical Distribution

- How do we create a categorical classifier?
- Use a softmax function:

$$\sigma(z_i) = \frac{e^{z_i}}{\sum_{k=1}^{K} e^{z_k}}$$

The normalization, $\sum_{k=1}^{K} e^{z_k}$, ensures the probabilities sum to 1.0

Classification with the Categorical Distribution

- What is the output of softmax?
- One value for each category
  - For example, if we have 10 categories, there are 10 output values
  - Take the max as the most probable category
- Label must be one-hot encoded
  - Binary value for each possible category
  - Only one 1, others 0

Tensors for Deep Learning

For deep learning models we need a way to represent high dimensional values

- Input data
- Model parameters
- Transformations
- Output

Tensors are a generalization of multi-dimensional arrays

Not to be confused with tensors in physics and engineering

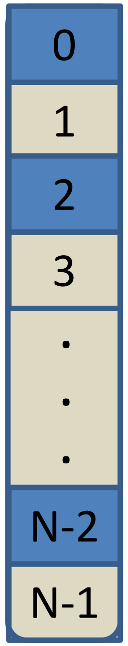
Tensors for Deep Learning

Zero dimensional tensor = scalar

0

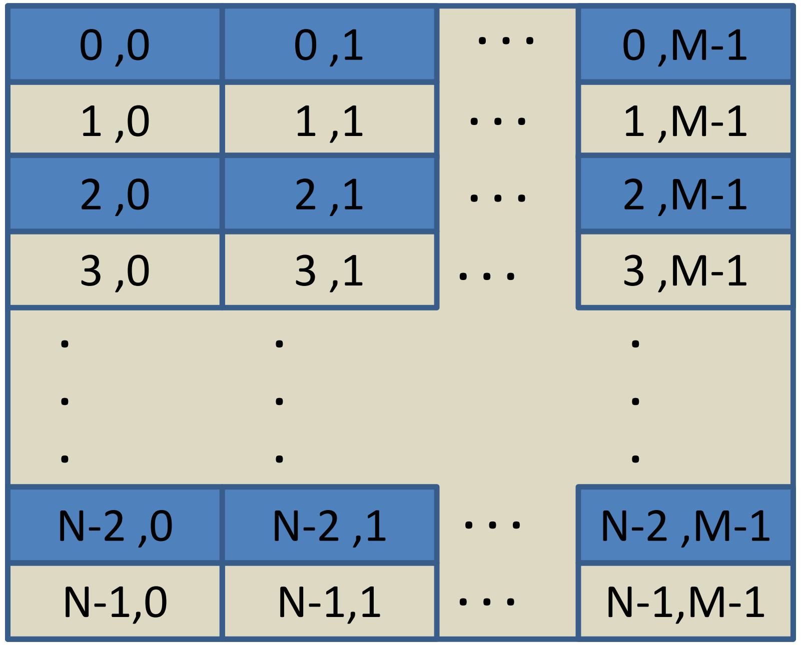
Tensors for Deep Learning

One dimensional tensor = vector



Tensors for Deep Learning

Two dimensional tensor = matrix



0 ,0	0 ,1	· · ·	0 ,M-1
1 ,0	1 ,1	· · ·	1 ,M-1
2 ,0	2 ,1	· · ·	2 ,M-1
3 ,0	3 ,1	· · ·	3 ,M-1
⋮	⋮		⋮
N-2 ,0	N-2 ,1	· · ·	N-2 ,M-1
N-1,0	N-1,1	· · ·	N-1,M-1

Working with Image Data

Deep learning has revolutionized image analysis and understanding

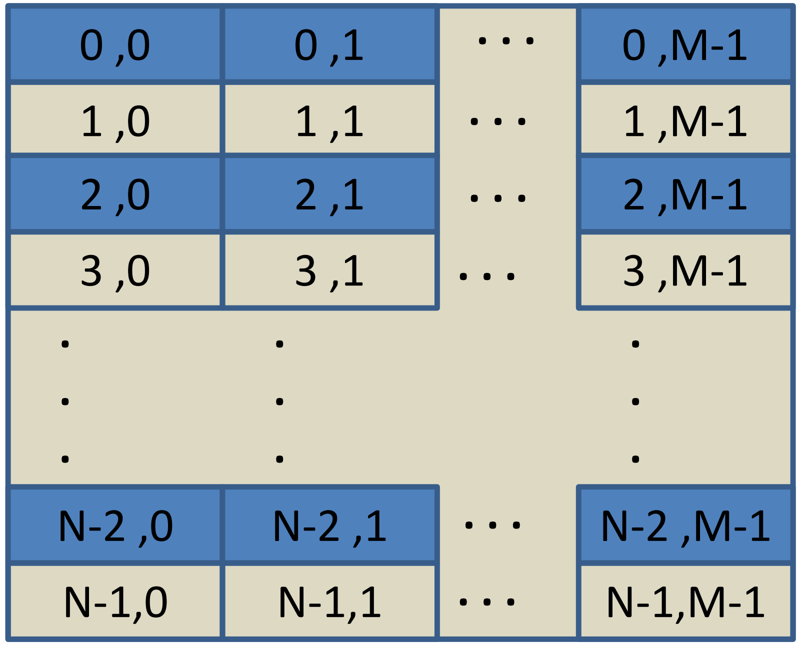
Common types of image data:

- Grey scale
- Color images
- Color video

Image data is represented by tensors

Working with Image Data

A grey scale image is represented as a two dimensional tensor of pixel values

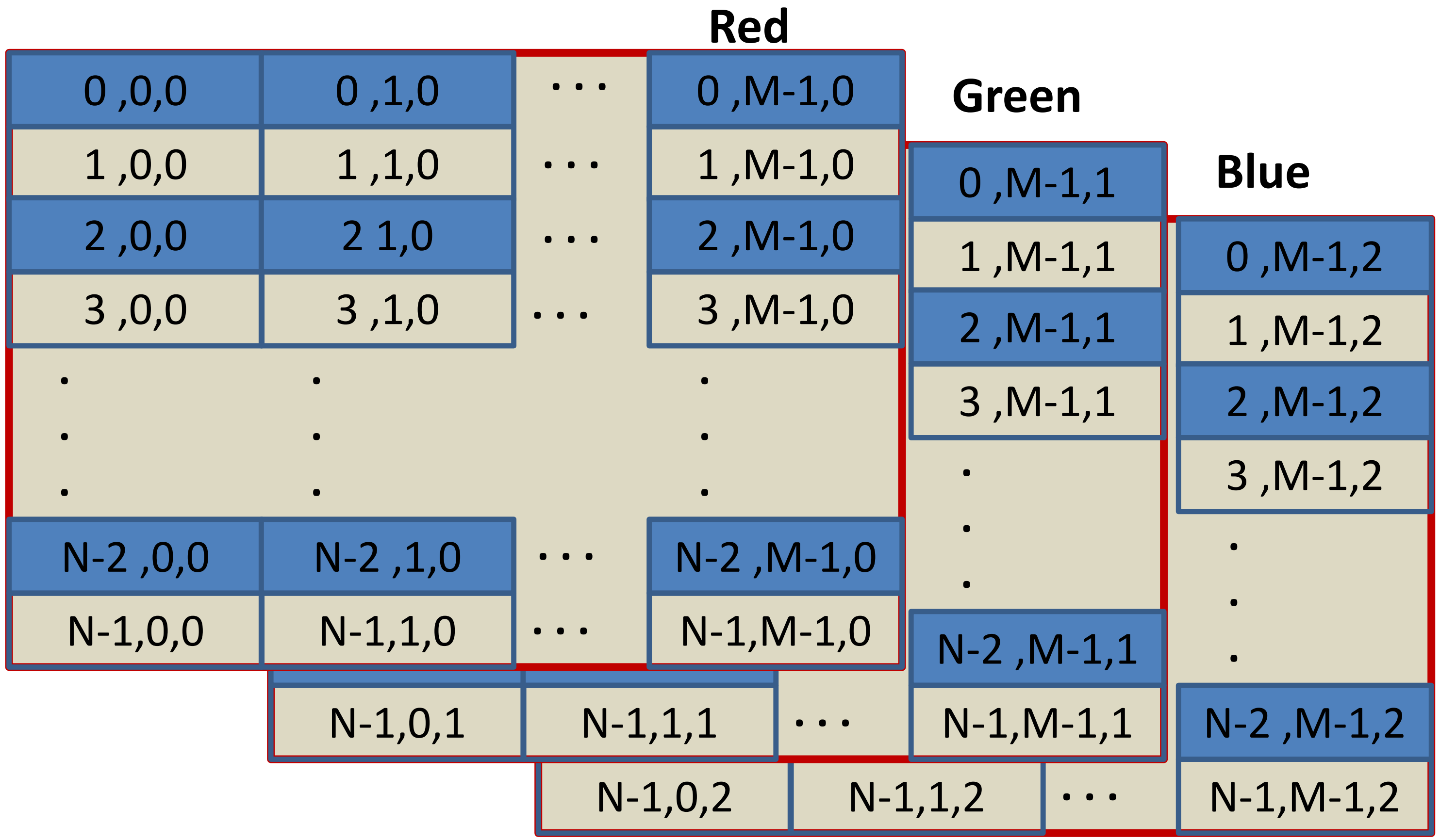


0 ,0	0 ,1	⋯	0 ,M-1
1 ,0	1 ,1	⋯	1 ,M-1
2 ,0	2 ,1	⋯	2 ,M-1
3 ,0	3 ,1	⋯	3 ,M-1
⋮	⋮		⋮
N-2 ,0	N-2 ,1	⋯	N-2 ,M-1
N-1,0	N-1,1	⋯	N-1,M-1

Pixel values have range {0-255}; white-black

Working with Image Data

A color image is a 3-dimensional tensor representing the three color channels



Red

0 ,0,0	0 ,1,0	···	0 ,M-1,0
1 ,0,0	1 ,1,0	···	1 ,M-1,0
2 ,0,0	2 1,0	···	2 ,M-1,0
3 ,0,0	3 ,1,0	···	3 ,M-1,0
⋮	⋮		⋮
N-2 ,0,0	N-2 ,1,0	···	N-2 ,M-1,0
N-1,0,0	N-1,1,0	···	N-1,M-1,0

Green

- 0 ,M-1,1
- 1 ,M-1,1
- 2 ,M-1,1
- 3 ,M-1,1
- ⋮
- N-2 ,M-1,1
- N-1,0,1 | N-1,1,1 | ··· | N-1,M-1,1

Blue

- 0 ,M-1,2
- 1 ,M-1,2
- 2 ,M-1,2
- 3 ,M-1,2
- ⋮
- N-2 ,M-1,2
- N-1,0,2 | N-1,1,2 | ··· | N-1,M-1,2

Intensity of color in each channel is on a scale of {0-255}

Working with Image Data

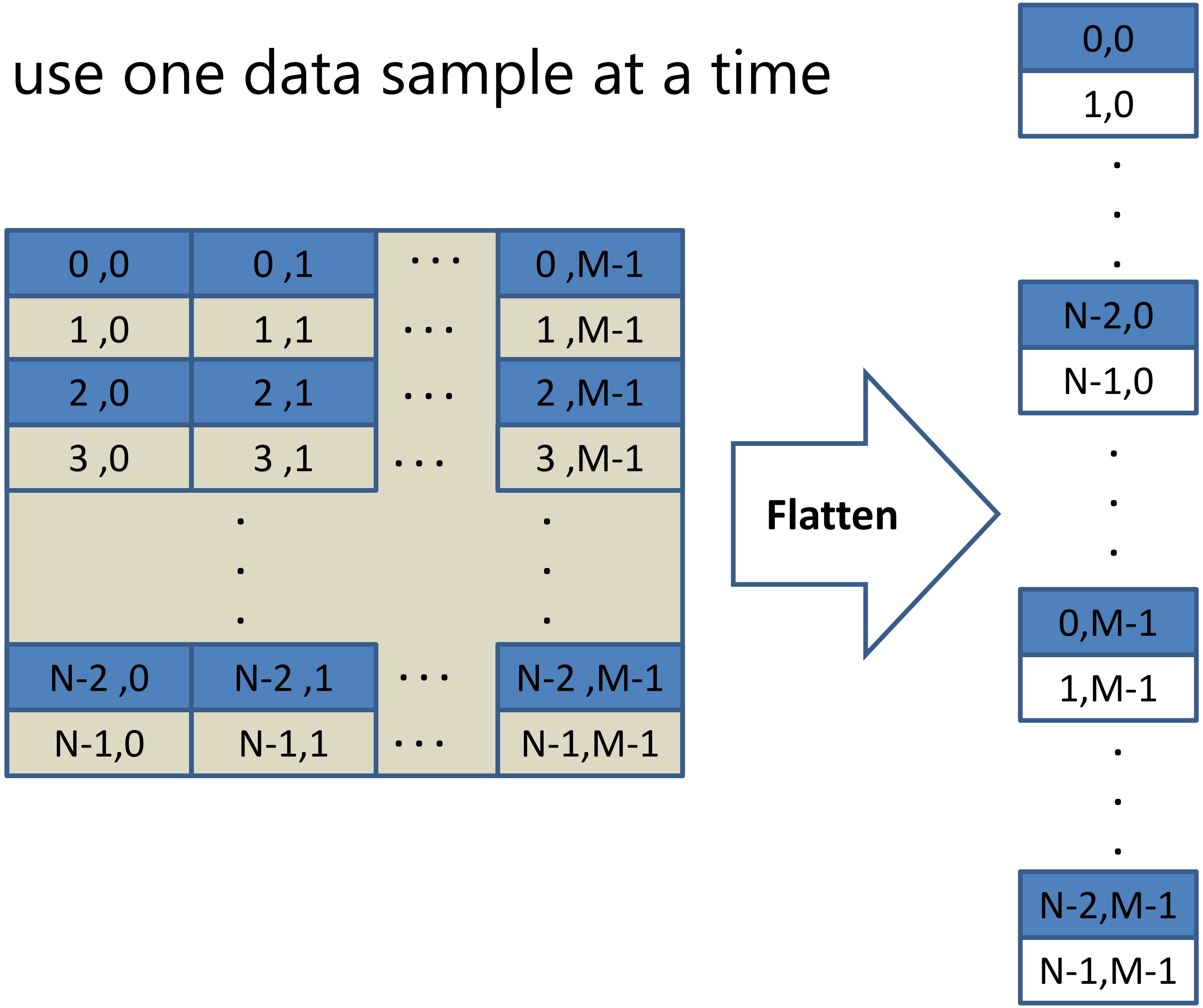
Video is represented as a 4-dimensional tensor

- 2 dimensions for each color channel
- 3rd dimension is color channel
- 4th dimension is the time sequence of images

Working with Image Data

Machine learning algorithms use one data sample at a time

For image data, we must **flatten** the image:

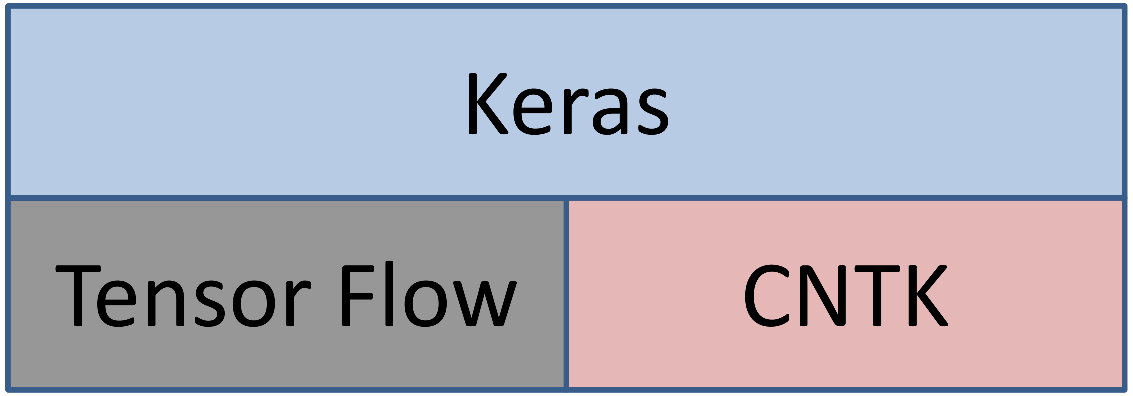


0 ,0	0 ,1	· · ·	0 ,M-1
1 ,0	1 ,1	· · ·	1 ,M-1
2 ,0	2 ,1	· · ·	2 ,M-1
3 ,0	3 ,1	· · ·	3 ,M-1
⋮			⋮
N-2 ,0	N-2 ,1	· · ·	N-2 ,M-1
N-1,0	N-1,1	· · ·	N-1,M-1

0,0
1,0
⋮
N-2,0
N-1,0
⋮
0,M-1
1,M-1
⋮
N-2,M-1
N-1,M-1

Introduction to Keras

- Keras abstracts common deep learning model definitions and operations
- Use on top of deep learning framework:



Keras

Tensor Flow

CNTK

- Extensive documentation at www.keras.io

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