Introduction to PyTorch

INTRODUCTION TO DEEP LEARNING WITH PYTORCH

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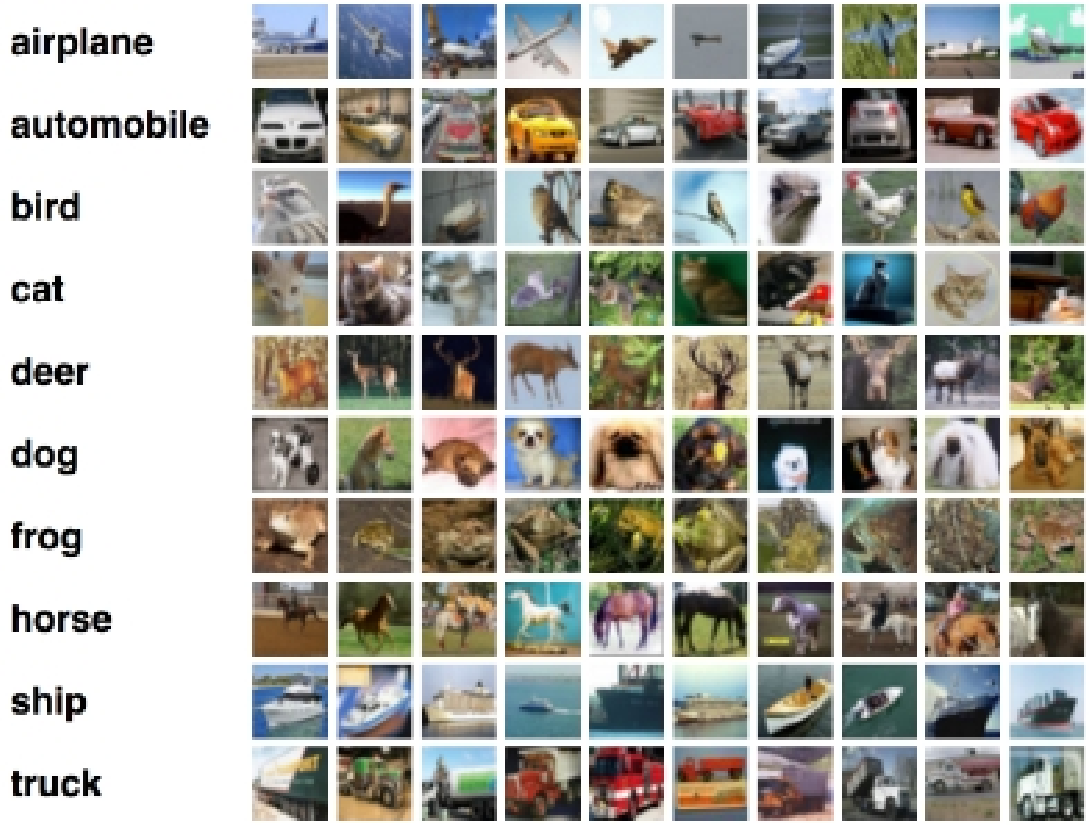
airplane
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A B C D E F G H I J K L M N O P Q R S
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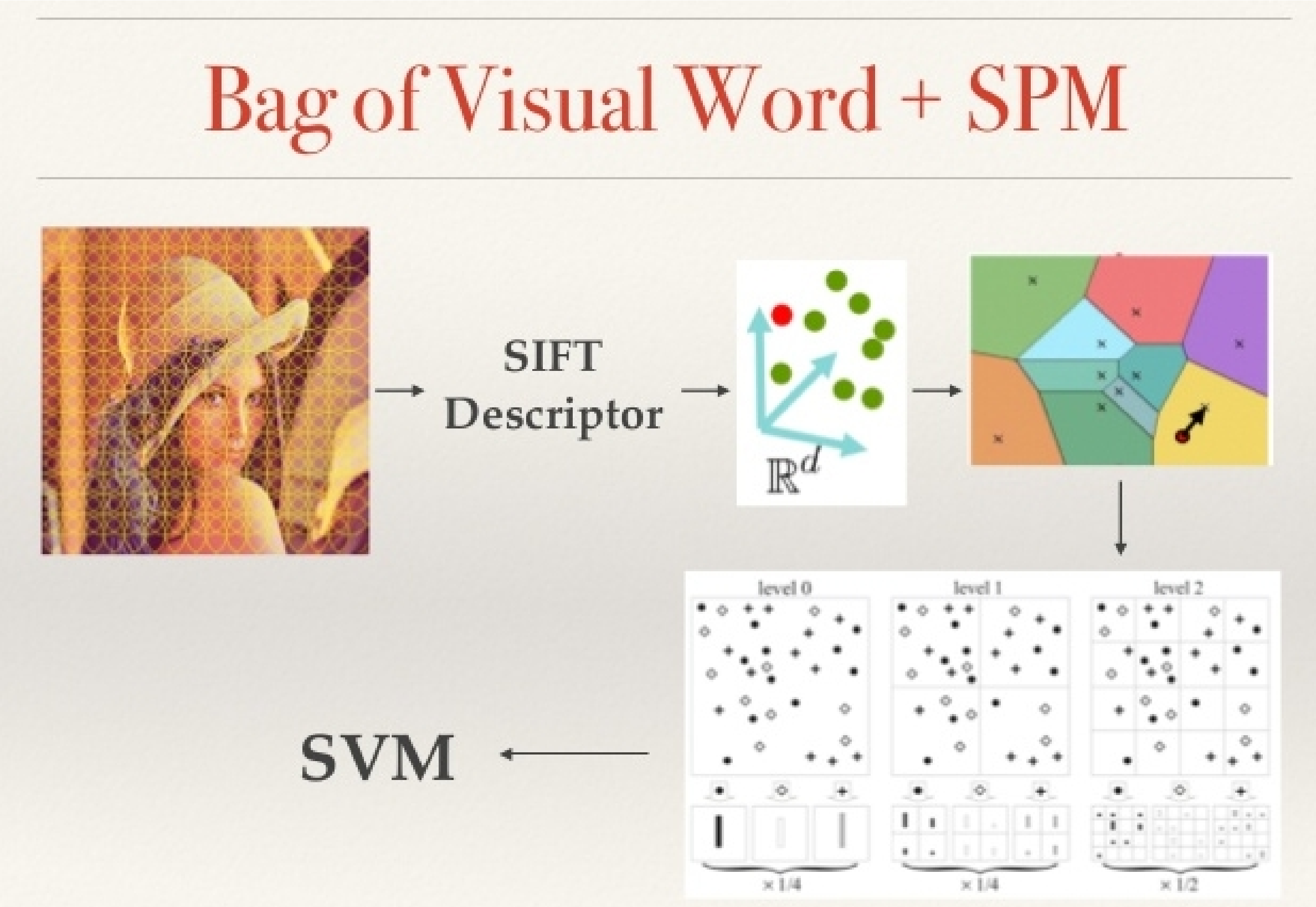
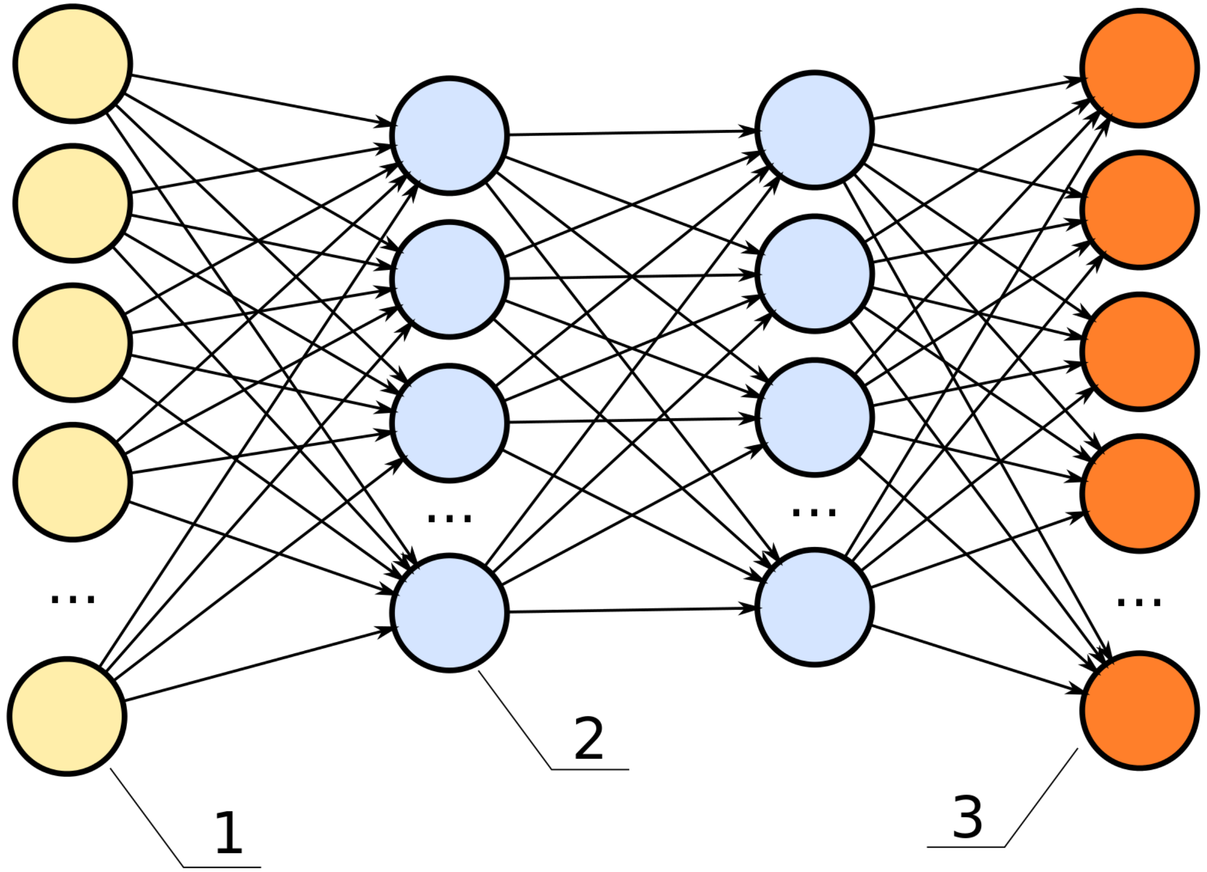
STARCRAFT II
LEGACY OF THE VOID

Neural networks

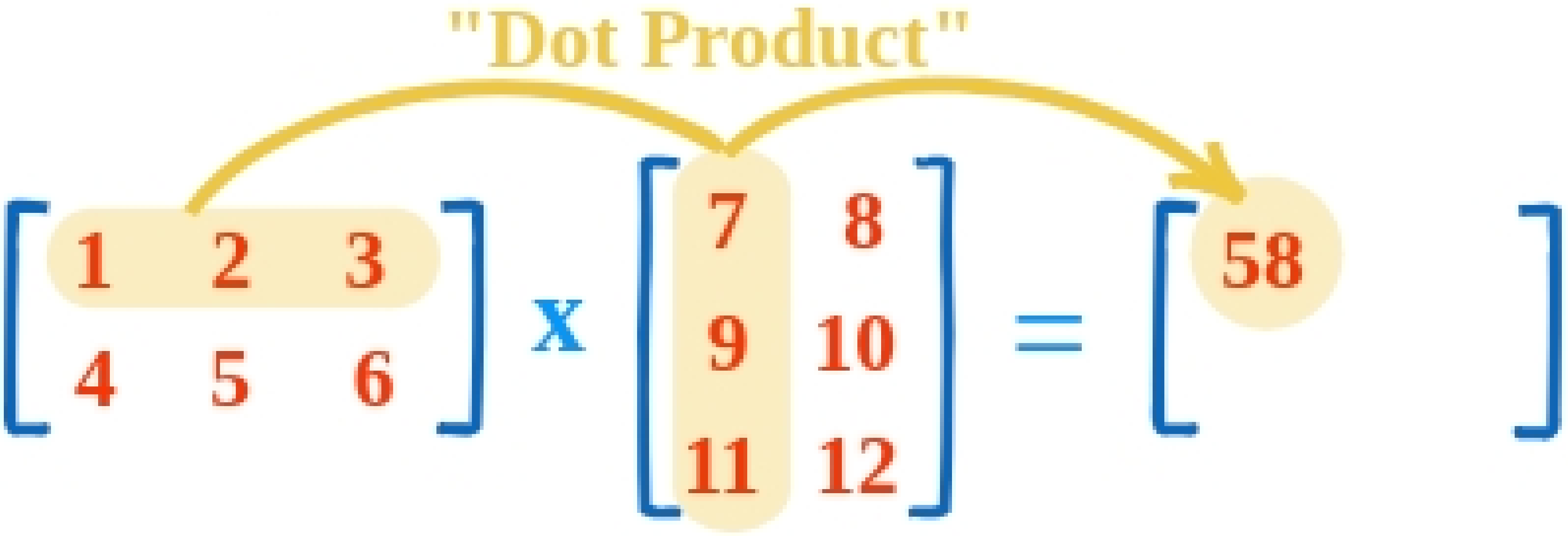




Why PyTorch?

- "PyThonic" - easy to use
- Strong GPU support - models run fast
- Many algorithms are already implemented
- Automatic differentiation - more in next lesson
- Similar to NumPy

Matrix Multiplication



PyTorch compared to NumPy

```python
import torch
torch.tensor([[2, 3, 5], [1, 2, 9]])
```

```
tensor([[ 2,  3,  5],
        [ 1,  2,  9]])
```

```python
torch.rand(2, 2)
```

```
tensor([[ 0.0374, -0.0936],
        [ 0.3135, -0.6961]])
```

```python
a = torch.rand((3, 5))
a.shape
```

```
torch.Size([3, 5])
```

```python
import numpy as np
np.array([[2, 3, 5], [1, 2, 9]])
```

```
array([[ 2,  3,  5],
       [ 1,  2,  9]])
```

```python
np.random.rand(2, 2)
```

```
array([[ 0.0374, -0.0936],
       [ 0.3135, -0.6961]])
```

```python
a = np.random.randn(3, 5)
a.shape
```

```
(3, 5)
```

Matrix operations

```python
a = torch.rand((2, 2))
b = torch.rand((2, 2))
```

```
tensor([[-0.6110,  0.0145],
        [ 1.3583, -0.0921]])
tensor([[ 0.0673,  0.6419],
        [-0.0734,  0.3283]])
```

```python
torch.matmul(a, b)
```

```
tensor([[-0.0422, -0.3875],
        [ 0.0981,  0.8417]])
```

```python
a = np.random.rand(2, 2)
b = np.random.rand(2, 2)
```

```
array([[-0.6110,  0.0145],
        [ 1.3583, -0.0921]])
array([[ 0.0673,  0.6419],
        [-0.0734,  0.3283]])
```

```python
np.dot(a, b)
```

```
array([[-0.0422, -0.3875],
       [ 0.0981,  0.8417]])
```

Matrix operations

```
a * b
```

```
tensor([[-0.0411,  0.0093],
        [-0.0998, -0.0302]])
```

```
np.multiply(a, b)
```

```
array([[-0.0411,  0.0093],
       [-0.0998, -0.0302]])
```

Zeros and Ones

```
a_torch = torch.zeros(2, 2)
```

```
tensor([[0., 0.],
        [0., 0.])
```

```
b_torch = torch.ones(2, 2)
```

```
tensor([[1., 1.],
        [1., 1.])
```

```
c_torch = torch.eye(2)
```

```
tensor([[1., 0.],
        [0., 1.]
```

```
a_numpy = np.zeros((2, 2))
```

```
array([[0., 0.],
       [0., 0.]])
```

```
b_numpy = np.ones((2, 2))
```

```
array([[1., 1.],
       [1., 1.]])
```

```
c_numpy = np.identity(2)
```

```
array([[1., 0.],
       [0., 1.]])
```

PyTorch to NumPy and vice versa

```
d_torch = torch.from_numpy(c_numpy)
```

```
tensor([[1., 0.],
        [0., 1.],
        dtype=torch.float64)
```

```
d = c_torch.numpy()
```

```
array([[1., 0.],
       [0., 1.]])
```

Summary

```
torch.matmul(a, b)   # multiples torch tensors a and b

*                    # element-wise multiplication between two torch tensors

torch.eye(n)         # creates an identity torch tensor with shape (n, n)

torch.zeros(n, m)    # creates a torch tensor of zeros with shape (n, m)

torch.ones(n, m)     # creates a torch tensor of ones with shape (n, m)

torch.rand(n, m)     # creates a random torch tensor with shape (n, m)

torch.tensor(l)      # creates a torch tensor based on list l
```

Let's practice

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Forward propagation

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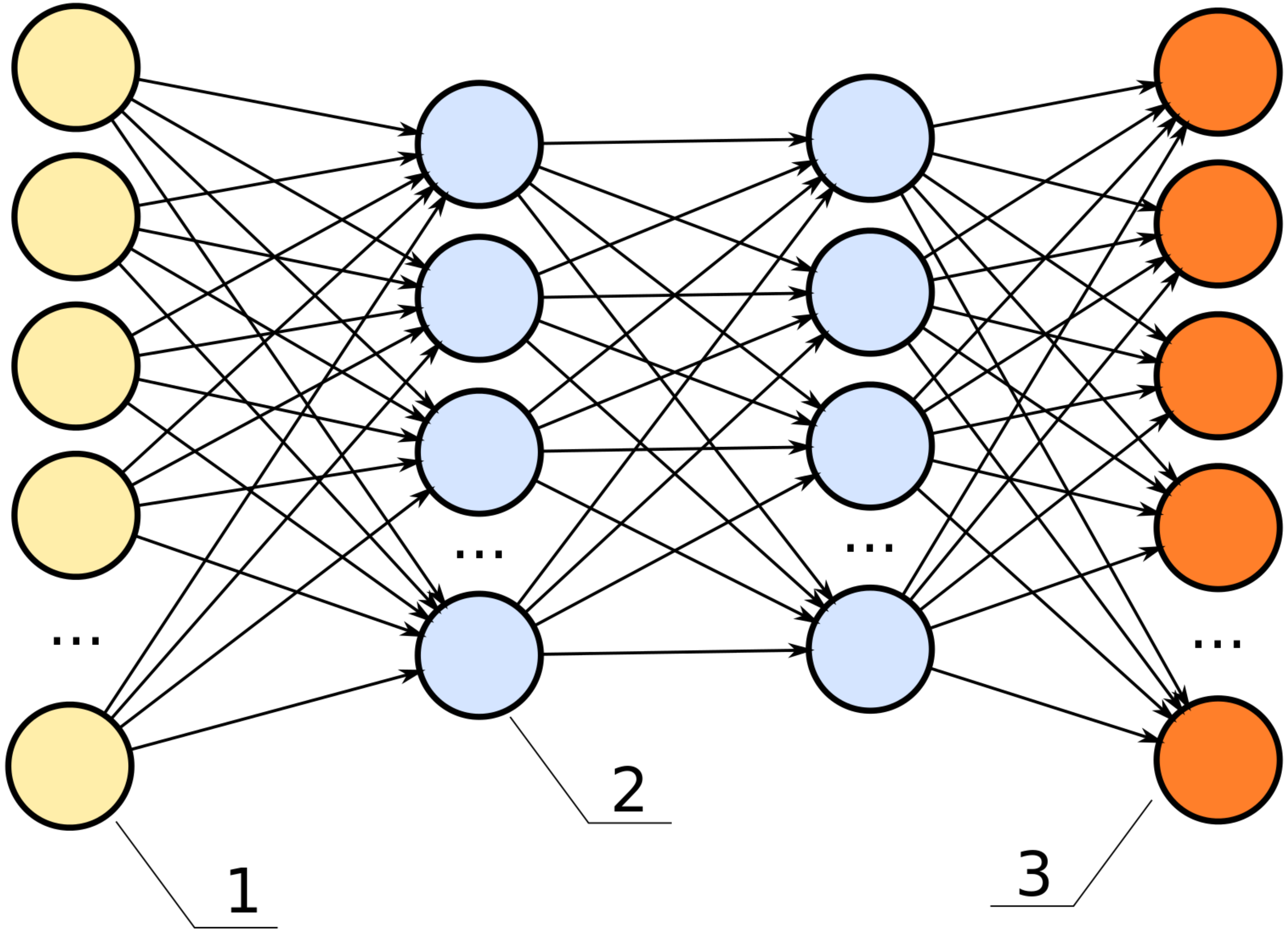
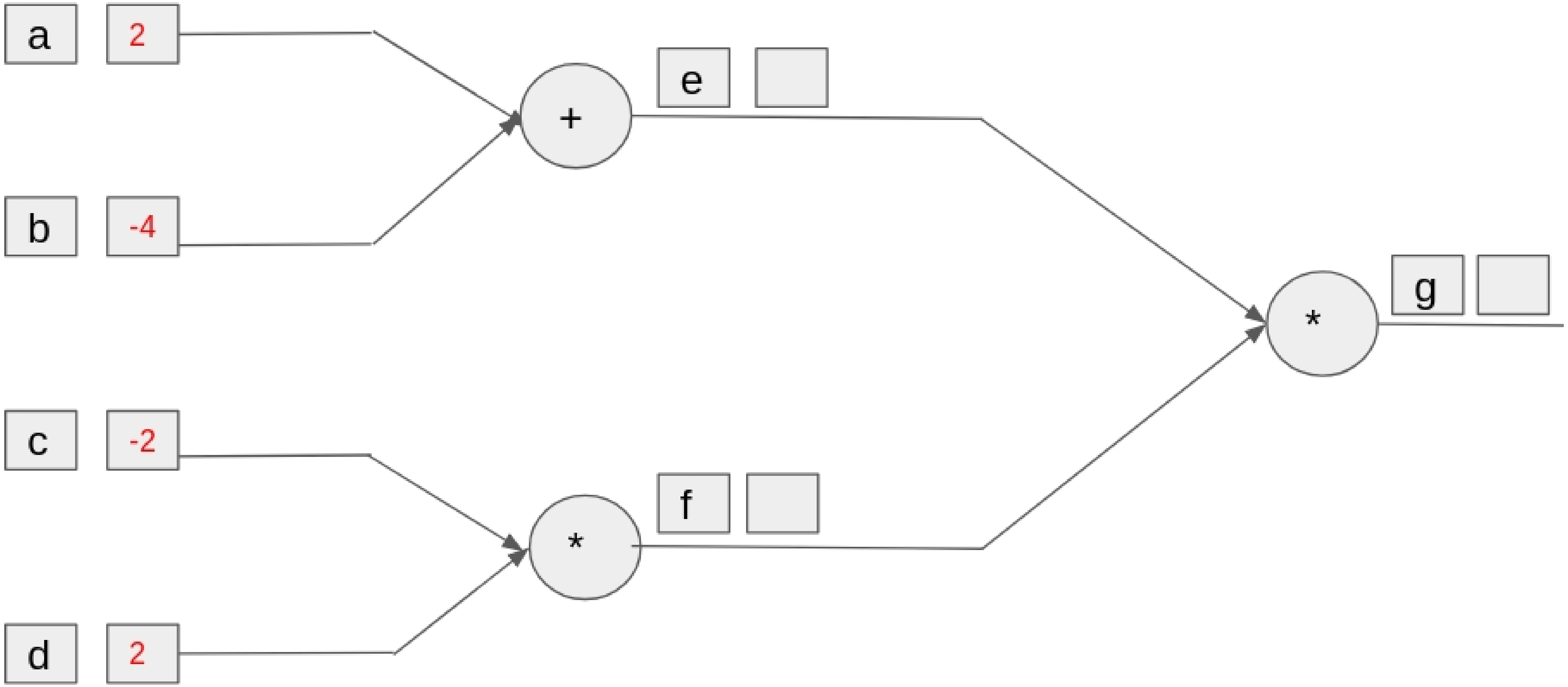
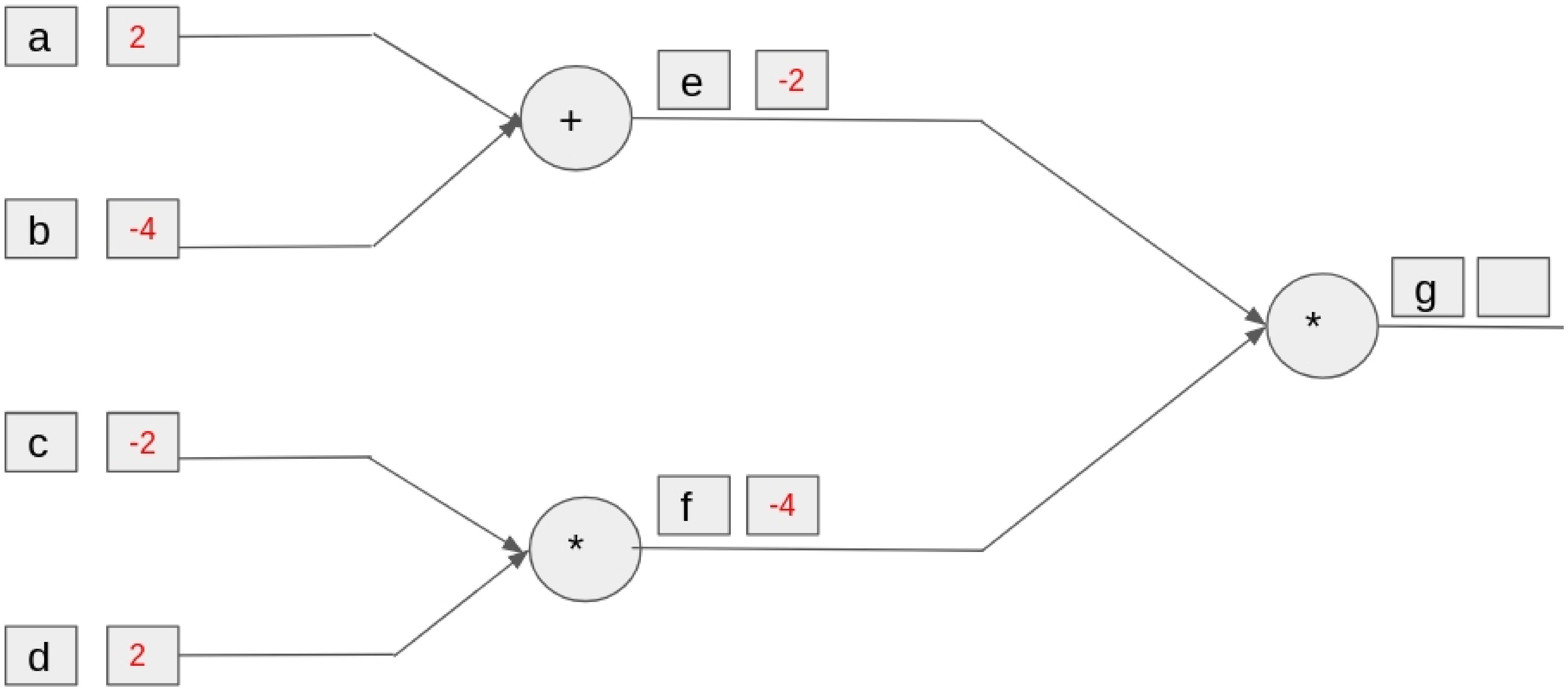
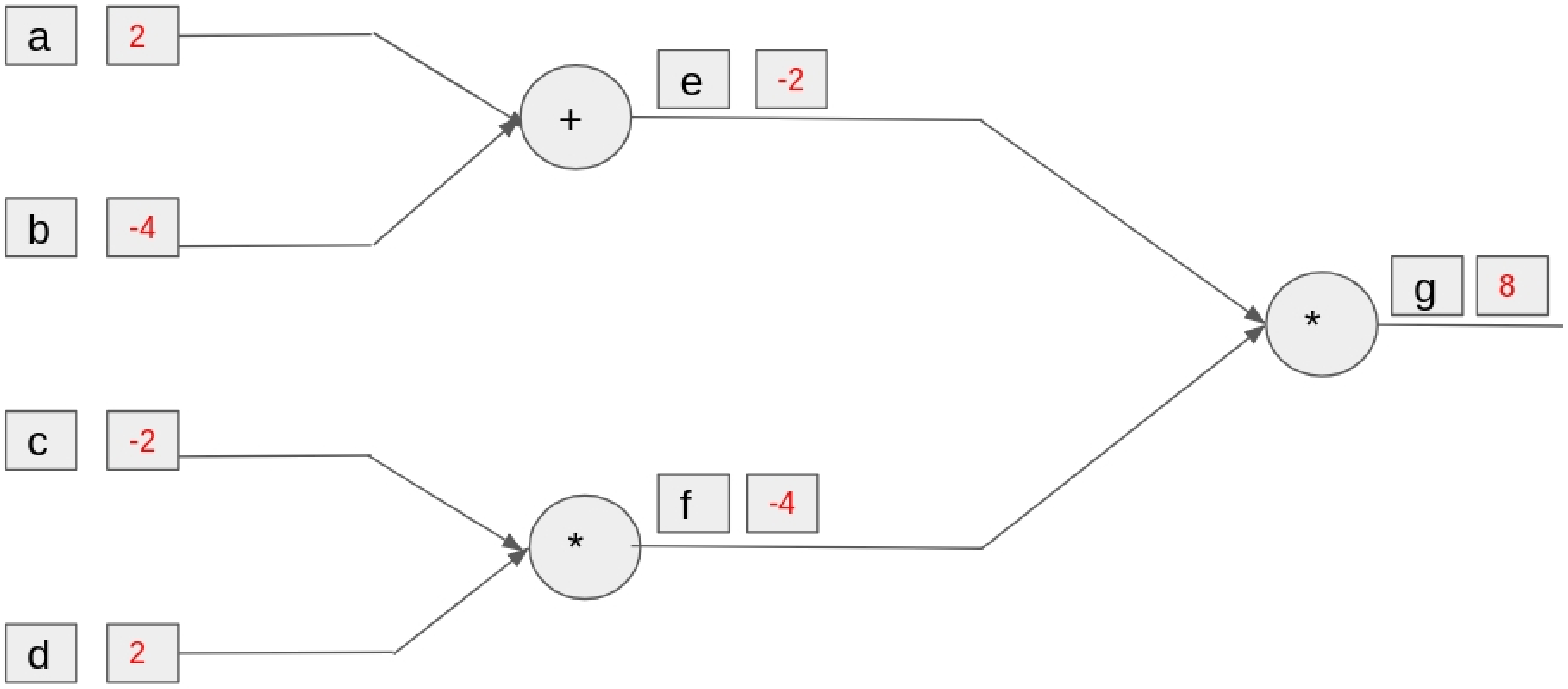


1
2
3


a
2
b
-4
c
-2
d
2
+
e
*
f
*
g


a
2
b
-4
c
-2
d
2
+
*
e
-2
f
-4
*
g


a
2
b
-4
+
e
-2
c
-2
d
2
*
f
-4
*
g
8

PyTorch implementation

```python
import torch

a = torch.Tensor([2])
b = torch.Tensor([-4])
c = torch.Tensor([-2])
d = torch.Tensor([2])
```

```python
e = a + b
f = c * d
```

```python
g = e * f
print(e, f, g)
```

```
tensor([-2.]), tensor([-4.]), tensor([8.])
```

Let's practice!

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Backpropagation by auto-differentiation

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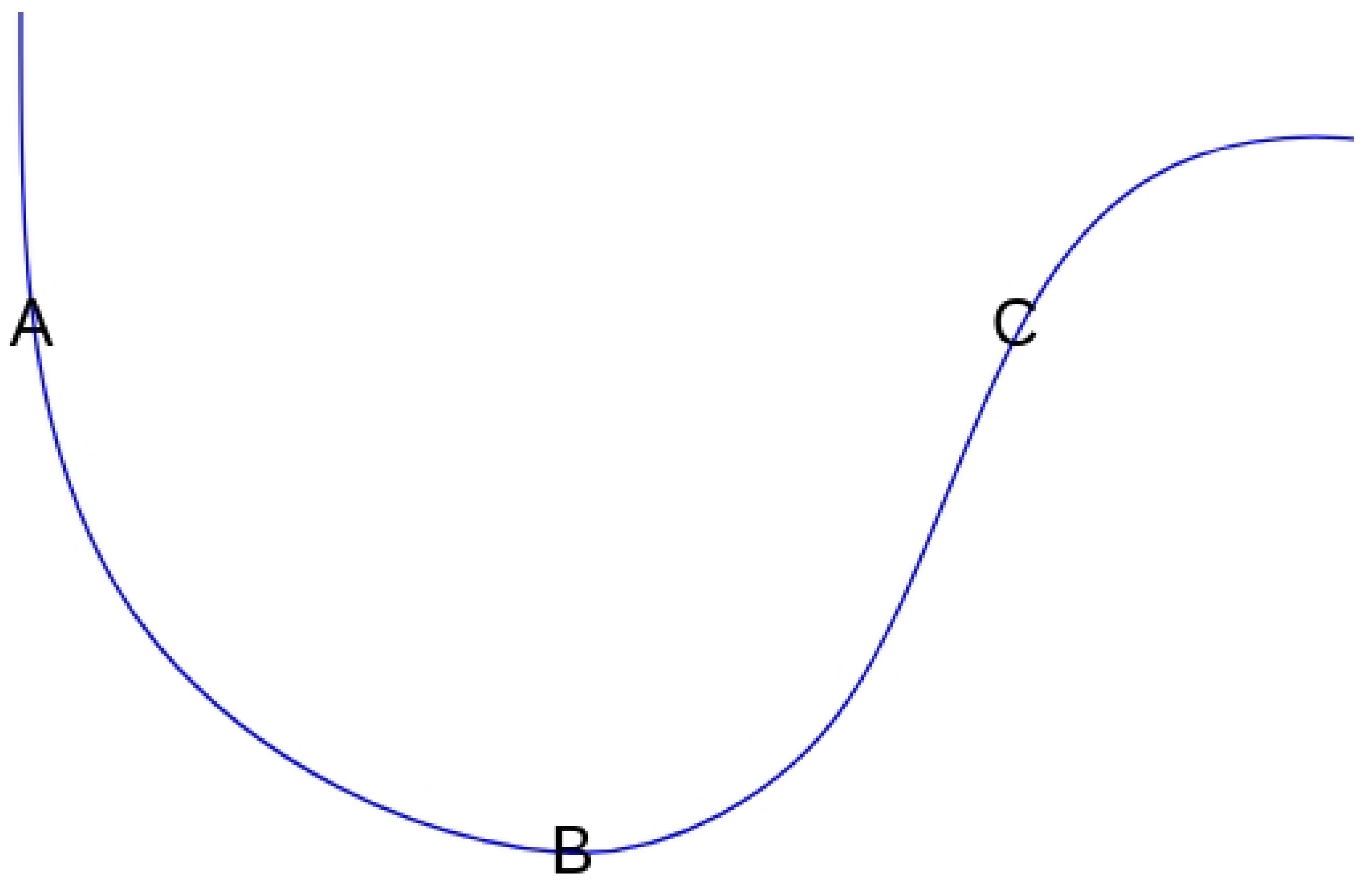
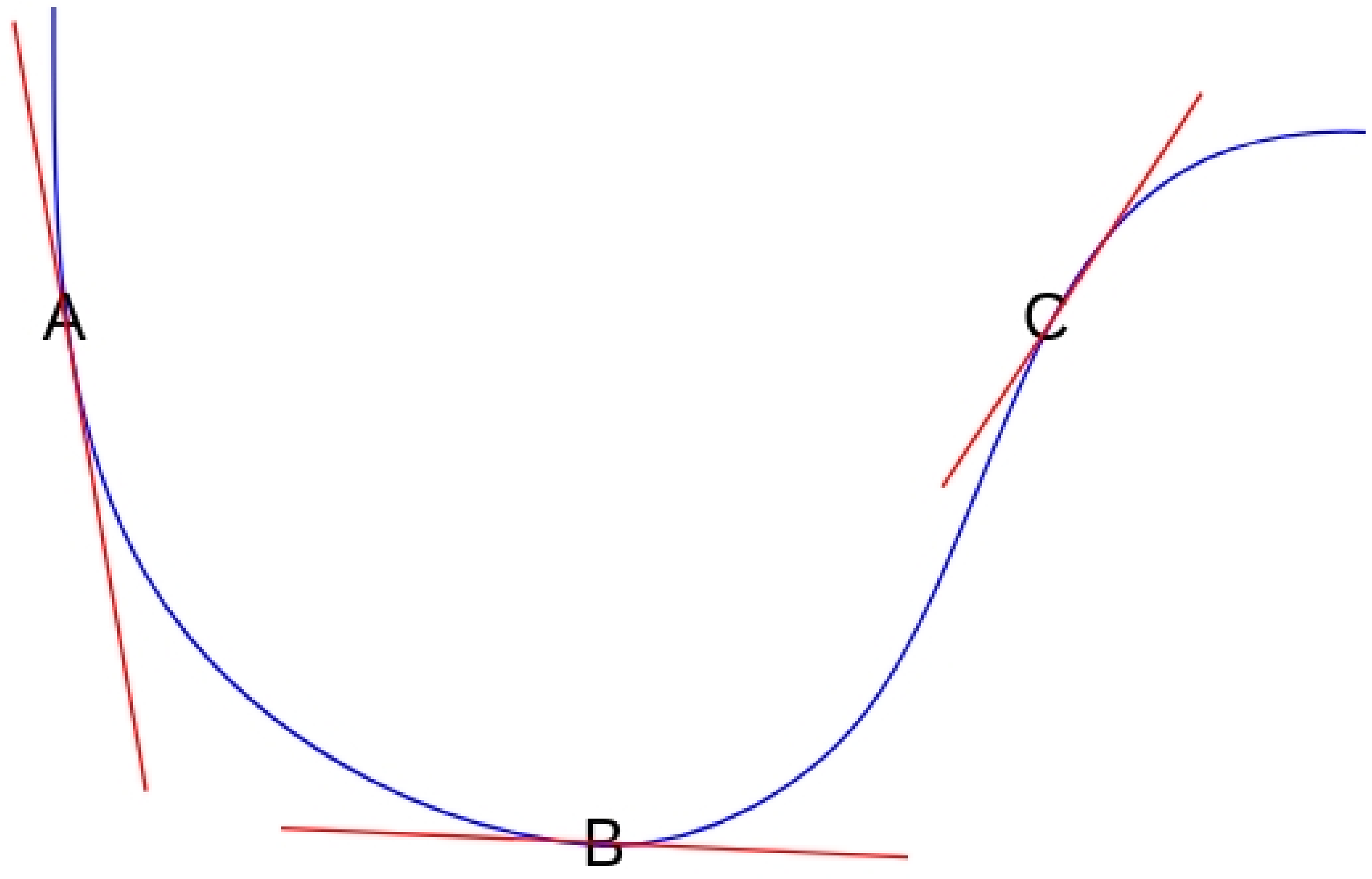
Derivatives





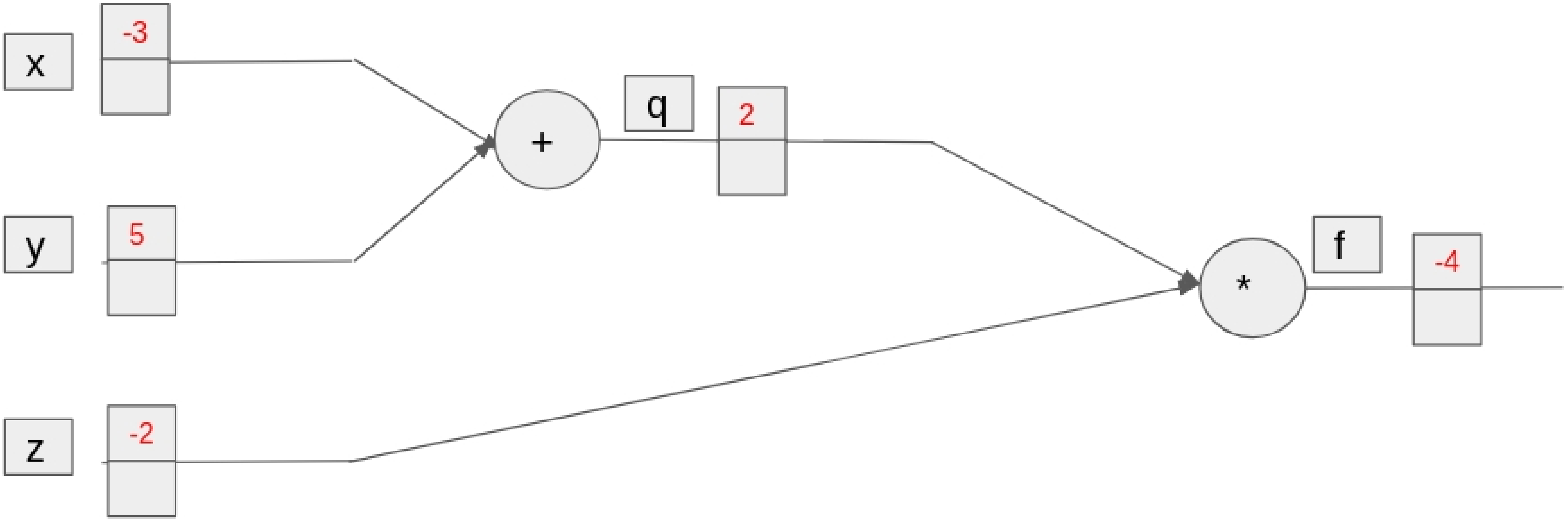
Derivative Rules

Interaction	Overall Change
Addition	$(f+g)' = f' + g'$
Multiplication	$(f \cdot g)' = f \cdot dg + g \cdot df$
Powers	$(x^n)' = \frac{d}{dx} x^n = n x^{n-1}$
Inverse	$\left(\frac{1}{x}\right)' = -\frac{1}{x^2}$
Division	$\left(\frac{f}{g}\right)' = \left(df \cdot \frac{1}{g}\right) + \left(\frac{-1}{g^2} dg \cdot f\right)$

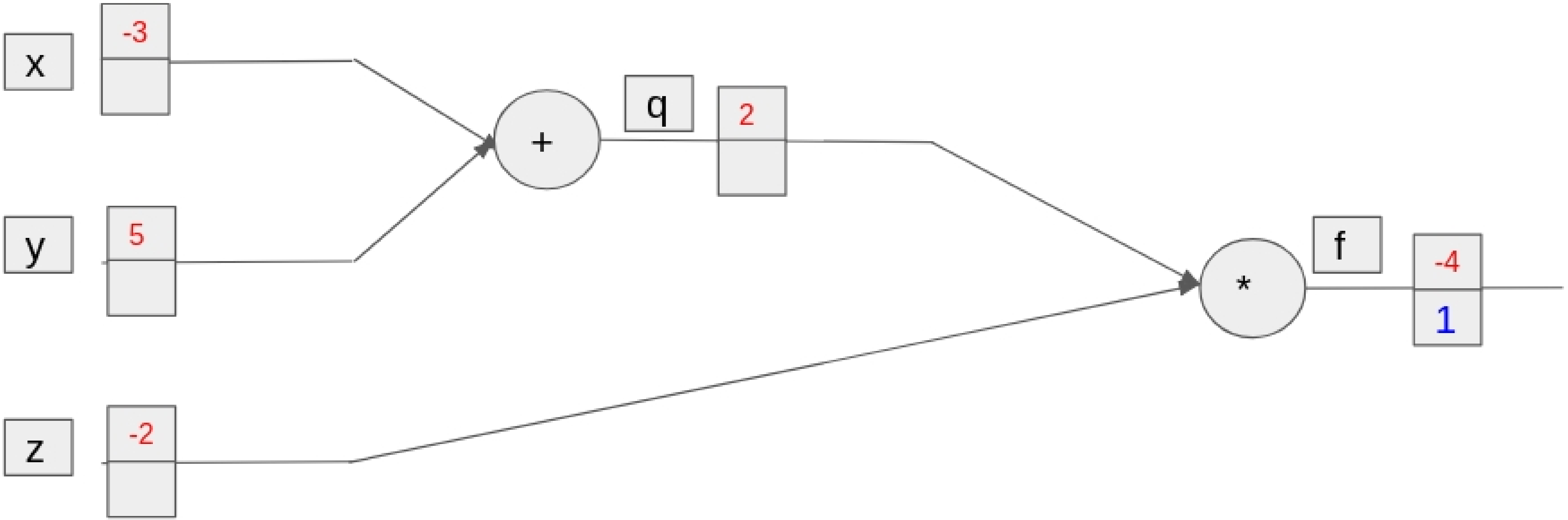
$$\frac{d}{dx}\left[\left(f(x)\right)^n\right] = n\left(f(x)\right)^{n-1} \cdot f'(x)$$

$$\frac{d}{dx}\left[f(g(x))\right] = f'(g(x))g'(x)$$

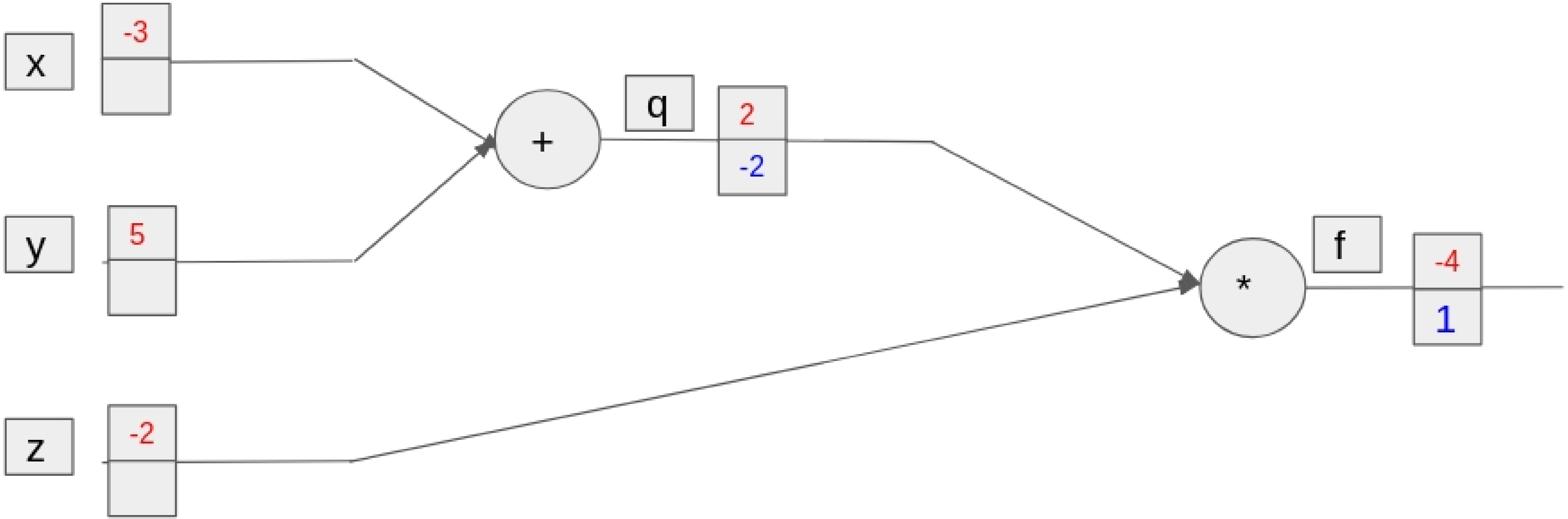
Derivative Example - Forward Pass



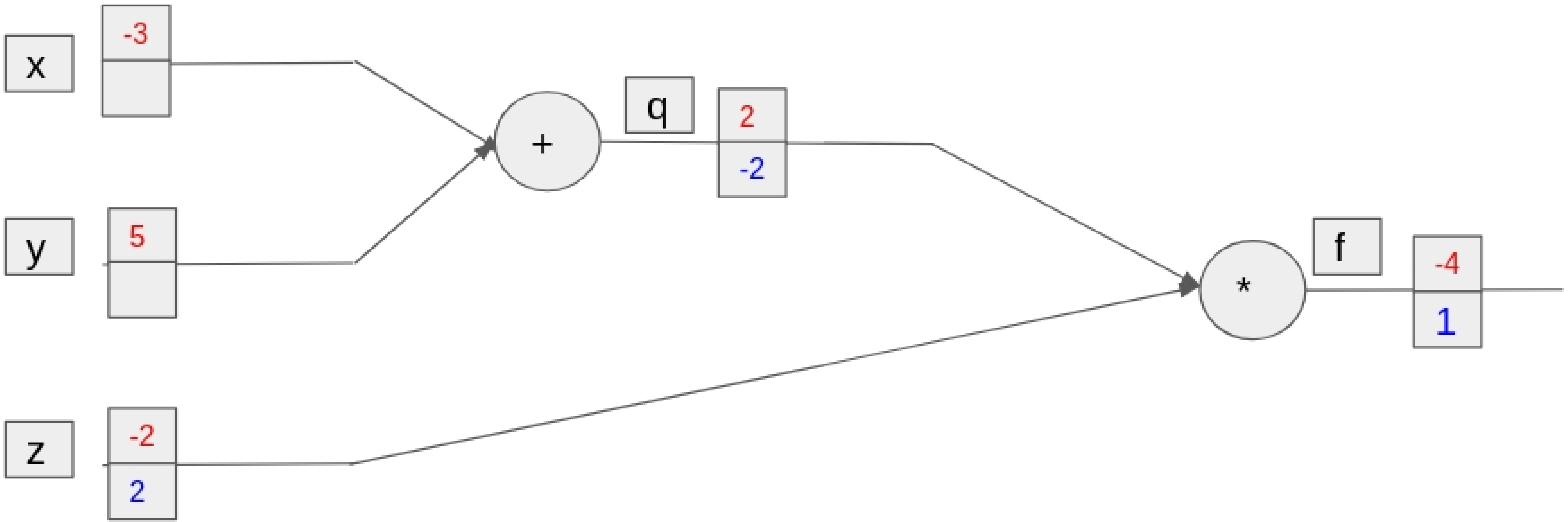
Derivative Example - Backward Pass



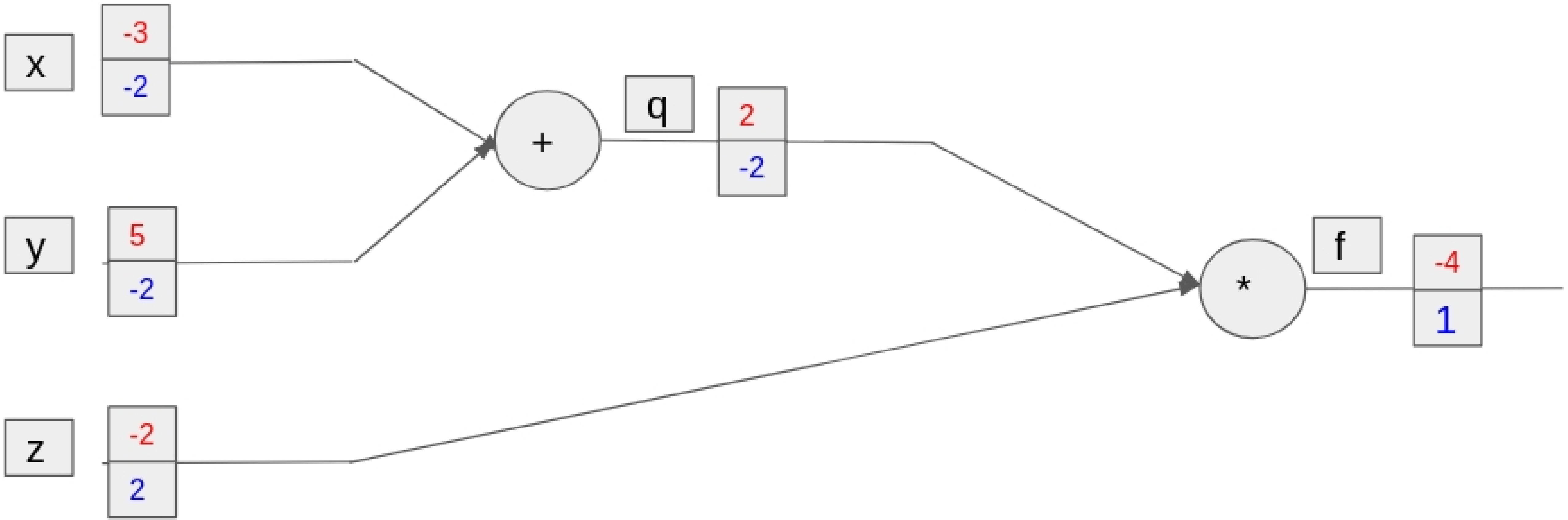
Derivative Example - Backward Pass



Derivative Example - Backward Pass



Derivative Example - Backward Pass



Backpropagation in PyTorch

```python
import torch

x = torch.tensor(-3., requires_grad=True)
y = torch.tensor(5., requires_grad=True)
z = torch.tensor(-2., requires_grad=True)


q = x + y
f = q * z

f.backward()



print("Gradient of z is: " + str(z.grad))
print("Gradient of y is: " + str(y.grad))
print("Gradient of x is: " + str(x.grad))
```

```
Gradient of z is: tensor(2.)
Gradient of y is: tensor(-2.)
Gradient of x is: tensor(-2.)
```

Let's practice

Introduction to Neural Networks

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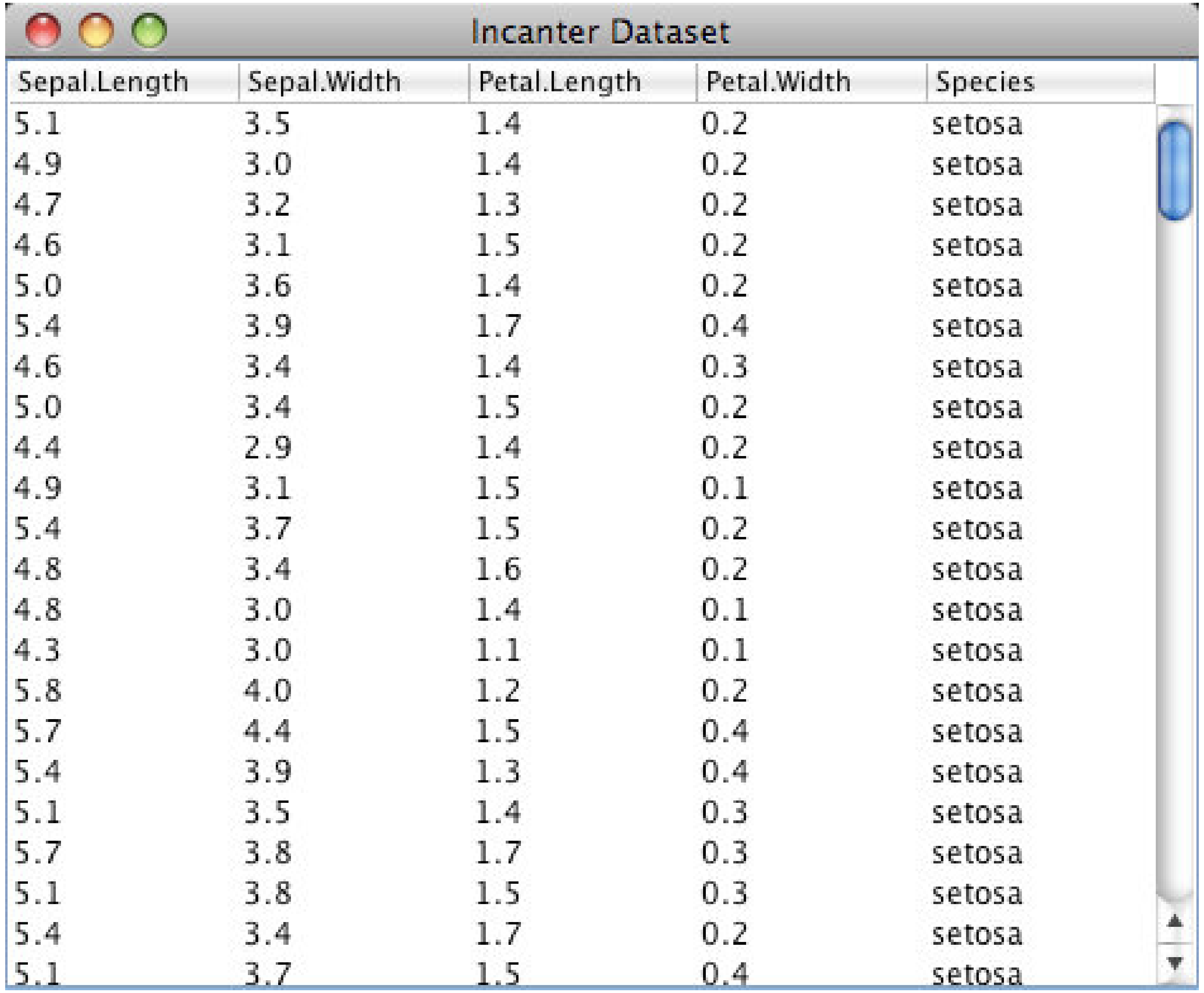
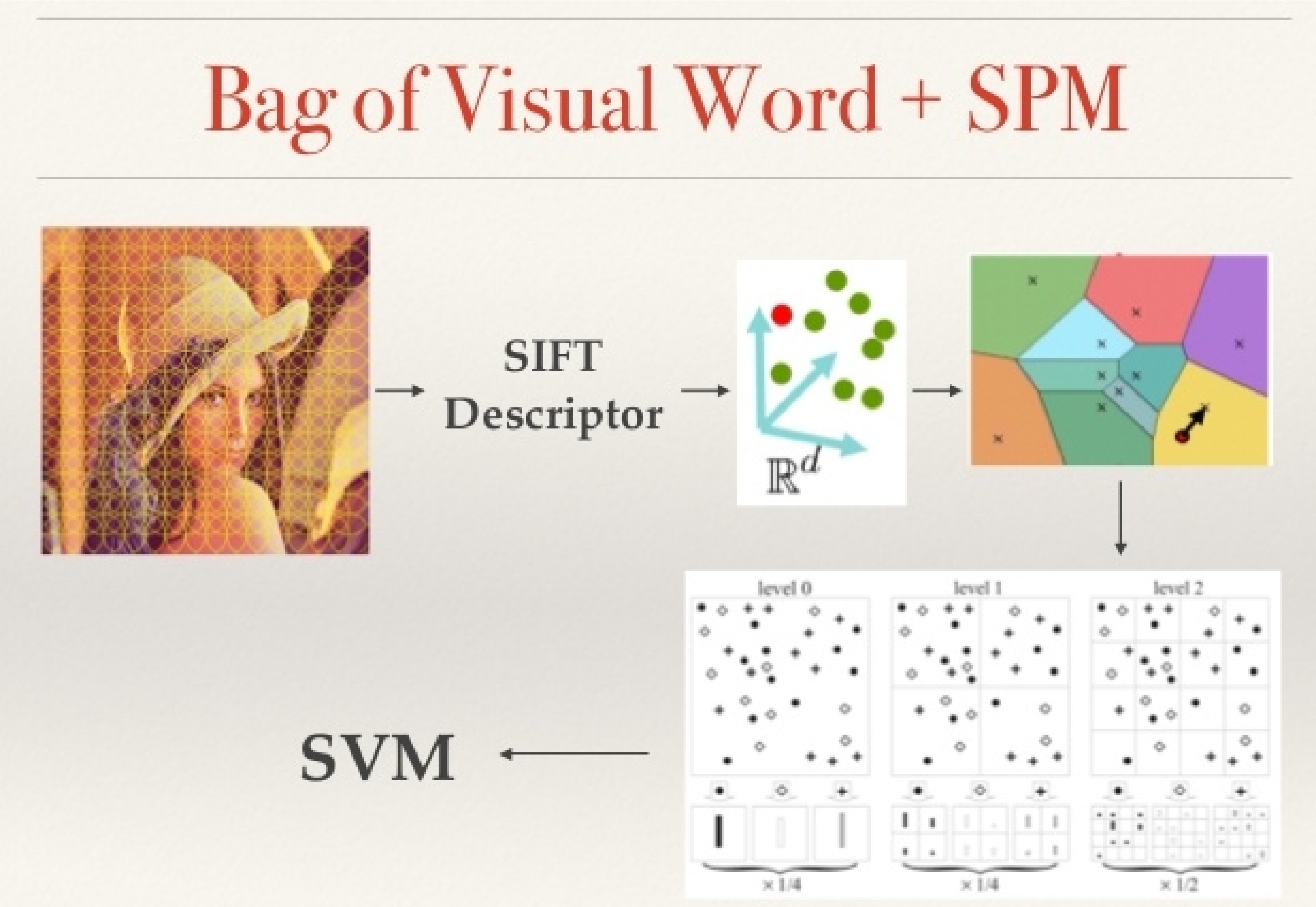
Other classifiers

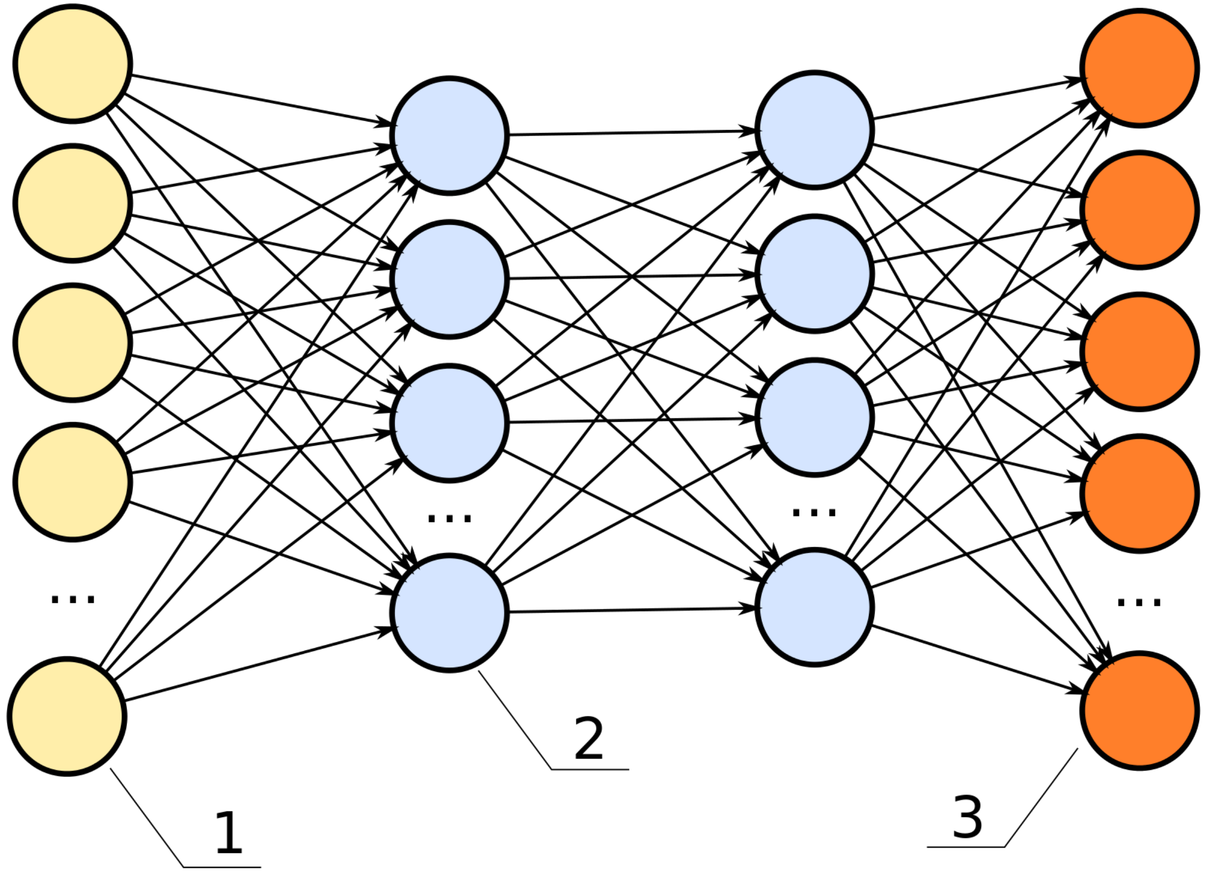
- k-Nearest Neighbour
- Logistic/Linear Regression
- Random Forests
- Gradient Boosted Trees
- Support Vector Machines
- ...


Incanter Dataset

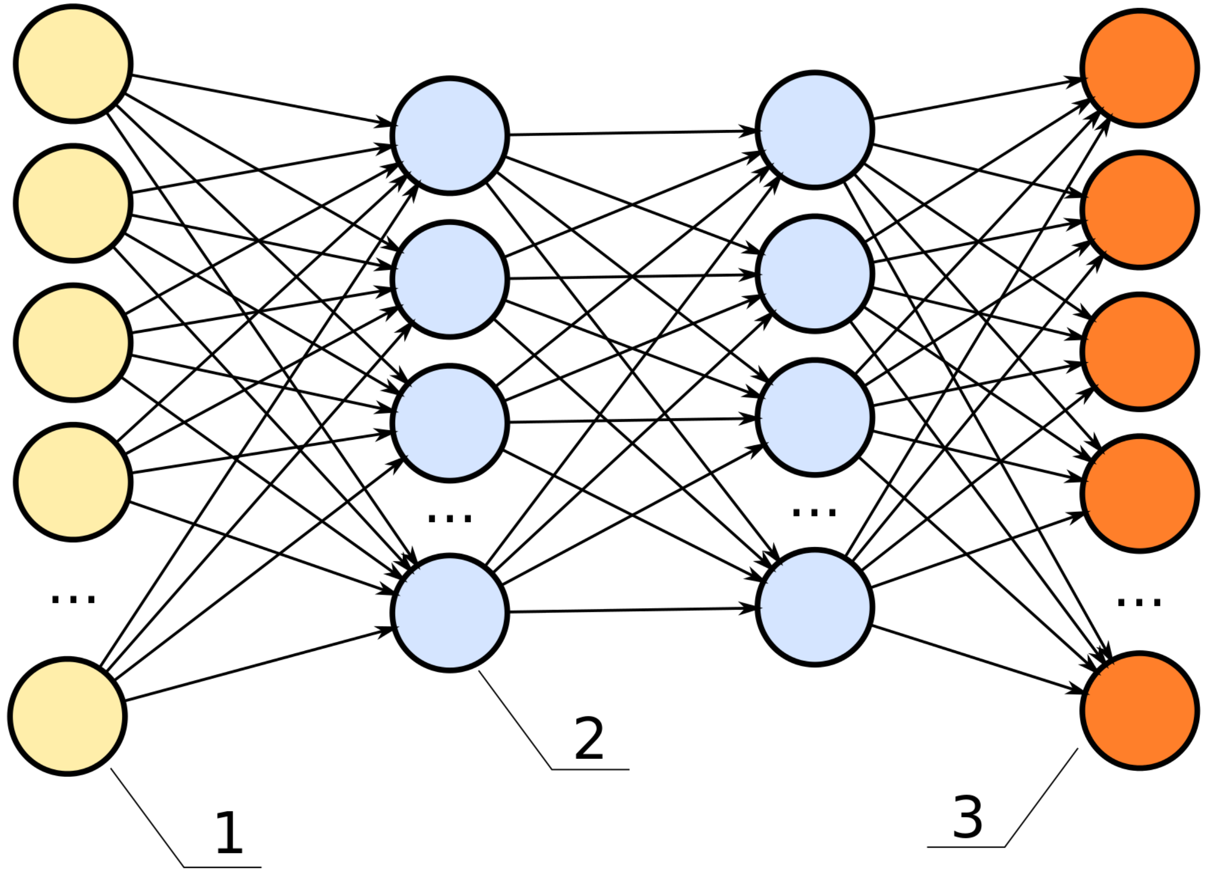
Sepal.Length	Sepal.Width	Petal.Length	Petal.Width	Species
5.1	3.5	1.4	0.2	setosa
4.9	3.0	1.4	0.2	setosa
4.7	3.2	1.3	0.2	setosa
4.6	3.1	1.5	0.2	setosa
5.0	3.6	1.4	0.2	setosa
5.4	3.9	1.7	0.4	setosa
4.6	3.4	1.4	0.3	setosa
5.0	3.4	1.5	0.2	setosa
4.4	2.9	1.4	0.2	setosa
4.9	3.1	1.5	0.1	setosa
5.4	3.7	1.5	0.2	setosa
4.8	3.4	1.6	0.2	setosa
4.8	3.0	1.4	0.1	setosa
4.3	3.0	1.1	0.1	setosa
5.8	4.0	1.2	0.2	setosa
5.7	4.4	1.5	0.4	setosa
5.4	3.9	1.3	0.4	setosa
5.1	3.5	1.4	0.3	setosa
5.7	3.8	1.7	0.3	setosa
5.1	3.8	1.5	0.3	setosa
5.4	3.4	1.7	0.2	setosa
5.1	3.7	1.5	0.4	setosa

ANN vs other classifiers





Fully connected neural networks




```python
import torch

input_layer = torch.rand(10)

w1 = torch.rand(10, 20)
w2 = torch.rand(20, 20)
w3 = torch.rand(20, 4)
h1 = torch.matmul(input_layer, w1)
h2 = torch.matmul(h1, w2)
output_layer = torch.matmul(h2, w3)
print(output_layer)
```

```
tensor([413.8647, 286.5770,
        361.8974, 294.0240])
```

Building a neural network - PyTorch style

```python
import torch
import torch.nn as nn


class Net(nn.Module):
    def __init__(self):
        super(Net, self).__init__()
        self.fc1 = nn.Linear(10, 20)
        self.fc2 = nn.Linear(20, 20)
        self.output = nn.Linear(20, 4)

    def forward(self, x):
        x = self.fc1(x)
        x = self.fc2(x)
        x = self.output(x)
        return x
```

```python
input_layer = torch.rand(10)
net = Net()
result = net(input_layer)
```

Let's practice!

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