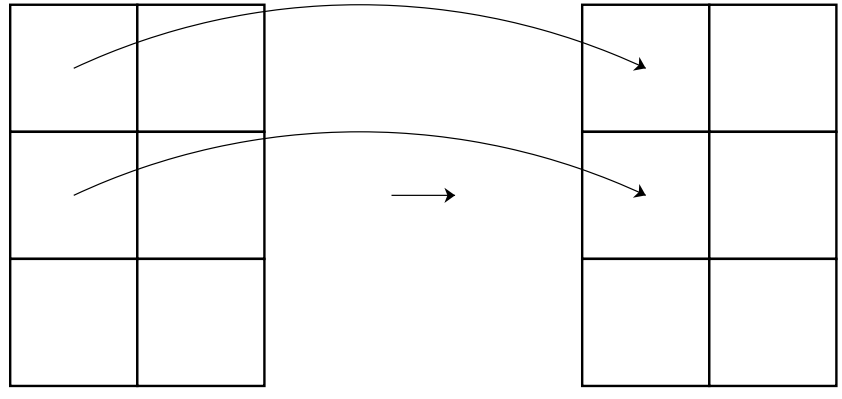
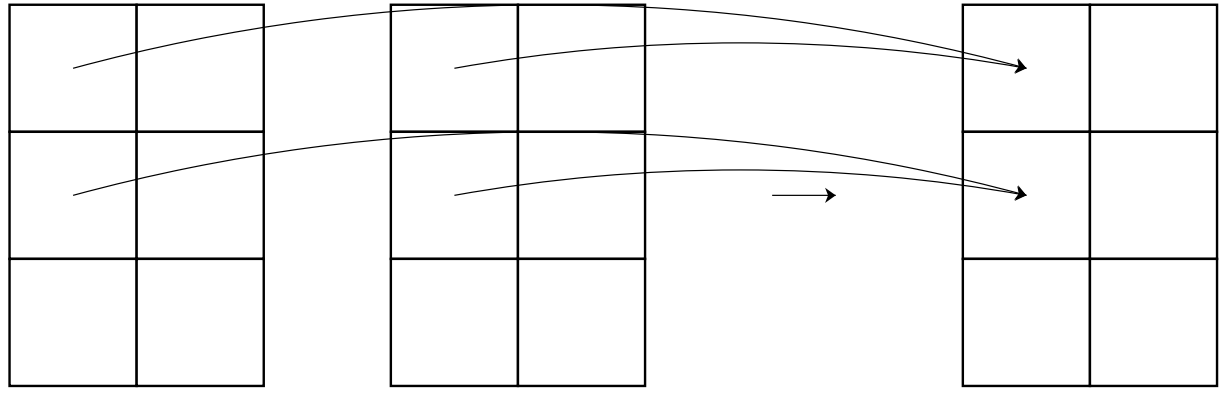
Module 2.3 - Advanced Tensors

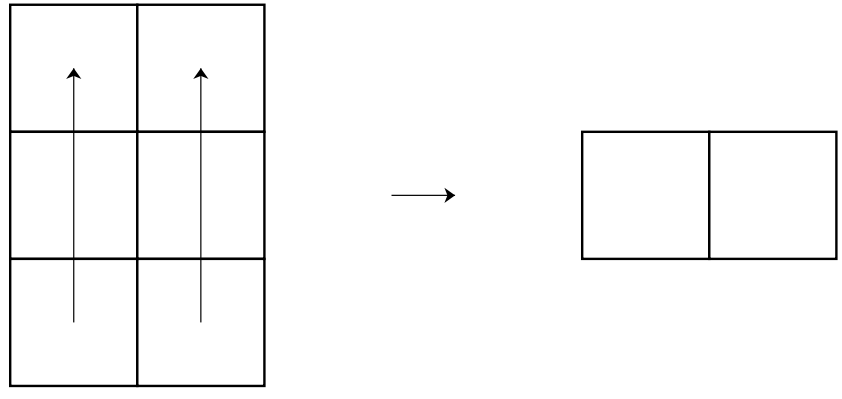
Map



Zip



Reduce



Quiz

Outline

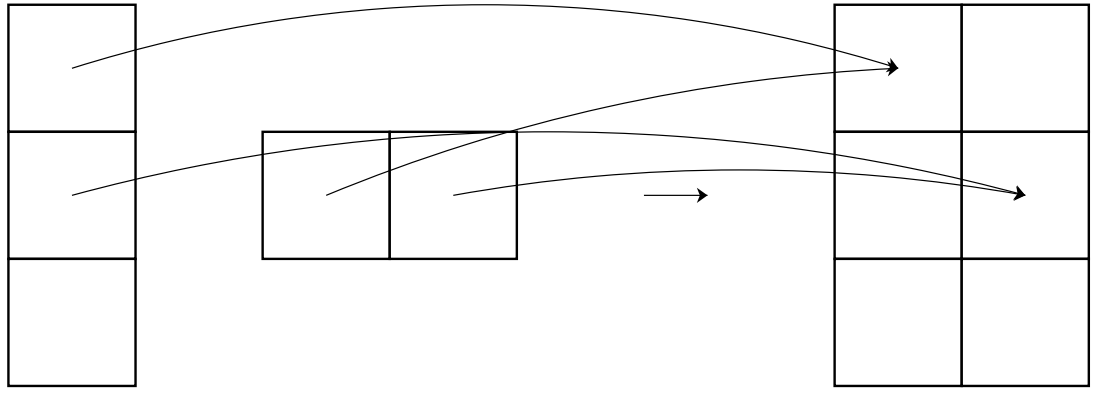
- Broadcasting
- Gradients
- Tensor Puzzles

Broadcasting

Motivation: Scalar Addition

$vector1 + 10$

Zip Broadcasting



Rules

- **Rule 1**: Dimension of size 1 broadcasts with anything
- **Rule 2**: Extra dimensions of 1 can be added with `view`
- **Rule 3**: Zip automatically adds starting dims of size 1

Applying the Rules

- (3, 4, 5) | (3, 1, 5) => (3, 4, 5)
- (3, 4, 1) | (3, 1, 5) => (3, 4, 5)
- (3, 4, 1) | (1, 5) => (3, 4, 5)
- (3, 4, 1) | (3, 5) => X

Broadcasting Example

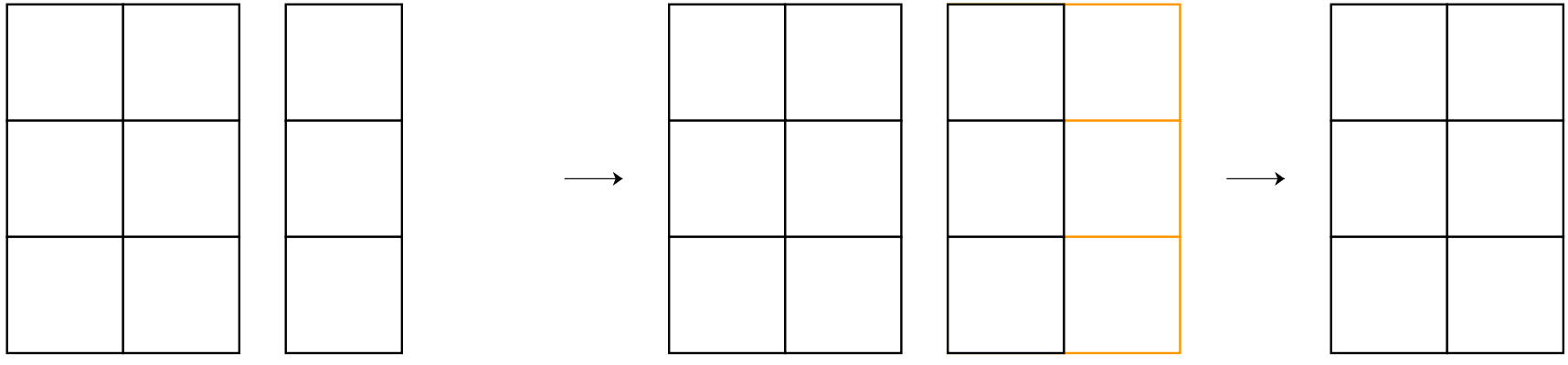
```
3   4   1
    1   5
-------
3   4   5
```

Matrix-Vector

```
x = minitorch.tensor([[1, 2], [3, 4], [5, 6]])
y = minitorch.tensor([[1], [3], [5]])
z = x + y
z.shape
```

```
(3, 2)
```

Matrix-Vector

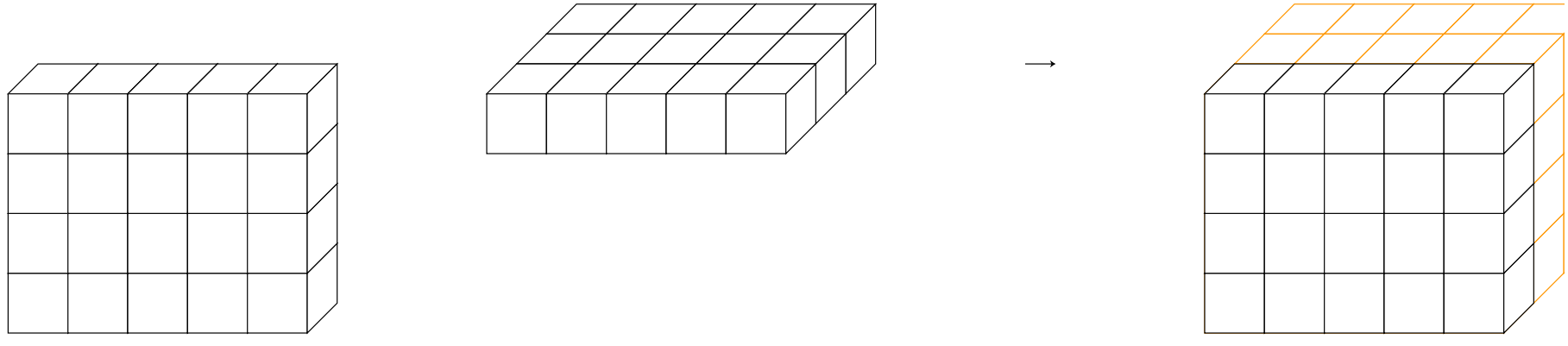


Matrix-Matrix

```
x = minitorch.zeros((4, 5))
y = minitorch.zeros((3, 1, 5))
z = x + y
z.shape
```

```
(3, 4, 5)
```

Matrix-Matrix

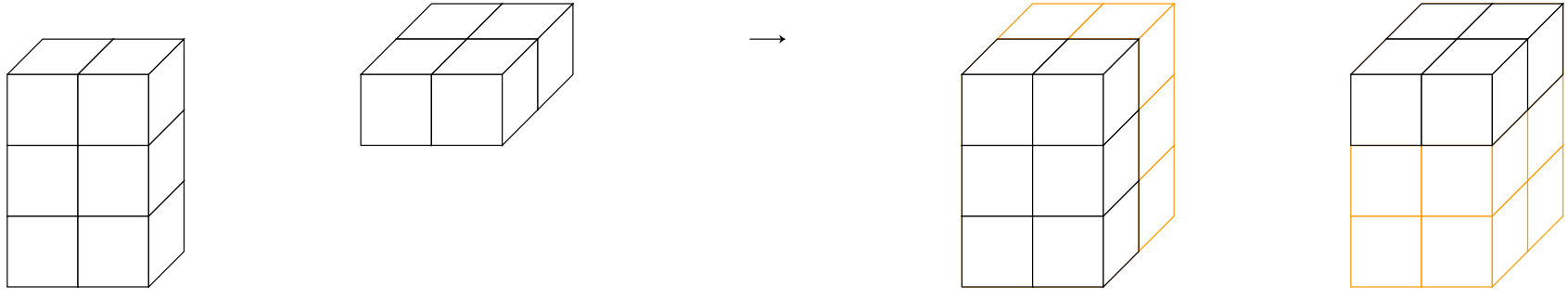


”Matrix multiplication”

```
x = minitorch.zeros((3, 2))
y = minitorch.zeros((2, 1, 2))
z = (x * y).sum(2)
z.shape
```

```
(2, 3, 1)
```

”Matrix multiplication”



Implementation

- Never create an intermediate value.
- Implicit map between output space / input space

Functions

- `shape_broadcast` - create the broadcast dims
- `broadcast_index` - map from broadcasted to original value

Tensor Puzzles

Special PyTorch Syntax

(Not avaiable in minitorch)

```
import torch

x = torch.tensor([1, 2, 3])
print(x.shape)
print(x[None].shape)
print(x[:, None].shape)
```

```
torch.Size([3])
torch.Size([1, 3])
torch.Size([3, 1])
```

Tensor Function

```
x = torch.arange(10)
print(x)

y = torch.arange(4)
print(y)
```

```
tensor([0, 1, 2, 3, 4, 5, 6, 7, 8, 9])
tensor([0, 1, 2, 3])
```

Tensor Function

```
x = torch.where(
    torch.tensor([True, False]),
    torch.tensor([1, 1]),
    torch.tensor([0, 0]),
)
print(x)
```

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

Tensor Puzzles

Tensor Puzzles

Q&A