Numpy Arrays

Basic Python

Winter 2022: Dan Calderone

Python - Base Data Structures

list : x = **[** 1, ’a’, func **]**

dict : X = **{** ‘key1’: 1,
‘key2’: ‘a’,
‘key3’: func **}**

np.array: A = **np.array([[**1, 2, 3**],**
[3, 2, 1**],**
[2, 1, 3**]])**

np.array : A = **np.array([[**1, 2, 3**], [**3, 2, 1**], [**2, 1, 3**]])**

A[np.newaxis,:] A[:,np.newaxis]

np.stack([x,x,x]) …stack along new axis

np.vstack([x,x,x]) …stack vertically

np.hstack([x,x,x]) …stack horizontally

np.block([[A,B]
[C,D]]) …block matrix

np.eye(n)

np.ones([m,n])

np.zeros([m,n])

np.arange(start,stop,step=1)

np.arange(start,stop,num=50)

np.append(A,newarray) …adds newarray to the end

np.insert(A,index,newarray) …adds new array at index

np.reshape(A,newshape) …cycle through deepest axes first

np.concatenate((A,B,C),axis=0) …must have same shape except along axis

np.flip(A,axis=None) …by default flips all axes

np.where(A,axis=None)

Python - Indexing

x = **np.array([** 1 , 1 , 1 , 1 , … , 1 , 1 **])**

index 0 1 2 3 n-1 *or* -1

np.array: A = **np.array([[**1, 2, 3**],**
[3, 2, 1**]])**

zero indexed

x[0] - *first element…*
x[1] - *second element…*

negative indexing

x[-1] - last element…

slicing **start : end : step**

x[k1:k2:s1] - from k1 to k2 step by s1

array indexing

ind = [0, 2, 3];
x[ind] - returns 0,2, and 3 elements

ind1 = [0, 2, 3]; ind2 = [0,3,2];
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boolean indexing

bool = **[True, True, False, True];** MUST BE ARRAY LENGTH
x[bool] - returns 0,1, and 3 element.

X[bool,bool] - returns the [0,0], [1,1], and [3,3]

block indexing - np.ix_

X[np.ix_(ind1,ind2)] - returns the [0,2,3] x [3,2] block
X[np.ix_(bool,bool)] - returns the [0,1,3] x [0,1,3] block

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x = **np.array([** 1 , 1 , 1 , 1 , … , 1 , 1 **])**

index 0 1 2 3 n-1 *or* -1

x[1] **np.array([** 1 , 1 , 1 , 1 , … , 1 , 1 **])**

1

x[1:4] **np.array([** 1 , 1 , 1 , 1 , … , 1 , 1 **])**

1 4

x[:4] **np.array([** 1 , 1 , 1 , 1 , … , 1 , 1 **])**

4

x[1:] **np.array([** 1 , 1 , 1 , 1 , … , 1 , 1 **])**

1

x[:-1] **np.array([** 1 , 1 , 1 , 1 , … , 1 , 1 **])**

-1

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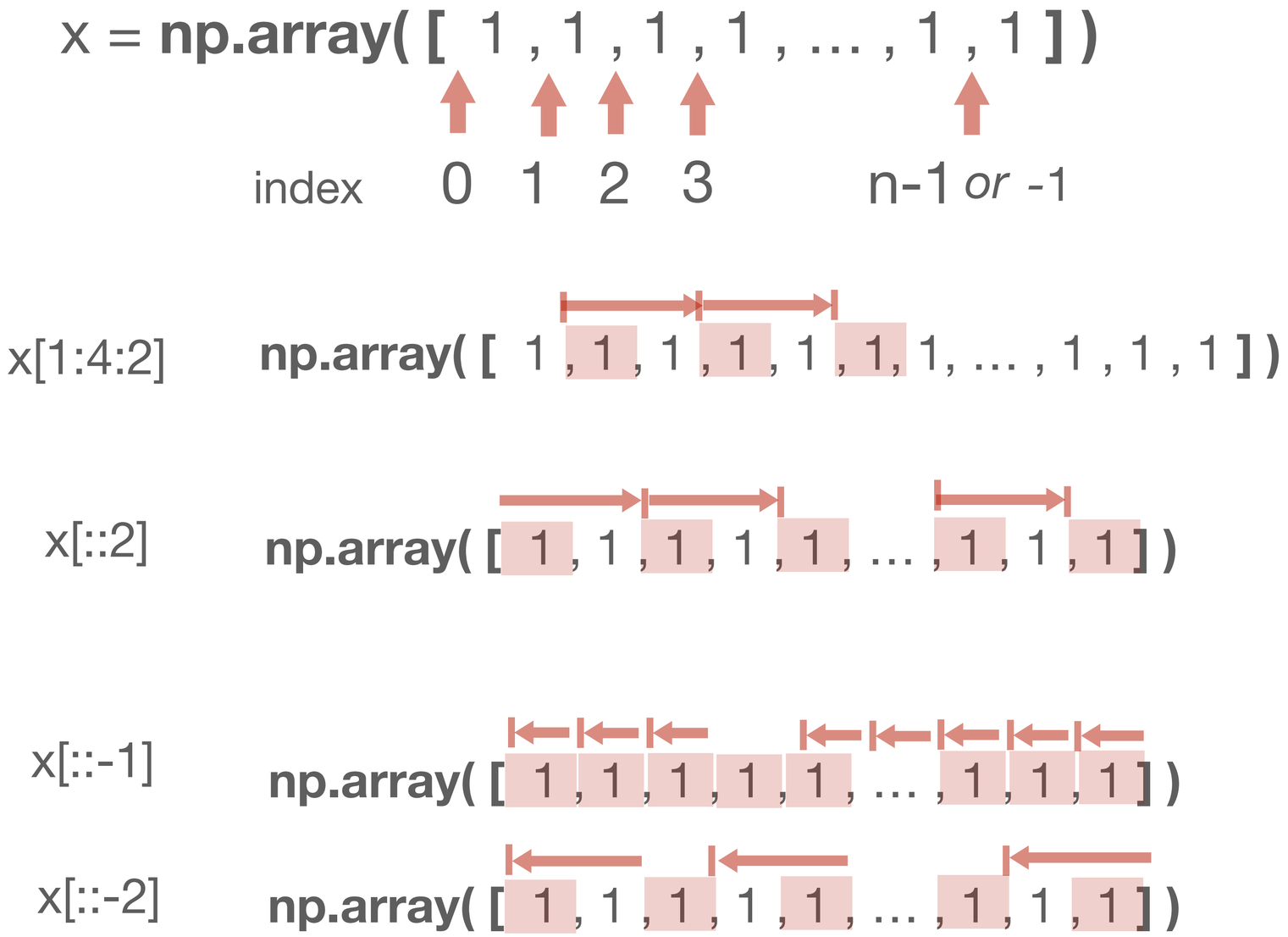

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2nd index

X = **np.array([[** 1 , 1 , 1 , 1 , 1 **],**
[1 , 1 , 1 , 1 , 1 **],**
[1 , 1 , 1 , 1 , 1 **],**
[1 , 1 , 1 , 1 , 1 **],**
[1 , 1 , 1 , 1 , 1 **]])**

1st index (rows)

X[0]

or

X[0,:]

np.array([[1 , 1 , 1 , 1 , 1 **],**
[1 , 1 , 1 , 1 , 1 **],**
[1 , 1 , 1 , 1 , 1 **],**
[1 , 1 , 1 , 1 , 1 **],**
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```
X = np.array( [[ 1 , 1 , 1 , 1 , 1 ],
               [ 1 , 1 , 1 , 1 , 1 ],
               [ 1 , 1 , 1 , 1 , 1 ],
               [ 1 , 1 , 1 , 1 , 1 ],
               [ 1 , 1 , 1 , 1 , 1 ]])
```

X[1]

or

X[1,:]

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

X[2]

or

X[2,:]

```
np.array( [[ 1 , 1 , 1 , 1 , 1 ],
           [ 1 , 1 , 1 , 1 , 1 ],
           [ 1 , 1 , 1 , 1 , 1 ],
           [ 1 , 1 , 1 , 1 , 1 ],
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ind = [0, 2, 3];
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```
X = np.array( [[ 1 , 1 , 1 , 1 , 1 ],
               [ 1 , 1 , 1 , 1 , 1 ],
               [ 1 , 1 , 1 , 1 , 1 ],
               [ 1 , 1 , 1 , 1 , 1 ],
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```

X[3]

or

X[3,:]

```
np.array( [[ 1 , 1 , 1 , 1 , 1 ],
           [ 1 , 1 , 1 , 1 , 1 ],
           [ 1 , 1 , 1 , 1 , 1 ],
           [ 1 , 1 , 1 , 1 , 1 ],
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```
X = np.array( [[ 1 , 1 , 1 , 1 , 1 ],
               [ 1 , 1 , 1 , 1 , 1 ],
               [ 1 , 1 , 1 , 1 , 1 ],
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```

X[4]

or

X[4,:]

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

X[:,0]

```
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```

X[:,1]

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

X[:,2]

```
np.array( [[ 1 , 1 , 1 , 1 , 1 ],
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```
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1st index (rows)

X[:,4]

np.array([[1 , 1 , 1 , 1 , 1 **],**
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```

X[2,3]

```
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               [ 1 , 1 , 1 , 1 , 1 ]])
```

X[2:4,3:5]

```
np.array( [[ 1 , 1 , 1 , 1 , 1 ],
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           [ 1 , 1 , 1 , 1 , 1 ],
           [ 1 , 1 , 1 , 1 , 1 ],
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2nd index

1st index (rows)

```
X = np.array( [[ 1 , 1 , 1 , 1 , 1 ],
               [ 1 , 1 , 1 , 1 , 1 ],
               [ 1 , 1 , 1 , 1 , 1 ],
               [ 1 , 1 , 1 , 1 , 1 ],
               [ 1 , 1 , 1 , 1 , 1 ]])
```

X[2:,3:]

```
np.array( [[ 1 , 1 , 1 , 1 , 1 ],
           [ 1 , 1 , 1 , 1 , 1 ],
           [ 1 , 1 , 1 , 1 , 1 ],
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Python - Indexing

np.array: A = **np.array([[**1, 2, 3**],**
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zero indexed

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X[:2,:3]

```
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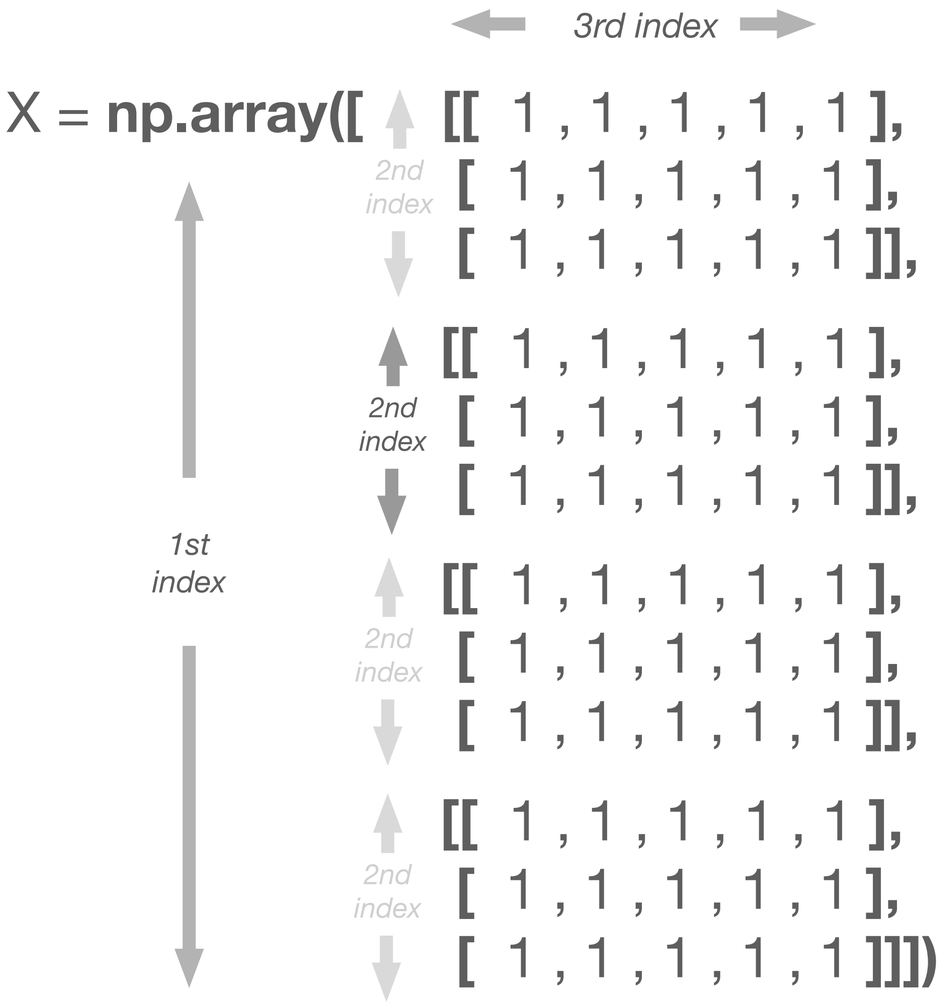

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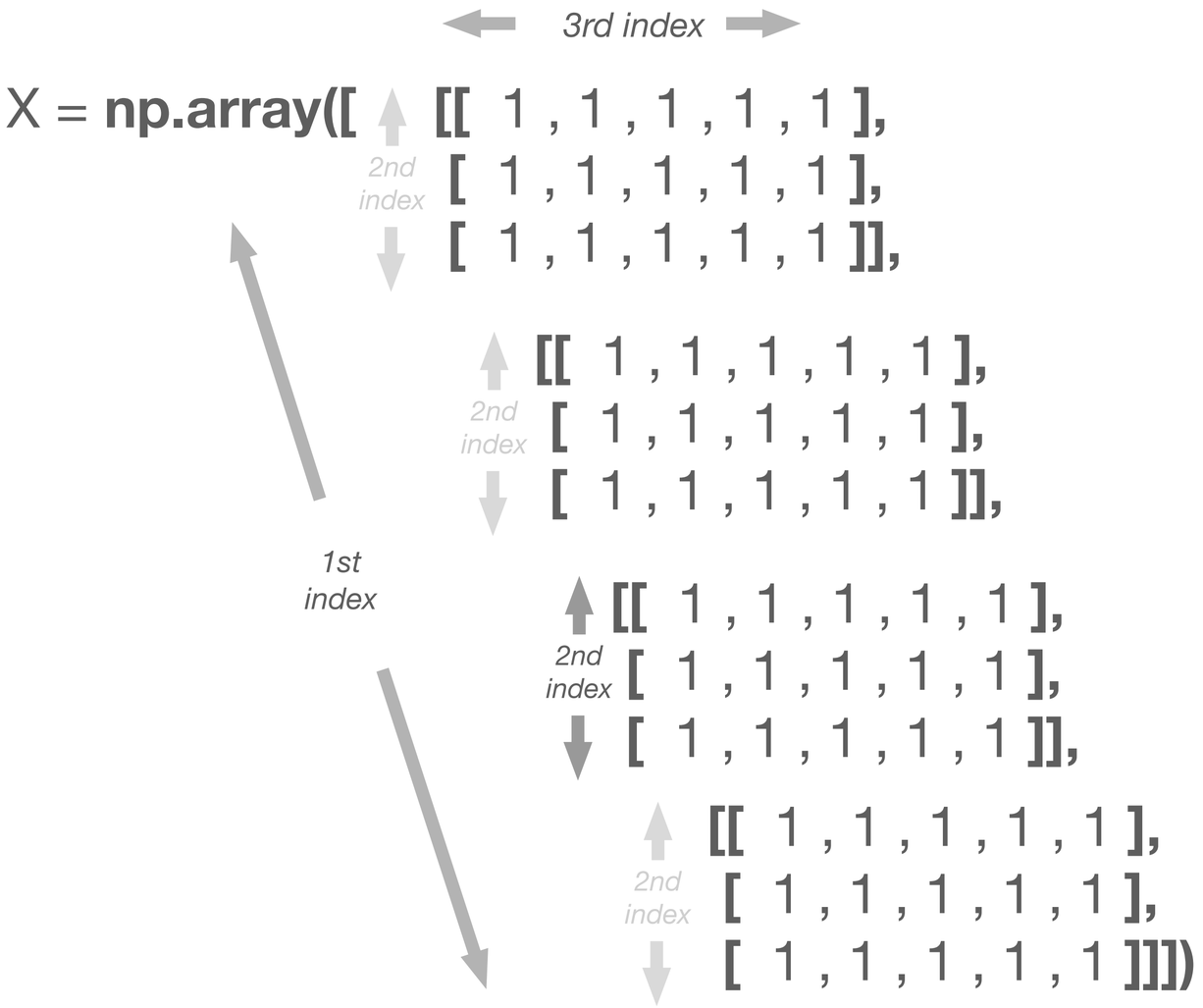

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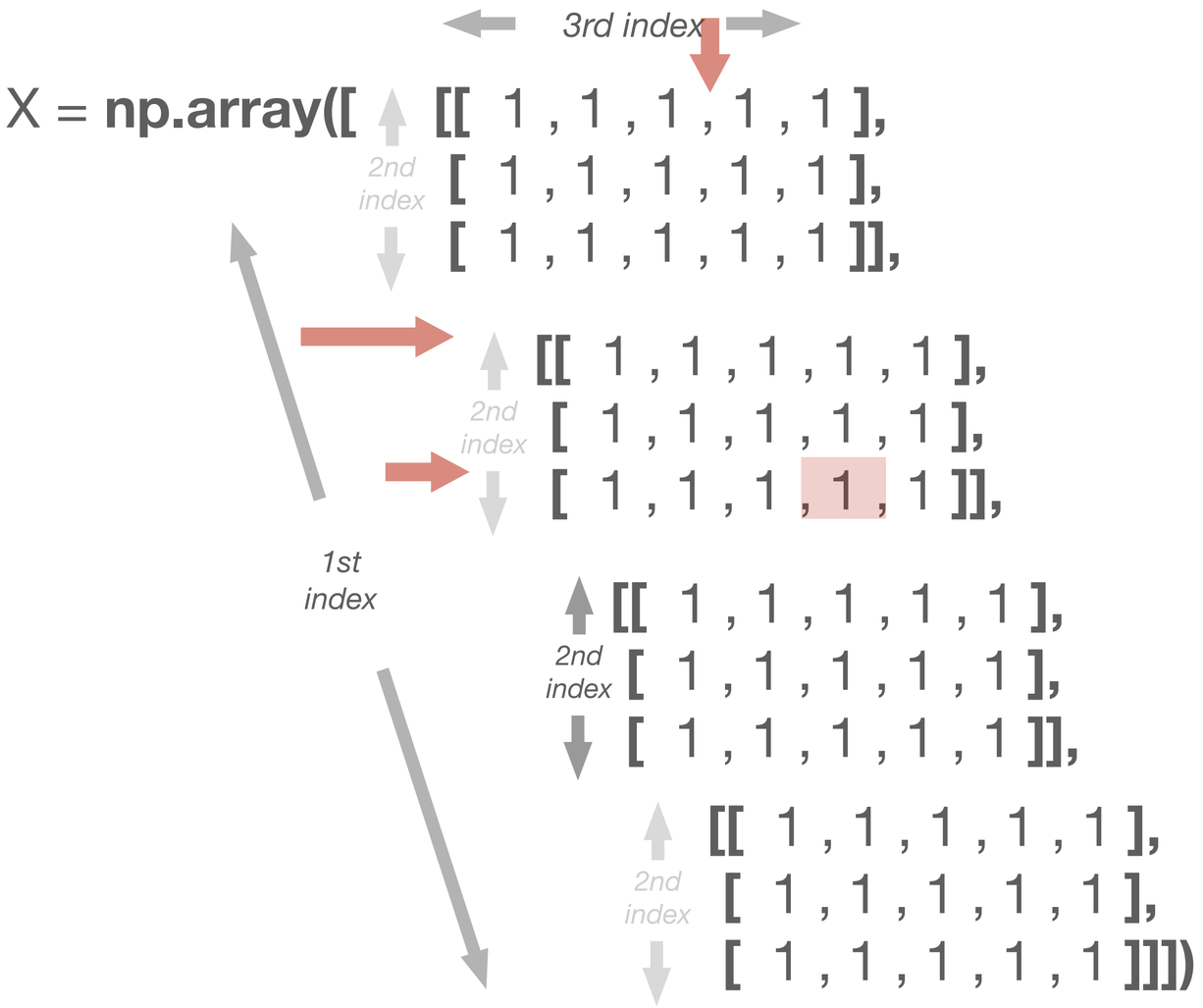
X[1,2,3]

or

X[1][2][3]



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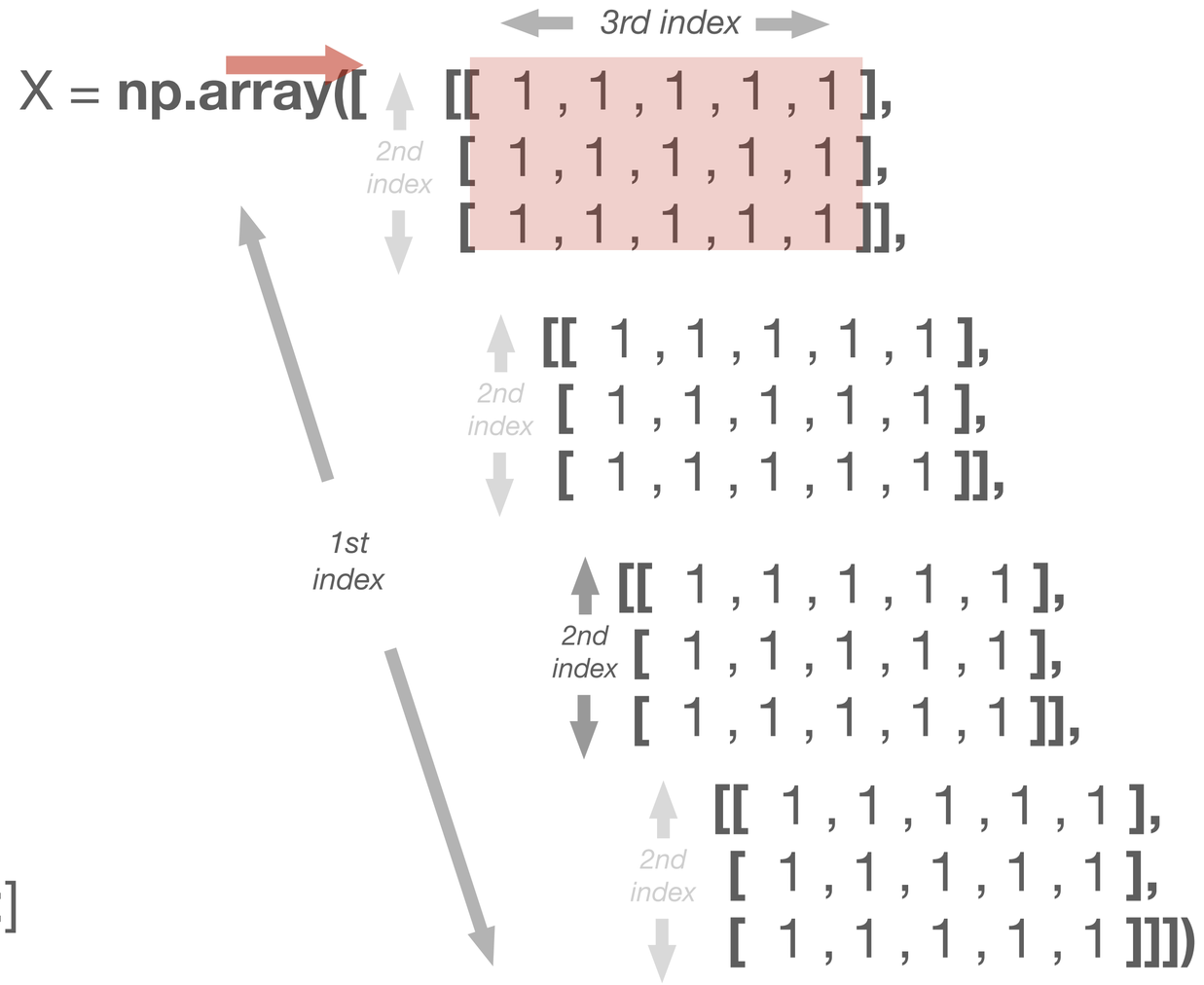
X[0]

or

X[0,:]

or

X[0,:,:]



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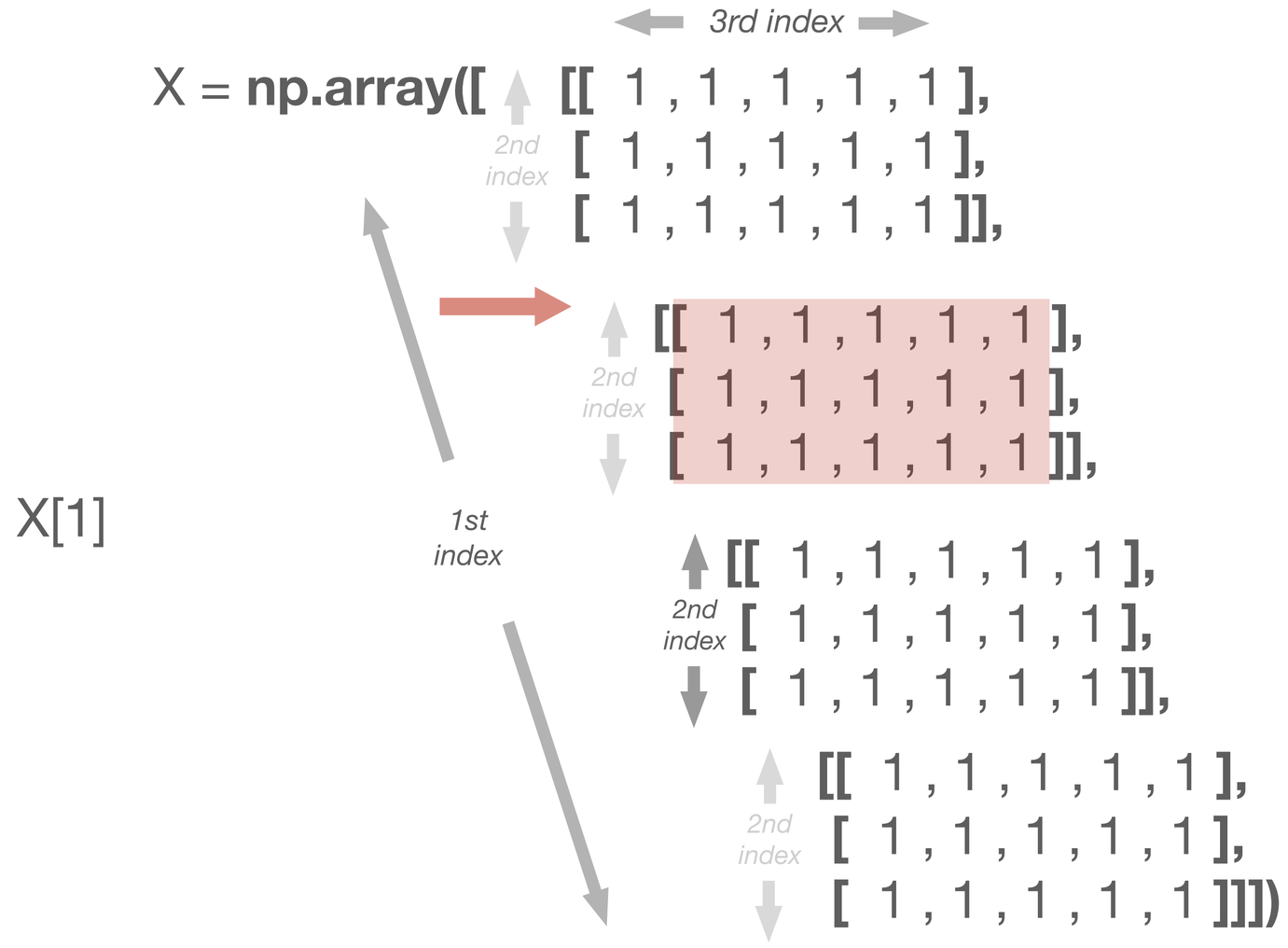

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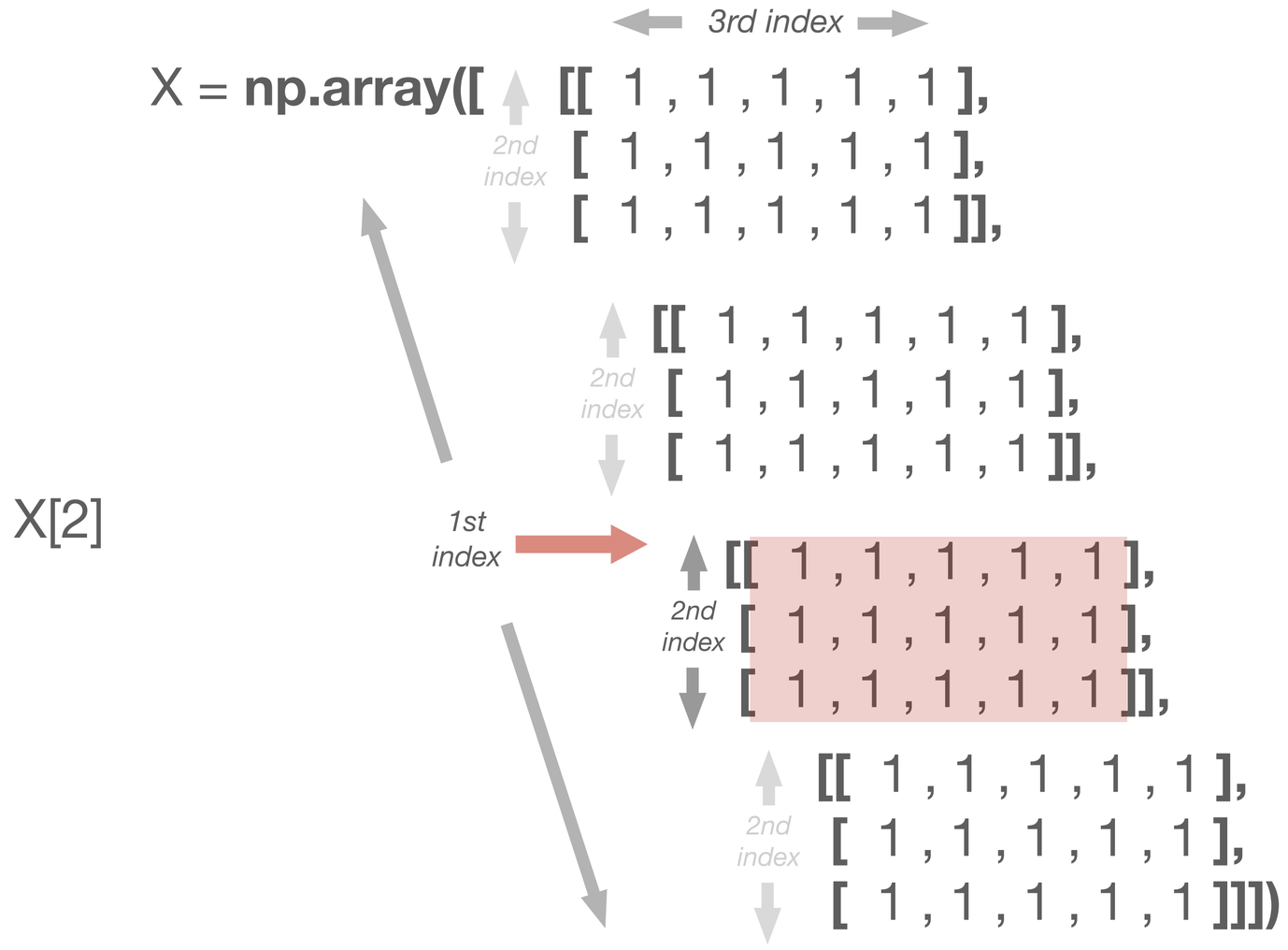

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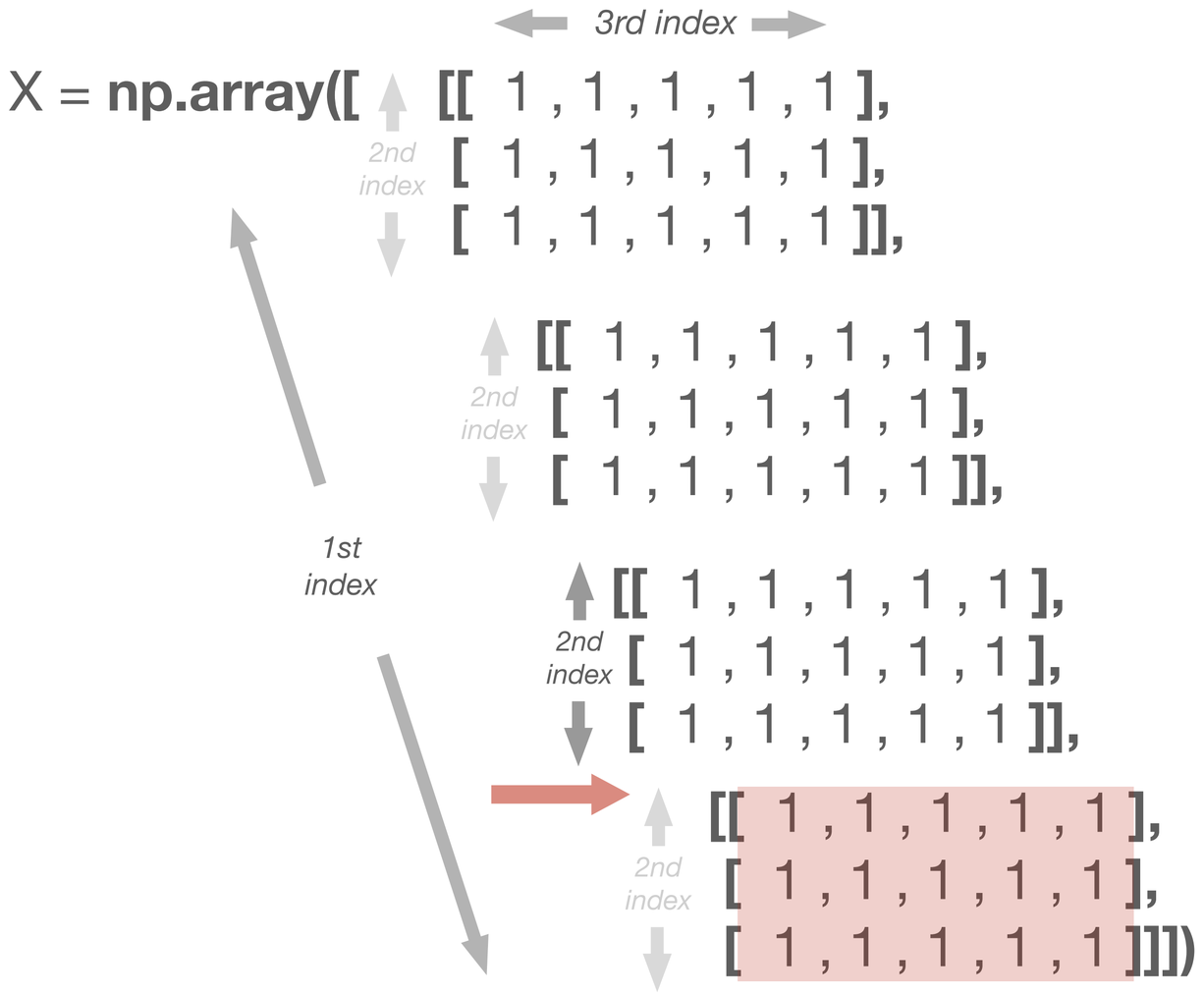

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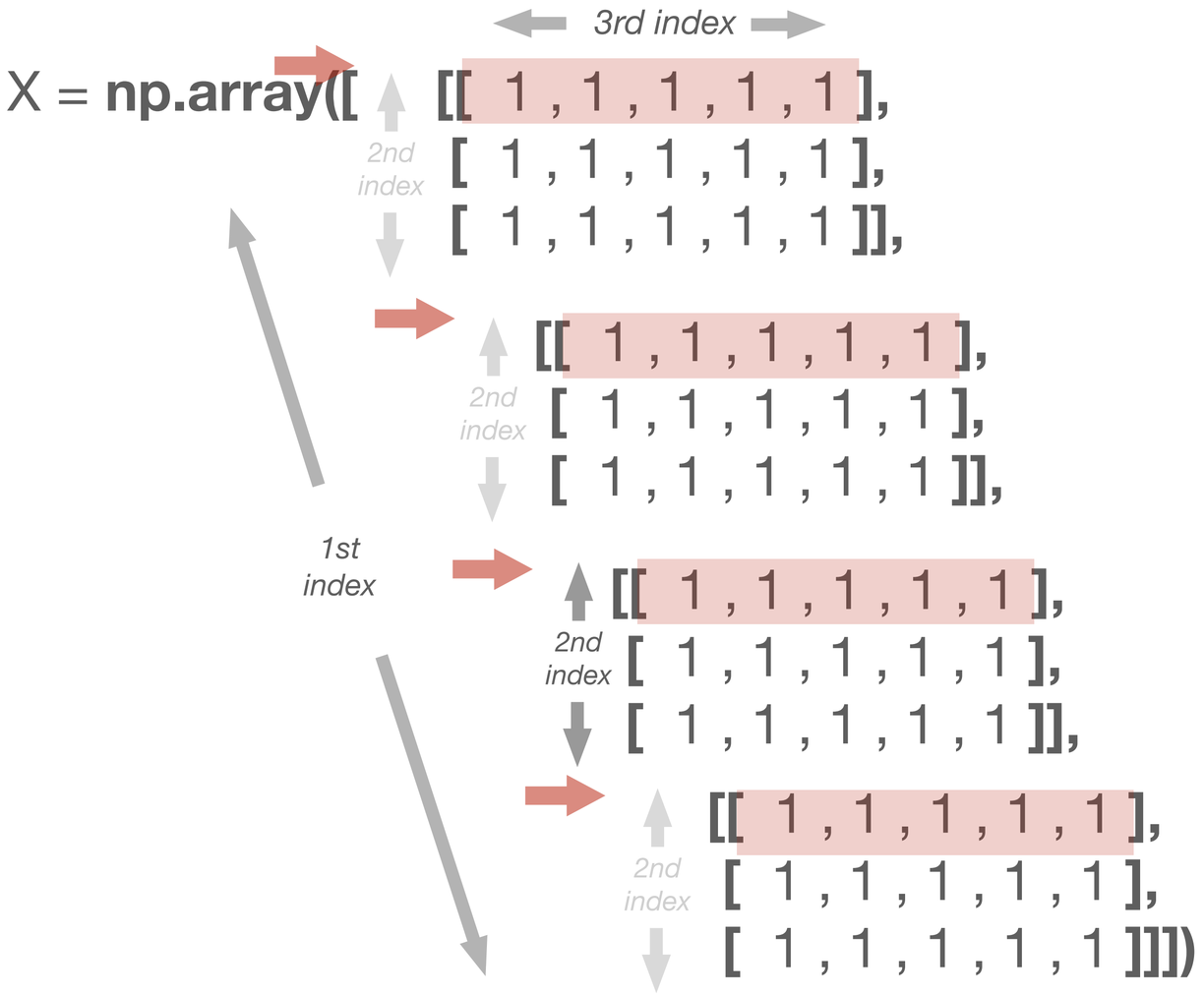
X[:,0]



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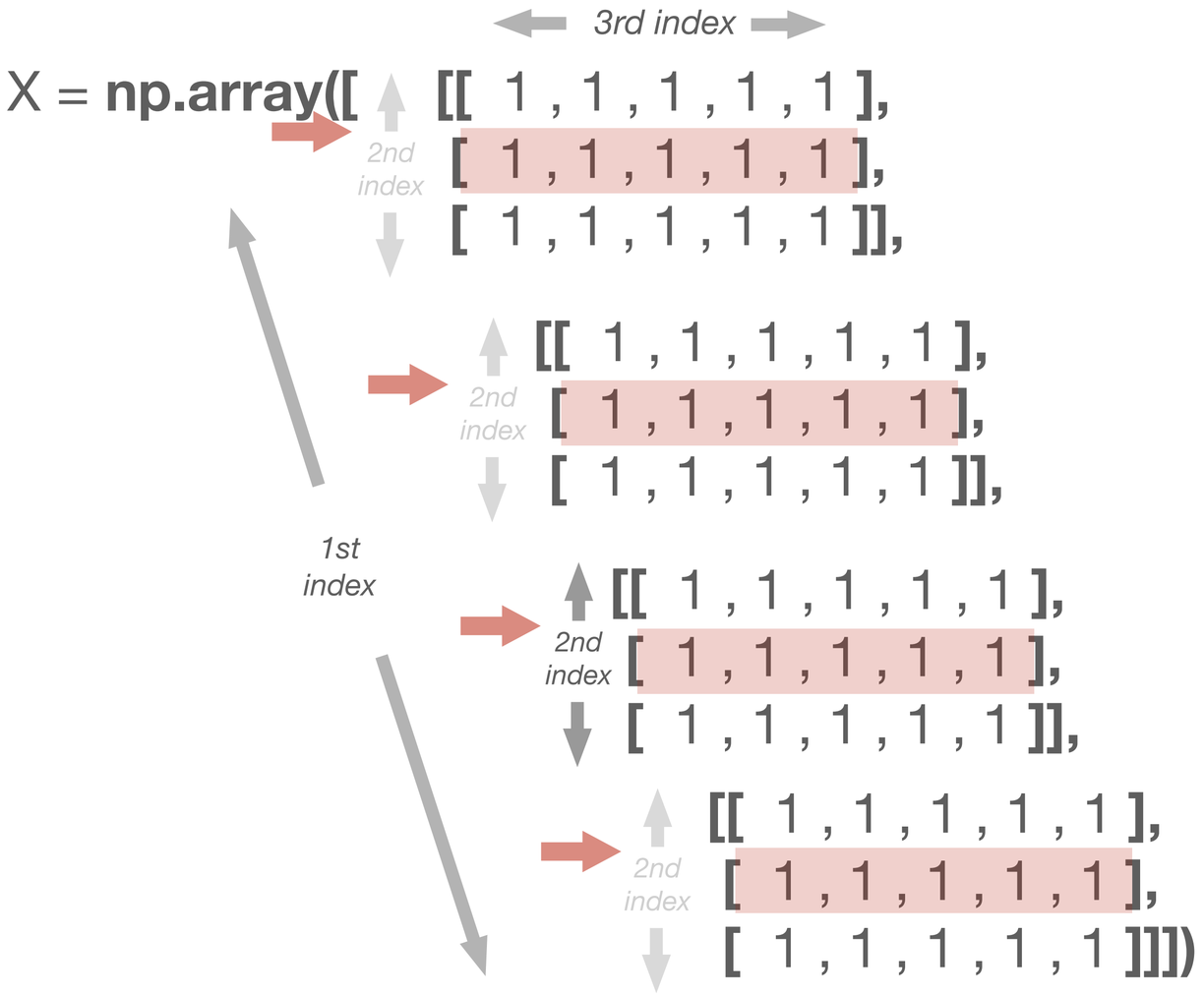

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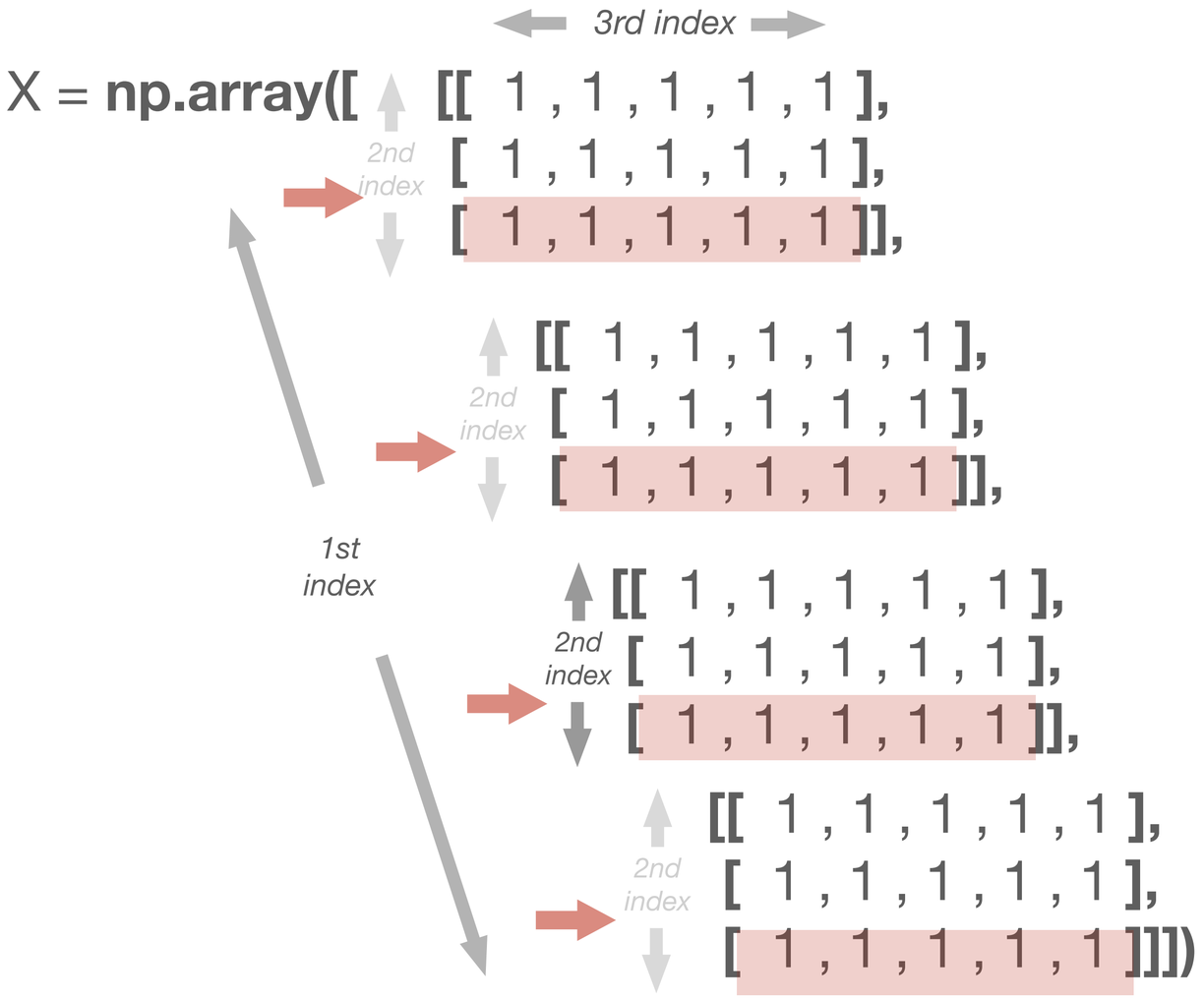

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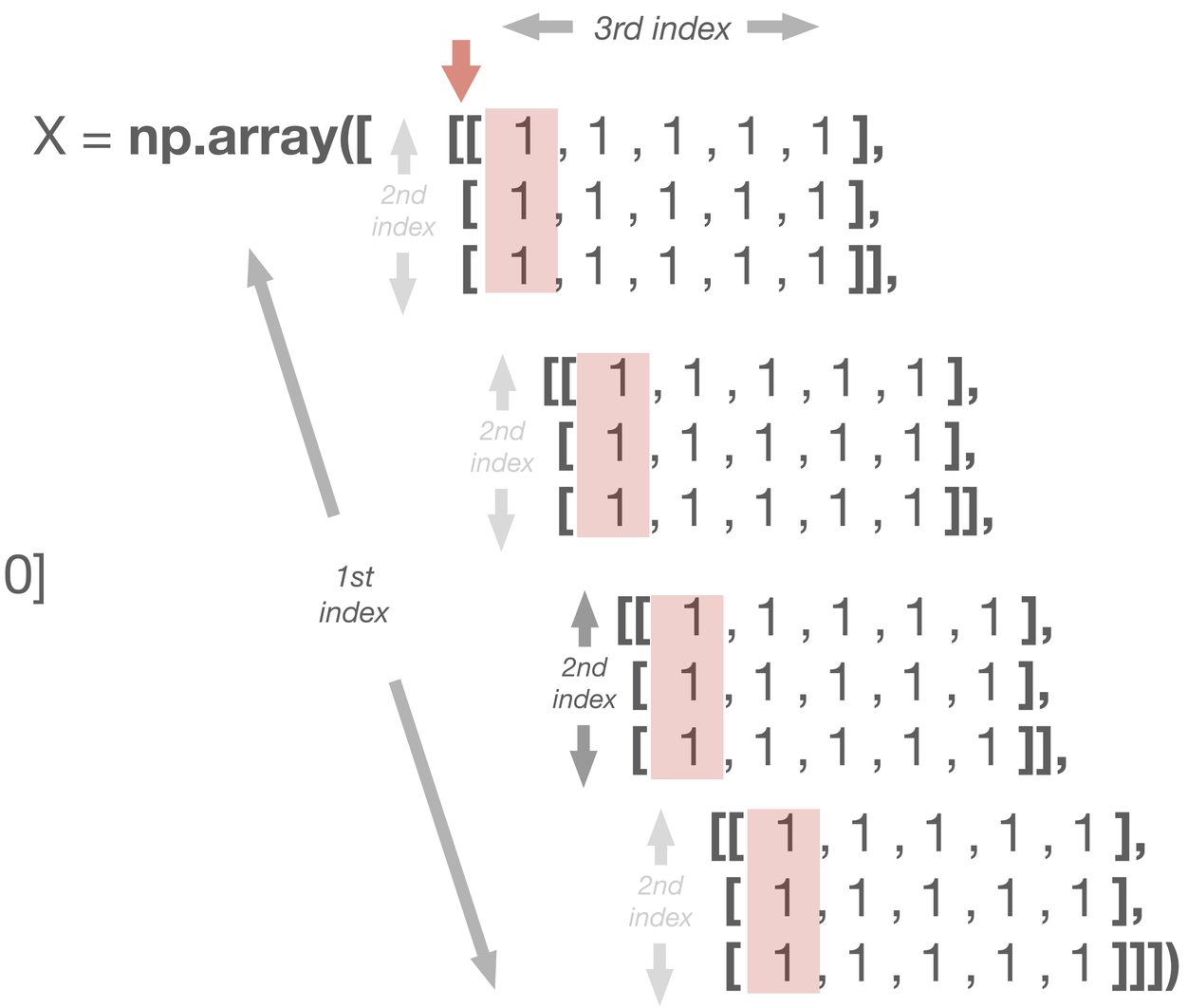

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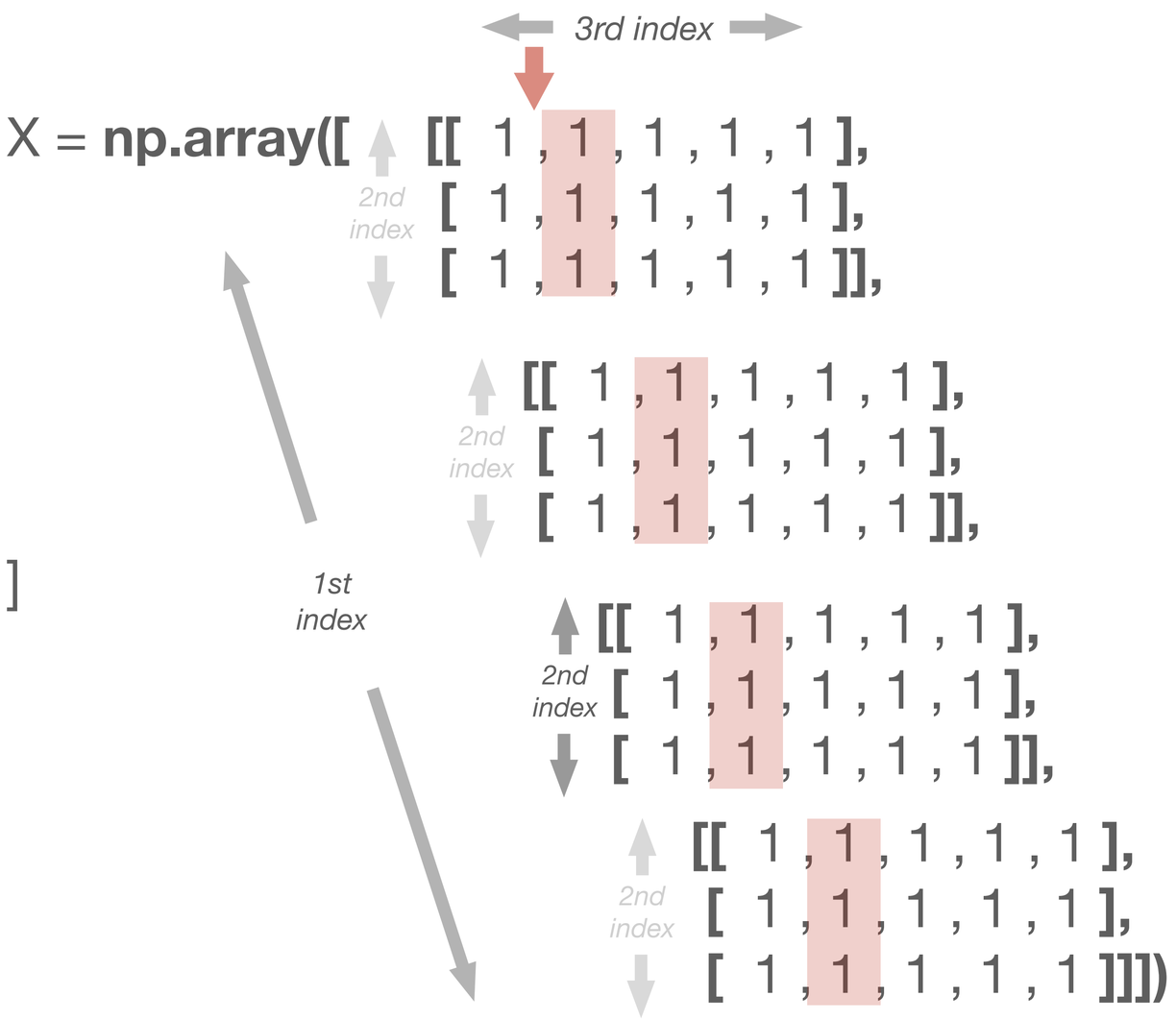

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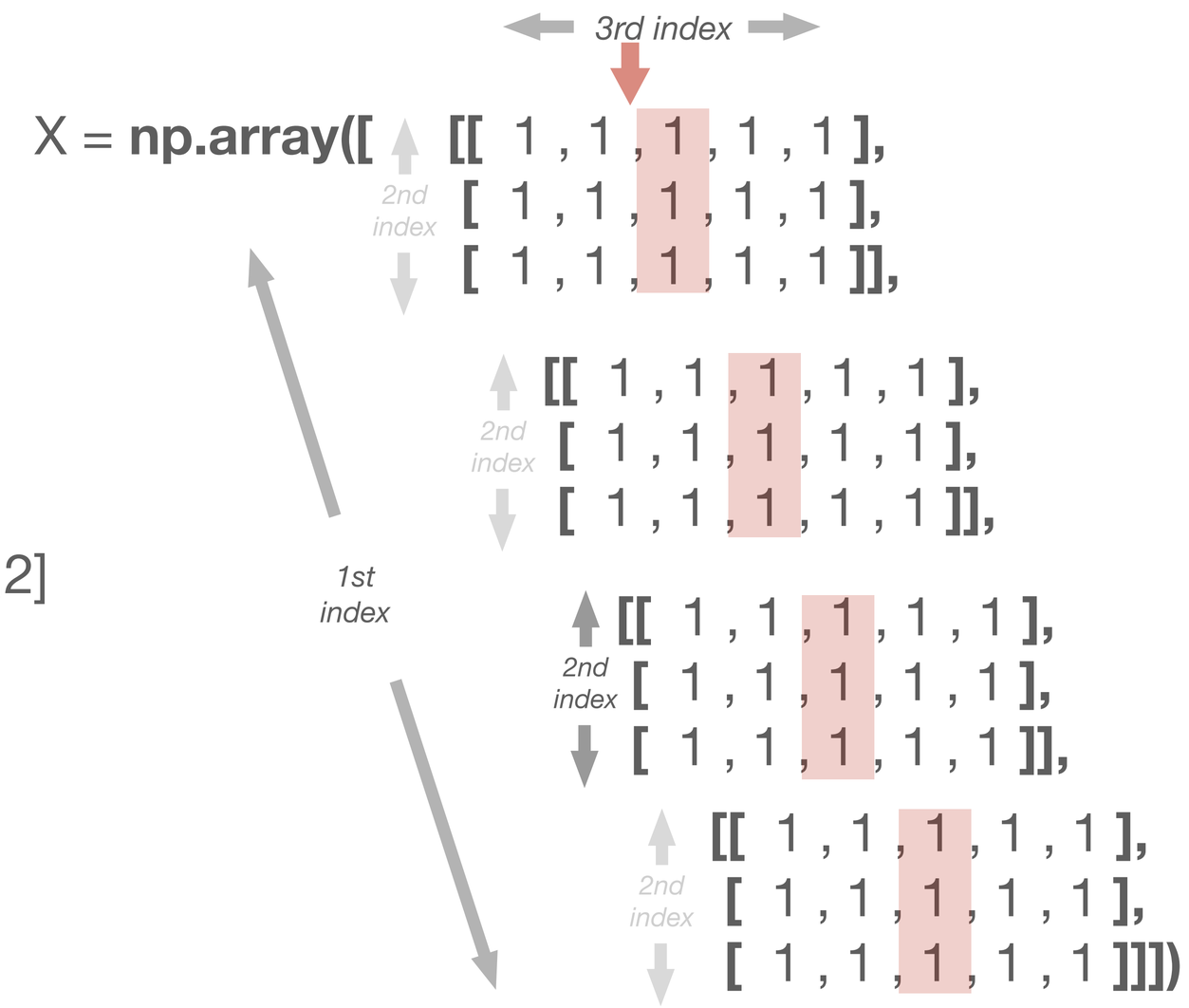

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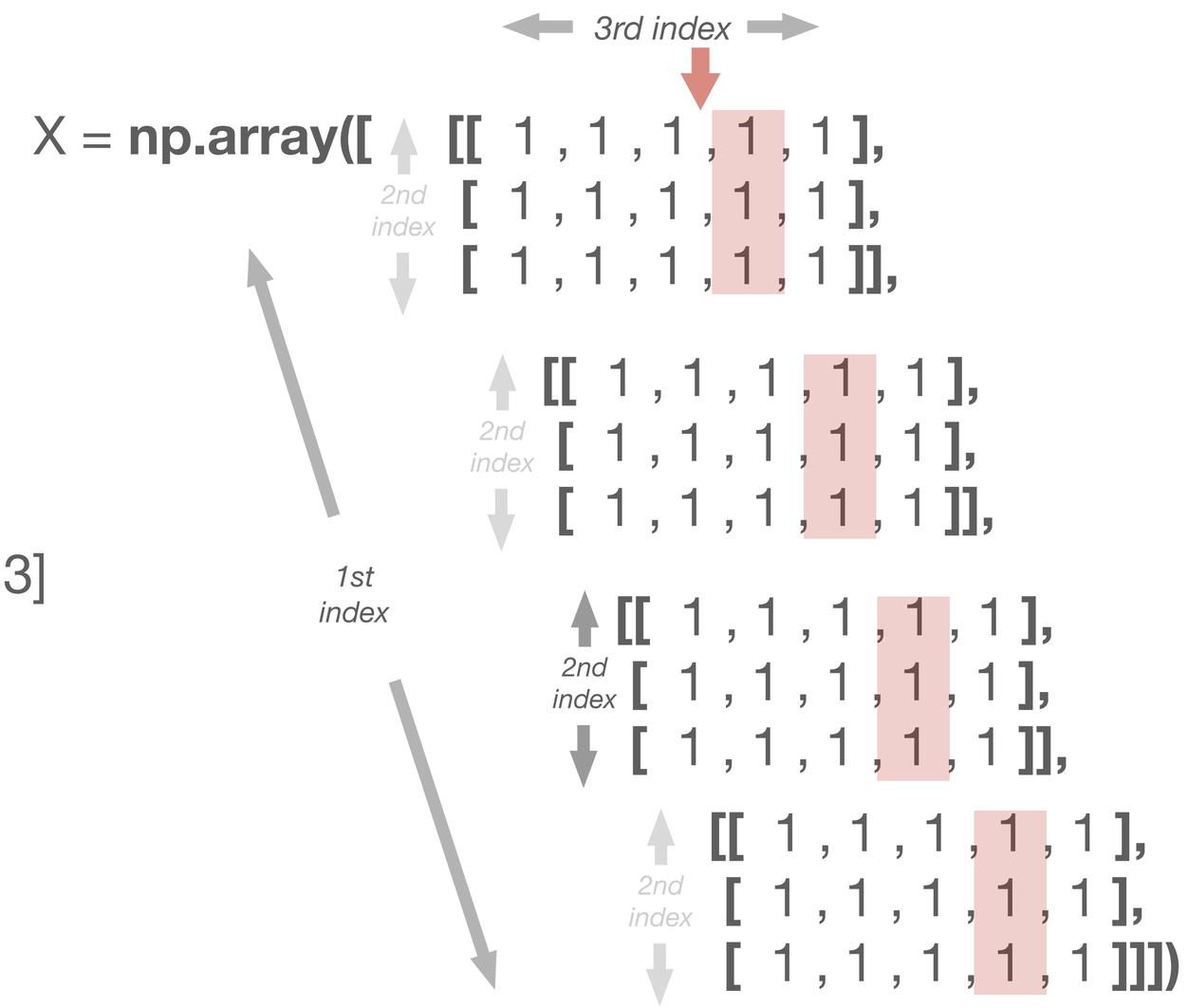

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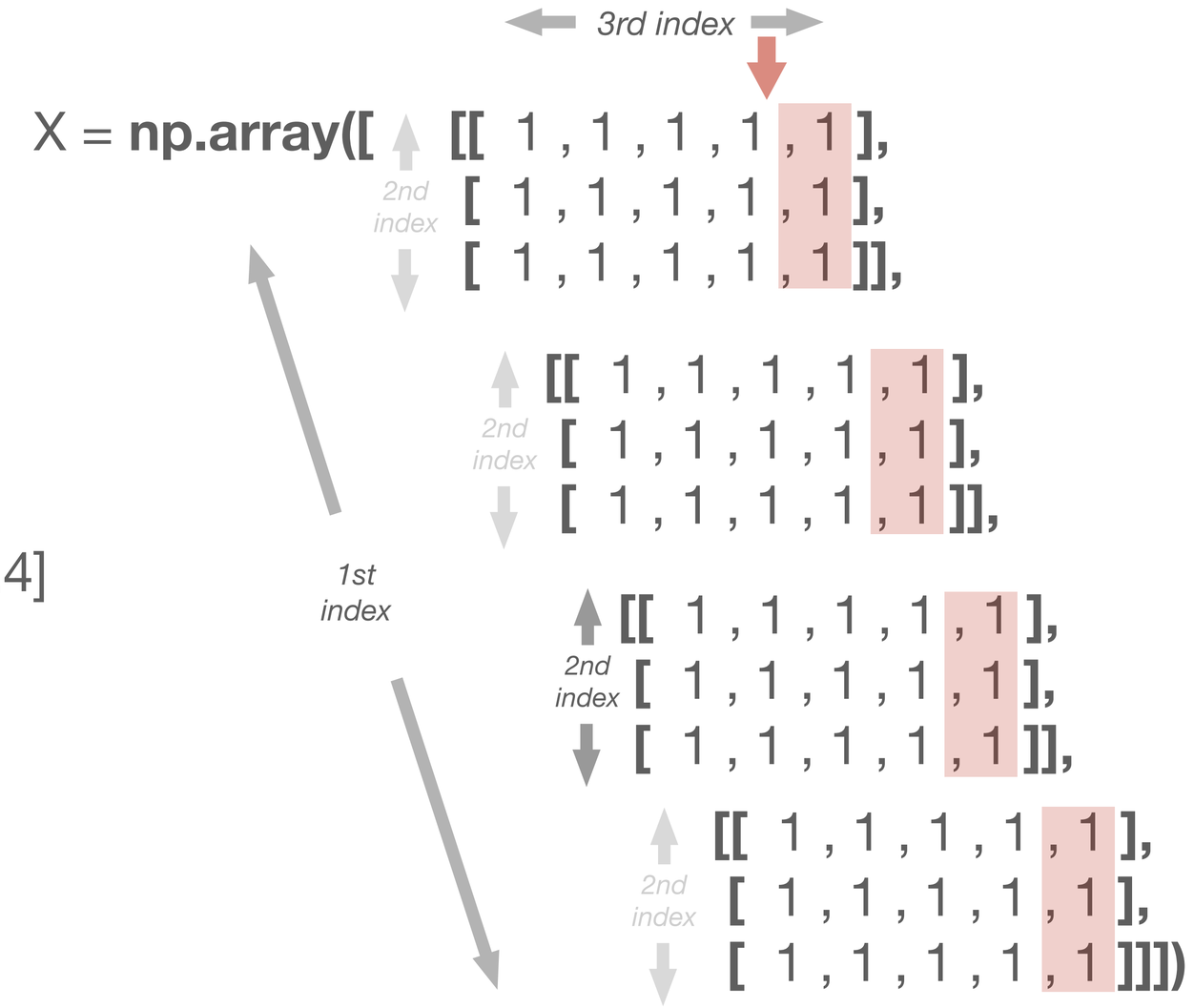

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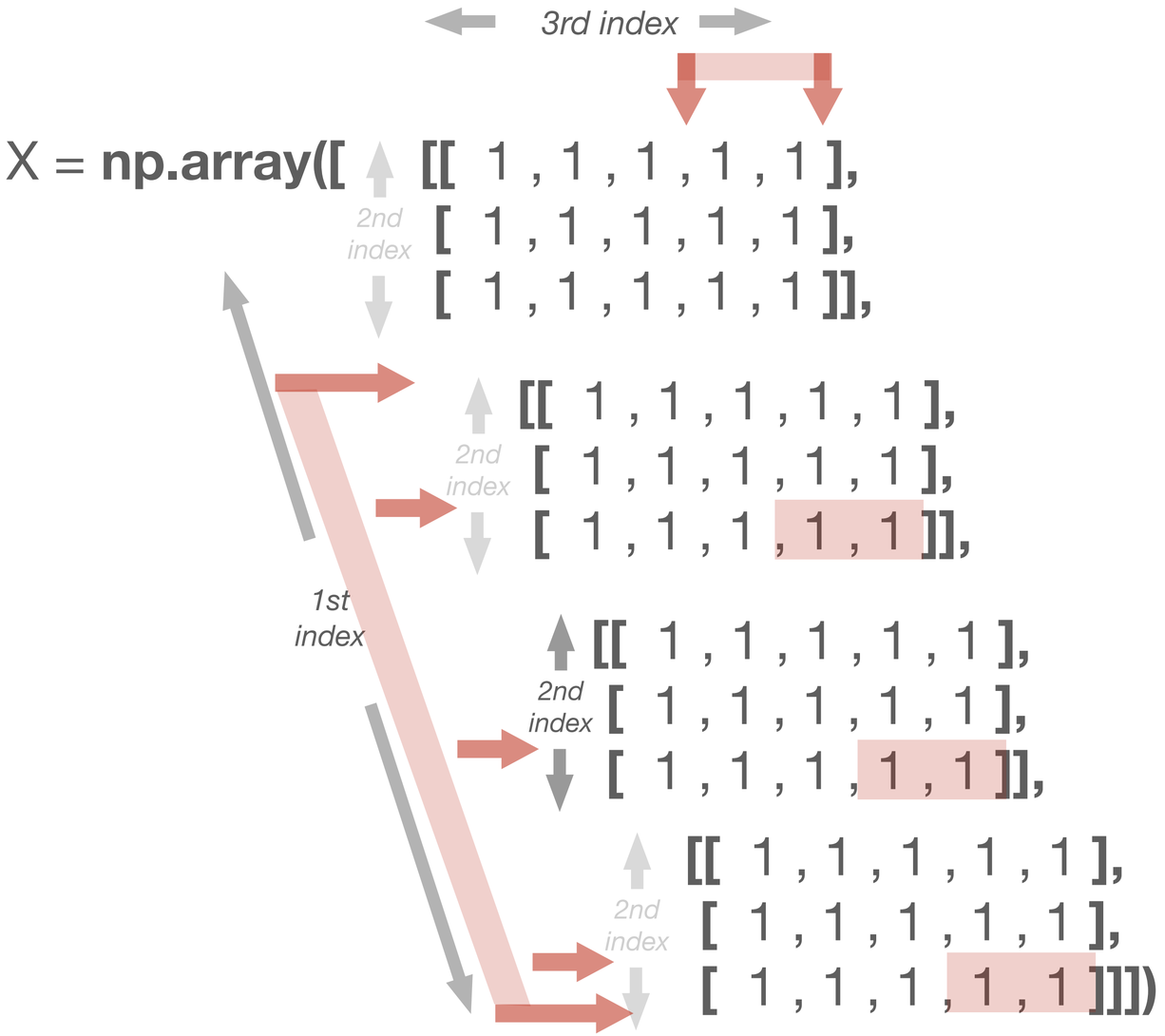

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negative indexing

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slicing **start : end : step**

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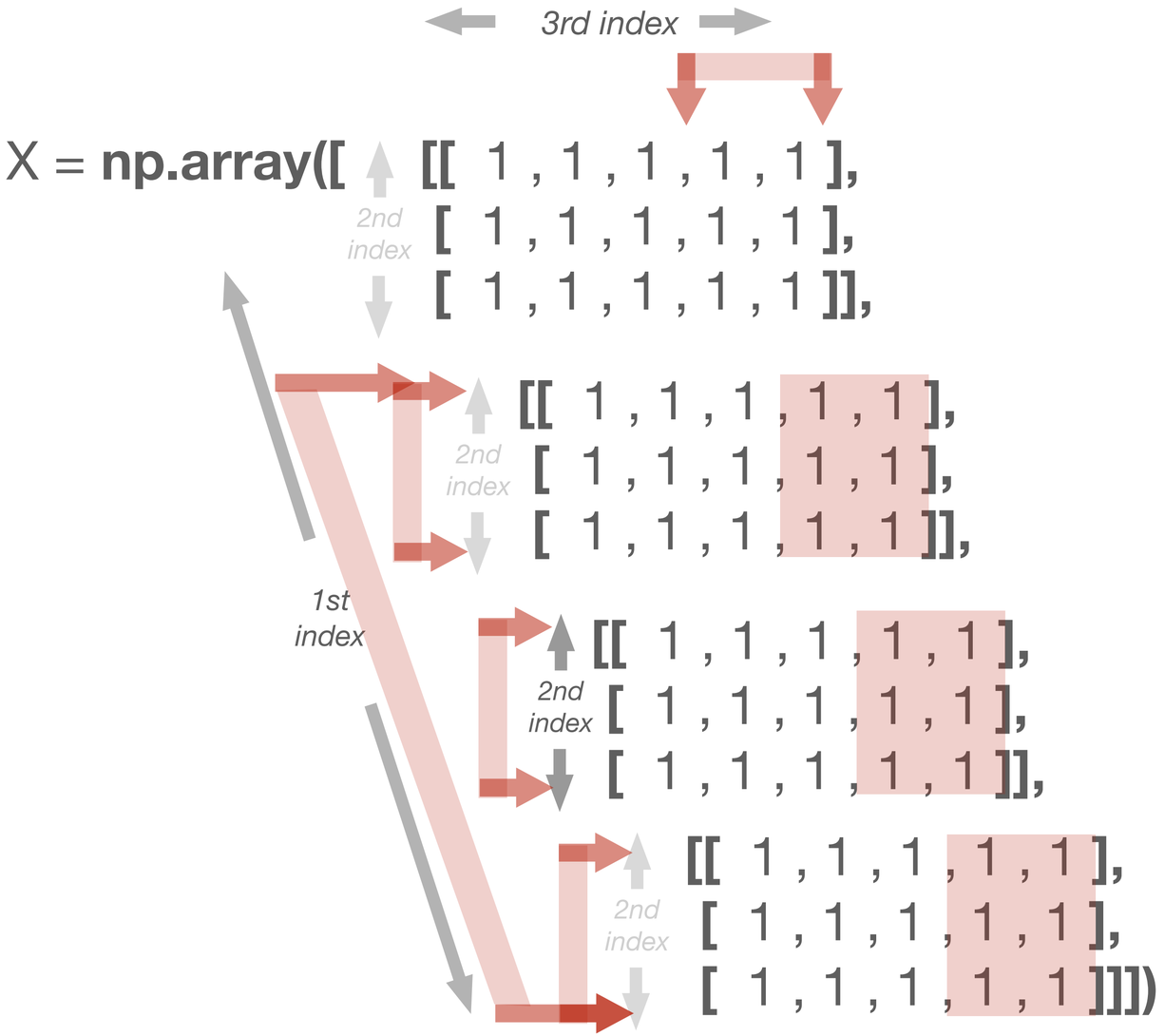

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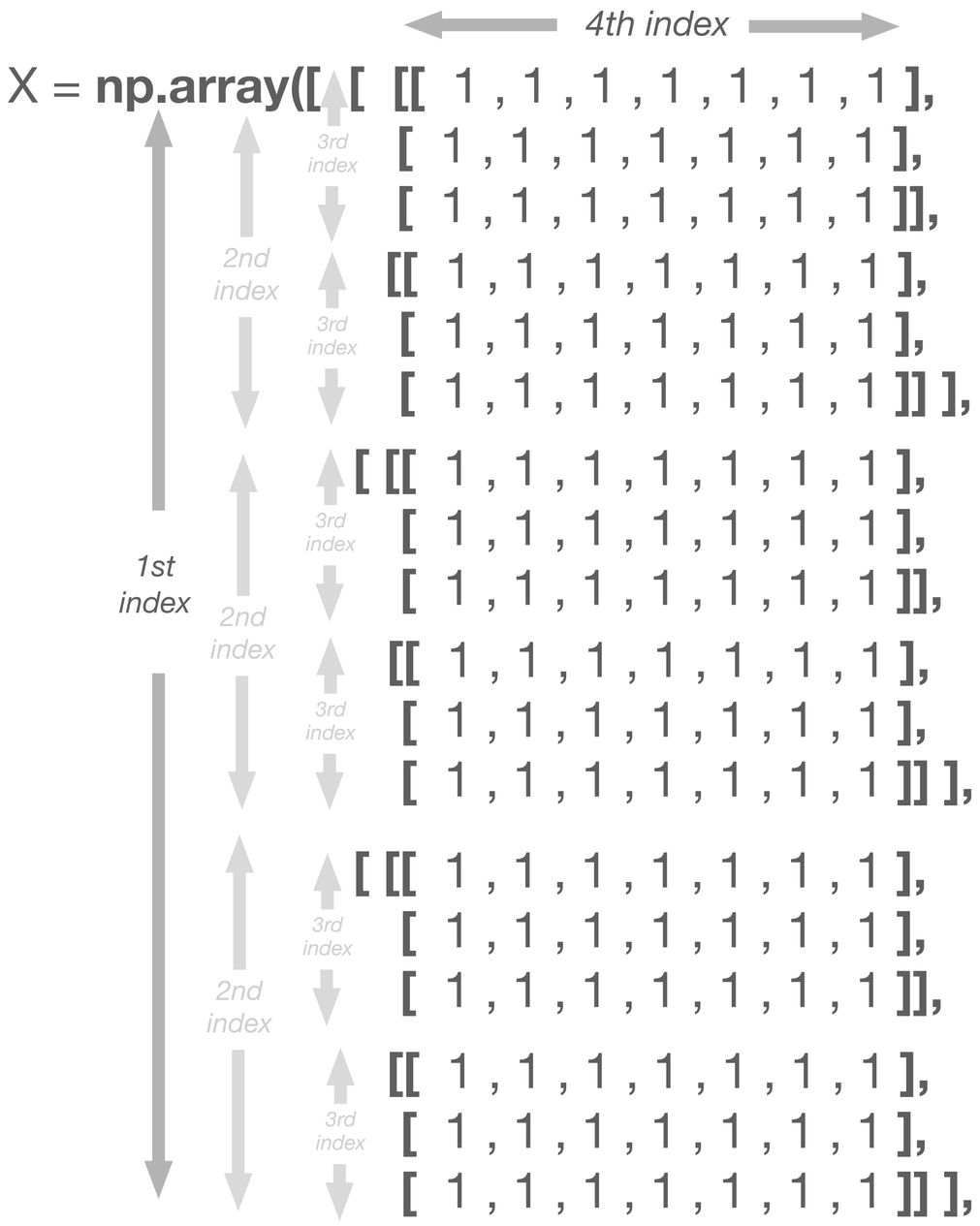

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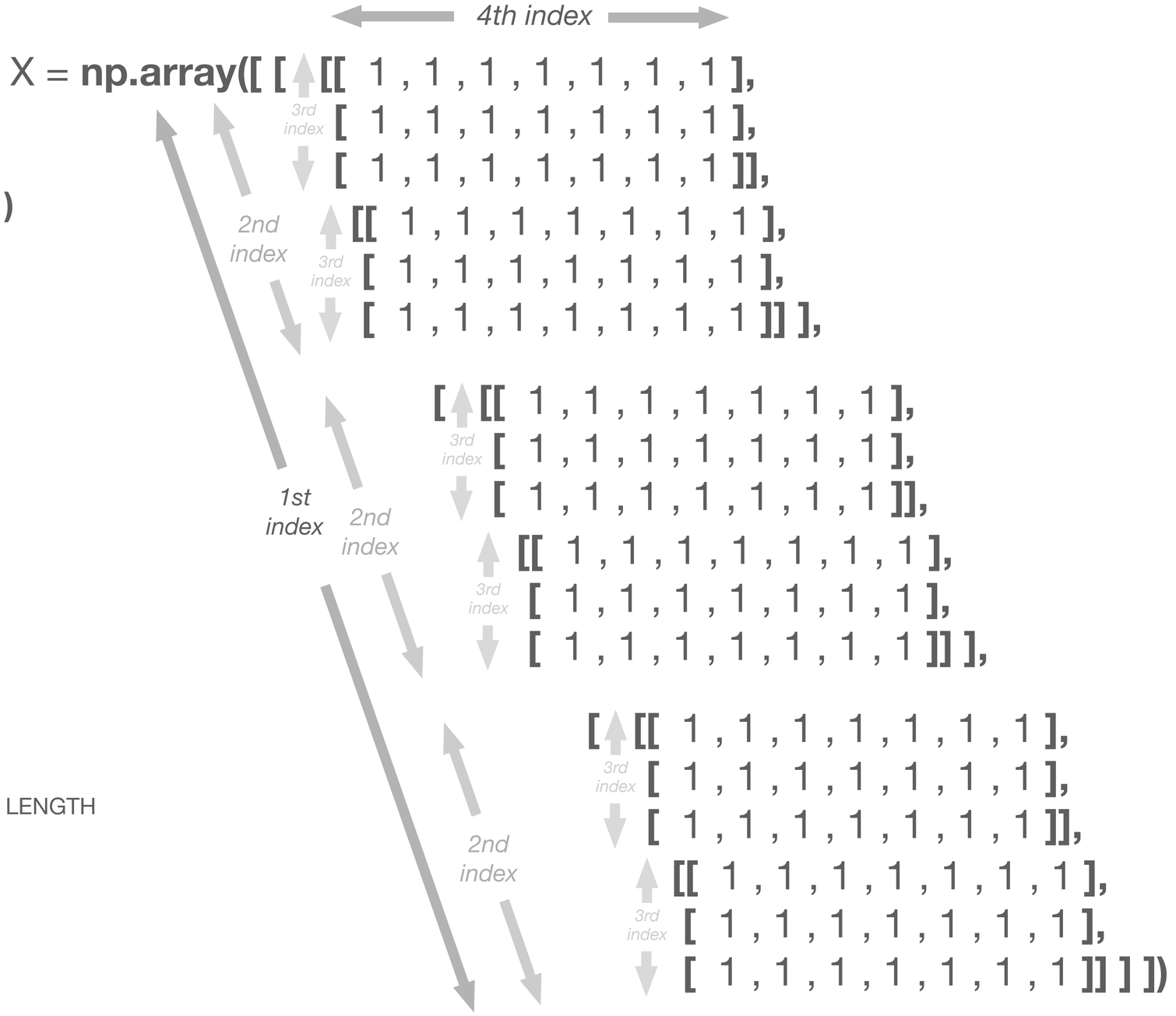

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X[0]

array indexing

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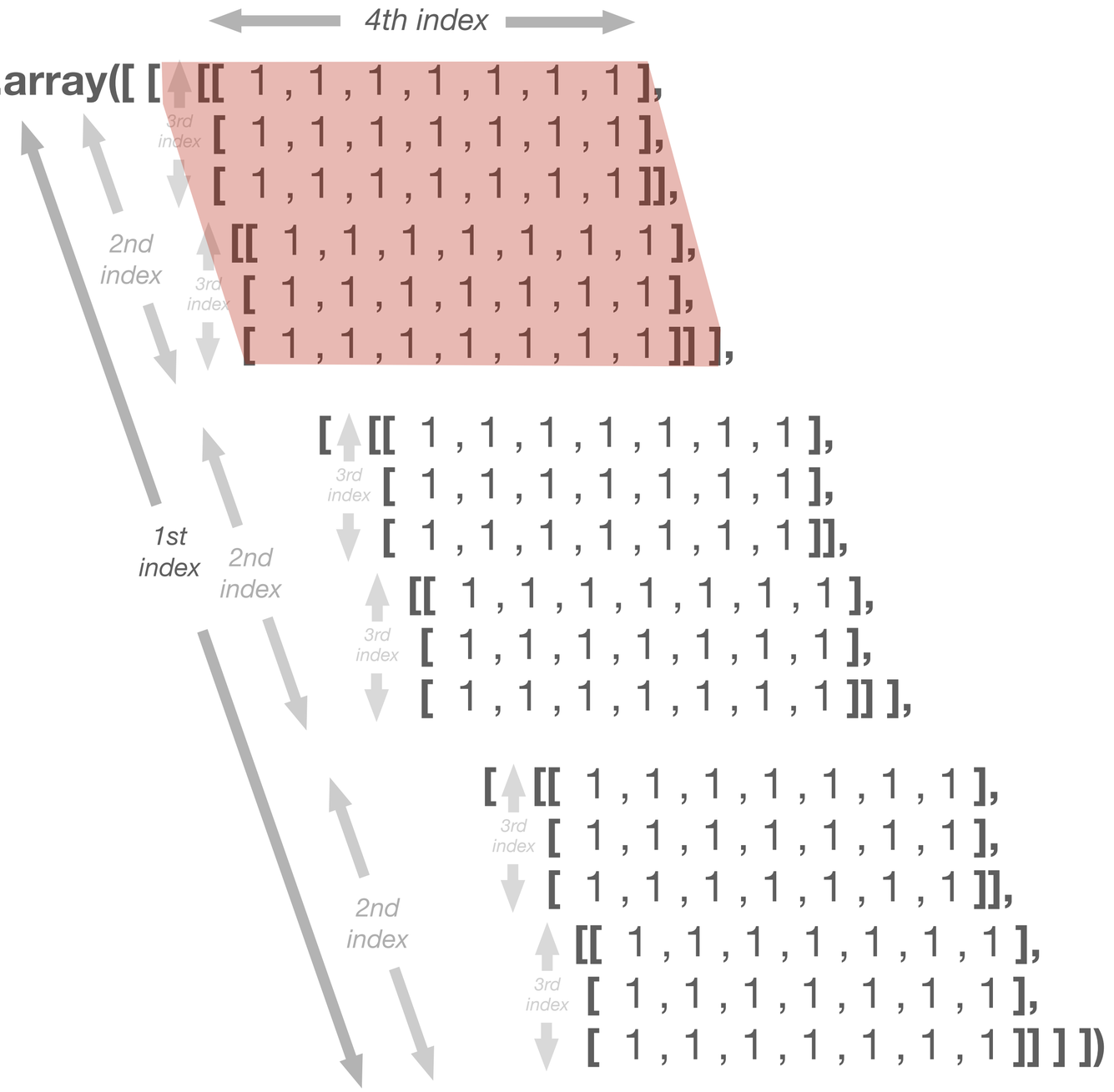

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X[1]

array indexing

ind = [0, 2, 3];
x[ind] - returns 0,2, and 3 elements

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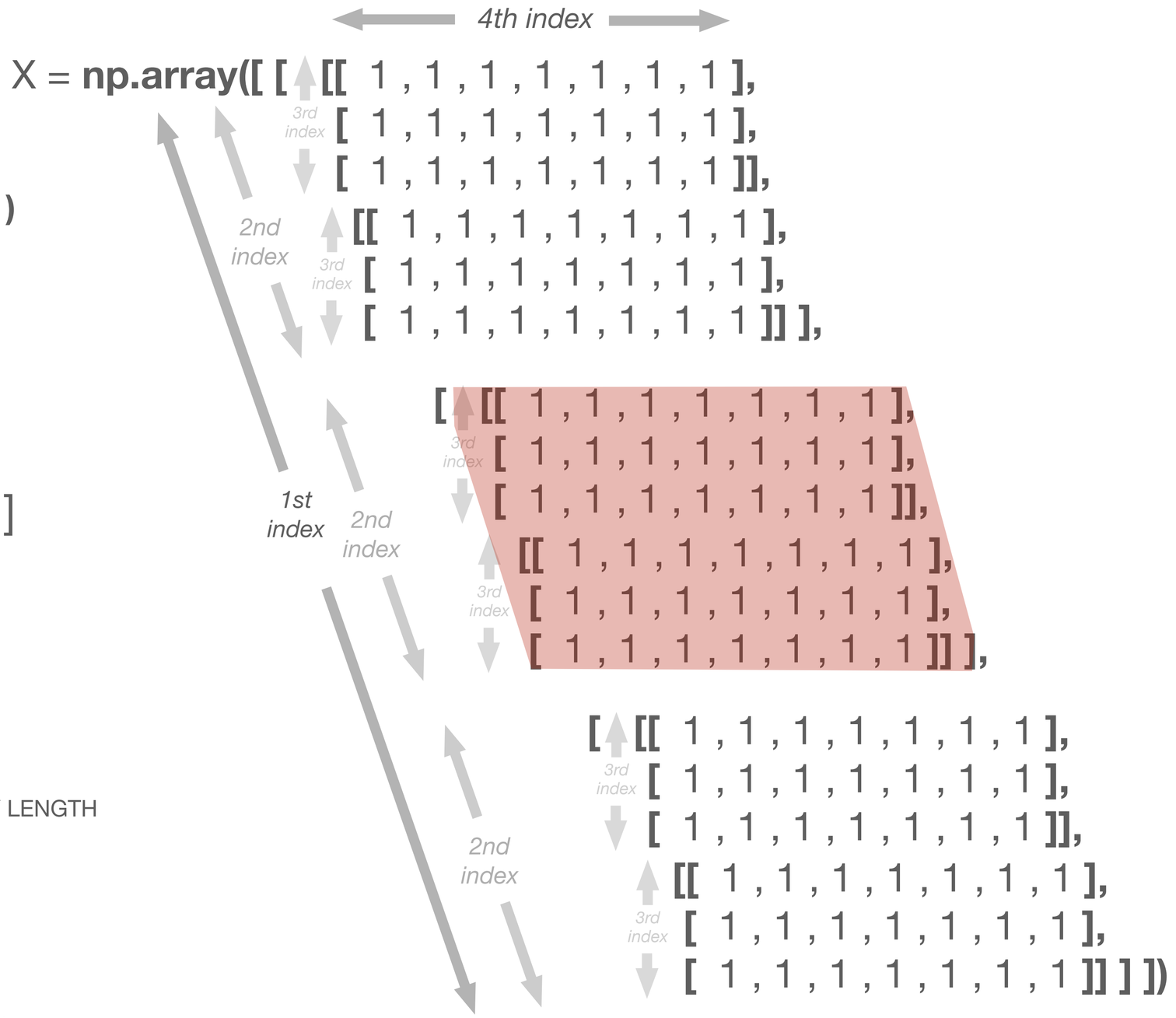

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slicing **start : end : step**

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X[2]

array indexing

ind = [0, 2, 3];
x[ind] - returns 0,2, and 3 elements

ind1 = [0, 2, 3]; ind2 = [0,3,2];
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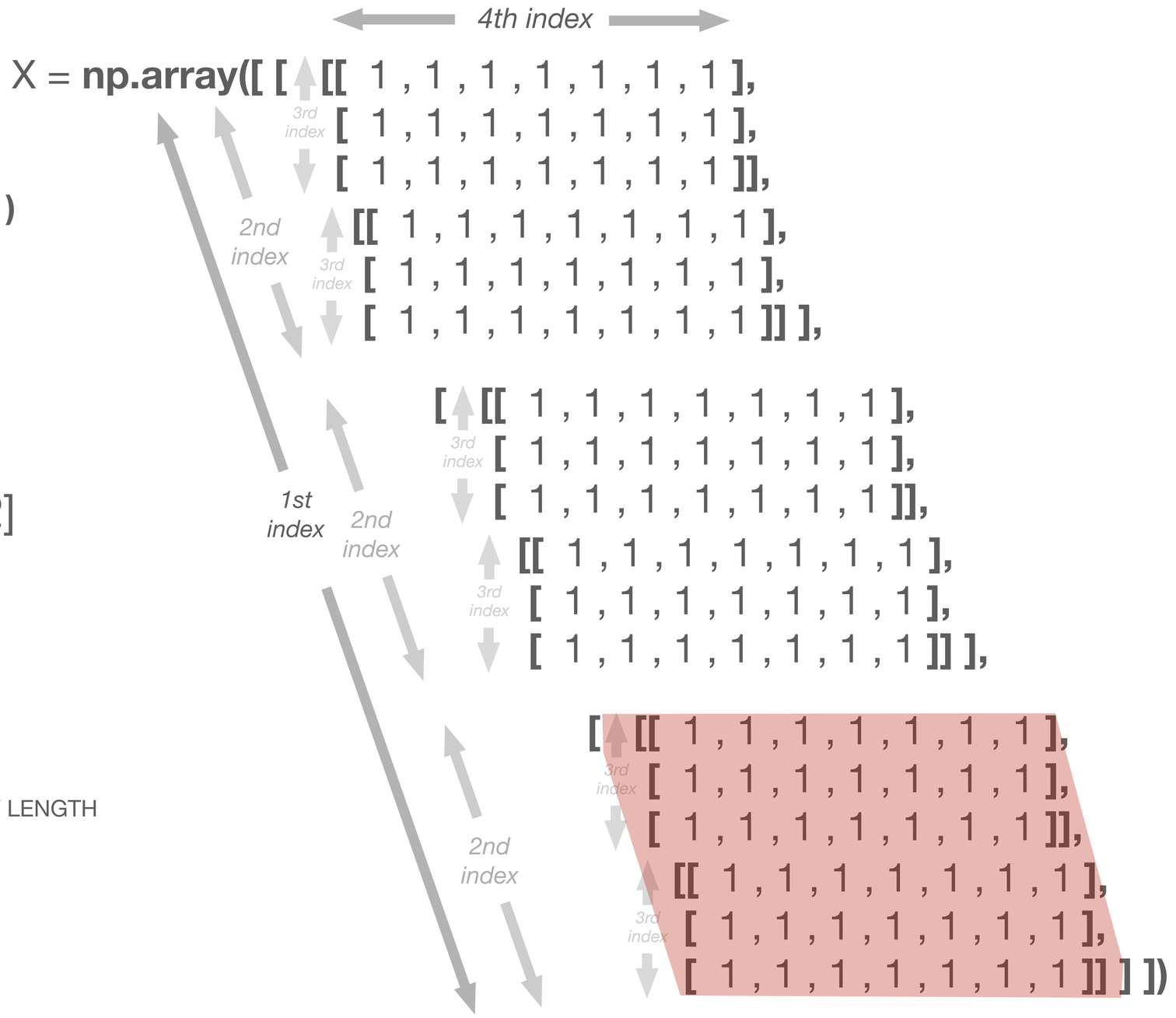

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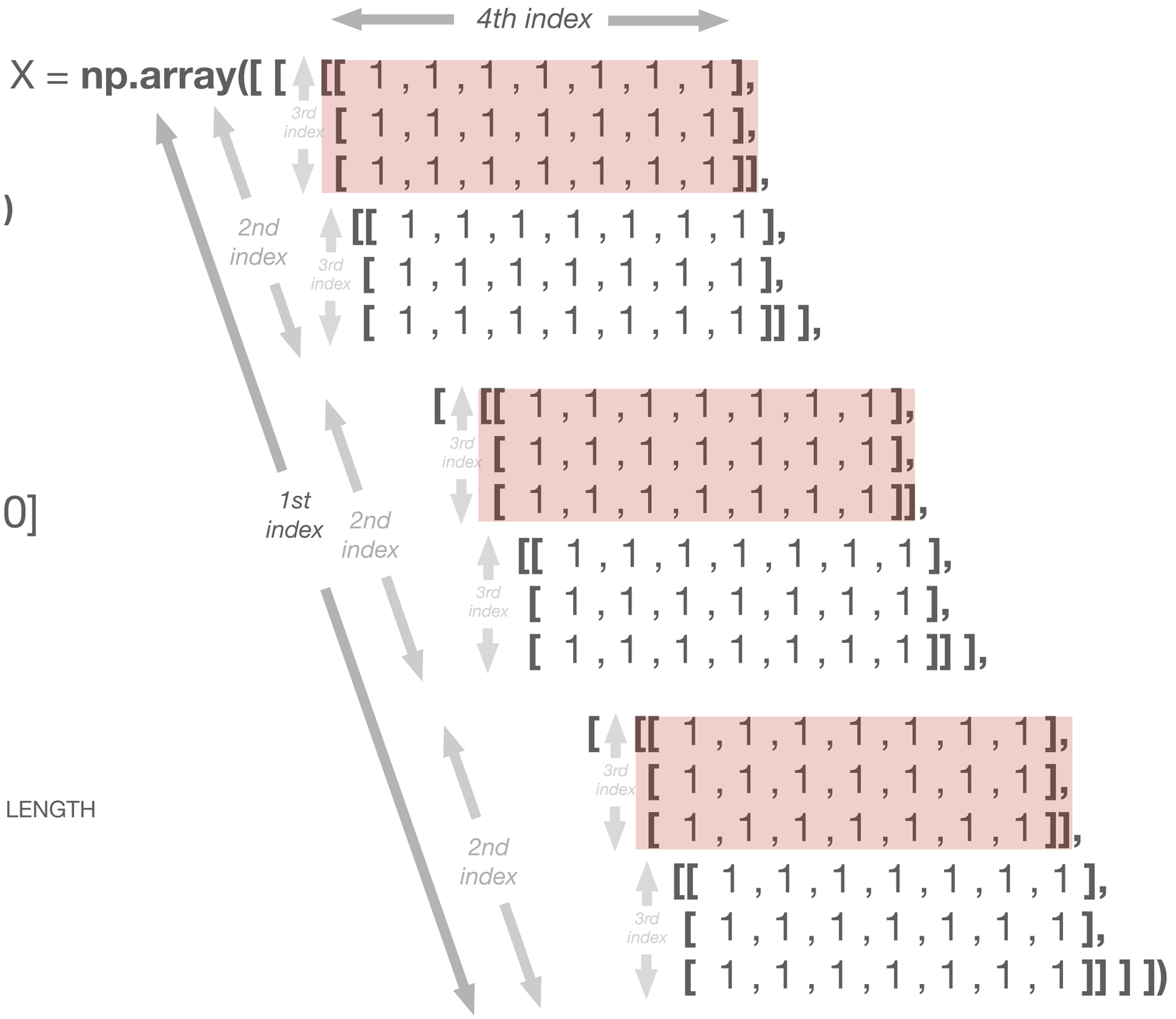

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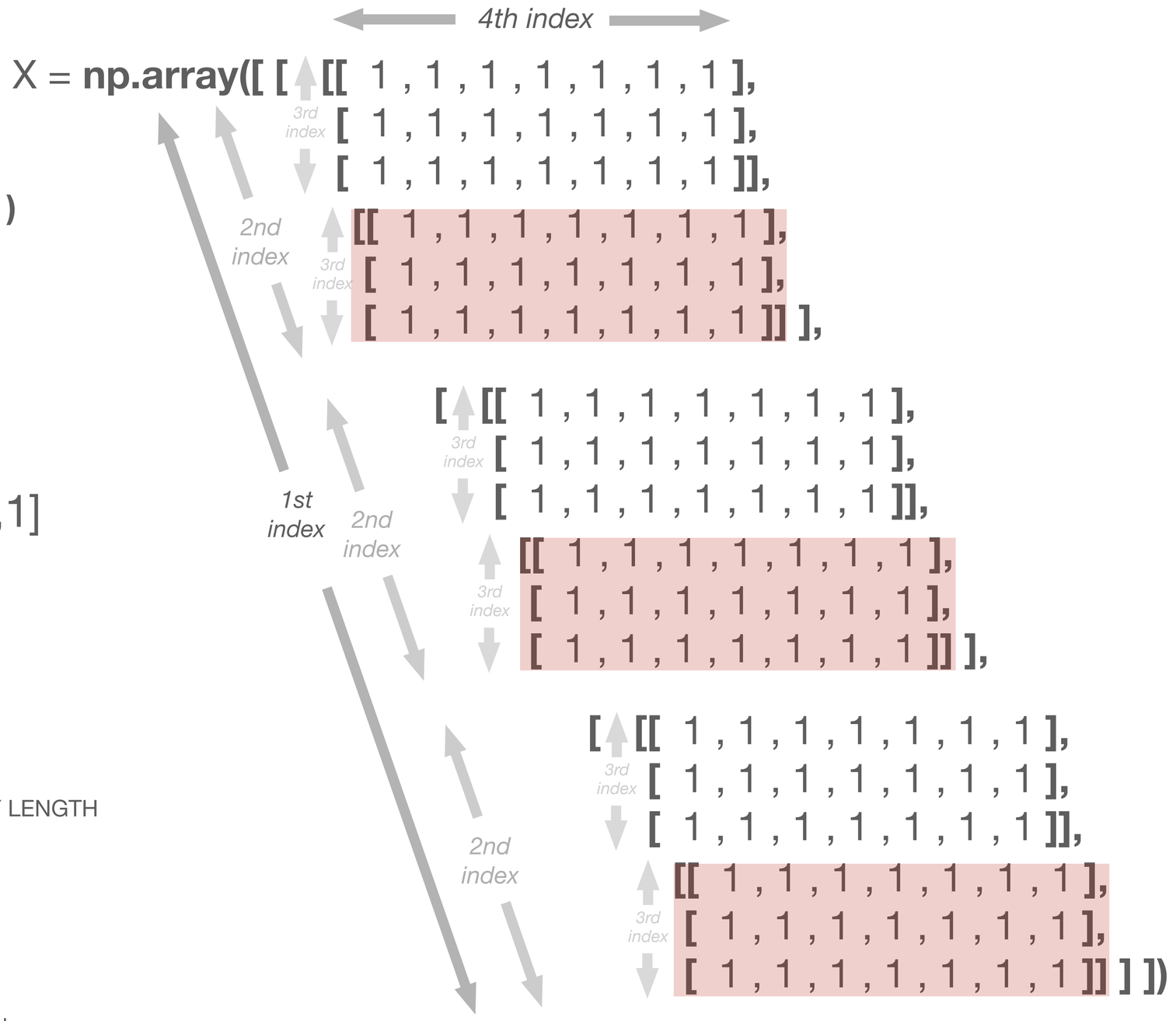

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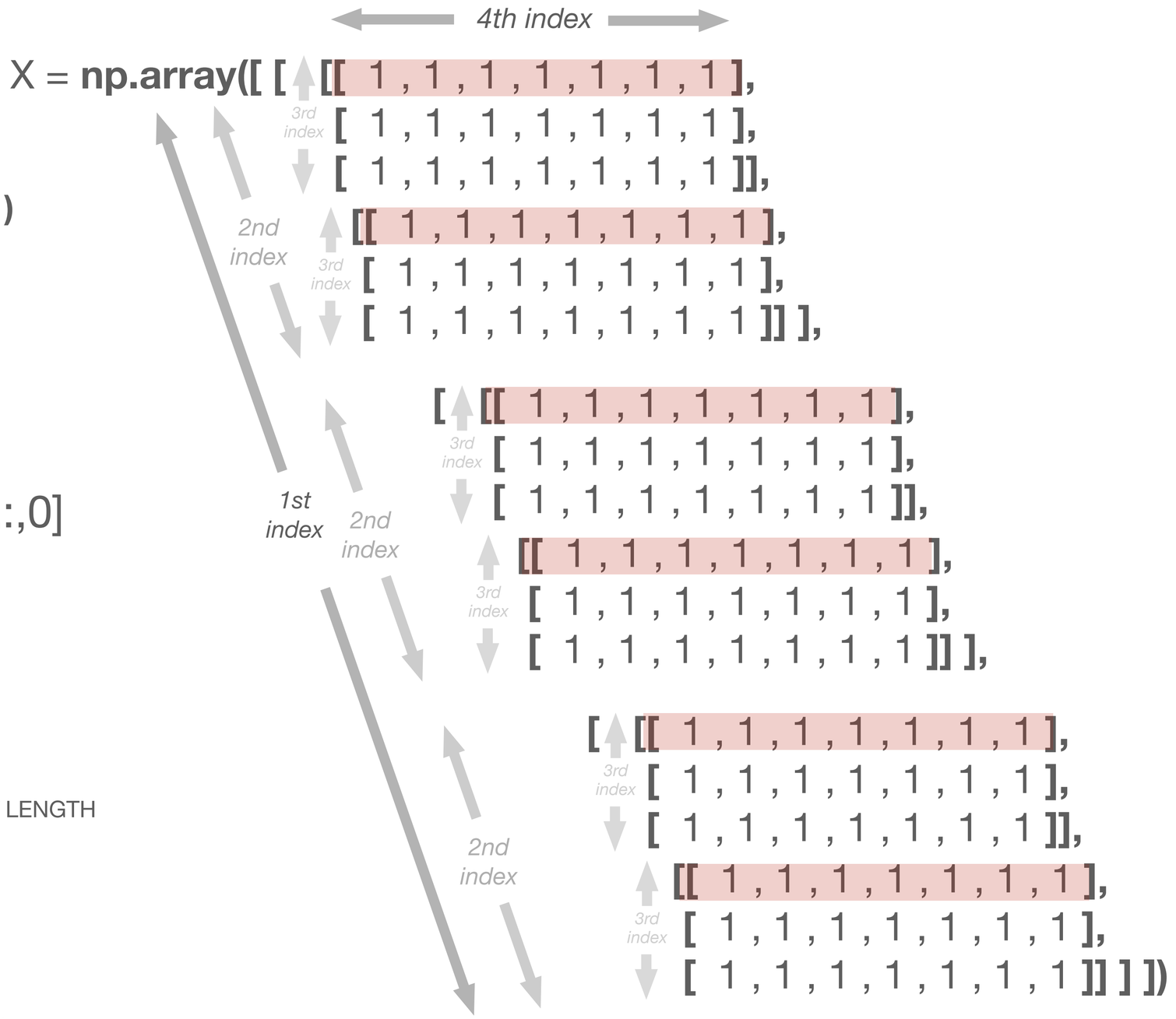

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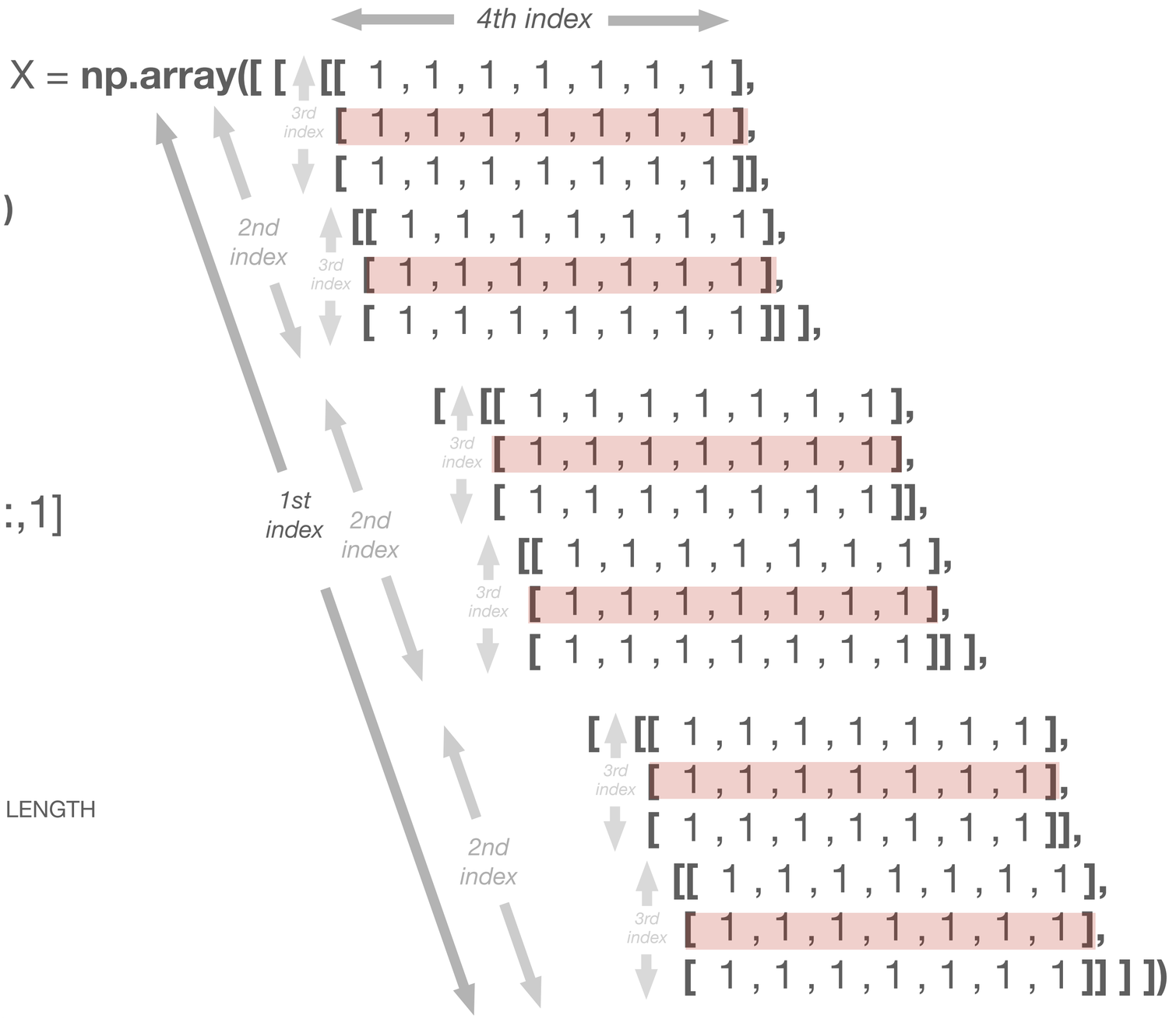

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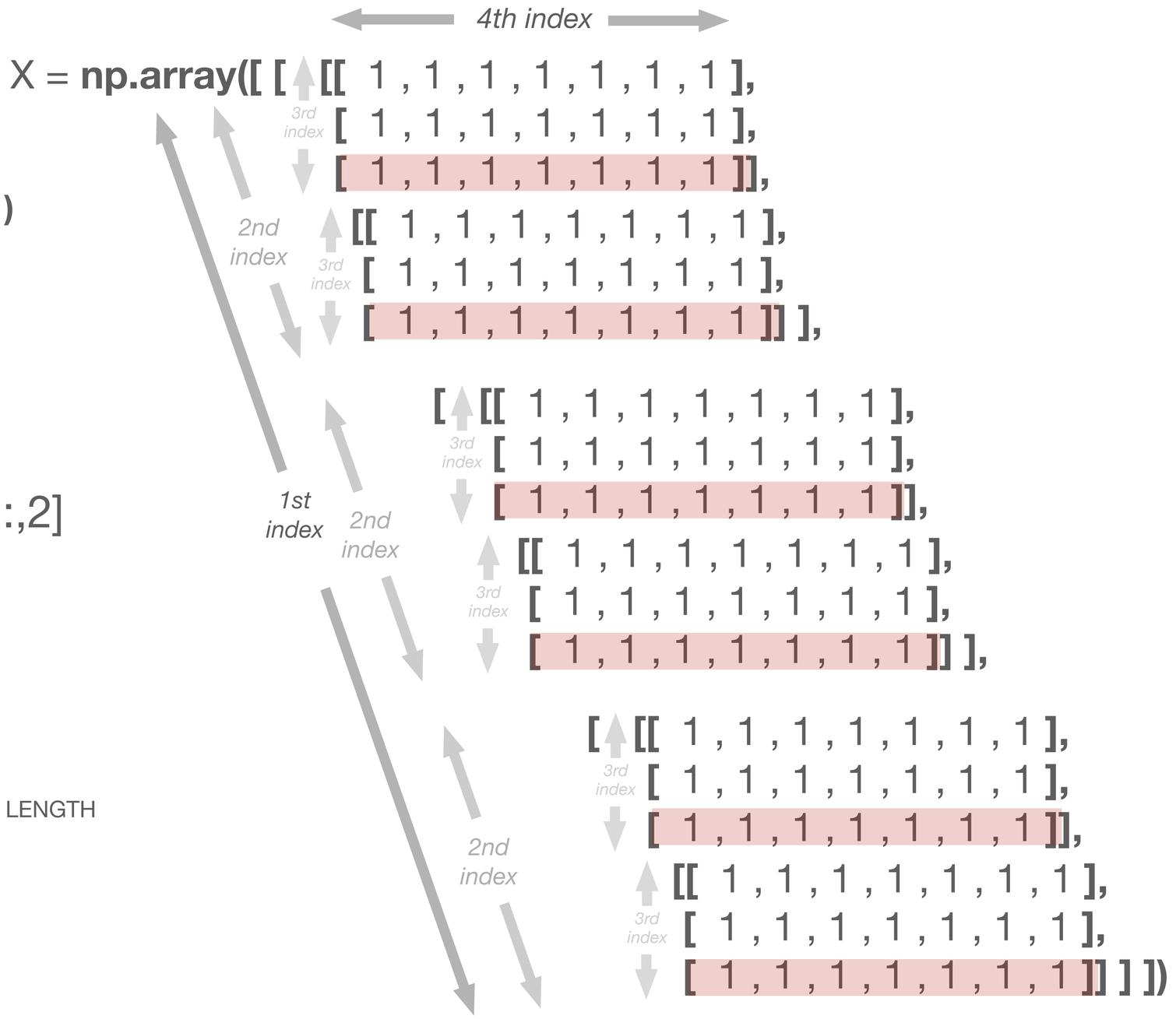

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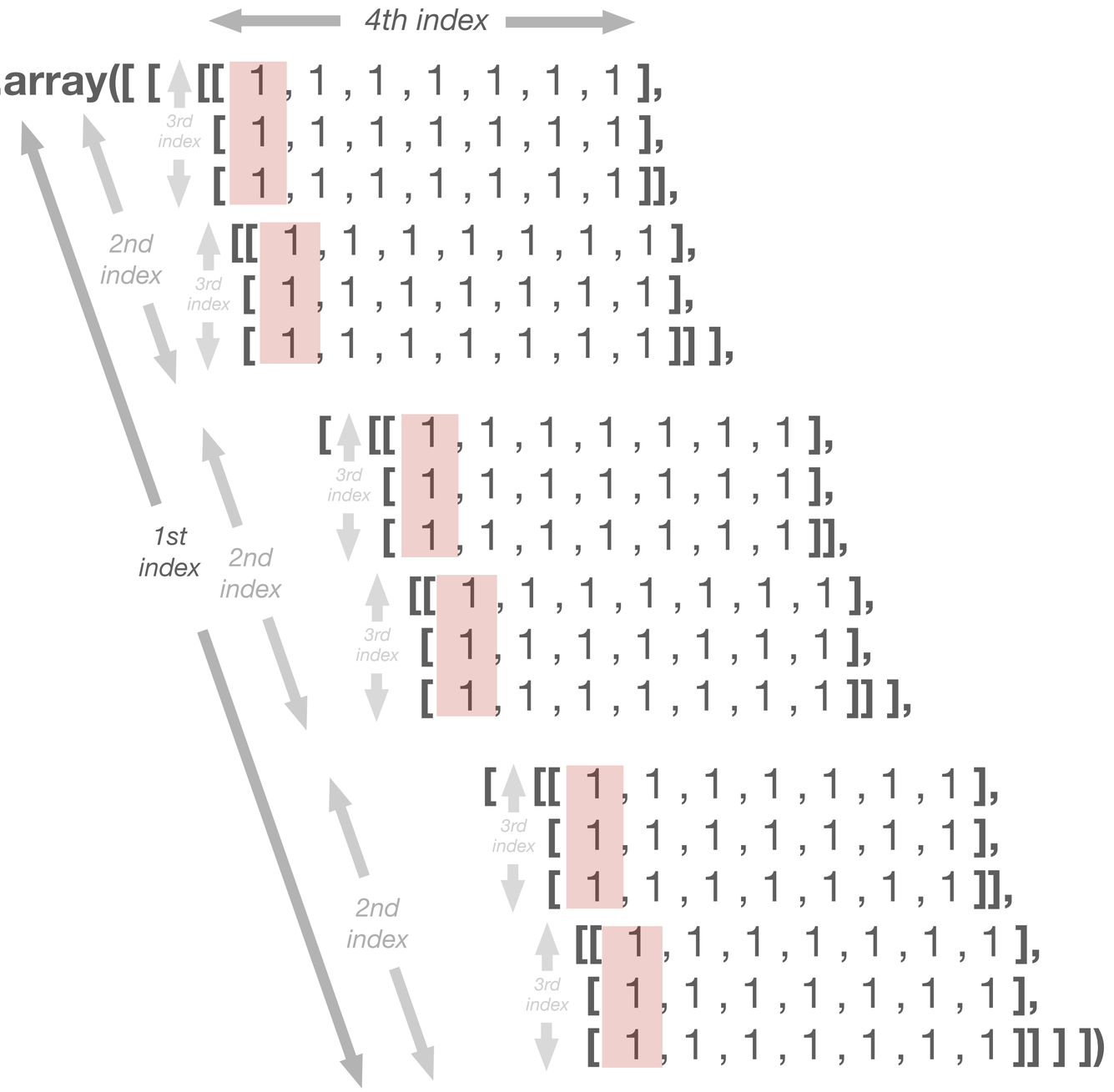

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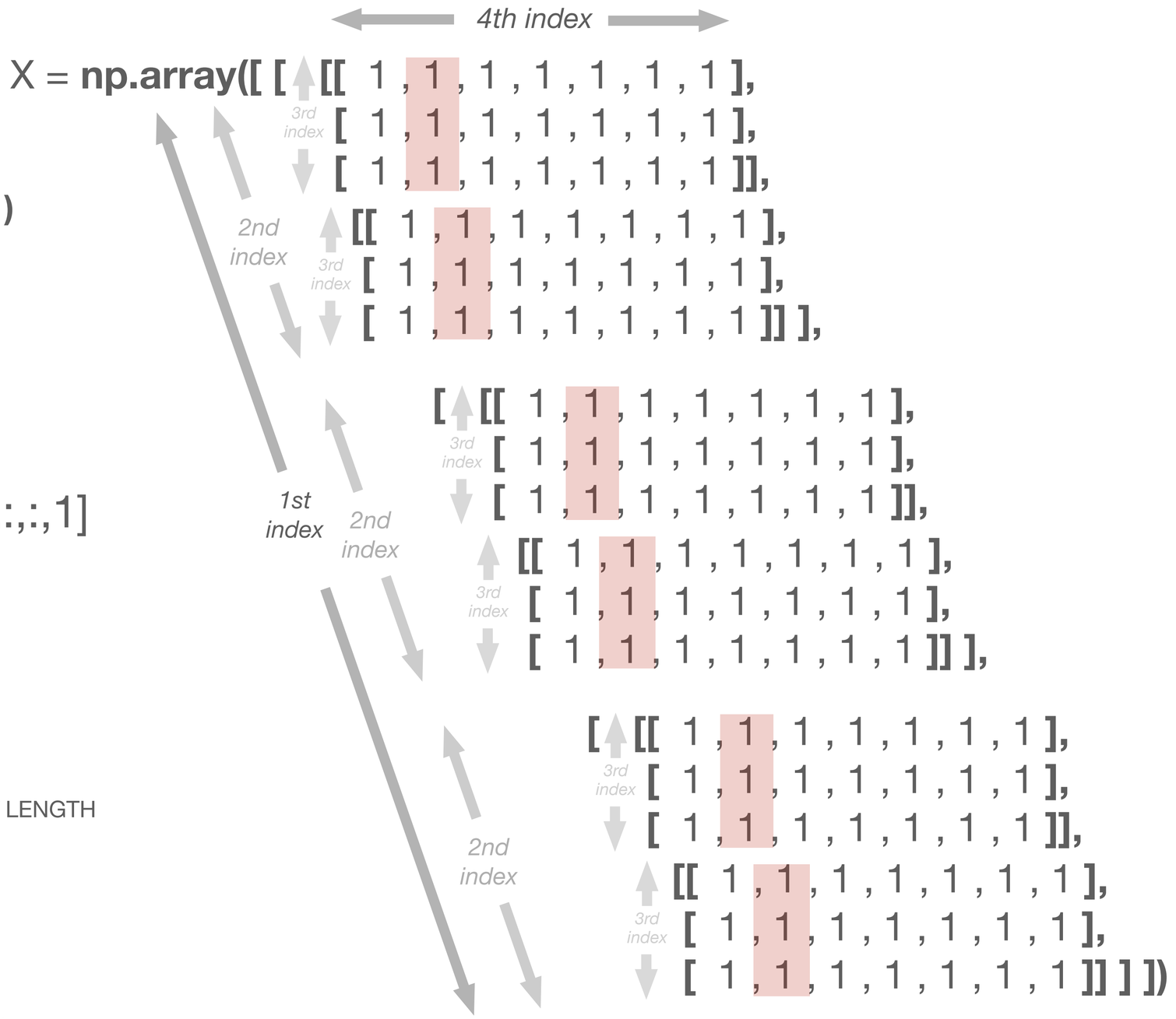

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X[:,:,:,2]

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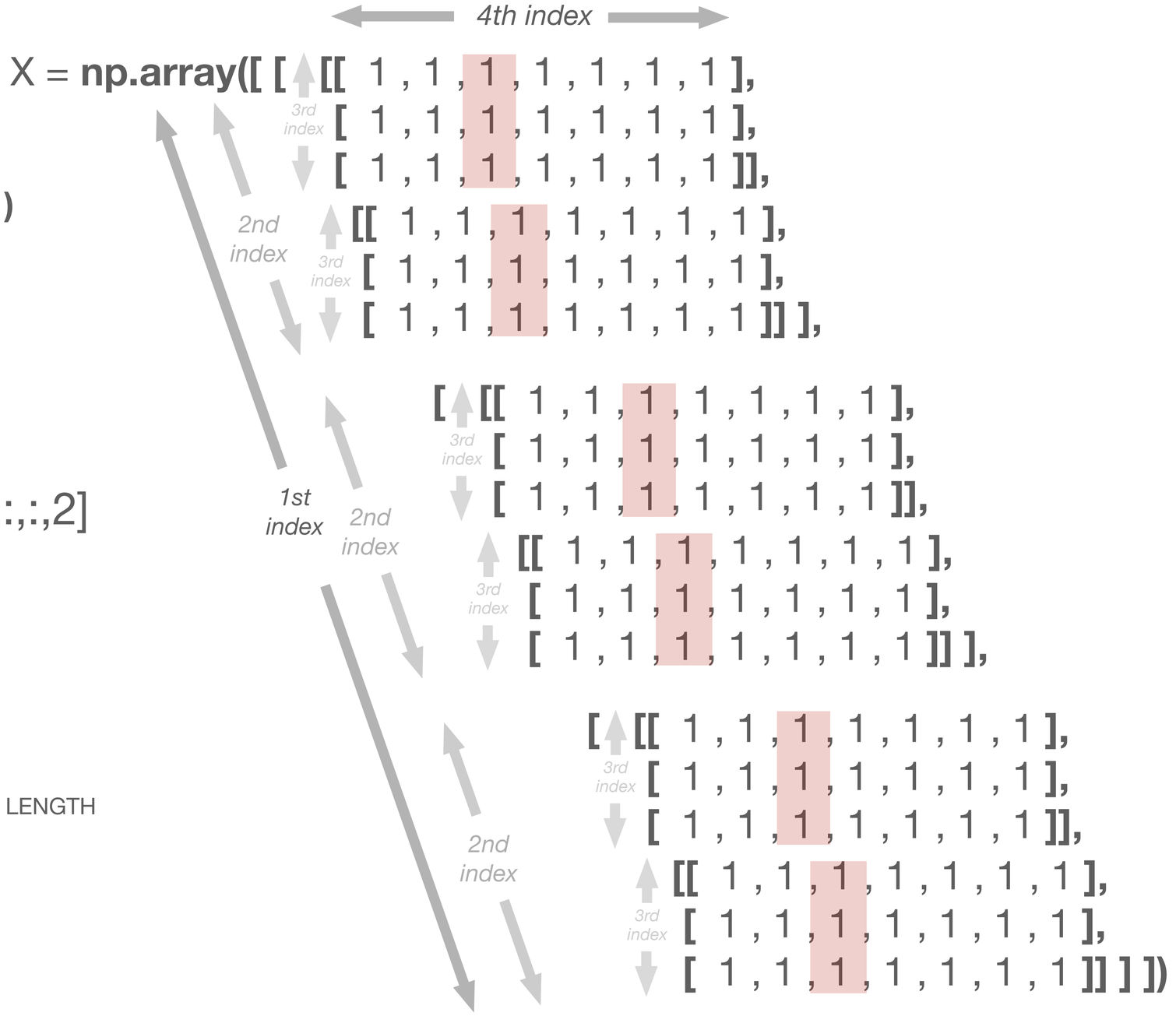

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X[:,:,:,3]

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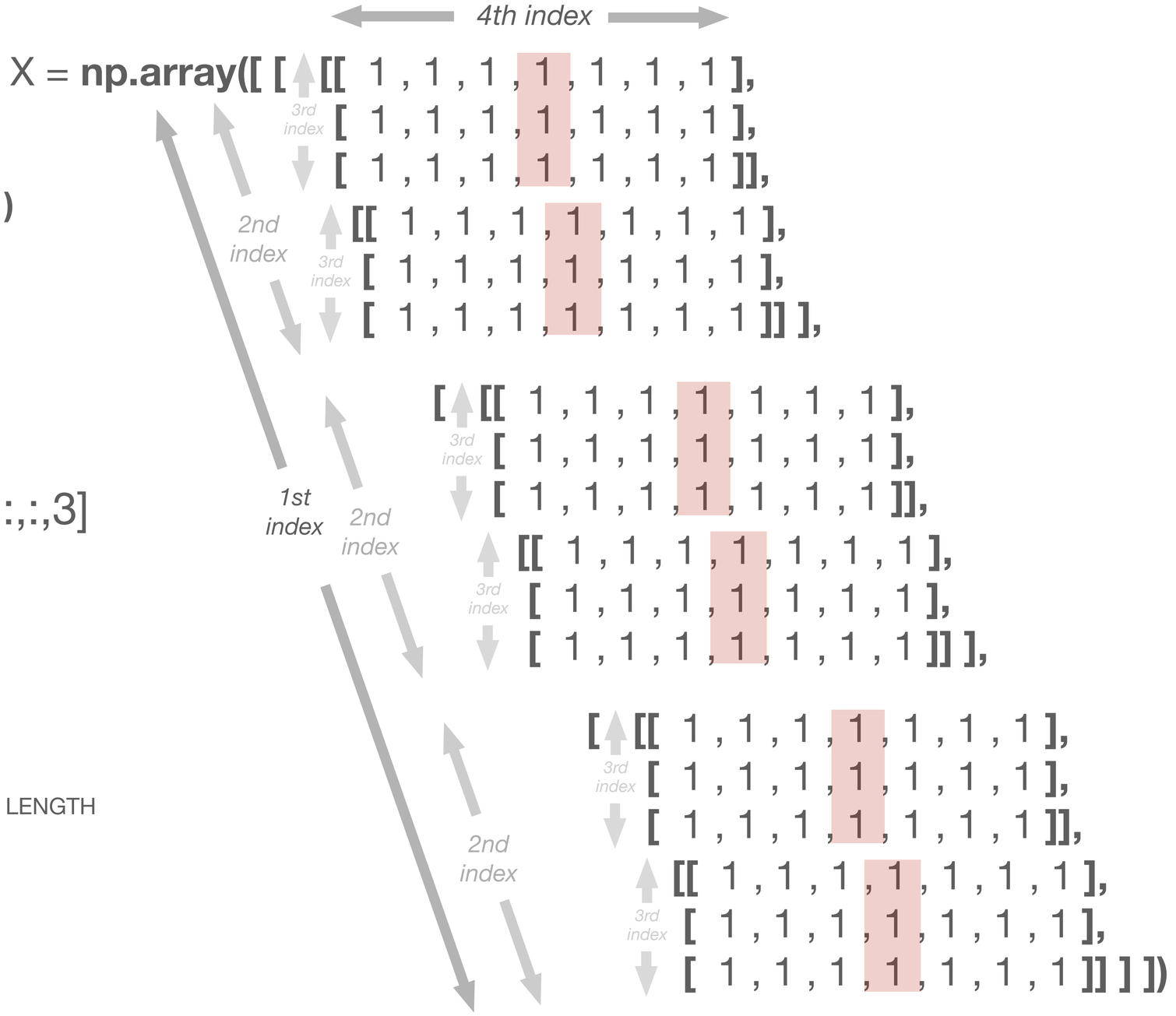

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slicing **start : end : step**

x[k1:k2:s1] - from k1 to k2 step by s1

X[:,:,:,4]

array indexing

ind = [0, 2, 3];
x[ind] - returns 0,2, and 3 elements

ind1 = [0, 2, 3]; ind2 = [0,3,2];
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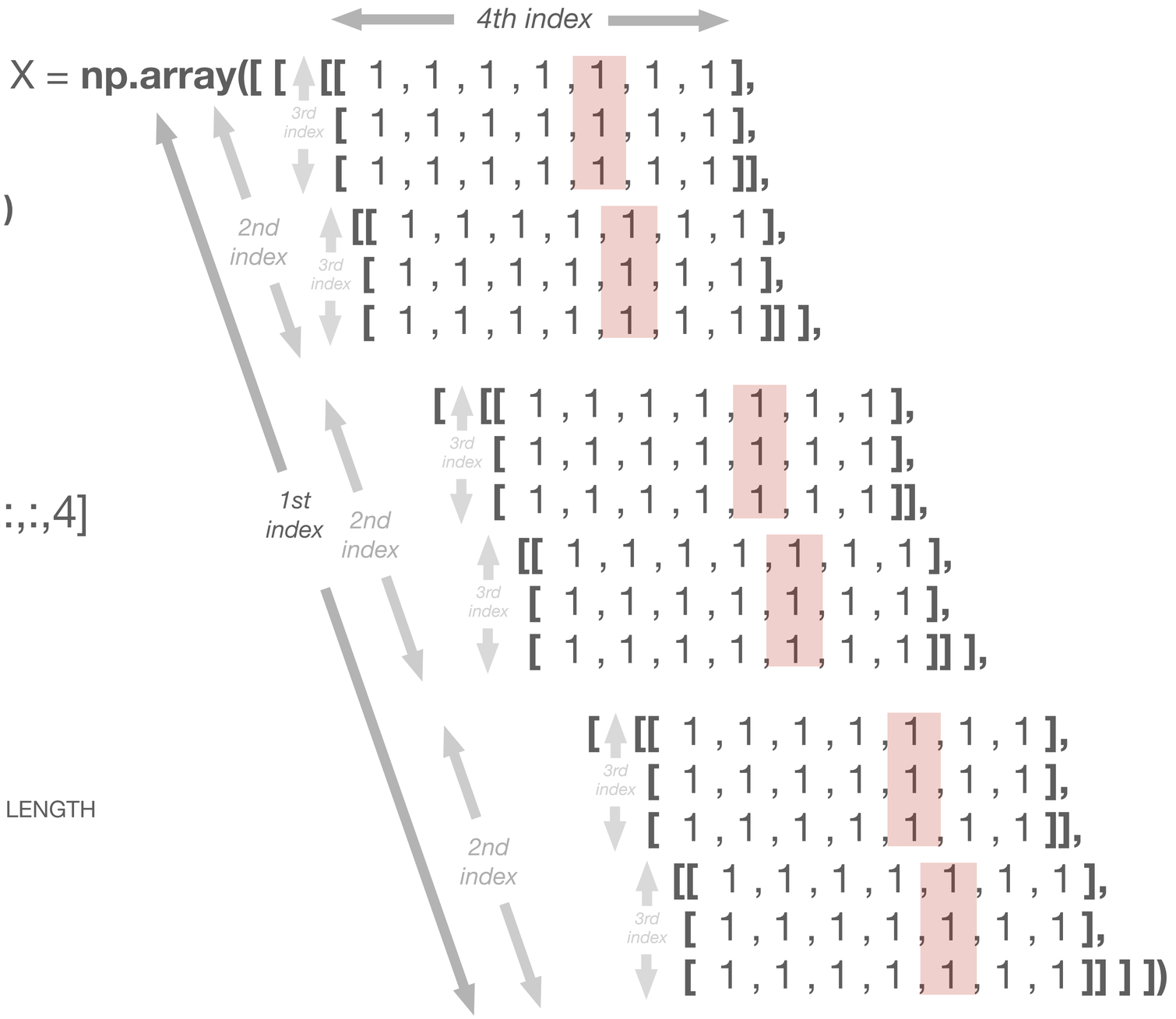

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slicing **start : end : step**

x[k1:k2:s1] - from k1 to k2 step by s1

X[:,:,:,5]

array indexing

ind = [0, 2, 3];
x[ind] - returns 0,2, and 3 elements
ind1 = [0, 2, 3]; ind2 = [0,3,2];
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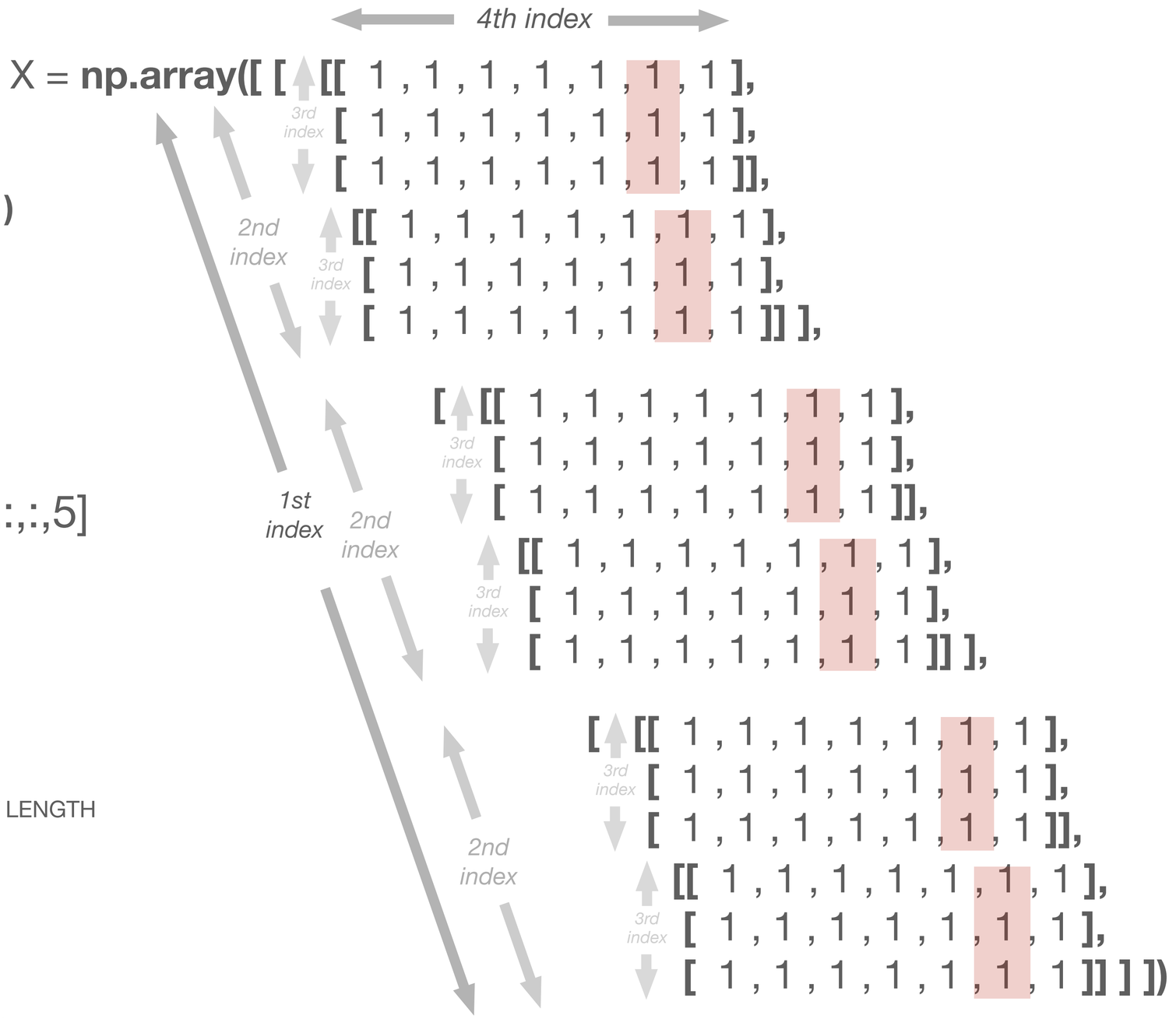
X[np.ix_(bool,bool)] - returns the [0,1,3] x [0,1,3] block



Python - Indexing

np.array: A = **np.array([[**1, 2, 3**],**
[3, 2, 1**]])**

zero indexed

x[0] - *first element…*
x[1] - *second element…*

negative indexing

x[-1] - last element…

slicing **start : end : step**

x[k1:k2:s1] - from k1 to k2 step by s1

X[:,:,:,6]

array indexing

ind = [0, 2, 3];
x[ind] - returns 0,2, and 3 elements

ind1 = [0, 2, 3]; ind2 = [0,3,2];
X[ind1,ind2] - returns [0,0],[2,3], and [3,2] elements

boolean indexing

bool = **[True, True, False, True];** MUST BE ARRAY LENGTH
x[bool] - returns 0,1, and 3 element.

X[bool,bool] - returns the [0,0], [1,1], and [3,3]

block indexing - np.ix_

X[np.ix_(ind1,ind2)] - returns the [0,2,3] x [3,2] block
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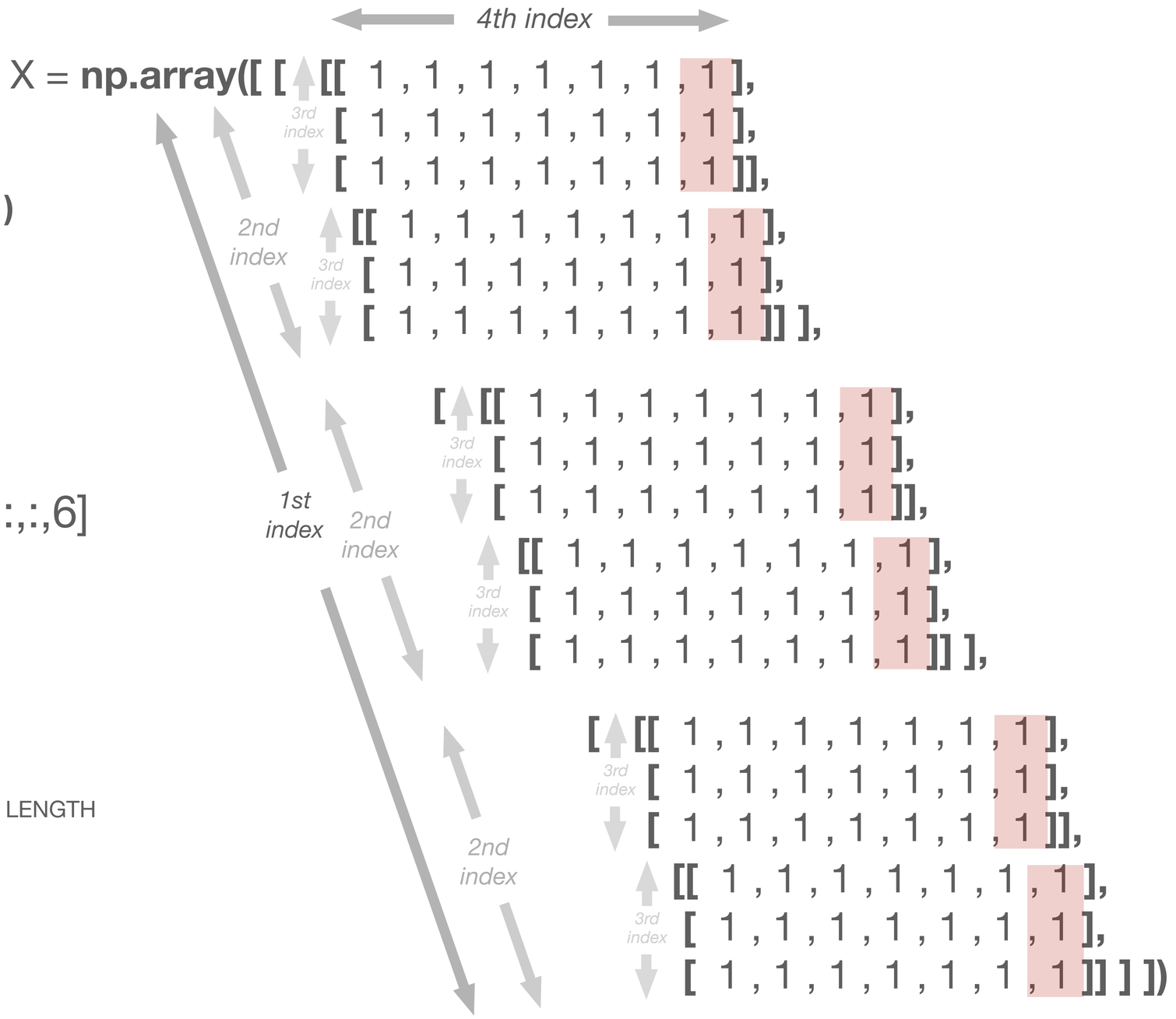

Python - Indexing

np.array: A = **np.array([[**1, 2, 3],
[3, 2, 1**]])**

zero indexed

x[0] - *first element…*
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negative indexing

x[-1] - last element…

slicing **start : end : step**

x[k1:k2:s1] - from k1 to k2 step by s1

array indexing

ind = [0, 2, 3];
x[ind] - returns 0,2, and 3 elements
ind1 = [0, 2, 3]; ind2 = [0,3,2];
X[ind1,ind2] - returns [0,0],[2,3], and [3,2] elements

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bool = **[True, True, False, True];** MUST BE ARRAY LENGTH
x[bool] - returns 0,1, and 3 element.
X[bool,bool] - returns the [0,0], [1,1], and [3,3]

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X[np.ix_(ind1,ind2)] - returns the [0,2,3] x [3,2] block
X[np.ix_(bool,bool)] - returns the [0,1,3] x [0,1,3] block

2nd index

1st index (rows)

```
X = np.array( [[ 1 , 1 , 1 , 1 , 1 ],
               [ 1 , 1 , 1 , 1 , 1 ],
               [ 1 , 1 , 1 , 1 , 1 ],
               [ 1 , 1 , 1 , 1 , 1 ],
               [ 1 , 1 , 1 , 1 , 1 ]])
```

X[[1,3,4]]

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

Python - Indexing

np.array: A = **np.array([[**1, 2, 3],
[3, 2, 1**]])**

zero indexed

x[0] - *first element…*
x[1] - *second element…*

negative indexing

x[-1] - last element…

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x[k1:k2:s1] - from k1 to k2 step by s1

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ind = [0, 2, 3];
x[ind] - returns 0,2, and 3 elements
ind1 = [0, 2, 3]; ind2 = [0,3,2];
X[ind1,ind2] - returns [0,0],[2,3], and [3,2] elements

boolean indexing

bool = **[True, True, False, True];** MUST BE ARRAY LENGTH
x[bool] - returns 0,1, and 3 element.
X[bool,bool] - returns the [0,0], [1,1], and [3,3]

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1st index (rows)

```
X = np.array( [[ 1 , 1 , 1 , 1 , 1 ],
               [ 1 , 1 , 1 , 1 , 1 ],
               [ 1 , 1 , 1 , 1 , 1 ],
               [ 1 , 1 , 1 , 1 , 1 ],
               [ 1 , 1 , 1 , 1 , 1 ]])
```

X[[1,3,4],[2,4,0]]

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

Python - Indexing

np.array: A = **np.array([[**1, 2, 3],
[3, 2, 1**]])**

zero indexed

x[0] - *first element…*
x[1] - *second element…*

negative indexing

x[-1] - last element…

slicing **start : end : step**

x[k1:k2:s1] - from k1 to k2 step by s1

array indexing

ind = [0, 2, 3];
x[ind] - returns 0,2, and 3 elements
ind1 = [0, 2, 3]; ind2 = [0,3,2];
X[ind1,ind2] - returns [0,0],[2,3], and [3,2] elements

boolean indexing

bool = **[True, True, False, True];** MUST BE ARRAY LENGTH
x[bool] - returns 0,1, and 3 element.
X[bool,bool] - returns the [0,0], [1,1], and [3,3]

block indexing - np.ix_

X[np.ix_(ind1,ind2)] - returns the [0,2,3] x [3,2] block
X[np.ix_(bool,bool)] - returns the [0,1,3] x [0,1,3] block

2nd index

X = **np.array([[** 1 , 1 , 1 , 1 , 1 **],**
[1 , 1 , 1 , 1 , 1 **],**
[1 , 1 , 1 , 1 , 1 **],**
[1 , 1 , 1 , 1 , 1 **],**
[1 , 1 , 1 , 1 , 1 **]])**

1st index (rows)

X[np.ix_([1,3,4],[2,4,0])]

np.array([[1 , 1 , 1 , 1 , 1 **],**
[1 , 1 , 1 , 1 , 1 **],**
[1 , 1 , 1 , 1 , 1 **],**
[1 , 1 , 1 , 1 , 1 **],**
[1 , 1 , 1 , 1 , 1 **]])**

Python - Indexing

np.array: A = **np.array([[**1, 2, 3],
[3, 2, 1**]])**

zero indexed

x[0] - *first element…*
x[1] - *second element…*

negative indexing

x[-1] - last element…

slicing **start : end : step**

x[k1:k2:s1] - from k1 to k2 step by s1

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ind = [0, 2, 3];
x[ind] - returns 0,2, and 3 elements

ind1 = [0, 2, 3]; ind2 = [0,3,2];
X[ind1,ind2] - returns [0,0],[2,3], and [3,2] elements

boolean indexing

bool = **[True, True, False, True];** MUST BE ARRAY LENGTH
x[bool] - returns 0,1, and 3 element.

X[bool,bool] - returns the [0,0], [1,1], and [3,3]

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X[np.ix_(ind1,ind2)] - returns the [0,2,3] x [3,2] block
X[np.ix_(bool,bool)] - returns the [0,1,3] x [0,1,3] block

2nd index

1st index (rows)

X = **np.array([[** 1 , 1 , 1 , 1 , 1 **],**
[1 , 1 , 1 , 1 , 1 **],**
[1 , 1 , 1 , 1 , 1 **],**
[1 , 1 , 1 , 1 , 1 **],**
[1 , 1 , 1 , 1 , 1 **]])**

bools = [False,True,False,True,True]

X[bools]

np.array([[1 , 1 , 1 , 1 , 1 **],**
[1 , 1 , 1 , 1 , 1 **],**
[1 , 1 , 1 , 1 , 1 **],**
[1 , 1 , 1 , 1 , 1 **],**
[1 , 1 , 1 , 1 , 1 **]])**

Python - Indexing

np.array: A = **np.array([[**1, 2, 3],
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zero indexed

x[0] - *first element…*
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negative indexing

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ind = [0, 2, 3];
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ind1 = [0, 2, 3]; ind2 = [0,3,2];
X[ind1,ind2] - returns [0,0],[2,3], and [3,2] elements

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bool = **[True, True, False, True];** MUST BE ARRAY LENGTH
x[bool] - returns 0,1, and 3 element.

X[bool,bool] - returns the [0,0], [1,1], and [3,3]

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2nd index

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```
X = np.array( [[ 1 , 1 , 1 , 1 , 1 ],
               [ 1 , 1 , 1 , 1 , 1 ],
               [ 1 , 1 , 1 , 1 , 1 ],
               [ 1 , 1 , 1 , 1 , 1 ],
               [ 1 , 1 , 1 , 1 , 1 ]])
```

bools = [False,True,False,True,True]

X[bools,bools]

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

Python - Indexing

np.array: A = **np.array([[**1, 2, 3],
[3, 2, 1**]]**)

zero indexed

x[0] - *first element…*
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negative indexing

x[-1] - last element…

slicing **start : end : step**

x[k1:k2:s1] - from k1 to k2 step by s1

array indexing

ind = [0, 2, 3];
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ind1 = [0, 2, 3]; ind2 = [0,3,2];
X[ind1,ind2] - returns [0,0],[2,3], and [3,2] elements

boolean indexing

bool = **[True, True, False, True];** MUST BE ARRAY LENGTH
x[bool] - returns 0,1, and 3 element.

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X[np.ix_(bool,bool)] - returns the [0,1,3] x [0,1,3] block

2nd index

X = **np.array([[** 1 , 1 , 1 , 1 , 1 **],**
[1 , 1 , 1 , 1 , 1 **],**
[1 , 1 , 1 , 1 , 1 **],**
[1 , 1 , 1 , 1 , 1 **],**
[1 , 1 , 1 , 1 , 1 **]])**

1st index (rows)

np.array([[1 , 1 , 1 , 1 , 1 **],**
[1 , 1 , 1 , 1 , 1 **],**
[1 , 1 , 1 , 1 , 1 **],**
[1 , 1 , 1 , 1 , 1 **],**
[1 , 1 , 1 , 1 , 1 **]])**

bools = [False,True,False,True,True]

X[np.ix_(bools,bools)]

Python - Indexing

np.array: A = **np.array([[**1, 2, 3**],**
[3, 2, 1**]])**

zero indexed

x[0] - *first element…*
x[1] - *second element…*

negative indexing

x[-1] - last element…

slicing **start : end : step**

x[k1:k2:s1] - from k1 to k2 step by s1

array indexing

ind = [0, 2, 3];
x[ind] - returns 0,2, and 3 elements

ind1 = [0, 2, 3]; ind2 = [0,3,2];
X[ind1,ind2] - returns [0,0],[2,3], and [3,2] elements

boolean indexing

bool = **[True, True, False, True];** MUST BE ARRAY LENGTH
x[bool] - returns 0,1, and 3 element.

X[bool,bool] - returns the [0,0], [1,1], and [3,3]

block indexing - np.ix_

X[np.ix_(ind1,ind2)] - returns the [0,2,3] x [3,2] block
X[np.ix_(bool,bool)] - returns the [0,1,3] x [0,1,3] block

2nd index

1st index (rows)

X = **np.array([[** 1 , 2 , 3 , 4 , 5 **],**
[2 , 3 , 4 , 5 , 6 **],**
[3 , 4 , 5 , 6 , 7 **],**
[4 , 5 , 6 , 7 , 8 **],**
[5 , 6 , 7 , 8 , 9 **]])**

Finding Elements:

np.where(X==4) = [(0,1,2,3,), (3,2,1,0)]

X[np.where(X==4)] = [4 , 4 , 4 , 4]

…returns all elements of array satisfying condition collapsed

Python - Indexing

np.array: A = **np.array([[**1, 2, 3],
[3, 2, 1**]]**)

zero indexed

x[0] - *first element…*
x[1] - *second element…*

negative indexing

x[-1] - last element…

slicing **start : end : step**

x[k1:k2:s1] - from k1 to k2 step by s1

array indexing

ind = [0, 2, 3];
x[ind] - returns 0,2, and 3 elements

ind1 = [0, 2, 3]; ind2 = [0,3,2];
X[ind1,ind2] - returns [0,0],[2,3], and [3,2] elements

boolean indexing

bool = **[True, True, False, True];** MUST BE ARRAY LENGTH
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X[np.ix_(ind1,ind2)] - returns the [0,2,3] x [3,2] block
X[np.ix_(bool,bool)] - returns the [0,1,3] x [0,1,3] block

2nd index

1st index (rows)

X = **np.array([[** 1 , 2 , 3 , 4 , 5 **],**
[2 , 3 , 4 , 5 , 6 **],**
[3 , 4 , 5 , 6 , 7 **],**
[4 , 5 , 6 , 7 , 8 **],**
[5 , 6 , 7 , 8 , 9 **]])**

Finding Elements:

np.where(condition, X, Y)

…chooses elements from X if true…
…chooses elements from Y if false…
…respects array structure…

Y = **np.array([[** 1 , 1 , 1 , 1 , 1 **],**
[1 , 1 , 1 , 1 , 1 **],**
[1 , 1 , 1 , 1 , 1 **],**
[1 , 1 , 1 , 1 , 1 **],**
[1 , 1 , 1 , 1 , 1 **]])**

np.where(X >= 5, X, Y) = **np.array([[** 1 , 1 , 1 , 1 , 5 **],**
[1 , 1 , 1 , 5 , 6 **],**
[1 , 1 , 5 , 6 , 7 **],**
[1 , 5 , 6 , 7 , 8 **],**
[5 , 6 , 7 , 8 , 9 **]])**

or…

np.where(X >= 5, X, 1)

Python - Matrix Multiplication

vector: 1D x = np.array([1,2,3])

matrix 2D A = np.array([[1, 1, 1],
[1, 1, 1],
[1, 1, 1]])

row vector:

x = np.array([[1 , 1 ,1]])

col vector:

x = np.array([[1],
[1],
[1]])

BOTH

x = np.array([1 , 1 ,1])

Matrix multiplication:

A@x = A.dot(x) = np.dot(A,x)

x = np.array([1,1,1])

A@x - A times col vector x
x@A - row vector x times A

Tranpose A.T

$$y = Ax$$

$$y_i = \sum_j A_{ij} x_j = A_{ij} x_j$$

A @ x

x = **np.array([1 , 1 , 1 , 1 , 1])**

A = **np.array([[1 , 1 , 1 , 1 , 1],**
[1 , 1 , 1 , 1 , 1],
[1 , 1 , 1 , 1 , 1],
[1 , 1 , 1 , 1 , 1],
[1 , 1 , 1 , 1 , 1]])

np.einsum('ij,j',A,x)

Python - Matrix Multiplication

vector: 1D x = np.array([1,2,3])

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[1, 1, 1]])

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x = np.array([[1 , 1 ,1]])

col vector:

x = np.array([[1],
[1],
[1]])

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x = np.array([1 , 1 ,1])

Matrix multiplication:

A@x = A.dot(x) = np.dot(A,x)

x = np.array([1,1,1])

A@x - A times col vector x
x@A - row vector x times A

Tranpose A.T

$$x^T A = y^T$$

$$y_j = \sum_i A_{ij} x_i = A_{ij} x_i$$

x @ A

x = **np.array([1 , 1 , 1 , 1 , 1])**

A = **np.array([[1 , 1 , 1 , 1 , 1],**
[1 , 1 , 1 , 1 , 1],
[1 , 1 , 1 , 1 , 1],
[1 , 1 , 1 , 1 , 1],
[1 , 1 , 1 , 1 , 1]])

np.einsum('ij,i',A,x)

np.einsum('i,ij',x,A)

Python - Matrix Multiplication

vector: 1D x = np.array([1,2,3])

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[1, 1, 1],
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row vector:

x = np.array([[1 , 1 ,1]])

col vector:

x = np.array([[1],
[1],
[1]])

BOTH

x = np.array([1 , 1 ,1])

Matrix multiplication:

A@x = A.dot(x) = np.dot(A,x)

x = np.array([1,1,1])

A@x - A times col vector x
x@A - row vector x times A

Tranpose A.T

$A_{ijk}x_k$

x = **np.array([1 , 1 , 1 , 1 , 1])**

3rd index

A = **np.array([**

```
[[ 1 , 1 , 1 , 1 , 1 ],
 [ 1 , 1 , 1 , 1 , 1 ],
 [ 1 , 1 , 1 , 1 , 1 ]],
[[ 1 , 1 , 1 , 1 , 1 ],
 [ 1 , 1 , 1 , 1 , 1 ],
 [ 1 , 1 , 1 , 1 , 1 ]],
[[ 1 , 1 , 1 , 1 , 1 ],
 [ 1 , 1 , 1 , 1 , 1 ],
 [ 1 , 1 , 1 , 1 , 1 ]],
[[ 1 , 1 , 1 , 1 , 1 ],
 [ 1 , 1 , 1 , 1 , 1 ],
 [ 1 , 1 , 1 , 1 , 1 ]])
```

2nd index

1st index

np.einsum('ijk,k',A,x)

Python - Matrix Multiplication

vector: 1D x = np.array([1,2,3])

matrix 2D A = np.array([[1, 1, 1],
[1, 1, 1],
[1, 1, 1]])

row vector:

x = np.array([[1 , 1 ,1]])

col vector:

x = np.array([[1],
[1],
[1]])

BOTH

x = np.array([1 , 1 ,1])

Matrix multiplication:

A@x = A.dot(x) = np.dot(A,x)

x = np.array([1,1,1])

A@x - A times col vector x
x@A - row vector x times A

Tranpose A.T

$A_{ijk}x_j$

x = **np.array([1 , 1 , 1])**

3rd index

A = **np.array([**

```
[[ 1 , 1 , 1 , 1 , 1 ],
 [ 1 , 1 , 1 , 1 , 1 ],
 [ 1 , 1 , 1 , 1 , 1 ]],
[[ 1 , 1 , 1 , 1 , 1 ],
 [ 1 , 1 , 1 , 1 , 1 ],
 [ 1 , 1 , 1 , 1 , 1 ]],
[[ 1 , 1 , 1 , 1 , 1 ],
 [ 1 , 1 , 1 , 1 , 1 ],
 [ 1 , 1 , 1 , 1 , 1 ]],
[[ 1 , 1 , 1 , 1 , 1 ],
 [ 1 , 1 , 1 , 1 , 1 ],
 [ 1 , 1 , 1 , 1 , 1 ]]])
```

2nd index

1st index

np.einsum('ijk,j',A,x)

Python - Matrix Multiplication

vector: 1D x = np.array([1,2,3])

matrix 2D A = np.array([[1, 1, 1],
[1, 1, 1],
[1, 1, 1]])

row vector:

x = np.array([[1 , 1 ,1]])

col vector:

x = np.array([[1],
[1],
[1]])

BOTH

x = np.array([1 , 1 ,1])

Matrix multiplication:

A@x = A.dot(x) = np.dot(A,x)

x = np.array([1,1,1])

A@x - A times col vector x
x@A - row vector x times A

Tranpose A.T

$A_{ijk}x_i$

x = **np.array([1 , 1 , 1 , 1])**

3rd index

A = **np.array([**

```
[[ 1 , 1 , 1 , 1 , 1 ],
 [ 1 , 1 , 1 , 1 , 1 ],
 [ 1 , 1 , 1 , 1 , 1 ]],
[[ 1 , 1 , 1 , 1 , 1 ],
 [ 1 , 1 , 1 , 1 , 1 ],
 [ 1 , 1 , 1 , 1 , 1 ]],
[[ 1 , 1 , 1 , 1 , 1 ],
 [ 1 , 1 , 1 , 1 , 1 ],
 [ 1 , 1 , 1 , 1 , 1 ]],
[[ 1 , 1 , 1 , 1 , 1 ],
 [ 1 , 1 , 1 , 1 , 1 ],
 [ 1 , 1 , 1 , 1 , 1 ]]])
```

2nd index

1st index

np.einsum('ijk,i',A,x)

Python - Matrix Multiplication

vector: 1D x = np.array([1,2,3])

matrix 2D A = np.array([[1, 1, 1],
[1, 1, 1],
[1, 1, 1]])

row vector:

x = np.array([[1 , 1 ,1]])

col vector:

x = np.array([[1],
[1],
[1]])

BOTH

x = np.array([1 , 1 ,1])

Matrix multiplication:

A@x = A.dot(x) = np.dot(A,x)

x = np.array([1,1,1])

A@x - A times col vector x
x@A - row vector x times A

Tranpose A.T

RESULT:

y = **np.array([** 15 , 15, 15, 15 **])**

$A_{ijk}x_{jk}$

x = **np.array([[** 1 , 1 , 1 , 1 , 1 **],**
[1 , 1 , 1 , 1 , 1 **],**
[1 , 1 , 1 , 1 , 1 **],**
[1 , 1 , 1 , 1 , 1 **]])**

3rd index

A = **np.array([[[** 1 , 1 , 1 , 1 , 1 **],**
2nd index
[1 , 1 , 1 , 1 , 1 **],**
[1 , 1 , 1 , 1 , 1 **]],**

[[1 , 1 , 1 , 1 , 1 **],**
2nd index
[1 , 1 , 1 , 1 , 1 **],**
[1 , 1 , 1 , 1 , 1 **]],**

1st index

[[1 , 1 , 1 , 1 , 1 **],**
2nd index
[1 , 1 , 1 , 1 , 1 **],**
[1 , 1 , 1 , 1 , 1 **]],**

[[1 , 1 , 1 , 1 , 1 **],**
2nd index
[1 , 1 , 1 , 1 , 1 **],**
[1 , 1 , 1 , 1 , 1 **]])**

np.einsum('ijk,jk',A,x)

Python - Matrix Multiplication

vector: 1D x = np.array([1,2,3])

matrix 2D A = np.array([[1, 1, 1],
[1, 1, 1],
[1, 1, 1]])

row vector:

x = np.array([[1 , 1 ,1]])

col vector:

x = np.array([[1],
[1],
[1]])

BOTH

x = np.array([1 , 1 ,1])

Matrix multiplication:

A@x = A.dot(x) = np.dot(A,x)

x = np.array([1,1,1])

A@x - A times col vector x
x@A - row vector x times A

Tranpose A.T

RESULT:

y = **np.array([[** 5 , 5, 5 **],**
[5 , 5 , 5 **],**
[5 , 5 , 5 **],**
[5 , 5 , 5 **]])**

x = **np.array([[** 1 , 1 , 1 , 1 , 1 **],**
[1 , 1 , 1 , 1 , 1 **],**
[1 , 1 , 1 , 1 , 1 **],**
[1 , 1 , 1 , 1 , 1 **]])**

3rd index

A = **np.array([[[** 1 , 1 , 1 , 1 , 1 **],**
2nd index
[1 , 1 , 1 , 1 , 1 **],**
[1 , 1 , 1 , 1 , 1 **]],**
[[1 , 1 , 1 , 1 , 1 **],**
2nd index
[1 , 1 , 1 , 1 , 1 **],**
[1 , 1 , 1 , 1 , 1 **]],**
1st index
[[1 , 1 , 1 , 1 , 1 **],**
2nd index
[1 , 1 , 1 , 1 , 1 **],**
[1 , 1 , 1 , 1 , 1 **]],**
[[1 , 1 , 1 , 1 , 1 **],**
2nd index
[1 , 1 , 1 , 1 , 1 **],**
[1 , 1 , 1 , 1 , 1 **]])**

np.einsum('ijk,ik->ij',A,x)