

Unified Compilation for Lossless Compression and Sparse Computing

Daniel Donenfeld, Stephen Chou, Saman Amarasinghe



Real world data is often redundant



Kristina

★★★★★ Great Product

March 30, 2017

Color: White | [Verified Purchase](#)

Great product. Large enough for all spoons and fits nicely on my stovetop. Would definitely buy it again.



Teresa

★★★★★ Excellent buy

October 25, 2017

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This is a great product for your boy who loves sports! It was a good value as well. Other stores sell for 3x the cost. I bought one for a basketball and football and my 9 year old loves it in his room. Solid item too, not flimsy. Will hold items nicely.



Lisa

★★★★★ I was really disappointed. The spoon holder it self was great and ...

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Sarah

★★★★★ Malfunctioned within a month. Waste of \$.

December 5, 2017

Style: Battery Powered Alarm | Size: 1 Pack | [Verified Purchase](#)

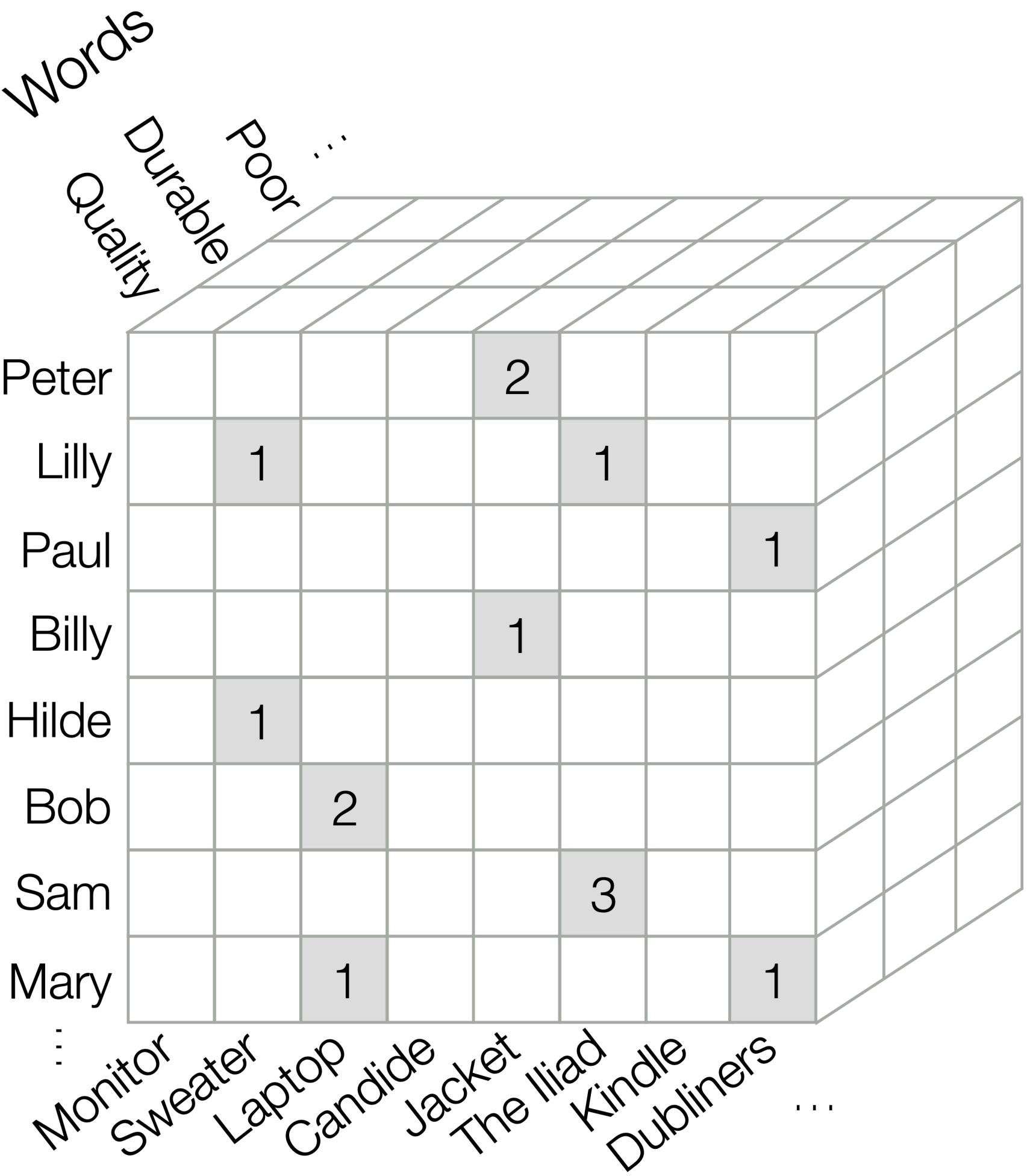
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Users

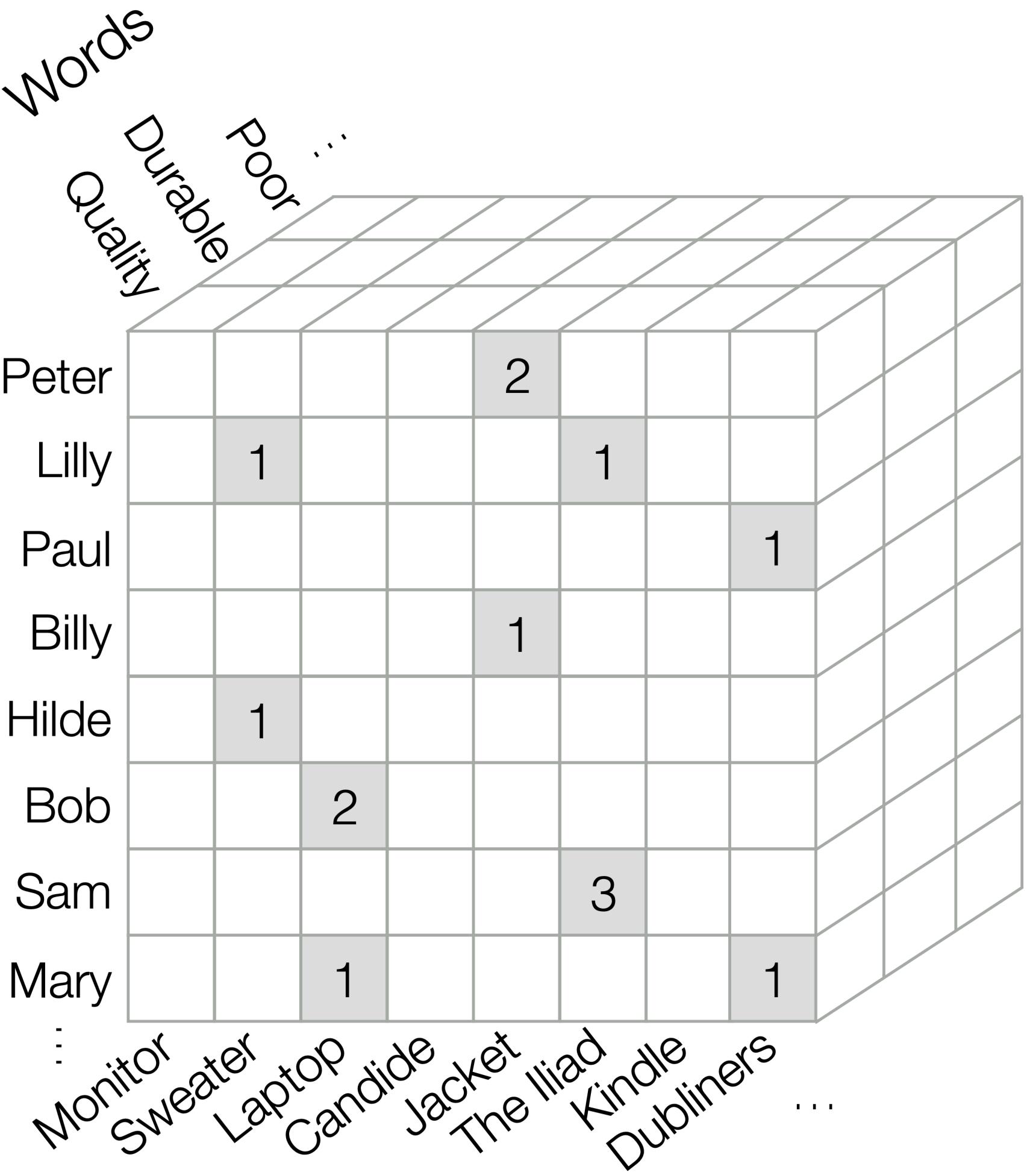


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Users



Dense storage: 107 exabytes
Sparse storage: 13 gigabytes

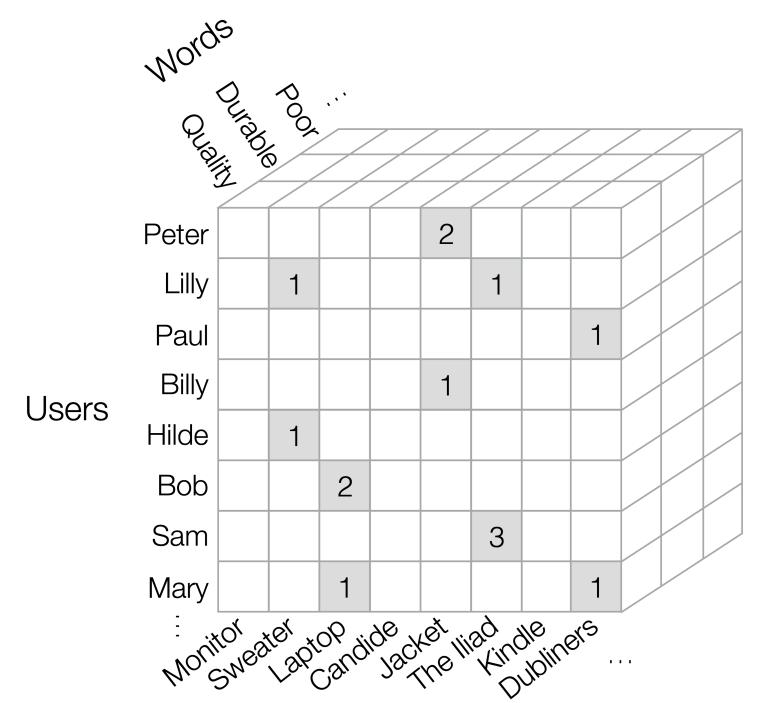
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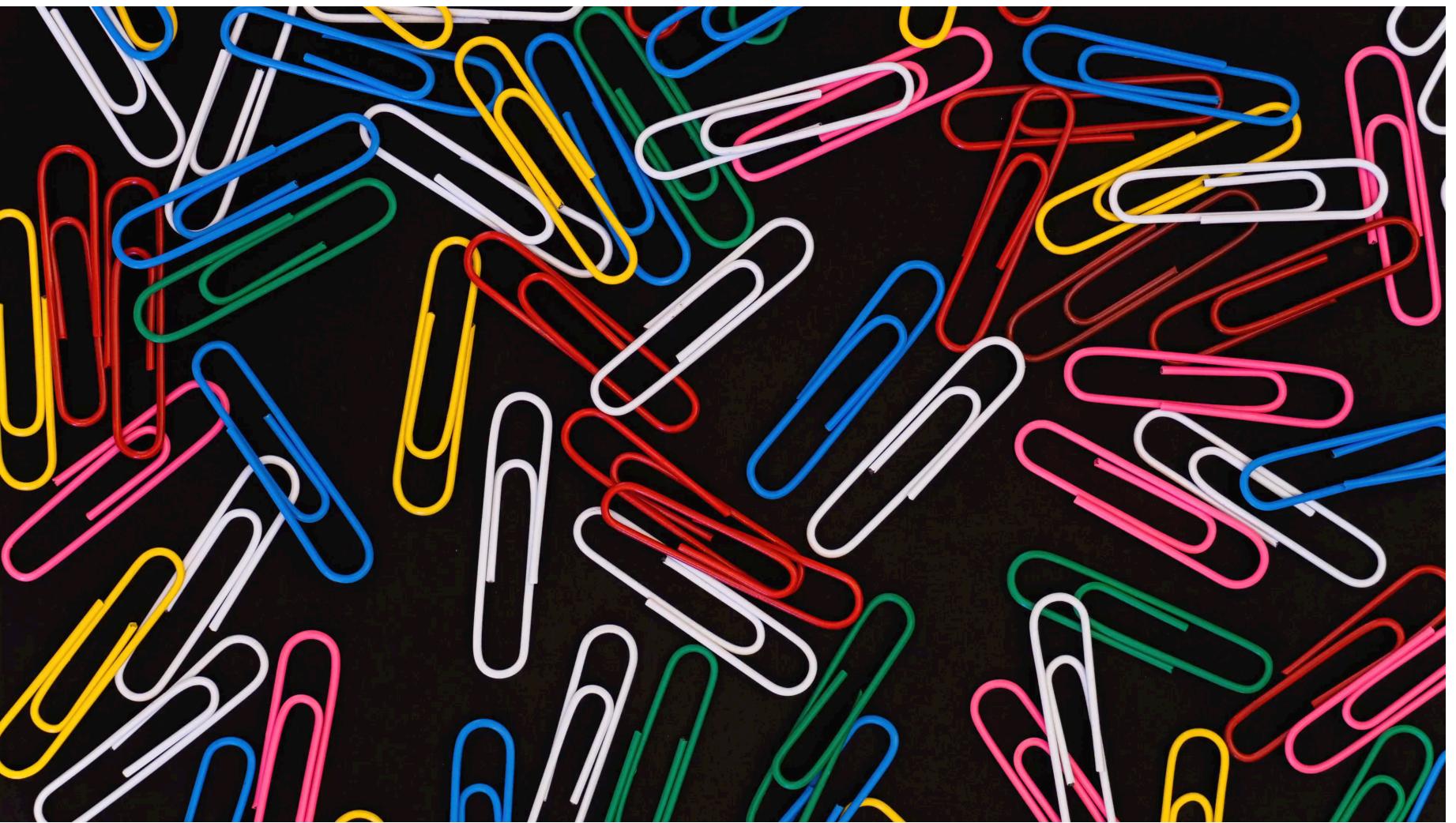
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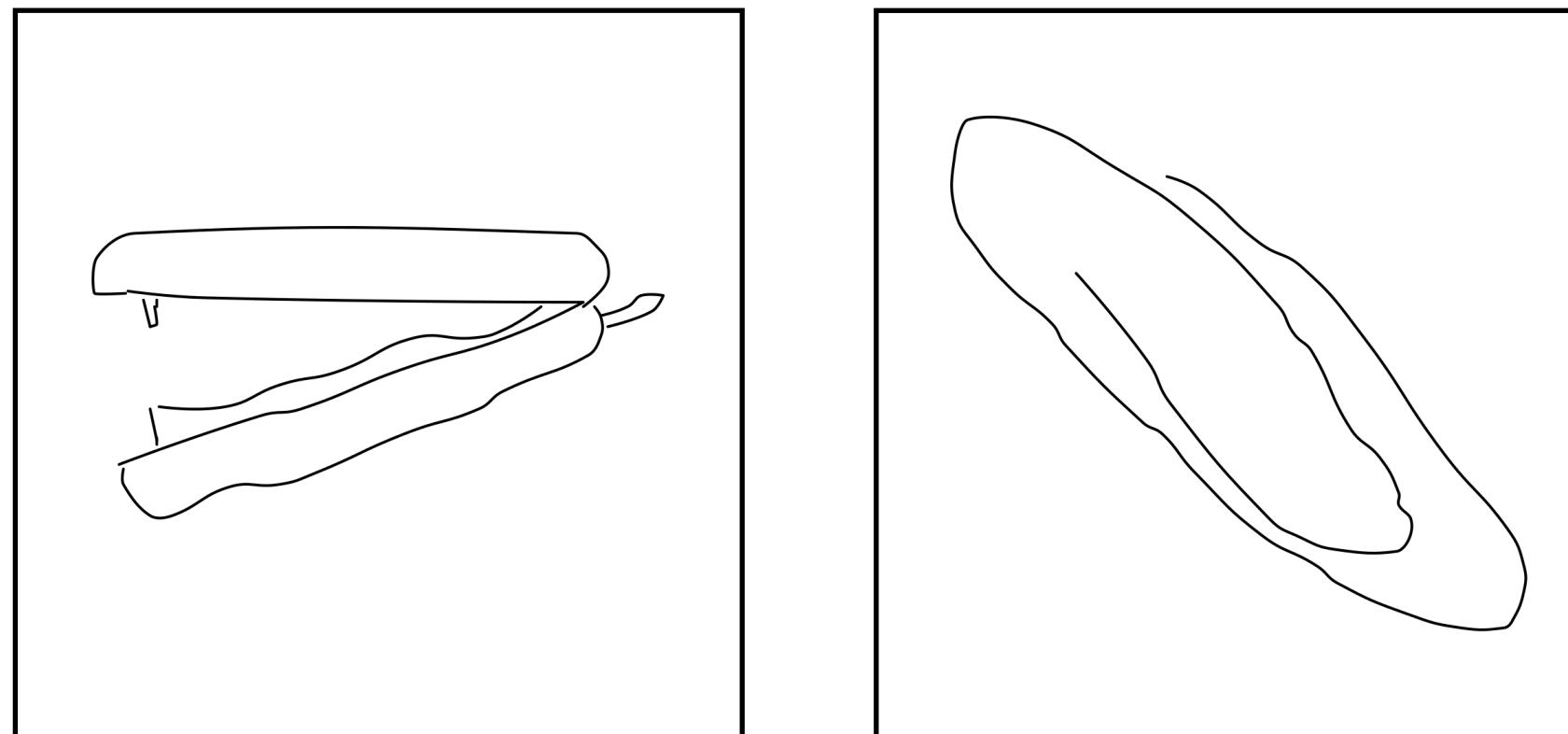


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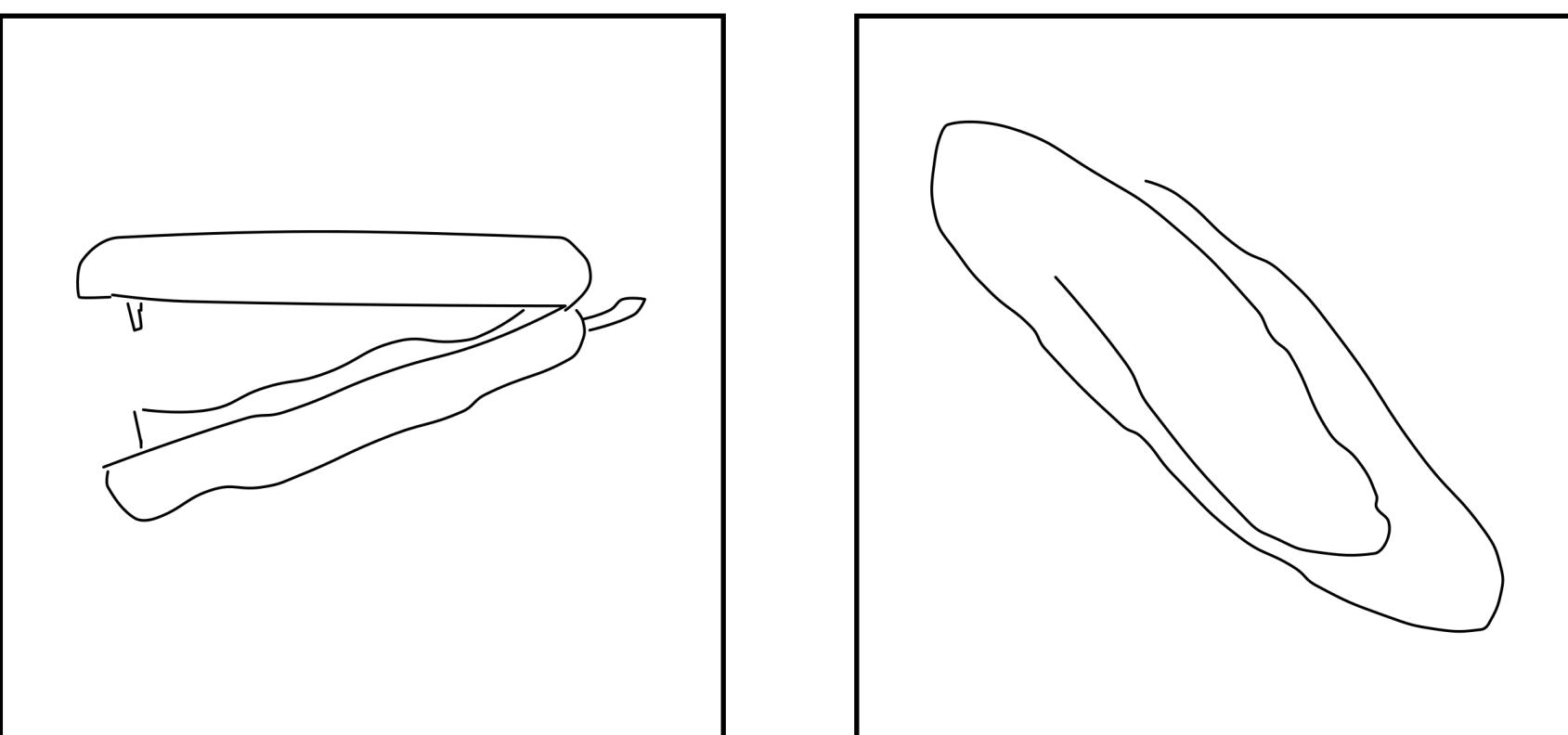
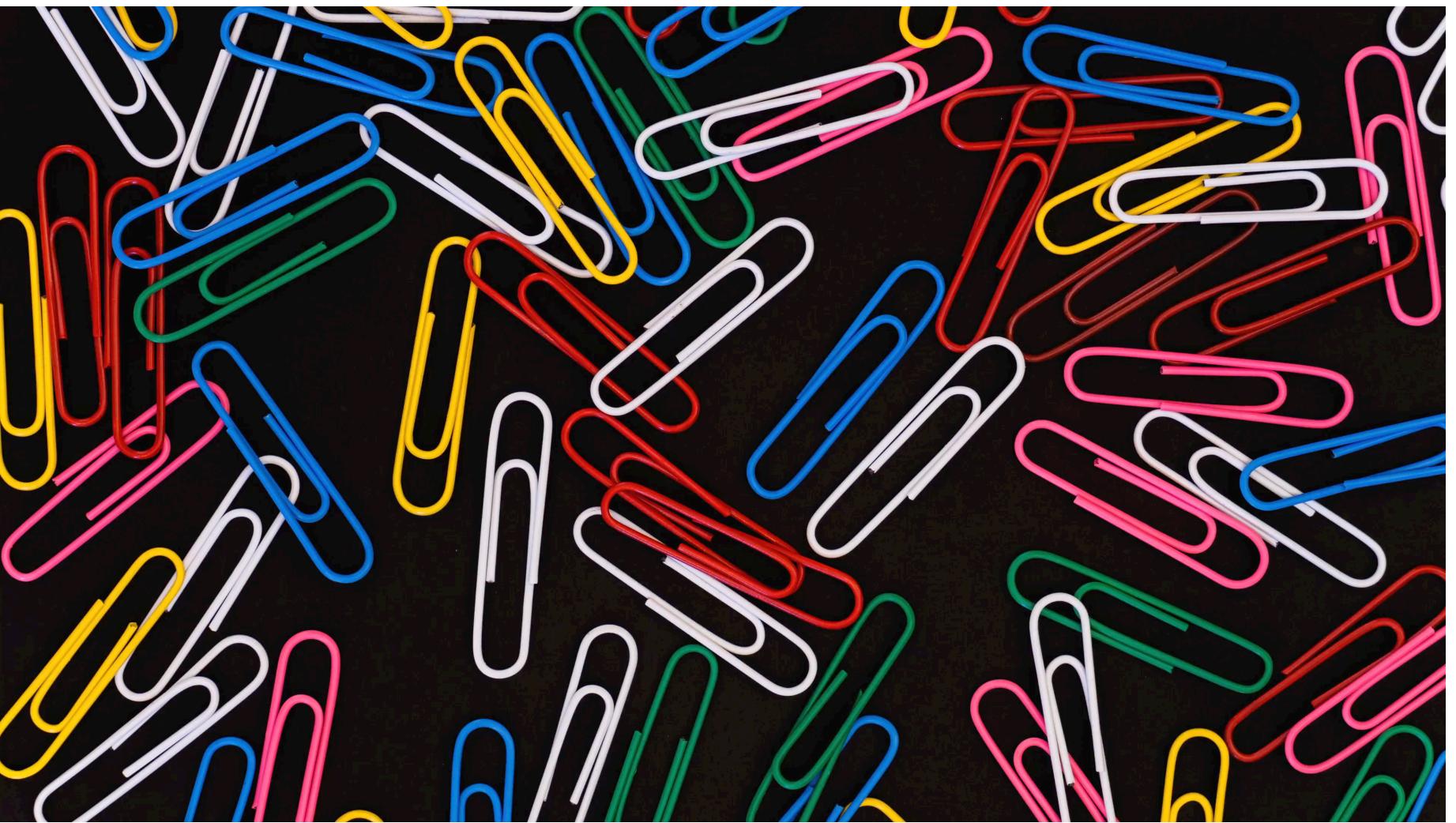


Users	Words	Products									
		Monitor	Sweater	Laptop	Candide	Jacket	The Iliad	Kindle	Dubliners	...	
Peter					2						
Lilly		1				1					
Paul								1			
Billy				1							
Hilde		1									
Bob			2								
Sam						3					
Mary		1							1		
	...	Monitor	Sweater	Laptop	Candide	Jacket	The Iliad	Kindle	Dubliners	...	



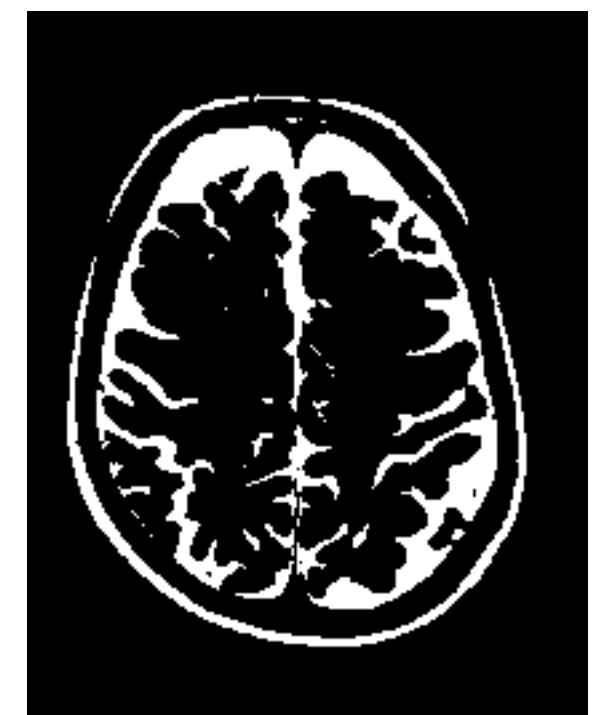
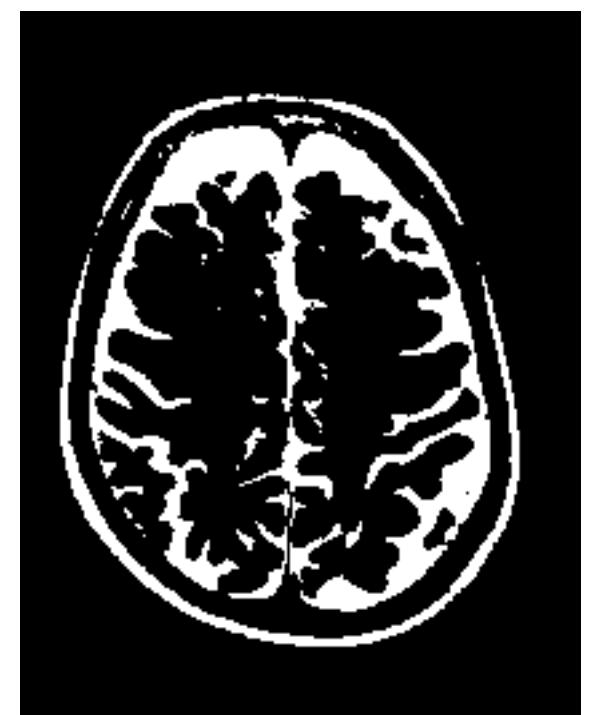
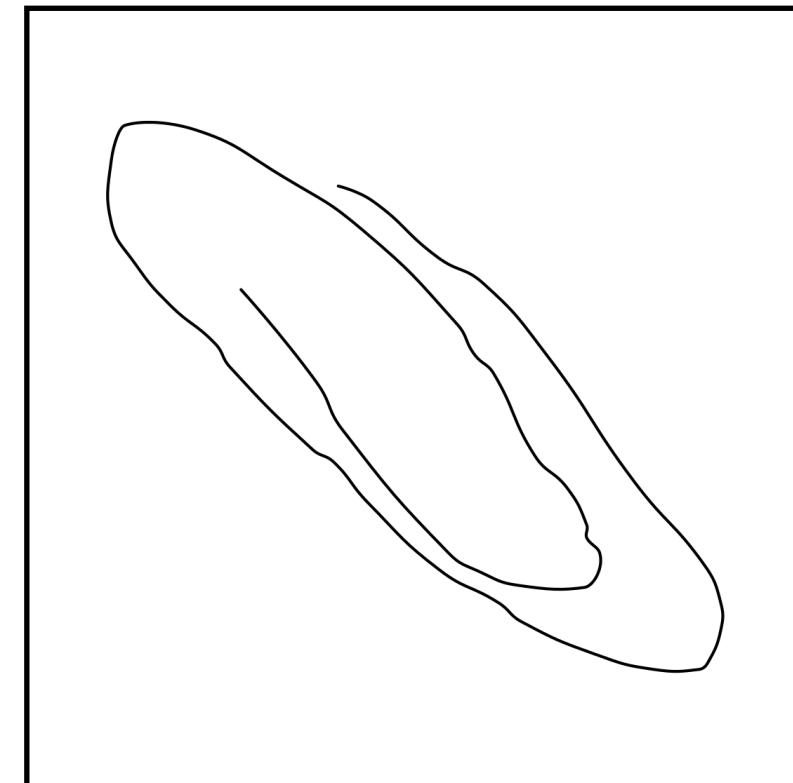
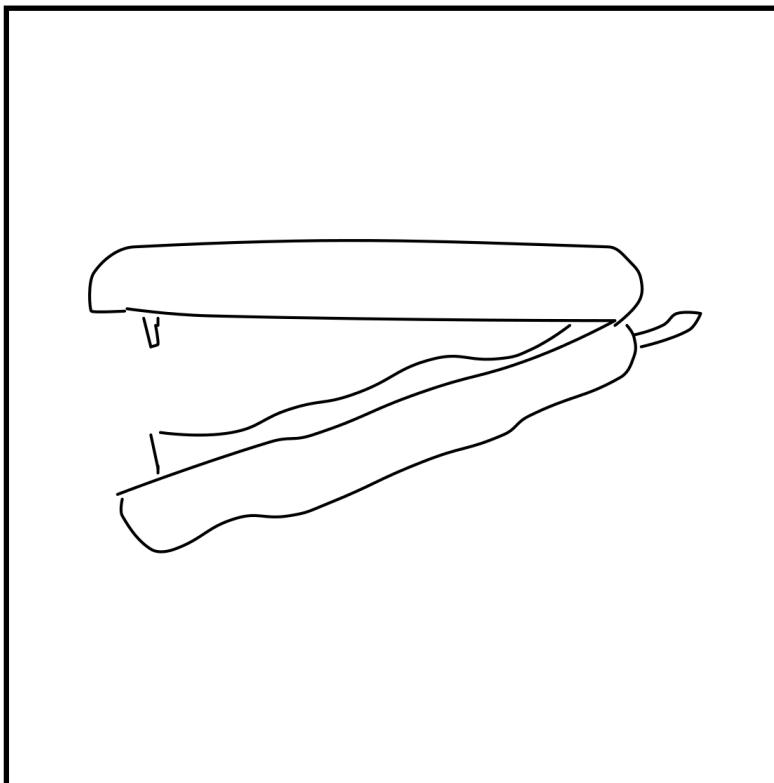
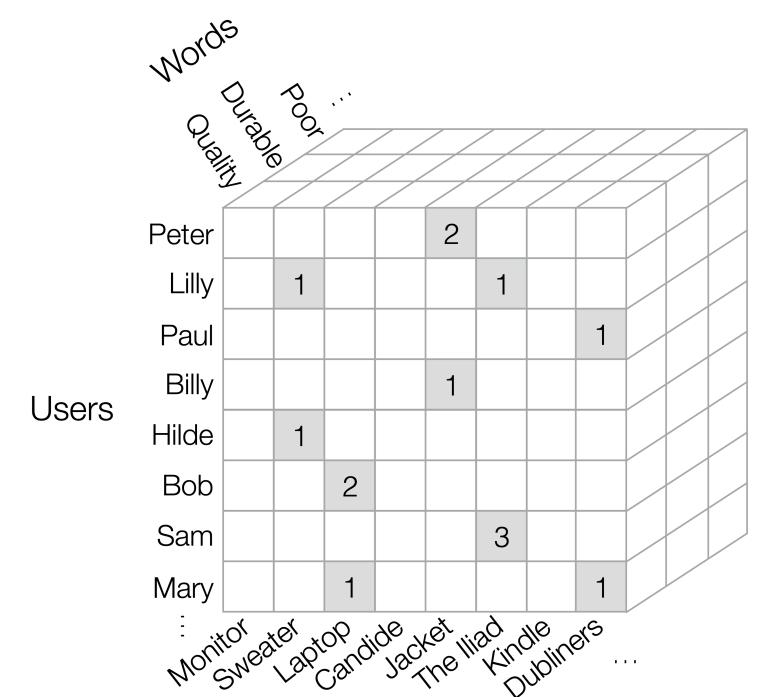
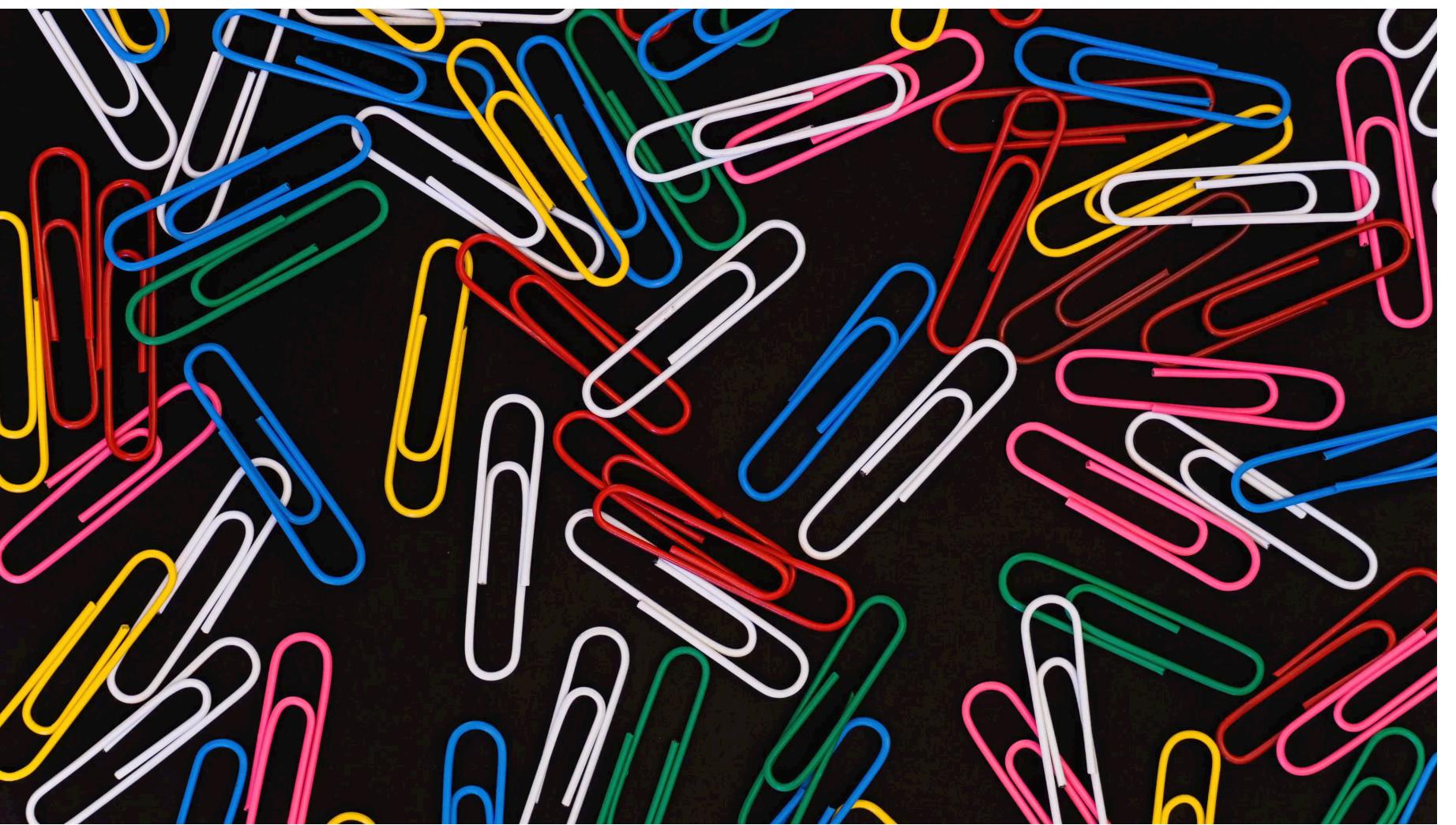
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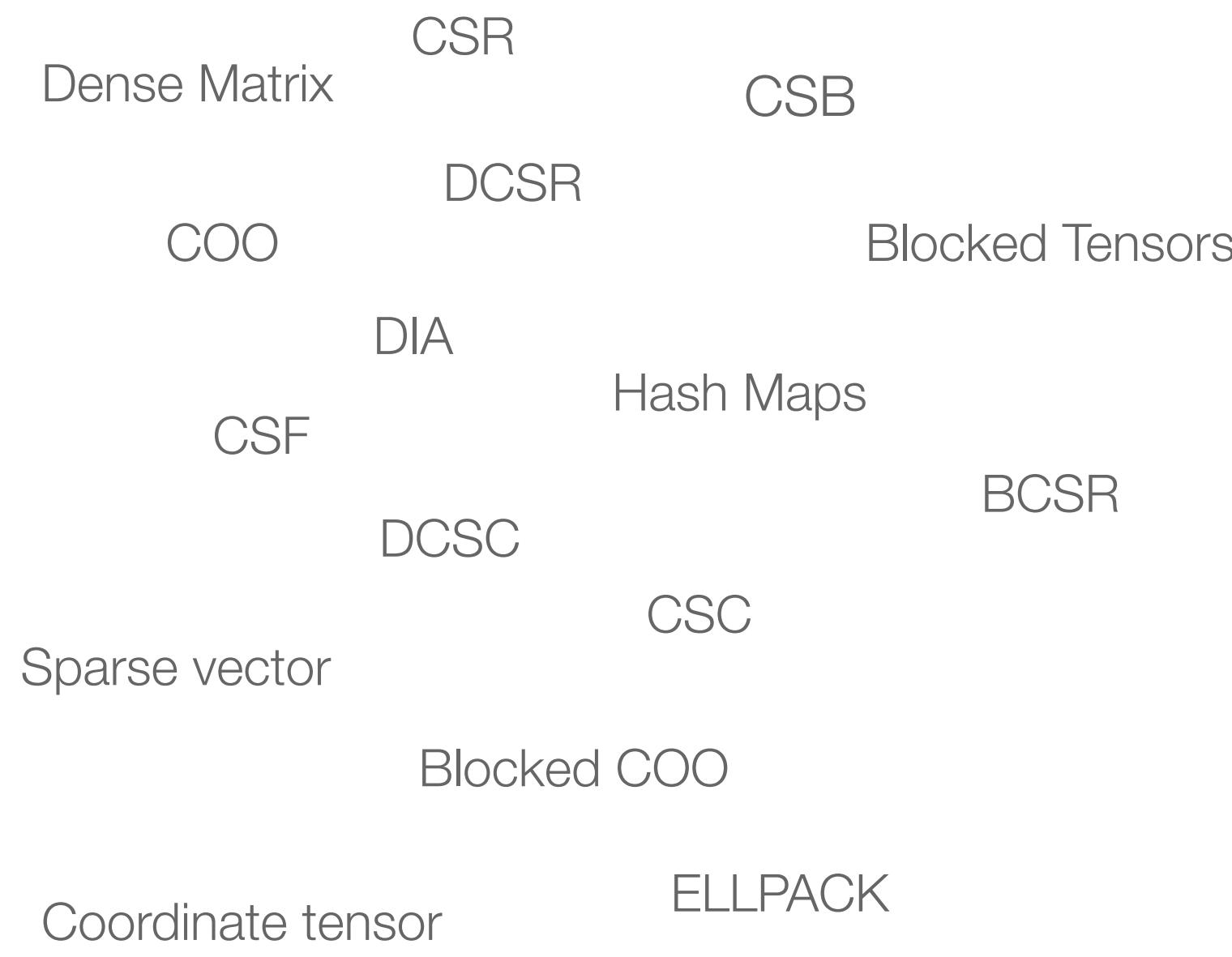


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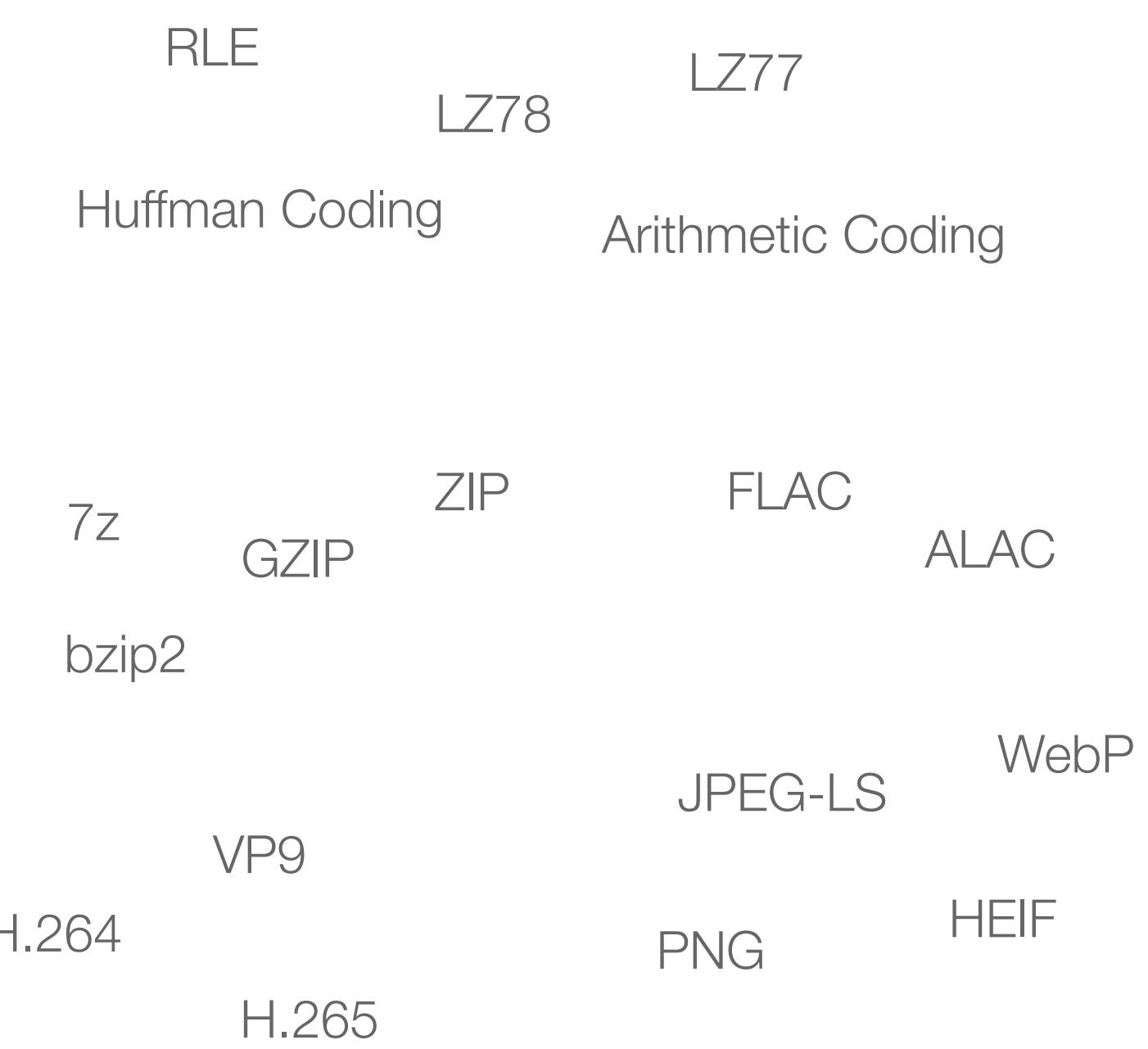
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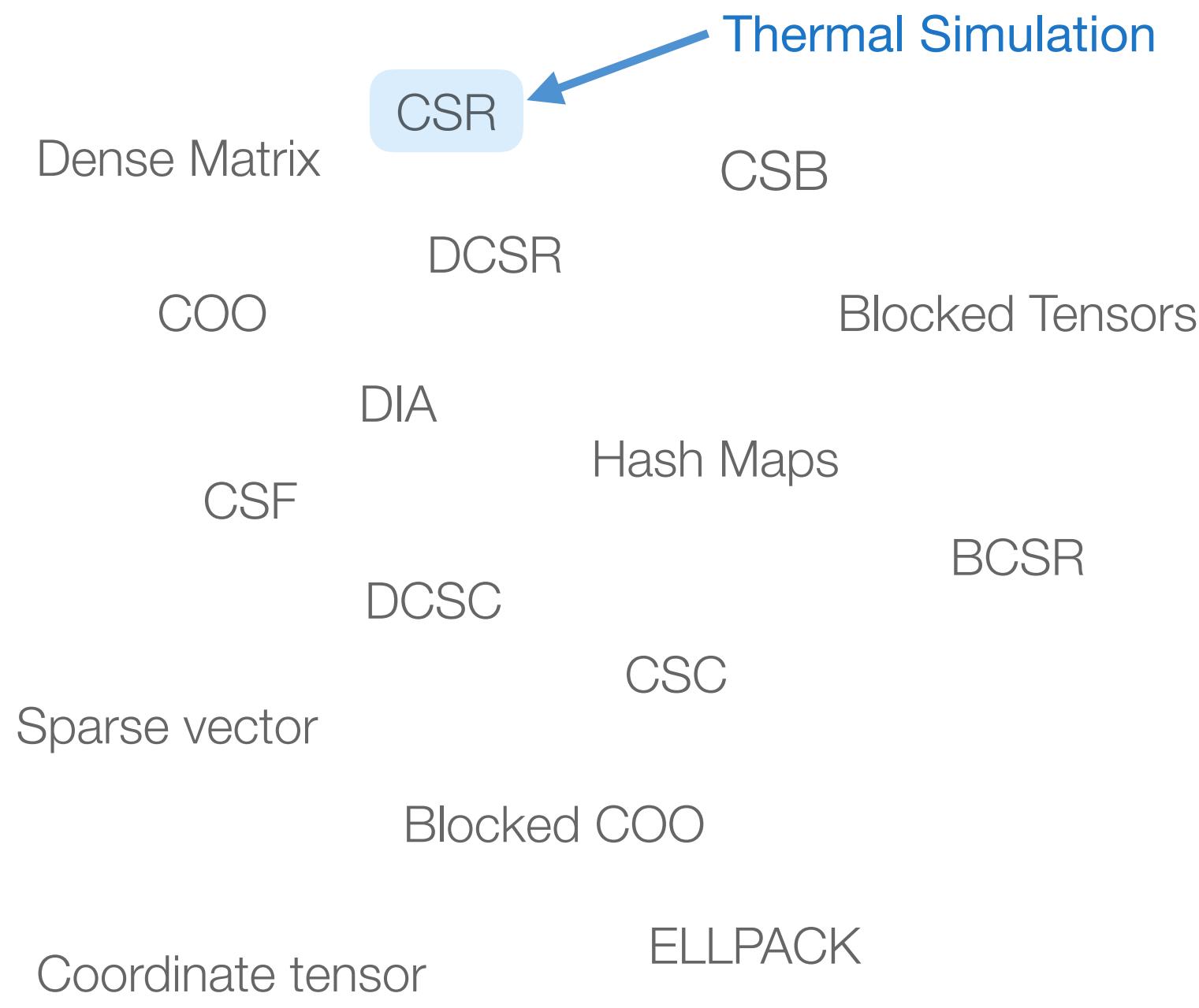
Sparsity



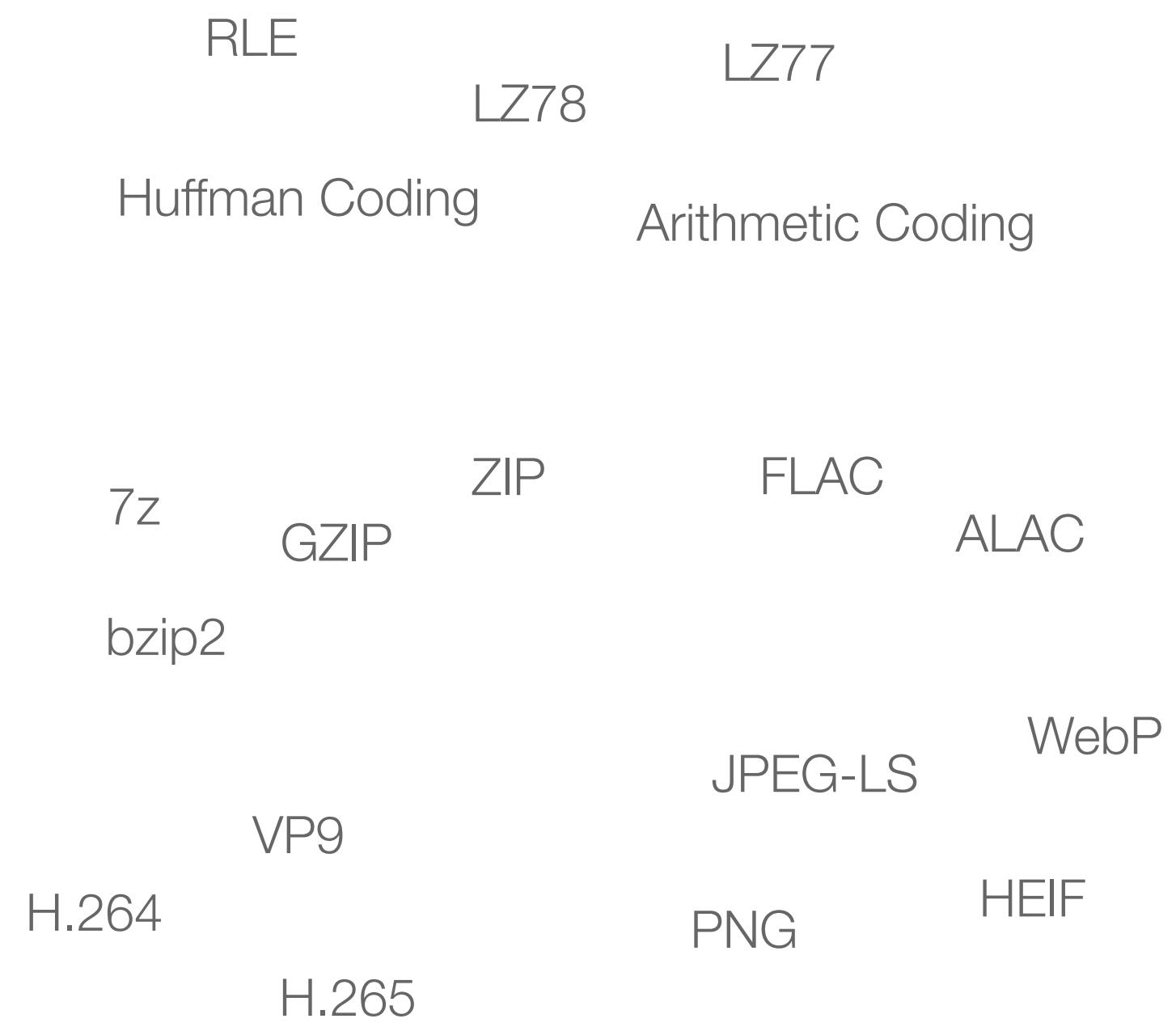
Lossless Compression



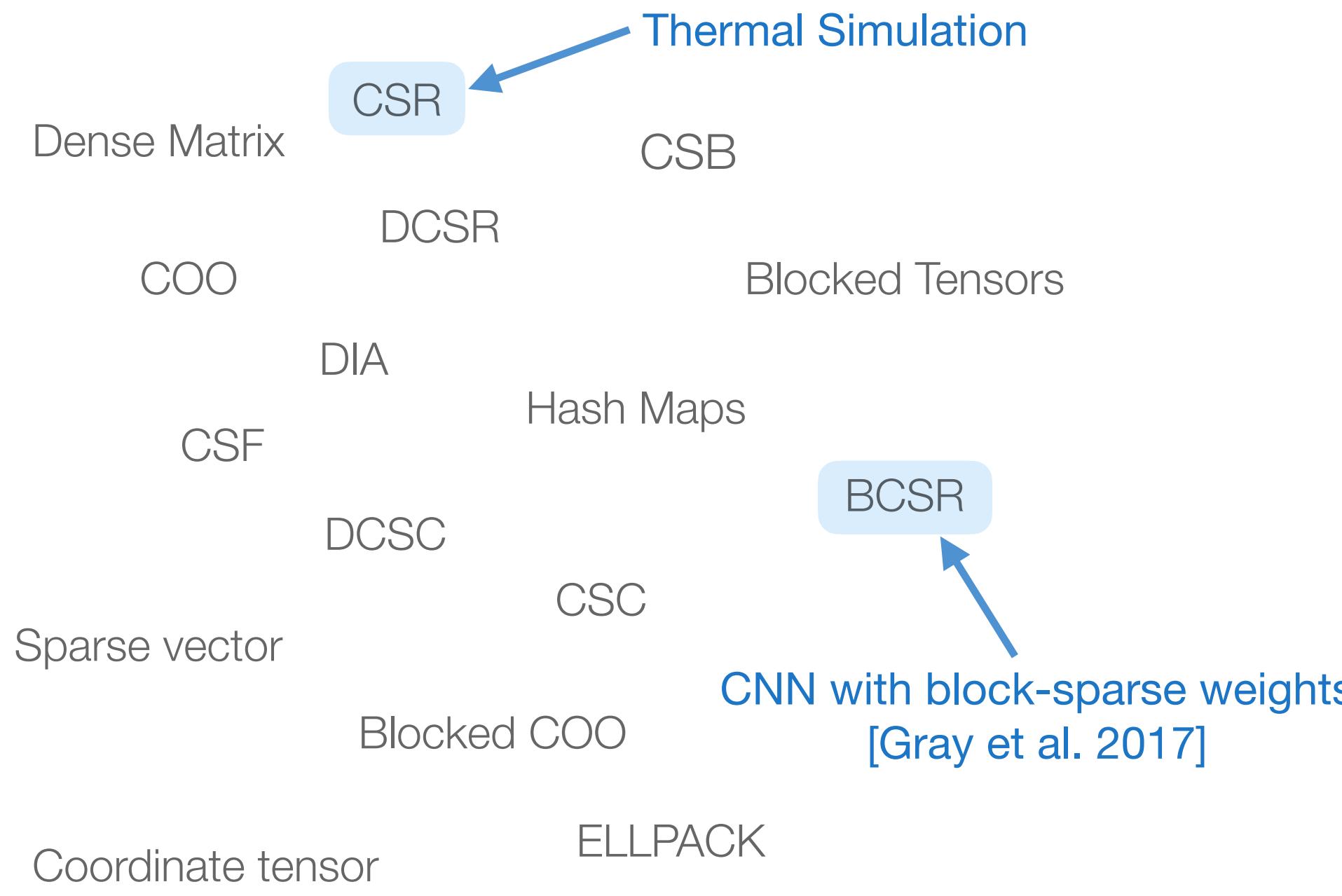
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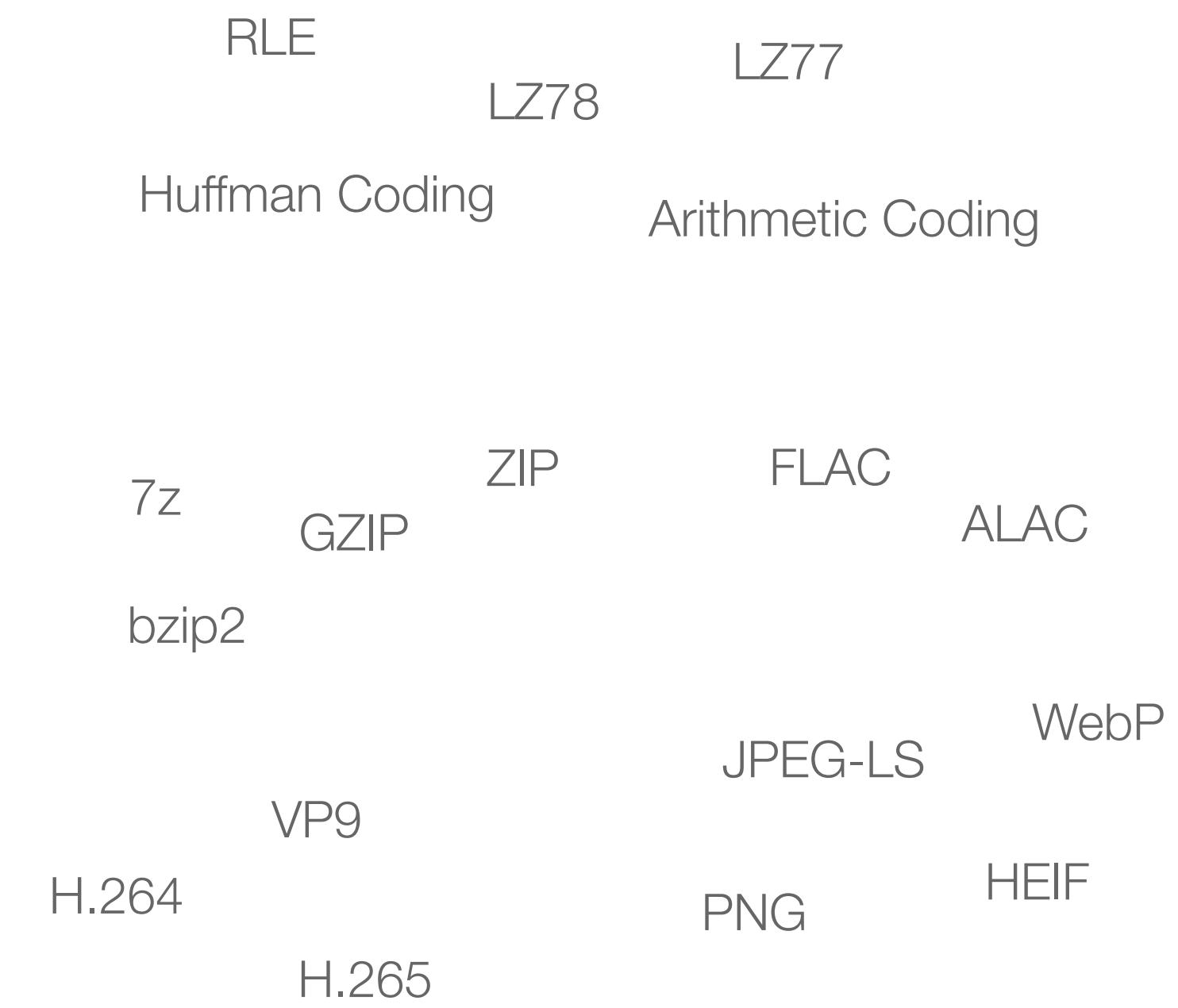
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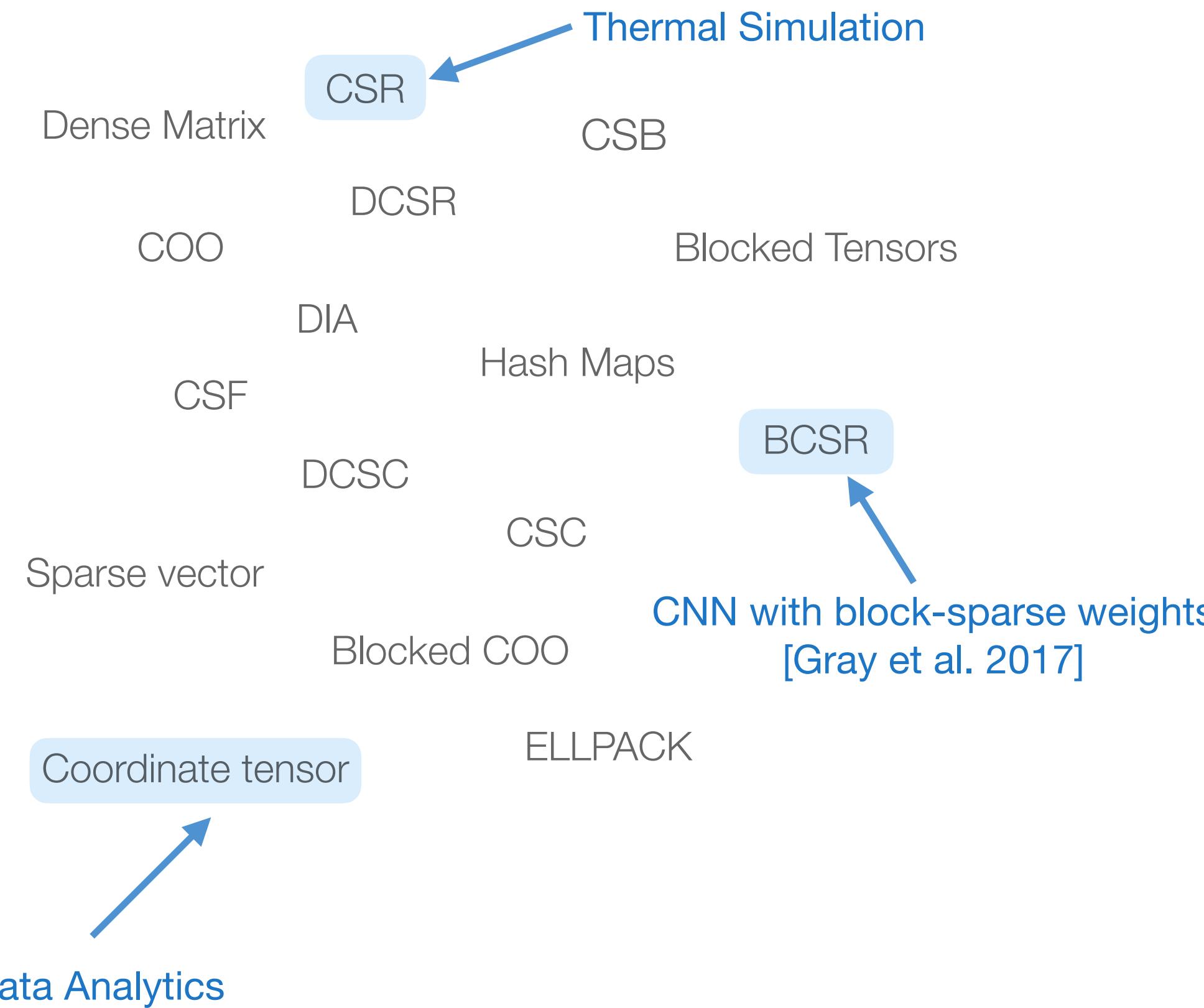
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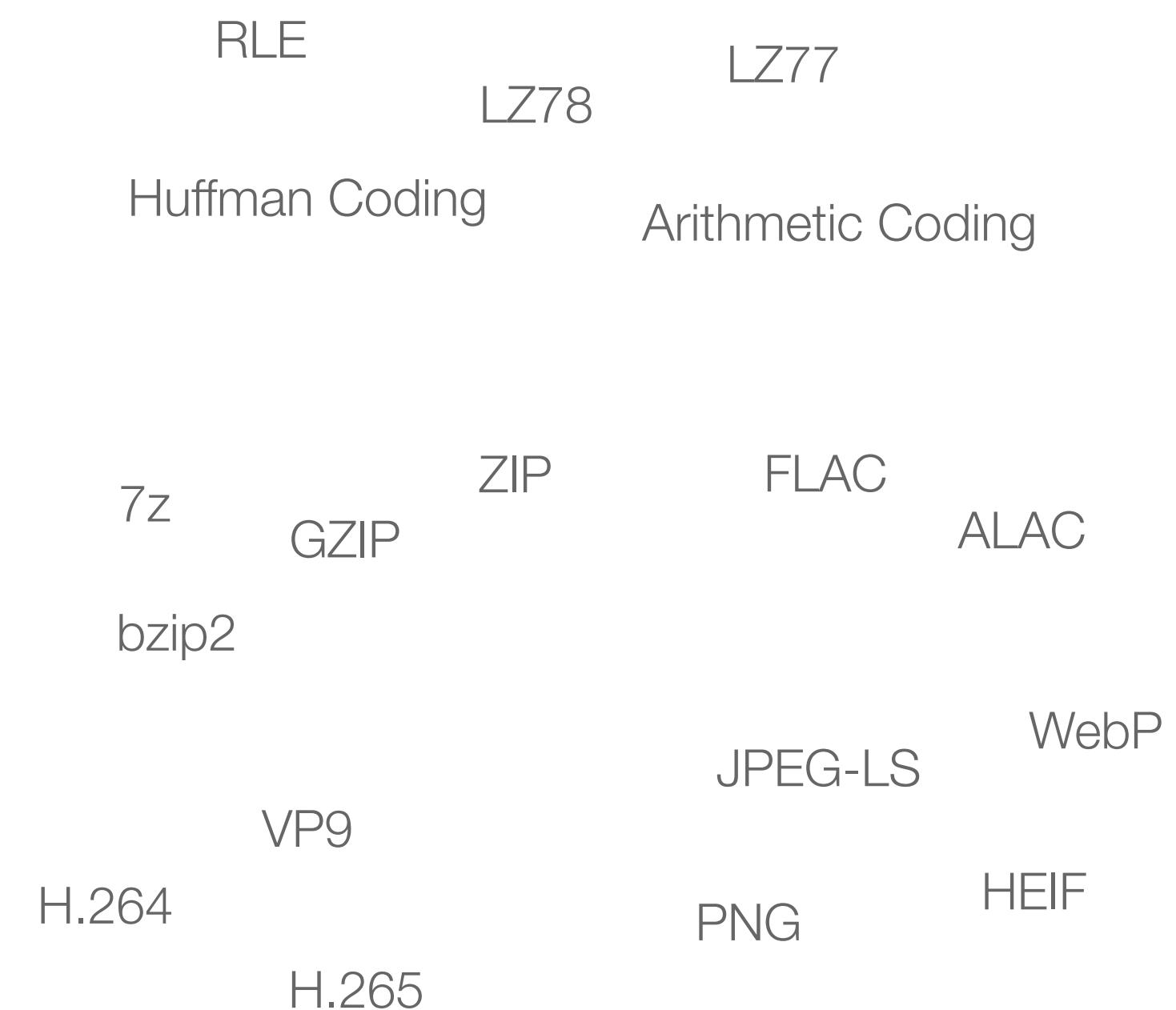
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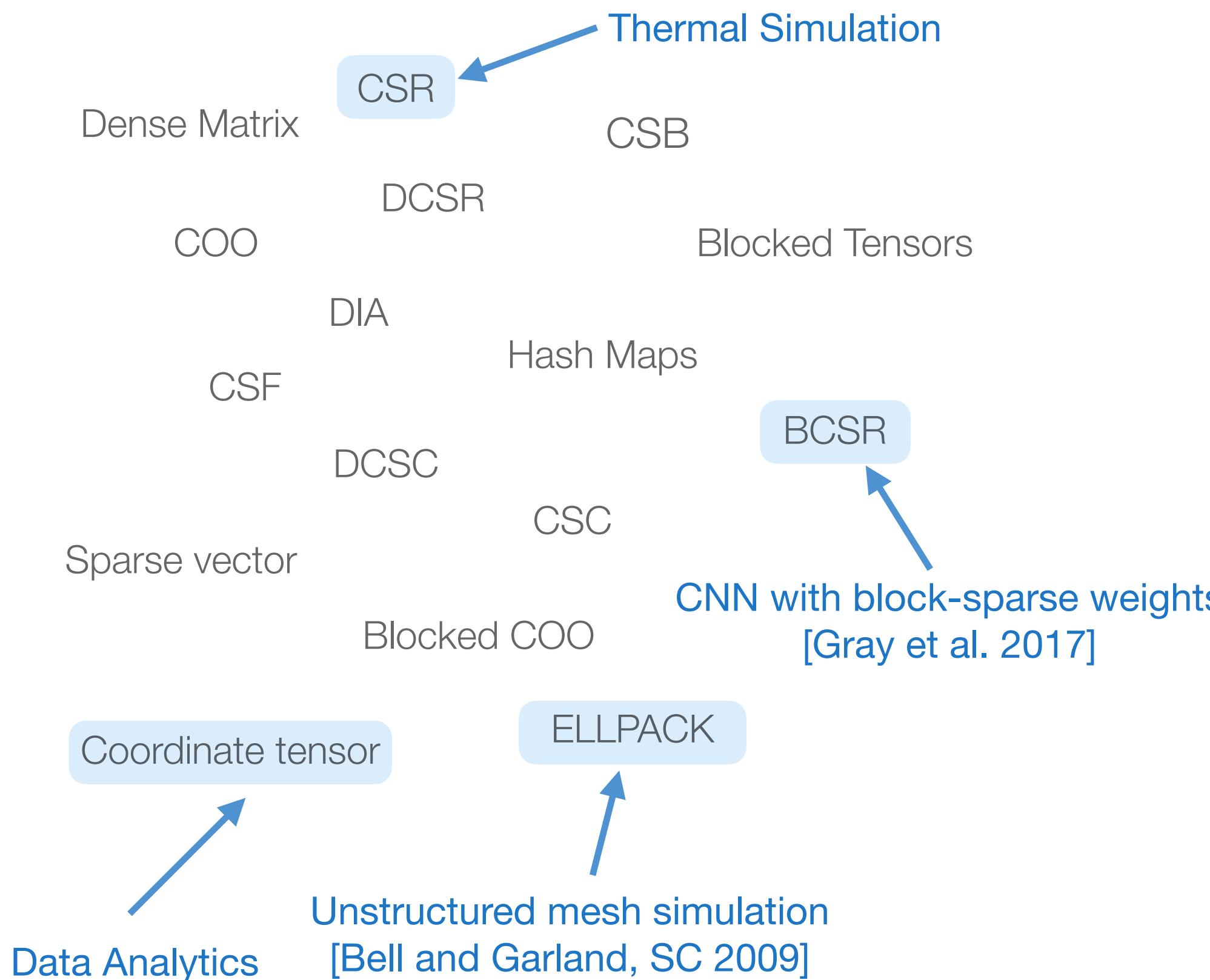
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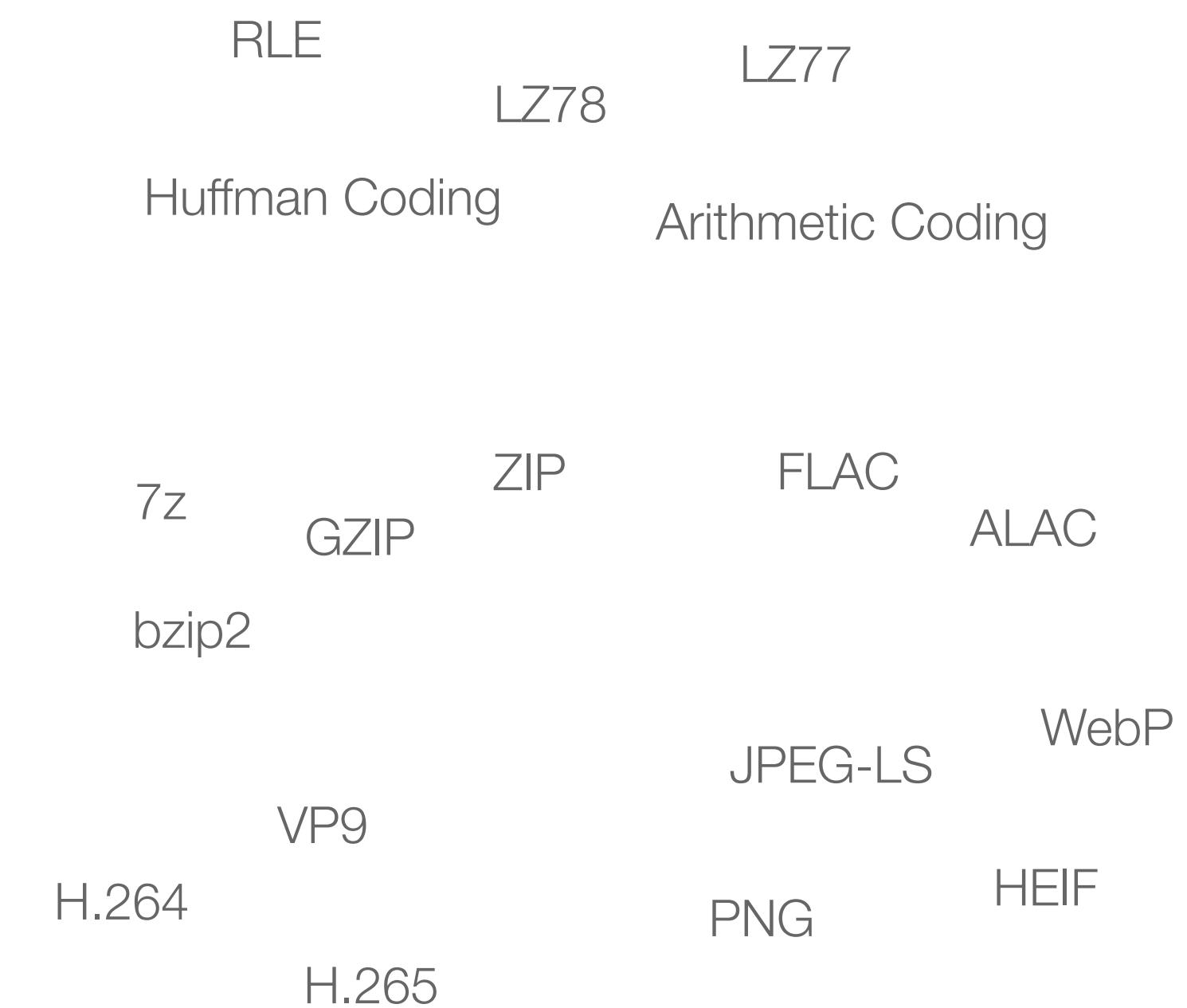
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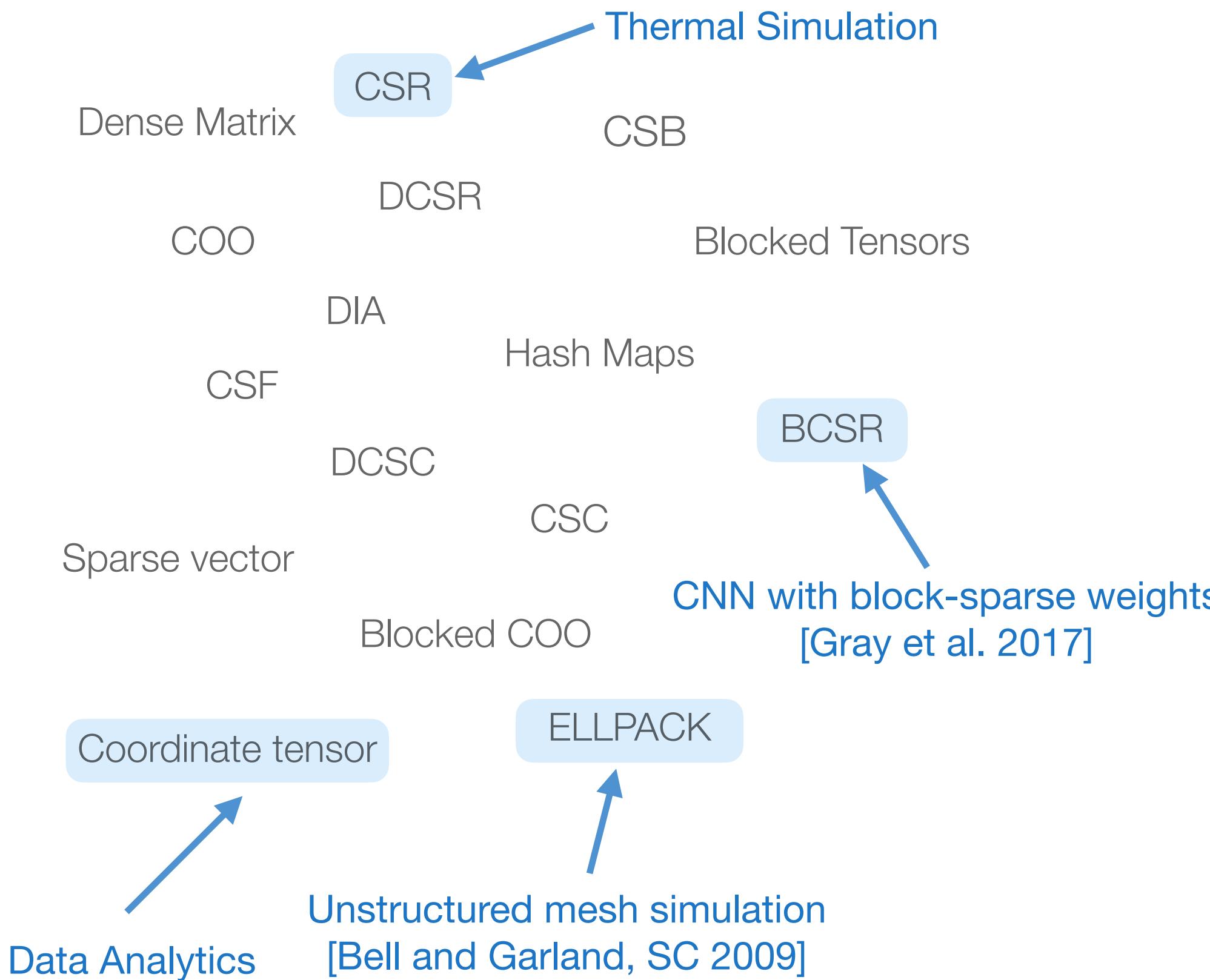
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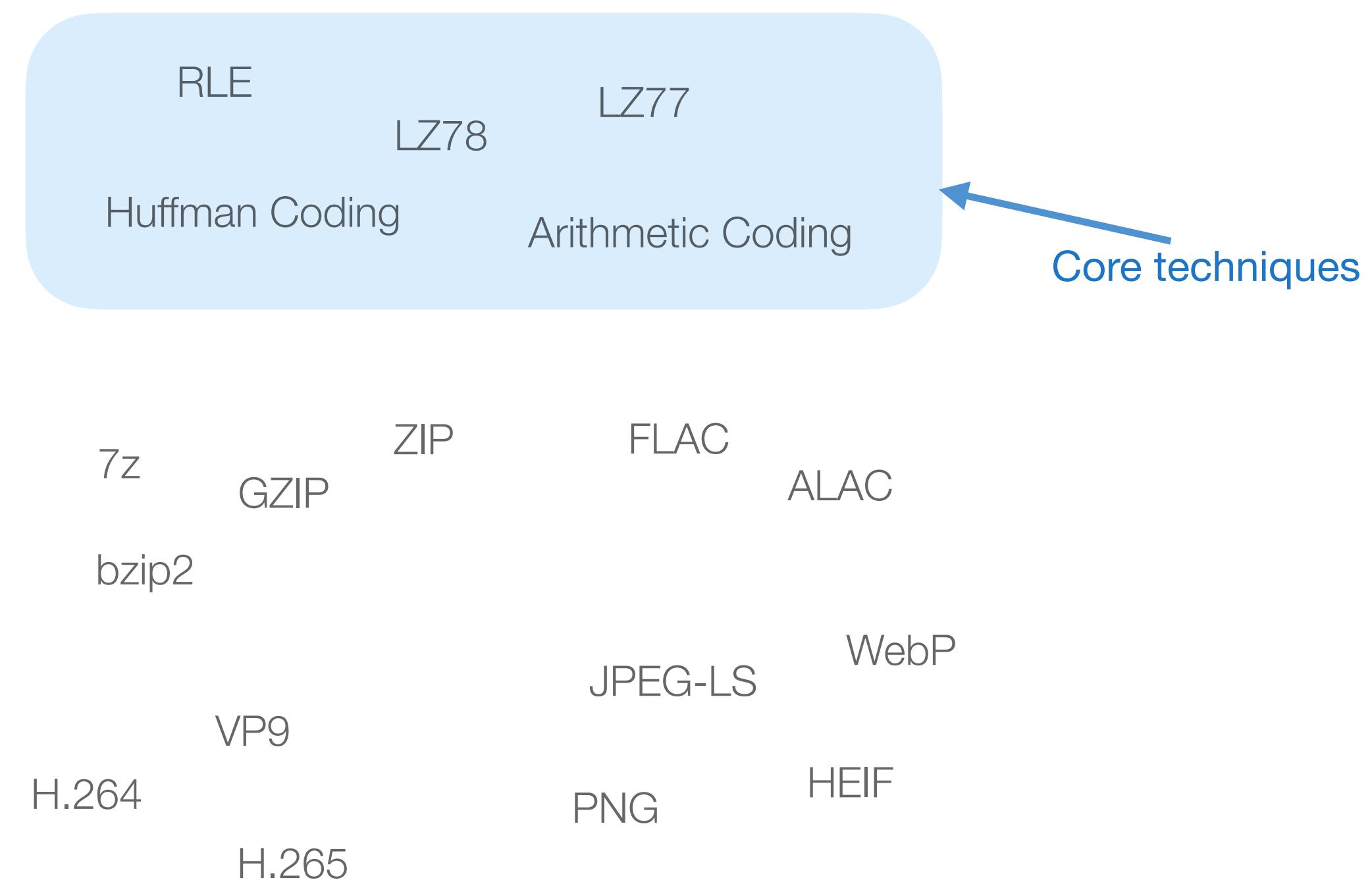
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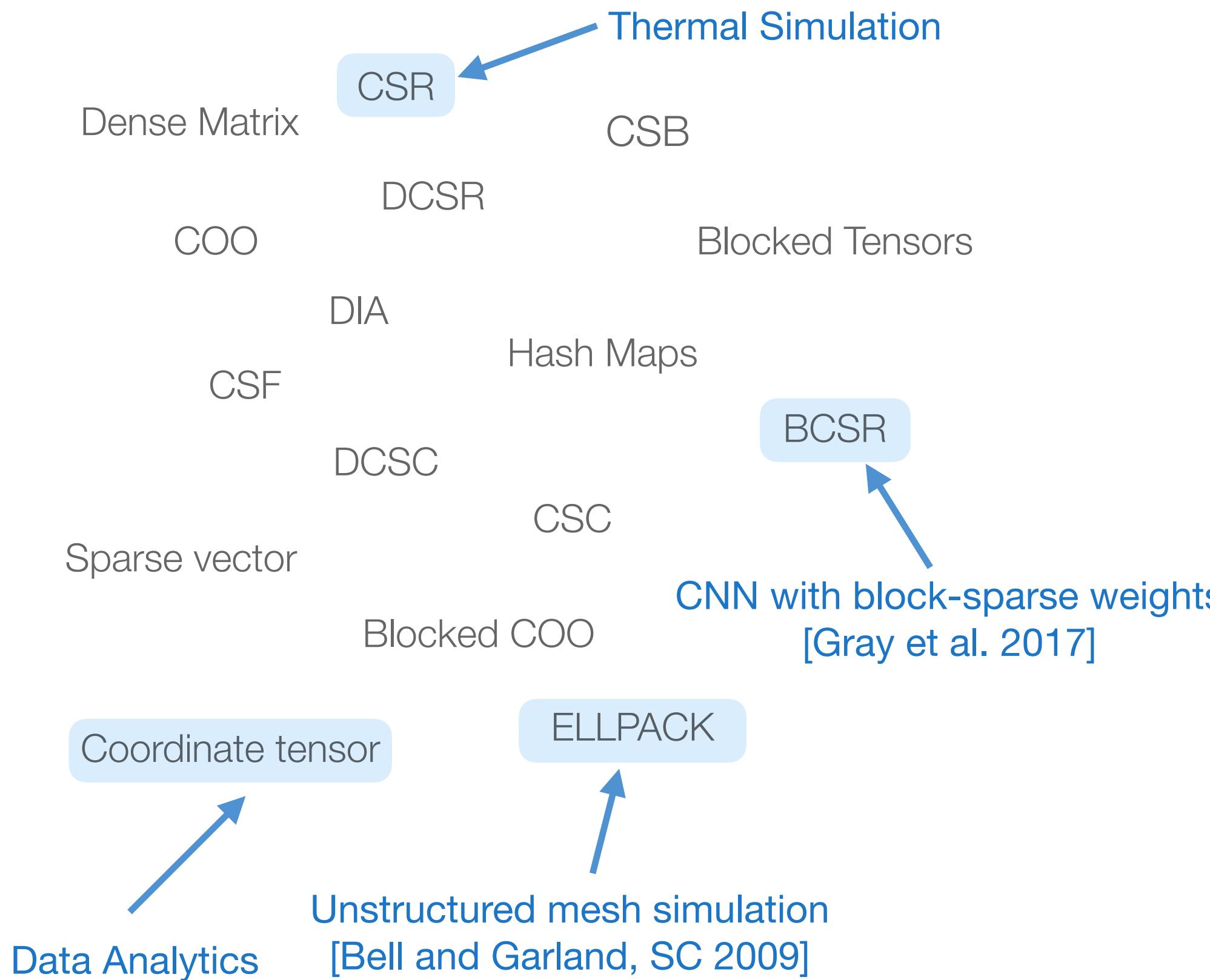
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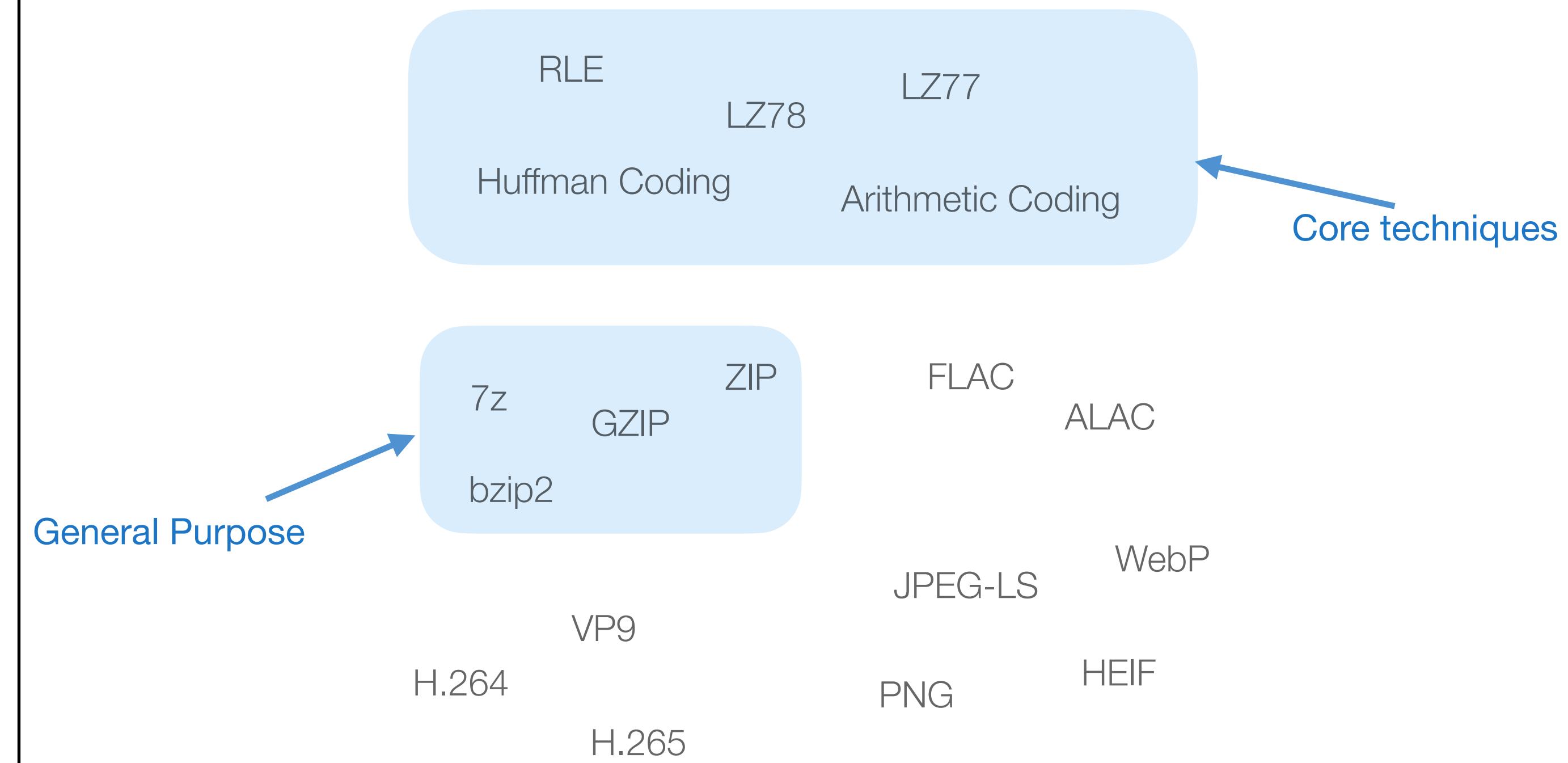
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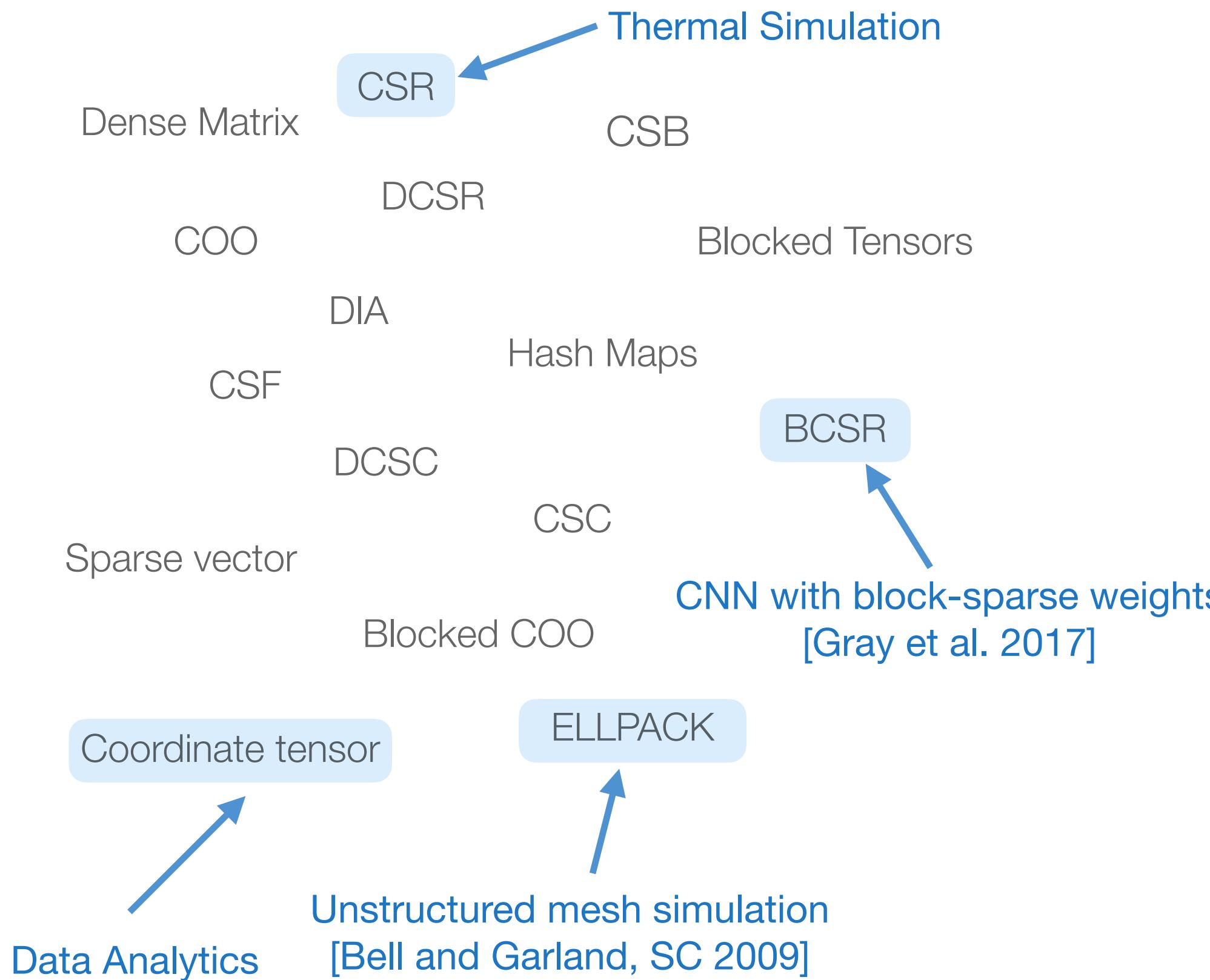
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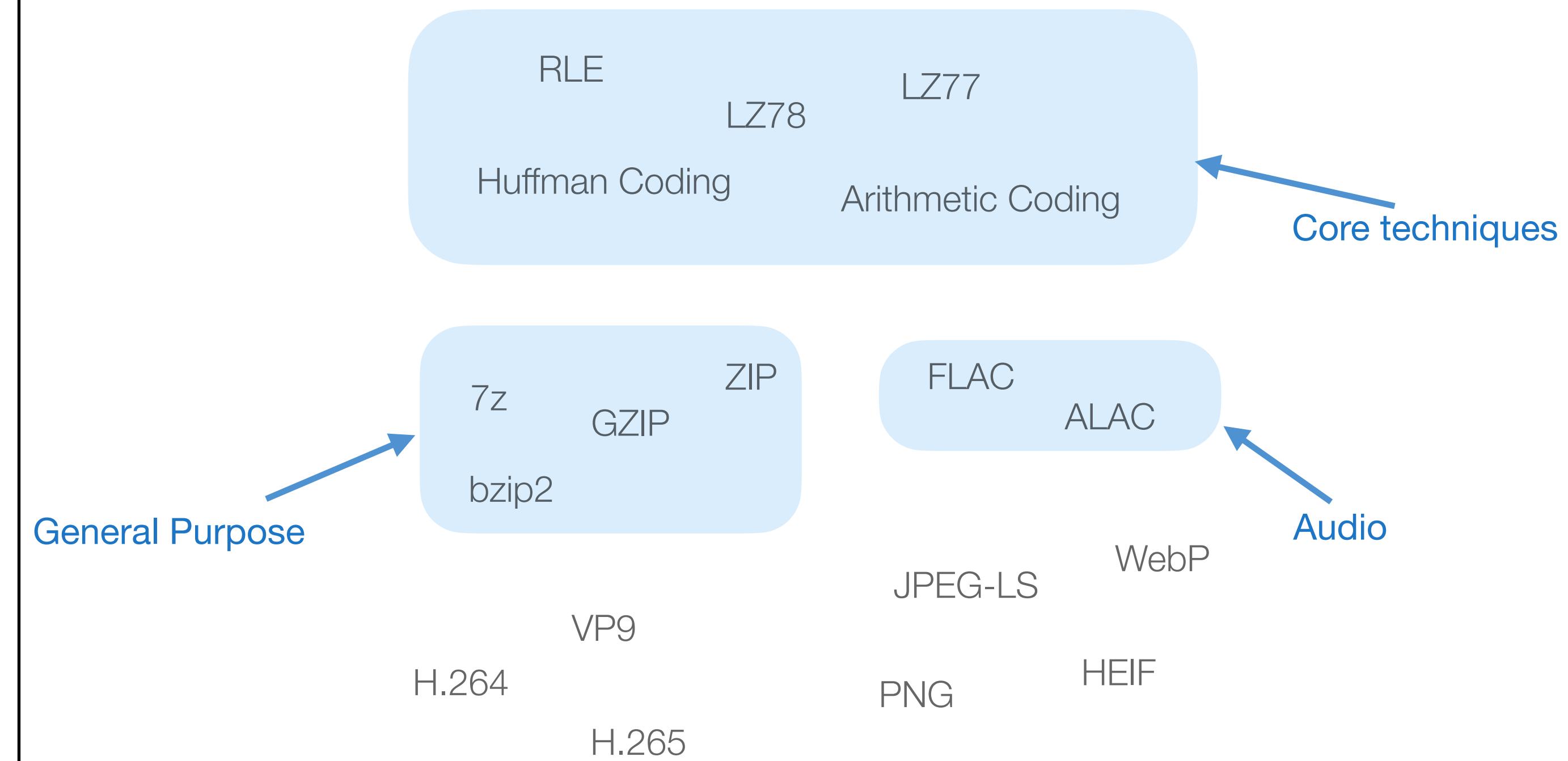
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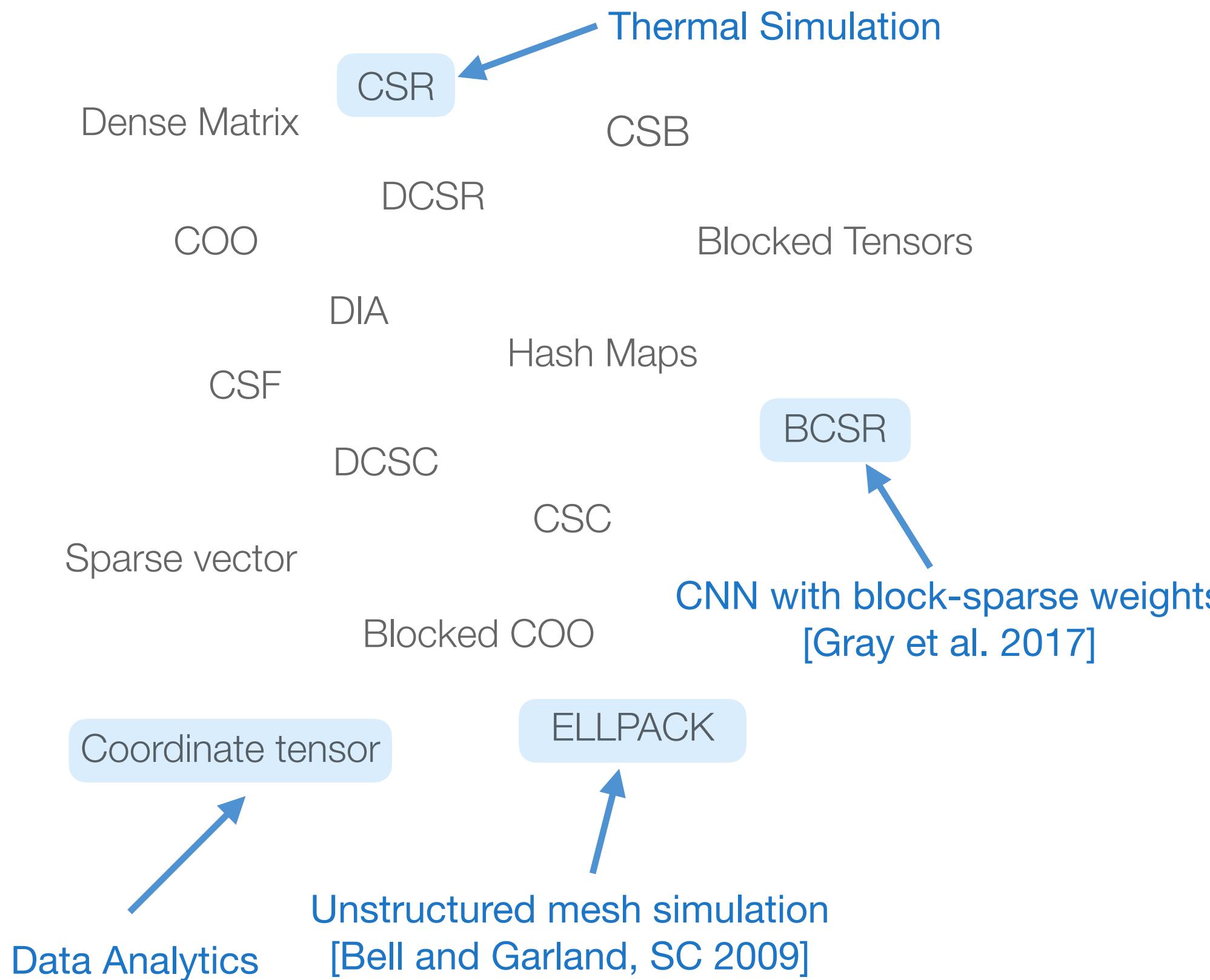
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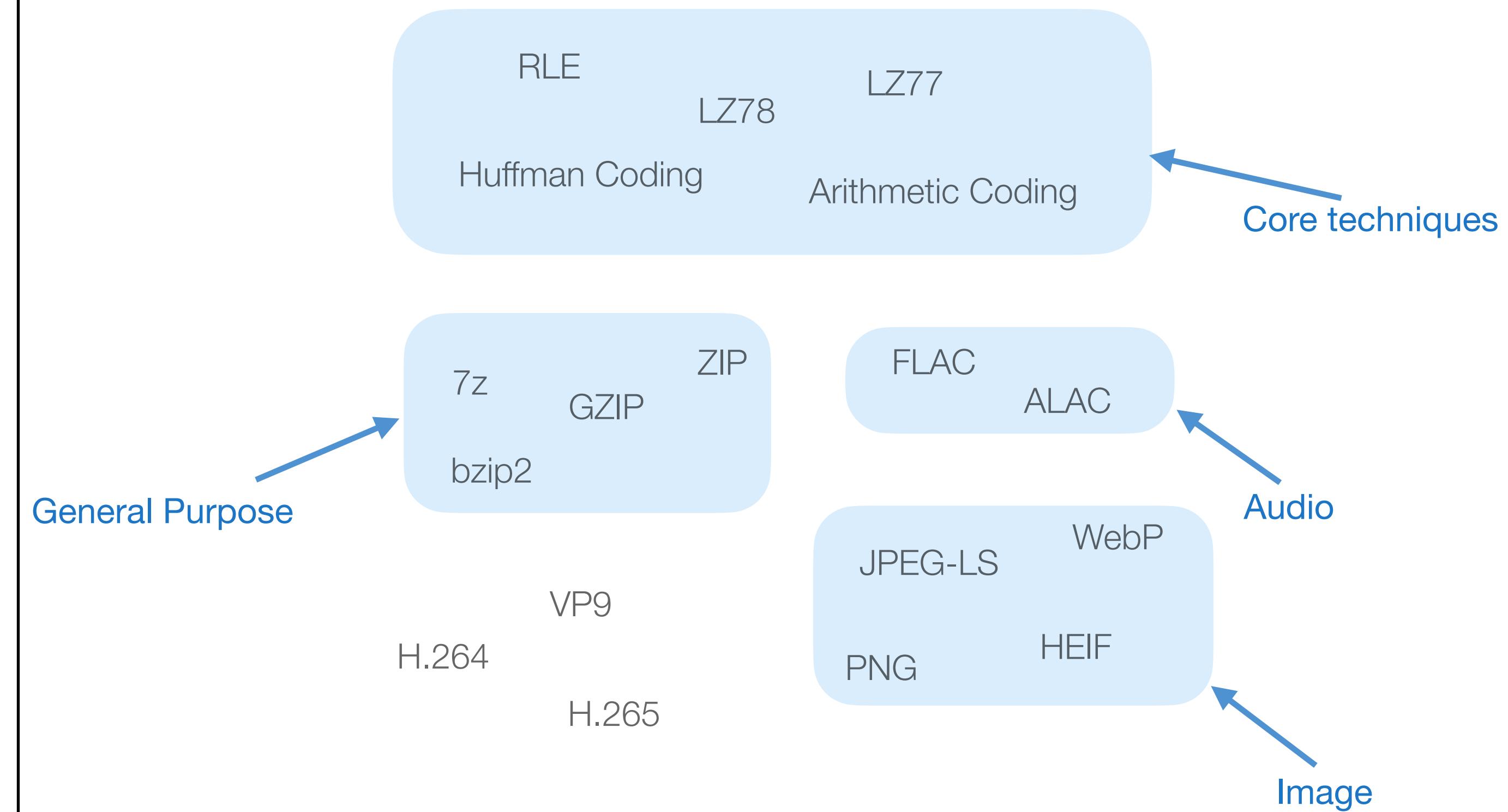
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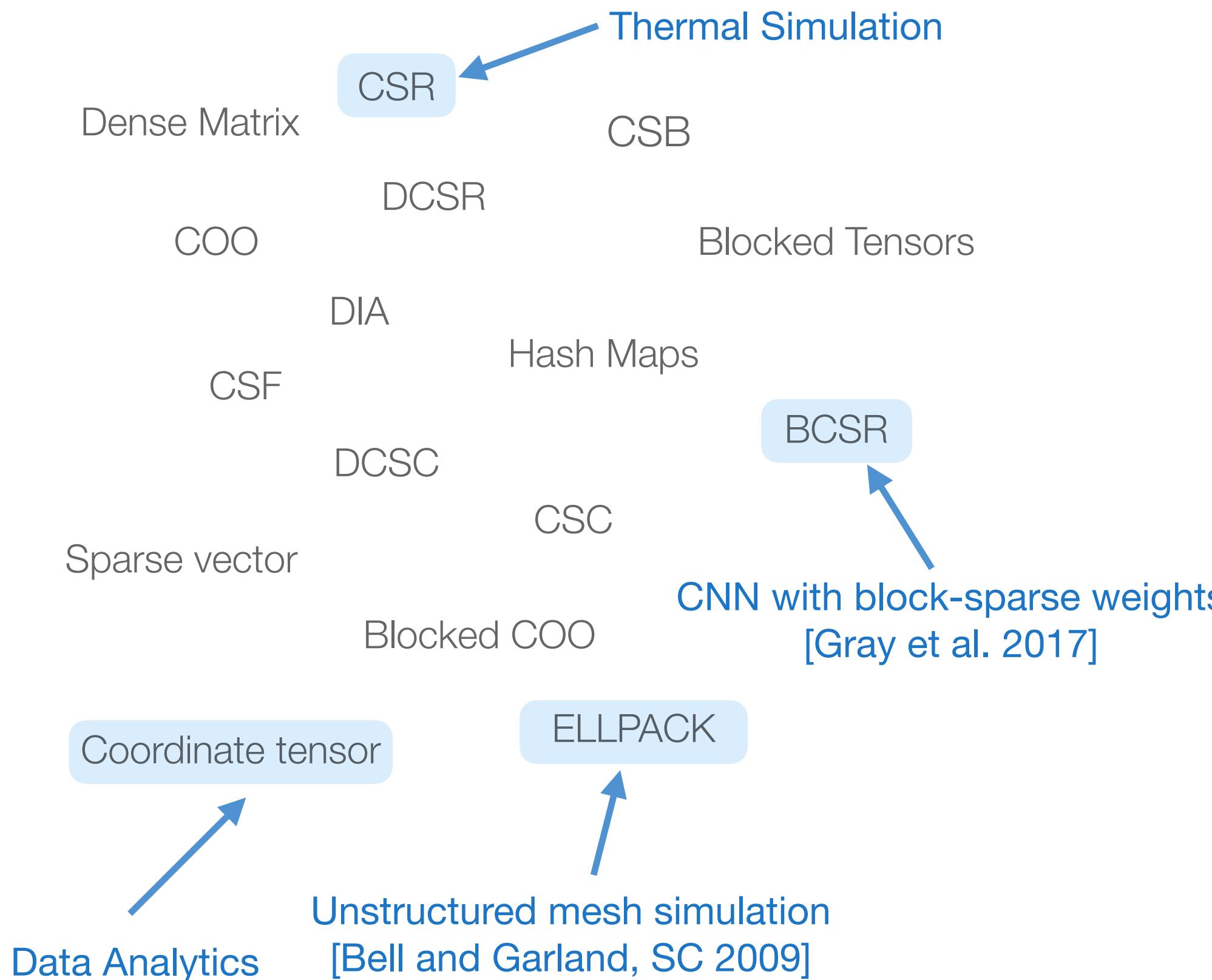
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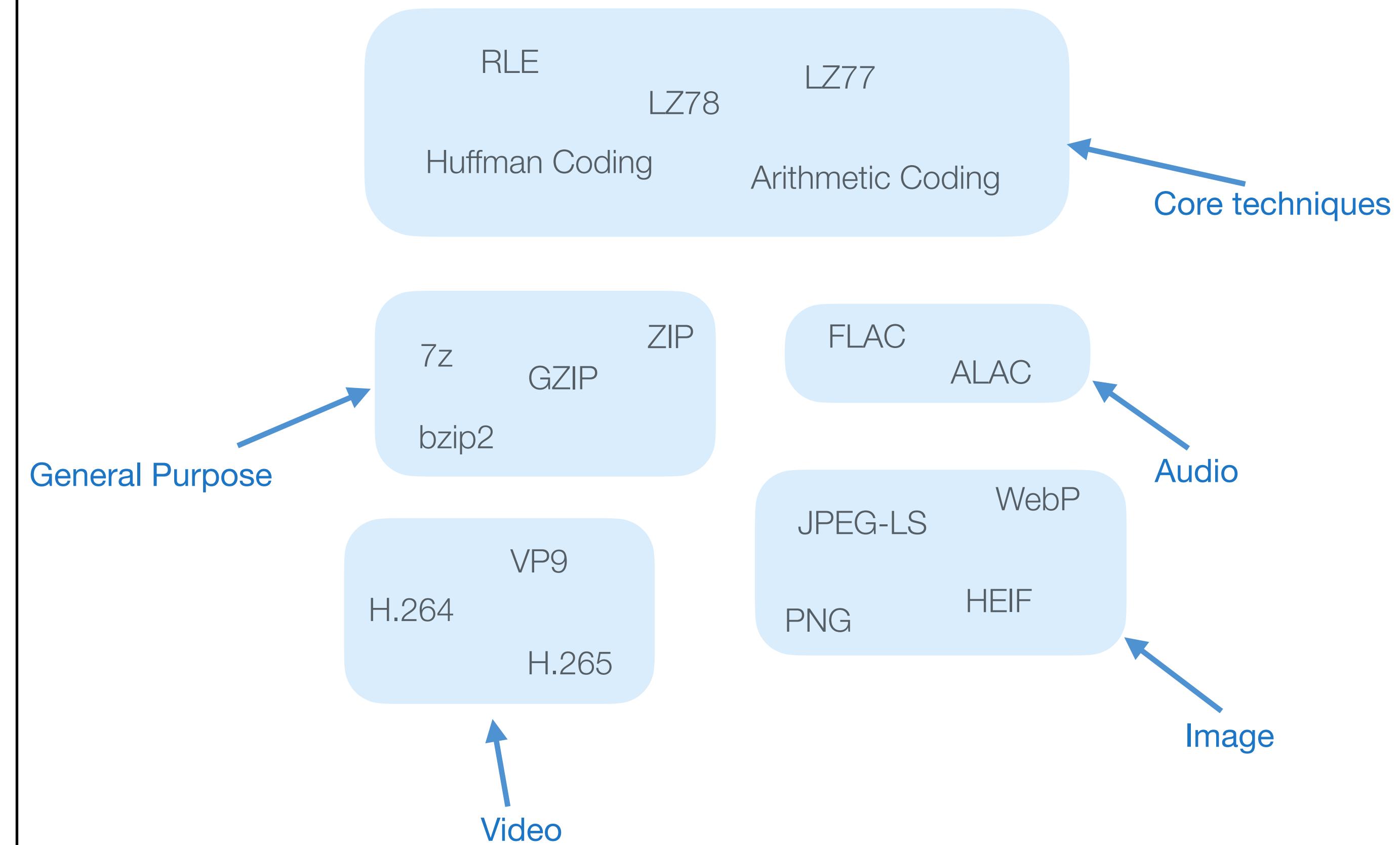
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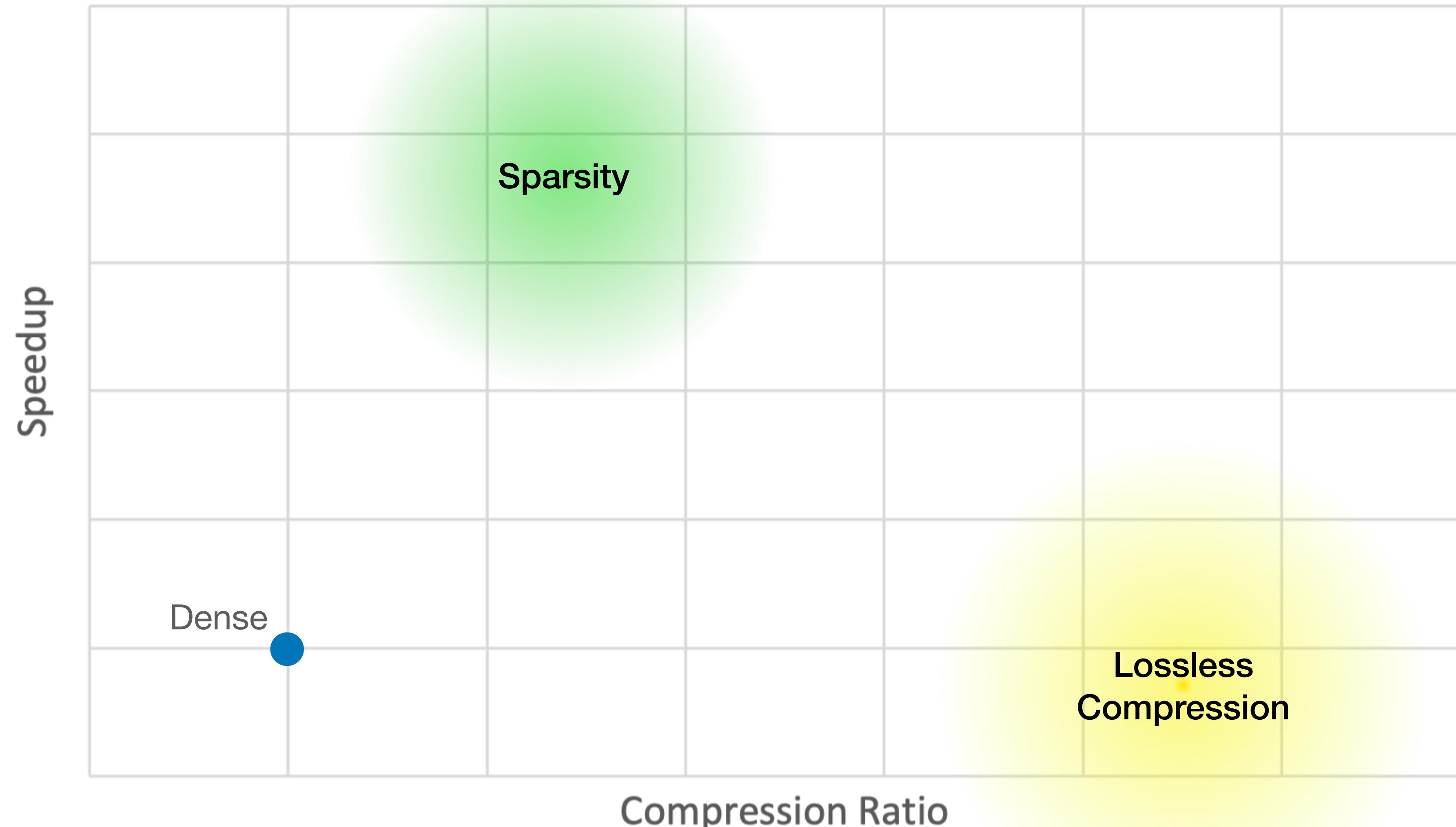
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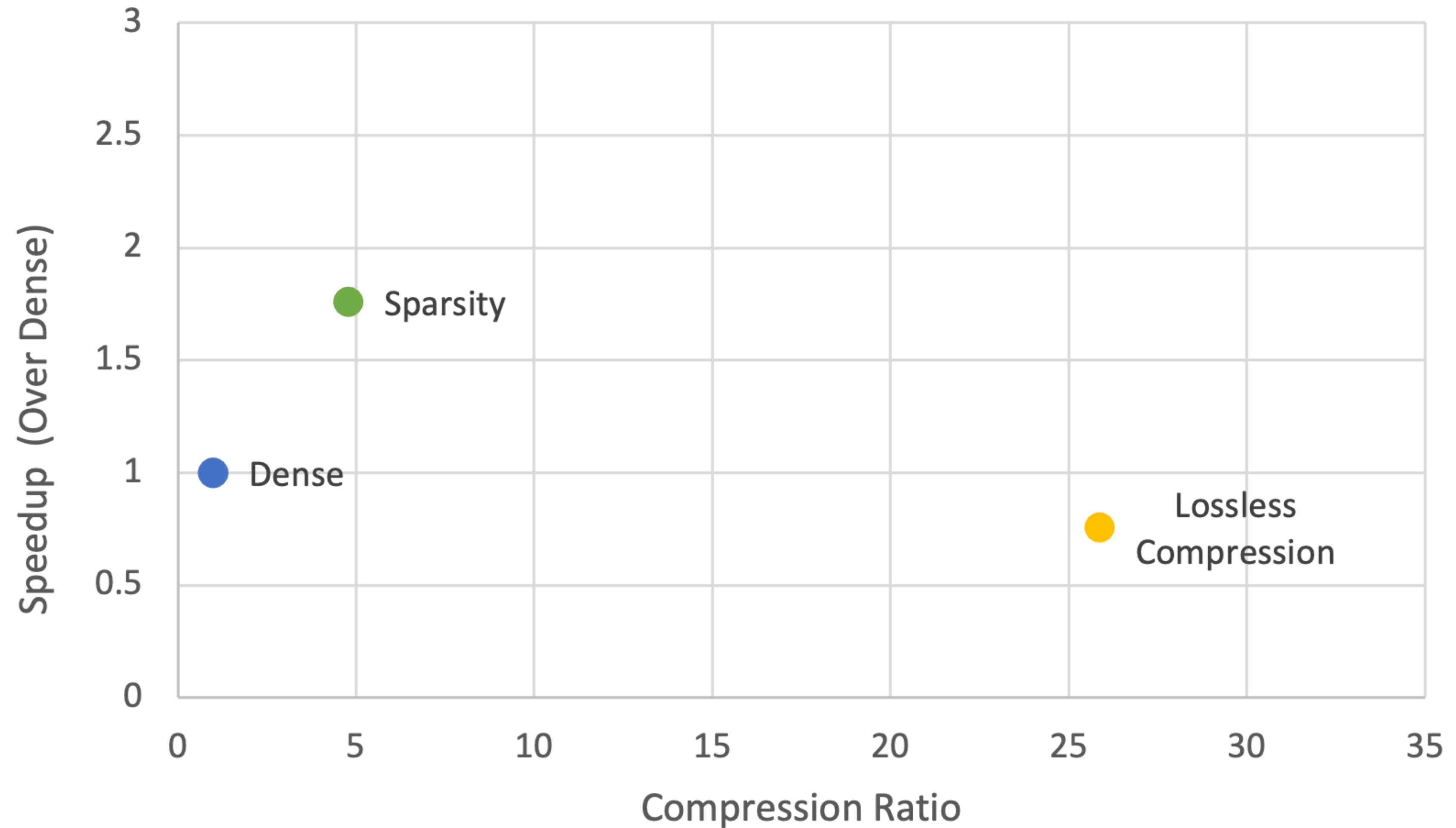


Sparsity and Compression have traditionally had different goals



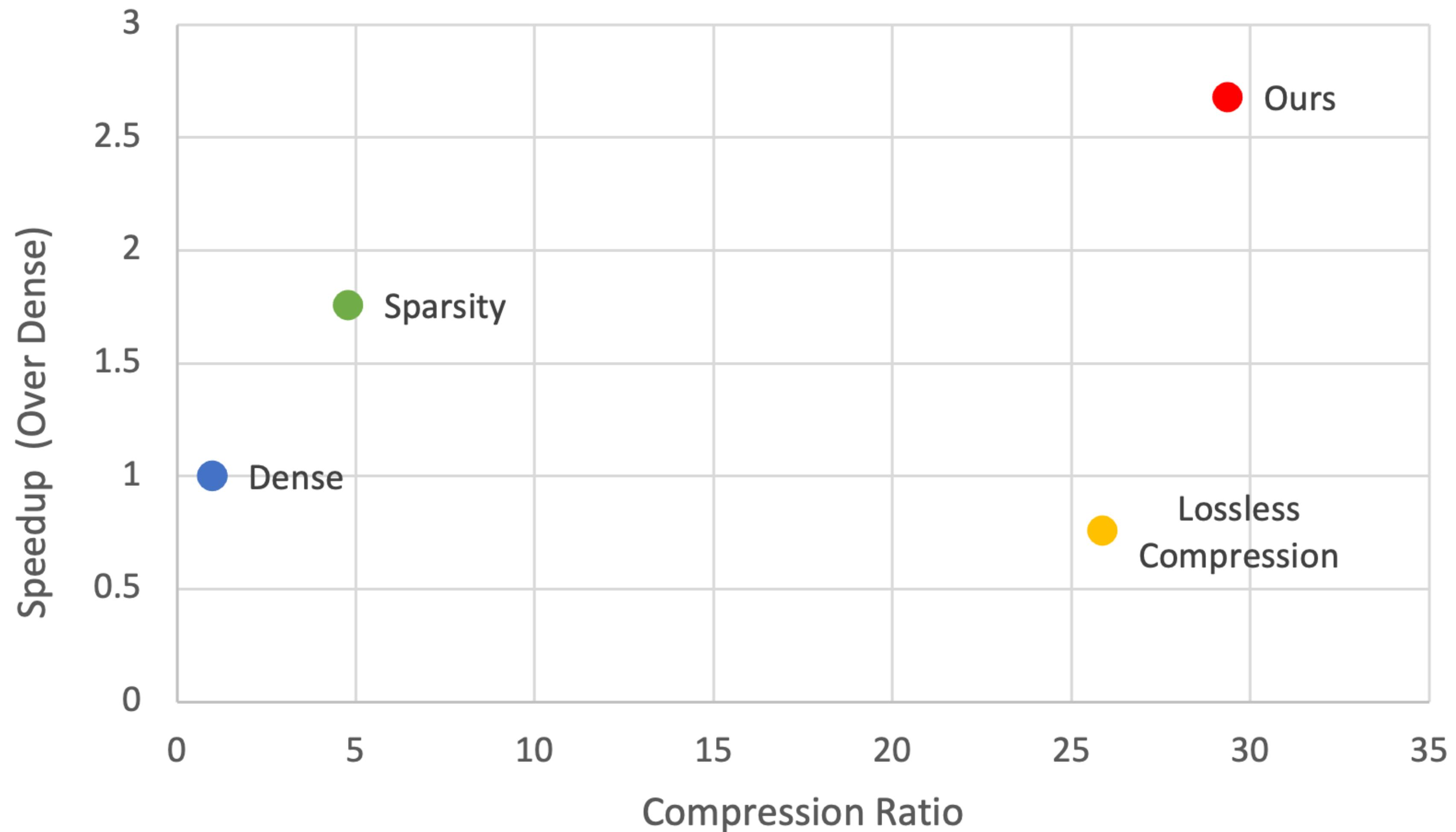
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Edge Detection



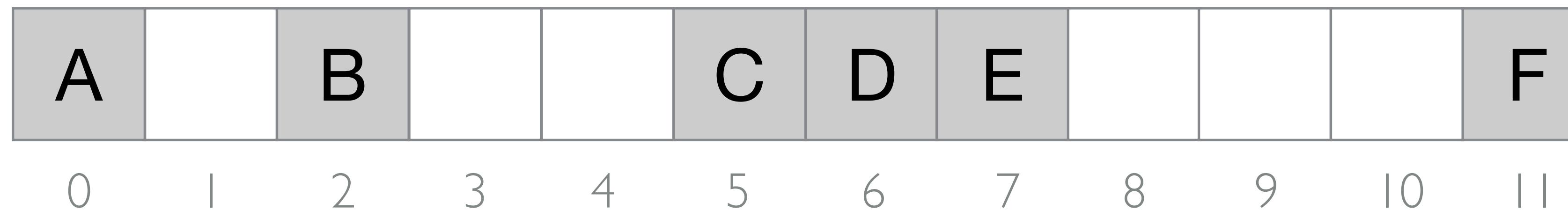
Unifying both can result in the best of both compression and performance

Edge Detection



Sparse tensors can be compressed by adding metadata

0		2	3
0	A	B	
1		C	D
2			E



Sparse tensors can be compressed by adding metadata

A	B	C	D	E	F
0		2	3	4	5

0	A		B	
1		C	D	E
2				F

Sparse tensors can be compressed by adding metadata

row(3) = ???

col(3) = ???



0	1	2	3
A		B	
	C	D	E
			F

Sparse tensors can be compressed by adding metadata

Coordinate

	Coordinate					
rows	0	0	1	1	1	2
cols	0	2	1	2	3	3
	A	B	C	D	E	F

0 | 2 | 1 | 2 | 4 | 5

3

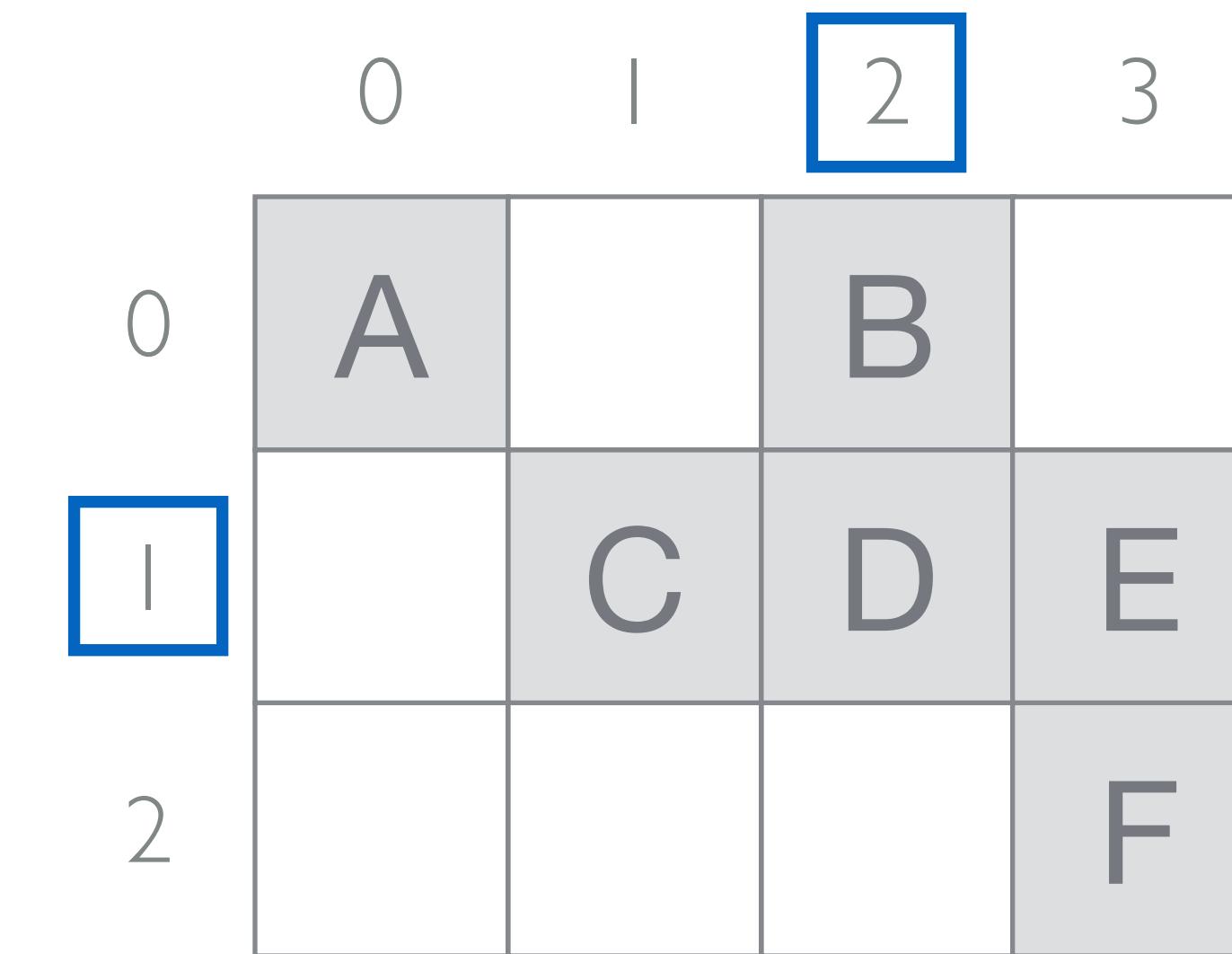
0	A	B		
1		C	D	E
2				F

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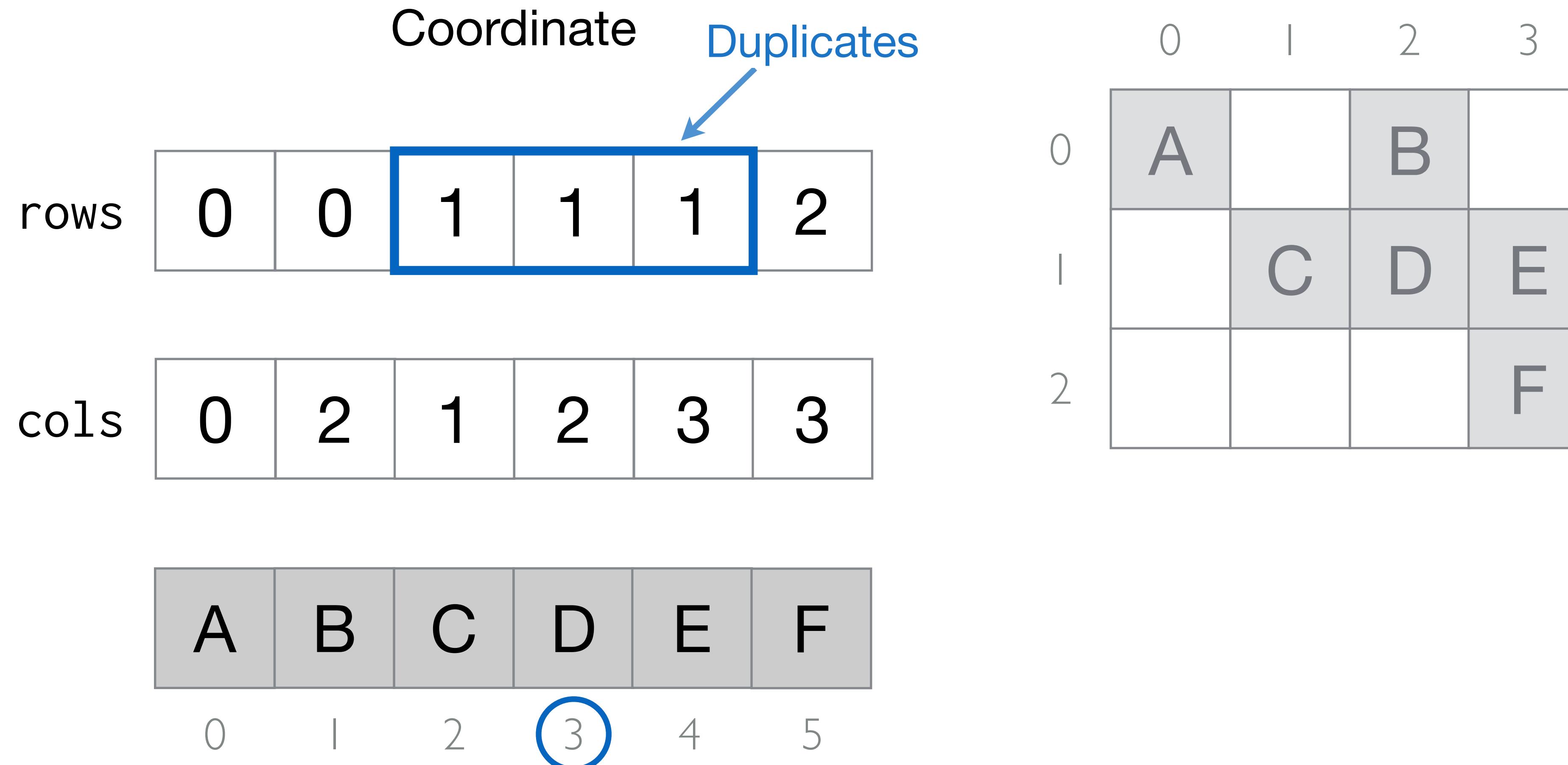
Coordinate

	rows					
	0	0	1	1	1	2
cols	0	2	1	2	3	3

	cols					
	A	B	C	D	E	F
rows	0	1	2	3	4	5

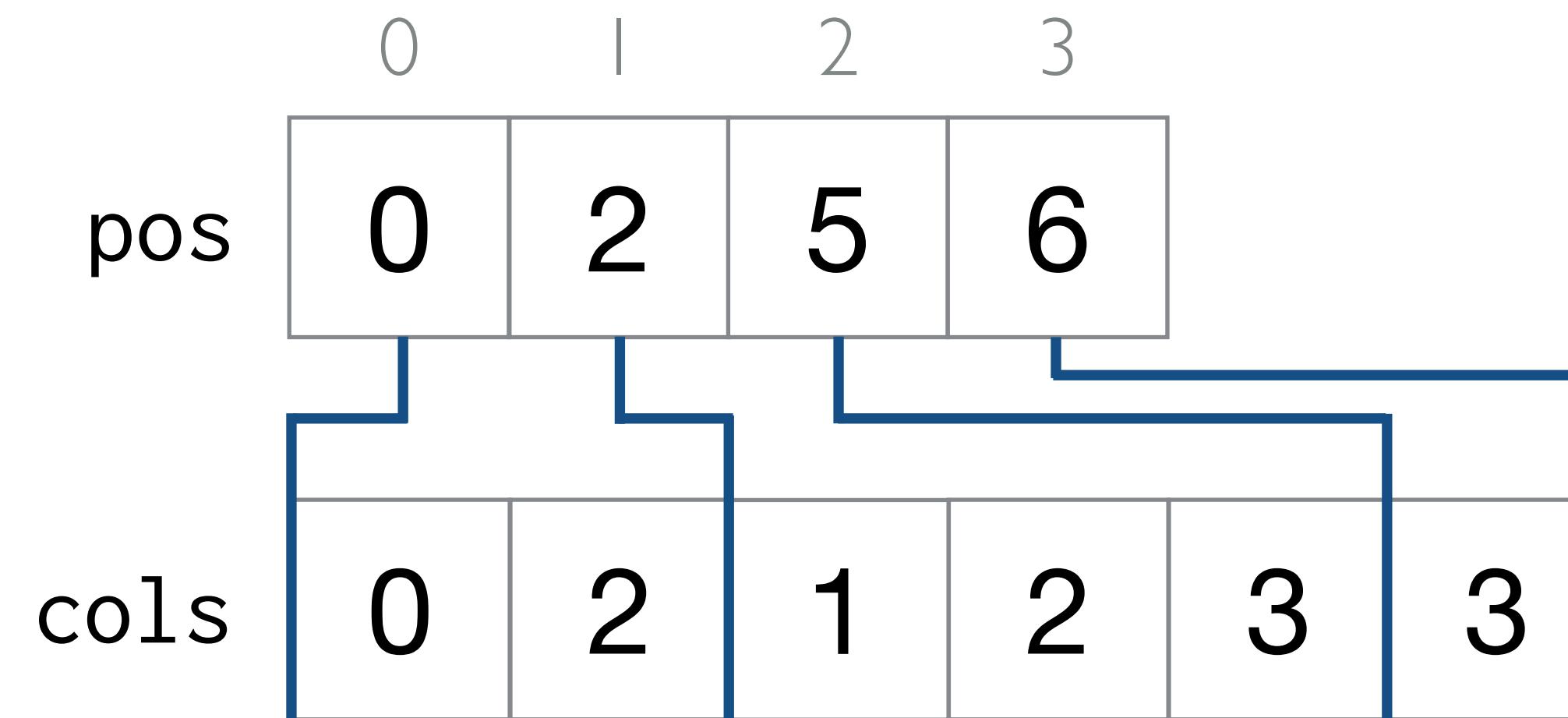


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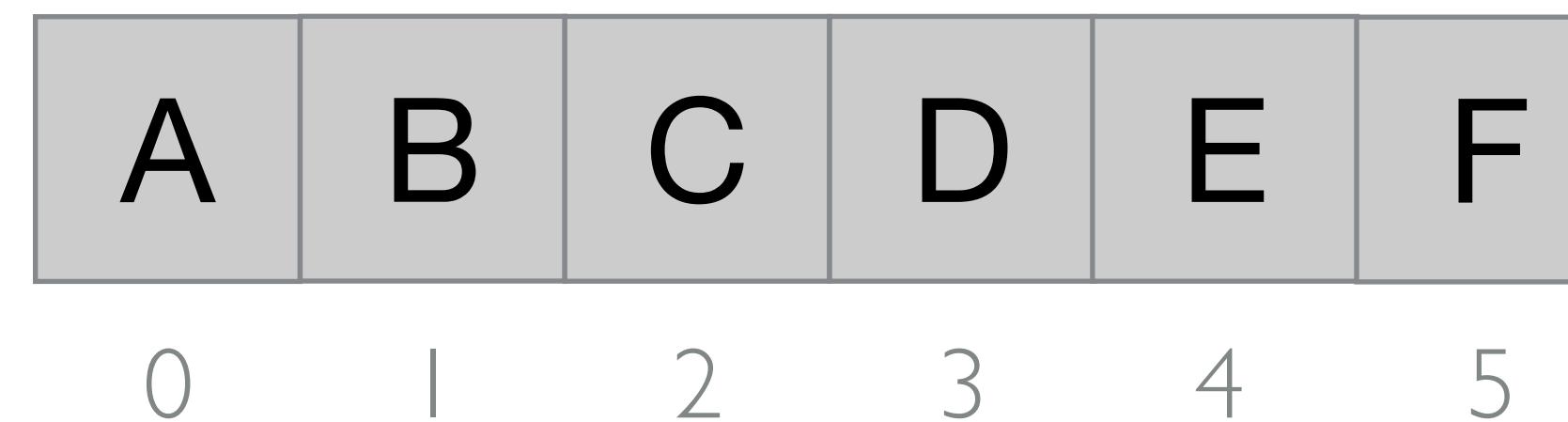


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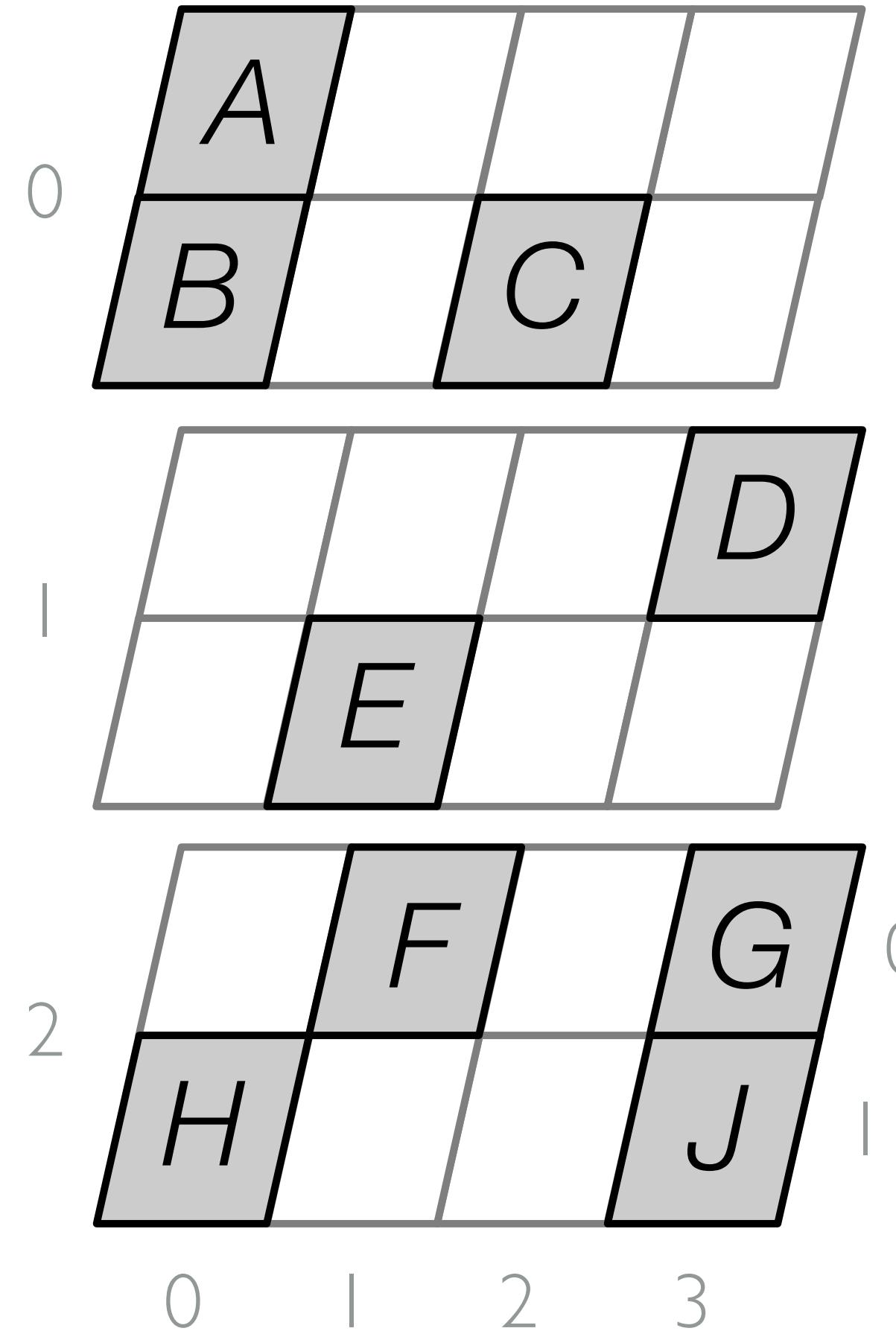
Compressed Sparse Rows (CSR)



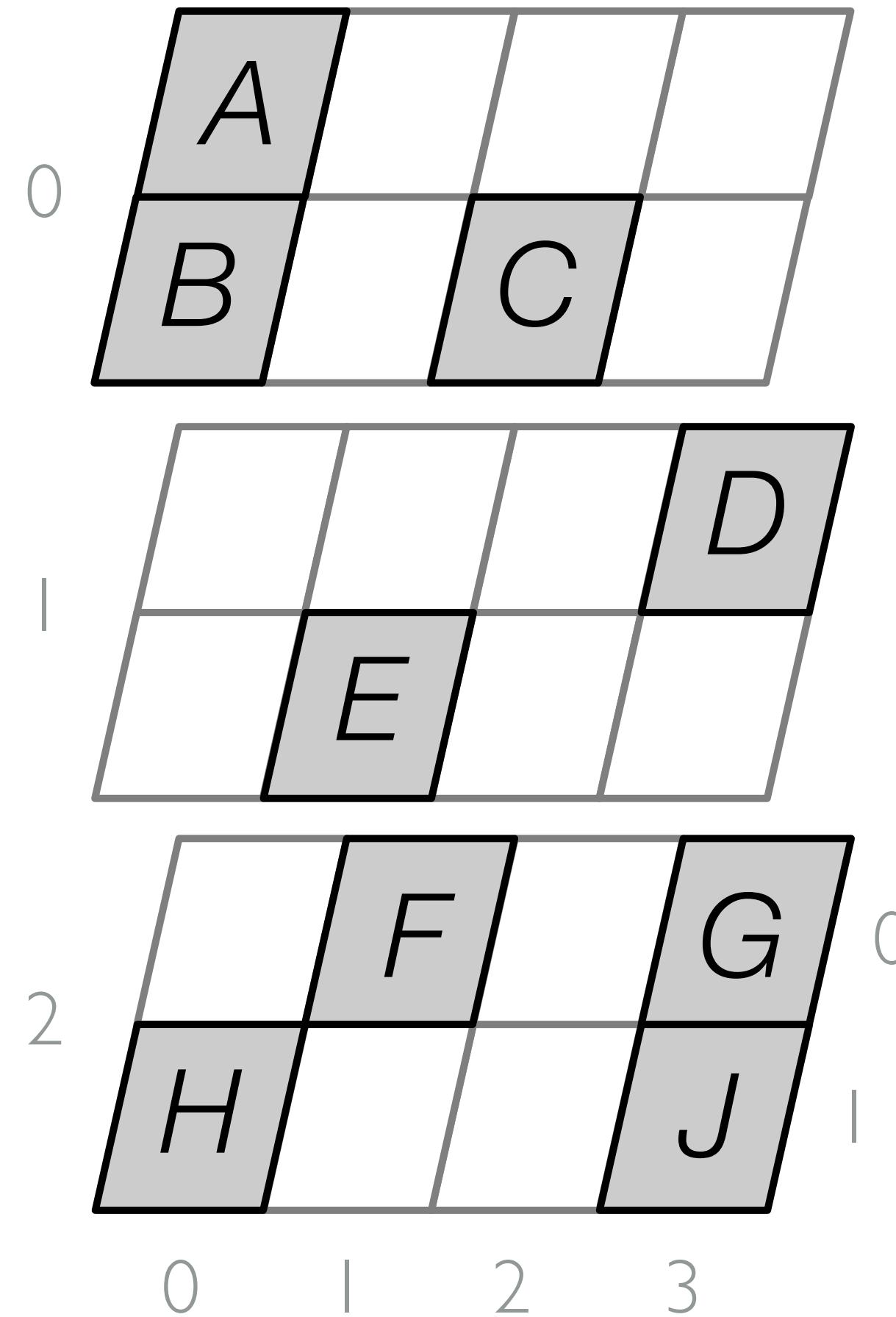
0		2	3
A		B	
	C	D	E
			F



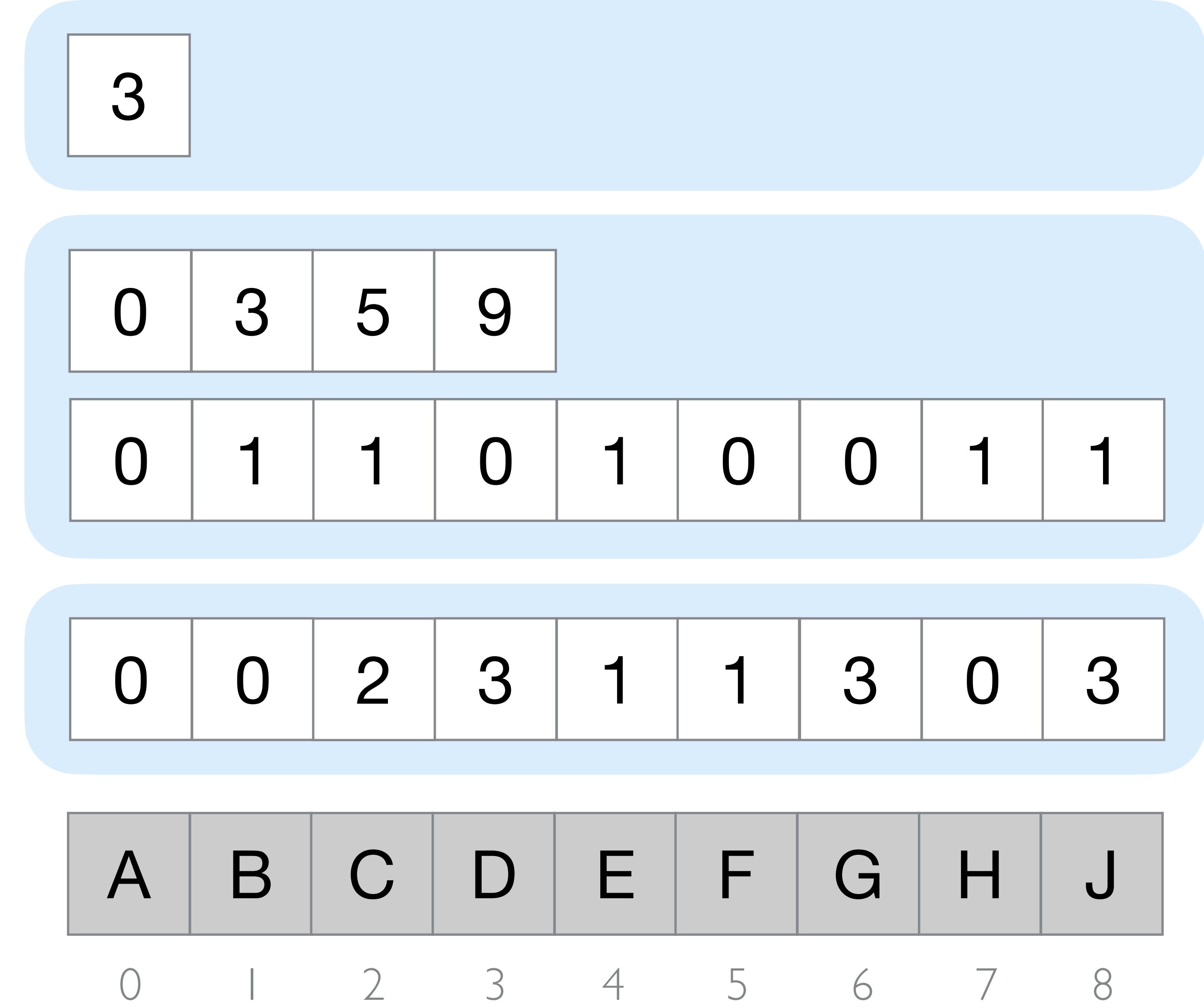
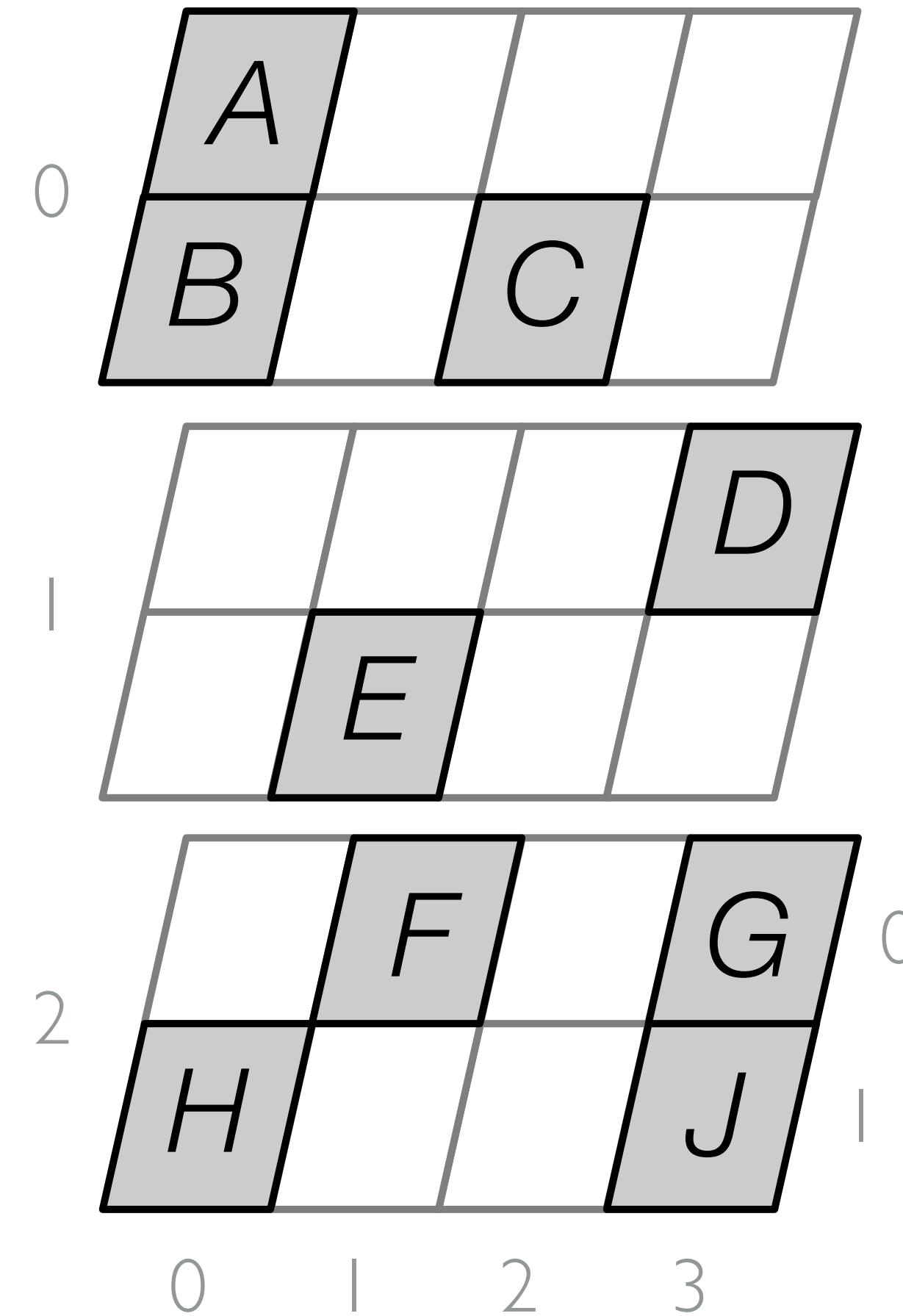
TACO models tensor formats as a hierarchy of per-dimension formats



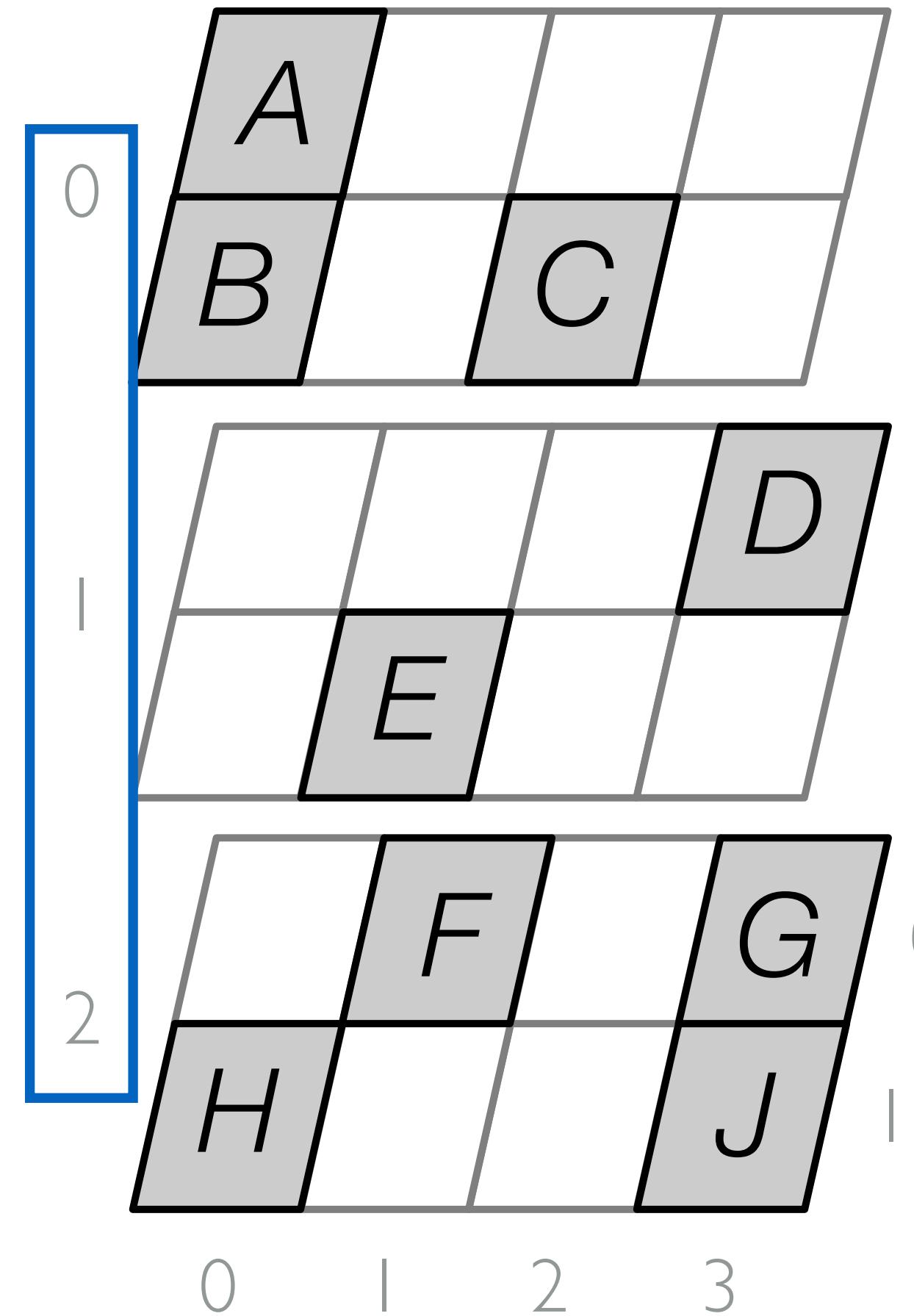
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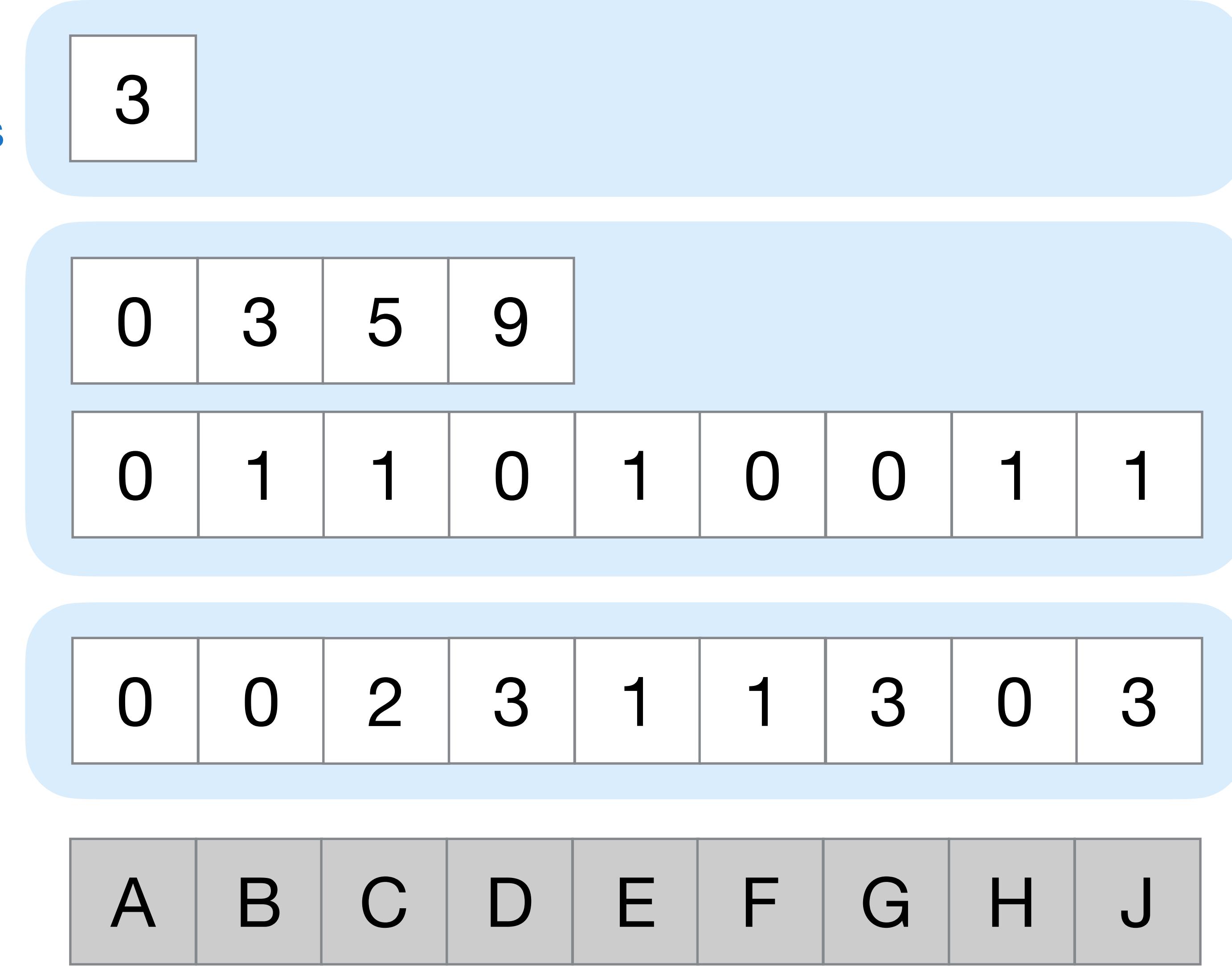
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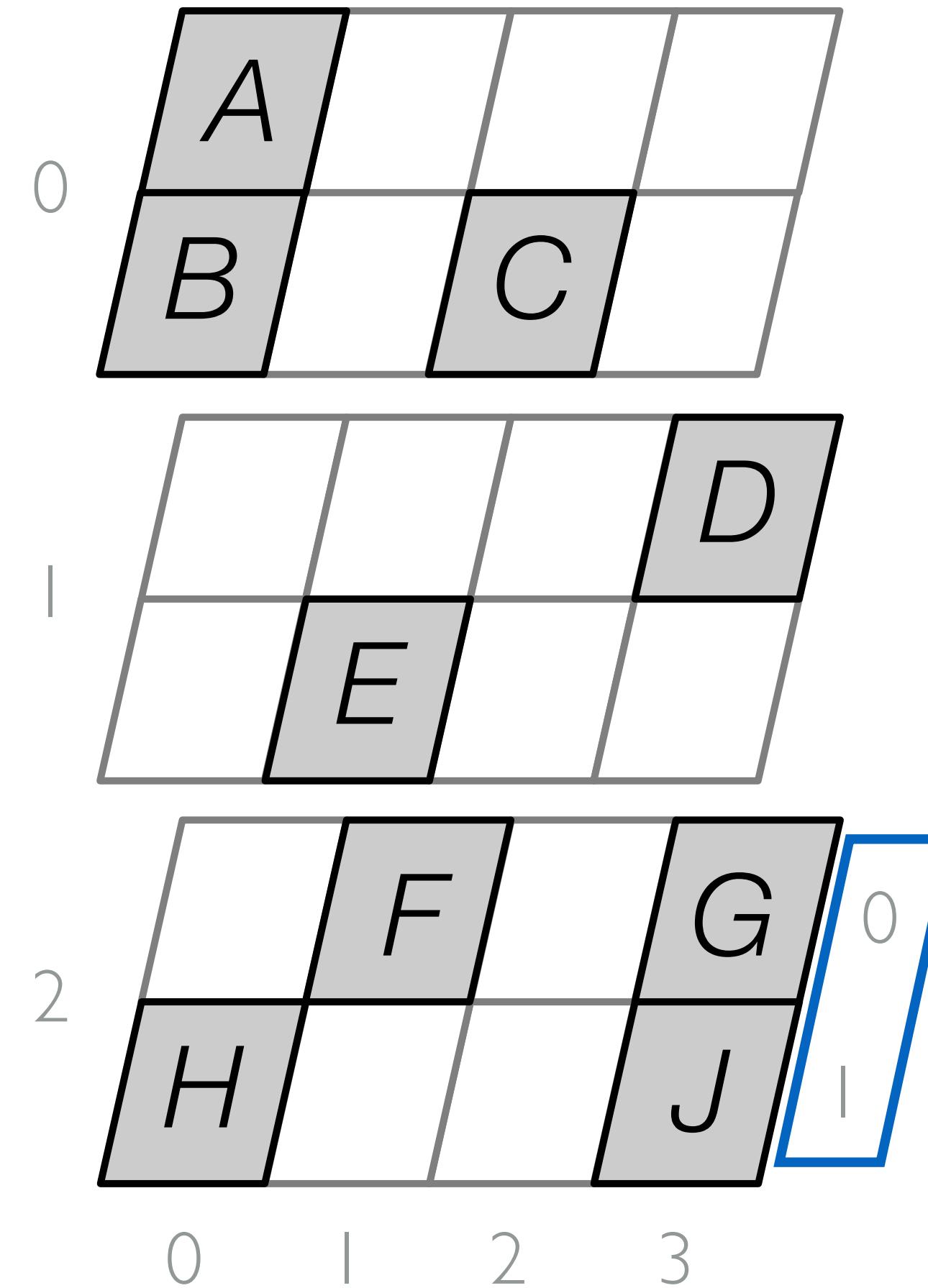
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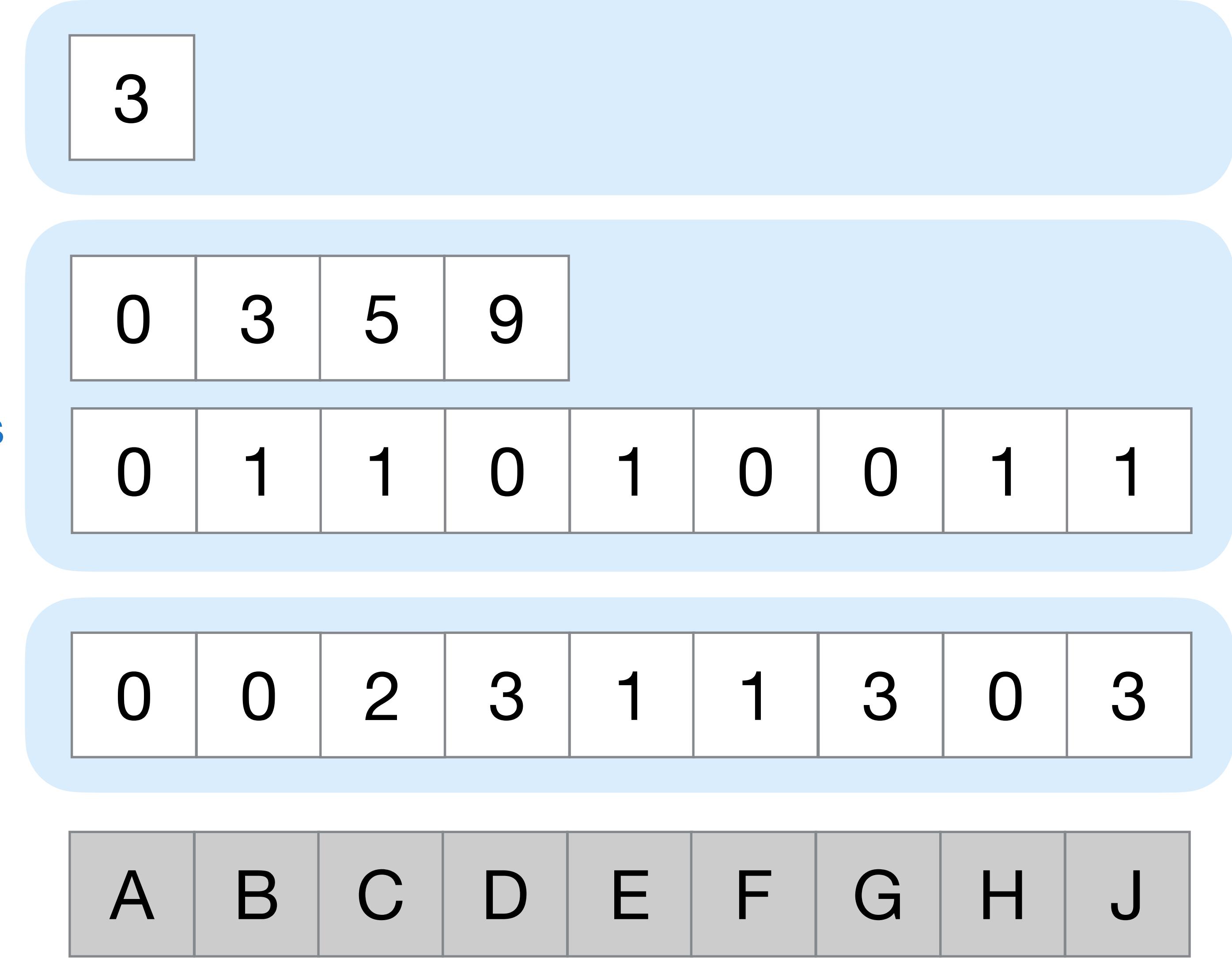
Slice
Coordinates



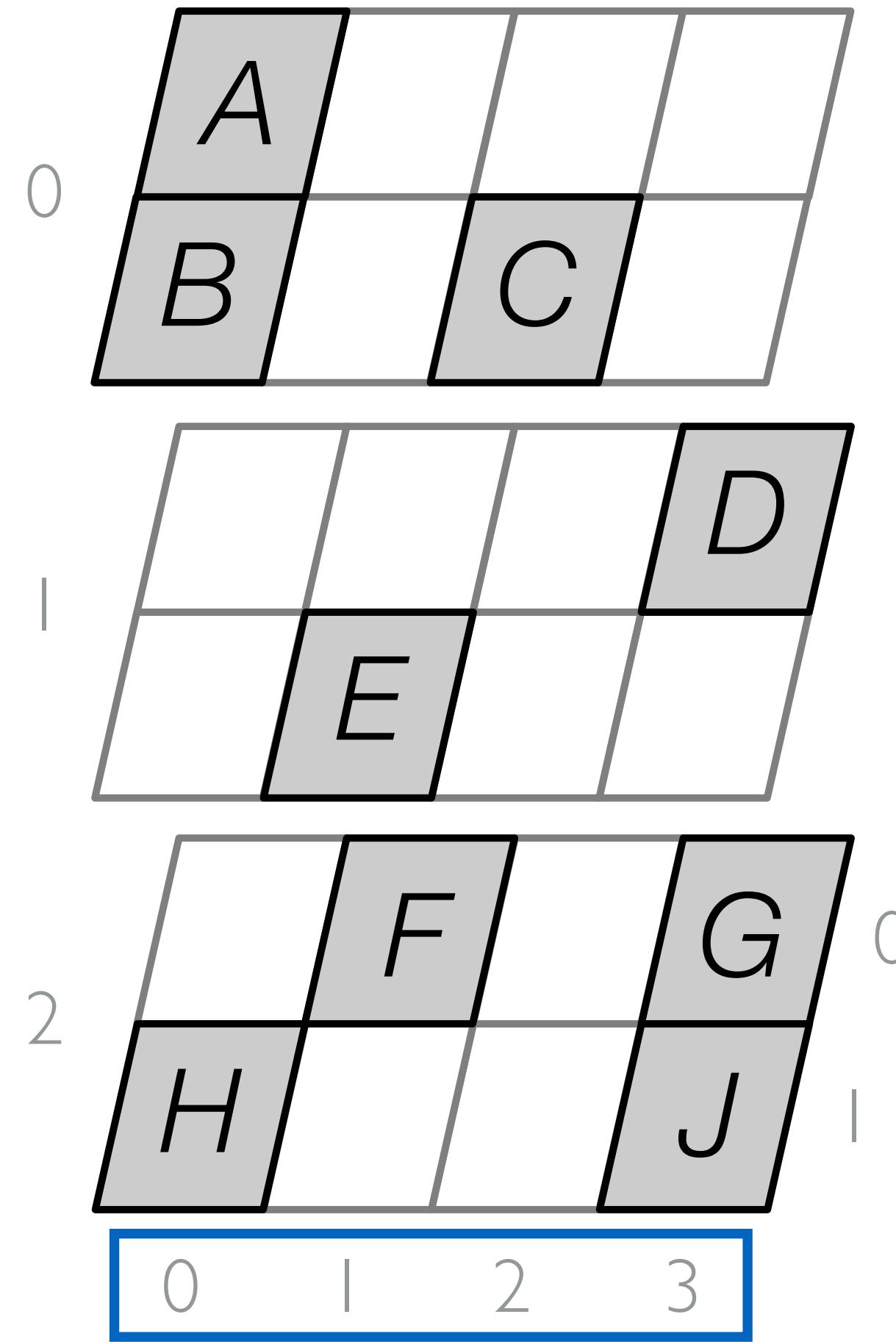
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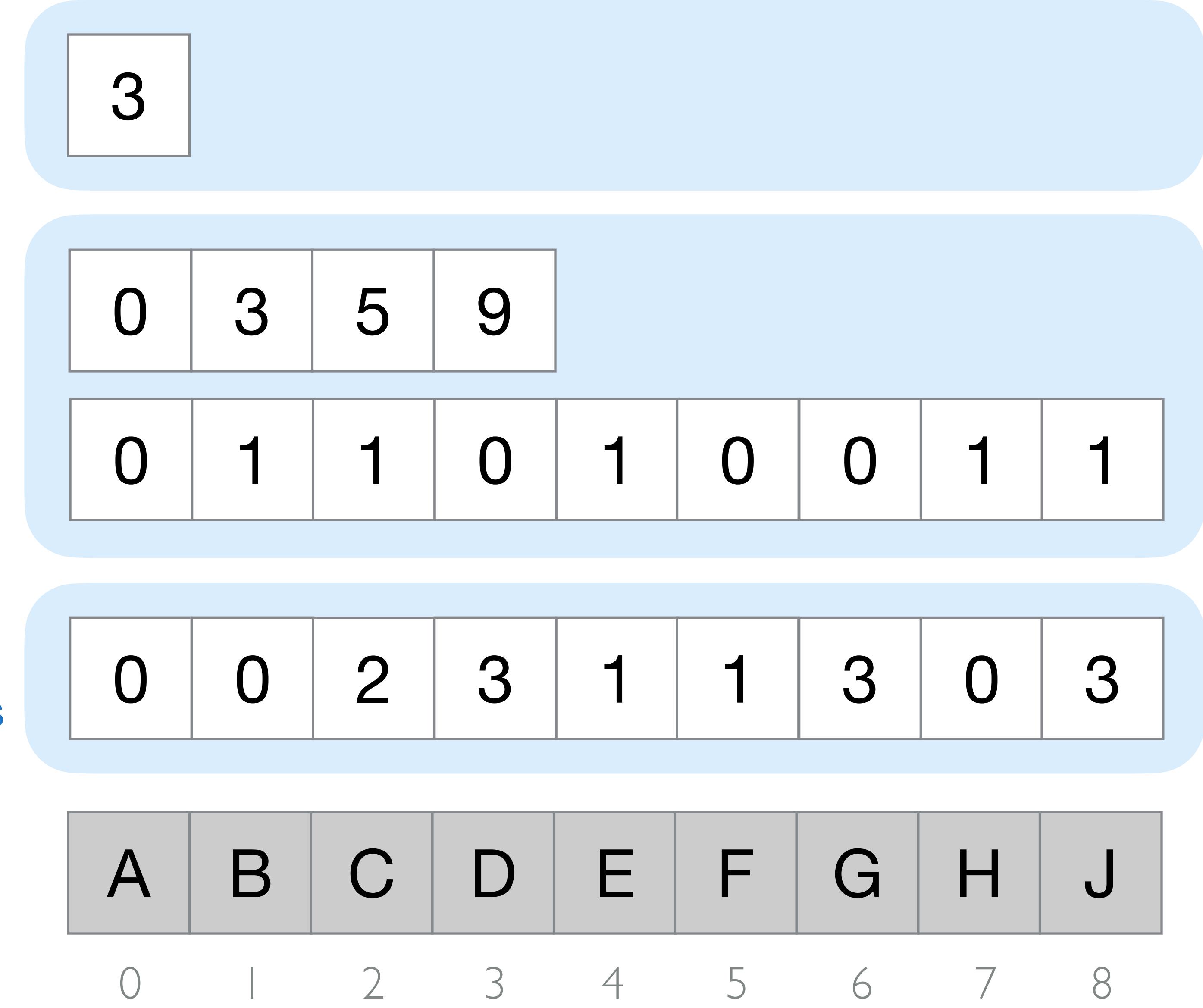
Row
Coordinates



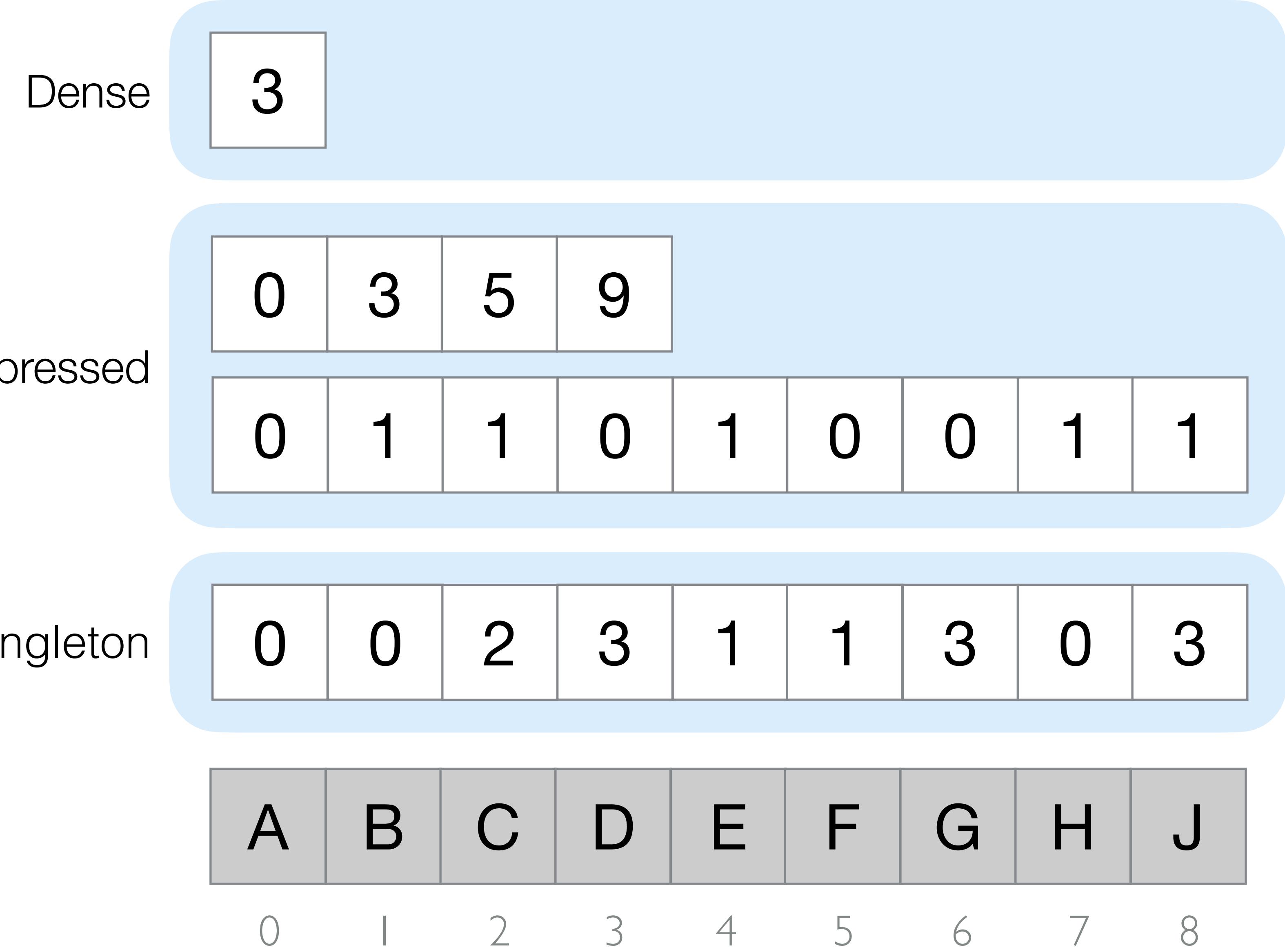
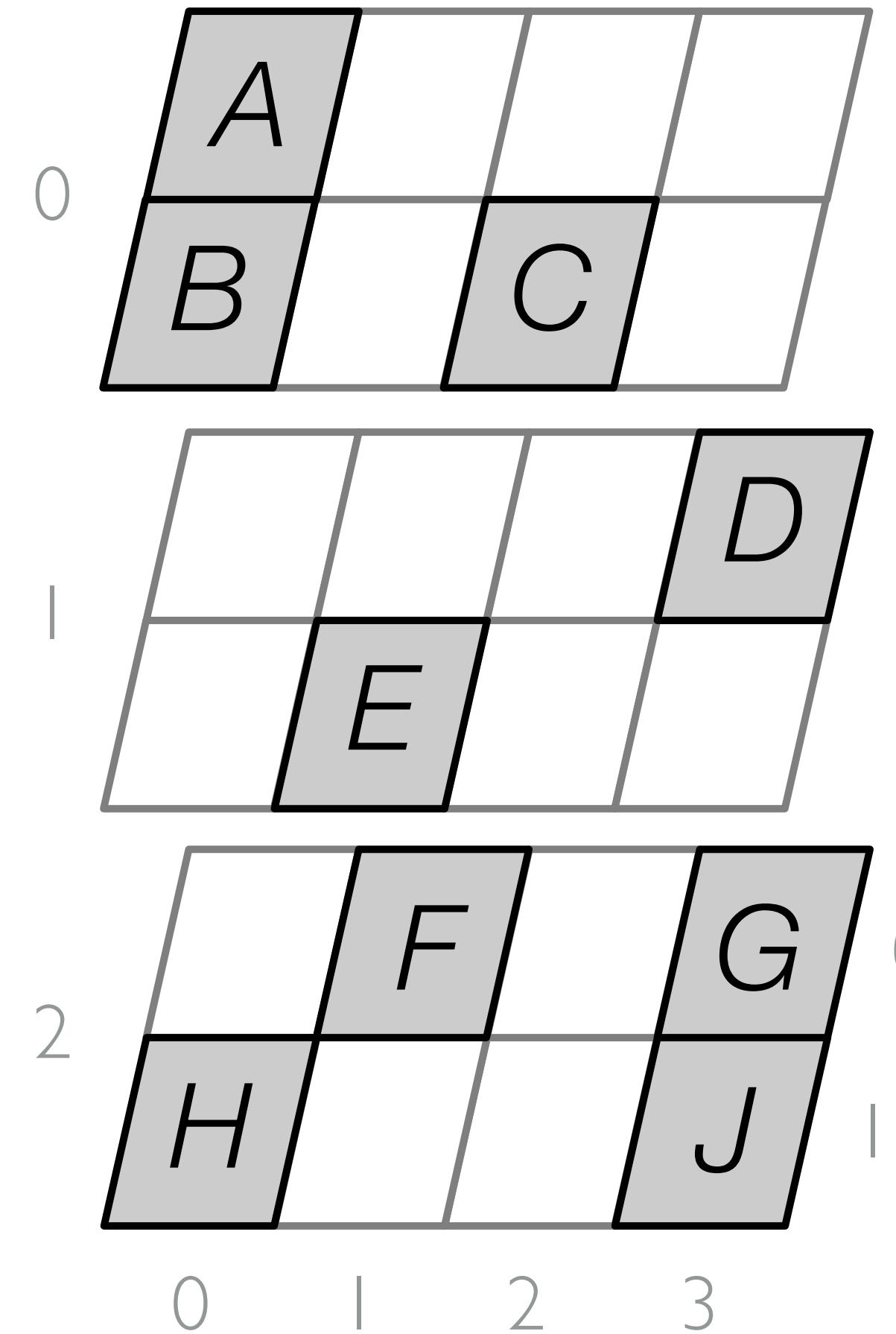
TACO models tensor formats as a hierarchy of per-dimension formats



Column
Coordinates



TACO models tensor formats as a hierarchy of per-dimension formats

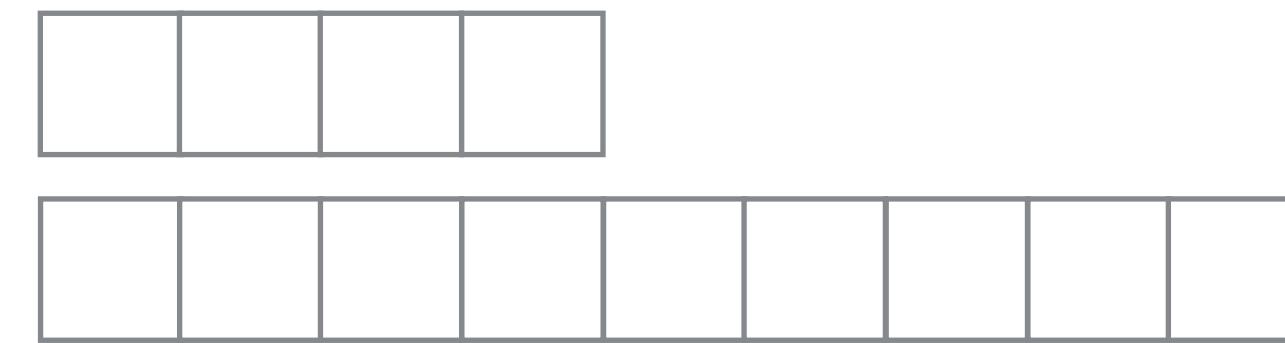


Per-dimension formats can be composed in many ways

Dense



Compressed



Singleton

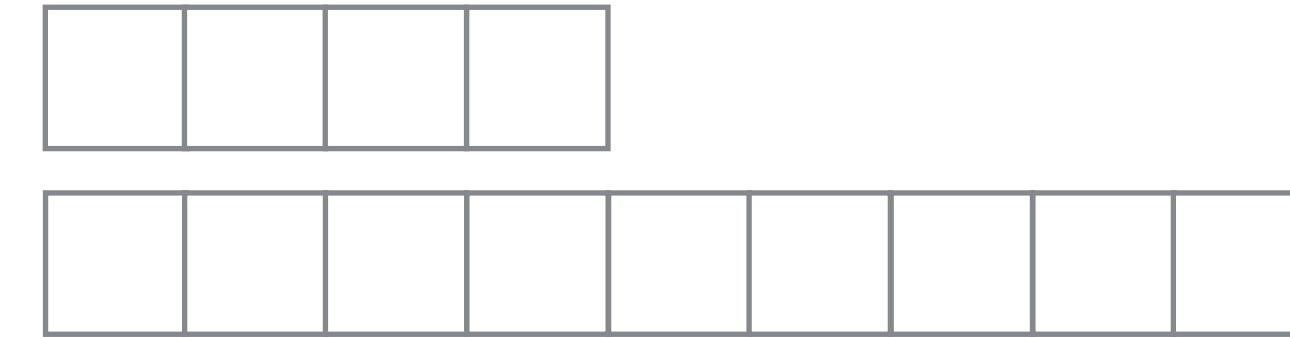


Per-dimension formats can be composed in many ways

Dense



Compressed



Singleton



0 | 1 | 2 | 3

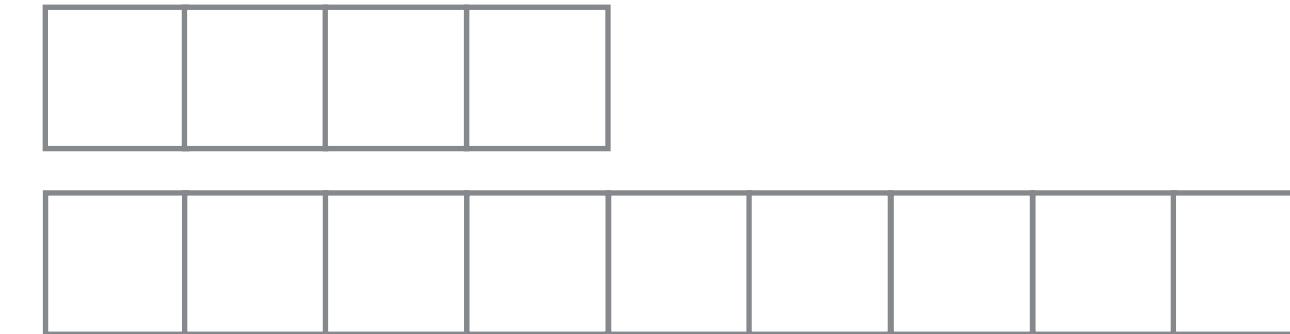
A		B	
	C	D	E
			F

Per-dimension formats can be composed in many ways

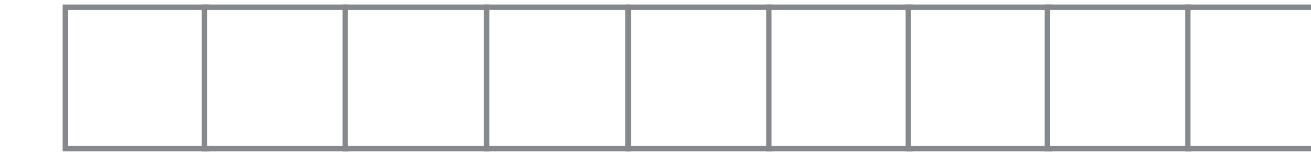
Dense



Compressed



Singleton



Dense

3

0 | 1 | 2 | 3

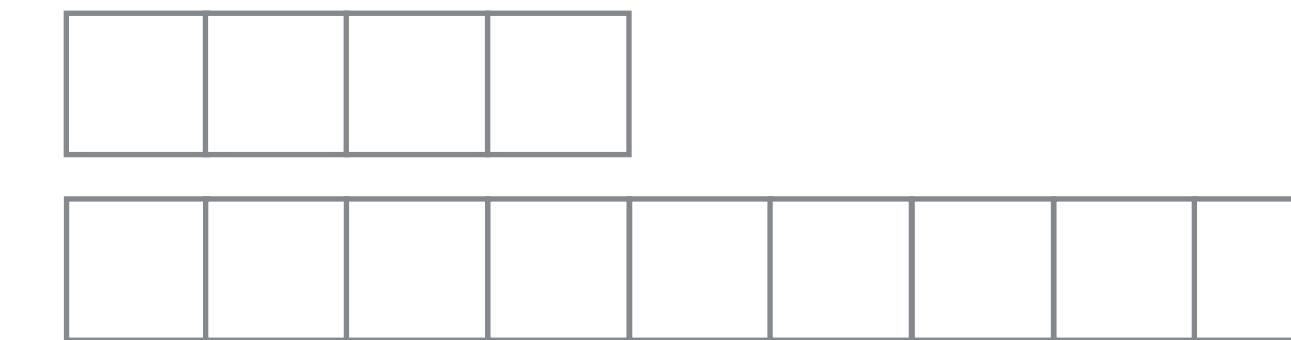
A		B	
C	D	E	
			F

Per-dimension formats can be composed in many ways

Dense



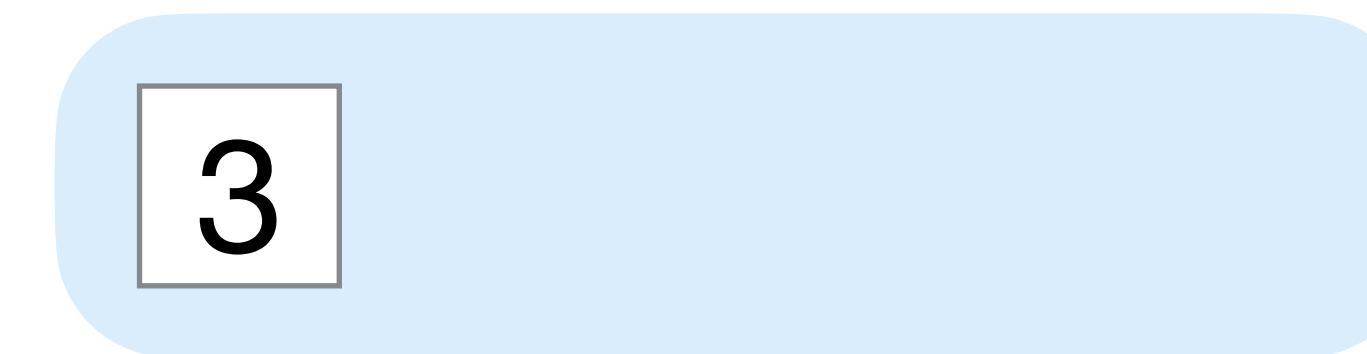
Compressed



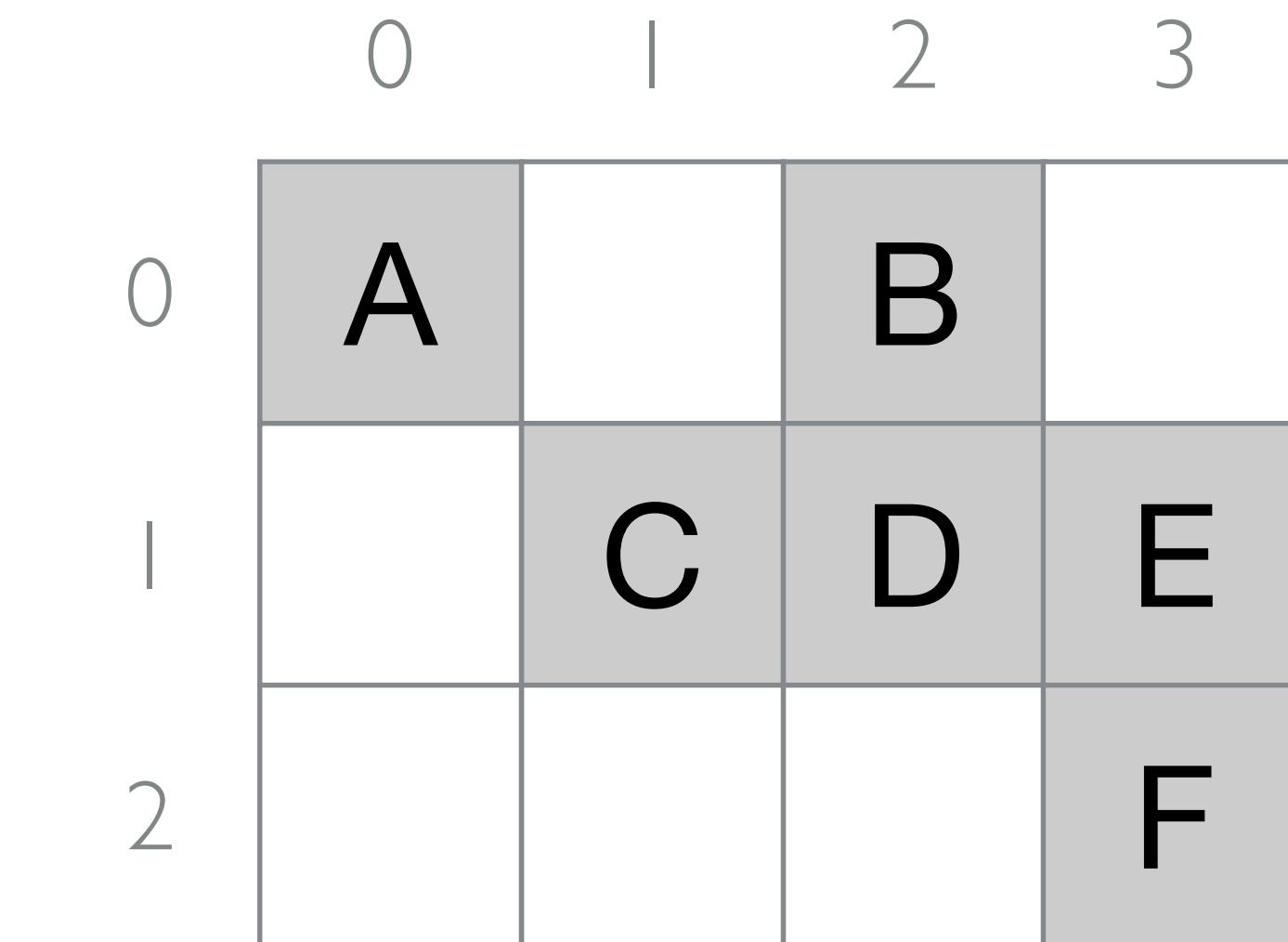
Singleton



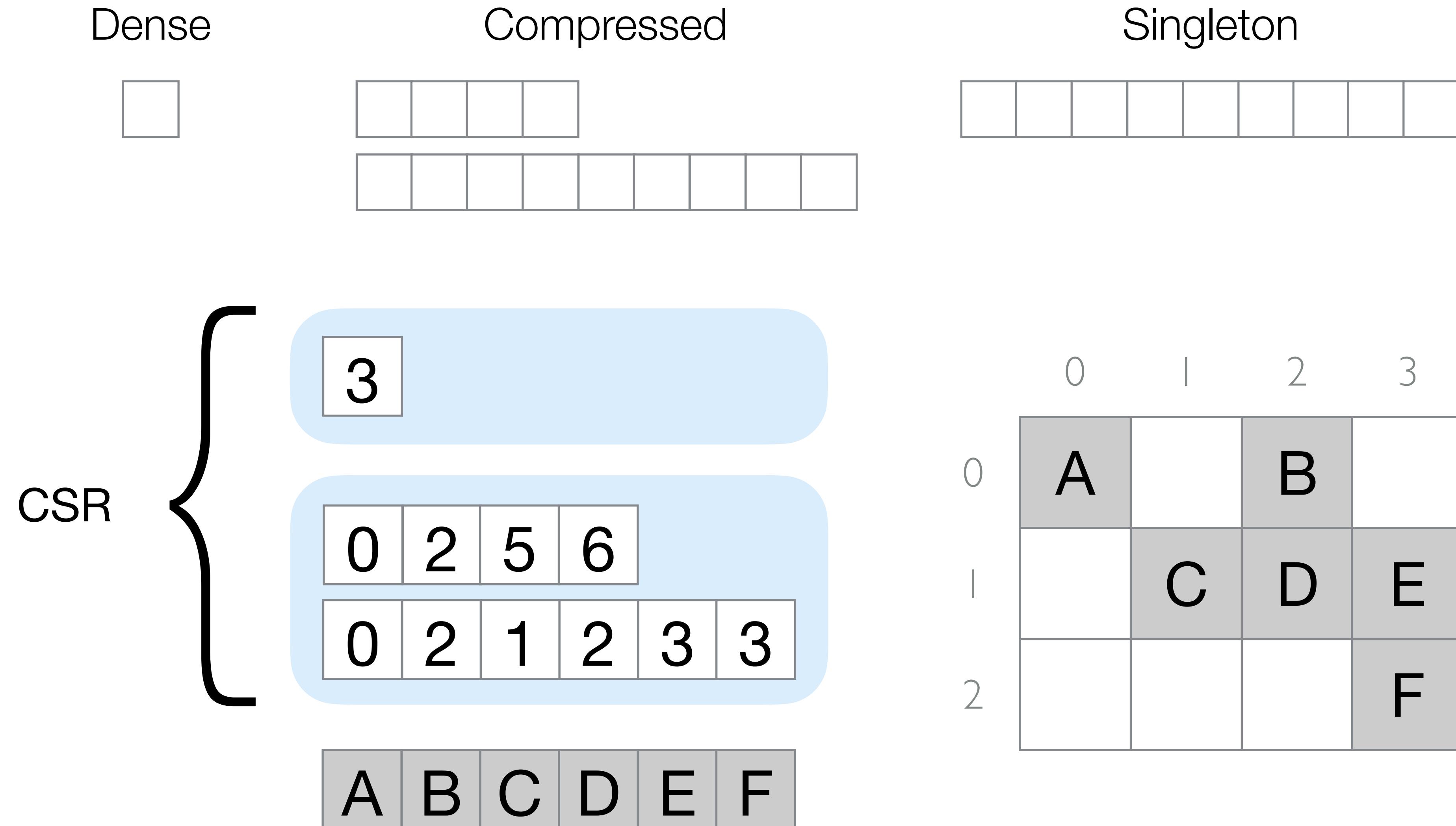
Dense



Compressed



Per-dimension formats can be composed in many ways

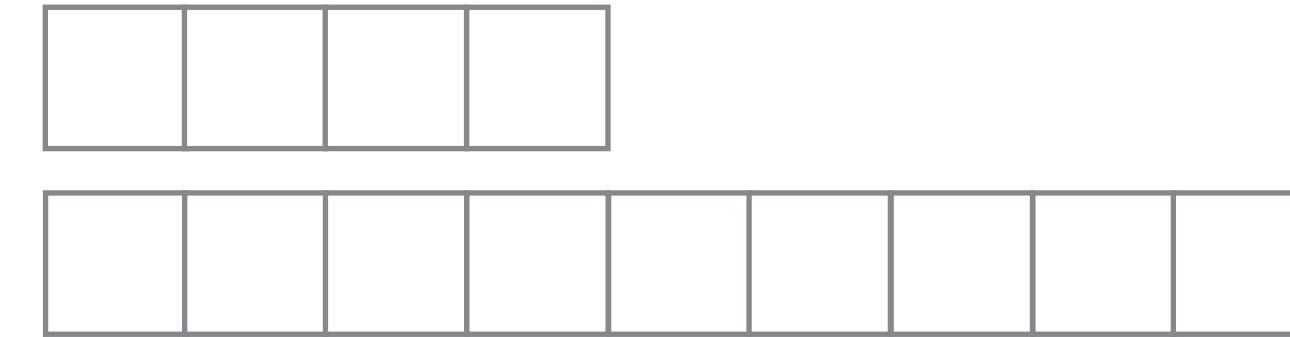


Per-dimension formats can be composed in many ways

Dense



Compressed



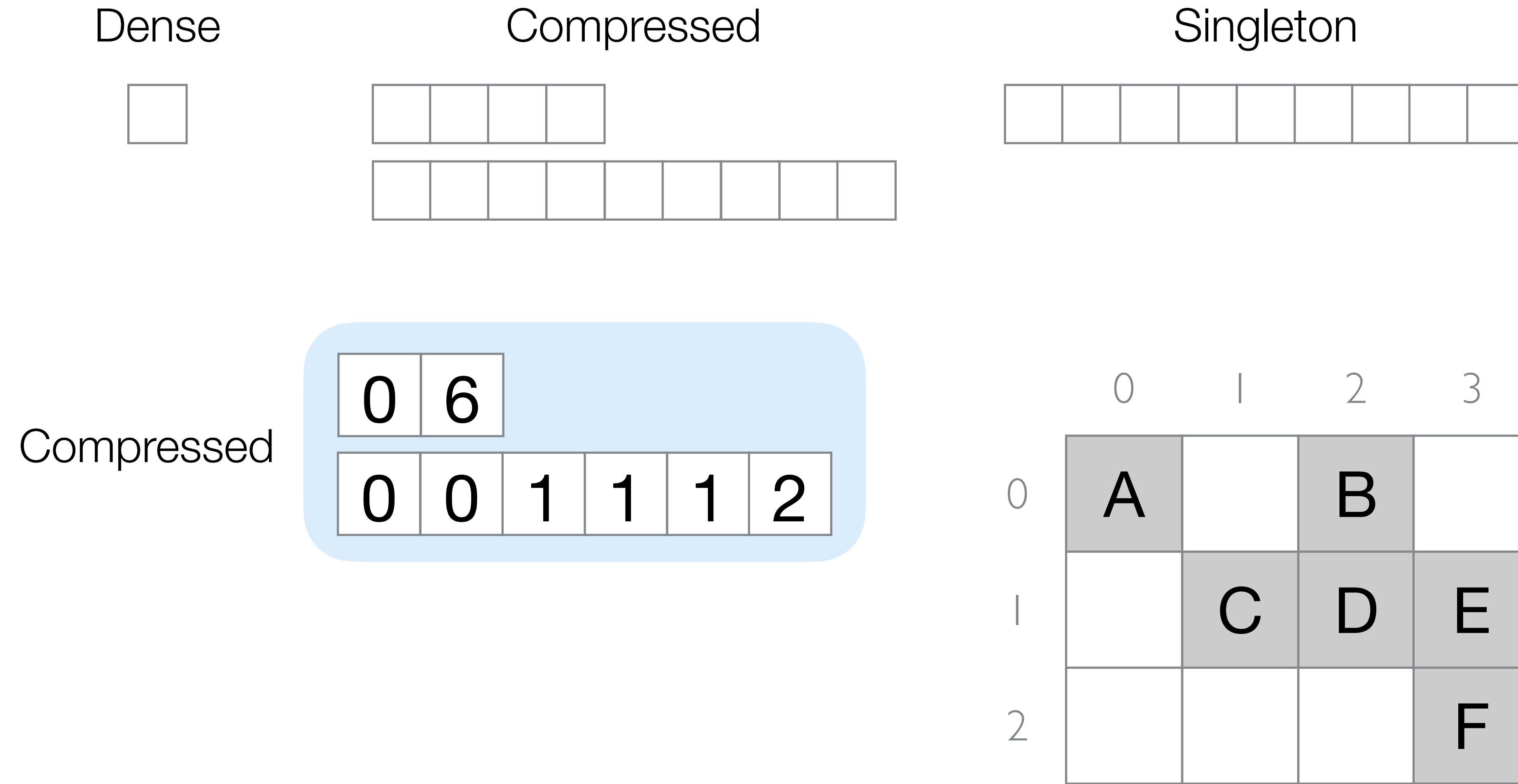
Singleton



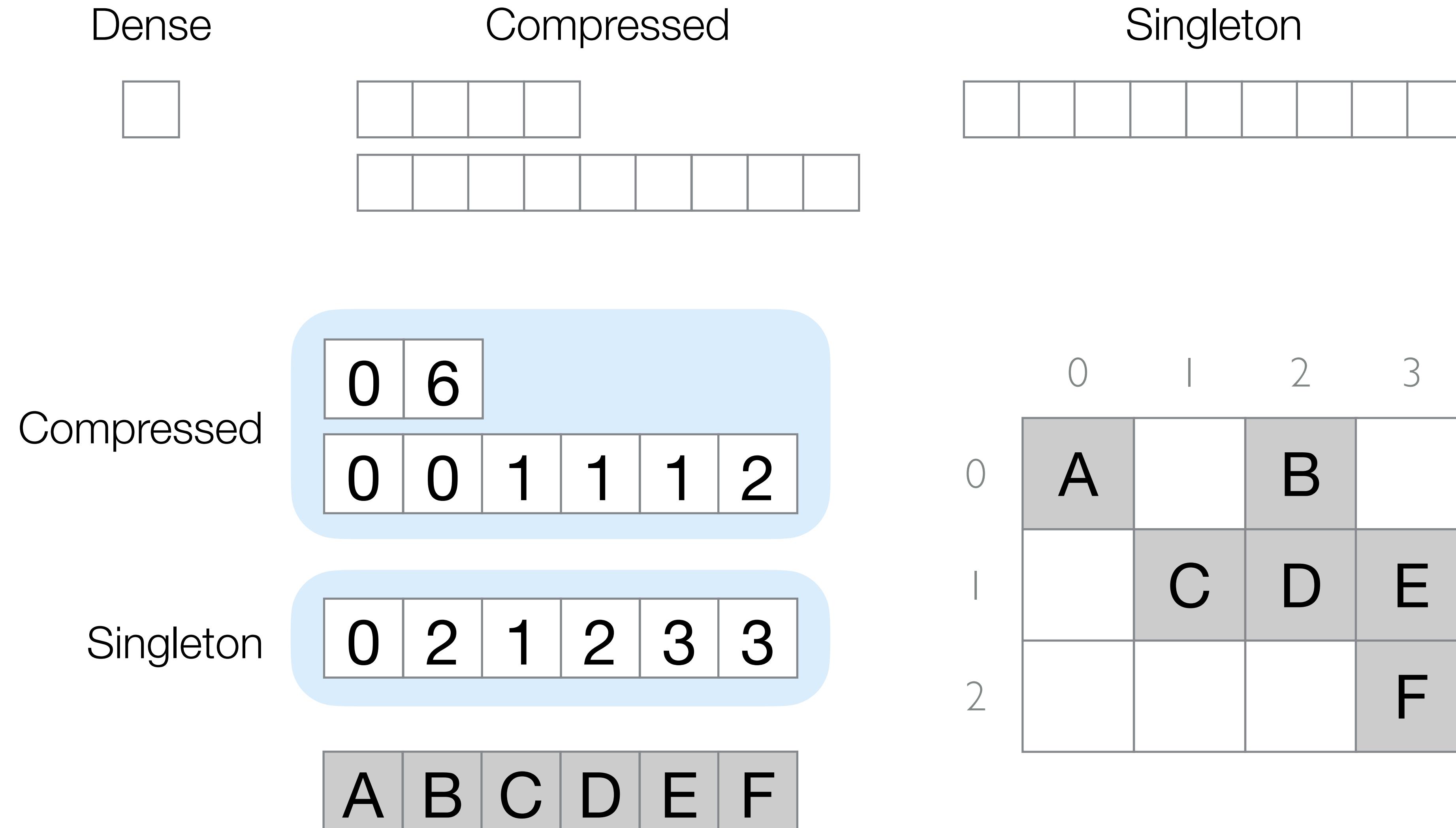
0 | 1 | 2 | 3

A		B	
	C	D	E
			F

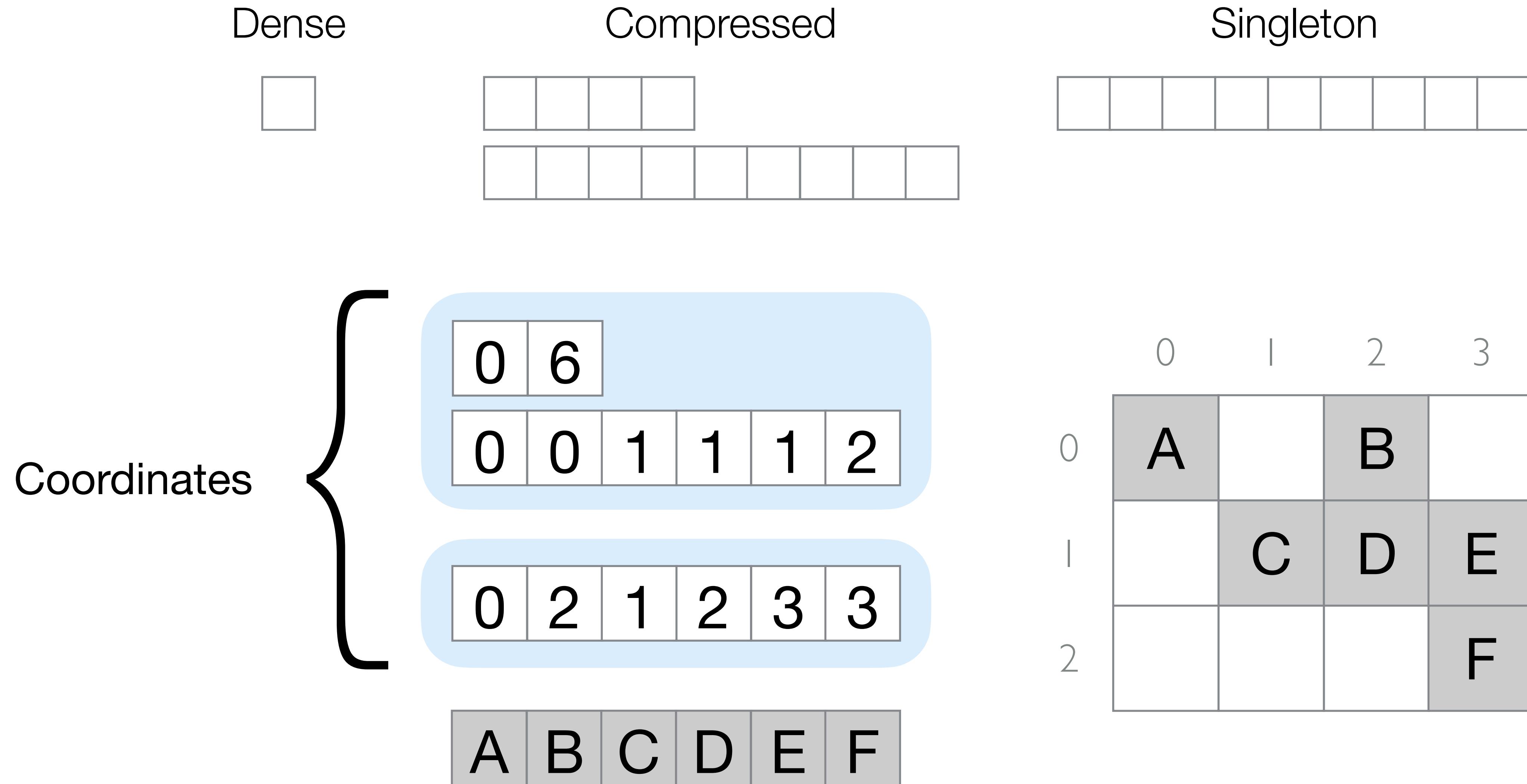
Per-dimension formats can be composed in many ways



Per-dimension formats can be composed in many ways



Per-dimension formats can be composed in many ways



Level formats can be composed in many ways

Dense

Compressed

Singleton

Level formats can be composed in many ways

Tensor
formats

Level
formats

Dense

Compressed

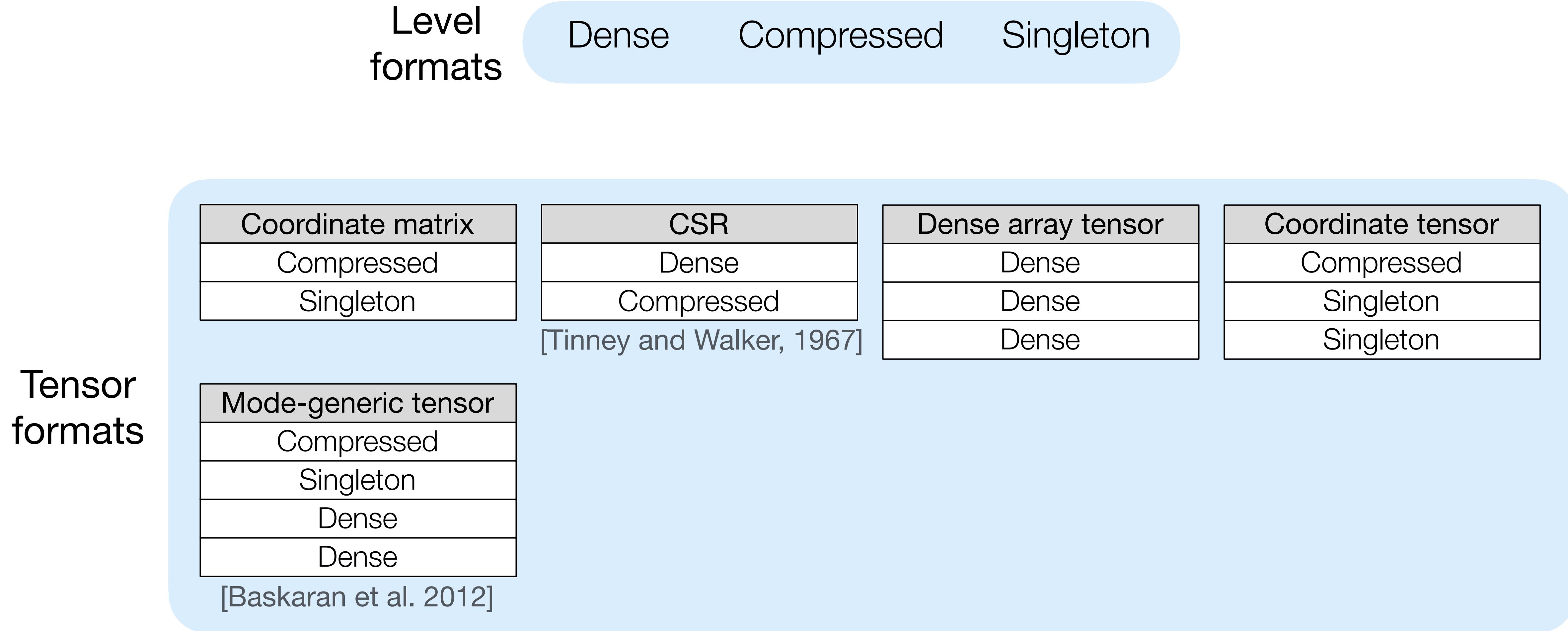
Singleton

Coordinate matrix
Compressed
Singleton

CSR
Dense
Compressed

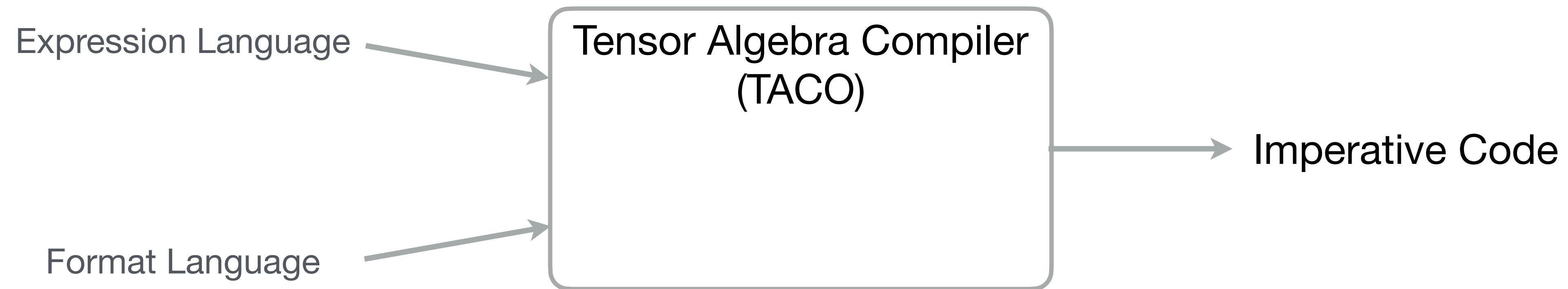
[Tinney and Walker, 1967]

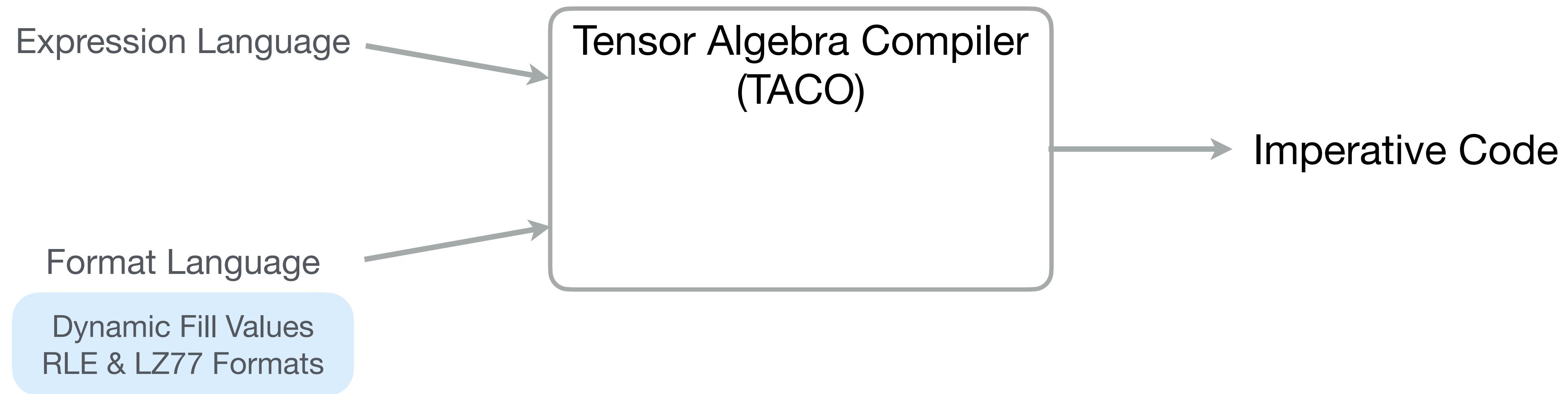
Level formats can be composed in many ways

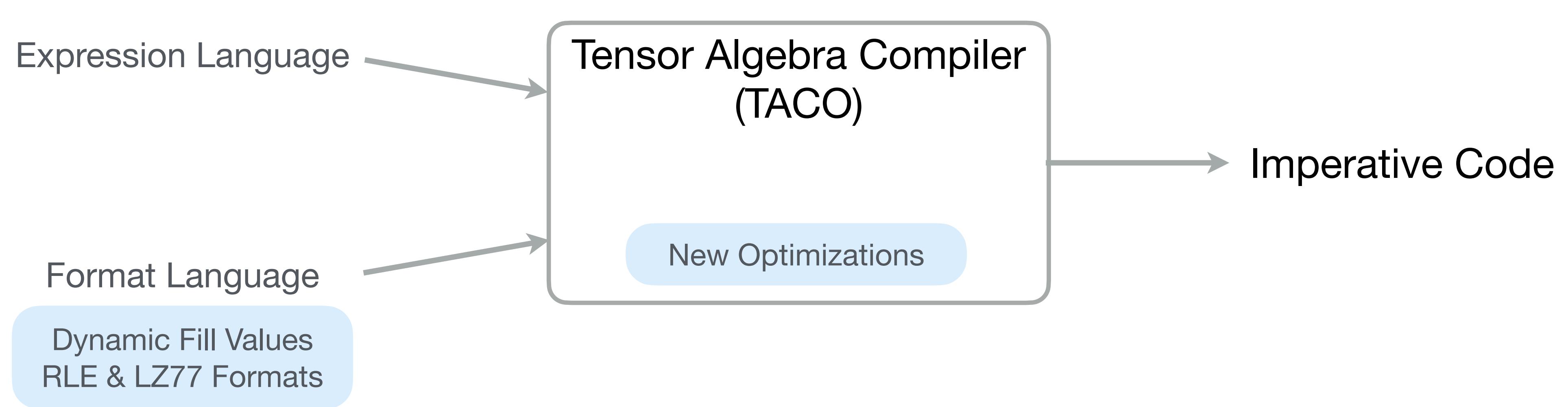


Level formats can be composed in many ways

Tensor formats	Level formats	Dense	Compressed	Singleton
	Coordinate matrix	Compressed		
		Singleton		
	CSR	Dense		
		Compressed		
		[Tinney and Walker, 1967]		
	Dense array tensor	Dense		
		Dense		
		Dense		
	Coordinate tensor	Compressed		
		Singleton		
		Singleton		
	Mode-generic tensor	Compressed		
		Singleton		
		Dense		
		Dense		
	BCSR	Dense		
		Compressed		
		Dense		
		Dense		
	CSB	Dense		
		Dense		
		Compressed		
		Singleton		
	ELLPACK	Dense		
		Dense		
		Singleton		
	[Kincaid et al. 1989]			
	[Baskaran et al. 2012]			
	[Im and Yelick 1998]			
	[Buluç et al. 2009]			







Sparsity beyond zero Fill Values

	0	1	2	3	4	5	6	7
0	1	1	1	0	0	0	5	5
1	6	6	6	6	1	1	1	1
2	3	3	3	0	0	0	0	0
3	1	1	1	8	8	8	2	2

Sparsity beyond zero Fill Values

	0	1	2	3	4	5	6	7
0	1	1	1	0	0	0	5	5
1	6	6	6	6	1	1	1	1
2	3	3	3	0	0	0	0	0
3	1	1	1	8	8	8	2	2

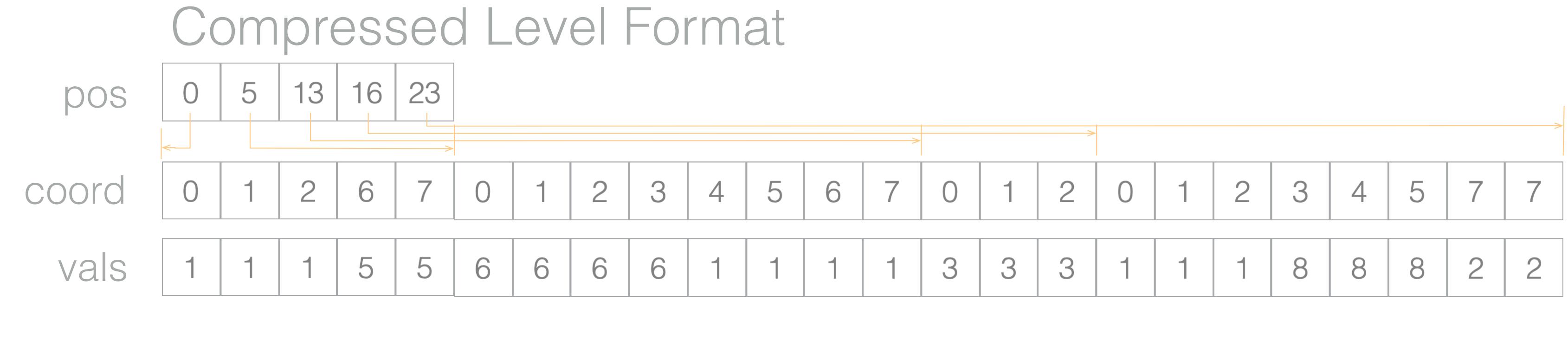
Sparsity beyond zero Fill Values

Compressed Level Format

	pos	coord	vals
pos	0 5 13 16 23		
coord		0 1 2 6 7 0 1 2 3 4 5 6 7 0 1 2 0 1 2 3 4 5 7 7	
vals			1 1 1 5 5 6 6 6 6 1 1 1 1 3 3 3 1 1 1 8 8 8 2 2

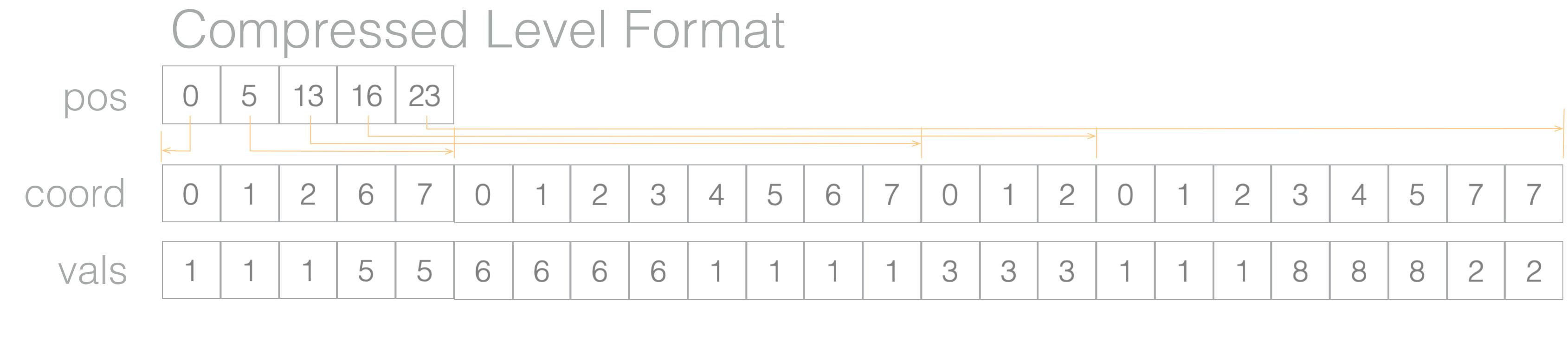
	0	1	2	3	4	5	6	7
0	1	1	1	0	0	0	5	5
1	6	6	6	6	1	1	1	1
2	3	3	3	0	0	0	0	0
3	1	1	1	8	8	8	2	2

Sparsity beyond zero Fill Values



	0	1	2	3	4	5	6	7
0	1	1	1	0	0	0	5	5
1	6	6	6	6	1	1	1	1
2	3	3	3	0	0	0	0	0
3	1	1	1	8	8	8	2	2

Sparsity beyond zero Fill Values



	0	1	2	3	4	5	6	7
0	1	1	1	0	0	0	5	5
1	6	6	6	6	1	1	1	1
2	3	3	3	0	0	0	0	0
3	1	1	1	8	8	8	2	2

Sparsity beyond zero Fill Values

Compressed Level Format

pos	0 5 13 16 23
coord	0 1 2 6 7 0 1 2 3 4 5 6 7 0 1 2 0 1 2 3 4 5 7 7
vals	1 1 1 5 5 6 6 6 1 1 1 1 3 3 3 1 1 1 8 8 8 2 2

0	1	1	1	0	0	0	5	5
1	6	6	6	6	1	1	1	1
2	3	3	3	0	0	0	0	0
3	1	1	1	8	8	8	2	2

Compressed Level Format with a Fill Value [Henry et al. OOPSLA, 2021]

pos	0 5 9 17 21
coord	3 4 5 6 7 0 1 2 3 0 1 2 3 4 5 6 7 3 4 5 6 7
vals	0 0 0 5 5 6 6 6 6 3 3 3 0 0 0 0 8 8 8 2 2
Fill	1

Sparsity beyond zero Fill Values

Compressed Level Format

pos	0 5 13 16 23
coord	0 1 2 6 7 0 1 2 3 4 5 6 7 0 1 2 0 1 2 3 4 5 7 7
vals	1 1 1 5 5 6 6 6 1 1 1 1 3 3 3 1 1 1 8 8 8 2 2

0	1	1	1	0	0	0	5	5
1	6	6	6	6	1	1	1	1
2	3	3	3	0	0	0	0	0
3	1	1	1	8	8	8	2	2

Compressed Level Format with a Fill Value [Henry et al. OOPSLA, 2021]

pos	0 5 9 17 21
coord	3 4 5 6 7 0 1 2 3 0 1 2 3 4 5 6 7 3 4 5 6 7
vals	0 0 0 5 5 6 6 6 6 3 3 3 3 0 0 0 0 0 8 8 8 2 2
Fill	1

Sparsity beyond zero Fill Values

Compressed Level Format

pos	0 5 13 16 23
coord	0 1 2 6 7 0 1 2 3 4 5 6 7 0 1 2 0 1 2 3 4 5 7 7
vals	1 1 1 5 5 6 6 6 6 1 1 1 1 3 3 3 1 1 1 8 8 8 2 2

0	1	1	1	0	0	0	5	5
1	6	6	6	6	1	1	1	1
2	3	3	3	0	0	0	0	0
3	1	1	1	8	8	8	2	2

Compressed Level Format with a Fill Value [Henry et al. OOPSLA, 2021]

pos	0 5 9 17 21
coord	3 4 5 6 7 0 1 2 3 0 1 2 3 4 5 6 7 3 4 5 6 7
vals	0 0 0 5 5 6 6 6 6 3 3 3 3 0 0 0 0 8 8 8 2 2
Fill	1

Why are we limited to a single repeated value?

Sparsity beyond zero Fill Values

Compressed Level Format

pos	0 5 13 16 23
coord	0 1 2 6 7 0 1 2 3 4 5 6 7 0 1 2 0 1 2 3 4 5 7 7
vals	1 1 1 5 5 6 6 6 6 1 1 1 1 3 3 3 1 1 1 8 8 8 2 2

0	1	1	1	0	0	0	5	5
1	6	6	6	6	1	1	1	1
2	3	3	3	0	0	0	0	0
3	1	1	1	8	8	8	2	2

Compressed Level Format with a Fill Value [Henry et al. OOPSLA, 2021]

pos	0 5 9 17 21
coord	3 4 5 6 7 0 1 2 3 0 1 2 3 4 5 6 7 3 4 5 6 7
vals	0 0 0 5 5 6 6 6 6 3 3 3 3 0 0 0 0 8 8 8 2 2
Fill	1

Why are we limited to a single repeated value?

Run Length Encoding (RLE)

Dynamic Fill Values

	0	1	2	3	4	5	6	7
0	1	1	1	0	0	0	5	5
1	6	6	6	6	1	1	1	1
2	3	3	3	0	0	0	0	0
3	1	1	1	8	8	8	2	2

Dynamic Fill Values

	0	1	2	3	4	5	6	7
0	1	1	1	0	0	0	5	5

	0	1	2	3	4	5	6	7
0	1	1	1	0	0	0	5	5
1	6	6	6	6	1	1	1	1
2	3	3	3	0	0	0	0	0
3	1	1	1	8	8	8	2	2

Dynamic Fill Values

	0	1	2	3	4	5	6	7
0	1	1	1	0	0	0	5	5

	0	1	2	3	4	5	6	7
0	1	1	1	0	0	0	5	5
1	6	6	6	6	1	1	1	1
2	3	3	3	0	0	0	0	0
3	1	1	1	8	8	8	2	2

Dynamic Fill Values

	0	1	2	3	4	5	6	7
0	1	1	1	0	0	0	5	5

	0	1	2	3	4	5	6	7
0	1	1	1	0	0	0	5	5
1	6	6	6	6	1	1	1	1
2	3	3	3	0	0	0	0	0
3	1	1	1	8	8	8	2	2

Fill

Dynamic Fill Values

	0	1	2	3	4	5	6	7
0	1	1	1	0	0	0	5	5

	0	1	2	3	4	5	6	7
0	1	1	1	0	0	0	5	5
1	6	6	6	6	1	1	1	1
2	3	3	3	0	0	0	0	0
3	1	1	1	8	8	8	2	2

coord	0	3	6
-------	---	---	---

vals	1	0	5
------	---	---	---

Fill

Dynamic Fill Values

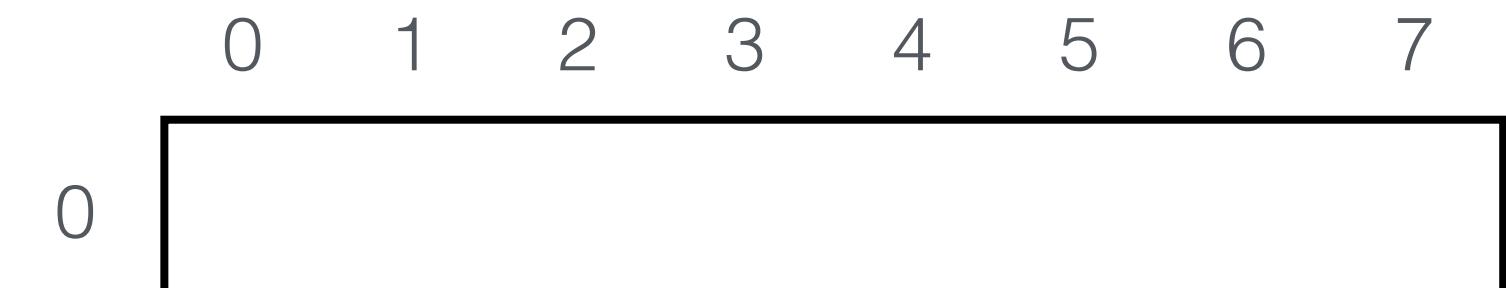
	0	1	2	3	4	5	6	7
0	1	1	1	0	0	0	5	5

	0	1	2	3	4	5	6	7
0	1	1	1	0	0	0	5	5
1	6	6	6	6	1	1	1	1
2	3	3	3	0	0	0	0	0
3	1	1	1	8	8	8	2	2

coord	0	3	6
vals	1	0	5

Fill

Dynamic Fill Values

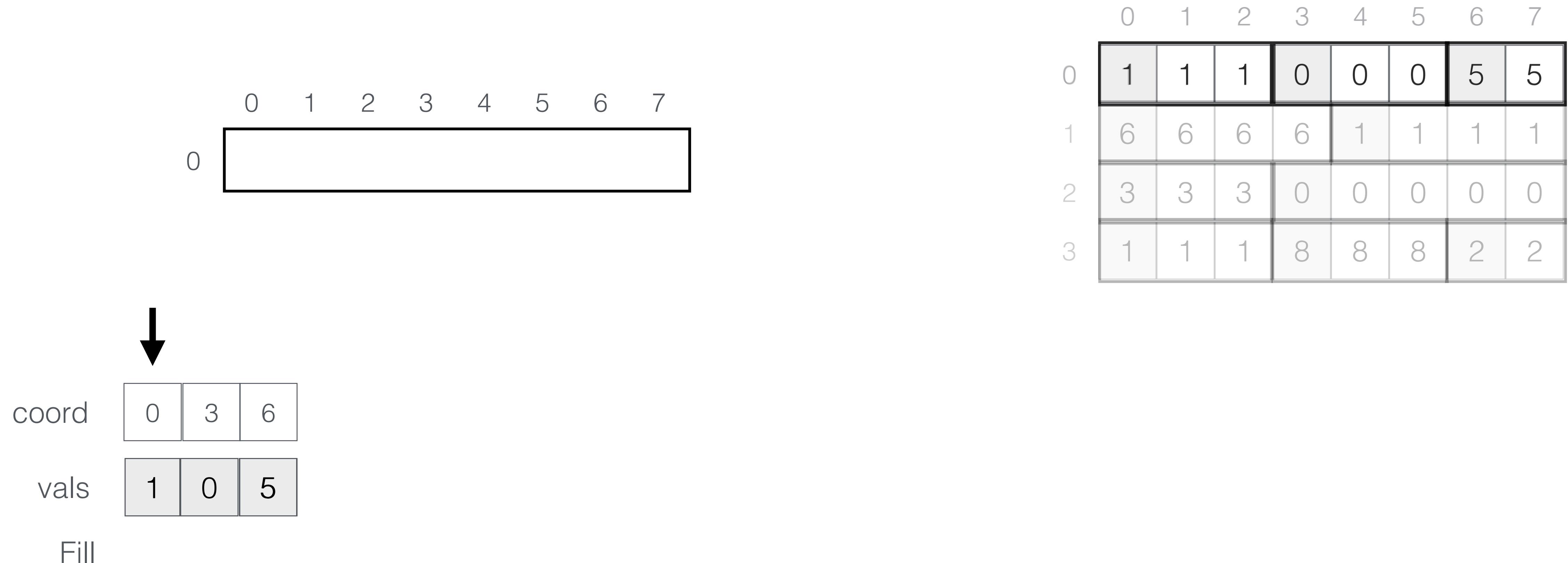


0	1	2	3	4	5	6	7
0	1	1	1	0	0	0	5
1	6	6	6	6	1	1	1
2	3	3	3	0	0	0	0
3	1	1	1	8	8	8	2

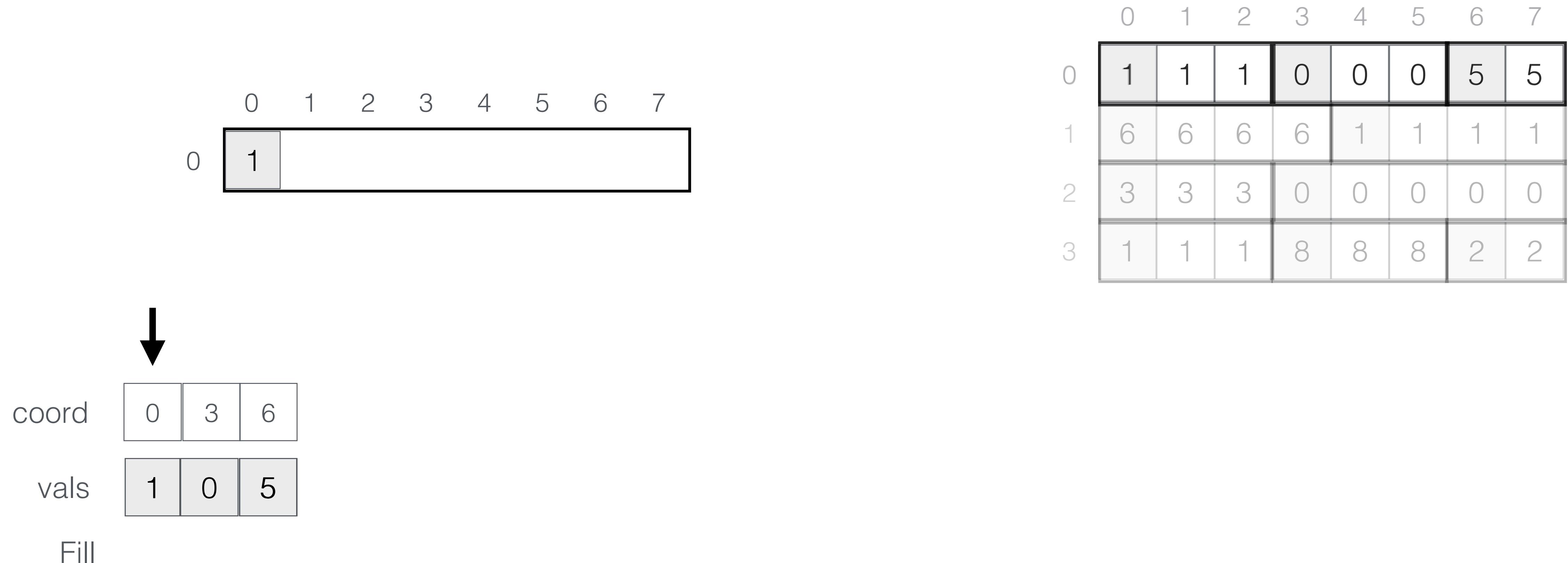
coord	0	3	6
vals	1	0	5

Fill

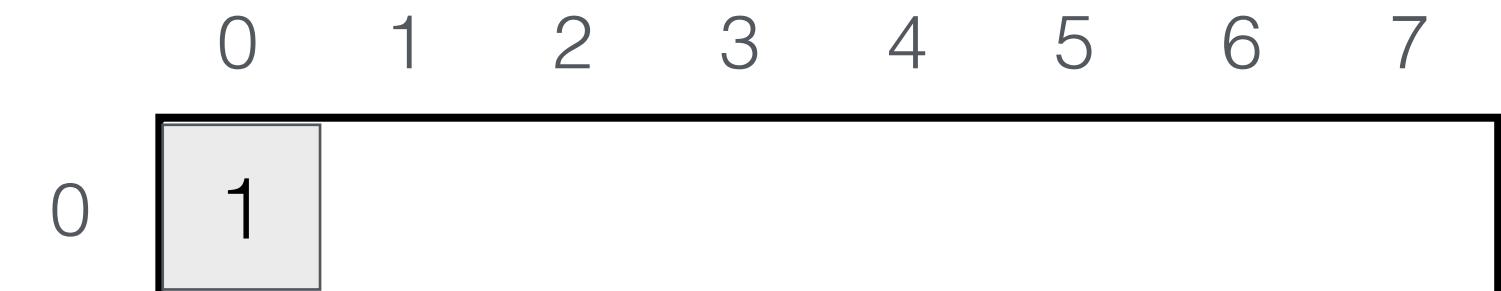
Dynamic Fill Values



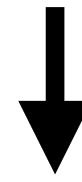
Dynamic Fill Values



Dynamic Fill Values



0	1	2	3	4	5	6	7
0	1	1	1	0	0	0	5
1	6	6	6	6	1	1	1
2	3	3	3	0	0	0	0
3	1	1	1	8	8	8	2

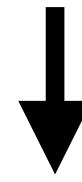


coord	0	3	6
vals	1	0	5
Fill	1		

Dynamic Fill Values



0	1	2	3	4	5	6	7
0	1	1	1	0	0	0	5
1	6	6	6	6	1	1	1
2	3	3	3	0	0	0	0
3	1	1	1	8	8	8	2

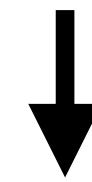


coord	0	3	6
vals	1	0	5
Fill	1		

Dynamic Fill Values

	0	1	2	3	4	5	6	7
0	1	1						

	0	1	2	3	4	5	6	7
0	1	1	1	0	0	0	5	5
1	6	6	6	6	1	1	1	1
2	3	3	3	0	0	0	0	0
3	1	1	1	8	8	8	2	2

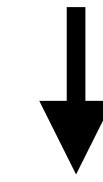


coord	0	3	6
vals	1	0	5
Fill	1		

Dynamic Fill Values

	0	1	2	3	4	5	6	7
0	1	1	1					

	0	1	2	3	4	5	6	7
0	1	1	1	0	0	0	5	5
1	6	6	6	6	1	1	1	1
2	3	3	3	0	0	0	0	0
3	1	1	1	8	8	8	2	2

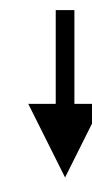


coord	0	3	6
vals	1	0	5
Fill	1		

Dynamic Fill Values

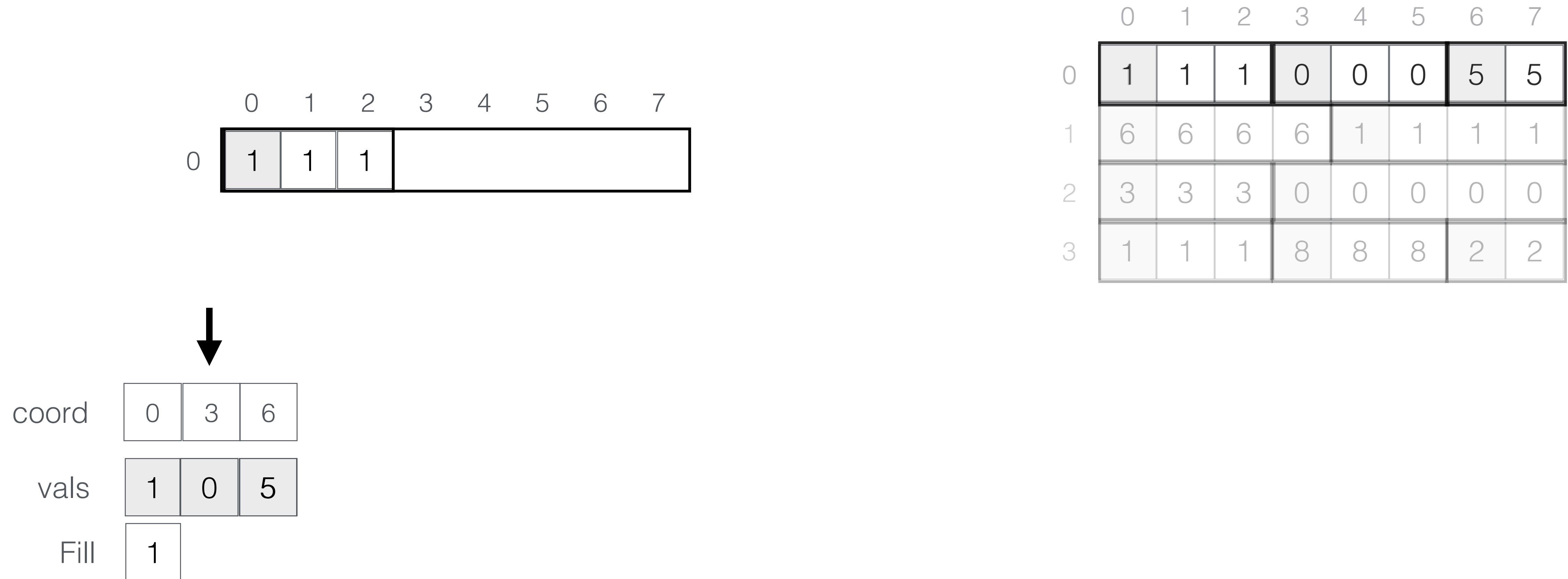
	0	1	2	3	4	5	6	7
0	1	1	1					

	0	1	2	3	4	5	6	7
0	1	1	1	0	0	0	5	5
1	6	6	6	6	1	1	1	1
2	3	3	3	0	0	0	0	0
3	1	1	1	8	8	8	2	2

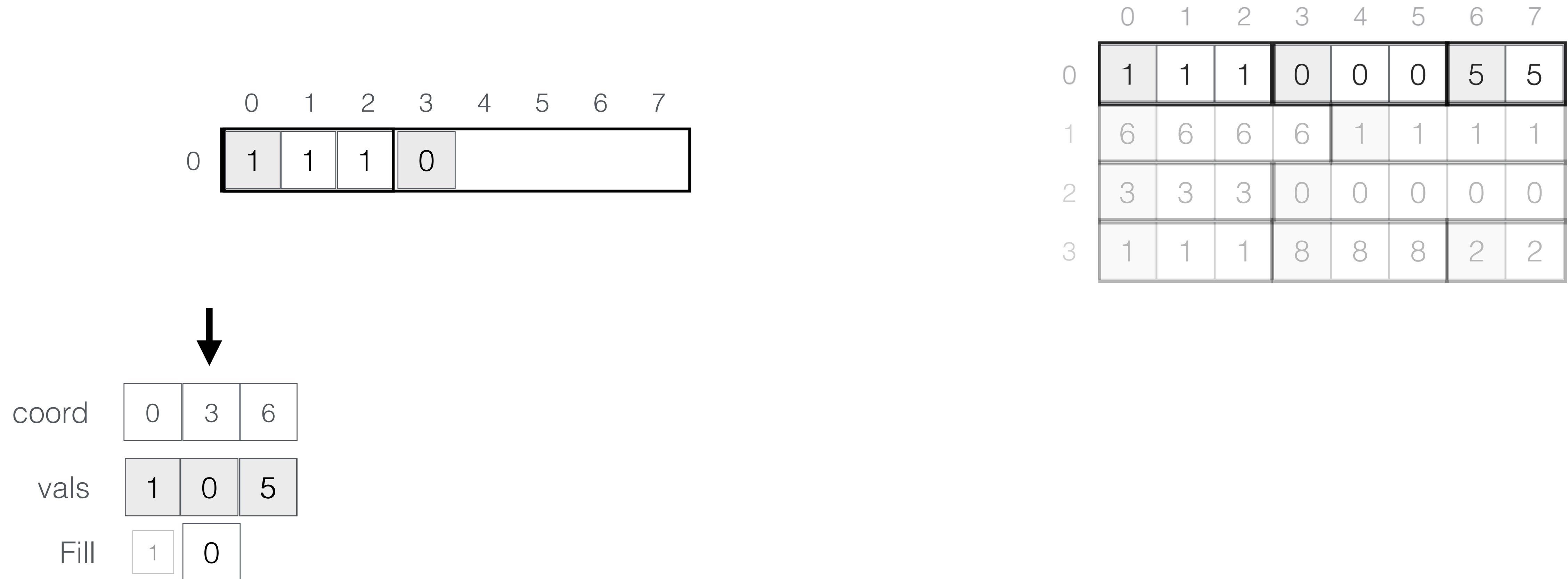


coord	0	3	6
vals	1	0	5
Fill	1		

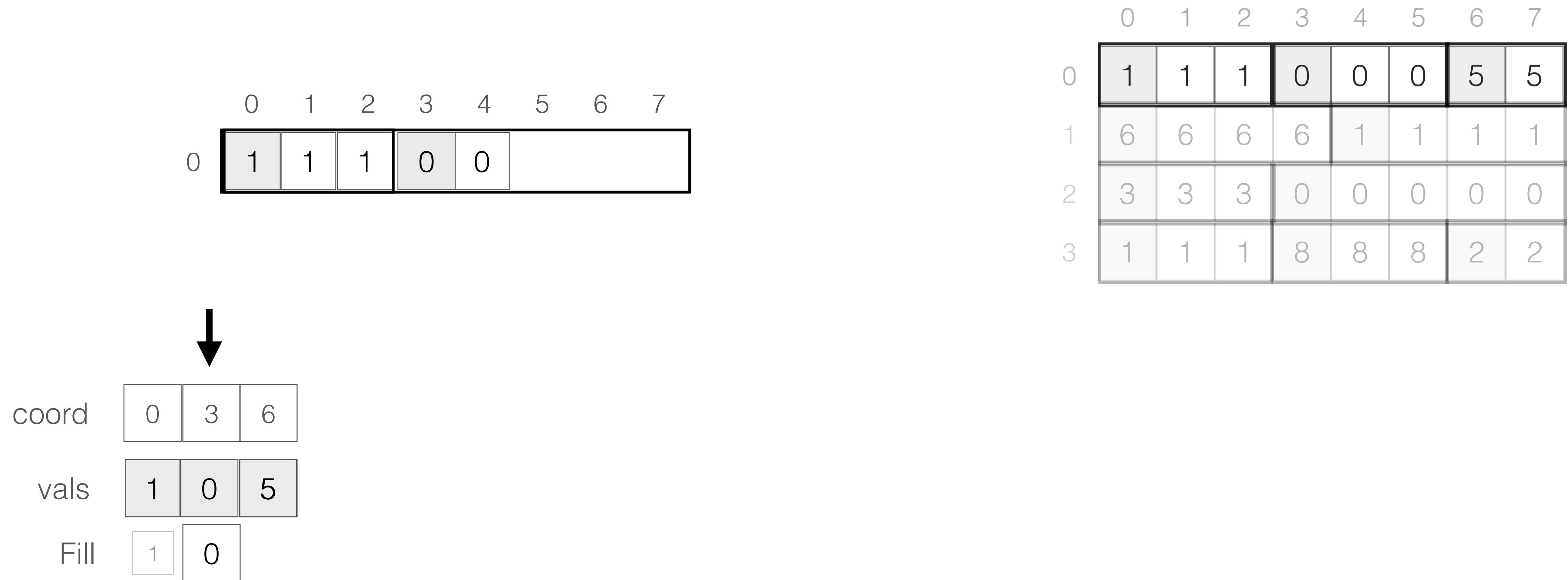
Dynamic Fill Values



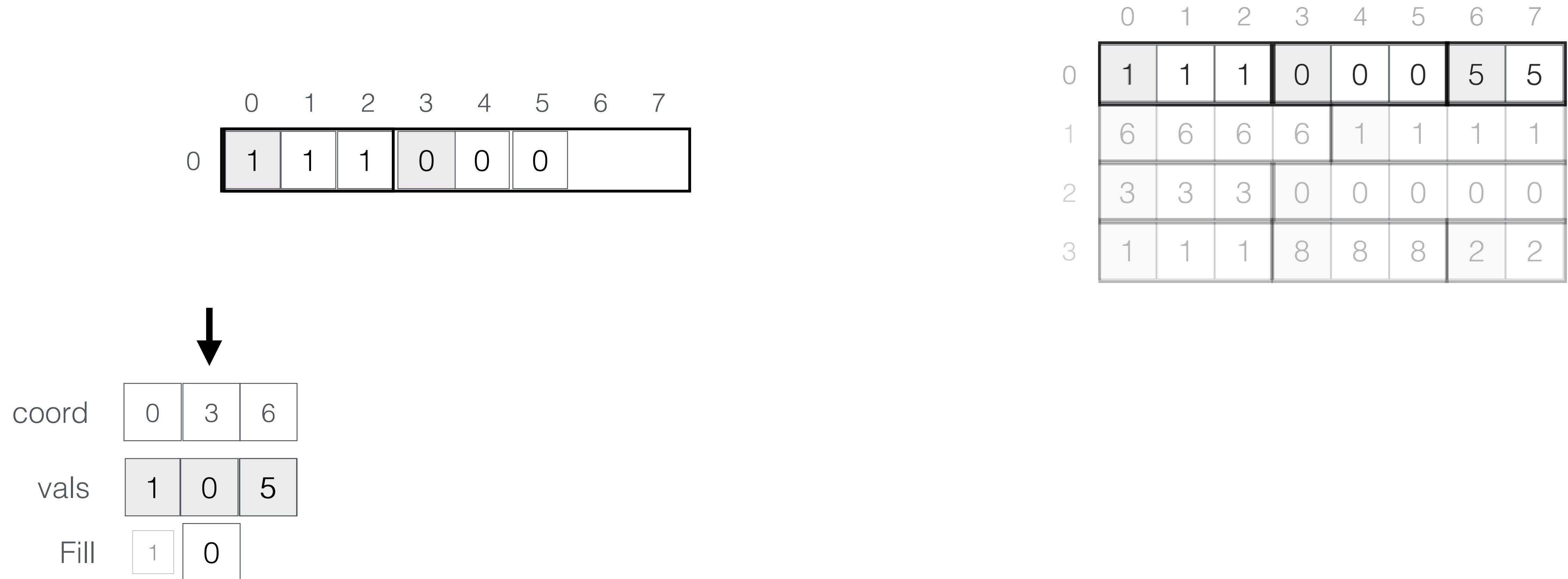
Dynamic Fill Values



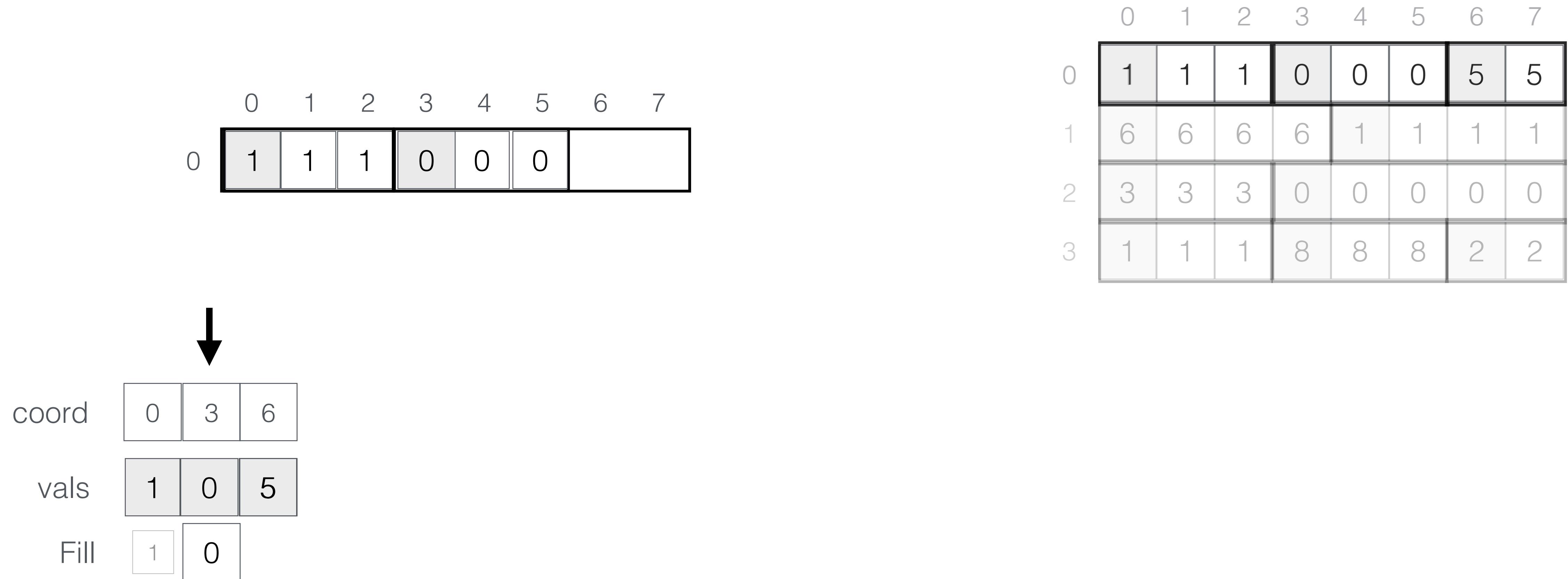
Dynamic Fill Values



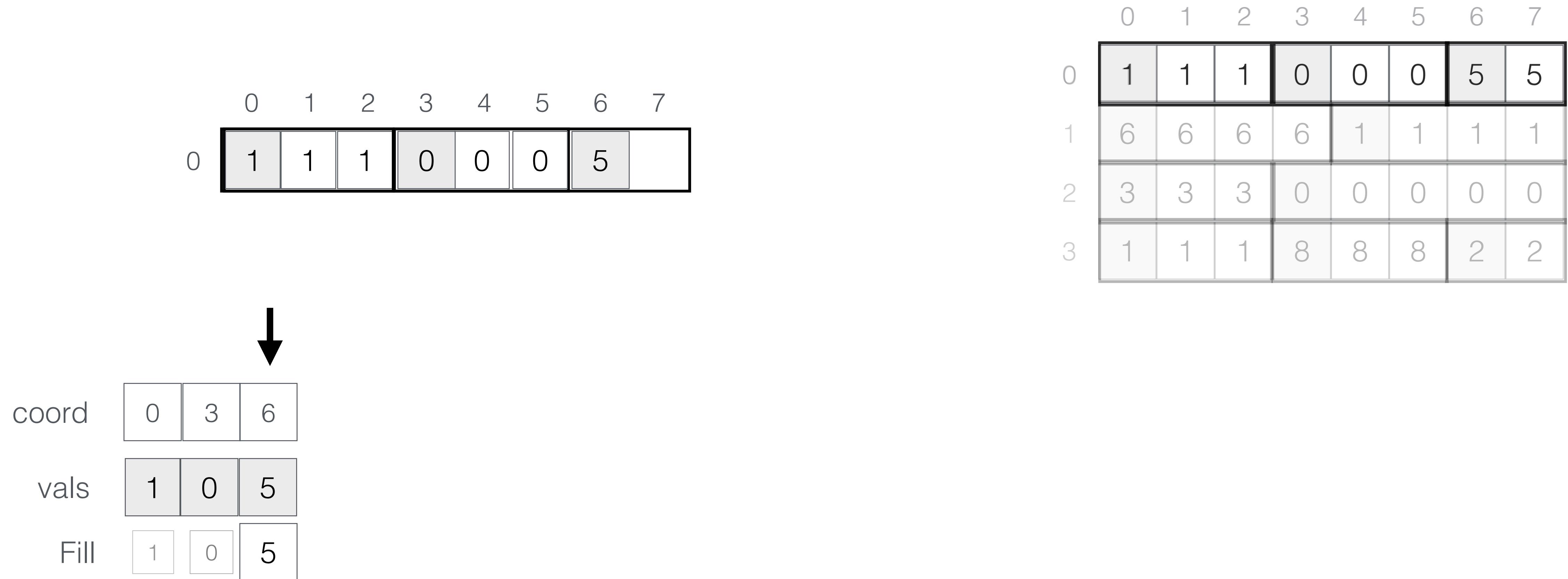
Dynamic Fill Values



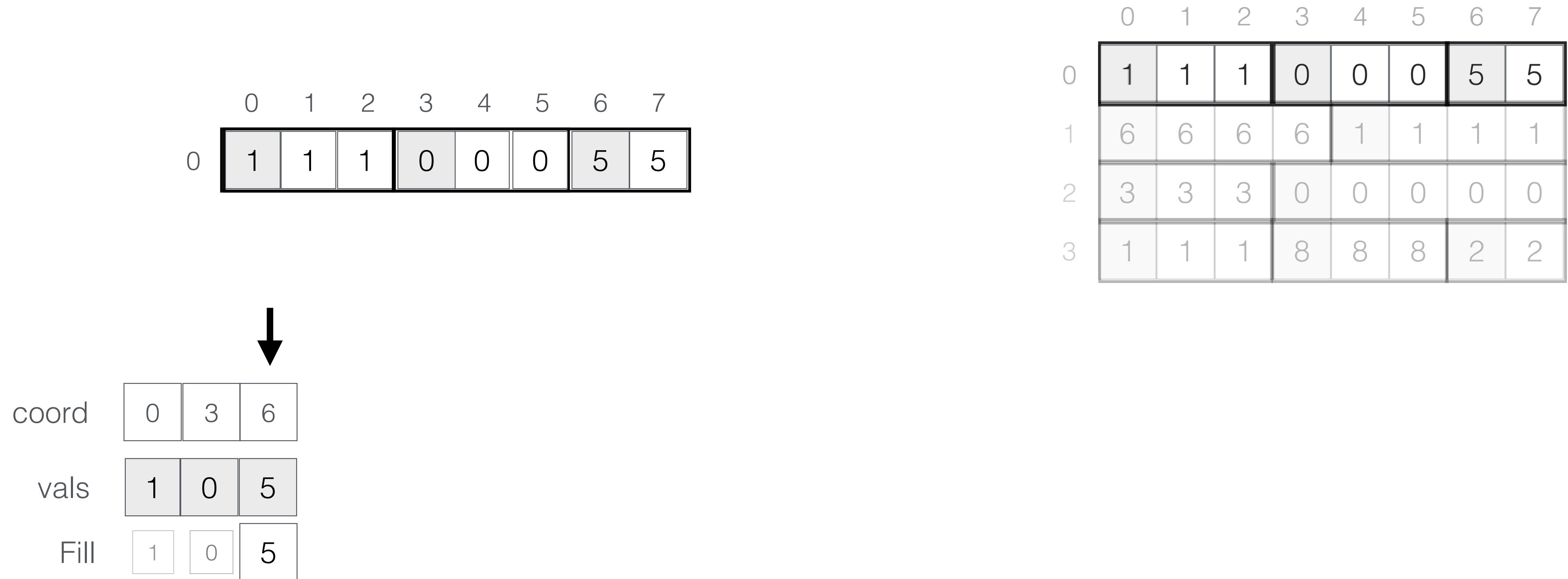
Dynamic Fill Values



Dynamic Fill Values



Dynamic Fill Values



Dynamic Fill Values

	0	1	2	3	4	5	6	7
0	1	1	1	0	0	0	5	5
1	6	6	6	6	1	1	1	1
2	3	3	3	0	0	0	0	0
3	1	1	1	8	8	8	2	2

	0	1	2	3	4	5	6	7
0	1	1	1	0	0	0	5	5
1	6	6	6	6	1	1	1	1
2	3	3	3	0	0	0	0	0
3	1	1	1	8	8	8	2	2

Compressed Level Format

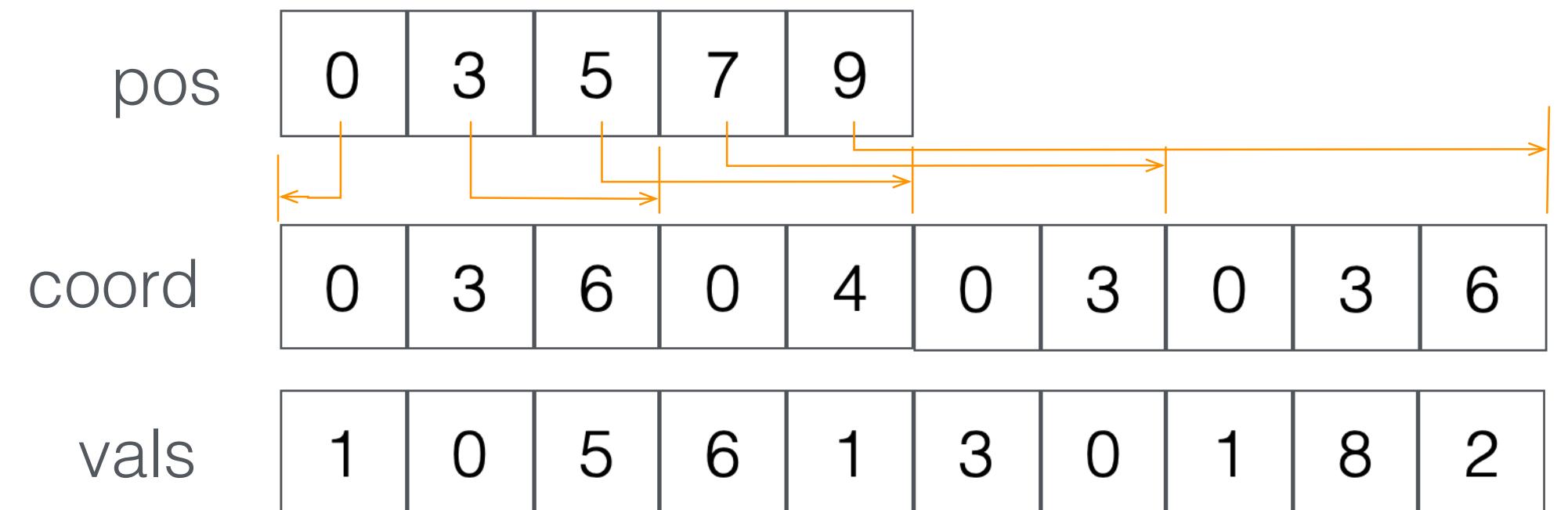
pos	0	5	13	16	23																			
coord	0	1	2	6	7	0	1	2	3	4	5	6	7	0	1	2	3	4	5	7	7			
vals	1	1	1	5	5	6	6	6	6	1	1	1	1	3	3	3	1	1	1	8	8	8	2	2

Run Length Encoding (RLE) Level Format

pos	0	3	5	7	9					
coord	0	3	6	0	4	0	3	0	3	6
vals	1	0	5	6	1	3	0	1	8	2

New Level Formats

Run Length Encoding (RLE) Level Format



New Level Formats

Run Length Encoding (RLE) Level Format

pos	0	3	5	7	9					
coord	0	3	6	0	4	0	3	0	3	6
vals	1	0	5	6	1	3	0	1	8	2

LZ77 Level Format

New Level Formats

Run Length Encoding (RLE) Level Format

pos	0	3	5	7	9				
coord	0	3	6	0	4	0	3	0	3
vals	1	0	5	6	1	3	0	1	8

The diagram illustrates the Run Length Encoding (RLE) level format. It shows three parallel arrays: 'pos', 'coord', and 'vals'. The 'pos' array contains indices [0, 3, 5, 7, 9]. The 'coord' array contains values [0, 3, 6, 0, 4, 0, 3, 0, 3, 6]. The 'vals' array contains values [1, 0, 5, 6, 1, 3, 0, 1, 8, 2]. Orange arrows indicate the mapping from 'pos' to 'coord' and 'vals'. Specifically, the first run starts at pos 0 with value 1 (coord 0, val 1), followed by runs of length 3 (coord 3, val 0), length 2 (coord 5, val 5), length 1 (coord 7, val 6), length 1 (coord 9, val 1), length 3 (coord 0, val 3), length 1 (coord 4, val 0), length 2 (coord 6, val 3), length 1 (coord 0, val 0), length 2 (coord 3, val 1), length 1 (coord 6, val 8), and length 1 (coord 9, val 2).

LZ77 Level Format

3	6	4	3	6	4	3	6	4
---	---	---	---	---	---	---	---	---

New Level Formats

Run Length Encoding (RLE) Level Format

pos	0	3	5	7	9				
	0	3	6	0	4	0	3	0	3
coord	0	3	6	0	4	0	3	0	3
vals	1	0	5	6	1	3	0	1	8
	1	0	5	6	1	3	0	1	8

LZ77 Level Format

3	6	4	3	6	4	3	6	4
3	6	4	<3,6>					

New Level Formats

Run Length Encoding (RLE) Level Format

pos	0	3	5	7	9				
	0	3	6	0	4	0	3	0	3
coord	0	3	6	0	4	0	3	0	3
vals	1	0	5	6	1	3	0	1	8
	1	0	5	6	1	3	0	1	8

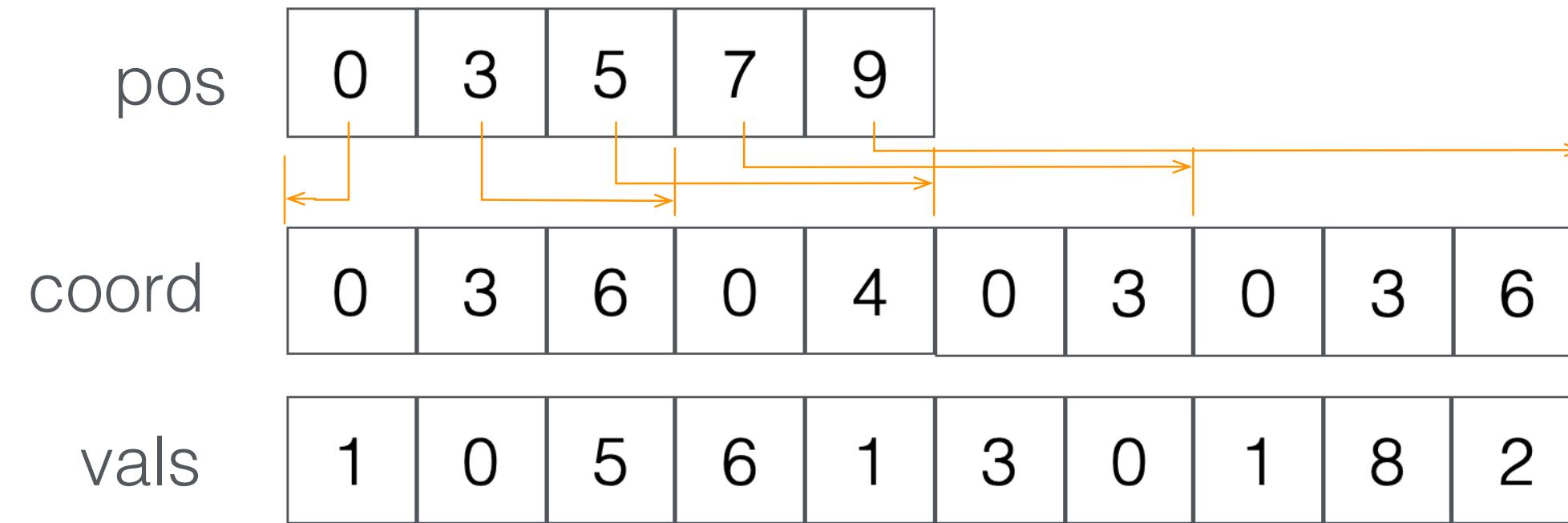
LZ77 Level Format

3	6	4	3	6	4	3	6	4
3	6	4	<3,6>					

Distance

New Level Formats

Run Length Encoding (RLE) Level Format



LZ77 Level Format

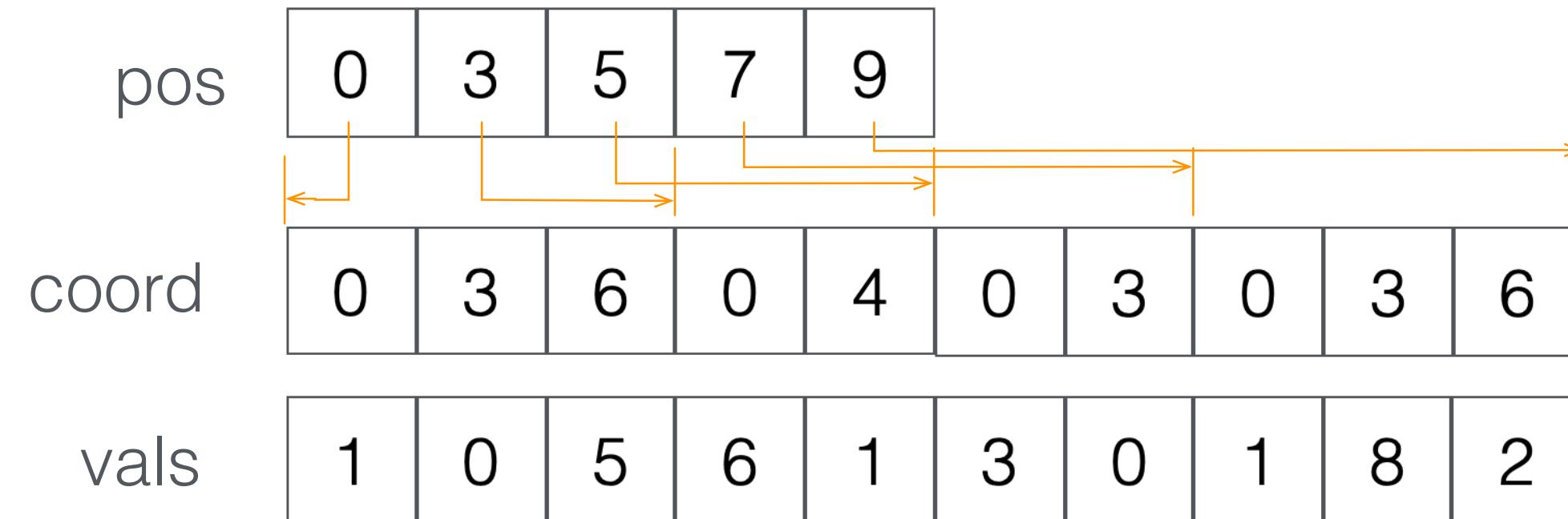
3	6	4	3	6	4	3	6	4
---	---	---	---	---	---	---	---	---

3	6	4	<3,6>
---	---	---	-------

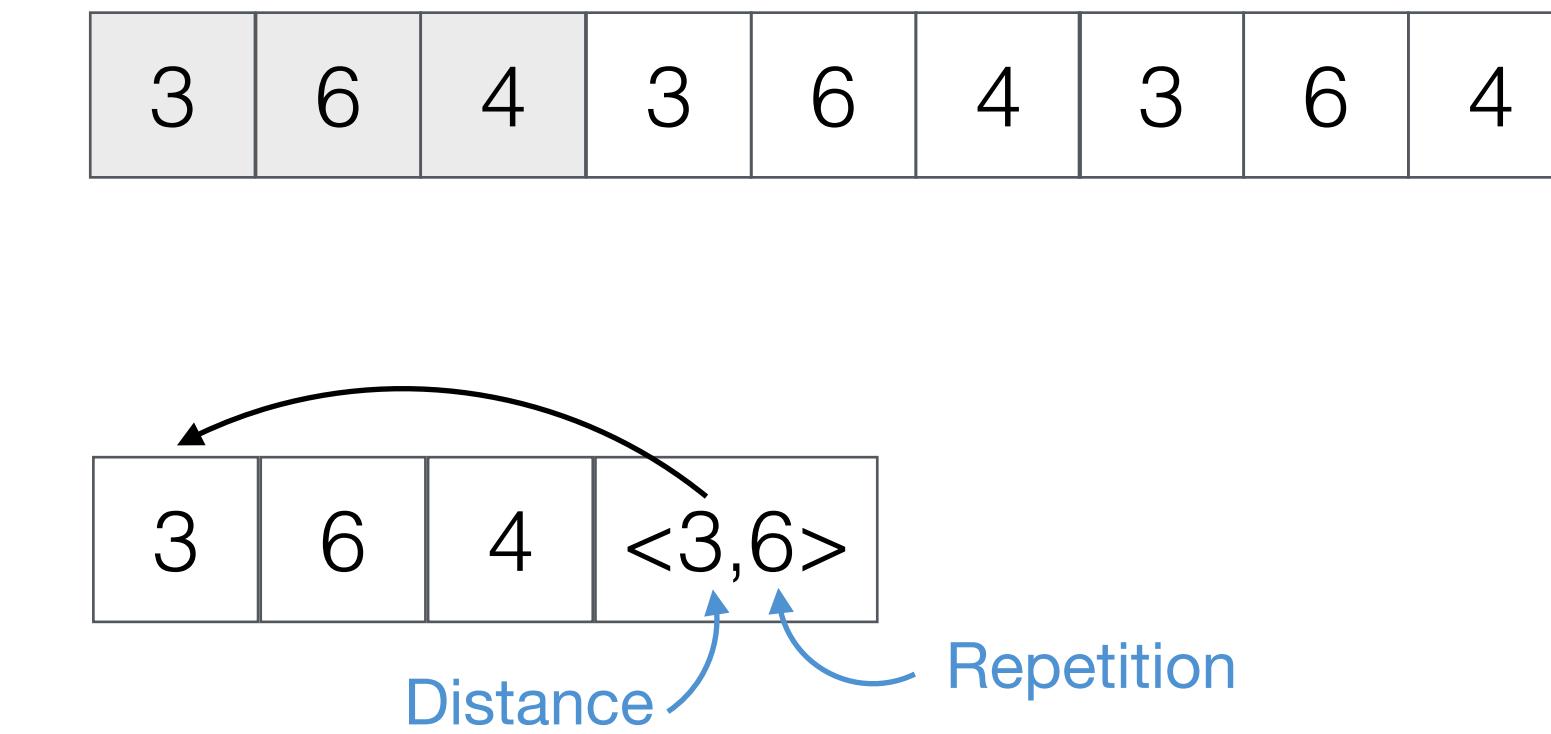
Distance

New Level Formats

Run Length Encoding (RLE) Level Format

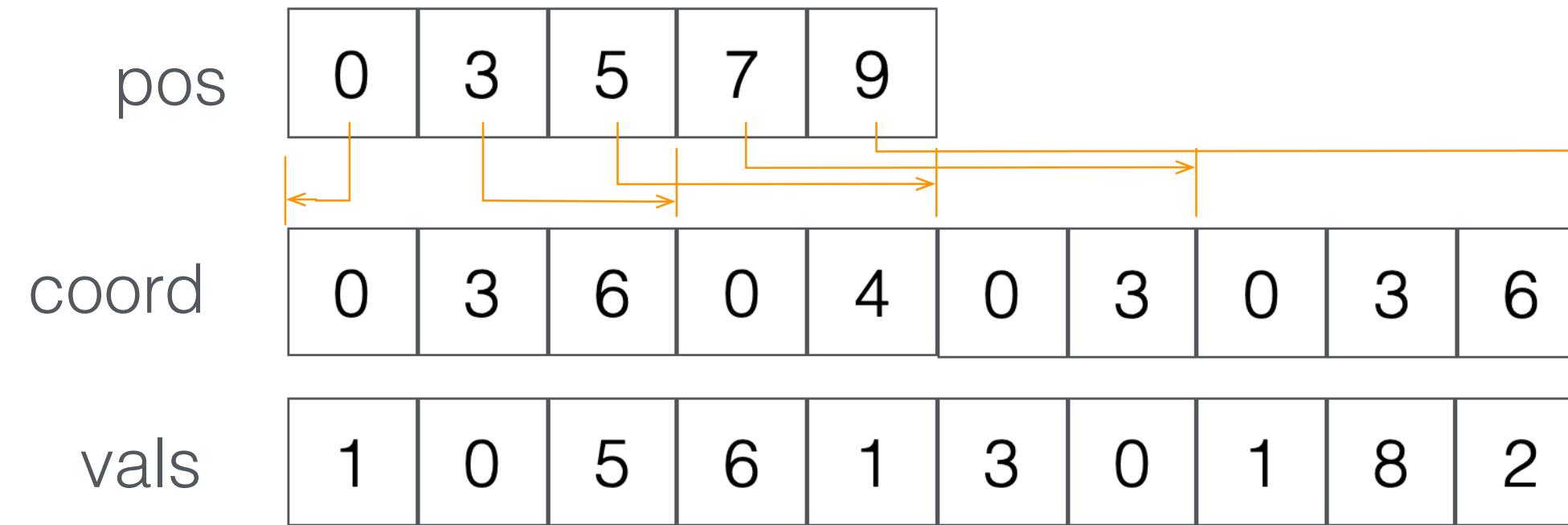


LZ77 Level Format

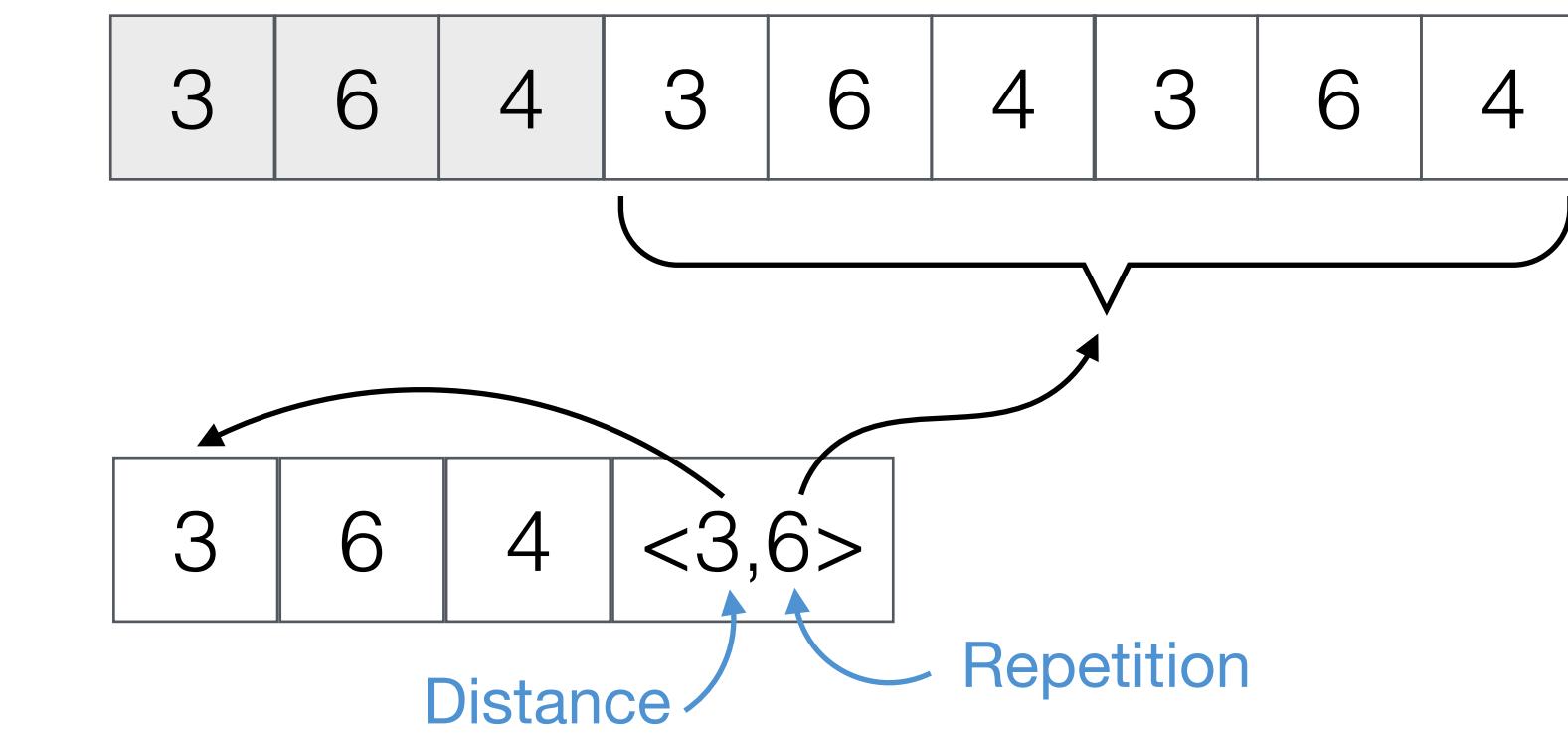


New Level Formats

Run Length Encoding (RLE) Level Format



LZ77 Level Format



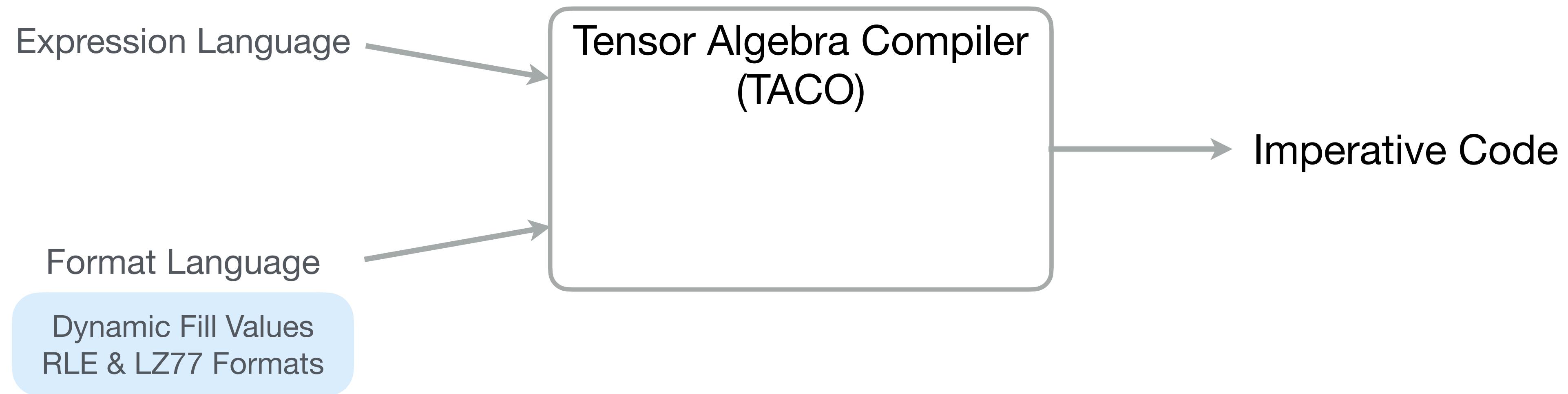
New Level Formats

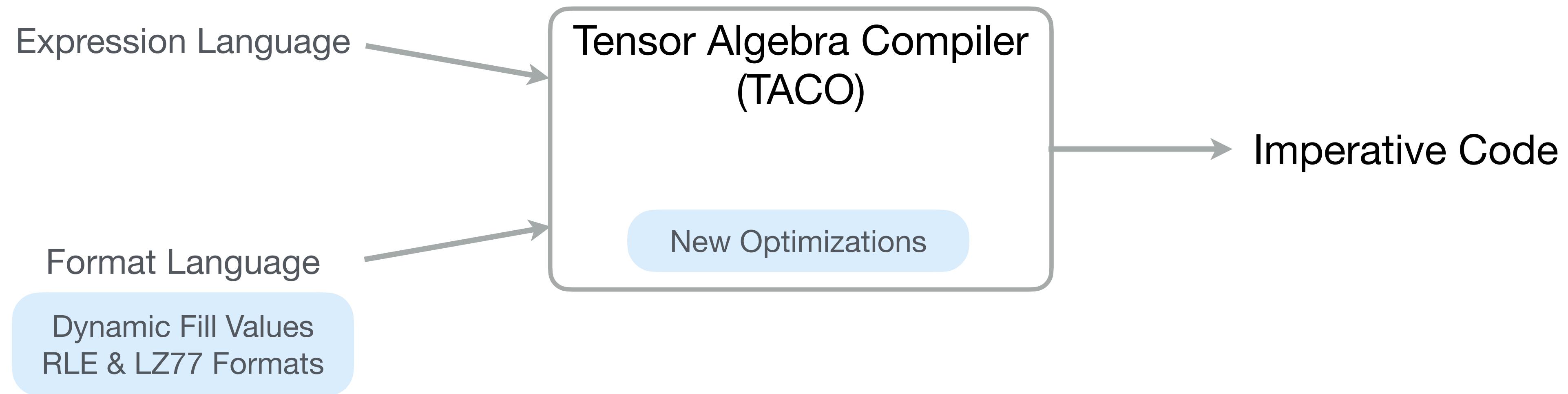
Run Length Encoding (RLE) Level Format

pos	0	3	5	7	9					
	0	3	6	0	4	0	3	0	3	6
coord	1	0	5	6	1	3	0	1	8	2
vals										

LZ77 Level Format

3	6	4	<3,6>
---	---	---	-------





Optimizing computations on lossless compression formats

Elementwise computation

1	1	1	2	2	2	5	5
---	---	---	---	---	---	---	---

RLE

$$\begin{array}{l} \times \end{array} \begin{array}{|c|c|c|c|c|c|c|c|} \hline & 6 & 6 & 6 & 6 & 1 & 1 & 1 & 1 \\ \hline \end{array}$$

RLE

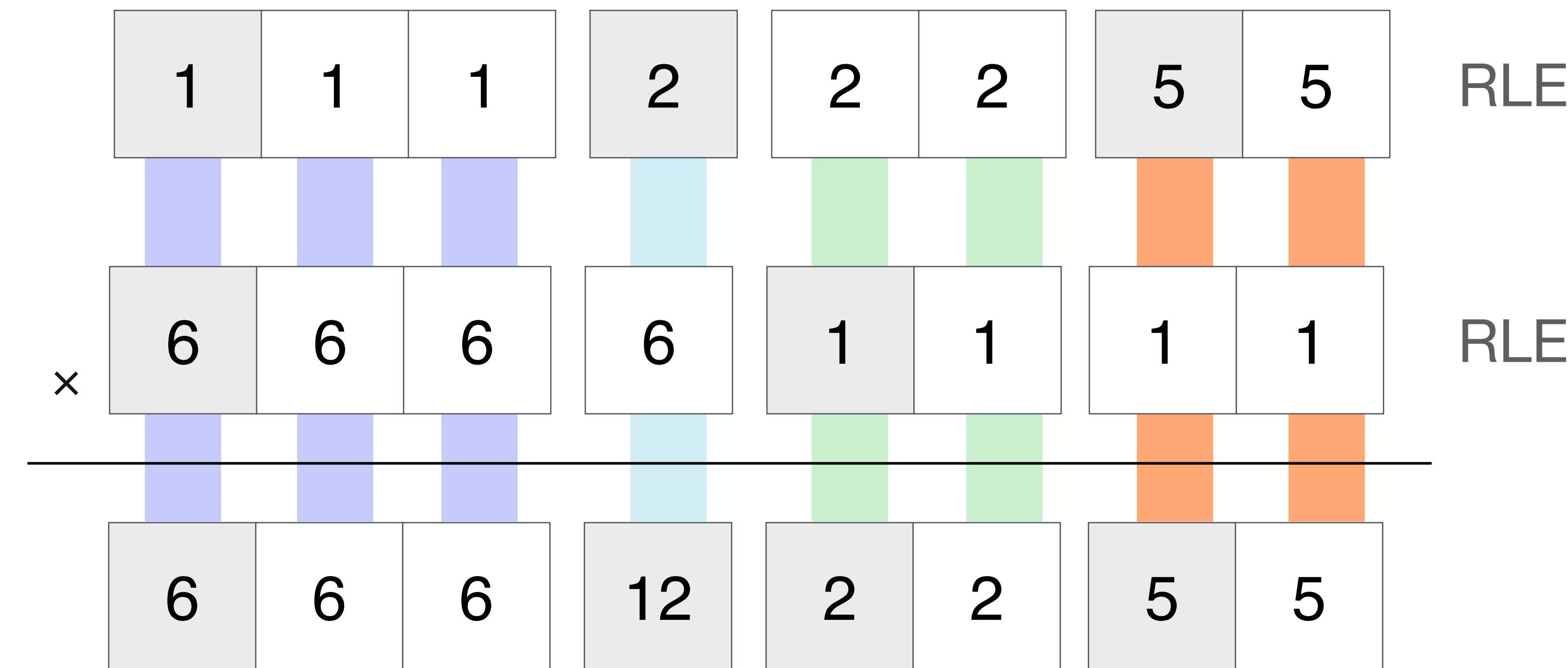
Optimizing computations on lossless compression formats

Elementwise computation



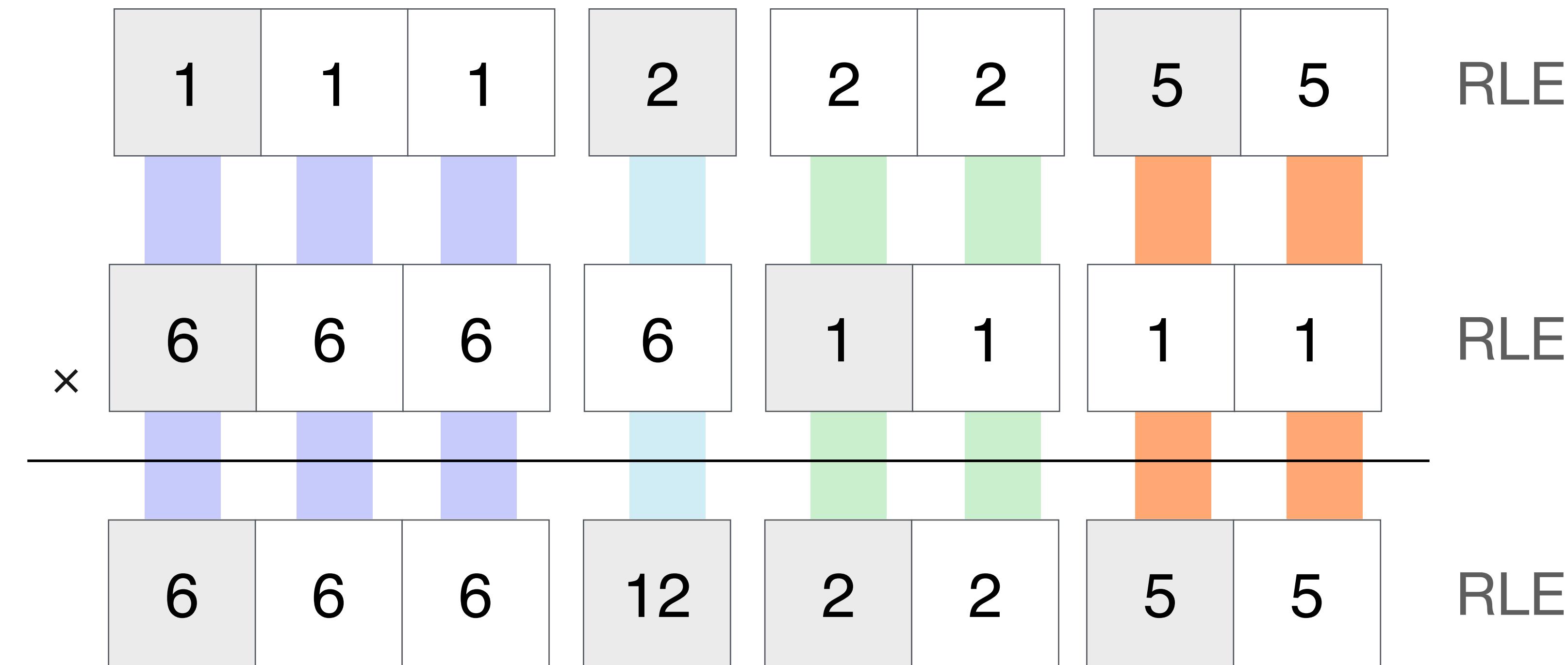
Optimizing computations on lossless compression formats

Elementwise computation



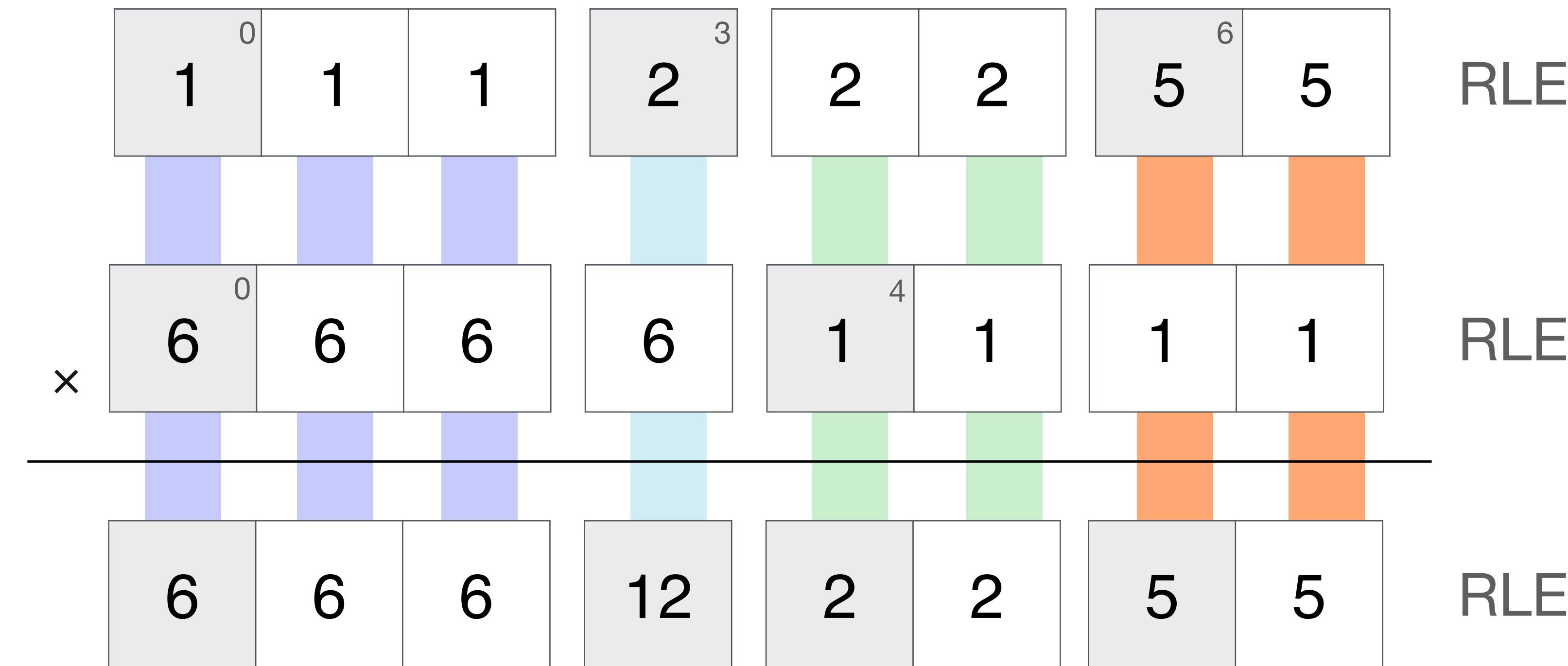
Optimizing computations on lossless compression formats

Elementwise computation



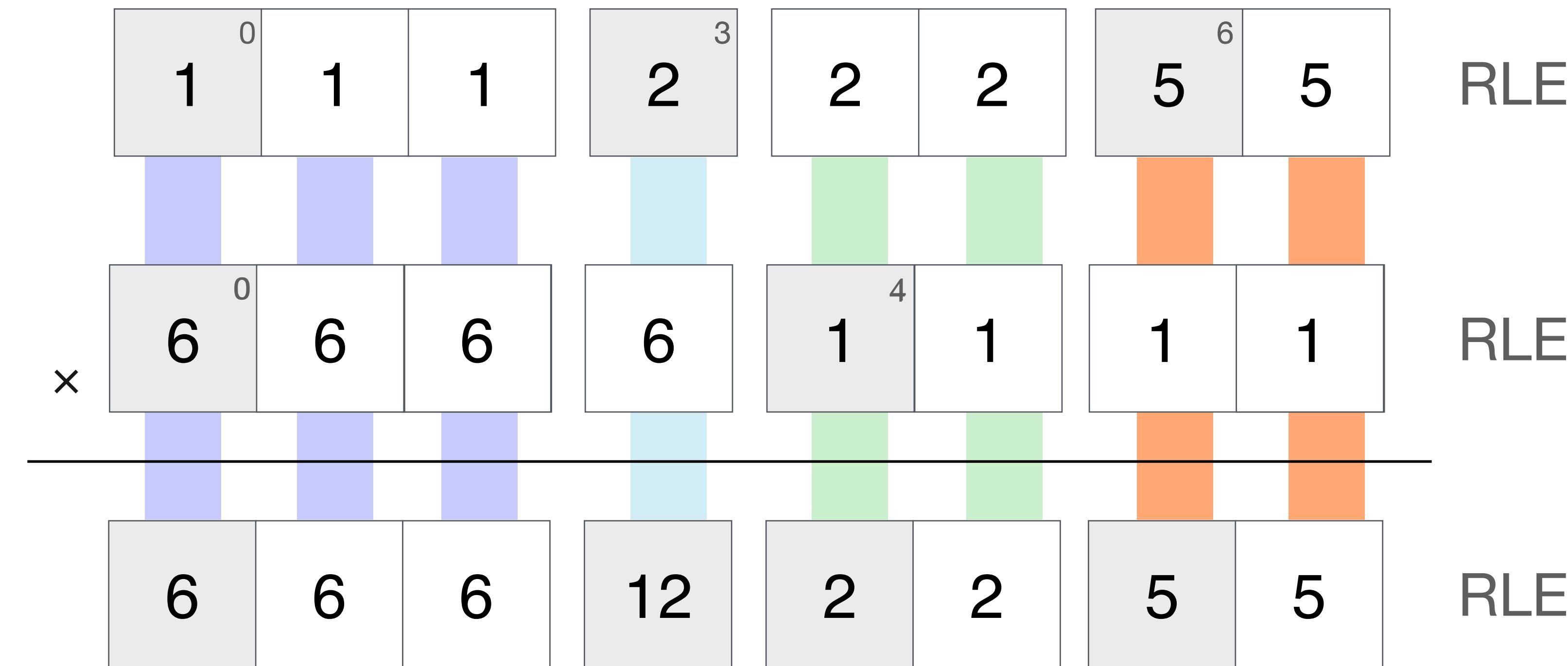
Optimizing computations on lossless compression formats

Elementwise computation



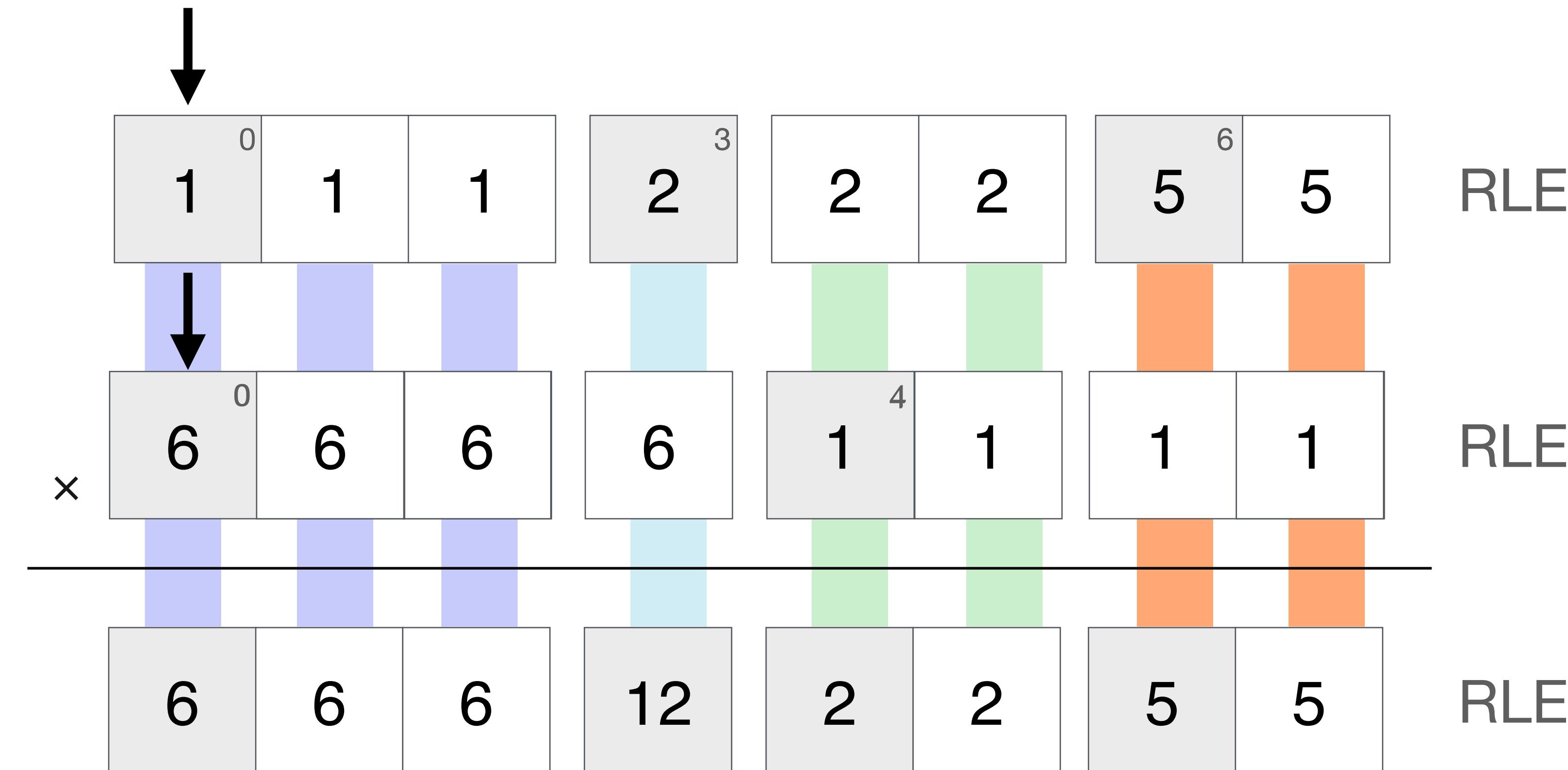
Optimizing computations on lossless compression formats

Elementwise computation



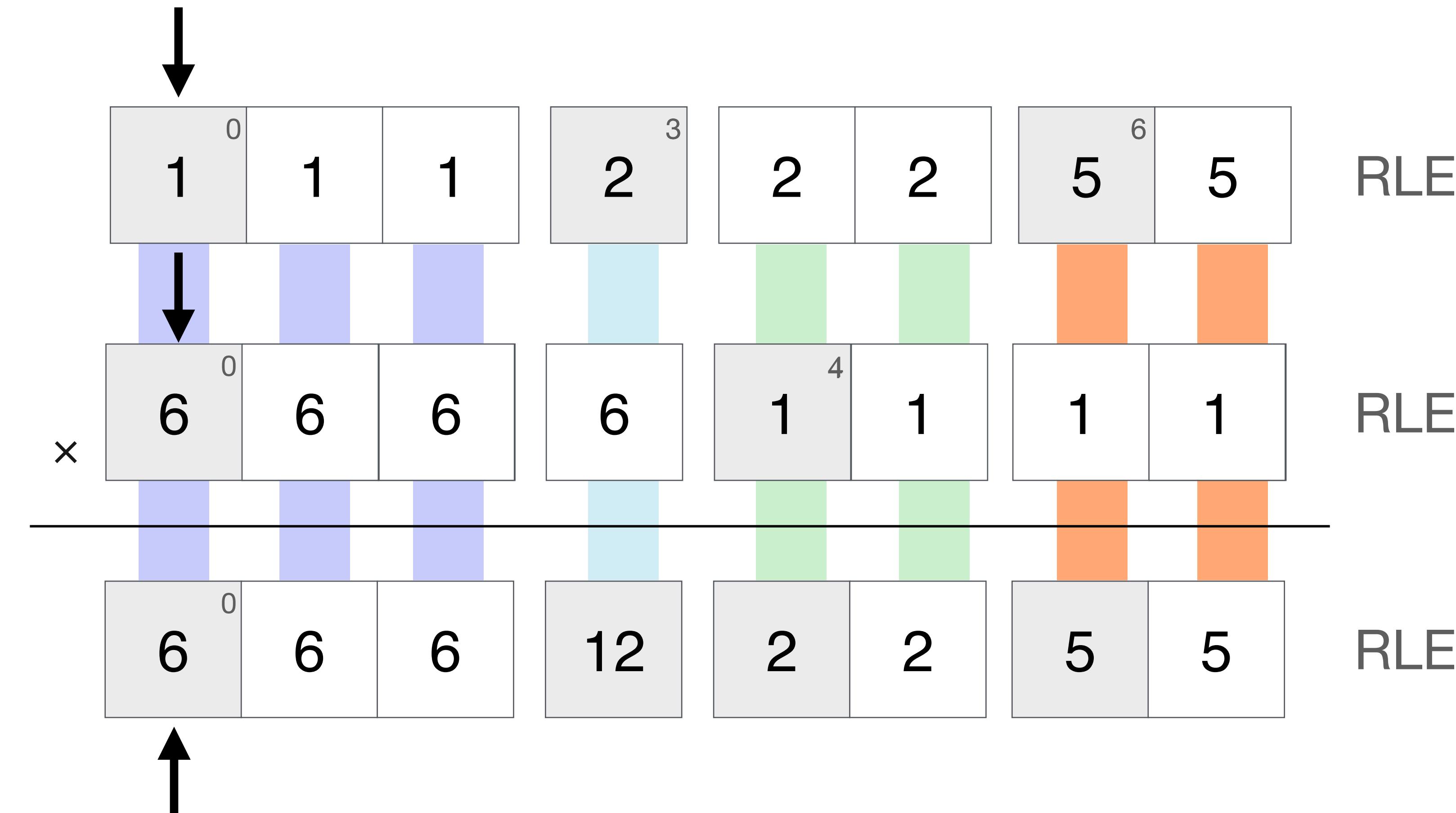
Optimizing computations on lossless compression formats

Elementwise computation



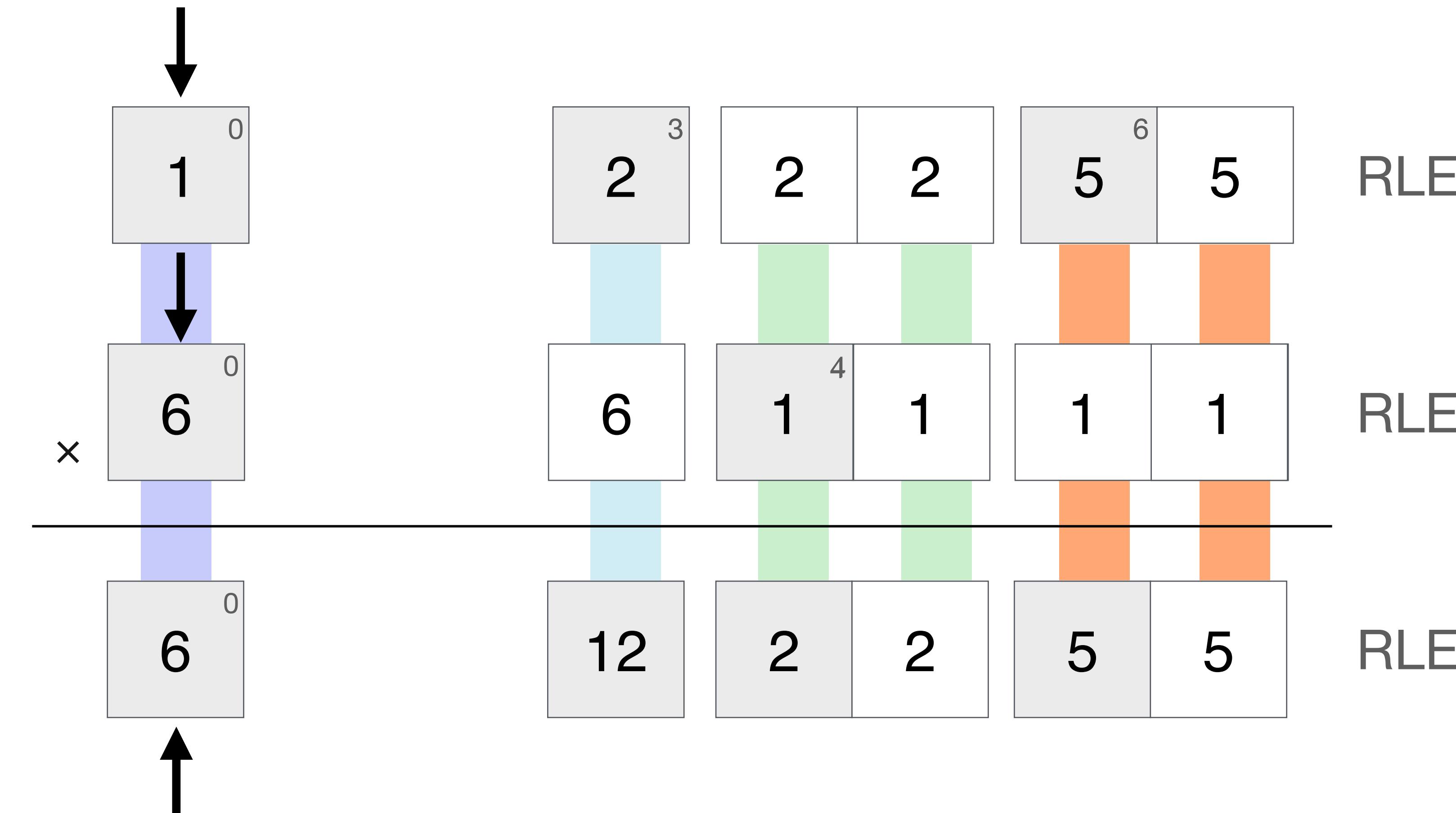
Optimizing computations on lossless compression formats

Elementwise computation



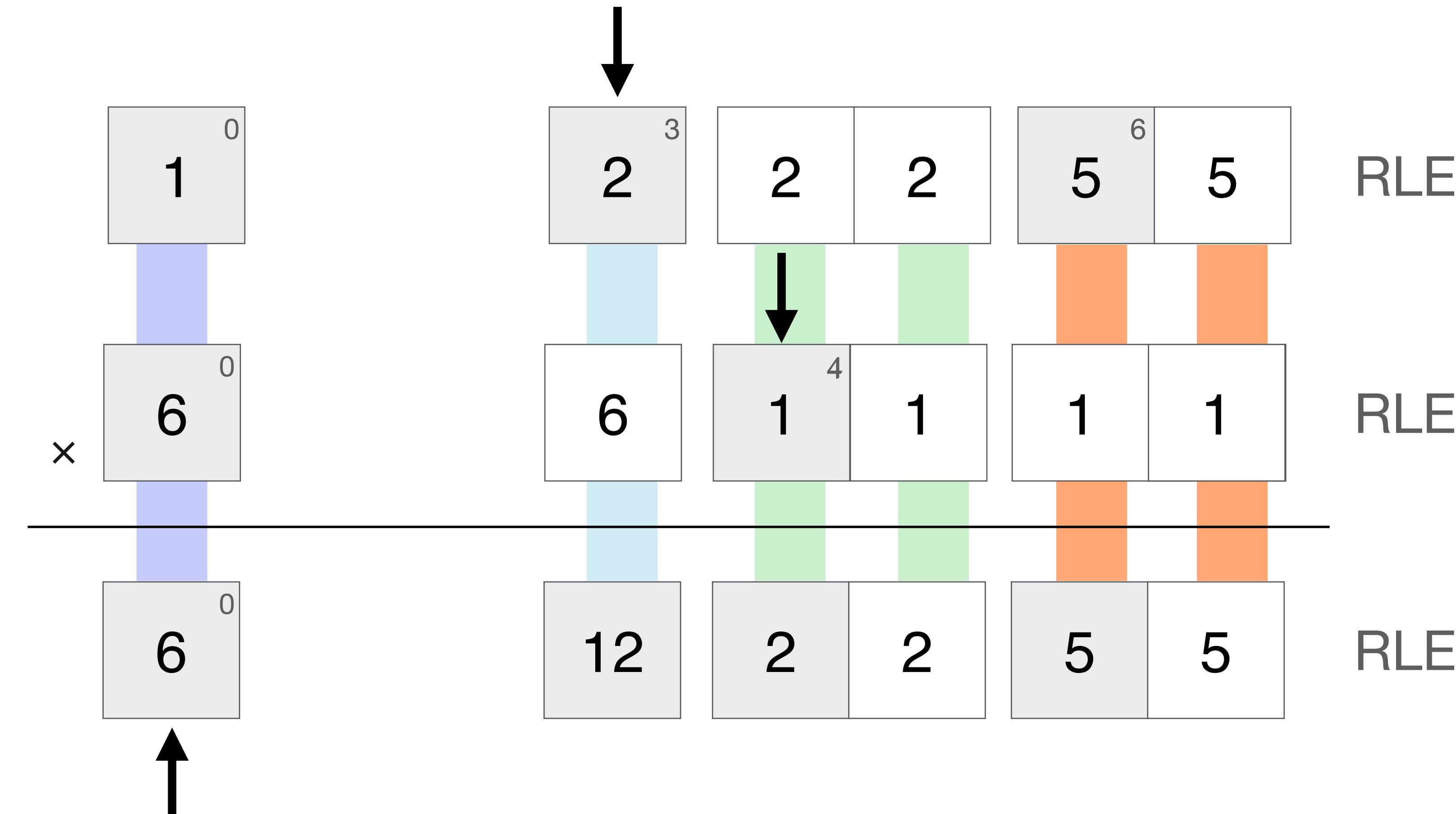
Optimizing computations on lossless compression formats

Elementwise computation



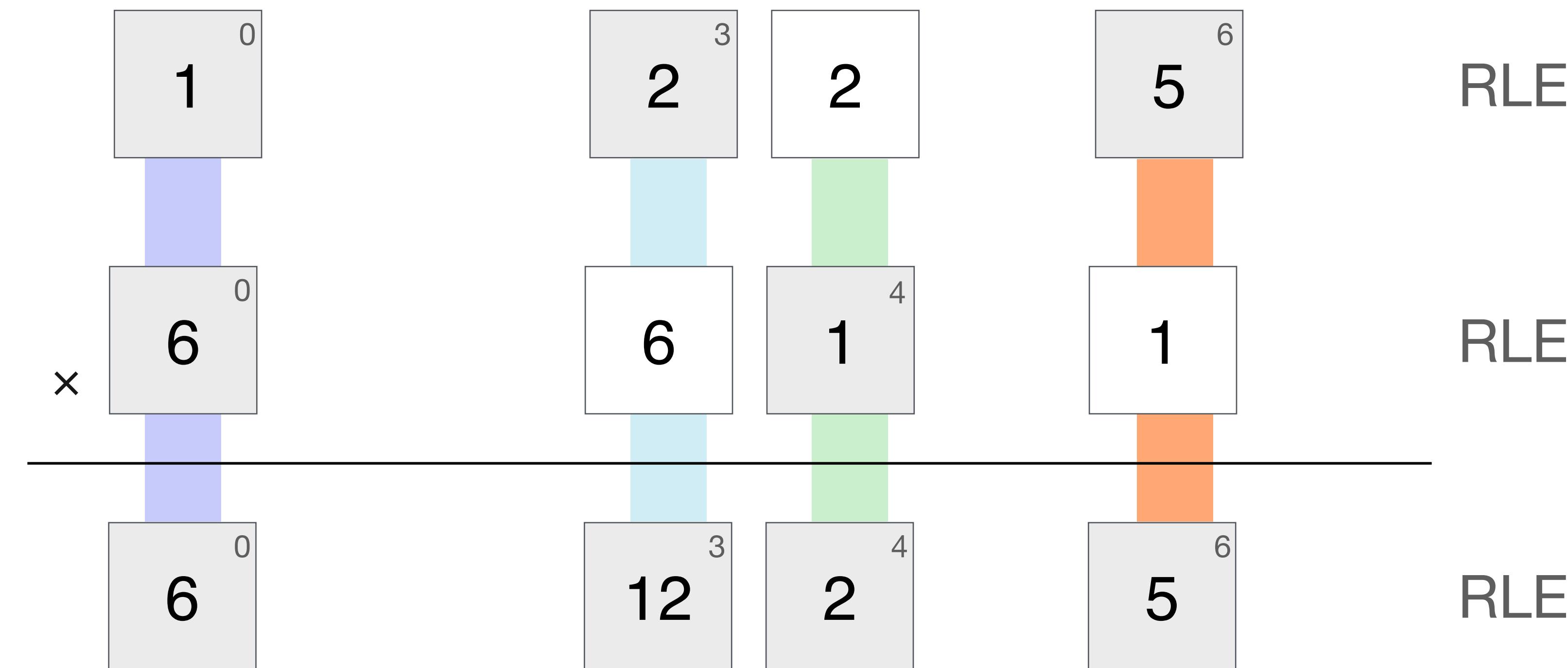
Optimizing computations on lossless compression formats

Elementwise computation



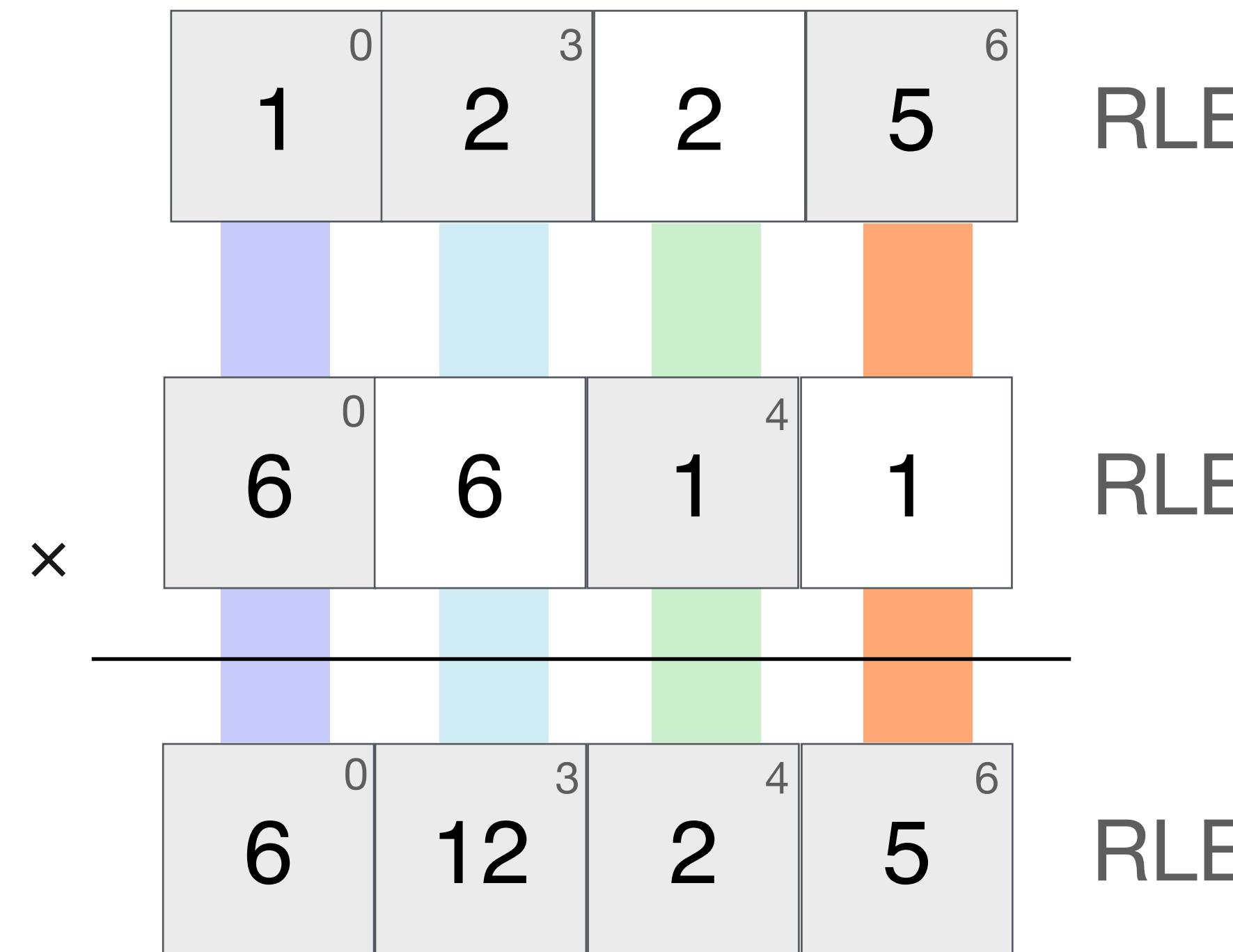
Optimizing computations on lossless compression formats

Elementwise computation



Optimizing computations on lossless compression formats

Elementwise computation



Optimizing computations on lossless compression formats

Reduction

1	1	1	2	2	2	5	5
---	---	---	---	---	---	---	---

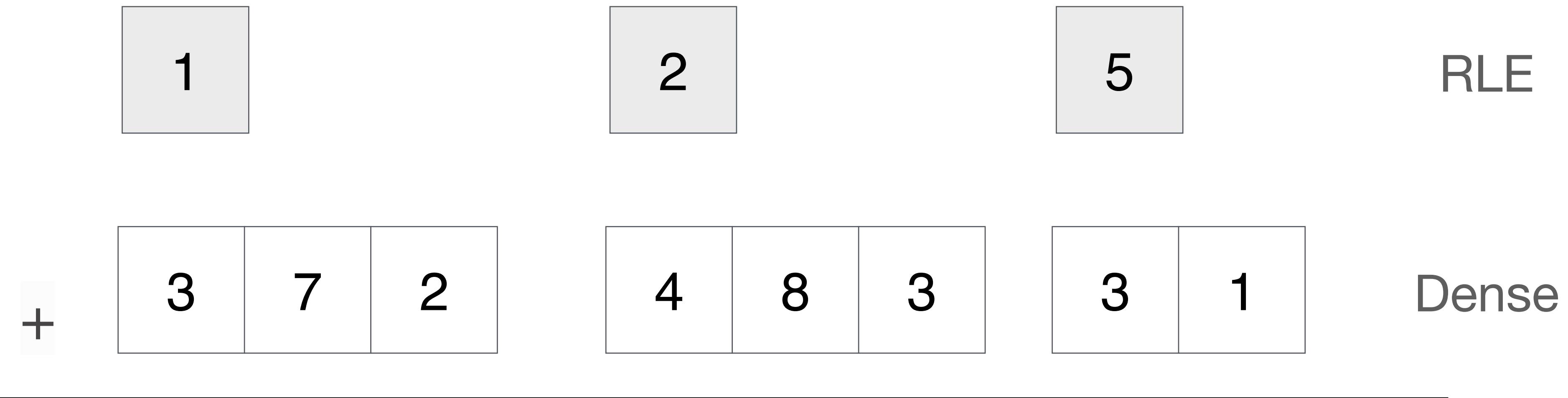
RLE

.	3	7	2	4	8	3	3	1
---	---	---	---	---	---	---	---	---

Dense

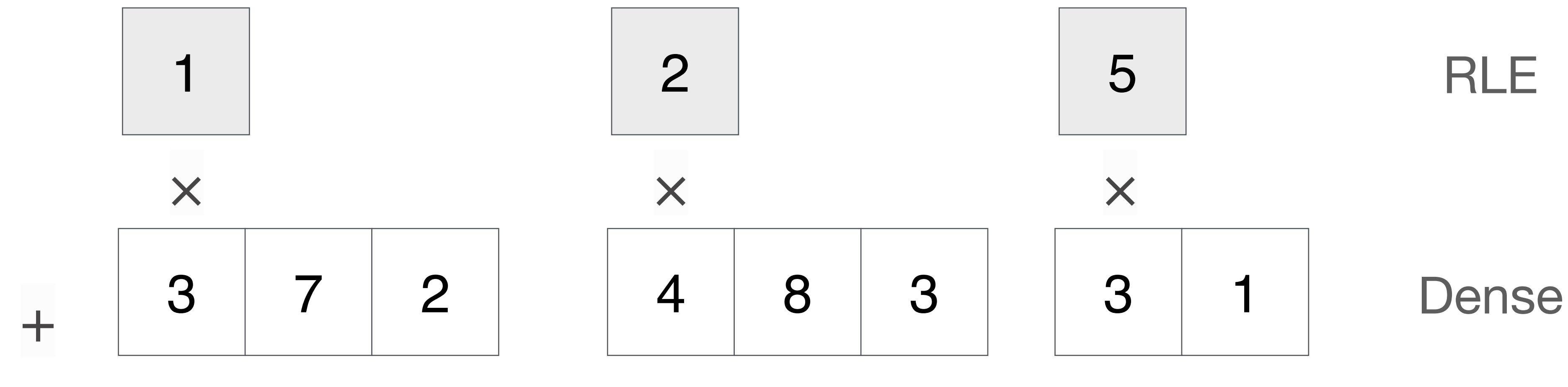
Optimizing computations on lossless compression formats

Reduction



Optimizing computations on lossless compression formats

Reduction



Optimizing computations on lossless compression formats

Reduction

$$\begin{array}{r} \boxed{1} \\ \times \\ + \quad 3 \quad + \quad 7 \quad + \quad 2 \\ \hline \end{array} \quad \begin{array}{r} \boxed{2} \\ \times \\ + \quad 4 \quad + \quad 8 \quad + \quad 3 \\ \hline \end{array} \quad \begin{array}{r} \boxed{5} \\ \times \\ + \quad 3 \quad + \quad 1 \\ \hline \end{array}$$

Optimizing computations on lossless compression formats

Reduction

1	2	5
×	×	×
3 + 7 + 2	4 + 8 + 3	3 + 1
+ 12	15	4
<hr/>		

Optimizing computations on lossless compression formats

Reduction

$$\begin{array}{ccccccc} & \boxed{1} & & \boxed{2} & & \boxed{5} & \\ & \times & & \times & & \times & \\ 3 & + & 7 & + & 2 & 4 & + & 8 & + & 3 & 3 & + & 1 \\ & & & & & & & & & & & & \\ + & 12 & & & & 15 & & & & & 4 & & \\ \hline & 12 & + & & 30 & + & & & 20 & & & & \end{array}$$

Optimizing computations on lossless compression formats

Reduction

$$\begin{array}{c} 1 \\ \times \\ 3 + 7 + 2 \\ + 12 \\ \hline \end{array} \quad \begin{array}{c} 2 \\ \times \\ 4 + 8 + 3 \\ 15 \\ + \end{array} \quad \begin{array}{c} 5 \\ \times \\ 3 + 1 \\ 4 \\ + \end{array}$$
$$12 + 30 + 20 = 62$$

Optimizing computations on lossless compression formats

Reduction

The diagram illustrates the reduction of three parallel summations into a single summation. It shows three parallel tasks (1, 2, and 5) with their respective local sums (12, 15, and 4) being combined into a global sum (62).

Task 1: $1 \times 3 + 7 + 2 = 12$

Task 2: $2 \times 4 + 8 + 3 = 15$

Task 5: $5 \times 3 + 1 = 4$

Global Sum: $12 + 30 + 20 = 62$

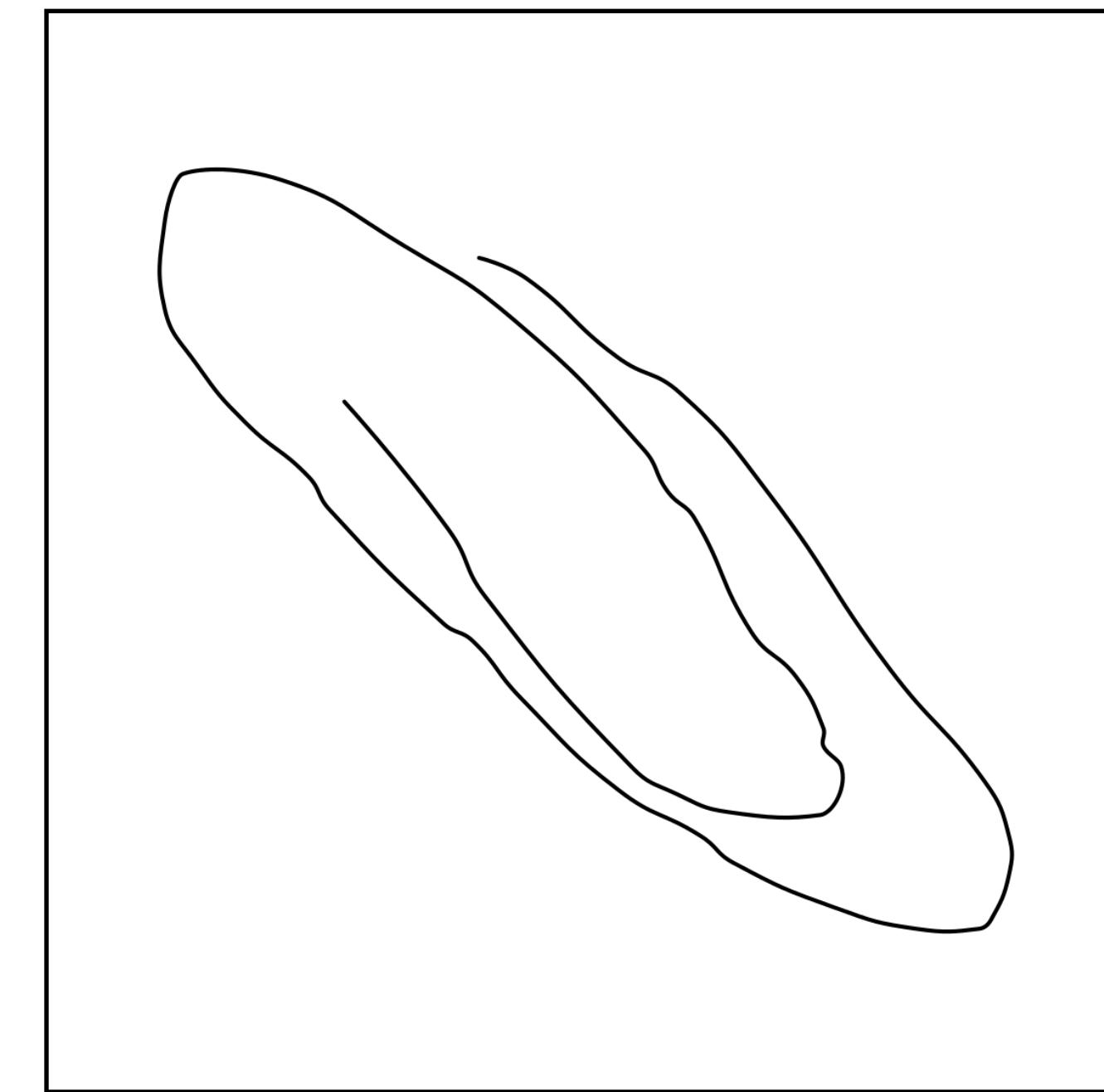
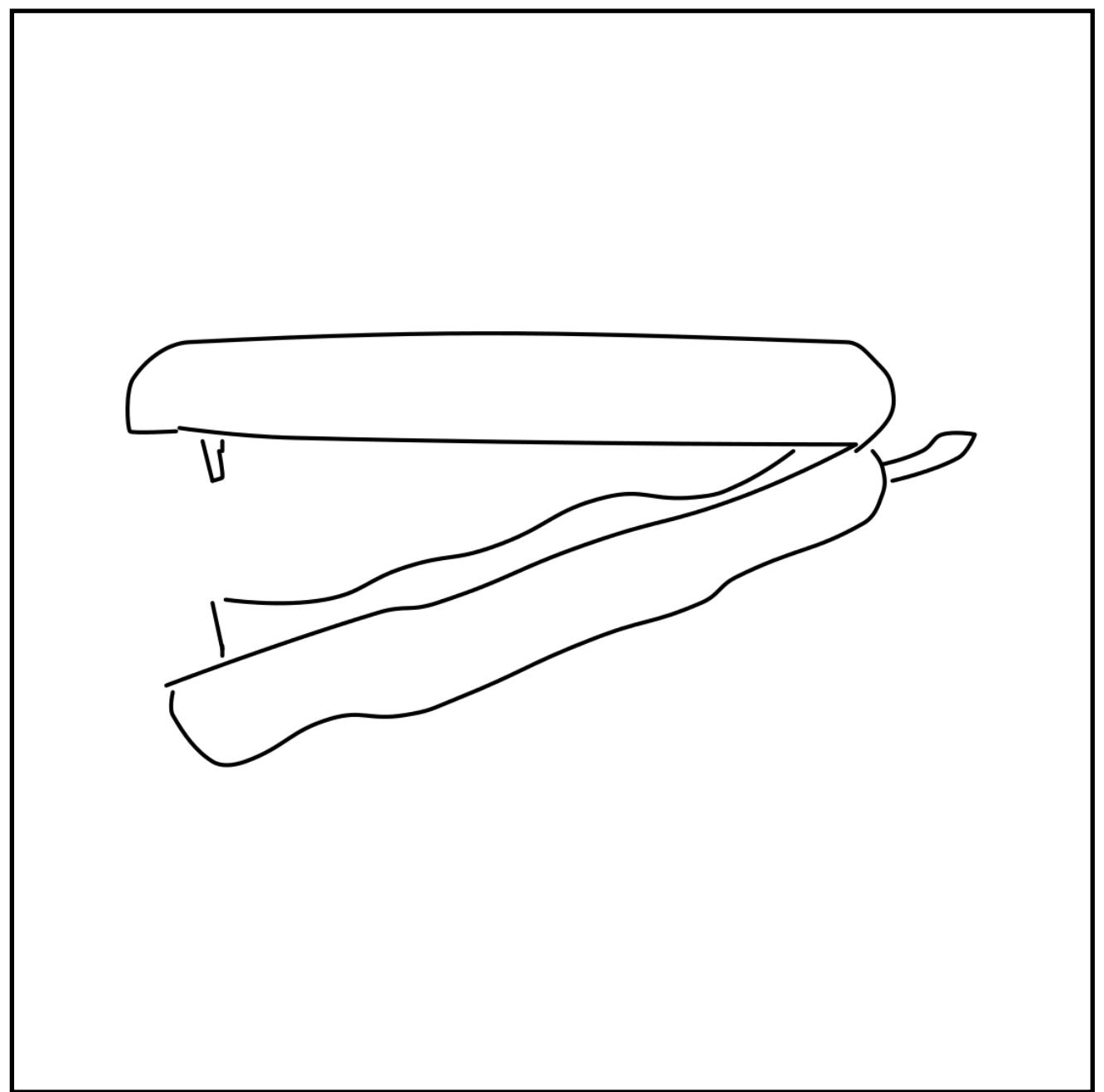
Task	Multiplicand	Addends	Local Sum	Contribution to Global Sum
1	1	3 + 7 + 2	12	12
2	2	4 + 8 + 3	15	15
5	5	3 + 1	4	4
Total			62	62

Code Generation

- Implemented as an extension to TACO
- Integrated support for our new abstractions into the format language
- Added compiler support for generating efficient code using our abstractions
- Added our new level formats

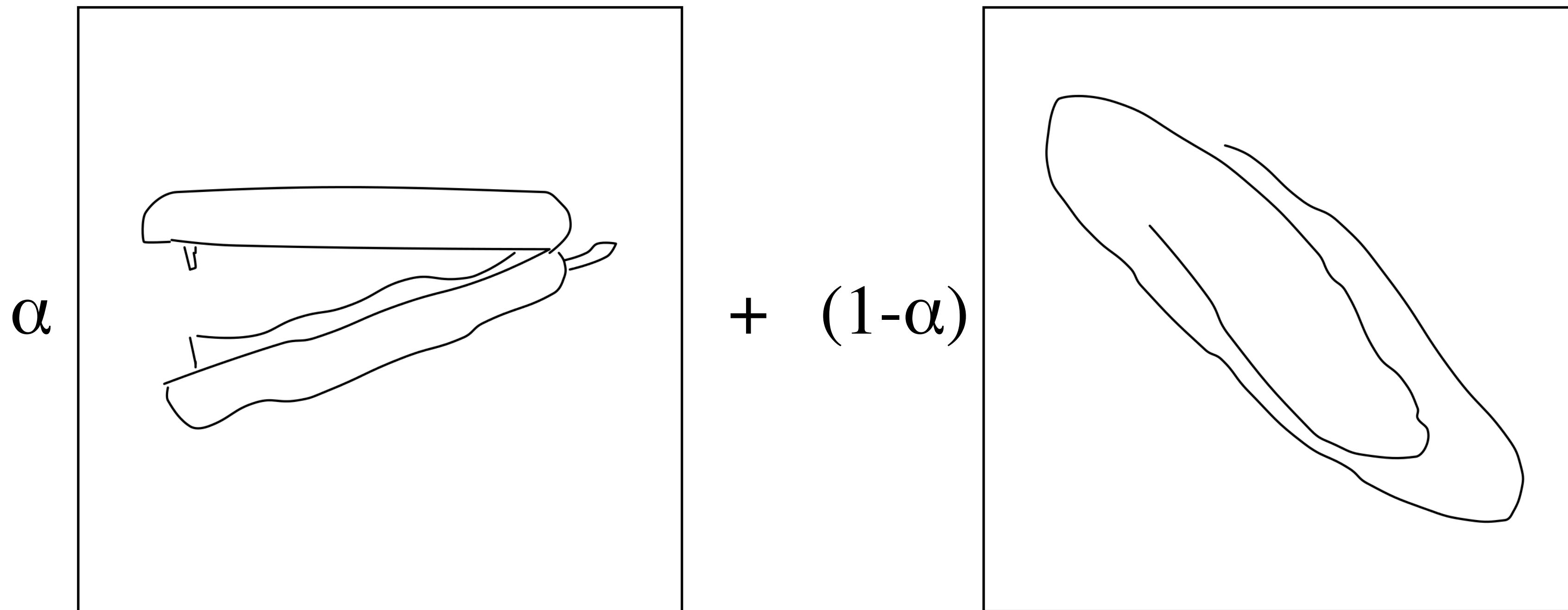
Results

$$A_{ij} = \alpha B_{ij} + (1 - \alpha) C_{ij}$$



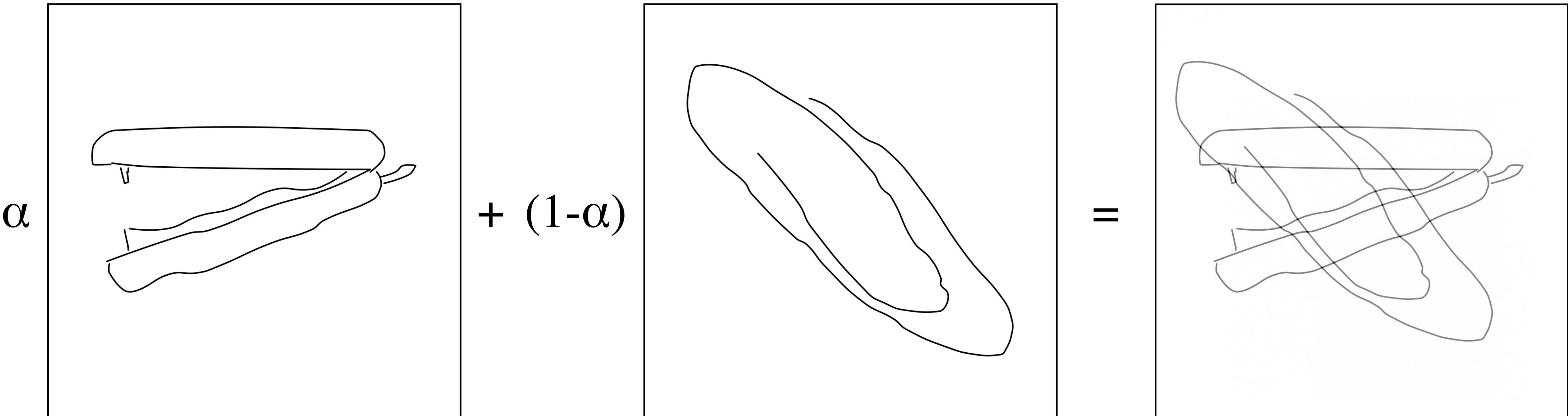
Results

$$A_{ij} = \alpha B_{ij} + (1 - \alpha) C_{ij}$$



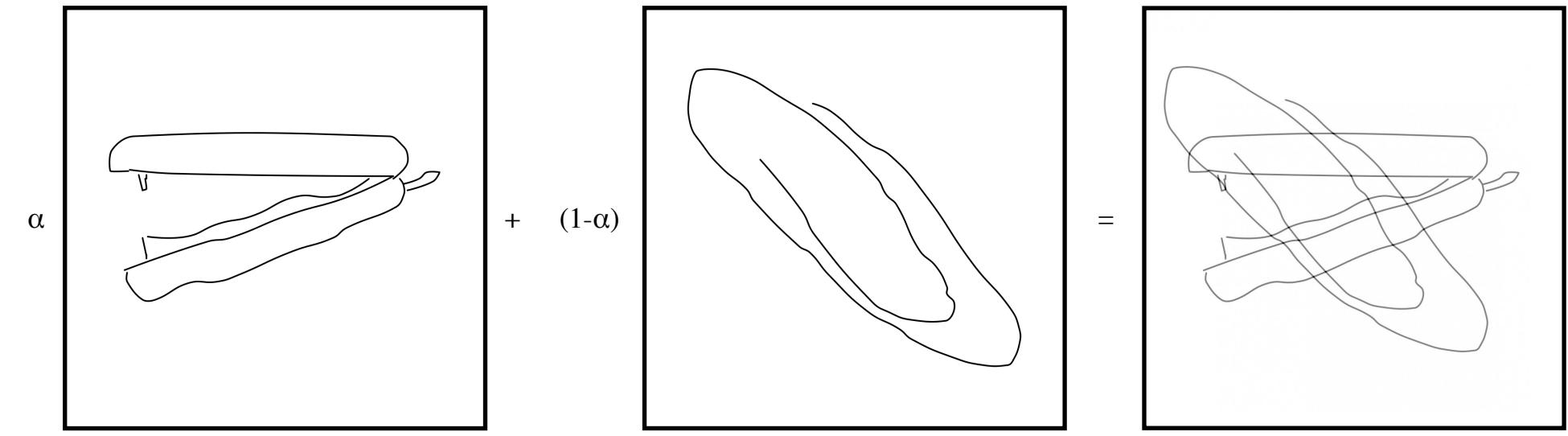
Results

$$A_{ij} = \alpha B_{ij} + (1 - \alpha) C_{ij}$$



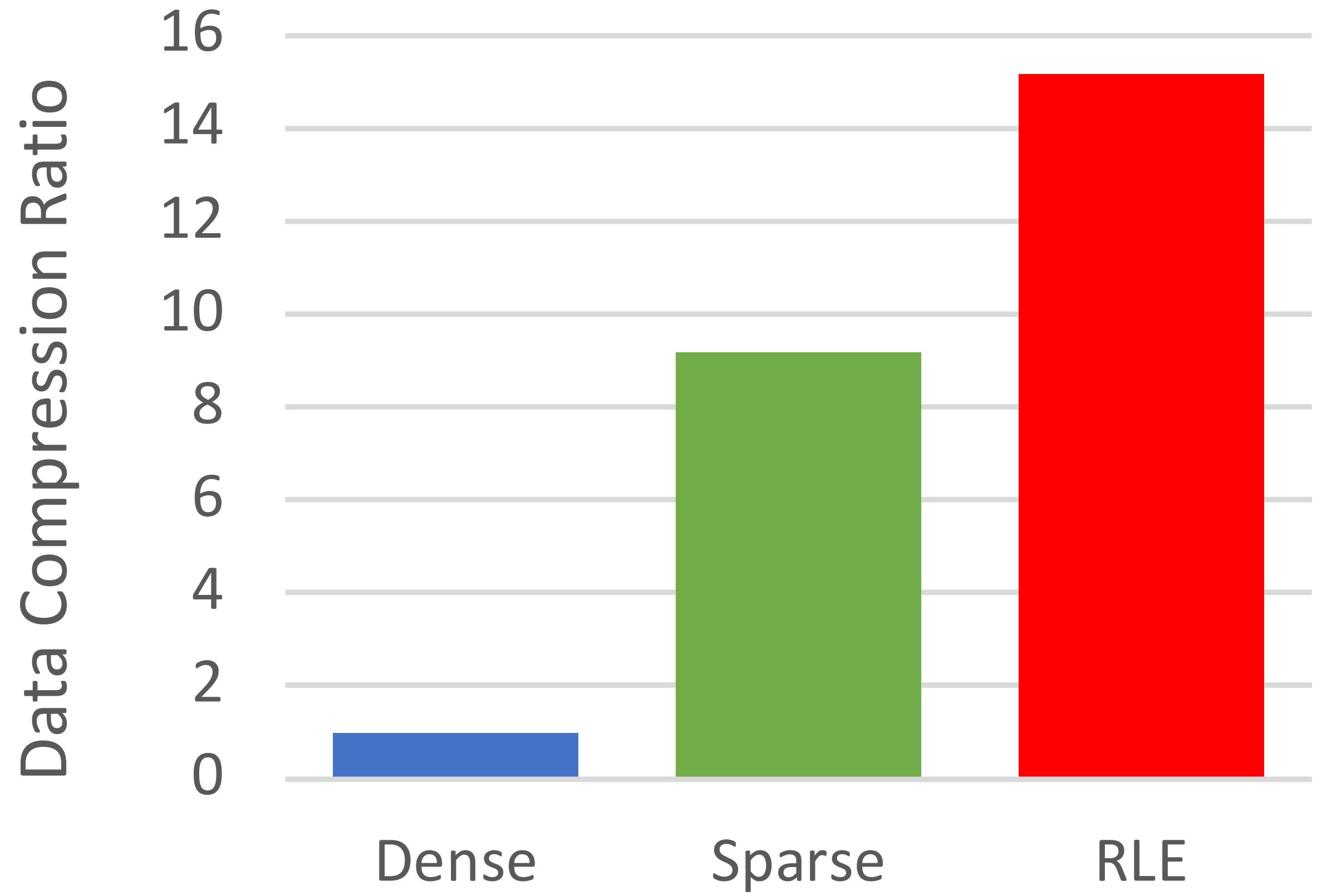
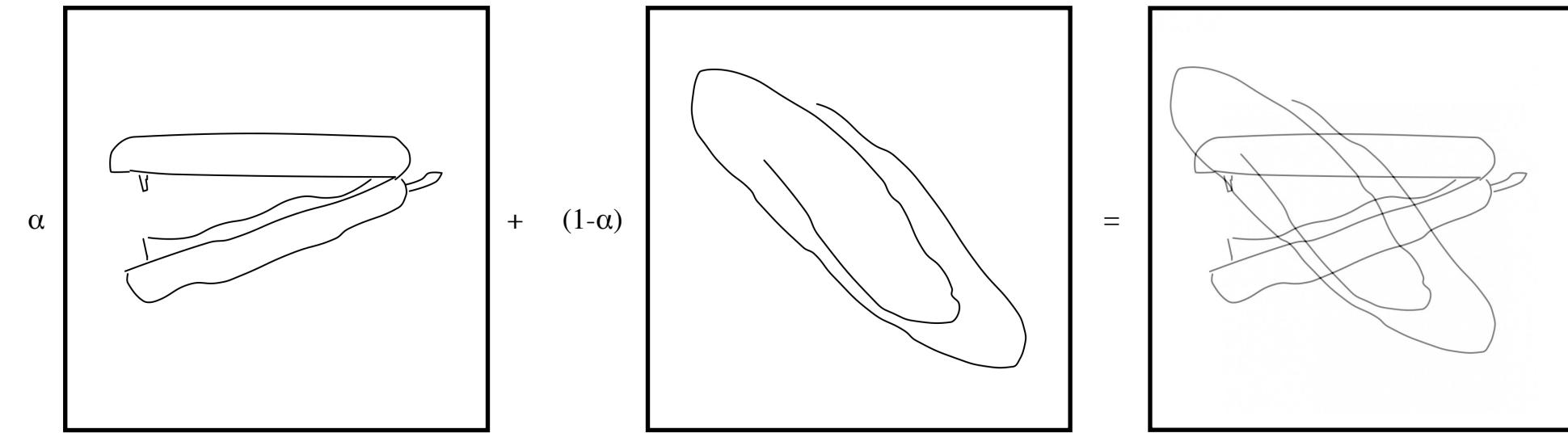
Results

$$A_{ij} = \alpha B_{ij} + (1 - \alpha) C_{ij}$$



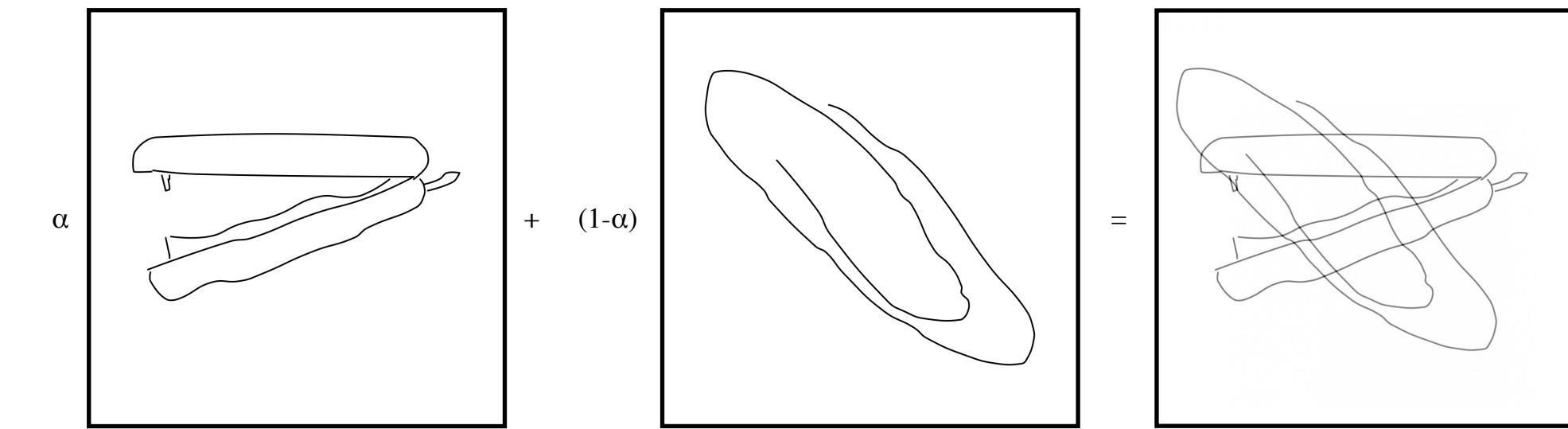
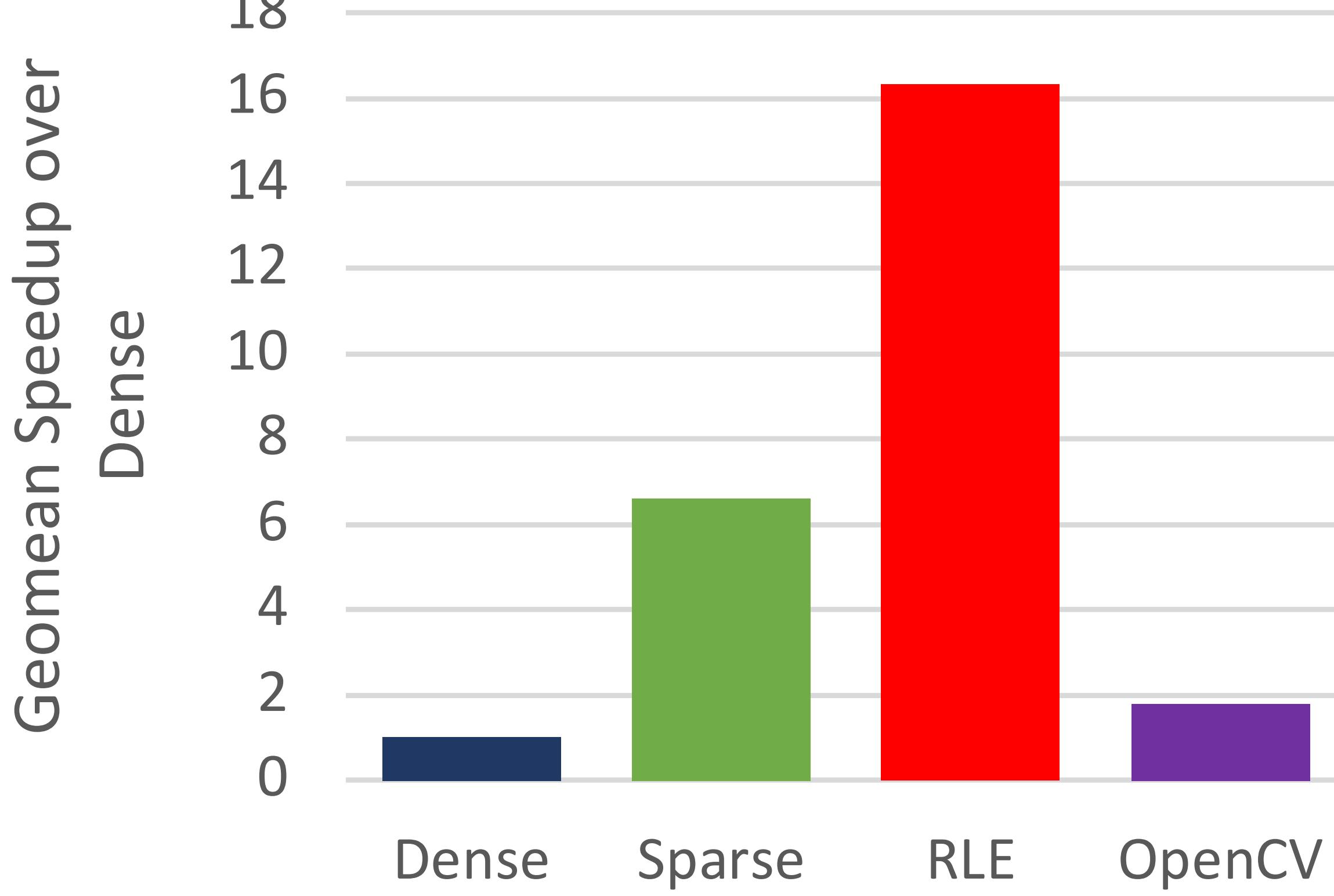
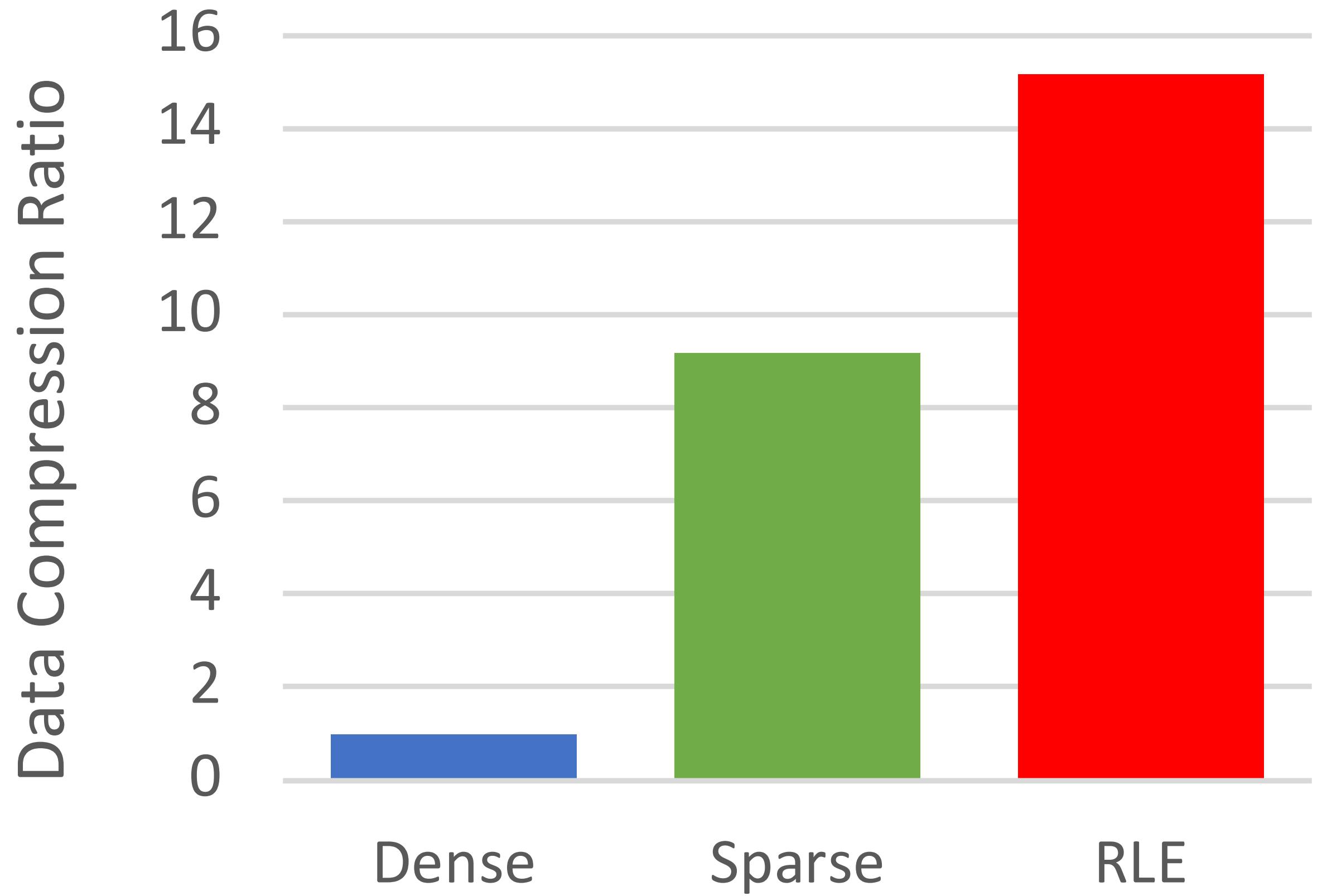
Results

$$A_{ij} = \alpha B_{ij} + (1 - \alpha) C_{ij}$$



Results

$$A_{ij} = \alpha B_{ij} + (1 - \alpha) C_{ij}$$



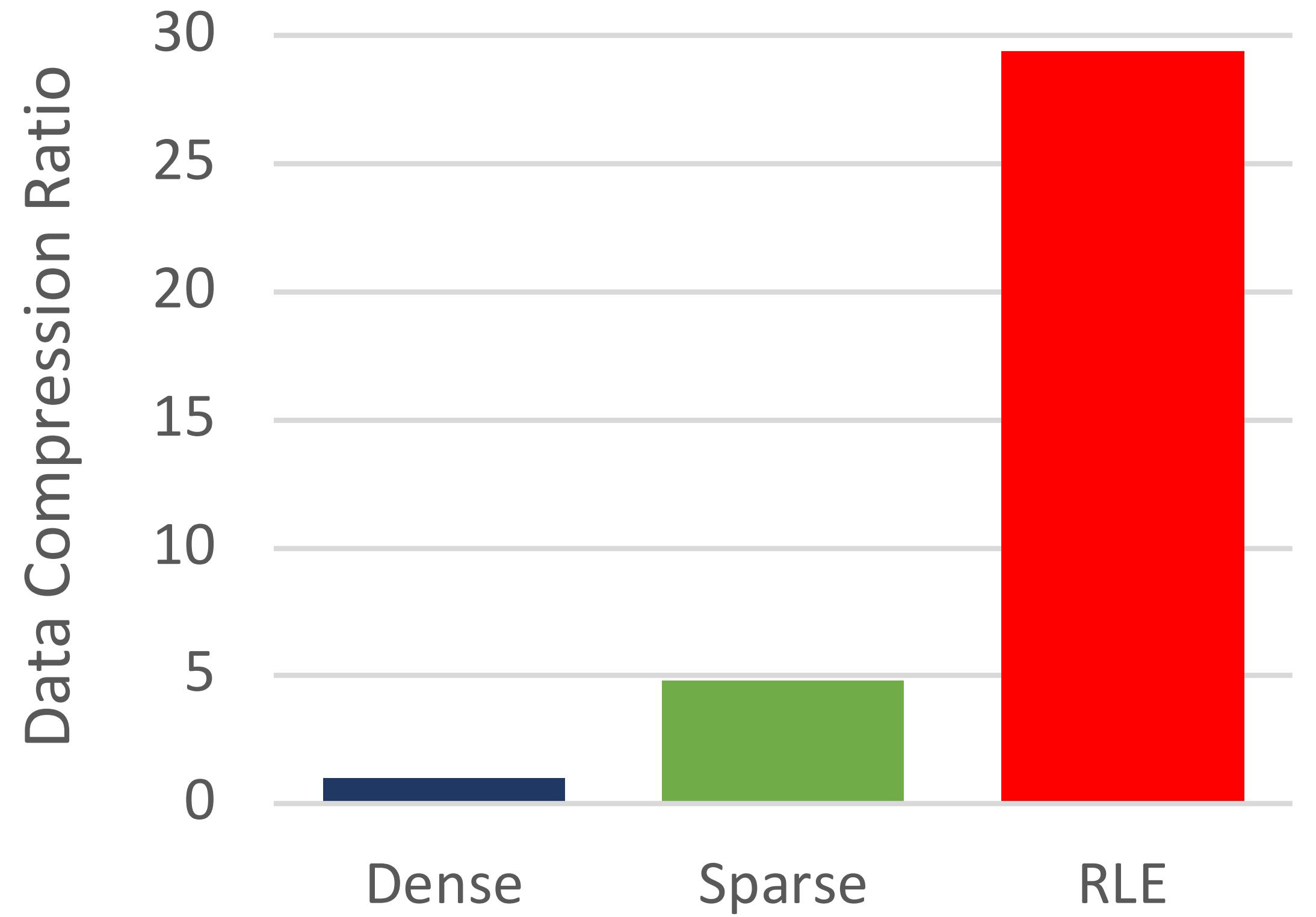
Results

$$Out_{ij} = (A_{ij} \wedge ROI_{ij}) \oplus (B_{ij} \wedge ROI_{ij})$$



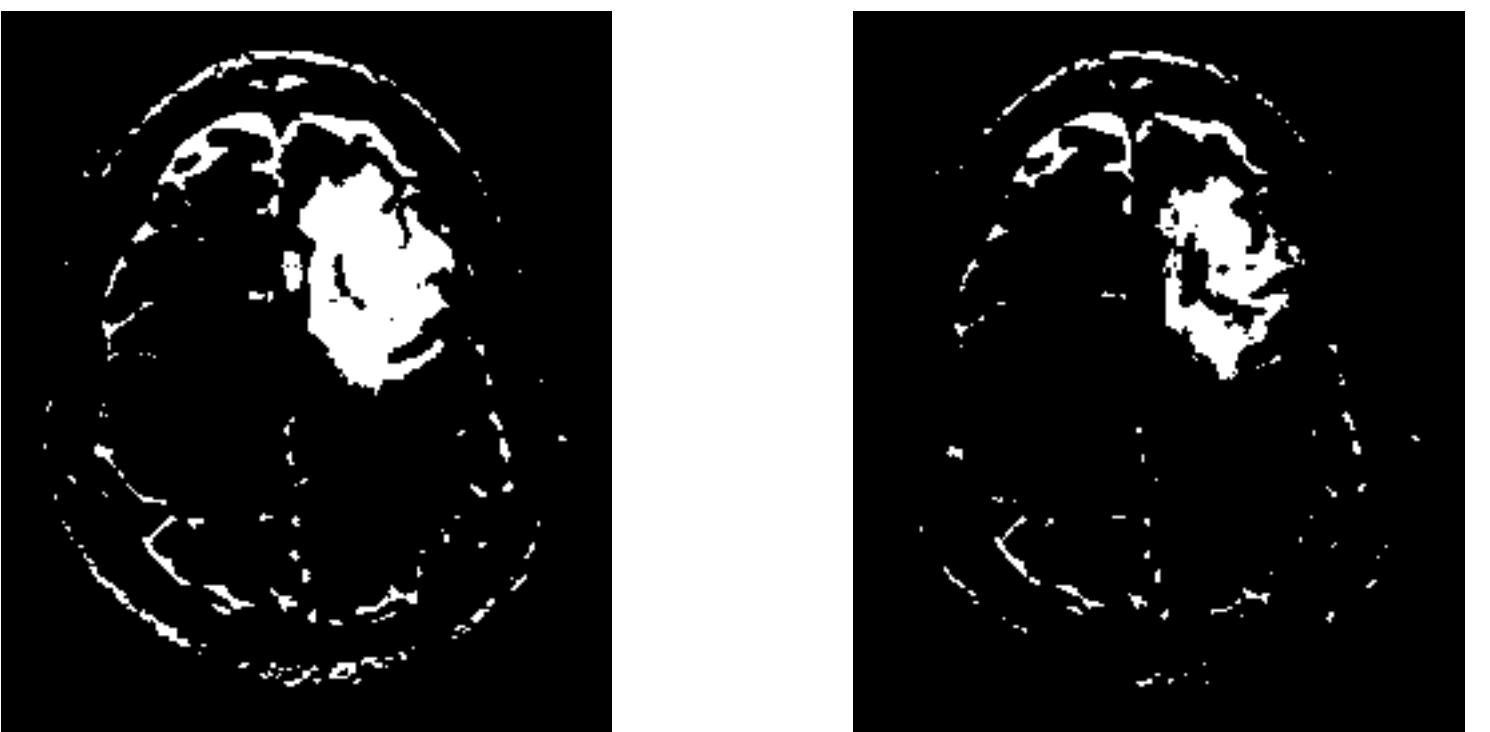
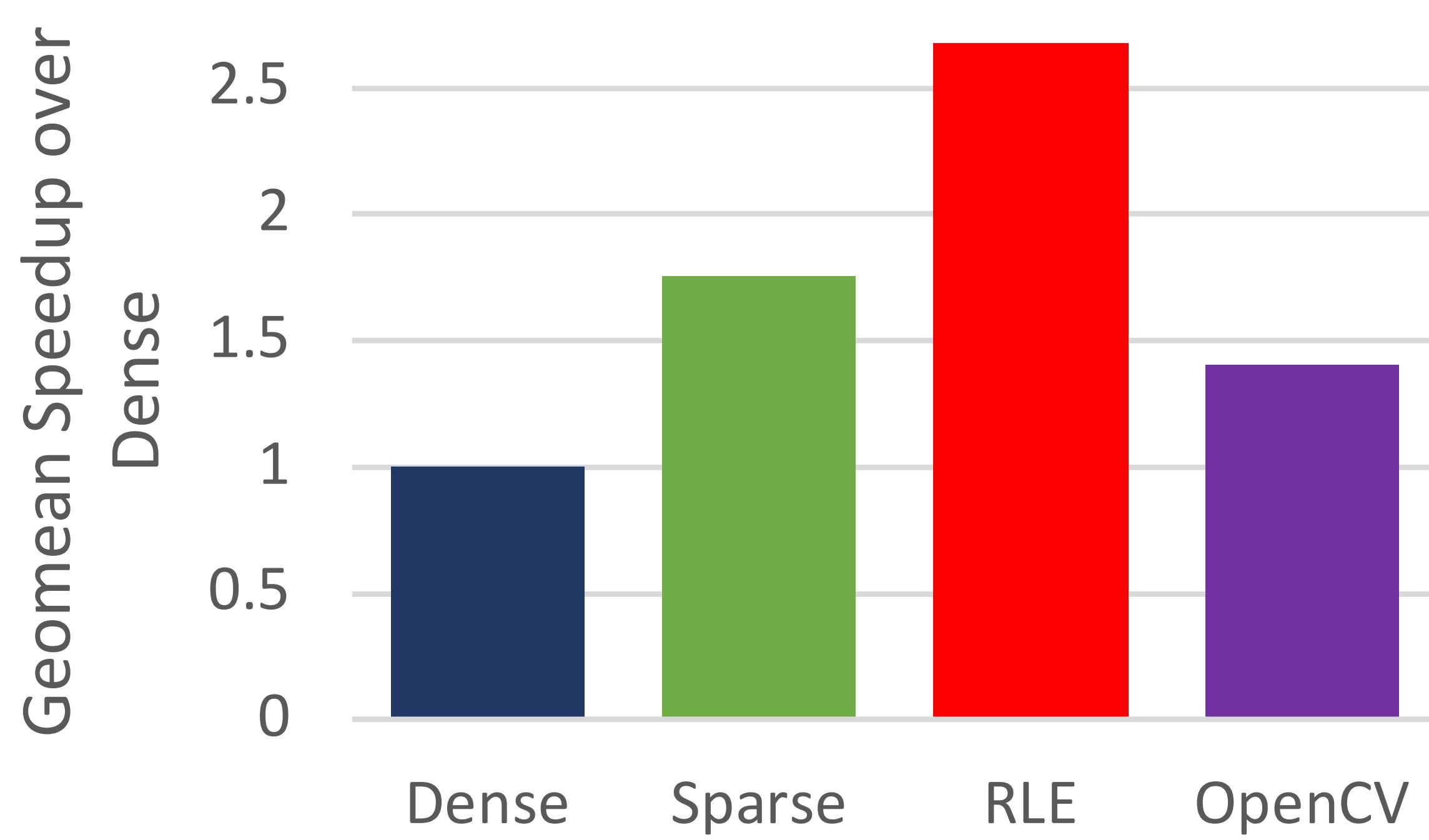
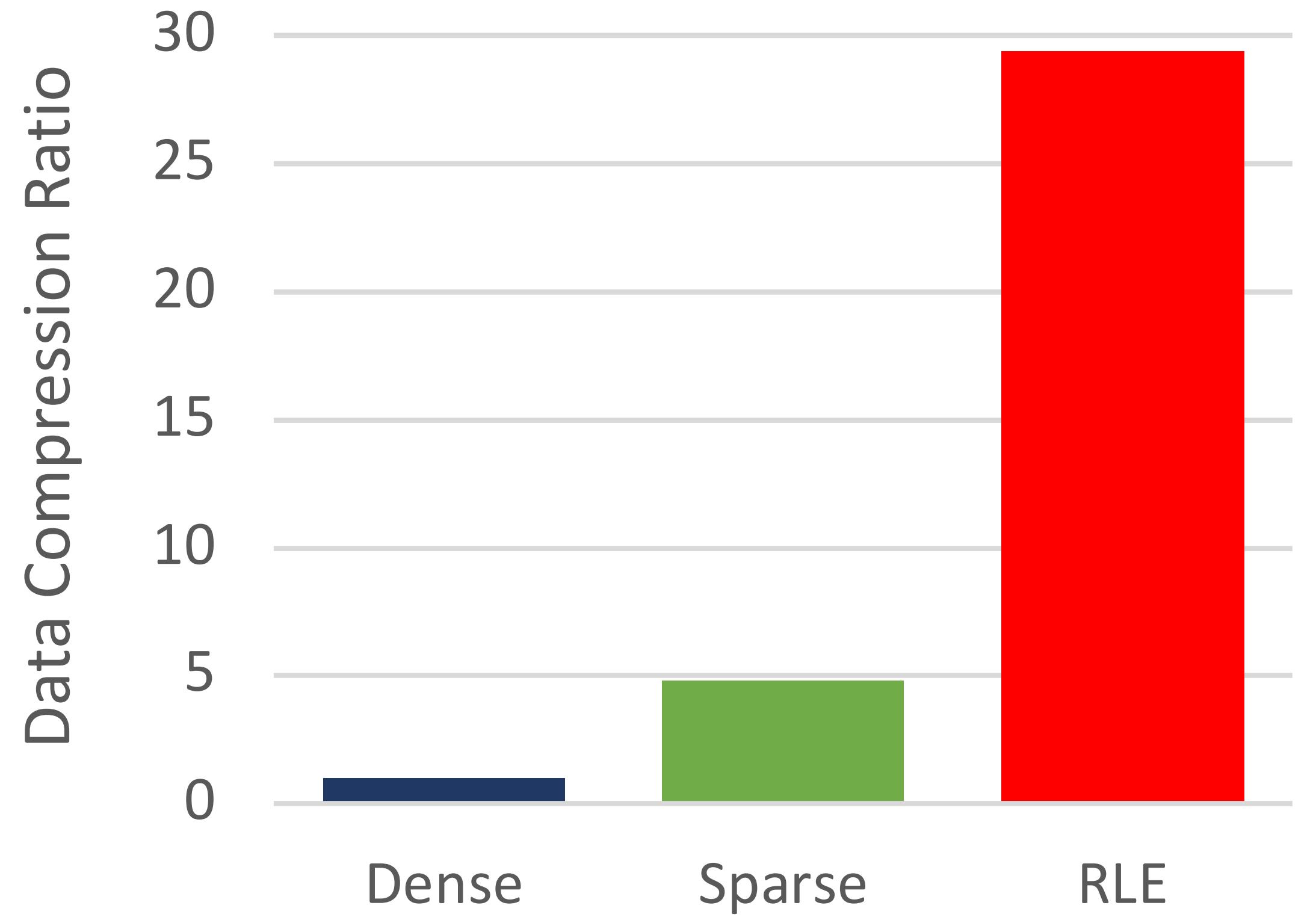
Results

$$Out_{ij} = (A_{ij} \wedge ROI_{ij}) \oplus (B_{ij} \wedge ROI_{ij})$$



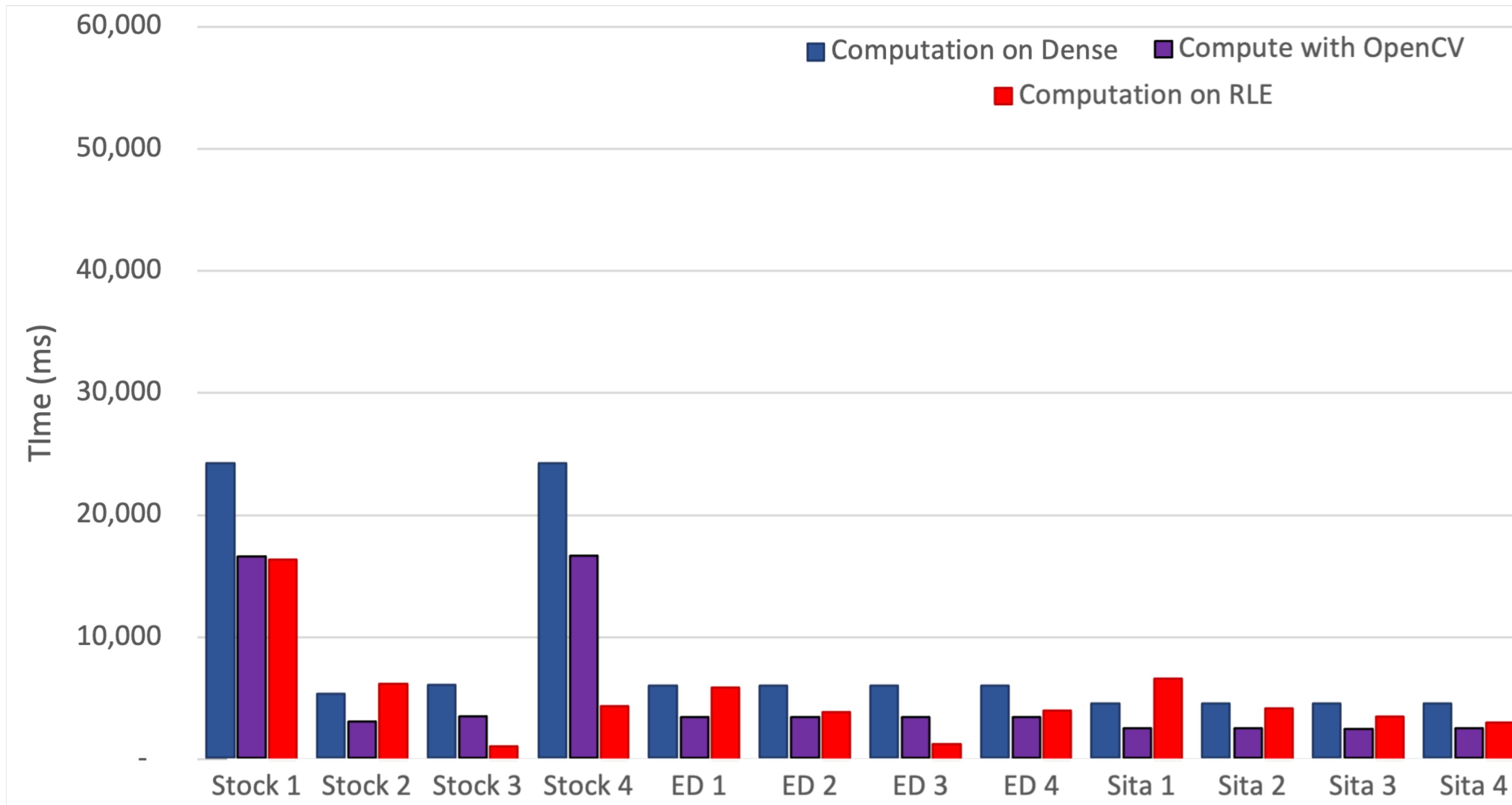
Results

$$Out_{ij} = (A_{ij} \wedge ROI_{ij}) \oplus (B_{ij} \wedge ROI_{ij})$$



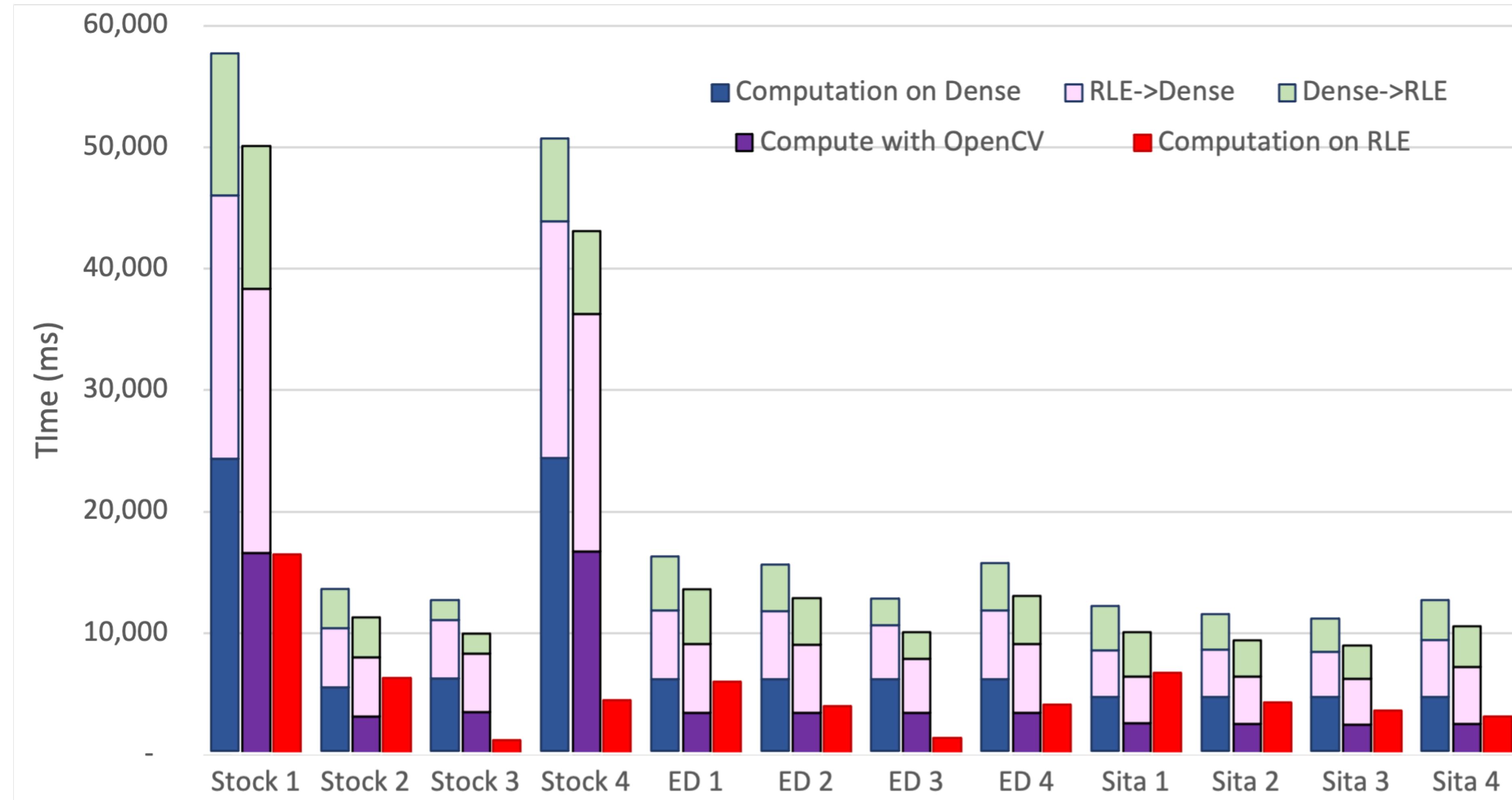
Results

$$Out_{ijc} = (F_{ijc} * M_{ij}) + (S_{ij} * !M_{ij})$$



Results

$$Out_{ijc} = (F_{ijc} * M_{ij}) + (S_{ij} * !M_{ij})$$



In conclusion

- We can automatically generate kernels that compute with both lossless compressed and sparse formats



<http://tensor-compiler.org/>

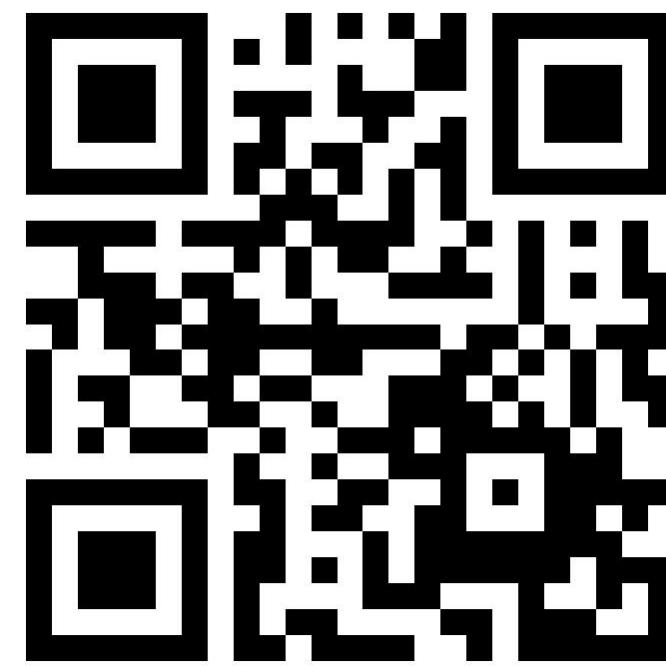


This Work Supported By:



In conclusion

- We can automatically generate kernels that compute with both lossless compressed and sparse formats
- Our new abstractions enable implementation of many lossless compression formats



<http://tensor-compiler.org/>



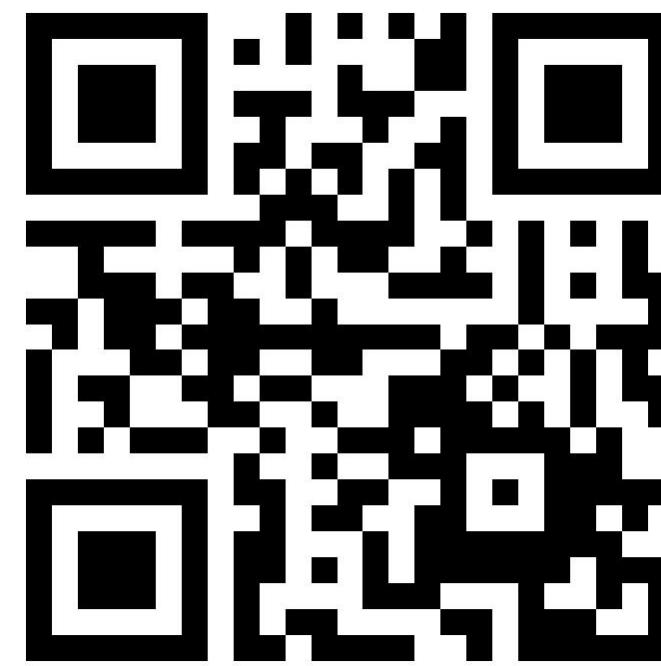
This Work Supported By:



Semiconductor
Research
Corporation

In conclusion

- We can automatically generate kernels that compute with both lossless compressed and sparse formats
- Our new abstractions enable implementation of many lossless compression formats
- It is possible to get both the best compression and performance



<http://tensor-compiler.org/>



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