

Concepts in CUTLASS.CuTe

Basics

IntTuple

- `rank(IntTuple) / tuple_size` : number of elements
 - `get<I>(IntTuple)`
 - `depth(IntTuple)`
 - `size(InputTuple)` : product of all elements of the IntTuple
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Layout=(Shape, Stride)

- Layout can be considered as a mapping from coordinates to indices

Special cases:

- vector: any layout with rank = 1
 - matrix: any layout with rank = 2
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Tensor

- Tensor mainly consists of a layout and a data pointer
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Layout Concepts

Layout Compatibility

layout A is **compatible** with layout B if the shape of A is compatible with the shape of B.

Shape A is compatible with shape B if

- the size of A is equal to the size of B and
- all coordinates within A are valid coordinates within B.

Compatible is a weak partial order on Shapes as it is **reflexive, antisymmetric, and transitive**.

Layout Coordinates ☒

Every `Layout` accepts coordinates for any `Shape` that is compatible with it.

- 1-D coordinate space
 - R-D coordinate space, where R is the rank of the layout
 - h-D (natural) coordinate space, where h is “hierarchical”
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Layouts provide two fundamental mappings:

- the map from an input coordinate to the corresponding natural coordinate via the `Shape` , and
- the map from a natural coordinate to the index via the `Stride` .

Input Coordinate → Natural Coordinate

Example:

Shape `(3, (2, 3))` has three coordinate sets, 1D, 2D, and Natural:

1-D	2-D	Natural		1-D	2-D	Natural
0	(0,0)	(0,(0,0))		9	(0,3)	(0,(1,1))
1	(1,0)	(1,(0,0))		10	(1,3)	(1,(1,1))
2	(2,0)	(2,(0,0))		11	(2,3)	(2,(1,1))
3	(0,1)	(0,(1,0))		12	(0,4)	(0,(0,2))
4	(1,1)	(1,(1,0))		13	(1,4)	(1,(0,2))
5	(2,1)	(2,(1,0))		14	(2,4)	(2,(0,2))
6	(0,2)	(0,(0,1))		15	(0,5)	(0,(1,2))

7	(1,2)	(1,(0,1))		16	(1,5)	(1,(1,2))
8	(2,2)	(2,(0,1))		17	(2,5)	(2,(1,2))

- For this shape, 1D coordinates goes from 0 to size(Shape) - 1=3x2x3 - 1=17
- How to translate 1D coordinate to 2D/Natural coordinates?

“The map from an input coordinate to a natural coordinate is the application of a colexicographical order (reading right to left, instead of “lexicographical,” which reads left to right) within the Shape.”

“generalized-column-major order”

- Shape (3, (2, 3)), 1D coordinate 16 → 2D coordinate (1, 5) → Naturla (3D) coordinate (1, (1, 2))
16 div 3 = 5 ... 1, 2D coordinate is (1, 5),
5 div 2 = 2 ... 1, 3D coordinate is (1, (1, 2))
- API: `cute::idx2crd(idx, shape)`

Natural Coordinate → Index

The map from a natural coordinate to an index is performed by taking the inner product of the natural coordinate with the Layout’s Stride .

- Layout = (Shape, Stride) = ((3, (2,3), (3, (12, 1)))) , natural coordinate (i, (j, k)) → index i*3 + j*12 + k*1
- Example:

	0	1	2	3	4	5	<== 1-D col coord
	(0,0)	(1,0)	(0,1)	(1,1)	(0,2)	(1,2)	<== 2-D col coord (j,k)
0	0	12	1	13	2	14	
1	3	15	4	16	5	17	
2	6	18	7	19	8	20	

- API: `cute::crd2idx(coord, shape, stride)`

Layout Manipulation

- sublayout
- concat
- grouping and flattening
- slicing