DTU

30/11/23

Real-Time Visual and Machine Learning Systems

Types

- GPU Hand-in
  - Any Questions?
  - Common problems?
    - Bind groups and unused elements

- Analysis Hand-in
  - Any Questions?

- Projects
  - Any Questions?

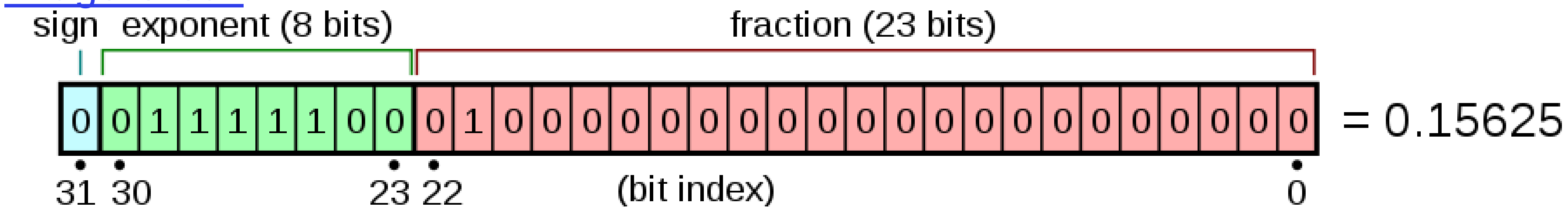
Types

Integers and floats

Bitwise operators

Any questions?

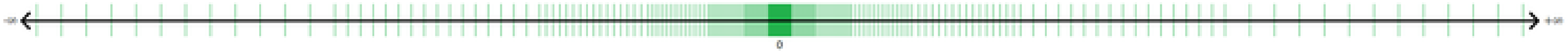
Image Credit



Types - Precision

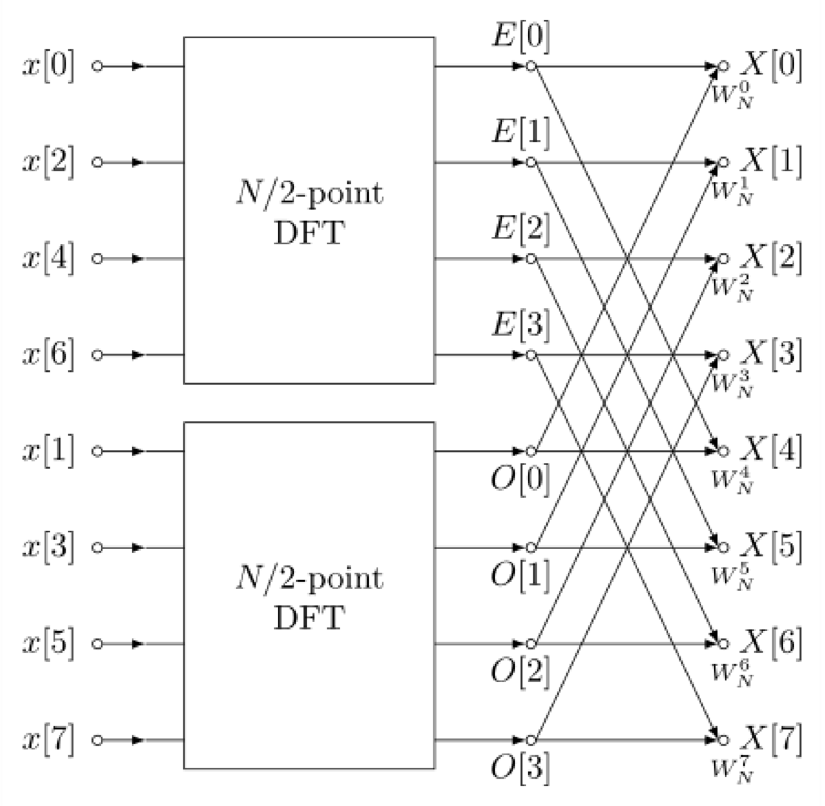
- It is almost impossible for two floats to be exactly equal, which also makes it hard to compress
- Every calculation results in an error
- X / N is only the same as X * (1/N) when N is in the set of numbers 2^M

Image credits



Types - Precision

- Floating point numbers – small to large and sorting
- Pairwise additions



[Image credits](#)

The upper bound on the relative error for the Cooley–Tukey algorithm is $O(\varepsilon \log n)$, compared to $O(\varepsilon n^{3/2})$ for the naïve DFT formula,[18] where ε is the machine floating-point relative precision. In fact, the root mean square (rms) errors are much better than these upper bounds, being only $O(\varepsilon \sqrt{\log n})$ for Cooley–Tukey and $O(\varepsilon \sqrt{n})$ for the naïve DFT (Schatzman, 1996).[37] These results, however, are very

Types - Precision

- Fused multiplication-addition results in 1 error instead of 2

  – Rust:

```
let m: f32 = 3.12;
let m = m.mul_add(x, b);
```

WGSL:

`fn fma(e1: T, e2: T, e3: T) -> T`	`S is AbstractFloat, f32, or f16T is S or vecN<S>`

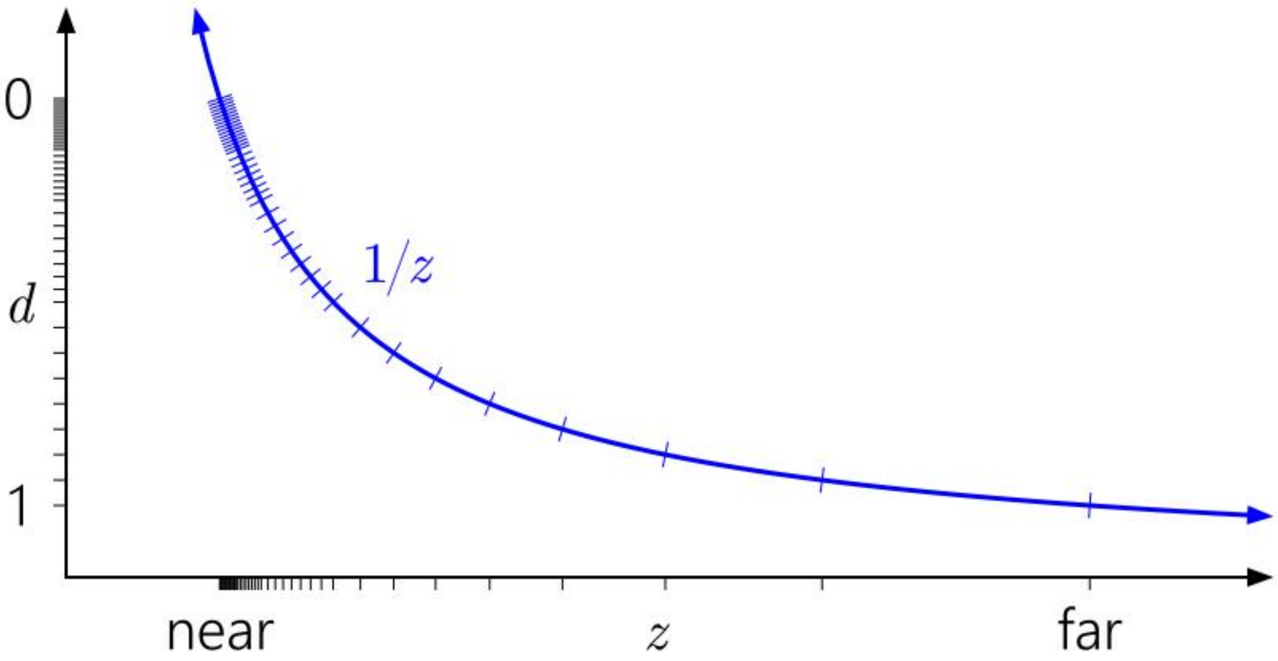
$$d = a\frac{1}{z} + b$$

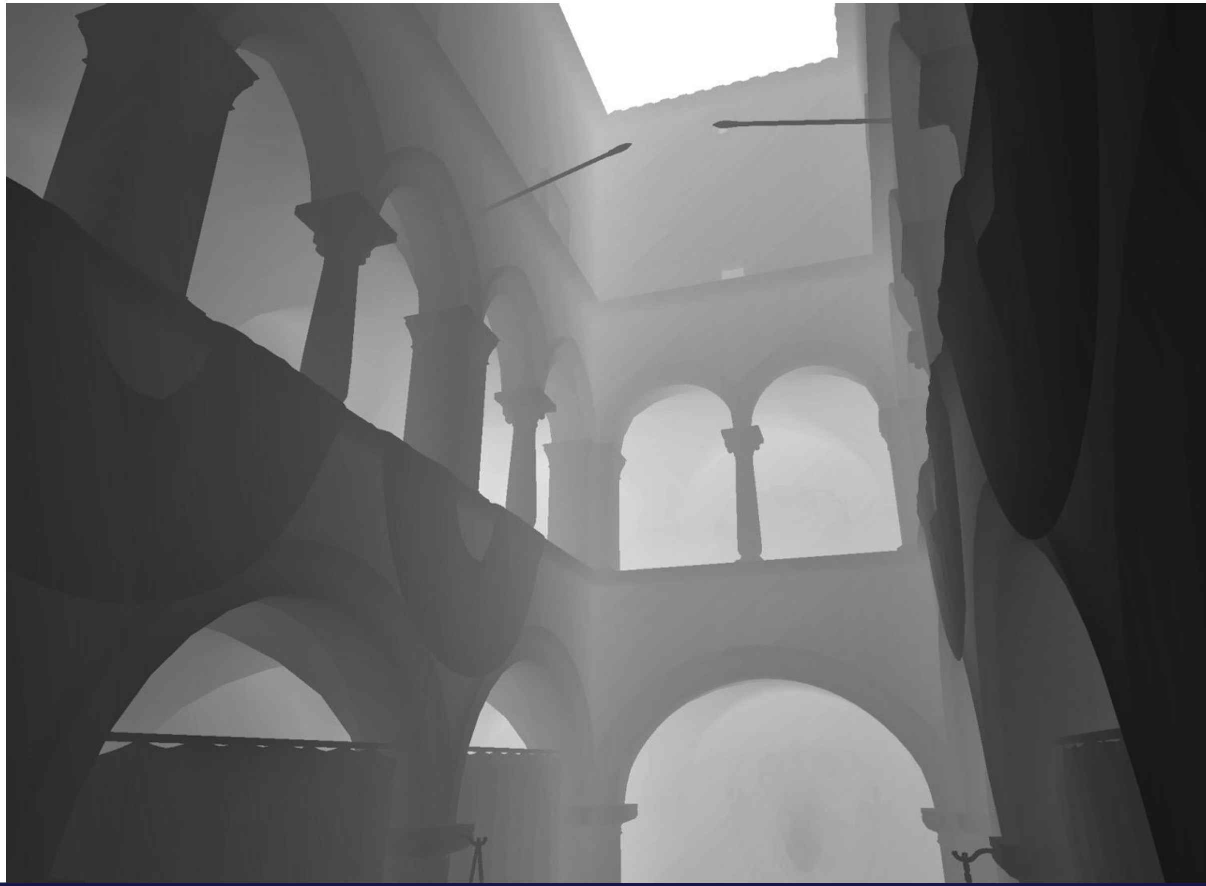
Types - Precision

- Precision in Depth Buffers (reversing the logarithm)
  - Depth values stored as 1/z
  - Near plane (a) = 0.0, Far plane (b) = 1.0

Image Credit

Image credit

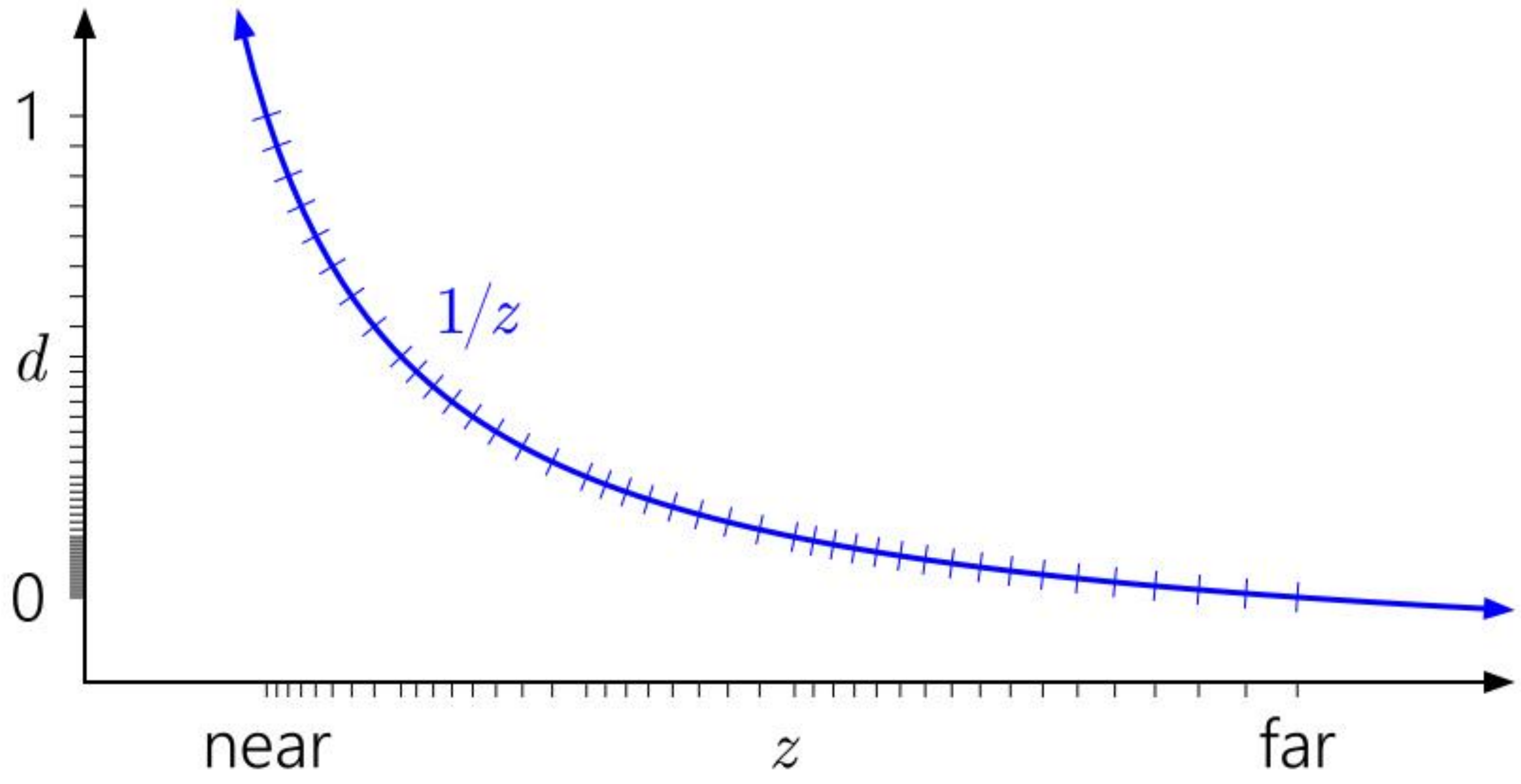




Types - Precision

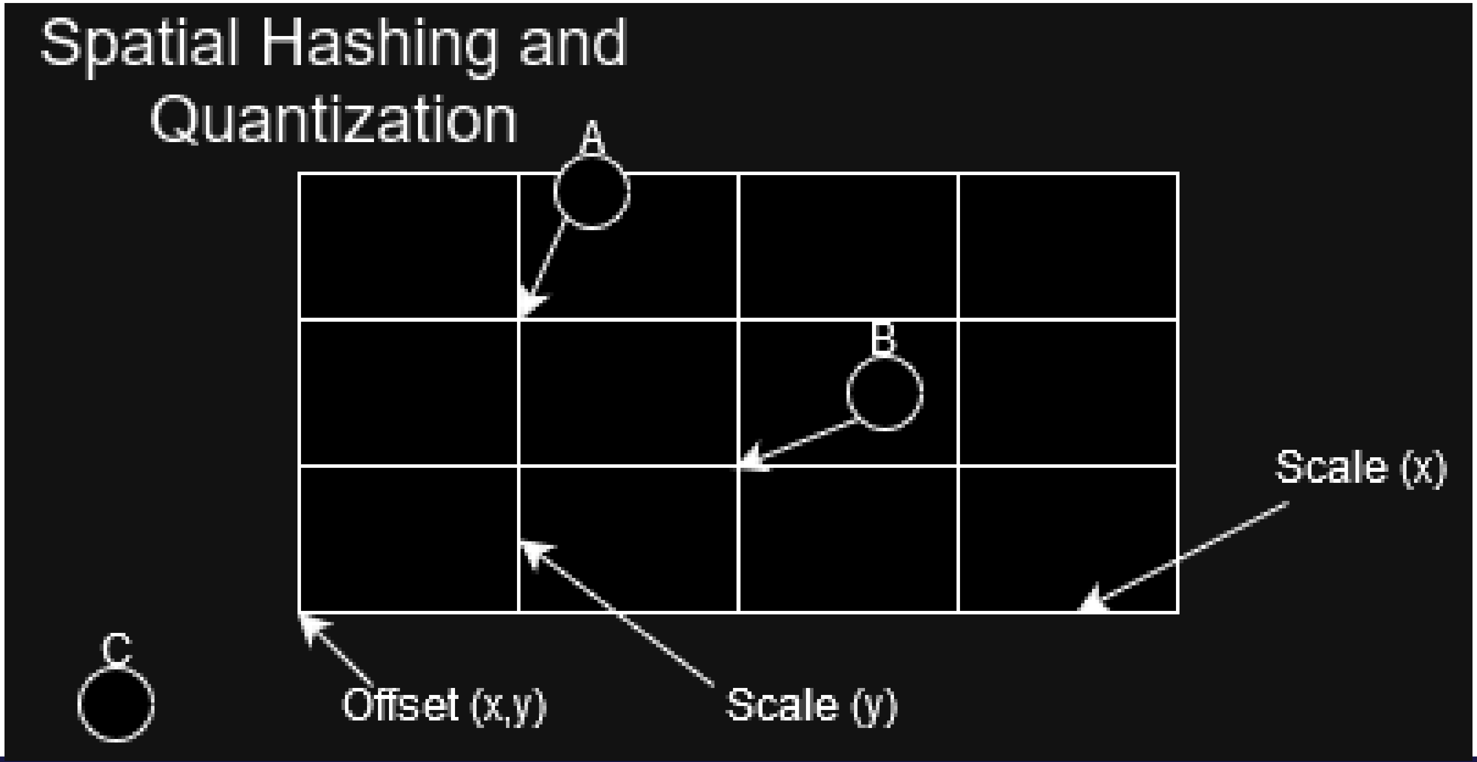
- [Precision in Depth Buffers](#) (reversing the logarithm)
  - – Reverse Depth Buffer: Near plane = 1.0, Far plane = 0.0

[Image Credit](#)



Types - Precision

- We can quantize floats to integers
- Integers compress much better than floats and can be sorted in an exciting number of ways
- Integers allow us to do bit tricks! Yay!



Types - Precision

- Spatial hashing is basically quantization, some shifts and some additions

```rust
// This would be given for this specific grid
// If we aren't TOO bothered by the loss of precision we can
// multiply by the inverse of the scaling term.
let x_scale: f32 = 5.0f;
let x_offset: f32 = 0.32f;

let y_scale: f32 = 4.0f;
let y_offset: f32 = 3.50f;

let z_scale: f32 = 2.0f;
let z_offset: f32 = 0.42f;


let x: f32 = 7.2f;
let y: f32 = 5.5f;
let z: f32 = 2.2f;

let x_quantized: u64 = ((x - x_offset ) / x_scale) as u64;
let y_quantized: u64 = ((y - y_offset ) / y_scale) as u64;
let z_quantized: u64 = ((z - z_offset ) / z_scale) as u64;

let x_hash: u64 = (x_quantized & 0xFFFFF) << 40;
let y_hash: u64 = (y_quantized & 0xFFFFF) << 20;
let z_hash: u64 =  z_quantized & 0xFFFFF;

let hash: u64 = x_hash | y_hash | z_hash;
```

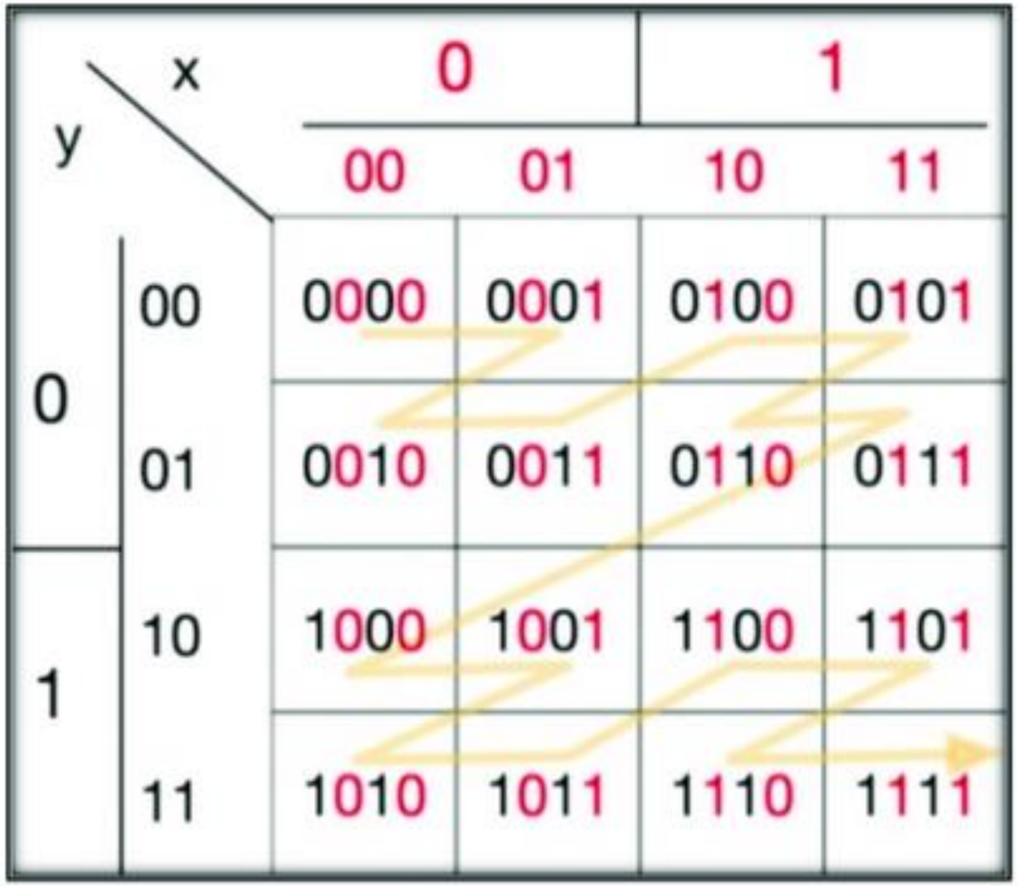
Types - Sorting

- .sort() and floats/ordering in Rust
- Quantizing floats to integers
- Sorting usually also has performance implications and is usually a good idea in preprocessing

Types – Morton Codes

- An encoding, not a sorting method, but we can change the way numbers are sorted by encoding them differently and shuffling bits around

Types – Sorting – Morton



(a)

node	bits	index
0,0,0	000	0
0,0,1	001	1
0,1,0	010	2
0,1,1	011	3
1,0,0	100	4
1,0,1	101	5
1,1,0	110	6
1,1,1	111	7

(b)

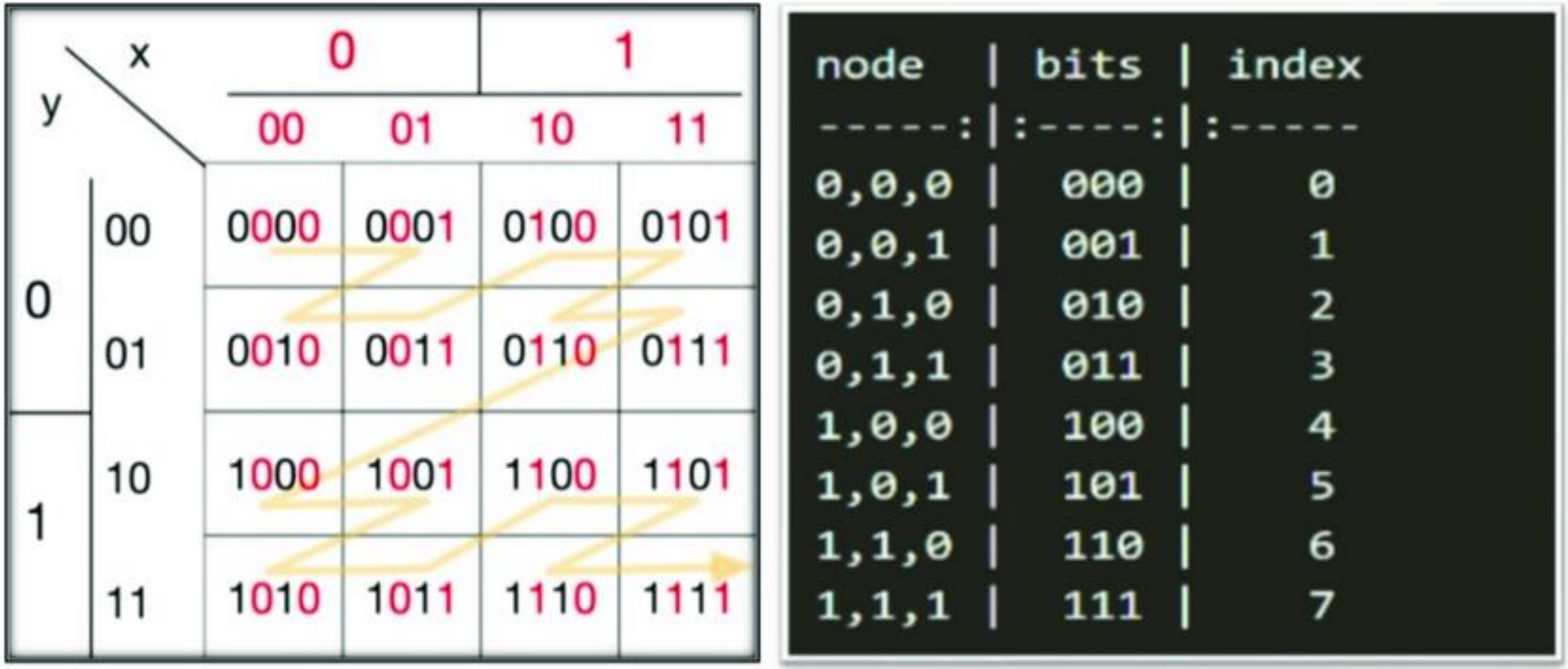
Types – Sorting – Morton

```rust
let x: u32 = 8;
let y: u32 = 1;
let z: u32 = 2;

let component_count: u32 = 3;
let bits_of_precision: u32 = 10;

let mut encoded: u32 = 0;
let mut mask: u32 = 1;
for index in 0..bits_of_precision {
    encoded |= ((x & (1 << index)) <<  component_count * index);
    encoded |= ((y & (1 << index)) << (component_count * index + 1));
    encoded |= ((z & (1 << index)) << (component_count * index + 2));
}
```

Types – Sorting – Morton



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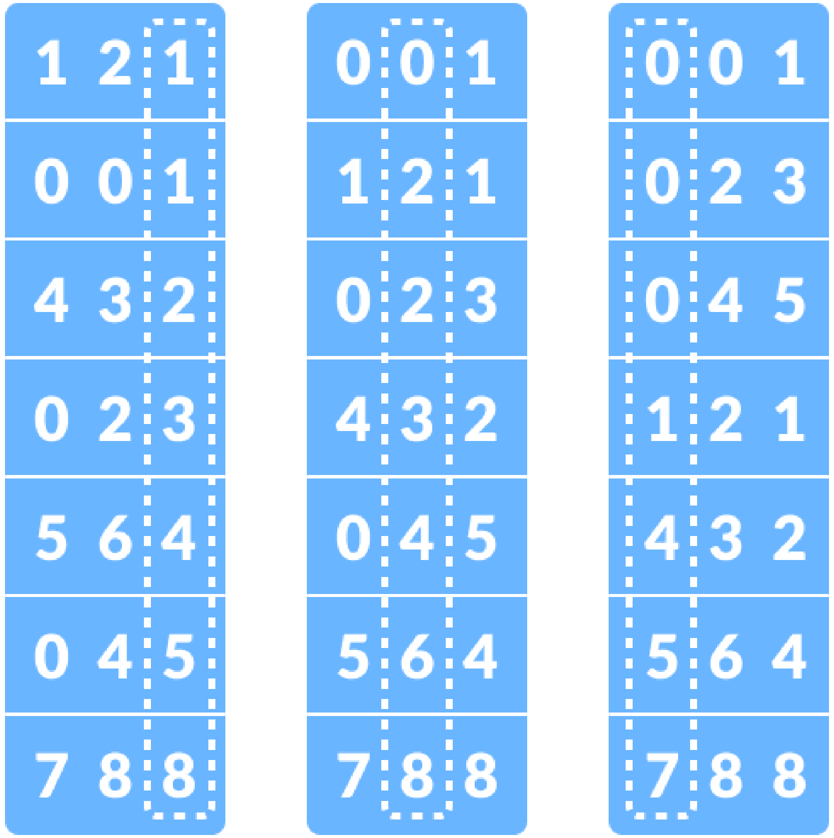
(a) (b)

Types – Sorting – Radix

- Radix sort!
- There are many ways to sort, but Radix has known GPU implementations to do so in a single shader dispatch



sorting the integers according to units, tens and hundreds place digits

Types - Compression

- Optimize your data for a more advanced algorithm to do the heavy lifting
- Avoid floats and strings if you can, especially floats represented as strings
- Point cloud compression case:
  - .Hierarchical data structure and spatial hashing
  - Quantification (16-bits)
  - Bit nulling
  - Sorting
  - Delta encoding
  - Gzip
  - Transfer
  - Un-gzip
  - Transfer to gpu
  - Dequantify in shader

Types – Energy Usage

Table VI ENERGY CONSUMPTION OF ARITHMETIC OPERATIONS ON THE INTEL XEON X5670 TEST SYSTEM

Workload	**operations per 16 Byte**	***biop***	E_{calc}
add pi	2 (64 Bit)	8 Byte/op	428 pJ/op
mul_pi	2 (64 Bit)	8 Byte/op	476 pJ/op
add_pd	2 (64 Bit)	8 Byte/op	319 pJ/op
mul_pd	2 (64 Bit)	8 Byte/op	387 pJ/op
mul+add _pd	4 (64 Bit)	4 Byte/op	464 pJ/op
add ps	4 (32 Bit)	4 Byte/op	111 pJ/op
mul_ps	4 (32 Bit)	4 Byte/op	164 pJ/op

Types – Energy Usage

Table V COMPARISON OF THE ENERGY CONSUMPTION OF DATA TRANSFERS (movAP s), AMD OPTERON 2435 AND INTEL XEON X5670

Location	Et,. AMD	E_{trans}Intel	Factor
Li	105 pJ/Byte	64 pJ/Byte	1.6
L2	357 pJ/Byte	121 pJ/Byte	2.9
L3	654 pJ/Byte	254 pJ/Byte	2.6
RAM	3590 pJ/Byte	1250 pJ/Byte	2.8

Profilers

- Timing
- System monitoring (Task manager, htop, nvidia-smi)
- General profilers (Visual Studio, perf, tracy)
- System specific (AMD, Intel VTune)
- GPU specific(nsight-compute, Renderdoc, AMD)
- App specific (PyTorch profiler)

- Disk is hard to profile, system monitors are likely the way to go

Too many profilers to go into too much detail, do the exercise!