SIGGRAPH2007

Fast Object Distribution

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Distributing Objects

- Goal: Place objects over an area
- Vary attributes (colour, size, etc.)

- Lots and lots of solutions
  - Pseudo Random: LCG, Mersenne Twister
  - Dart throwing
  - Blue noise (Ostromoukhov et al.)
  - Wang tiles (Hall and Oates)

Our Constraints

- Fast! (Game use)
- Low memory (Low memory -> Fast)
- Re-produceable

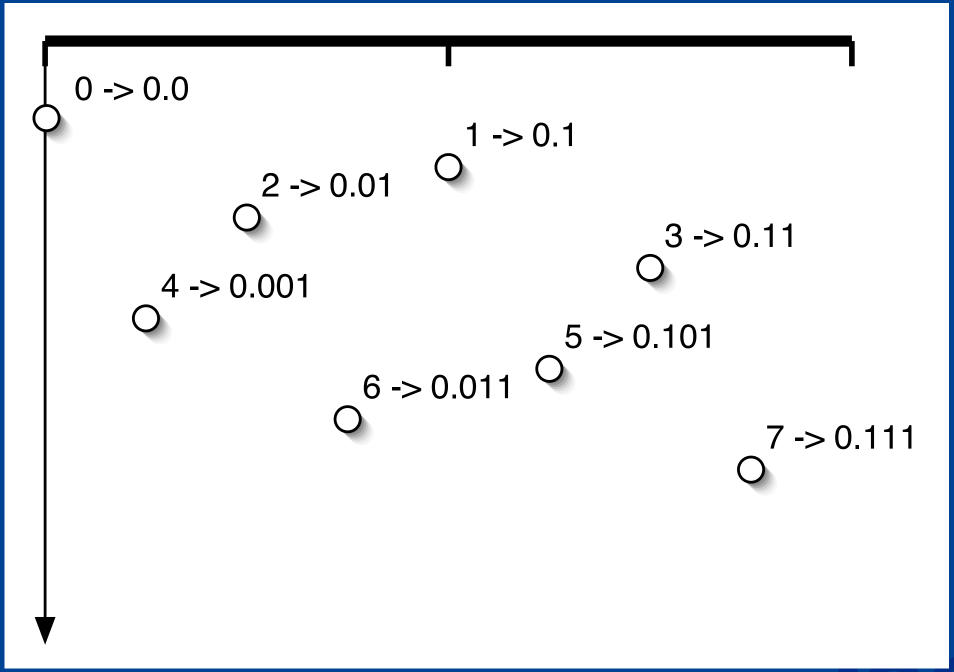
- Control
  - Position
  - Orientation, Colour, Alpha, etc.
  - Density

Summary

- Use Halton Sequence to generate *N* samples
- Make it incremental for speed reasons
- Use *i / N* as a magic number
  - To index attribute tables
  - To perform rejection sampling against maps
- (You may leave now)

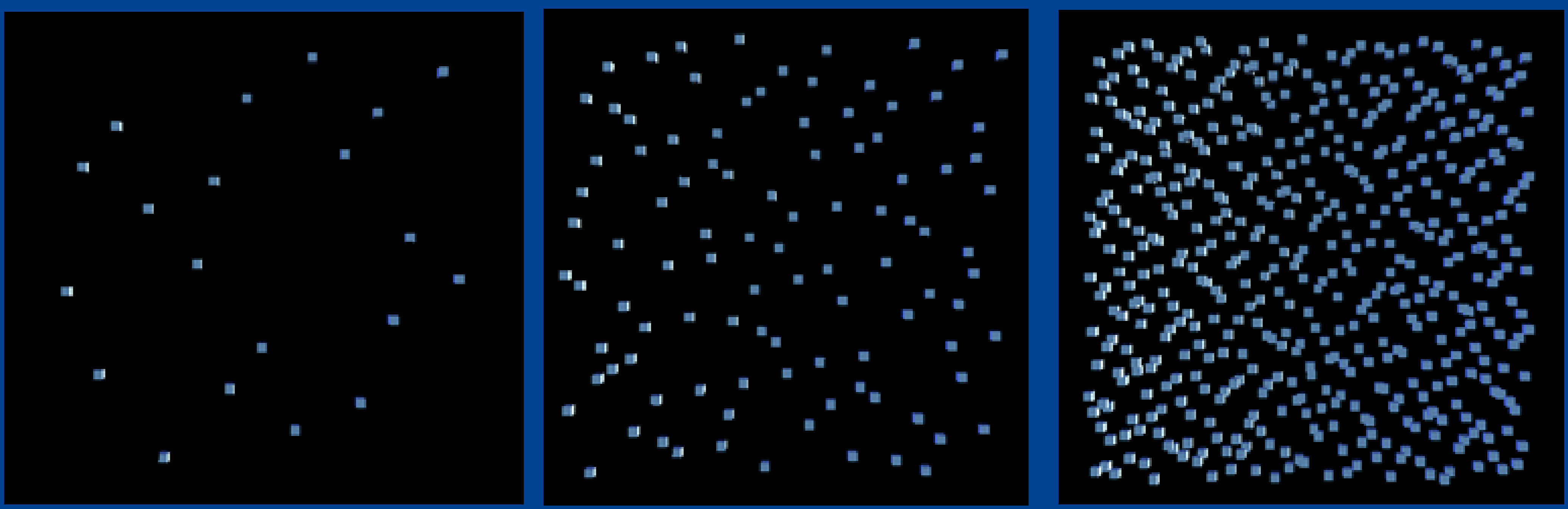
Halton Sequence

- Basic idea: take the sample count in base *b*, and digit reverse it
- In binary:



Halton Sequence

- Extends to higher dimensions
- Use base 3, 5, 7... to avoid correlation



20 100 500

Why Halton?

- Ensures samples are well-spaced
- It is extendable
  - Later samples in the sequence fill in between previous samples
- It's simple: no subdivision, spatial data structures, no state...

But

- Too expensive for our purpose
  - Requires digit reversal of base 2, 3, 5 (3D) numbers
  - *log_b(x)* with divides in inner loop
  - Problem: Recalculate from scratch for each sample
- Could use look-up tables
  - But that's expensive too, for large tables
  - Also imposes an upper sample count limit

Incremental Halton Sequence

- What changes between H_n and H_{n+1}?

- For base 2:
  - Bottom *m* bits, depending on carry propagation
  - Each bit *x* that flips adds $+-2^{-x}$
  - So, form the difference, XOR(n, $(n+1)$)
  - Adjust H_n accordingly

- Expected iterations: 2

Incremental: Other Bases

- Store count in BC<B> form.
  - Base 3 = 2 bits per digit, Base 5 = 3 bits per digit
- As we manually propagate the carry, adjust H_n accordingly, either $-(b-1)b^{-x}$, or $+b^{-x}$
- Expected carries/iterations
  - base 3 = 1.5, base 5 = 1.25

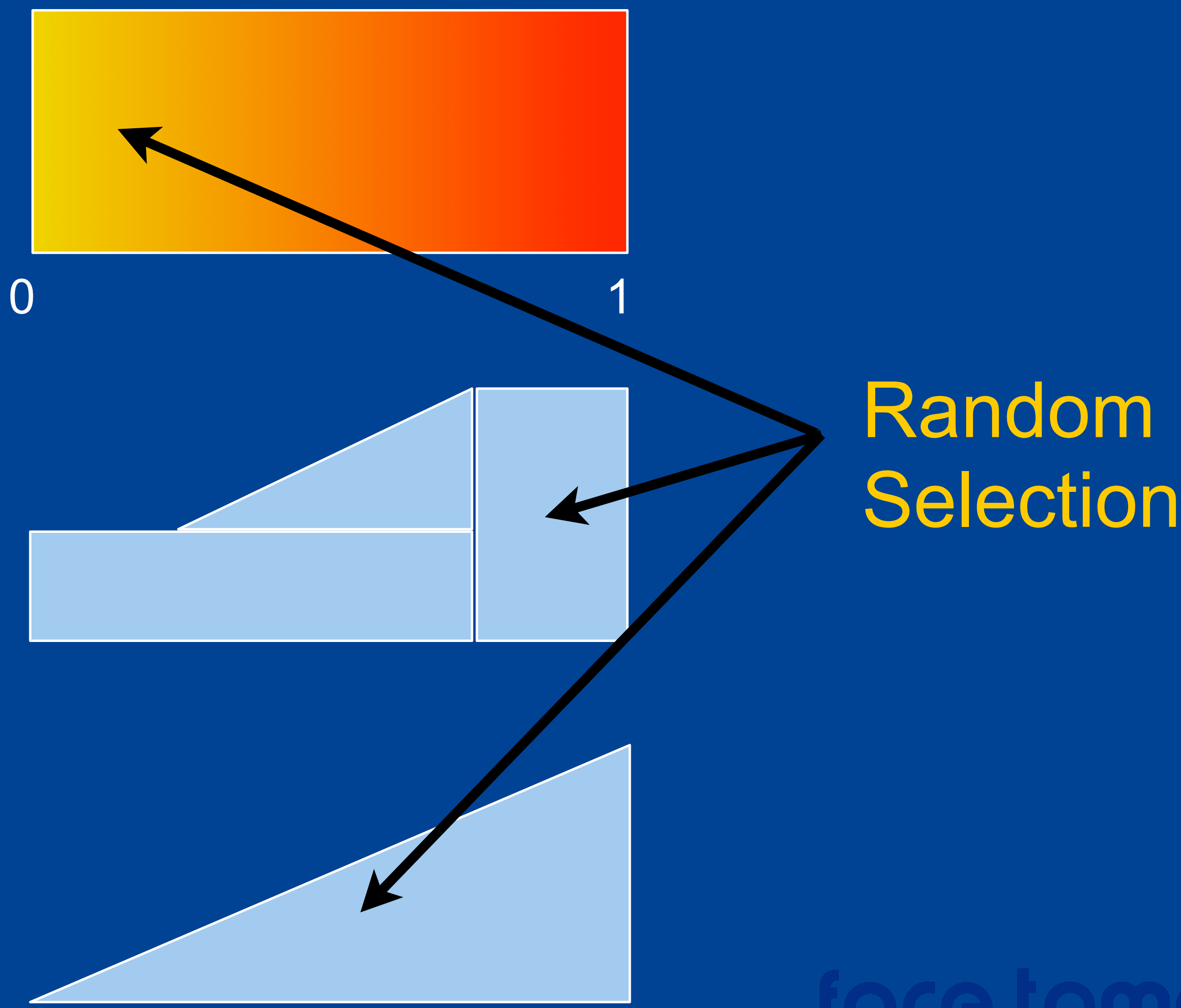
Choosing Attributes

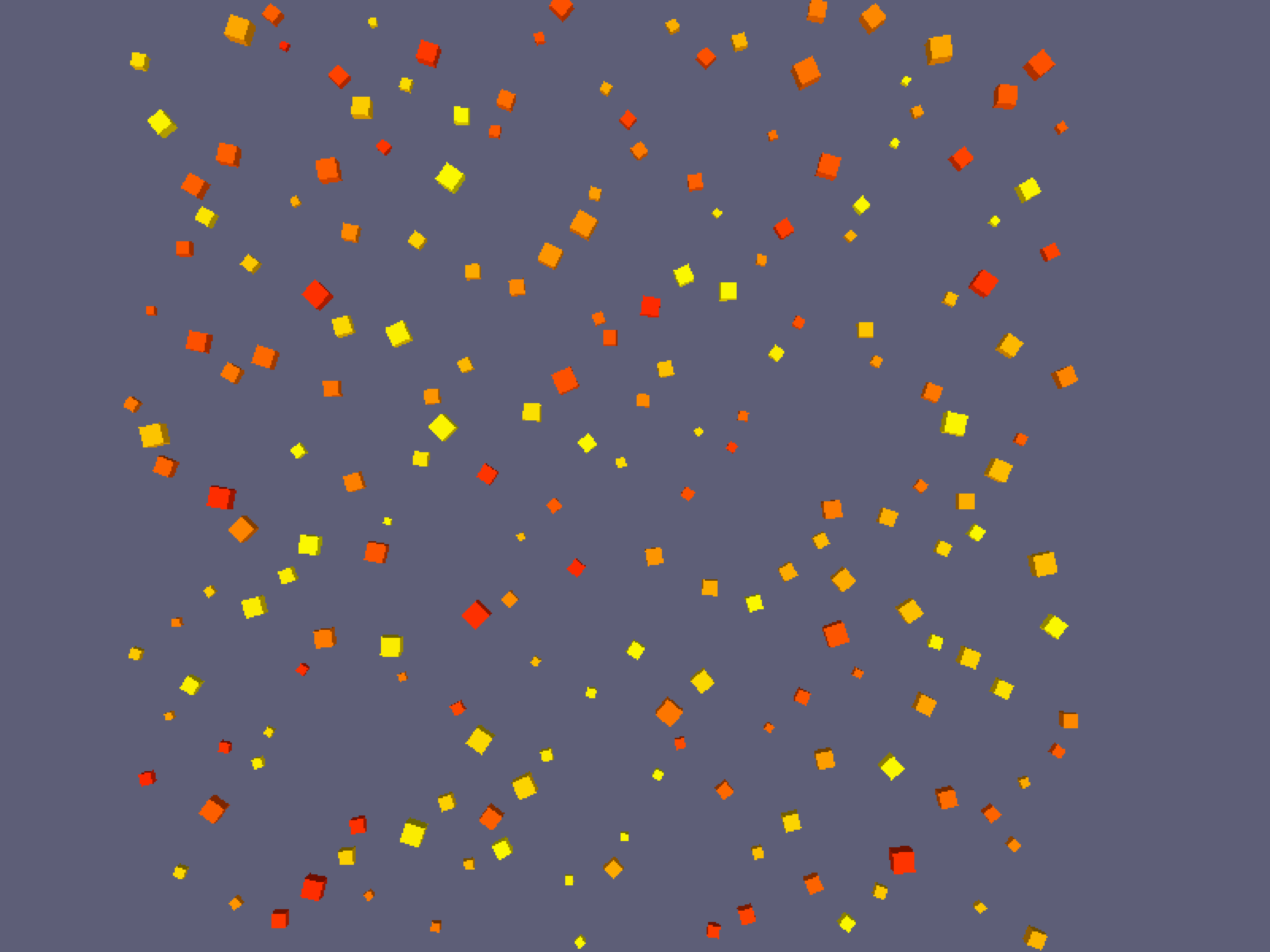
- Orientation, colour, transparency, size

- Our usual approach: Data-drive from table
  - index with e.g. particle age (0-1)
  - or random number
- New approach
  - *i* is sample number, use *i / N* to index
  - Areas well apart in the curve correspond to well-separated objects

Attribute Tables

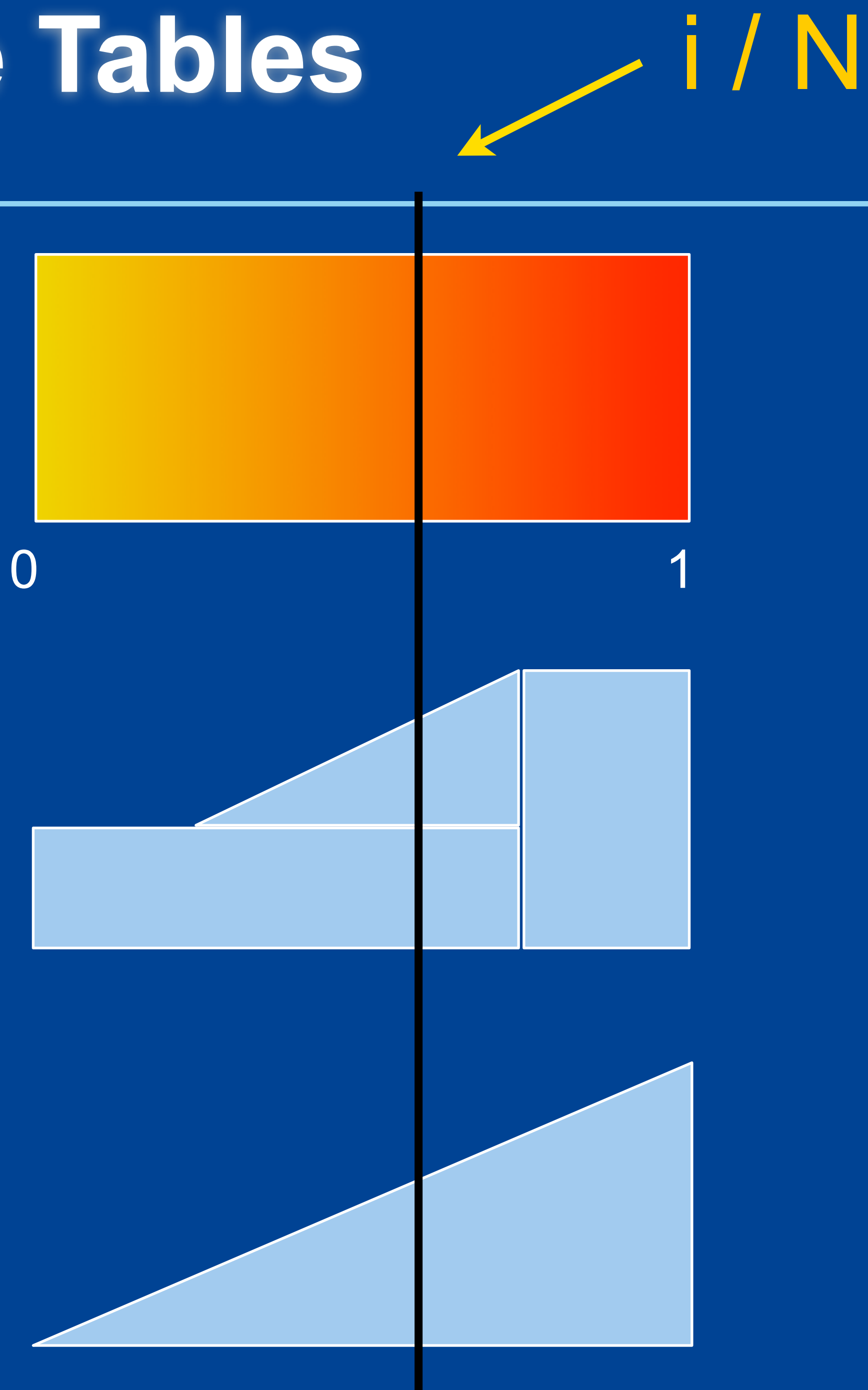
- Colour:
- Size:
- Rotation:

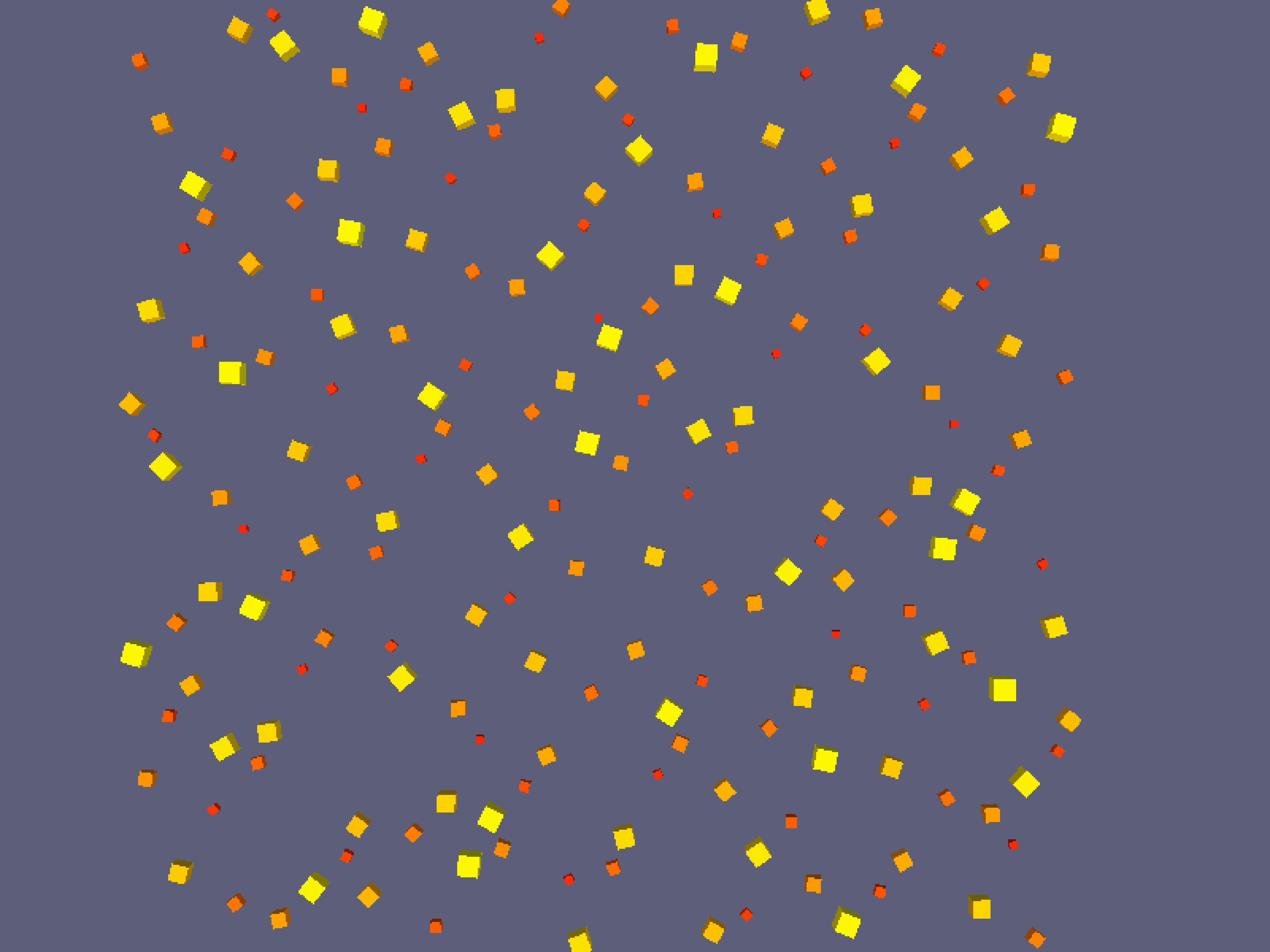


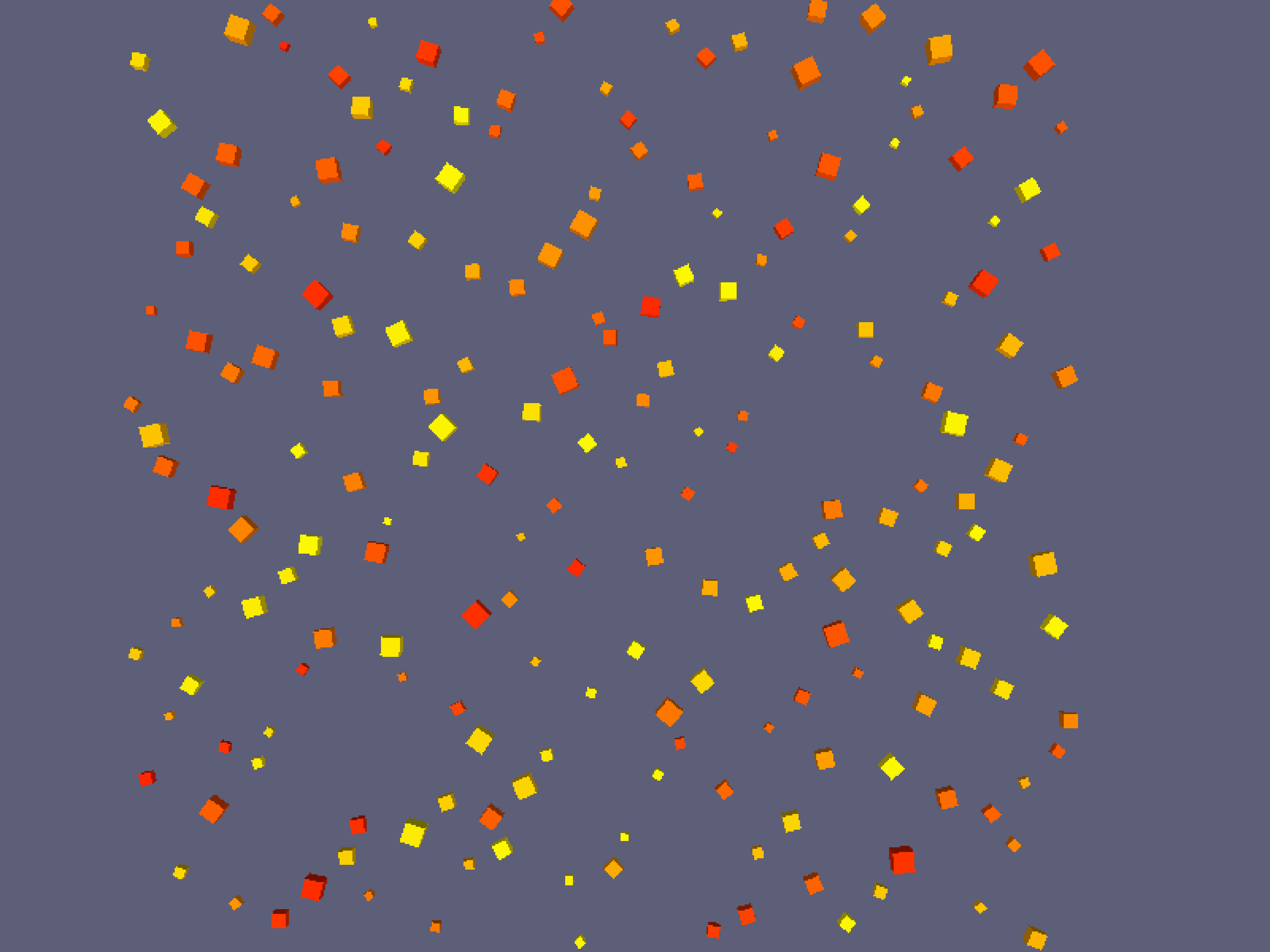


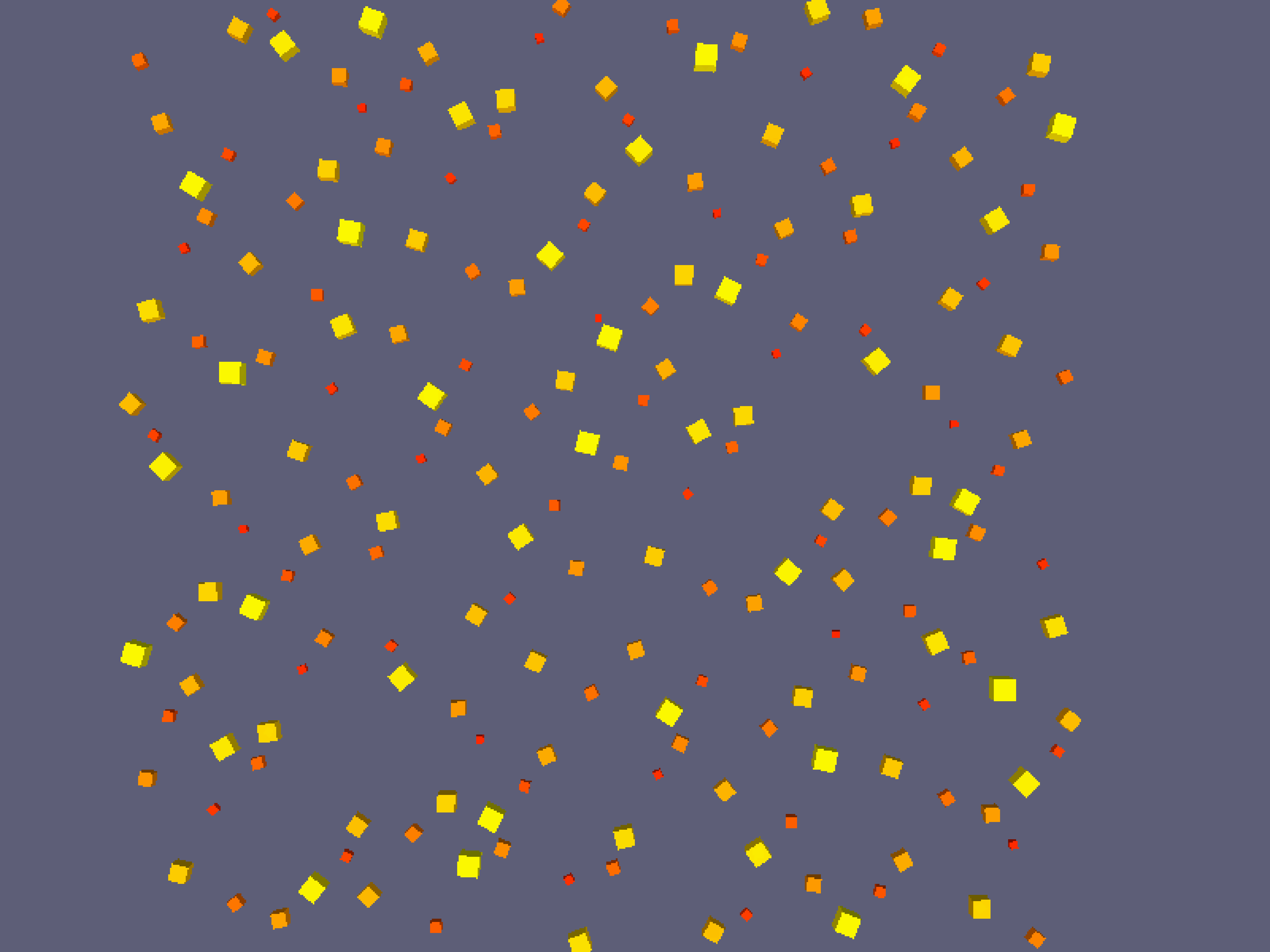
Attribute Tables

- Colour:
- Size:
- Rotation:









Advantages

- More controllable
- As well as weighting, curve is controlling effect over distance
  - Red boxes farthest from yellow boxes
- Curves are correlated too
  - Big yellow boxes, small red boxes

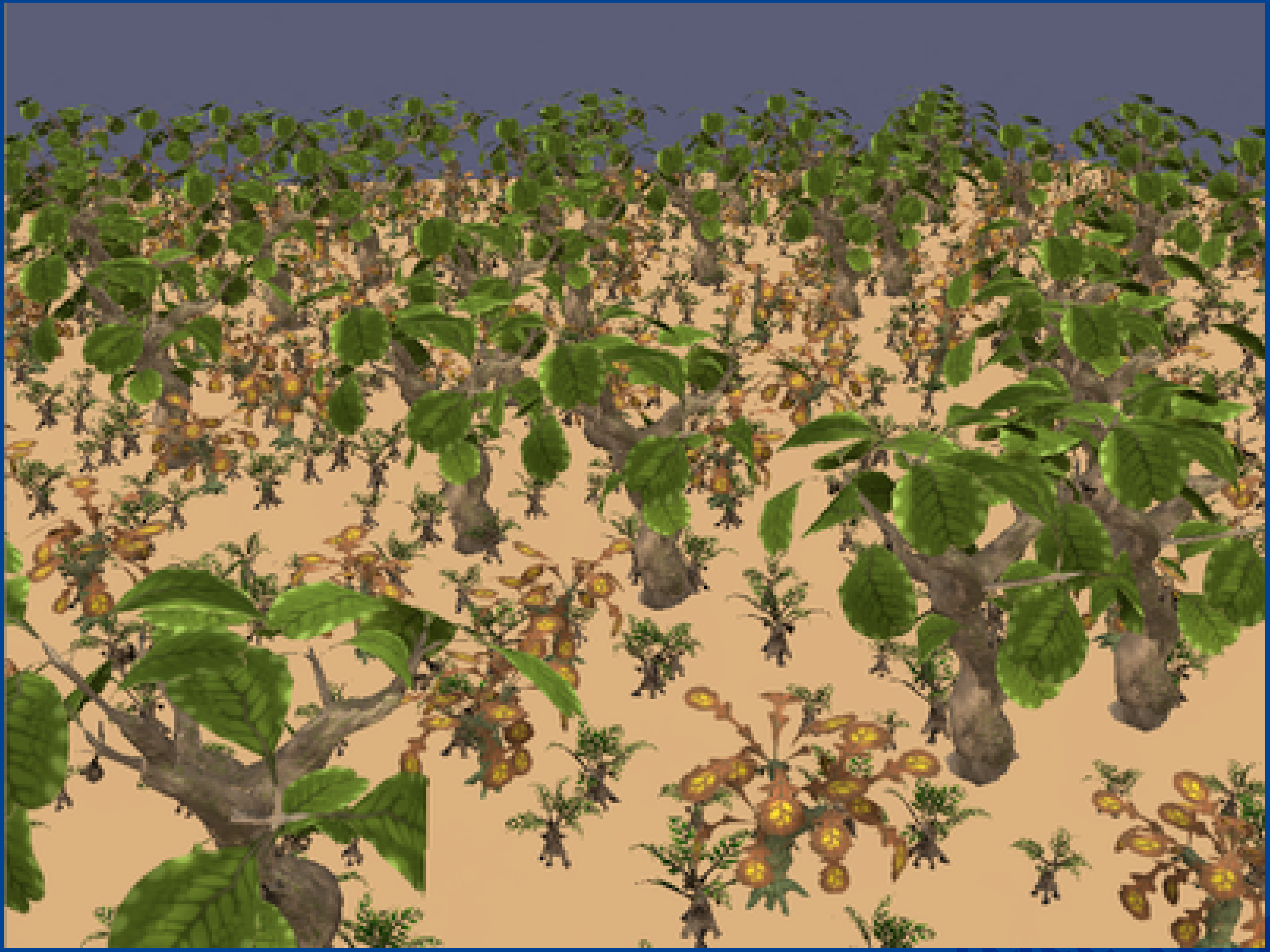
Object Nesting

- Can apply the same technique to different model types
- Allow artist control over where range starts
- Subsequent types “fill in” without collision

Large Trees

Medium Trees

Bushes



Object Density Control

- Want control either by image map or procedural map
- Either may be game-affected, so minimal pre-processing desirable

- Key observation:
  - As sample count increases, samples fill in between previous samples
  - Thus can affect overall density by varying *N*

Density Control

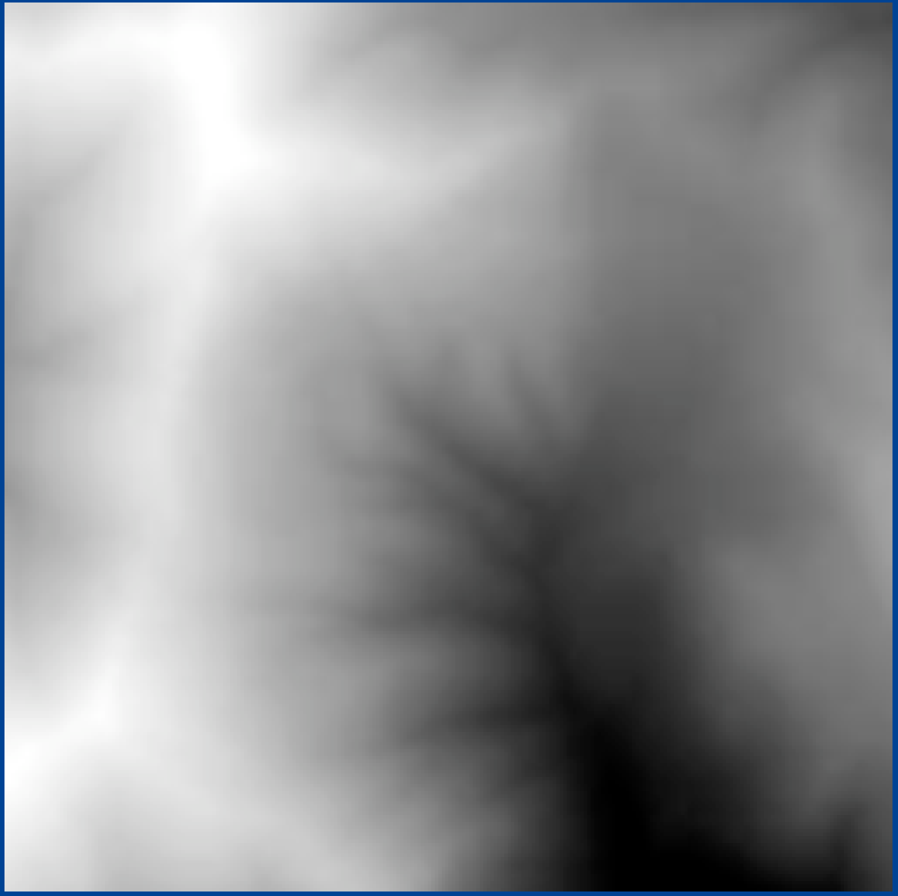
- Can achieve the same effect *locally* by dropping out samples larger than a given cutoff *N*, depending on a local density control value

- This reduces to:

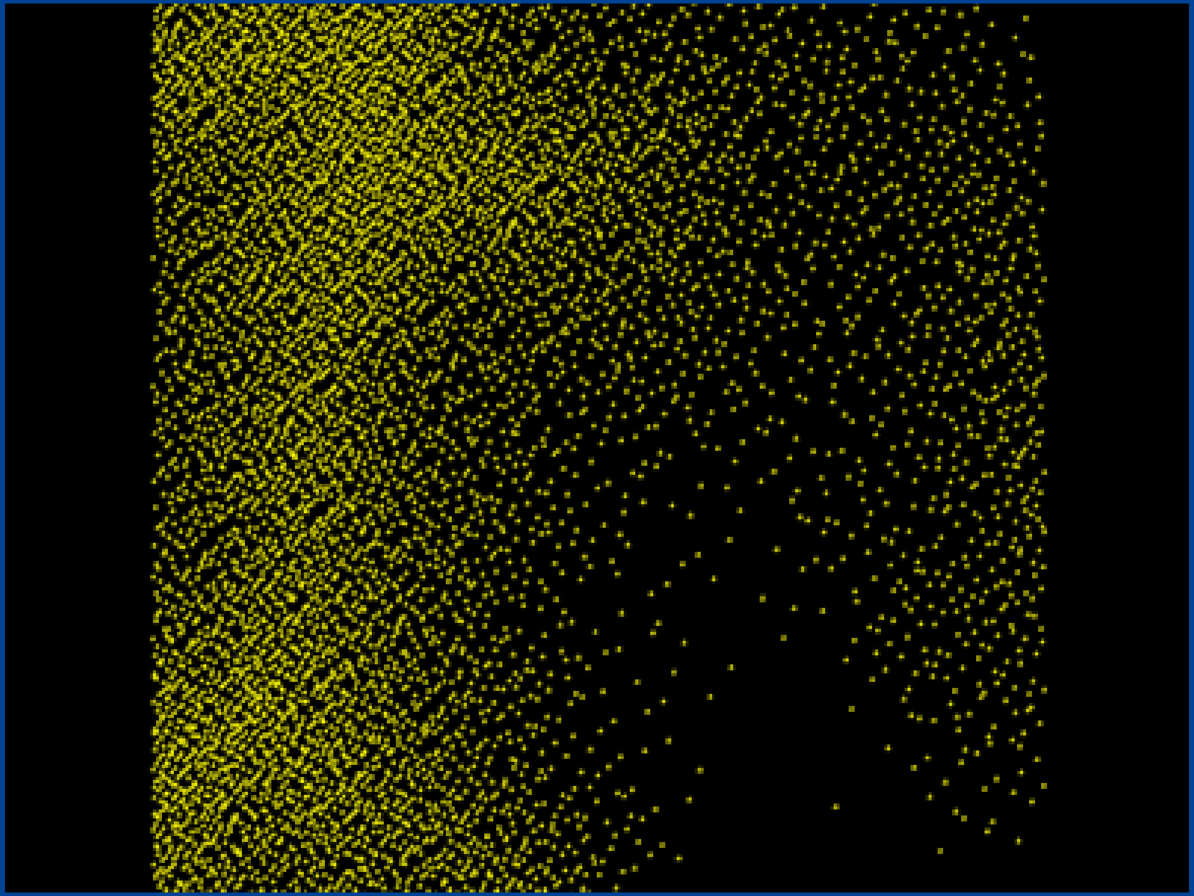
$$f(p_i) < i / N: \textbf{reject}$$

- (p is sample i's position, f is density function)

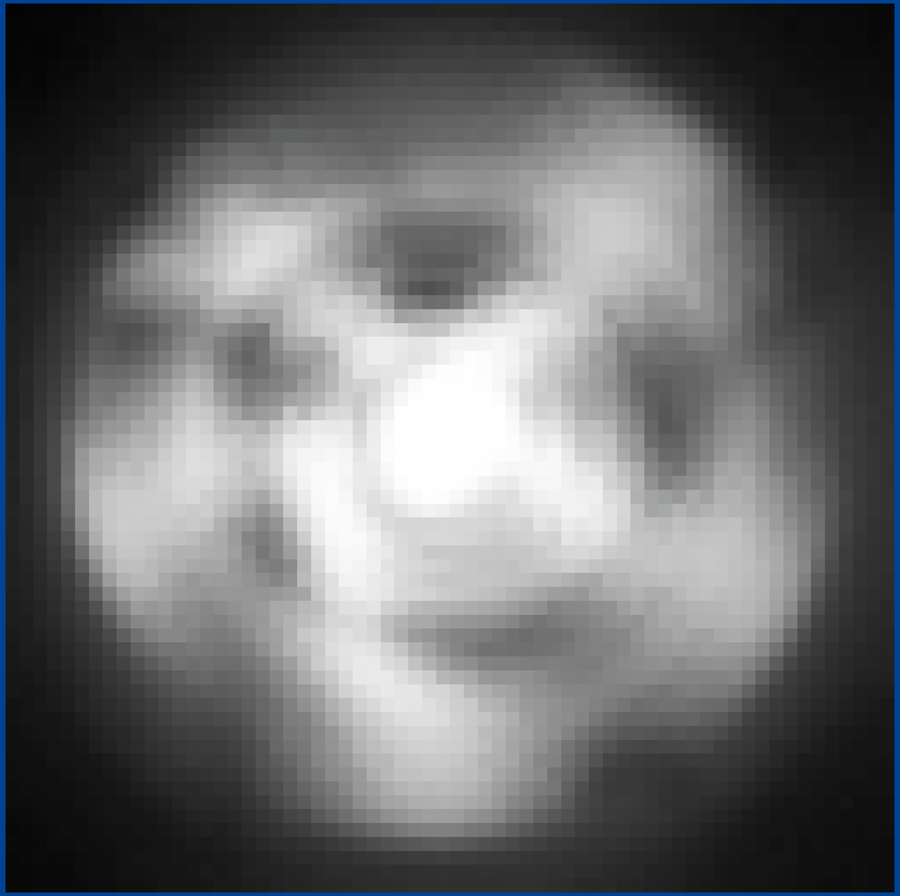
Density Map



Distribution



Density Map



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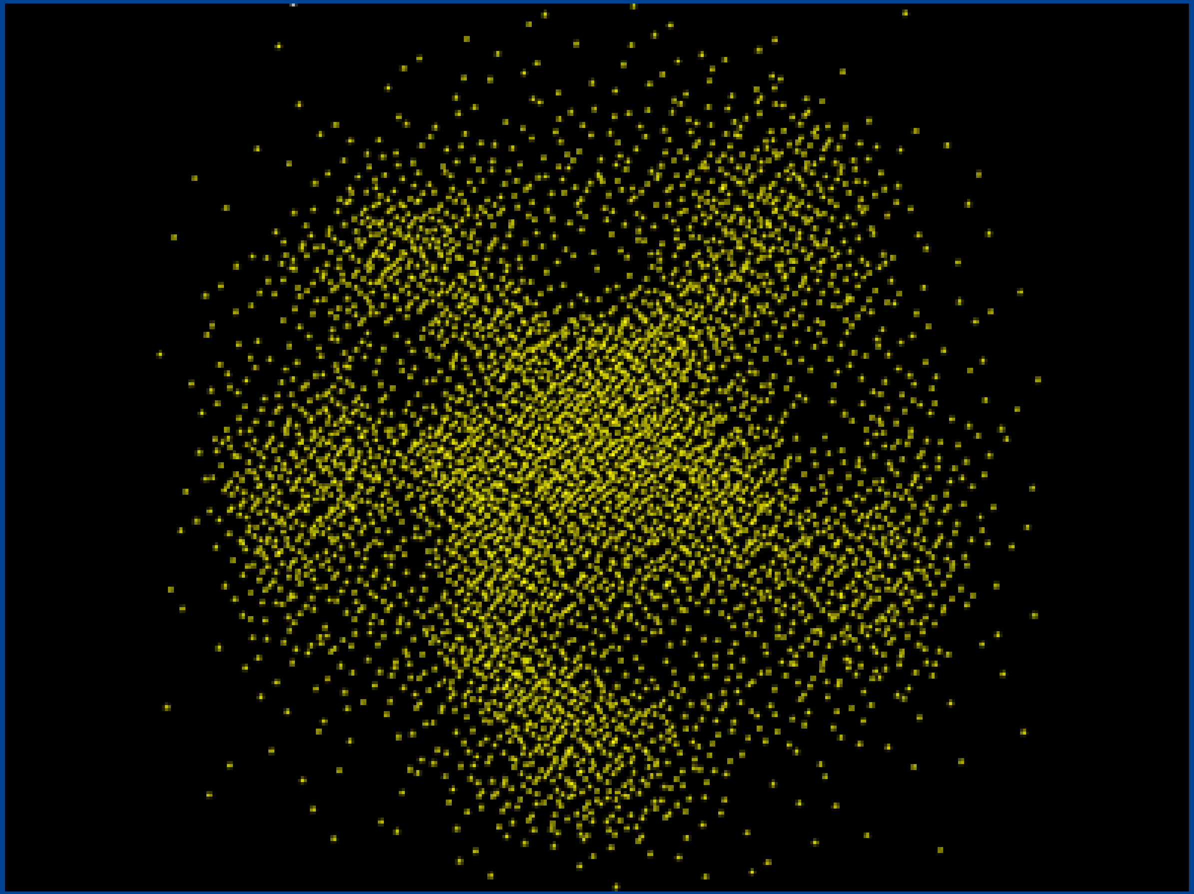
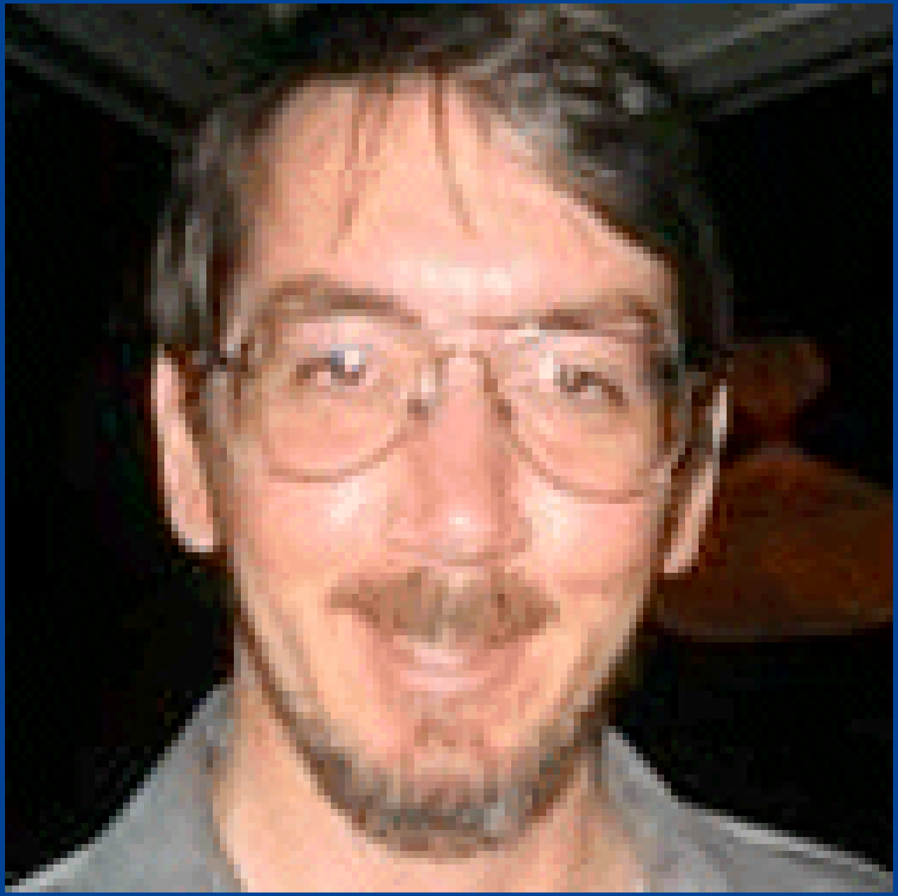


Images

Images



Questions?