



INDEPENDENT GAMES
summit

Practical Procedural Generation

Kate Compton

independent mad scientist/inventor

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Today's schedule:

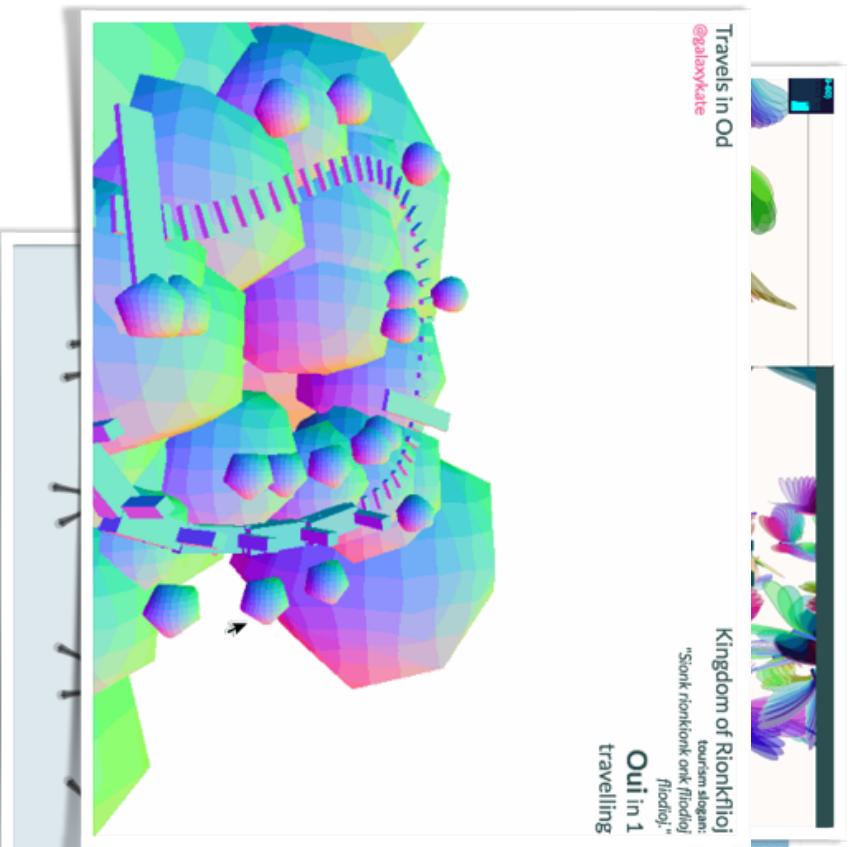
"Hey, we should have some PCG in our game!"

- Generative techniques
- Additive: building up and out
- Subtractive: removing the bad stuff
- "PCG MSG": easy cheap additives to improve taste



about me @galaxykate

- 5 years on Spore, SimCity (and some cancelled properties)
- 5+ years of a PhD in generative games and creativity tools for casual users
- Contracting for chatbots on the Google Home and 3D printing apps
- Made Tracery, a language for generative text. Used for CheapBotsDoneQuick, hosting 3791 **active** bots
- I make generative artbots, games, art tools and more
- I write about and teach others how to make generative things.



about me @galaxykate

22
2 / 2016

So you want to build a generator...

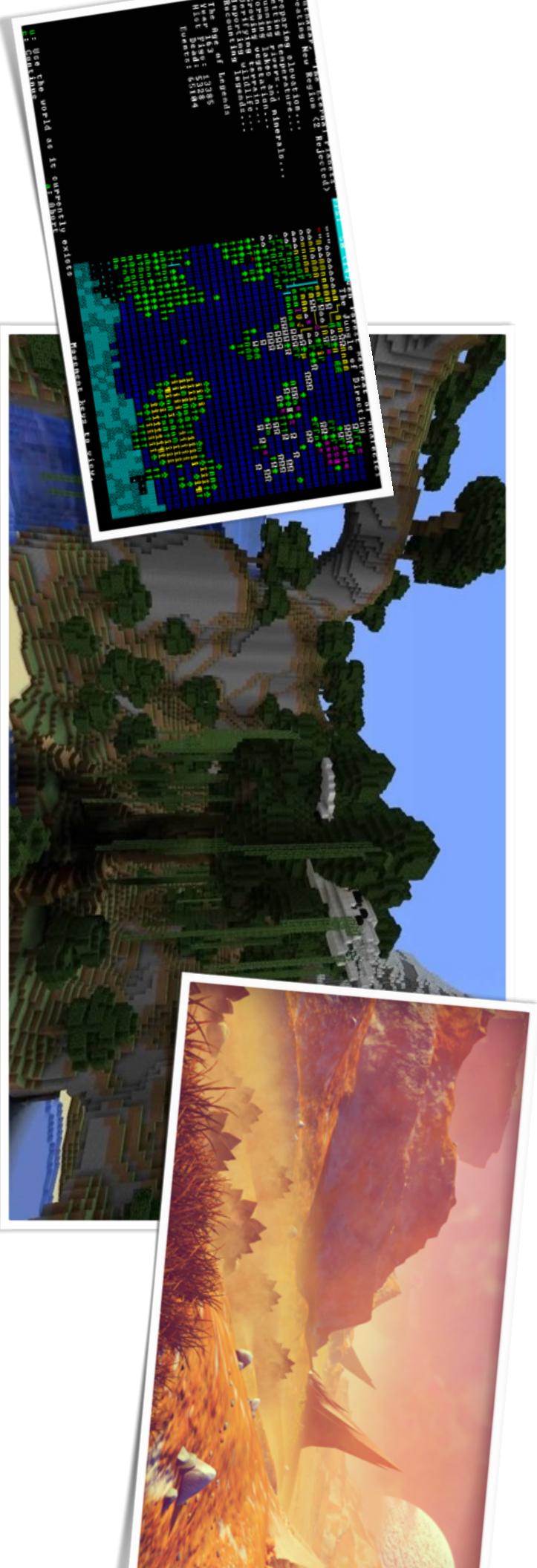


This is a beginner-level advice essay for people just getting started with building generators. It's also for practiced experts who want a way to



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You want to generate something



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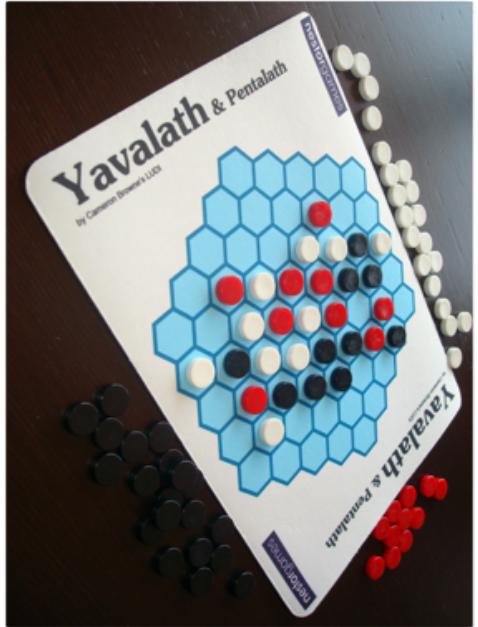
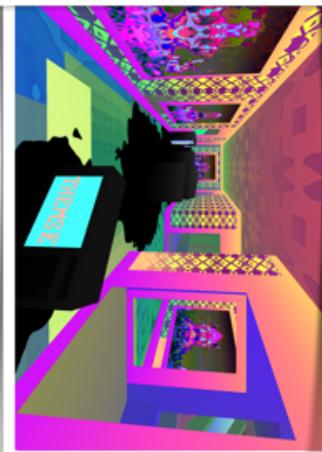
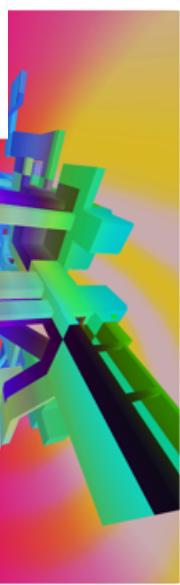
"These Monsters" Strangethink

"Yavalath" Cameron Browne, "Panoramical"
"Ultima Ratio Regum" Mark R Johnson

"It is as if you were playing chess" Pippin Barr

"Mr. Darcy Dance Simulator" Dietrich Squinkifer

It is as if you were
playing chess



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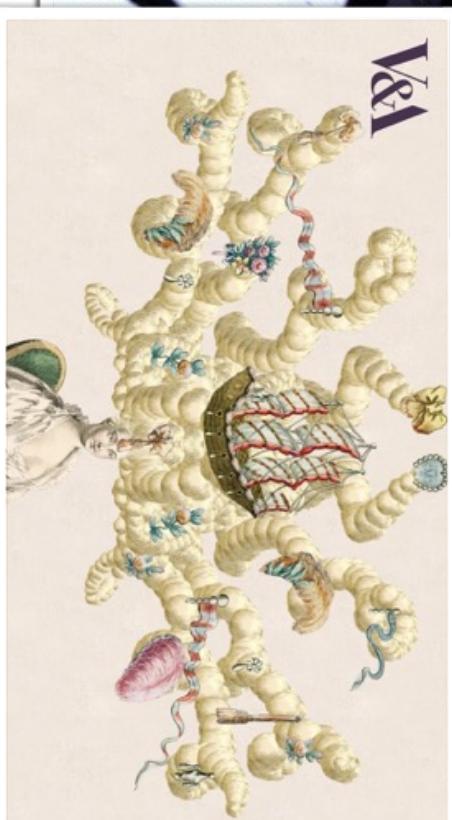
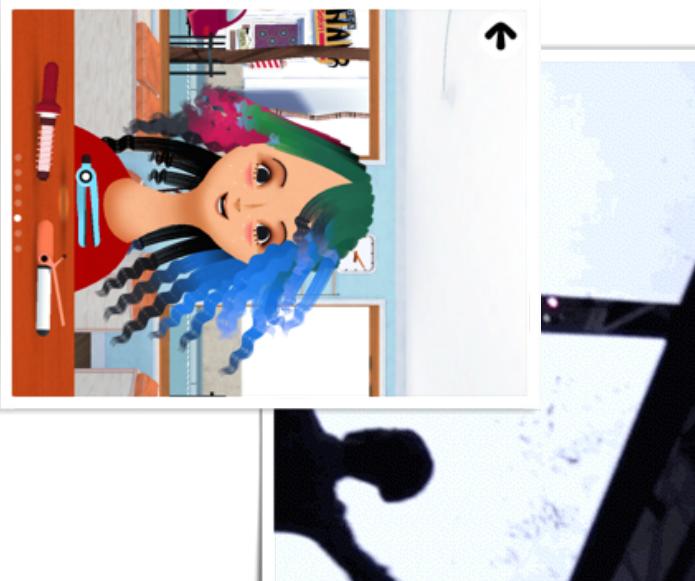
You want to generate something

"Treachery of Sanctuary" Chris Milk

"Kinematics Dress" Nervous System

"Designawig" V&A Museum

"Hair Salon" Toca Boca



For more info:
*ICCC International Conference on
Computational Creativity*

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You want to generate something

for a hackathon **big** for a creativity tool
in the background **small** to make impossible spaces in VR

for procjam **small** to make your indie game stand out
for surreal humor **simple** to add complexity to a AAA open world game

that responds to music **complex** to improve Twitchability

for your Burning Man camp **complex** for an art show



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Lots of generative content uses

extremely sophisticated and brilliant AI

and fails anyway

here's your reminder @tinycarebot · Feb 16
✿ ; please remember to take a quick moment to rest your eyes

↑ 7 ↓ 123 ❤ 454

johnny sun ✅ @johnnysun · Feb 16
@tinycarebot ok ok ill bot soon i promise soon

↑ 5 ↓ 2 ❤ 139

here's your reminder @tinycarebot · Feb 16
✿ ; remember to take a quick second to go outside if you can please! i love u!!

↑ 1 ↓ 2 ❤ 2 ❤ 50

Some of the best generative content is Simple

The hardest part of procedural content is DESIGN

♥ YOU CAN DO THIS! ♥

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Lets get started!

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You want to generate something

Understand the design space

Enumerate your constraints

Understand the process

Pick a generative method

Iterate! (and be flexible)

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So you want to make a generative...

What are you making?

- level generator
- character creator
- abstract art generator
- cocktail recipe generator
- game title generator
- conversational character
- poetry generator
- twitterbot



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Making an artist-in-a-box

Find an expert (or read their writing)

How do they think through the problem?



For more info:

http://chrishecker.com/My_liner_notes_for_spore

<http://www.levitylab.com/blog/2011/02/brief-history-of-spore/>



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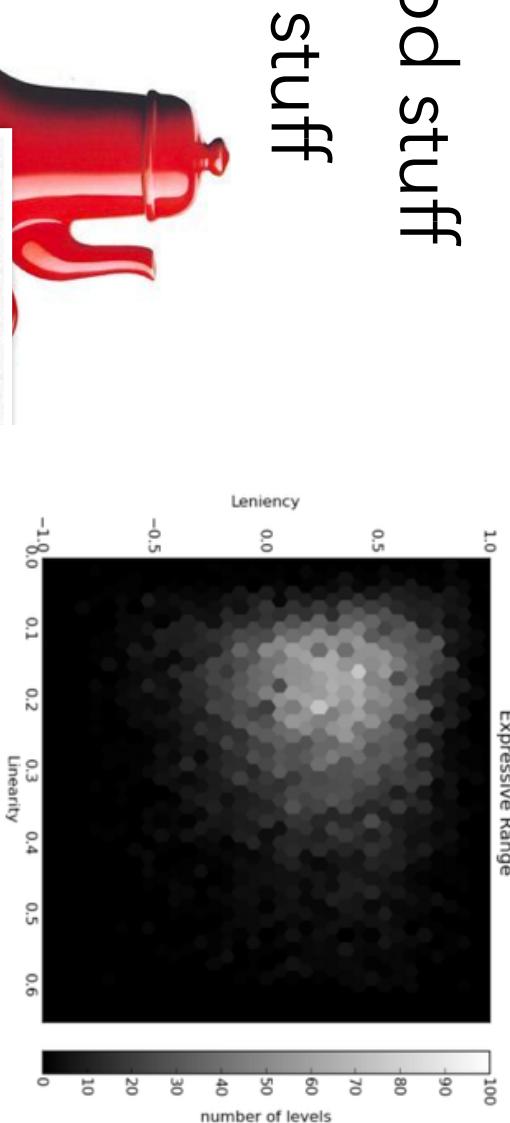
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Additive and subtractive methods

- Build up a space of good stuff
- (optional) Remove bad stuff
- Vocab:
- Possibility space
- Expressive range



For more info about constraints

Mike Cook's Danesh project Tues 11:20am 2005 West
So you Want to build a Generator - Kate Compton
Expressive Range: Evaluating and Comparing
Generative Systems - Gillian Smith



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Part 1: The IKEA catalog of Generativity

The **full catalog** of generative methods
and why you might choose each

Additive methods to build things

Subtractive methods to get to the good stuff



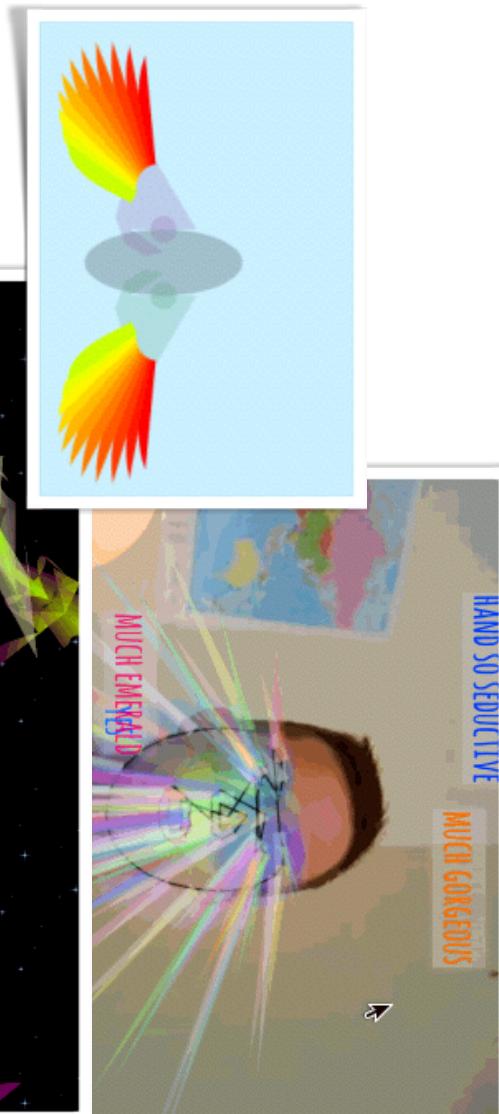
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Additive methods

- Tiles
- Grammars
- Distribution
- Parametric
- Interpretive
- Simulations



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Tiles

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Tiles

Works well for

- something you can break into regions
- where tile-to-tile placement don't need to be constrained
- But you can still get emergence from the placement of tiles



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producing 1116 - 45,949,729,863,572,161 different

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Tiles

W. A. MOZART.

INSTRUCTION

ISTRUZIONE

To compose without
the least knowledge
of Music so much German
Walzer or Schleifer
one pleases, by thro
certain Number with t

Per comporre
delle Walzer
oppure Schleifer

TABLE de MUSIQUE.

5.



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producing 1116 - 45949729 863 572 161 different

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Grammars

- Recursively make things from other things



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Grammars

- Tracery and other templating systems (for text)

- L-Systems (for geometry)

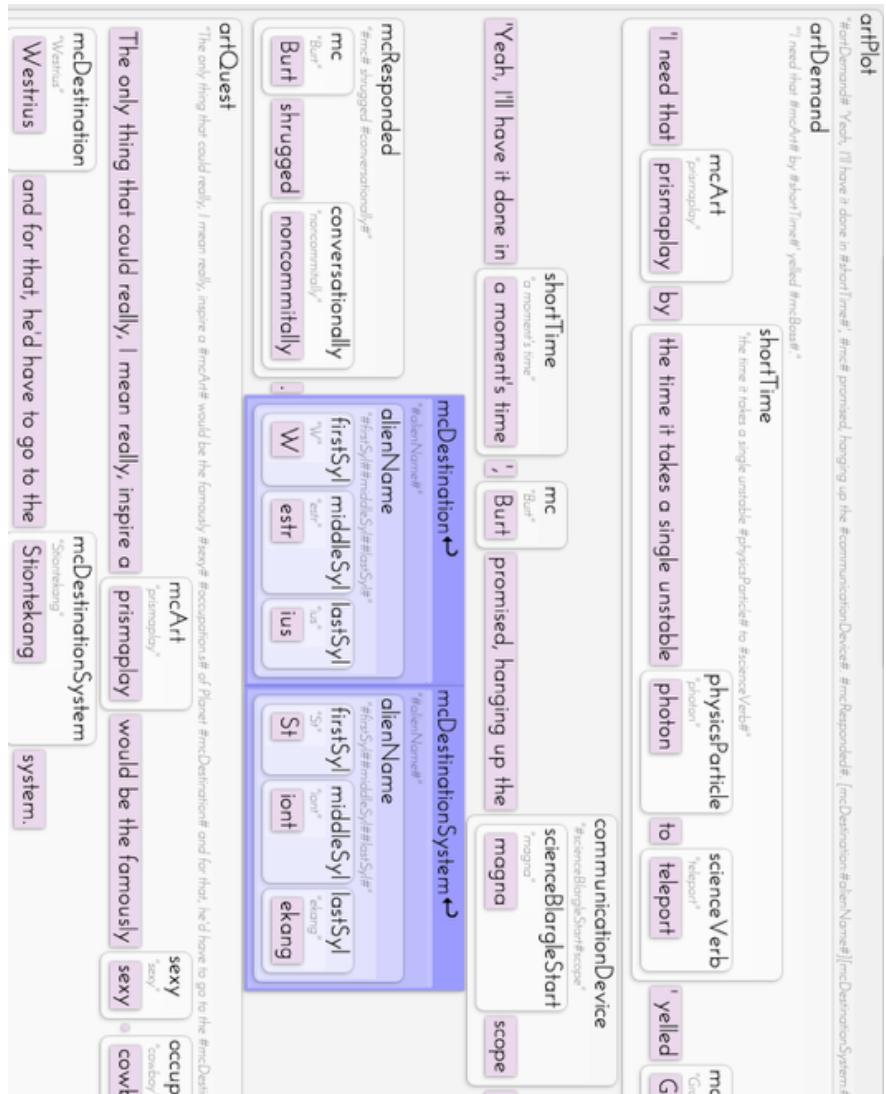
- Replacement grammars

For more info about grammars

GDC Tech Toolbox 2016 on youtube

[tracery.io](#)

Joris Dormans, Level Design as Model
Transformation, "Unexplored"



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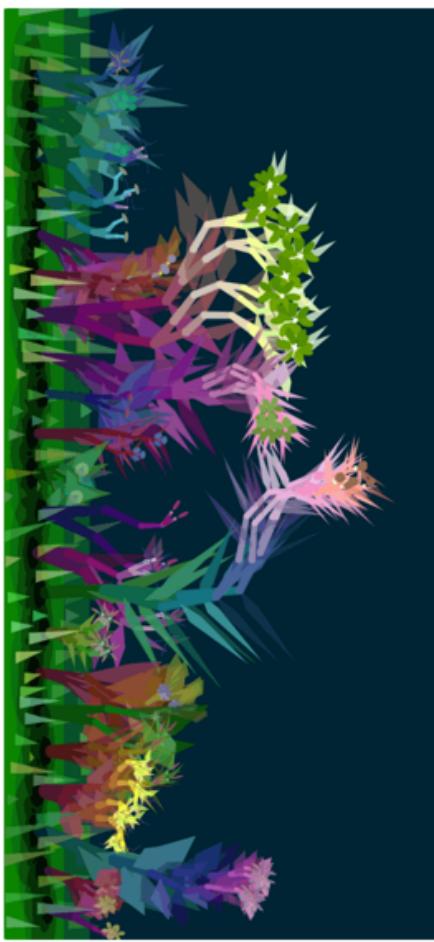
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Context Free Art

The screenshot shows a software interface for generating fractal art. On the left is a colorful, multi-layered fractal flower. On the right is a window titled "Context Free Art" displaying an L-System grammar. The grammar includes rules for "GARDEN", "SEED", and various geometric shapes like "curveleft" and "curveright". The interface has a menu bar with "File", "Edit", "Render", "Examples", "Window", and "Help". A status bar at the bottom indicates "249 rules loaded" and "6959 shapes; 435x415 pixels".

```
startshape GARDEN
include i_curves.cfdg
rule GARDEN {
    SEED {}
}
rule SEED {
    curveleft_0 98 -3 {x -2}
    curveleft_0 98 2 {}}
    curveleft_0 98 1 {x 2}
    curveleft_0 98 4 {x 2}
    curveleft_0 98 1 {x 2}
    curveleft_0 98 2 {x 8}
    curveleft_0 98 3 {x 10}
    curveright_0 98 2 {x 8}
    curveright_0 98 3 {x 10}
}
rule LEFT_OR_RIGHT {
    LEFT_F
    LEFT_F
}
rule LEFT_OR_RIGHT {
```



For more info about grammars
GDC Tech Toolbox 2016 on youtube

tracery.io

Joris Dormans, Level Design as Model
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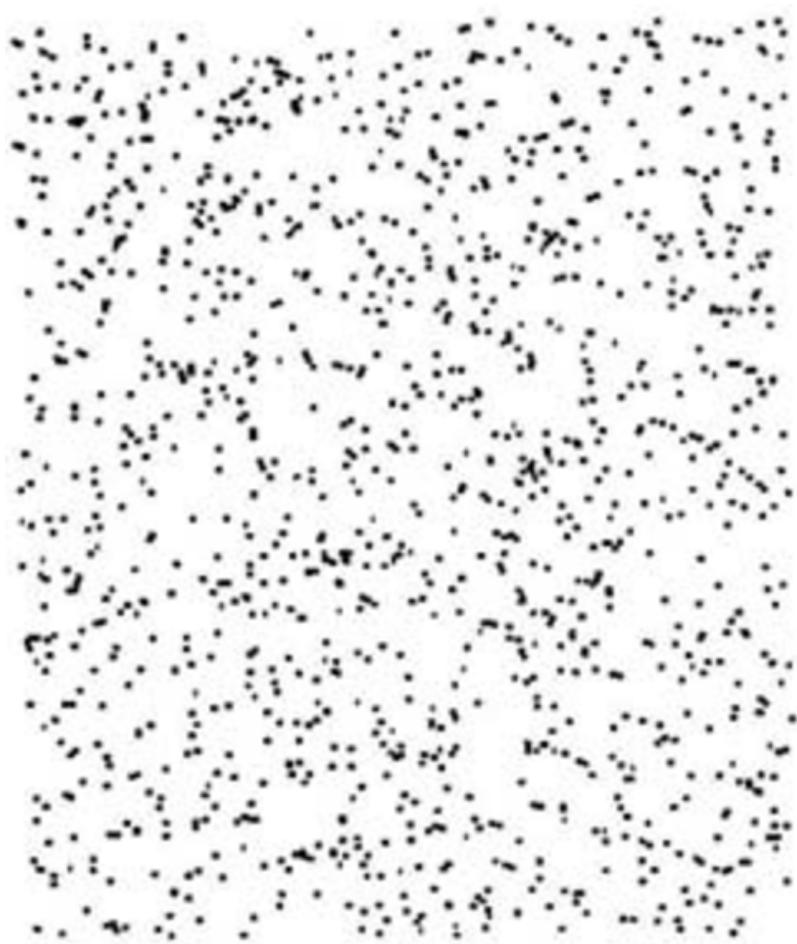
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Distribution

- Put down some objects
- $x = \text{random}(100)$, $y = \text{random}(100)$
- "actual" random looks bad, clumps strangely





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Distribution

- "real" distributions are hierarchical and clustered, but also maintain spacing



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Distribution

Options:

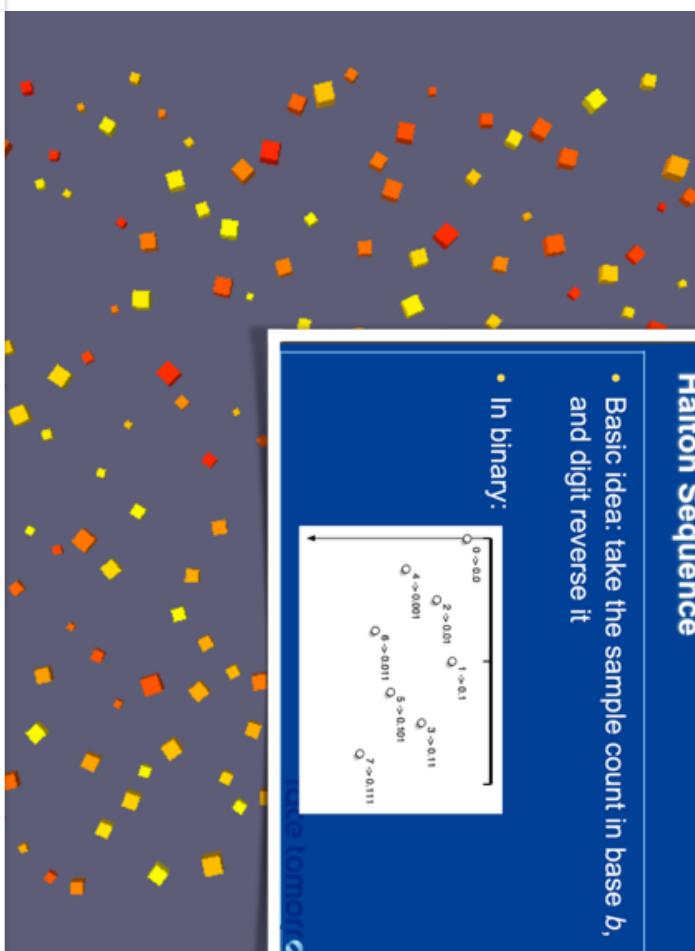
- start with a grid, and offset a bit
 - (less obvious with a hex grid)
- Use a voronoi diagram with easing
- do it properly with a Halton Sequence
- barnacling, greebling, footing

Halton Sequence

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

In binary:

0 => 0.0	1 => 0.1
2 => 0.01	3 => 0.11
4 => 0.001	5 => 0.101
6 => 0.011	7 => 0.111



For more info:
Fast Object Distribution, Andrew Willmott on Spore

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Parametric



spread
angleSkew

bushiness

hueStart

hueDiff

wiggle

leafVolume

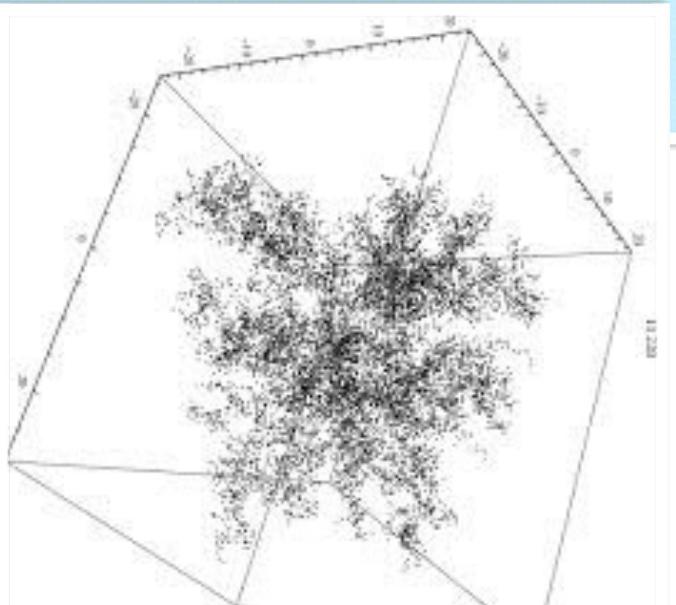
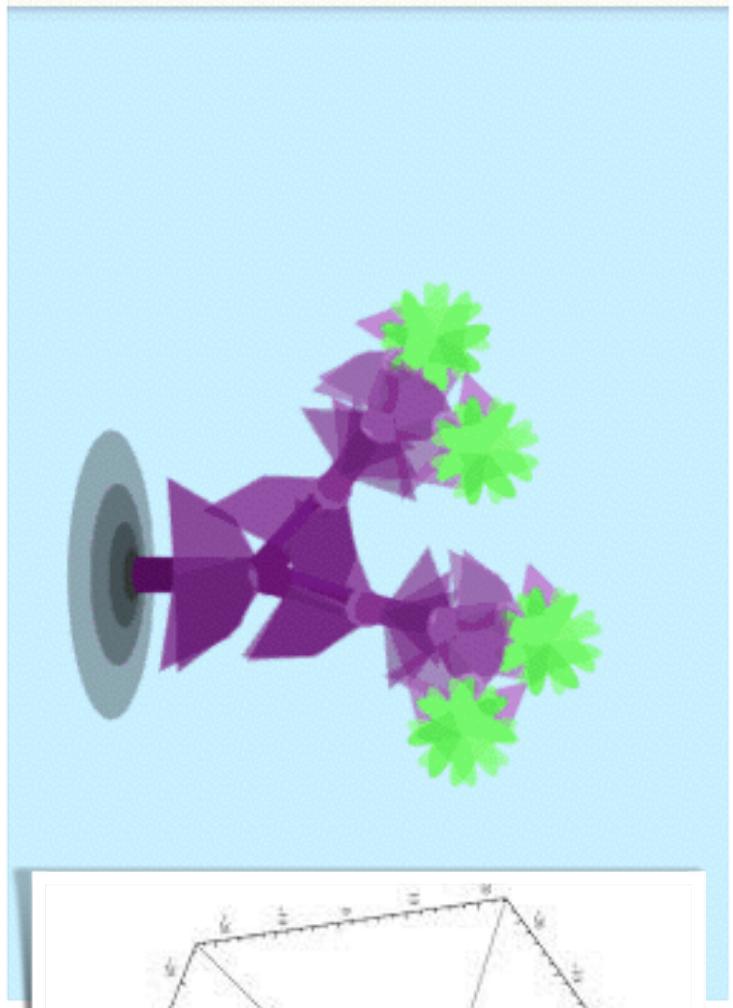
leafShape

leafVariation

leafCount

leafAspect

saturation



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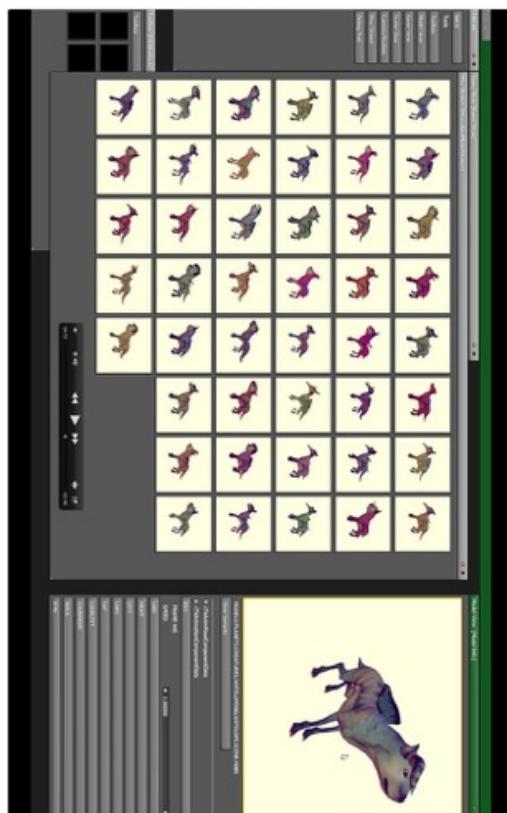
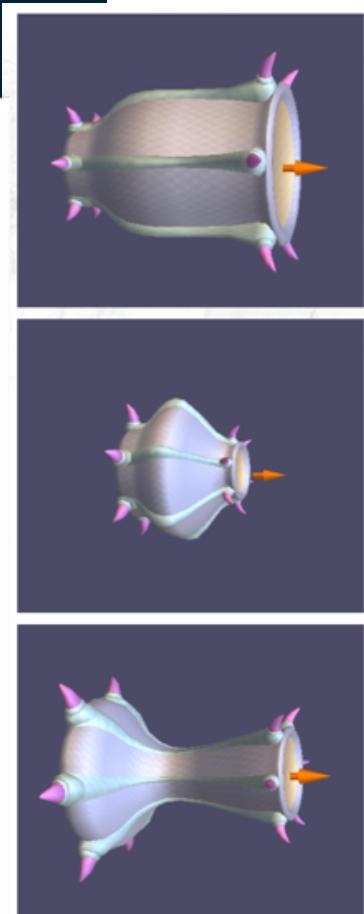
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Parametric

An array of floats representing settings,
“morph handles”



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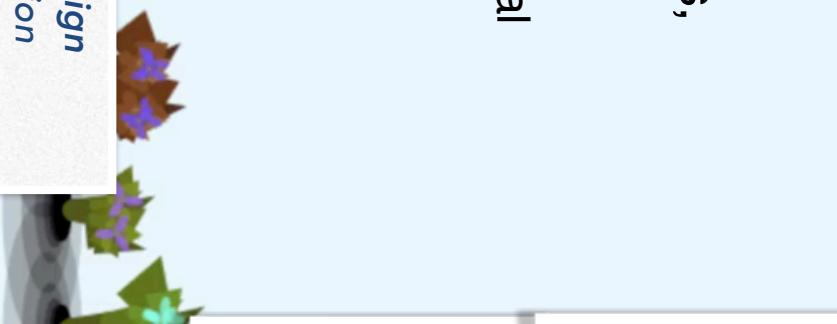


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Parametric

An array of floats representing settings,
“morph handles”

- modellable as points in an N-dimensional cube
- any position is a valid artifact!
- You can do genetic algorithms
- or user directed walks through the space
- or “regionize” the space



*For more info about user-controlled parametric design
"Petalz: Search-based Procedural Content Generation
for the Casual Gamer"*

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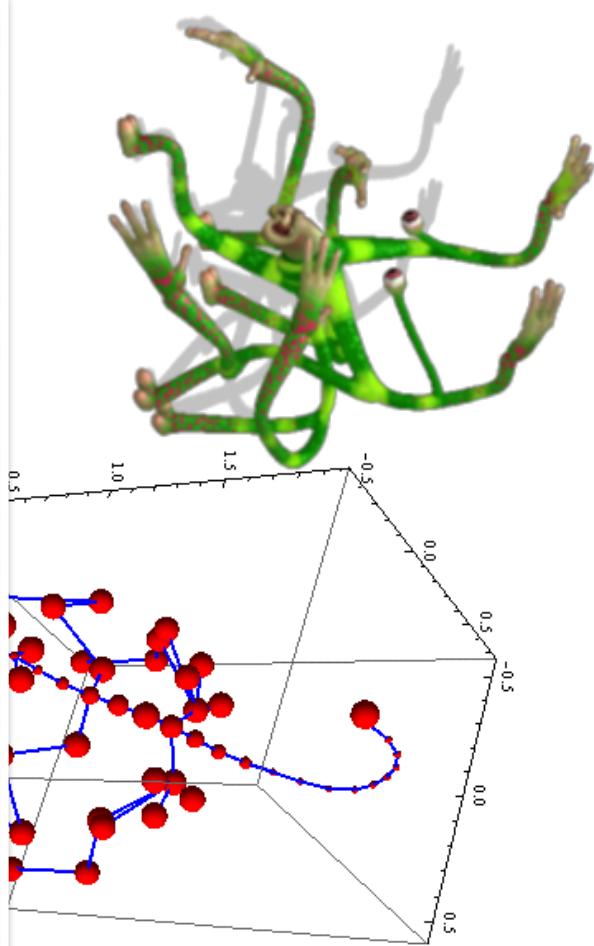
Interpretive

- Start with some input
- Run an algorithm to process data into some other data

You have a simple structure:

some distribution of points, a skeleton, a connectivity map, a curve or path

and want to make it more **complex**



For more info about the Spore pipeline

Real-time Motion Retargeting to Highly Varied User-Created

Morphologies - Chris Hecker

How To Animate a Character You've Never Seen Before

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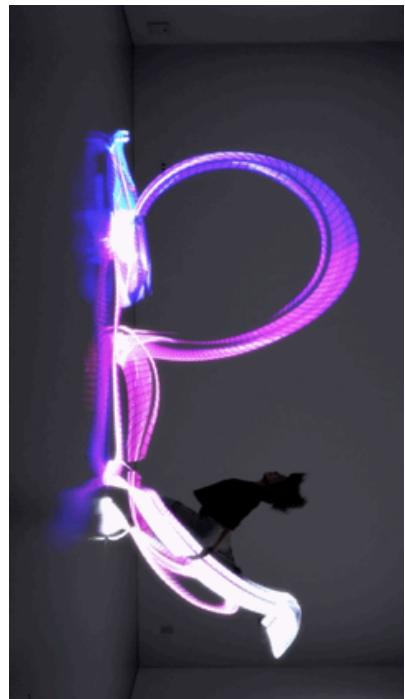
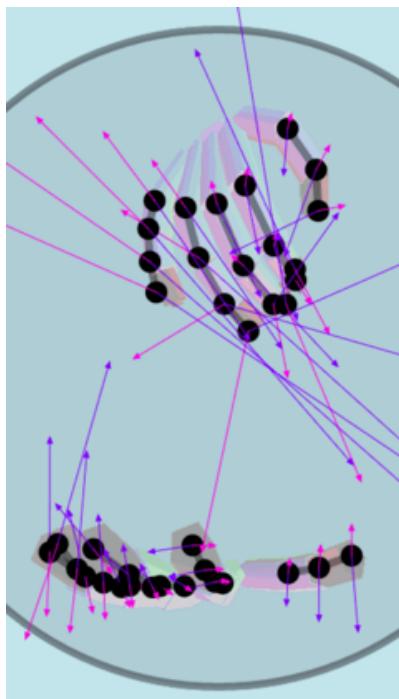
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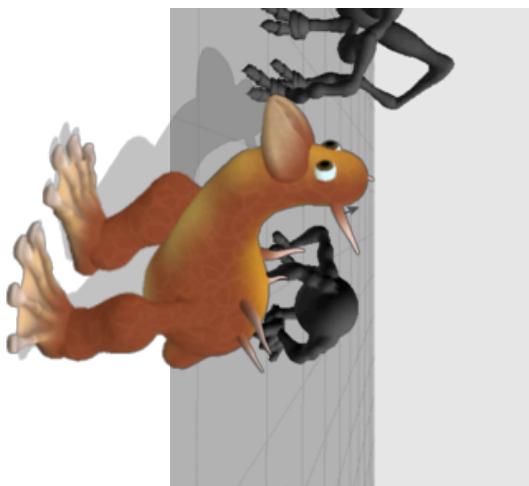
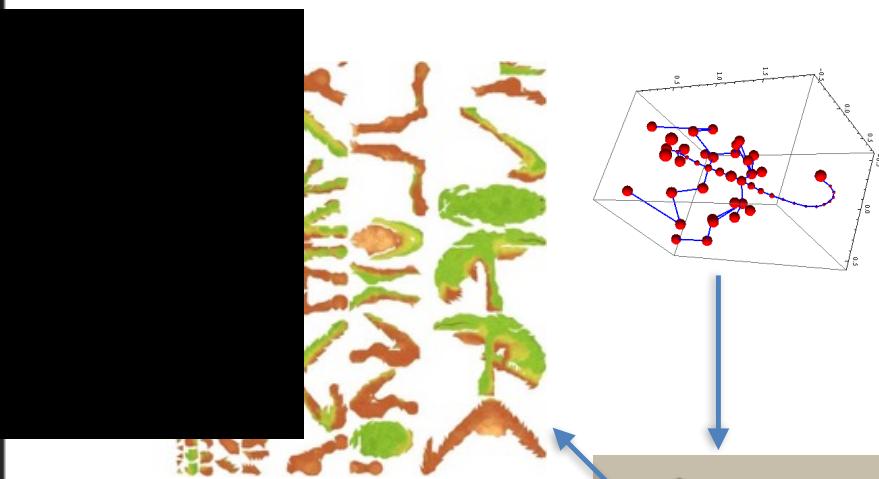
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- Start with some input
- Run an algorithm to process data into some other data
- Examples:
 - Noise (Perlin/simplex)
 - Voronoi/Delaunay
 - Constructive Solid Geometry
- Extrusion, revolution
- Metaballs

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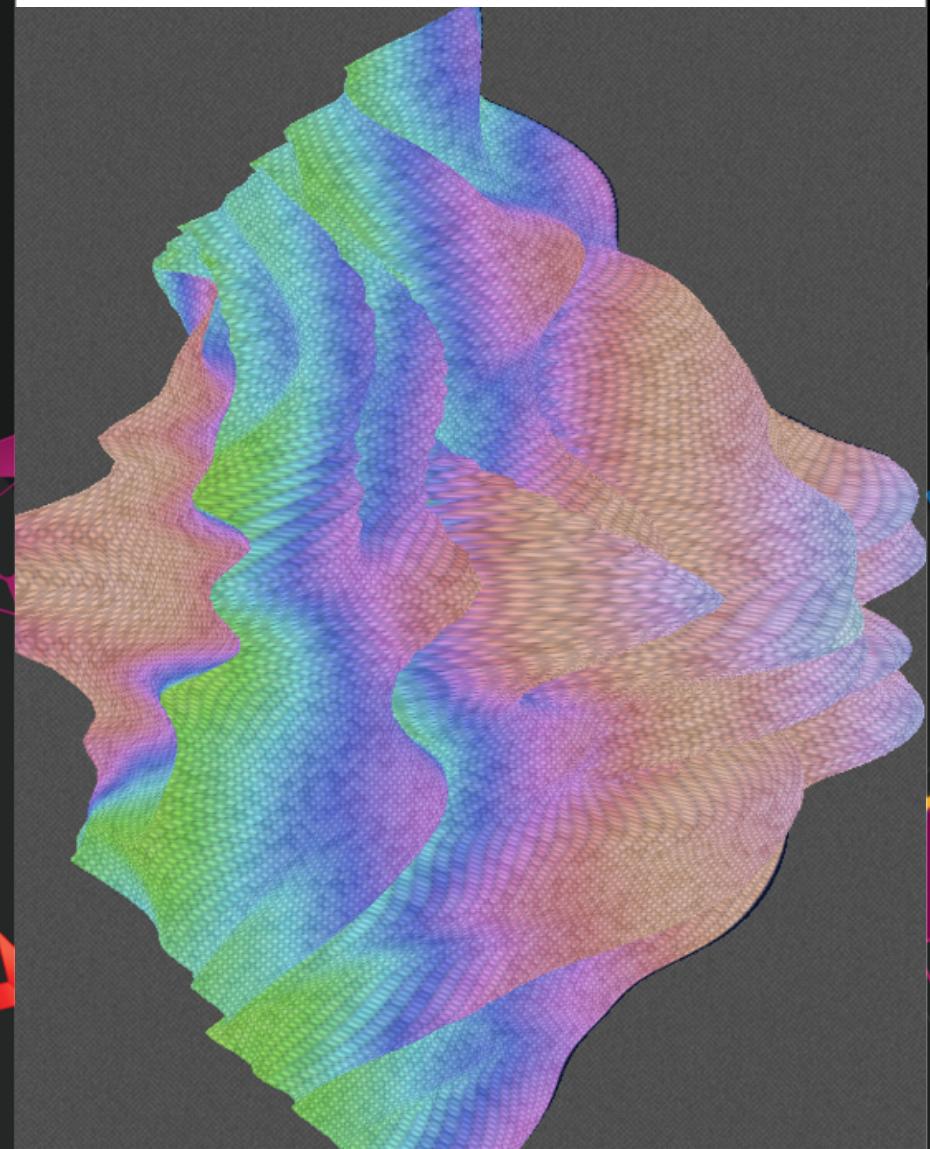
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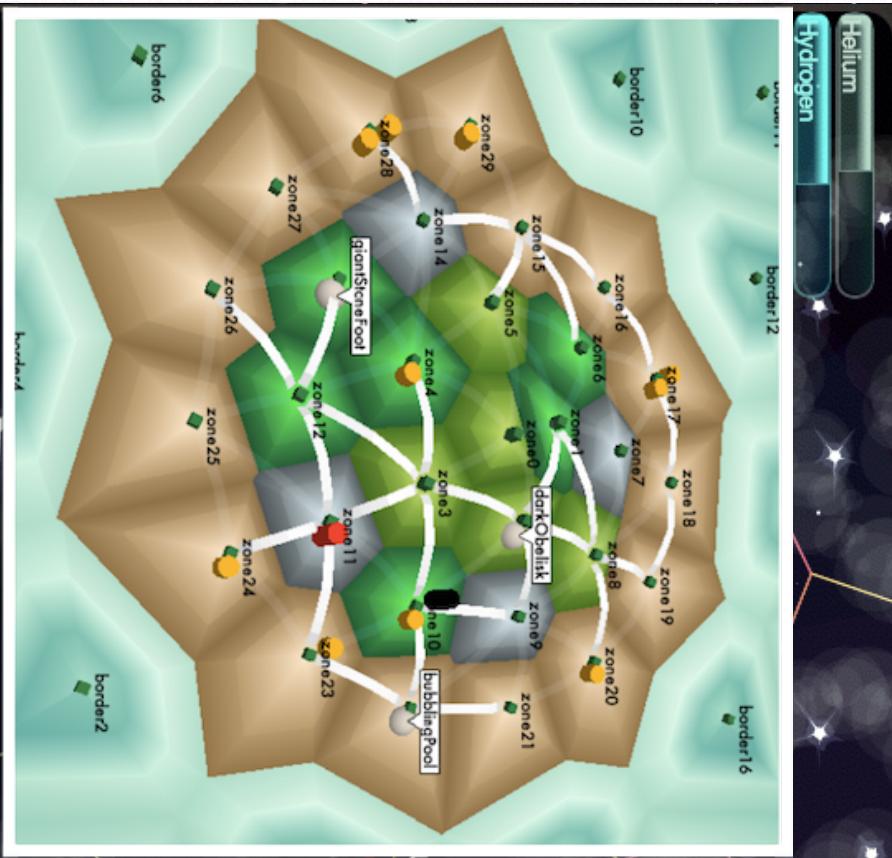
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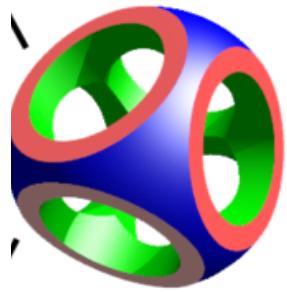
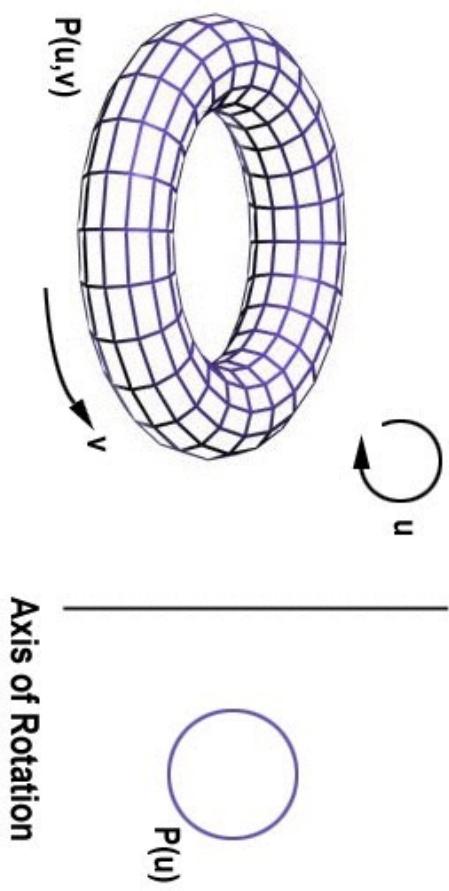
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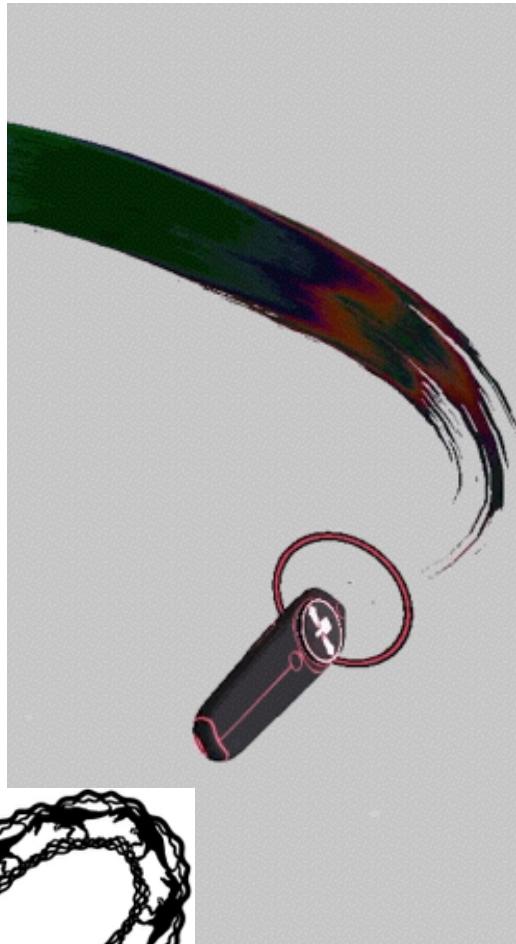
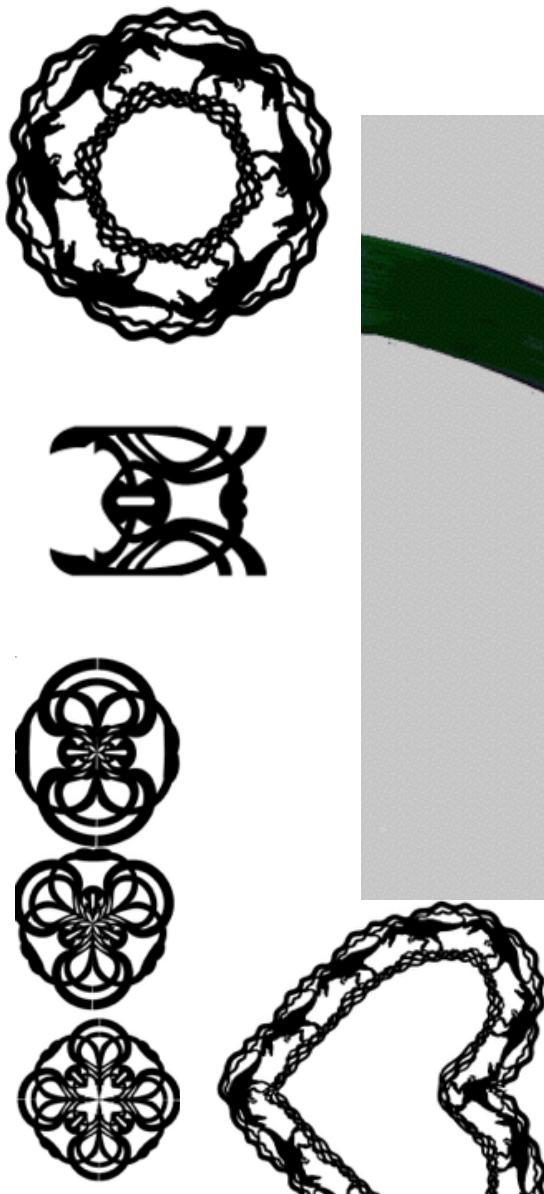
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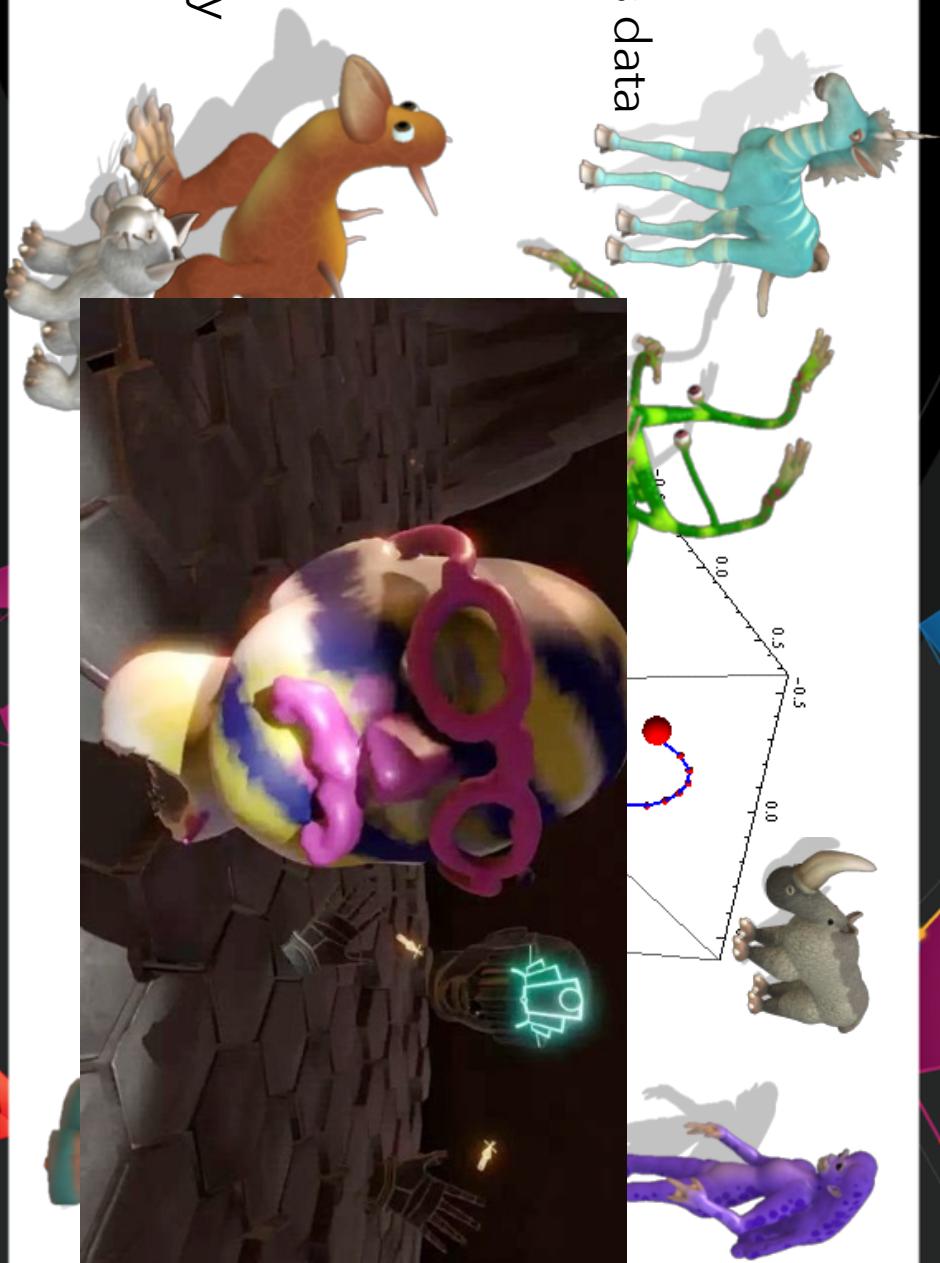
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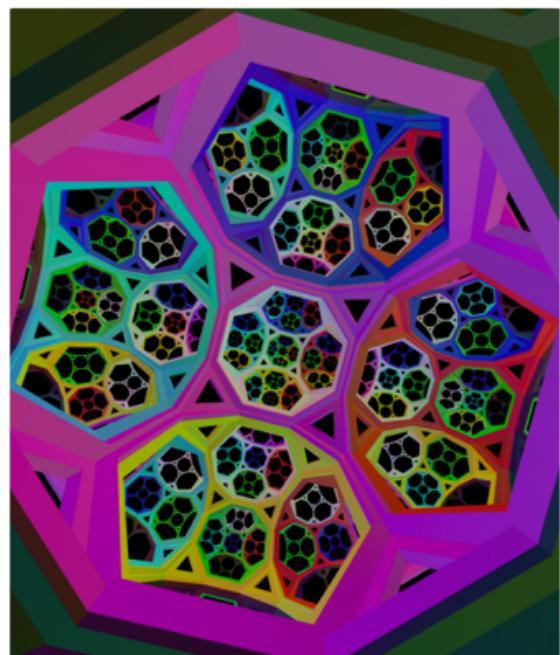
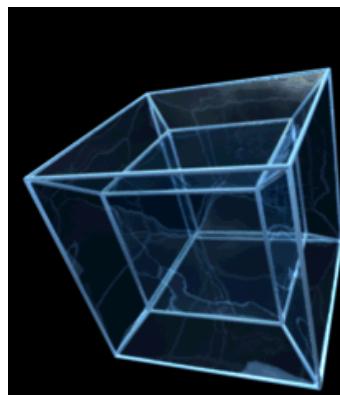
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Interpretive

- Start with some input
- Run an algorithm to process data into some other data
- Examples:
- Fractals, mathematical models of impossible shapes
- (Hypernom, Miegakure)
- **low control, high weirdness,
not suitable for most games**



For more info:

<http://marctenbosch.com/news/category/miegakure/>
<http://elevr.com/hypernom/> (github and arxiv paper)

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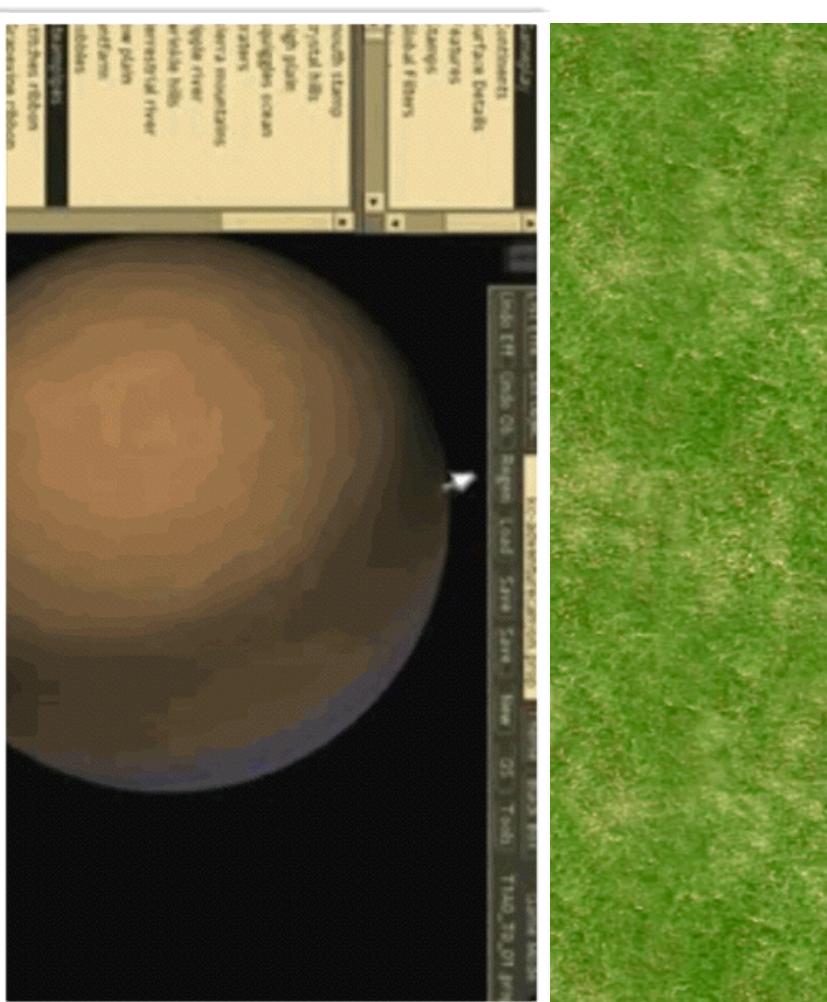
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Simulations

- Particle trails
- simulate particle path responding to forces
- draw directly
- OR record path and use for extrusions or distributions
(photoshop brushes)



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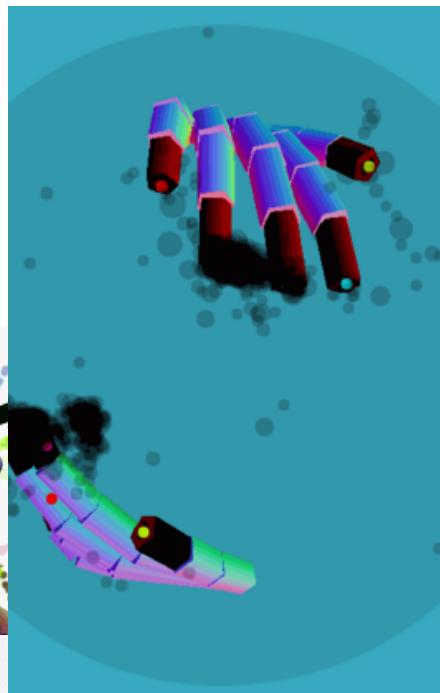
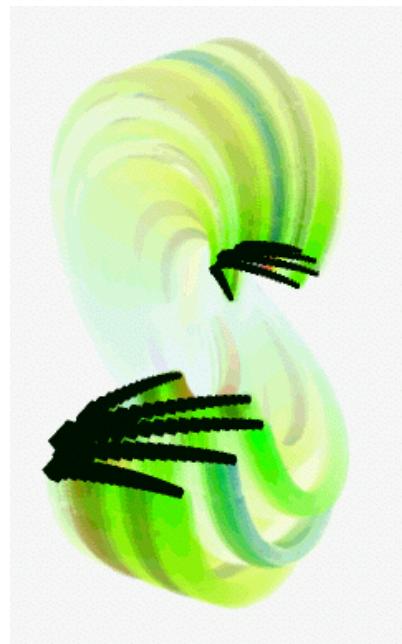
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Simulations

- Particle trails
- Goes GREAT with user input
(Leapmotion, Kinect)



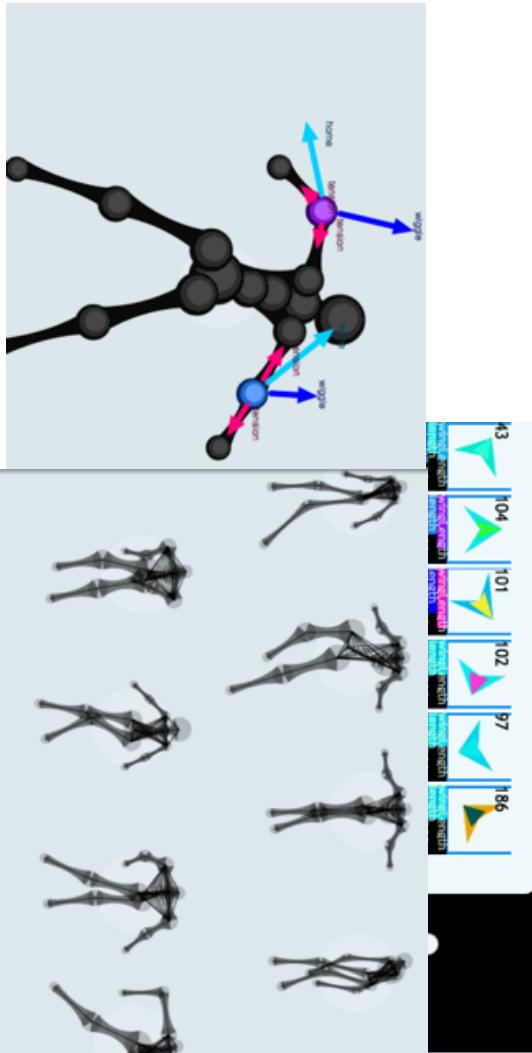
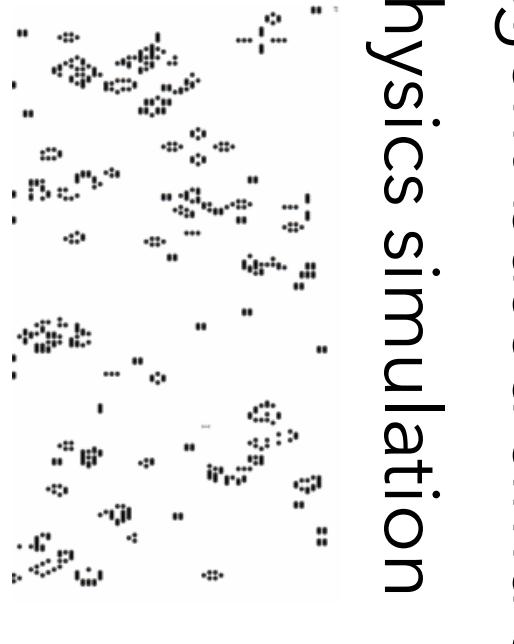
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Simulations

- Cellular automata
- Agent-based simulations
- Physics simulation





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Subtractive methods

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Saving seeds

- Seeded random numbers
- Same seed? Same random generation! (make sure nothing is framerate or input dependent!)
- Whitelist a catalog of **known good** content
 - It's faster to verify questionable content than to build a testing function



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Generate and test

- If you can write an algorithm to judge "quality"...
- Throwaway vs ranking/prioritization
- Test for brokenness/connectivity
- Beware of false functions
 - The "fun equation"

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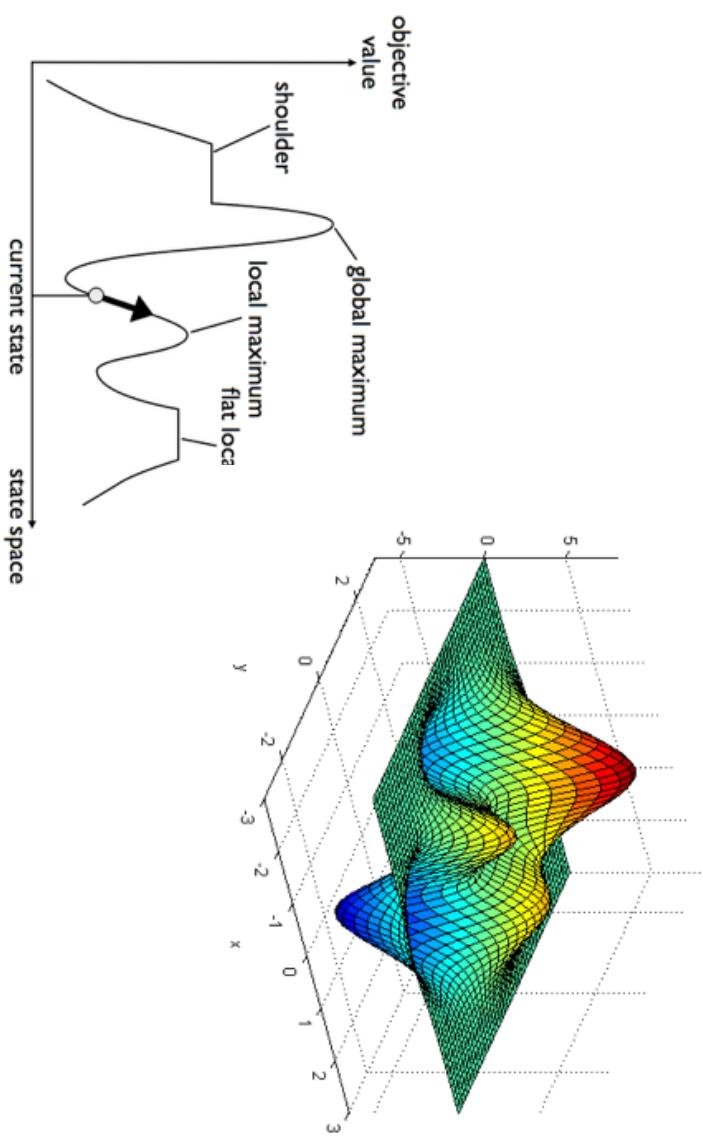
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Computationally exploring the possibility space

- Also called "search"
- Brute force search
- Hill-climbing
- Genetic algorithms
- Works best with parametric



Constraint-solving

You can describe a possibility space and constraints, just find the valid parameters.

- I_K-solving
- Answer set solving
- Potassco Clingo
- Brute force!



```
// For each male and female actor, make them in love with 0 or 1 member of the opposite
staticProgram.add(" { loves(A, B) :- male(B) } 1 :- female(A), actor(A).");
staticProgram.add(" { loves(A, B) : female(B) } 1 :- male(A), actor(A).");

staticProgram.add("requiredLove(A, B) :- loves(A, B), loves(B, A), A < B.");
staticProgram.add(":- not 1 { requiredLove(A, B) : person(A) :person(B) } 3.");
```

```
// jealous rage
staticProgram.add("jealousRage(A, C) :- loves(A, B), loves(B, C), A != C.");
```

DO. NOT. WRITE. YOUR. OWN.

if a member of your team starts doing this, STOP THEM
(brute force is ok. just pay attention to exponential growth)



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Congratulations, you've made a generator
with a possibility space of good artifacts
and good expressive range

What now?

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Part 2: Making use of generativity

So you have 18,446,744,073,709,551,616 planets...



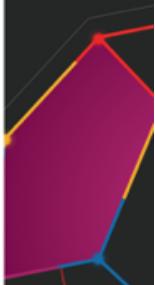
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10,000 bowls of oatmeal

- You can generate many... things
- They are all mathematically unique
- But they aren't **perceived** as unique
- Is this a problem?
- did you say the Really Big Number? In your marketing? Because it got you a lot of media coverage? Then its a problem. **Never listen to the Really Big Number**

For more info:

Michael Cook, "Alien Languages: How We Talk About
Procedural Generation"



Different kinds of generative content

- Background
 - In-fill (don't be empty)

- Perceptual uniqueness

- Characterful

(test: would you write fanfic for this generated item?)



Different kinds of generative content

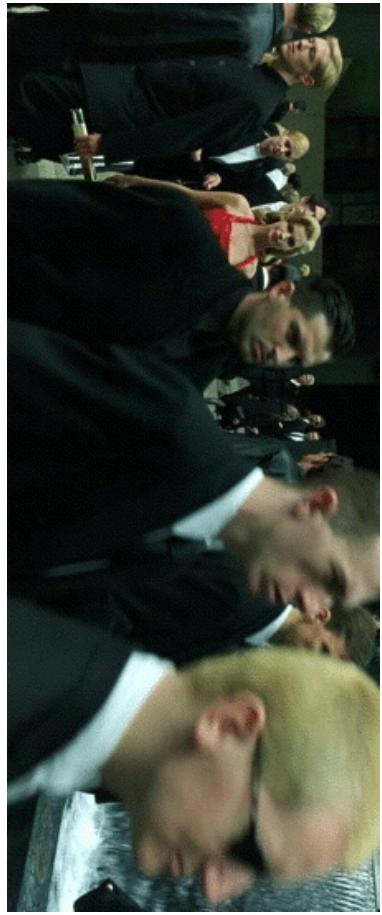
- Background
 - In-fill (don't be empty)

- Perceptual differentiation

- Perceptual uniqueness

- Characterful

(test: would you write fanfic for this generated item?)



Ownership: MSG for PCC

<https://dfstories.com/oilfurnace/>

- Allow users to name content
- Showing off content with their name attached, to a large audience (the "victorian explorers club" model, DIY anti-colonialist reading here)

Although there are around seventy casualties, not all is lost.
While the beast finishes off the livestock above ground...

FIVE DWARVES ARE ALIVE,
GATHERED IN THE DINING HALL

- Let players take credit for your generativity: creators, curators, retellers



Review

- Allow users to claim ownership
 - Tiles
 - Grammars
- Beware of 10,000 bowls of oatmeal
 - Distribution
- How "unique" is your content?
 - Parametric
 - Interpretive
 - Simulations
- Background
 - Perceptual differentiation
 - Possibility space
 - Expressive range
 - Characterful



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GDC PCG sampler menu

Continuous World Generation in 'No Man's Sky'

Wed 9:30-10:30 W2016

Building Worlds Using Math(s)

Thurs 5:30-6:30 N134

The Sound of 'No Man's Sky'

Fri 10am-11am W3002

Procedural Narrative Generation
Monday 3:50-4:20 Chris Martens, Rogelio Cardona-Rivera, W3016

Math for Game Programmers: Harmonic Functions and Mean-Value
Monday 4:40-5:10 Nicholas Vining, 3002 W

You Look Smashing: Procedural Art Direction of 'We Happy Few'
Whitney Clayton W 2002, **Fri 1:30-2:30**

The Design of Time: Understanding Human Attention and Economies of Engagement
Chelsea Howe 2005 West, **Wed 12pm**

GPU-Based Run-Time Procedural Placement in 'Horizon: Zero Dawn'
Jaap Van Muijden 3005 west, **Wed 5-6**

Technical Artist Bootcamp: Introduction to Proceduralism
Luiz Kruei, 2006 W, **Tuesday 10:00 -11:00**

Using Predictive Text to Generate Lore in 'Caves of Qud'
Jason Grinblat Overlook 3018 W, **Thurs 12:45-1:45** (poster session)

PCG Shotgun: 6 Techniques for Leveraging AI in Content Generation
MANY PEOPLE (incl, Tarn Adams of Dwarf Fortress)
2002 W, **Tuesday 11:20-12:20**

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Thanks!

Ask me anything about PCG during the week

or later on twitter @galaxykate (galaxykate@gmail)

(I normally charge \$150 an hour for this)

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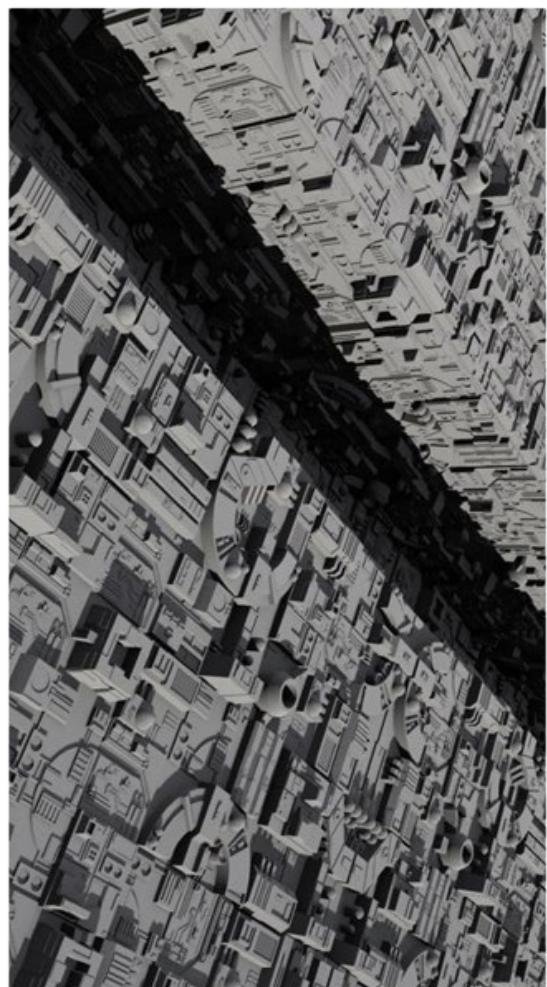
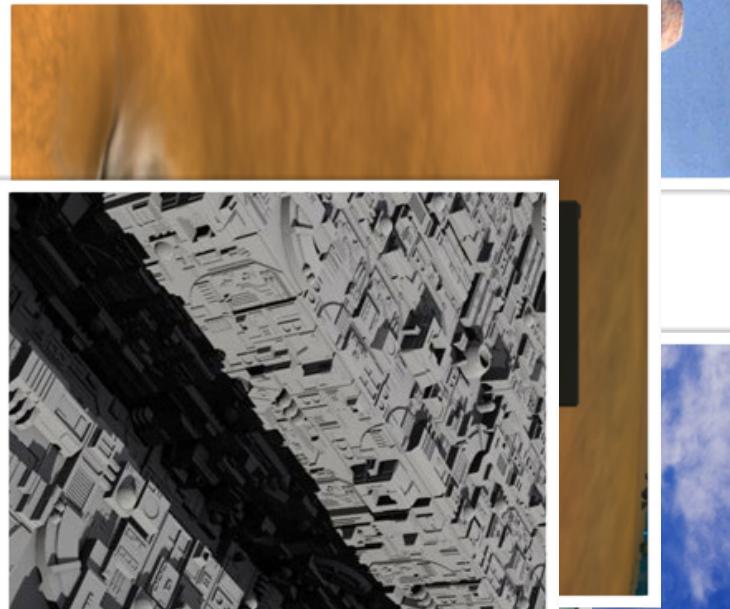
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Distribution

- Barnacling
- Footing
- Greebling



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