Procedural generation

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What is?
THE FRIENDSHIP ALGORITHM
DR. SHELDON COOPER, PH.D.

PLACE PHONE CALL

HOME?

YES

"WOULD YOU LIKE TO SHARE A MEAL?"

HOME?

NO

LEAVE MESSAGE

WAIT FOR CALLBACK

WHAT IS THE RESPONSE?

YES

"DO YOU SHARE A HABITUAL INTEREST?"

BEGIN FRIENDSHIP!

NO

WHAT IS THE RESPONSE?

NO

"DO YOU SHARE A HABITUAL INTEREST?"

DO YOU SHARE A HABITUAL INTEREST?

NO

N = 0

BEGIN FRIENDSHIP!

YES

N = N + 1

CHANGE HABITUAL INTEREST

MAKE HABITUAL INTEREST

DRINK COFFEE

DRINK COFFEE

SAME COFFEE
Where used?
Real-time content generation

Cube world (alpha)

No Man’s Sky
Pre-computing content

Path of Exile

Starbound
Developing assets

Kuldarpunk walkthrough
Why used?
World scale

Galaxy in Elite Dangerous
Replayability
Variation (replayability again?)

Dungeon Defenders
Adjustability

AI Director in Left 4 Dead
Reduce game file size

.kkrieger (97,280 bytes)
Why not used?
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- **Visual uniqueness**
  - Handcrafted content is far more powerful
  - Lack of control over what player experiences
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- **Time and resources to develop**
  - Complexity
  - Real-time generation
  - Edge-cases
  - Level count and sizes
Why not used?

● Visual uniqueness
  ○ Handcrafted content is far more powerful
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● Time and resources to develop
  ○ Complexity
  ○ Real-time generation
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  ○ Level count and sizes

● Some games are not meant to provide replayability
Sampling
Sampling
Uniform sampling
Poisson Disk sampling
Poisson Disk sampling
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Wave Function Collapse
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https://bolddunkley.itch.io/wfc-mixed
Examples

https://github.com/mxgmn/WaveFunctionCollapse/blob/master/images/circuit-1.png
Examples

https://github.com/mxgmn/WaveFunctionCollapse/blob/master/images/knots.png
Examples

https://youtu.be/_ygPtCQsd4I
Grammars
BNF - Backus-Naur form

- Metasyntax notation for context-free grammars
- Many different variants (EBNF & ABNF)
- `<symbol> ::= __expression__`
  - `<character> ::= <letter> | <digit> | <symbol>`

- Idea of this is old (6th and 4th century BCE)

https://en.wikipedia.org/wiki/P%C4%81%E1%B9%87ini
DUNGEON GENERATOR

<Room> := Empty_Room | Mine | Pit | Lava | Ice
<Boss> := Dragon | Giant | Wizard | Hydra
<Treasure> := Gold | Sword | Armor
Graph rewriting

https://www.youtube.com/watch?v=RAtdFKiqs34&ab_channel=naughtyyt
L-systems

- Also known as Lindenmayer systems
- Consist of
  - Variables
  - Constants
  - An axiom
  - Rules
- Results in a string

```plaintext
variables: X F
constants: + - [ ]
start: X
rules: (X -> F+[X]-X-F[-FX]+X), (F -> FF)
angle: 25°
```

https://en.wikipedia.org/wiki/L-system (example 7: fractal fern)
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Usage:

1. Define grammar
2. Calculate string for n-iterations
3. Execute operations based on symbols
4. Render resulting structure
5. Enjoy result *(optional)*
Realistic Procedural Plant Modeling from Multiple View Images (J. Guo, S. Xu, et. al),
Fig. 6
Variations of L-systems

**Stochastic** L-systems:

- More than one production rule for a single variable
- Each rule has a *probability*
- For example:
  - $F(0.5) \rightarrow F$
  - $F(0.5) \rightarrow F [+F][-F]$

- Great for plants, trees
Try this out yourself: shorturl.at/ajknB
Variations of L-systems

Context sensitive L-systems:
- Not just the symbol, also it’s surroundings
  - $b < a > c \rightarrow aa$

Parametric L-systems:
- Each symbol has a parameter list
  - $a(x,y) : x == 0 \rightarrow a(1, y+1)b(2,3)$
Common themes for grammars

Define rules

\[\downarrow\]

Derive a structure

\[\downarrow\]

Render resulting structure

\[\downarrow\]

Enjoy result
It just ended

Finally, inner peace.
Interesting stuff to check out

- [https://youtu.be/TgbuWfGeG2o](https://youtu.be/TgbuWfGeG2o) (Extra Credits, nice summary)
- [https://youtu.be/TlLIOgWYVpI](https://youtu.be/TlLIOgWYVpI) (Roguelike map generation, a lot of methods)
- [https://youtu.be/2SuvO4Gi7uY](https://youtu.be/2SuvO4Gi7uY) (Wave Function Collapse explanation and demo in 3D)
References

- L-systems:
  - [https://en.wikipedia.org/wiki/L-system](https://en.wikipedia.org/wiki/L-system)
- [https://josauder.github.io/procedural_city_generation/](https://josauder.github.io/procedural_city_generation/)
- [https://en.wikipedia.org/wiki/Graph_rewriting](https://en.wikipedia.org/wiki/Graph_rewriting)