COMP250 Artificial Intelligence

8: Procedural Content Generation

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What is PCG?

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- **Procedural**: by computer program or algorithm, with little or no direct input from designer or user
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Types of PCG

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  - Tool for developers

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- Randomness in PCG is generally **constrained** to produce desired content
- Shuffling a deck of cards for a game of Solitaire is **not** PCG!

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Why PCG?

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- Allow game mechanics based on unseen content

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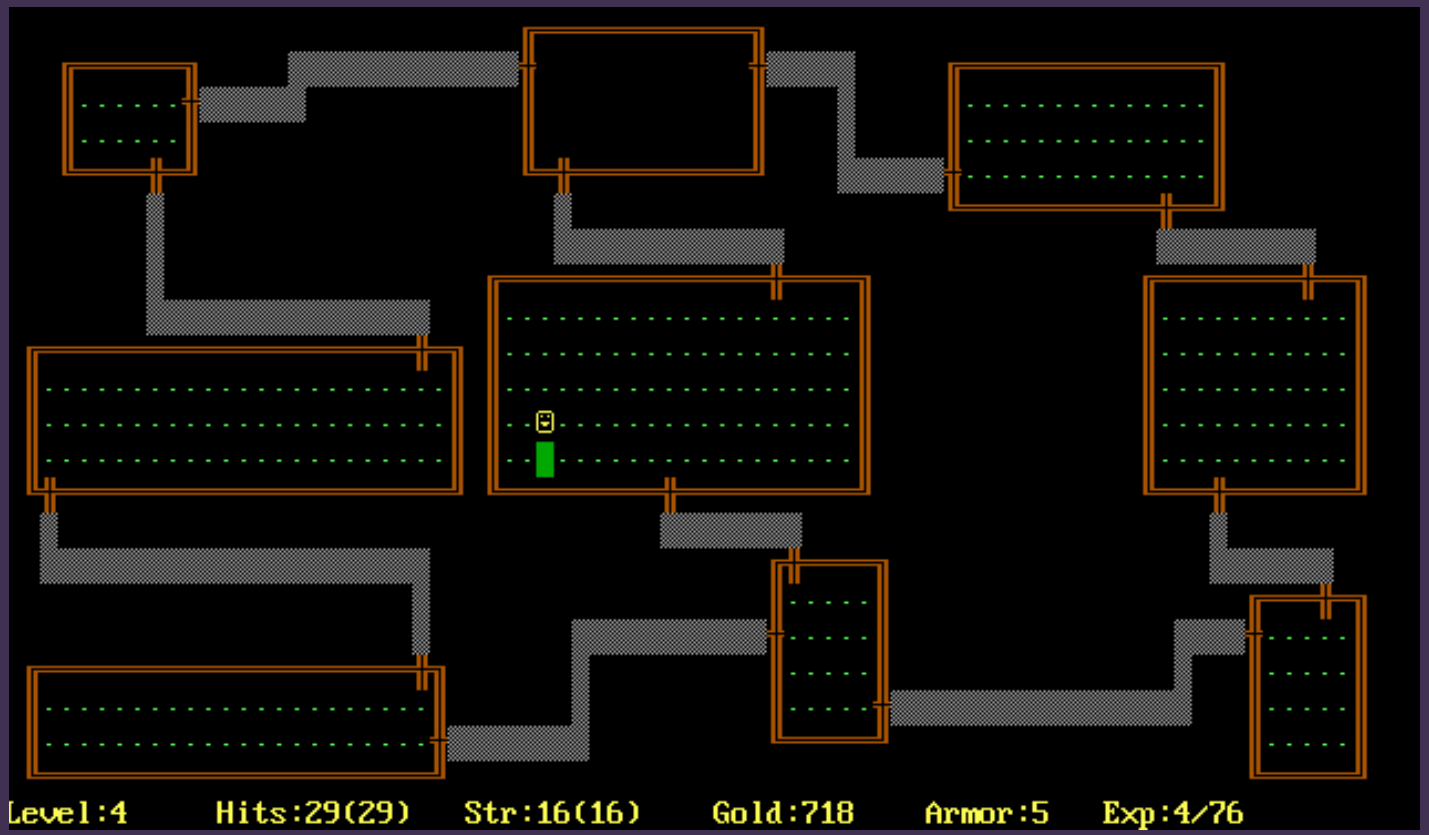
A brief history of PCG

Dungeons & Dragons (1974)

Rogue (1980)



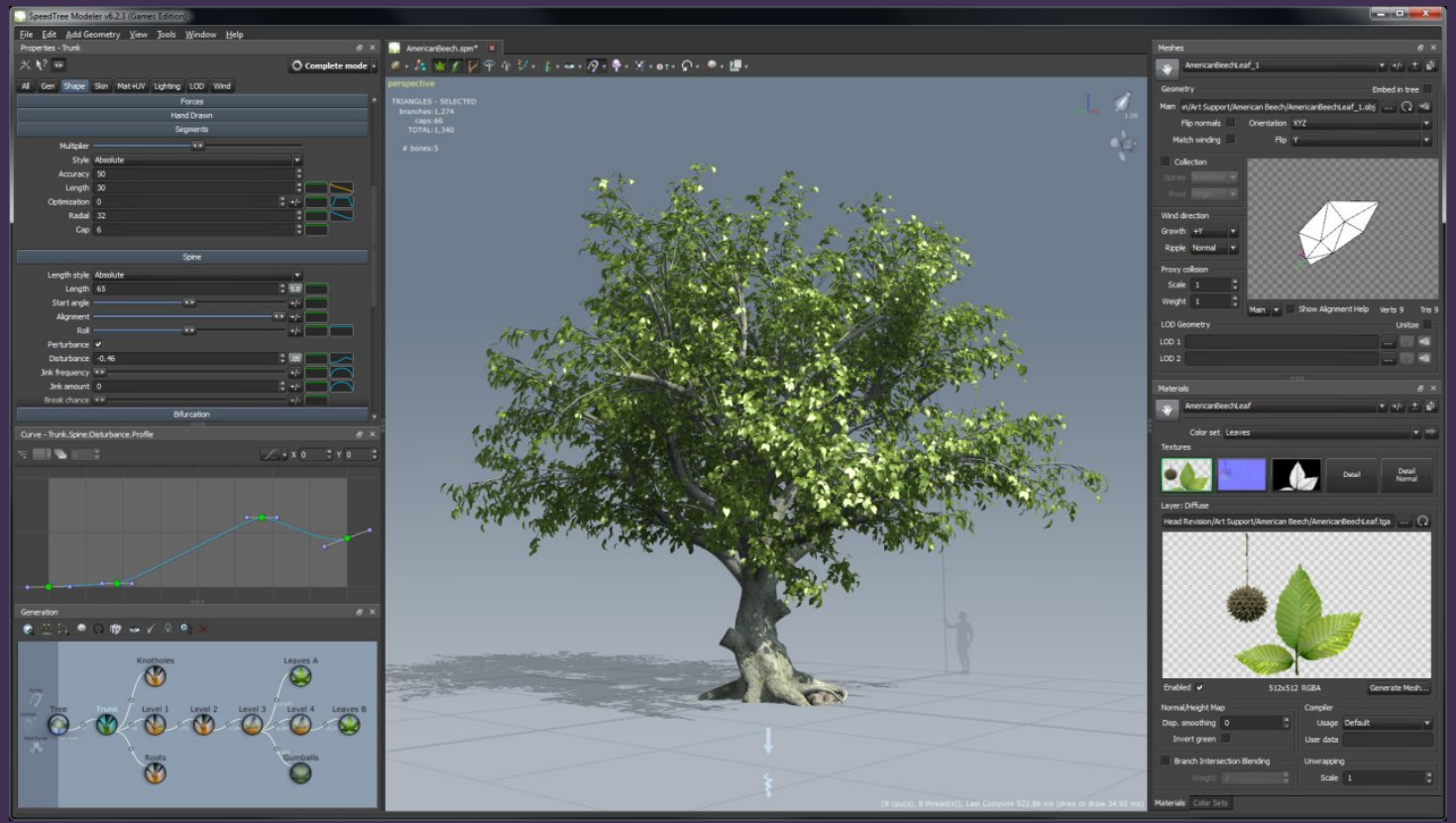
Elite (1984)

Sid Meier's Civilization (1991)

Frontier: Elite II (1993)

The Elder Scrolls II: Daggerfall (1996)

SpeedTree (2002)



.kkrieger (2004)

Dwarf Fortress (2006)

Spelunky (2008)

Spore (2008)

Left 4 Dead (2008)

Borderlands (2009)

Minecraft (2011)

The Binding of Isaac (2011)

Ultima Ratio Regum (2012)

To That Sect (2013)

Elite: Dangerous (2014)

No Man's Sky (2016)

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The role of PCG in games

Lessons from No Man's Sky

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- If you overscope, pray that you don't have to cut any features that you announced on stage at E3...
- PCG is not a substitute for gameplay
- PCG is not magic — it doesn't (by itself) let an indie-sized team produce a AAA game
- When talking about scale and PCG, it's easy to set unrealistic expectations

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- They could have said "a near infinite number of planets"
- They could easily have made it "over 340 undecillion" planets ($2^{128} =$ 340 282 366 920 938 463 463 374 607 431 768 211 456)

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- There are

$$52! = 80\,658\,175\,170\,943\,878\,571\,660\,636\,856\,403\,766$$
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  ways of shuffling a deck of playing cards
- When you shuffle a deck, it is almost certain that **no deck of cards in human history** has ever existed in that order
- But how **interesting** is that particular shuffled deck?
- How **different** from another shuffled deck?

Uniqueness

"I can easily generate 10,000 bowls of plain oatmeal, with each oat being in a different position and different orientation, and *mathematically speaking* they will all be completely unique. But the user will likely just see *a lot of oatmeal*."
— Kate Compton

http://galaxykate0.tumblr.com/post/139774965871/so-you-want-to-build-a-generator

Uniqueness

" `Every Planet Unique' might mean that each planet has a complex sci-fi backstory rich enough to fill a two-part Star Trek episode. It might also mean that, mathematically speaking, there's a rock somewhere on the planet that doesn't look like any other rock in the universe."
— Michael Cook

http://www.gamesbyangelina.org/2016/08/procedurallanguage/

Lessons from Spelunky

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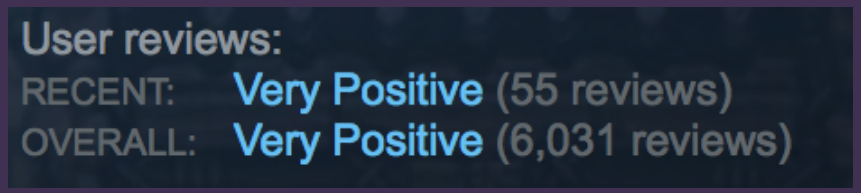

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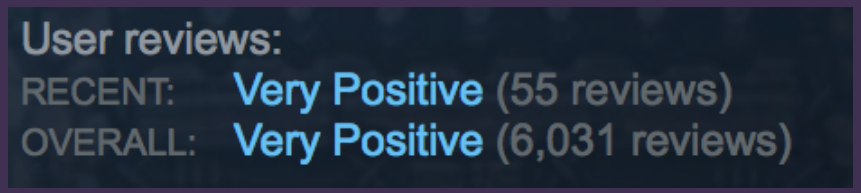

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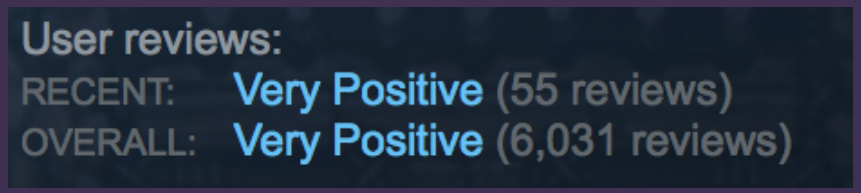

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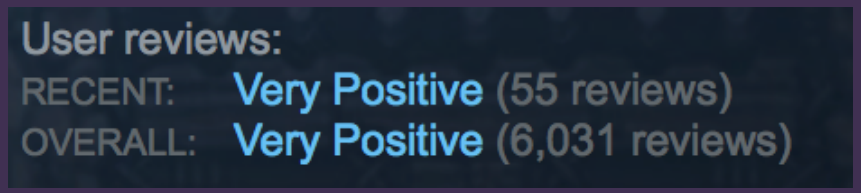

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- PCG can **enable** new (discovery-based) game mechanics
- No need to dazzle the audience with big numbers

Curation

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- Smart PCG should not **merely generate**: it should also **evaluate**

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- In a game with **procedurally-generated content**, who (or what) is the author? Is it the developer, the player, the system, or all three?

Authorship

"(We) create the systems (including some fixed content), and the choices made at that stage are influenced by our preferences, worldviews, talents and flaws, and then the system creates the content. The players are exposed to the content and can manipulate it using the tools we (and others) create for them. How they use the tools is up to them, and how the content reacts is up to our systems."
— Tarn Adams

http://www.nullpointer.co.uk/content/interview-dwarf-fortress/

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The future of PCG

"You are playing an "open world" game, something like Grand Theft Auto or Skyrim. Instead of going straight to the next mission objective in the city you are in, you decide to drive (or ride) five hours in some randomly chosen direction. The game makes up the landscape as you go along, and you end up in a new city that no human player has visited before. In this city, you can enter any house (though you might have to pick a few locks), talk to everyone you meet, and involve yourself in a completely new set of intrigues and carry out new missions. If you would have gone in a different direction, you would have reached a different city with different architecture, different people and different missions. Or a huge forest with realistic animals and eremites, or a secret research lab, or whatever the game engine comes up with."
— Julian Togelius

http://togelius.blogspot.co.uk/2015/10/what-if-videogames-had-actual-ai.html

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Whole game generation

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- Generate **entire games** from scratch, possibly using ideas or themes provided by the user
- **Democratise** game design — create games in **collaboration** with a non-skilled user
  - (i.e. make it so that you don't need to do a degree to learn how to make games...)

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- Beyond generating **content** to generating **ideas**

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- **Higher** scores are **better**
- We are exploring a **fitness landscape**

Running example

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- Want to generate a map where there is a path from start to goal, and that path is as long as possible
- Fitness measure:

$$f(x) = \begin{cases} \text{path length} & \text{if a path exists} \\ 0 & \text{otherwise} \end{cases}$$

Hillclimbing (a.k.a. gradient ascent)

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- Repeat

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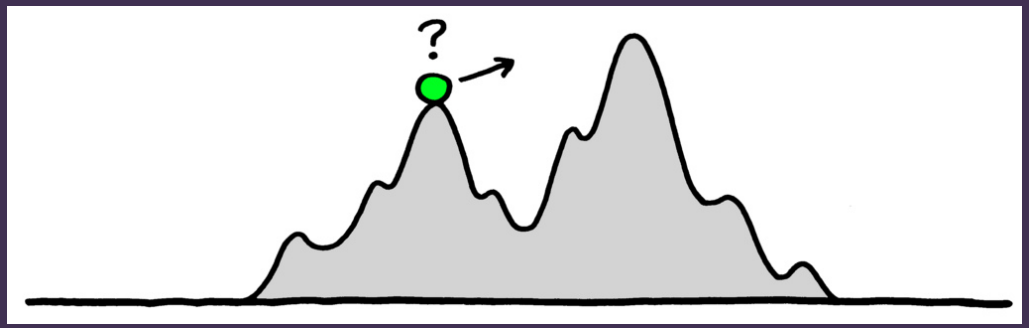

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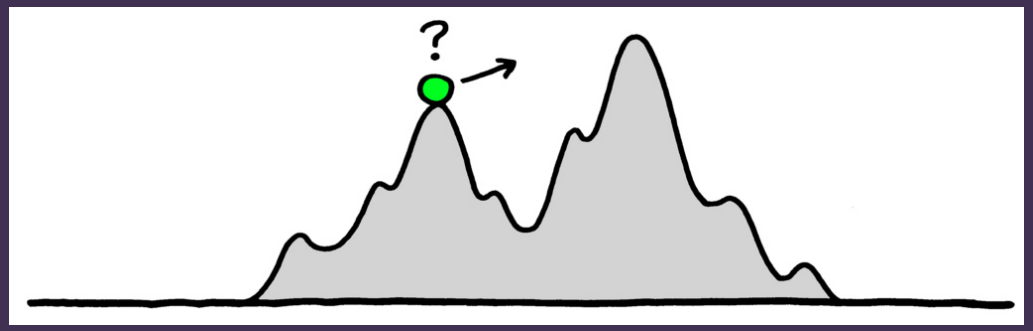

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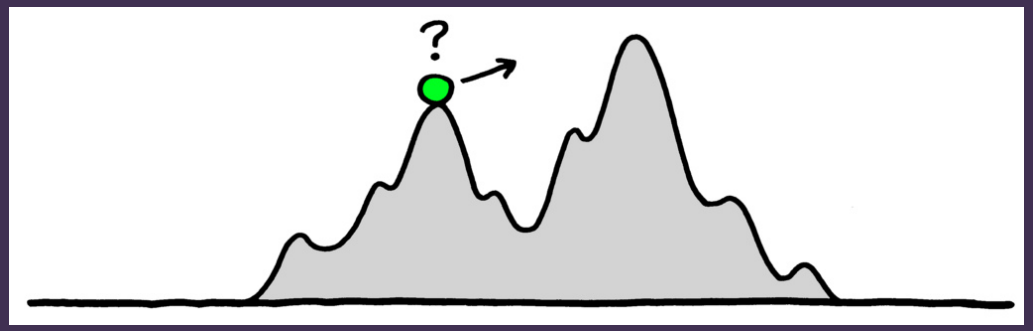

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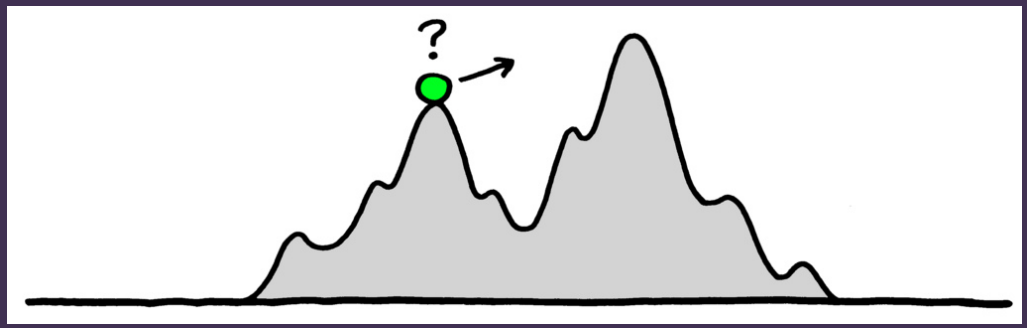

- Hillclimbing tends to get stuck at a **local optimum**
- This may be much worse than the **global optimum**
- Have to let the solution get worse before it gets better — hillclimbing doesn't allow this

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- Simulated annealing
  - Probability of allowing the search to keep a worse solution
  - This probability decreases as search progresses

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Evolutionary algorithms

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- Generation 0: choose N solutions at random
- Generation $i + 1$: choose N new solutions based on the **fittest** individuals from generation i

Selecting the fittest

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  - Randomly choose t individuals
  - Select the fittest out of those t

Mutation

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- Make a small change to it

Mutation

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- Make a small change to it
- Add the changed individual to the new population

Crossover

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Elitism

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- Take the top x% of generation i, and pass it straight through to generation $i + 1$