



FALMOUTH
UNIVERSITY

COMP250 Artificial Intelligence 8: Procedural Content Generation

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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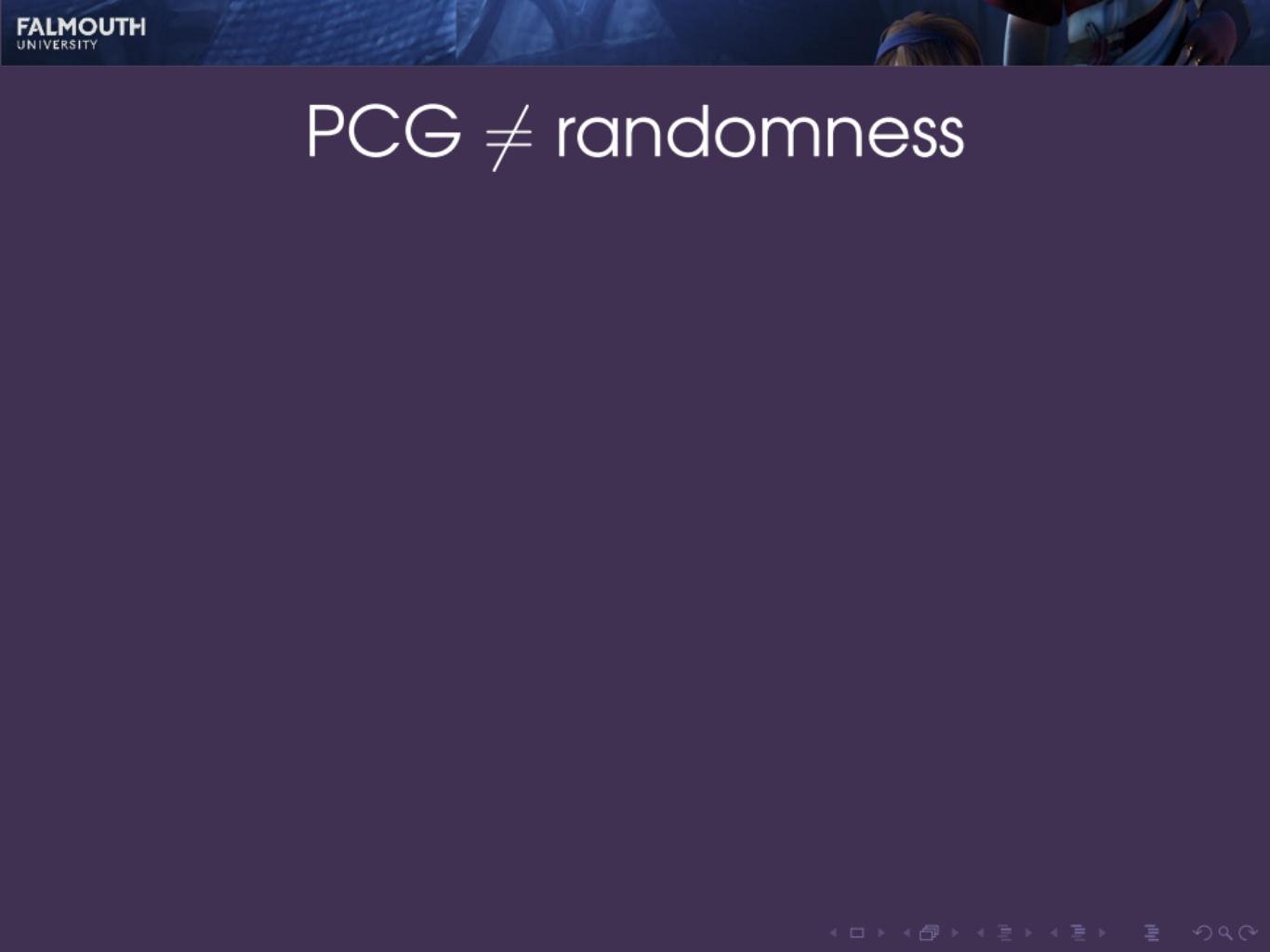
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 - ▶ Tool for developers



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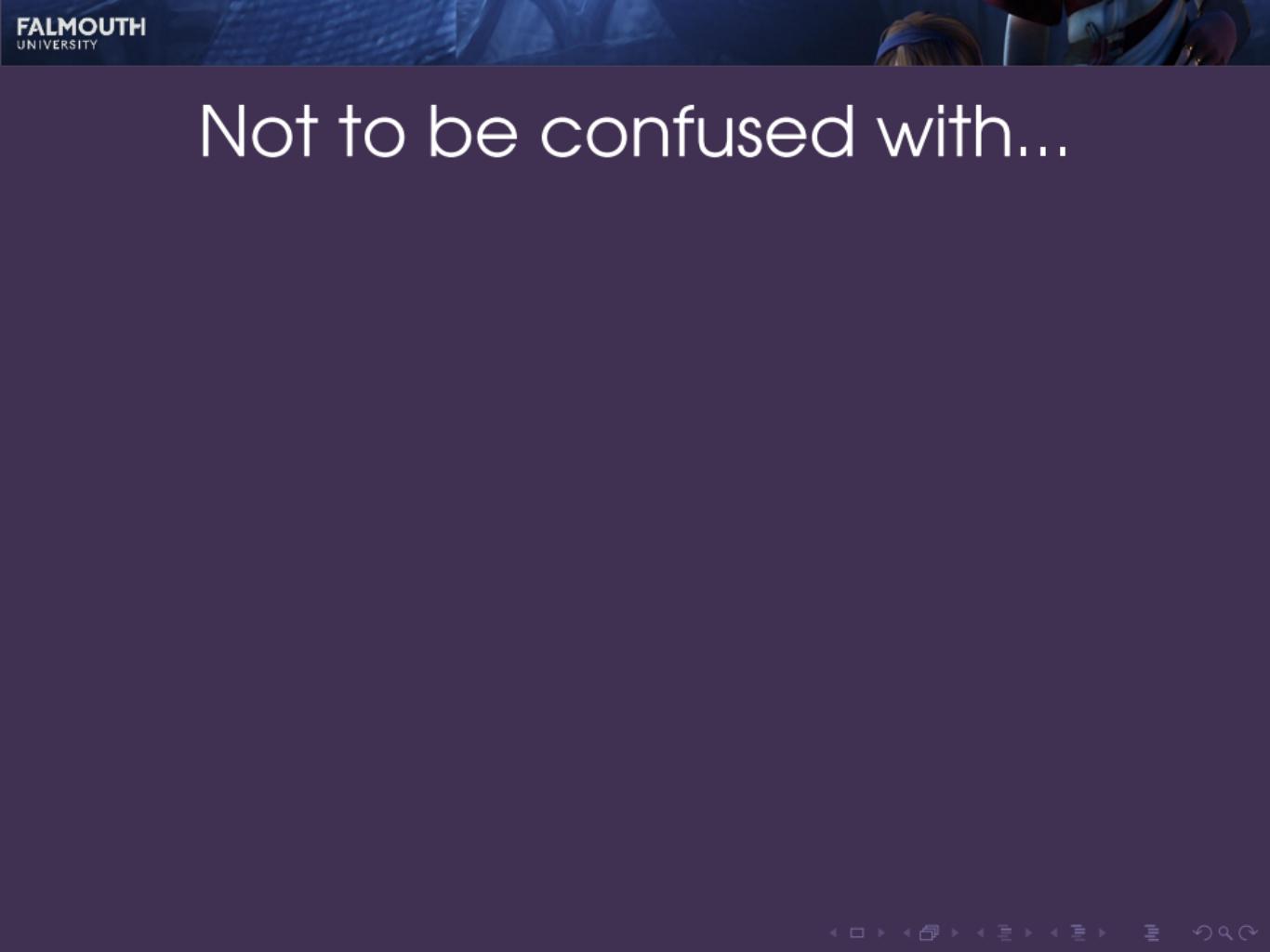
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- ▶ Can have PCG without randomness, e.g. based on fractals or simulations
- ▶ Randomness in PCG is generally **constrained** to produce desired content
- ▶ Shuffling a deck of cards for a game of Solitaire is **not** PCG!



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- ▶ Here: “procedural” = “algorithmic”

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- ▶ Allow game mechanics based on unseen content

A brief history of PCG



Dungeons & Dragons (1974)



Rogue (1980)



Elite (1984)



Sid Meier's Civilization (1991)



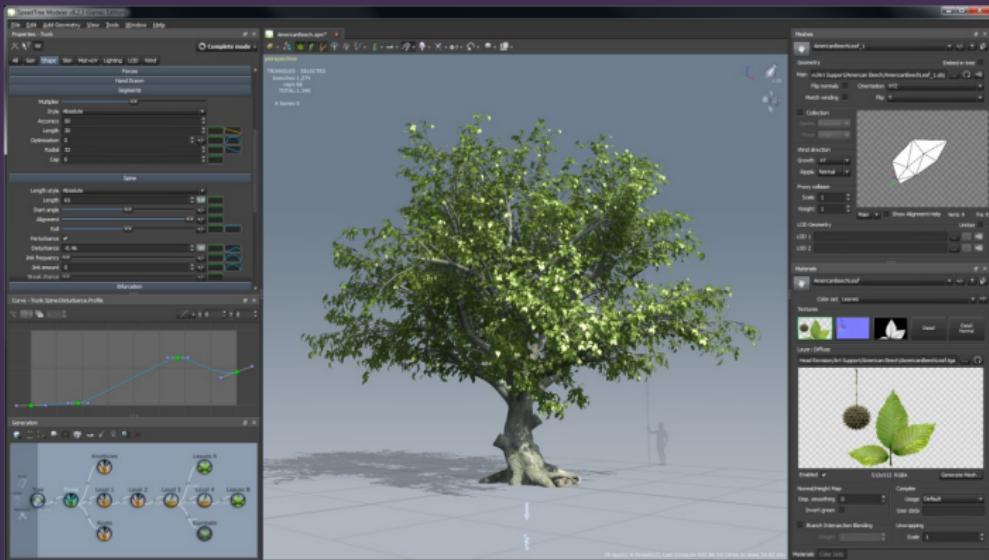
Frontier: Elite II (1993)



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)



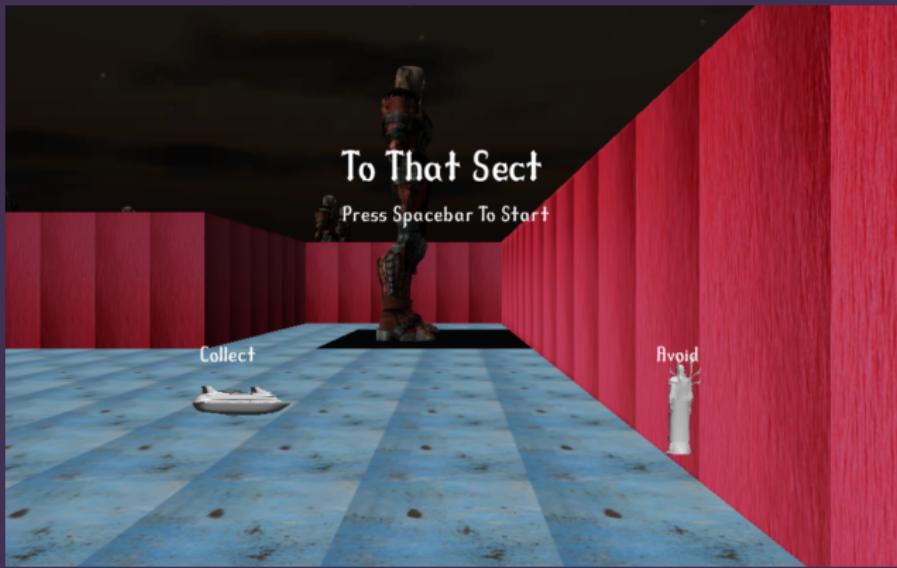
The Binding of Isaac (2011)



Ultima Ratio Regum (2012)



To That Sect (2013)



Elite: Dangerous (2014)



No Man's Sky (2016)



The role of PCG in games



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RECENT: Overwhelmingly Negative (16,433 reviews)

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- ▶ 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 ($2^{128} = 340\,282\,366\,920\,938\,463\,463\,374\,607\,431\,768\,211\,456$)



Even bigger numbers

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- There are

$52! = 80\,658\,175\,170\,943\,878\,571\,660\,636\,856\,403\,766$
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- ▶ But how **interesting** is that particular shuffled deck?

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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/>

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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 **emergent narrative**, who is the author? Is it the developer, the player, or both?
- ▶ 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/>

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

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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 **mere generation**
- ▶ Beyond generating **content** to generating **ideas**

Optimisation



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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:

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

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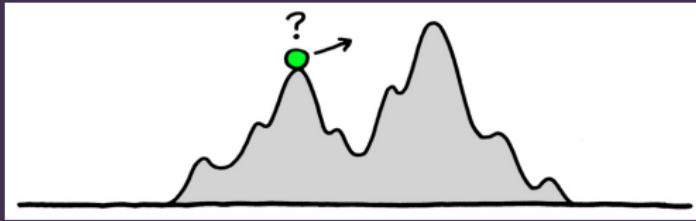
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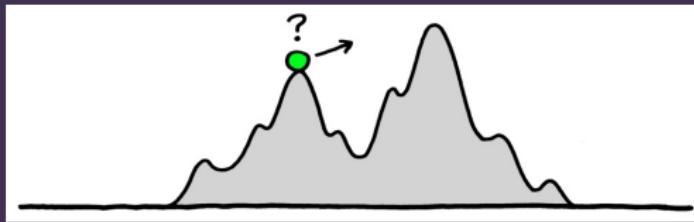
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- ▶ Repeat

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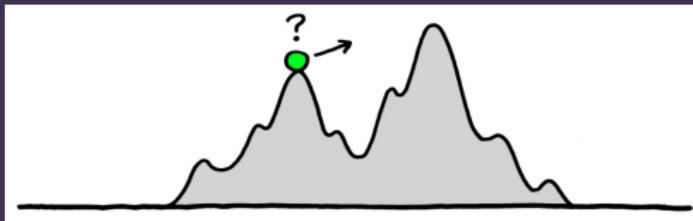


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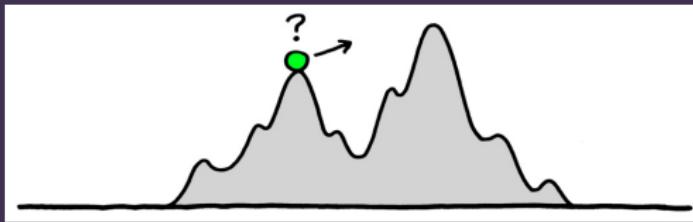
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Local optima



- ▶ 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

Escaping the local optimum

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 - ▶ This probability decreases as search progresses

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

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- ▶ Simple method: **tournament selection**
 - ▶ Randomly choose t individuals
 - ▶ Select the fittest out of those t

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- ▶ Add the changed individual to the new population

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Elitism

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