



GAM310 Theory 3: Games as Culture

## 2: Procedural Content Generation

# What is PCG?



# What is procedural content generation (PCG)?

- ▶ **Generation:** creating stuff

# What is procedural content generation (PCG)?

- ▶ **Content:** levels, maps, art, animations, stories, items, quests, music, weapons, vehicles, characters, ...
- ▶ **Generation:** creating stuff

# What is procedural content generation (PCG)?

- ▶ **Procedural:** by computer program or algorithm, with little or no direct input from designer or user
- ▶ **Content:** levels, maps, art, animations, stories, items, quests, music, weapons, vehicles, characters, ...
- ▶ **Generation:** creating stuff

# Types of PCG

# Types of PCG

- ▶ **Online**

# Types of PCG

- ▶ **Online**
  - ▶ Generate content at run-time

# Types of PCG

- ▶ **Online**

- ▶ Generate content at run-time
- ▶ Part of the game

# Types of PCG

- ▶ **Online**

- ▶ Generate content at run-time
- ▶ Part of the game

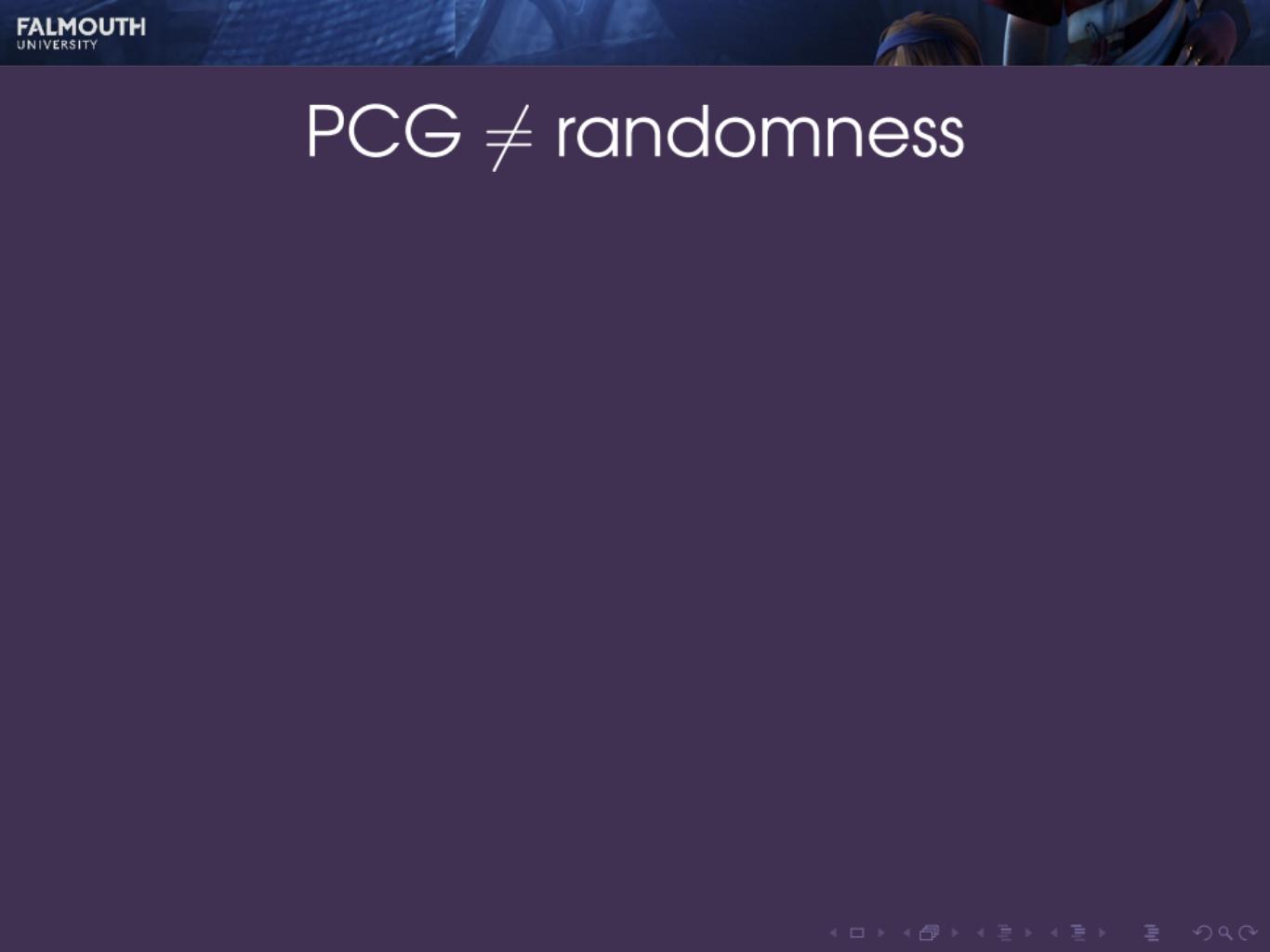
- ▶ **Offline**

# Types of PCG

- ▶ **Online**
  - ▶ Generate content at run-time
  - ▶ Part of the game
- ▶ **Offline**
  - ▶ Generate content at design-time

# Types of PCG

- ▶ **Online**
  - ▶ Generate content at run-time
  - ▶ Part of the game
- ▶ **Offline**
  - ▶ Generate content at design-time
  - ▶ Tool for developers



PCG  $\neq$  randomness

# PCG $\neq$ randomness

- ▶ Many PCG systems use random numbers, but randomness in itself is not PCG

# PCG $\neq$ randomness

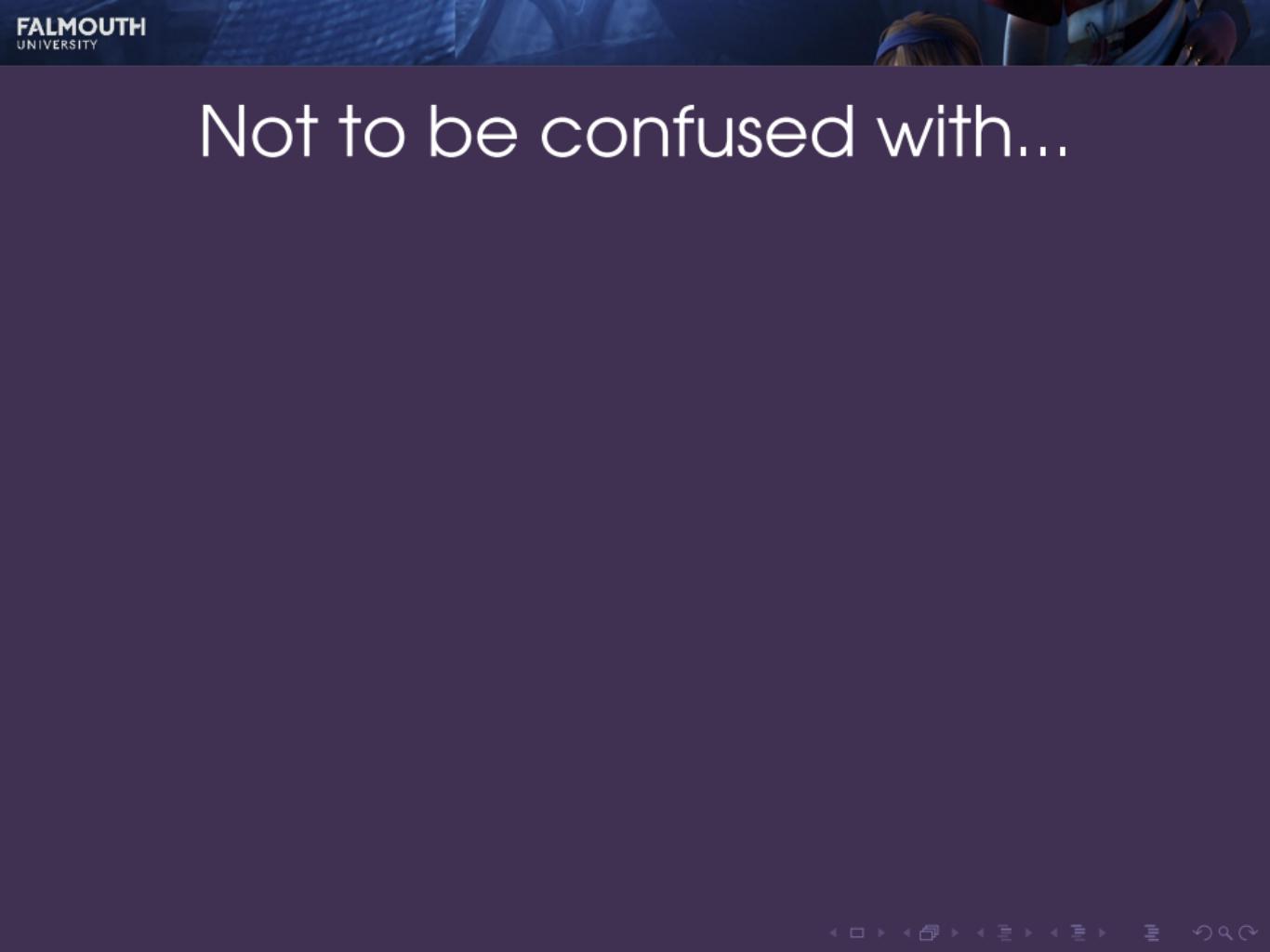
- ▶ Many PCG systems use random numbers, but randomness in itself is not PCG
- ▶ Can have PCG without randomness, e.g. based on fractals or simulations

# PCG $\neq$ randomness

- ▶ Many PCG systems use random numbers, but randomness in itself is not PCG
- ▶ Can have PCG without randomness, e.g. based on fractals or simulations
- ▶ Randomness in PCG is generally **constrained** to produce desired content

# PCG ≠ randomness

- ▶ Many PCG systems use random numbers, but randomness in itself is not PCG
- ▶ 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!



# Not to be confused with...

# Not to be confused with...

- ▶ **Procedural Rhetoric / Procedurality** (Bogost)

# Not to be confused with...

- ▶ **Procedural Rhetoric / Procedurality** (Bogost)
- ▶ “the art of persuasion through rule-based representations and interactions, rather than the spoken word, writing, images, or moving pictures”

# Not to be confused with...

- ▶ **Procedural Rhetoric / Procedurality** (Bogost)
- ▶ “the art of persuasion through rule-based representations and interactions, rather than the spoken word, writing, images, or moving pictures”
- ▶ There: “procedural” = “rule-based”

# Not to be confused with...

- ▶ **Procedural Rhetoric / Procedurality** (Bogost)
- ▶ “the art of persuasion through rule-based representations and interactions, rather than the spoken word, writing, images, or moving pictures”
- ▶ There: “procedural” = “rule-based”
- ▶ Here: “procedural” = “algorithmic”

# Why PCG?

# Why PCG?

- ▶ More content for less development effort

# Why PCG?

- ▶ More content for less development effort
- ▶ Decrease development costs

# Why PCG?

- ▶ More content for less development effort
- ▶ Decrease development costs
- ▶ Increase replayability

# Why PCG?

- ▶ More content for less development effort
- ▶ Decrease development costs
- ▶ Increase replayability
- ▶ Decrease storage requirements

# Why PCG?

- ▶ More content for less development effort
- ▶ Decrease development costs
- ▶ Increase replayability
- ▶ Decrease storage requirements
- ▶ Allow game mechanics based on unseen content

# PCG approaches

# PCG approaches

- ▶ Combining hand-authored blocks

# PCG approaches

- ▶ Combining hand-authored blocks
- ▶ Noise functions

# PCG approaches

- ▶ Combining hand-authored blocks
- ▶ Noise functions
- ▶ Fractals

# PCG approaches

- ▶ Combining hand-authored blocks
- ▶ Noise functions
- ▶ Fractals
- ▶ L-Systems

# PCG approaches

- ▶ Combining hand-authored blocks
- ▶ Noise functions
- ▶ Fractals
- ▶ L-Systems
- ▶ Simulation

# PCG approaches

- ▶ Combining hand-authored blocks
- ▶ Noise functions
- ▶ Fractals
- ▶ L-Systems
- ▶ Simulation
- ▶ Evolutionary algorithms

# PCG approaches

- ▶ Combining hand-authored blocks
- ▶ Noise functions
- ▶ Fractals
- ▶ L-Systems
- ▶ Simulation
- ▶ Evolutionary algorithms
- ▶ Constraint solving

# PCG approaches

- ▶ Combining hand-authored blocks
- ▶ Noise functions
- ▶ Fractals
- ▶ L-Systems
- ▶ Simulation
- ▶ Evolutionary algorithms
- ▶ Constraint solving
- ▶ Machine learning

# PCG approaches

- ▶ Combining hand-authored blocks
- ▶ Noise functions
- ▶ Fractals
- ▶ L-Systems
- ▶ Simulation
- ▶ Evolutionary algorithms
- ▶ Constraint solving
- ▶ Machine learning
- ▶ ...

# Further reading

Noor Shaker, Julian Togelius and Mark J. Nelson.

*Procedural Content Generation in Games: A textbook and an overview of current research.* Springer, 2016.

Available online: <http://pcgbook.com>

# A brief history of PCG



# Dungeons & Dragons (1974)



## Rogue (1980)



# Elite (1984)



# Sid Meier's Civilization (1991)



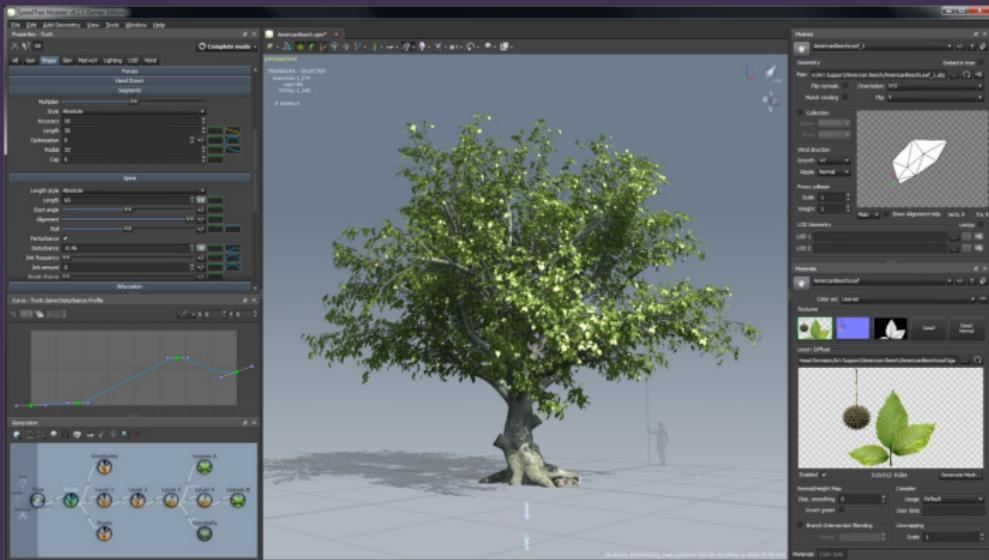
# Frontier: Elite II (1993)



# 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)



# Road Not Taken (2014)



# PROCJAM (2014–present)



# No Man's Sky (2016)



# The role of PCG in games



# Lessons from No Man's Sky

# Lessons from No Man's Sky

## User reviews:

RECENT: Overwhelmingly Negative (16,433 reviews)

OVERALL: Mostly Negative (69,022 reviews)

# Lessons from No Man's Sky

## User reviews:

RECENT: Overwhelmingly Negative (16,433 reviews)

OVERALL: Mostly Negative (69,022 reviews)

- If you overscope, pray that you don't have to cut any features that you announced on stage at E3...

# Lessons from No Man's Sky

## User reviews:

RECENT: Overwhelmingly Negative (16,433 reviews)  
OVERALL: Mostly Negative (69,022 reviews)

- ▶ 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

# Lessons from No Man's Sky

## User reviews:

RECENT: Overwhelmingly Negative (16,433 reviews)  
OVERALL: Mostly Negative (69,022 reviews)

- ▶ 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

# Lessons from No Man's Sky

## User reviews:

RECENT: Overwhelmingly Negative (16,433 reviews)  
OVERALL: Mostly Negative (69,022 reviews)

- ▶ 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

# Big numbers

# Big numbers

- ▶ “Over 18 quintillion planets”

# Big numbers

- ▶ “Over 18 quintillion planets”
- ▶  $2^{64} = 18\,446\,744\,073\,709\,551\,616$

# Big numbers

- ▶ “Over 18 quintillion planets”
- ▶  $2^{64} = 18\,446\,744\,073\,709\,551\,616$
- ▶ What does this number even **mean**?

# Big numbers

- ▶ “Over 18 quintillion planets”
- ▶  $2^{64} = 18\,446\,744\,073\,709\,551\,616$
- ▶ What does this number even **mean?**
- ▶ What it **really** means: “our random number generator uses a 64-bit seed”

# Big numbers

- ▶ “Over 18 quintillion planets”
- ▶  $2^{64} = 18\,446\,744\,073\,709\,551\,616$
- ▶ What does this number even **mean**?
- ▶ What it **really** means: “our random number generator uses a 64-bit seed”
- ▶ They could have said “a near infinite number of planets”

# Big numbers

- ▶ “Over 18 quintillion planets”
- ▶  $2^{64} = 18\,446\,744\,073\,709\,551\,616$
- ▶ What does this number even **mean**?
- ▶ What it **really** means: “our random number generator uses a 64-bit seed”
- ▶ 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

# Even bigger numbers

- There are

$$52! = 80\,658\,175\,170\,943\,878\,571\,660\,636\,856\,403\,766\\ 975\,289\,505\,440\,883\,277\,824\,000\,000\,000\,000$$

ways of shuffling a deck of playing cards

# Even bigger numbers

- ▶ There are

$$52! = 80\,658\,175\,170\,943\,878\,571\,660\,636\,856\,403\,766\\ 975\,289\,505\,440\,883\,277\,824\,000\,000\,000\,000$$

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

# Even bigger numbers

- ▶ There are

$$52! = 80\,658\,175\,170\,943\,878\,571\,660\,636\,856\,403\,766\\ 975\,289\,505\,440\,883\,277\,824\,000\,000\,000\,000$$

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?

# Even bigger numbers

- ▶ There are

$$52! = 80\,658\,175\,170\,943\,878\,571\,660\,636\,856\,403\,766\\ 975\,289\,505\,440\,883\,277\,824\,000\,000\,000\,000$$

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

# Lessons from Spelunky

## User reviews:

RECENT: **Very Positive** (55 reviews)

OVERALL: **Very Positive** (6,031 reviews)

# Lessons from Spelunky

## User reviews:

RECENT: **Very Positive** (55 reviews)

OVERALL: **Very Positive** (6,031 reviews)

- ▶ PCG can complement solid game mechanics

# Lessons from Spelunky

## User reviews:

RECENT: **Very Positive** (55 reviews)

OVERALL: **Very Positive** (6,031 reviews)

- ▶ PCG can complement solid game mechanics
- ▶ PCG can **enable** new (discovery-based) game mechanics

# Lessons from Spelunky

## User reviews:

RECENT: **Very Positive** (55 reviews)

OVERALL: **Very Positive** (6,031 reviews)

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

# Curation

# Curation



# Curation



- ▶ Human creators constantly ask themselves: **is this any good?**

# Curation



- ▶ Human creators constantly ask themselves: **is this any good?**
- ▶ Smart PCG should not **merely generate**: it should also **evaluate**

# Authorship

# Authorship

- ▶ In a game with **emergent narrative**, who is the author? Is it the developer, the player, or both?

# Authorship

- ▶ 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

# Whole game generation

# Whole game generation



# Whole game generation

- ▶ E.g. ANGELINA (Michael Cook)



# Whole game generation



- ▶ E.g. ANGELINA (Michael Cook)
- ▶ Generate **entire games** from scratch, possibly using ideas or themes provided by the user

# Whole game generation



- ▶ E.g. ANGELINA (Michael Cook)
- ▶ 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

# Whole game generation



- ▶ E.g. ANGELINA (Michael Cook)
- ▶ 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...)

# Deep learning

# Deep learning



# Deep learning



- ▶ Artificial neural networks (ANNs)

# Deep learning



- ▶ Artificial neural networks (ANNs)
- ▶ Already used for tournament-level game AI, image classification, language translation, ...

# Deep learning



- ▶ Artificial neural networks (ANNs)
- ▶ Already used for tournament-level game AI, image classification, language translation, ...
- ▶ Generative Adversarial Networks (GANs)

# Computational creativity

# Computational creativity



# Computational creativity



# Computational creativity



- ▶ Open question: can an AI system be **creative**?



# Computational creativity



- ▶ Open question: can an AI system be **creative**?
- ▶ Beyond **mere generation**

# Computational creativity



- ▶ Open question: can an AI system be **creative**?
- ▶ Beyond **mere generation**
- ▶ Beyond generating **content** to generating **ideas**

# AI, ethics and society



# Some ethical issues around AI

# Some ethical issues around AI

- ▶ Bias in, bias out

# Some ethical issues around AI

- ▶ Bias in, bias out
  - ▶ E.g. Google Translate

# Some ethical issues around AI

- ▶ Bias in, bias out
  - ▶ E.g. Google Translate
- ▶ Bias inherited from tech industry

# Some ethical issues around AI

- ▶ Bias in, bias out
  - ▶ E.g. Google Translate
- ▶ Bias inherited from tech industry
  - ▶ E.g. facial recognition struggling with non-Caucasian faces

# Some ethical issues around AI

- ▶ Bias in, bias out
  - ▶ E.g. Google Translate
- ▶ Bias inherited from tech industry
  - ▶ E.g. facial recognition struggling with non-Caucasian faces
- ▶ Bias caused by deliberate manipulation of training data

# Some ethical issues around AI

- ▶ Bias in, bias out
  - ▶ E.g. Google Translate
- ▶ Bias inherited from tech industry
  - ▶ E.g. facial recognition struggling with non-Caucasian faces
- ▶ Bias caused by deliberate manipulation of training data
  - ▶ E.g. Microsoft Tay chatbot

# Some ethical issues around AI

- ▶ Bias in, bias out
  - ▶ E.g. Google Translate
- ▶ Bias inherited from tech industry
  - ▶ E.g. facial recognition struggling with non-Caucasian faces
- ▶ Bias caused by deliberate manipulation of training data
  - ▶ E.g. Microsoft Tay chatbot
- ▶ Privacy, security and safety

# Some ethical issues around AI

- ▶ Bias in, bias out
  - ▶ E.g. Google Translate
- ▶ Bias inherited from tech industry
  - ▶ E.g. facial recognition struggling with non-Caucasian faces
- ▶ Bias caused by deliberate manipulation of training data
  - ▶ E.g. Microsoft Tay chatbot
- ▶ Privacy, security and safety
- ▶ Public perception (trust or mistrust) of AI

# Some ethical issues around AI

- ▶ Bias in, bias out
  - ▶ E.g. Google Translate
- ▶ Bias inherited from tech industry
  - ▶ E.g. facial recognition struggling with non-Caucasian faces
- ▶ Bias caused by deliberate manipulation of training data
  - ▶ E.g. Microsoft Tay chatbot
- ▶ Privacy, security and safety
- ▶ Public perception (trust or mistrust) of AI
- ▶ Responsibility for AI's actions

# Some ethical issues around AI

- ▶ Bias in, bias out
  - ▶ E.g. Google Translate
- ▶ Bias inherited from tech industry
  - ▶ E.g. facial recognition struggling with non-Caucasian faces
- ▶ Bias caused by deliberate manipulation of training data
  - ▶ E.g. Microsoft Tay chatbot
- ▶ Privacy, security and safety
- ▶ Public perception (trust or mistrust) of AI
- ▶ Responsibility for AI's actions
- ▶ Automation of jobs

# Money laundering for bias

“Instead of relying on algorithms, which we can be accused of manipulating for our benefit, we have turned to machine learning, an ingenious way of disclaiming responsibility for anything. Machine learning is like money laundering for bias. It’s a clean, mathematical apparatus that gives the status quo the aura of logical inevitability. The numbers don’t lie.”

— Maciej Ceglowski

[http://idlewords.com/talks/sase\\_panel.htm](http://idlewords.com/talks/sase_panel.htm)

English ▾



Turkish ▾



He is a nurse. She is  
a doctor. Edit

O bir hemşire. O bir  
doktor.

[Open in Google Translate](#)

[Feedback](#)

Turkish ▾



English ▾



O bir hemşire. O bir  
doktor. Edit

She is a nurse. He is  
a doctor.

[Open in Google Translate](#)

[Feedback](#)

## Automated Inference on Criminality using Face Images

Xiaolin Wu

McMaster University

Shanghai Jiao Tong University

xwu510@gmail.com

Xi Zhang

Shanghai Jiao Tong University

zhangxi.19930818@sjtu.edu.cn

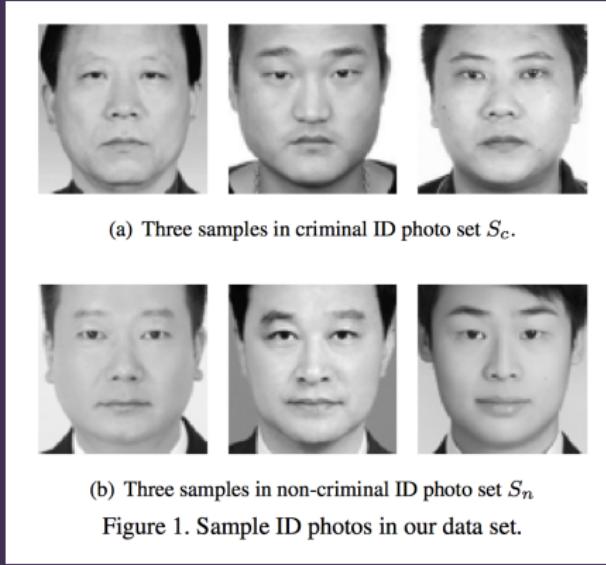
### Abstract

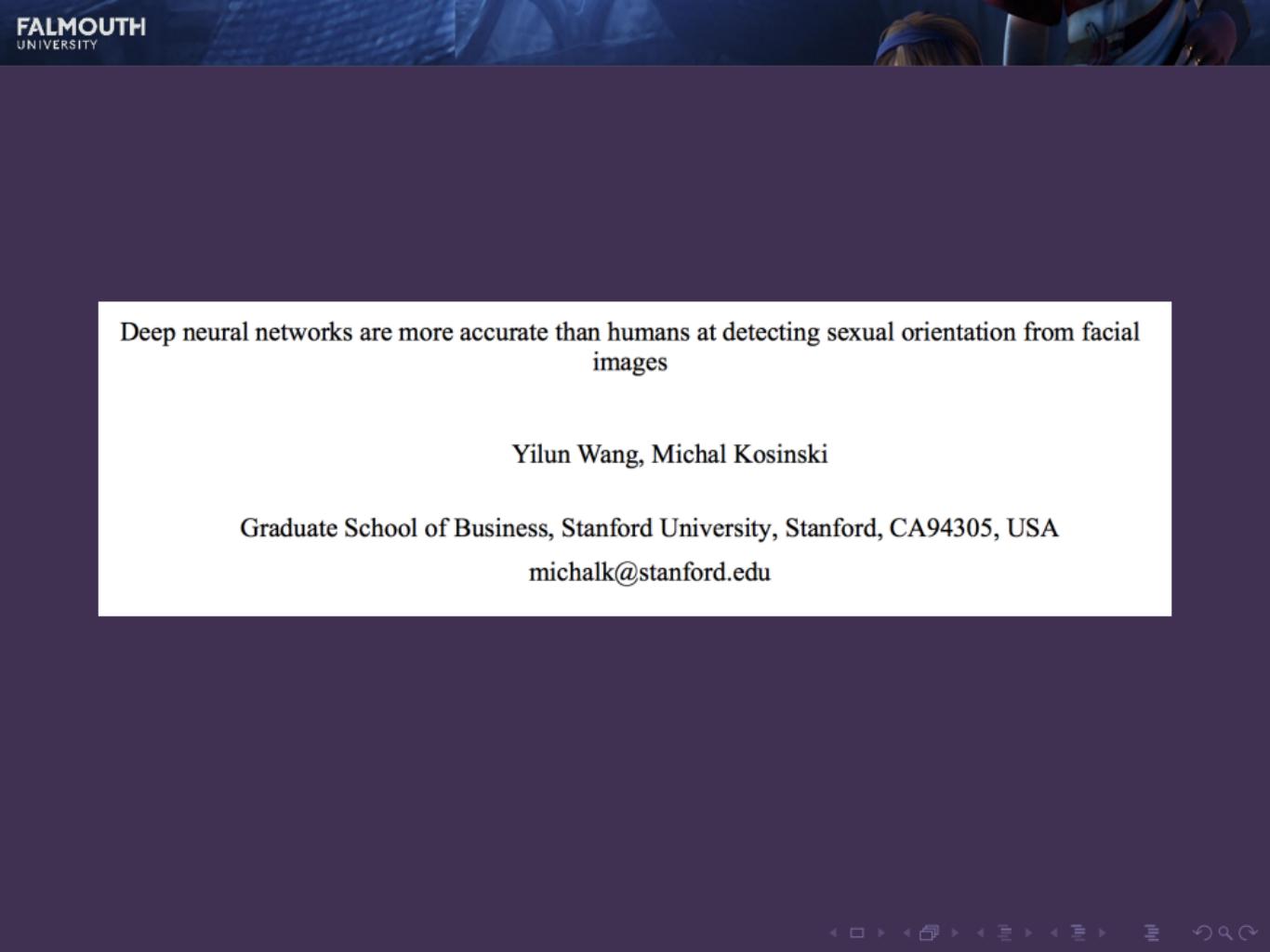
*We study, for the first time, automated inference on criminality based solely on still face images, which is free of any biases of subjective judgments of human observers. Via supervised machine learning, we build four classifiers (logistic regression, KNN, SVM, CNN) using facial images of 1856 real persons controlled for race, gender, age and facial expressions, nearly half of whom were convicted criminals, for discriminating between criminals and non-criminals. All four classifiers perform consistently well and empirically establish the validity of automated face-induced inference on criminality, despite the historical controversy surrounding this line of enquiry. Also, some discriminat-*

management science, criminology, etc.

In all cultures and all periods of recorded human history, people share the belief that the face alone suffices to reveal innate traits of a person. Aristotle in his famous work Prior Analytics asserted, "It is possible to infer character from features, if it is granted that the body and the soul are changed together by the natural affections". Psychologists have known, for as long as a millennium, the human tendency of inferring innate traits and social attributes (e.g., the trustworthiness, dominance) of a person from his/her facial appearance, and a robust consensus of individuals' inferences . These are the facts found through numerous studies [3, 39, 5, 6, 10, 26, 27, 34, 32].

Independent of the validity of pedestrian belief in the





Deep neural networks are more accurate than humans at detecting sexual orientation from facial images

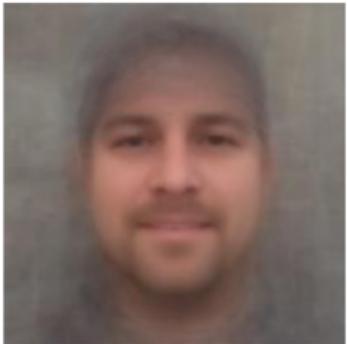
Yilun Wang, Michal Kosinski

Graduate School of Business, Stanford University, Stanford, CA94305, USA  
[michalk@stanford.edu](mailto:michalk@stanford.edu)

### Abstract

We show that faces contain much more information about sexual orientation than can be perceived and interpreted by the human brain. We used deep neural networks to extract features from 35,326 facial images. These features were entered into a logistic regression aimed at classifying sexual orientation. Given a single facial image, a classifier could correctly distinguish between gay and heterosexual men in 81% of cases, and in 71% of cases for women. Human judges achieved much lower accuracy: 61% for men and 54% for women. The accuracy of the algorithm increased to 91% and 83%, respectively, given five facial images per person. Facial features employed by the classifier included both fixed (e.g., nose shape) and transient facial features (e.g., grooming style). Consistent with the prenatal hormone theory of sexual orientation, gay men and women tended to have gender-atypical facial morphology, expression, and grooming styles. Prediction models aimed at gender alone allowed for detecting gay males with 57% accuracy and gay females with 58% accuracy. Those findings advance our understanding of the origins of sexual orientation and the limits of human perception. Additionally, given that companies and governments are increasingly using computer vision algorithms to detect people's intimate traits, our findings expose a threat to the privacy and safety of gay men and women.

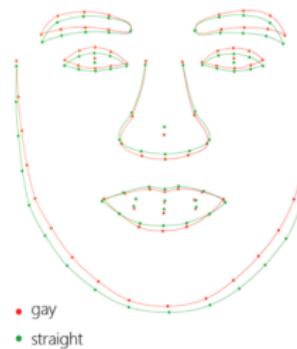
Composite heterosexual faces



Composite gay faces



Average facial landmarks



● gay  
● straight

Male

Female

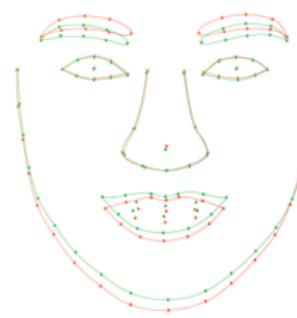
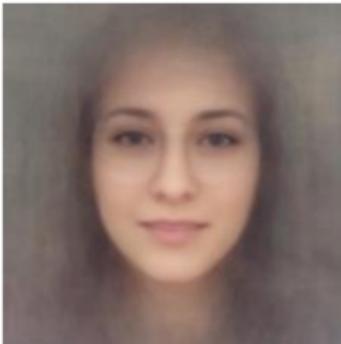
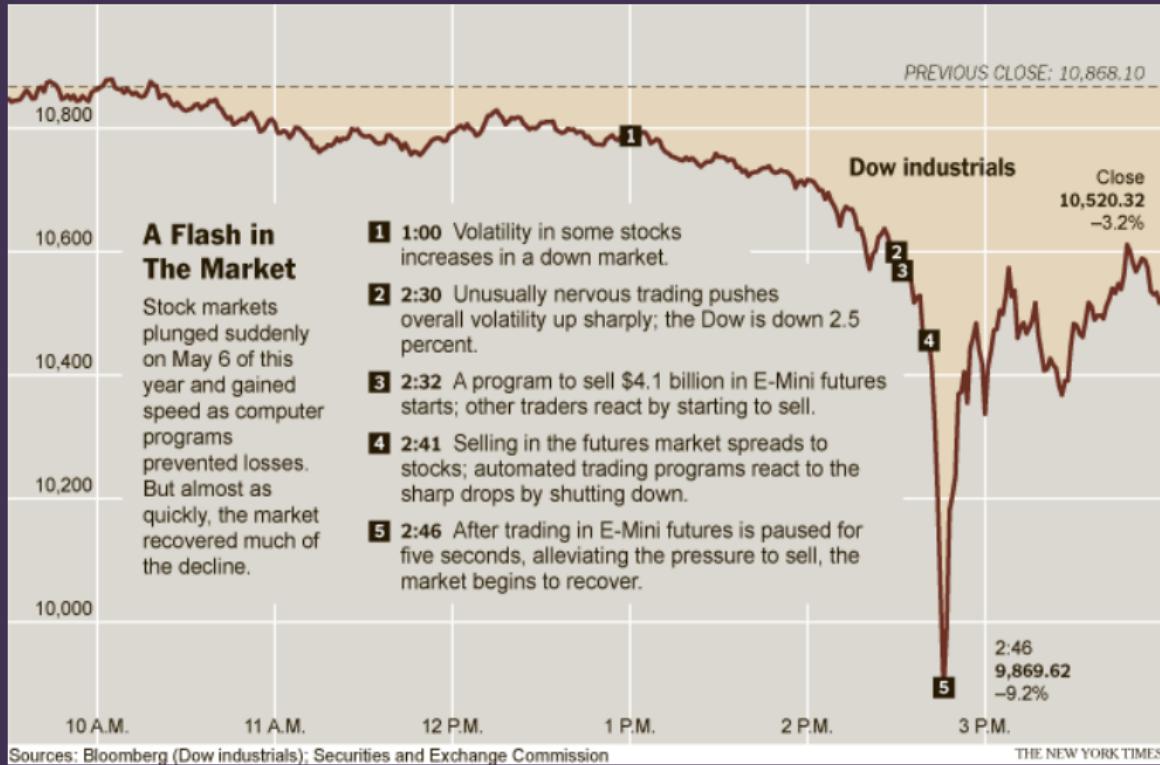


Figure 4. Composite faces and the average facial landmarks built by averaging faces classified as most and least likely to be gay.





DEVELOPING STORY

## WHO'S TO BLAME FOR CRASH?

The logo for ABC 15 Arizona, featuring the ABC television network logo followed by the number 15 and the word ARIZONA.

4:33 53°

**DRIVE TIME** **SPORTS** NHL: FLAMES 2 COYOTES 5 FINAL

4:33 53°