Learning to Make Stuff

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Computational creativity
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Once upon a time...
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• 2001: automated story generation via cognitively informed search
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- 2005: Mark discovers the International Joint Workshop series on Computational Creativity

Once upon a time…

• 2001: automated story generation via cognitively informed search

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• Whose creativity?
Once upon a time...

- 2001: automated story generation via cognitively informed search

- 2005: Mark discovers the International Joint Workshop series on Computational Creativity


- Whose creativity?

- What is creativity?
What is creativity?
Learning
Learning

Expectation

Novelty

Intention
Learning
Learning

• **Phase 1**: imitation
Learning

- **Phase 1:** imitation

- **Phase 2:** imitation + exploration
Learning

- **Phase 1:** imitation
- **Phase 2:** imitation + exploration
- **Phase 3:** Intentional deviation from expectations
Learning

- **Phase 1**: imitation
- **Phase 2**: imitation + exploration
- **Phase 3**: Intentional deviation from expectations

Loss measured as $\Delta$ from exemplars
Learning

- **Phase 1:** imitation \(\rightarrow\) Loss measured as \(\Delta\) from exemplars

- **Phase 2:** imitation + exploration \(\rightarrow\) Loss = discriminator + novelty

- **Phase 3:** Intentional deviation from expectations
Learning

- **Phase 1**: imitation $\overset{\text{Loss measured as } \Delta \text{ from exemplars}}{\longrightarrow}$
- **Phase 2**: imitation + exploration $\overset{\text{Loss } = \text{ discriminator } + \text{ novelty}}{\longrightarrow}$
- **Phase 3**: Intentional deviation from expectations $\overset{??}{\longrightarrow}$
Audience expectation

From arXiv:1706.07068
Intentionality
Intentionality

- Goals of computational creativity systems come from the operator
Intentionality

- Goals of computational creativity systems come from the operator
- Exemplars provided by operator
Intentionality

• Goals of computational creativity systems come from the operator

• Exemplars provided by operator

• Human creators change their goals mid-creation

Intentionality

• Goals of computational creativity systems come from the operator

• Exemplars provided by operator

• Human creators change their goals mid-creation


• Exploration via intentional manipulation of models
With sweaty palms and heart racing, John drove to Sally’s house for their first date. Sally, her pretty white dress flowing in the wind, carefully entered John’s car. John and Sally drove to the movie theater. John and Sally parked the car in the parking lot. Wanting to feel prepared, John had already bought tickets to the movie in advance. A pale-faced usher stood before the door; John showed the tickets and the couple entered. Sally was thirsty so John hurried to buy drinks before the movie started. John and Sally found two good seats near the back. John sat down and raised the arm rest so that he and Sally could snuggle. John paid more attention to Sally while the movie rolled and nervously sipped his drink. Finally working up the courage to do so, John extended his arm to embrace Sally. He was relieved and ecstatic to feel her move closer to him in response. Sally stood up to use the restroom during the movie, smiling coyly at John before that exit. John and Sally also held hands throughout the movie, even though John’s hands were sweaty. John and Sally slowly got up from their seats. Still holding hands, John walked Sally back to his car through the maze of people all scurrying out of the theater. The bright sunshine temporarily blinded John as he opened the doors and held them for Sally as they left the dark theater and stepped back out onto the street. John let go of Sally’s hand and opened the passenger side door of his car for her but instead of entering the car, she stepped forward, embraced him, and gave him a large kiss. John drove Sally back to her home.
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Automatic computer game generation

Automatically and autonomously produce a novel, complete, and playable computer game
Why?
Why?

- Computer games are dynamic systems
Why?

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- Rich design space, clustered into genres
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- Rich design space, clustered into genres
- Provide a space that affords human decision-making
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- Evaluation *might* be easier
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- Rich design space, clustered into genres
- Provide a space that affords human decision-making
- Evaluation *might* be easier
- Mechanics + content + storytelling
Procedural content generation
Procedural content generation

No Man’s Sky
Procedural content generation

No Man’s Sky

Star Trek Online
Procedural content generation

No Man’s Sky

Star Trek Online

Elder Scrolls II
Procedural content generation

Super Mario Bros.: The Drosophila of AI level generation
Procedural content generation

Togelius & Schmidhuber

Game-O-Matic

Zook & Riedl
Goals
Goals

• Learn a generative model of “good” levels & mechanics
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• Generate levels that are unlike anything ever seen before (but still good)
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• Generate levels that are unlike anything ever seen before (but still good)

• Future work: blend games to make new games never played before
Learn a model of level design

(a) Deriving Level Chunks
Learn a model of level design.

(a) Deriving Level Chunks

(b) Categorizing Level Chunks

Guzdial & Riedl. AIIDE 2016 Conference.
Learn a model of level design.
Probabilistic model

Guzdial & Riedl. AIIDE 2016 Conference.
Level generation
But...
But…

• Is our generator creative?
But…

• Is our generator creative?

• Where in the system is the creativity?
But…

- Is our generator creative?
- Where in the system is the creativity?

In the model…
But…

• Is our generator creative?

• Where in the system is the creativity?

In the model…

…error
But…

- Is our generator creative?
- Where in the system is the creativity?

In the model…

…error

In the algorithm…
But...

- Is our generator creative?
- Where in the system is the creativity?

In the model...
  ...error

In the algorithm...
  ...sampling
Creativity in the algorithm
Creativity in the algorithm

• Transform the model
  – Mutate
  – Pick another model and interpolate
  – Pick another model and cross-over
  – Pick another model and blend
  – etc…
Creativity in the algorithm

• Transform the model
  – Mutate
  – Pick another model and interpolate
  – Pick another model and cross-over
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  – etc…

• Give system agency to choose the transformation
Creativity in the algorithm

• Transform the model
  – Mutate
  – Pick another model and interpolate
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  – Pick another model and blend
  – etc…

• Give system agency to choose the transformation
Concept blending

- A theoretical model of creativity
- Find correspondences between two spaces & project into a third space
Concept blending

Overworld

Underworld

Guzdial & Riedl. ICCC 2016 Conference. 2nd Best Paper Award.
Does it work?

• Super Mario Bros.: The Lost Levels

• Some Lost Levels are blends

• What is the probability that a learned model could recreate a Lost Level?
Level 9-3: castle + overworld
Level 9-3: castle + overworld

Probability that the level can be produced by a model
Level 9-3: castle + overworld

Probability that the level can be produced by a model
Level 9-3: castle + overworld

Probability that the level can be produced by a model
Level 9-1: underwater + overworld
Level 9-1: underwater + overworld

Probability that the level can be produced by a model
Level 9-1: underwater + overworld

Probability that the level can be produced by a model

Graph showing box plots for different categories: Full Blend, Blend, SMB Model, Overworld, Underwater.
Level 9-1: underwater + overworld

Probability that the level can be produced by a model
Learning game mechanics

Original game engine
- Code
- The “rules” of the game

Game video

Learned game engine
- Entity position change
- Entity appear/disappear
- Animation plays
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Engine search

Guzdial & Riedl. IJCAI 2017 Conference.
• Predicts next frame better than a CNN

• Improves learning rate of reinforcement learning agent
• Predicts next frame better than a CNN

• Improves learning rate of reinforcement learning agent
The future
The future

• Generate novel game that blends level + mechanic models from 2 or more existing games
The future

- Generate novel game that blends level + mechanic models from 2 or more existing games

- Game design space meta-search
  - Non-deterministically choose strategies for transforming models
Concluding thoughts

• Current ML creative systems need to move beyond learning the past

• Need to factor in audience expectation

• Proposal: intentional manipulation of learned models of a design space

• Computational creativity research is about agents responding gracefully to unanticipated circumstances

• … is about making human-level problem-solving peers
Thanks!

- Matthew Guzdial
- Alex Zook
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