Aalto University
School of Science

jamk
University of
Applied Sciences

Machine Learning in Games

Amin Babadi

Aalto University

JAMK University of Applied Sciences

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Finland

Agenda

- Why game AI research?
- What Is machine learning?
  - Artificial neural networks
- AI in games
  - AI for playing games
  - Procedural content generation
  - Player modeling
- How/where to begin?

About Me

- Academia
  - 2007-2011: B.Sc. in Software Engineering, University of Kashan, Iran
  - 2011-2013: M.Sc. in AI, Sharif University of Technology, Iran
  - 2013-2017: Ph.D. in AI, Isfahan University of Technology, Iran (Dropped Out)
  - 2017-Present: Ph.D. in Computer Science, Aalto University, Finland
  - 2019: Visiting Researcher, University of British Columbia, Canada
  - 2021-Present: Part-Time Lecturer in JAMK University of Applied Sciences
- Industry
  - 2011-2012: E.T. Armies (AI Programmer)
  - 2012-2013: Awakening: Burning Ashes (Lead Programmer)
  - 2016-2017: Cut (Gameplay and AI Programmer)

Agenda

- **Why game AI research?**
- What Is machine learning?
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- How/where to begin?

1966

1997

2015

2016

2019

AI in Games Is Popular Because Games Are …

- A rich source of challenging problems:
  - Planning
  - Adversarial search
  - Navigation
  - Data Mining
  - Natural language processing
  - Signal processing
  - Artificial Creativity
  - Artificial Psychology
  - …
- Cheap
- Fun

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Machine Learning

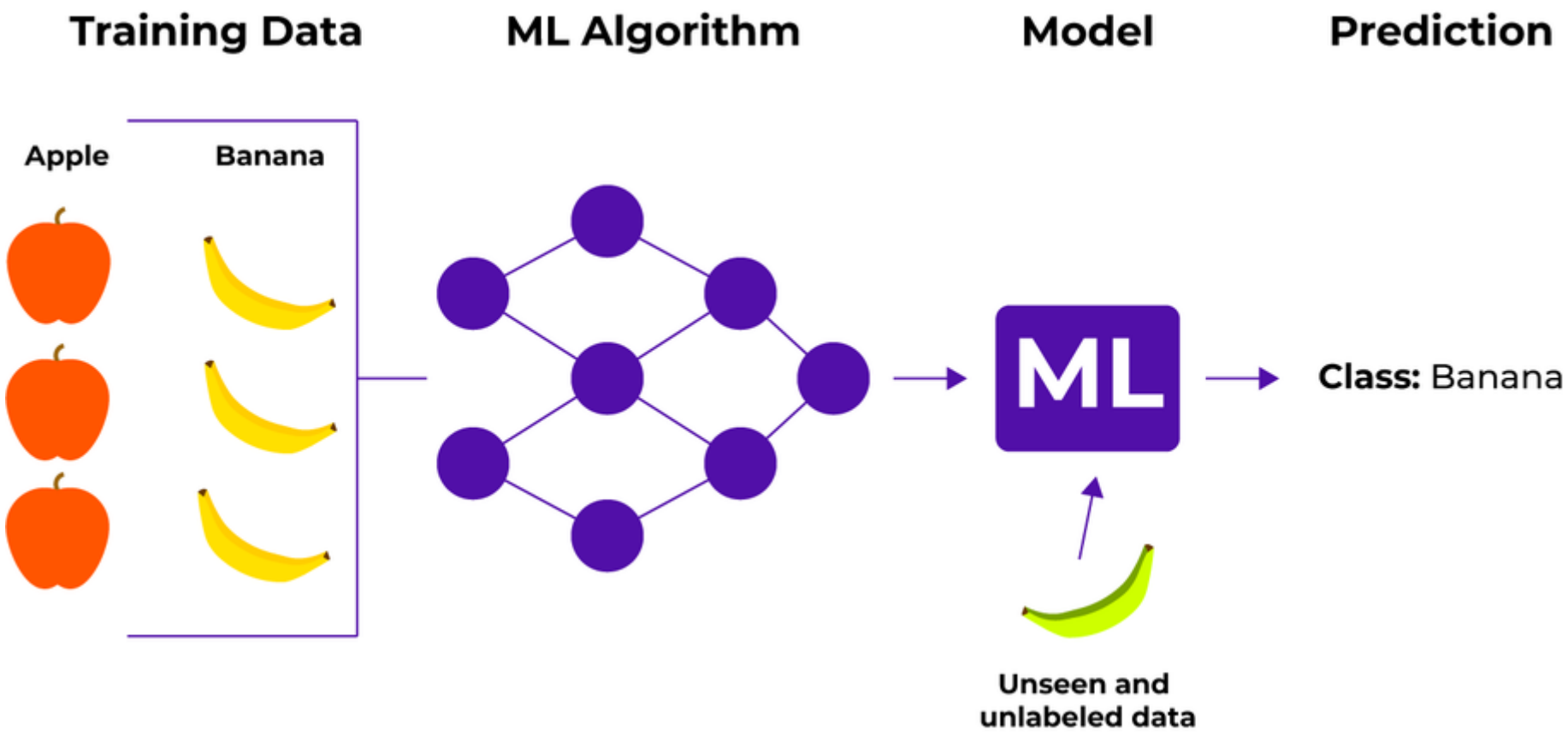
- Computer algorithms that improve automatically through experience.

SUPERVISED LEARNING

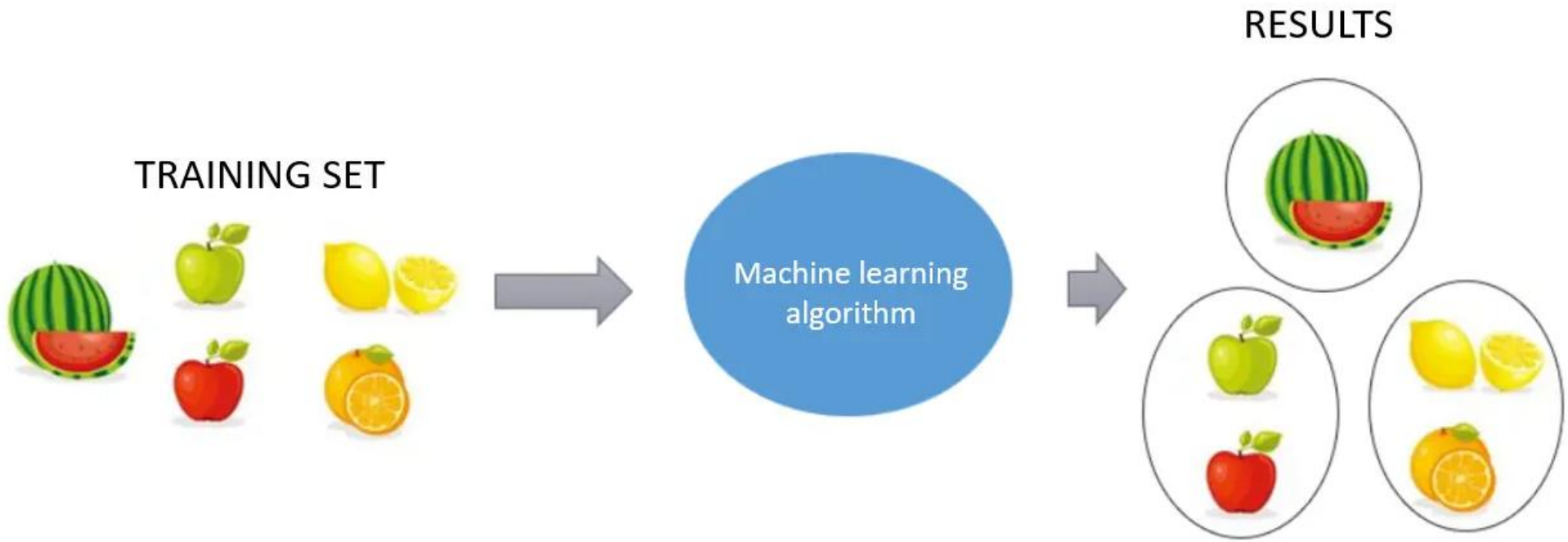
UNSUPERVISED LEARNING

REINFORCEMENT LEARNING

Supervised Learning: An Example

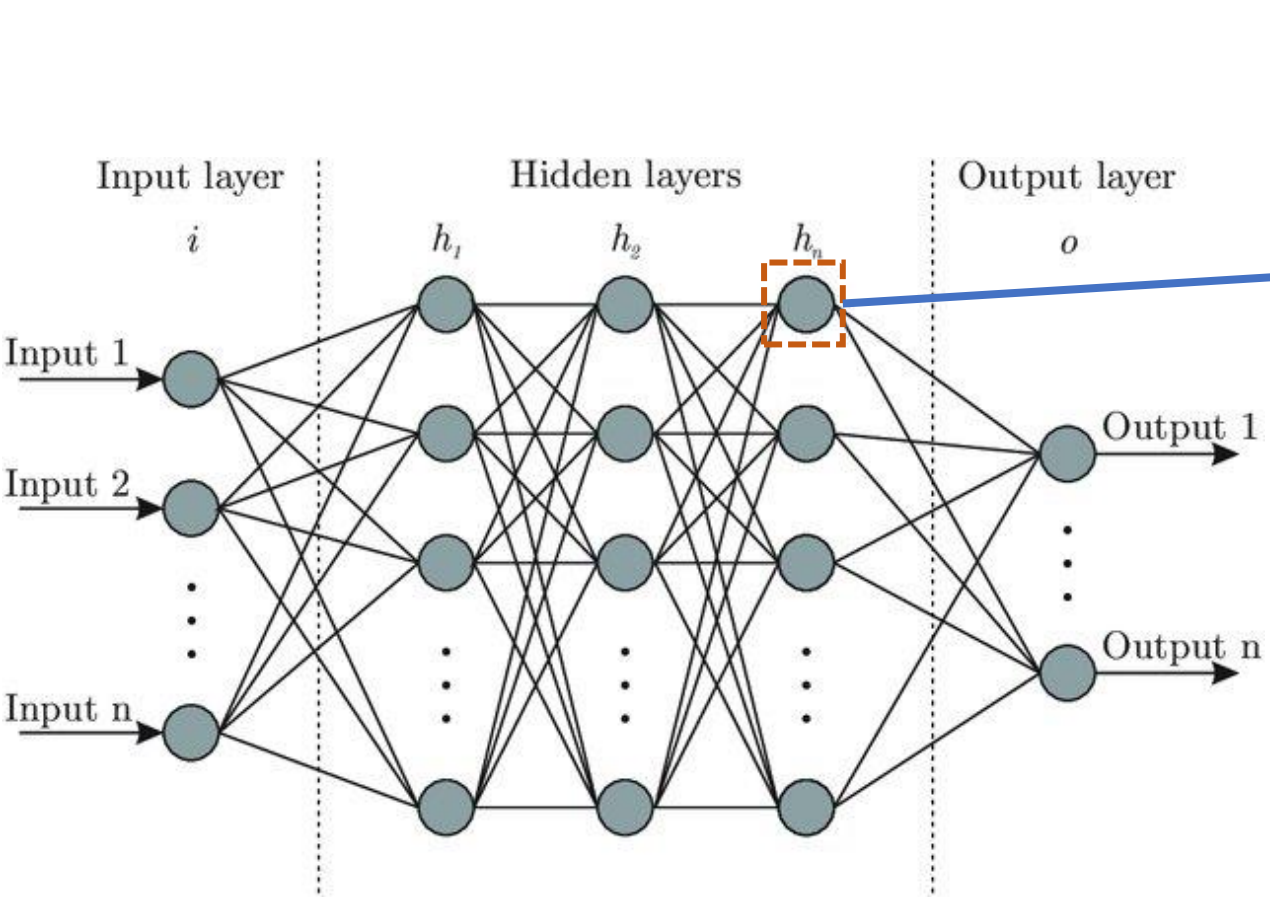


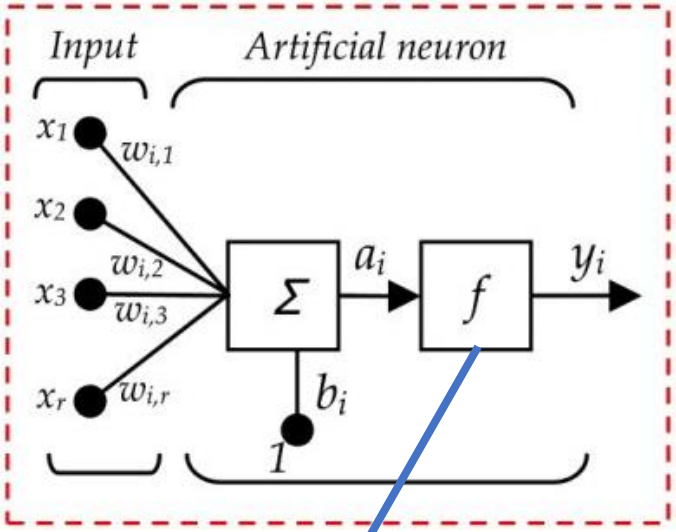
Unsupervised Learning: An Example



Reinforcement Learning: An Example

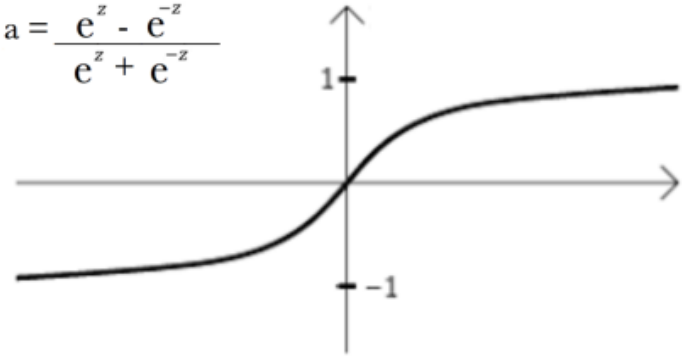
Artificial Neural Network



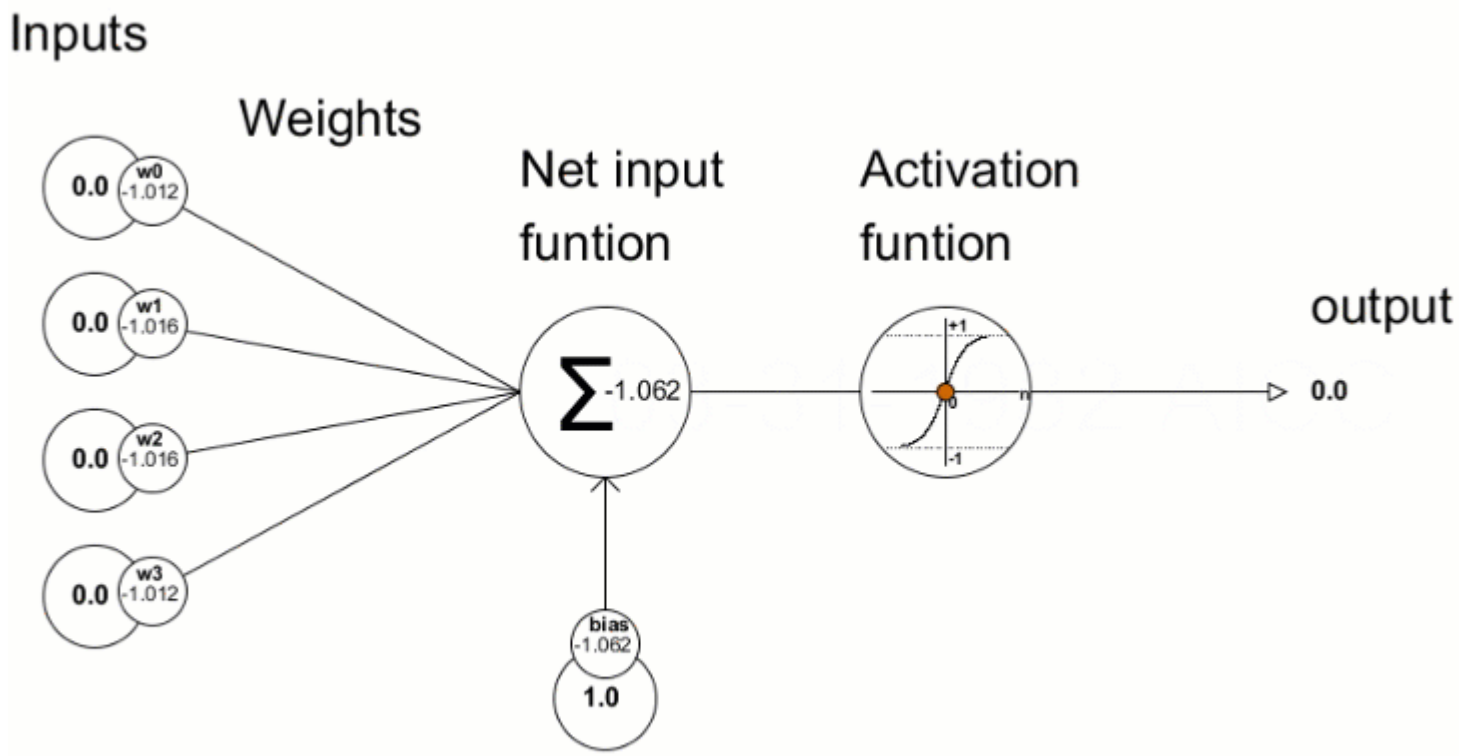


Tanh Function

$$a = \frac{e^{z} - e^{-z}}{e^{z} + e^{-z}}$$



Neural Network: An Example



Want to Know More?

- An Interactive Visualization of Convolutional Neural Networks
  - https://www.cs.ryerson.ca/~aharley/vis/fc/
- Convolutional Neural Networks for Visual Recognition Online Lectures by Stanford University
  - https://youtube.com/playlist?list=PL3FW7Lu3i5JvHM8ljYj-zLfQRF3EO8sYv

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AI for Playing Games: Motivations

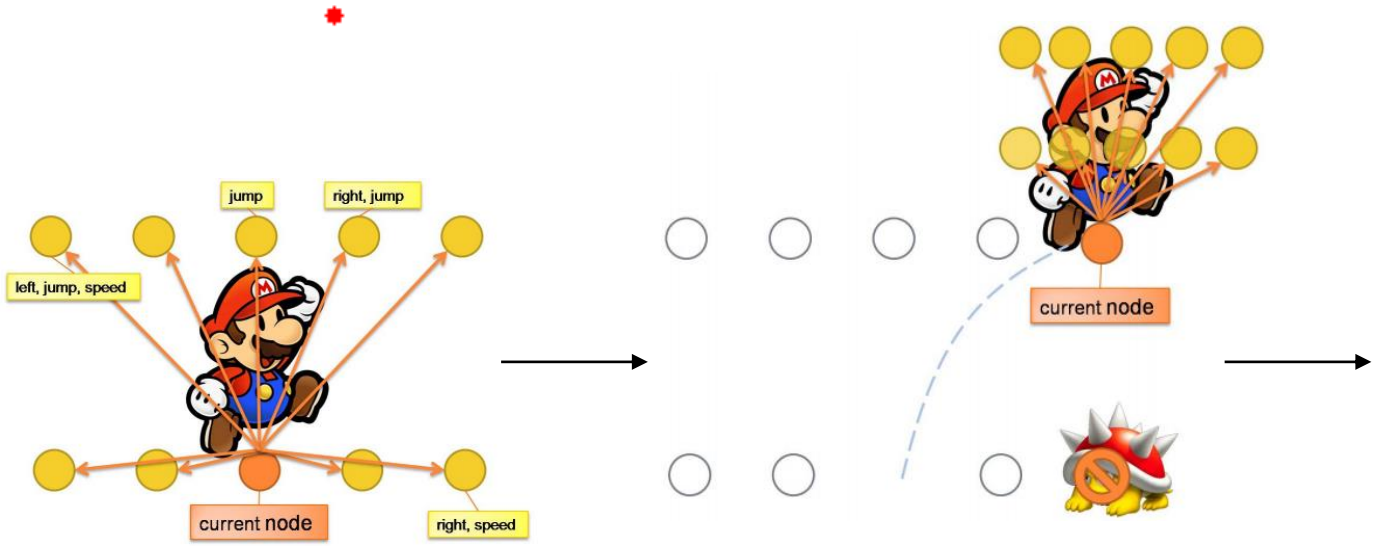
- As a player
  - Testbeds for AI algorithms
  - Gameplay testing
  - Game balancing
- As a non-player
  - Non-playable characters
  - Human-like agents
  - Game balancing

AI for Playing Games: Approaches

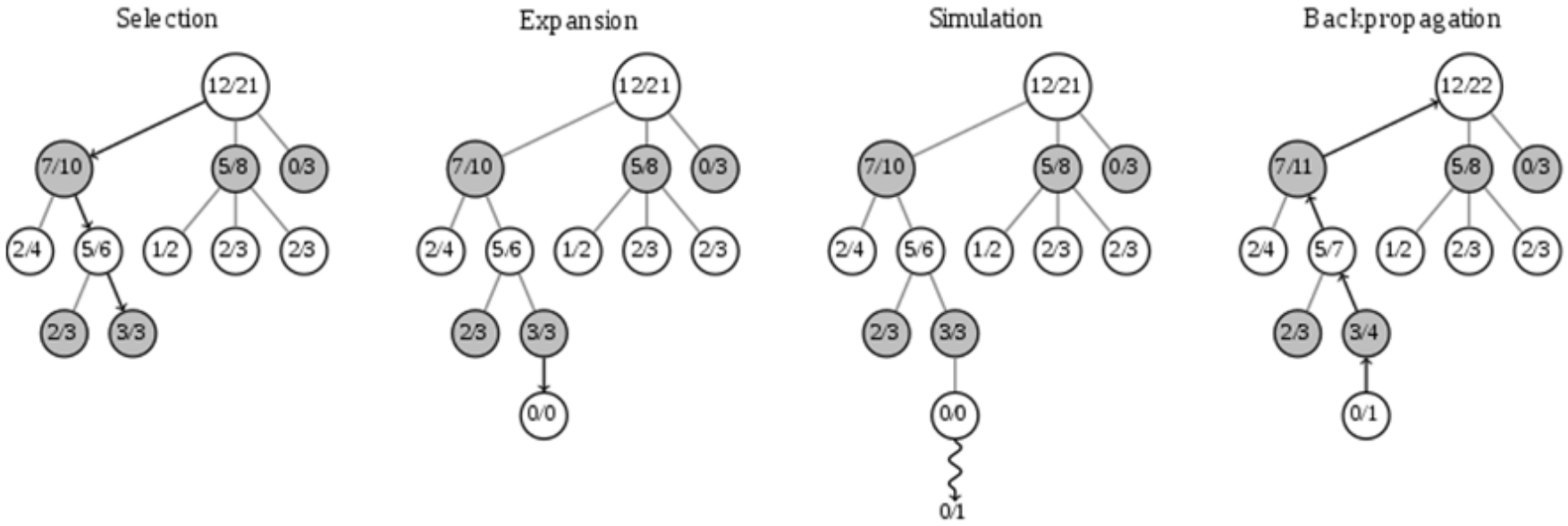
- Planning-based approaches
  - A* search
  - MCTS
  - Evolutionary planning
- Reinforcement learning
  - Classic RL
  - Deep RL
  - Evolutionary RL
- Supervised learning
  - Imitation learning

A* Search

Togelius, J., Karakovskiy, S. and Baumgarten, R., 2010, July. The 2009 mario ai competition. In IEEE Congress on Evolutionary Computation (pp. 1-8). IEEE.



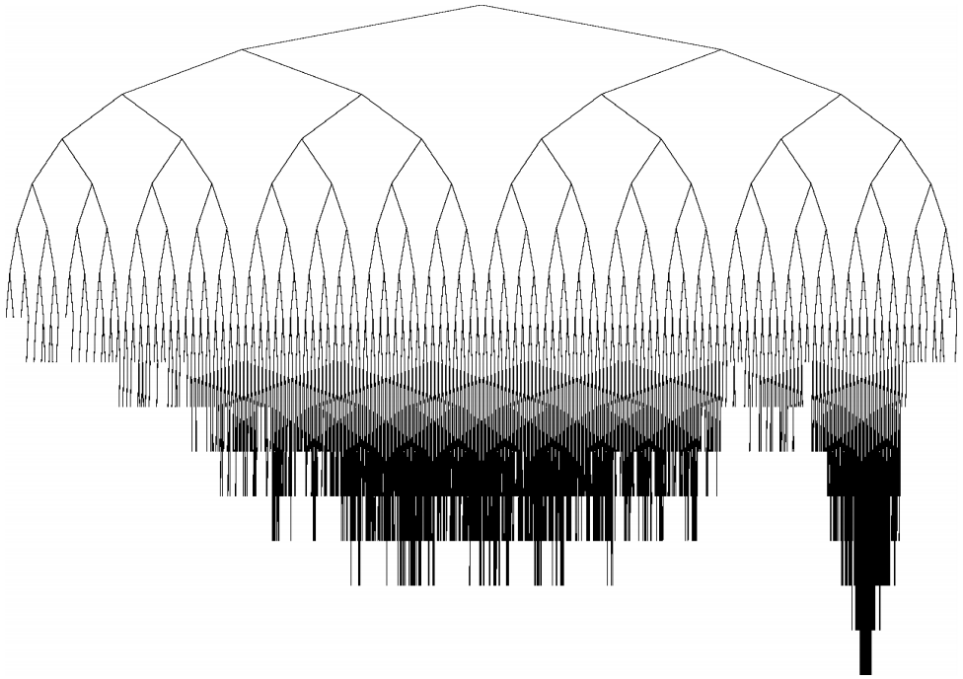
Monte Carlo Tree Search (MCTS)



Browne, C.B., Powley, E., Whitehouse, D., Lucas, S.M., Cowling, P.I., Rohlfshagen, P., Tavener, S., Perez, D., Samothrakis, S. and Colton, S., 2012. A survey of monte carlo tree search methods. IEEE Transactions on Computational Intelligence and AI in games, 4(1), pp.1-43.

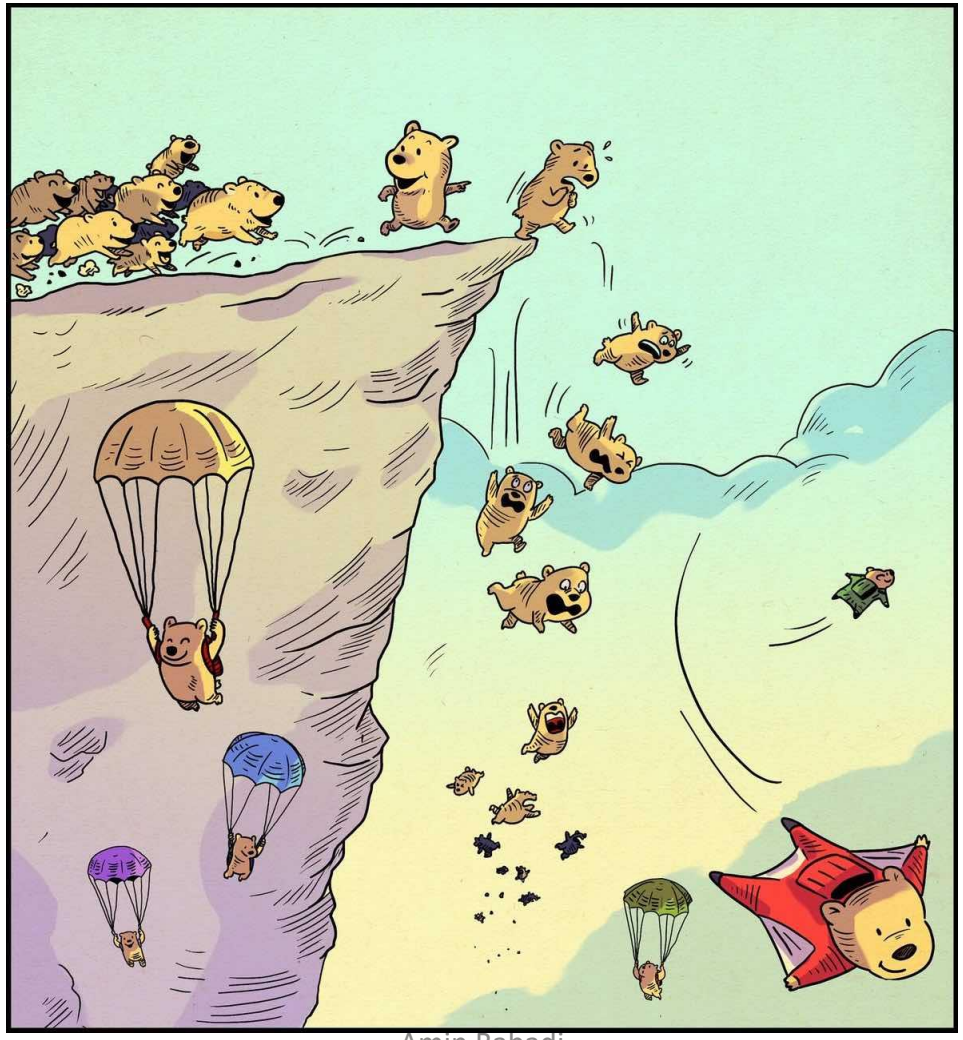
MCTS Characteristics

- Aheuristic
- Anytime
- Asymmetric

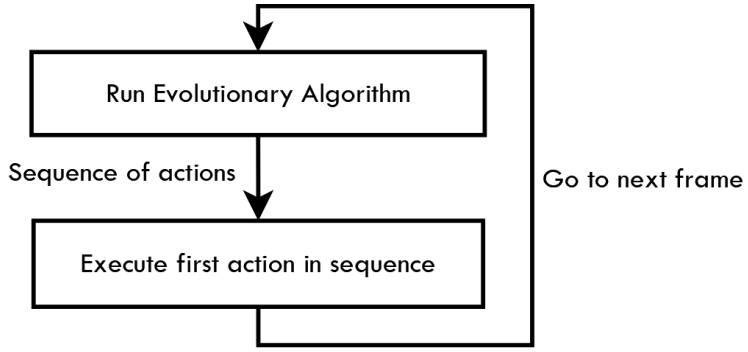


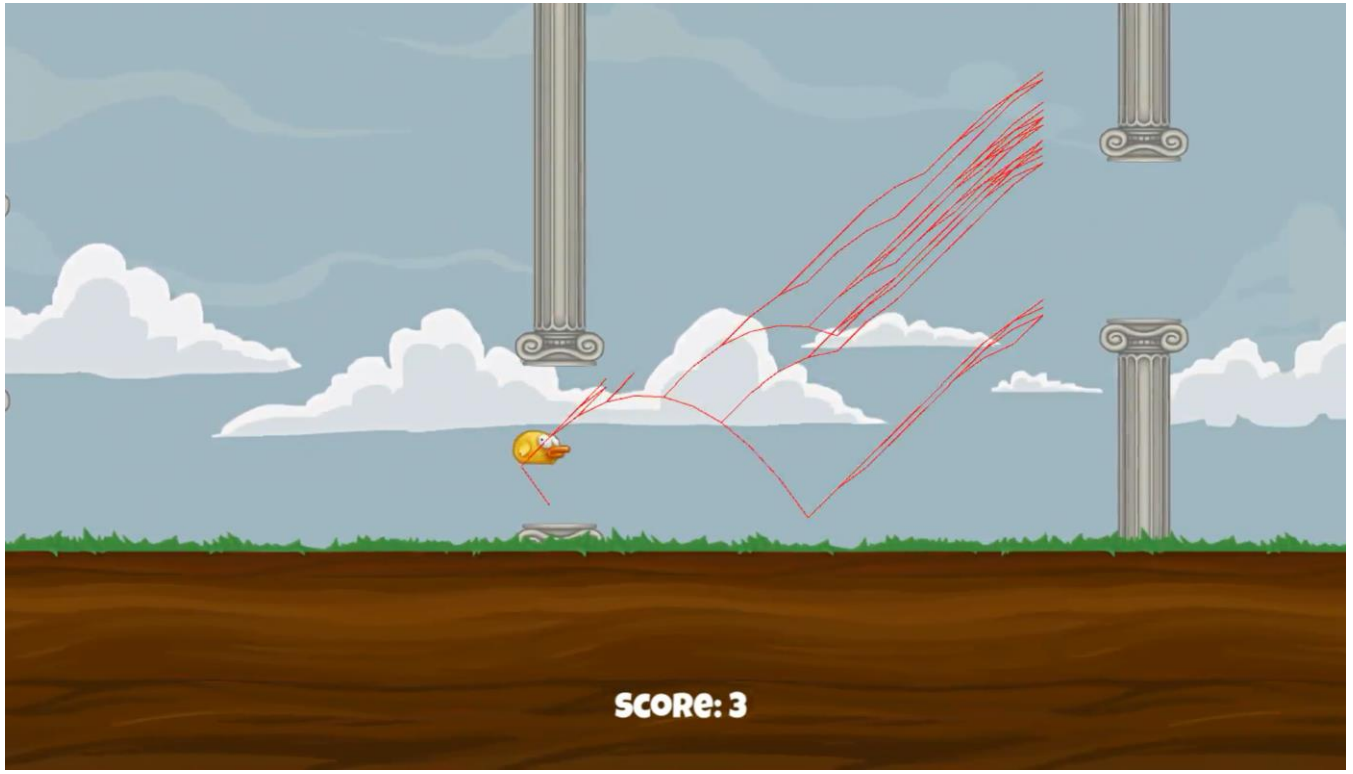
Fischer, J., Falsted, N., Vielwerth, M., Togelius, J. and Risi, S., 2015. Monte-Carlo Tree Search for Simulated Car Racing. In FDG.

Evolutionary Planning



Rolling (Receding) Horizon Evolution





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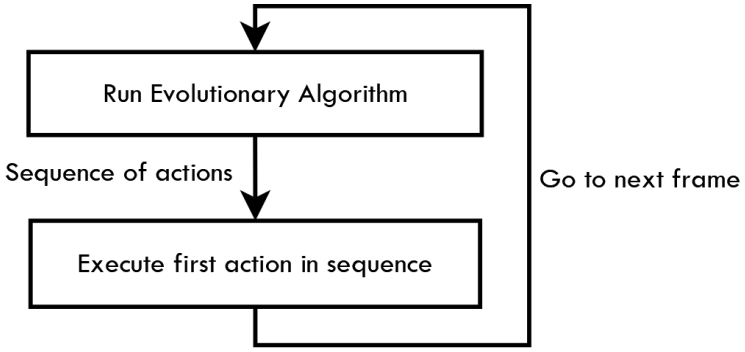
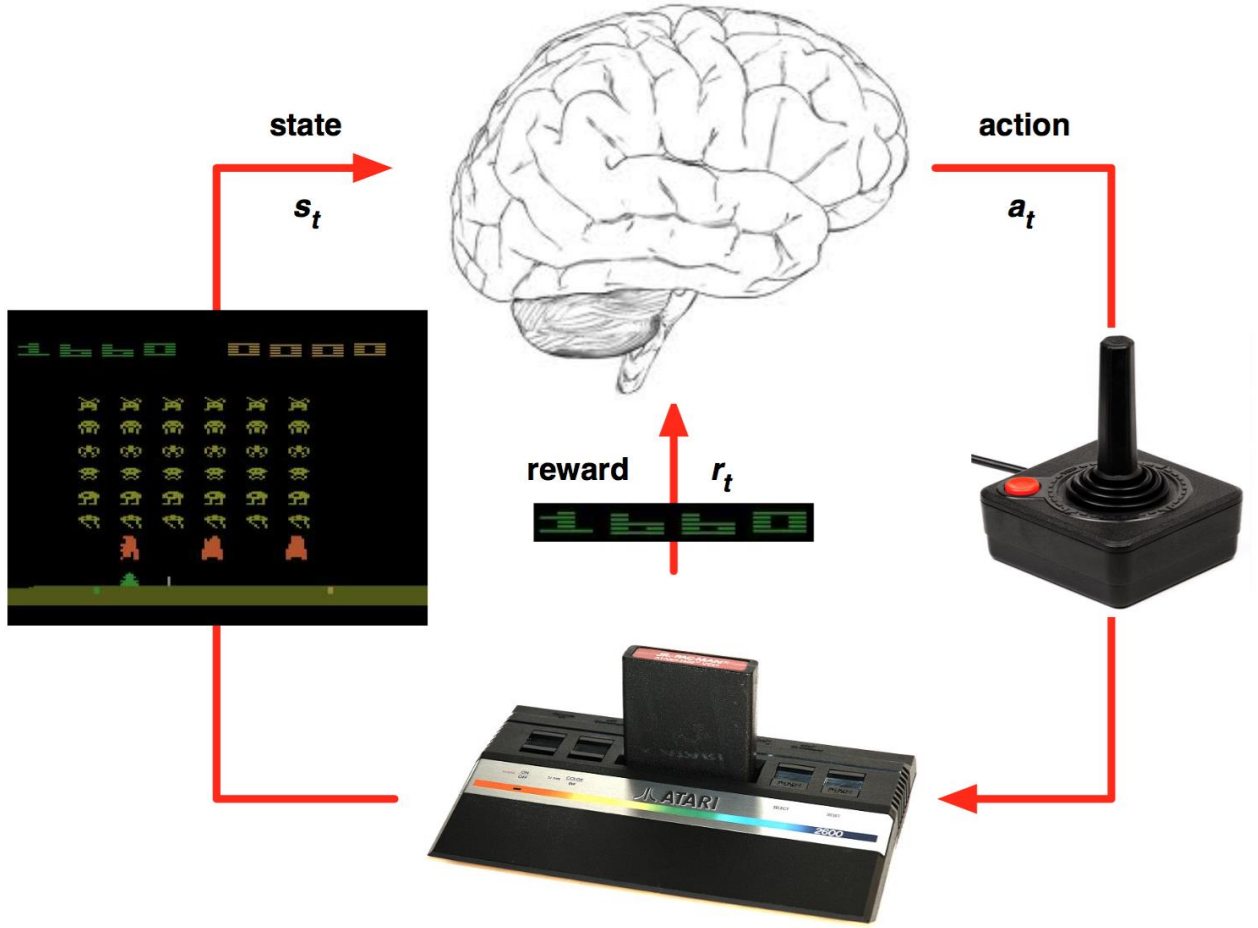
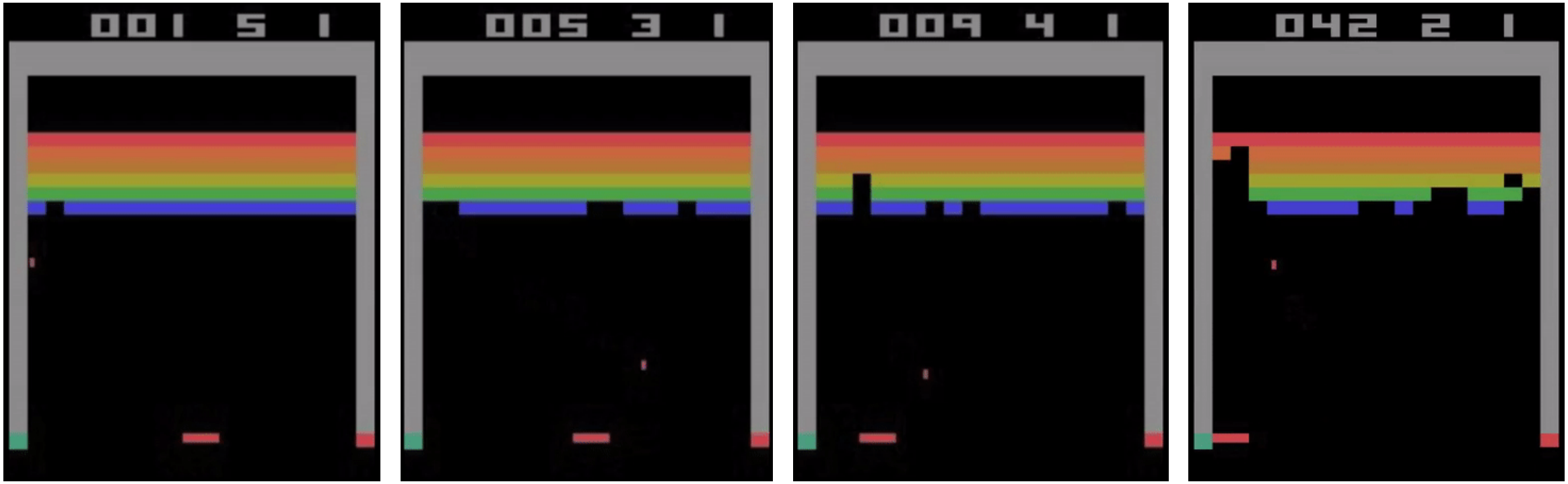


- Genetic algorithm (for discrete actions)
- Evolution strategy (for continuous actions): CMA-ES

Classic/Deep Reinforcement Learning



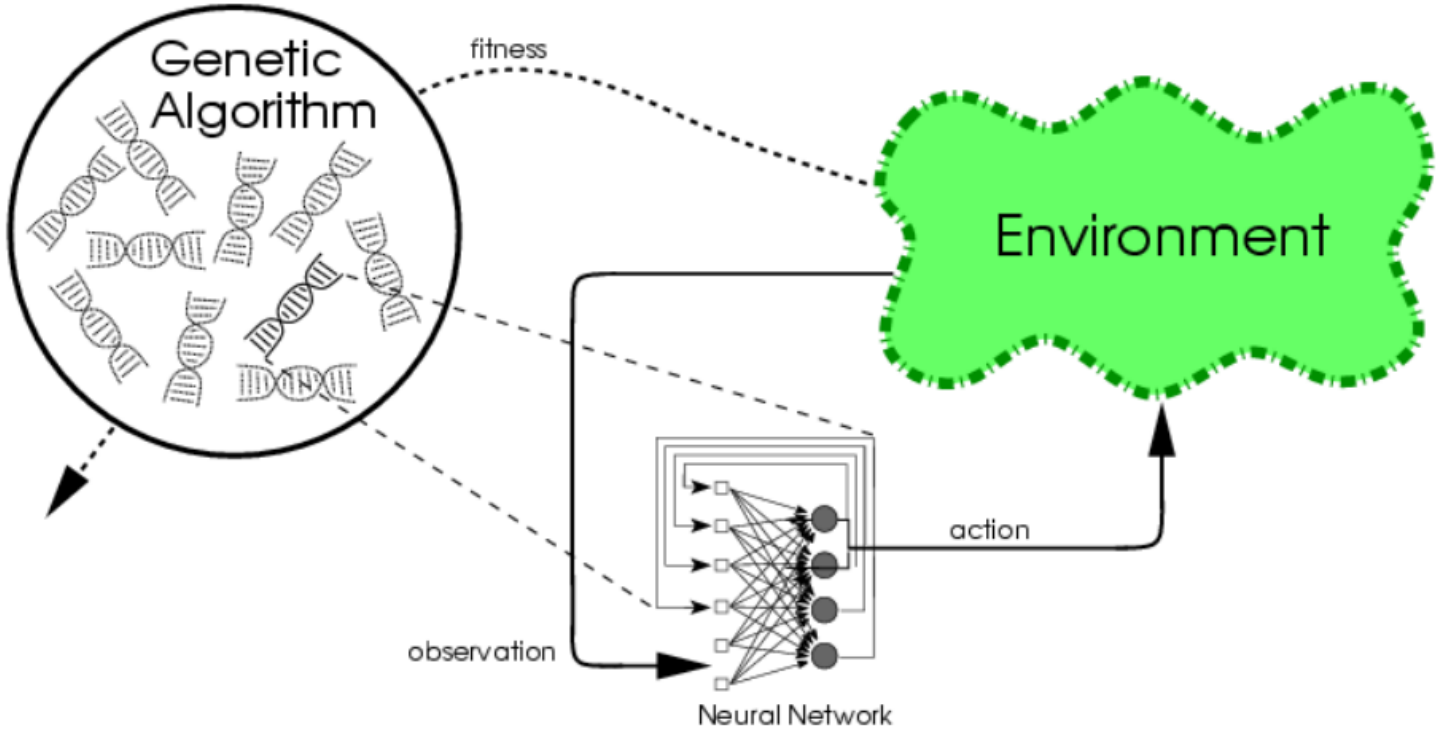
Reinforcement Learning: An Example



Mnih, V., Kavukcuoglu, K., Silver, D., Rusu, A.A., Veness, J., Bellemare, M.G., Graves, A., Riedmiller, M., Fidjeland, A.K., Ostrovski, G. and Petersen, S., 2015. Human-level control through deep reinforcement learning. nature, 518(7540), pp.529-533.

Evolutionary Reinforcement Learning

- A.k.a. Neuroevolution

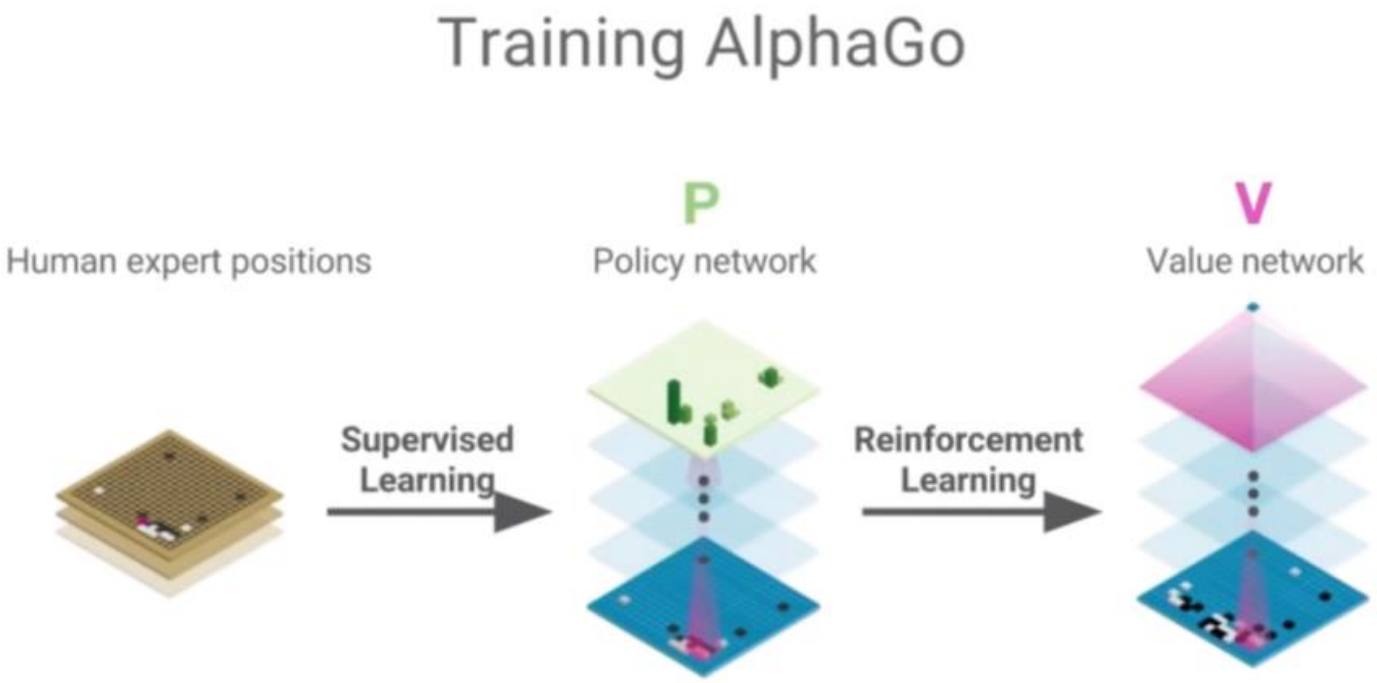


Imitation Learning

x_i	$\Rightarrow$	y_i
	$\Rightarrow$	JUMP
	$\Rightarrow$	DOWN
	$\Rightarrow$	RIGHT
⋮		

$\Rightarrow$?

Imitation Learning: An Example



Silver, D., Schrittwieser, J., Simonyan, K., Antonoglou, I., Huang, A., Guez, A., Hubert, T., Baker, L., Lai, M., Bolton, A. and Chen, Y., 2017. Mastering the game of go without human knowledge. nature, 550(7676), pp.354-359.

Babadi, A., Naderi, K. and Hämäläinen, P., 2019. Self-imitation learning of locomotion movements through termination curriculum. In Motion, Interaction and Games (pp. 1-7).

Self-Imitation Learning

Online Optimization

Cycle Detection

Reinforcement Learning

Initial policy (Epochs = 0)

After 5 minutes (Epochs = 50)

After 1 hour (Epochs = 1000)

After 3 hours (Epochs = 3500)

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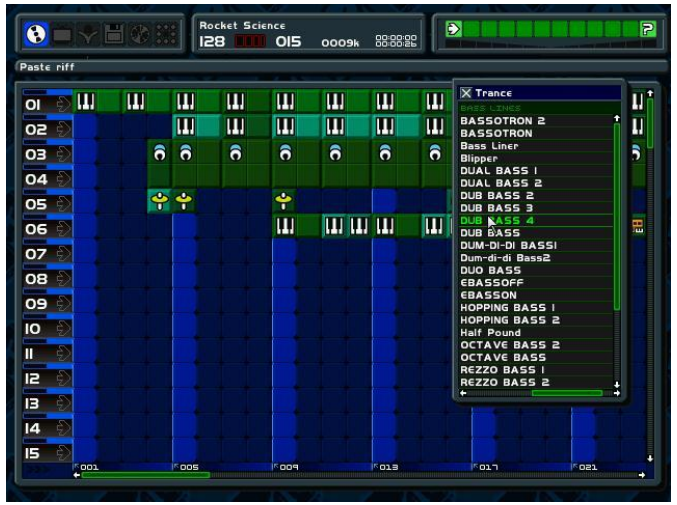
- How/where to begin?

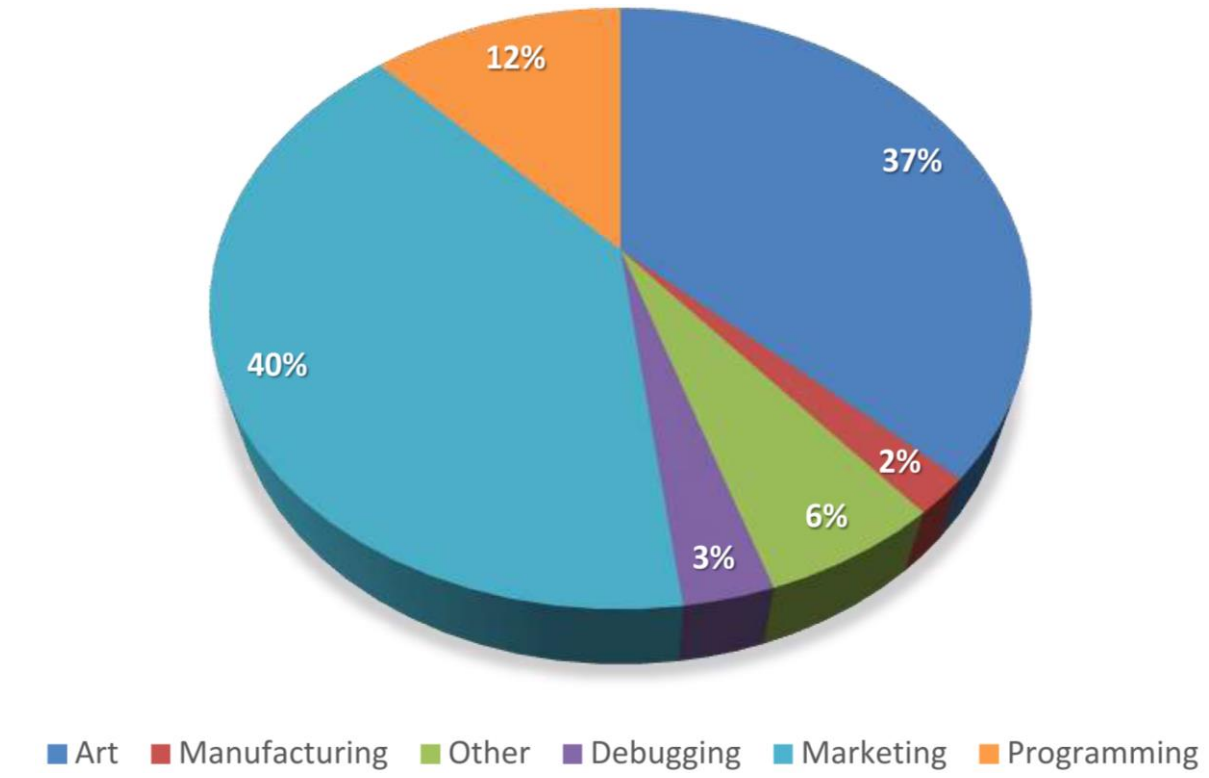
What Content?

- Models
  - Characters, vehicles, weapons, etc.
- Textures
- Animations
- Levels
- Maps
- Music
- Game rules
- Stories
- Dialogs
- Items
- Quests
- …



Motivations

- Faster development
- More creativity
- Player-adaptive games
- Cheaper development

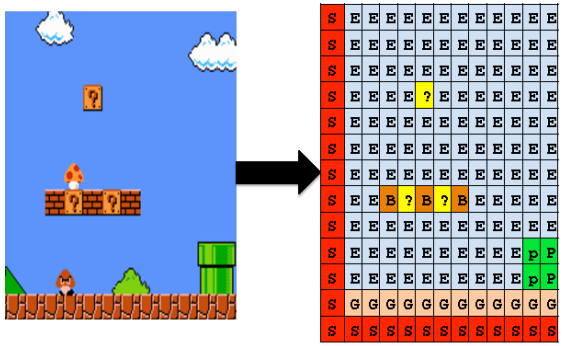


Approaches

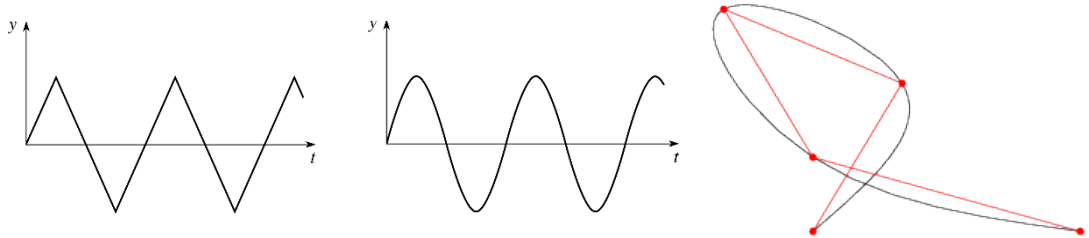
- Search-based methods
- Solver-based methods
- Grammar-based methods
- (Unsupervised) machine learning
- Cellular automata
- Noise and fractals

Search-Based Methods

- Maps/levels/Textures

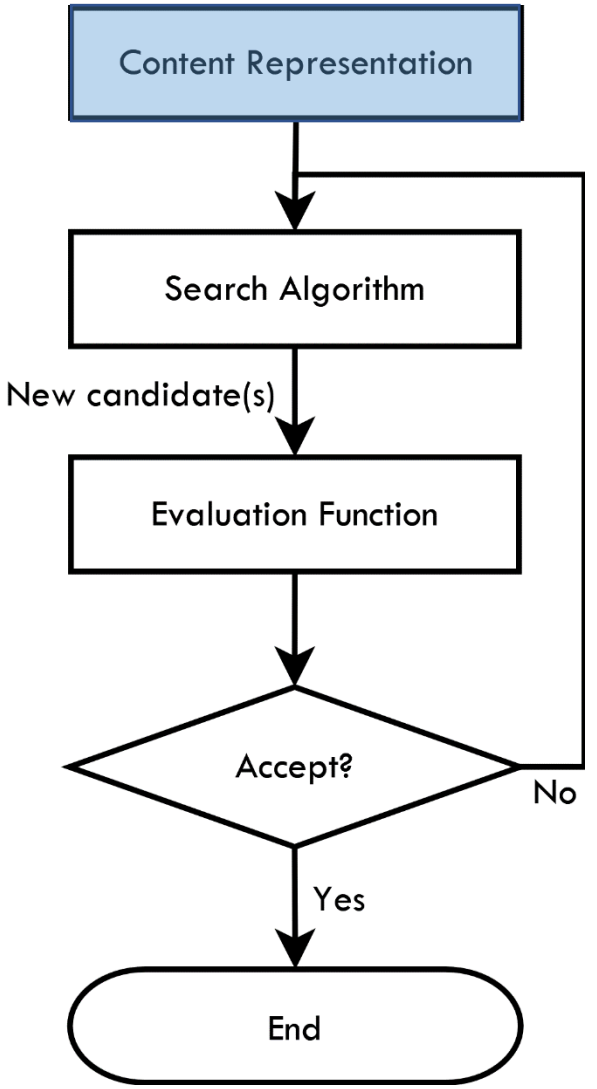


- Animations/Music



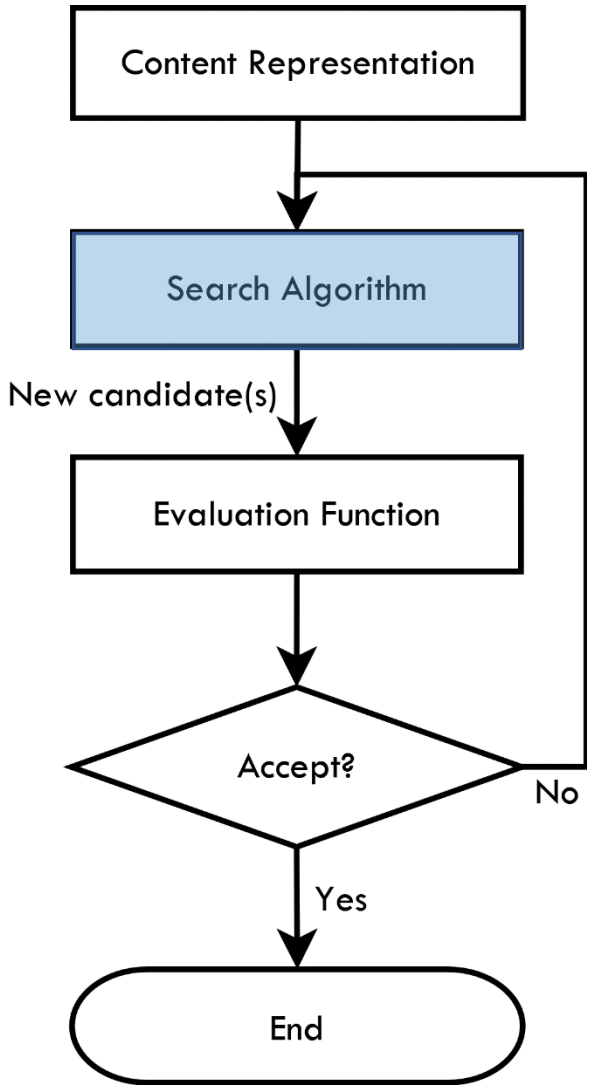
- Stories/Dialogs

I	1	0	0	0	0
love	0	1	0	0	0
cake	0	0	1	0	0
hate	0	0	0	1	0
pizza	0	0	0	0	1



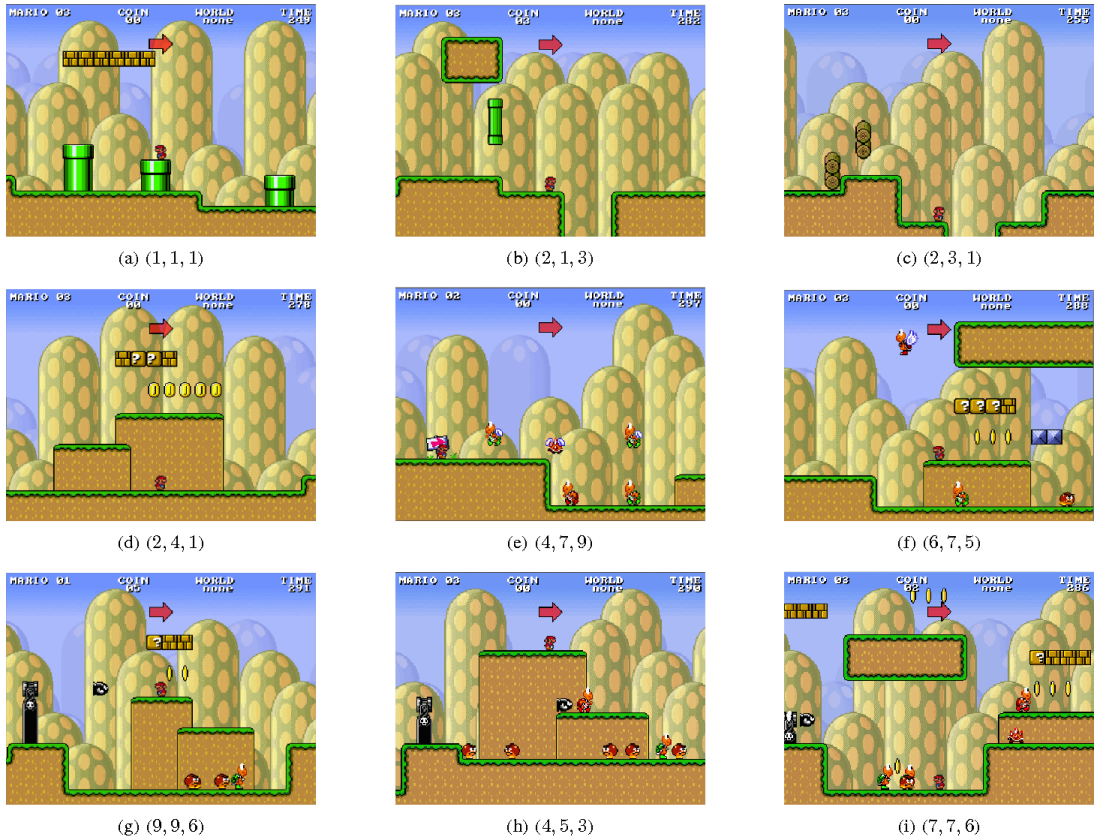
Search-Based Methods

- Evolutionary algorithms
  - Genetic algorithm
  - Genetic programming
  - Evolution strategy
- Search algorithms
  - A* search



Search-Based Methods

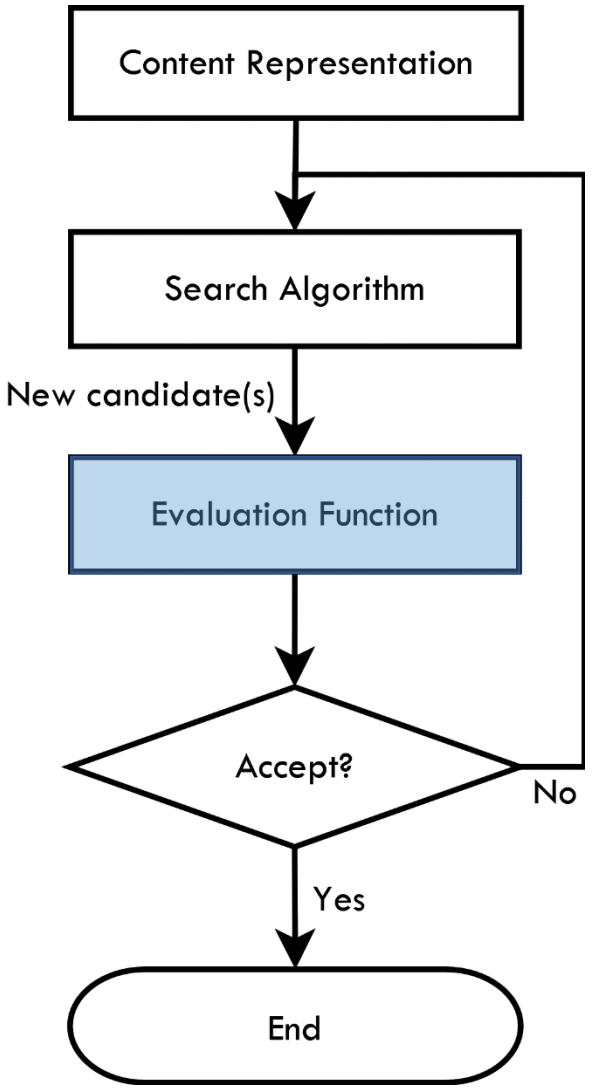
- Direct
- Simulation-based
- Interactive



(a) (1, 1, 1) (b) (2, 1, 3) (c) (2, 3, 1)

(d) (2, 4, 1) (e) (4, 7, 9) (f) (6, 7, 5)

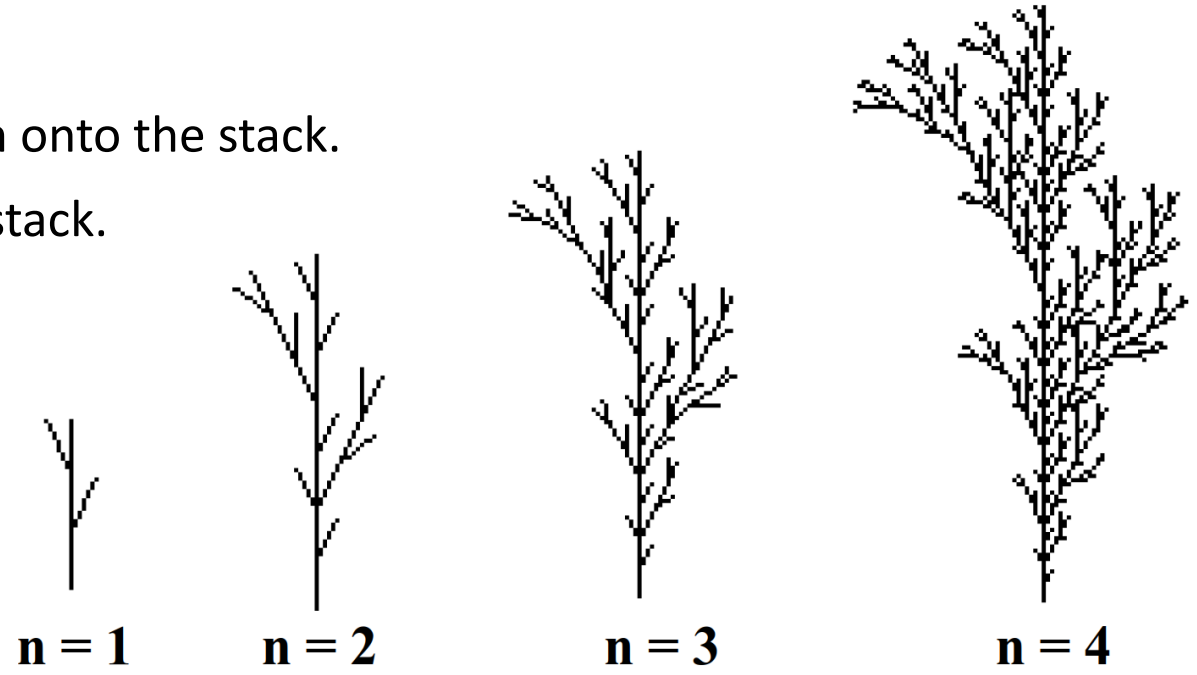
(g) (9, 9, 6) (h) (4, 5, 3) (i) (7, 7, 6)



Grammar-Based Methods

$$F \rightarrow F[-F]F[+F][F]$$

- F: move forward a certain distance (e.g., 10 pixels).
- +: turn left 30 degrees.
- −: turn right 30 degrees.
- [: push the current position and orientation onto the stack.
-]: pop the position and orientation off the stack.



Solver-Based Methods

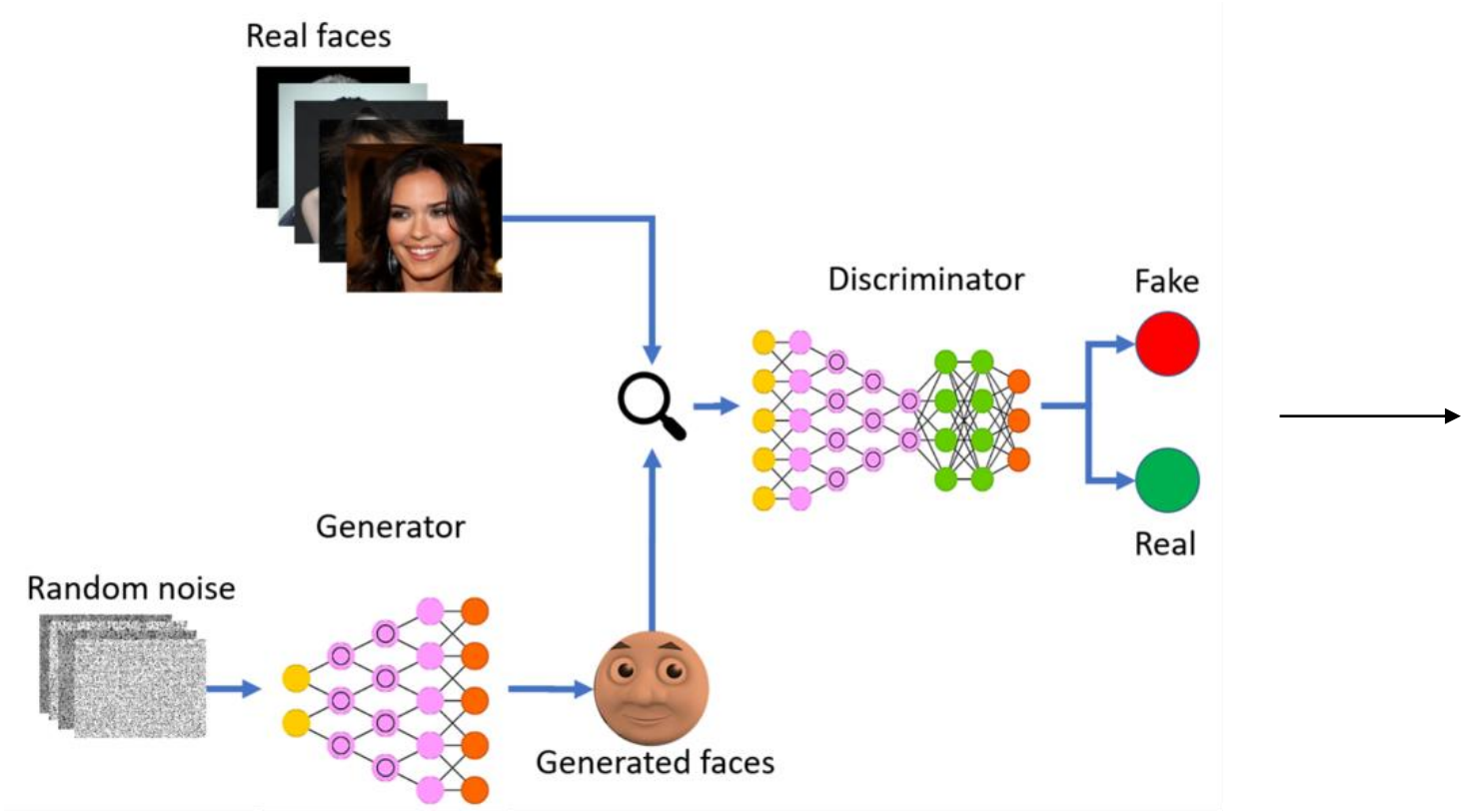
- Use constraint solvers
  - Satisfiability (SAT)
  - Answer Set Programming (ASP)
- Usually not anytime

(Unsupervised) Machine Learning

- Mostly suitable for generating textures, models, text, …

- Approaches:
  - Generative Adversarial Network (GAN)
  - Variational Autoencoder (VAE)
  - Recurrent neural network (RNN)

Generative Adversarial Network (GAN)



Karras, T., Aila, T., Laine, S. and Lehtinen, J., 2018, February. Progressive Growing of GANs for Improved Quality, Stability, and Variation. In International Conference on Learning Representations.

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  - **Player modeling**
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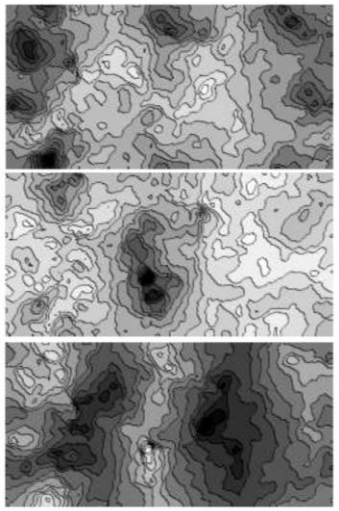
What Is Player Modeling?



Cause of Death: Opponent

Cause of Death: Environment

Cause of Death: Falling

Motivations

A High-Level Taxonomy of Approaches

- Model-based (top-down)
- Model-free (bottom-up, data-driven)

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- **How/where to begin?**

How/Where to Begin?

- Books
  - Artificial Intelligence: A Modern Approach
  - Artificial Intelligence and Games
  - Reinforcement Learning: An Introduction
- Frameworks
  - InteractML, an Interactive Machine Learning Visual Scripting framework for Unity3D
  - Obstacle Tower
  - Unity ML-Agents
  - Marathon Environments: A Set of High-Dimensional Continuous Control Environments for Use with Unity ML-Agents Toolkit.
  - OpenAI Gym
  - OpenAI Baselines
  - Google Research Football
  - General Video Game Playing
  - ViZDoom

- Conferences
  - ACM SIGGRAPH
  - ACM SIGGRAPH Conference on Motion, Interaction and Games (MIG)
  - ACM SIGGRAPH / Eurographics Symposium on Computer Animation (SCA)
  - ACM SIGCHI - Special Interest Group on Computer-Human Interaction
  - CHI Play
  - IEEE Conference on Games (IEEE CoG) – *Formerly Known as IEEE Conference on Computational Intelligence and Games (IEEE CIG)*
  - Artificial Intelligence in Digital Entertainment (AIIDE)
  - Foundations of Digital Games (FDG)
  - Computer Games; Challenges and Opportunities (CGCO)
- Journals
  - ACM Transactions on Graphics (TOG)
  - IEEE Transactions on Visualizations and Computer Graphics (IEEETVCG)
  - Computer Graphics Forum (CGF)
  - IEEE Transactions on Games (TOG) – Formerly Known as IEEE Transactions on Computational Intelligence and AI in Games (TCAIG)

Thanks :)

https://users.aalto.fi/~babadia1/ amin.babadi@yahoo.com