

Introduction to Neuroevolution

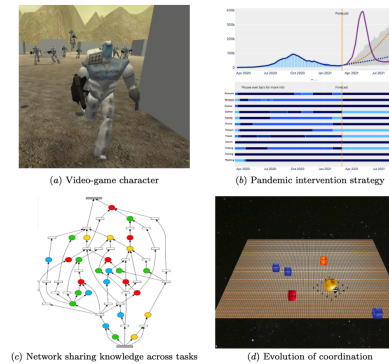
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Navigation icons

Introduction to Neuroevolution

- ▶ Neuroevolution: Optimization of neural network designs through evolutionary computation.
- ▶ Approach: Not just about optimizing a single metric but solving complex, multi-objective problems.
- ▶ Focus: Discovering creative, adaptable solutions that can operate in dynamic environments.



Illustrative opportunities for neuroevolution.

Navigation icons

Challenge 1: Designing a Video Game Character

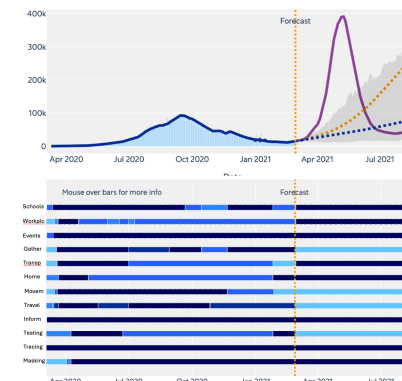
- ▶ Scenario: Creating a search-and-rescue sidekick in a video game.
- ▶ Requirements: Anticipate player's needs, act in a human-like manner, manage limited resources.
- ▶ Difficulty: Many behaviors are hard to define but must feel natural and believable.



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Challenge 2: Pandemic Intervention Strategy

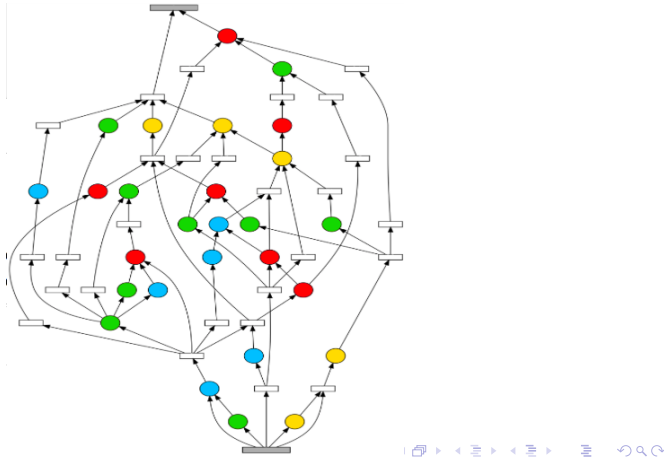
- ▶ Scenario: A new pandemic requires immediate, tailored intervention strategies.
- ▶ Problem: Strategies must adapt to different regions and changing circumstances.
- ▶ Difficulty: General rules may not be effective; customization is key.



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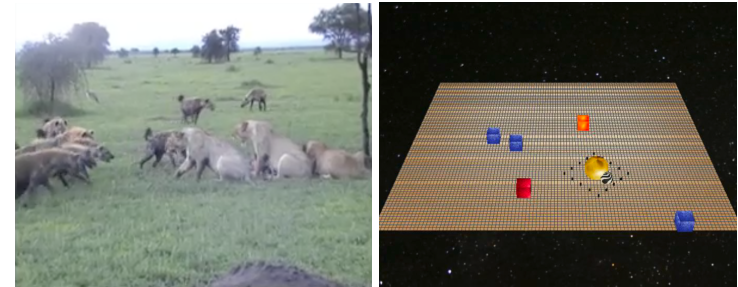
Challenge 3: Retail Sales Prediction

- Scenario: Predicting sales across various stores with limited data.
- Problem: Traditional deep learning struggles with small datasets.
- Solution: Leveraging data from other domains to improve predictions.
- Goal: Generalize beyond the small dataset to minimize waste and optimize inventory.



Challenge 4: Evolution of Coordination in Hyenas

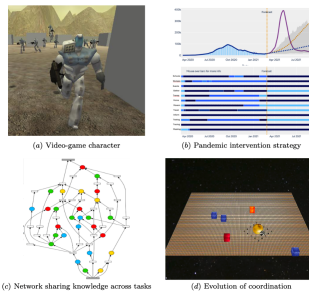
- Scenario: Biologists observe sophisticated coordination among hyenas.
- Question: Could this be an evolutionary adaptation indicating a leap in social intelligence?
- Solution: Simulate the evolutionary process to understand how such behaviors emerge.



Simulating the evolution of coordination in hyenas.

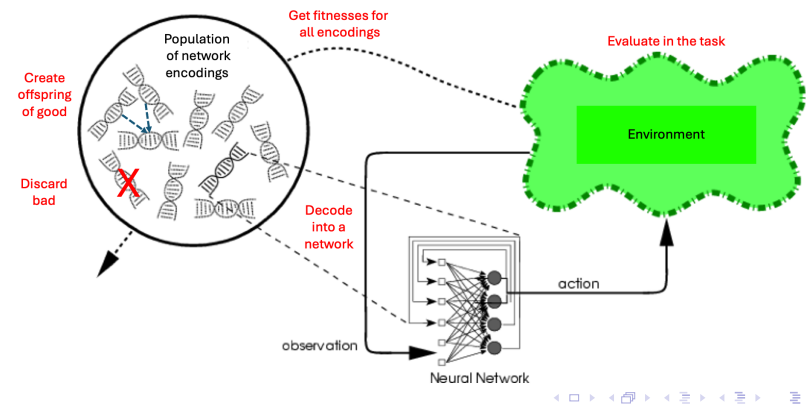
Key Insight: Neuroevolution in Action

- Neuroevolution is not just about optimizing known metrics.
- It's about discovering creative, effective solutions that can adapt to complex, dynamic environments.
- Examples illustrate how neuroevolution can address a wide range of challenges.
- Not just about replacing human creativity, but extending it.
- Potential to improve decision-making in engineering, science, and society.
- Neuroevolution is a powerful tool in the AI toolbox.



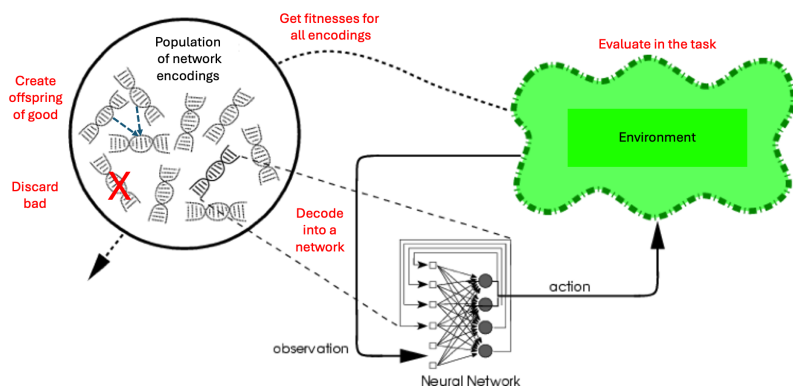
How Does Neuroevolution Work?

- Start with a population of randomly initialized neural networks.
- Evaluate each network's performance on a specific task.
- Select the top-performing networks to serve as parents for the next generation.
- Use crossover and mutation to generate new networks from these parents.
- Repeat the process until the networks evolve to meet the task's needs.



Advantages of Neuroevolution

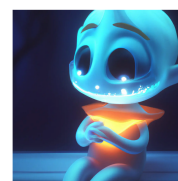
- ▶ Beyond Backpropagation: Does not rely on gradient information; useful for tasks with non-differentiable objectives.
- ▶ Systematic Evolution: Builds on successful strategies while still allowing for random exploration.
- ▶ Creative Exploration: Able to explore a wide range of potential solutions.



Navigation icons: back, forward, search, etc.

Creativity: A Paradigm Shift in AI

- ▶ AI is transitioning from **prediction** to **prescription**.
- ▶ Moving beyond imitation to **creating new solutions**.
- ▶ Enabler 1: Availability of massive amounts of data from text, code, images, and more.
- ▶ Enabler 2: Exponential increase in computational power.
- ▶ Examples include generating images, writing prose, and creating new molecules.



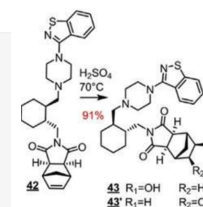
"Infite joy"

Write a recipe for chocolate-chip cookies in the style of Shakespeare.

Hark, fair bakers, lend me thine ears,
For I shall present a recipe that appeases,
A delectable creation, fit for the gods,
Chocolate-chip cookies, amidst baking applause!

Gather ye ingredients, with utmost care,
To commence this culinary affair:
One cup of butter, of the unsalted breed,
Softened, as tender as a lover's creed.

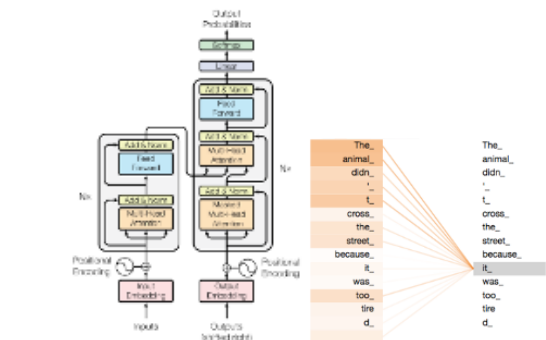
Next: Pan runs of sunar white and sunset



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Large Language Models (LLMs)

- ▶ LLMs scale up neural network training to unprecedented levels.
- ▶ Transformational in encoding general knowledge about the world.
- ▶ Capable of performing a wide range of tasks, often with human-like competence.



RI Tell me a joke about Cognizant.

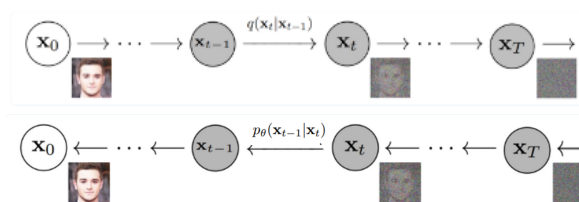
Why did the Cognizant employee bring a ladder to work?

Because they heard there were lots of opportunities for climbing the corporate ladder at Cognizant!

The Transformer Architecture: Navigation icons: back, forward, search, etc.

Image Generation Models

- ▶ Techniques like diffusion models enable AI to generate novel images.
- ▶ Systems learn general principles about the visual world.
- ▶ Extends to video and sound, encoding knowledge about objects, relationships, and styles.



teddy bears working on new AI research on the moon in the 1980s

Navigation icons: back, forward, search, etc.

The Emergence of Decision AI

- ▶ AI now drives decision-making in behavior, design, and strategy.
- ▶ Examples include autonomous agents, optimized designs, and strategic recommendations.
- ▶ Unlike other methods, it is based on **search** rather than pattern recognition.

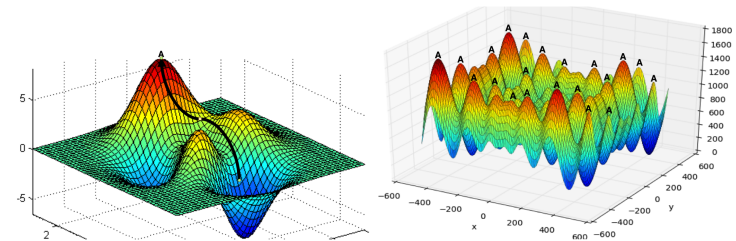


Decision-making AI explores new solutions.

Navigation icons: back, forward, search, etc.

Challenges in Decision AI

- ▶ Traditional methods like reinforcement learning (RL) rely on hill-climbing.
- ▶ This approach limits exploration and creativity.
- ▶ Struggles with high-dimensional, nonlinear, and deceptive search spaces.

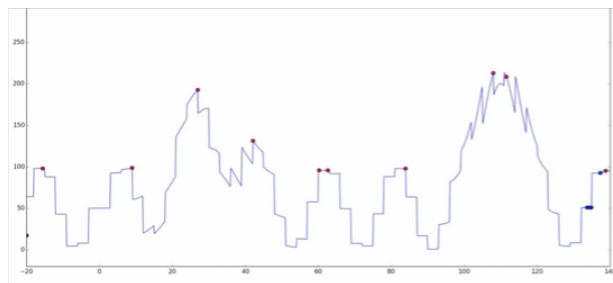


Limitations of hill-climbing in Decision AI.

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Evolution's Role in Creative AI

- ▶ Evolution offers a population-based search approach.
- ▶ Allows for exploration across a wide search space.
- ▶ Combines good solutions through crossover, accelerating discovery.

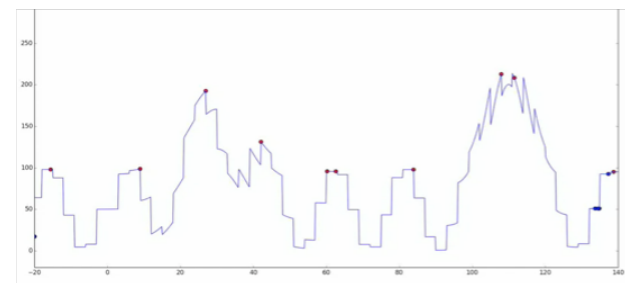


Population-based search.

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Evolution Makes Scale-up Possible

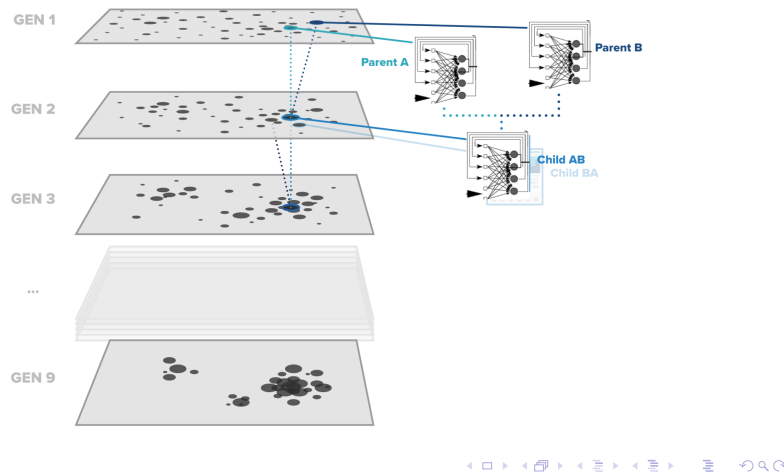
- ▶ In space: solutions to 70-bit multiplexer (2^{70} space)
- ▶ In dimensionality: 1B dimensions possible
- ▶ In complexity: get around deception with novelty and multiobjectivity



Navigation icons: back, forward, search, etc.

Illustration of Population-based Search

- ▶ Population-based search explores diverse solutions.
- ▶ Allocates resources to most promising areas.
- ▶ Discovers multiple alternative solutions



How Does Neuroevolution Improve the World?

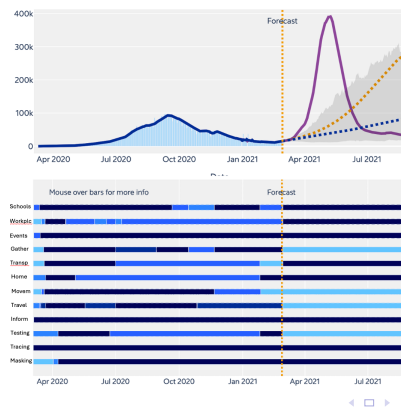
1. Optimizing Intelligent Agents

- ▶ Neuroevolution optimizes behavior for intelligent agents in dynamic environments.
- ▶ Applications:
 - ▶ Control systems for cars, planes, and robots.
 - ▶ Non-player characters in simulated worlds.
 - ▶ Strategies for logistics, manufacturing, and smart cities.



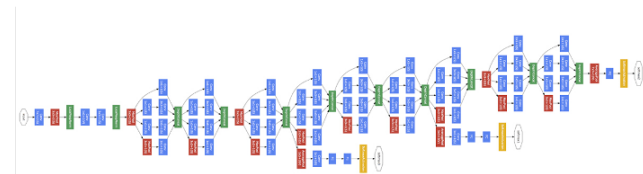
2. Customizing Decision-Making Strategies

- ▶ Neuroevolution discovers tailored solutions for decision-making.
- ▶ Applications:
 - ▶ Personalized wellness and healthcare plans.
 - ▶ Customized marketing and investment strategies.
 - ▶ AI for Good: Pandemic mitigation, climate change strategies, and more.



3. Optimizing Other Learning Methods

- ▶ Neuroevolution optimizes designs for other AI methods.
- ▶ Applications:
 - ▶ Enhancing deep learning, reinforcement learning, and neuromorphic computing.
 - ▶ Evolving architectures and functions for specific tasks and hardware.
 - ▶ Combining multiple datasets to improve learning when data is sparse.



4. Understanding Biological Behavior

- ▶ Neuroevolution provides insight into biological processes.
- ▶ Applications:
 - ▶ Studying the evolution of behaviors like mating, hunting, and communication.
 - ▶ Modeling the emergence of language and intelligence.
 - ▶ Inspiring designs for effective and resource-efficient AI systems.



Conclusion: The Role of Neuroevolution

- ▶ Extending Creativity: Neuroevolution expands the creative potential of AI, enabling the discovery of novel and effective solutions.
- ▶ Solving Complex Problems: It excels in optimizing behavior, decision-making, and learning in dynamic, real-world environments.
- ▶ Bridging Biology and AI: Provides insights into biological processes, offering inspiration for more efficient and robust AI designs.
- ▶ Impact on Society: Neuroevolution has far-reaching applications, from optimizing intelligent systems to solving global challenges like climate change and healthcare.

