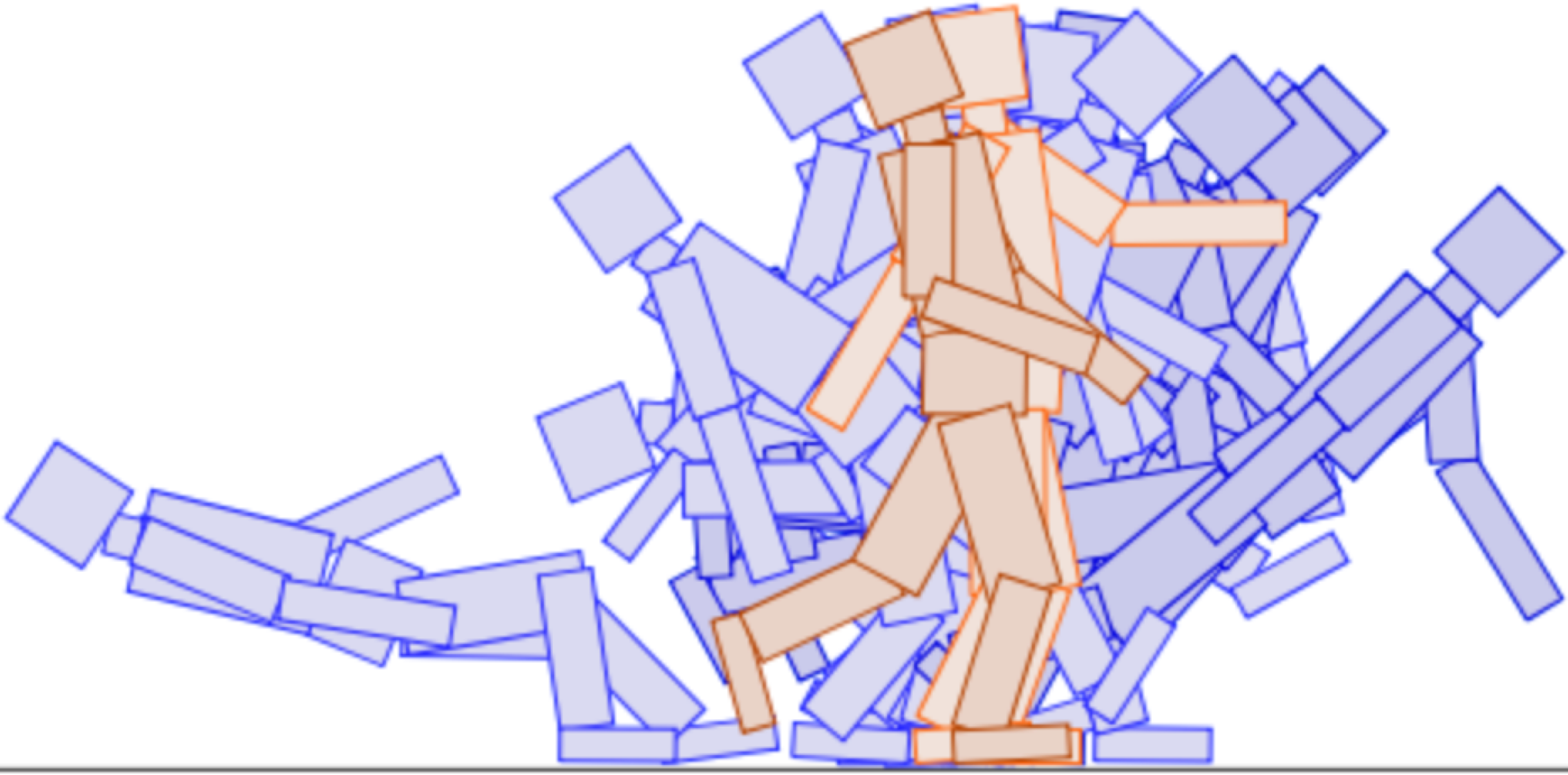


EVOLUTIONARY ALGORITHMS

ECS170 Spring 2018

Josh McCoy, jamccoy@ucdavis.edu

Computational Intelligence

Subfield of AI focused on learning from data or observations.

Consists mainly of:

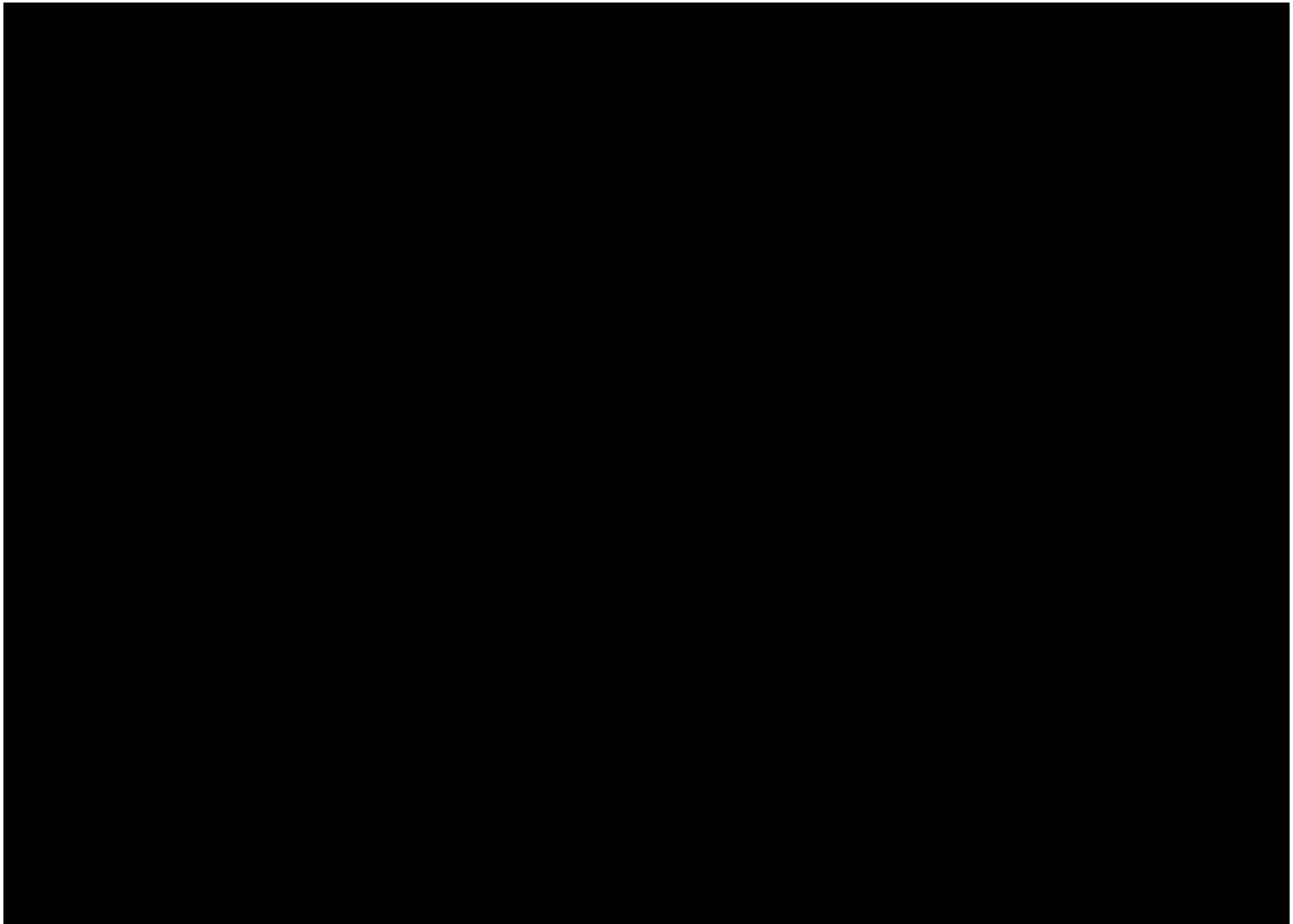
- Evolutionary Computation
- Fuzzy Logic
- Neural Networks
- Probabilistic Reasoning

Evolved Virtual Creatures by Karl Sims

http://karlsims.com/evolved-virtual-creatures.html

Locomotion Studies, 1987

DeepMind's Walker

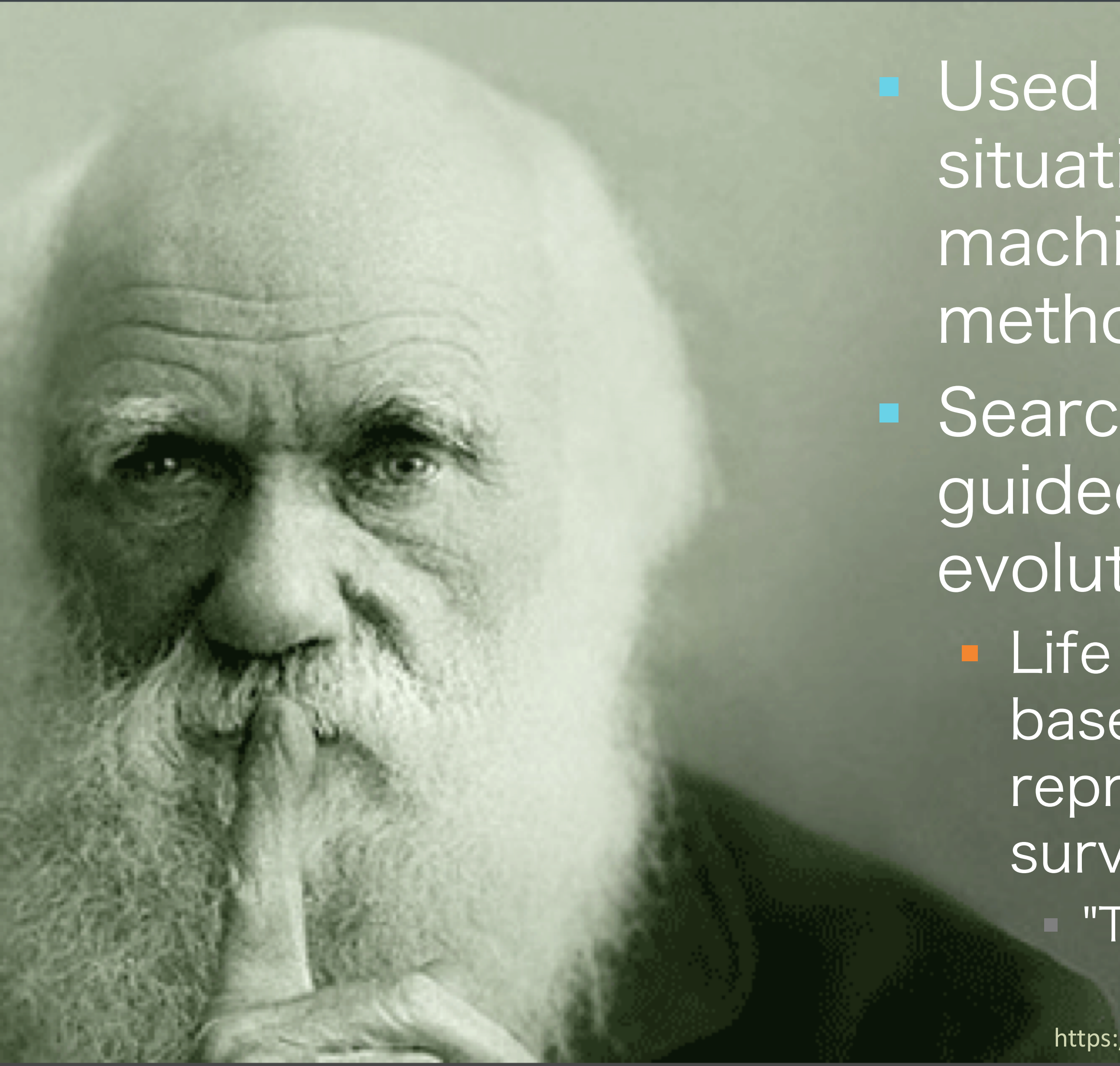


https://deepmind.com/blog/producing-flexible-behaviours-simulated-environments/

An Example

- http://rednuht.org/genetic_walkers/

Search Inspired by Darwinian Evolution



- Used in similar situations as many machine learning methods.
- Search strategy guided by stylized evolution.
  - Life on earth evolved based on reproduction and survival.
    - "The fittest."

https://www.sociology.org/the-ideology-of-darwin/

General Evolutionary System

- 1+ populations of individuals competing for limited resources
- Dynamic population
  - Birth, death, etc.
- Fitness that reflects ability to survive and reproduce
- Variational inheritance
  - Children resemble parents.

Simplifications Over Natural System

- Blurring between genotype and phenotype
- No notion of environment, adulthood, maturation, conditioning, or learning.
- Asexual reproduction only.
- Survival and reproduction combined into a fitness value.
- Population size restrictions.
  - Typically used to enforce limited resources.

Genotype

- Genetic makeup of an individual.
- Genotype and phenotype are blended.
- Vector of genetic values:
  - e.g. <hair color, eye color, height, weight>
- Variation in genetic values makes a genospace.
- Tailored to each problem space.

Fitness Functions

- Assessment of survival, reproduction, etc. based on genotype of an individual.
  - All fitness is known at birth based on genotype.

- Takes an individual i and returns a scalar fitness value.

Genetic Variance/Evo. Change

- Natural selection:
  - the fittest survive in a competitive environment resulting in better organisms
  - individuals with better survival traits generally survive for a longer period of time
  - this provides a better chance for reproducing and passing the successful traits on to offspring
  - over many generations the species improves since better traits will out-number weaker ones

Genetic Variance/Evo. Change

- Crossover (Alteration)
  - the (random) combination of 2 parents's genotypes during reproduction resulting in offspring that have some traits of each parent
  - Crossover requires genetic diversity among the parents to ensure sufficiently varied offspring

Genetic Variance/Evo. Change

- Mutation:
  - the rare occurrence of errors during the process of copying genes resulting in
    - changes that are nonsensical or deadly, producing organisms that can't survive
    - changes that are beneficial, producing "stronger" organisms
    - changes that aren't harmful or beneficial, producing organisms that aren't improved

Generating Initial Population

- How is a diverse initial population generated?
  - uniformly random: generate individuals randomly from a solution space with uniform distribution
  - grid initialization: choose individuals at regular "intervals" from the solution space
  - non-clustering: require individuals to be a predefined "distance" away from those already in the population
  - local optimization: use another technique (e.g. HC) to find initial population of local optima; doesn't ensure diversity but guarantees solution to be no worse than the local optima

The EV Algorithm

- Switch to reading.

Genetic Algorithm (GA)

```
GA:

Randomly generate a population of m parents.

Repeat:
    Compute and save the fitness u(i) for each individual i
       in the current parent population.

    Define selection probabilities p(i) for each parent i
       so that p(i) is proportional to u(i).

    Generate m offspring by probabilistically selecting
       parents to produce offspring.

    Select only the offspring to survive.

    End Repeat
```

Fitness-Biased Selection

- Which selection algorithms have a better chance of finding a maximally fit genotype?
  - x_* - genotype with unique and maximal fitness

- With a finite population model, selection algorithms typically converge to a fixed point that is usually not x_*.

Truncation Selection

- Strongest/most elitist.
- k most fit individuals from population.
  - No further sub-selection.
- Rapid convergence.
- If population is finite, likely to converge on non-optimal fixed points.

Rank-Proportional Selection

- All members of the population are ranked by fitness.
- Each has a chance of being chosen for reproduction.
- Each genotype in the population is assigned a probability based on rank.
  - i is the rank, ϵ controls slope of linear probability distribution, and m is the population size.

$$prob(i) = \left(\frac{2}{m} - \epsilon\right) - \left(\frac{2}{m} - 2\epsilon\right) * \frac{i-1}{m-1}$$

- Slower logistics-like convergence.
- Explores more space and more optima.

Tournament Selection

- Sorting is expensive.
- Uniformly pick q individuals, highest fitness wins.
- Best fitness in population may not be chosen.
- Same convergence time as some rank-proportional selection (e.g. $\epsilon = 1/m^2$).
- $O(n)$

Parameterizing Your EA

- How to choose and parameterize crossover and mutation?
- How to chose a selection mechanism?
- There is no best representation for all cases.
  - Instead, experiment to find the best exploration/exploitation values for your problem.
  - In general, balance out exploration in reproduction with selection:
    - e.g. high rates of mutation paired with strong selection or low rates of mutation with crossover paired with weaker selection.

EA	m	n	parent_sel	survival_sel	mutate	crossover	repres
EP	< 20	$n = m$	uniform	truncation	yes	no	pheno
ES	< 10	$n >= m$	uniform	truncation	yes	no	pheno
GA	> 20	$n = m$	fitness-prop	uniform	yes	yes	geno

Table 4.3: Characterization of traditional EAs.

Fitness-Proportional Selection

- Selection pressures so far: strong (truncation) to moderate (tournament) to weak (linear ranking).
- Stuck with just one? Can we adapt?
- Yes with $p(i) = fitness(i)/total\_fitness(t)$
  - Individual i at generation t.
- Convergence is higher when an individual is more fit than the rest of the population.
- Homogenous populations, pressure approaches uniform.

- https://github.com/formikaio/HTML5-Genetic-3-wheelers
- http://francisshanahan.com/tsa/tsaGAworkers.htm
- https://blog.sicara.com/getting-started-genetic-algorithms-python-tutorial-81ffa1dd72f9
  - Intro via knapsack problem.
- Galactic Arms Race
  - https://www.youtube.com/watch?v=N8q2uOwWcFc
- https://cie.acm.org/articles/use-interactive-genetic-algorithms-sound-design-comparison-study/