CT421 Artificial Intelligence - Search

Landscapes

Landscapes

- A visualisation of the relationship between genotype and fitness
- Can give an insight into the complexity of the problem at hand.
- Landscapes can be adaptive.

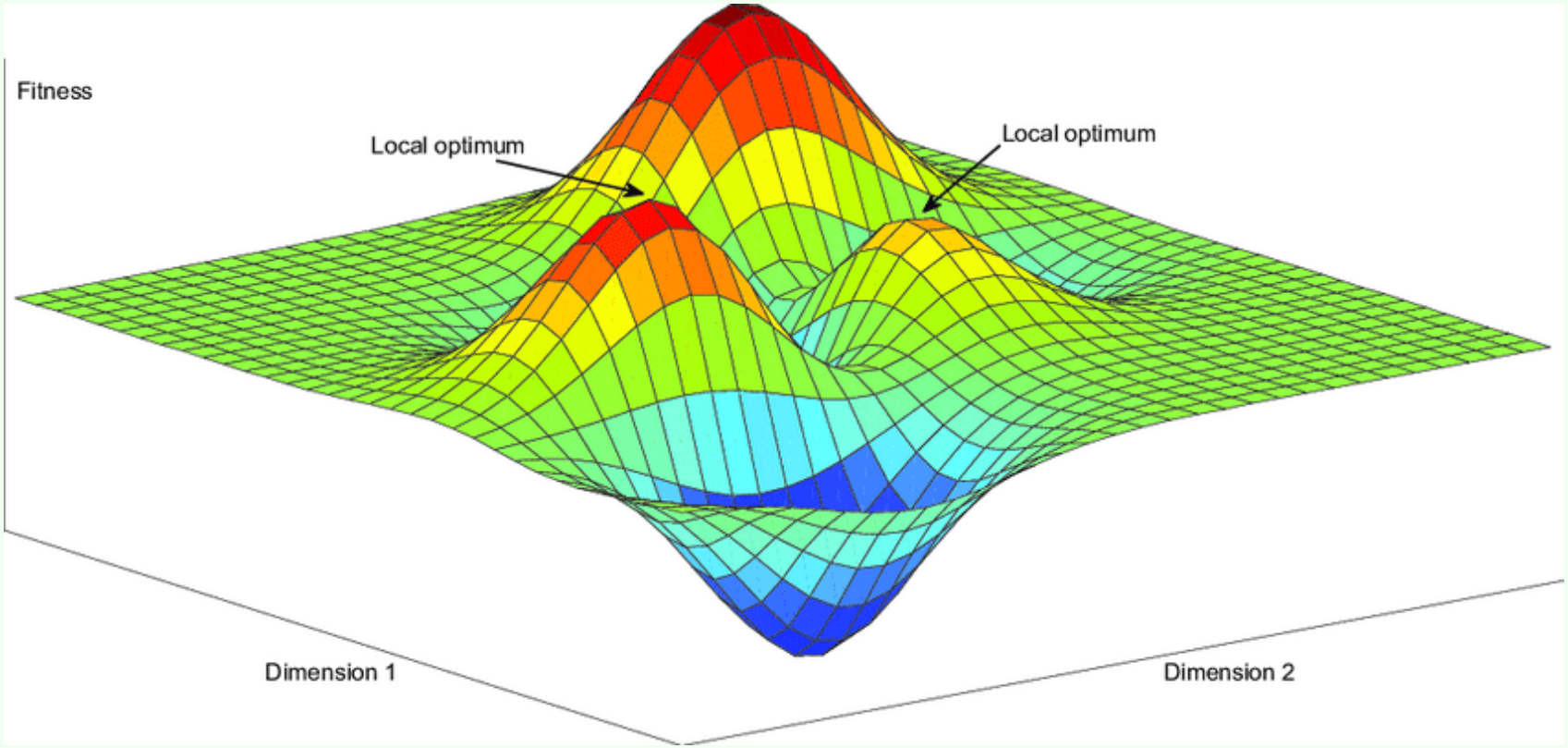
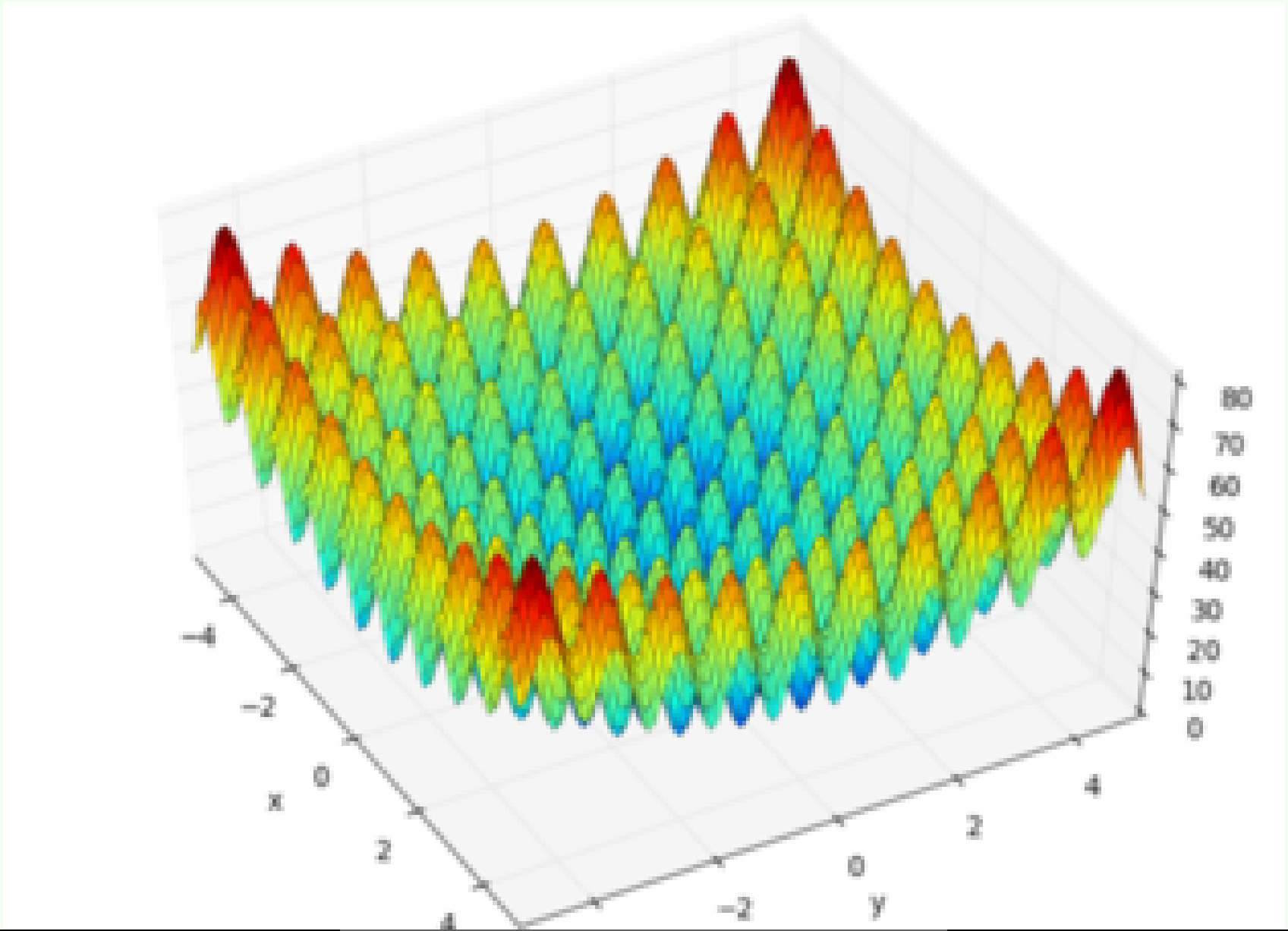


Figure: Fitness Landscape - T. Nygaard (c)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Landscapes

- The peaks on the landscape represent high fitness and hence the ability of the genotype to survive
- The valleys or troughs indicate low fitness

NK Fitness Landscapes

- Stuart Kaufmann (1993) in his text Origins of Order
- A model of genetic interactions
- Developed to explain and explore the effects of local features on the ruggedness of a fitness landscape
- Ruggedness plays a key roles in ascertaining how difficult it is to find the global optimum
- NK landscapes allow us to tune the ruggedness

NK Fitness Landscapes

- Each component (gene) of the solution space makes a contribution to the fitness
- The contribution to the landscape depends on the value of that gene itself but also the state of K other nodes
- The value of K can be changed to give different landscapes.
- If K=0, all genes are independent and this is typically a smooth multi-modal landscape
- As K increases, the landscape becomes more rugged

NK Fitness Landscapes - an approach

- Use a lookup table; the size of the table is 2^K
- Each row in the lookup table represents the neighbourhood values and the fitness achieved

NK Fitness Landscapes - Variations

- The size of the interactions doesn't have to be uniform
- The genes influencing each other's fitness do not have to be adjacent

Fitness Landscapes - others

- Can you define others?
- For well known problems - how can we visualise landscape?

Fitness Landscapes - Fitness clouds

- Randomly sample the population
- Generate k mutated versions of the sampled genotypes
- Measure their fitness
- Plots the fitnesses overtime - gives insight into the landscape

On Objective/Fitness functions

- Usually specify the objective in a function - something we are trying to minimise/maximise or some constraint we are hoping to satisfy
- Can be very difficult - sometimes we don't know how to specify the function
- fitness function can be costly to evaluate.

Issues arise

- "Most ambitious objectives don't illuminate a path to themselves"
- "Many great discoveries are not the result of objective-driven search."
- "Natural evolution innovates through an open ended process that lacks a final objective."
- "Searching for a fixed objective – dominant paradigm in EC and ML, may ultimately limit what can be achieved."

Issues arise

- The more ambitious the objective fitness function, the less likely it is that evolution will solve it.
- Two big issues with fitness landscapes:
  - neutral plains
  - and ruggedness
- both can be attributed, at least in part, to the fitness function.

Diversity

- It is important to maintain diversity in the population.
- Once a population converges on local optima it can be difficult to introduce sufficient diversity to climb out of local optima
- Many approaches have been proposed to maintain diversity.

Hypermutation

- If the diversity decreases, then big increase in mutation levels of existing solutions in the hope of introducing novelty
- Need a measure of diversity?

Hypermutation

- If the diversity decreases, then big increase in mutation levels of existing solutions in the hope of introducing novelty
- Need a measure of diversity?
- Diversity can be measured at genotypic, phenotypic or fitness levels

Co-evolution

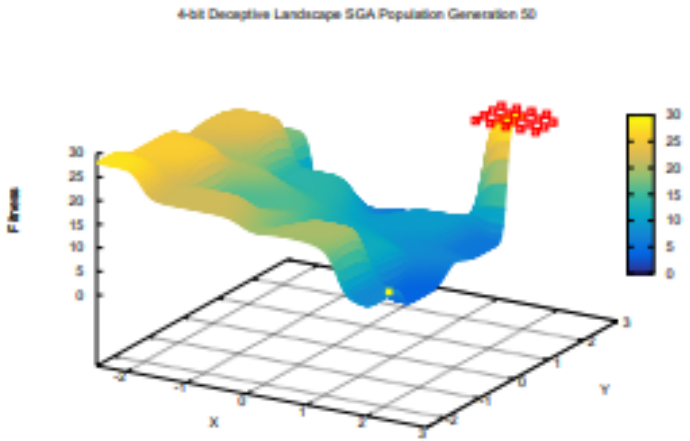
- Often used as a means to help diversity
- Interactions between individuals contribute to the fitness
- Goal is that a form of competition will lead to better performance

Alternate representations

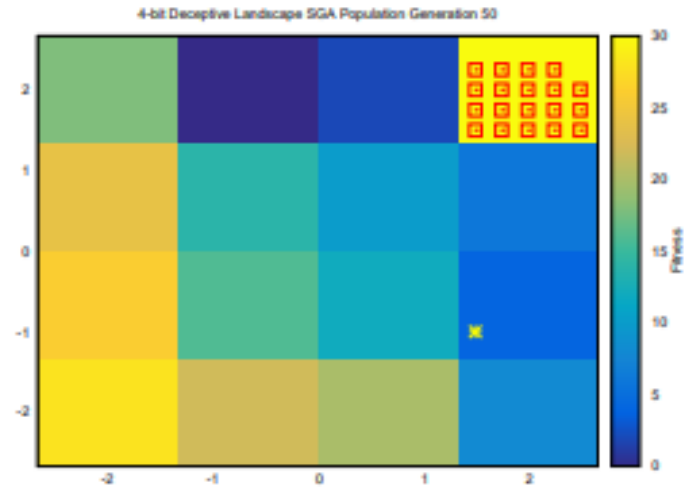
- Build redundancy into the representation; this can allow greater diversity in the representation
- Multi-layered GA
- Diploid representations
- Island models for the GA

Alternate representations

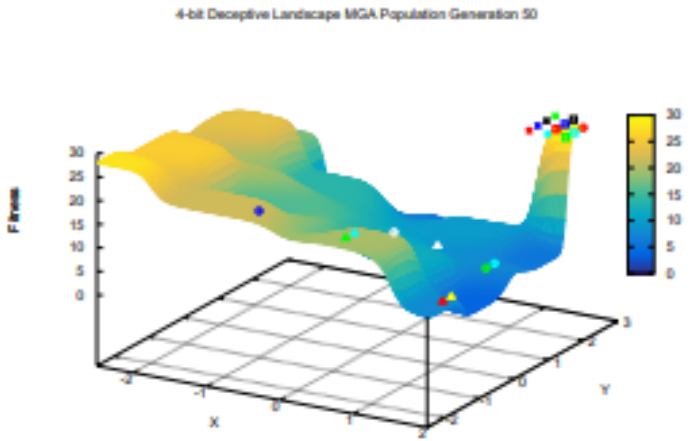
- Multi-layered GA: add an extra layer(s) between the genotype and the phenotype. The structure allows multiple genotypes to map to a phenotype. This can allow multiple mutations to occur which aren't immediately represented in the phenotype. Maintains increased diversity.
- Diploid representations: Represent each chromosome by two genetic sequences; one of these is subject to evolutionary pressures. The other follows a random walk. Periodically, a small percentage of chromosomes swap their sequences.
- Island models for the GA: partition the population of solutions into sub-groups. Each subgroup/population evolves separately. Periodically some solutions are swapped among the separate populations.



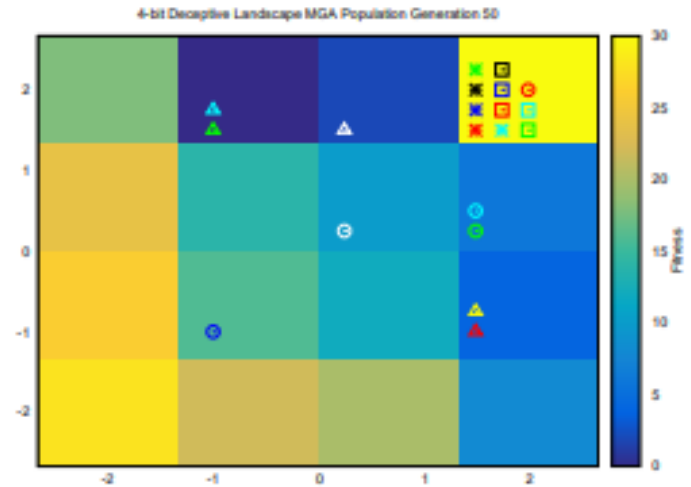
(a) SGA Population Generation 50



(b) SGA Heat Map Generation 50



(c) MGA Population Generation 50



(d) MGA Heat Map Generation 50

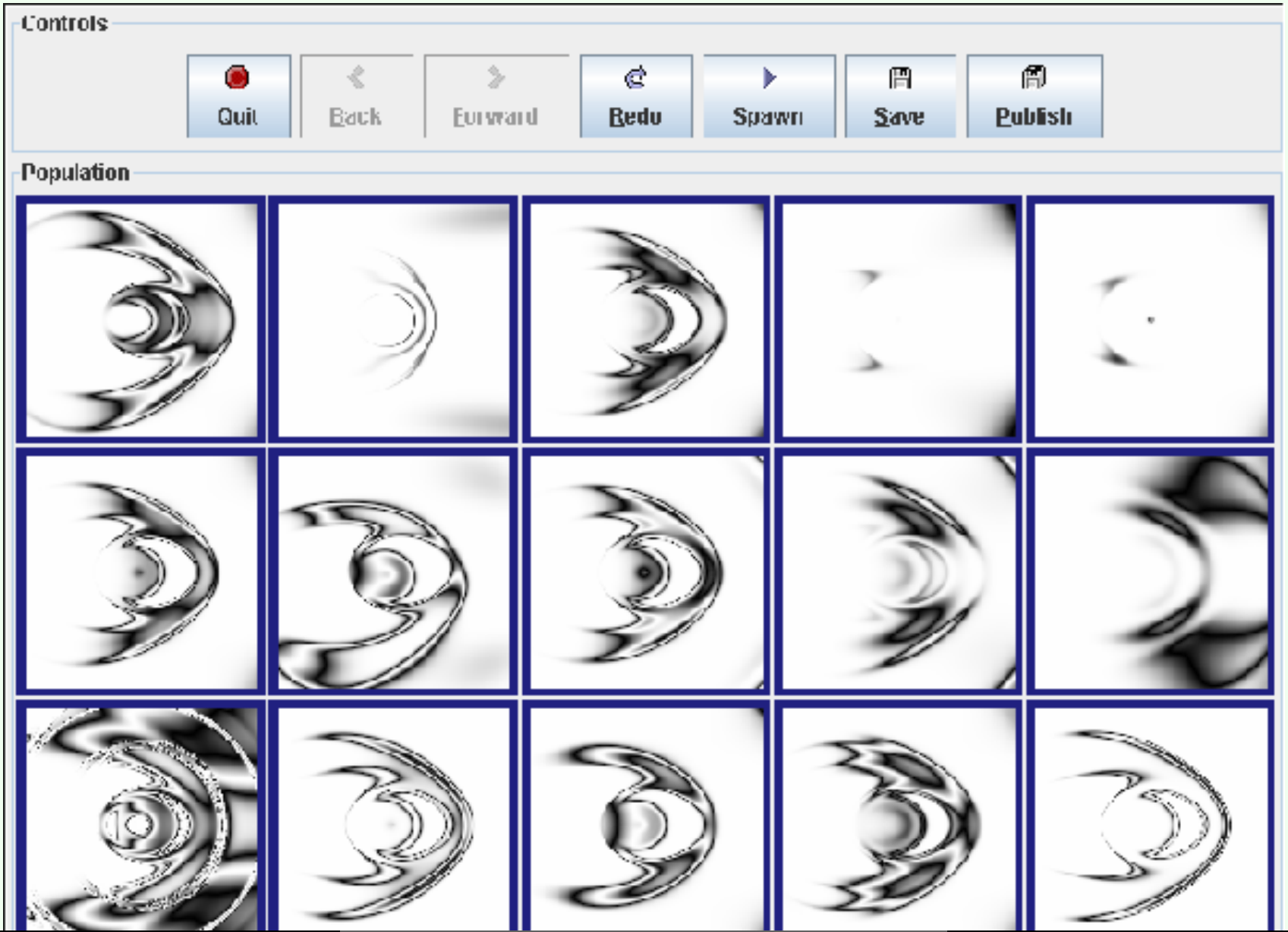
Self adaption

- Several approaches have attempted to make the rates of mutation and crossover subject to evolution itself
- For example, add a gene to each chromosome which represents the rate at which mutation should be applied to that chromosome/solution
- The goal is that the evolutionary process itself will find a suitable mutation rate

Novelty Search

Novelty Search

- "Why greatness can't be planned: the myth of the objective function" - K. Stanley and J. Lehman
- Originated with work on the Picbreeder project (picbreeder.org)
- Central thesis is that by solely evolving according towards an objective function, we decrease creativity, novelty and innovation.
- Argues that this is because many objective functions are deceptive
- Argues that we should instead reward solutions (or sub-solutions) are are unique and phenotypically/behaviourally novel.
- Successfully applied in a range of domains including the evolution of movement for robots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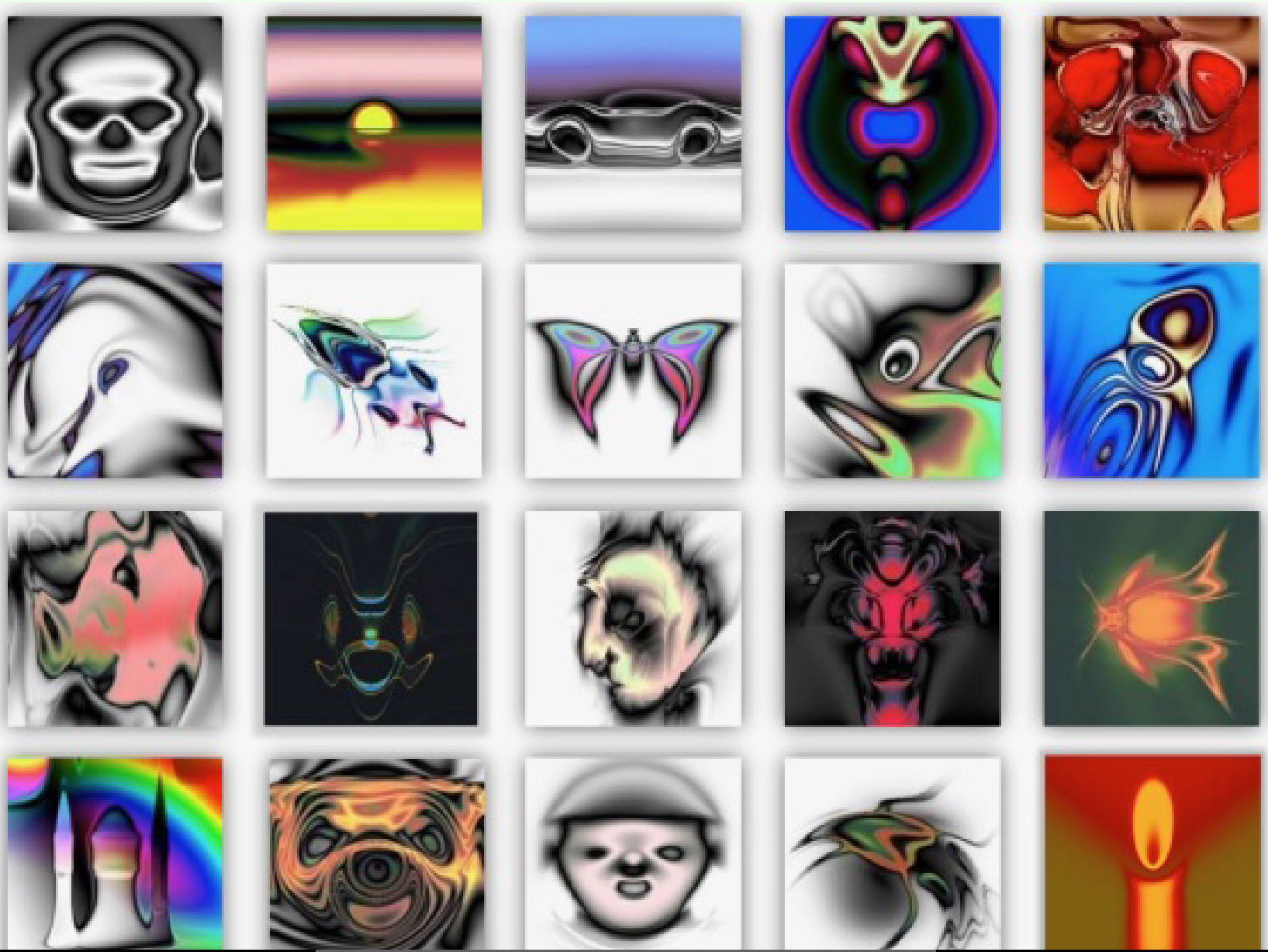

Novelty Search

- Domains? Applications?

Novelty Search

- Domains? Applications?
- In many domains, novelty search has out performed searching directly for an objective.

Novelty Search - how?

- Standard approach involves maintaining an archive of previously found novel solutions
- To decide: size of archive, similarity measure, balance between novelty and fitness?

Further concepts

- Combining more forms of learning
- Neuro-evolution