Application of evolutionary algorithms to solve complex problems in quantitative genetics and bioinformatics

7. Managing constraints

Those that trespass will be penalized. Or otherwise fixed up.

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Simple logic constraints: examples

- The number of mates to allocate to a bull should not be negative.
- The amount of feed to offer an animal should not be negative.
- The date to wean should not be before birth date.
- A natural mating bull can be used on a maximum of one farm at a time.

Stakeholder applied constraints: examples

- Maximum breeding herd size should be 200 females mated.
- The maximum acceptable coancestry among parents in this mating round is 0.1.
- The maximum number of individuals in a group for pooled tissue quantitative genotyping is ten.
- The maximum permissible number of genetic marker mismatches per animal (various applications …)

Ask your self: Do I need this constraint?

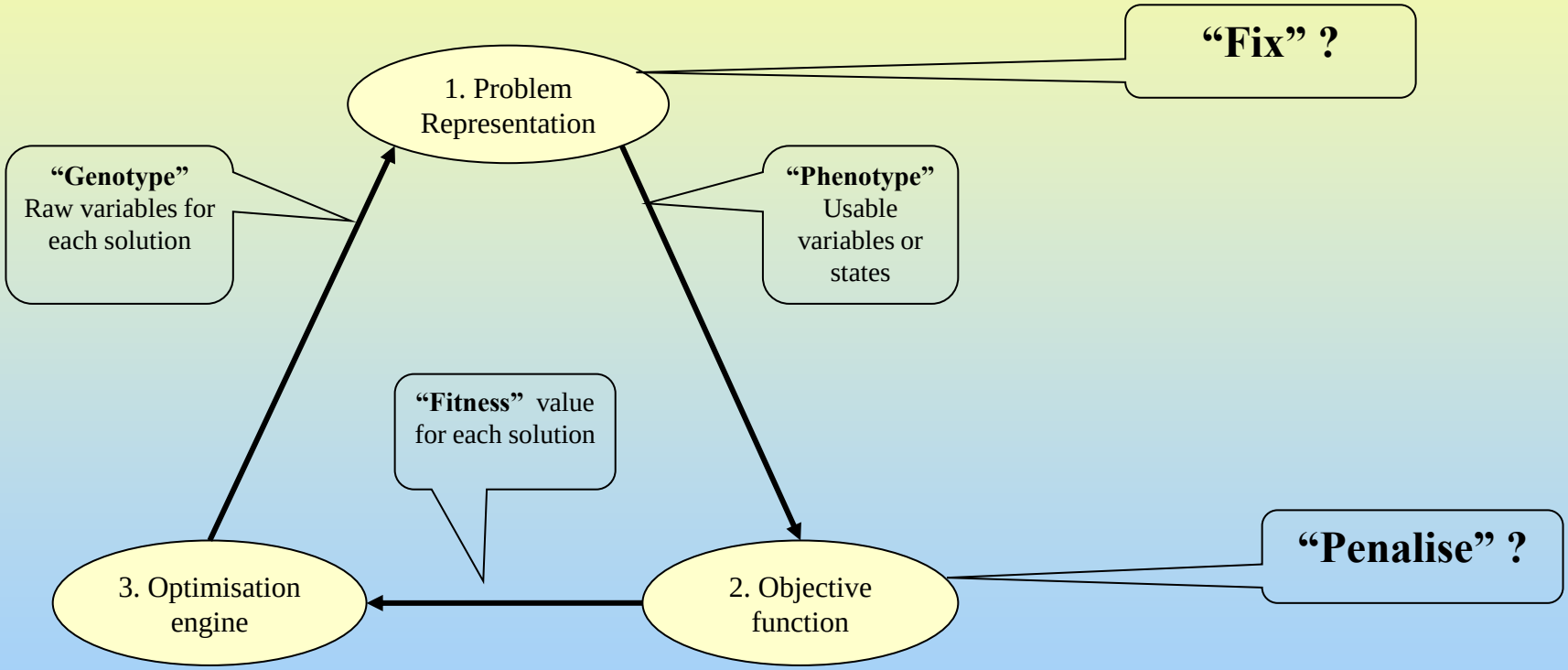
- Constraints often requested because of preconceived ideas about the optimal solution.
- This prevents the computer from “thinking outside the box”!
- You might get a surprise and discover an unusual solution ... (see “Let your computer make you famous.” in Chapter 1).
- Investigate the impact of removing constraints that are not needed to give a feasible solution.
- If these constraints were well-founded, then the optimal solution should not break them.

How to apply a constraint

Penalise: Apply penalty in the objective function to solutions that break constraints. The penalty should be sufficiently large to prevent the optimal solution being one that breaks the constraint.

Fix: If the constraint is on the variables passed to the objective function, you can choose to change these appropriately before passing them to the objective function.

Application of constraints



Simple Fix – make boundaries

- Simple fix is to set bounds for variables, as in DE_Demo

```
For j = 1 To loci
    If allele(j) < MinVal(j) Then allele(j) = MinVal(j)
    If allele(j) > MaxVal(j) Then allele(j) = MaxVal(j)
Next
```

- … before allele() gets evaluated in the Criterion subroutine. Setting values exactly to the boundaries is simple but not the best strategy.
- See “Assigning animals into groups” in Chapter 6.

Fix: Dealing cards

			Female →	1	2	3	4 …
Male↓	**No of uses**	Ranking criterion	Rank	1	0	1	1
1	2	**5.32** **2.16**	**2** **3**			✓	✓
2	0	-	-				
3…	1	**7.64**	**1**	✓			

Fixing up: comments

- "Fixing up" is the better strategy for most "logical" constraints. Fix them up before going to the objective function.
- Store the solution in its fixed state, especially if the fixing process is stochastic.
  - Misleading in notes: "However, you must do this in a repeatable manner. If two solutions have exactly the same "unfixed" set of parameters, they should have the same "fixed" set of parameters" … Not needed if store population member in the fixed state.
- Some danger that the strategy you use prevents good exploration of the solution space.
  - Preferably do not "Fix" parameters to the same sort of region, for example at the boundaries of constraints.

Penalising fitness

- "The big advantage of the "Penalise" strategy is that it so easy to apply…

```
If (ConstraintBroken) fitness = fitness – 999999
```

… that should cure the problem!

- Penalisation is easy to implement, but it makes for much slower convergence if most solutions are illegal.

Penalising: Hard constraints and Soft constraints

- In some such cases all solutions break one or more constraints in the first generation(s) of optimization.
- So, apply “softer” penalties – so that the optimization engine can give reward to solutions that break fewer constraints.
- Eventually it finds solutions that break no constraints.
- You might have to play with constraint penalties to help a complex optimization to “get off the ground”.
- A ‘hard constraint’ would allocate the smallest possible fitness. That is rarely needed ...

Penalising: Hard constraints and Soft constraints

- A hard constraint:

```
If (Para > ParaConstraint) fitness = minus infinity
```

- A softer constraint:

```
If (Para > ParaConstraint) fitness = -999
```

- A soft constraint with reward:

```
If (Para > ParaConstraint) fitness = fitness – 99*(Para – ParaConstraint)
```


The End