16th ICCRTS
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Game Theory, Adaptation, and Genetic Programming: Some Perspectives on Operations Research for Counter-IED

Paper 055

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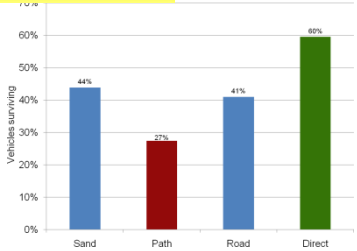
The IED Problem

photo from www.army.mil

Overview of this talk

A simple simulation model



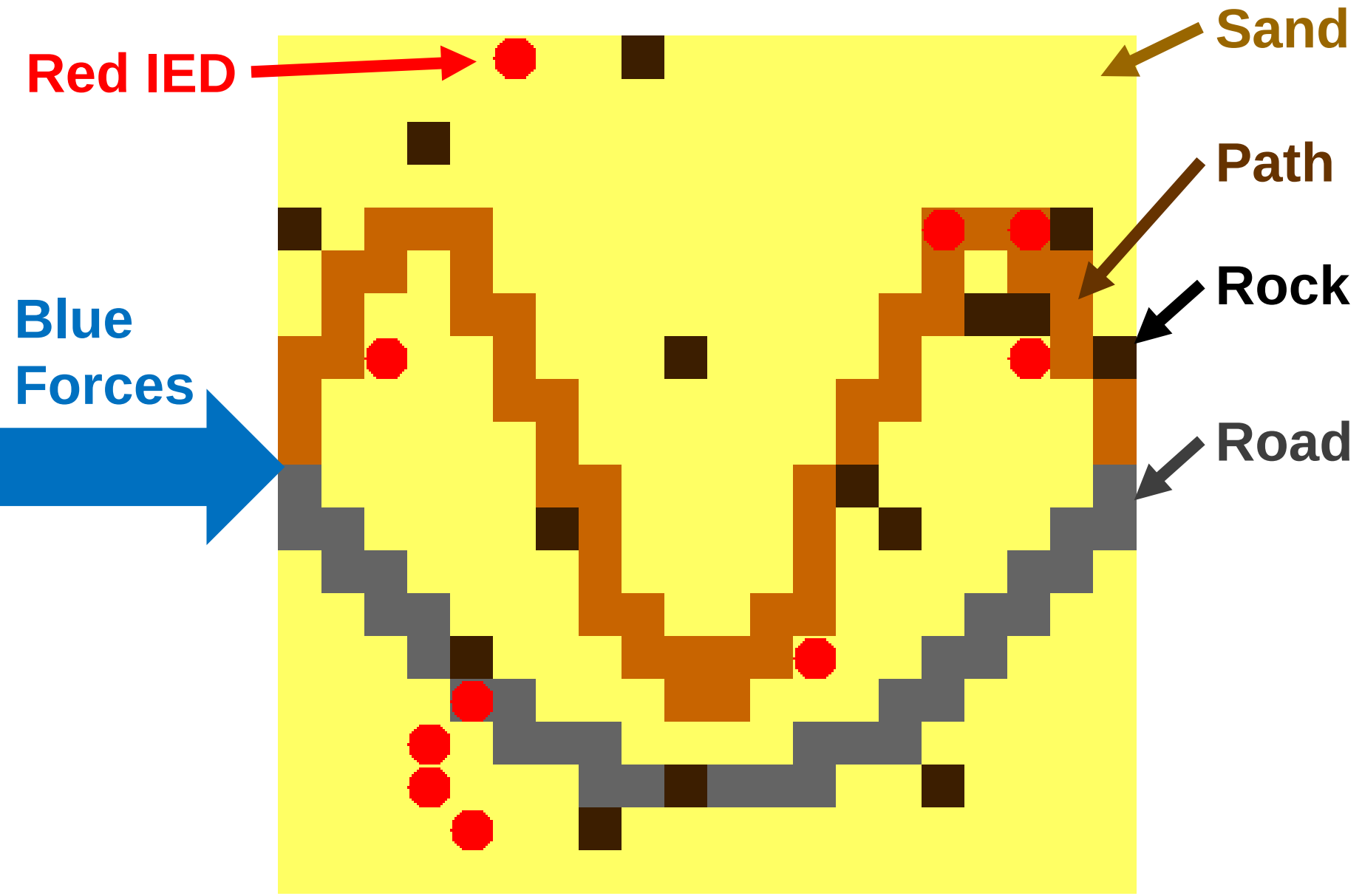
Simple optimisation

Game theory

Adaptation

Genetic programming

A simple simulation model



Blue & Red options in real life

Blue

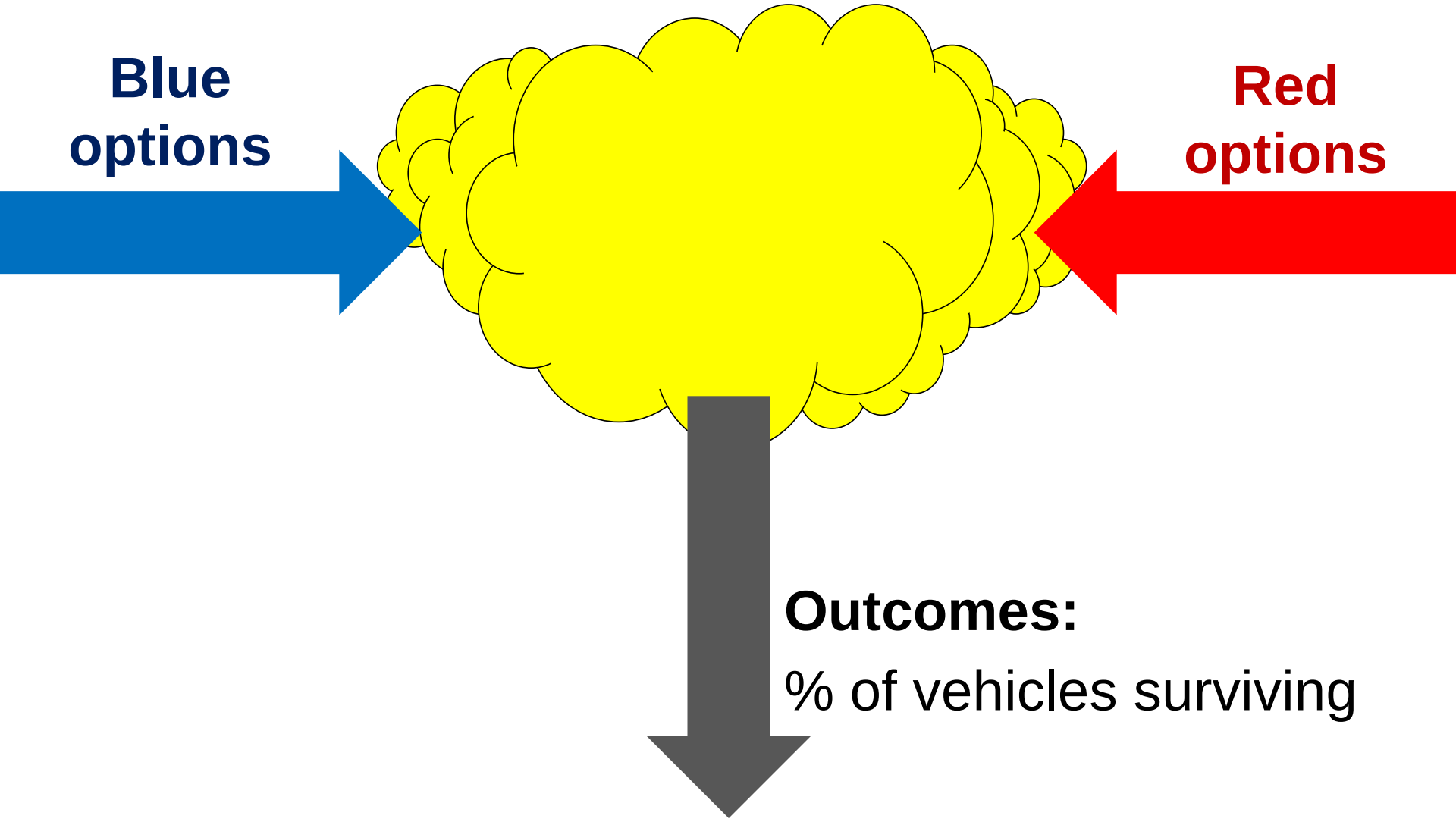
- **IED detection**
- **IED countermeasures**
- **IED-resistant vehicles**
- **IED disposal techniques**
- **Route planning**
- **SOPs**
- **Counterinsurgency (COIN)**

Red

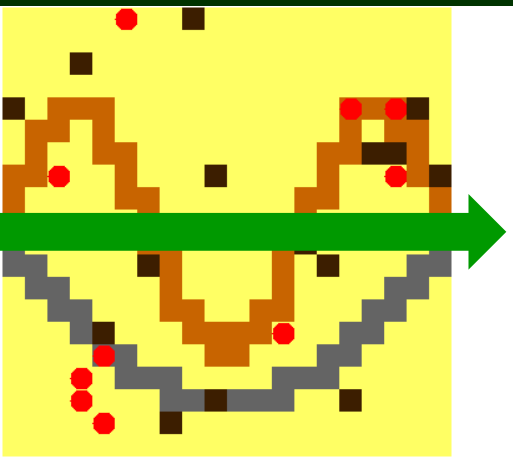
- **IED type** (buried, EFP, etc.),
- **Triggering device** (radio, wire, phone, pressure plate, IR, etc.)
- **Placement options**
- **Camouflage options**
- **Decoy devices**.

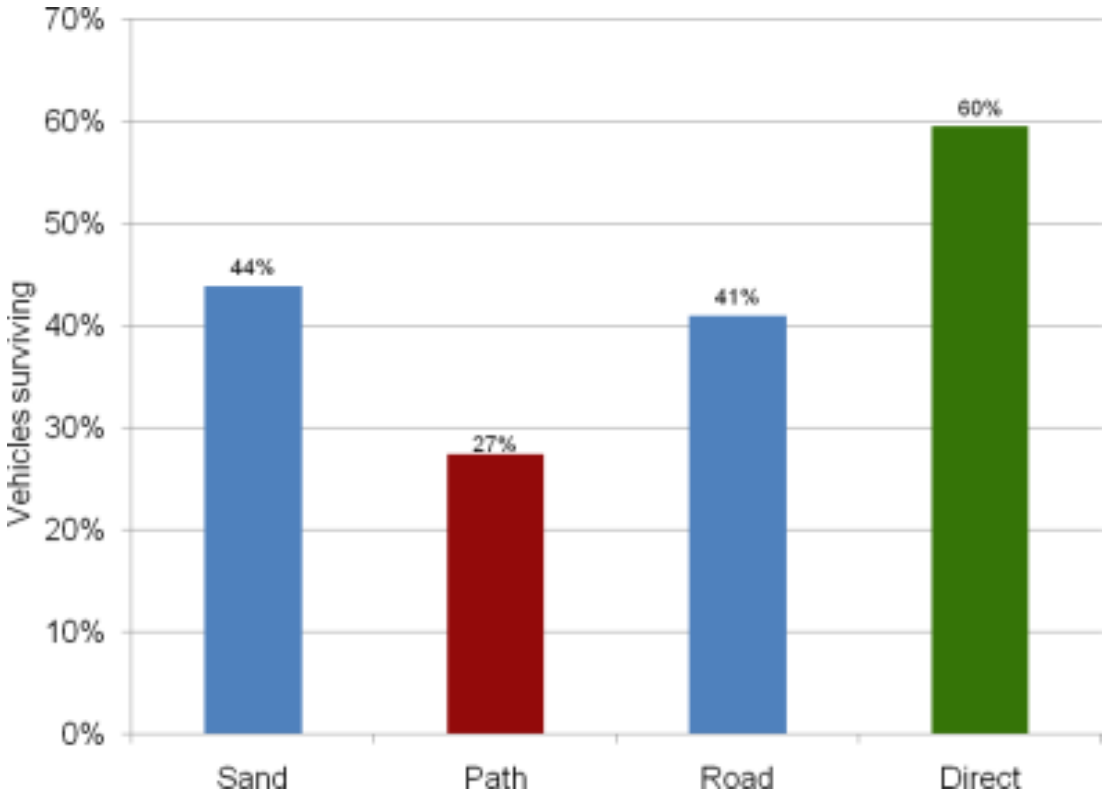
photos from www.army.mil & www.defenselink.mil

In both the simulation & real life …



Simple optimisation





Assume a fixed Red strategy (random)

Construct a "fitness landscape" of Blue options

The peak is the best option (direct route)

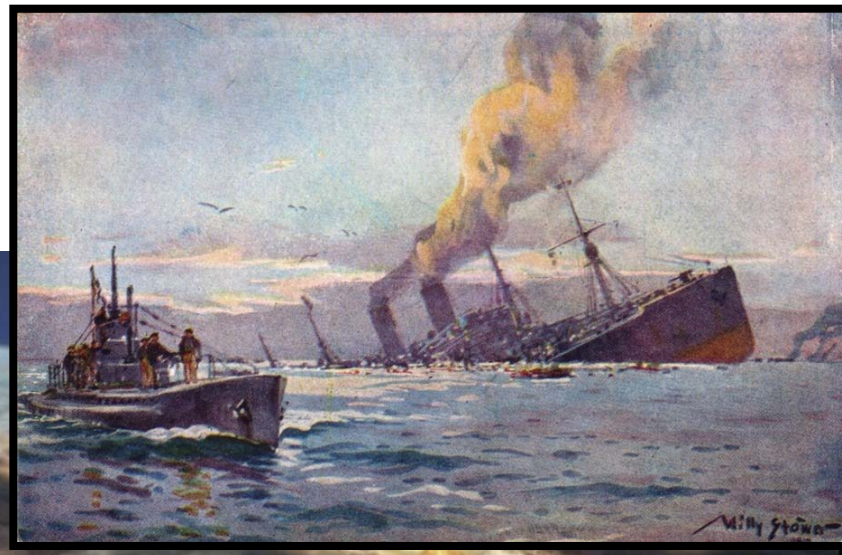
Limitations of simple optimisation

Assumes a fixed Red strategy, but IEDs are **improvised**.

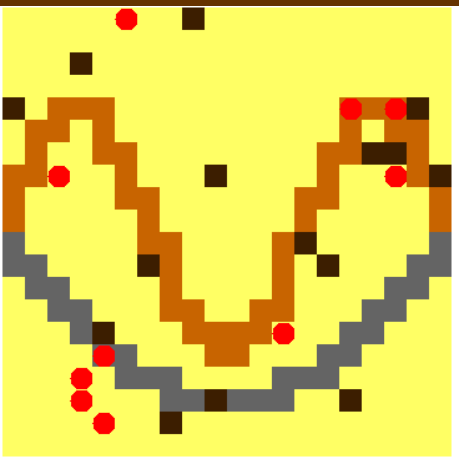
Ignores Red's **mind** – Red **chooses** a strategy.

Game theory – taking Red's mind into account

Has been used for anti-submarine warfare, cold-war strategy, etc.

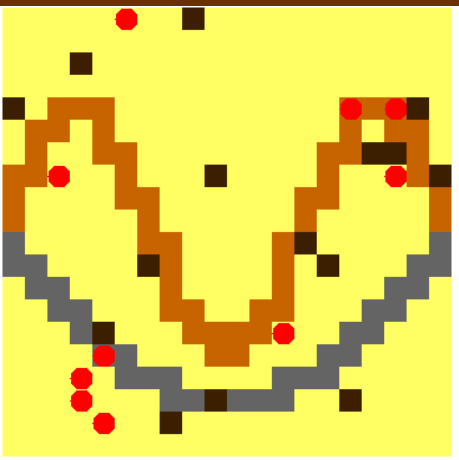


Game theory uses a matrix of options & outcomes



Red Options \ Blue Options	Sand	Path	Road	Direct
Sand	37%	87%	93%	63%
Path	70%	0%	94%	41%
Road	66%	65%	1%	49%
Rock	81%	54%	66%	59%
Central	26%	10%	94%	19%
Random	44%	27%	41%	60%

Textbook methods exist for “solving” the matrix



The result is two “pessimistic” probability distributions over options

45% getting through is the best each side can hope for

Red Options & probabilities	Blue Options & probabilities: **Sand** 0.58	**Road** 0.29	**Direct** 0.12
Road 0.28	66%	1%	49%
Central 0.29	26%	94%	19%
Random 0.44	44%	41%	60%

Limitations of “textbook” game theory

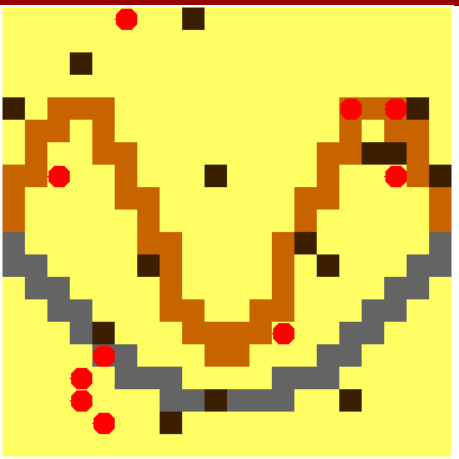
For the IED problem, **the table is not fully known**, and is constantly changing as well.

“Standard” game theory is “single-shot.” **The IED problem is an iterated game, where both sides adapt**, but neither side can do so instantly – buying equipment & changing SOPs takes time.

Counterinsurgency (COIN) is a nonzero-sum game – the desired solution is a “win-win” where insurgents stop placing IEDs, and counter-IED tactics should take COIN into account

Adaptation ...

… using the table options

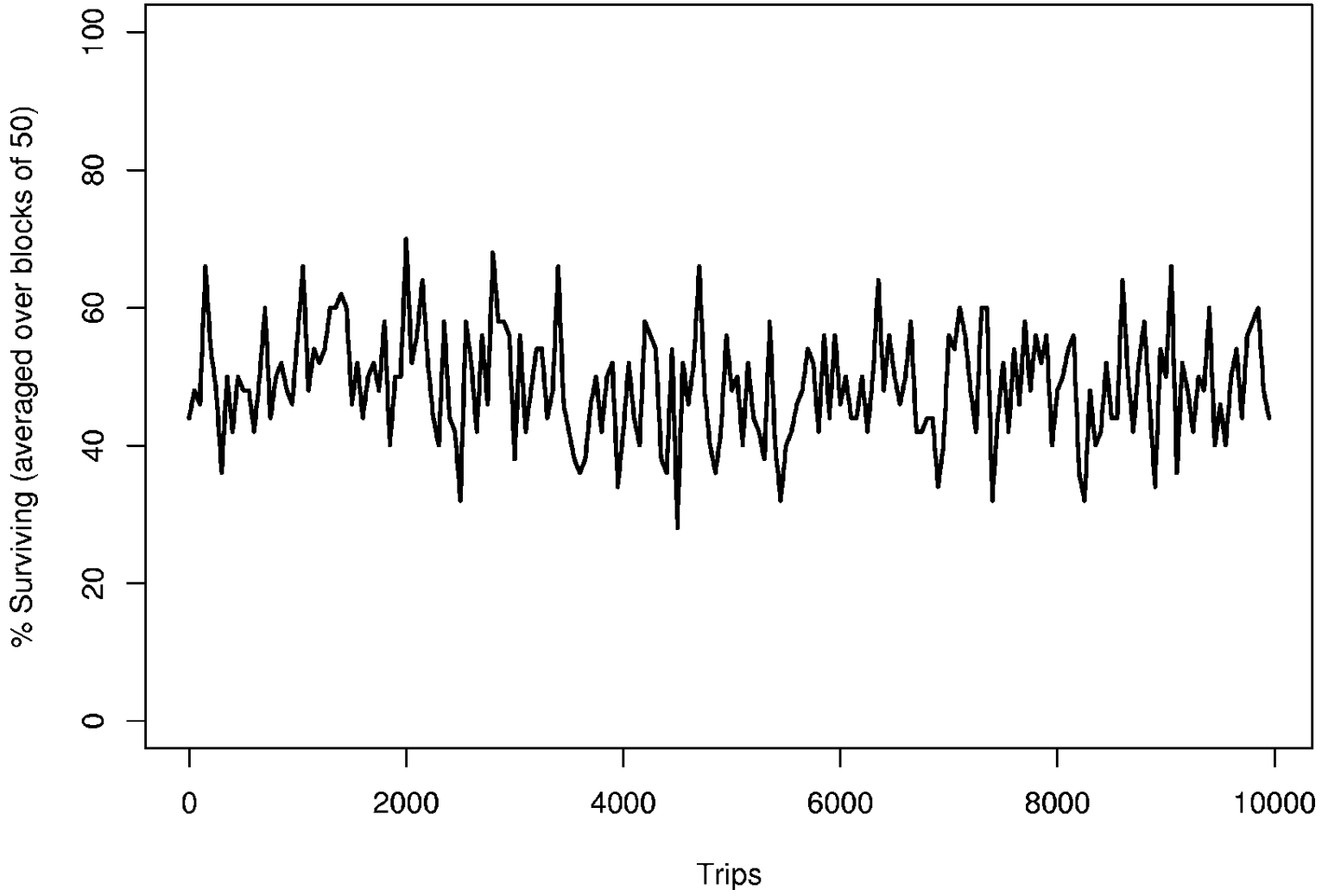


Blue Options

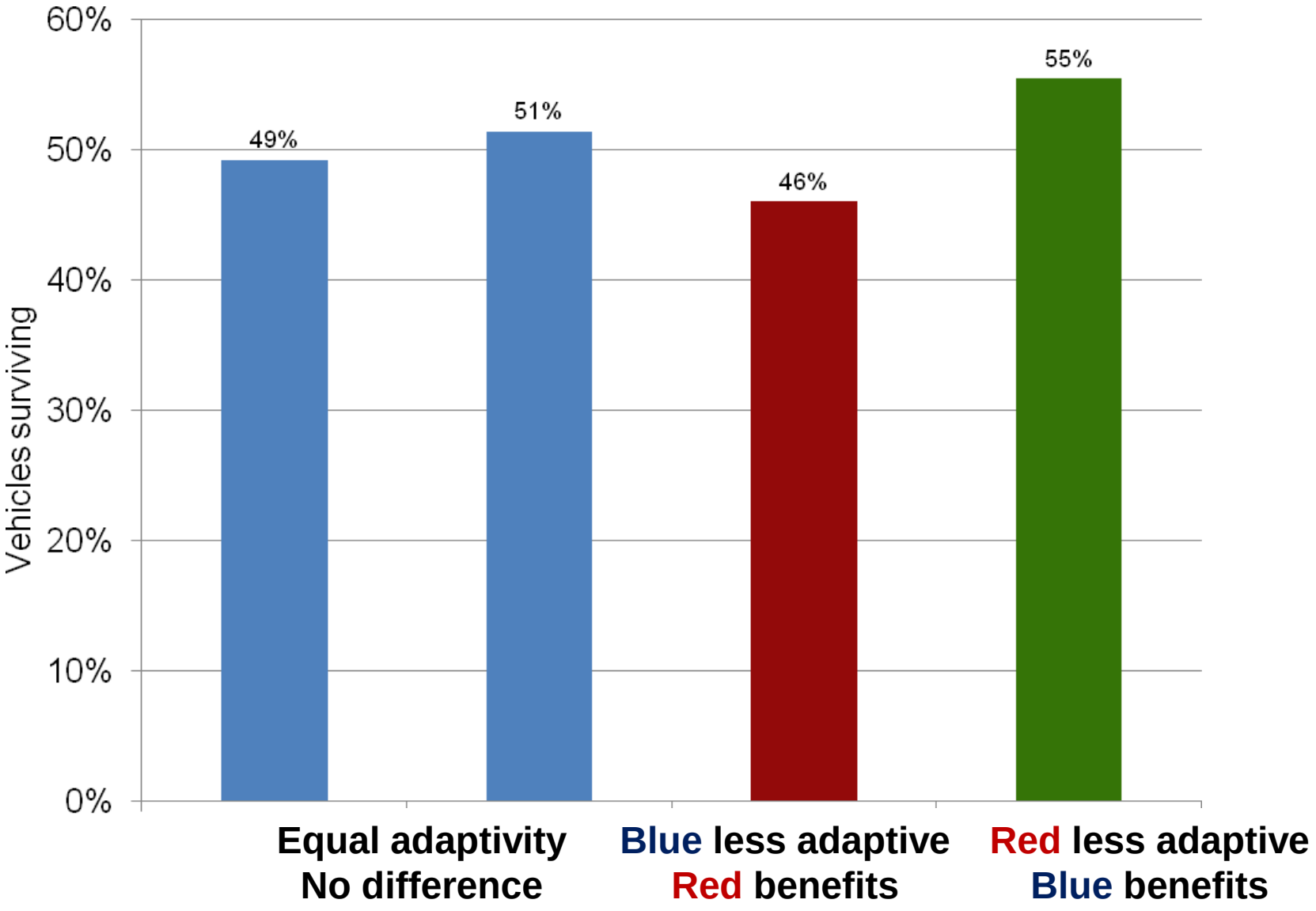
Red Options	Sand	Path	Road	Direct
Sand				
Path				
Road				
Rock				
Central				
Random				

Each side keeps track of how well their options are currently doing, and prioritises the ones that are doing well

Performance oscillates, as one or other side gets ahead



Crippling one side (delayed learning) benefits the other

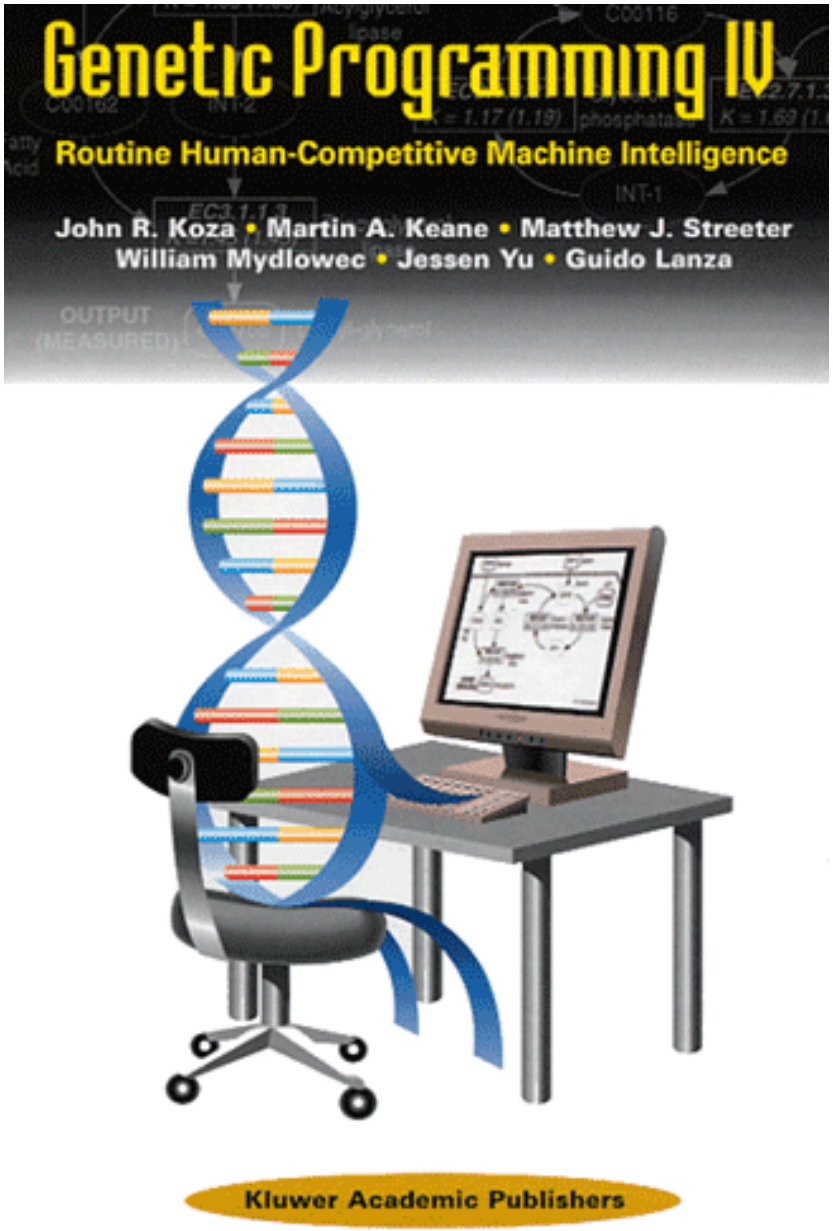


Limitations of this approach

Ad-hoc learning mechanism – doesn't easily generalise to more complex problems.

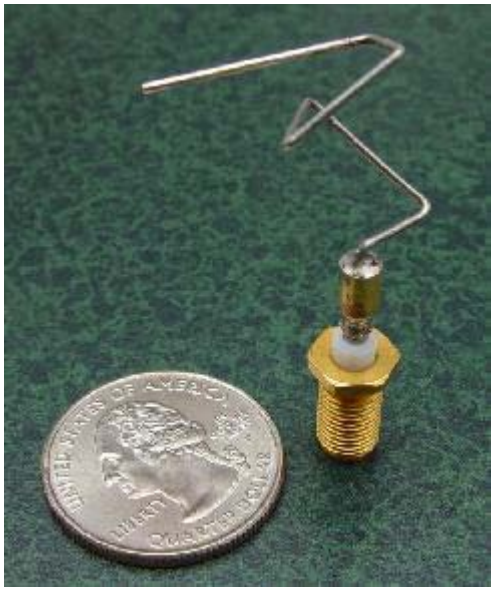
Doesn't allow for innovation.

Genetic programming CAN produce innovation

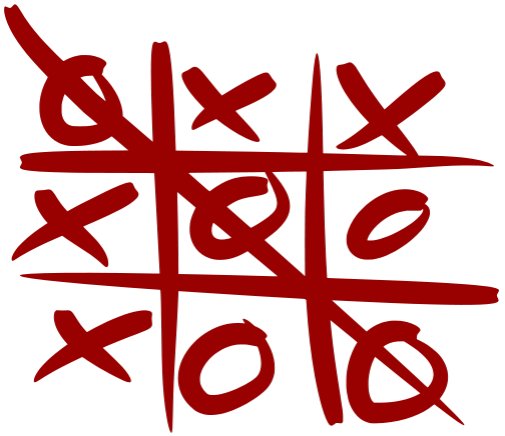


Genetic programming (GP) has been used for …

Simulation of cooperative hunting strategies in lions

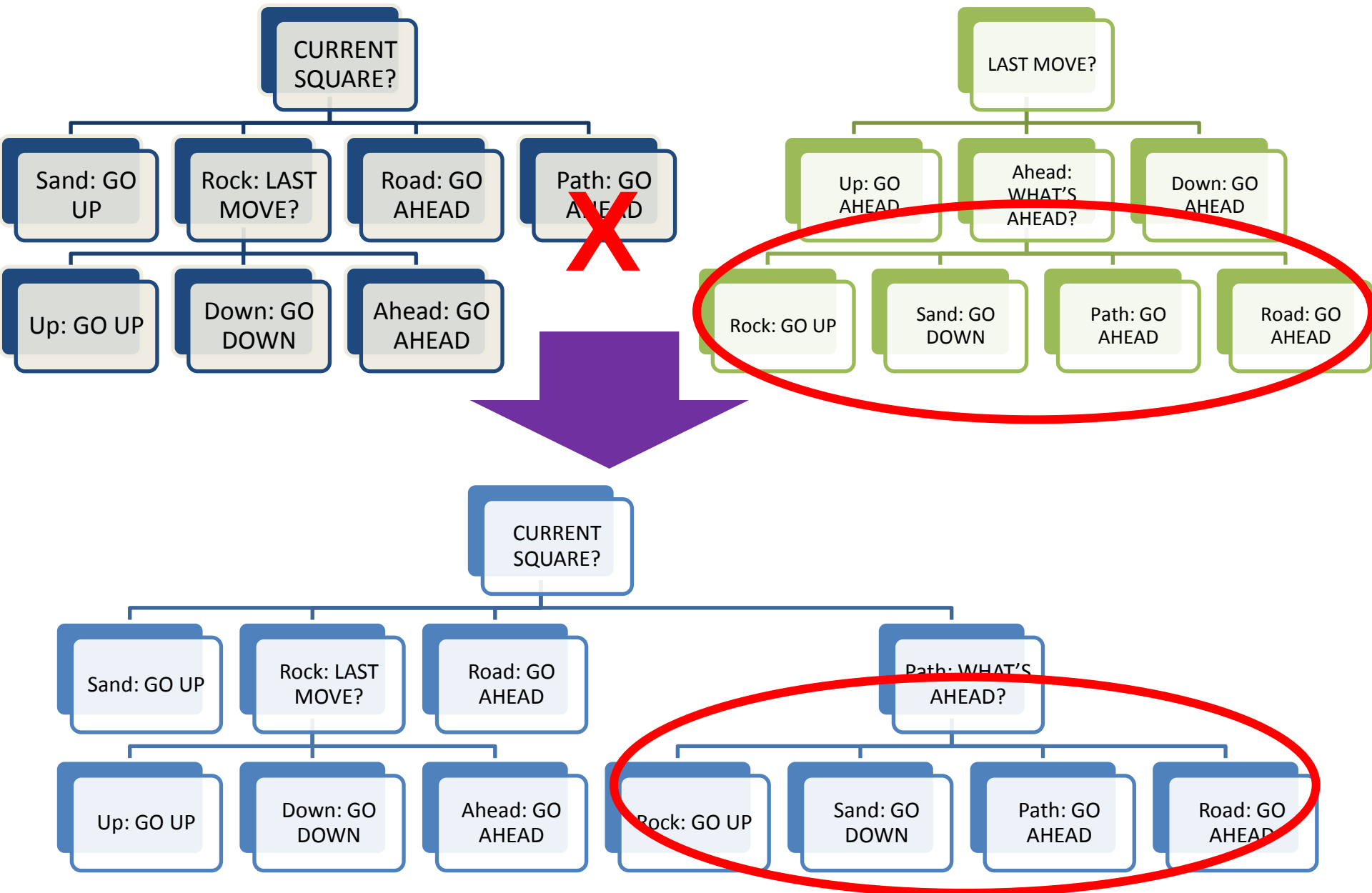


Evolved X-band antenna (NASA)

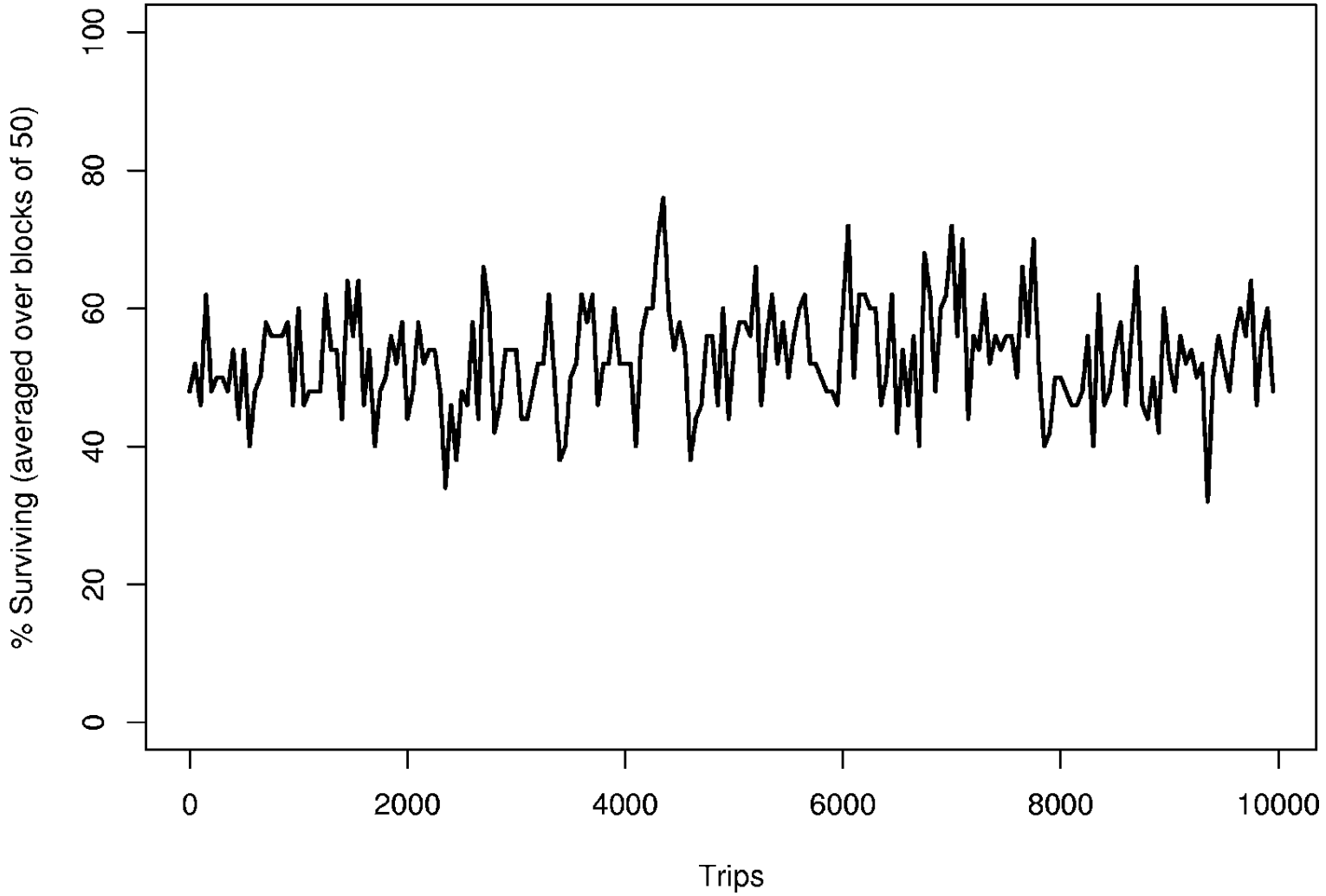


Evolved strategies for Tic-Tac-Toe

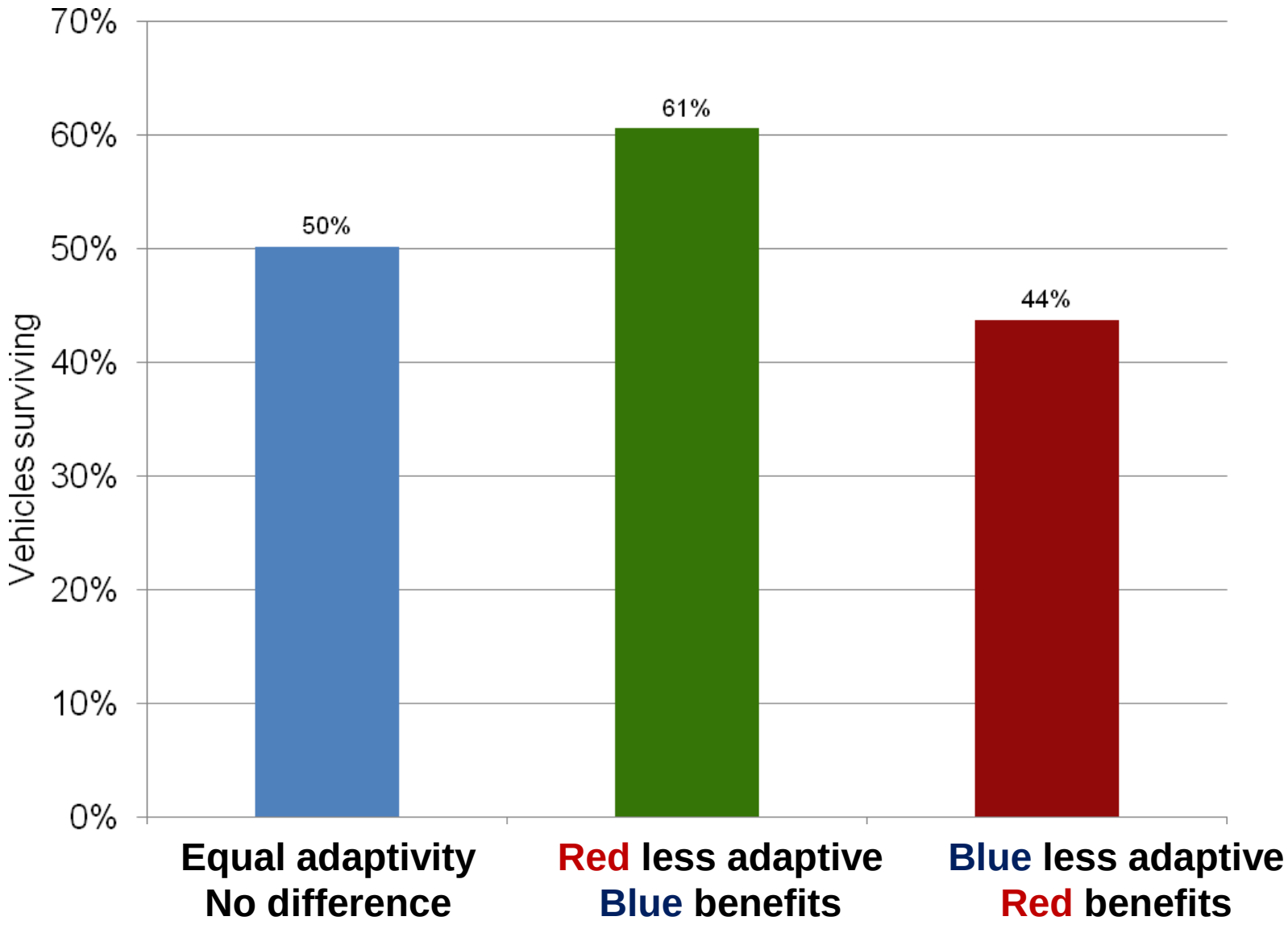
“Genes” are tree-structured programs, not 0’s & 1’s



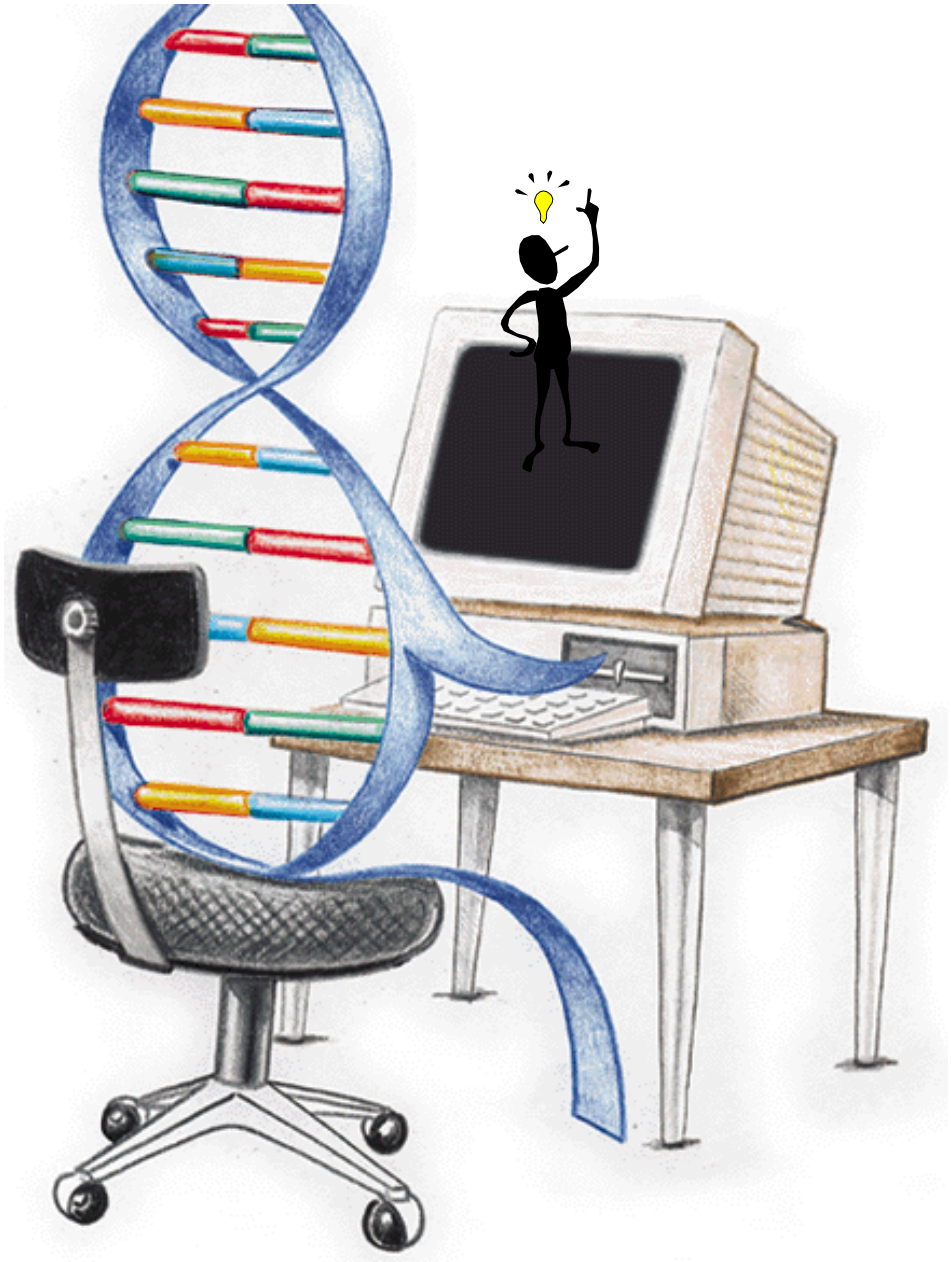
Oscillation again – sides take turns being “ahead”



The adaptivity effect is stronger this time

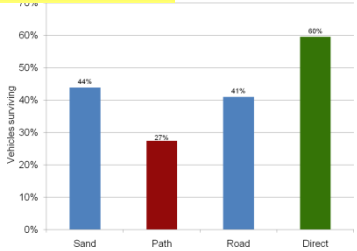


GP has potential for simulating adaptation & innovation



Summary

A simple model, for looking at basic principles



Simple optimisation ignores Red's mind

Simple game theory doesn't adapt

Adaptation yes, but innovation?

Yes! With GP!