Developing Epigenetic Networks to Optimise Traffic Control Systems

PRESENTED BY JACOB BUSFIELD

Introduction

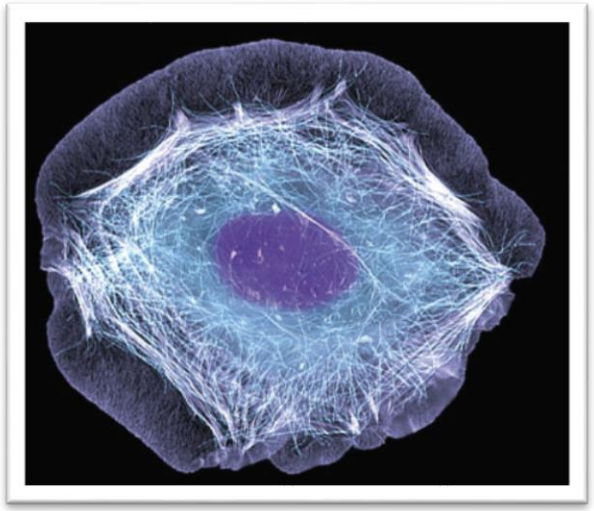
- Epigenetics & EpiNet
- Motivation
- Overview
- Current Findings
- Future Work
- Conclusion

Epigenetics?

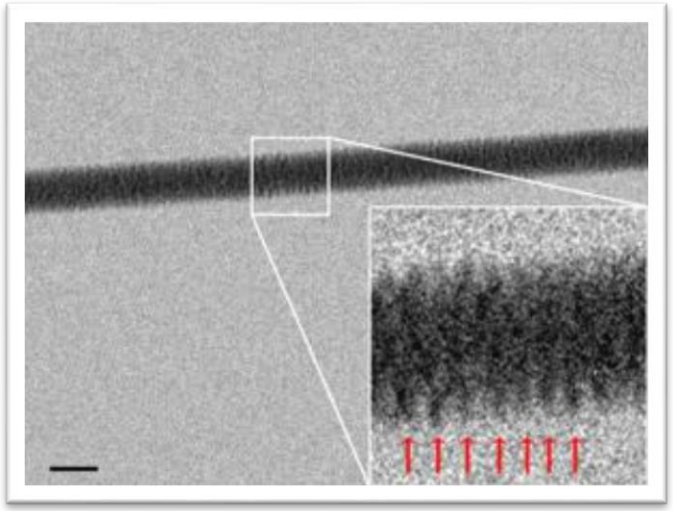
Epigenetics: Skin Example

Skin [1]

Skin Cell [2]



DNA [3]



When Skin is damaged, how does it **react**?

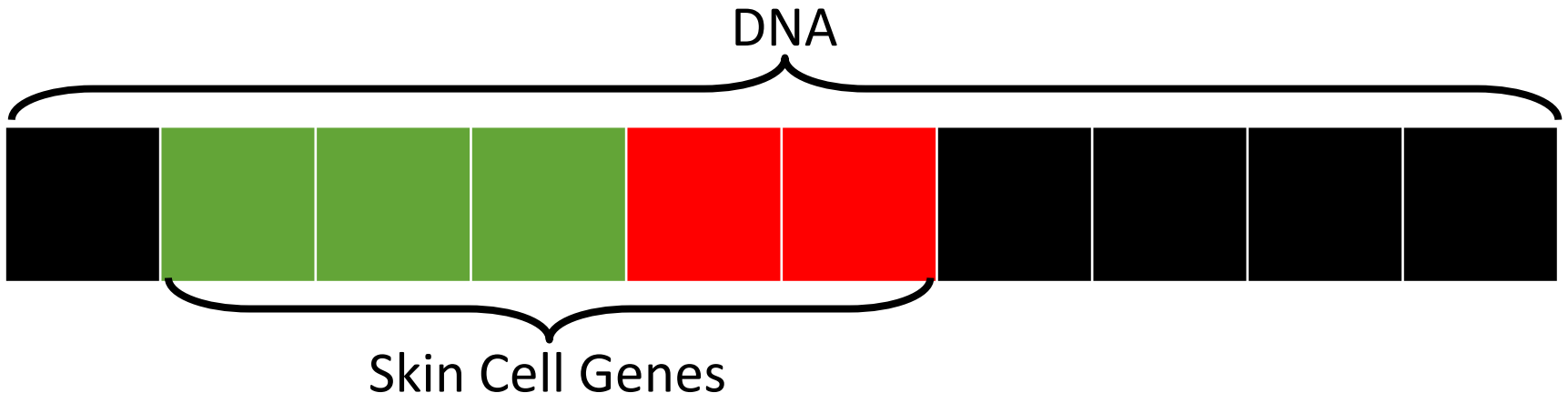
[1] D. Georgiev, "Skin layer grown from human stem cells could replace animals in drug, cosmetics testing," ScienceDaily, 2014. [Online]. Available: http://www.sciencedaily.com/releases/2014/04/140424125245.htm. Accessed: Apr. 11, 2016.

[2] A. Maxmen, "Single-cell analysis: Imaging is everything," *Nature*, vol. 480, no. 7375, pp. 139–141, Nov. 2011. [Online]. Available: http://www.nature.com/naturejobs/science/articles/10.1038/nj7375-139a. Accessed: Apr. 11, 2016.

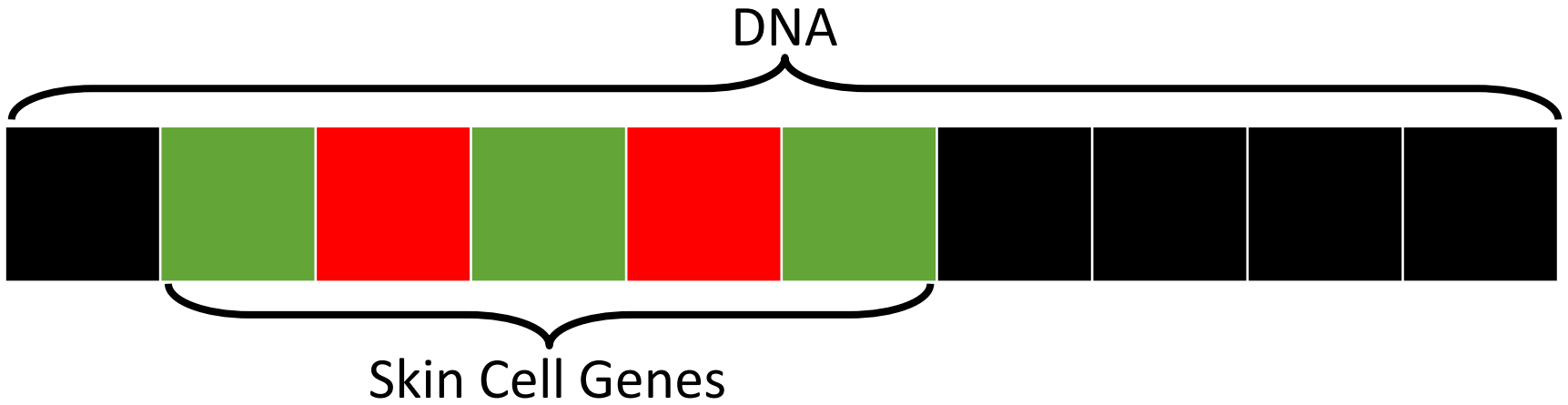
[3] R. Pease, "DNA imaged with electron microscope for the first time," New Scientist, 2012. [Online]. Available: http://www.newscientist.com/article/dn22545-dna-imaged-with-electron-microscope-for-the-first-time/. Accessed: Apr. 11, 2016.

Epigenetics: Process

Normal Operation



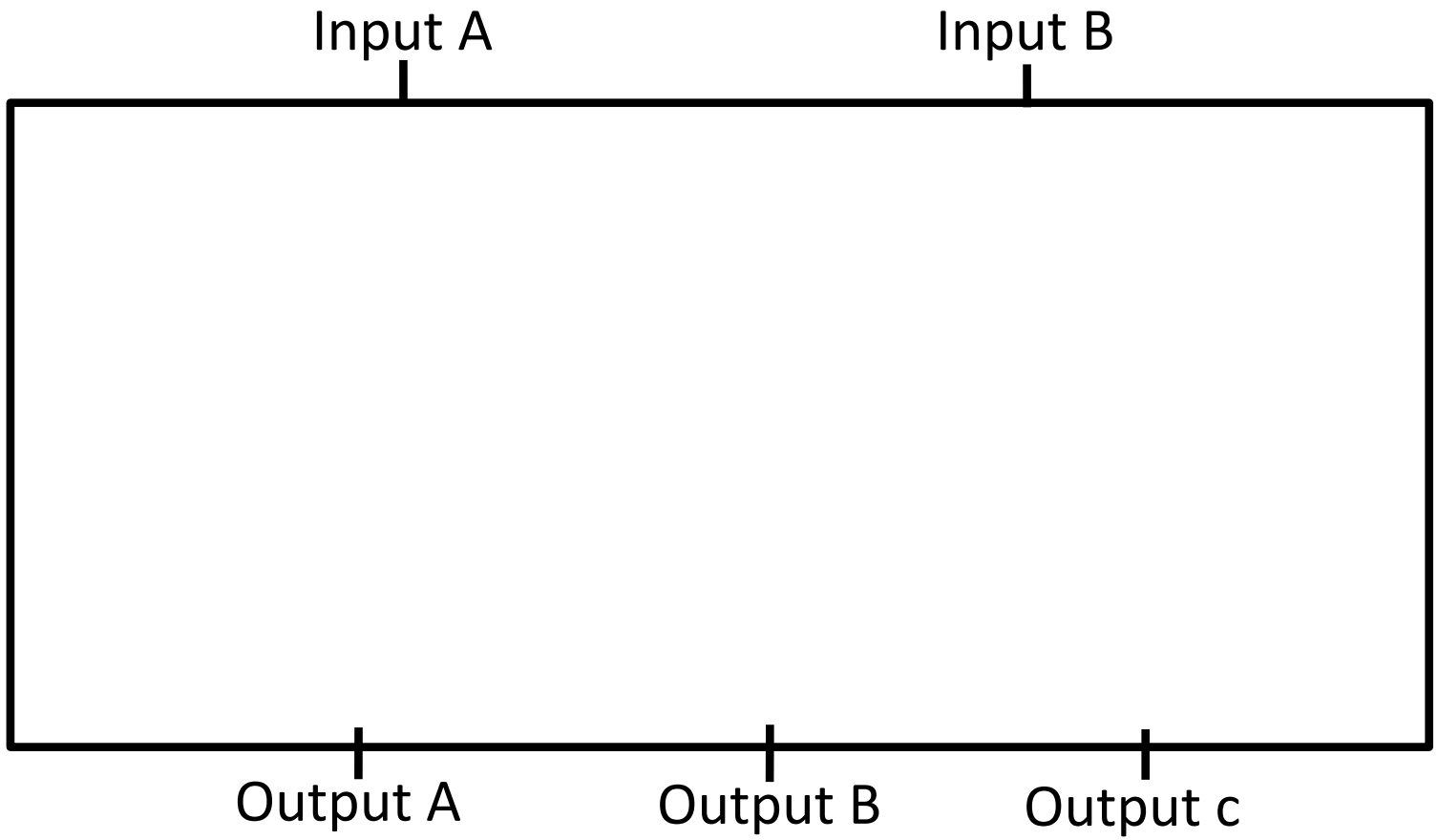
Under Injury



Epigenetics: Advantages

- Adaptive
- Fault Tolerant
- Scalable
- Modular

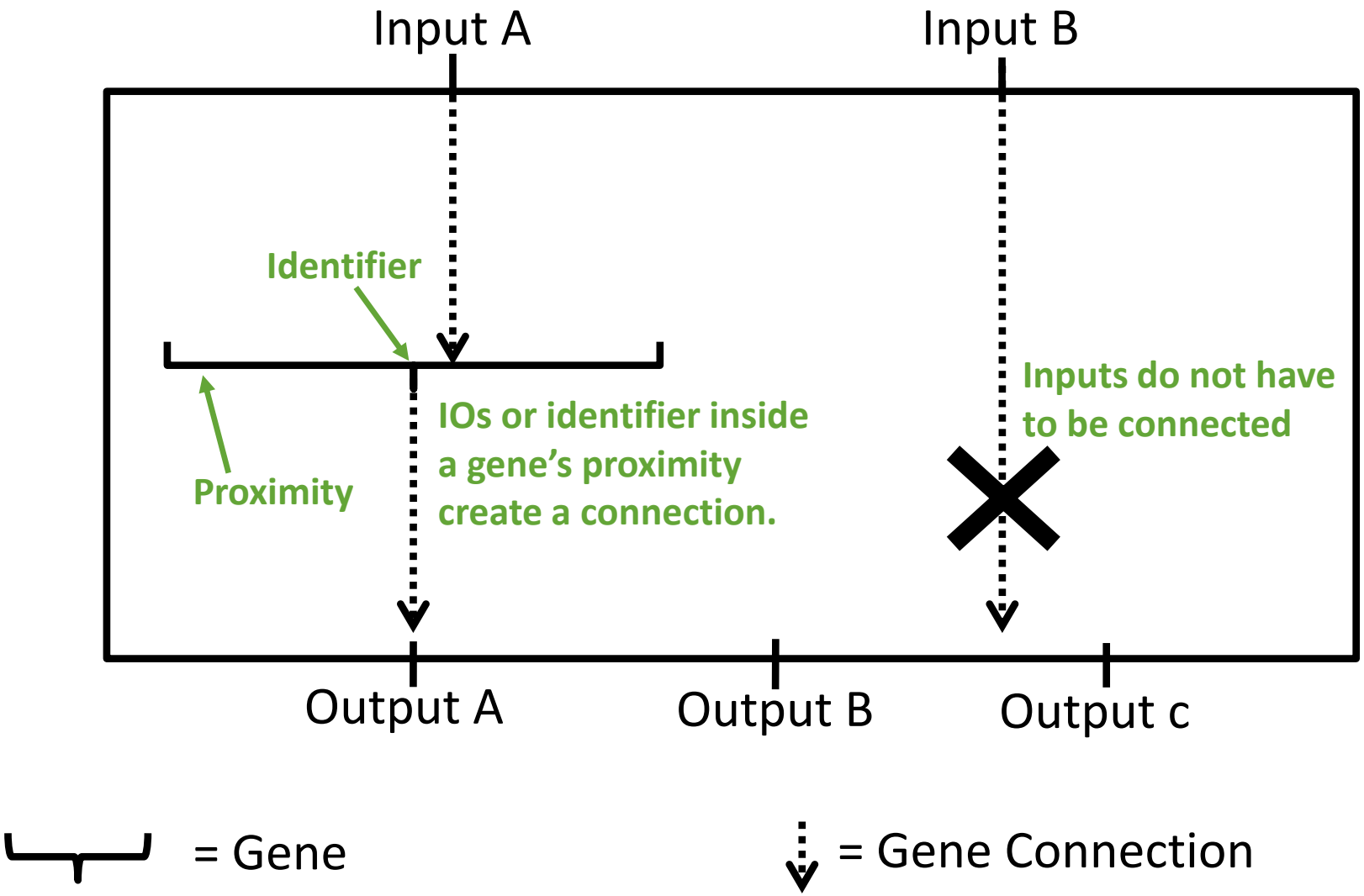
EpiNet: Black Box



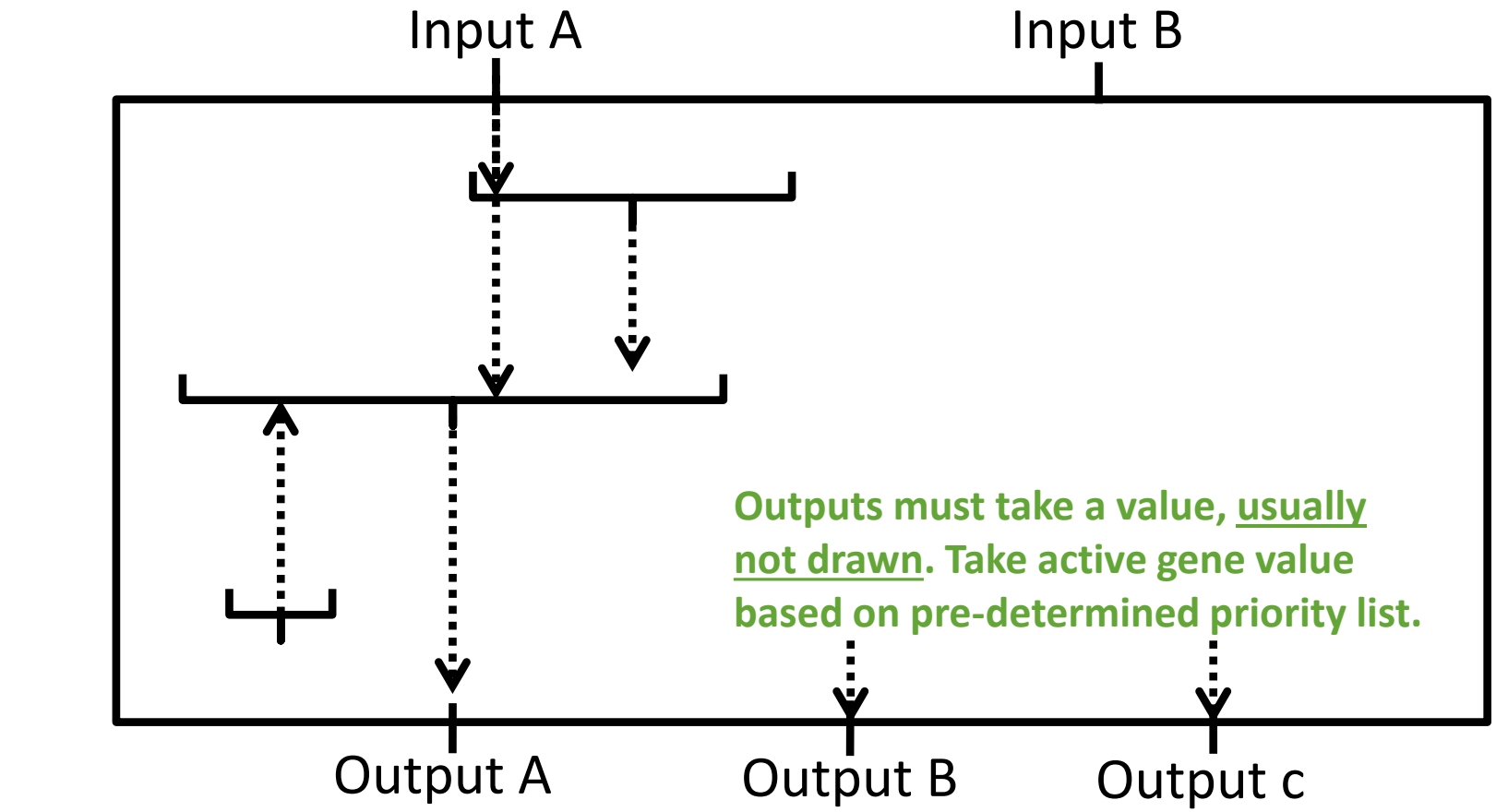
Inputs ≈ Local Environment

Outputs ≈ Protein Formed

EpiNet: Single Gene

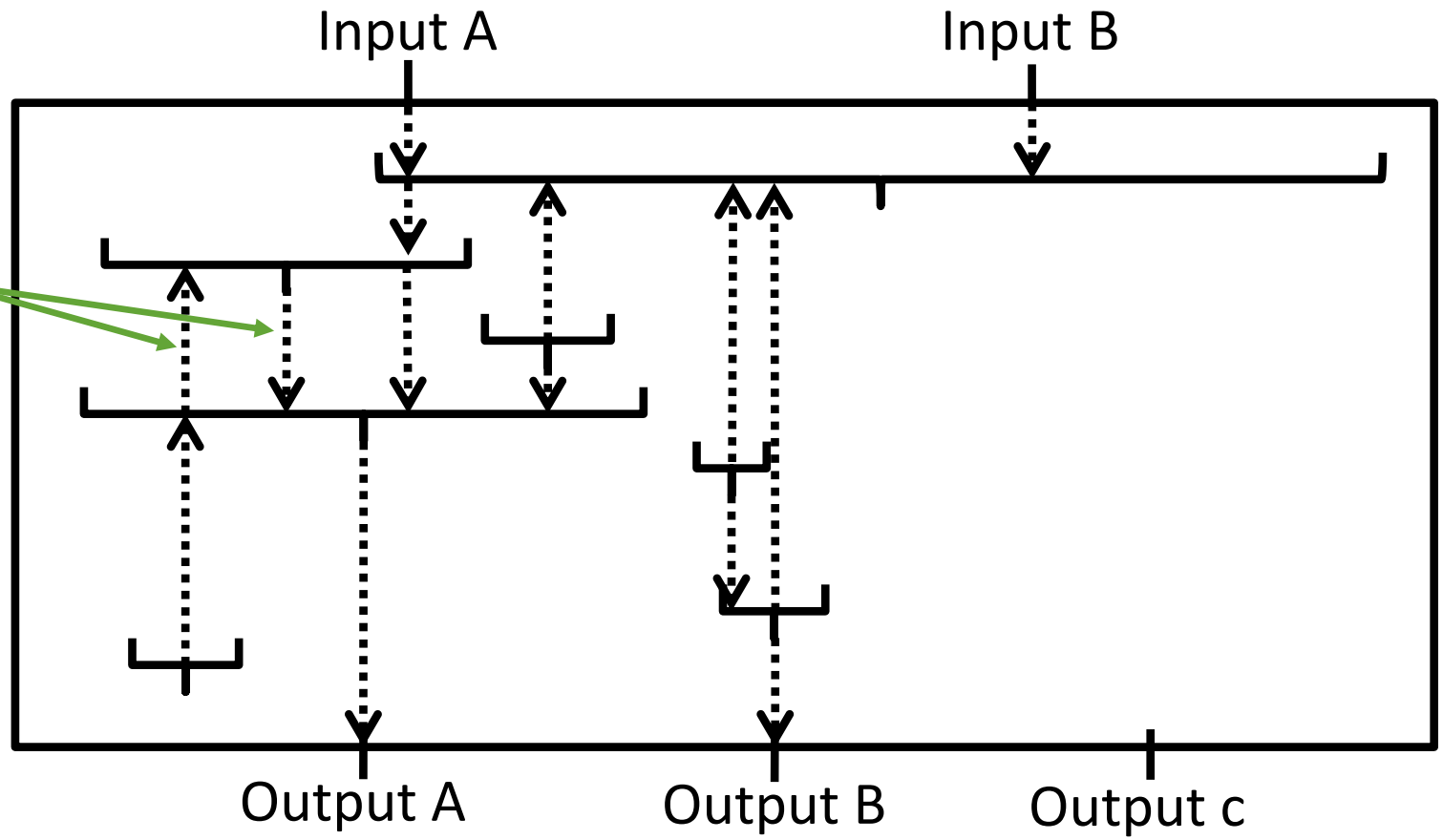


EpiNet: Connections



EpiNet: Complex Example

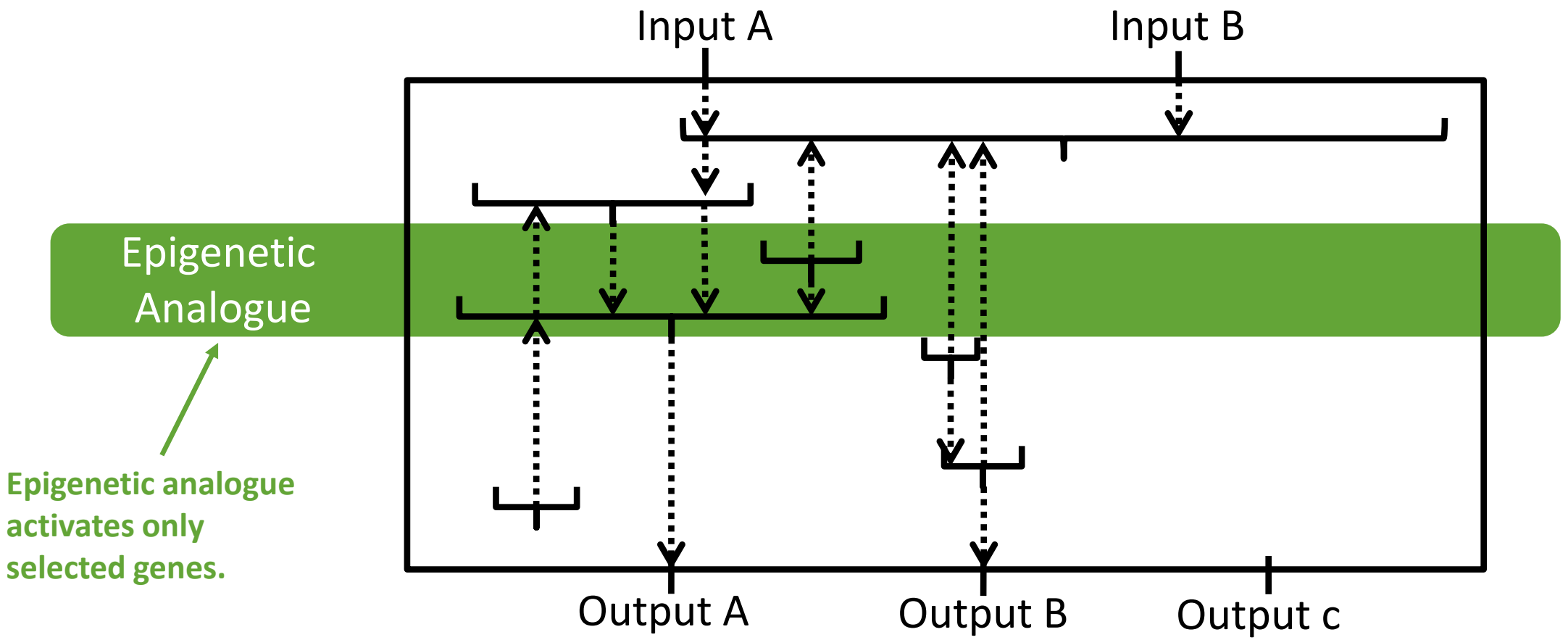
Genes update once per global update. Hence loops create form of memory.



= Gene

= Gene Connection

EpiNet: Epigenetic Analogue



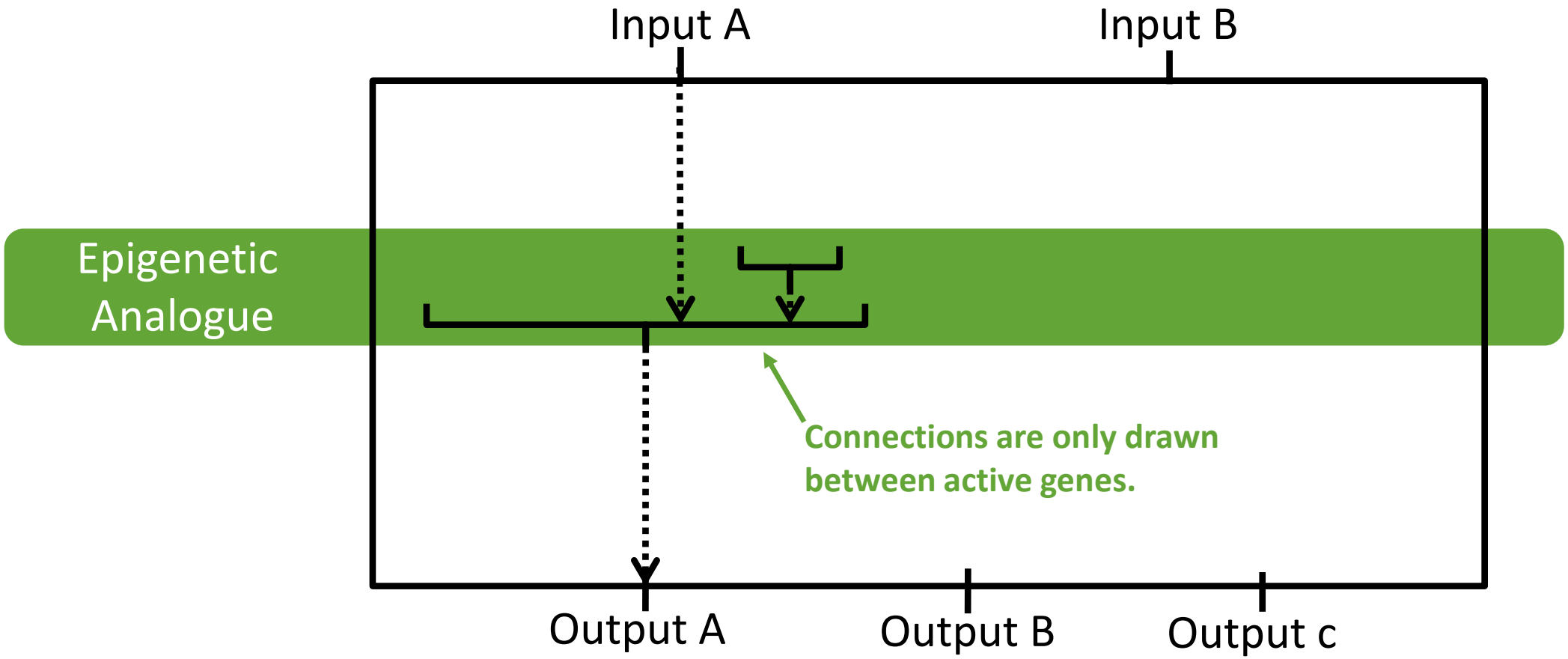
Epigenetic analogue activates only selected genes.

= Inactive Gene

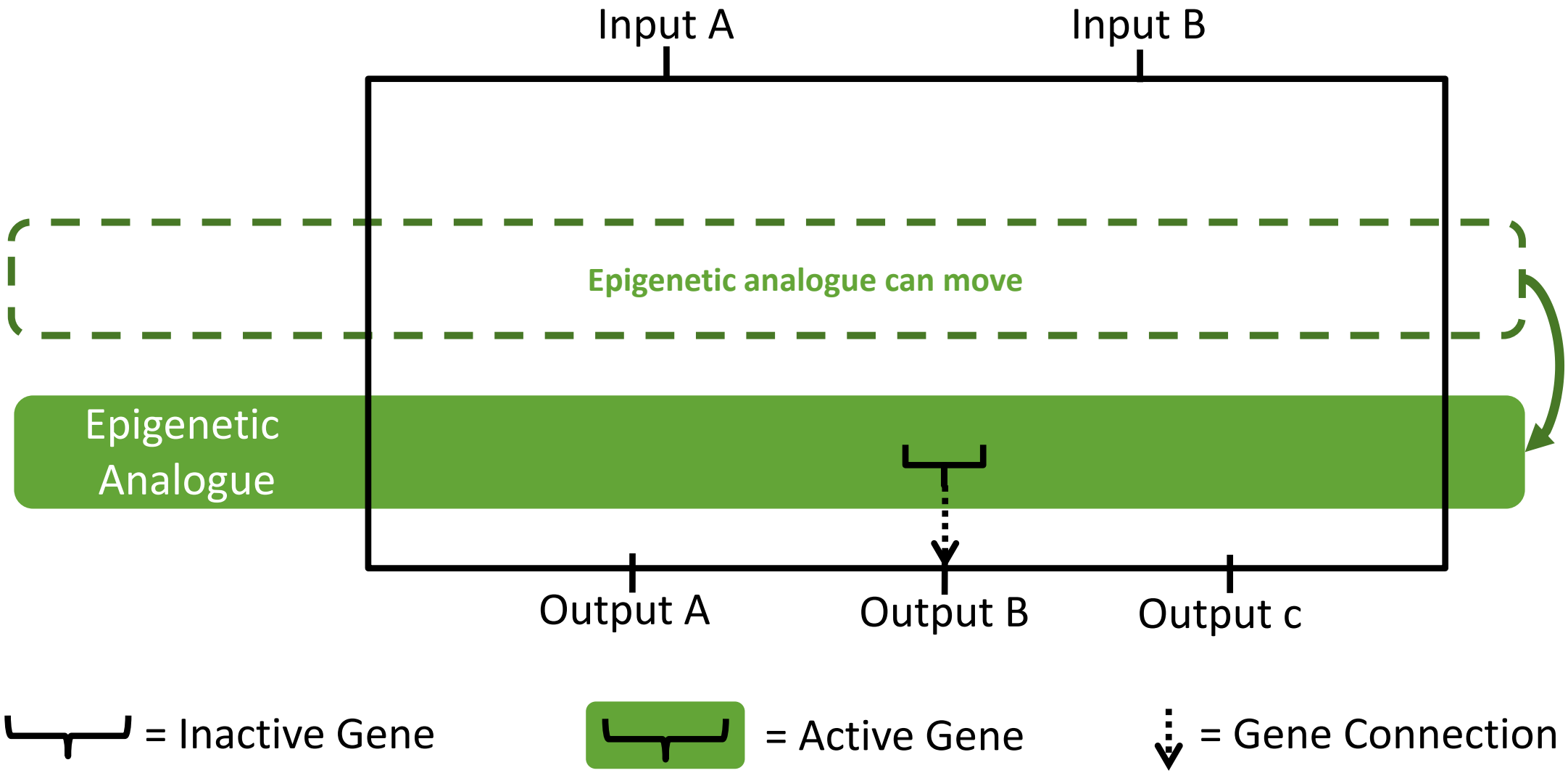
= Active Gene

= Gene Connection

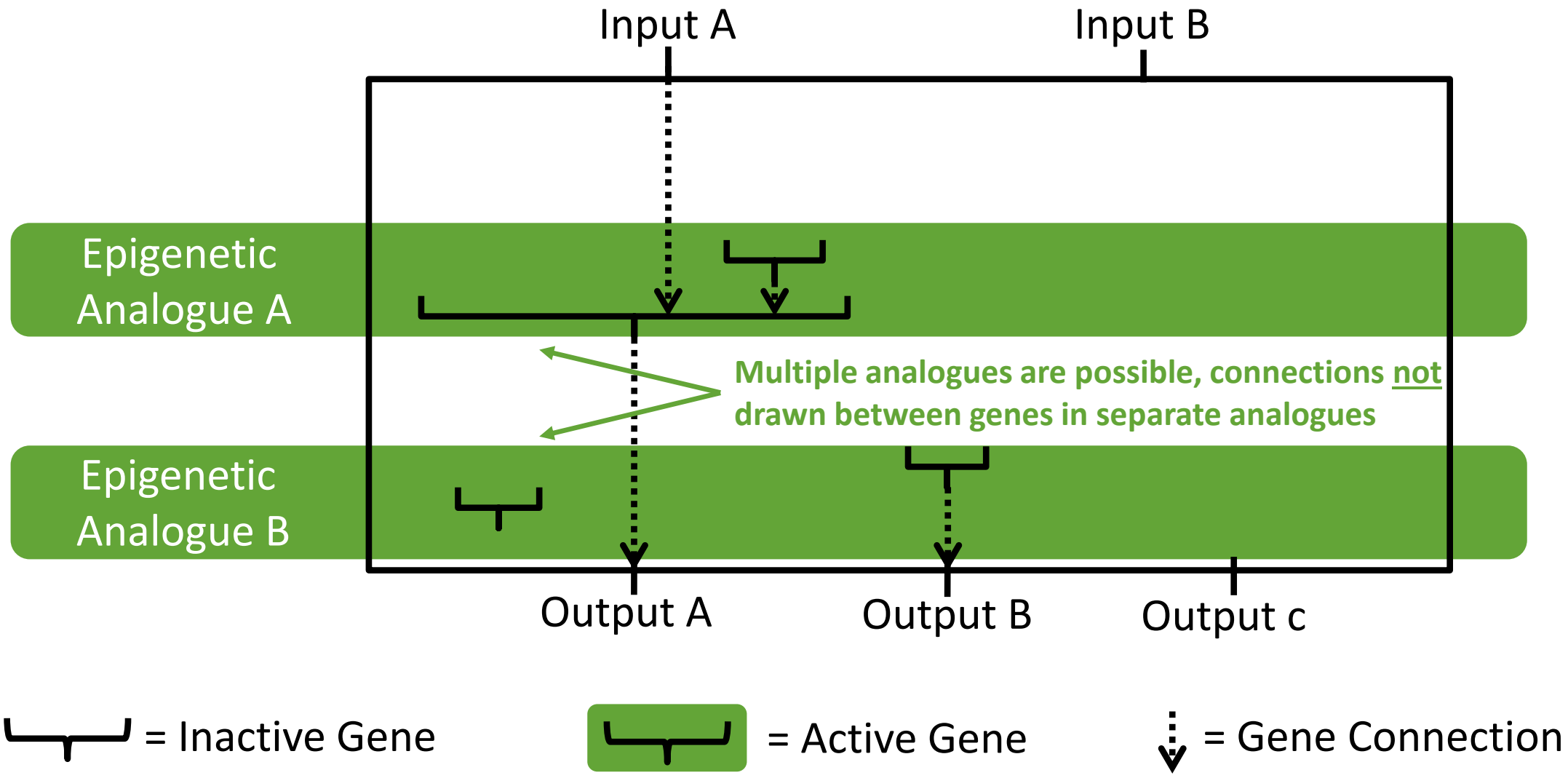
EpiNet: Protein Network



EpiNet: Dynamic Behaviour



EpiNet: Multiple Analogues



How does this relate to my work?

Motivation: Research

EpiNet **successful** in:

- ✓ Audio, visual recognition
- ✓ Data Analysis
- ✓ Control

Research: How should networked individuals be controlled?

- Separate or shared genomes?
- Identical or independent genomes?

Motivation: Traffic Application

UK **Congestion**:

- Annual cost of £21.4 billion by 2030 [4]
- 5000 pollution-related deaths annually [5]
- Poor alternatives.

Project: Can epiNet improve traffic control?

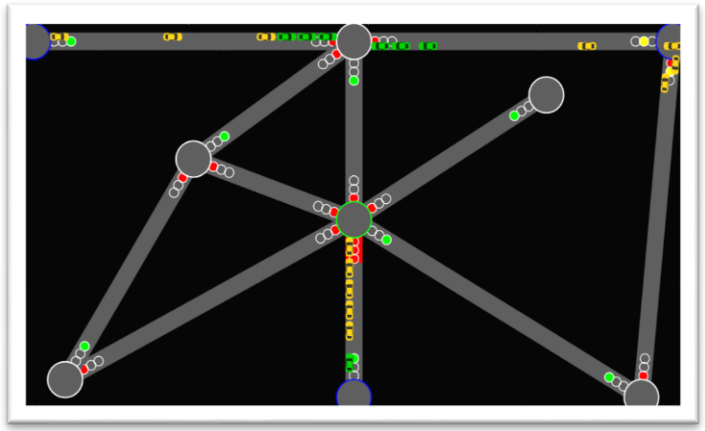
- Allows research of networked controllers (previous slide).
- Reduce congestion.

[4] INRIX (2014, Oct. 14). “Traffic Congestion to Cost the UK Economy More Than 300 Billion Over the Next 16 Years,” inrix.com. [Online]. Available: http://inrix.com/press/traffic-congestion-to-cost-theuk-economy-more-than-300-billion-over-the-next-16-years/ [Accessed: Apr. 11, 2016].
[5] S. H. L. Yim and S. R. H. Barrett, "Public health impacts of combustion emissions in the United Kingdom," *Environmental Science & Technology*, vol. 46, no. 8, pp. 4291–4296, Apr. 2012.

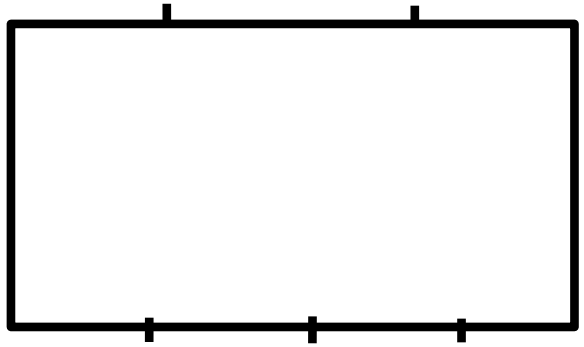
How to investigate?

Overview: Project

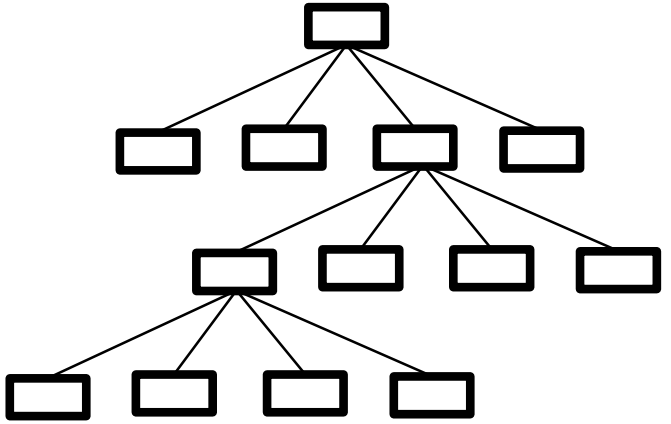
Simulation



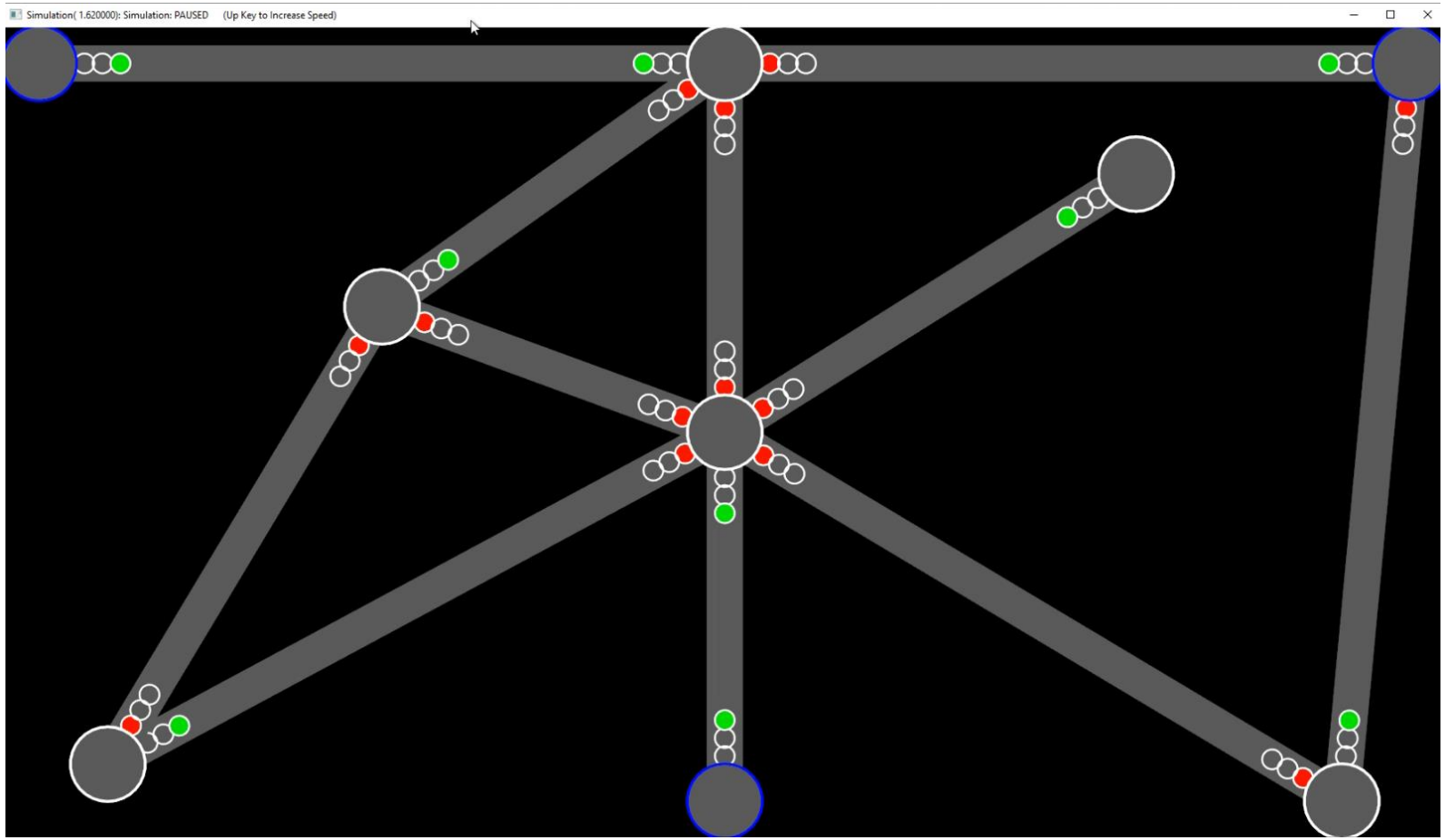
EpiNet Controller



Evolution



Overview: Simulation

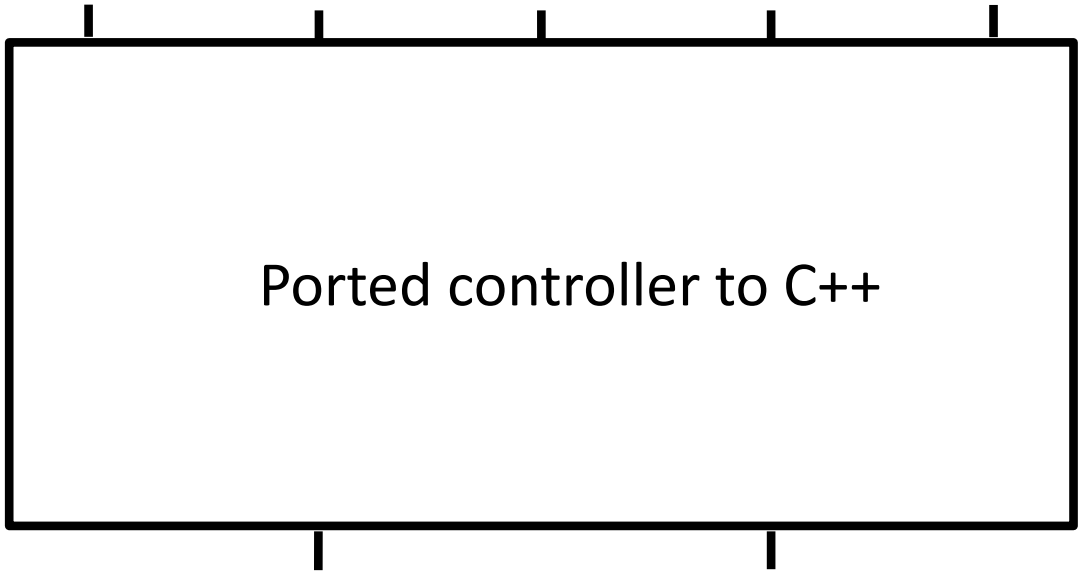


- C++
- SFML graphics Library
- Agent based
- Cars can be given routes (green)
- Load designs, controllers and tests easily
- Change speed (paused, exact and fast)

Overview: EpiNet Controller

Road state

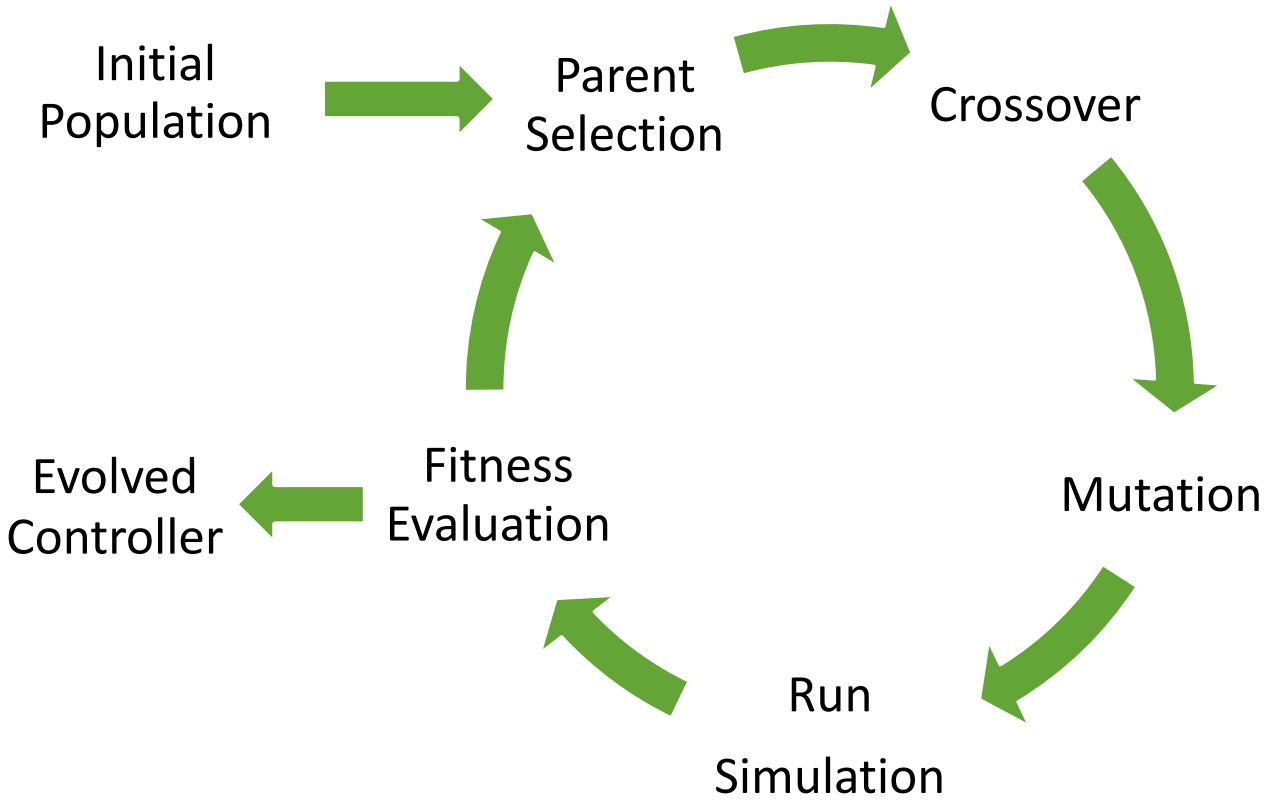
(roads with cars, waiting duration, currently active)



Instruction

(next active road, duration to remain active)

Overview: Evolution



Bottleneck is simulation (no visuals, thread support)

Evolutionary Algorithm (EA)

- Small Population
- Only best individual survives
- Genetically similar
- Fast

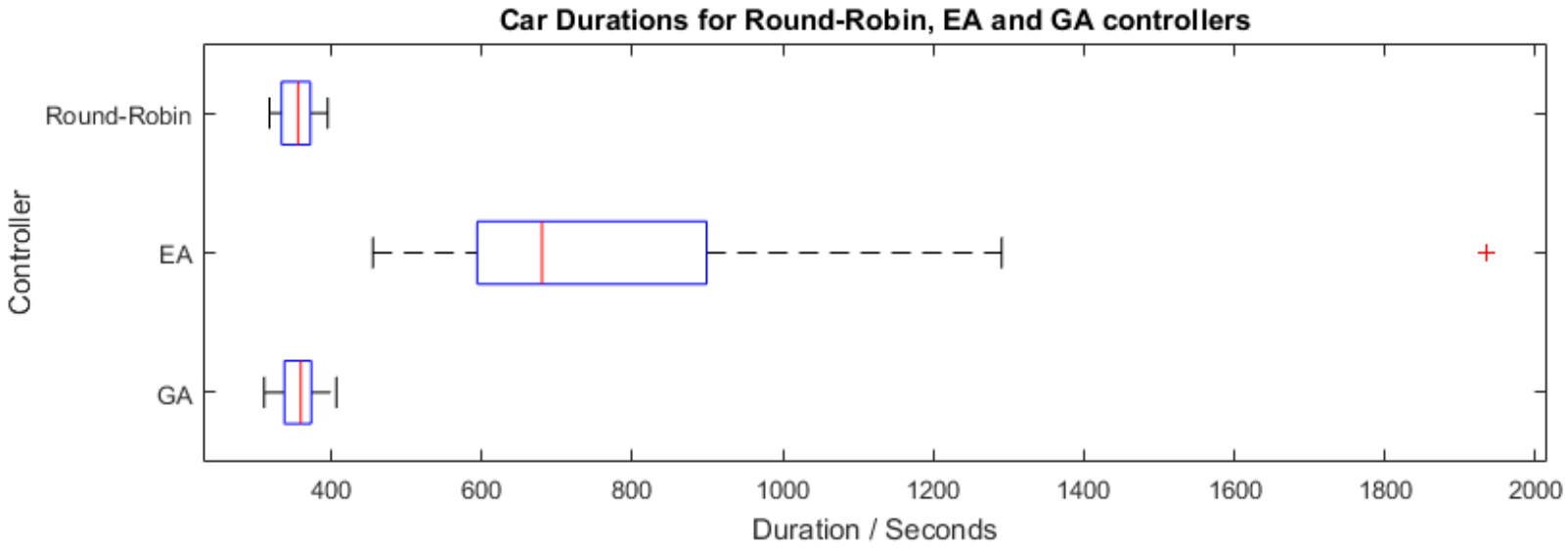
Genetic Algorithm (GA)

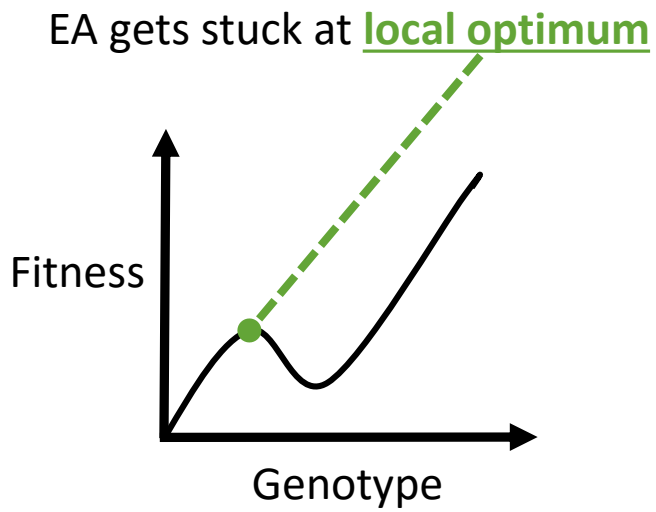
- Large Population
- Many individuals survive
- Genetically diverse
- Slow

What has been found out?

Results: EA vs GA

Test: Evolve four way junction controller using EA and GA.

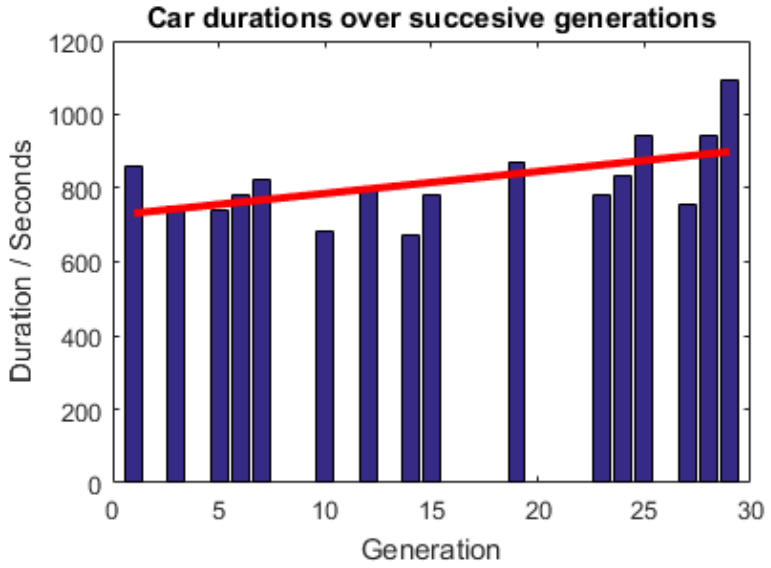


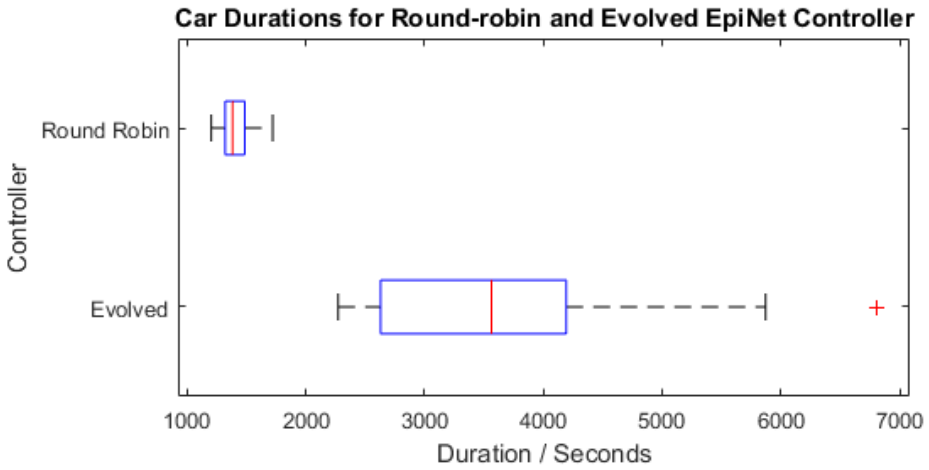


Finding: GA required to navigate complex fitness landscape owing to its better genetic diversity.

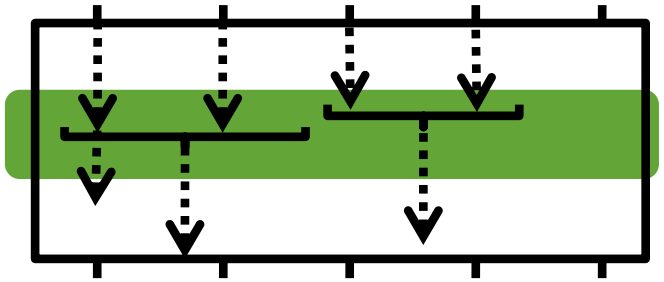
Results: IO Concerns (Kitchen Sink Approach)

Test: Evolve four way junction controller with complex IOs.





Hard to **evolve** decoding genes and have inputs make no further connections.

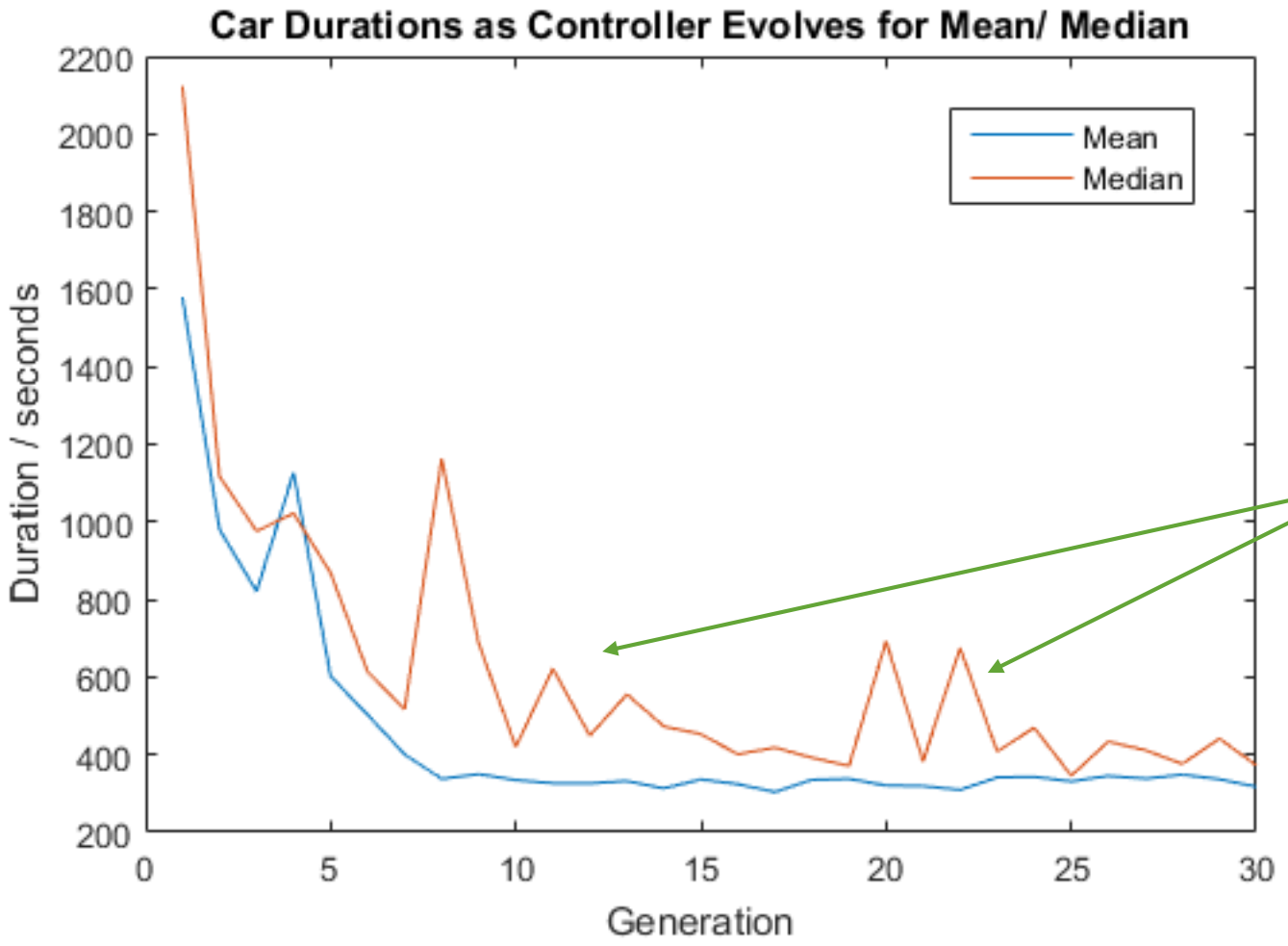


Hard to map many outputs.

Findings:

- Reduce total IOs, especially for outputs.
- Remove encoded IOs, especially for inputs.

Results: Mean vs Median Duration

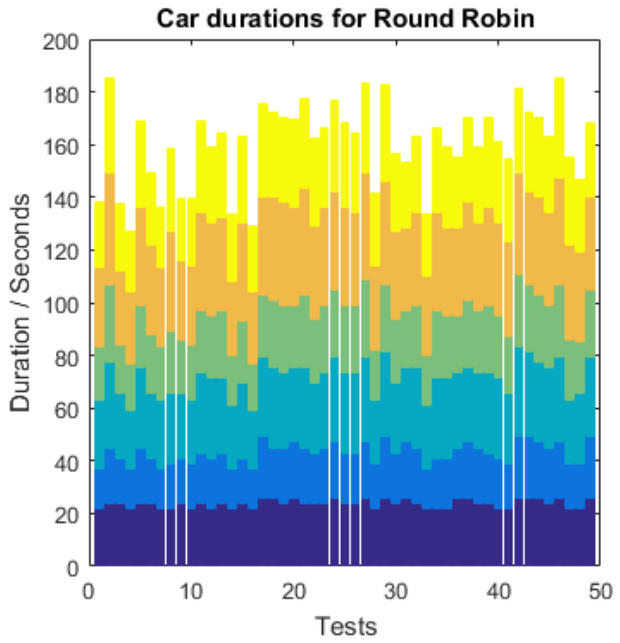


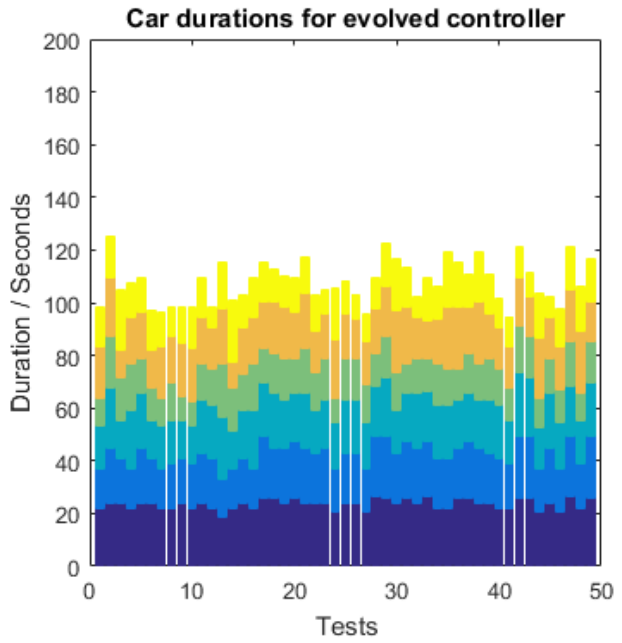
Test: Evolve four way junction controller with GA where multiple tests average is mean or median.

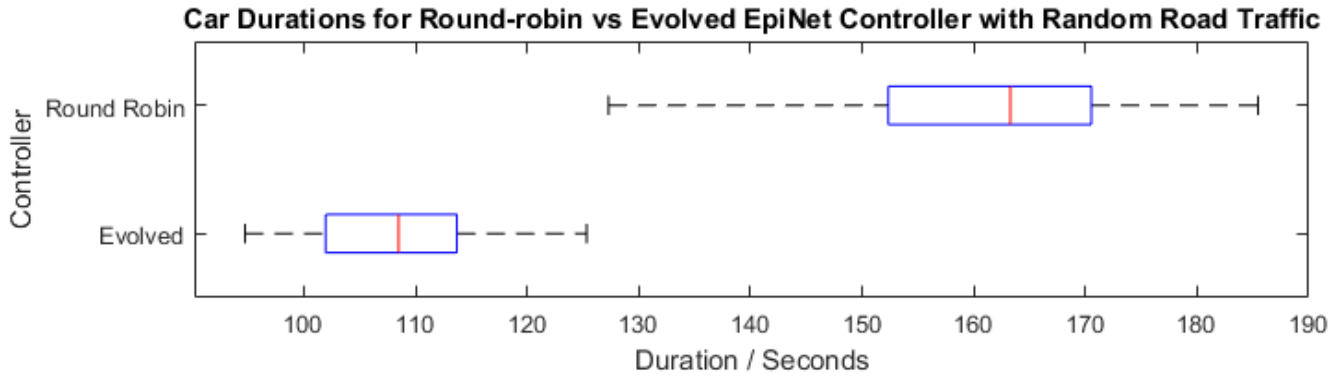
Mean fluctuates less as '*Freak*' good controllers don't exist so median is only removing '*freak*' bad outliers, not ideal.

Findings: Average GA tests using mean.

Results: Unbalanced Traffic







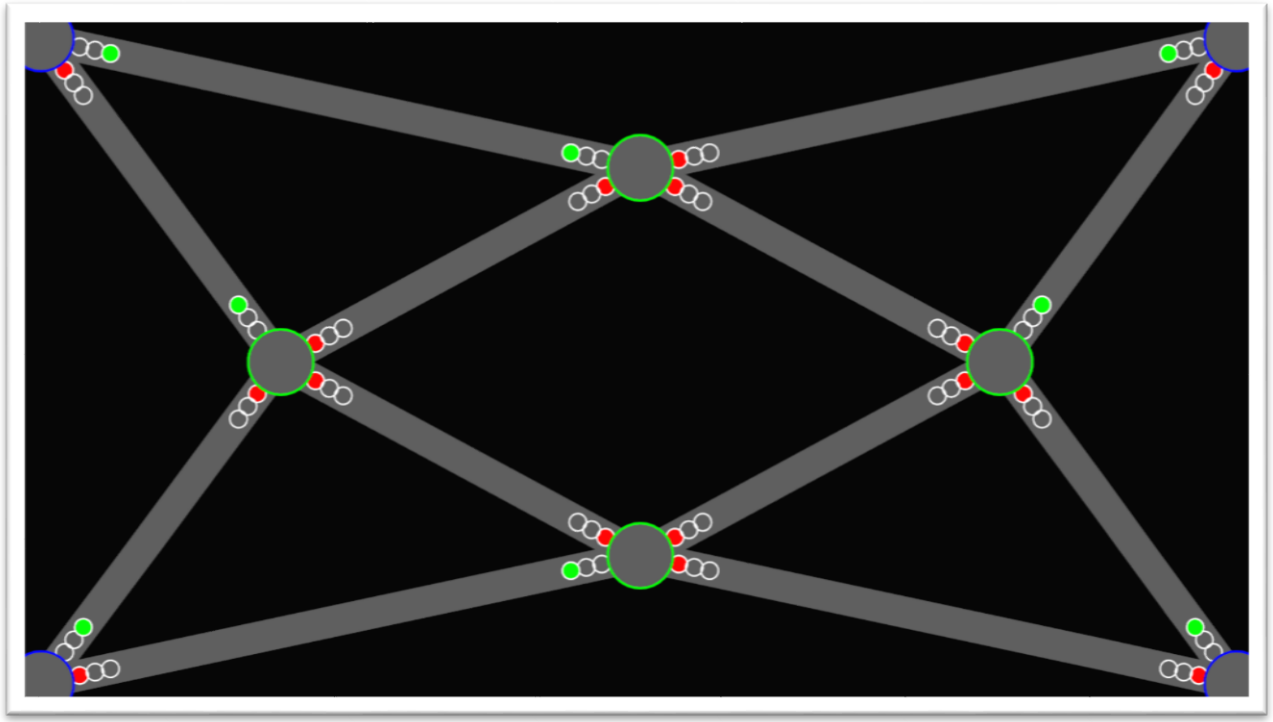
Test: Cars only spawn on one road entering four way junction.

Round robin wastes time servicing roads with no traffic.

Findings: Verification that epiNet controller uses inputs to determine which road to make active (hasn't just learnt pattern).

Results: Evolution Strategies (test)

Test: Determine best strategy for evolving network of 4 controllers.

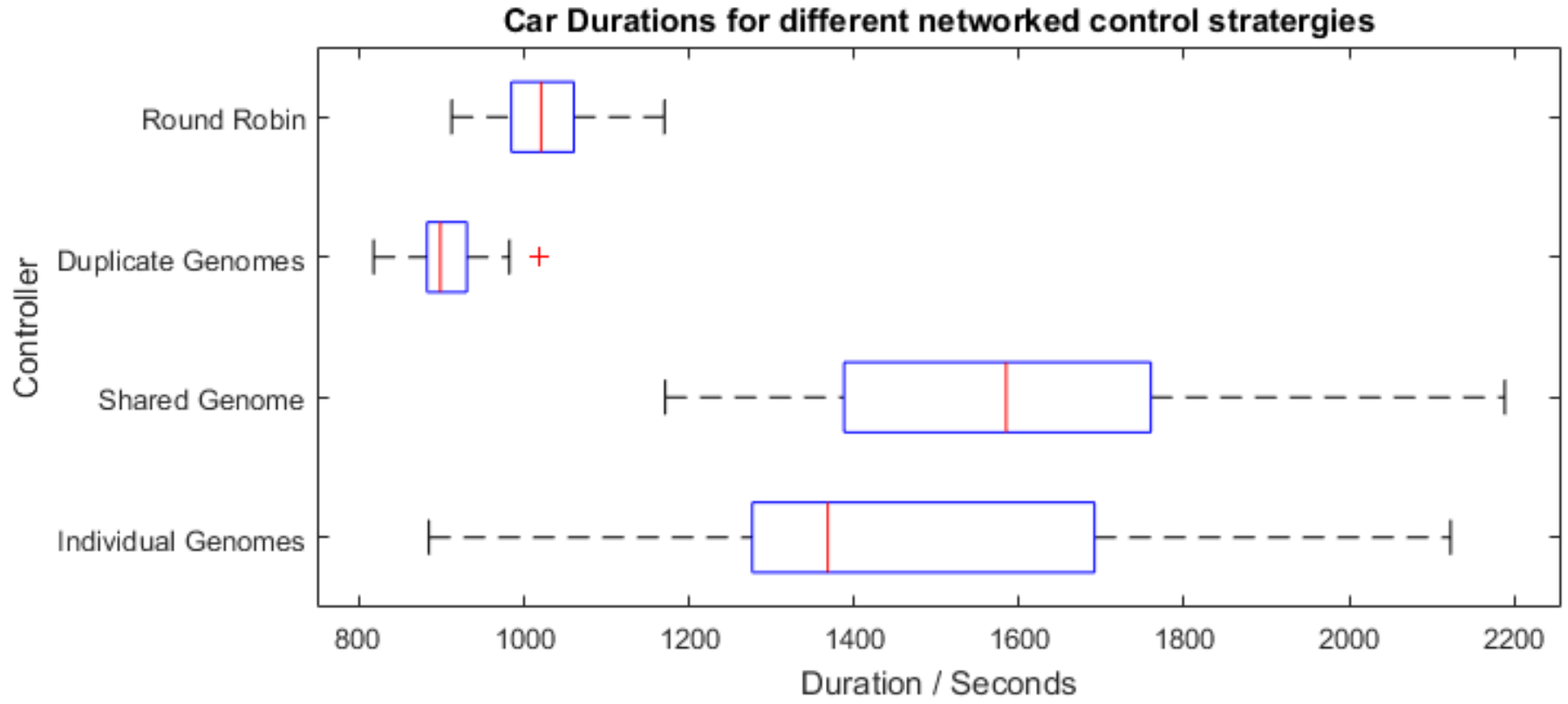


Individual - 4 separate genomes.

Duplicate - 4 identical genomes.

Shared - Single, large genome.

Results: Evolution Strategies (findings)



Findings: Duplicated genome currently best option with information obtained for multiple similar networks strengthening its structure. Emergence of complex behaviour; lights do not greedily change. Other strategies' evolution became stuck.

What is the next step?

Points left to investigate

- Will **more tested co-evolution methodologies** improve individual genome performance?
- **Given longer**, will evolution of a large **shared genome** converge on better performance?
- What strategy is best for **networks with** controllers that having **different IO sizes**?

Conclusion

Conclusion

EpiNet is a promising artificial epigenetic network.

Through investigating traffic control it was found:

- **Genetic algorithms** are required using the **mean to average** simulated testing.
- Controllers need **simple IOs** to be evolvable.
- Duplicate genomes allow the **emergence of complex behavior**.

Further investigation is required to understand how to best network epiNet controllers and whether they are feasible in combating congestion.

Any Questions?