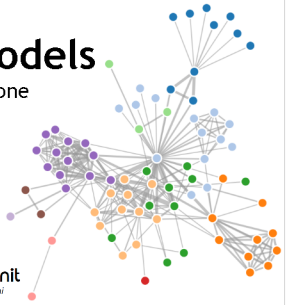
Discrete Models

Alberto Calderone



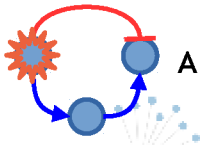
Why Discrete Dynamical Models

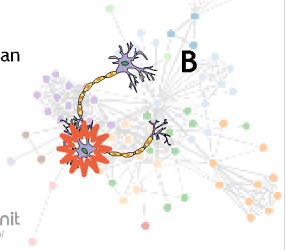
Systems that exhibit switch-like behaviour

Two examples:

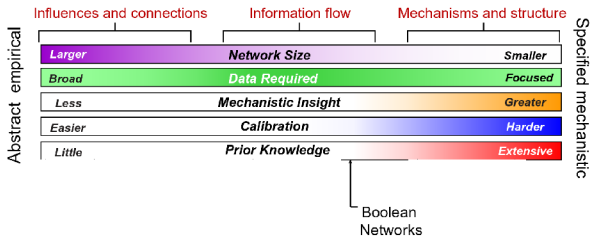
A) Gene regulatory networks, in which at a given moment a gene can be expressed or not expressed and can influence the expression of other genes
B) Neuronal networks, in which a neuron can be either active or at rest

These systems can be analysed with the Boolean models.





Modelling Spectrum



Boolean Networks

Discrete Dynamical Models

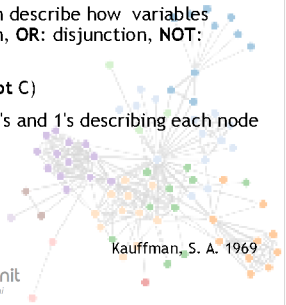
- Entities in the network can either be 1 or 0 (ON or OFF)
- Interaction are directed and can have a positive(+) or negative(-) effect on the target entity
- Entities are the variables and interaction describe how variables influence one another: **AND**: conjunction, **OR**: disjunction, **NOT**: negation.

A = B **and** (**not** C)

- A state of the network is a snapshot of 0's and 1's describing each node in the network
- Variants:

  1)More than one state (0, 1, 2…)

  2)Probabilistic



Kauffman, S. A. 1969

The Three Main Operations

A = B and C

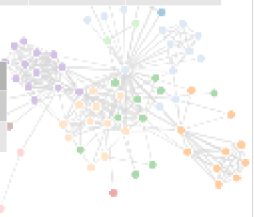
A	B	C
0	0	0
0	0	1
0	1	0
1	1	1

A = B or C

A	B	C
0	0	0
1	0	1
1	1	0
1	1	1

A = not C

A	C
1	0
0	1



Combining Operations

A = B and C

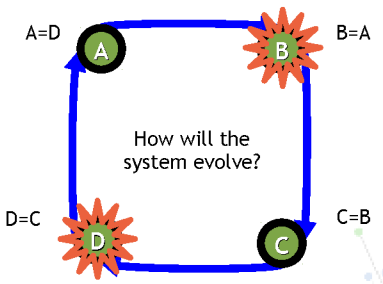
A	B	C
0	0	0
0	0	1
0	1	0
1	1	1

A = not C

A	C
1	0
0	1

A = B and (not C)

A	B	C
0	0	0
0	0	1
1	1	0
0	1	1

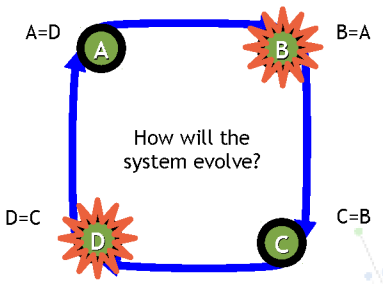


Option 1
A is ON e C is ON

Option 2
A, B, C and D are OFF

Option 3
A is ON

Option 3
A and C are ON, B and D are OFF



Option 1
A is ON e C is ON

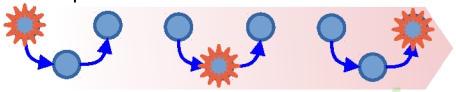
Option 2
A, B, C and D are OFF

Option 3
A is ON

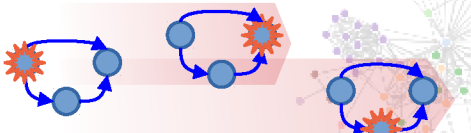
Option 4
A and C are ON, B and D are OFF

Update Schema
Synchronous or Asynchronous

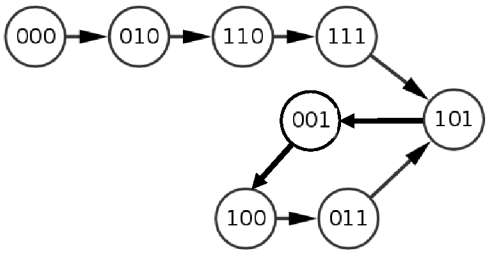
- **Synchronous**: Updating values simultaneously, based on the values at the previous instant.



- **Asynchronous**: Randomly choose and entity and update its status. The system can evolve in different directions.

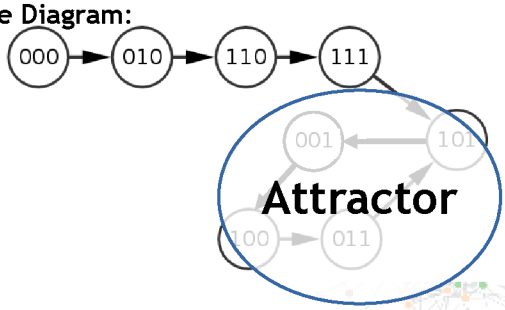


State Diagram: Simple Attractors

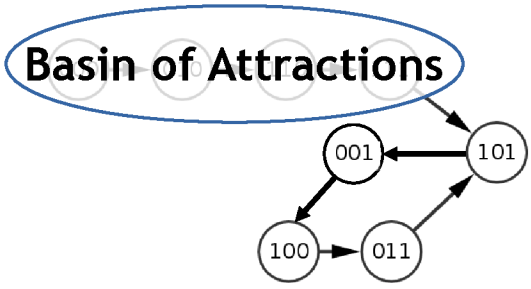


State Diagram: Simple Attractors

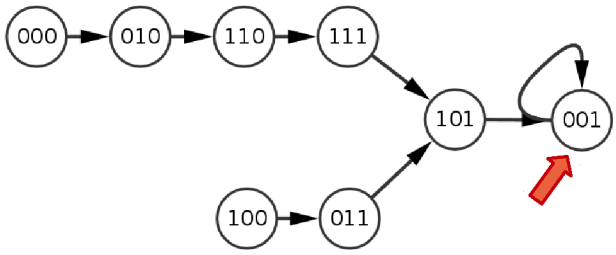
State Diagram:



Simple Attractors



State Diagram: Steady States



Circuits

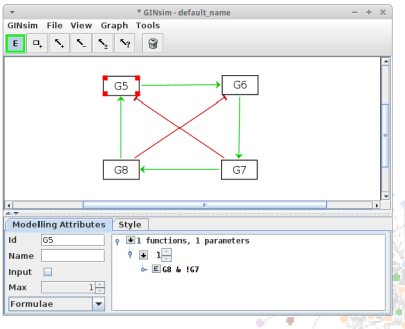
Regulatory Circuit: A regulatory circuit is defined as a sequence of interactions forming a simple closed directed path.

Functional Regulatory Circuit: a circuit is **functional** if it generates the expected dynamical property

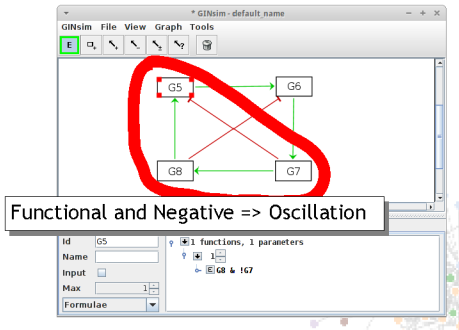
Positive: a circuit is positive if it has an even number of inhibitions → stationary

Negative: a circuit is negative if it has an odd number of inhibitions → stable oscillations

Circuits

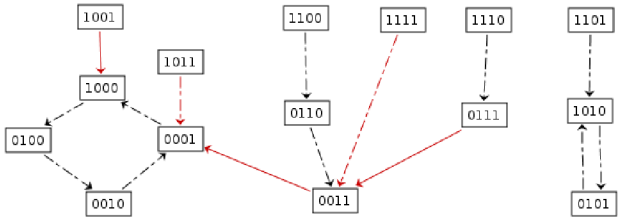


Circuits



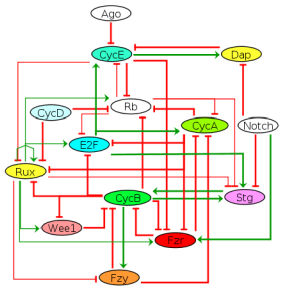
Functional and Negative => Oscillation

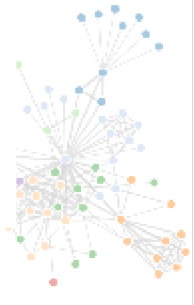
Circuits



An Example

A Classical Example in Modelling: Drosphila Cell Cycle





An Example

A Classical Example in Modelling: Drosophila Cell Cycle