Simulating the Evolution of Regulatory Networks

W. Garrett Mitchener

College of Charleston

March 15, 2013

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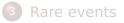
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2 Simulated evolution



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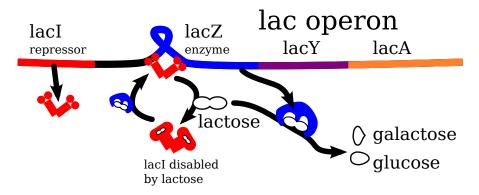
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Image: A matrix

Regulatory networks



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Artificial life is difficult

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Artificial life is difficult



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So I made a toy

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So I made a toy

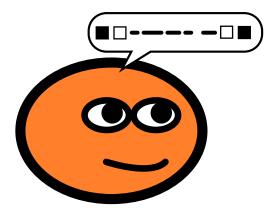


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Agents, their job, & their brains



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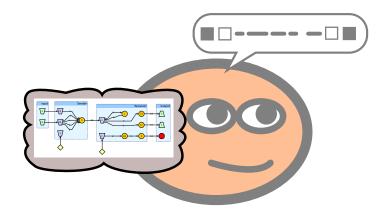
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Agents, their job, & their brains

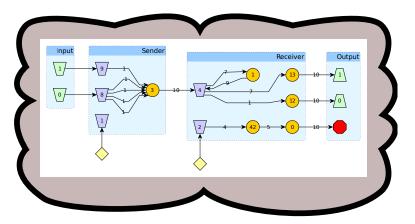


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Agents, their job, & their brains



$A[8] \ge 1 \Rightarrow \text{inc} A[3], \text{dec} A[5]$

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2 Simulated evolution



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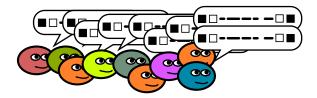
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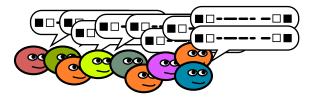
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Selection-mutation processes



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Selection-mutation processes





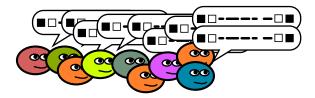
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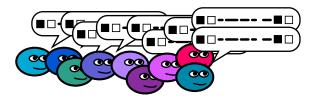
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Selection-mutation processes



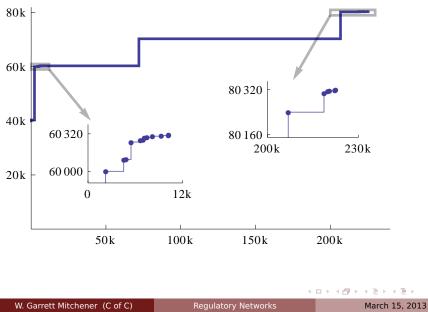


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Punctuated equilibrium

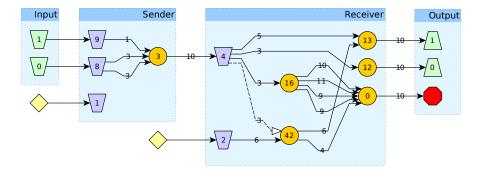


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Perfect solution

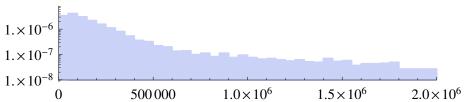


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Time for last innovation

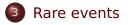


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• Time steps *t* = 0, 1, 2, . . .

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- Time steps *t* = 0, 1, 2, . . .
- All independent

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- Time steps *t* = 0, 1, 2, . . .
- All independent
- Waiting for a rare event

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- Time steps *t* = 0, 1, 2, . . .
- All independent
- Waiting for a rare event
- q = probability that it happens each time step

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- Time steps *t* = 0, 1, 2, . . .
- All independent
- Waiting for a rare event
- q = probability that it happens each time step
- q is small, think 1/100

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- Time steps *t* = 0, 1, 2, . . .
- All independent
- Waiting for a rare event
- *q* = probability that it happens each time step
- q is small, think 1/100
- When does it first happen?

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• **P**(happens at *this* step) = q

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- **P**(happens at *this* step) = q
- **P** (first happens at t = 0) = q

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- **P**(happens at *this* step) = q
- **P** (first happens at t = 0) = q
- **P**(first happens at t = 1) =?

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- **P**(happens at *this* step) = q
- **P** (first happens at t = 0) = q
- **P**(first happens at *t* = 1) =?
 - **P** (doesn't happen at t = 0) = 1 q

- **P**(happens at *this* step) = q
- **P** (first happens at t = 0) = q
- **P**(first happens at *t* = 1) =?
 - **P** (doesn't happen at t = 0) = 1 q
 - **P** (does happen at t = 1) = q

- **P**(happens at *this* step) = q
- **P** (first happens at t = 0) = q
- **P**(first happens at *t* = 1) =?
 - **P** (doesn't happen at t = 0) = 1 q
 - **P** (does happen at t = 1) = q
 - **P** (first happens at t = 1) = (1 q)q

- **P**(happens at *this* step) = q
- **P** (first happens at t = 0) = q
- **P** (first happens at t = 1) = (1 q)q

- **P**(happens at *this* step) = q
- **P** (first happens at t = 0) = q
- **P**(first happens at t = 1) = (1 q)q
- **P**(first happens at *t* = 2) =?

- **P**(happens at *this* step) = q
- **P** (first happens at t = 0) = q
- **P**(first happens at t = 1) = (1 q)q
- **P**(first happens at *t* = 2) =?
 - **P** (doesn't happen at t = 0) = 1 q

- **P**(happens at *this* step) = q
- **P** (first happens at t = 0) = q
- **P**(first happens at t = 1) = (1 q)q
- **P**(first happens at *t* = 2) =?
 - **P** (doesn't happen at t = 0) = 1 q
 - **P** (doesn't happen at t = 1) = 1 q

- **P**(happens at *this* step) = q
- **P** (first happens at t = 0) = q
- **P**(first happens at t = 1) = (1 q)q
- **P**(first happens at *t* = 2) =?
 - **P** (doesn't happen at t = 0) = 1 q
 - **P** (doesn't happen at t = 1) = 1 q
 - **P** (does happen at t = 2) = q

- **P**(happens at *this* step) = q
- **P** (first happens at t = 0) = q
- **P**(first happens at t = 1) = (1 q)q
- **P**(first happens at *t* = 2) =?
 - **P** (doesn't happen at t = 0) = 1 q
 - **P** (doesn't happen at t = 1) = 1 q
 - **P** (does happen at t = 2) = q
 - **P**(first happens at t = 2) = $(1 q)^2 q$

- **P**(happens at *this* step) = q
- **P** (first happens at t = 0) = q
- **P**(first happens at t = 1) = (1 q)q
- **P**(first happens at t = 2) = $(1 q)^2 q$

- **P**(happens at *this* step) = q
- **P** (first happens at t = 0) = q
- **P**(first happens at t = 1) = (1 q)q
- **P**(first happens at t = 2) = $(1 q)^2 q$

• . . .

- **P**(happens at *this* step) = q
- **P** (first happens at t = 0) = q
- **P**(first happens at t = 1) = (1 q)q
- **P**(first happens at t = 2) = $(1 q)^2 q$

• . . .

- **P**(first happens at t) = $(1 q)^t q$
 - Doesn't happen on steps $0, 1, \ldots t 1$
 - Does happen on step t

Geometric distribution

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```
f(t) = \mathbf{P} \text{ (first happens at } t)
f(t) = (1 - q)^{t}q
f(t)
f
```

400

0

600

1000

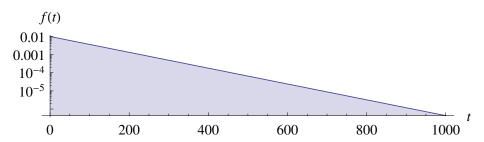
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Geometric distribution

$$f(t) = (1-q)^t q$$

$$\ln(f(t)) = \ln((1-q)^t q) = t \ln(1-q) + \ln(q)$$



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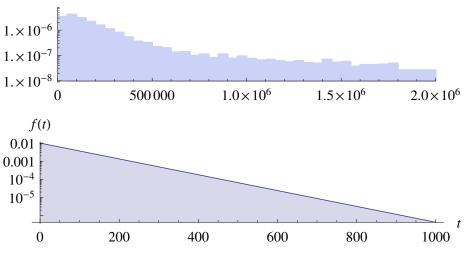
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Time for last innovation



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Conclusion

- Distribution of time for last innovation isn't geometric
- Biased toward smaller times
- More likely to happen shortly after next-to-last innovation
- Some kind of memory effect?

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