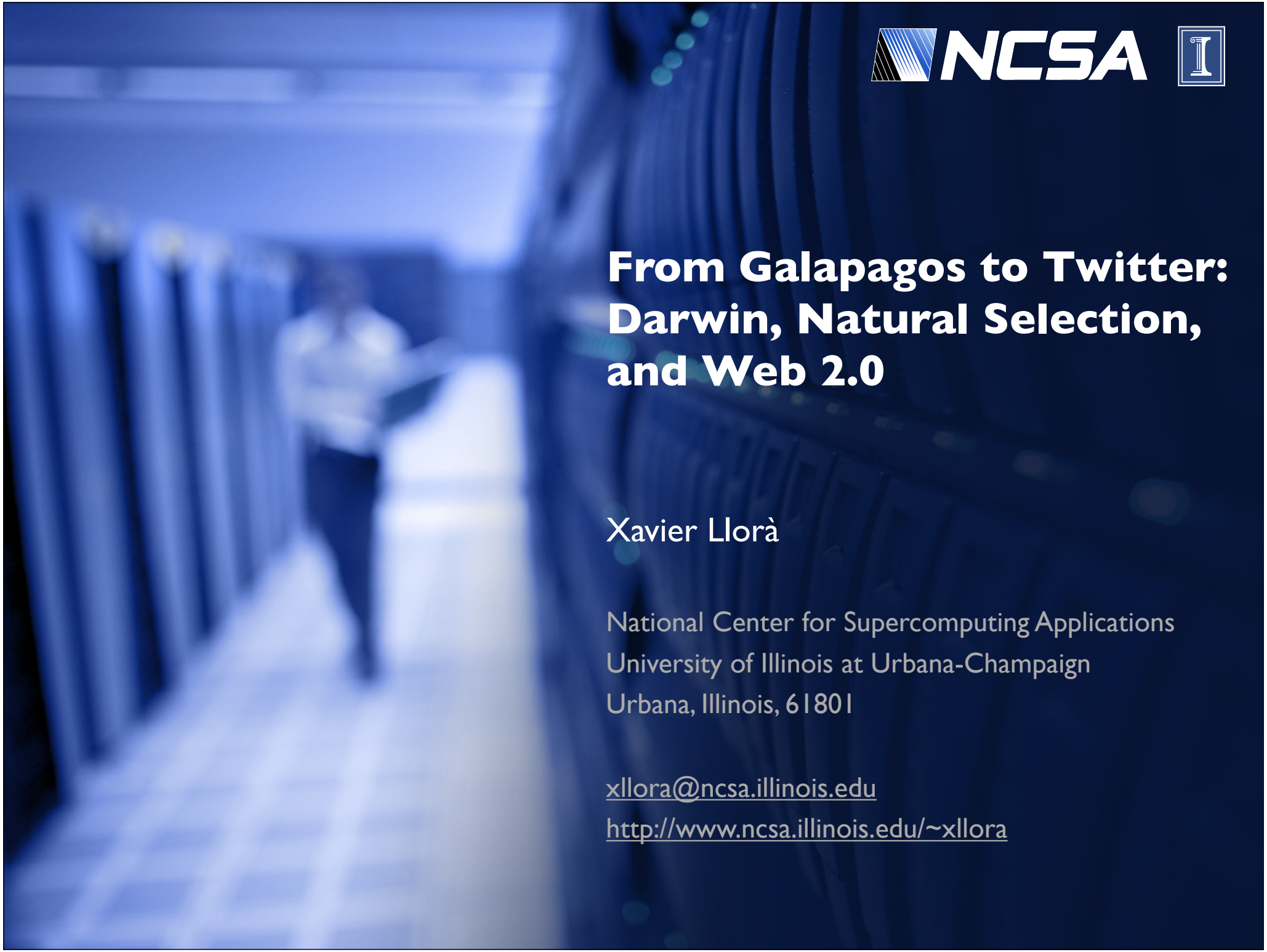

From Galapagos to Twitter: Darwin, Natural Selection, and Web 2.0

Xavier Llorà

National Center for Supercomputing Applications
University of Illinois at Urbana-Champaign
Urbana, Illinois, 61801

xllora@ncsa.illinois.edu
http://www.ncsa.illinois.edu/~xllora

What is this talk about?

- Simple answer:
  Darwin's natural selection concept and information technologies

- Natural selection?

  Natural selection is the process by which heritable traits that make it more likely for an organism to survive and successfully reproduce become more common in a population over successive generations.

- Remember, back on Darwin's time genetics were unknown

Darwin on HMS Beagle

A quick Darwin background check

- In Edinburgh Charles Darwin
  - Learnt standard geology (Robert Jameson)
  - Exposed to British catastrophism of 1820s
  - Run into Lamarckian ideas with Robert Grant
- Cambridge provide him a chance to
  - Under John Henslow, explored boundaries between varieties and species
  - Read and accepted traditional theological explanations of the world
- Evolution existed *before* and *after* Darwin
- HMS Beagle
  - Left Plymouth 2pm on December 27, 1831
  - Returned October 2, 1836

HMS Beagle

http://www.solarnavigator.net/history/hms_beagle.htm

And Galapagos happened

Massive diversity

http://www.flickr.com/photos/ole/1040941928/

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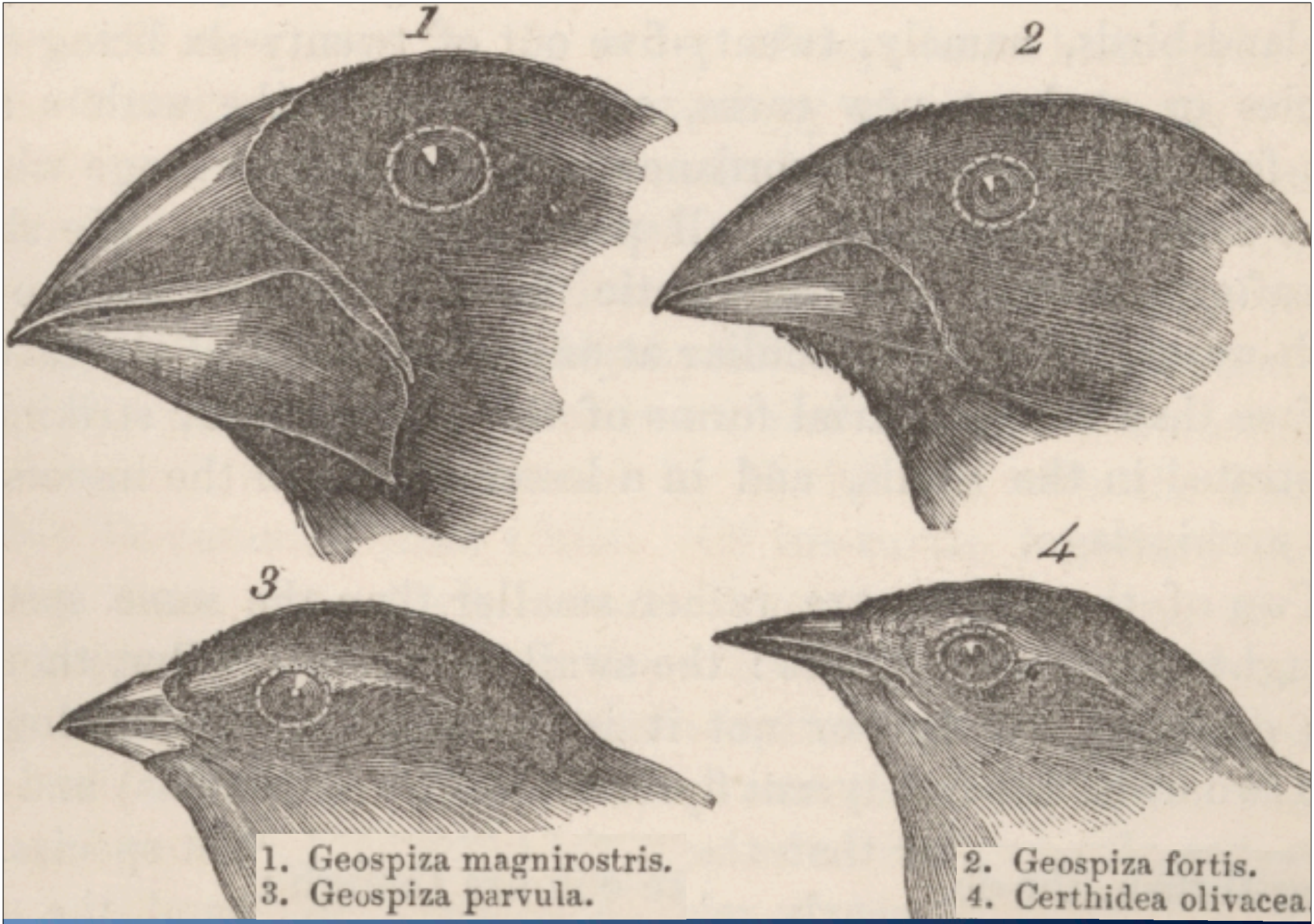
A key realization

- Knowledge on the boundaries of variation/species
- The facts
  - Large number of islands
  - Islands are spatially separated
  - Wide diversities of species (different sources of food)
  - Very close species (beyond variation)
- Start accumulating descriptions of specimens


1
2
3
4
1. Geospiza magnirostris.
3. Geospiza parvula.
2. Geospiza fortis.
4. Certhidea olivacea.

The basic building blocks

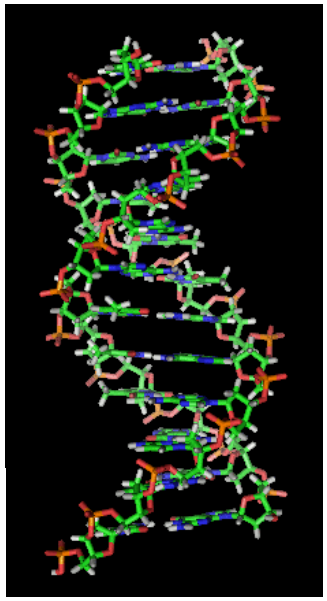
- Large variation of features
- Highly correlated to food sources
- The basic sketch of a crazy thought:
  - Assume you start with a diverse population of As
  - Split As and place them in different environments
  - Individual a_i features may or may not help live in the environment
  - If individual a_i features help in the environment a_i as a result has increased chances to reproduce
- The underlying distilled idea of natural selection
  - Variation will arise in a population
  - Selection by environment adaptation
- The uncanny idea: Variation can be random

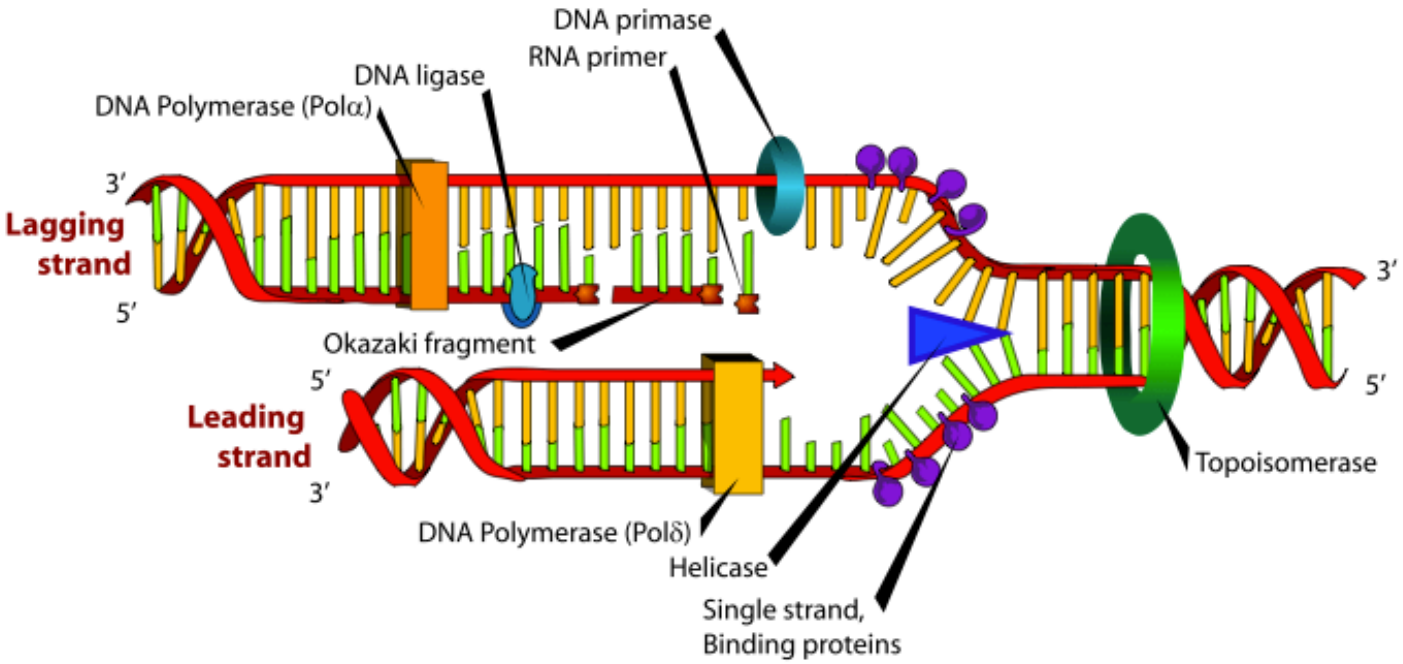
A simple abstraction

[Fast forward] ... and genomics arise

DNA and basics of reproduction

- Watson & Crick (1953)
- Four bases:
  Adenine (A), cytosine (C), guanine (G), thymine (T)
- Groups in to base pairs: A-T, C-G
- Reproduction of DNA (*crossover* and *mutation*)





[Fast forward] ... and computers happen

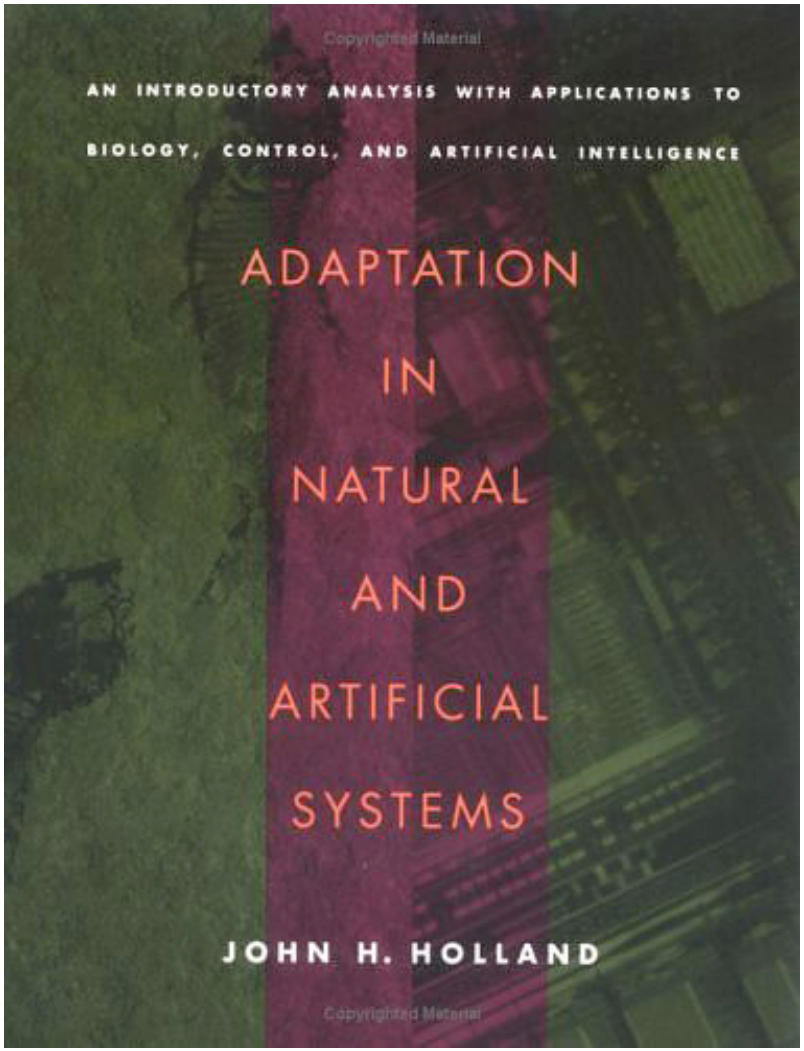
A quick stop in the late 60s

- Computers were the next cool thing
- Genetics were on the rise
- A professor at University of Michigan
- Natural evolution
  - Diverse population of individual
  - Individual a_i features may or may not help live in the environment
  - If individual a_i features help in the environment a_i as a result has increased chances to reproduce
- Artificial evolution?
  - Model of such evolutionary process
  - Use it to solve some real problem

Prof. John H. Holland

What is a genetic algorithm?

- ANAS published in 1975
- Chromosomes encode a solution to a problem
- Evaluation of fitness based on the quality solving the problem
- The process
  - Survival of the fitness
  - Mutation
  - Crossover
  - Repeat until good enough

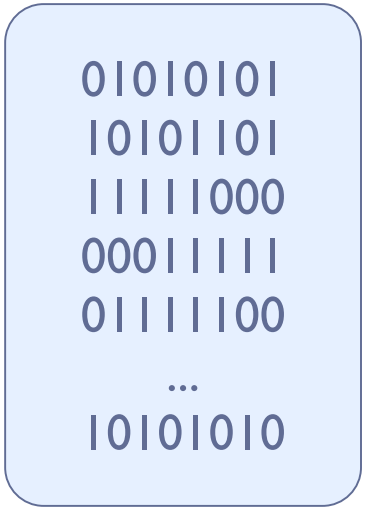


A simple example

- Imagine you have a box with an array of switches
- 0 off, 1 on
- Depending on the switch arrangement you get some payoff
- Payoff is equivalent to the number of switches that are on
- The goal: Maximize the payoff

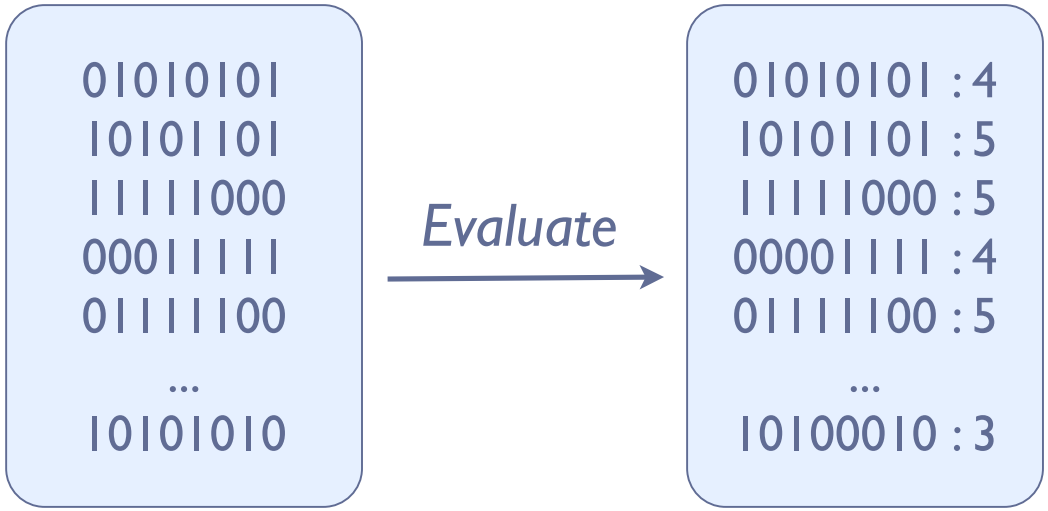
Encoding the problem

- Solutions are a string of 0s and 1s.
- We need a population



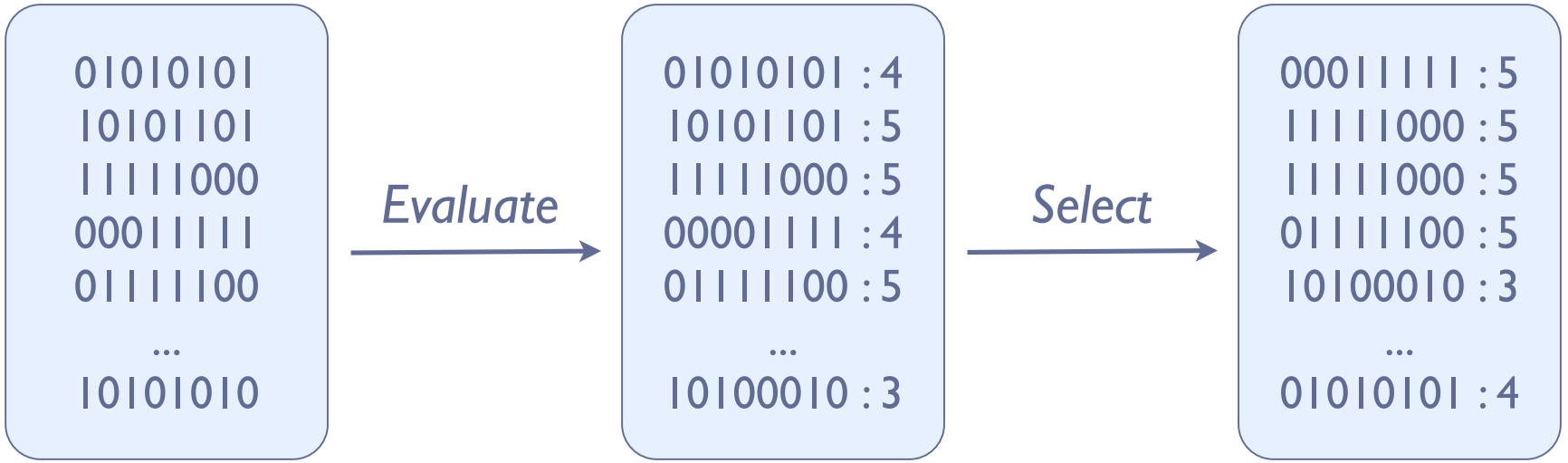
Evaluate solutions performance

- Solutions represent a solution to a particular environment
- Solutions get measured based on their performance



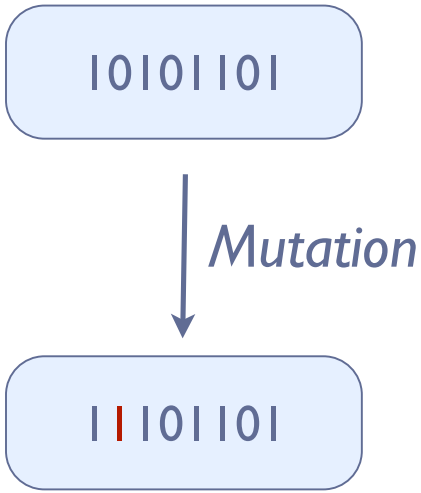
Selection based on performance

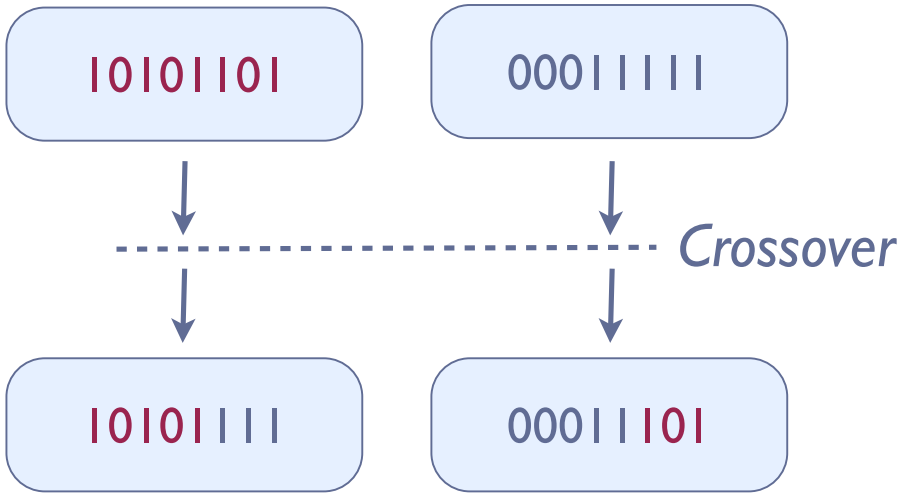
- Proportional to their performance
- Proportionate roulette wheel selection



Reproduction

- Mutation introduce random changes in the solution
- Crossover recombines parent solutions





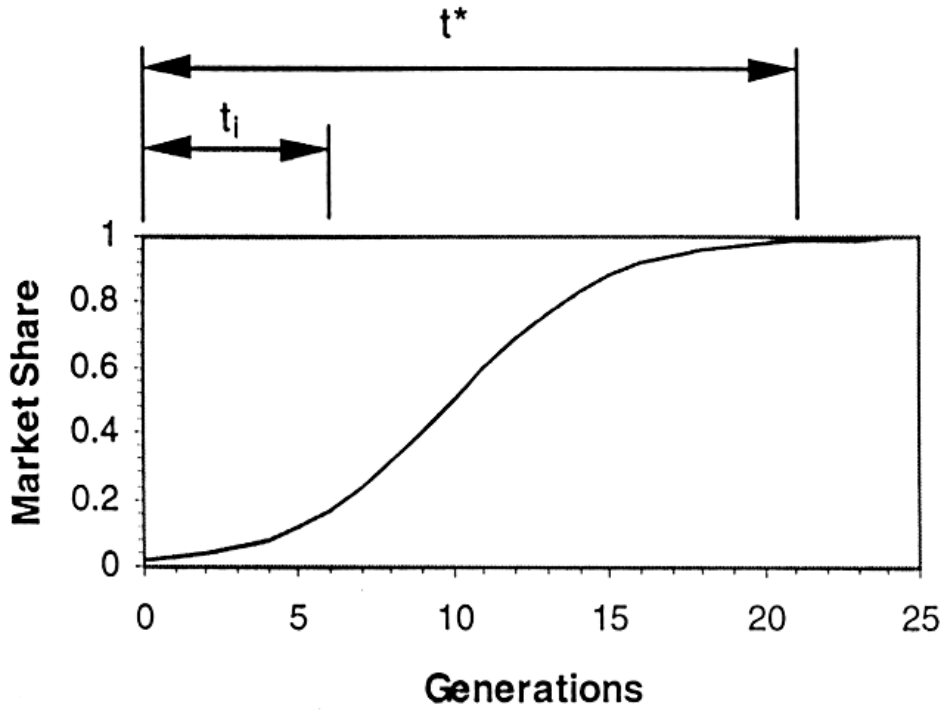
A nagging question

- In early 80s by David E. Goldberg
- How do uninteresting operators yield interesting behavior?
- 1983 proposed the innovation intuition:
  "Genetic algorithm power like that of human innovation"
- The underlying elements:
  - Selection + mutation as hillclimbing or *kaizen*
  - Selection + crossover = *innovation*
- In another words
  - Introducing small changes and keeping them if the improve performance
  - [...] Takes two to invent anything. One makes up combinations; the other one chooses [...] (*Paul Valéry*)

Remember the simple abstraction

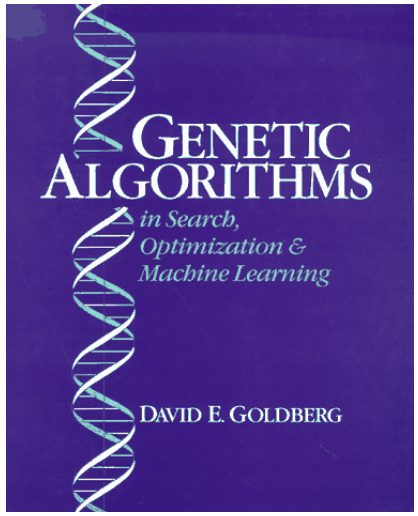
Goldberg's intuition

- Interesting behavior (emergence) is a balance
- Two components
  - Takeover time (t*)
  - Time to innovate (t_i)



Goldberg's intuition

- A design theory for scalable and efficient GAs
  - Understanding building blocks (concepts or ideas)
  - Ensure building block supply
  - Ensure building block growth
  - Control building block speed
  - Ensure good building block decisions
  - Ensure good building block mixing
  - Know building block challengers

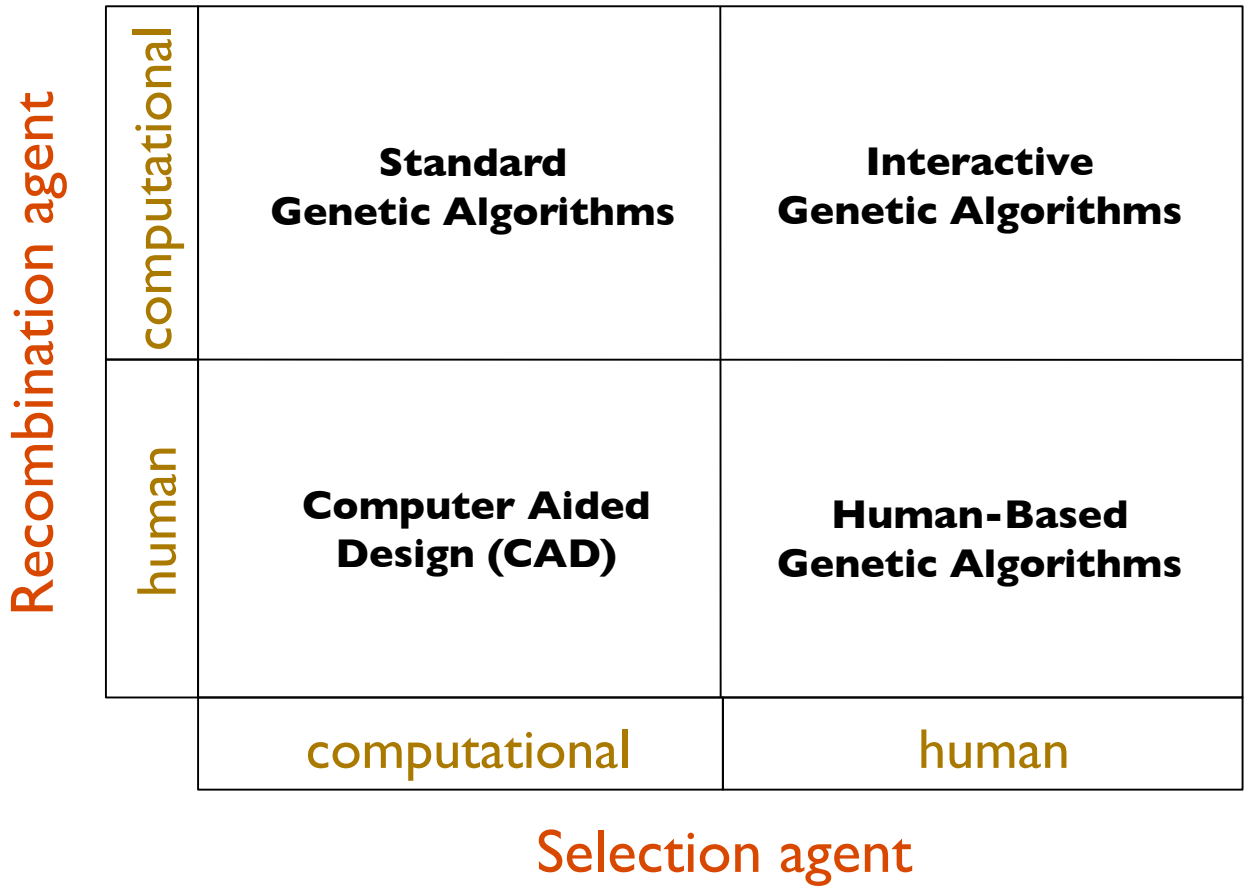


An interesting social insight

- GAs used for optimization, search, machine learning, ...
- But Valéry's quote also implied a social aspect to innovation
  - Solutions may be created in the vacuum, randomly, or carefully crafted
  - There is a social element of acceptance/rejection
- Paul Valéry (1871-1945) lived after Darwin published his ideas

[Fast forward] … The 2.0 information age

Adding social to genetic algorithms



(Kosorukoff & Goldberg, 2002)

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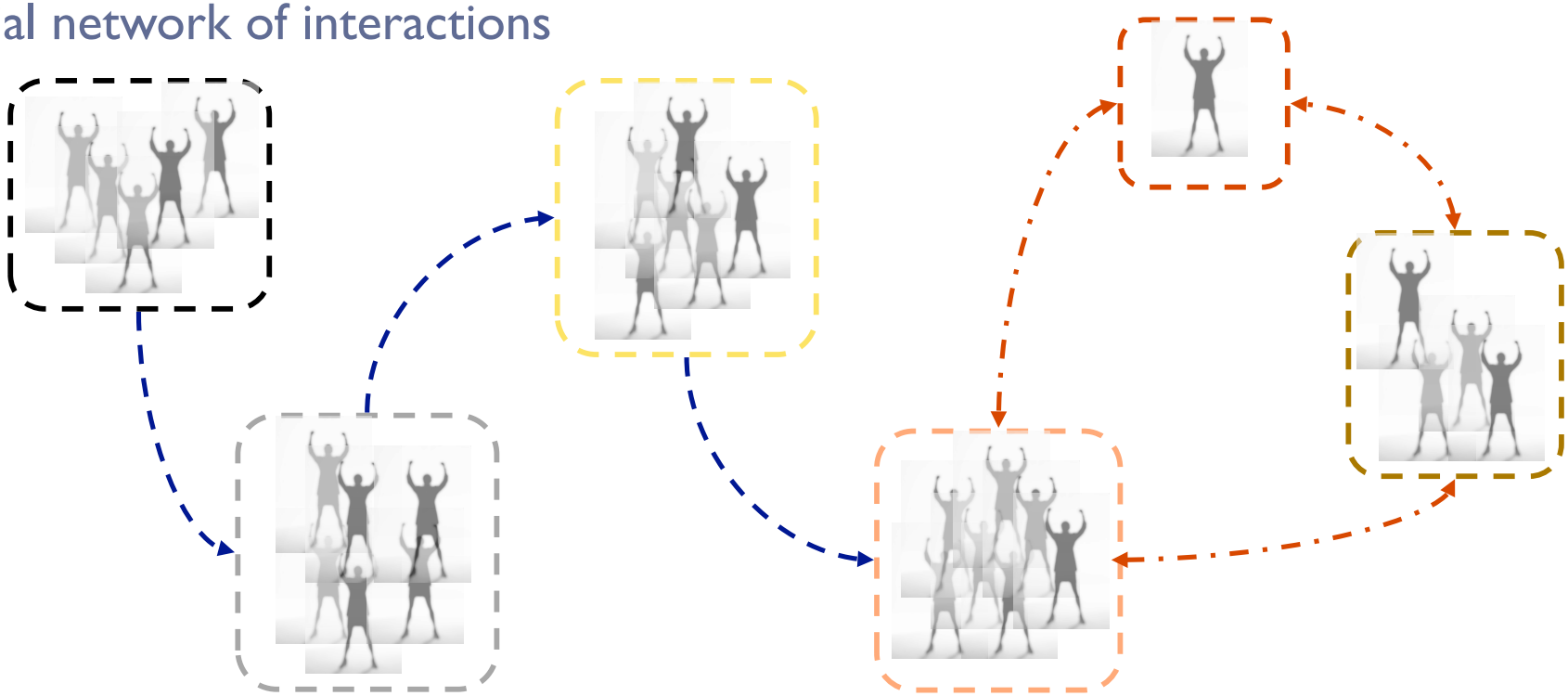
Social aspects of genetic algorithms

- Population-based method
- Parallel genetic algorithms
  - Groups of working units
  - Communication between groups for a common goal
  - Models for collaborative work
- Social network of interactions



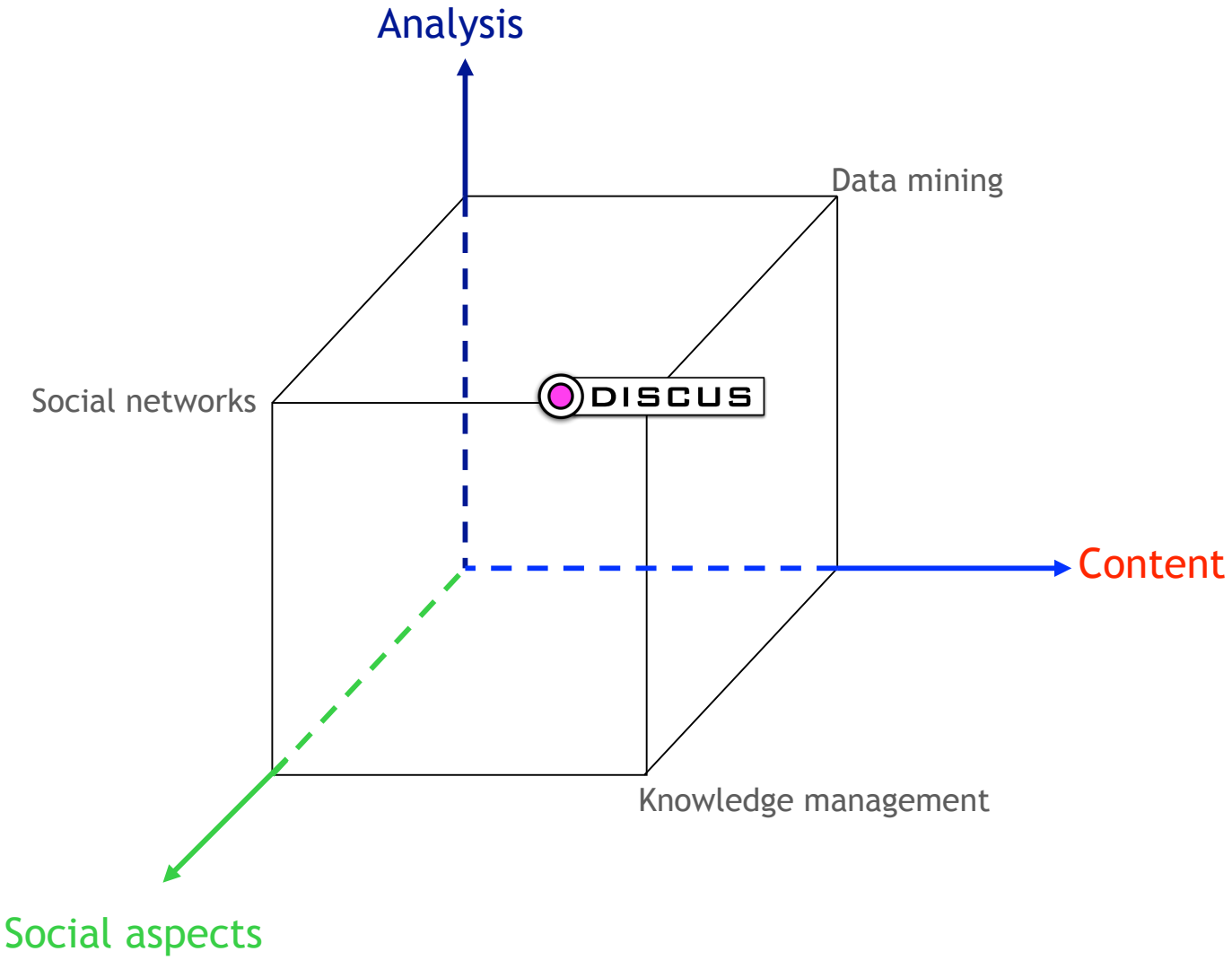
The DISCUS project

- IlliGAL & NCSA collaboration started in 2003
- Computers have become mediators of collaborations
  - Email, chat rooms, blogs, wikis…
  - A flood of available information
  - Different modes of communication
- Let's take advantage of such information
  - Logs of conversations
  - Archive of documents (email attachments, blogs, personal web pages…)
  - Human-computer interactions
  - Social aspect of the communication and collaboration

The question

- Could we help build a system using genetic algorithms/natural selection ideas that could foster innovation and creativity?
- The era of available Web 2.0 tools
  - Web portals
  - Collaboration and communication tools (message boards, chats, blogs, Twitter…)
  - Genetic algorithm (Interactive, Human-based, and Parallel GAs)
  - Chance discovery (KeyGraphs and Influence Diffusion Models)
  - Data and text mining
  - Information retrieval
  - Web services
  - Data-intensive computing

In a picture

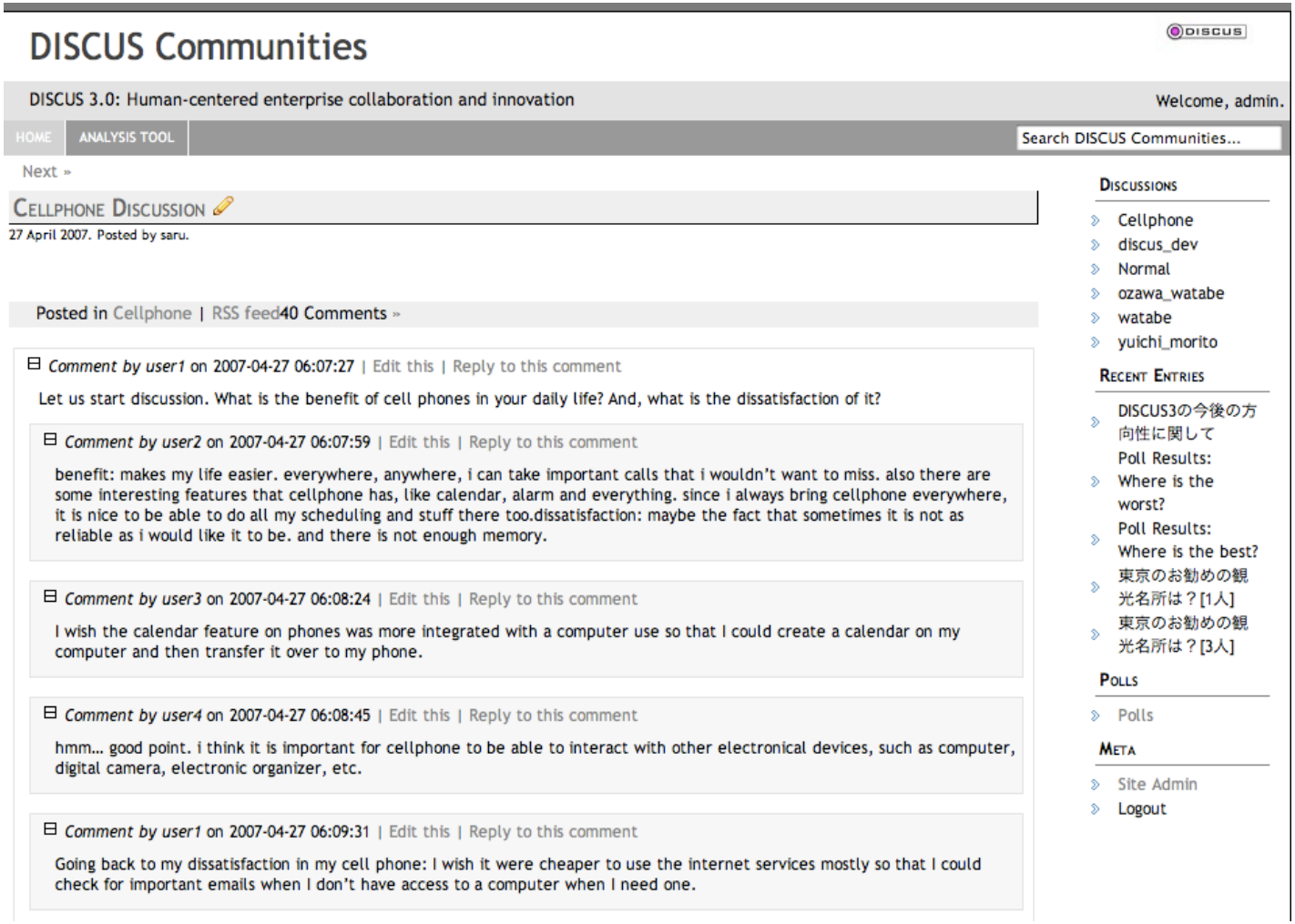


(Llorà et al., 2004)

A simple exercise

- Imagine you are chatting with your friends
- Your ideas are bundled in messages
  - You pass them your your friends
  - They read them, think about them
  - Your friends reply to you
- Could we model it using natural selection?
  - Valéry suggest so
  - Goldberg proposed a simple model using the human-based GA analogy
- If so, Goldberg's methodology should apply

People interacting online



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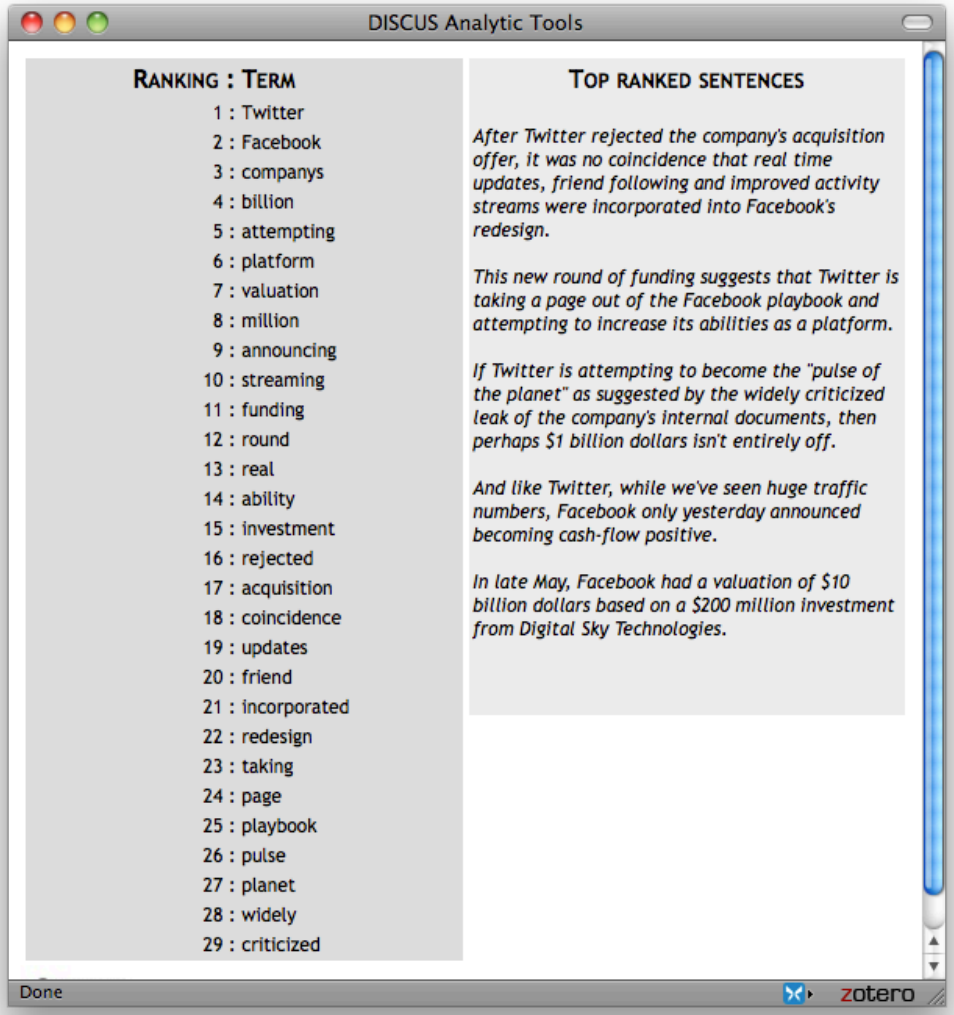
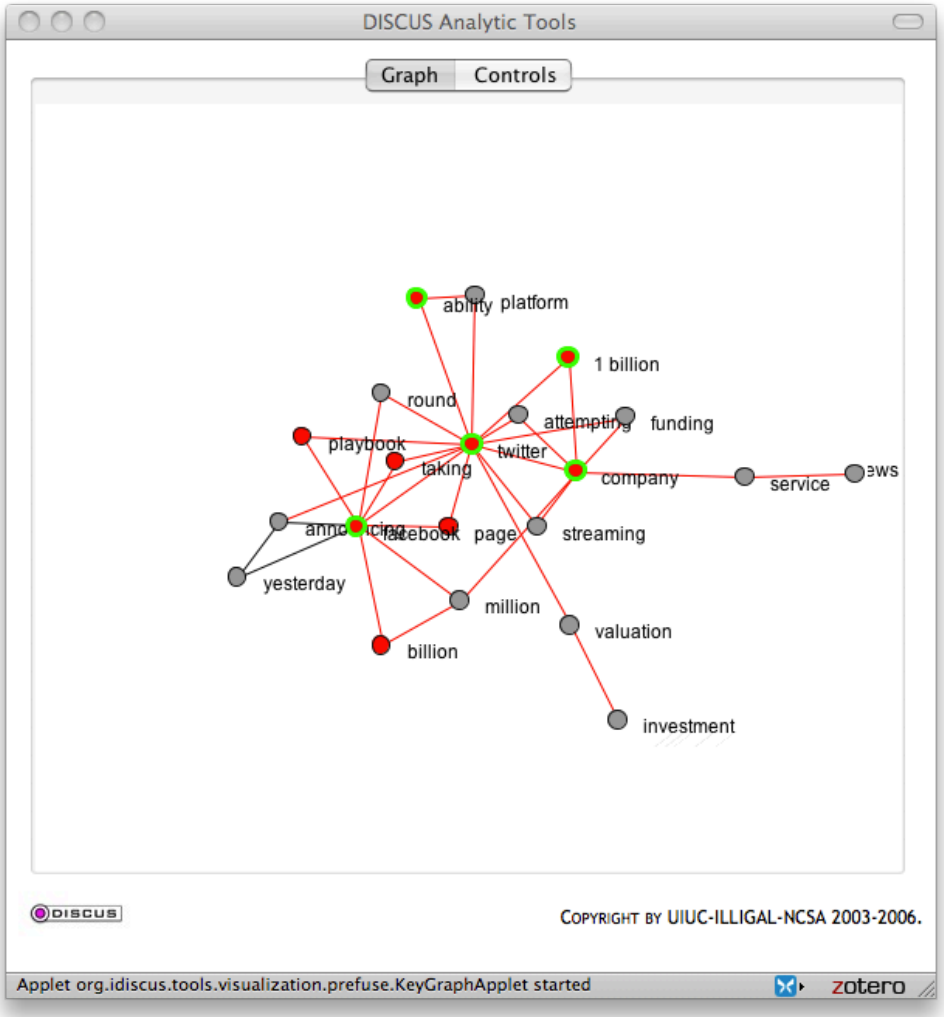
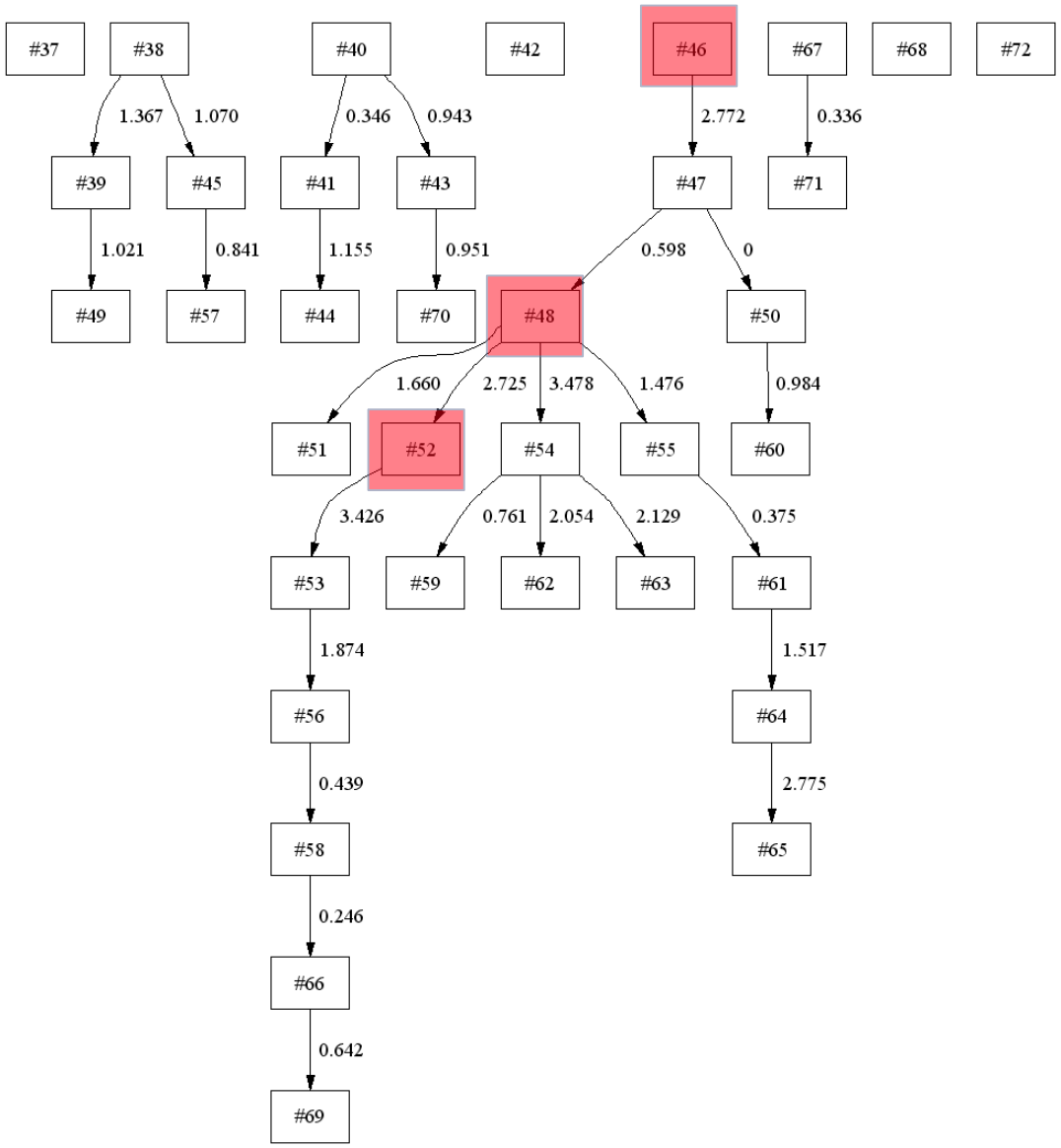
Concepts as building blocks





(Llorà et al., 2004)

Things you can measure: Concept diffusion



(Llorà et al., 2005)

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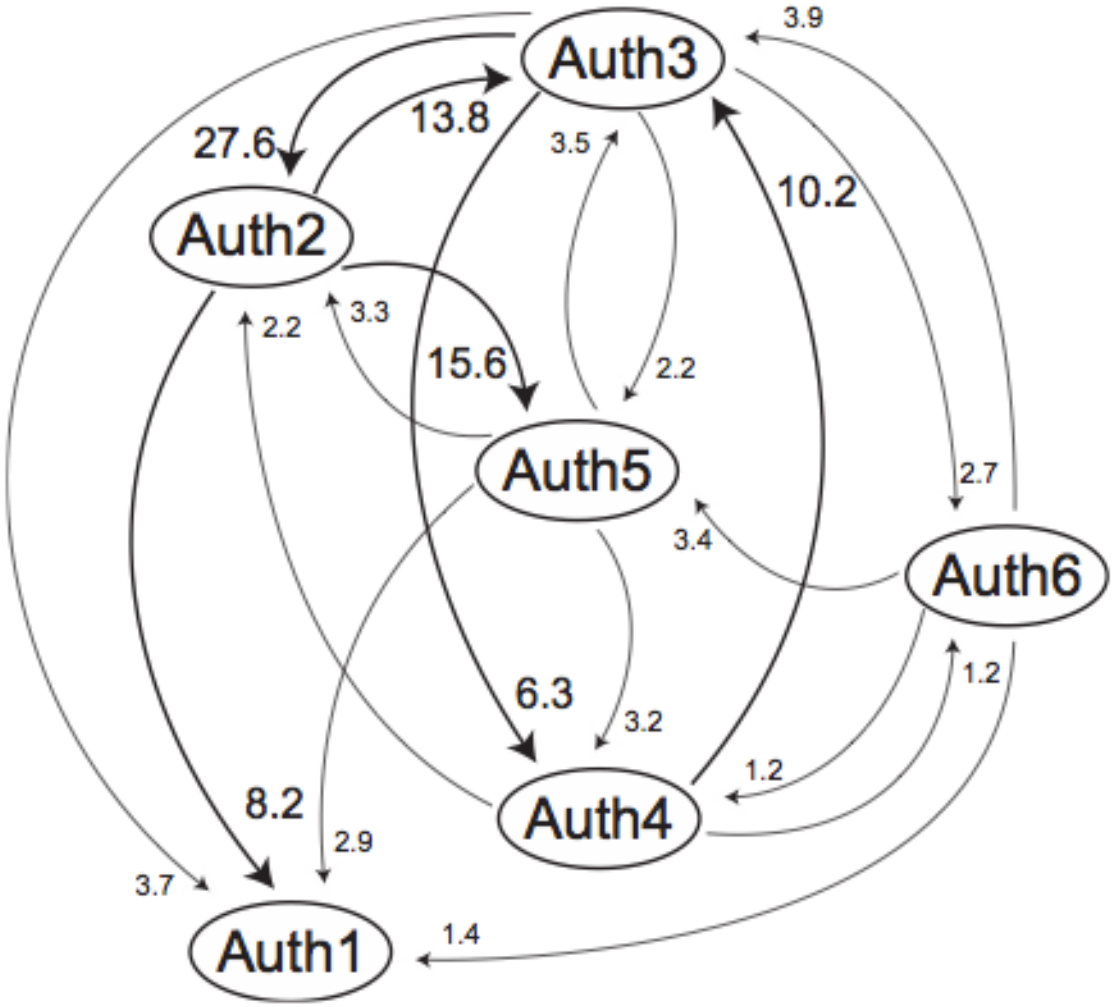
Social acceptance and roles

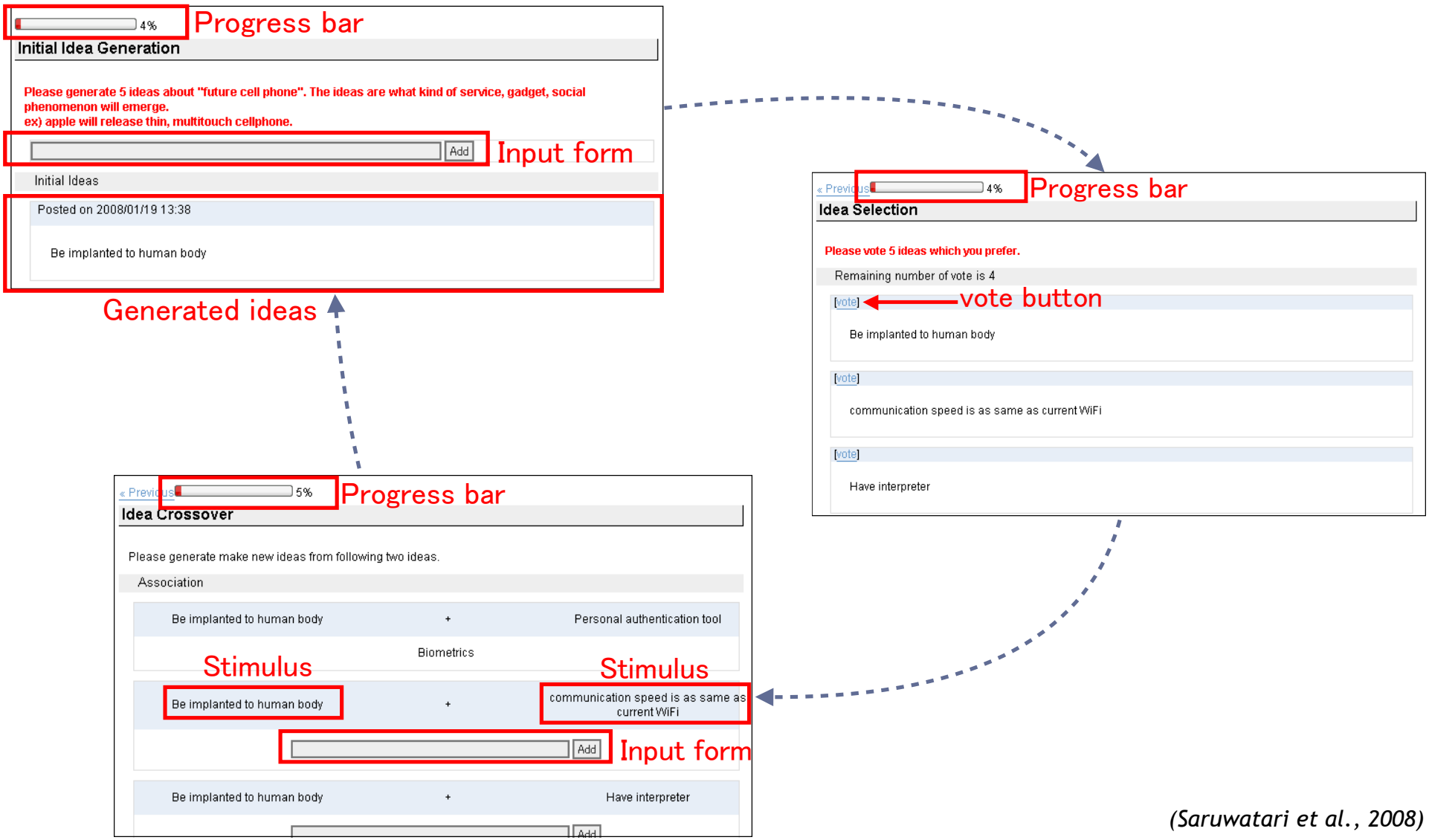


(Yasui et al., 2006)

Everything together

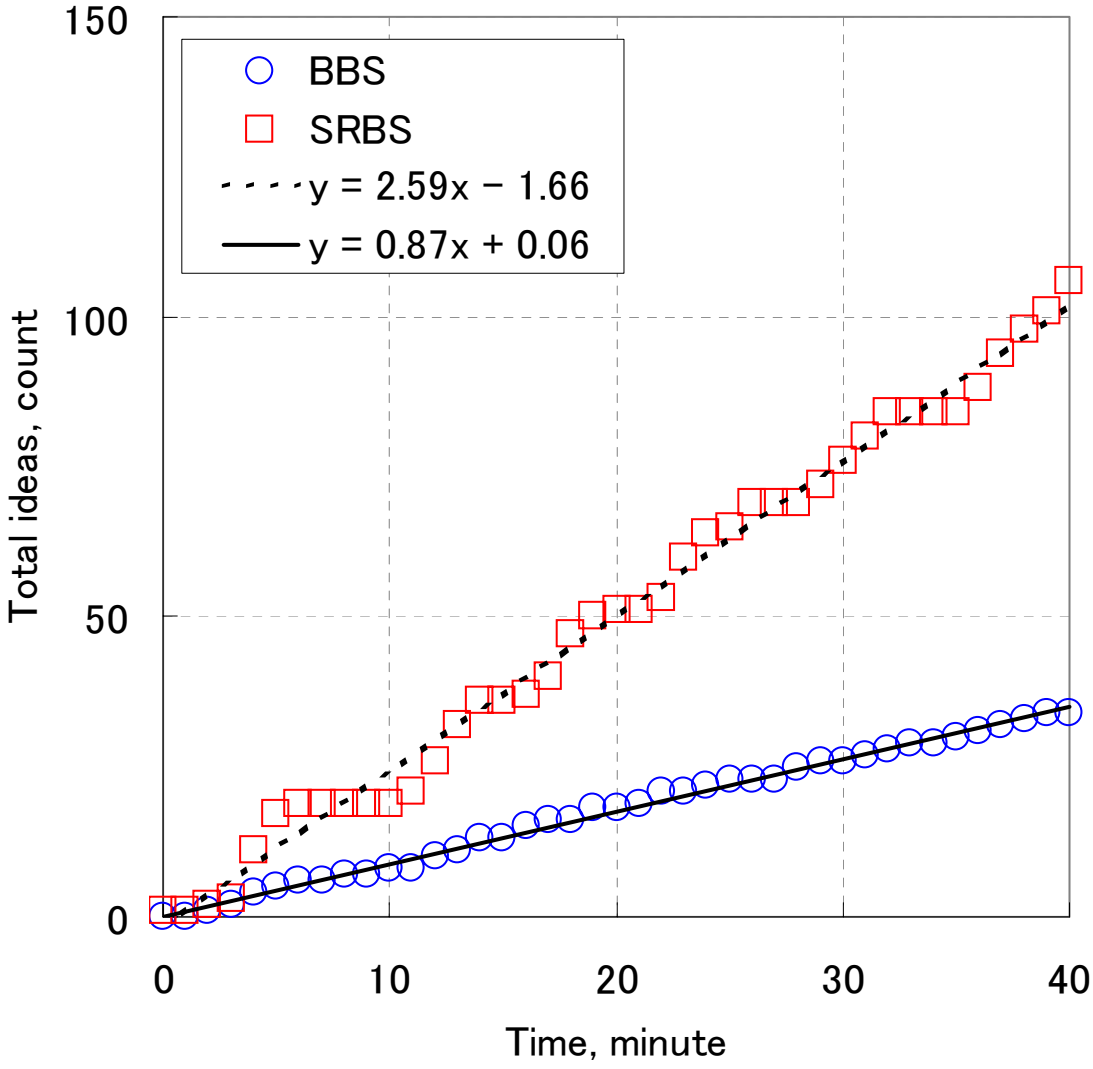
(Saruwatari et al., 2008)

Everything together



(Saruwatari et al., 2008)

In action



(Saruwatari et al., 2008)

Other possible usages

- Tracking influence on social media (e.g. Twitter)
- User preference modeling
- Topic overlap
- Topic/trend dynamics (how conversation is changing on the fly)
- Blogosphere and company message misalignment
- ...

... and beyond

SW development and Darwin's ideas?

- Data deluge, processing large volumes of data starting to become the norm, not the exception
- Another nagging question back on 2007
- Could we use the basic design principles by Goldberg to build software?
- A subset of those could have the answer
  - Understanding building blocks (concepts or ideas)
  - Ensure building block supply
  - Ensure building block growth
  - Ensure good building block mixing
- Also
  - Exploiting parallelism efficiently is becoming a more pressing issue
  - SW is a social activity

A little thinking

- Understanding building blocks (concepts or ideas)
  - Basic units of data processing
  - Building blocks should be easy to group and swap
- Ensure building block supply
  - Create a basic set of building block
- Ensure building block growth
  - Provide a set of tools for developers to add more building blocks
- Ensure good building block mixing
  - Facilitate the reproduction of solutions (programs)
  - Provide means to make those recombination possible

Modeling Meandre

- The basic outline
  - Data-flow execution paradigm
  - Semantic-web driven
  - Web oriented
  - Facilitate distributed computing
  - Support publishing services
  - Promote reuse, sharing, and collaboration
- Fall 2007 Meandre was adopted as the data-intensive platform for a collection of projects
- More information at http://seasr.org/meandre

Data flow execution in Meandre

- A simple example $c \leftarrow a+b$
- A traditional control-driven language

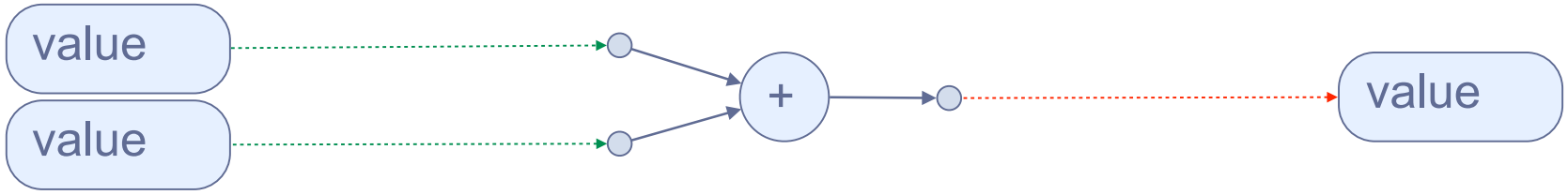
```
a = 1
b = 2
c = a+b
```

- Execution following the sequence of instructions
- One step at a time
  - a+b+c+d requires 3 steps
  - Could be easily parallelized

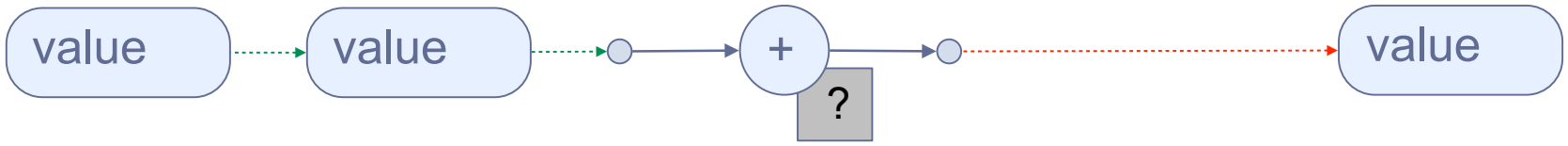
Data flow execution in Meandre

- Data flow execution is driven by data
- The previous example may have 2 possible data flow versions

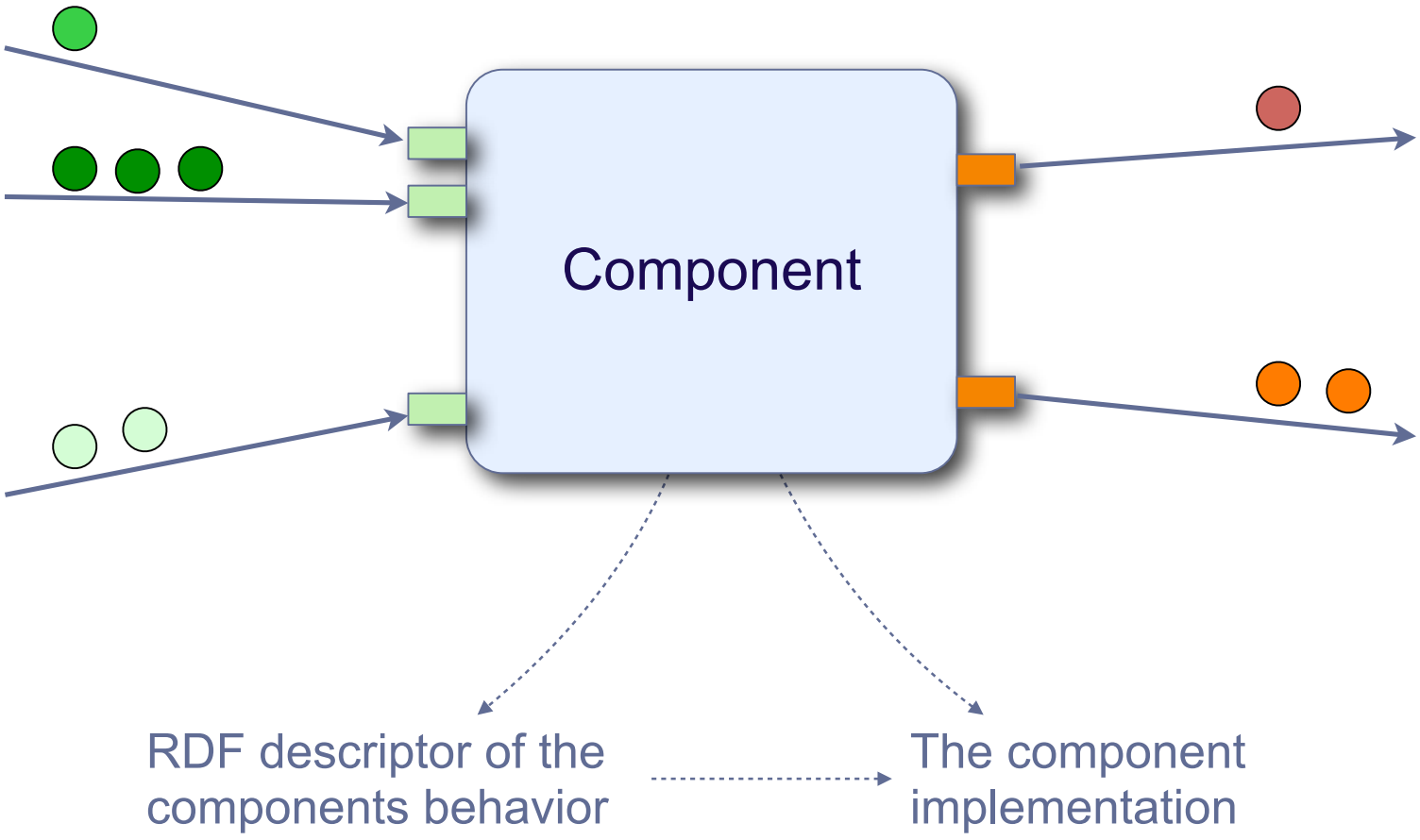
Stateless data flow



State-based data flow

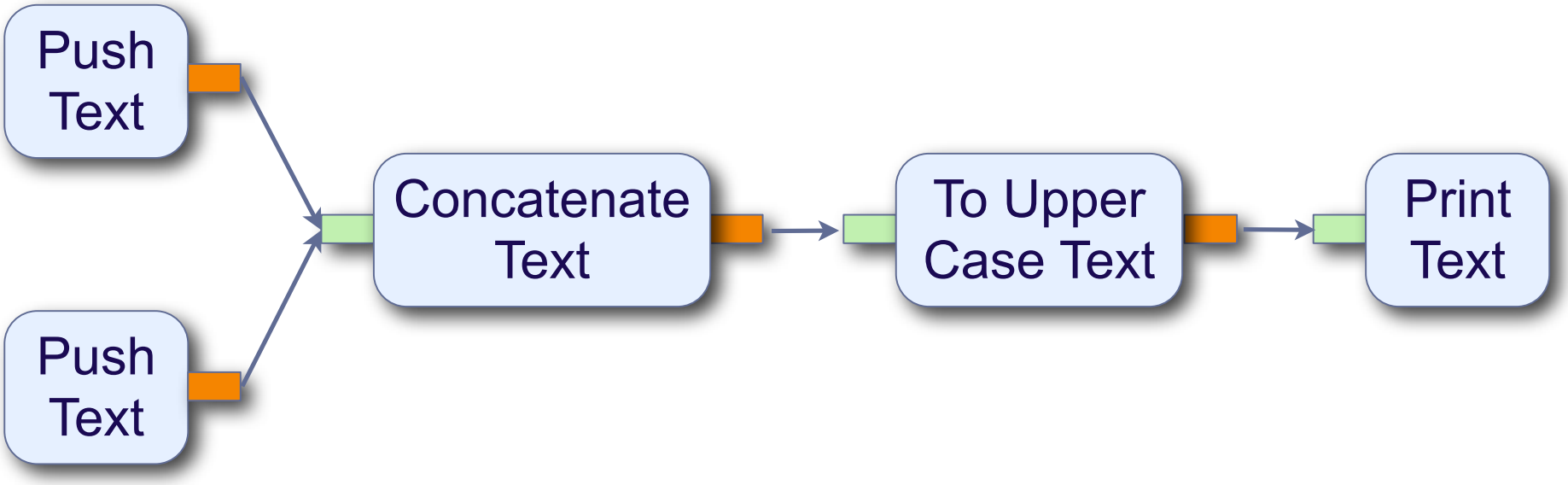


The basic building blocks: Components



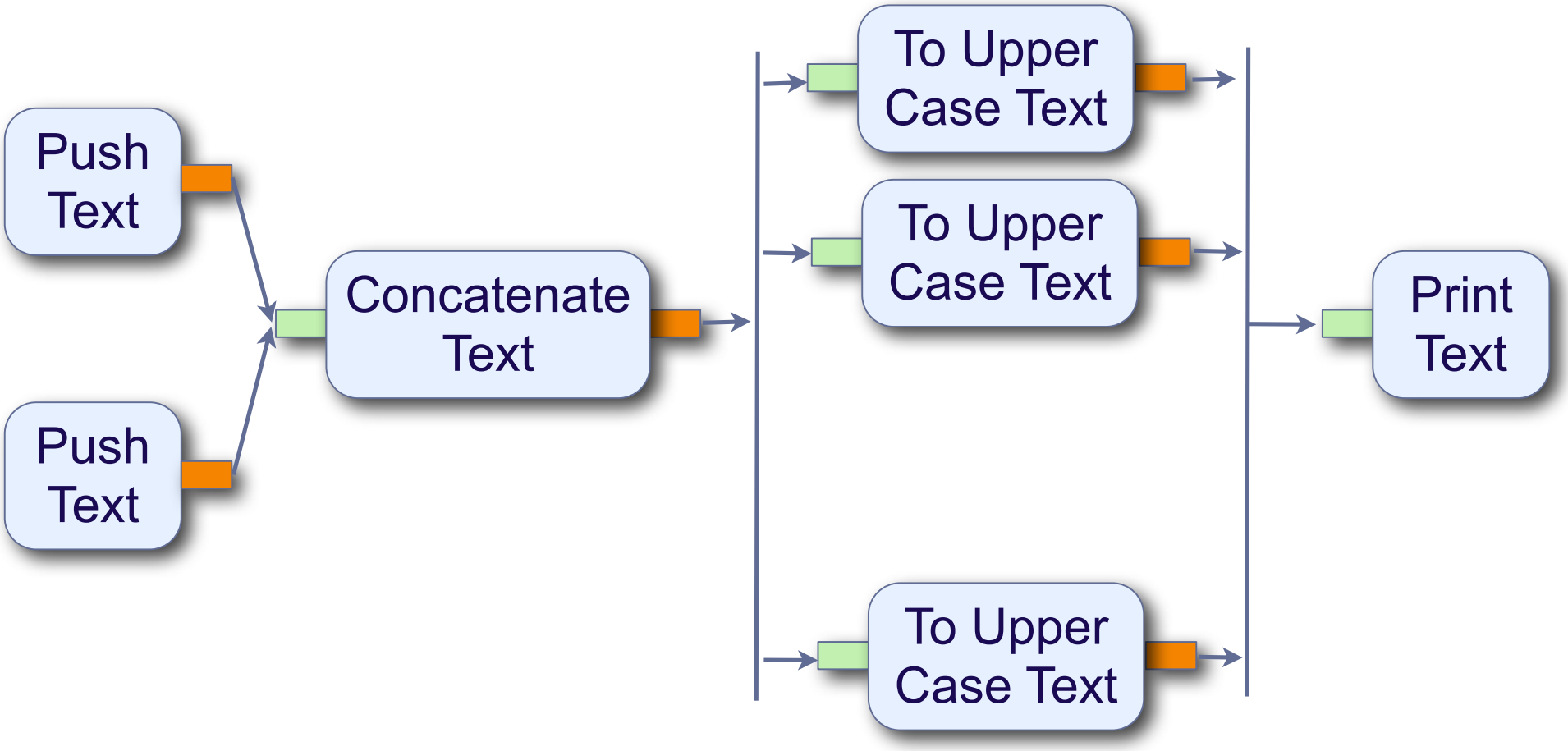
Go with the flow: Creating complex tasks

- Directed multigraph of components creates a flow

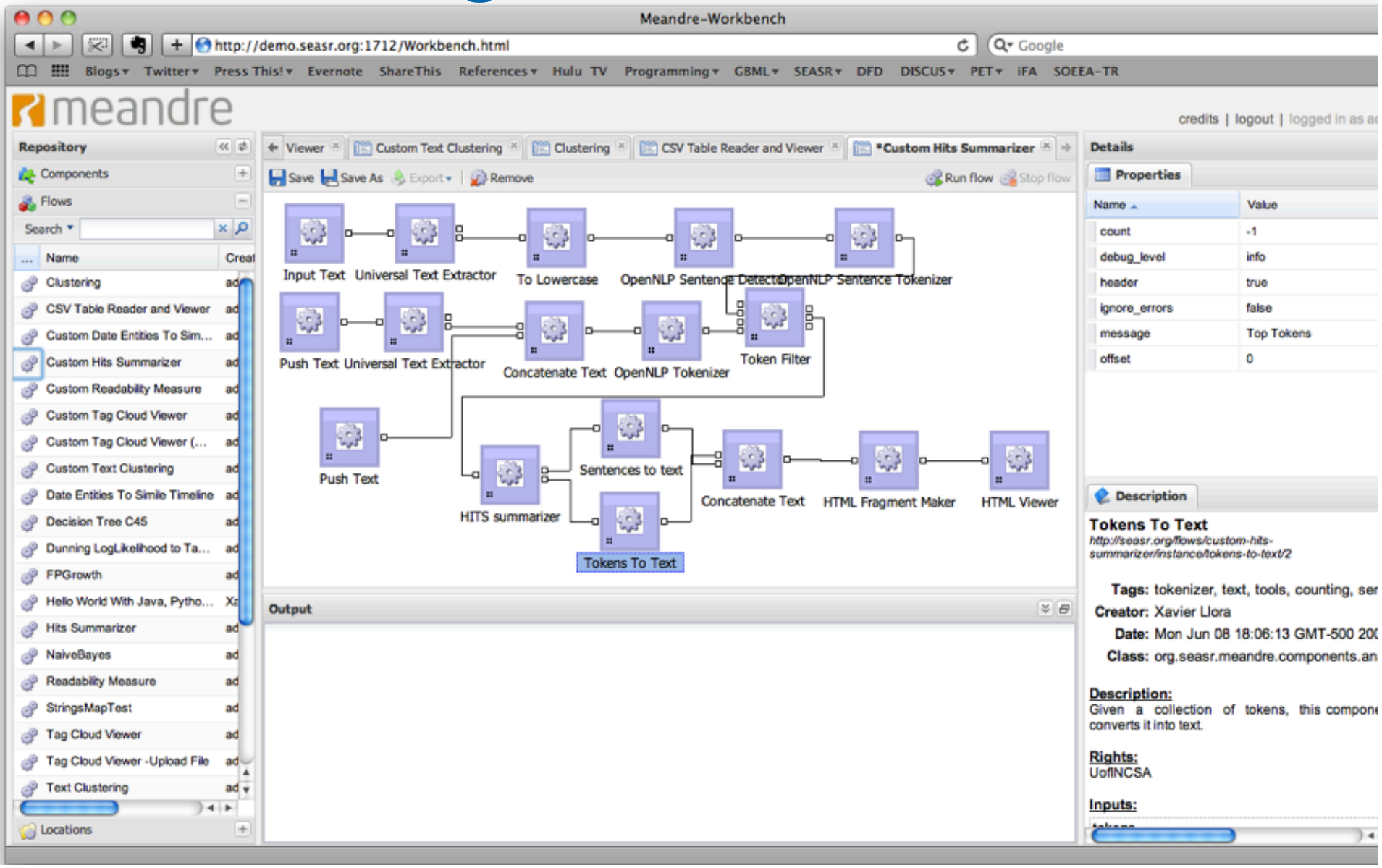


Automatic parallelization: Speed and robustness

- Meandre ZigZag language allow automatic parallelization



Visual building block recombination



Where is natural selection?

- More DISCUS-like evolutionary modeling
- Variations (components) in a population of solutions (flows)
- Selection by usage/adoption
- Recombination of flow available (encapsulation)

The take away message

Basic food for thought

- The underlying distilled idea of natural selection
  - Variation will arise in a population
  - Selection by environment adaptation
- Powerful modeling tool
  - Problem solving (optimization and search)
  - Machine learning
  - Human social interaction modeling
  - Defining new ways to explore computer programming
  - ...
- Don't be afraid to try and explore

More information

- Illinois Genetic Algorithms Laboratory
  - http://www.illigal.uiuc.edu/web
- The DISCUS project
  - http://www.i-discus.org
- The Meandre project
  - http://seasr.org/meandre
  - http://seasr.org
- National Center for Supercomputing Applications
  - http://www.ncsa.illinois.edu
- Homepage
  - http://www.xavierllora.net
- Some related Twitter users
  - People: @xllora, @deg511
  - Labs and projects: @illigal, @projectmeandre, @seasrproject

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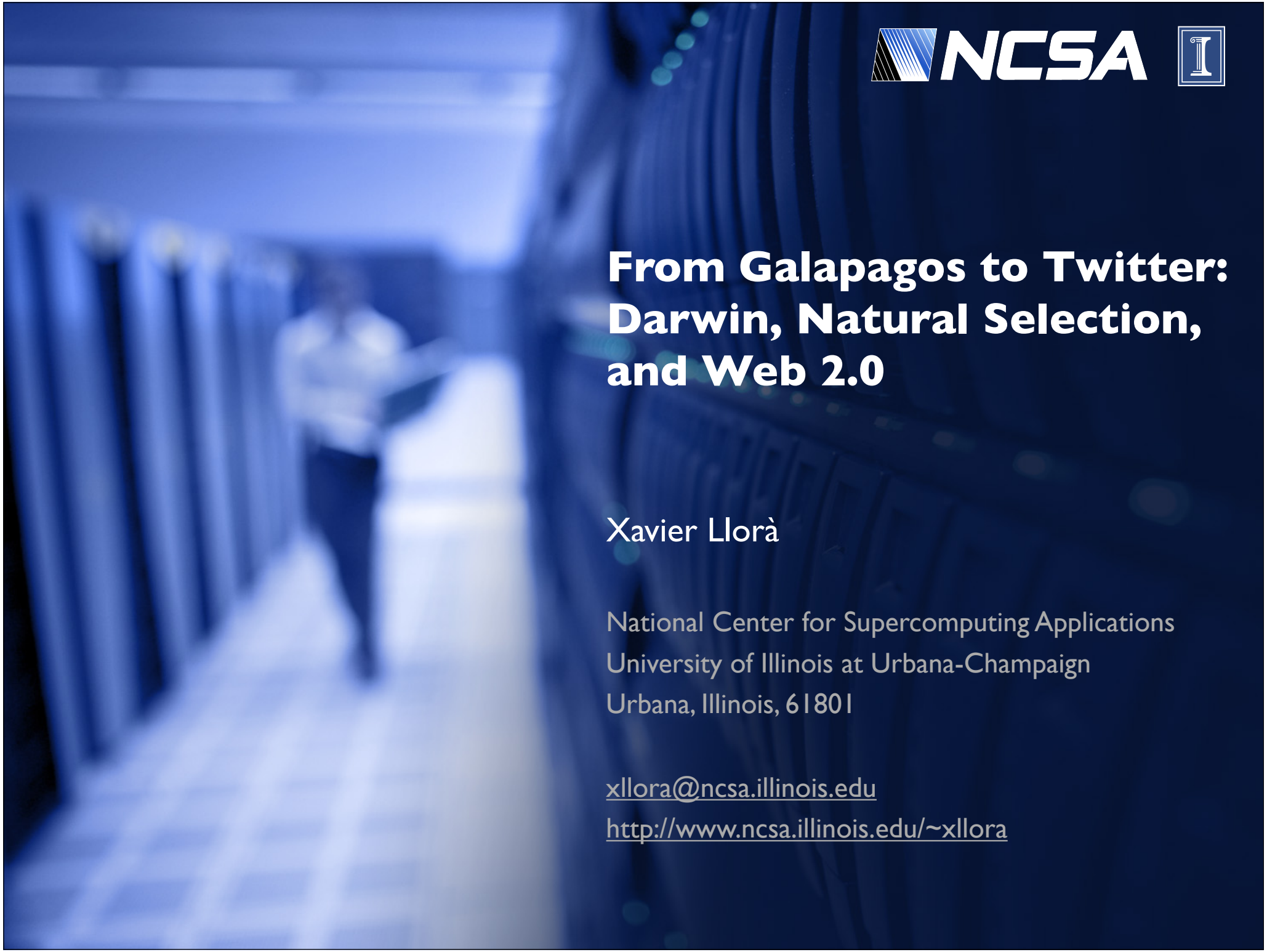

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Xavier Llorà

National Center for Supercomputing Applications
University of Illinois at Urbana-Champaign
Urbana, Illinois, 61801

xllora@ncsa.illinois.edu
http://www.ncsa.illinois.edu/~xllora