

Computational Behavioral Ecology

Tanya Berger-Wolf

Computational Population Biology Lab

University of Illinois at Chicago

+

Large Network of

Students, Colleagues, Friends

SCIENCE AND METHOD

BY HENRI POINCARÉ. TRANSLATED BY FRANCIS MAITLAND. WITH A PREFACE BY THE HON. BERTRAND RUSSELL, F.R.S.

THOMA
LONDON, E

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IN this work I have collected various studies which are more or less directly concerned with scientific methodology. The scientific method consists in observation and experiment. If the scientist had an infinity of time at his disposal, it would be sufficient to say to him, "Look, and look carefully." But, since he has not time to look at everything, and above all to look carefully, and since it is better not to look at all than to look carelessly, he is forced to make a selection. The first question, then, is to know how to make this selection. This question confronts the physicist as well as the historian; it also confronts the mathematician, and the principles which should guide them all are not very dissimilar. The scientist conforms to

Computation + Science



Question

Answer

Available tools, expertise, reality

Plausible explanation

Supported hypothesis

Visualization
Model testing

Experiments analysis

Data

Genomics, sensors, GPS, photo, video, …., crowdsourcing, data integration, storage,…

Intuition, logic, statistical analysis

Patterns, structure, models, optimization

Hypotheses

Statistically testable, parsimony, bigger, scale predictive and descriptive

Behavioral ecology
study of the ecological and evolutionary basis for animal behavior, and the roles of behavior in enabling an animal to adapt to its environment

What does an animal gain, in fitness terms, by doing this rather than that?

Behavior is too important to be left to psychologists.
Donald Griffin










1280 × 853 - thingsorganizedneatly.tumblr.com

















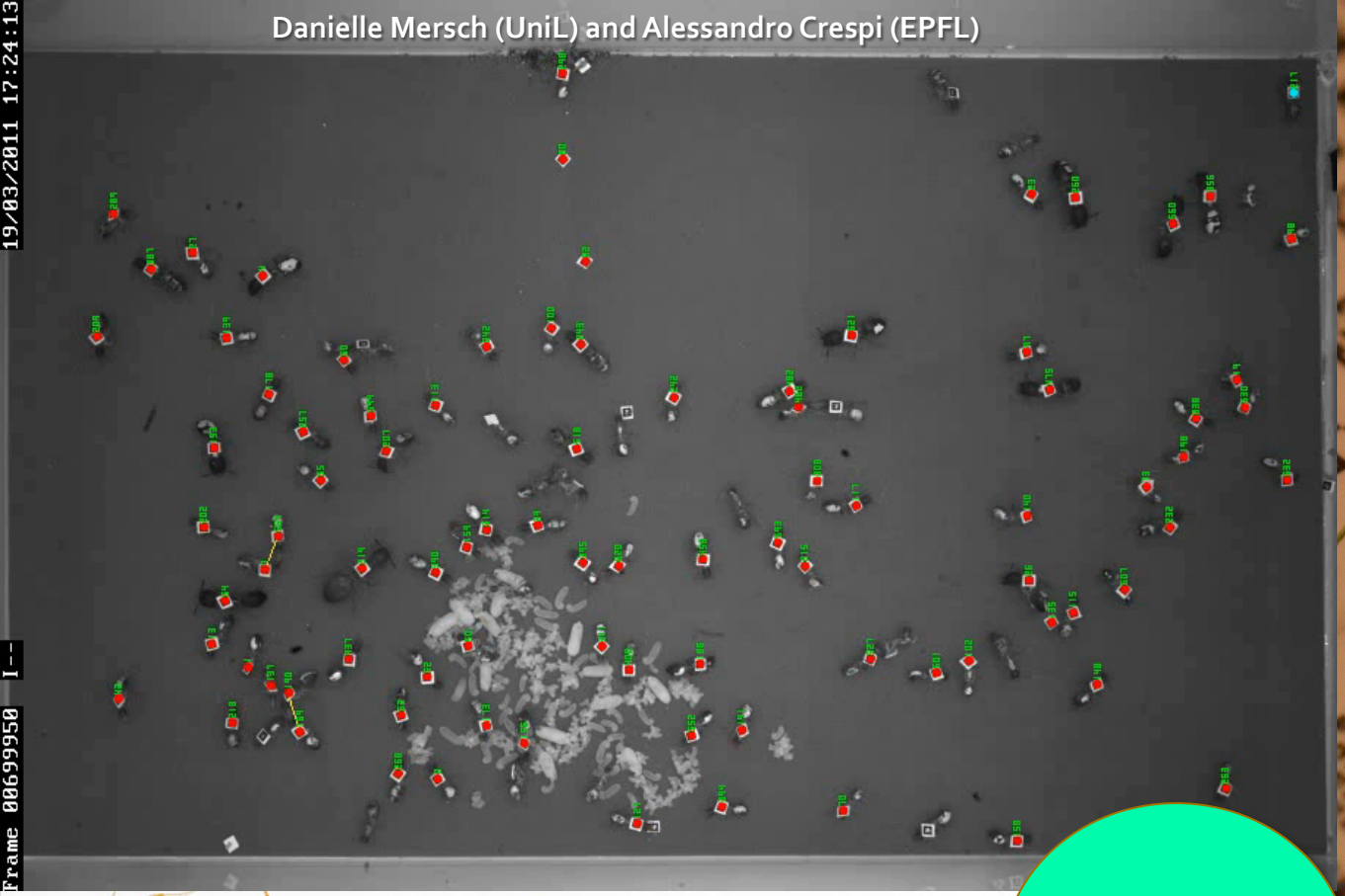


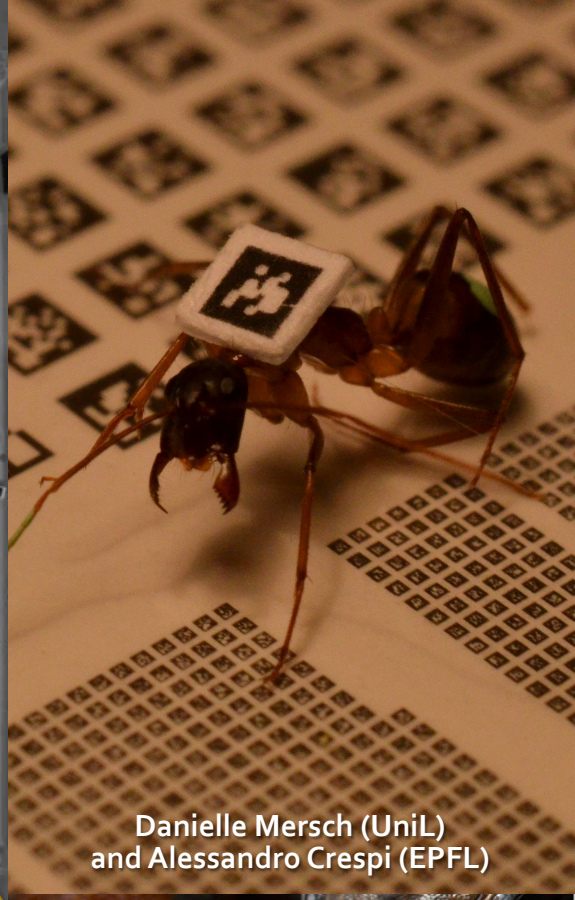






David Pappano, UMich

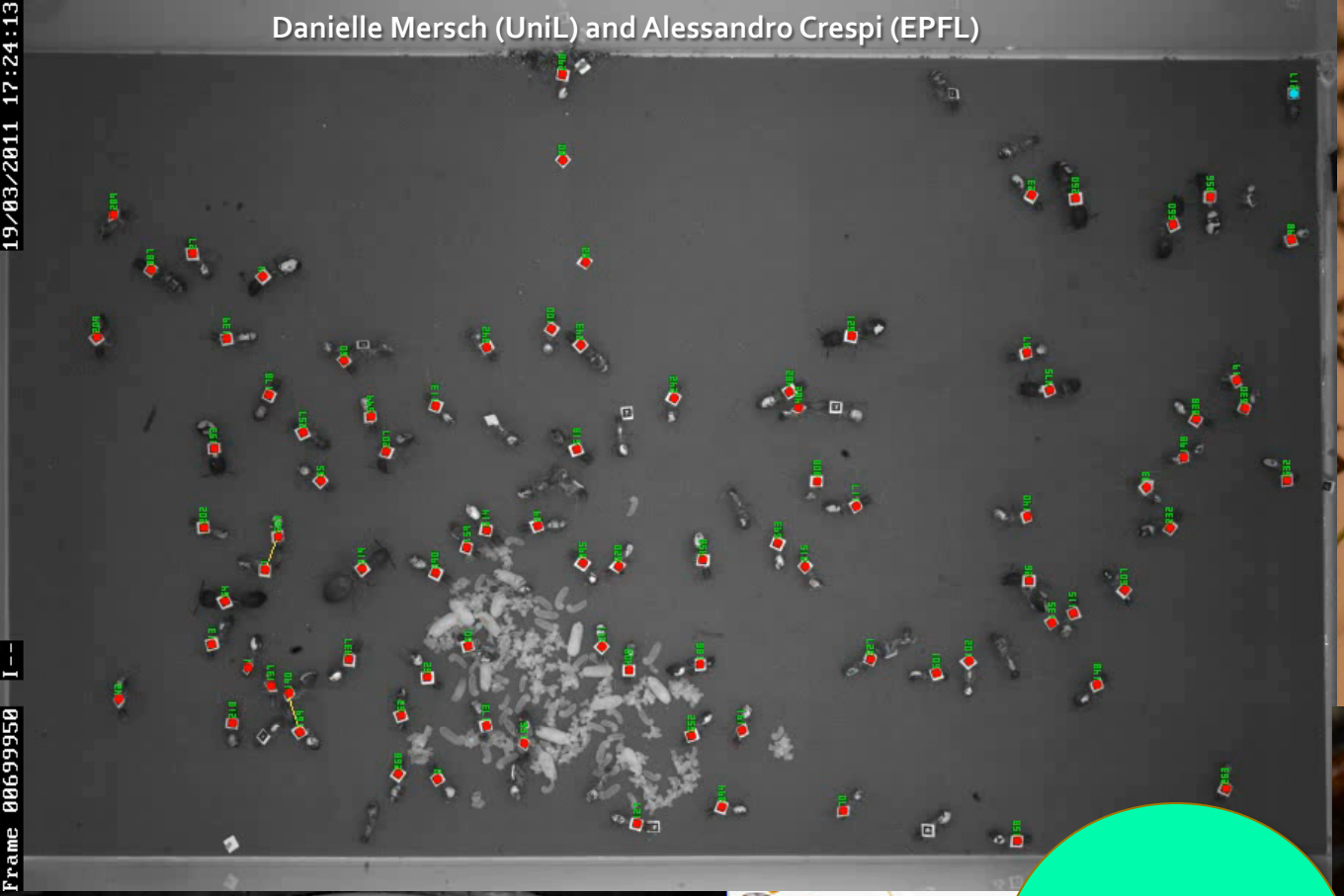

Danielle Mersch (UniL) and Alessandro Crespi (EPFL)
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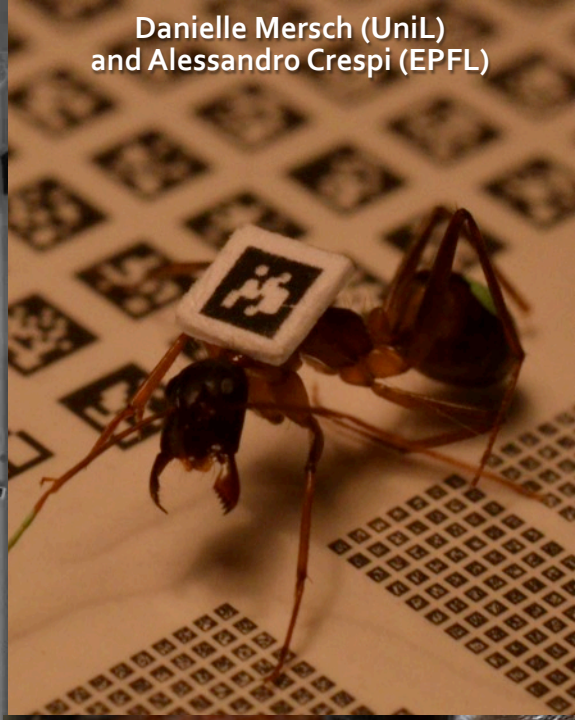

Danielle Mersch (UniL)
and Alessandro Crespi (EPFL)

Data


Anna Dornhaus (UArizona)




Danielle Mersch (UniL) and Alessandro Crespi (EPFL)
19/03/2011 17:24:13
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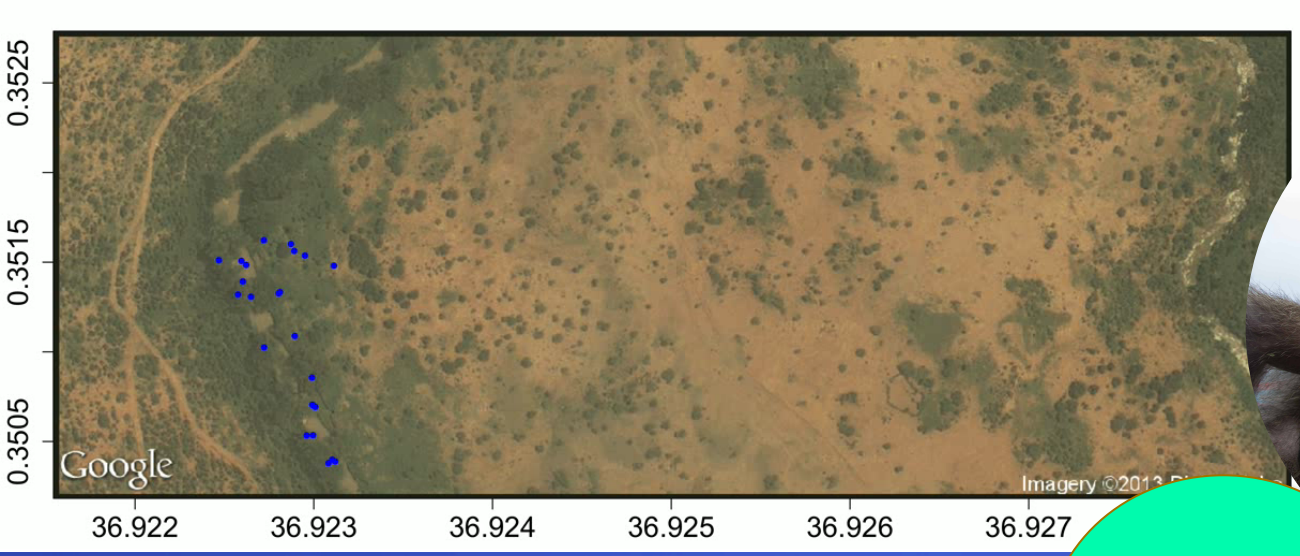

Danielle Mersch (UniL)
and Alessandro Crespi (EPFL)



Data


9/22/2014 19:56:43
Amanda Lea (UTexas)

Anna Dornhaus (UArizona)



Meg Crofoot (STRI and UCDavis) and Damien Farine (+Oxford)



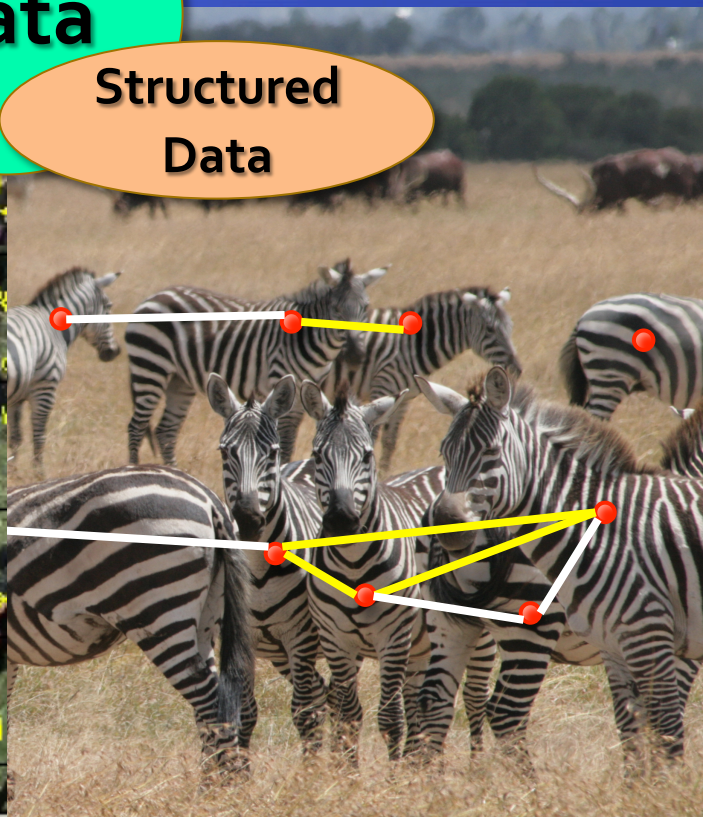
Meg Crofoot STRI and UCDavis)

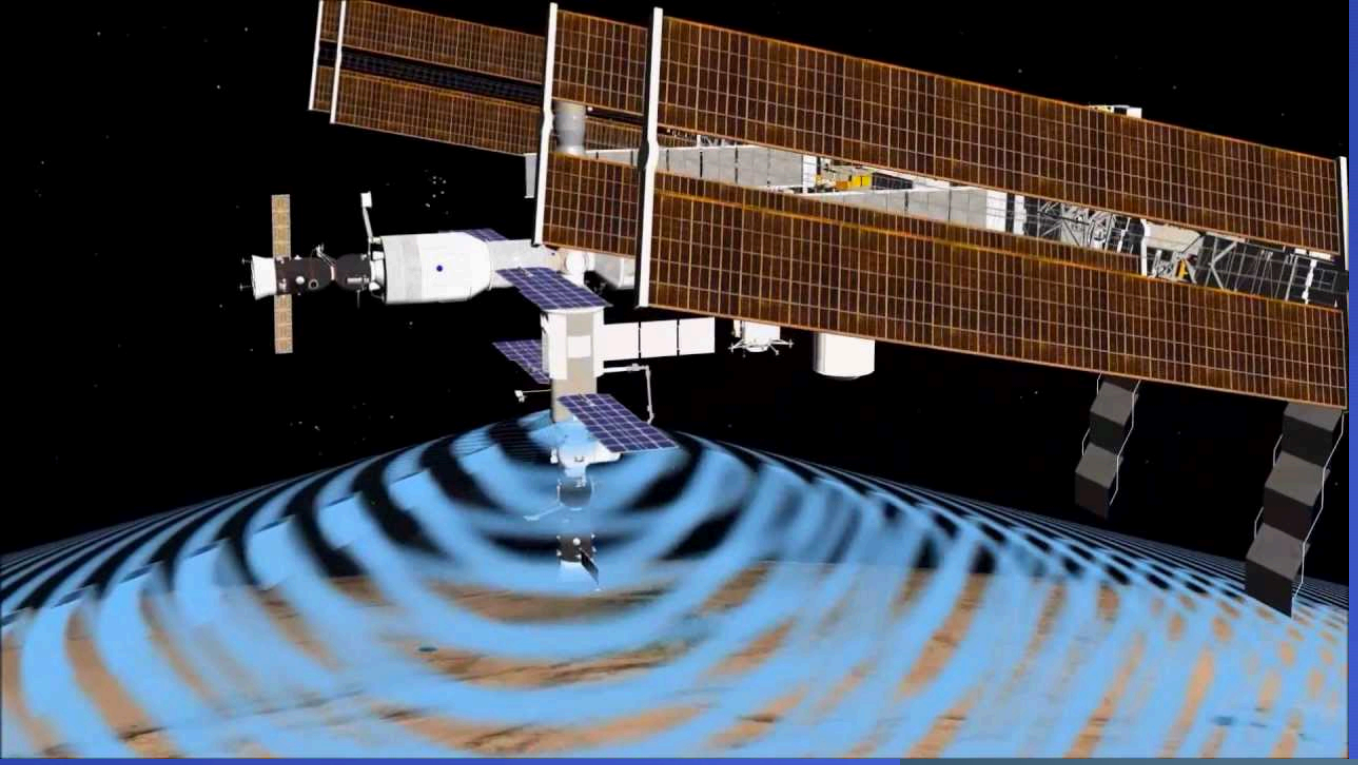
Data

Structured Data



Gallup, A.C., Hale, J.J., Garnier, S., Sumpter, D.J.T., Kacelnik, A., Krebs, J. & Couzin, I.D. (2012) *PNAS*



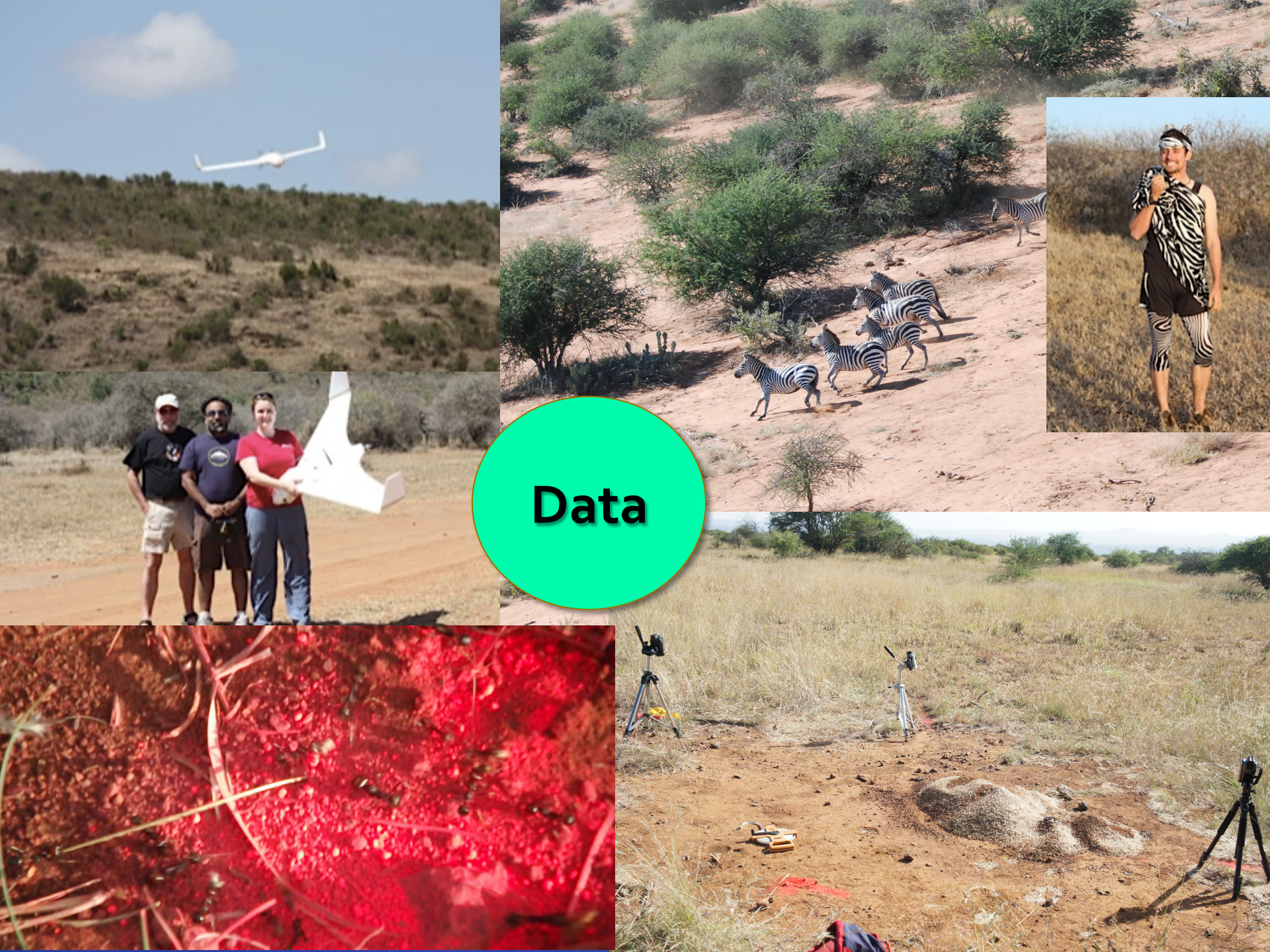


ICARUS INITIATIVE

INTERNATIONAL COOPERATION FOR ANIMAL RESEARCH USING SPACE






Data





Data



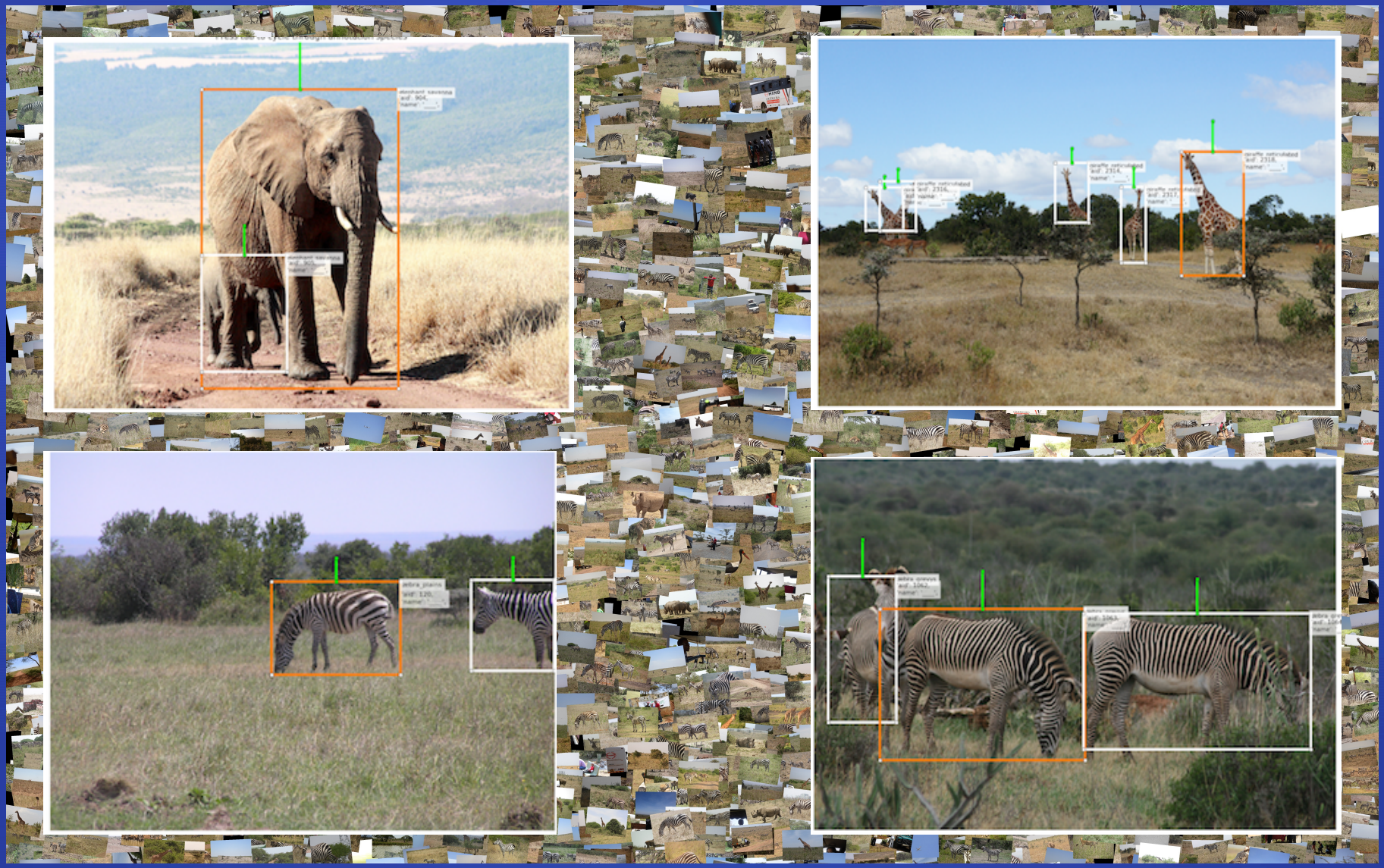


Telling zebras apart is a hard road
and I'm making mistakes by the car load.
So I got this device that keeps track of their stripes
and just scans them like they are a … BARCODE!

NPR, Wait Wait Don't Tell Me, April 16, 2011

From pixels to science and conservation



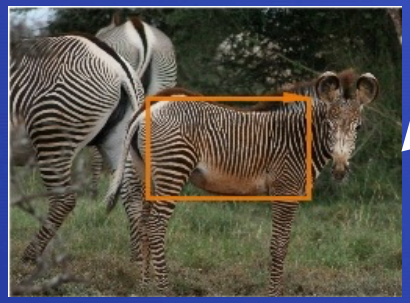


Animal Identification

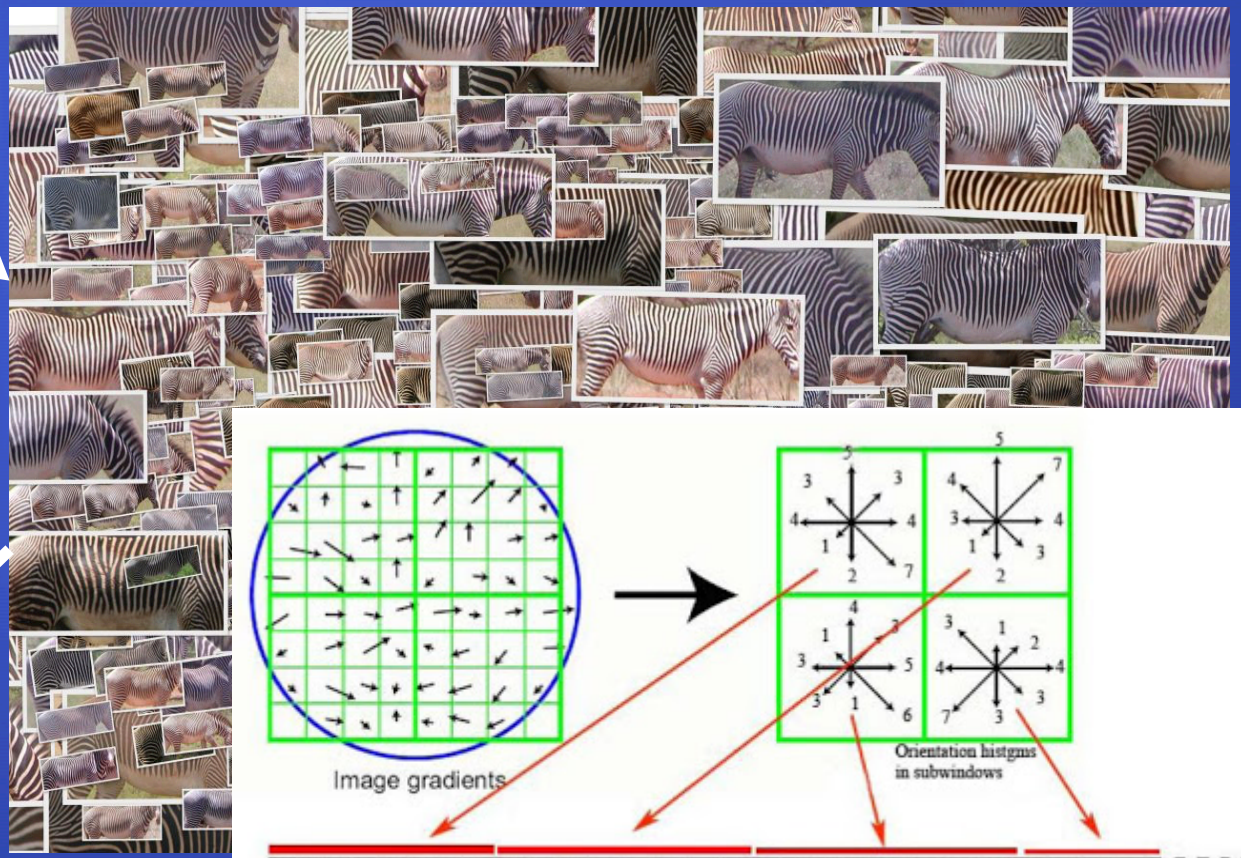
Who is this?

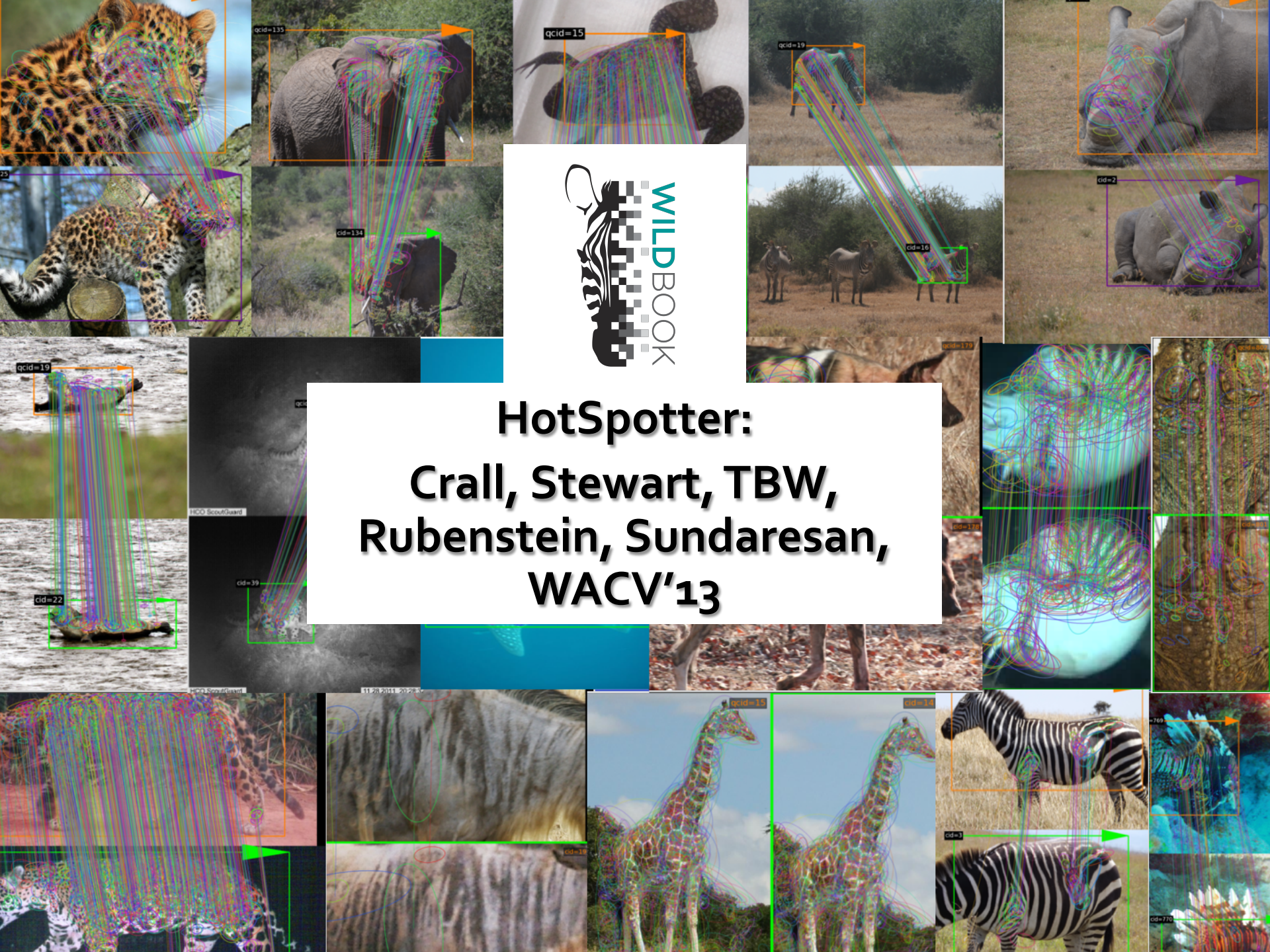


Zippy the Zebra!



Database of thousands

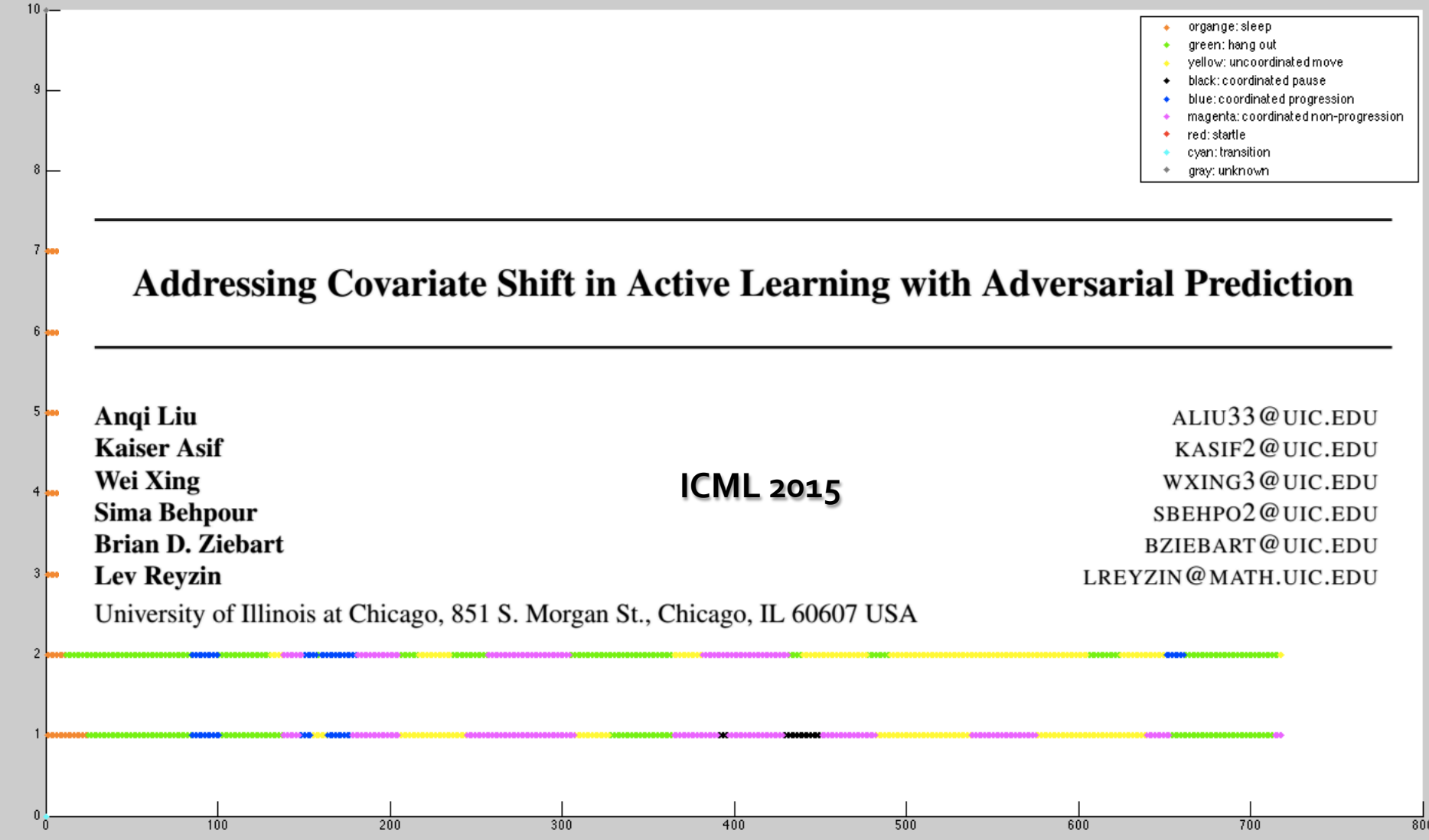




HotSpotter:

Crall, Stewart, TBW, Rubenstein, Sundaresan, WACV'13

Inferring behavior from remote sensing



Addressing Covariate Shift in Active Learning with Adversarial Prediction

Anqi Liu ALIU33@UIC.EDU
Kaiser Asif KASIF2@UIC.EDU
Wei Xing WXING3@UIC.EDU
Sima Behpour SBEHPO2@UIC.EDU
Brian D. Ziebart BZIEBART@UIC.EDU
Lev Reyzin LREYZIN@MATH.UIC.EDU
University of Illinois at Chicago, 851 S. Morgan St., Chicago, IL 60607 USA

ICML 2015

Biases in remotely sensed data

See related great work by Tom Dietterich, Dan Sheldon, Weng-Keen Wong



Biased by:

- camera location
- sensitivity of the motion sensor
- quality of captured image of animal



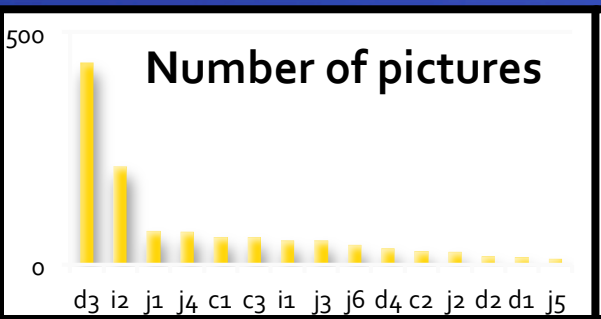
Biased by:

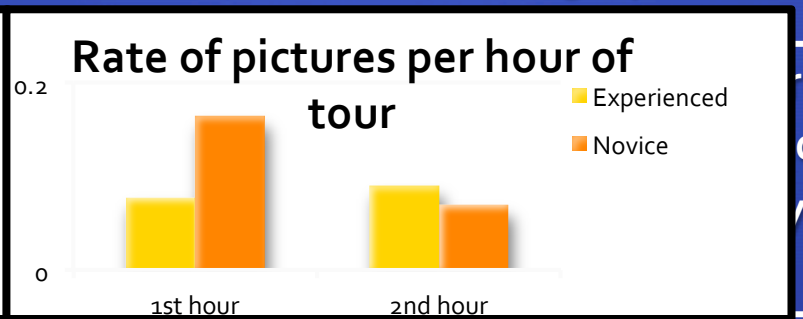
- geometry of route
- presence at location
- resolution of images



Biased by:

- observer/photo selection bias
- goal alignment
- species fatigue
- species charismatics
- range of training, expertise
- demographics: sex, age, etc.





re behavior
dangered species
yptic species

Network Inference

Data → Structured Data



Brugere ??



Farine, Whitehead '15



Behav Ecol Sociobiol (2009) 63:989–997
DOI 10.1007/s00265-009-0742-5

REVIEW

Potential banana skins in animal social network analysis

Richard James · Darren P. Croft · Jens Krause

Journal of Animal Ecology

British Ecological Society

Journal of Animal Ecology 2015, **84**, 1144–1163 doi: 10.1111/1365-2656.12418

'HOW TO. . .' PAPER

Constructing, conducting and interpreting animal social network analysis

Damien R. Farine[1,2,3,*] and Hal Whitehead[4]

Inferring Networks from Non-Network Data - Parts I & II
Wednesday, July 13

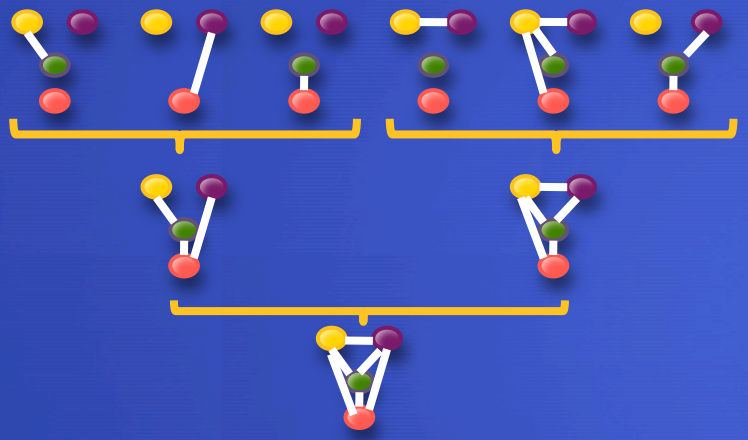
10:30 AM - 12:30 PM, 4:00 – 6:00PM
Room: Grand Ballroom A - Concourse Level

Structured Data

Preprocess:
What is a time step?



Sulo Caceres, B-W Grossman '10-13

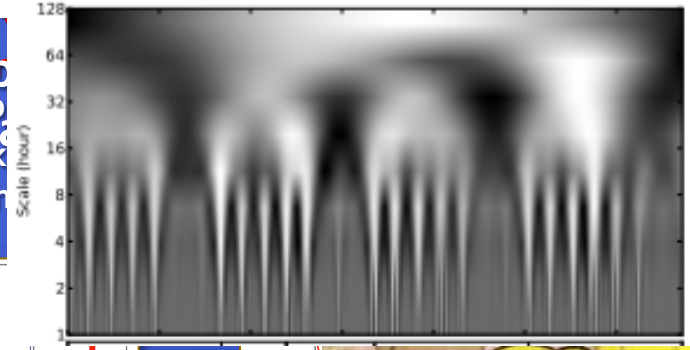


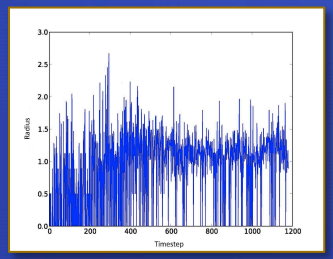
On Nonstationarity of Human Contact Networks

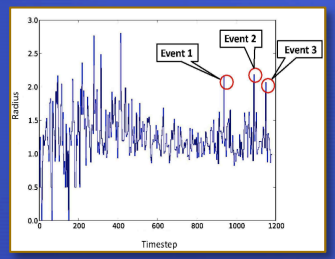
Salvatore Scellato*, Mirco Musolesi†, Cecilia Mascolo*, Vito Latora‡
*Computer Laboratory, University of Cambridge, United Kingdom
†School of Computer Science, University of St. Andrews, United Kingdom§
‡Dipartimento di Fisica, Università di Catania, Italy

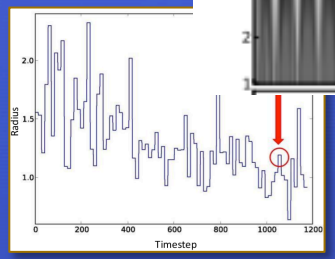
2. Let
will b
info
3. Pick
com

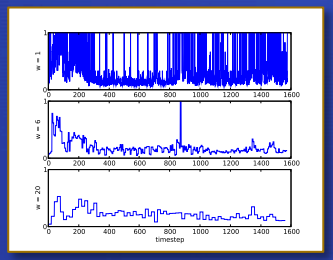
ise. Let
window
low and

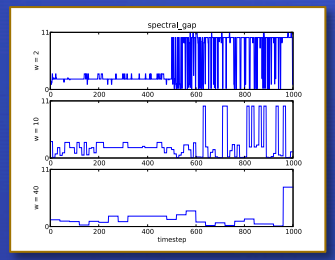


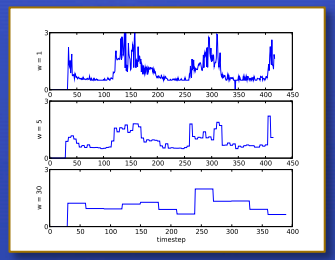


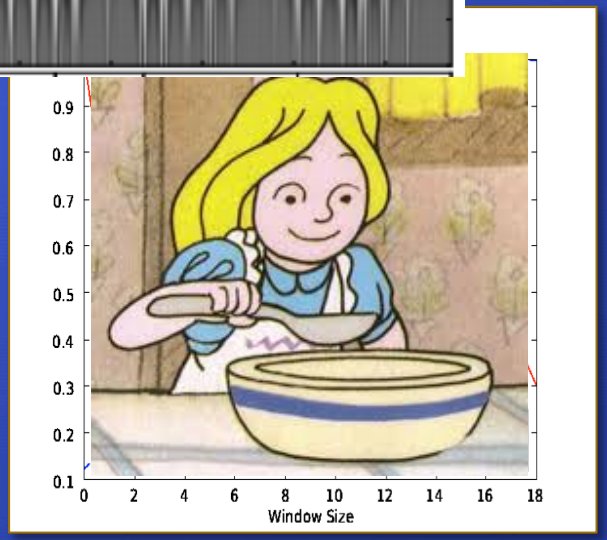












Structured Data

Preprocess:
Whom should we sample?



Maiya, B-W '10 + '11

Sampling Strategy

Sample Properties

Network Properties

Sampling Bias

- On the Bias of Traceroute Sampling (Achlioptis et al. 2005)
- Subnets of Scale-free networks are not scale-free (Stumpf et al. 2005)
- On the Bias of BFS (Kurant et al. 2010)
- A Walk in Facebook (Gjoka et a. 2009)

Sampling Bias as an Asset to be Exploited

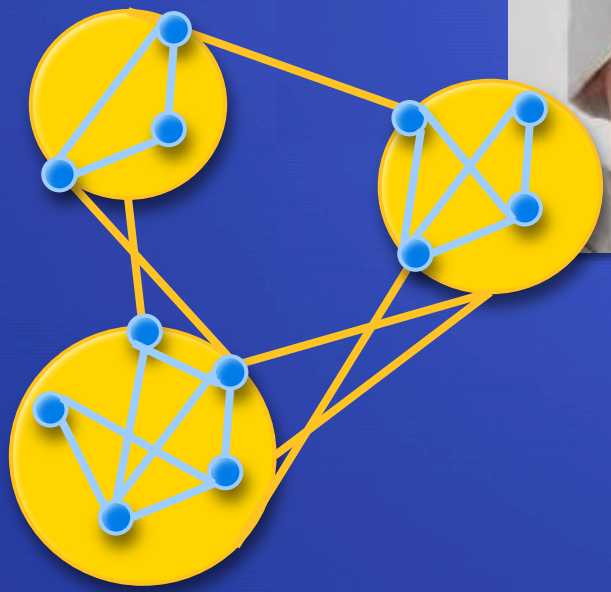
similar in concept to stratified sampling

- BFS, DFS, and Random Walks stationary prob. = $\frac{d_v}{2|E|}$
- FFS: Forest-Fire Sampling (Leskovec et al. 2006)
- DEG: Degree-based Sampling (Adamic et al. 2001)

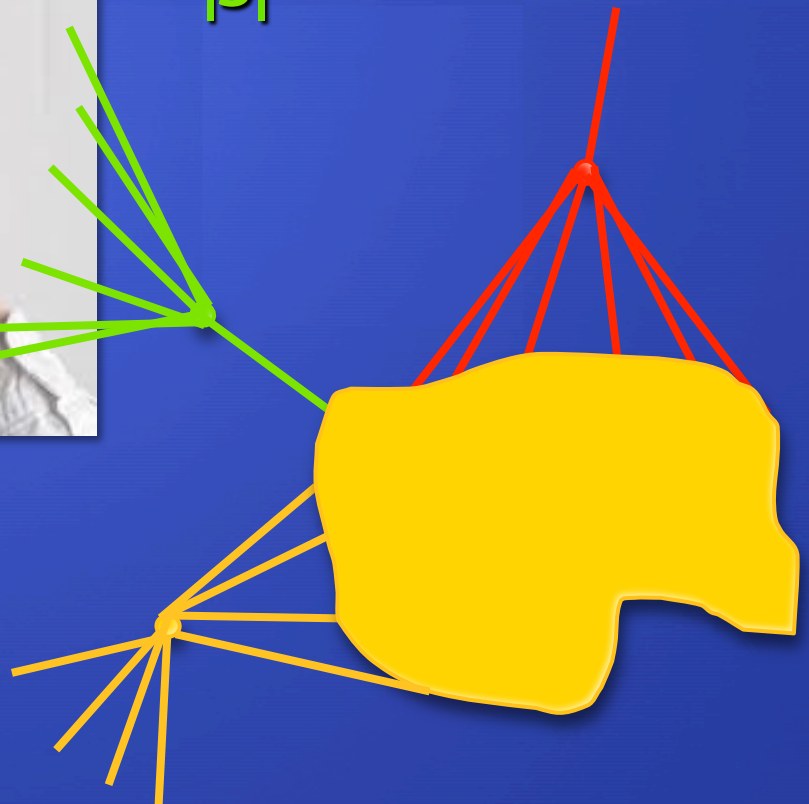


Structured Data

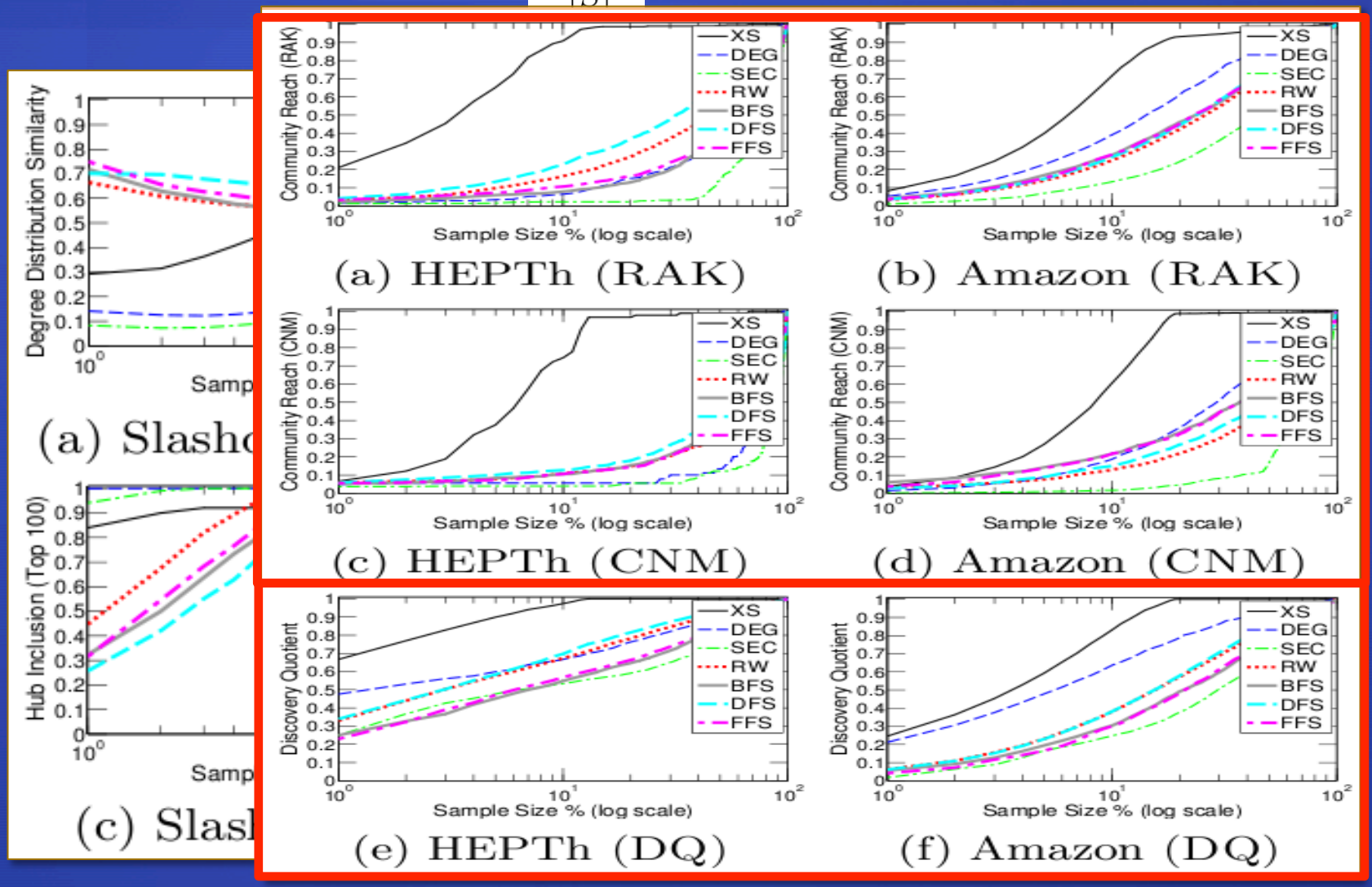
- SEC: Sample Edge Count induced subgraph of $S \cup \{v\}$
- XS: Expansion Sampling expansion = $\frac{|N(S)|}{|S|}$







- BFS, DFS, and Random Walks stationary prob. = $\frac{d_v}{2 \cdot |E|}$
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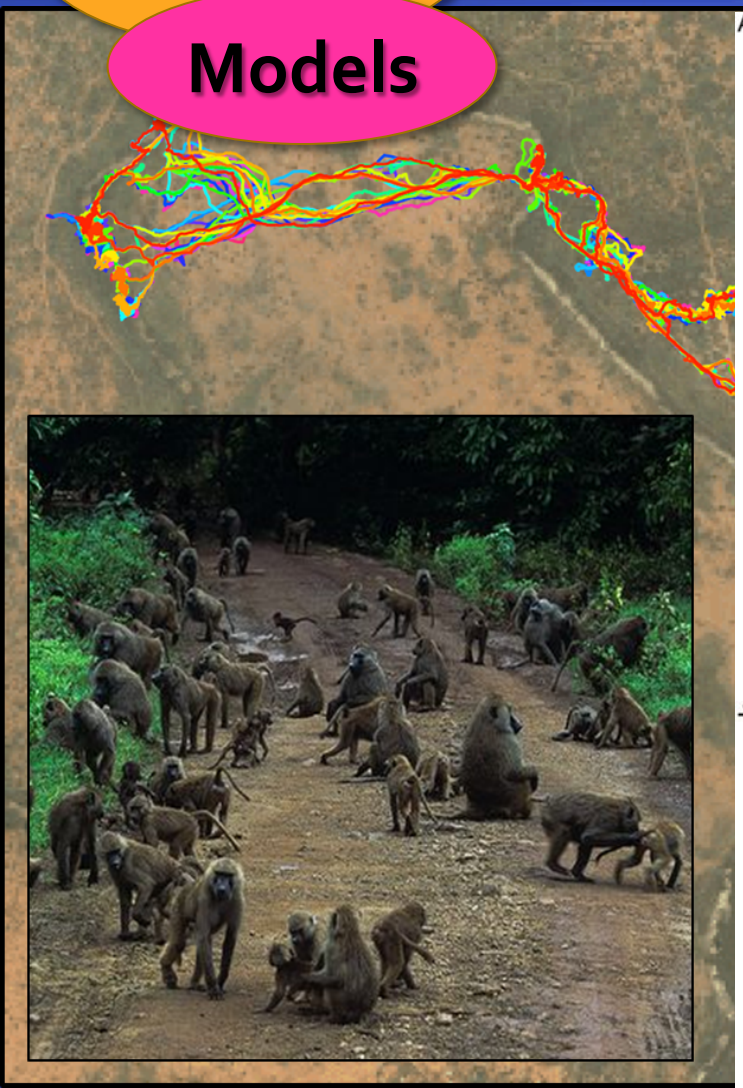


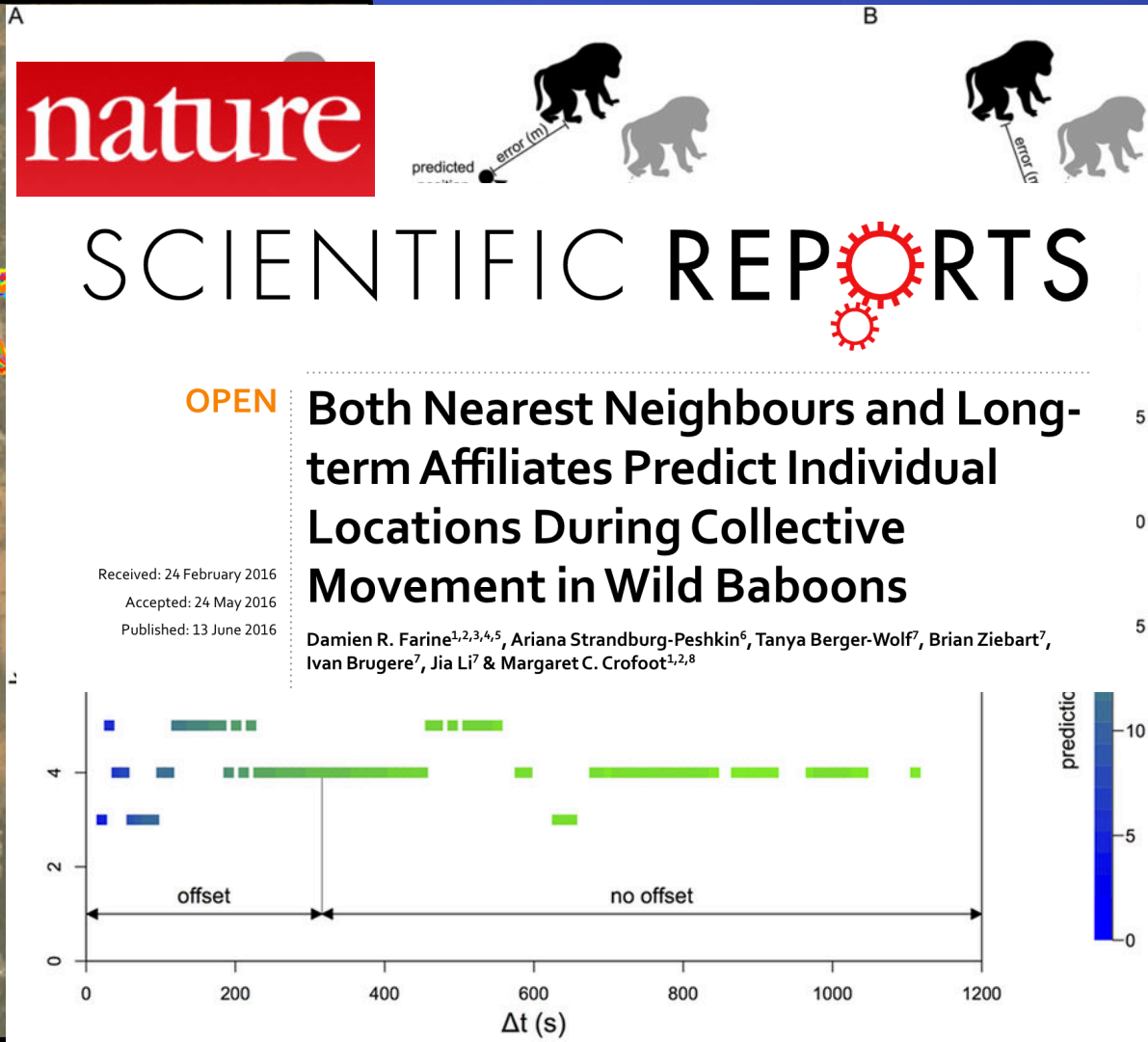
Does network predict behavior?

Analysis

Models







Leadership Inference





Amornbunchanvej et al '?

Analysis

Models



Dynamic 'Following' Network Inference



Coordination Interval Identification



Leadership Measurement and Classification

Rank Ordering and Comparison



Science 19 June 2015:
Vol. 348 no. 6241 pp. 1358-1361
DOI: 10.1126/science.aaa5099

Science

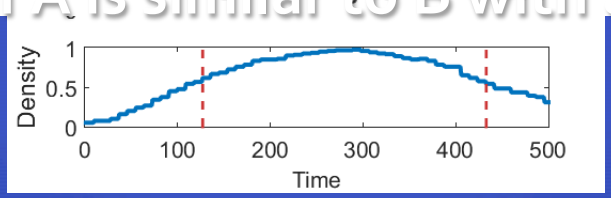
AAAS

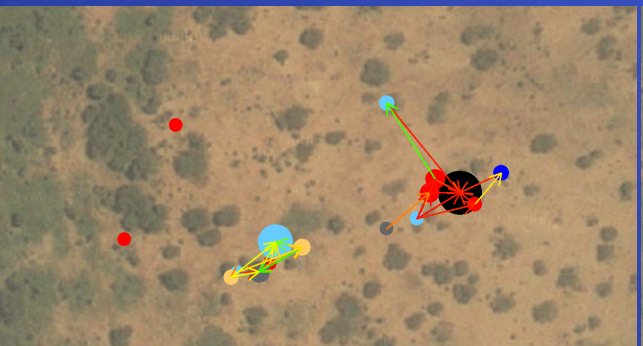
REPORT

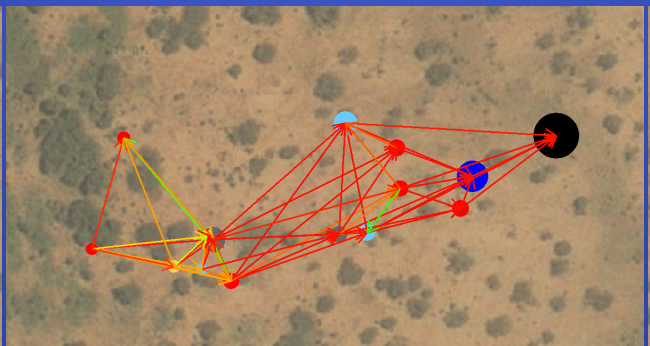
Shared decision-making drives collective movement in wild baboons

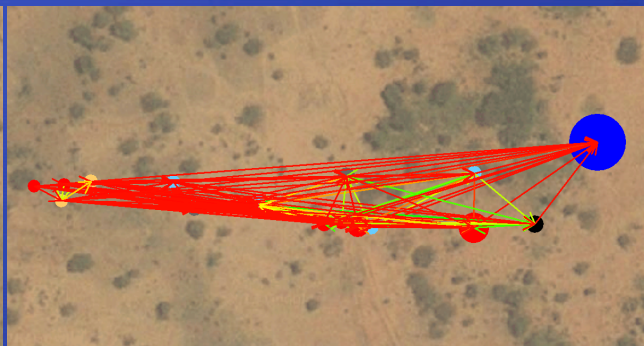
Ariana Strandburg-Peshkin[1,*,†], Damien R. Farine[2,3,4,*,†], Iain D. Couzin[1,5,6], Margaret C. Crofoot[2,3,*]

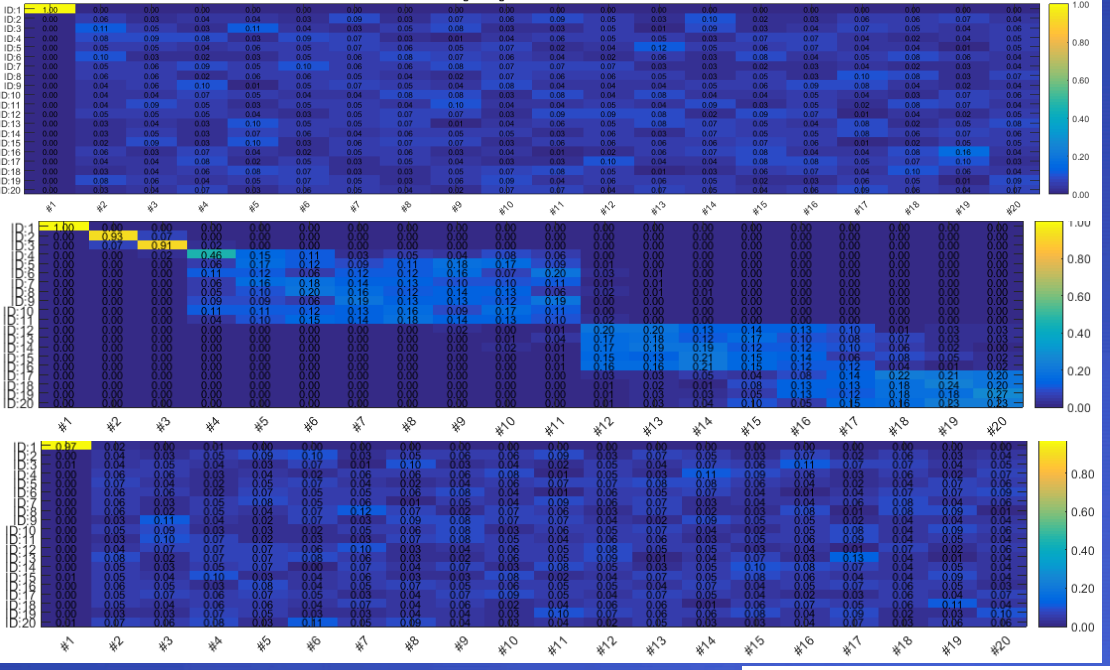
A follows B if A is similar to B with a time shift t

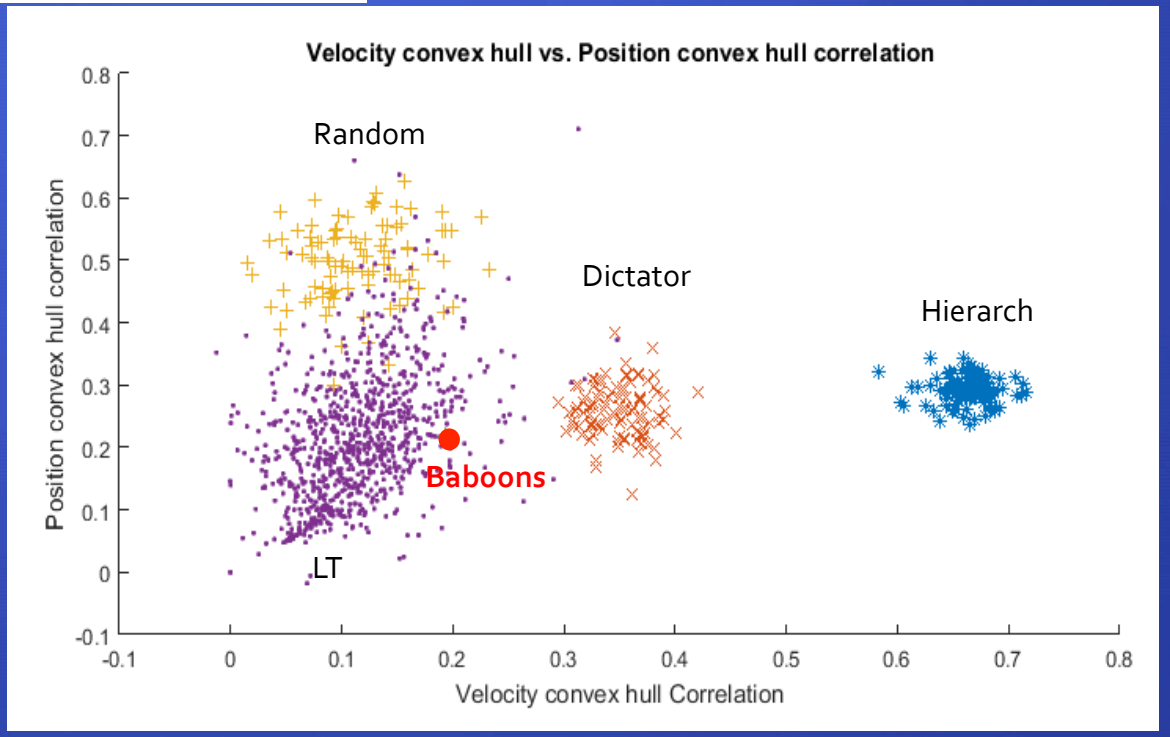










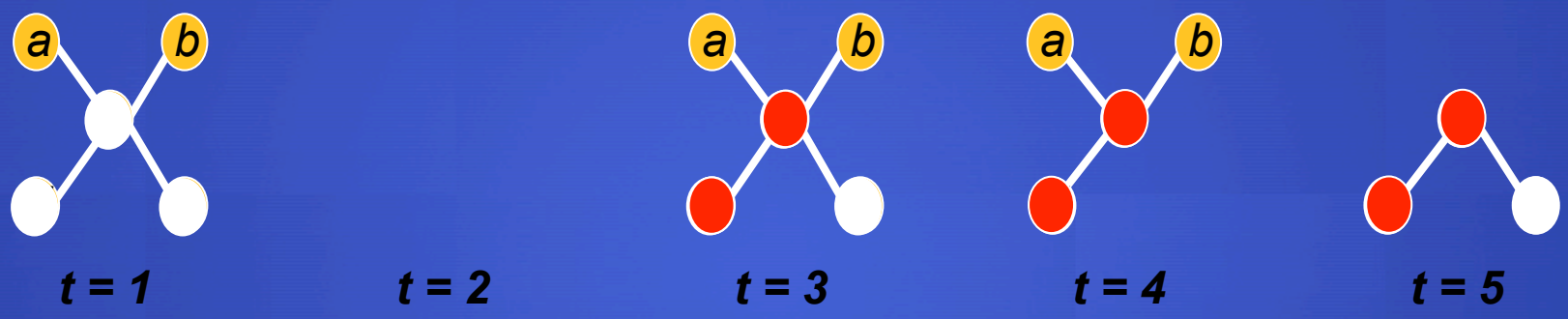

Velocity convex hull vs. Position convex hull correlation
Random
Dictator
Hierarch
Baboons
LT
Position convex hull correlation
Velocity convex hull Correlation
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8

Patterns & Structure

Periodic Pattern Discovery



Lahiri & B-W '08 + '10



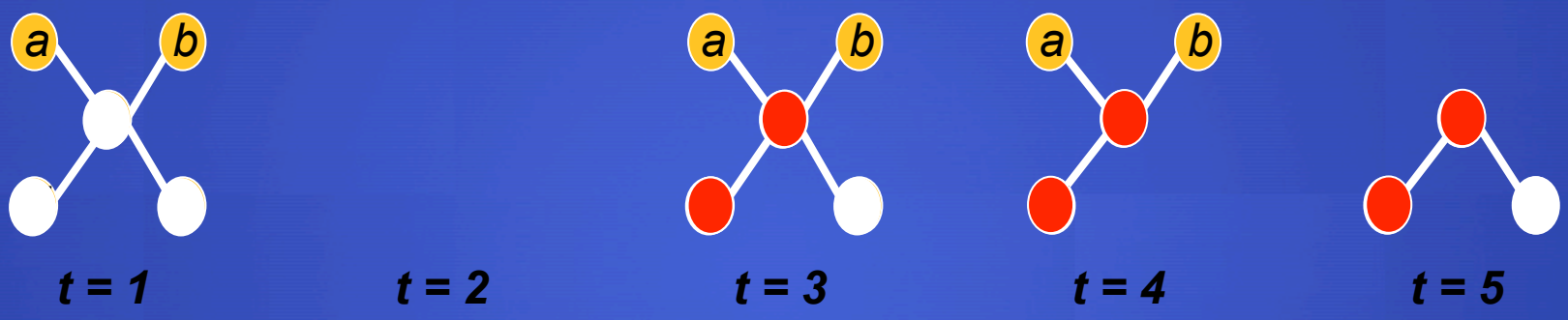
Given a dynamic network, find all subgraphs that occur periodically more than σ times.

Downward closure: Any subgraph of a periodic subgraph is also periodic.

Periodic Pattern Discovery



Lahiri & B-W '08 + '10



Given a dynamic network, find all subgraphs that occur periodically more than σ times.

1. Occurs more than σ times
2. Cannot be extended structurally
3. Cannot be extended in time

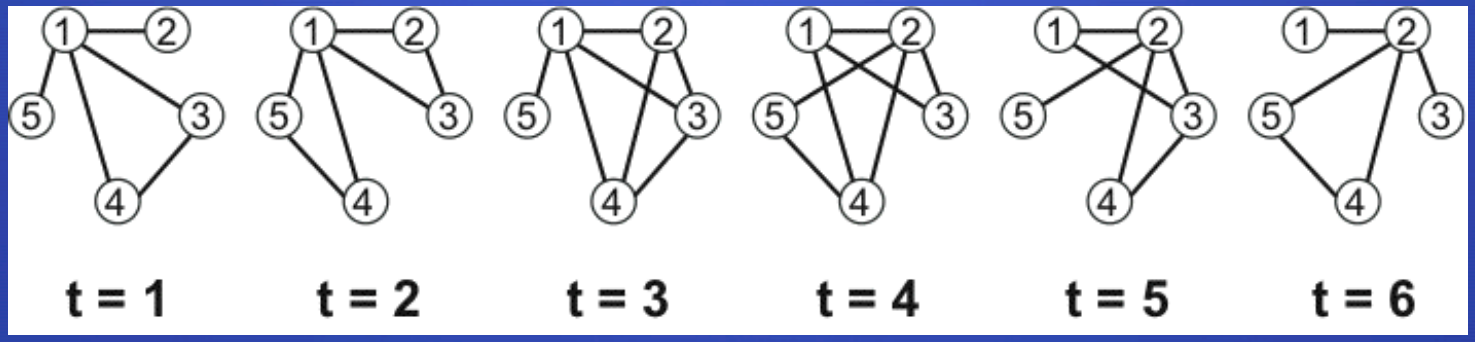
} Closed periodic subgraphs

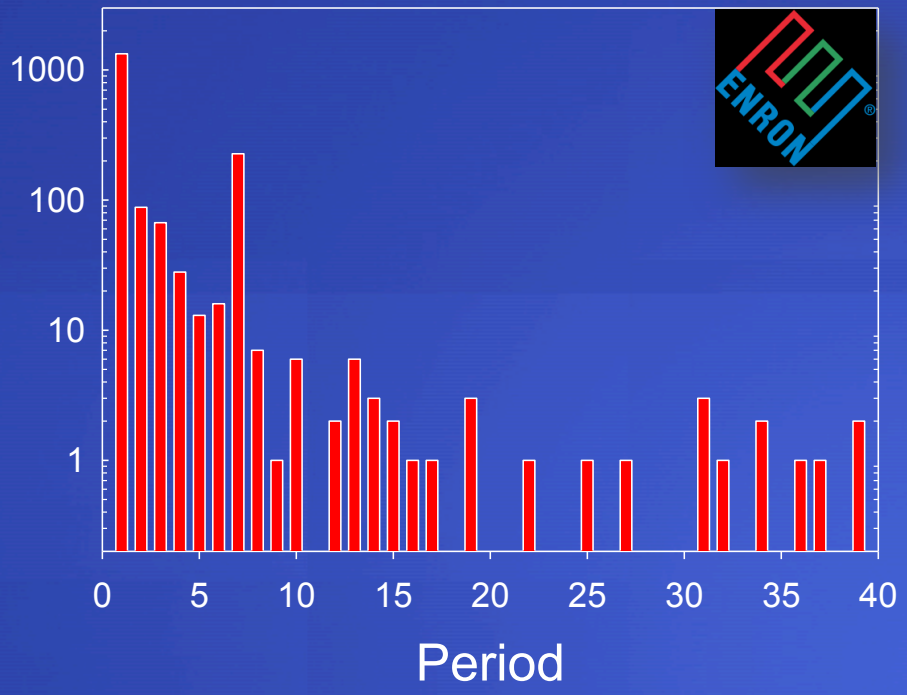
Periodic Pattern Discovery

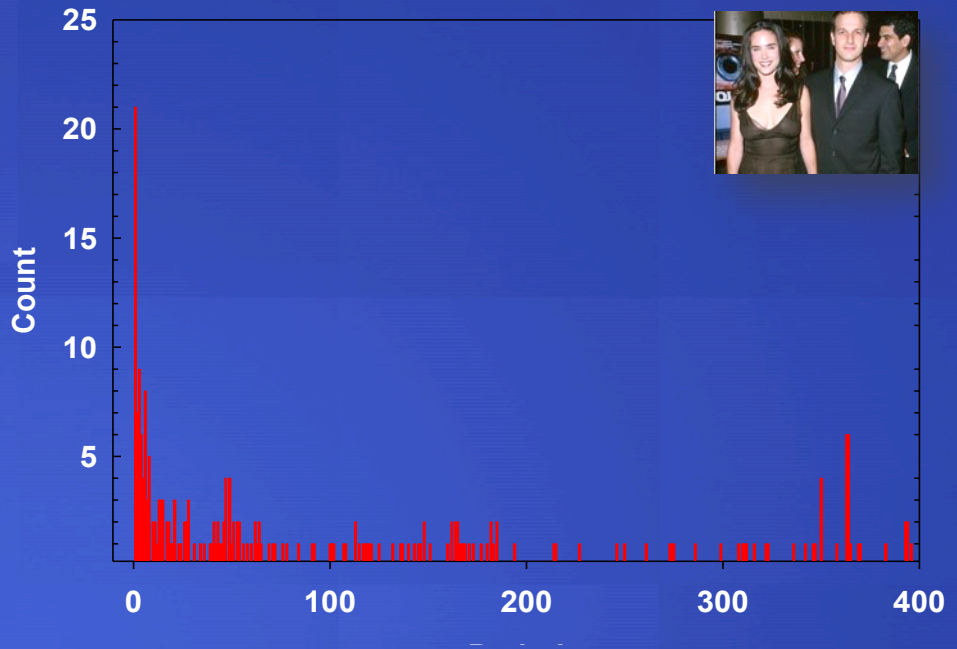


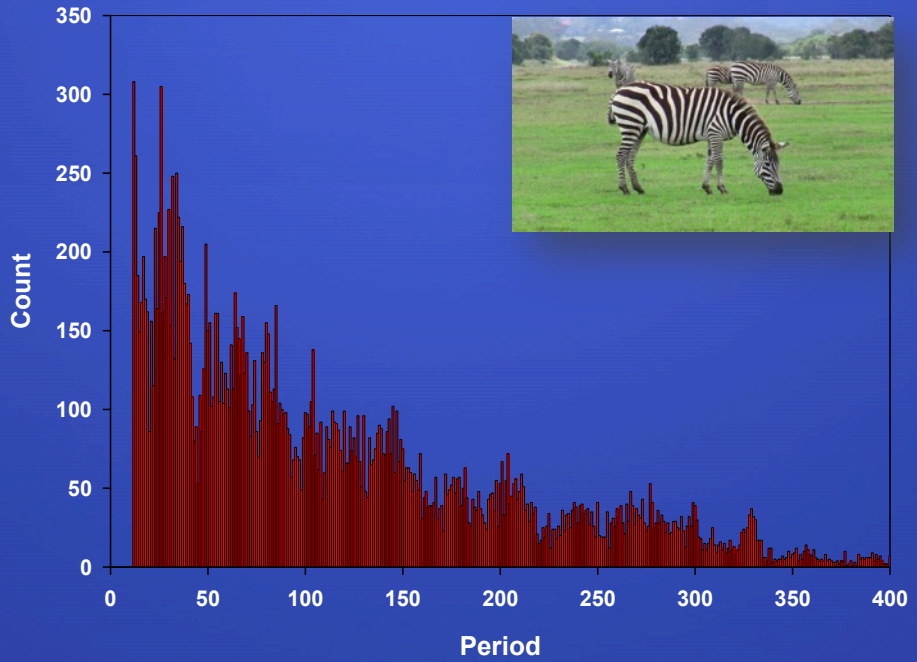
- In a finite amount of data:
  - Maximum period has a natural upper bound
- Construct worst-case example from a mining point of view
  - Each possible periodic subgraph is present
  - Iterate over all possible periodic positions, "creating" a new subgraph
  - Polynomial number of closed periodic subgraphs.
- Algorithm to enumerate this is $O(T^2 \ln(T/\sigma) (V+E))$*

  * When each graph has unique node labels

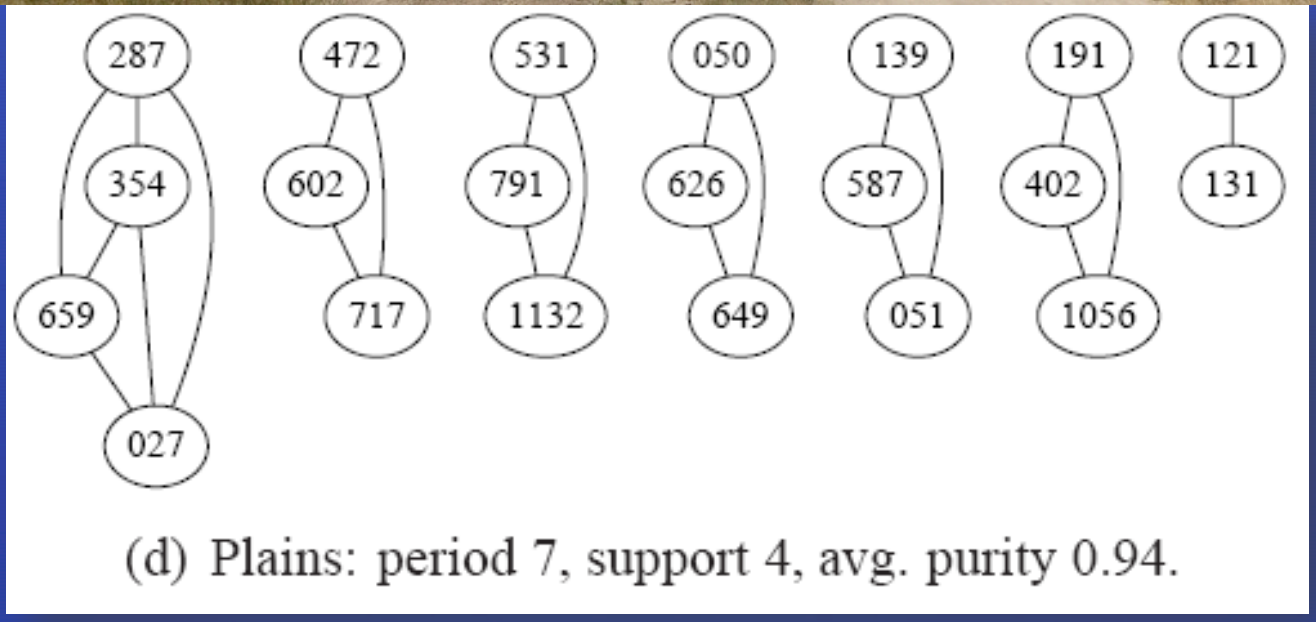



1000
100
10
1
0
5
10
15
20
25
30
35
40
Period

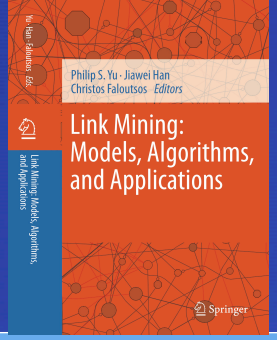

Count
25
20
15
10
5
0
100
200
300
400


Count
350
300
250
200
150
100
50
0
0
50
100
150
200
250
300
350
400
Period





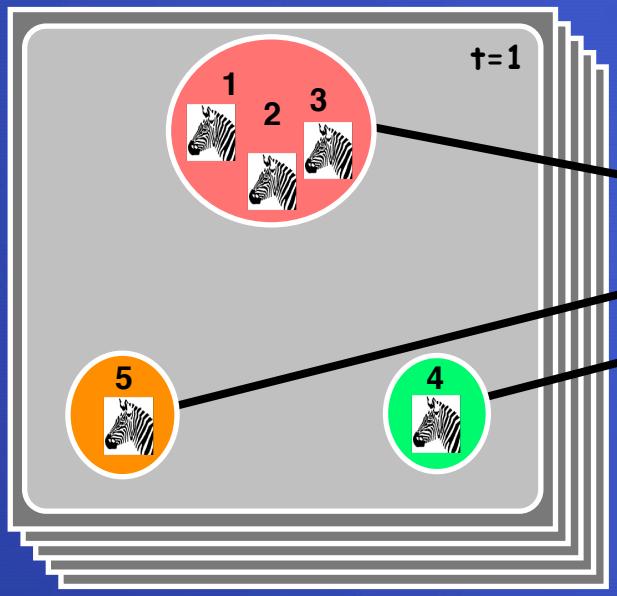
(d) Plains: period 7, support 4, avg. purity 0.94.

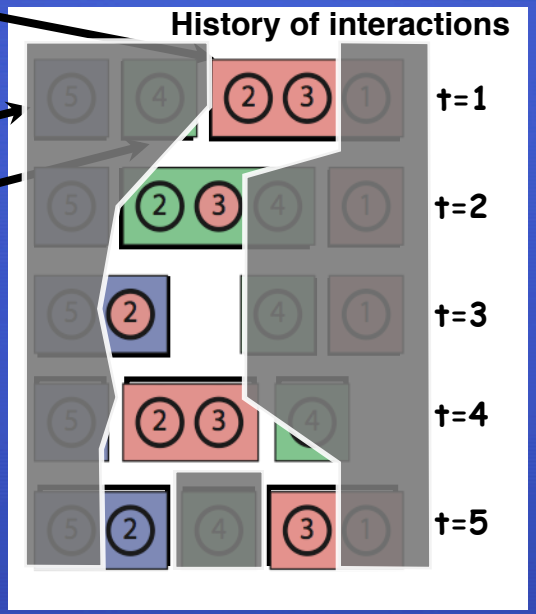


Analyze:
Dynamic Communities




Tantipathananandh, TB-W & Kempe '07 + '10
Tantipathananandh, TB-W '09 + '11





Individuals change affiliations, group split and merge

Are there cohesive/ persistent groups?

How does community structure arise from interactions and how are the interactions affected by the latent community structure?

Want to allow fluid community structure

Analysis

Models

Dynamic Communities

What is a community?

"Cohesive subgroups are subsets of actors among whom there are relatively strong, direct, intense, frequent, or positive ties." [Wasserman & Faust '97]

Community = cluster
Dynamic community = dynamic cluster: members of community interact more frequently (consecutively) among them than with individuals outside the community.
Dynamic community = identity.

Computational Approaches

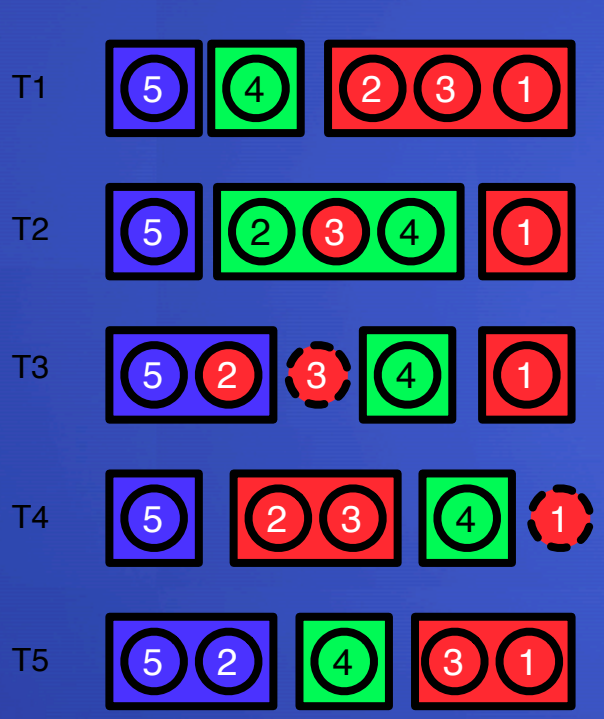
- Aggarwal and Yu '05
- Metagroups [Berger-Wolf & Saia '06]
- MONIC [Spiliopoulou et al '06]
- Palla et al '07
- Falkowski et al '06
- GraphScope [Sun et al '07]
- FacetNet [Lin et al '08], Yang et al '09, Colibri [Tong et al '08], Sarkar and Moore '05, Fu et al '09

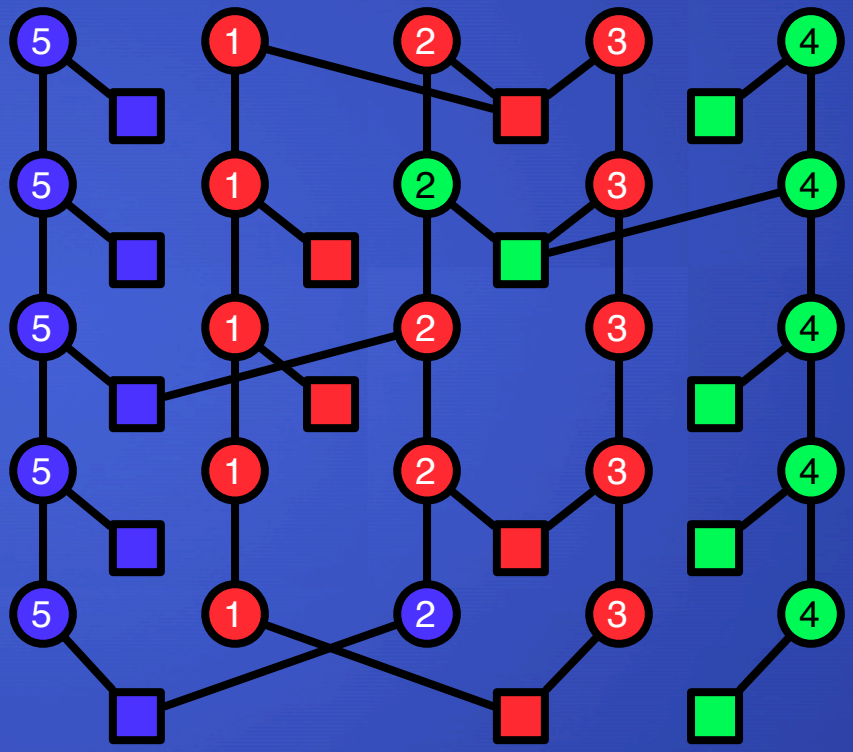
Social Costs

- Individuals are reluctant to switch community affiliations
  cost of switching
- Individuals mostly are seen with their own community
  cost of visit
- Individuals a rarely absent from their own community
  cost of absence

Parsimony = minimize the total cost across all individuals

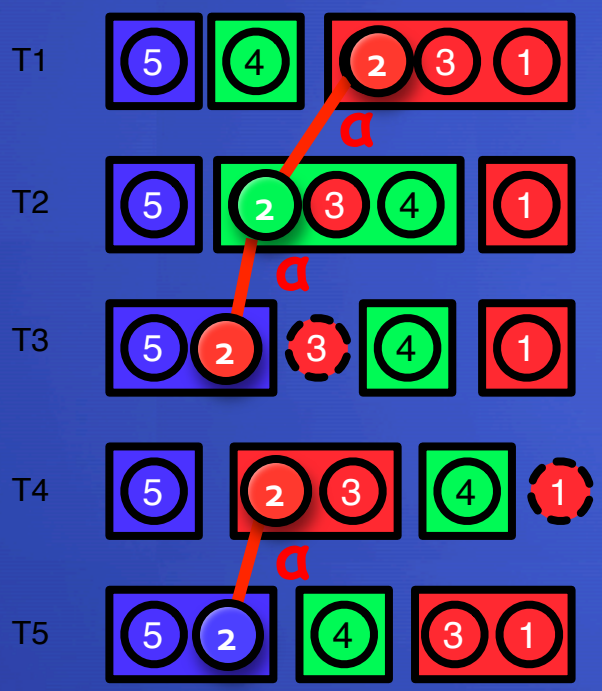
Community = Color

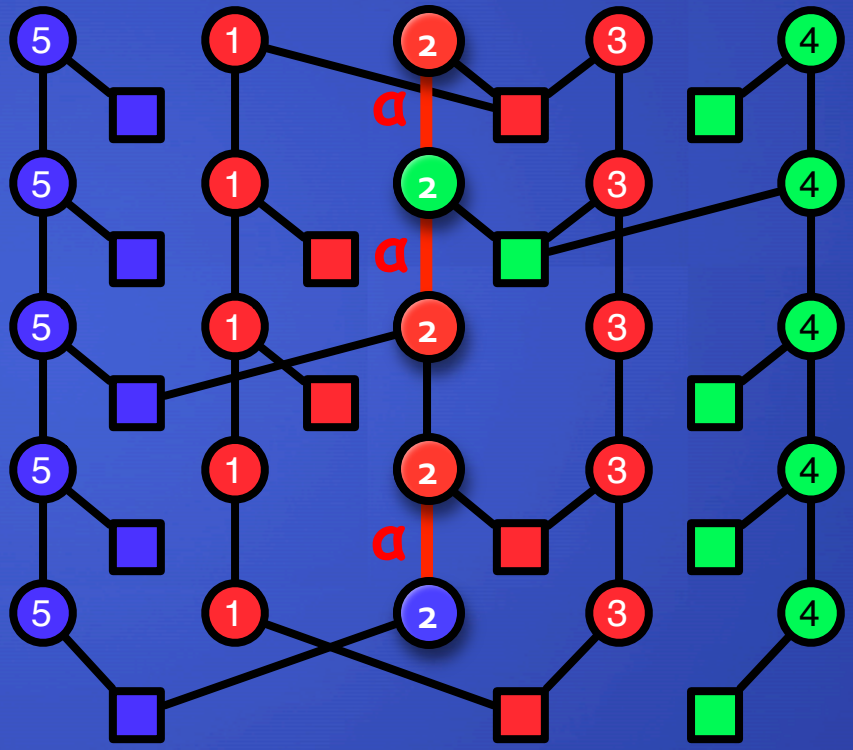




Valid coloring: In each time step, different groups have different colors.

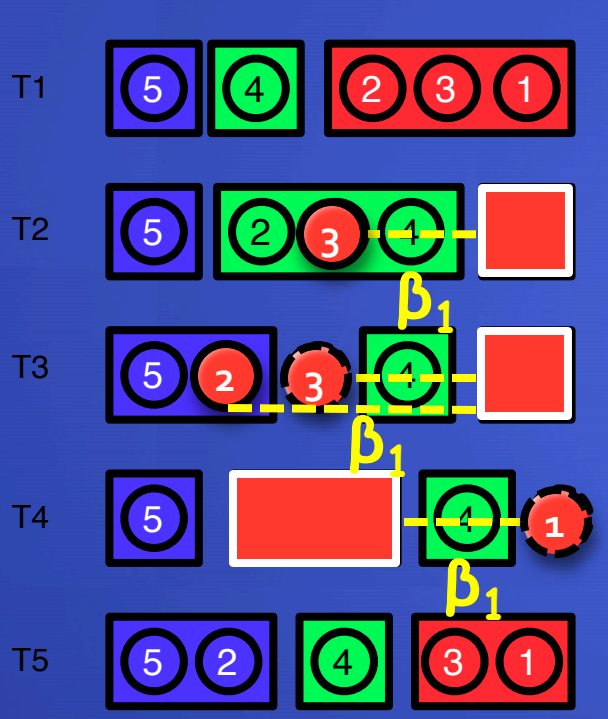
Social Costs: Conservatism

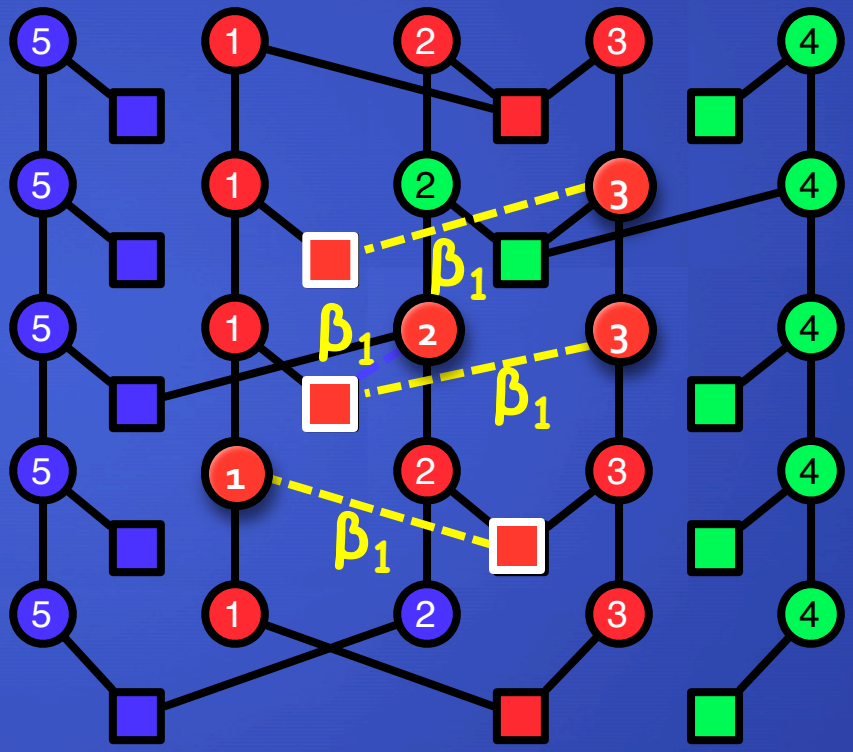




Switching cost α Absence cost β_1 Visiting cost β_2

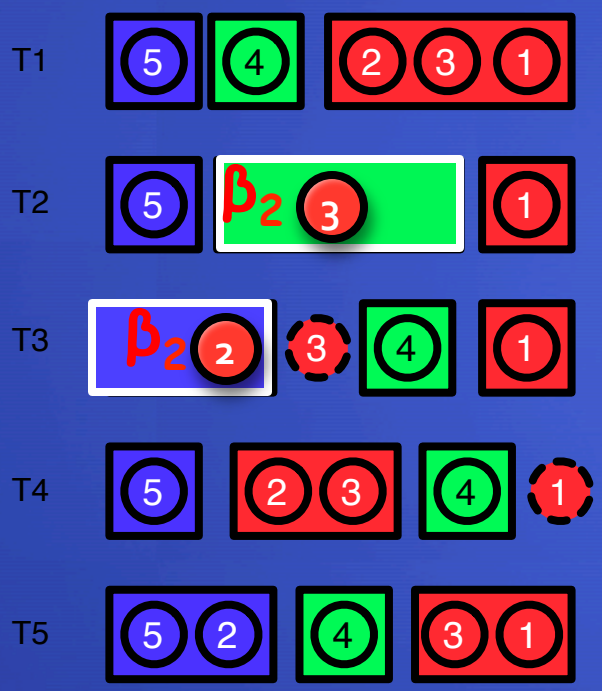
Social Costs: Loyalty

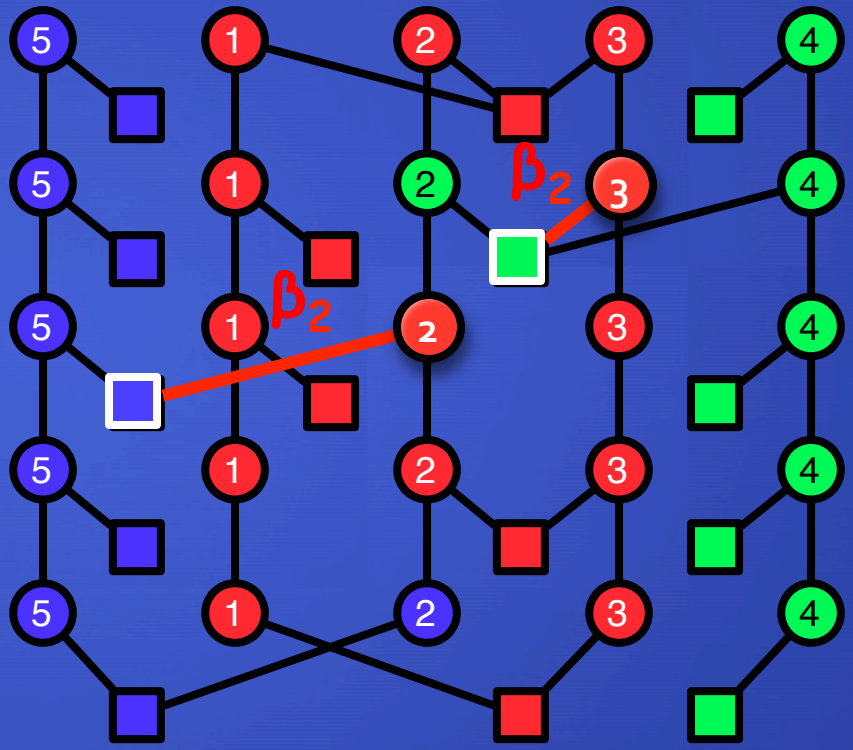




Switching cost **α** **Absence cost β1** Visiting cost β_2

Social Costs: Loyalty





Switching cost **α** Absence cost β_1 **Visiting cost β_2**

Community as a Coloring

Minimum Community Interpretation:

For a given cost setting, $(\alpha, \beta_1, \beta_2)$, find vertex coloring that minimizes total cost.

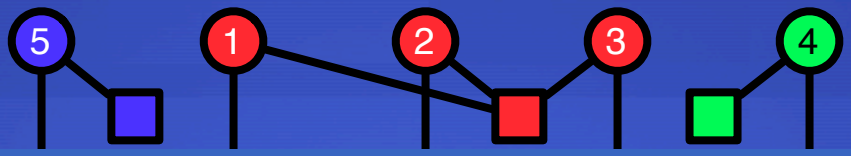
Color of group vertices = Community structure

Color of individual vertices = Affiliation sequences

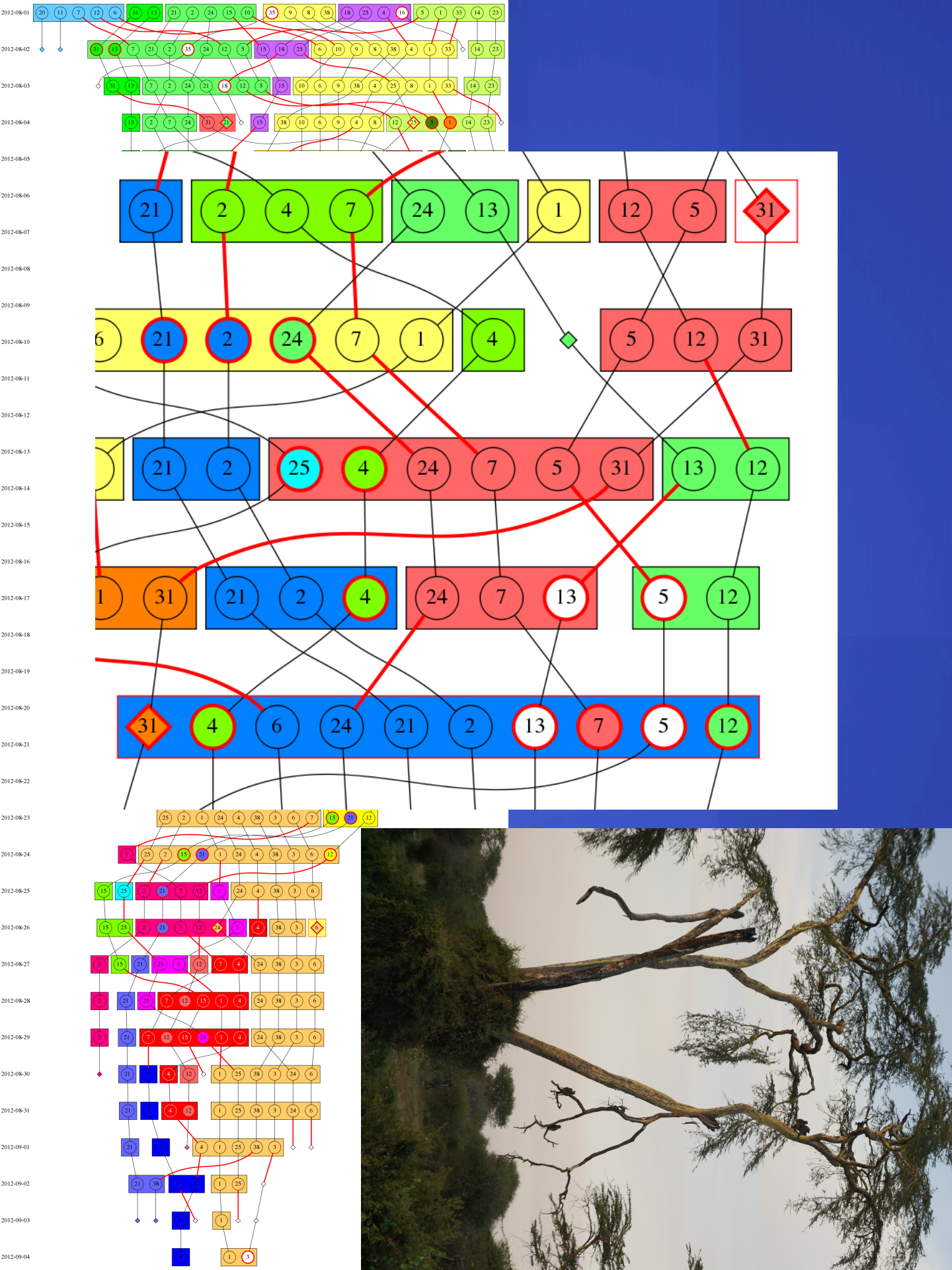
Problem is NP-Complete and APX-Hard

But fast flow-based constant factor approximations

Model

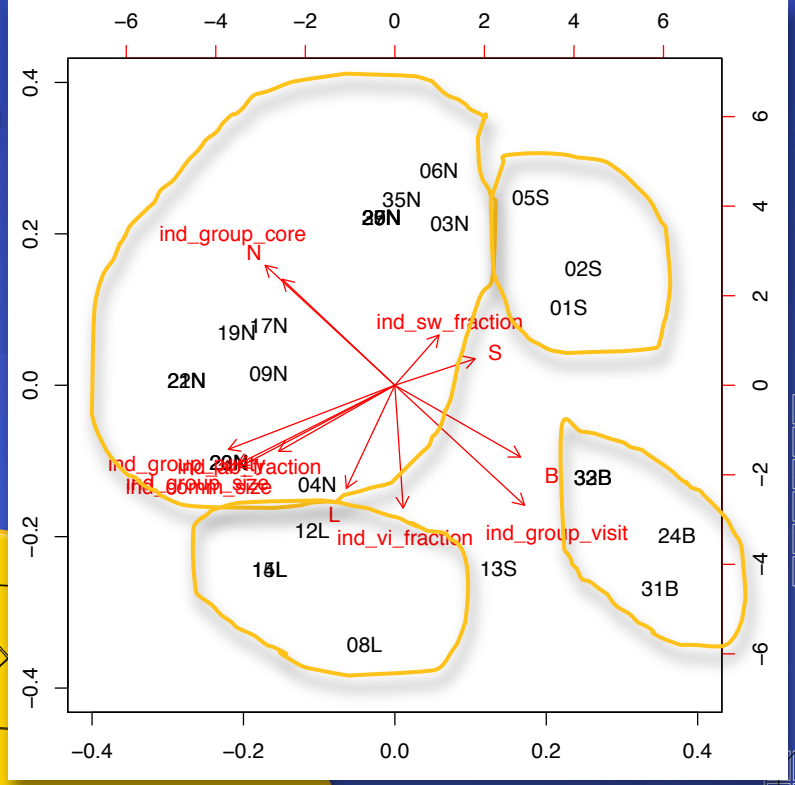


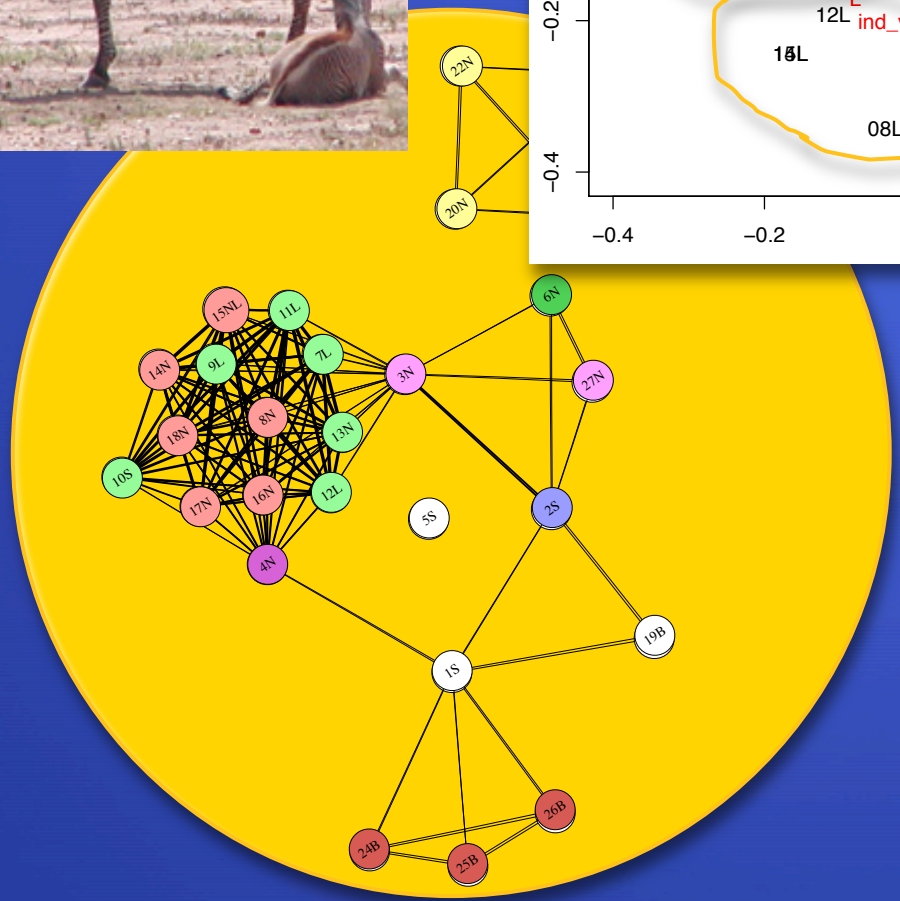
Cost optimal coloring = Maximum likelihood

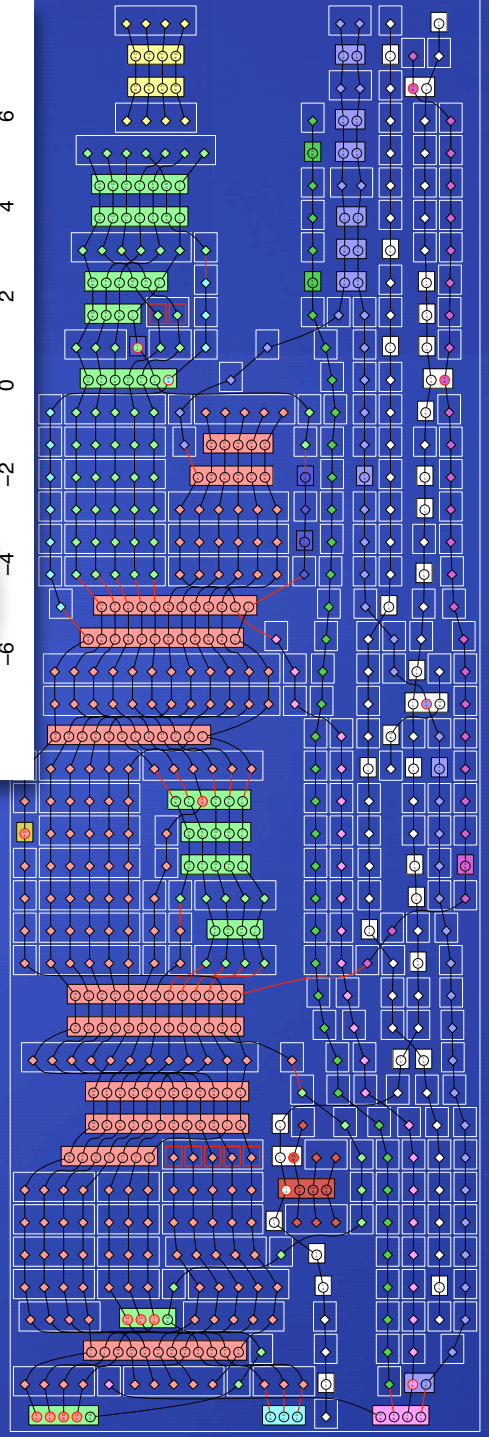

2012-08-01
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Grevy's Ze

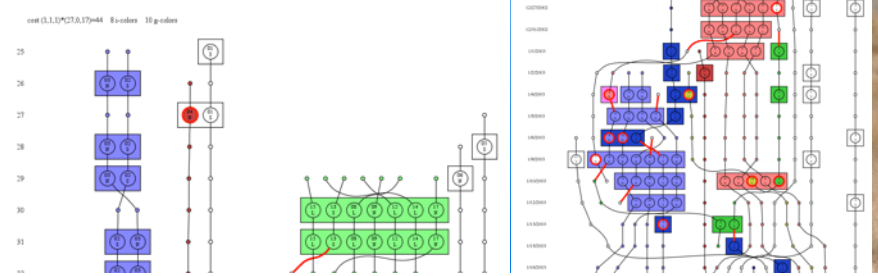



ind_group_core
N
ind_sw_fraction
S
ind_vi_fraction
L
ind_group_visit
B
ind_group_size
06N
35N
03N
05S
02S
01S
19N
17N
09N
04N
12L
13S
24B
31B
08L

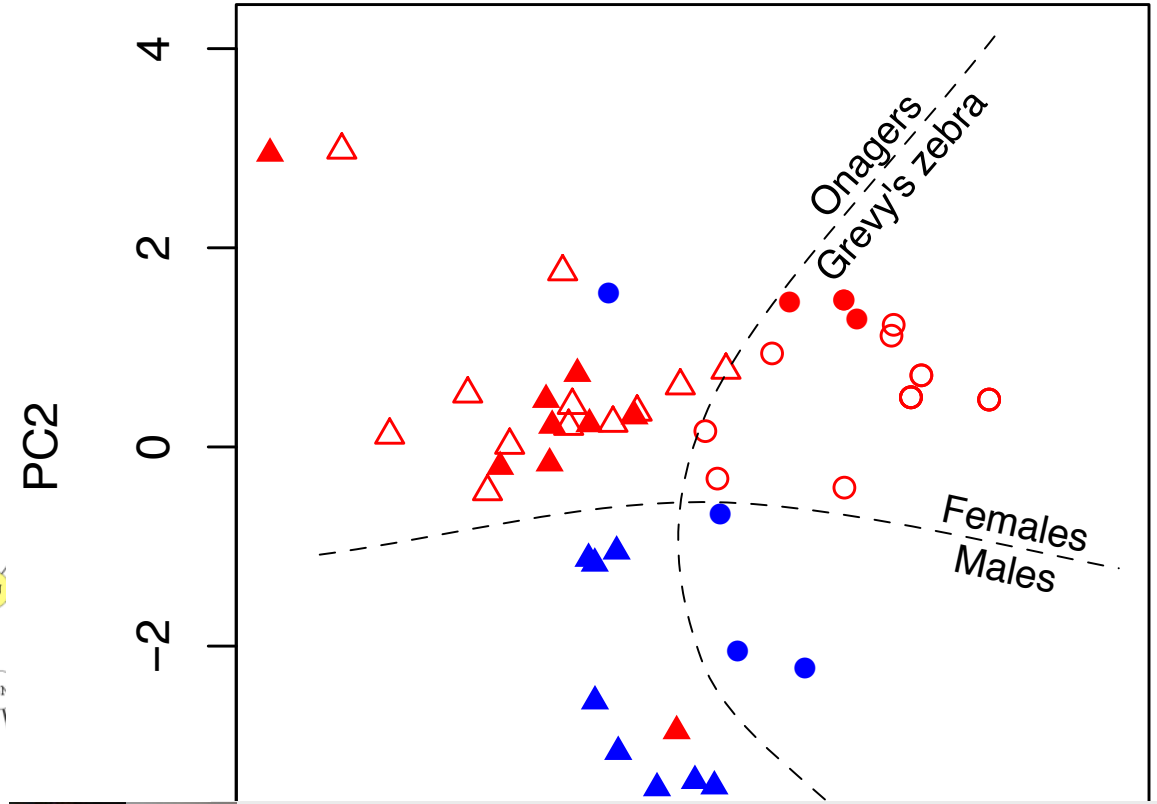

22N
20N
15NL
11L
6N
14N
9L
7L
3N
27N
18N
8N
13N
10S
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1S
26B
24B
25B

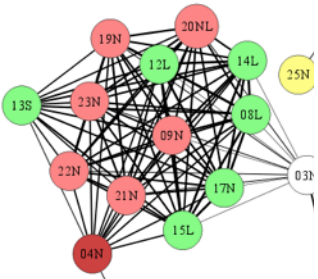


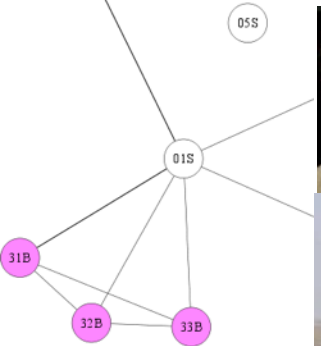


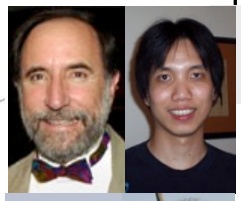














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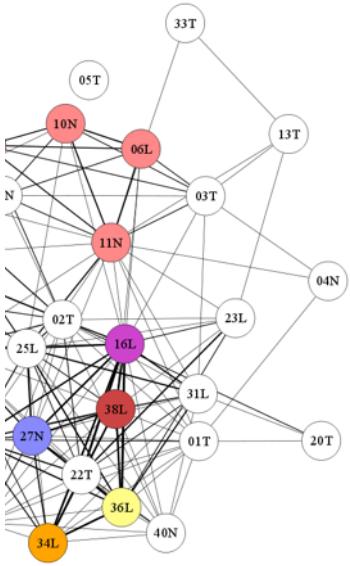
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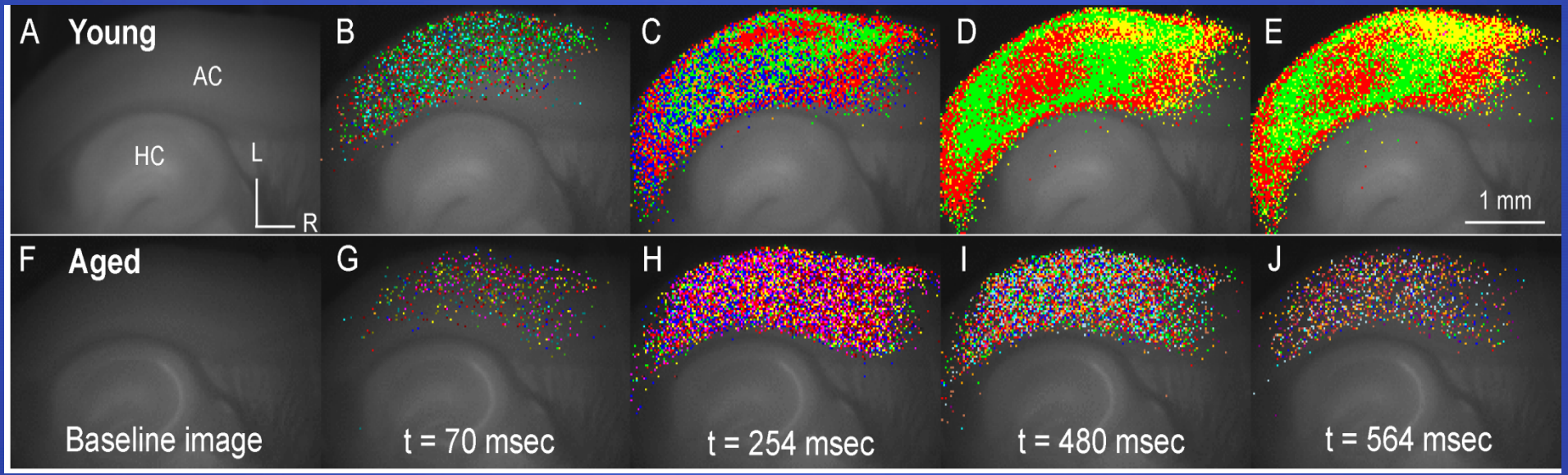
Similar but Different: Dynamic Social Network Analysis Highlights Fundamental Differences between the Fission-Fusion Societies of Two Equid Species, the Onager and Grevy's Zebra

Daniel I. Rubenstein, Siva R. Sundaresan, Ilya R. Fischhoff, Chayant Tantipathananandh, Tanya Y. Berger-Wolf

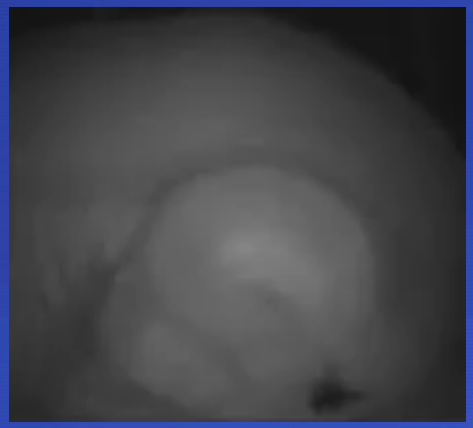
Published: October 21, 2015 • DOI: 10.1371/journal.pone.0138645

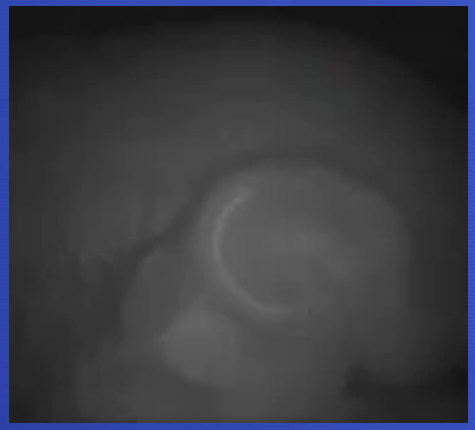


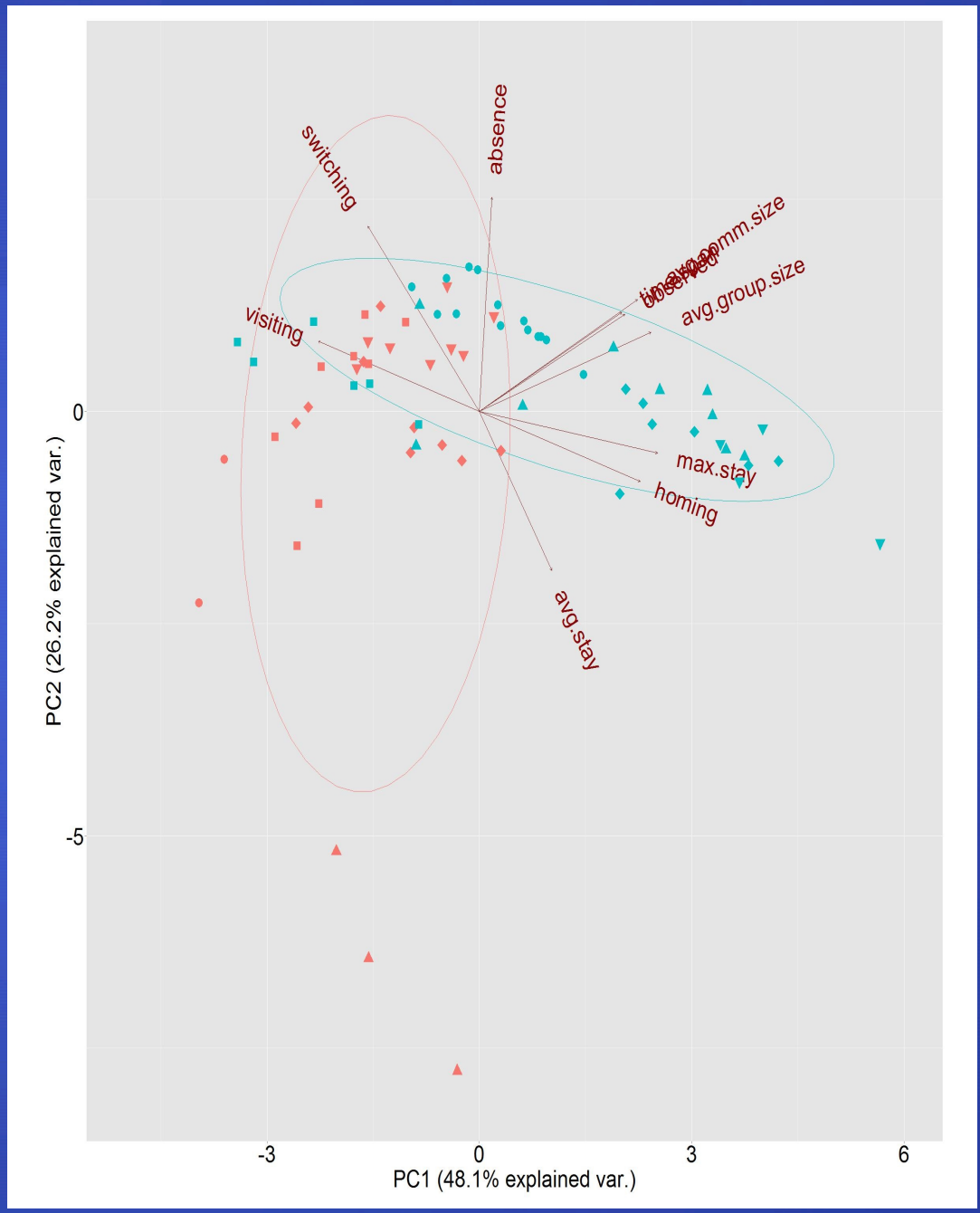
Dynamic Communities of an Aging Auditory System

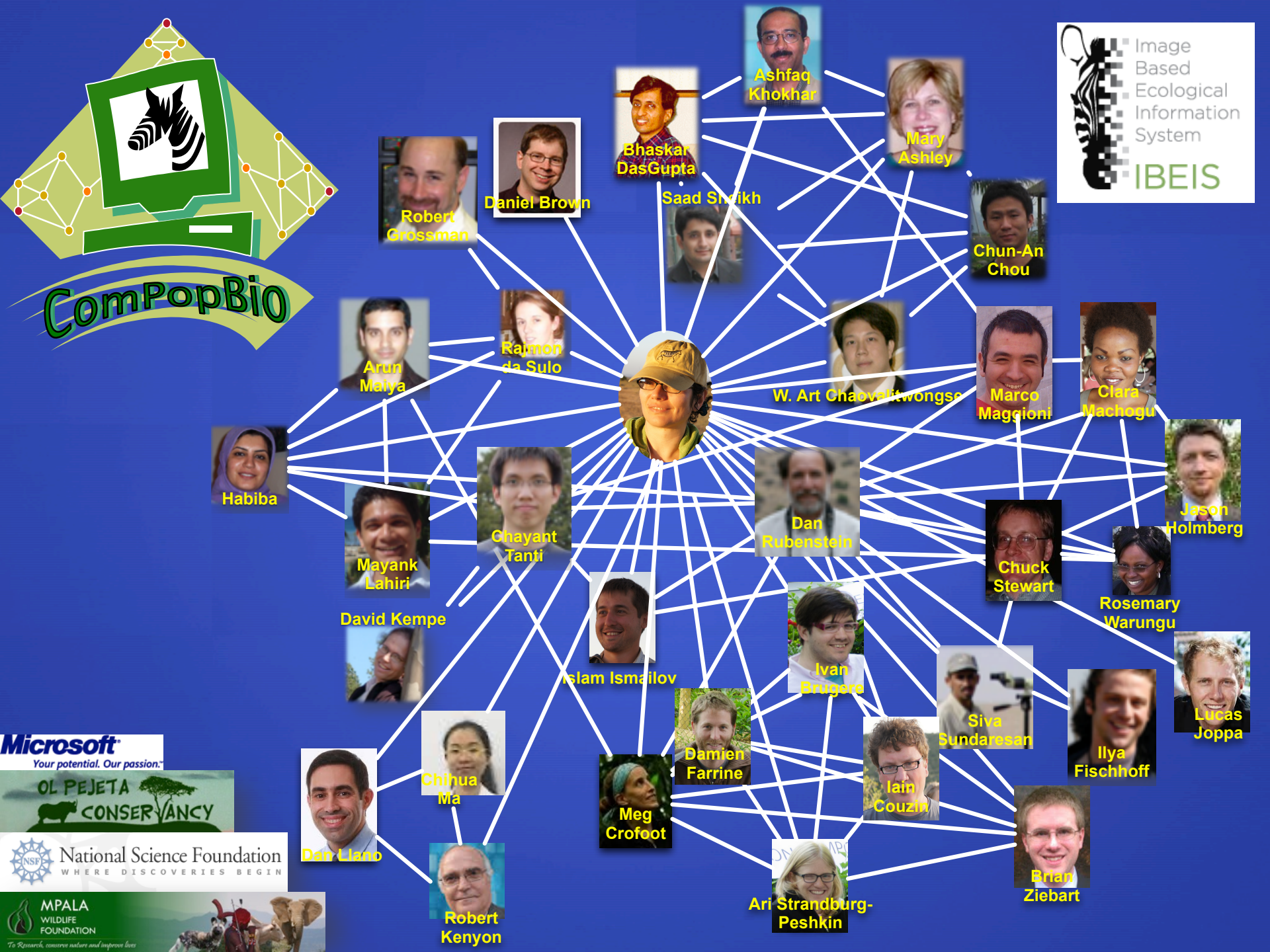


Application






switching
absence
visiting
avg.group.size
max.stay
homing
avg.stay
PC2 (26.2% explained var.)
PC1 (48.1% explained var.)
0
-5
-3
0
3
6


ComPopBio
Image Based Ecological Information System
IBEIS
Ashfaq Khokhar
Bhaskar DasGupta
Mary Ashley
Robert Grossman
Daniel Brown
Saad Sheikh
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Arun Maiya
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Ada Byron, Lady Lovelace

Journal entry, 5 January 1841



We talk much of Imagination. We talk of the Imagination of Poets, the Imagination of Artists etc.; I am inclined to think that in general we don't know very exactly what we are talking about…

It is that which penetrates into the unseen world around us, the world of Science. It is that which feels and discovers what *is*, the *real* which we see not, which *exists* not for our *senses*. Those who have learned to walk on the threshold of the unknown worlds… may then with the fair white wings of Imagination hope to soar further into the unexplored amidst which we live.