Mining Communities in Large Networks from Big Data

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Talk @ MST, Fri, Nov 06, 2015

Outline of Talk

- **Big Data is Everywhere**
- **Big Data gives Large Networks**
- **Community Structures**
- **Mining Community in Large Networks**
- **Demo** (from a recent undergraduate project)
- **Algorithms for Community Detection**

Hon Wai Leong, Computer Science, NUS

Our research in CD in Networks (1)

Started with Finding Hubs and Quasi Cliques

- S. Srihari*, H.K. Ng, K. Ning, H.W. Leong, "Detecting Hubs and Quasi Cliques in Scale-free Networks," *ICPR*, Tampa, (2008).

Finding Hubs and Essential Genes in PPI Networks

- K. Ning, H.K. Ng, S. Srihari, H.W. Leong, and A.I. Nesvizhskii, "Examination of the Relationship between Essential Genes in PPI Network and Hub Proteins in Reverse Nearest Neighbor Topology," *BMC Bioinformatics* Vol. 11:505 (Oct 2010).

Our research in CD in Networks (2)

Predicting Communities (Protein Complexes) in PPI Networks

- S. Srihari, K. Ning, and H.W. Leong, "Refining Markov Clustering for Protein Complex Prediction by Incorporating ***Core-attachment Structure***," Genome Informatics, Vol. 23, (2009), pp. 159-166.

Community Detection in *Weighted* PPI Networks

- S. Srihari, and H.W. Leong, "MCL-CAw: A refinement of MCL for detecting yeast complexes from weighted PPI networks by incorporating core-attachment structure," BMC Bioinformatics, Vol. 11:504 (Oct 2010).

Our research in CD in Networks (3)

Dealing with *Missing Data* and *Sparse* Complexes

- S. Srihari, and H.W. Leong, "Employing functional interactions for characterisation and detection of sparse complexes from yeast PPI networks", IJBRA, **8**:3/4, 286-304, (2012). .

Protein Complexes are *Dynamic* (*Time Dependent*)

- S. Srihari, K. Ning, and H.W. Leong, "Temporal Dynamics of Protein Complexes in PPI Networks: A Case Study using Yeast Cell Cycle Dynamics," BMC Bioinformatics, 13(Suppl 17):S16, Dec 2012.

Our research in CD in Networks (4)

Put together a Tutorial on Complex Detection from PPI

- S. Srihari and H.W. Leong, "A Tutorial on Computational Methods for Protein Complex Prediction from Protein Interaction Networks," INCoB, (Oct 2012) and elsewhere since.

Writing a Survey Paper…

- Sriganesh Srihari and Hon Wai Leong, "A Survey of Computational Methods for Protein Complex Prediction from Protein Interaction Networks," JBCB, (2013), 11:2, (2013)

Our research in CD in Networks (5)

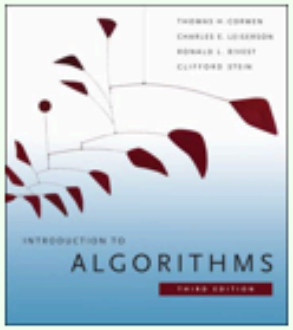
Leveraging conservation of interactions…

- Phi-Vu Nguyen, Sriganesh Srihari and Hon Wai Leong, "Identifying ***conserved protein complexes*** between species by constructing interolog networks," *BMC Bioinformatics*, 2013, 14(S-16):S8

Turning Research into Undergraduate Education (Sp 2014)

- 8 undergraduates working on CD in Large Networks
- A student, Yujian YAO (sophomore) developed a Cool FB App

This talk on Mining Communities from Large Networks



CS3230R: Design and Analysis of Algorithms (R)
Spring 2014
R Section for CS3230R of Fall 2013, Spring 2014
(Leong Hon Wai and Ken Sung Wing Kin)

Course Web-Site

LATEST UPDATE

- **27-Mar-2014 (W10): Talk by Yu ShuZhi, Nguyen Truong Huy**
  Links to the Data-Sets for Comm Detection is coming up soon.

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  - ShuZhi to chair the session.
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    "Towards the Ground Truths: Exact Algorithms for Bioinformatics Research"

(See bottom of page for past announcements...)

BIG data

NYT, Feb 11, 2012: "The Age of Big Data"

- "What is Big Data? A meme and a marketing term, for sure, but also shorthand for advancing trends in technology that open the door to a new approach to understanding the world and making decisions. …"

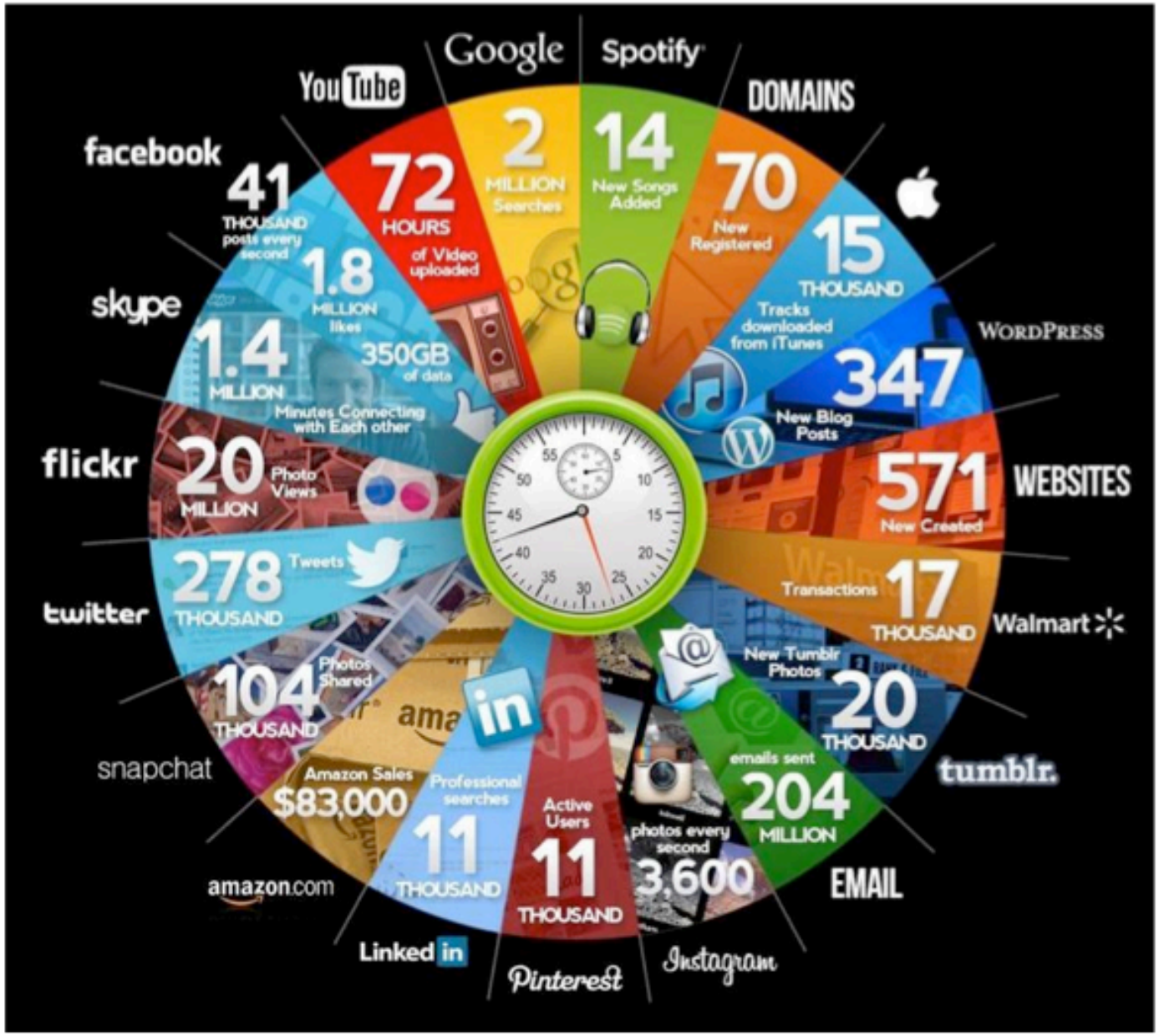
A lot of people are talking about big data, but most people are just creating it

The real value is in the analysis

And all others (we) are indeed bringing data!

What happens in an Internet minute!

Every two days now we create as much information as we did from the dawn of civilization up until 2003 (Eric Schmidt, Google CEO)



Big Data and Large networks

- **Big Data is notable,**
  - not just because of its size,
  - but because of its relationship to other data.

- **Big Data**
  - Are collected & aggregated
  - Are fundamentally networked
  - Data are threaded with connections

Big Data and Large networks

- The value of big data comes from
  - the patterns that can be derived by making connections between pieces of data,

- The Pattern could be
  - About an individual,
  - Or about individuals in relation to others,
  - Or about groups of people,
  - Or simply about the structure of information.

Large Real-World Networks

- Internet graphs, WWW graphs
- Citation networks, actor networks
- Transportation network, Email networks
- Food Web,
- Social Networks (FB, Linked-In, etc)
- Biochemical networks
- **Protein-Protein Interaction (PPI) networks**

Networks from Big-Data

- **Nodes**

  People, Customers, household/family, patient, doctor, author, terrorist, webpage, Items

- **Edges (directed or undirected)**
  - Relationship of some kind, e.g. FB-friends, colleagues, disease, contact, reference, bought-together
  - (could be weighted based on importance, frequency, reliability, etc)

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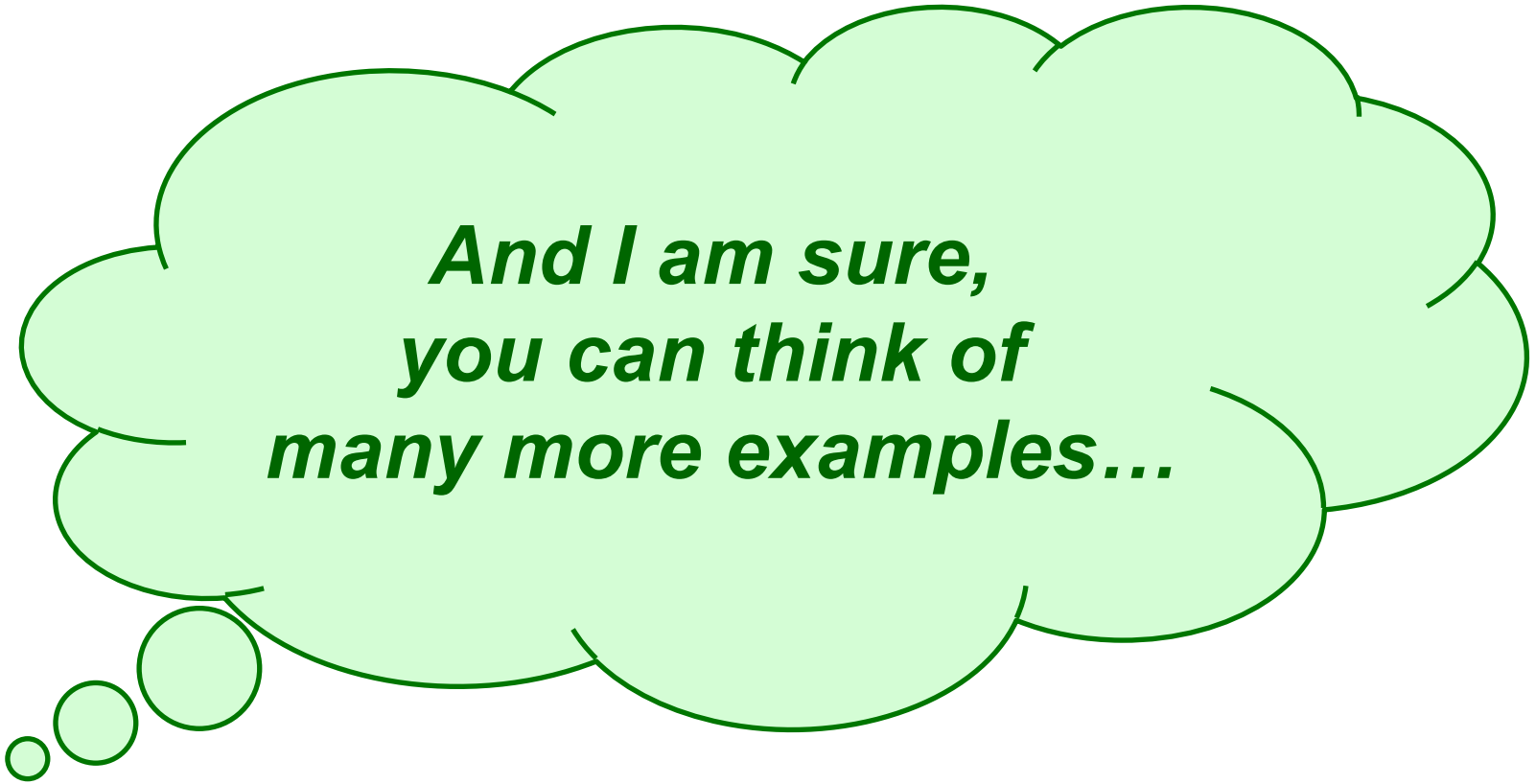
Networks from BigData: Examples

- **Classic Supermarket Example**
  - Nodes are items
  - Edge indicates the two items in same receipt
- **Classic Terrorist Network**
  - Nodes are people
  - Edge if there is some contact between them
- **Churn detection in Telco**
  - Nodes are customers
  - Edges are calling patterns between customers

Networks from BigData: Examples

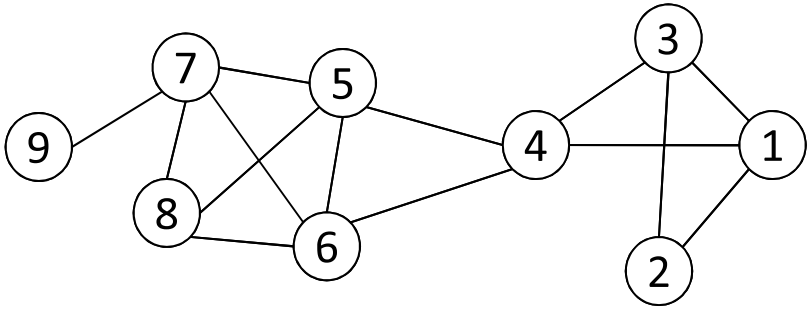
- PPIN (protein-protein interaction network)
  - Nodes are proteins
  - Edge indicates the two proteins interact
- Anti-Money Laundering
  - Nodes are bank account
  - Edges are money transfer
- System Risk in a Credit Risk setting
  - Nodes are banks
  - Edges are liquidity dependencies



Networks and Representation

Network: A graph structure made of nodes (individuals or organizations) and edges that connect nodes in various relationships like friendship, kinship etc.

- Graph Representation



- Matrix Representation

Node	1	2	3	4	5	6	7	8	9
1	-	1	1	1	0	0	0	0	0
2	1	-	1	0	0	0	0	0	0
3	1	1	-	1	0	0	0	0	0
4	1	0	1	-	1	1	0	0	0
5	0	0	0	1	-	1	1	1	0
6	0	0	0	1	1	-	1	1	0
7	0	0	0	0	1	1	-	1	1
8	0	0	0	0	1	1	1	-	0
9	0	0	0	0	0	0	1	0	-

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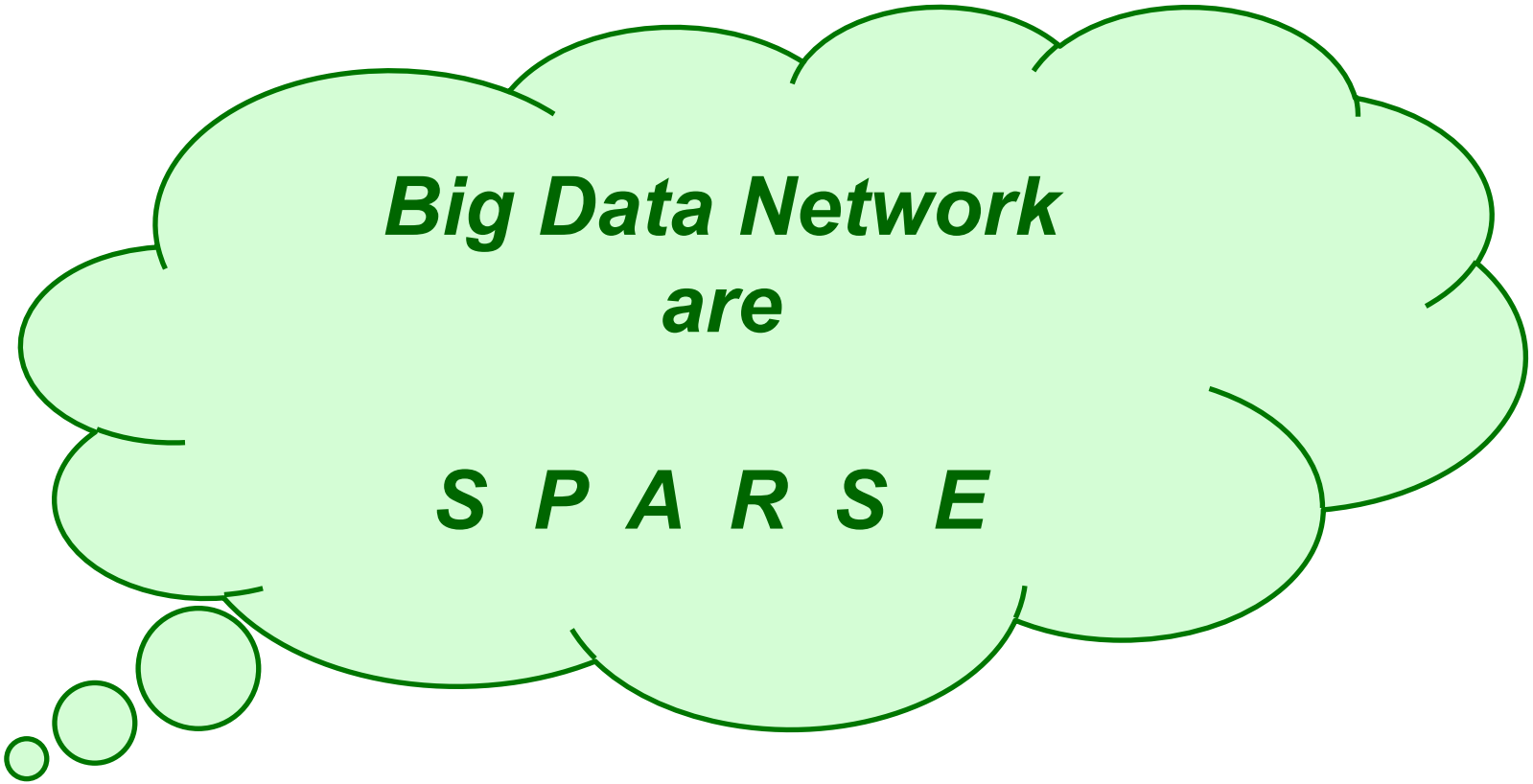
- Big Data gives Large Networks
- Community Structures
- Demo (from a recent undergraduate project)
- Detecting Community in Large Networks
- *Application Example (from Computational Biology)*



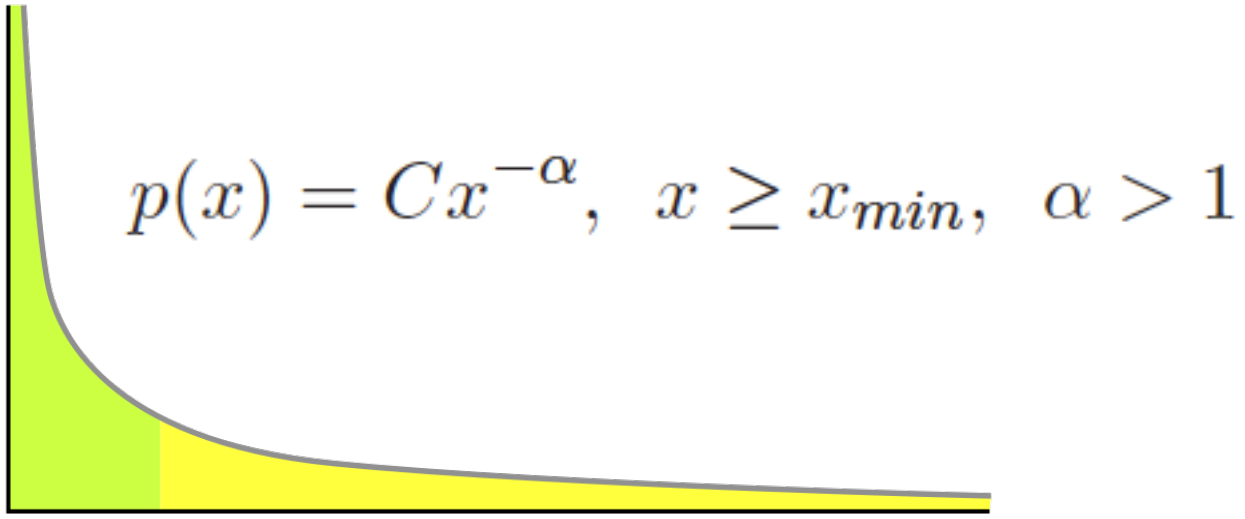
Properties of Large-Scale Networks

- Networks from big-data are typically huge, involving millions of nodes and connections.

- Large-scale networks in real world demonstrate similar patterns
  - Scale-free distributions
  - Small-world effect
  - Strong Community Structure

Scale-free Distributions

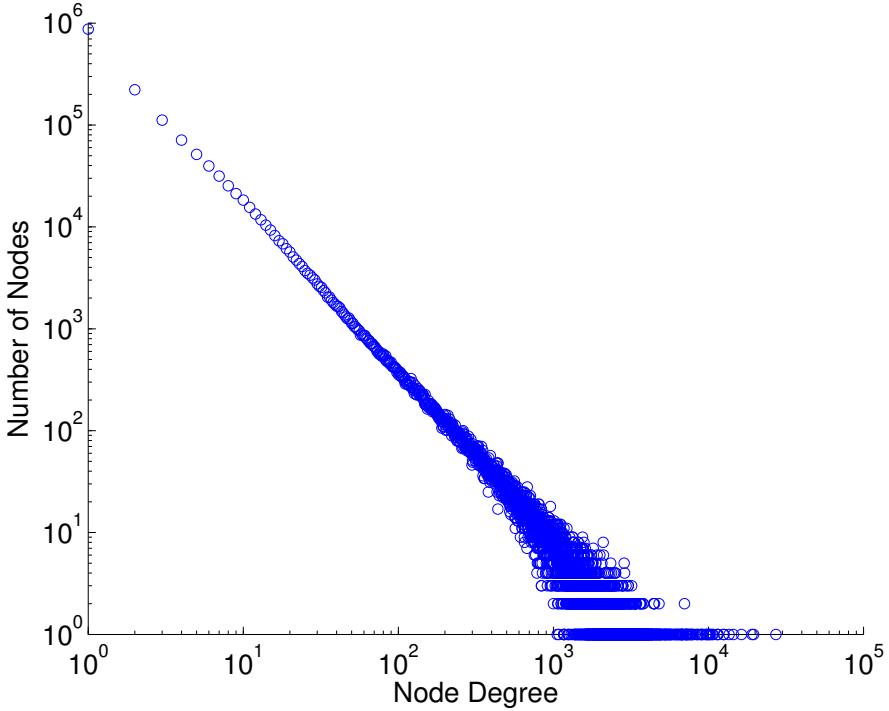
- Degree distribution in large-scale networks often follows a power law.



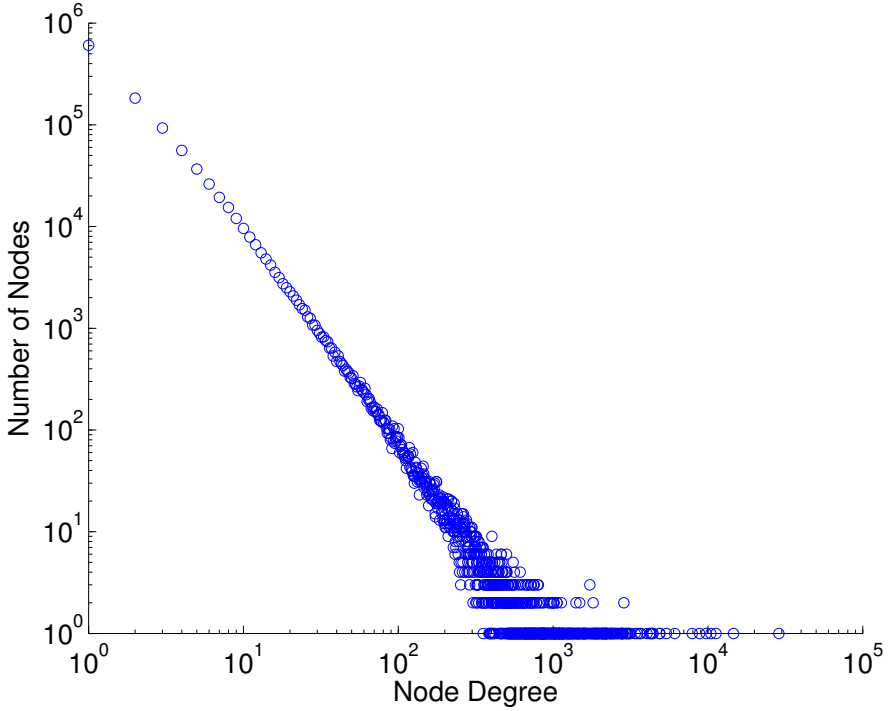
- A.k.a. long tail distribution, scale-free distribution

log-log plot

- Power law distribution becomes a straight line if plot in a log-log scale



Friendship Network in Flickr



Friendship Network in YouTube

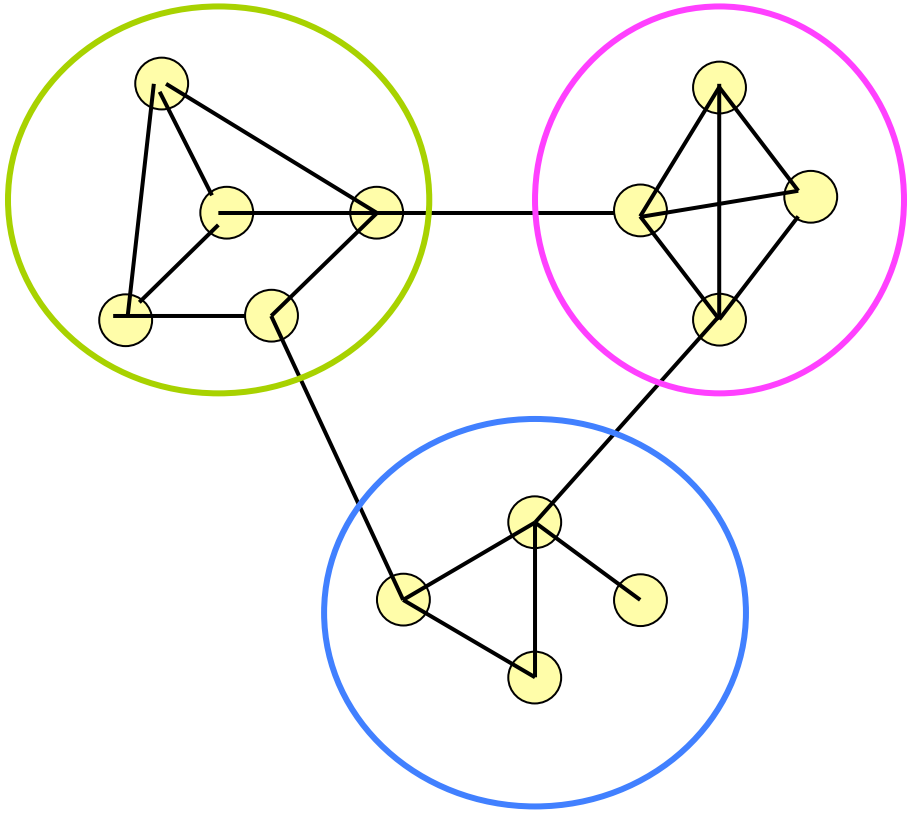
Now
if the network is sparse,
then,
what is a community?

My drive from St. Louis to Rolla:
https://goo.gl/maps/H6G1aQYSyr12

Map to Rolla (from St. Louis)

- First see the overall map
- Zoom in on St-Clair
- Zoom in on Sullivan
- Zoom in on Cuba

Community Structure (example)



Density of a Graph

- **If a graph $G=(V,E)$ with n nodes, e edges**
  - Density = $e / (n(n-1)/2)$
  - A clique K_n has density = 1,
  - An empty graph (E={}) has density = 0,
  - A spanning-tree T has density = $2/n$.

Community Structure (informal defn)

"groups of vertices with
***dense intra-group connections*, and**
sparse inter-group connections."

Within-group (intra-group) edges: High density

Between-group (inter-group) edges: Low density

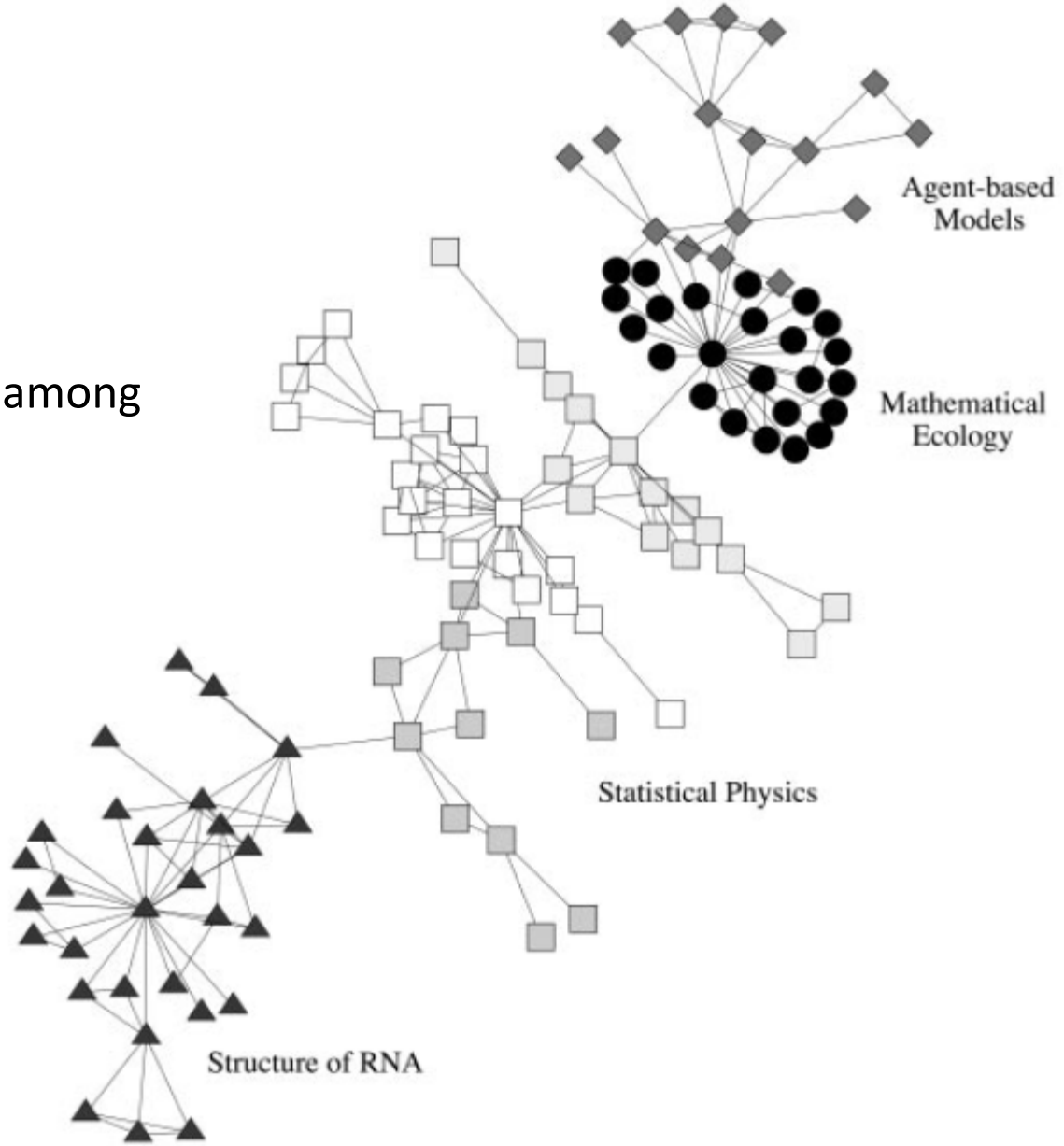
Hon Wai Leong, Computer Science, NUS

Examples of Community Structures

- Communities of biochemical network might correspond to “functional units” of some kind.

- Communities of a web graph might correspond to sets of “web sites dealing with a related topics”.

Different Communities among Collaborations of SFI (Santa Fe Institute)

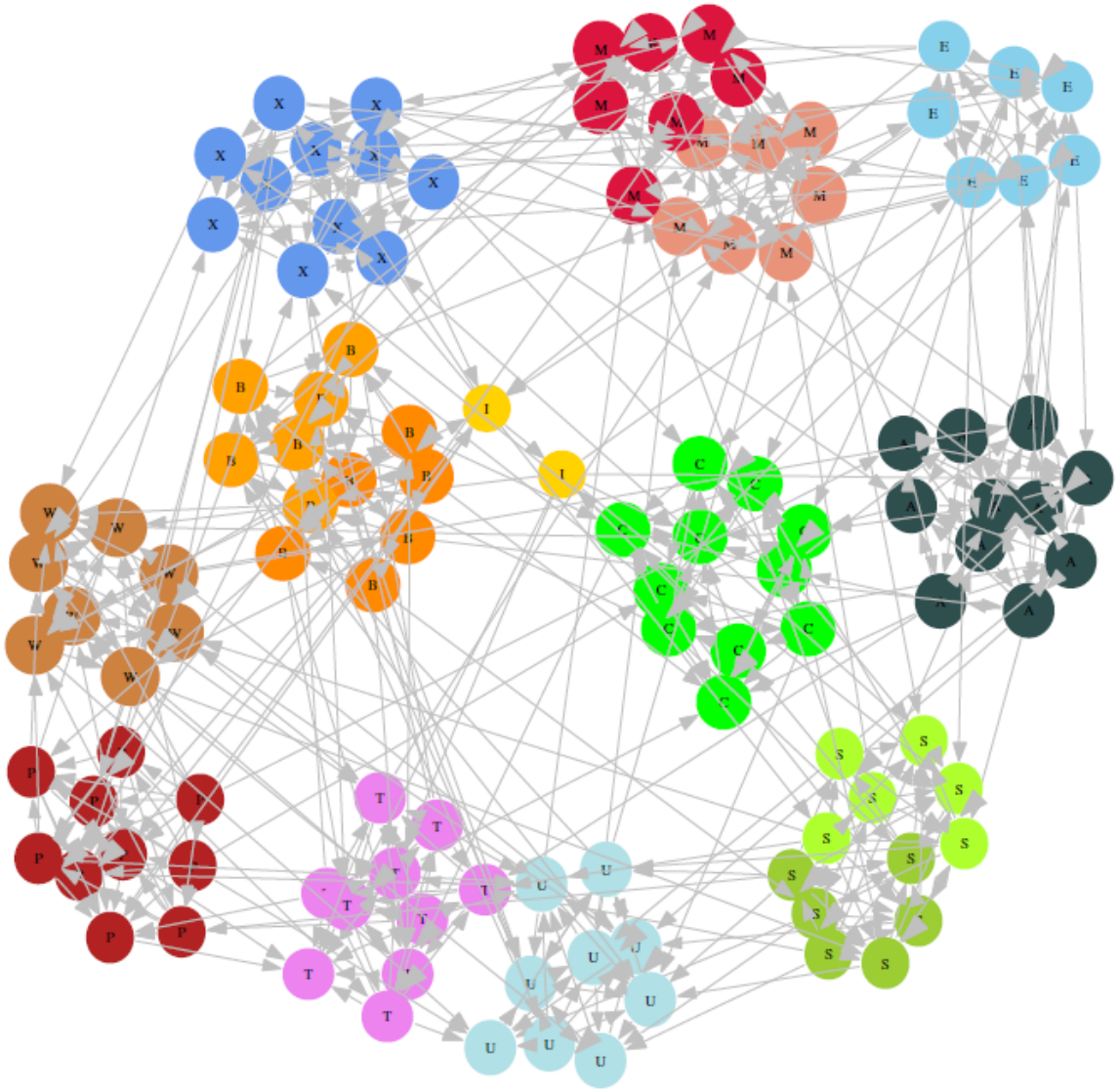


Community structure in social and biological networks

M. Girvan*†‡ and M. E. J. Newman*§

Output of Girvan-Newman Alg

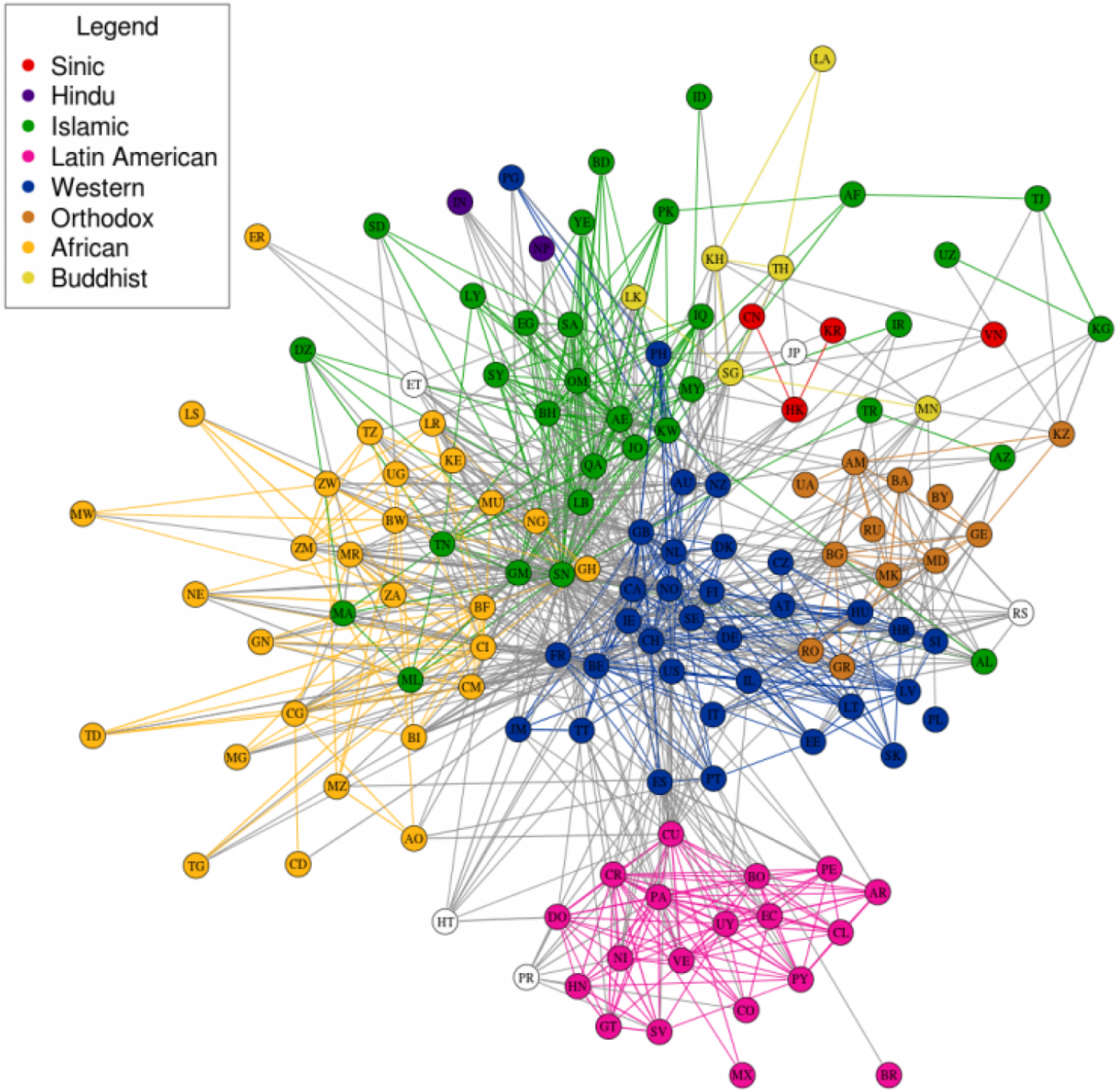
US College Football Conferences



Journal of Statistical Mechanics: Theory and Experiment
An IOP and SISSA journal

A network-based ranking system for US college football

Juyong Park and M E J Newman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So, what can communities be good for?

Dilemma in Big Data analysis

- Don't know what we know
- Know what we know
- Know what we don't know
- Don't know what we don't know

What can we do?
How can CD help?

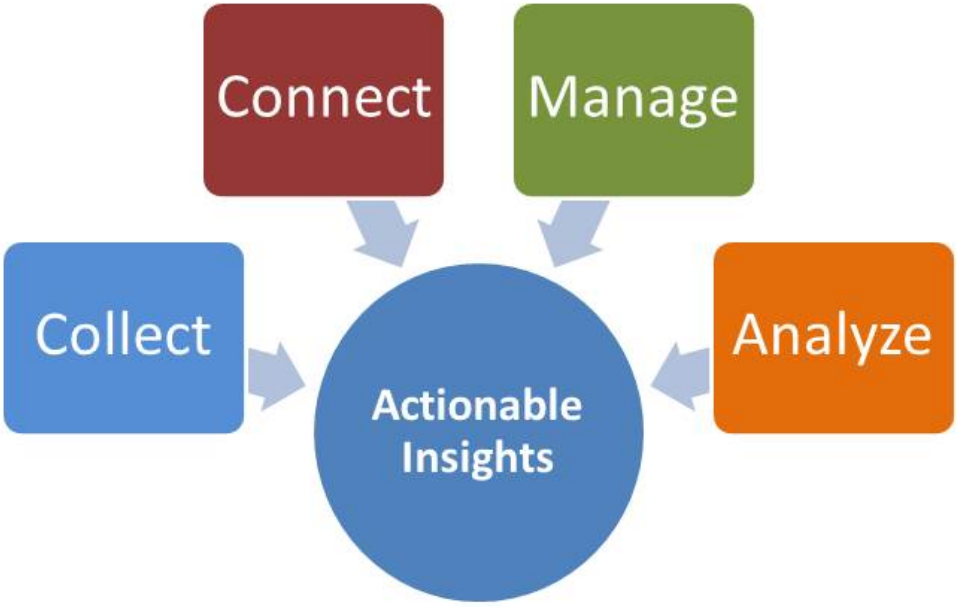
Use of Community Detection (CD)

1. Big data gives us Large Graphs

2. Detect communities in these Graphs

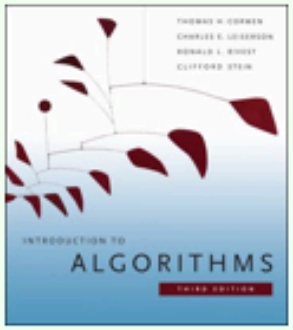
3. Analyze the communities detected
   - Develop/confirm relationships between your data, your entities, the groups
   - Derive new insights from community relationships
   - Learn new things from your Big Data
   - Turn into competitive advantage

New buzzword…



A Cool project…

http://pals.yjyao.com



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An Undergraduate Student Project

CS3230R:

A research-component add-on to
CS3230: Analysis of Algorithm

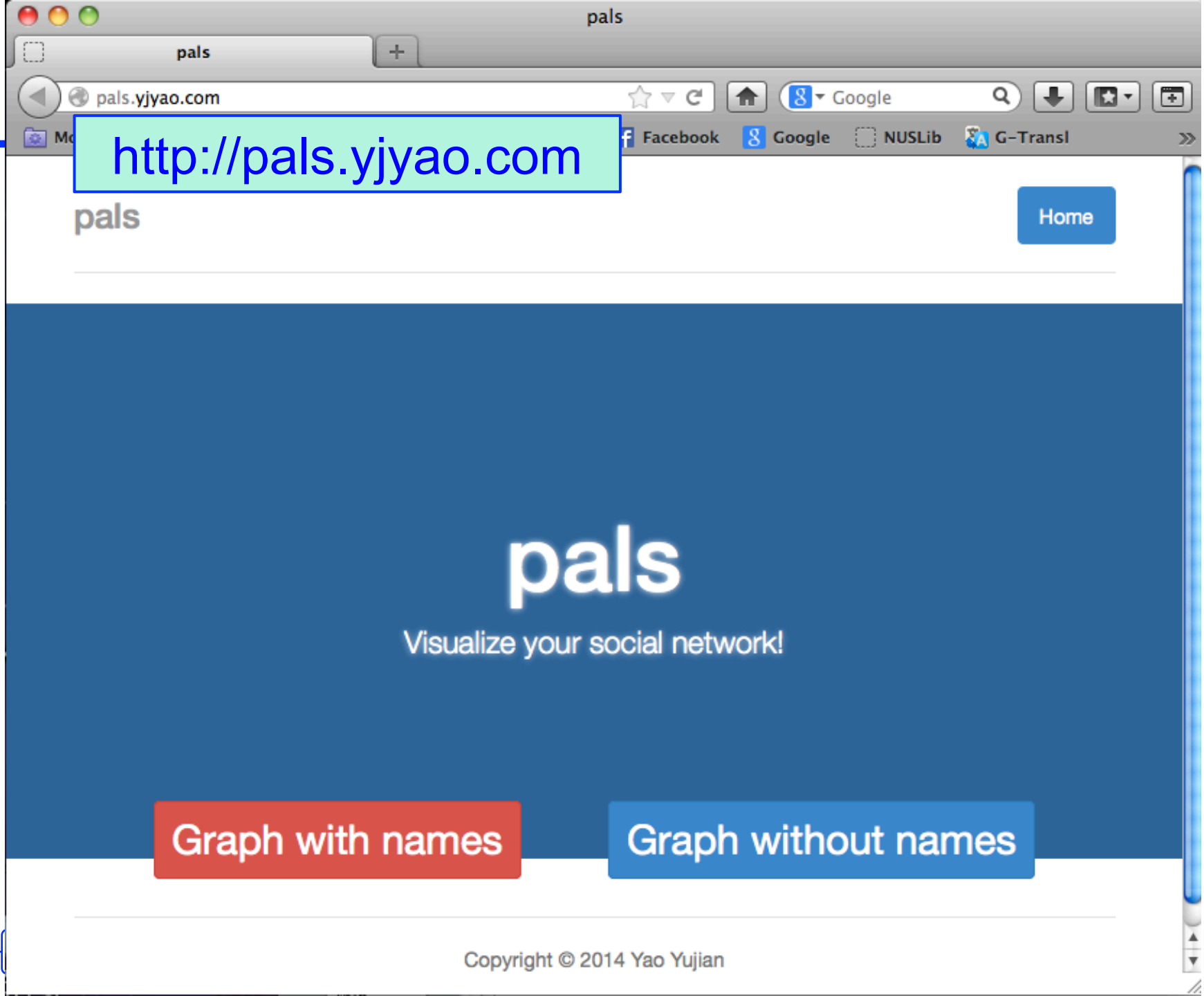
Yao YuJian: (2nd year undergrad, NUS-SOC)

"Improved Fuzzy Clustering and
Force-Directed Algorithms for
Visualization of Personal Social Networks"

YuJian's Project Overview…

- Download your FB friend network
- Compute communities
  - Using an Improved Fuzzy Clustering Algorithm
- Visualize Communities computed
  - Using Force-Directed Layout

http://pals.yjyao.com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Google
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NUSLib
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http://pals.yjyao.com
pals
Home
pals
Visualize your social network!
Graph with names
Graph without names
Copyright © 2014 Yao Yujian

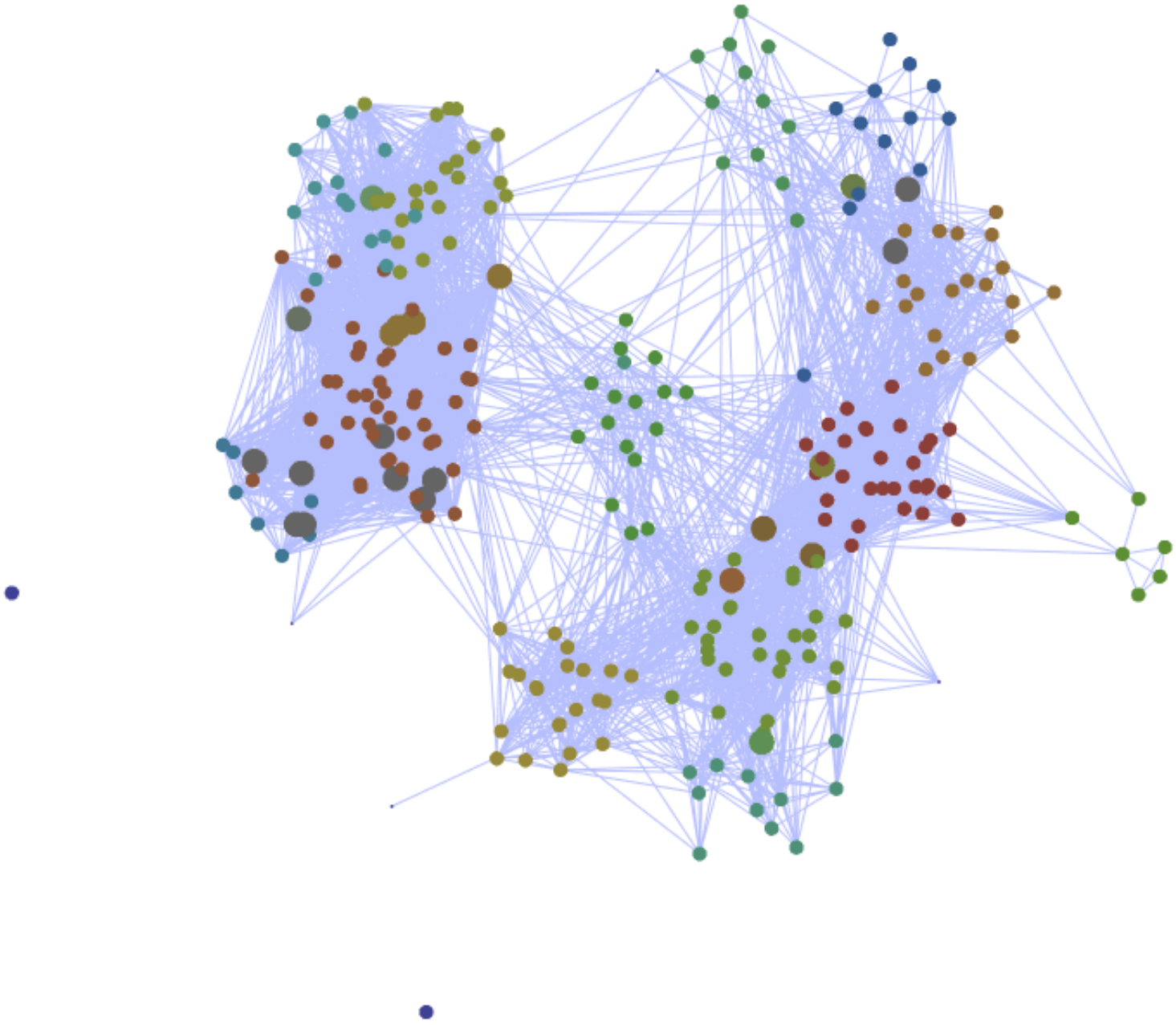
- **Try out the app written by YuJian**

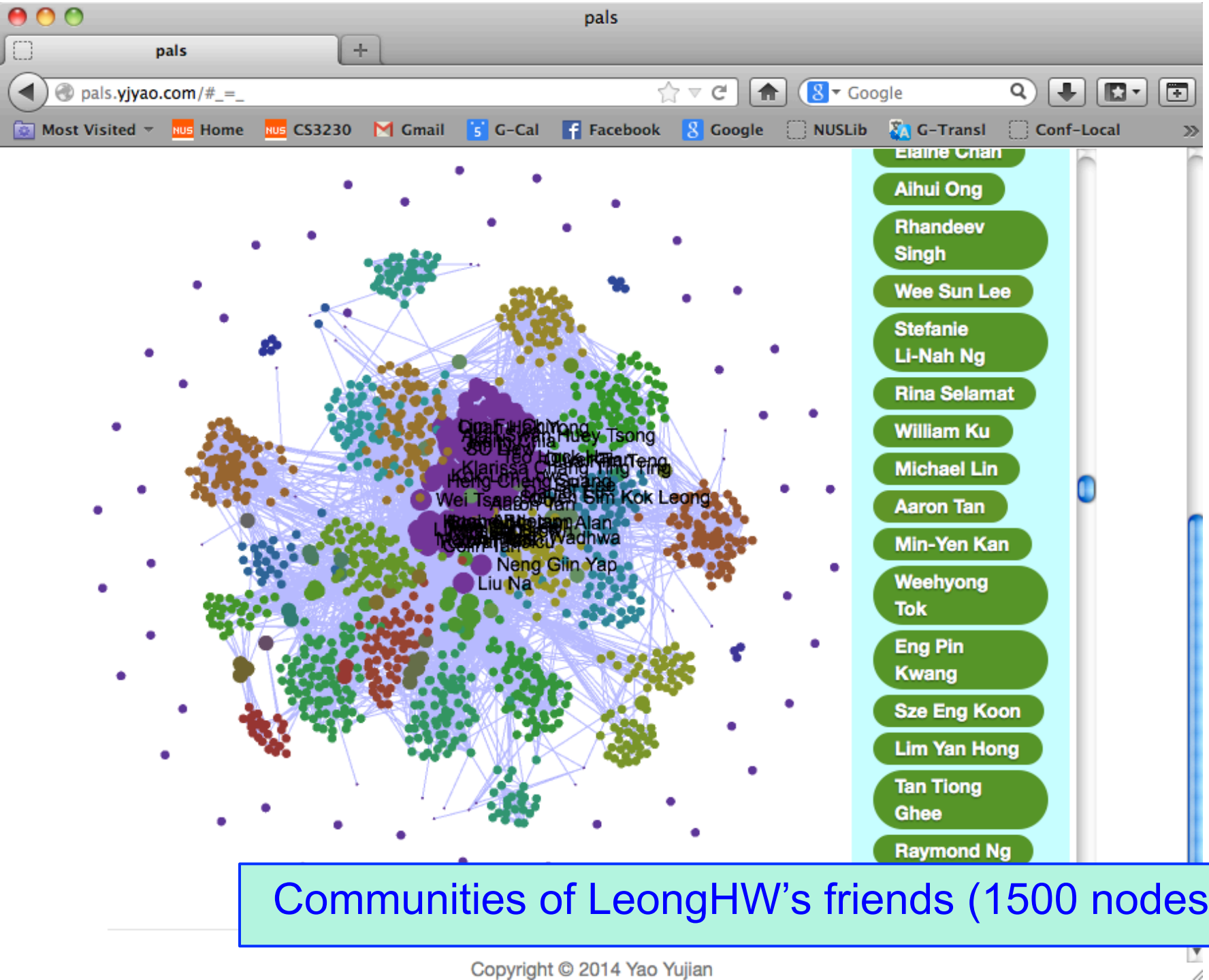
  http://pals.yjyao.com

- **See if you can discover some of "What you don't know that you don't know.**

Send me email at leonghw@gmail.com to give me feedback

Community of YuJian's friends

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G-Transl
Conf-Local
Elaine Chan
Aihui Ong
Rhandeev Singh
Wee Sun Lee
Stefanie Li-Nah Ng
Rina Selamat
William Ku
Michael Lin
Aaron Tan
Min-Yen Kan
Weehyong Tok
Eng Pin Kwang
Sze Eng Koon
Lim Yan Hong
Tan Tiong Ghee
Raymond Ng
Huey Tsong
Sim Kok Leong
Alan
Wadhwa
Neng Glin Yap
Liu Na
Communities of LeongHW's friends (1500 nodes)
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About YuJian's project…

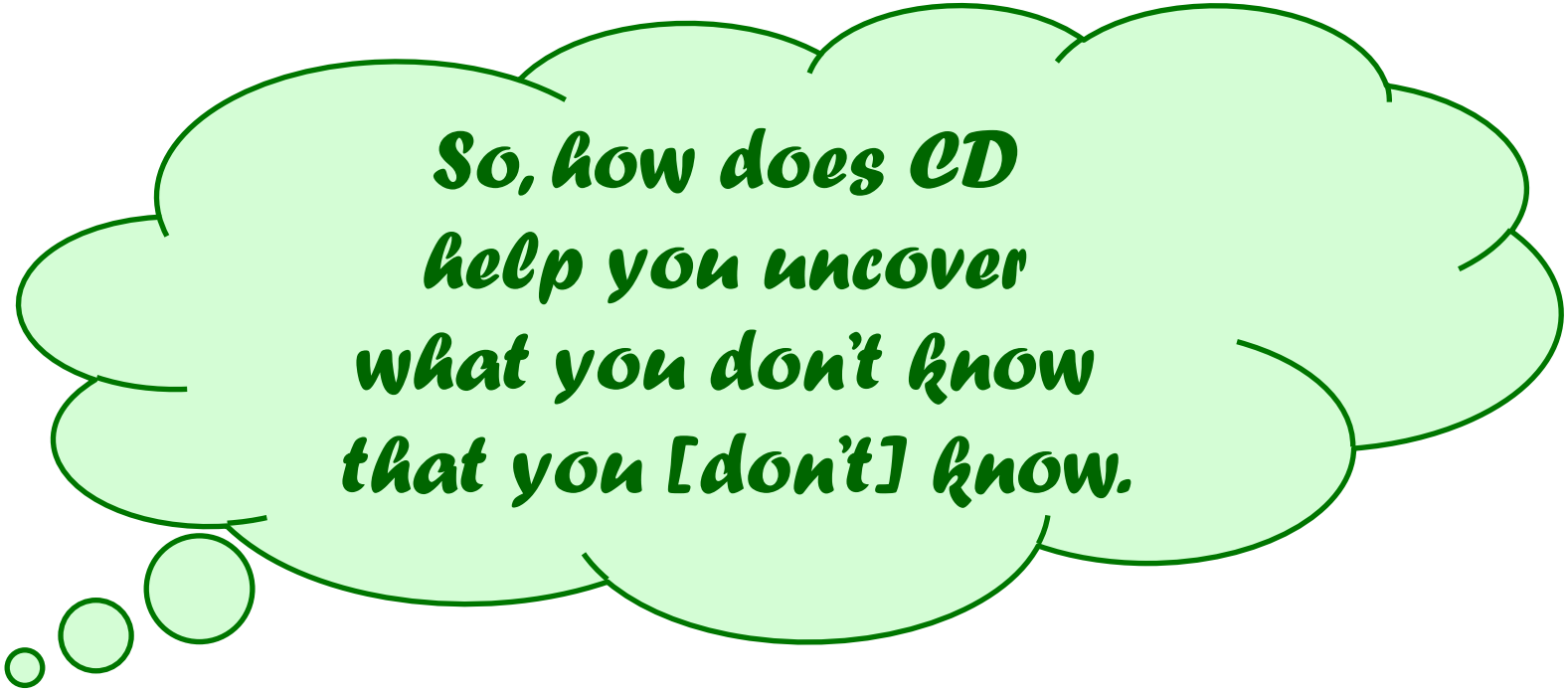
Fun and Fulfilling Project

- Learns research on algorithms
- Develop a cool apps
- Work still in progress…

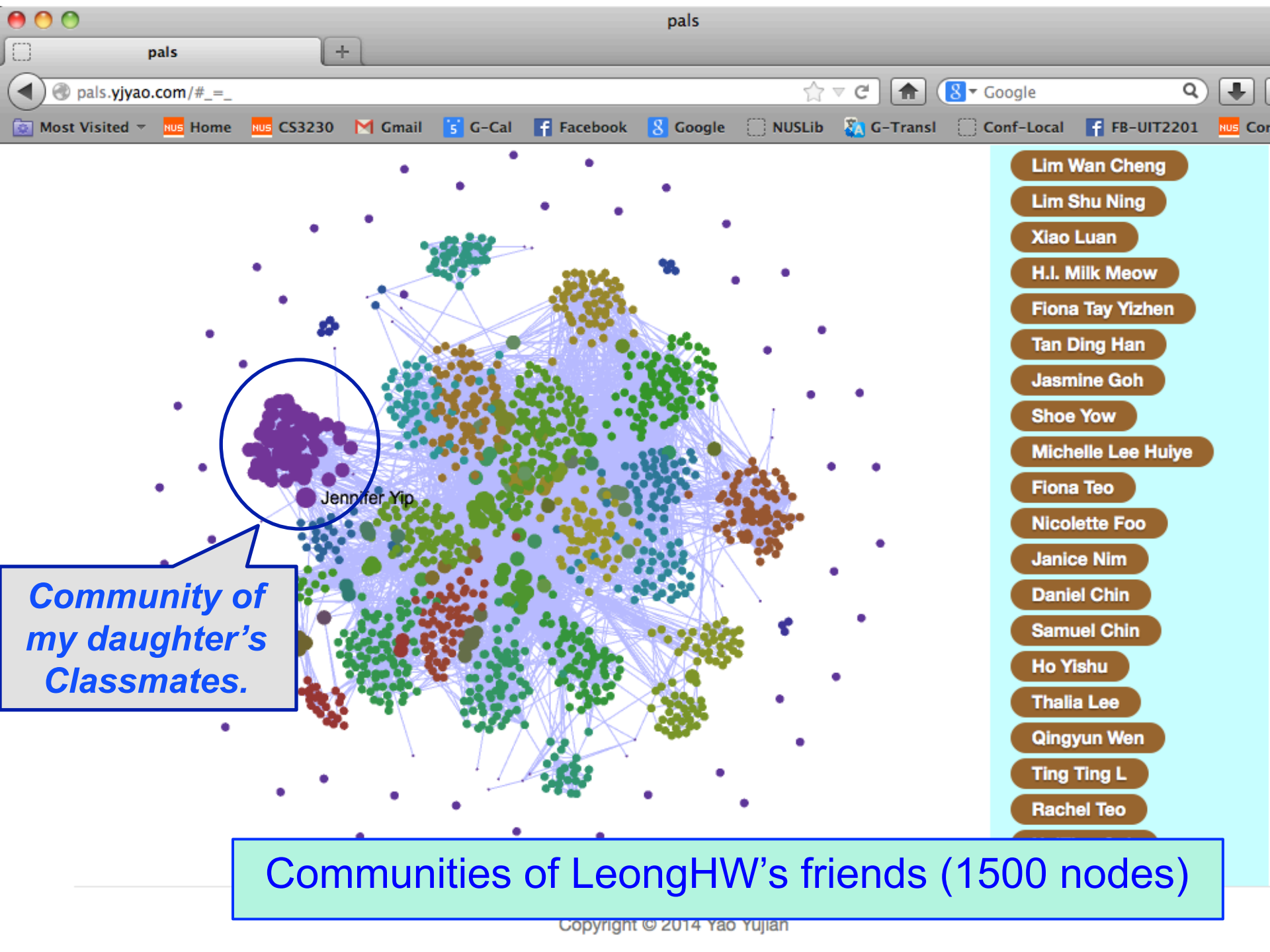
That summer,
Yujian got internship in Dropbox

implemented a new feature
(can see it if you use the paid version)

CD helps develop new insights



I ran the system on my FB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G-Cal
Facebook
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NUSLib
G-Transl
Conf-Local
FB-UIT2201
Jennifer Yip
Community of my daughter's Classmates.
Lim Wan Cheng
Lim Shu Ning
Xiao Luan
H.I. Milk Meow
Fiona Tay Yizhen
Tan Ding Han
Jasmine Goh
Shoe Yow
Michelle Lee Huiye
Fiona Teo
Nicolette Foo
Janice Nim
Daniel Chin
Samuel Chin
Ho Yishu
Thalia Lee
Qingyun Wen
Ting Ting L
Rachel Teo
Communities of LeongHW's friends (1500 nodes)
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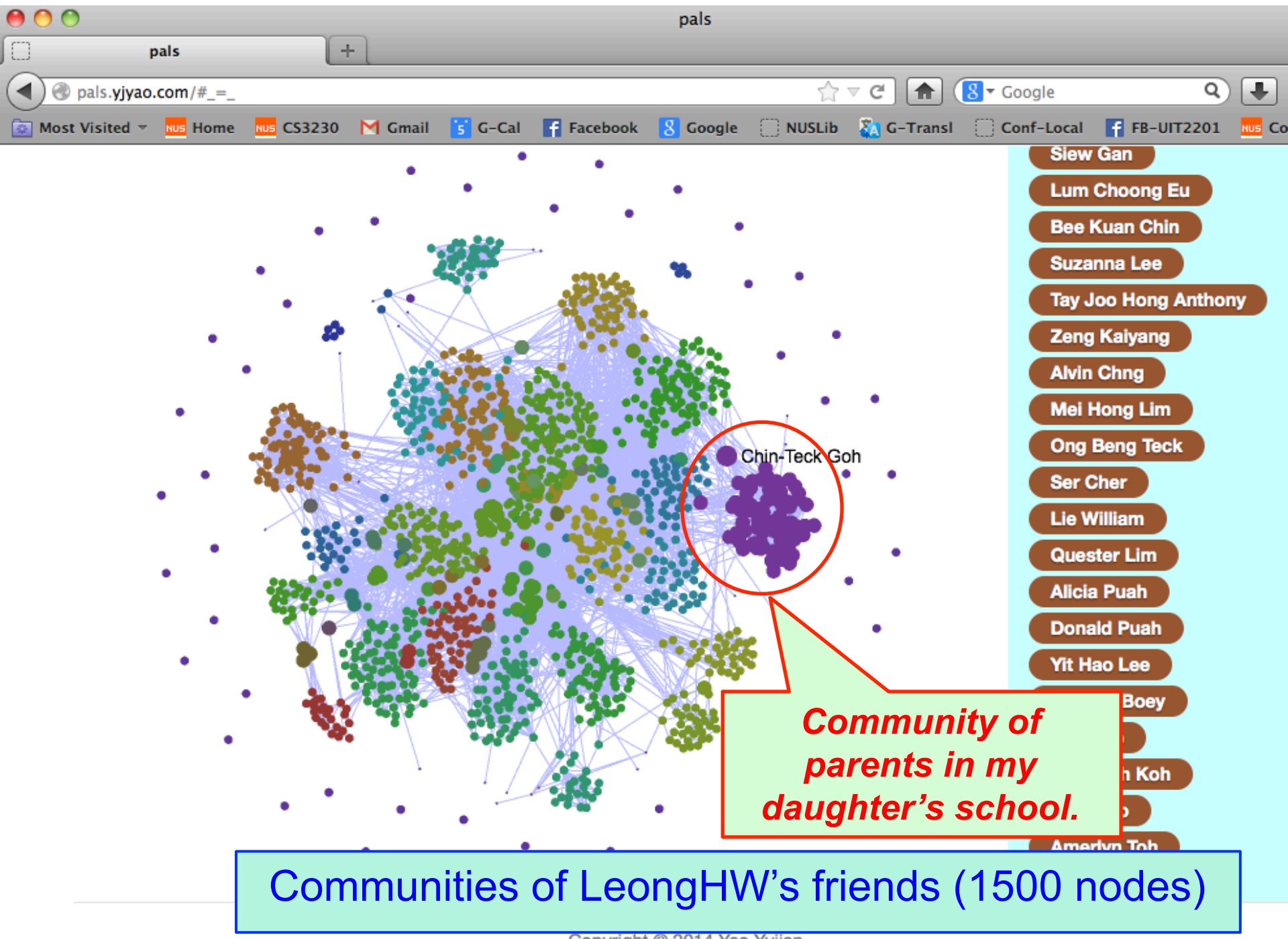

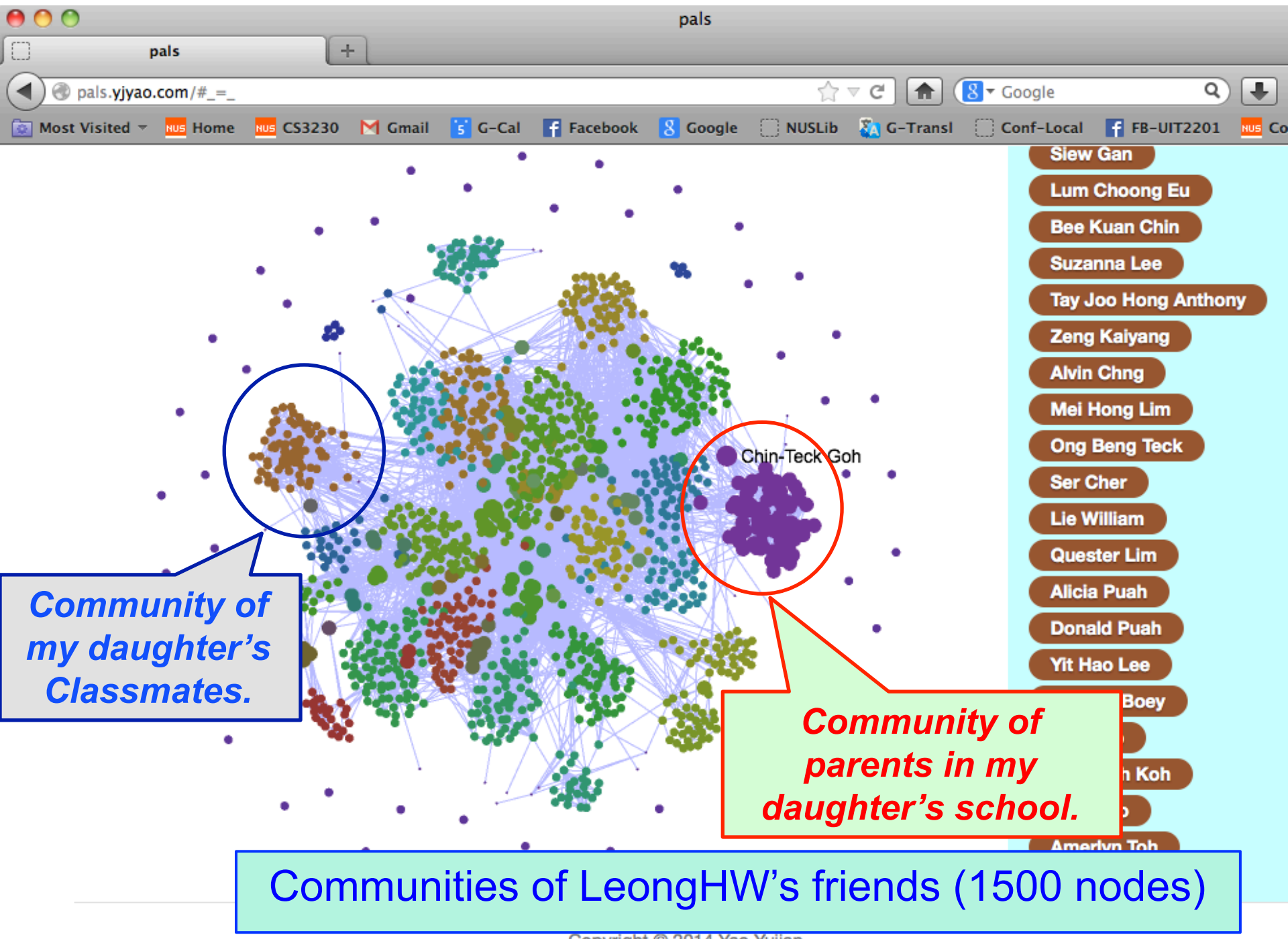

New insights from CD

- **Children's Community** is far apart from the **Parent's Community**

- **New insight:**

> The children are not FB friends of their parents.

This new insights makes a lot of sense.

But Pals is no longer functional?

"Hi Prof Leong,

Yes it's not functional because Facebook updated their API to disallow getting mutual friends out of any friend. Without that we can't construct a friendship graph.

According to this:

http://techcrunch.com/2015/04/28/facebook-api-shut-down/#.yt0obn:nael

it happened some time in April this year (2015)."

Hope this helps!

Cheers, Yujian

Community Detection Algorithms

(See next presentation)

For more details, go to
Santo Fortunato, "Community detection in Graphs", Physics Reports, 486 (2010), 75-174.

Some additional references…

Santo Fortunato, "Community Detection in Graphs", Physics Reports, 486 (2010), 75-174.

Lei Tang, Huan Liu, "*Community Detection and Mining in Social Media*", Morgan and Claypool Publishing, 2010.

http://dmml.asu.edu/cdm/

http://www.cscs.umich.edu/~crshalizi/notebooks/community-discovery.html

School of Computing

Thank you.

Q & A

Contact:
Hon Wai Leong（梁汉槐）
FB, email: leonghw@comp.nus.edu.sg
http://www.comp.nus.edu.sg/~leonghw/