

# NetworkWorkbench

A Workbench for Network Scientists

Network Analysis, Modeling, and Visualization

**NWB Team**

<http://nwb.slis.indiana.edu>

Indiana University, Bloomington, IN

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## NetworkWorkbench

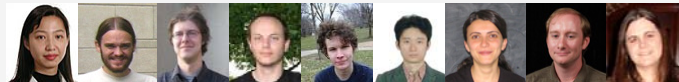
A Workbench for Network Scientists

### Project Details

**Investigators:** Katy Börner, Albert-Laszlo Barabasi, Santiago Schnell, Alessandro Vespignani & Stanley Wasserman, Eric Wernert



**Software Team:** Lead: Weixia (Bonnie) Huang  
Members: Bruce Herr, Russell Duhon, Tim Kelley, Micah Linnemeier, Heng Zhang, Duygu Balcan, Bryan Hook & Ann McCranie  
Previous Developers: Ben Markines, Santo Fortunato, Felix Terkhorn, Megha Ramawat, Ramya Sabbineni, Vivek S. Thakre, & Cesar Hidalgo



**Goal:** Develop a large-scale network analysis, modeling and visualization toolkit for physics, biomedical, and social science research.

**Amount:** \$1,120,926, NSF IIS-0513650 award

**Duration:** Sept. 2005 - Aug. 2008

**Website:** <http://nwb.slis.indiana.edu>

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**NWB Advisory Board:**

- James Hendler (Semantic Web) <http://www.cs.umd.edu/~hendler/>
- Jason Leigh (CI) <http://www.evl.uic.edu/spiff/>
- Neo Martinez (Biology) <http://online.sfsu.edu/~webhead/>
- Michael Macy, Cornell University (Sociology)  
<http://www.soc.cornell.edu/faculty/macy.shtml>
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- Mark Gerstein, Yale University (Bioinformatics) <http://bioinfo.mbb.yale.edu/>
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- NWB Research Results
- NWB Tool Overview and Demo
- ~~NWB Tool in Bioinformatics Research~~
- NWB Tool for Scientometrics Research
- Discussion of CShell and Future Work

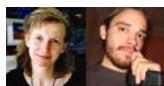
- Computational Social Science
- Computational Scientometrics
- Computational Economics
- Computational Proteomics
- Computational Epidemics

## Computational Social Science

*Studying large scale social networks such as Wikipedia*

### Vizzards 2007 Entry

Second Sight: An Emergent Mosaic of Wikipedian Activity, The NewScientist, May 19, 2007



## Second sight

Image: Bruce W. Herr and Todd M. Holloway

### Power struggle

How do you keep track of the bubbling mass of information that is Wikipedia? This chaotic-looking mosaic is one attempt to show which topics are



locked until the mood cools (locked pages at the time of writing include entries on Sheffield Wednesday football club, Mikhail Gorbachev and pigs).

The mosaic has been commended in a competition for images that visualise network dynamics, coinciding with this week's International Workshop and Conference on Network Science in Bloomington.

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A Workbench for Network Sciences

## 113 Years of Physical Review

Bruce W. Herr II and Russell Duhon (Data Mining & Visualization), Elisha F. Hardy (Graphic Design), Shashikant Penumarthy (Data Preparation) and Katy Börner (Concept)

**113 Years of Physical Review**

**Nobel Prizes in Physical Review**

**Bar Graph**

**Lines**

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## Computational Scientometrics

*Studying science by scientific means*

Börner, Katy, Chen, Chaomei, and Boyack, Kevin. (2003). **Visualizing Knowledge Domains**. In Blaise Cronin (Ed.), *Annual Review of Information Science & Technology*, Volume 37, Medford, NJ: Information Today, Inc./American Society for Information Science and Technology, chapter 5, pp. 179-255.

Shiffrin, Richard M. and Börner, Katy (Eds.) (2004). **Mapping Knowledge Domains**. *Proceedings of the National Academy of Sciences of the United States of America*, 101(Suppl\_1).

**Places & Spaces: Mapping Science** exhibit, Currently on display at the American Museum for Science and Energy, Oak Ridge, TN, see also <http://scimaps.org>.

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### Illuminated Diagram Display

W. Bradford Paley,  
Kevin W. Boyack,  
Richard Klavans,  
and Katy Börner  
(2007) Mapping,  
Illuminating, and  
Interacting with  
Science.  
SIGGRAPH 2007,  
San Diego, CA.

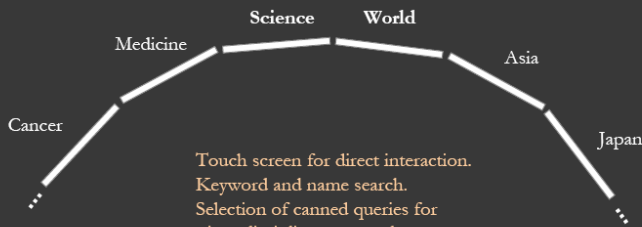


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Re-implementation of Illuminated Diagram Software (in progress)  
by *Advanced Visualization Lab, Indiana University*

Drives unlimited number of ID screens.



Touch screen for direct interaction.  
Keyword and name search.  
Selection of canned queries for  
- interdisciplinary research areas  
- famous people  
- activity patterns, e.g., bursts, trends, etc.



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### 学科分布图：科学学科是怎样相互关联的

### 世界地图：科学研究在哪里进行着

你可以通过触摸并在地图上随意地点来改变所列之处的光亮程度。当你触摸世界地图的某一点时，在那个地理位置上的所有研究机构会被点亮，同时在这些研究机构工作的学者的论文所属的学科会在学科分布图上被点亮。而当你触摸学科分布图的某一点时，在那个位置上的科学学科会被点亮，同时从事这些学科研究的研究机构在世界地图上的分布会被点亮。

#### 米技术

显示所有和纳米技术相关的科学学科。纳米和科学研究人员在无形的空间里改造世界的。这些空间存在于极其微小以至单个原子的1/4中。目前大部分有关纳米的研究主要集中在化学和材料科学领域。它们主要位于学科图上上半部分的右侧。不过，纳米技术在生物医药学研究中的应用也越来越多。生物学和学位于学科分布图下半部分的右侧。

#### 探索科学学科的相互关联性

<b>所有科学学科</b> 显示所有776种科学学科	<b>纳米技术</b> 有关观粒子的科学
<b>可持续性</b> 一些与人类有于长期希望相关的科学	<b>化学和生物</b> 化学和生物科学的交叉部分

#### 探索某个学者的科学著作的影响力传播

<b>弗郎西·科里克</b> DNA双螺旋结构的发现者之一	<b>阿尔伯特·爱因斯坦</b> 用相对论重新激活了物理学	<b>迈克尔·费舍尔</b> 发现了物质转变模式的关键步骤	<b>苏珊·费斯克</b> 研究人的认知是如何产生偏见的
<b>约舒亚·雷德伯格</b> 细菌遗传机制研究先驱	<b>德里克·德索拉·普里斯</b> 著名的“科学计量学之父”	<b>理查德·扎尔</b> 采用激光化学技术研究分子动态分布	<b>关于本次展览</b> 与此展览相关人员机构

光扫快速的扫过所有相互关联的科学学科，每一个学科以及从事这方面科学研究的研究机构在世界地图上的位置会被逐一点亮。首先，显示屏会点亮那些产出论文最多、最活跃的科学学科，然后那些小学科或冷门学科会被逐一点亮。

显示屏通过四步来展示某个学者对科学的贡献以及影响力的传播。首先，显示屏会亮出该作者发表的论文所属的学科在学科分布图上的位置以及该作者从事这项研究所在的研究机构在世界地图上的位置。到目前为止，所有这些论文的引用率仍然很高。第二步，显示屏点亮所有引用在第一步中被亮出的原始论文的论文在学科分布图上的位置以及它们在世界地图上的位置。第三步，显示屏点亮所有引用了在第二步中被亮出的论文的论文在学科分布图上的位置以及它们在世界

## Computational Economics

*Does the type of product that a country exports matter for subsequent economic performance?*

C. A. Hidalgo, B. Klinger, A.-L. Barabási, R. Hausmann (2007) *The Product Space Conditions the Development of Nations. Science* 317, 482 (2007).

**Fig. 1. The product space. (A)** Hierarchically clustered proximity (q) matrix representing the 775 SITC-4 product classes exported in the 1998–2000 period. **(B)** Network representation of the product space. Links are color coded with their proximity value. The sizes of the nodes are proportional to world trade, and their colors are chosen according to the classification introduced by Leamer.

## Computational Proteomics

What relationships exist between protein targets of all drugs and all disease-gene products in the human protein-protein interaction network?

Yildirim, Muhammed A., Kwan-II Goh, Michael E. Cusick, Albert-László Barabási and Marc Vidal. (2007) Drug-target Network. Nature Biotechnology 25 no. 10: 1119-1126.



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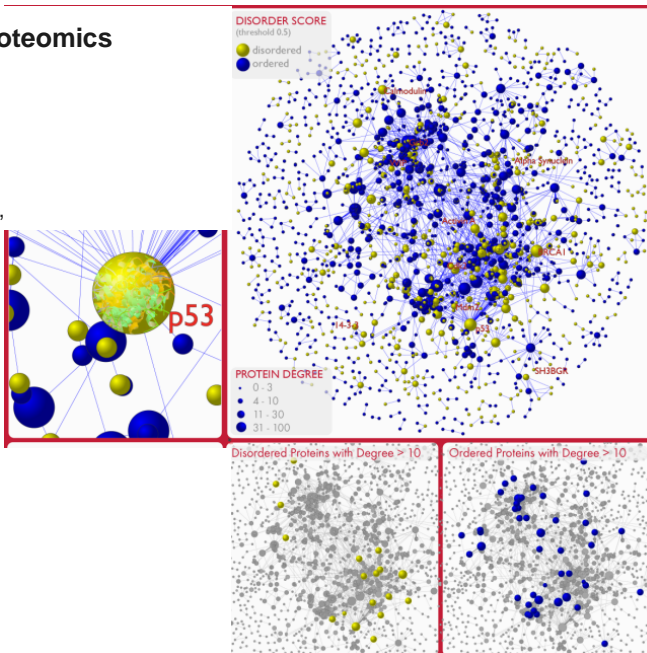
Figure 2 Drug-target network (DT network). The DT network is generated by using the known associations between FDA-approved drugs and their target proteins. Circles and rectangles correspond to drugs and target proteins, respectively. A link is placed between a drug node and a target node if the protein is a known target of that drug. The area of the drug (protein) node is proportional to the number of targets that the drug has (the number of drugs targeting the protein). Color codes are given in the legend. Drug nodes (circles) are colored according to their Anatomical Therapeutic Chemical Classification, and the target proteins (rectangular boxes) are colored according to their cellular component obtained from the Gene Ontology database.

## Computational Proteomics

S. Schnell, S. Fortunato, and S. Roy (2007). Is the intrinsic disorder of proteins the cause of the scale-free architecture of protein-protein interaction networks? *Proteomics* 7, 961-964.



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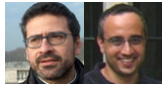
## Computational Epidemics

*Forecasting (and preventing the effects of) the next pandemic.*

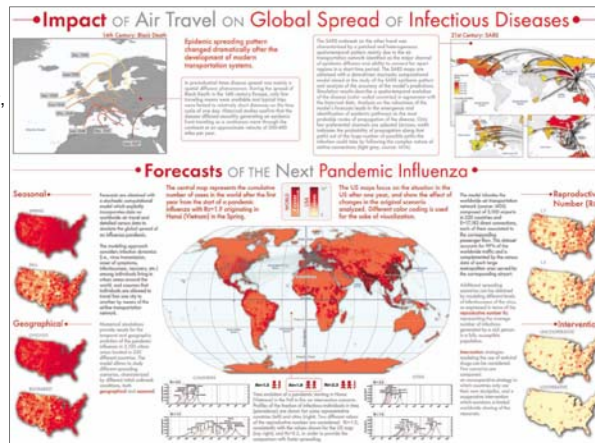
Epidemic Modeling in Complex realities, V. Colizza, A. Barrat, M. Barthelemy, A. Vespignani, *Comptes Rendus Biologie*, 330, 364-374 (2007).

Reaction-diffusion processes and metapopulation models in heterogeneous networks, V. Colizza, R. Pastor-Satorras, A. Vespignani, *Nature Physics* 3, 276-282 (2007).

Modeling the Worldwide Spread of Pandemic Influenza: Baseline Case and Containment Interventions, V. Colizza, A. Barrat, M. Barthelemy, A.-J. Valleron, A. Vespignani, *PLoS-Medicine* 4, e13, 95-110 (2007).



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**The NWB Tool**

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❑ Data

- Different data formats
- Different data models

❑ Algorithms

- Different research purposes (preprocessing, modeling, analysis, visualization, clustering)
- Different implementations of the same algorithm
- Different programming languages

❑ Match between Data and Algorithms

❑ Different communities and practices

❑ Different tools (Pajek, UCInet, Guess, Cytoscape, R, NWB tool)

**Network Workbench (NWB) Tool**

- A network analysis, modeling, and visualization toolkit for physics, biomedical, and social science research.
- Install and run on multiple Operating Systems.
- Uses Cyberinfrastructure Shell Framework underneath.

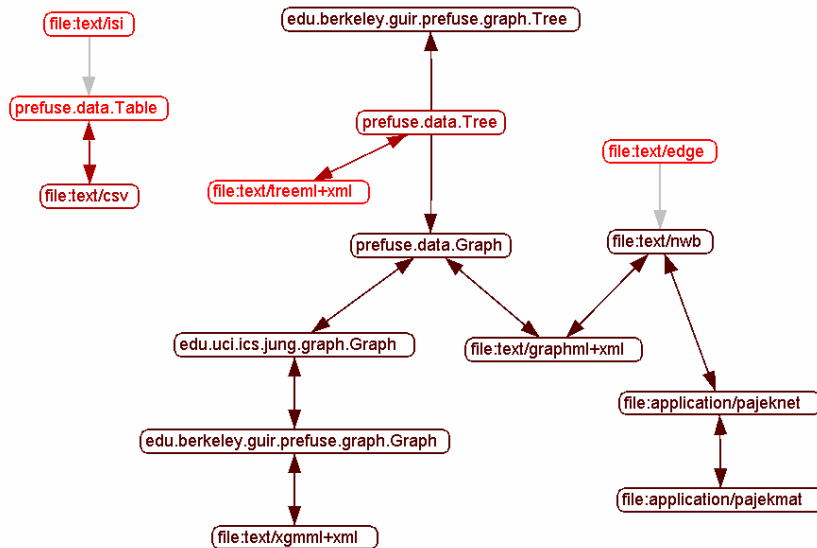
**Cyberinfrastructure Shell (CIShell)**

- An open source, software framework for the integration and utilization of datasets, algorithms, tools, and computing resources.

**NWB Community Wiki**

- A place for users of the NWB Tool, the Cyberinfrastructure Shell (CIShell), or any other CIShell-based program to request, obtain, contribute, and share algorithms and datasets.
- All algorithms and datasets that are available via the NWB Tool have been well documented in the Community Wiki.

- ❑ Can load, view, process and save the following file formats:
  - GraphML (.xml or .graphml)
  - XGMML (.xml)
  - Pajek .net (.net)
  - Pajek .mat(.mat)
  - **NWB** (.nwb)
  - TreeML (.xml)
  - Edge list (.edge)
  - CSV (.csv)
  - isi (.isi)
- ❑ Can load two CSV files (node list and edge list) and construct a network.
- ❑ Can load an isi file, extract co-authorship network and update graph by merging nodes if needed.



Download from <http://nwb.slis.indiana.edu/software.html>

**Major features in v0.8.0 Release**

- Installs and runs on Windows, Linux x86 and Mac OsX.
- Provides over 60 modeling, analysis and visualization algorithms. Half of them are written in Fortran, others in Java.
- Supports large scale network modeling and analysis (over 100,000 nodes)
- Supports various visualization layouts with node/edge annotation.
- Provides several sample datasets with various formats.
- Supports multiple ways to introduce a network to the NWB tool.
- Supports automatic Data Conversion.
- Provides a Scheduler to monitor and control the progress of running algorithms.
- Integrates a 2D plotting tool – Gnuplot (requires pre-installation on Linux and Mac).
- Integrates GUESS (runs on Linux and Mac. \*Windows forthcoming)

Category	Algorithm	Language	Analysis Algorithm	Language
Preprocessing	Random Node Deletion	JAVA	Node Betweenness Centrality	FORTRAN
	High Degree Node Deletion	JAVA	Average Shortest Path	FORTRAN
	Pathfinder Network Scaling	JAVA	Connected Components	FORTRAN
	Directory Hierarchy Reader	JAVA	Diameter	FORTRAN
Modeling	Erdős-Rényi Random	FORTRAN	Page Rank	FORTRAN
	Barabási-Albert Scale-Free	FORTRAN	Shortest Path Distribution	FORTRAN
	Watts-Strogatz Small World	FORTRAN	Watts-Strogatz Clustering Coefficient	FORTRAN
	Chord	JAVA	Watts-Strogatz Clustering Coefficient Versus Degree	FORTRAN
	CAN	JAVA	Directed k-Nearest Neighbor	FORTRAN
	Hypergrid	JAVA	Undirected k-Nearest Neighbor	FORTRAN
	PRU	JAVA	Indegree Distribution	FORTRAN
	TARL	JAVA	Outdegree Distribution	FORTRAN
	Tree Map	JAVA	Node Indegree	FORTRAN
Visualization	Tree Viz	JAVA	Node Outdegree	FORTRAN
	Radial Tree / Graph	JAVA	One-point Degree Correlations	FORTRAN
	Kamada-Kawai	JAVA	Undirected Degree Distribution	FORTRAN
	Force Directed	JAVA	Node Degree	FORTRAN
	Spring	JAVA	k Random-Walk Search	JAVA
	Fruchterman-Reingold	JAVA	Random Breadth First Search	JAVA
	Circular	JAVA	CAN Search	JAVA
			Chord Search	JAVA
		Weak Component Clustering	JAVA	
		Tool: GnuPlot		

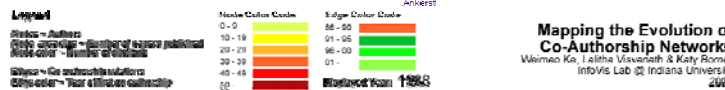
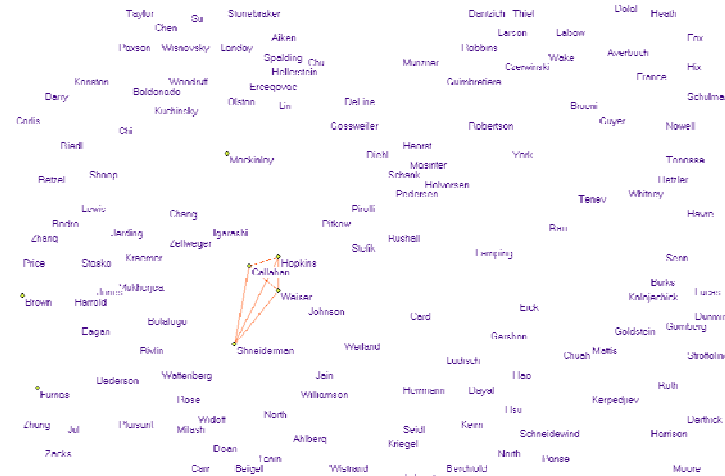
### NWB tool and CShell provide

- A testbed for diverse algorithm implementations
- A mechanism to quickly integrate an algorithm and disseminate it through the NWB tool and community wiki.
- A bridge between what application users need and what algorithm developers can provide.

### NWB Tool for Scientometrics Research

## Mapping the Evolution of Co-Authorship Networks in Information Visualization, 1988 - 2004

Ke, Viswanath & Börner (2004)



**Mapping the Evolution of Co-Authorship Networks**  
 Weimao Ke, alpha Viswanath & Katy Börner  
 InfoVis Lab @ Indiana University  
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## Data Acquisition from Web of Science

Download all papers by

- o Eugene Garfield
- o Stanley Wasserman
- o Alessandro Vespignani
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Eugene Garfield

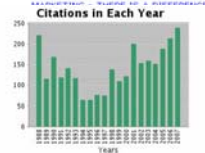
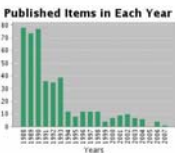
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# papers/citations for last 20 years

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- 1. **GARFIELD E**  
CITATION ANALYSIS AS A TOOL IN JOURNAL EVALUATION - JOURNALS CAN BE RANKED BY FREQUENCY AND IMPACT OF CITATIONS FOR SCIENCE POLICY STUDIES  
SCIENCE 178 (4060): 471-4 1972  
Times Cited: 674  
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- 2. **GARFIELD E**  
CITATION INDICES FOR SCIENCE - NEW DIMENSION IN DOCUMENTATION THROUGH ASSOCIATION OF IDEAS  
SCIENCE 122 (3159): 108-111 1955  
Times Cited: 325  
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- 3. **Garfield E**  
How can impact factors be improved?  
BRITISH MEDICAL JOURNAL 313 (7054): 411-413 AUG 17 1996  
Times Cited: 156  
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- 4. **GARFIELD E**  
NEW YEAR, NEW BUILDING  
CURRENT CONTENTS (1): 5-8 1980  
Times Cited: 256  
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- 5. **GARFIELD E**  
INTRODUCING CITATION CLASSICS - HUMAN SIDE OF SCIENTIFIC REPORTS  
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Average Citations per Item (i): 3.44  
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## Data Acquisition from Web of Science (cont.)

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 Times Cited: **672**  
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- 2. **GARFIELD E**  
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[How can impact factors be improved?](#)  
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- 4. **GARFIELD E**  
[CITATION INDEXING FOR STUDYING SCIENCE](#)  
 NATURE 227 (5259): 669& 1970  
 Times Cited: 134  
[IU Link](#)
- 5. **GARFIELD E**  
[SCIENCE CITATION INDEX-NEW DIMENSION IN INDEXING - UNIQUE APPROACH UNDERLIES VERSATILE BIBLIOGRAPHIC SYSTEMS FOR COMMUNICATING + EVALUATING INFORMATION](#)  
 SCIENCE 144 (361): 649& 1964  
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## Data Acquisition from Web of Science (cont.)

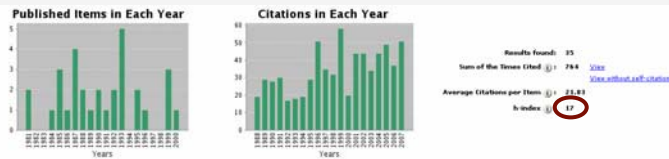
Stanley Wasserman  
35 papers

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- 1. GALASKIEWICZ J, WASSERMAN S  
[MIMETIC PROCESSES WITHIN AN INTERORGANIZATIONAL FIELD - AN EMPIRICAL-TEST](#)  
 ADMINISTRATIVE SCIENCE QUARTERLY 34 (3): 454-479 SEP 1989  
 Times Cited: **122**  
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- 2. Wasserman S, Pattison P  
[Logit models and logistic regressions for social networks .I. An introduction to Markov graphs and p](#)  
 PSYCHOMETRIKA 61 (3): 401-425 SEP 1996  
 Times Cited: 59  
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- 3. FIENBERG SE, MEYER MM, WASSERMAN SS  
[STATISTICAL-ANALYSIS OF MULTIPLE SOCIOMETRIC RELATIONS](#)  
 JOURNAL OF THE AMERICAN STATISTICAL ASSOCIATION 80 (389): 51-67 1985  
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- 4. WASSERMAN S  
[ANALYZING SOCIAL NETWORKS AS STOCHASTIC-PROCESSES](#)  
 JOURNAL OF THE AMERICAN STATISTICAL ASSOCIATION 75 (370): 280-294 1980  
 Times Cited: 38  
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- 5. JACOBUCCI D, WASSERMAN S  
[A GENERAL FRAMEWORK FOR THE STATISTICAL-ANALYSIS OF SEQUENTIAL DYADIC INTERACTION DATA](#)  
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Alessandro Vespignani

101 papers

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1. Pastor-Satorras R, Vespignani A  
[Epidemic spreading in scale-free networks](#)  
PHYSICAL REVIEW LETTERS 86 (14): 3200-3203 APR 2 2001  
Times Cited: 851  
[Full Text](#)
2. Pastor-Satorras R, Vazquez A, Vespignani A  
[Dynamical and correlation properties of the Internet](#)  
PHYSICAL REVIEW LETTERS 87 (25): Art. No. 258701 DEC 17 2001  
Times Cited: 725  
[Full Text](#)
3. Barrat A, Barthélemy M, Pastor-Satorras R, et al.  
[The architecture of complex weighted networks](#)  
PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF THE UNITED STATES OF AMERICA 101 (11): 3747-3752 MAR 16 2004  
Times Cited: 150  
[Full Text](#)
4. Pastor-Satorras R, Vespignani A  
[Epidemic dynamics and endemic states in complex networks](#)  
PHYSICAL REVIEW E 63 (6): Art. No. 066117 Part 2 JUN 2001  
Times Cited: 163  
[Full Text](#)
5. Vazquez A, Pastor-Satorras R, Vespignani A  
[Large-scale topological and dynamical properties of the Internet](#)  
PHYSICAL REVIEW E 65 (6): Art. No. 066130 Part 2 JUN 2002  
Times Cited: 122  
[Full Text](#)
6. Vespignani A, Zappelli S  
[How self-organized criticality works: A unified mean-field picture](#)  
PHYSICAL REVIEW E 57 (6): 6345-6362 JUN 1998  
Times Cited: 111  
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**Published Items in Each Year**

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Albert-László Barabási

126 papers

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Network Workbench (<http://nwb.sls.indiana.edu>)

126 results found (Set #9) (Why 126?)

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1. Barabasi AL, Albert R  
[Emergence of scaling in random networks](#)  
SCIENCE 286 (5439): 509-512 OCT 15 1999  
Times Cited: 6110  
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2. Albert R, Barabasi AL  
[Statistical mechanics of complex networks](#)  
REVIEWS OF MODERN PHYSICS 74 (1): 47-97 JAN 2002  
Times Cited: 2069  
[Full Text](#)
3. Jeong H, Tombor B, Barabasi AL, et al.  
[The large-scale organization of metabolic networks](#)  
NATURE 407 (6804): 651-654 OCT 5 2000  
Times Cited: 939  
[Full Text](#)
4. Albert R, Jeong H, Barabasi AL  
[Error and attack tolerance of complex networks](#)  
NATURE 406 (6794): 378-382 JUL 27 2000  
Times Cited: 225  
[Full Text](#)
5. Jeong H, Mason SP, Barabasi AL, et al.  
[Lethality and centrality in protein networks](#)  
NATURE 411 (6833): 41-42 MAY 3 2001  
Times Cited: 245  
[Full Text](#)
6. Albert R, Jeong H, Barabasi AL  
[Internet - Diameter of the World-Wide Web](#)  
NATURE 401 (6749): 130-131 SEP 9 1999  
Times Cited: 628  
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**h-index: 47**

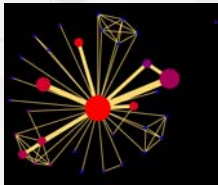


## Comparison of Counts

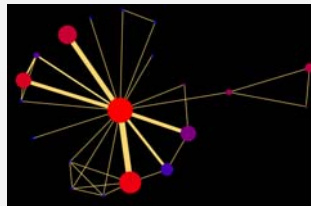
	Age	Highest Cited Paper	H-Index
Eugene Garfield	82	672	31
Stanley Wasserman		122	17
Alessandro Vespignani	42	451	33
Albert-László Barabási	40	2218	47

## Comparison of Networks

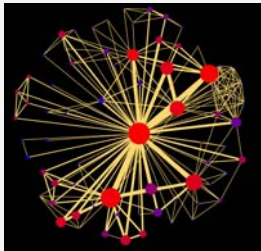
Eugene Garfield



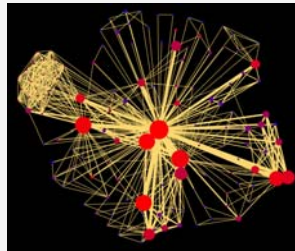
Stanley Wasserman

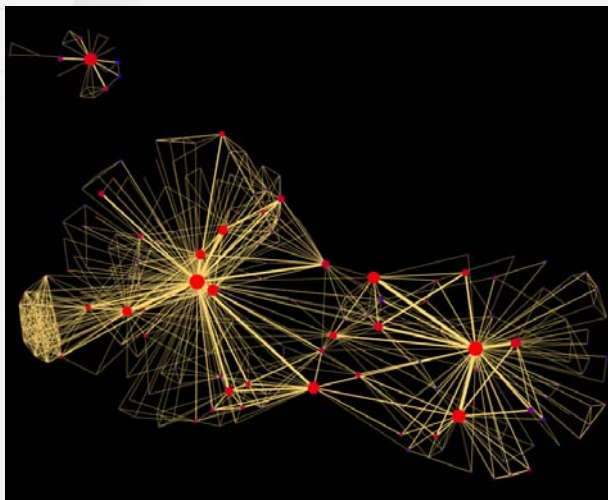


Alessandro Vespignani



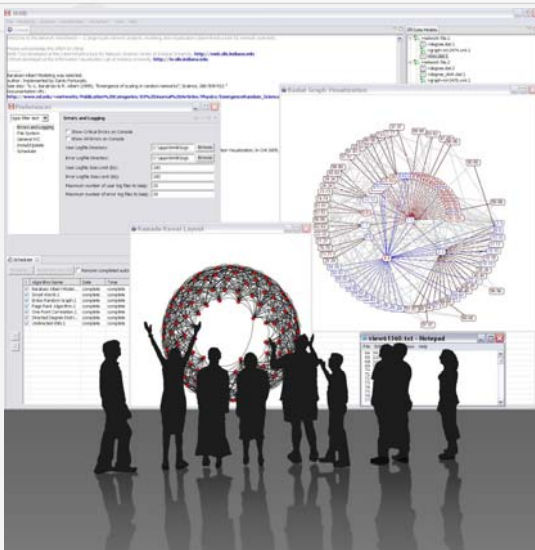
Albert-László Barabási





Network Workbench (<http://nwb.sls.indiana.edu>).

35

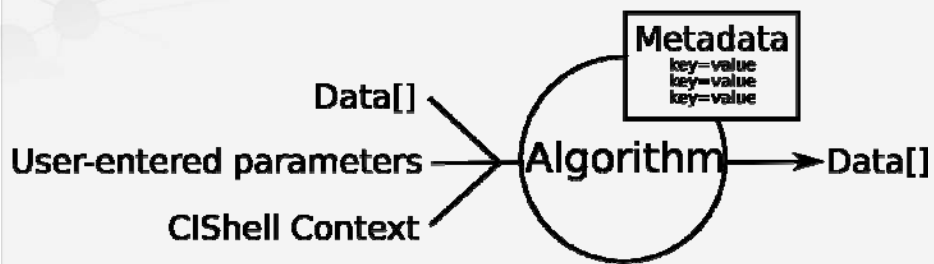


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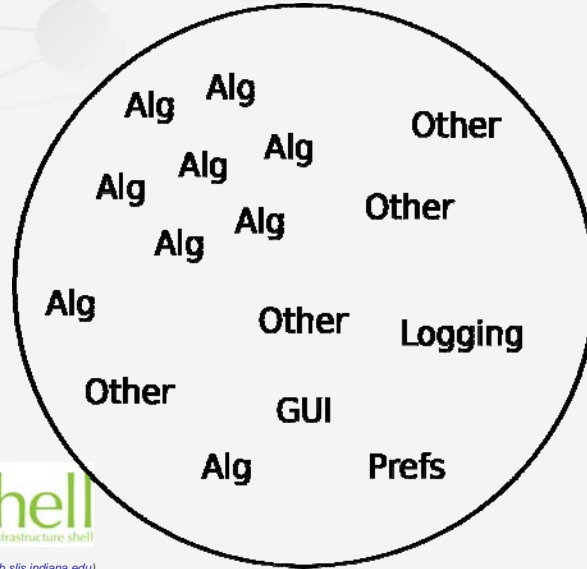
36



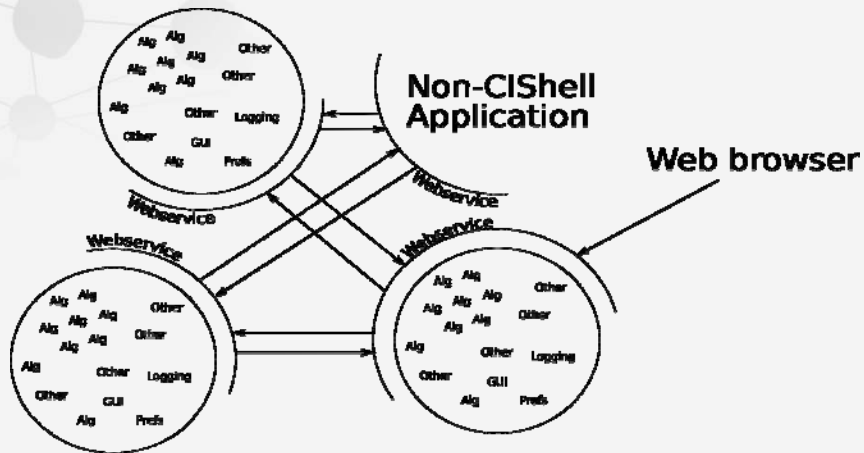
The Cyberinfrastructure Shell (CIShell) is an open source, community-driven platform for the integration and utilization of datasets, algorithms, tools, and computing resources. Algorithm integration support is built in for Java and most other programming languages. Being Java based, it will run on almost all platforms. The software and specification is released under an [Apache 2.0 License](#).



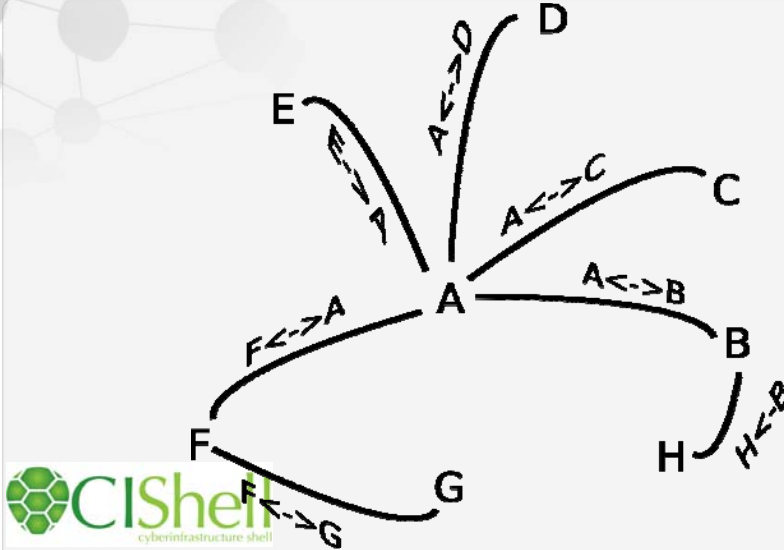
# Pooling Algorithms



# Inter-Pool Interaction



## Data Conversion



## Adding New Plugins

- Using update sites
- Using OSGi Console Magick™!
- Dropping plugins into the plugins directory
- Using the NWB Community Wiki

- Wizard-driven templates ease development
- Documentation Forthcoming
  - CShell Specification
  - CShell Developer's Guide
- Some preliminary documentation is available at <http://cishell.org>
- A future workshop will address this
- We are available for consulting

- New release (v0.8.0) of the NWB tool and a complete user manual with tutorials (v1.0) will be ready for Sunbelt 2008.
- An end-user workshop is scheduled in the middle of February at IUB (Alex for physics and internet research, Ann & Stan for social network research)
- CShell specification and CShell/NWB algorithm developer guide will be available in late February.
- Workshop for algorithm developers will be planned accordingly.

### Add features to serve communities including Physics, Biology, Social Science, and Scientometrics.

- Integrate classic datasets
- Support the most popular data formats for biology and social science research.
- Develop the converters to bridge those formats to the current formats supported by NWB tool.
- Design and deliver better visualization algorithms and modularity
- Develop components to connect and query SDB
- R bridge
- Customize Menu – Users can re-organize the algorithms for their needs
- Continue integrating best algorithm implementations

- ❑ Hidalgo, César A. and C. Rodriguez-Sickert. [Persistence, Topology and Sociodemographics of a Mobile Phone Network](#). 2007. (Submitted to Physica A)
- ❑ Hidalgo, C.A., B. Klinger, A. L. Barabási, and R. Hausmann. [The Product Space and its Consequences for Economic Growth](#). *Science*. Vol. 317 (2007, July 27): 482-487.
- ❑ Börner, Katy. [Making Sense of Mankind's Scholarly Knowledge and Expertise: Collecting, Interlinking, and Organizing What We Know and Different Approaches to Mapping \(Network\) Science](#). *Environment and Planning B: Planning and Design*. Vol. 34(5), 808-825, Pion.
- ❑ Yildirim, Muhammed A., Kwan-II Goh, Michael E. Cusick, Albert-László Barabási, and Marc Vidal. (2007). [Drug-target Network](#). *Nature Biotechnology* 25 no. 10: 1119-1126.
- ❑ Vespignani, Alessandro, Soma Sanyal, and Katy Börner. (2007). [Network Science](#). In *Annual Review of Information Science & Technology*, vol. 41, ed. Blaise Cronin, 537-607. Medford, NJ: Information Today, Inc./American Society for Information Science and Technology.
- ❑ Herr II, Bruce W., Weixia (Bonnie) Huang, Shashikant Penumarthy, and Katy Börner. (2007). [Designing Highly Flexible and Usable Cyberinfrastructures for Convergence](#). In *Progress in Convergence – Technologies for Human Wellbeing*, vol. 1093, eds. William S. Bainbridge and Mihail C. Roco, 161-179. Boston: Annals of the New York Academy of Sciences.

- ❑ Colizza, V., A. Barrat, M. Barthelemy, and A. Vespignani. (2007). [Epidemic modeling in complex realities](#). *Comptes Rendus Biologie* 330: 364-374. Elsevier.
- ❑ Colizza, Vittoria, Romualdo Pastor-Satorras, and Alessandro Vespignani. (2007). [Reaction-diffusion processes and metapopulation models in heterogeneous networks](#). *Nature Physics* 3: 276-282. Nature Publishing Group.
- ❑ Vermeirssen, Vanessa, M. Inmaculada Barrasa, César A. Hidalgo, Jenny Aurelle B. Babon, Reynaldo Sequerra, Lynn Doucette-Stamm, Albert-László Barabási, and Albertha J. M. Walhout. (2007). [Transcription factor modularity in a gene-centered C. elegans core neuronal protein-DNA interaction network](#). *Network Genome Research*. Cold Spring Harbor Laboratory Press.
- ❑ Börner, Katy, Elisha F. Hardy, Bruce W. Herr II, Todd Holloway, and W. Bradford Paley. (2007). [Taxonomy Visualization in Support of the Semi-Automatic Validation and Optimization of Organizational Schemas](#). *Journal of Informetrics* 1 (3): 214-225. Elsevier.
- ❑ More papers at <http://nwb.slis.indiana.edu/papers.html>

### Websites

- ❑ <http://nwb.slis.indiana.edu>
- ❑ <https://nwb.slis.indiana.edu/community>
- ❑ <http://cishell.org>
- ❑ <http://cns-trac.slis.indiana.edu/trac/nwb/>

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