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Identifying Clusters with Attribute Homogeneity and Similar Connectivity in Information Networks

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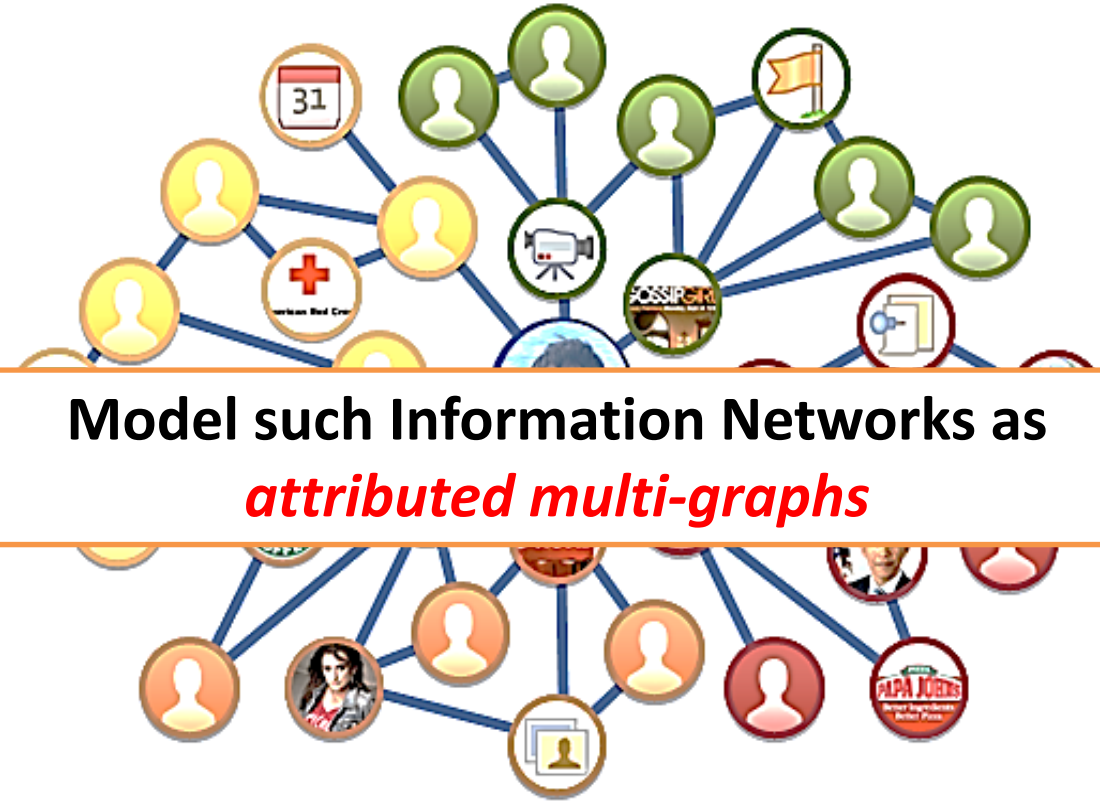
Atlanta, GA
USA

The Real World: Information Networks



Model such Information Networks as

attributed multi-graphs

An Online Social Network

Clustering

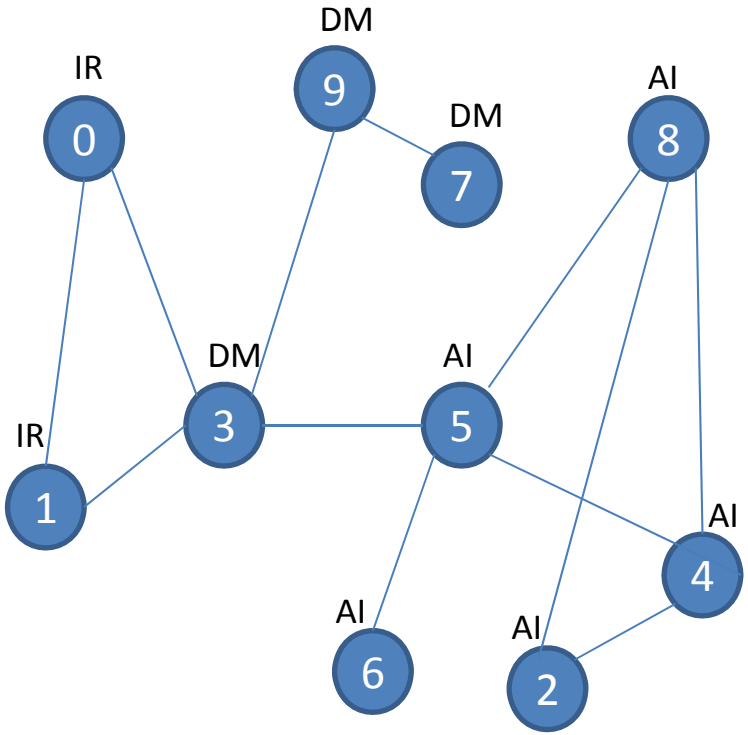
- The process of identifying groups of related data/objects in a dataset/information network
- Why? Discover hidden knowledge!

Network	Applications
Co-author Networks	**Recommending new collaborations**
Social Networks	**Recommend friendships, group targeted advertisement**

Clustering

Challenges

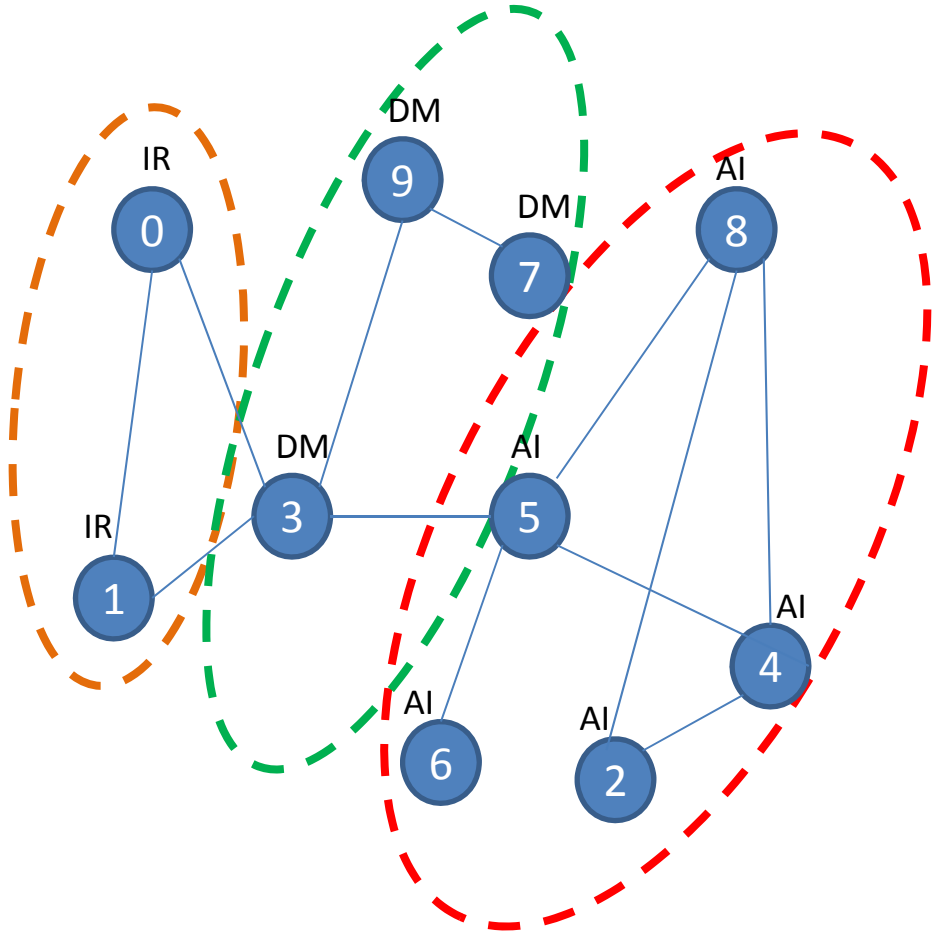
- A vertex may belong to more than one cluster
  - Fuzzy clustering
- Cluster based on:
  - Structure
  - Attributes



Challenges

Cluster based on:

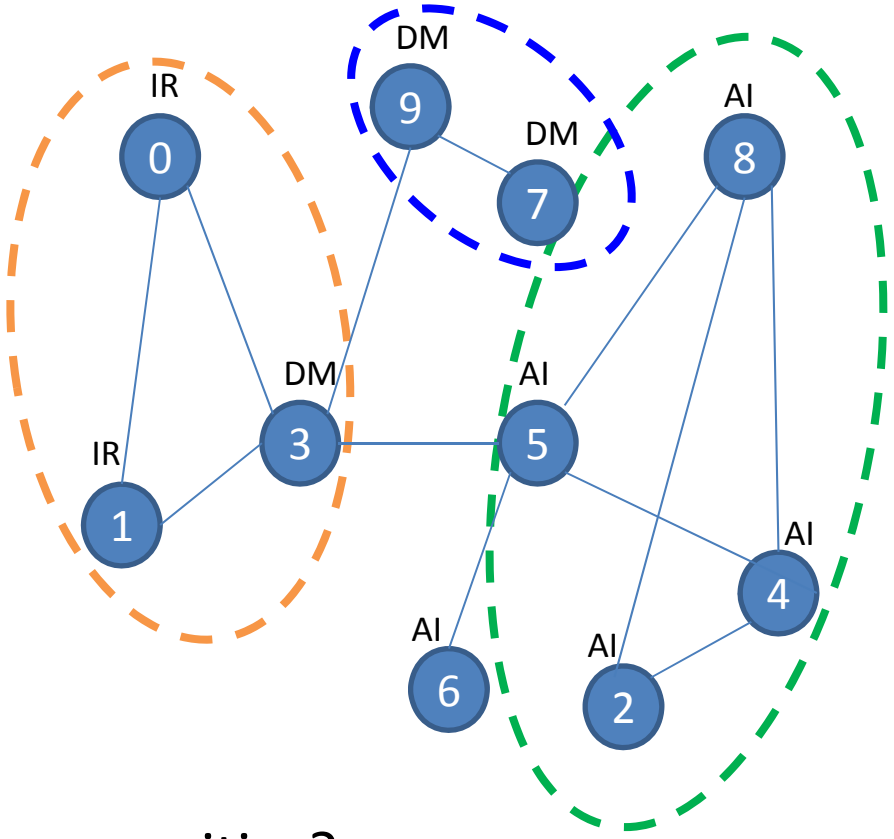
- Attributes
- Structure



Challenges

Cluster based on:

- Attributes
- Structure

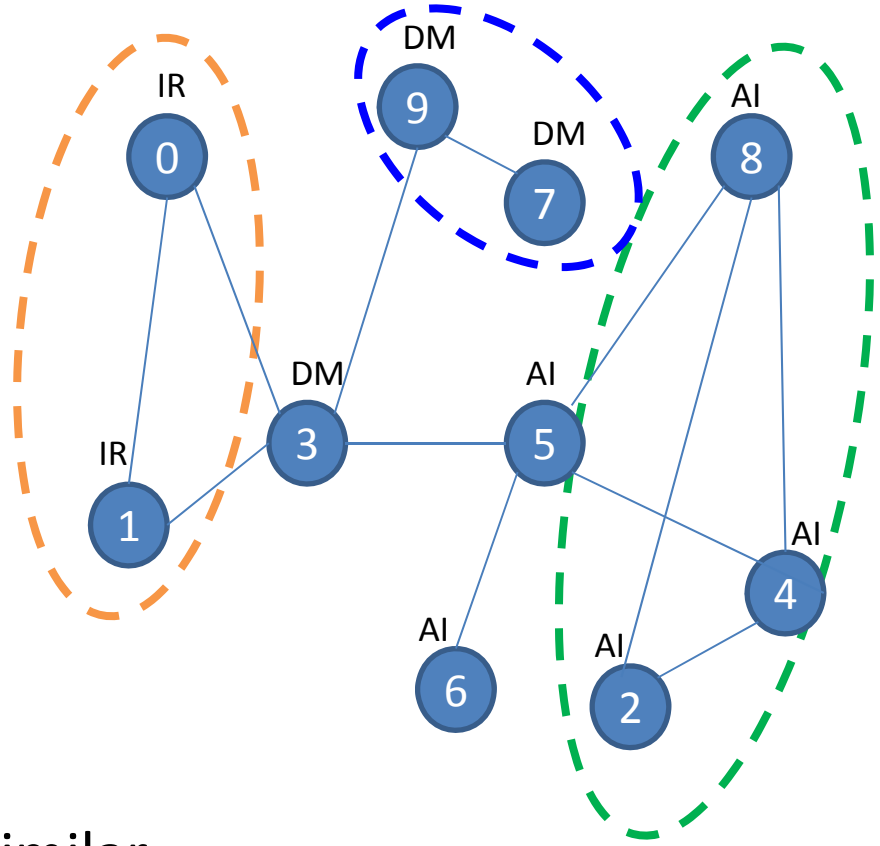


Communities?

Challenges

Cluster based on:

- Attributes
- Structure

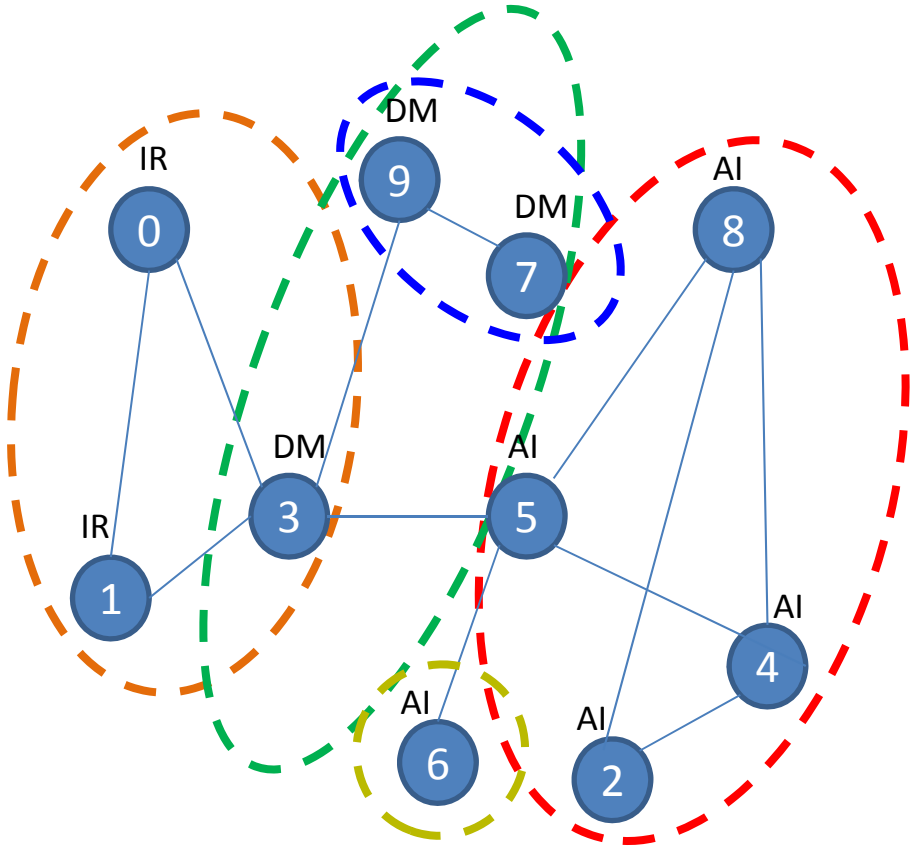


Similar Connectivity?

Challenges

Cluster based on:

- Structure
- Attributes



Challenges

- How to balance the attribute and structural properties of the vertices?
- How to identify which link type is more important?
  - A request to join a political group is more important than sharing a funny video
- How to identify which attribute is more important?
  - The attribute political views of a person is clearly more important than its name or gender

Related Work

Distance Based

- **SA-Cluster (ACM TKDD 2011)**
  - Graph augmentation with attributes and random walks
  - Different attributes importance
- **PICS (SIAM SDM 2012)**
  - MDL Compression
  - Similar connectivity
  - Parameter Free

Model Based

- **BAGC (SIGMOD 2012)**
  - Bayesian Inference Model
  - Directed graphs
- **GenClus (VLDB 2012)**
  - EM algorithm
  - Multi-graphs
  - Different link types importance

HASCOP

Related Work

	Directed	Weighted	Multi graph	Attribute weights	Link-Type weights	Similar Connectivity	Parameter Free
SA-Cluster[1]	✔	✔		✔			
BAGC[2]	✔						
GenClus[3]	✔	✔			✔		
PICS[4]	✔					✔	✔
HASCOP	✔		✔	✔	✔	✔	✔

[1] H. Cheng, Y. Zhou, and J. X. Yu. Clustering large attributed graphs: A balance between structural and attribute similarities. *ACM Trans. Knowl. Discov. Data*, Feb. 2011.

[2] Z. Xu, Y. Ke, Y. Wang, H. Cheng, and J. Cheng. A model-based approach to attributed graph clustering. In *Proceedings of* SIGMOD '12, 2012.

[3] Y. Sun, C. C. Aggarwal, and J. Han. Relation strength-aware clustering of heterogeneous information networks with incomplete attributes. *Proc. VLDB Endow.*, Jan. 2012.

[4] L. Akoglu, H. Tong, B. Meeder, and C. Faloutsos. PICS: Parameter-free identification of cohesive subgroups in large attributed graphs. *SDM,* Apr. 2012

HASCOP

Objective Function
Similar Connectivity
Attribute Coherence
Weight Adjustment Mechanism
Clustering Process

HASCOP

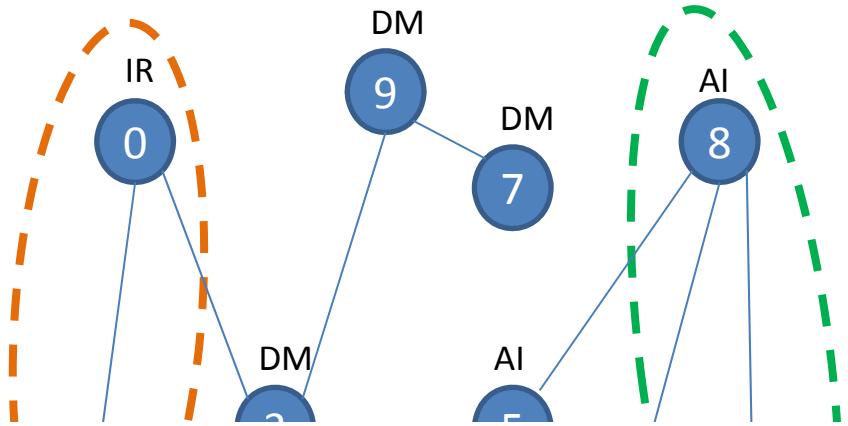
Assigns vertices in the same cluster so as to exhibit **both similar connectivity** and **attribute coherence**

- *Given function $s(v_i, c_j)$ the clustering objective function is:*

$$O(\Theta, \vec{\omega_t}, \vec{w_\alpha}) = \sum_{i=1}^{|V|} \sum_{j=1}^{k} \Theta_{i,j} \cdot s(v_i, c_j, \vec{\omega_t}, \vec{w_a})$$

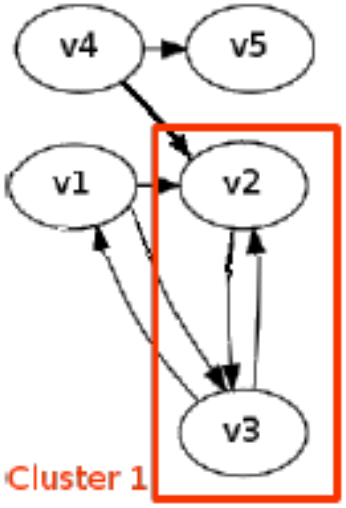
Similar Connectivity

- Two vertices v_i, v_j have similar connectivity pattern if $S(v_i)$ and $S(v_i)$ highly



Similar Connectivity represents how similar two vertices are based on their outgoing links

Similar Connectivity



(a) Example graph

L^0	v_1	v_2	v_3	v_4	v_5
c_1	1	1	1	0	0

v_1	1	1	1	0	0
v_2	0	1	1	0	0
v_3	1	1	1	0	0
v_4	0	1	0	1	1
v_5	0	0	0	0	1

(b) Cluster c_1 properties and adjacency matrix.

$$link\_sim(v_1, c_1) = 1$$

$$link\_sim(v_5, c_1) = \frac{1}{3}$$

(c) Similar Connectivity

$$link\_sim(v_i, c_j) = \frac{}{1 + \sqrt{\sum_{x=1}^{|V|} \left(L_{i,x} - C_{j,x}^{links}\right)^2}}$$

Attribute Coherence

- Weighted Euclidean distance

- It is close to one if the attribute vector of v_i is very close to the attribute centroid of c_j

$$attr\_sim(v_i, c_j, \vec{w_\alpha}) = \frac{1}{1 + \sqrt{\sum_{l=1}^{p} w_{\alpha l} \cdot \left(A_{i,l} - C_{j,l}^{attr}\right)^2}}$$

HASCOP: Approach

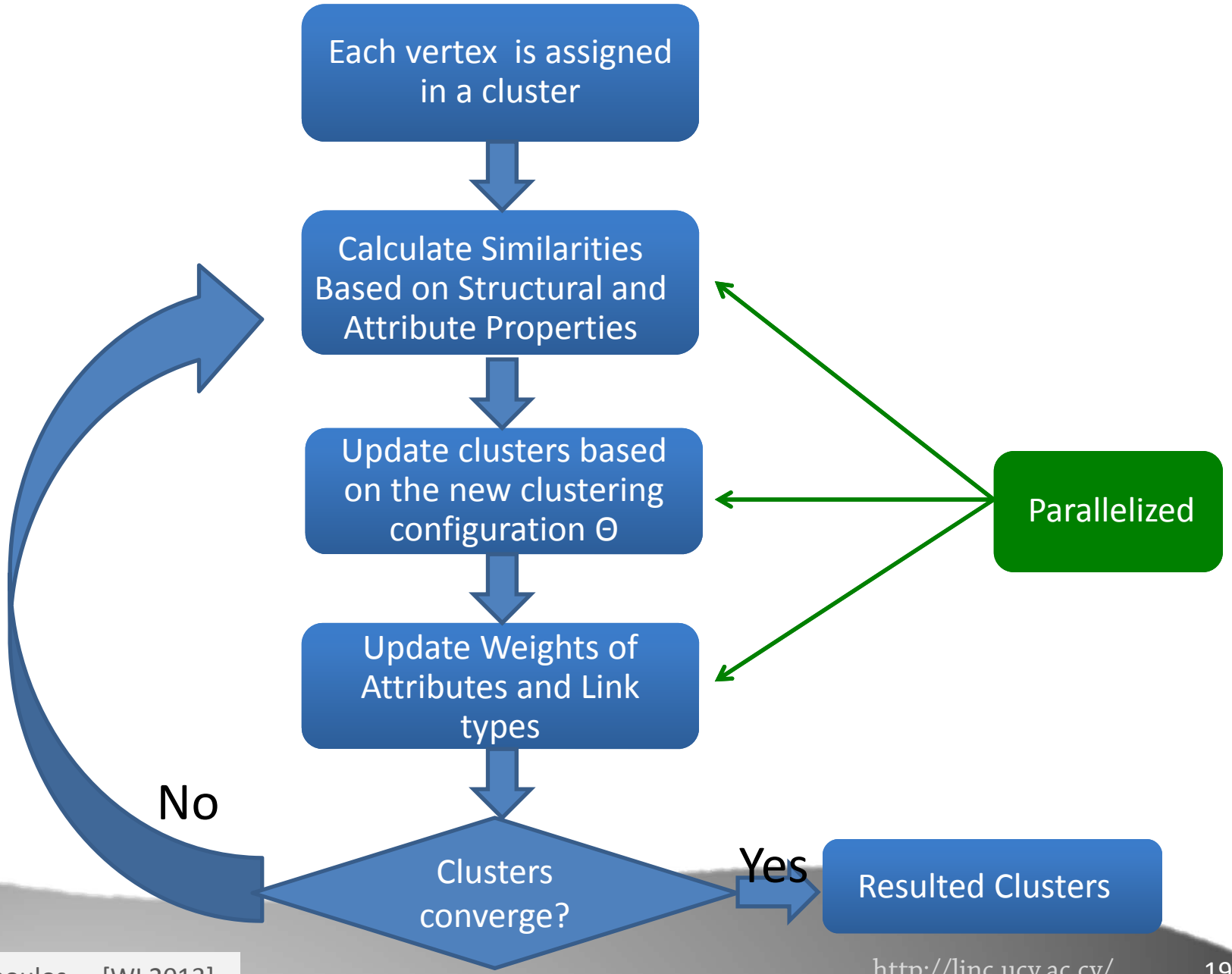
- A vertex has high similarity with a cluster if **both** their similar connectivity and attribute coherence are high.

$$s(c_j, v_i, \vec{w}_a) = link\_sim(v_i, c_j) \cdot attr\_sim(v_i, c_j, \vec{w}_\alpha)$$

Weight Adjustment

- Voting mechanism
- The weights are adjusted towards the direction of increasing the clustering objective function:
  - If vertices in the same cluster are connected by link-type A then the weight of link-type A is increased
  - If vertices in the same cluster share the same value for an attribute X then the weight of attribute X is increased

Clustering Process



Evaluation

Datasets

Evaluation Measures

Evaluations

Datasets

GoogleSP-23: Google Software Packages

- Built from software files installed on Cloud
- Software files are **not** densely connected components

- Vertex: software file
- Attributes:
  - File Size
  - File Type
  - Last Access Time
  - Last Content Modified Time
  - Time of the most recent metadata change
- Link-types:
  - File name similarities
  - File path similarities

Datasets

DBLP: Bibliography Network

- Vertex: author
- Attributes:
  - Number of publications
  - Research area
- Link-types:
  - Co-author relationship

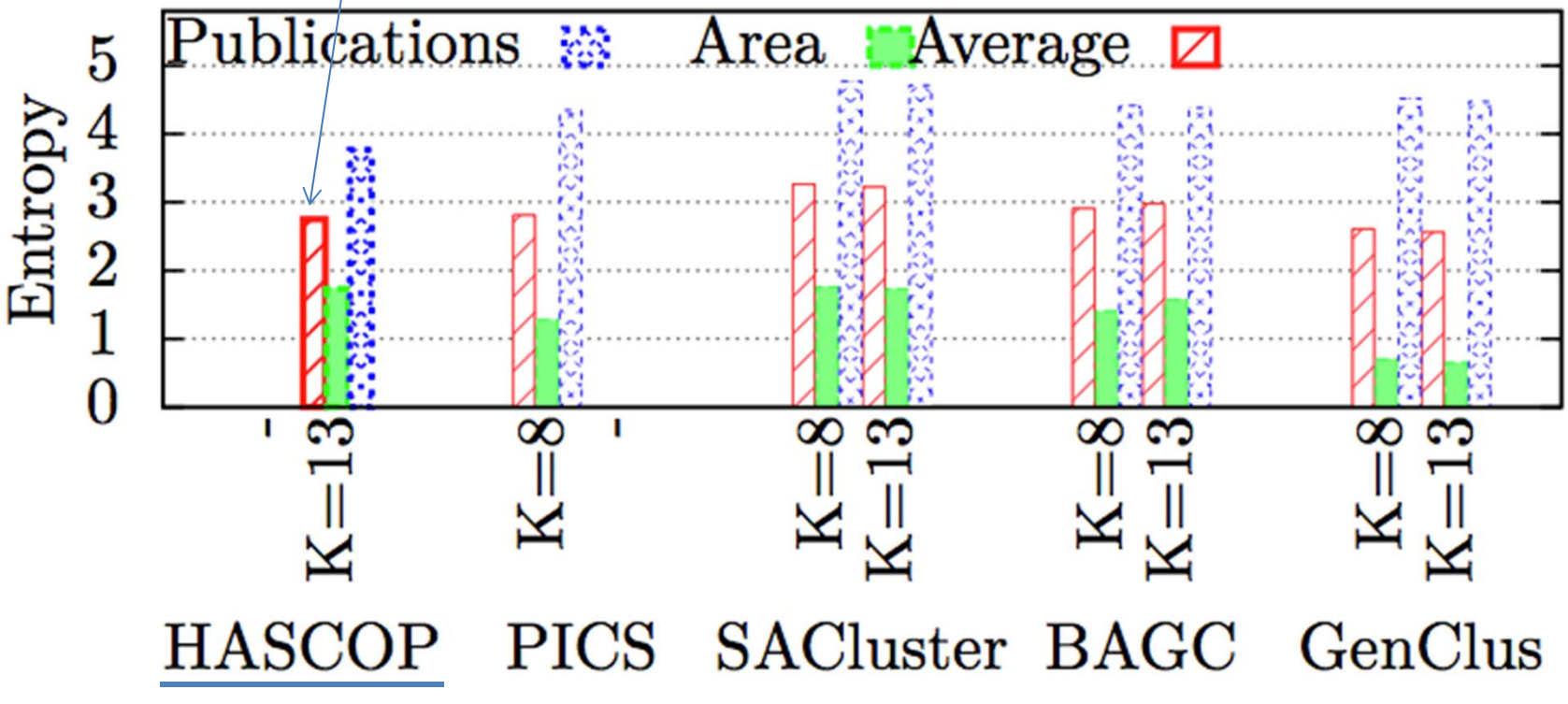
Dataset	DBLP-1000	GoogleSP-23
Nodes	1000	1297
Edges	17128	24153
Attributes	2	5
Link Types	1	2
Type of Graph	Undirected	Undirected

Evaluation Measures

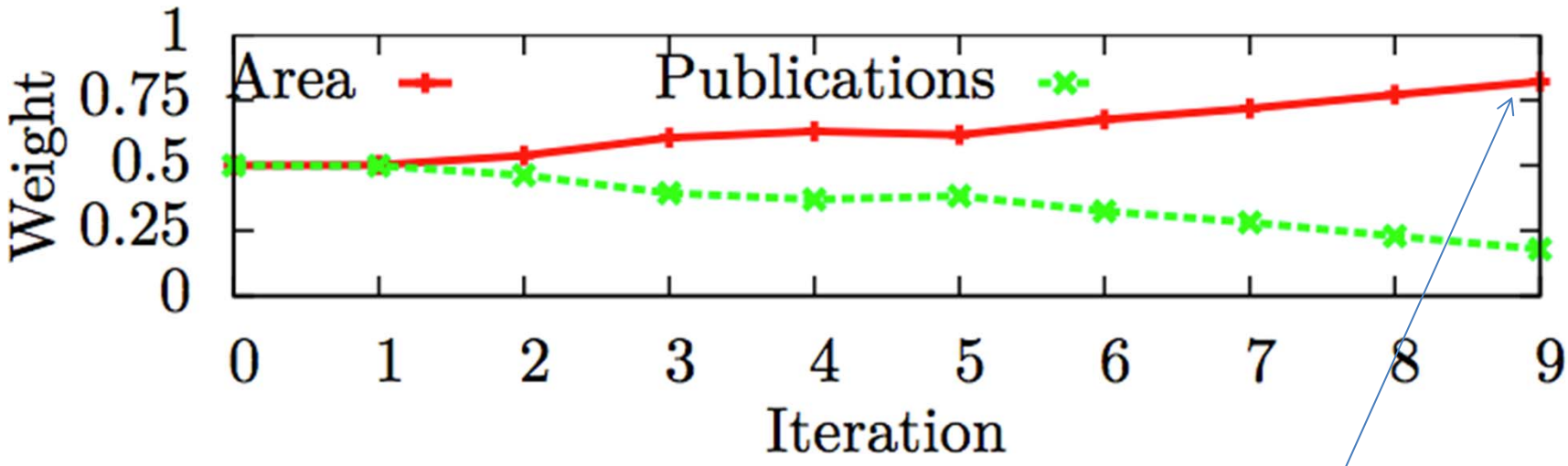
- Entropy
  - Attribute properties
  - Close to zero for attribute cohesive clusters
- For GoogleSP-23 dataset we measure:
  - The percentage of clusters overlapping with a software package
  - The percentage of software packages that were actually identified

Evaluation – DBLP-1000

Very close to the lowest average entropy



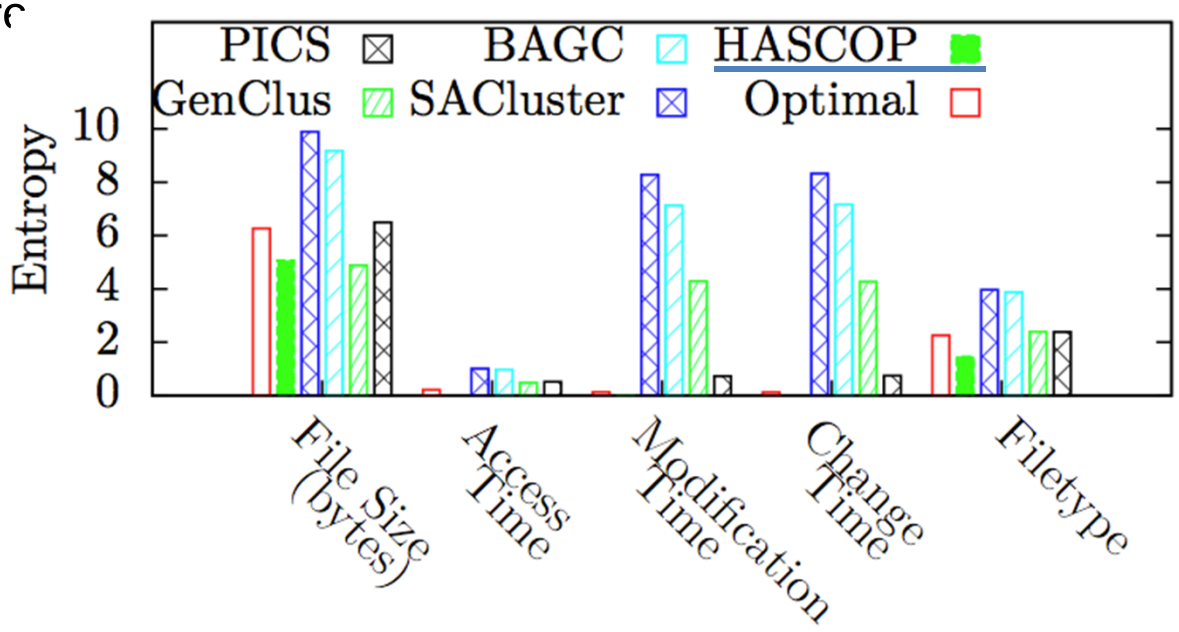
Evaluation – DBLP-1000



Successfully identified the importance of "Area of interest" against "No of publications"

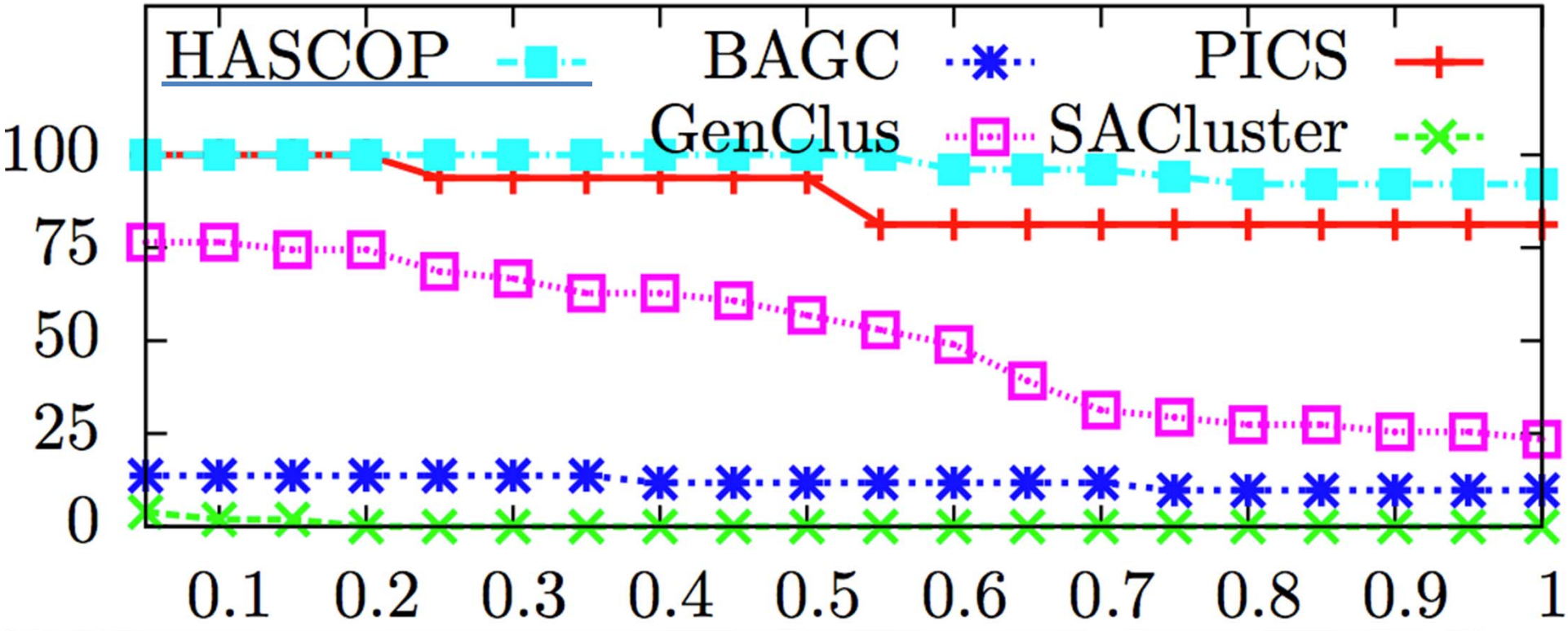
Evaluation – GoogleSP-23

- Comparison to the "ground truth"
- Must identify the software packages
- HASCOP is **closest to the "optimal"** entropy



Evaluation – GoogleSP-23

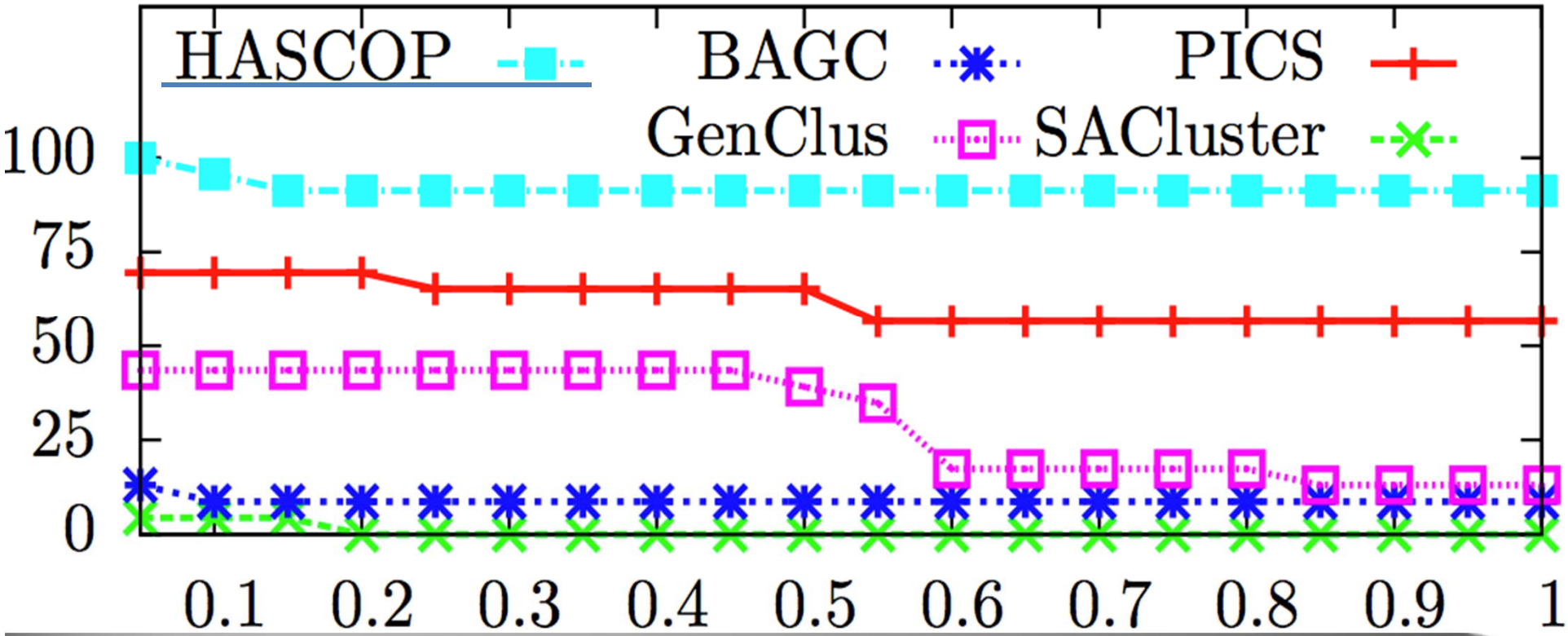
- HASCOP found 51 clusters
- More than **80%** of returned clusters by HASCOP and PICS are consisted of files from the same software packages



Evaluation – GoogleSP-23

- Almost all clusters (**>90%**) returned by HASCOP have full overlap with a software package

- Almost all (**21 of 23**) software packages have been identified



Conclusions

Conclusions

Future Work

Conclusions

- HASCOP succeeded in returning clusters useful to many applications studying such information networks
  - Correctly identified software packages installed on a Cloud infrastructure
- Experiments confirmed that HASCOP finds clusters characterized by **attribute homogeneity**
- **Similar Connectivity** is important

Future Work

- Integrate into MinerSoft[1] (a software file search engine)

- Extend HASCOP to handle:
  - Weighted multi-graphs
  - Heterogeneous information networks
  - Deploy to a large scale Hadoop cluster

1: Minersoft is available at: http://euclid.grid.ucy.ac.cy:1997/MinerSoft/SimpSearch

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Thank You!

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Department of Computer Science
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http://linc.ucy.ac.cy

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[1] L. Akoglu, H. Tong, B. Meeder, and C. Faloutsos. Pics: Parameter-free identification of cohesive subgroups in large attributed graphs. In *Proceedings of the 12th SIAM International Conference on Data Mining, SDM 2012,* Anaheim, CA, April 2012.

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[10] Y. Zhou, H. Cheng, and J. Yu. Clustering large attributed graphs: An efficient incremental approach. In *Data Mining (ICDM), IEEE 10th International Conference on,* pages 689–698, Dec. 2010.

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MinerSoft hadoop Search Advanced Search

270 results from 1601896 indexed docs in (0.52 seconds)

Binary files Library files Script/Source files

Maybe you want to search for: **filoop**

[binary] =2 [library] =51 [script/source] =217

[library] libhadoop.so.1.0.0

Add your Tag for this result

Located at

[library] libhadoop.so

Add your Tag for this result

Located at

[library] libhadoop.so.1

Add your Tag for this result

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[library] libhadoop.a

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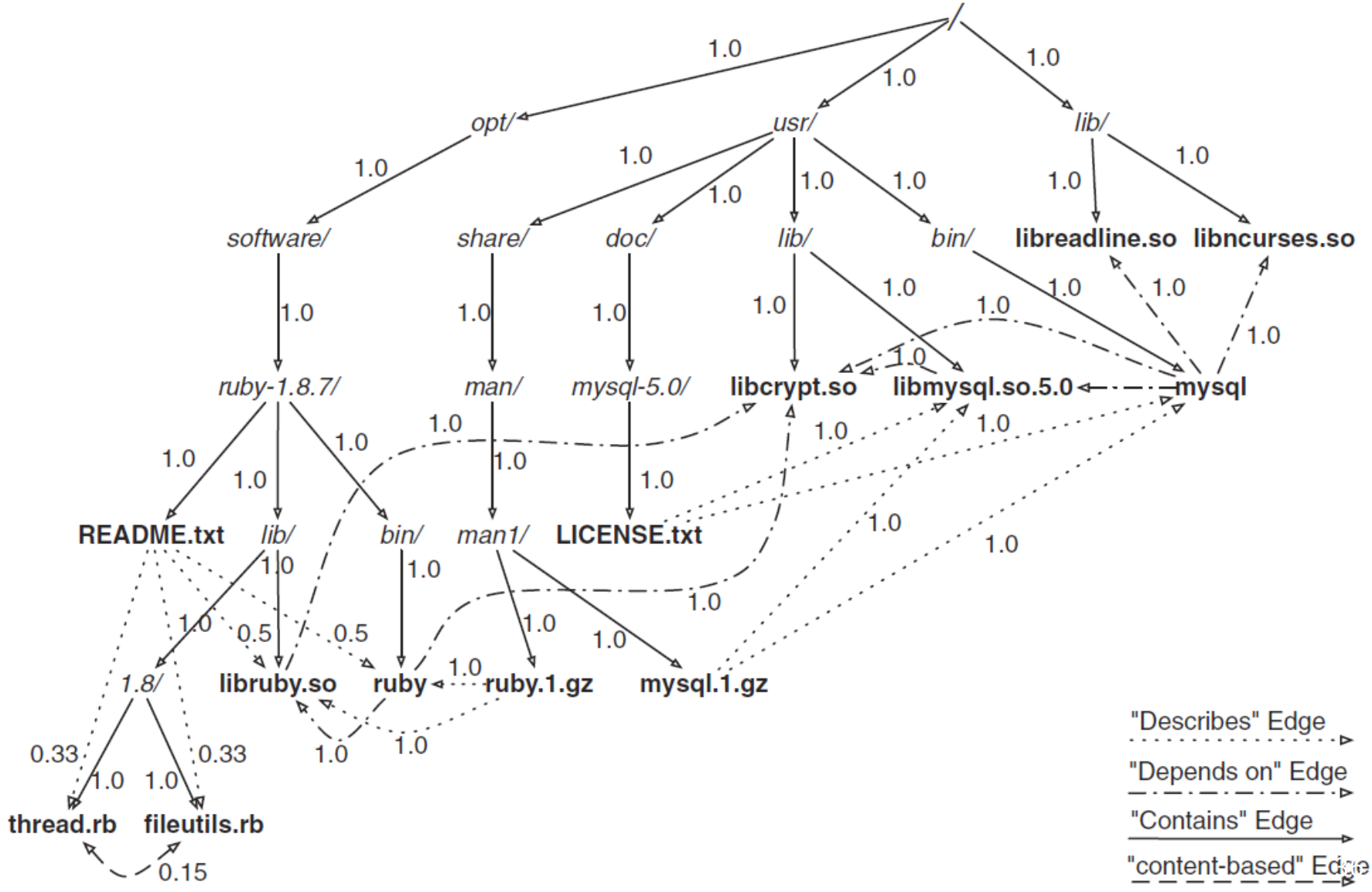
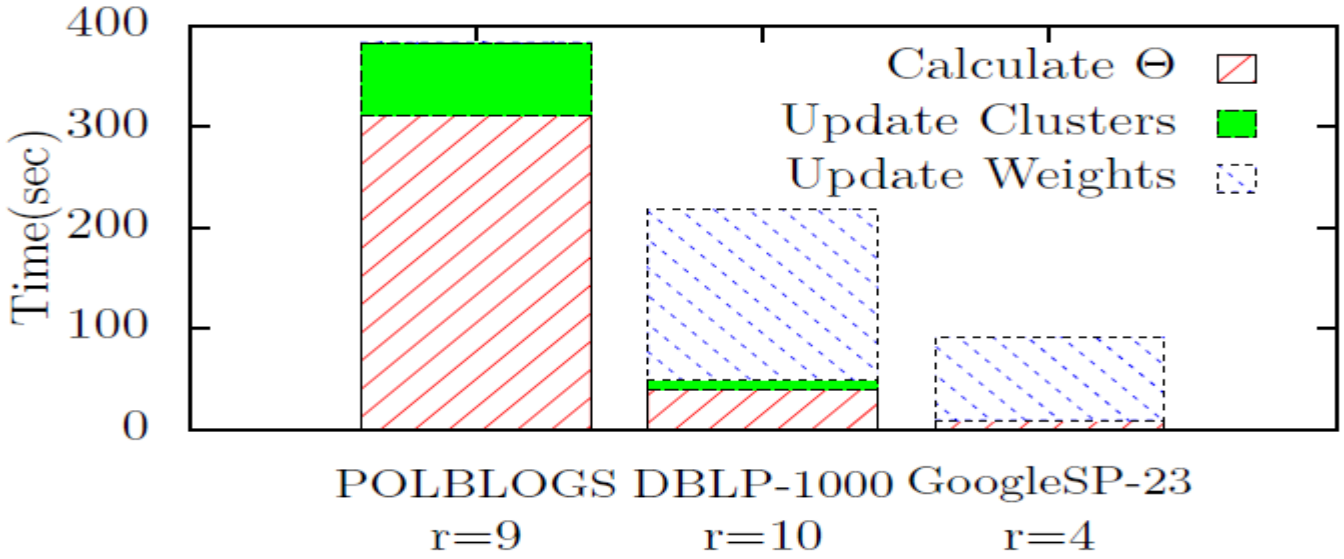
Software Graph



Evaluation – Runtime



- For the GoogleSP-23 dataset containing two different types of links, and five attributes HASCOP converged at the fourth iteration
- Weight adjustment process is time consuming
  - The importance of each link type and attribute has been successfully identified
  - HASCOP converges faster
  - HASCOP reveals important characteristics of the information network under study