DEMON

A Local-first Discovery Method For Overlapping Communities

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DEMON

Democratic Estimate of the Modular Organization of a Network

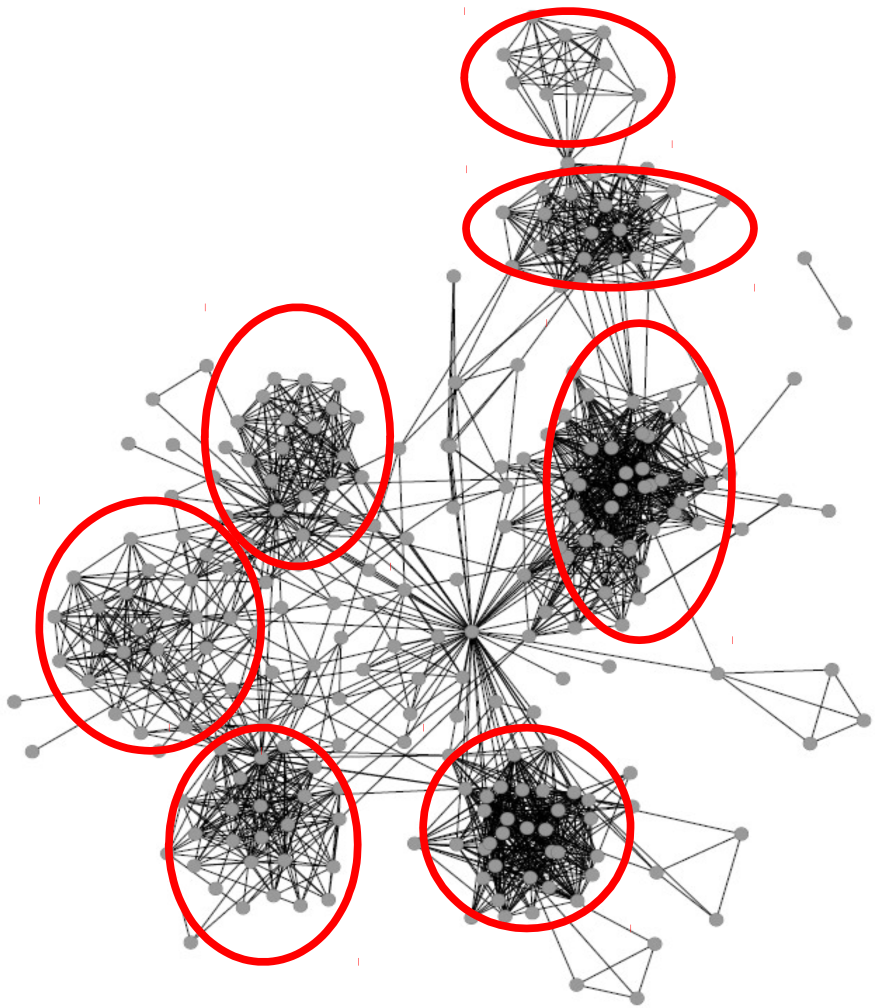
Outline

- Communities and complex networks
  - A matter of perspective
- DEMON Algorithm
  - Properties
  - Experiments
  - Evaluation
- Future Works & Conclusions

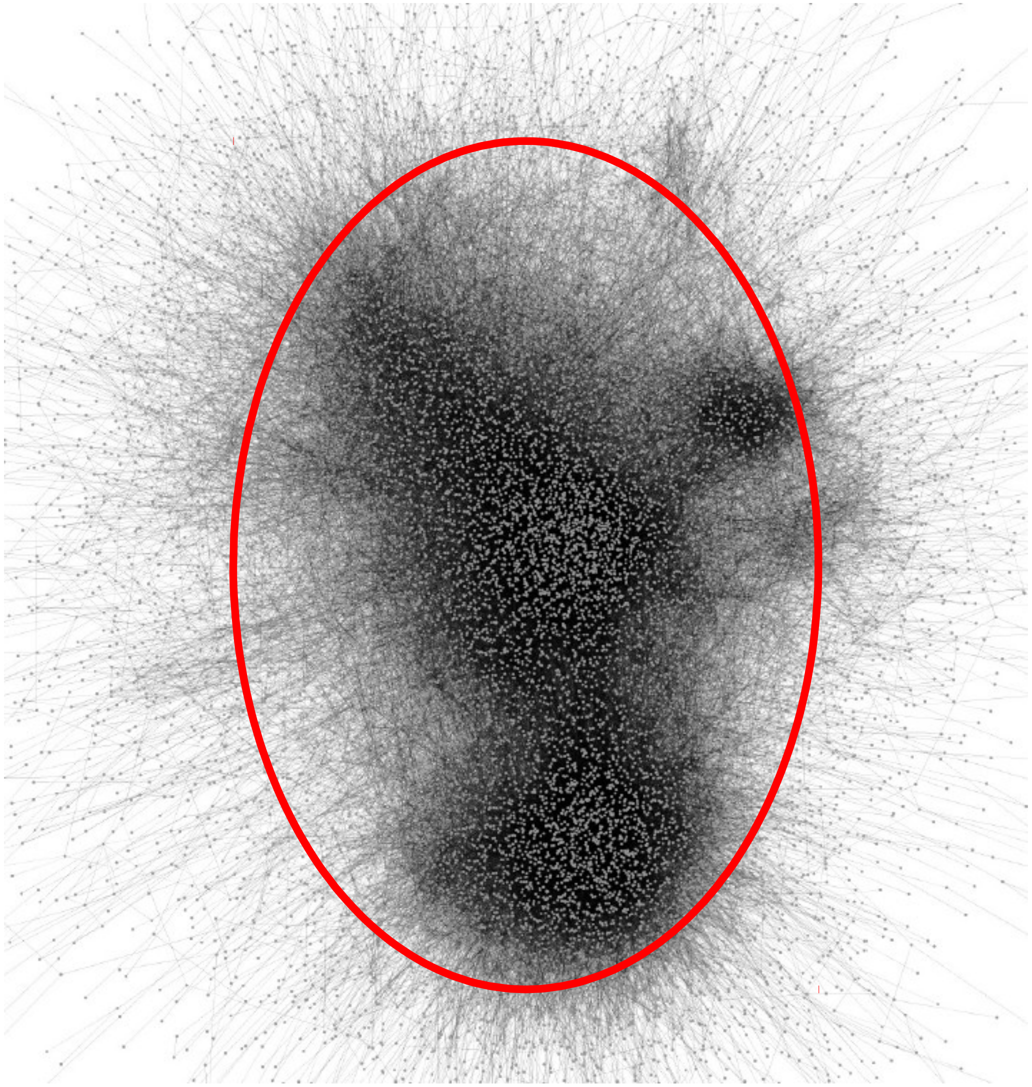
Communities

- Communities can be seen as the basic bricks of a network

- In simple, small, networks it is easy to identify them by looking at the structure..

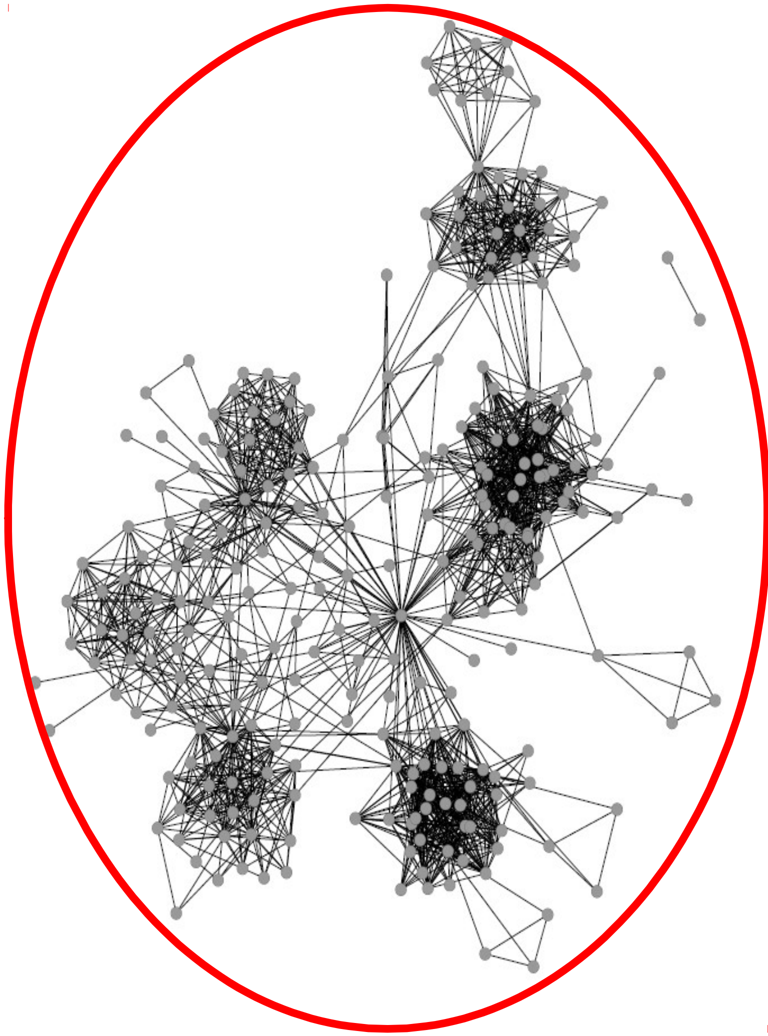


…but real world networks are not “simple”

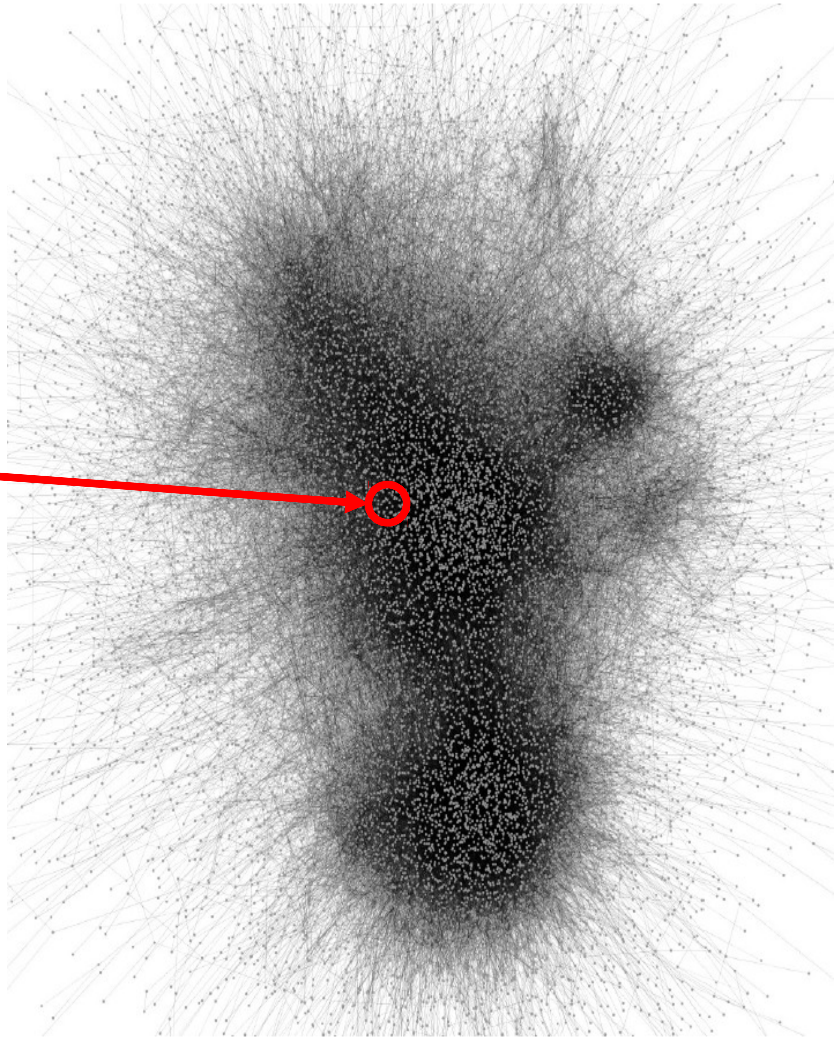


- We can’t identify easily different communities
- Too many nodes and edges

Are they two different phenomena?

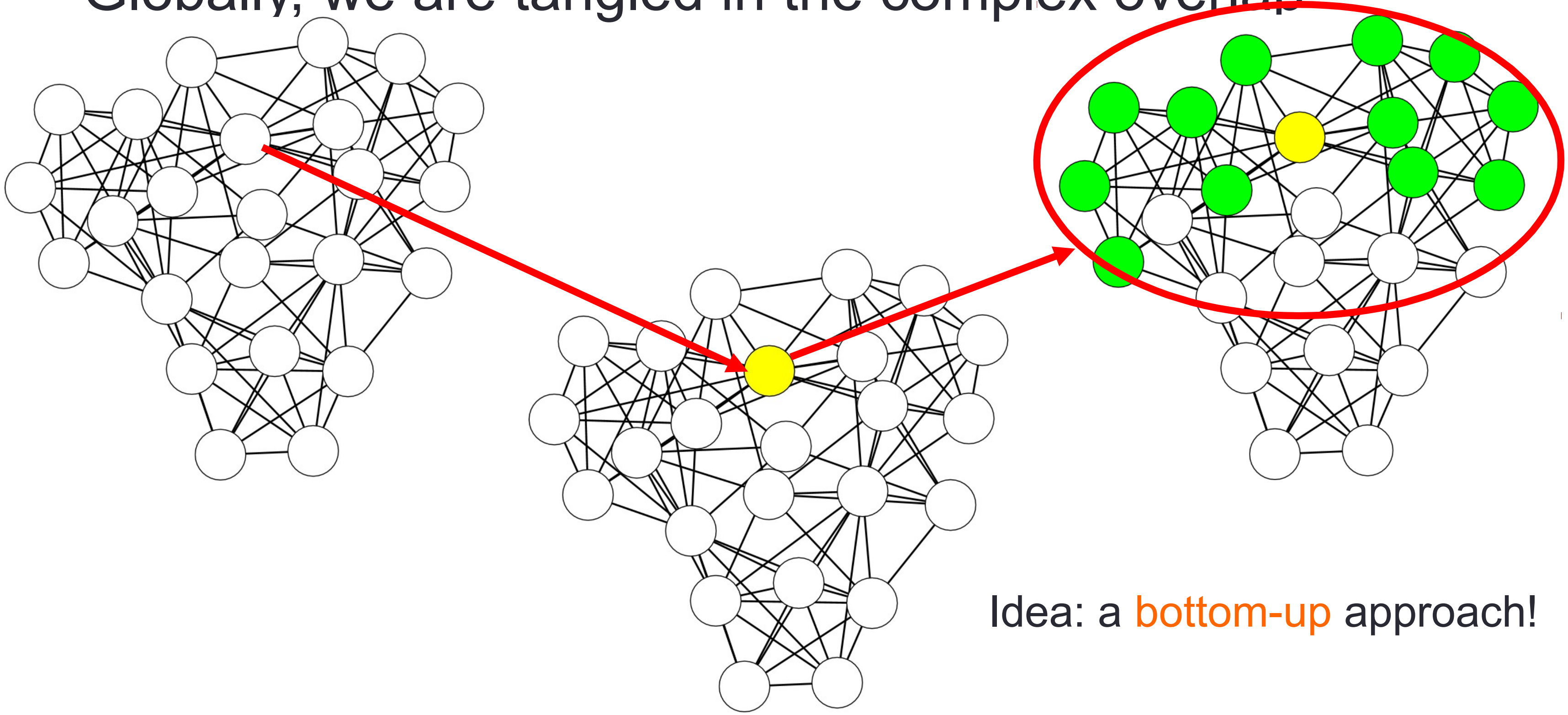


No!



A Matter of Perspective

- The only difference is in the scale
- Locally, for each node the structure makes sense
- Globally, we are tangled in the complex overlap



Idea: a bottom-up approach!

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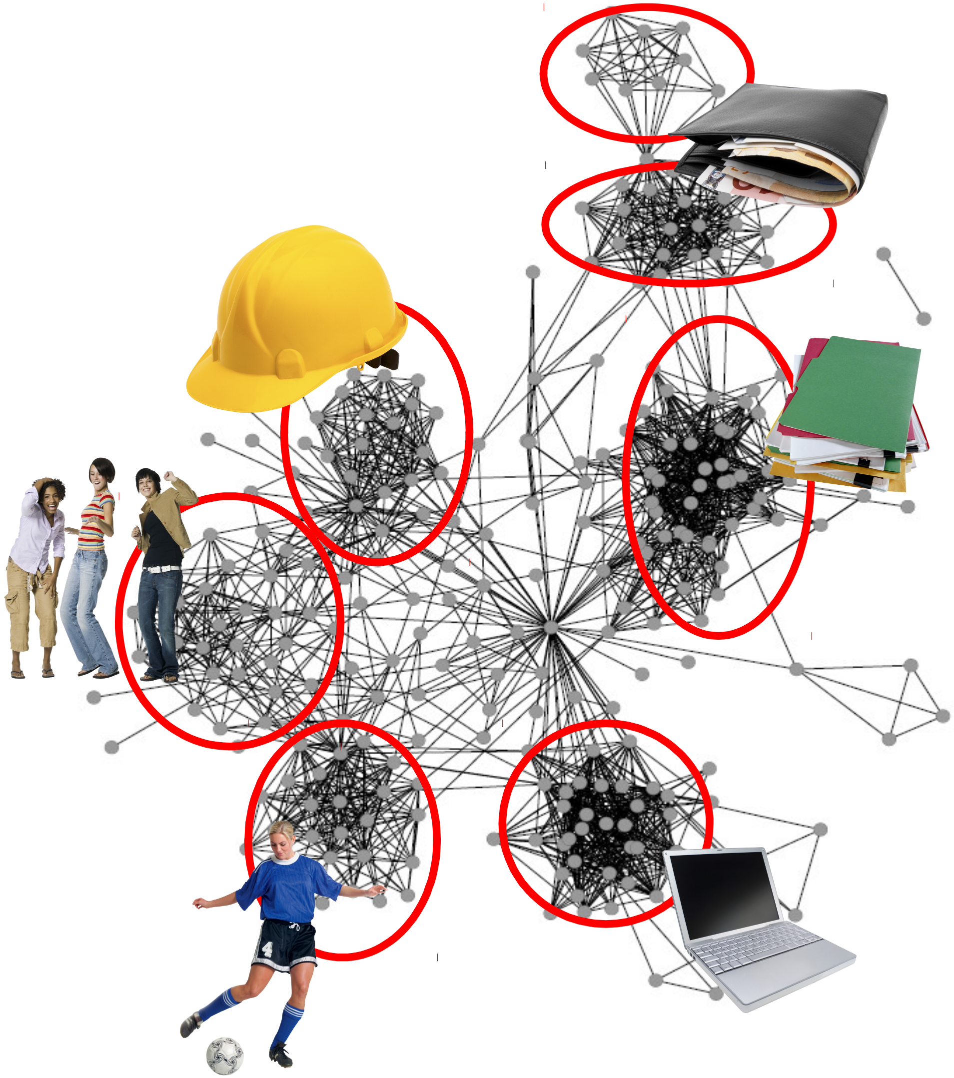
Reducing the complexity

Real Networks are Complex Objects

Can we make them “simpler”?

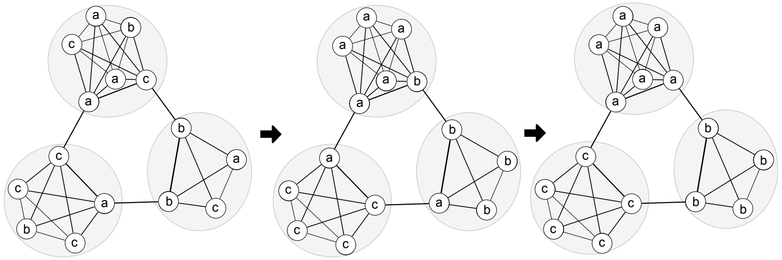
Ego-Networks

(networks builded upon a focal node , the "*ego*”, and the nodes to whom *ego* is directly connected to plus the ties, if any, among the alters)



DEMON Algorithm

- For each node n:
  1. Extract the Ego Network of n
  2. Remove n from the Ego Network
  3. Perform a Label Propagation1
  4. Insert n in each community found
  5. Update the raw community set C



- For each raw community c in C
  1. Merge with “similar” ones in the set (given a threshold)
     (i.e. merge iff at most the ε% of the smaller one is not included in the bigger one)

1 Usha N. Raghavan, R´eka Albert, and Soundar Kumara. Near linear time algorithm to detect community structures in large-scale networks. Physical Review E

Two nice properties

- Incrementality:
  Given a graph G, an initial set of communities C and an incremental update ΔG consisting of new nodes and new edges added to G, where ΔG contains the entire ego networks of all new nodes and of all the preexisting nodes reached by new links, then

$$DEMON(\Delta G \cup G, C) = DEMON(\Delta G, DEMON(G, C))$$

- Compositionality:
  Consider any partition of a graph G into two subgraphs G1, G2 such that, for any node v of G, the entire ego network of v in G is fully contained either in G1 or G2. Then, given an initial set of communities C:

$$DEMON(G1 \cup G2, C) = Max(DEMON(G1, C), DEMON(G2, C))$$

Those property makes the algorithm highly parallelizable: it can run independently on different fragments of the overall network with a relatively small combination work

Experiments

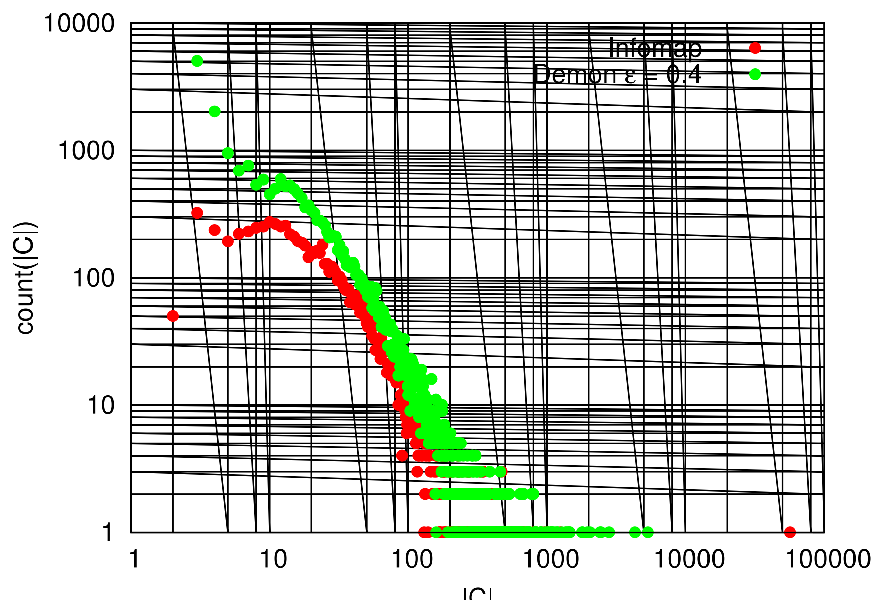
- **Networks** (with metadata):
  - Congress
    (nodes US politicians, connected if they co-sponsor the same bills)
  - IMDb
    (nodes Actors, connected if they play in the same movies)
  - Amazon
    (nodes Products, connected if they were purchased together)
- **Compared Algorithms:**
  - Infomap, non-overlapping state-of-the-art
  - Rosvall and Bergstrom “Maps of random walks on complex networks reveal community structure”, PNAS, 2008
  - HLC, overlapping state-of-the-art
  - Ahn, Bagrow and Lehmann “Link communities reveal multiscale complexity in networks”, Nature, 2010

Quality Evaluation – Community size

Network	Demon		HLC		Infomap		Modularity		Walktrap	
	$\lvert\mathcal{C}\rvert$	$\lvert\bar{c}\rvert$	$\lvert\mathcal{C}\rvert$	$\lvert\bar{c}\rvert$	$\lvert\mathcal{C}\rvert$	$\lvert\bar{c}\rvert$	$\lvert\mathcal{C}\rvert$	$\lvert\bar{c}\rvert$	$\lvert\mathcal{C}\rvert$	$\lvert\bar{c}\rvert$
Congress	425	63.3671	1,476	4.5867	6	87.6667	3	175.3333	7	71.8571
IMDb	14,004	12.6824	88,119	8.3426	5,991	27.1574	4,746	11.9157	7,877	7.1781

Table 3: Statistics of the community set returned by the different algorithms.

- $\lvert\mathcal{C}\rvert$ number of communities
- $\lvert\bar{c}\rvert$ average community size



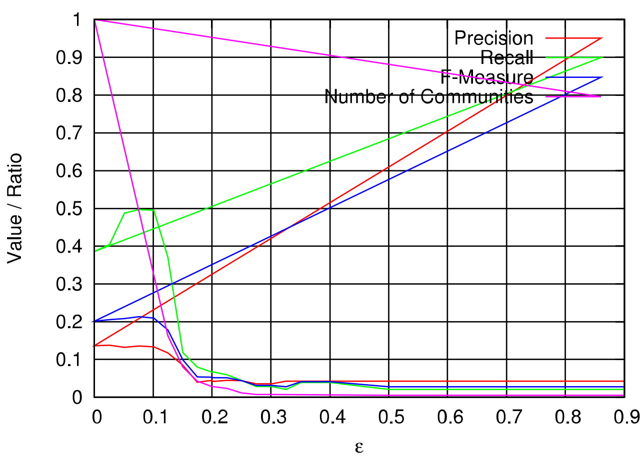
Amazon

Quality Evaluation - Label Prediction

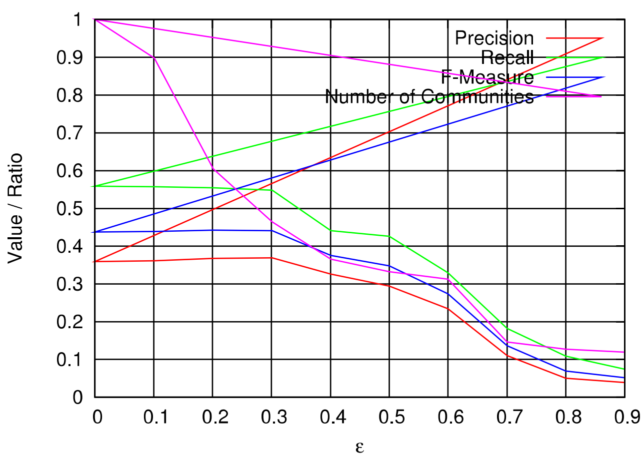
- Multilabel Classificator (BRL, Binary Relevance Learner)
  - Community memberships of a node as known attributes, real world labels (qualitative attributes) target to be predicted;

Network	*DEMON*	HLC	Infomap	Modularity	Walktrap
Congress	**0.21275**	0.14740	0.00535	0.00099	0.00725
IMDb	**0.44252**	0.43078	0.38470	0.10692	0.17488

Table 2: The F-Measure scores for Congress and IMDb dataset and each community partition.



Congress



IMDb

Quality Evaluation - Community Cohesion

- How good is our community partition in describing real world knowledge about the clustered entities?
  - “Similar nodes share more qualitative attributes than dissimilar nodes”

$$CQ(P) = \frac{\sum_{(n_1,n_2)\in P} \frac{|QA(n_1)\cap QA(n_2)|}{|QA(n_1)\cup QA(n_2)|}}{\sum_{(n_1,n_2)\in E} \frac{|QA(n_1)\cap QA(n_2)|}{|QA(n_1)\cup QA(n_2)|}}$$

Iff CQ(P)>1 we are grouping together similar nodes

Network	*DEMON*	HLC	Infomap	Modularity	Walktrap
Congress	**1.1792**	1.1539	1.0229	1.0373	1.0532
IMDb	**5.6158**	5.1589	0.1400	1.4652	0.0211

Table 4: The Community Quality scores for Congress and IMDb dataset and each community partition.

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Future works

- Extension to weighted and directed networks (completed)
- Parallel implementation
- Modify the merging strategy (in progress)
  - Hierarchical merging
  - …
- Framework structure
  - i.e. different hosted algorithms that can be used in place of LP to extract communities (according to different definitions)

Conclusions

- DEMON approaches the community discovery problem trough the analysis of simpler structures (ego-networks)

- The proposed algorithm outperforms state-of-the-art methodologies

- Possible parallel implementation: high scalability

Thanks!

Questions?

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Code available @ http://kdd.isti.cnr.it/~giulio/demon/