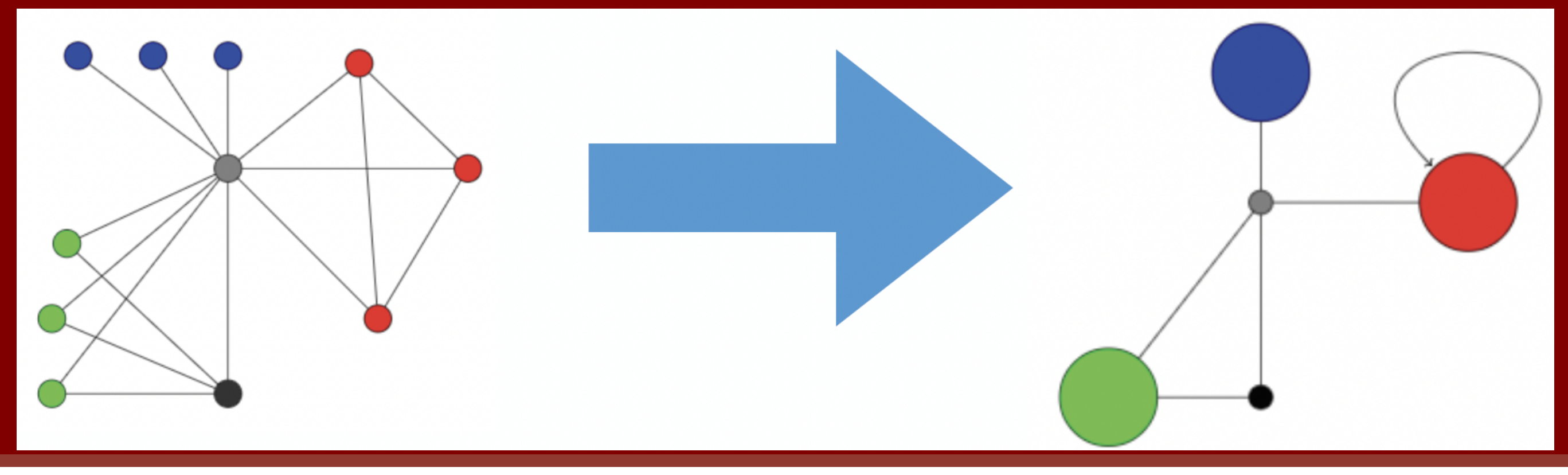

Scalable Algorithm for Graph Summarization

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Background

Why graphs are popular?

Graphs are the most natural representation of real world data as set of nodes and set of edges:

- Protein-Protein interactions
- Social networks, Web graphs, Collaboration networks
- Transportation networks

Challenges:

Graphs are increasing exponentially:

- 3.5 billion web pages connected by 129 billion hyperlinks
- Online social networks with 300 billion connections
- Storing, mining and visualization are the main challenges.

Graph Summarization is used for:

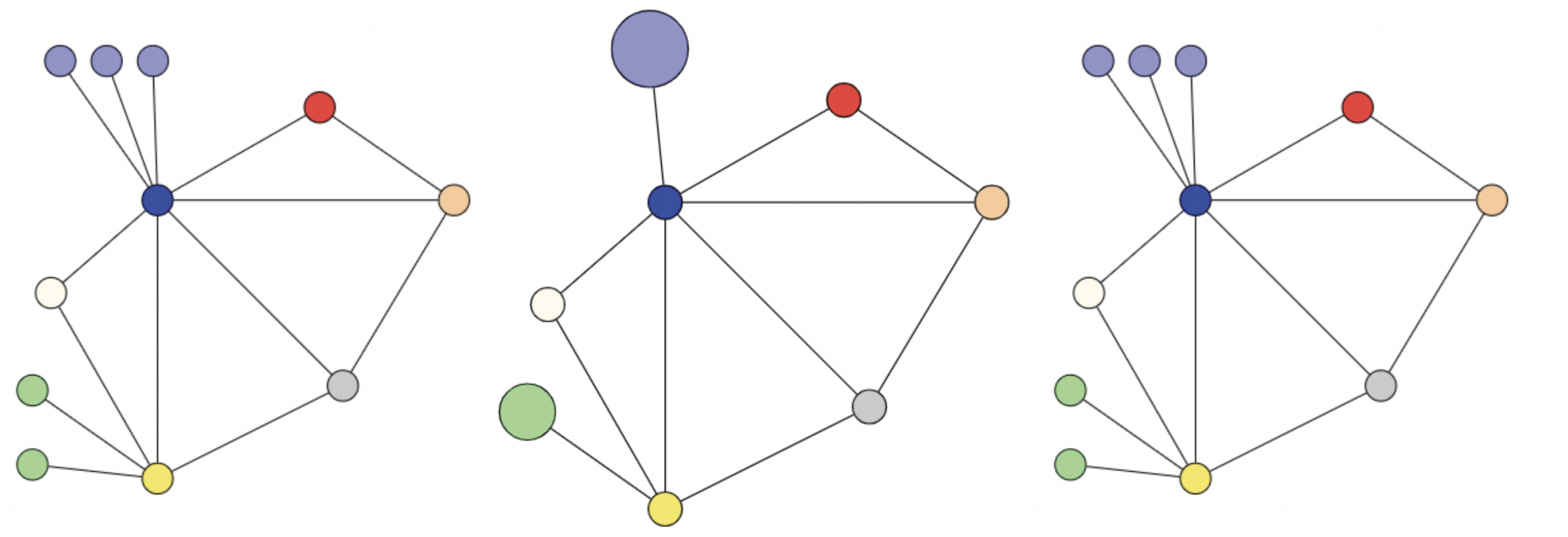
- Better Visualization
- Effective query answering
- Decreasing the footprint of graph

Definition of Graph Summarization:

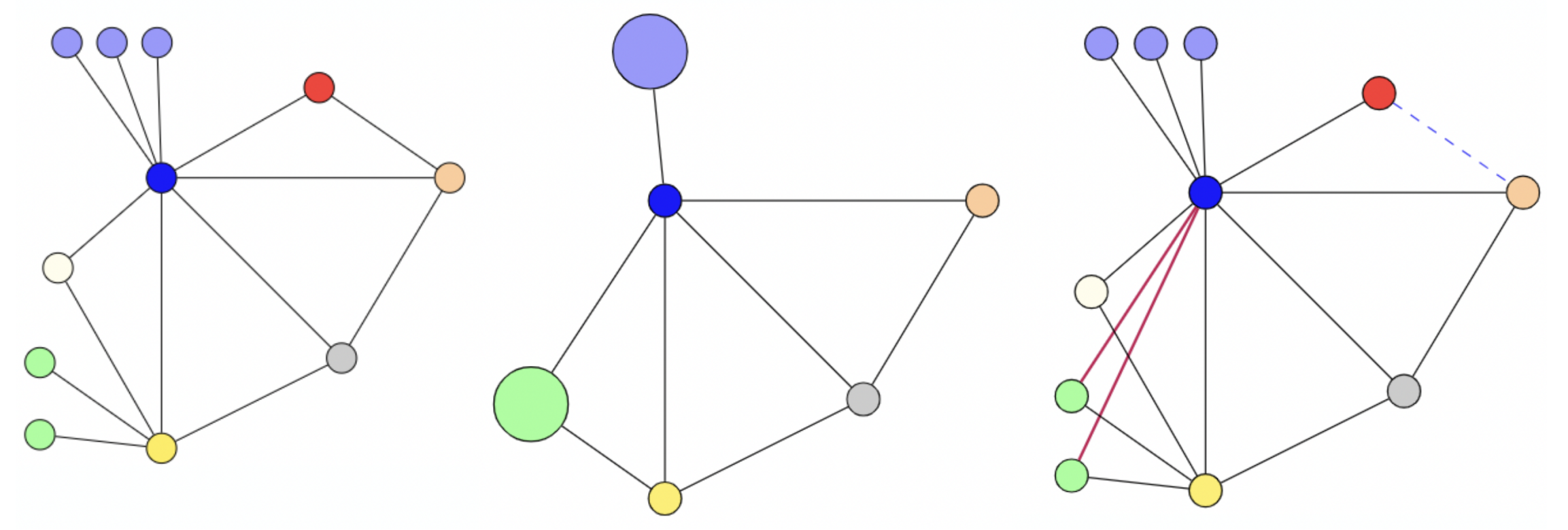
Find compact representation of the original graph called summary.

Graph Summarization can be either:

- Lossless: Summarizing graph without loosing any information:



- Lossy: Loosing some information from the original graph in order to gain more compression.



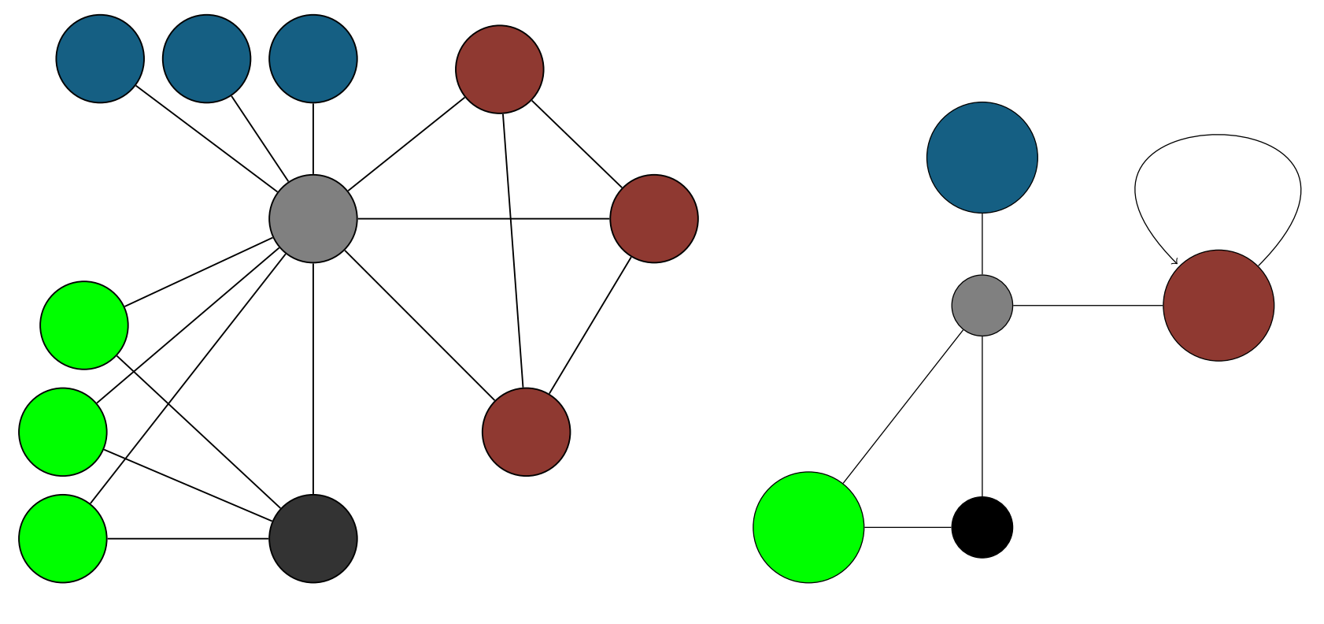
Contribution:

- We present a super fast lossless algorithm, G-SCIS
- Using G-SCIS summary for query answering

Intuition

In a lossless summary each node can be either

- In a supernode with size 1 (grey and black nodes in the following Figure)
- Inside a supernode representing a clique (Red nodes)
- Inside a supernode representing an independent set (Green nodes)



(a) Original Graph   (b) Summary Graph

G-SCIS:

A Naive Approach:

The task is finding a set of nodes which share above features, and merge them together in the same supernode

A naive approach is comparing the neighbors of each node with the neighbors of all other nodes. This approach is not scalable on large graphs ($O(VE)$). (It takes around one and a half year for a large graph with 39 million nodes and 1.5 billion edges).

Proposed Method (G-SCIS):

Alternatively we use the hash function which is highly applicable in data clustering and cryptography. Hashing is a probabilistic algorithm which does not have any **False Negative** errors but it may have **False Positive** error.

Steps:

- Using a hash fucntion to bucketize all the nodes in the graph according to its neighborhood
- Filter buckets in order to make them **false positive free**
- Now each filtered bucket is a supernode
- Draw superedge between supernodes

Dataset Description

We used seven web and social graphs from (`http://law.di.unimi.it/datasets.php`) varying from moderate size to very large. The following Table describes the data in terms of number of nodes, number of edges, and abbreviation.

Graph	Abbr	Nodes	Edges
cnr-2000	CN	325,557	5,565,380
hollywood-2009	H1	1,139,905	113,891,327
hollywood-2011	H2	2,180,759	228,985,632
indochina-2004	IC	7,414,866	304,472,122
uk-2002	U1	18,520,486	529,444,615
arabic-2005	AR	22,744,080	1,116,651,935
uk-2005	U2	39,459,925	1,581,073,454

Table 1. Summary of datasets

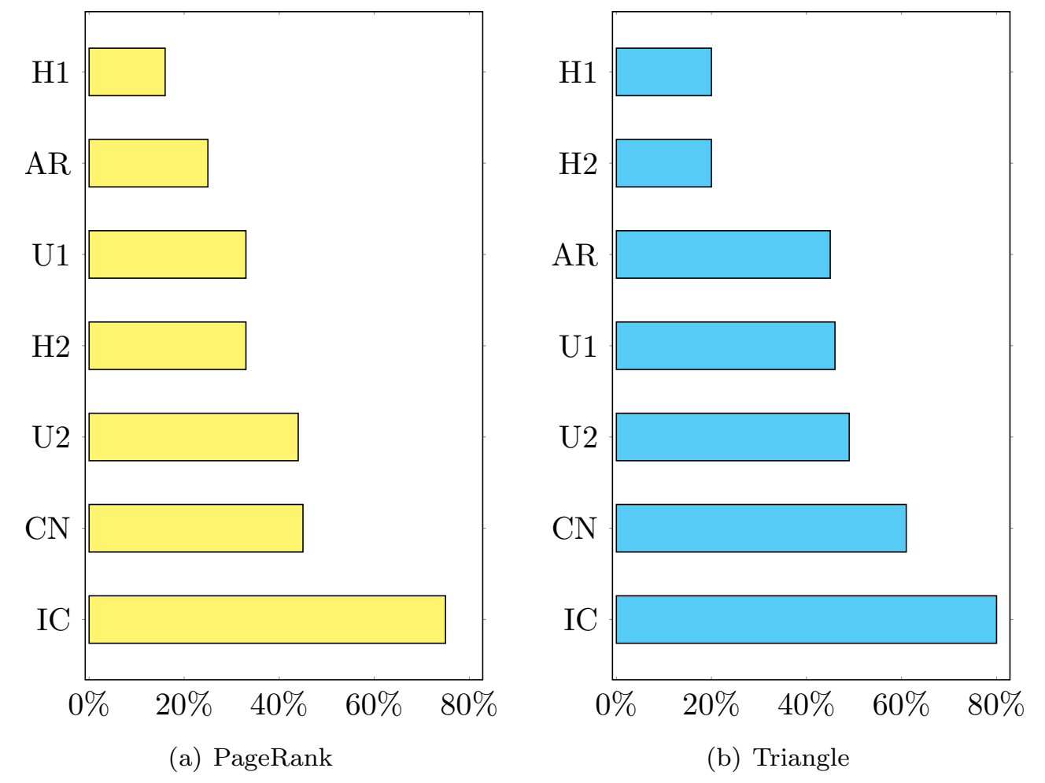
Experiments

RN value and running time

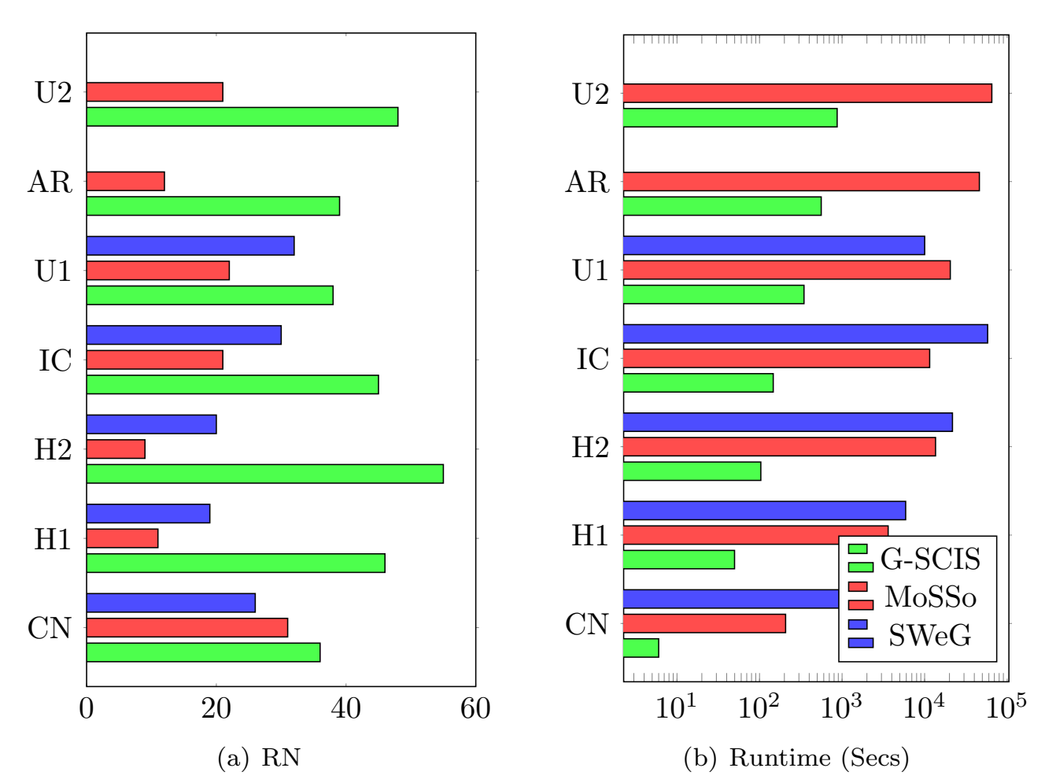
- The proposed method, G-SCIS (Graph Summarization based on Clique and Independent Set), is compared with MoSSo [1] and SWeG [2] in terms of compression (RN) and running time.
- Figure 1 shows the comparisons in terms of RN and running time in log-scale
- G-SCIS is up to 1000 time faster and it achieves 2.5x more compression compared with others
- It takes just 15-20 minutes to summarize a huge graph with 39 million nodes and 1.5 billion edges (U2) while the other one (MoSSO) takes a day to get the job done.

Query answering using summary graph

- We use G-SCIS summary graph as-is in order to answer
- We compare the running time of running query on the original graph vs running time of G-SCIS + running query on G-SCIS graph.
- We chose two different queries (PageRank, Triangle counting).
- Figure shows the relative improvement of using G-SCIS for answering queries.
- It is up to 5x faster if we use G-SCIS to answer queries



(c)



(d)

Conclusion

- We presented a fast algorithm which is up to 1000 time faster and 2x more compression
- We showed using the summary graph can speed up the query answering

This was a part of our recent publication in Knowledge Discovery and Data Mining Conference (SIGKDD 2021). You can have access the paper here

Future Work

- Graphs are dynamic and huge in nature and we have to summarize them

References

[1] Jihoon Ko, Yunbum Kook, and Kijung Shin.
Incremental lossless graph summarization.
In *KDD*, 2020.

[2] Kijung Shin, Amol Ghoting, Myunghwan Kim, and Hema Raghavan.
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