Graph Mining Using SQL

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December 1, 2014

Abstract

In this project, we investigated the possibility of using only SQL to do graph manipulations on *graphMiner*. *graphMiner* contains generic methods for RDBMS manipulations and some graph mining algorithms such as PageRank, Degree Distribution, Weak Connected Components, etc. Many useful properties of graphs can be found using these methods. *graphMiner* is based on Python, Postgres Database and SQL. Python provides basic control and logic as well as file operations, while all the important calculations are done through SQL on Postgres Database. We also implemented kcore algorithm within the framework, which gives useful information of the importance of nodes in the graph. We created unit tests on kcore and other algorithms in the system to test their functionality and correctness as well as to gain better understanding of these methods. For real world testing, we also ran kcore and other algorithms in the framework on 20 realworld datasets. We found some interesting properties of these datasets and explained them with the findings from the results of these graph mining algorithms.

1 Introduction

Specify the problem; Give the motivation; List your main contributions

The problem we are trying to solve is: Given a graph of source-destination pairs on disk, we try to use only SQL to implement basic matrix and vector operations, which make it possible to handle more complex graph manipulations. We will then be able to implement algorithms like PageRank and Degree distribution without the need of an additional language.

The motivation is that we can use only SQL and do not need to depend on other languages. With SQL we can enjoy the benefits of various features of databases and become more effcient in implementing and testing some of the algorithms without the worries like data structure, memory optimization, file IO, etc.

Doing graph mining with SQL is an important method for all scales, research or industry use, as database provides easier interface to scale and deploy. And graph manipulation and mining has many real world applications and is a very important topic. Thus a convenient way of implementing graph manipulation algorithms are highly desired.

The contributions of this project are the following:

- Our implemented *K-core Decomposition* is fast and uses only SQL to do the calculations. Python only works as some basic loop control and input output format handling.
- We tested various graph handling algorithm on unit tests and some real world datasets.

2 Survey

Next we list the papers that each member read, along with their summary and critique.

2.1 Papers read by Ye Zhou

The first paper was the Pegasus paper by U Kang

- *Main idea*: When graph data grows larger and larger, using traditional graph mining algorithms is difficult to deal with trend. In order to solve the graph mining problems with several Petabytes data, Pegasus is the first such library, impelemted on the top of Hadoop platform. In the paper, first they try to find out the common operation, which is the matrix-vector multipilication, underlying several primitive graph mining operations. They call it GIM-V. As GIM-V is so important, they successfully proposed several optimizations, and got more than 5 times faster performance. They also took real big data graph into Pegasus to get the mining result, which revealed important patterns. This showed the succuess of Pegasus with large data graph mininig as the graph data they used had never been studied before.
- *Use for our project*: It showed that with large data, we always have new problems using traditional graph mining methods. It is really hard to say that with SQL, we can do enough with graph mining now, as SQL is based on RMDB. But with more and more new mature products/framework like hive, pig, shark which support traditional SQL operations on big data and No-SQL database, we can do more with SQL.
- *Shortcomings*: PEGASUS focus on large graph querying/mining and most of the job was focused on how to compute fast, but it ignored the storage part which can also take effect to improve the performance like indexing. In addition, PEGASUS essentially perform node/vertex-centralized computation but cannot supports edge-centralized processing like induced subgraphs. Finally, hadoop is not so efficient for iterative calculation, as everytime it needs to write output data to hard disk. Spark has better performance as it output its intermediate data in memory and can even cahche the data in memory.

2.2 Papers read by Ye Zhou

The second paper was the Spectral Analysis for Billion-Scale Graphs paper by U Kang

- *Main idea*: The paper proposed HEIGEN algorithm which is designed to be accurate, efficient to run on highly scalable hadoop environment and solve the problems that will calculate out the spectral value. The paper first showed specific observation using HEIGEN with real world data on billion-scale graphs, focusing on structural property of networks: spotting near-cliques and finding triangles. Then the author explained that the alternatives for computing the eigenvalues of symmetric matrix including Power Method, Simultaneous iteration and Lanczos-NO are not suitable for big data on mapreduce. So the author described the algorithm for computing the top K eigenvectors and eigenvalues with four speficic fields improvement: Careful Algorithm Choice, selective parallelization, blocking and skewness exploiting. Finally it turned out that performance improved in both scalabitily and skewed matrix data, compared with HEIGEN-PLAIN.
- *Use for our project*: Largely based on mapreduce, HEIGEN is a totally new algorithm. What we can learn is that with massive data, we can change the former way of thinking for graph mining, so that we can largely improve the performance without SQL. And also, with the infrastructure of hadoop, and the way map/reduce reading data, we can do modification to use the advantages to get even better performance.
- *Shortcomings*: Highly based on map/reduce architecture also brings lots of problems that hadoop has. Such as the job schedualing and data shuffling. As the matrix operation needs to read large amount of data, and for iterative calculation, spark is a better choice as everything is in memory.

2.3 Papers read by Ye Zhou

The third paper was the Unifying Guil-by-Association Approaches paper by Koutra

- *Main idea*: The paper mainly proposed FaBP, which is a Fast Belief Propagation algorithm on Hadoop. It first compare and contrast several very successful, guilt-by-association methods: Random Walk with Restarts, Semi-Supervised Learning and Belief Propagation. The author showed that these three methods are closedly related but not identical. Then he proposed the algorithm FaBP, showed the experiments result. It turned out that the accuracy keeps the same or even better with the traditional BP, but the performance is twice better. It also has convergence guarantee. It is even sensitive to the "about-half" homophily factor, as long as the latter is within the convergence bounds. It also scales linearly on the number of edges.
- *Use for our project*: Learn the way using hadoop to impelment the algorithm for machine learning.
- *Shortcomings*: Again it is based on Hadoop, the performance for iterative calculation is not so good compared with spark. And BP algorithm is not so efficient when dealing with graph which has circle. And the convergence is limited due to specific requirement.

2.4 Papers read by Jin Hu

The first paper was the GBASE paper by U Kang

- *Main idea*: The paper introduces a general graph management system GBase for large scale graph storage and computation.
- *The main contribution of the paper:*: GBase uses "compressed block encoding" method to make graph storage more efficiently. For graph indexing, the paper succeeds in handling multiple type of queries on a large graph instead of a specific type and is suitable for distributed environment. By supporting homogeneous block level indexing and being flexible in both edge and node centralized computing, GBase has better properties than similar distributed systems. The framework the paper proposes also supported both graph-level and node-level queries, making it applicable to various applications. GBase partitions data in two dimensions to better use the block and community-like properties of real-world graphs, which gives it advantage over either row-oriented or column-oriented storages.
- *Limitations*: The paper's indexing method handles large graphs successfully, but its property compared to frequent subgraph or significant graph pattern methods are not shown in the experiment. Optional indexing methods may be added to the system.

2.5 Papers read by Jin Hu

The second paper was by Danai Koutra

- *Main idea*: The paper does the comparison among some of the most popular guilt-by-association method.
- *The main contribution of the paper:*: The paper manages to prove that all methods result in a similar matrix inversion problem. In addition, the paper proposes a fast and accurate BP algorithm. In theory, the paper finds that RWR(Personalized Random Walk with Restats), SSL(Semi-Supervised Learning) and BP(Belief Propagation) are closely related, but not the same. RWR and SSL are not heterophily, but BP is heterophily. All three methods are scalable. RWR and SSL have convergence while BP is unknown. The proposed FABP method has nice property with all these perspectives. FABP is an approximation of standard BP, but FABP is significantly faster based on the experiment and guarantees convergence, which makes it better than BP. The experiments also verify the paper's ideas. The author tested the theory and the properties of the proposed FABP method in terms of accuracy, convergence, sensitivity to parameters and scalability.

2.6 Papers read by Jin Hu

The third paper was by Ignacio Alvarez-Hamelin

- *Main idea*: The paper introduces K-core decomposition and its application in the visulization of large scale networks.

- *The main contribution of the paper:*: K-core decomposition can find subgraphs which all of the nodes in the subgraph have degrees higher than k after removing nodes with lower coreness. This method can find the subgraphs which are more closely connected and achieves "clustering" in large graphs. As K-core decomposition can produce two-dimensional layout of large scale networks with their important topological and hierarchical properties, the paper takes advantage of the K-core algorithm to allow visulization of network and offer features like fingerprint identification and general analysis assistance. The visualization algorithm has linear running time proportional to the size of the network, making it well scalable for large networks. In addition, the algorithm offers 2D representation of networks which makes information visualization more accessible than other representations and the parameters of the algorithm are universally defined, which makes it suitable for all types of networks.
- *Limitations*: The proposed visualization algorithm still utilizes certain parameters to identify the properties of the network, which involves considerable human interactions and prior expemental knowledge. Self adjusting parameters might be a huge improvement and can be an interesting topic to follow.

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3 Proposed Method

We implemented K-core in *graphMiner* framework with SQL following the Batagelj and Zaversnik k-core variation [5]. We recursively prune the nodes and edges in the graph with degree less than k to finally arrive at points of degree greater than or equal to k.

3.1 K-core Decomposition: Definition

A graph G = (V, E), $|V|$ = n vertices and $|E|$ = e edges. Then a K-core is a subgraph of $H = (C, E|C)$ induced by the set $C \subseteq V if \forall v \in$ C: $degree_H(v) >= k$, and H is the maximum subgraph with this property.

K-cores in the graph can then be calculated by recursively removing all the vertices of degree less than k, until all vertices in the remaining graph have at least degree k.

A vertex i has coreness c if it belongs to the c-core but not to (c + 1)-core. We denote by c_i the coreness of vertex i.

A shell C_c is composed by all the vertices whose coreness is c. The maximum value c such that C_c is not empty is denoted c_max. The k-core is thus the union of all shells C_c with c k.

Each connected set of vertices having the same coreness c is a cluster Q^c. Each shell C_c is thus composed by clusters Q^c_m such that $C_c = U_(1mq_max^c)Q^c_m$, where q^c_max is the number of clusters in C_c.

Algorithm 1 K-core algorithm Description with SQL

Require: $UndirectGraph$ and $NodeDegrees$ are input data and prerequisite calculation, k is the number of iterations and the k in K-core algorithm.

```
function KCORE(UndirectGraph, NodeDegrees, n)
    for i ← 1 to k do
        create TempNodeDegrees, TempUndirectGraph table that do not contain nodes in the RemovedNodeTable
        INSERT INTO RemovedNodeTable SELECT nodeId FROM TempNodeDegrees WHERE inDegree ¡ i
        Do Connected Components Analysis and return distinct componentId in ConnectedComponentGraph
    Save Result to CSV File
```

4 Experiments

We implemented kcores method and tested other algorithms that are already implemented in the system with unit tests and other datasets from SNAP.

Figures below give the degree distribution and pagerank result of two dataset from SNAP. We can find that the degree distribution and pagerank results are consistent with the power law as nodes or pages with higher degree or rank have a small number while nodes or pages with lower degree or rank have a large number. You can also find the detailed results in the output folder, which contains csv files for the results of belief propagation, connected components, node degrees, degree distribution, eigen values, k-core connected components, pagerank results, radius, etc.

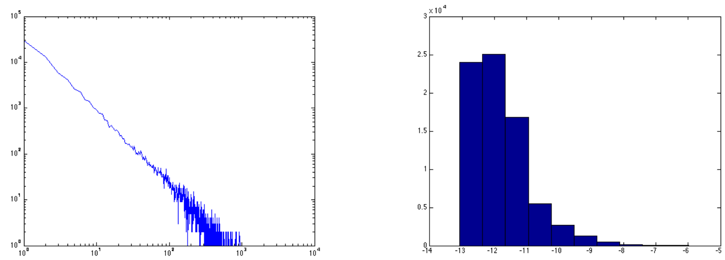
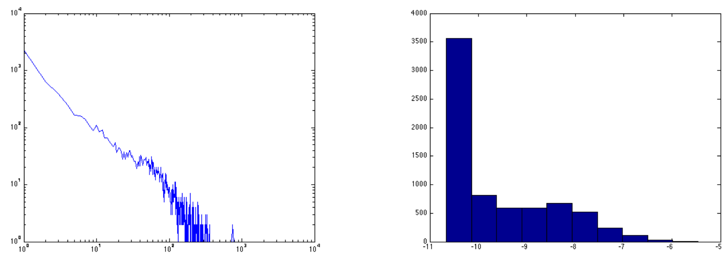


Figure 1: Degree Distribution(a) and PageRank(b) for Dataset SOC-Epinions1



(a) (b)

Figure 2: Degree Distribution(a) and PageRank(b) for Dataset wiki-Vote

The figures below also include the degree distribution, connected components, k=5 cores algorithm results on the 5 unit tests. As the unit tests are small, there is no nodes in the tests that satisfy k=5 cores, so the output result for these 5 unit tests are empty. However, you can find the node id, component id pairs in the stdout output from console or in the kcorecomponent.csv file, which shows that the k-core algorithm works as it claims to find correct coreness subgraphs.

Degree	Count
2	11

Node_id	Component_id
8	0
4	0
1	0
5	0
3	0
0	0
10	0
9	0
6	0
2	0
7	0

Figure 3: Degree Distribution(a), connected components(b) for Dataset1

Degree	Count
4	5

Node_id	Component_id
4	0
1	0
3	0
0	0
2	0

Figure 4: Degree Distribution(a), connected components(b) for Dataset2

Degree	Count
4	7
3	3
9	1

Node_id	Component_id
8	0
4	0
1	0
5	0
3	0
0	0
10	0
9	0
6	0
2	0
7	0

Figure 5: Degree Distribution(a), connected components(b) for Dataset3

Degree	Count
1	2
2	3

Node_id	Component_id
4	2
1	0
3	2
0	0
2	2

Figure 6: Degree Distribution(a), connected components(b) for Dataset4

Degree	Count
3	16
2	5

Node_id	Component_id
8	0
16	0
15	0
4	0
20	0
1	0
13	0
5	0
11	0
3	0
14	0
17	0
0	0
19	0
12	0
10	0
18	0
9	0
6	0
2	0
7	0

Figure 7: Degree Distribution(a) connected components(b) for Dataset5

We build index for algorithms Degree Distribution, K-core, Pagerank, Connected Components, All Radius, Eigen Value Computation on ten datasets:as-skitter.ungraph-75000, ca-AstroPh, cit-HepPh, cit-HepTh, com-amazon.ungraph-75000, com-dblp.ungraph-75000, email-Enron.ungraph, email-EuAll,p2p-Gnutella31, soc-Slashdot0811-75000.

We first conducted some simple tests to make sure that creating index can lead to performance improvement. For example, Degree Distribution:(no index on node degree), run time is 147.476911545 Degree Distribution:(index on node degree (in degree, out degree)), run time is 346.571922302 From the experiment, create index does consume system resources and it will make performance worse in general if we created index and used it only once. However, Degree Distribution:(no index on node degree)(run 10 times), run time is 2091.14193916, Degree Distribution:(index on node degree (in degree, out degree))(run 10 times, 1 time create index), run time is 1351.35889053. From the experiment, create index will improve performance in general if we created index and used it later a lot. Also, for a certain algorithm, create index for some tables like GMNODES are expensive, but if re run all the algorithms,or use the algorithm multiple times, then the cost of creating index on tables like GMNODES will be worth the effort.

This is the general intuitive for us to choose on which table and which column to create index and avoid some unnecessay tests.

We compared building index for different tables on different columns for each algorithm and get the following figures below.

All Radius				Combination Choice	
as-skitter.ungraph-75000.txt	Create Time	Whole Time			Whole Time
GM_TABLE_UNDIRECT (src_id)	117	94563	✖	NoIndex	91840
prev_hop_table (node_id)	115	95170	✖	WithBestIndex	✖
max_hop_ngh (id)	108	94377	✖		
ca-AstroPh.txt	Create Time	Whole Time			Whole Time
GM_TABLE_UNDIRECT (src_id)	37	22040	✖	NoIndex	20684
prev_hop_table (node_id)	42	22639	✖	WithBestIndex	✖
max_hop_ngh (id)	91	32491	✖		
cit-HepPh.txt	Create Time	Whole Time			Whole Time
GM_TABLE_UNDIRECT (src_id)	58	30688	✖	NoIndex	31902
prev_hop_table (node_id)	60	31537	✖	WithBestIndex	✖
max_hop_ngh (id)	68	26540	✖		
cit-HepTh.txt	Create Time	Whole Time			Whole Time
GM_TABLE_UNDIRECT (src_id)	54	25942	✖	NoIndex	25025
prev_hop_table (node_id)	53	25346	✖	WithBestIndex	✖
max_hop_ngh (id)	63	23666	✖		
com-amazon.ungraph-75000.txt	Create Time	Whole Time			Whole Time
GM_TABLE_UNDIRECT (src_id)	110	145466	✖	NoIndex	141871
prev_hop_table (node_id)	119	145499	✖	WithBestIndex	✖
max_hop_ngh (id)	150	148162	✖		
com-dblp.ungraph-75000.txt	Create Time	Whole Time			Whole Time
GM_TABLE_UNDIRECT (src_id)	112	87245	✖	NoIndex	82507
prev_hop_table (node_id)	121	89466	✖	WithBestIndex	✖
max_hop_ngh (id)	128	88248	✖		
email-Enron.ungraph.txt	Create Time	Whole Time			Whole Time
GM_TABLE_UNDIRECT (src_id)	60	30373	✖	NoIndex	28366
prev_hop_table (node_id)	67	30541	✖	WithBestIndex	✖
max_hop_ngh (id)	106	29462	✖		
email-EuAll.txt	Create Time	Whole Time			Whole Time
GM_TABLE_UNDIRECT (src_id)	412	155245	✖	NoIndex	149123
prev_hop_table (node_id)	347	158208	✖	WithBestIndex	✖
max_hop_ngh (id)	486	152816	✖		
p2p-Gnutella31.txt	Create Time	Whole Time			Whole Time
GM_TABLE_UNDIRECT (src_id)	94	48675	✖	NoIndex	46756
prev_hop_table (node_id)	114	49863	✖	WithBestIndex	✖
max_hop_ngh (id)	117	47568	✖		
soc-Slashdot0811-75000.txt	Create Time	Whole Time			Whole Time
GM_TABLE_UNDIRECT (src_id)	113	54130	✖	NoIndex	53396
prev_hop_table (node_id)	196	57284	✖	WithBestIndex	✖
max_hop_ngh (id)	129	53106	✖		

Figure 8: Creating Index Experiments on All Radius Algorithm

Connected Component				Combination Choice	
as-skitter.ungraph-75000.txt	Create Time	Whole Time			Whole Time
GM_TABLE_UNDIRECTED (node_id)	846	29178	✔	NoIndex	31738
GM_CC_TEMP (node_id)	115	29616	✔	WithBestIndex	29560
GM_TABLE_UNDIRECTED (node_id)	113	29122	✔		
ca-AstroPh.txt	Create Time	Whole Time			Whole Time
GM_TABLE_UNDIRECTED (node_id)	756	14033	✔	NoIndex	14231
GM_CC_TEMP (node_id)	35	13649	✔	WithBestIndex	13885
GM_TABLE_UNDIRECTED (node_id)	34	13513	✔		
cit-HepPh.txt	Create Time	Whole Time			Whole Time
GM_TABLE_UNDIRECTED (node_id)	796	14657	✔	NoIndex	16102
GM_CC_TEMP (node_id)	58	13135	✔	WithBestIndex	16180
GM_TABLE_UNDIRECTED (node_id)	63	13723	✔		
cit-HepTh.txt	Create Time	Whole Time			Whole Time
GM_TABLE_UNDIRECTED (node_id)	756	13606	✔	NoIndex	15178
GM_CC_TEMP (node_id)	47	13324	✔	WithBestIndex	14283
GM_TABLE_UNDIRECTED (node_id)	46	13168	✔		
com-amazon.ungraph-75000.txt	Create Time	Whole Time			Whole Time
GM_TABLE_UNDIRECTED (node_id)	369	83850	✔	NoIndex	91874
GM_CC_TEMP (node_id)	114	80122	✔	WithBestIndex	79700
GM_TABLE_UNDIRECTED (node_id)	117	78914	✔		
com-dblp.ungraph-75000.txt	Create Time	Whole Time			Whole Time
GM_TABLE_UNDIRECTED (node_id)	754	36159	✔	NoIndex	34391
GM_CC_TEMP (node_id)	115	29657	✔	WithBestIndex	31750
GM_TABLE_UNDIRECTED (node_id)	128	29727	✔		
email-Enron.ungraph.txt	Create Time	Whole Time			Whole Time
GM_TABLE_UNDIRECTED (node_id)	1315	15936	✔	NoIndex	14354
GM_CC_TEMP (node_id)	60	15088	✔	WithBestIndex	15775
GM_TABLE_UNDIRECTED (node_id)	60	14259	✔		
email-EuAll.txt	Create Time	Whole Time			Whole Time
GM_TABLE_UNDIRECTED (node_id)	1641	52163	✔	NoIndex	50984
GM_CC_TEMP (node_id)	213	47881	✔	WithBestIndex	49792
GM_TABLE_UNDIRECTED (node_id)	213	46924	✔		
p2p-Gnutella31.txt	Create Time	Whole Time			Whole Time
GM_TABLE_UNDIRECTED (node_id)	496	11825	✔	NoIndex	12905
GM_CC_TEMP (node_id)	95	10701	✔	WithBestIndex	10795
GM_TABLE_UNDIRECTED (node_id)	98	11060	✔		
soc-Slashdot0811-75000.txt	Create Time	Whole Time			Whole Time
GM_TABLE_UNDIRECTED (node_id)	1520	23275	✔	NoIndex	22870
GM_CC_TEMP (node_id)	126	20600	✔	WithBestIndex	22121
GM_TABLE_UNDIRECTED (node_id)	110	20316	✔		

Figure 9: Creating Index Experiments on Connected Components Algorithm

Degree Distribution				Combination Choice	
as-skitter.ungraph-75000.txt	Create Time	Whole Time			Whole Time
GM_NODE_DEGREES (in_degree)	118.96	210.53	✔	NoIndex	137.54
GM_NODE_DEGREES (out_degree)	170.25	298.91	✔	With✔Index	413.98
ca-AstroPh.txt	Create Time	Whole Time			Whole Time
GM_NODE_DEGREES (in_degree)	39.04	133.09	✔	NoIndex	87.94
GM_NODE_DEGREES (out_degree)	33.01	131.39	✔	WithBestIndex	169.04
cit-HepPh.txt	Create Time	Whole Time			Whole Time
GM_NODE_DEGREES (in_degree)	85.06	207.19	✔	NoIndex	540.9
GM_NODE_DEGREES (out_degree)	111.52	260.08	✔	WithBestIndex	265.35
cit-HepTh.txt	Create Time	Whole Time			Whole Time
GM_NODE_DEGREES (in_degree)	58.83	173.5	✔	NoIndex	739.02
GM_NODE_DEGREES (out_degree)	58.5	435.44	✔	WithBestIndex	194.34
com-amazon.ungraph-75000.txt	Create Time	Whole Time			Whole Time
GM_NODE_DEGREES (in_degree)	142.18	263.03	✔	NoIndex	125.27
GM_NODE_DEGREES (out_degree)	164.74	750.66	✔	WithBestIndex	352.07
com-dblp.ungraph-75000.txt	Create Time	Whole Time			Whole Time
GM_NODE_DEGREES (in_degree)	156.32	270.31	✔	NoIndex	110.62
GM_NODE_DEGREES (out_degree)	124.51	235.19	✔	WithBestIndex	2668.33
email-Enron.ungraph.txt	Create Time	Whole Time			Whole Time
GM_NODE_DEGREES (in_degree)	70.88	193.11	✔	NoIndex	101.54
GM_NODE_DEGREES (out_degree)	105.33	259.64	✔	WithBestIndex	250.97
email-EuAll.txt	Create Time	Whole Time			Whole Time
GM_NODE_DEGREES (in_degree)	426.1	619.24	✔	NoIndex	225.74
GM_NODE_DEGREES (out_degree)	1598.54	1791.75	✔	WithBestIndex	965.82
p2p-Gnutella31.txt	Create Time	Whole Time			Whole Time
GM_NODE_DEGREES (in_degree)	173.58	336.88	✔	NoIndex	138.97
GM_NODE_DEGREES (out_degree)	827.34	1417.15	✔	WithBestIndex	330.83
soc-Slashdot0811-75000.txt	Create Time	Whole Time			Whole Time
GM_NODE_DEGREES (in_degree)	171.23	1507.81	✔	NoIndex	137.84
GM_NODE_DEGREES (out_degree)	152.01	278.07	✔	WithBestIndex	317.91

Figure 10: Creating Index Experiments on Degree Distribution Algorithm

Eigen				Combination Choice	
as-skitter.ungraph-75000.txt	Create Time	Whole Time			Whole Time
% (EVal) + (row_id)	5	66153	✖	NoIndex	69930
% (EVal) + (col_id)	5	70915	✖	WithBestIndex	✖
% (basis_vect_0) + (id)	139		✖		
% (basis_vect_1) + (id)	191	70338	✖		
ca-AstroPh.txt	Create Time	Whole Time			Whole Time
% (EVal) + (row_id)	5	20034	✖	NoIndex	19574
% (EVal) + (col_id)	5	19624	✖	WithBestIndex	✖
% (basis_vect_0) + (id)	39		✖		
% (basis_vect_1) + (id)	52	20021	✖		
cit-HepPh.txt	Create Time	Whole Time			Whole Time
% (EVal) + (row_id)	5	40535	✖	NoIndex	32798
% (EVal) + (col_id)	5	42522	✖	WithBestIndex	✖
% (basis_vect_0) + (id)	60		✖		
% (basis_vect_1) + (id)	88	37508	✖		
cit-HepTh.txt	Create Time	Whole Time			Whole Time
% (EVal) + (row_id)	5	22843	✖	NoIndex	23979
% (EVal) + (col_id)	5	22116	✖	WithBestIndex	✖
% (basis_vect_0) + (id)	54		✖		
% (basis_vect_1) + (id)	70	22393	✖		
com-amazon.ungraph-75000.txt	Create Time	Whole Time			Whole Time
% (EVal) + (row_id)	5	67768	✖	NoIndex	77713
% (EVal) + (col_id)	5	70561	✖	WithBestIndex	✖
% (basis_vect_0) + (id)	123		✖		
% (basis_vect_1) + (id)	170	58789	✖		
com-dblp.ungraph-75000.txt	Create Time	Whole Time			Whole Time
% (EVal) + (row_id)	5	31416	✖	NoIndex	29544
% (EVal) + (col_id)	5	30085	✖	WithBestIndex	✖
% (basis_vect_0) + (id)	79		✖		
% (basis_vect_1) + (id)	239	30129	✖		
email-Enron.ungraph.txt	Create Time	Whole Time			Whole Time
% (EVal) + (row_id)	5	18978	✖	NoIndex	18466
% (EVal) + (col_id)	5	19505	✖	WithBestIndex	✖
% (basis_vect_0) + (id)	61		✖		
% (basis_vect_1) + (id)	87	18322	✖		
email-EuAll.txt	Create Time	Whole Time			Whole Time
% (EVal) + (row_id)	5	56270	✖	NoIndex	57341
% (EVal) + (col_id)	5	54228	✖	WithBestIndex	✖
% (basis_vect_0) + (id)	454		✖		
% (basis_vect_1) + (id)	321	55777	✖		

p2p-Gnutella31.txt	Create Time	Whole Time			Whole Time
% (EVal) + (row_id)	5	368635	✖	NoIndex	90771
% (EVal) + (col_id)	5	244377	✖	WithBestIndex	✖
% (basis_vect_0) + (id)	141		✖		
% (basis_vect_1) + (id)	214	267490	✖		

K-core				Combination Choice	
as-skitter.ungraph-75000.txt	Create Time	Whole Time			Whole Time
GM_TABLE_UNDIRECTED (dst_id)	382	14694		NoIndex	17471
TEMP_GM_TABLE_UNDIRECT (src_id)	63	16723		WithBestIndex	16355
TEMP_GM_TABLE_UNDIRECT (dst_id)	62	14045			
ca-AstroPh.txt	Create Time	Whole Time			Whole Time
GM_TABLE_UNDIRECTED (dst_id)	703	28664		NoIndex	28359
TEMP_GM_TABLE_UNDIRECT (src_id)	19	27934		WithBestIndex	32589
TEMP_GM_TABLE_UNDIRECT (dst_id)	823	27822			
cit-HepPh.txt	Create Time	Whole Time			Whole Time
GM_TABLE_UNDIRECTED (dst_id)	805	28982		NoIndex	31040
TEMP_GM_TABLE_UNDIRECT (src_id)	28	30986		WithBestIndex	33887
TEMP_GM_TABLE_UNDIRECT (dst_id)	712	27733			
cit-HepTh.txt	Create Time	Whole Time			Whole Time
GM_TABLE_UNDIRECTED (dst_id)	637	25921		NoIndex	21903
TEMP_GM_TABLE_UNDIRECT (src_id)	24	22678		WithBestIndex	26026
TEMP_GM_TABLE_UNDIRECT (dst_id)	28	24197			
com-amazon.ungraph-75000.txt	Create Time	Whole Time			Whole Time
GM_TABLE_UNDIRECTED (dst_id)	355	34682		NoIndex	34847
TEMP_GM_TABLE_UNDIRECT (src_id)	89	37735		WithBestIndex	38220
TEMP_GM_TABLE_UNDIRECT (dst_id)	101	33985			
com-dblp.ungraph-75000.txt	Create Time	Whole Time			Whole Time
GM_TABLE_UNDIRECTED (dst_id)	401	22832		NoIndex	21399
TEMP_GM_TABLE_UNDIRECT (src_id)	86	22258		WithBestIndex	23766
TEMP_GM_TABLE_UNDIRECT (dst_id)	166	22398			
email-Enron.ungraph.txt	Create Time	Whole Time			Whole Time
GM_TABLE_UNDIRECTED (dst_id)	613	23353		NoIndex	24937
TEMP_GM_TABLE_UNDIRECT (src_id)	34	27131		WithBestIndex	28229
TEMP_GM_TABLE_UNDIRECT (dst_id)	619	26148			

Figure 12: Creating Index Experiments on K-core Algorithm

PageRank					
as-skitter.ungraph-75000.txt	Create Time	Whole Time			Whole Time
GM_TABLE (src_id)	912	9834	✔	NoIndex	10478.61
norm_table (src_id)	693	9113	✔	WithBestIndex	8821
offset_table (node_id)	154	7273	✔		
GM_PAGERANK (node_id)	269	9627	✔		
ca-AstroPh.txt	Create Time	Whole Time			Whole Time
GM_TABLE (src_id)	1373	8312	✔	NoIndex	8086.47
norm_table (src_id)	844	6294	✔	WithBestIndex	9089
offset_table (node_id)	43	6640	✔		
GM_PAGERANK (node_id)	47	5509	✔		
cit-HepPh.txt	Create Time	Whole Time			Whole Time
GM_TABLE (src_id)	423	7254	✔	NoIndex	9045.31
norm_table (src_id)	1124	8086	✔	WithBestIndex	9394
offset_table (node_id)	67	6647	✔		
GM_PAGERANK (node_id)	67	9074	✔		
cit-HepTh.txt	Create Time	Whole Time			Whole Time
GM_TABLE (src_id)	1086	8797	✔	NoIndex	5930
norm_table (src_id)	1332	9011	✔	WithBestIndex	8067
offset_table (node_id)	52	6467	✔		
GM_PAGERANK (node_id)	57	6061	✔		
com-amazon.ungraph-75000.txt	Create Time	Whole Time			Whole Time
GM_TABLE (src_id)	608	5237	✔	NoIndex	5431
norm_table (src_id)	734	5291	✔	WithBestIndex	6672
offset_table (node_id)	167	4906	✔		
GM_PAGERANK (node_id)	119	5313	✔		
com-dblp.ungraph-75000.txt	Create Time	Whole Time			Whole Time
GM_TABLE (src_id)	290	5272	✔	NoIndex	5244
norm_table (src_id)	933	5773	✔	WithBestIndex	6750
offset_table (node_id)	178	4774	✔		
GM_PAGERANK (node_id)	203	6694	✔		
email-Enron.ungraph.txt	Create Time	Whole Time			Whole Time
GM_TABLE (src_id)	869	18740	✔	NoIndex	20539
norm_table (src_id)	1626	20199	✔	WithBestIndex	19712
offset_table (node_id)	91	16475	✔		
GM_PAGERANK (node_id)	87	19306	✔		
email-EuAll.txt	Create Time	Whole Time			Whole Time
GM_TABLE (src_id)	290	64077	✔	NoIndex	61180
norm_table (src_id)	1375	65333	✔	WithBestIndex	59470
offset_table (node_id)	682	55714	✔		
GM_PAGERANK (node_id)	551	66967	✔		

Figure 13: Creating Index Experiments on PageRank Algorithm

The following are the results of the degree distribution and pagerank results for the ten datasets.

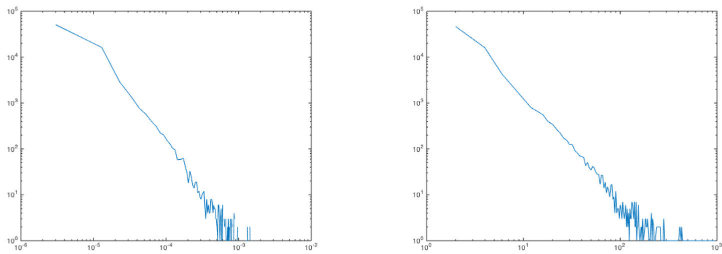


Figure 14: Result on PageRank Algorithm and Degree Distribution

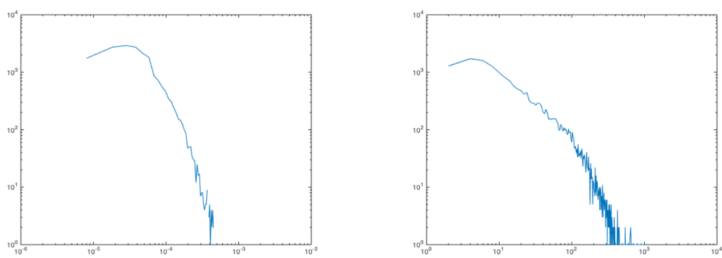


Figure 15: Result on PageRank Algorithm and Degree Distribution

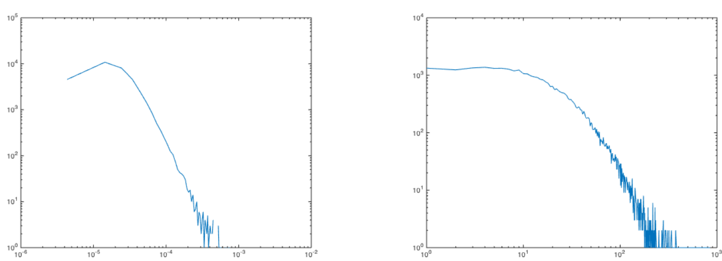


Figure 16: Result on PageRank Algorithm and Degree Distribution

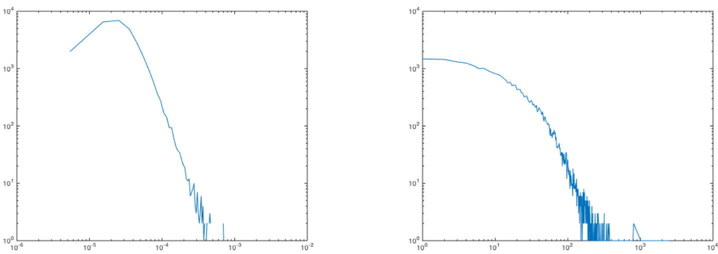


Figure 17: Result on PageRank Algorithm and Degree Distribution

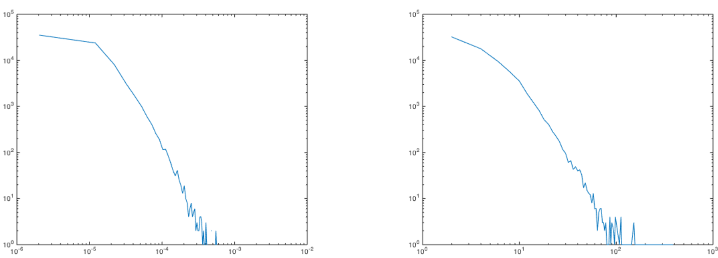


Figure 18: Result on PageRank Algorithm and Degree Distribution

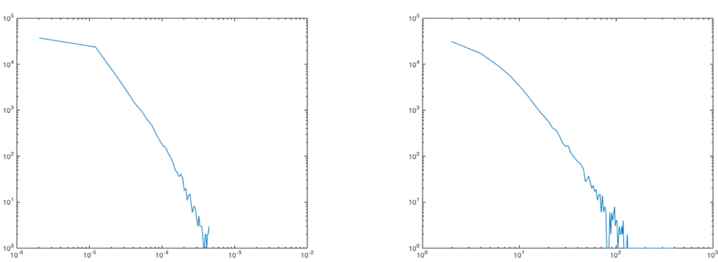


Figure 19: Result on PageRank Algorithm and Degree Distribution

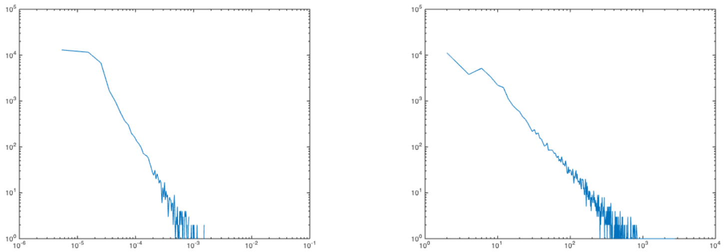


Figure 20: Result on PageRank Algorithm and Degree Distribution

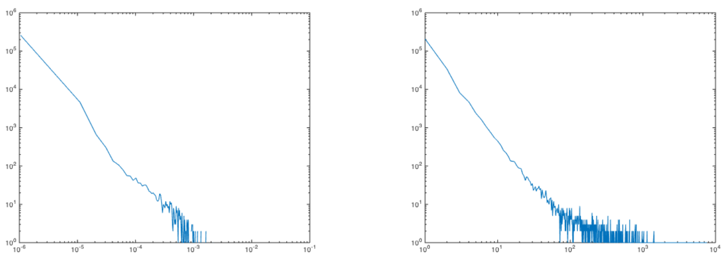


Figure 21: Result on PageRank Algorithm and Degree Distribution

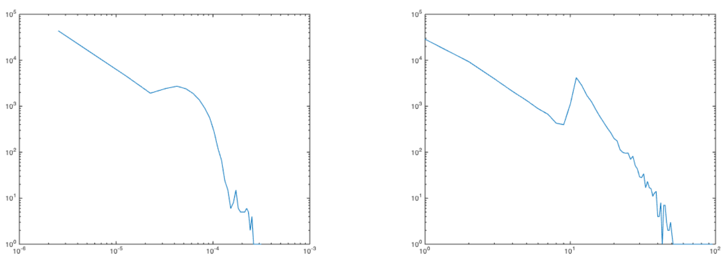


Figure 22: Result on PageRank Algorithm and Degree Distribution

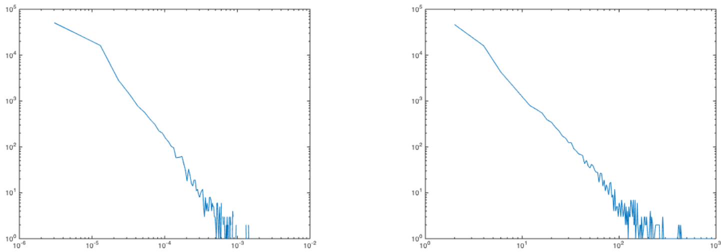


Figure 23: Result on PageRank Algorithm and Degree Distribution

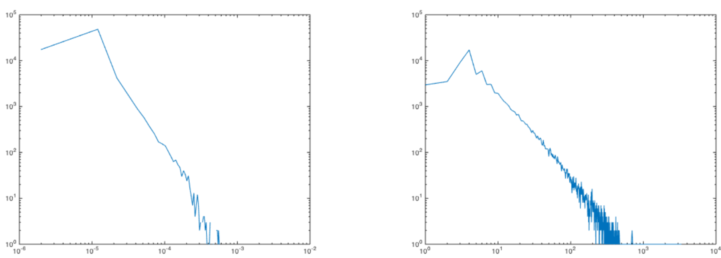


Figure 24: Result on PageRank Algorithm and Degree Distribution

5 Conclusions

Based on the experiments and the implementation of Kcore, we find that the Kcore algorithm can find subgraph structures effectively and we also find that the implemented algorithms in graphMiner, i.e. the pagerank, degree distribution, connected component etc works properly. Above this, we find that using SQL to do basic and advanced graph mining queries are viable and actually effective. We will have future exploration into this to make better use of SQL and advantage of database.

References

[1] U Kang , *PEGASUS: Mining Peta-Scale Graphs*, 3rd ed. ICDM, 2009.

[2] U Kang , *GBASE: an efficient analysis platform for large graphs*, 3rd ed. VLDB, 2012.

[3] U Kang , *HADI: Mining Radii of Large Graphs*, 3rd ed. ACM Transactions on Knowledge Discovery from Data, 2010.

[4] Danai Koutra , *Unifying Guilt-by-Association Approaches: Theorems and Fast Algorithms*, 3rd ed. ECML PKDD, 2011.

[5] Danai Koutra , *k-core decomposition: a tool for the visualization of large scale networks*, 3rd ed. Advances in Neural Information Processing Systems, 2005.

A Appendix

A.1 Labor Division

The team performed the following tasks

- Implementation of Kcore [Jin Hu]
- Unit Tests and visualization of results [Ye Zhou]
- General debugging and testing[Ye Zhou and Jin Hu]

A.2 Acknowledgement

Thanks to Professor Christos Faloutsos for the wonderful lectures on various aspects of multimedia database and data mining topics. Thanks to TA Neil Shah for the careful design of the project and helpful feedback after each phase was completed. Thanks to Nijith Jacob and Sharif Doghmi, who took this class in a previous year for the *graphMiner* framework.

A.3 Dataset and Origin

The realworld datasets are from SNAP, KONECT websites.

```
as-Caida.undir.txt-http://snap.stanford.edu/data/as-caida.html
bio-protein-undir.txt-http://konect.uni-koblenz.de/networks/moreno_propro
cit-Cora.txt-http://konect.uni-koblenz.de/networks/subelj_cora
soc-digg.txt-http://konect.uni-koblenz.de/networks/munmun_digg_reply
soc-flickr-75000.txt-http://konect.uni-koblenz.de/networks/flickr-growth
soc-hamsterster.undir.txt-http://konect.uni-koblenz.de/networks/petster-friendships-h
soc-pokec-75000.txt-http://snap.stanford.edu/data/soc-pokec.html
soc-Youtube-75000.undir.txt-http://konect.uni-koblenz.de/networks/com-youtube
soft-jdkdependency.txt-http://konect.uni-koblenz.de/networks/subelj_jdk
text-spanishbook.txt-http://konect.uni-koblenz.de/networks/lasagne-spanishbook
as-skitter.ungraph-75000.txt-http://konect.uni-koblenz.de/networks/as-skitter
ca-AstroPh.txt-http://konect.uni-koblenz.de/networks/ca-AstroPh
cit-HepPh.txt-http://konect.uni-koblenz.de/networks/cit-HepPh
cit-HepTh.txt-http://konect.uni-koblenz.de/networks/cit-HepTh
com-amazon.ungraph-75000.txt-http://snap.stanford.edu/data/com-Amazon.html
com-dblp.ungraph-75000.txt-http://snap.stanford.edu/data/com-DBLP.html
email-Enron.ungraph.txt-http://snap.stanford.edu/data/email-Enron.html
email-EuAll.txt-http://snap.stanford.edu/data/email-EuAll.html
p2p-Gnutella31.txt-http://snap.stanford.edu/data/p2p-Gnutella31.html
soc-Slashdot0811-75000.txt-http://snap.stanford.edu/data/soc-Slashdot0811.
html
```

A.4 Code for K-core

```
import argparse

from gm_params import *
from gm_sql import *
from math import sqrt
import os
import time

db_conn = None;


# Convert directed to undirected + remove multiple edges
def gm_to_undirected(rm_multiple = True):
    cur = db_conn.cursor()
    gm_sql_table_drop_create(db_conn, GM_TABLE_UNDIRECT, "src_id integer, dst

    if rm_multiple:
        stmt = "INSERT INTO %s " % (GM_TABLE_UNDIRECT) + \
                    " SELECT src_id, dst_id, AVG(weight) FROM " + \
                    " (SELECT src_id, dst_id, weight FROM %s " % (GM_TABLE) +
                    " UNION ALL" + \
                    " SELECT dst_id \"src_id\", src_id \"dst_id\", weight FRO
                    " GROUP BY src_id, dst_id"
    else:
        stmt = "INSERT INTO %s " % (GM_TABLE_UNDIRECT) + \
                    " (SELECT src_id, dst_id, weight FROM %s " % (GM_TABLE) +
                    " UNION ALL" + \
                    " SELECT dst_id \"src_id\", src_id \"dst_id\", weight FRO


    cur.execute(stmt)
    db_conn.commit()

    cur.close()

def gm_create_node_table ():
    cur = db_conn.cursor()

    gm_sql_table_drop_create(db_conn, GM_NODES, "node_id integer")
```

```
    cur.execute ("INSERT INTO %s" % GM_NODES +
                      " SELECT DISTINCT(src_id) FROM %s" % GM_TABLE_UN

    db_conn.commit()

    cur.close()

def gm_save_tables (dest_dir, belief):
    print "Saving tables..."

    gm_sql_save_table_to_file(db_conn, GM_DEGREE_DISTRIBUTION, "degree, count
                              os.path.join(dest_dir,"degreedist.csv"), ",
    gm_sql_save_table_to_file(db_conn, GM_INDEGREE_DISTRIBUTION, "degree, cou
                              os.path.join(dest_dir,"indegreedist.csv"),
    gm_sql_save_table_to_file(db_conn, GM_OUTDEGREE_DISTRIBUTION, "degree, co
                              os.path.join(dest_dir,"outdegreedist.csv"),

    gm_sql_save_table_to_file(db_conn, GM_NODE_DEGREES, "node_id, in_degree,
                              os.path.join(dest_dir,"degree.csv"), ",");

    gm_sql_save_table_to_file(db_conn, GM_PAGERANK, "node_id, page_rank", \
                              os.path.join(dest_dir,"pagerank.csv"), ",")


    gm_sql_save_table_to_file(db_conn, GM_CON_COMP, "node_id, component_id",
                              os.path.join(dest_dir,"conncomp.csv"), ",")

    gm_sql_save_table_to_file(db_conn, GM_RADIUS, "node_id, radius", \
                              os.path.join(dest_dir,"radius.csv"), ",");

    if (belief):
        gm_sql_save_table_to_file(db_conn, GM_BELIEF, "node_id, belief", \
                              os.path.join(dest_dir,"belief.csv"), ",");

    gm_sql_save_table_to_file(db_conn, GM_EIG_VALUES, "id, value", \
                              os.path.join(dest_dir,"eigval.csv"), ",");

    gm_sql_save_table_to_file(db_conn, GM_EIG_VECTORS, "row_id, col_id, value
                              os.path.join(dest_dir,"eigvec.csv"), ",");


def kcore (args):
```

```
global db_conn
global GM_TABLE
#Default Table names
TEMP_GM_TABLE = "TEMP_GM_TABLE"
TEMP_GM_TABLE_UNDIRECT = "TEMP_GM_TABLE_UNDIRECTED"
TEMP_GM_NODES = "TEMP_GM_NODES"
TEMP_GM_NODE_DEGREES = "TEMP_GM_NODE_DEGREES"
REMOVED_NODE_TABLE = "REMOVED_NODE_TABLE"
TEMP_GM_CON_COMP = "TEMP_GM_CON_COMP"
temp_table = "GM_CC_TEMP"
TEMP_GM_CON_COMP_2 = "TEMP_GM_CON_COMP_2"
cur = db_conn.cursor()
k = 5
i = 2
# create REMOVED_NODE_TABLE to record deleted node_id
gm_sql_table_drop_create(db_conn, REMOVED_NODE_TABLE, "node_id integer")
# create TEMP_GM_NODE_DEGREES
gm_sql_table_drop_create(db_conn, TEMP_GM_NODE_DEGREES, "node_id integer, \
                         in_degree integer, out_degree integer")
gm_sql_table_drop_create(db_conn, TEMP_GM_TABLE, "src_id integer, dst_id in
cur.execute ("INSERT INTO %s" % TEMP_GM_TABLE + " SELECT src_id, dst_id, we
cur.execute ("INSERT INTO %s" % TEMP_GM_NODE_DEGREES + " SELECT node_id, in
db_conn.commit()
print "begin kcore iteration..."
while(i<=5):
  cur.execute ("INSERT INTO %s" % REMOVED_NODE_TABLE +
              " SELECT node_id FROM %s" % TEMP_GM_NODE_DEGREES + " WHERE
  # remove degree < i nodes and associated edges in GM_TABLE and GM_TABLE_U
  gm_sql_table_drop_create(db_conn, TEMP_GM_TABLE, "src_id integer, dst_id
  gm_sql_table_drop_create(db_conn, TEMP_GM_TABLE_UNDIRECT, "src_id integer
  gm_sql_table_drop_create(db_conn, TEMP_GM_NODES, "node_id integer")
  cur.execute ("INSERT INTO %s" % TEMP_GM_NODES +
                           " SELECT DISTINCT(src_id) FROM %s" % GM_TABLE_UN
  cur.execute ("INSERT INTO %s" % TEMP_GM_TABLE + " SELECT src_id, dst_id,
  cur.execute ("INSERT INTO %s" % TEMP_GM_TABLE_UNDIRECT + " SELECT src_id,
  db_conn.commit()

  # Recomputing node degrees..."
  gm_sql_table_drop_create(db_conn, TEMP_GM_NODE_DEGREES, "node_id integer,
                           in_degree integer, out_degree integer")
  cur.execute ("INSERT INTO %s" % TEMP_GM_NODE_DEGREES +
                           " SELECT node_id, SUM(in_degree) \"in_degree\",
```

```
                              " (SELECT dst_id \"node_id\", count(*) \"in_degr
                                0 \"out_degree\" FROM %s" % TEMP_GM_TABLE +
                              " GROUP BY dst_id" +
                              " UNION ALL" +
                              " SELECT src_id \"node_id\", 0 \"in_degree\", \
                                count(*) \"out_degree\" FROM %s" % TEMP_GM_TAB
                              " GROUP BY src_id) \"TAB\" " +
                              " GROUP BY node_id")
        db_conn.commit()
        # print "iteration when i=", i
        # gm_sql_print_table(db_conn, REMOVED_NODE_TABLE)
        # print "TEMP_GM_NODES"
        # gm_sql_print_table(db_conn, TEMP_GM_NODES)
        # print "TEMP_GM_TABLE"
        # gm_sql_print_table(db_conn, TEMP_GM_TABLE)
        # print "TEMP_GM_NODE_DEGREES"
        # gm_sql_print_table(db_conn, TEMP_GM_NODE_DEGREES)
        i = i+1

    # gm_sql_print_table(db_conn, TEMP_GM_NODES)
    # print "finish kcore iteration, now calculate connected components"
    # gm_sql_print_table(db_conn, TEMP_GM_NODE_DEGREES)

    # Connected components
    # Create CC table and initialize component id to node id

    gm_sql_create_and_insert(db_conn, TEMP_GM_CON_COMP, GM_NODES, \
                            "node_id integer, component_id integer", \
                            "node_id, component_id", "node_id, node_id")
    # gm_sql_print_table(db_conn, TEMP_GM_TABLE_UNDIRECT)
    while True:
        gm_sql_table_drop_create(db_conn, temp_table,"node_id integer, componen
        # Set component id as the min{component ids of neighbours, node's compo
        cur.execute("INSERT INTO %s " % temp_table +
                          " SELECT node_id, MIN(component_id) \"component_id\
                              " SELECT src_id \"node_id\", MIN(component_id)
                              " WHERE dst_id = node_id GROUP BY src_id" +
                              " UNION" +
                              " SELECT * FROM %s" %  TEMP_GM_CON_COMP +
                          " ) \"T\" GROUP BY node_id")
        db_conn.commit()
        diff = gm_sql_vect_diff(db_conn, TEMP_GM_CON_COMP, temp_table, "node_id
```

```
        # Copy the new component ids to the component id table
        gm_sql_create_and_insert(db_conn, TEMP_GM_CON_COMP, temp_table, \
                                "node_id integer, component_id integer", \
                                "node_id, component_id", "node_id, componen
        print "Error = " + str(diff)
        # Check whether the component ids has converged
        if (diff == 0):
            print "Component IDs has converged"
            break
    cur.execute ("SELECT count(distinct component_id) FROM %s" % TEMP_GM_CON_CO
    num_components = cur.fetchone()[0]
    print "Number of Components =", num_components
    print "Now output decomposition (node_id,component_id) pairs"
    cur.execute ("SELECT node_id, component_id FROM %s" % TEMP_GM_CON_COMP + "
    for x in cur:
        print x
    print "finished kcore, writing to files"
    gm_sql_table_drop_create(db_conn, TEMP_GM_CON_COMP_2,"node_id integer, comp
    cur.execute ("INSERT INTO %s" % TEMP_GM_CON_COMP_2 + " SELECT node_id, comp
    gm_sql_save_table_to_file(db_conn, TEMP_GM_CON_COMP_2, "node_id, component_
                              os.path.join(args.dest_dir,"kcore_conncomp.cs
    # Drop temp tables
    gm_sql_table_drop(db_conn, temp_table)
    gm_sql_table_drop(db_conn, TEMP_GM_CON_COMP)
    cur.close()
    return

#Project Tasks

#Task 1: Degree distribution
#----------------------------------------------------------------------------
def gm_node_degrees():
    cur = db_conn.cursor()

    # Create Table to store node degrees
    # If the graph is undirected, all the degree values will be the same
    print "Computing Node degrees..."

    gm_sql_table_drop_create(db_conn, GM_NODE_DEGREES, "node_id integer, \
                             in_degree integer, out_degree integer")

    cur.execute ("INSERT INTO %s" % GM_NODE_DEGREES +
```

```
                              " SELECT node_id, SUM(in_degree) \"in_degree\",
                              " (SELECT dst_id \"node_id\", count(*) \"in_degr
                                0 \"out_degree\" FROM %s" % GM_TABLE +
                              " GROUP BY dst_id" +
                              " UNION ALL" +
                              " SELECT src_id \"node_id\", 0 \"in_degree\", \
                                count(*) \"out_degree\" FROM %s" % GM_TABLE +
                              " GROUP BY src_id) \"TAB\" " +
                              " GROUP BY node_id")
    db_conn.commit()

    cur.close()


# Degree distribution
def gm_degree_distribution (undirected):

    cur = db_conn.cursor()
    print "Computing Degree distribution of the nodes..."

    gm_sql_table_drop_create(db_conn, GM_DEGREE_DISTRIBUTION, "degree integer
    gm_sql_table_drop_create(db_conn, GM_INDEGREE_DISTRIBUTION, "degree integ
    gm_sql_table_drop_create(db_conn, GM_OUTDEGREE_DISTRIBUTION, "degree inte

    cur.execute ("INSERT INTO %s" % GM_INDEGREE_DISTRIBUTION +
                             " SELECT in_degree \"degree\", count(*) FROM %s"
                             " GROUP BY in_degree");

    cur.execute ("INSERT INTO %s" % GM_OUTDEGREE_DISTRIBUTION +
                             " SELECT out_degree \"degree\", count(*) FROM %s"
                             " GROUP BY out_degree");

    if (undirected):
        # Degree distribution is same as in/out degree distribution for undir
        cur.execute ("INSERT INTO %s" % GM_DEGREE_DISTRIBUTION +
                             " SELECT * FROM %s" % GM_INDEGREE_DISTRIBUTION);
    else:
        cur.execute ("INSERT INTO %s" % GM_DEGREE_DISTRIBUTION +
                             " SELECT in_degree+out_degree \"degree\", count(*
                             " GROUP BY in_degree+out_degree");

    db_conn.commit()
```

```
    cur.close()

# Task 2: PageRank
# ----------------------------------------------------------------------------#
def gm_pagerank (num_nodes, max_iterations = gm_param_pr_max_iter, \
                    stop_threshold = gm_param_pr_thres, damping_factor = gm_p

    offset_table = "GM_PR_OFFSET"
    next_table = "GM_PR_NEXT"
    norm_table = "GM_PR_NORM"

    cur = db_conn.cursor();
    print "Computing PageRanks..."

    gm_sql_table_drop_create(db_conn, norm_table," src_id integer, dst_id inte

    # Create normalized weighted table
    cur.execute("INSERT INTO %s " % norm_table +
          " SELECT src_id, dst_id, weight/weight_sm \"weight\" FROM %s \"TA
          " (SELECT src_id \"node_id\", sum(weight) \"weight_sm\" FROM %s G
          " WHERE \"TAB1\".src_id = \"TAB2\".node_id")
    db_conn.commit();

    # Create PageRank Table and initialize to 1/n
    gm_sql_create_and_insert(db_conn, GM_PAGERANK, GM_NODES, \
                             "node_id integer, page_rank double precision def
                             "node_id", "node_id")

    # Create offset table and initialize to 1-c/n
    gm_sql_create_and_insert(db_conn, offset_table, GM_NODES, \
                             "node_id integer, page_rank double precision def
                             "node_id", "node_id")
    num_iterations = 0
    while True:
        # Create Table to store the next pageRank
        gm_sql_table_drop_create(db_conn, next_table," node_id integer, page_r

        # Compute Next PageRank
        cur.execute ("INSERT INTO %s " % next_table +
                               " SELECT node_id, SUM(page_rank) FROM (" +
                               " SELECT dst_id \"node_id\", SUM(%s*weight*pa
                               " FROM %s, %s" % (norm_table, GM_PAGERANK) +
```

```
                                    " WHERE src_id = node_id GROUP BY dst_id" +
                                    " UNION ALL" +
                                    " SELECT node_id, page_rank * val \"page_rank
                                    " FROM %s, (SELECT SUM(page_rank) \"val\" FRO
                                    " ) \"TAB\" GROUP BY node_id" )

        db_conn.commit()

        diff = gm_sql_vect_diff(db_conn, GM_PAGERANK, next_table, \
                                    "node_id", "node_id", "page_rank", "page_rank

        # Copy the new page rank to the page rank table
        gm_sql_create_and_insert(db_conn, GM_PAGERANK, next_table, \
                                        "node_id integer, page_rank double precis
                                        "node_id, page_rank", "node_id, page_rank

        num_iterations = num_iterations + 1
        print "Iteration = %d, Error = %f" % (num_iterations, diff)

        if (diff<=stop_threshold or num_iterations>=max_iterations):
            break

    # Drop temp tables
    gm_sql_table_drop(db_conn, offset_table)
    gm_sql_table_drop(db_conn, next_table)
    gm_sql_table_drop(db_conn, norm_table)

    cur.close()

# Task 3: Weakly Connected Components
#------------------------------------------------------------------------------#
def gm_connected_components (num_nodes):
    temp_table = "GM_CC_TEMP"
    cur = db_conn.cursor()
    print 'Computing Weakly Connected Components...'

    # Create CC table and initialize component id to node id
    gm_sql_create_and_insert(db_conn, GM_CON_COMP, GM_NODES, \
                                "node_id integer, component_id integer", \
                                "node_id, component_id", "node_id, node_id")

    while True:
```

```
        gm_sql_table_drop_create(db_conn, temp_table,"node_id integer, compo

        # Set component id as the min{component ids of neighbours, node's com
        cur.execute("INSERT INTO %s " % temp_table +
                                " SELECT node_id, MIN(component_id) \"component_i
                                    " SELECT src_id \"node_id\", MIN(component_id
                                    " WHERE dst_id = node_id GROUP BY src_id" +
                                    " UNION" +
                                    " SELECT * FROM %s" % GM_CON_COMP +
                                " ) \"T\" GROUP BY node_id")
        db_conn.commit()

        diff = gm_sql_vect_diff(db_conn, GM_CON_COMP, temp_table, "node_id",

        # Copy the new component ids to the component id table
        gm_sql_create_and_insert(db_conn, GM_CON_COMP, temp_table, \
                                        "node_id integer, component_id integer",
                                        "node_id, component_id", "node_id, compo

        print "Error = " + str(diff)
        # Check whether the component ids has converged
        if (diff == 0):
            print "Component IDs has converged"
            break

    cur.execute ("SELECT count(distinct component_id) FROM %s" % GM_CON_COMP)
    num_components = cur.fetchone()[0]

    print "Number of Components =", num_components
    cur.close()

    # Drop temp tables
    gm_sql_table_drop(db_conn, temp_table)

# Task 4: Radius of every node
#------------------------------------------------------------------------------#
def gm_all_radius (num_nodes, max_iter = gm_param_radius_max_iter):

    hop_table = "GM_RD_HOP"
    max_hop_ngh = "GM_RD_MAX_HOP_NGH"

    cur = db_conn.cursor()
```

```
print 'Computing radius of every node...'

# initialize hop 0 table's hash
gm_sql_create_and_insert(db_conn, hop_table+"0", GM_NODES, \
                         "node_id integer, hash integer", \
                         "node_id, hash", "node_id, (((node_id%%%s+1)#(no

for cur_hop in range(1,max_iter+1):
    print "Hop number : " + str(cur_hop)

    # create ith hop table
    cur_hop_table = hop_table+str(cur_hop)
    prev_hop_table = hop_table+str(cur_hop-1)
    gm_sql_table_drop_create(db_conn, cur_hop_table,"node_id integer, has
    cur.execute("INSERT INTO %s " % cur_hop_table +
                        " SELECT node_id, bit_or(hash) FROM ( " +
                        " SELECT src_id \"node_id\", bit_or(hash) \"hash\
                        " FROM %s,%s" % (GM_TABLE_UNDIRECT, prev_hop_tabl
                        " WHERE dst_id = node_id GROUP BY src_id " +
                        " UNION ALL" +
                        " SELECT * FROM %s ) \"TAB\" GROUP BY node_id" %
    db_conn.commit()

    # Check convergence
    diff = gm_sql_vect_diff(db_conn, cur_hop_table, prev_hop_table, "node

    print "Current Error = " + str(diff)
    if (diff==0):
        print "Convergence acheived"
        break

nghbourhd_func = "2^(floor(log(2,hash)+1))/0.77351"
gm_sql_create_and_insert(db_conn, max_hop_ngh, cur_hop_table, \
                         "id integer, value double precision", \
                         "id, value", "node_id, %s" % (nghbourhd_func))



gm_sql_table_drop_create(db_conn, GM_RADIUS,"node_id integer, radius inte

for i in range(0,cur_hop+1):
    print "Getting nodes with eff. radius " + str(i)
```

```
        # effective radius is the hop at which neighbour fucntion value excee
        # 0.9 * the value at max hop
        cur.execute("INSERT INTO %s" % GM_RADIUS +
                    " SELECT node_id, %s \"radius\" FROM %s, %s " % (i, h
                    " WHERE node_id = id AND %s>=0.9*value " % (nghbourho

        db_conn.commit()
        cur.execute("DELETE FROM %s WHERE id IN(SELECT node_id FROM %s)" % (n
        db_conn.commit()


    cur.execute ("SELECT max(radius) FROM %s" % GM_RADIUS)
    max_radius = cur.fetchone()[0]
    print "Maximum effective radius =", max_radius

    # drop temp tables
    gm_sql_table_drop(db_conn, max_hop_ngh)
    for i in range(0,cur_hop+1):
        gm_sql_table_drop(db_conn, hop_table+str(i))


    cur.close()

# Task 5: Eigen values
# ------------------------------------------------------------------------ #
# The adjacency matrix should be symmetric

def gm_eigen_QR_decompose(T, n, Q, R):
    G = "GM_QR_DECOMPOSE_GIVENS"
    temp_table = "GM_QR_DECOMPOSE_TEMP"
    I = "GM_QR_DECOMPOSE_IDENTITY"

    cur = db_conn.cursor();

    gm_sql_table_drop_create(db_conn, R,"row_id integer, col_id integer, valu

    # Initialize R = T
    cur.execute("INSERT INTO %s" % (R) + " SELECT * FROM %s" % (T))
    db_conn.commit()


    for i in range(1,n):
```

```
    # Compute the givens matrix
    cur.execute("SELECT value FROM %s " % (R) +
                "WHERE col_id = %s AND row_id >= %s ORDER BY row_id"

    c = cur.fetchone()[0]
    s = cur.fetchone()[0]
    r = sqrt(c*c + s*s)
    c = c/r
    s = -s/r

    gm_sql_table_drop_create(db_conn, G,"row_id integer, col_id integer,
    cur.execute("INSERT INTO %s" % (G) + " SELECT * FROM %s" % (I))
    cur.execute('UPDATE %s' % (G) + ' SET value = %s WHERE row_id = %s AN
    cur.execute('UPDATE %s' % (G) + ' SET value = %s WHERE row_id = %s AN
    cur.execute('INSERT INTO %s' % (G) + ' VALUES (%s,%s,%s)' %(str(i),st
    cur.execute('INSERT INTO %s' % (G) + ' VALUES (%s,%s,%s)' %(str(i+1),
    db_conn.commit()

    # Compute Q
    if i == 1:
        # insert G*
        gm_sql_table_drop_create(db_conn, Q,"row_id integer, col_id integ
        cur.execute("INSERT INTO %s" % (Q) + " SELECT \"col_id\" row_id,
    else:
        gm_sql_table_drop_create(db_conn, temp_table,"row_id integer, col
        gm_sql_mat_mat_multiply (db_conn, Q, G, temp_table, "col_id", "co
                                "value", "row_id", "row_id", "ro
        gm_sql_table_drop_create(db_conn, Q,"row_id integer, col_id integ
        cur.execute("INSERT INTO %s" % (Q) + " SELECT * FROM %s" % (temp_

    db_conn.commit()
    # Compute R
    gm_sql_table_drop_create(db_conn, temp_table,"row_id integer, col_id
    gm_sql_mat_mat_multiply (db_conn, G, R, temp_table, "col_id", "row_id
                            "value", "row_id", "col_id", "ro
    gm_sql_table_drop_create(db_conn, R,"row_id integer, col_id integer,
    cur.execute("INSERT INTO %s" % (R) + " SELECT * FROM %s" % (temp_tabl

    db_conn.commit()

cur.close()
# Drop temp tables
```

```
    gm_sql_table_drop(db_conn, G)

    gm_sql_table_drop(db_conn, temp_table)



def gm_eigen_QR_iterate(T, n, EVal, EVec, steps, err):

    Q = "GM_QR_Q"
    R = "GM_QR_R"
    temp_table = "GM_QR_TEMP"
    I = "GM_QR_DECOMPOSE_IDENTITY"
    print 'Performing QR Algorithm. Max Iters=%s, Stop threshold=%s' % (steps

    cur = db_conn.cursor();

    gm_sql_table_drop_create(db_conn, EVal,"row_id integer, col_id integer, v
    gm_sql_table_drop_create(db_conn, EVec,"row_id integer, col_id integer, v

    gm_sql_table_drop_create(db_conn, I,"row_id integer, col_id integer, valu
    gm_sql_load_table(db_conn, I, [str(i) + " " + str(i) + " " + str(1) for i

    cur.execute("INSERT INTO %s" % (EVal) + " SELECT * FROM %s" % (T))
    db_conn.commit()

    for i in range(1,steps+1):

        try:
            gm_eigen_QR_decompose(EVal, n, Q, R)
        except psycopg2.DataError:
            db_conn.commit()
            break

        gm_sql_table_drop_create(db_conn, EVal,"row_id integer, col_id intege

        # Set EVal as RQ
        gm_sql_mat_mat_multiply (db_conn, R, Q, EVal, "col_id", "row_id", "va
                                            "value", "row_id", "col_id", "ro

        if i==1:
            # Copy Q to EVec
            cur.execute("INSERT INTO %s" % (EVec) + " SELECT * FROM %s" % (Q)
```

```
            db_conn.commit()
        else:
            # Set EVec = EVec * Q
            gm_sql_table_drop_create(db_conn, temp_table,"row_id integer, col
            gm_sql_mat_mat_multiply (db_conn, EVec, Q, temp_table, "col_id",
                                            "value", "row_id", "col_id", "ro

            gm_sql_table_drop_create(db_conn, EVec,"row_id integer, col_id in
            cur.execute("INSERT INTO %s" % (EVec) + " SELECT * FROM %s" % (te
            db_conn.commit()

            cur.execute("SELECT max(abs(value)) FROM %s" % (EVal) + " WHERE r
            cur_err = cur.fetchone()[0]

            print "QR Algorithm Error = %s" % cur_err
            if cur_err <= err:
                break

    cur.close()

    # Drop temp tables
    gm_sql_table_drop(db_conn, Q)
    gm_sql_table_drop(db_conn, R)
    gm_sql_table_drop(db_conn, temp_table)
    gm_sql_table_drop(db_conn, I)



def gm_eigen (steps, num_nodes, err1, err2, adj_table=GM_TABLE_UNDIRECT):

    QR_max_iter = gm_param_qr_max_iter
    QR_stop_threshold = gm_param_qr_thres

    basis_vect_0 = "GM_EG_BASIS_VECT0"
    basis_vect_1 = "GM_EG_BASIS_VECT1"
    next_basis_vect = "GM_EG_BASIS_VECT_NEXT"
    temp_vect = "GM_EG_TEMP_VECT"
    temp_vect2 = "GM_EG_TEMP_VECT2"
    temp_vect3 = "GM_EG_TEMP_VECT3"
    basis = "GM_EG_BASIS"
    tridiag_table = "GM_EG_TRIDIAGONAL"
    diag_table = "GM_EG_DIAG"
```

```
eigvec_table = "GM_EG_VEC"

cur = db_conn.cursor();
print "Computing Eigenvalues..."

# create basis vectors
gm_sql_vector_random(db_conn, basis_vect_1)
gm_sql_create_and_insert(db_conn, basis_vect_0, GM_NODES, \
                        "id integer, value double precision", \
                        "id, value", "node_id, 0")

# Create table to store the basis vectors
gm_sql_table_drop_create(db_conn, basis,"row_id integer, col_id integer,

gm_sql_table_drop_create(db_conn, tridiag_table,"row_id integer, col_id i

beta_0 = 0
beta_1 = 0
alph_1 = 0

for i in range(1, steps+1):
    print "Iteration No: " + str(i)

    # Get the next basis
    gm_sql_table_drop_create(db_conn, next_basis_vect,"id integer, value
    gm_sql_adj_vect_multiply(db_conn, adj_table, basis_vect_1, next_basis
                            "id", "id", "value", "value", "src_id")

    alph_1 = gm_sql_vect_dotproduct (db_conn, next_basis_vect, basis_vect

    gm_sql_table_drop_create(db_conn, temp_vect,"id integer, value double
    # Orthogonalize with previous two basis vectors
    cur.execute("INSERT INTO %s " % (temp_vect) +
                " (SELECT \"VECT_NEW\".id, " +
                " (\"VECT_NEW\".value - (%s * \"VECT_0\".value) - (%s
                                                        (beta_0, alph
                " FROM %s \"VECT_NEW\", %s \"VECT_0\", %s \"VECT_1\"
                                                        (next_basis_v
                " WHERE \"VECT_NEW\".id = \"VECT_0\".id AND \"VECT_0\

    db_conn.commit()
```

```
# Insert values into the tridiagonal table
cur.execute("INSERT INTO %s" % (tridiag_table) + " VALUES(%s,%s,%s)"
if i>1:
    cur.execute("INSERT INTO %s" % (tridiag_table) + " VALUES(%s,%s,%
    cur.execute("INSERT INTO %s" % (tridiag_table) + " VALUES(%s,%s,%

db_conn.commit()

# Save the basis vector
cur.execute("INSERT INTO %s " % (basis) +
            "SELECT id \"row_id\", %s \"col_id\", value " % (i) +
            "FROM %s" % (basis_vect_1))

db_conn.commit()

if i>1:
    gm_eigen_QR_iterate(tridiag_table, i, diag_table, eigvec_table, Q

    for j in range(1,i+1):
        cur.execute("SELECT abs(value) FROM %s" % (eigvec_table) +
                    " WHERE col_id=%s AND row_id=%s" % (j,i))

        thr = cur.fetchone()
        if thr:
            thr = thr[0]
        else:
            thr = 0

        if thr <= err1:
            print "Performing SO with EigenVector " + str(j)
            # Get corresponding eigenvector
            gm_sql_table_drop_create(db_conn, temp_vect2,"id integer,

            gm_sql_mat_colvec_multiply (db_conn, basis, eigvec_table,
                            "id", "value", "value", "value", "row_id"

            # Selectively orthogonalize
            r = gm_sql_vect_dotproduct (db_conn, temp_vect2, temp_vec

            gm_sql_table_drop_create(db_conn, temp_vect3,"id integer,
            cur.execute("INSERT INTO %s " % (temp_vect3) +
                    " (SELECT \"VECT1\".id, " +
```

```
                              " (\"VECT1\".value - (%s * \"VECT2\".value))
                              " FROM %s \"VECT1\", %s \"VECT2\" " % (temp_v
                              " WHERE \"VECT1\".id = \"VECT2\".id)")

                db_conn.commit()

                gm_sql_table_drop_create(db_conn, temp_vect,"id integer,
                cur.execute("INSERT INTO %s" % (temp_vect) + " SELECT * F

                db_conn.commit()

        beta_1 = gm_sql_normalize_vector (db_conn, temp_vect, "value");


        if abs(beta_1) <= err2:
            break

        # Prepare for next iteration
        gm_sql_table_drop_create(db_conn, basis_vect_0,"id integer, value dou
        cur.execute("INSERT INTO %s" % (basis_vect_0) + " SELECT * FROM %s" %
        db_conn.commit()

        gm_sql_table_drop_create(db_conn, basis_vect_1,"id integer, value dou
        cur.execute("INSERT INTO %s" % (basis_vect_1) + " SELECT * FROM %s" %
        db_conn.commit()

        beta_0 = beta_1

    # Get the eigen values and eigen vectors
    gm_eigen_QR_iterate(tridiag_table, i, diag_table, eigvec_table, QR_max_it

    gm_sql_table_drop_create(db_conn, GM_EIG_VALUES,"id integer, value double

    print "Getting EigenValues..."
    # Get top eigen values
    cur.execute("INSERT INTO %s" % (GM_EIG_VALUES) +
                " SELECT col_id \"id\", value \"value\" FROM %s" % (diag_
                " WHERE col_id = row_id ORDER BY abs(value) desc")

    db_conn.commit()

    # Get the top k eigenvectors
```

```
    print "Getting top %s EigenVectors..." % gm_param_eig_k
    cur2 = db_conn.cursor();
    gm_sql_table_drop_create(db_conn, GM_EIG_VECTORS,"row_id integer, col_id

    cur.execute("SELECT id FROM %s ORDER BY abs(value) desc LIMIT %s " % (GM
    for idx in cur:
        i = idx[0]
        print "Getting eigenvector %s" % i
        gm_sql_table_drop_create(db_conn, temp_vect2,"id integer, value doubl
        gm_sql_mat_colvec_multiply (db_conn, basis, eigvec_table, temp_vect2,
                                "id", "value", "value", "value", "row_id", "c

        cur2.execute("INSERT INTO %s SELECT id \"row_id\", %s \"col_id\", val
                                " FROM %s" % (temp_vect2))
        db_conn.commit()

    cur2.close()

#
#     gm_sql_mat_mat_multiply (db_conn, basis, eigvec_table, GM_EIG_VECTORS, "
#                                                "value", "row_id", "col_id", "r

    print "EigenValues computed: "
    gm_sql_print_table(db_conn, GM_EIG_VALUES)
    #gm_sql_print_table(db_conn, GM_EIG_VECTORS)

    cur.close()
    # Drop temp tables
    gm_sql_table_drop(db_conn, basis_vect_0)
    gm_sql_table_drop(db_conn, basis_vect_1)
    gm_sql_table_drop(db_conn, next_basis_vect)
    gm_sql_table_drop(db_conn, temp_vect)
    gm_sql_table_drop(db_conn, temp_vect2)
    gm_sql_table_drop(db_conn, temp_vect3)
    gm_sql_table_drop(db_conn, basis)
    gm_sql_table_drop(db_conn, tridiag_table)
    gm_sql_table_drop(db_conn, diag_table)
    gm_sql_table_drop(db_conn, eigvec_table)


# Task 6: Fast Belief Propagation
# ------------------------------------------------------------------------------ #
```

```
def gm_belief_propagation(belief_file, delim, undirected, \
               max_iterations = gm_param_bp_max_iter, stop_threshold = gm_pa

    next_table = "GM_BP_NEXT"
    print "Computing belief propagation..."

    # BP require that the graph is undirected.
    if (undirected):
        degree_col = "out_degree"
    else:
        degree_col = "out_degree+in_degree"

    cur = db_conn.cursor()
    cur.execute ("SELECT MAX(%s), SUM(%s), SUM((%s)*(%s))" % (degree_col, deg
                 "FROM %s" % GM_NODE_DEGREES)
    max_deg, sum_deg, sum_deg2  = cur.fetchone()

    c1 = 2+sum_deg
    c2 = sum_deg2 -1

    h = max(1 / (float)(2 + 2 * max_deg), sqrt((-c1 + sqrt(c1*c1 + 4*c2))/(8*
    print "Homophily factor = " + str(h)

    a = (4*h*h)/(1-4*h*h)
    c = (2*h)/(1-4*h*h)

    print "Getting the priors..."
    # Get the belief priors.
    gm_sql_table_drop_create(db_conn, GM_BELIEF_PRIOR, "node_id integer, beli
    gm_sql_load_table_from_file(db_conn, GM_BELIEF_PRIOR, "node_id, belief",

    # Initialize belief table as belief priors
    gm_sql_create_and_insert(db_conn, GM_BELIEF, GM_BELIEF_PRIOR, \
                             "node_id integer, belief double precision", \
                             "node_id, belief", "node_id, belief")

    num_iterations = 0
    while True:
        # Create Table to store the next belief
        gm_sql_table_drop_create(db_conn, next_table,"node_id integer, belief

        # Compute next belief
```

```
        cur.execute ("INSERT INTO %s " % next_table +
                            " SELECT node_id, SUM(belief) FROM (" +
                            " SELECT src_id \"node_id\", %s * SUM(belief)
                            " FROM %s, %s" % (GM_TABLE_UNDIRECT, GM_BELIE
                            " WHERE dst_id = node_id GROUP BY src_id" +
                            " UNION ALL" +
                            " SELECT \"D\".node_id \"node_id\", %s*(%s)*b
                            " FROM %s \"D\", %s \"B\" " % (GM_NODE_DEGREE
                            " WHERE \"D\".node_id = \"B\".node_id" +
                            " UNION ALL" +
                            " SELECT * FROM %s " % GM_BELIEF_PRIOR +
                            " ) \"TAB\" GROUP BY node_id" )

        db_conn.commit()

        diff = gm_sql_vect_diff(db_conn, GM_BELIEF, next_table, "node_id", "n

        # Recreate Belief table and copy values
        gm_sql_create_and_insert(db_conn, GM_BELIEF, next_table, \
                            "node_id integer, belief double precision",
                            "node_id, belief", "node_id, belief")

        num_iterations = num_iterations + 1
        print "Iteration = %d, Error = %f" % (num_iterations, diff)

        if (diff<=stop_threshold or num_iterations>max_iterations):
            break


    # Drop temp tables
    gm_sql_table_drop(db_conn, next_table)

    cur.close()



# Task 7: Triangle counting
# ------------------------------------------------------------------------------ #
def gm_naive_triangle_count(adj_table=GM_TABLE_UNDIRECT):

    temp_table = "GM_TRIANG_TEMP"
    temp_table2 = "GM_TRIANG_TEMP2"
```

```
    temp_table3 = "GM_TRIANG_TEMP3"

    cur = db_conn.cursor()
    gm_sql_table_drop_create(db_conn, temp_table,"row_id integer, col_id inte
    gm_sql_table_drop_create(db_conn, temp_table2,"row_id integer, col_id int
    gm_sql_table_drop_create(db_conn, temp_table3,"row_id integer, col_id int

    # Copy the adjacency matrix
    cur.execute("INSERT INTO %s" % (temp_table) + \
                " SELECT src_id \"row_id\", dst_id \"col_id\", 1 \"value\" FR

    db_conn.commit()

    # Compute A^2
    gm_sql_mat_mat_multiply (db_conn, temp_table, temp_table, temp_table2, "c
                                             "value", "row_id", "col_id", "ro
    # Compute A^3
    gm_sql_mat_mat_multiply (db_conn, temp_table2, temp_table, temp_table3, "
                                             "value", "row_id", "col_id", "ro


    cnt = gm_sql_mat_trace(db_conn, temp_table3, "row_id", "col_id", "value")

    print "Number of Triangles(naive) = " + (str(cnt/6))

    cur.close()

    # Drop temp tables
    gm_sql_table_drop(db_conn, temp_table)
    gm_sql_table_drop(db_conn, temp_table2)
    gm_sql_table_drop(db_conn, temp_table3)


def gm_eigen_triangle_count():

    cur = db_conn.cursor()
    #gm_eigen(steps, num_nodes, err1, err2, adj_table)
    print "Computing the count of triangles..."

    cur.execute("SELECT sum(value^3) FROM %s" % (GM_EIG_VALUES))
    cnt = cur.fetchone()[0]
```

```
    print "Number of Triangles = " + (str(cnt/6))

    cur.close()


# Innovative Task : Anomaly Detection for unidrected graphs
def gm_anomaly_detection():
    cur = db_conn.cursor()
    gm_sql_table_drop_create(db_conn, GM_EGONET,"node_id integer, edge_cnt in

    print "Extracting Features from Egonets"

    start_time = time.time()
    cur.execute("INSERT INTO %s " % (GM_EGONET) +
                    " SELECT node_id, sum(edge_cnt) \"edge_cnt\", sum(wgt
                    " (SELECT \"T2\".dst_id \"node_id\", count(*)/2 \"edg
                    " FROM %s \"T1\", %s \"T2\", %s \"T3\" " % (GM_TABLE_
                    " WHERE \"T1\".src_id = \"T2\".src_id AND \"T1\".dst_
                    " GROUP BY \"T2\".dst_id" +
                    " UNION ALL" +
                    " SELECT src_id \"node_id\", count(*) \"edge_cnt\", s
                    " FROM %s GROUP BY src_id) \"TAB\" " % (GM_TABLE_UNDI
                    " GROUP BY node_id");

    db_conn.commit();
    print "Time taken = " + str(time.time()-start_time)



def main():
    global db_conn
    global GM_TABLE
     # Command Line processing
    parser = argparse.ArgumentParser(description="Graph Miner Using SQL v1.0"
    parser.add_argument ('--file', dest='input_file', type=str, required=True
                         help='Full path to the file to load from. For weight
                         graphs, the file should have the format (<src_id>, <
                         . If unweighted please run with --unweighted option.
                         delimiter other than "," (default), use --delim opti
                        NOTE: The file should have proper permissions set fo
                         the postgres user.'
                         )
```

```
parser.add_argument ('--delim', dest='delimiter', type=str, default=',',
                     help='Delimiter that separate the columns in the inp

parser.add_argument ('--unweighted', dest='unweighted', action='store_con
                     help='For unweighted graphs. The input file should b
                     (<src_id>, <dst_id>). For algorithms that require we
                     of 1 will be used')

parser.add_argument ('--undirected', dest='undirected', action='store_con
                     help='Treat the graph as undirected instead of direc
                     the input graph is first converted into an undirecte
                     with same weight. NOTE: Graph algorithms like eigen
                     connected components etc require undirected graphs a
                     undirected version of the graph irrespective of whet

parser.add_argument ('--dest_dir', dest='dest_dir', type=str, required=Tr
                     help='Full path to the directory where the output ta

parser.add_argument ('--belief_file', dest='belief_file', type=str, defau
                     help='Full path to belief priors file. The file shou
                     (<node_id>, <belief>). Specify a different delimiter
                     The prior beliefs are expected to be centered around
                     nodes have priors >0, negative nodes <0 and unknown

args = parser.parse_args()

try:
    # Run the various graph algorithm below
    db_conn = gm_db_initialize()

    gm_sql_table_drop_create(db_conn, GM_TABLE, "src_id integer, dst_id i
    if (args.unweighted):
        col_fmt = "src_id, dst_id"
    else:
        col_fmt = "src_id, dst_id, weight"

    gm_sql_load_table_from_file(db_conn, GM_TABLE, col_fmt, args.input_fi

    gm_to_undirected(False)

    if (args.undirected):
        GM_TABLE = GM_TABLE_UNDIRECT
```

```
        # Create table of node ids
        gm_create_node_table()
        # Get number of nodes
        cur = db_conn.cursor()
        cur.execute("SELECT count(*) from %s" % GM_NODES)
        num_nodes = cur.fetchone()[0]

        gm_node_degrees()

        # Tasks
        gm_degree_distribution(args.undirected)                    # Degree dist
        kcore(args)
        gm_pagerank(num_nodes)                                     # Pagerank
        gm_connected_components(num_nodes)                         # Connected c
        gm_eigen(gm_param_eig_max_iter, num_nodes, gm_param_eig_thres1, gm_pa
        gm_all_radius(num_nodes)
        if (args.belief_file):
            gm_belief_propagation(args.belief_file, args.delimiter, args.undi


        gm_eigen_triangle_count()
        #gm_naive_triangle_count()

        # Save tables to disk
        gm_save_tables(args.dest_dir, args.belief_file)
        #gm_anomaly_detection()

        gm_db_bubye(db_conn)
    except:
        print "Unexpected error:", sys.exc_info()[0]
        if (db_conn):
            gm_db_bubye(db_conn)

        raise

if __name__ == '__main__':
    main()
```

Contents