

Test Report on gStore

Li Zeng¹

April 22, 2016

¹EECS of Peking University, zengli-bookug@pku.edu.cn

Contents

1	Preface	4
2	Environment Setup	5
3	Experiment Result	7
4	Comparative Analysis	10
5	Conclusion	13
6	Prospective	14
7	Appendix	15
7.1	WatDiv queries	15
7.1.1	C1.sql	15
7.1.2	C2.sql	15
7.1.3	C3.sql	16
7.1.4	F1.sql	16
7.1.5	F2.sql	16
7.1.6	F3.sql	17
7.1.7	L1.sql	17
7.1.8	L2.sql	17
7.1.9	L3.sql	18
7.1.10	S1.sql	18
7.1.11	S2.sql	19
7.1.12	S3.sql	19
7.2	LUBM queries	19
7.2.1	q0.sql	19

7.2.2	q1.sql	20
7.2.3	q2.sql	20
7.2.4	q3.sql	20
7.2.5	q4.sql	21
7.2.6	q5.sql	21
7.2.7	q6.sql	21
7.2.8	q7.sql	21
7.2.9	q8.sql	22
7.2.10	q9.sql	22
7.2.11	q10.sql	22
7.2.12	q11.sql	23
7.2.13	q12.sql	23
7.2.14	q13.sql	23
7.2.15	q14.sql	24
7.2.16	q15.sql	24
7.2.17	q16.sql	24
7.2.18	q17.sql	25
7.2.19	q18.sql	25
7.2.20	q19.sql	25
7.2.21	q20.sql	25
7.2.22	q21.sql	26
7.3	BSBM queries	26
7.3.1	self0.sql	26
7.3.2	self1.sql	26
7.3.3	self2.sql	26
7.3.4	self3.sql	27
7.3.5	self4.sql	27

7.3.6	self5.sql	27
7.3.7	self6.sql	28
7.3.8	self7.sql	28
7.3.9	self8.sql	28
7.3.10	self9.sql	29
7.4	DBpedia queries	29
7.4.1	q0.sql	29
7.4.2	q1.sql	30
7.4.3	q2.sql	30
7.4.4	q3.sql	30
7.4.5	q4.sql	30
7.4.6	q5.sql	31
7.4.7	q9.sql	31

1 Preface

gStore¹ is a graph-based database management system, which keeps the structure of original RDF² data.

The data model is directed graph with labels, and each vertex corresponds to a subject or object.

Given a SPARQL³ query(only select...where clause is well supported now), gStore will transfer it to a directed graph with labels first.

Then the query problem will be equivalent to a subgraph matching problem. An index called VSTree is used in gStore to speed up the matching process. For each variable in the SPARQL query, gStore acquires its candidates through VSTree, and finally a join process is performed to get the final result.

We compare the performance of gStore with apache-jena⁴, openrdf-sesame⁵ and virtuoso-openlinksw⁶ on several RDF datasets. The items needing to be considered include the time to build database, the size of database and the time to answer each SPARQL query. In addition, we will give a special explanation if the query results of each database do not match. (we will not consider the memory and disk cost except for special cases)

¹<https://github.com/Caesar11/gStore>

²<http://www.w3school.com.cn/rdf/>

³<https://www.w3.org/TR/sparql11-query/>

⁴<http://jena.apache.org/>

⁵<http://www.rdf4j.org/>

⁶<http://virtuoso.openlinksw.com/>

2 Environment Setup

We need to do some preparations before the experiment to ensure all datasets and corresponding queries can be run correctly by all database management systems. The limitations are listed below:

1. gStore does not support queries with unbounded predicates
2. Jena does not support datasets with prefix declarations
3. Sesame does not support entities without appropriate prefixes
4. Virtuoso will remove the '<' and '>' for entities, '"' for literals

We should not include the time to load database indexes(called offline time) when comparing the time to answer SPARQL queries. And we need to empty the buffer and cache of operation system when the experiment for each database management system is over.

The datasets used include WatDiv⁷, LUBM⁸, BSBM⁹ and DBpedia¹⁰. DBpedia are the background data of wikipedia, while the others are generated by programs. SPARQL queries are generated by programs or written manually.

When testing BSBM and DBpedia, some queries contain "^" and gStore will output nothing in these cases. In addition, if the output results contain "^", gStore and Virtuoso will ignore the properties linked by "^". What is more, Sesame does not support LUBM due to invalid IRI, and it is unable to deal with too large datasets like dbpedia2014, watdiv_300M, bsbm_100000. Virtuoso can not deal with watdiv_300M, lubm_5000 and dbpedia2014, neither.

⁷<http://dsg.uwaterloo.ca/watdiv/>

⁸<http://swat.cse.lehigh.edu/projects/lubm/>

⁹<https://sourceforge.net/projects/bsbmtools/files/bsbmtools/>

¹⁰<http://wiki.dbpedia.org/>

The experiment is finished on a Linux server with 82G memory and 7T disk. CentOS2.6.32-573.3.1.el6.x86_64 is installed and we require that the version of glibc should be at least 2.14.

The versions of all database management systems used here are all open source. Latest versions are choosed, i.e. 3.0.1 for apache-jena, 4.1.1 for openrdf-sesame and 7.2 for virtuoso-openlinksw.

3 Experiment Result

All results are saved in load.log/, result.log/ and time.log/, and the format is TSV.

Table 1 shows the index size and loading time of the datasets for different systems.

	Index Size(KB)			Loading Time(second)		
Datasets	gStore	Jena	Virtuoso	gStore	Jena	Virtuoso
DBpedia 2014	42,415,852	23,151,272	- ¹	8,639,666	15,555,000	-
Bsbm 10000	1,814,480	718,024	2,080,000	244,153	76,000	59999
LUBM 500	2,171,084	1,022,528	38,000,000	291,382	94,000	100,532
LUBM 5000	23,397,548	10,262,524	-	3,767,764	1,098,000	-
WatDiv 10M	2,563,168	1,315,764	10,320,000	532,542	304,000	225,464
WatDiv 100M	26,566,780	13,286,608	8,615,100	7,879,602	20,969,000	16,981,470
WatDiv 300M	80,166,500	38,108,940	-	19,864,431	25,041,000	-

¹ “-” means that loading does not terminate in 10 hour

Table 1: Offline Performance

The performance of different database management systems is shown in Figures 1, 2, 3 and 4.

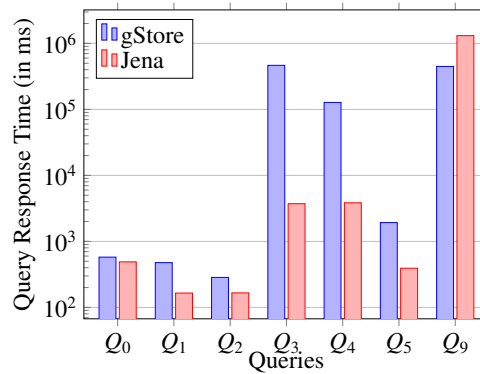


Figure 1: Query Performance over DBpedia 2014

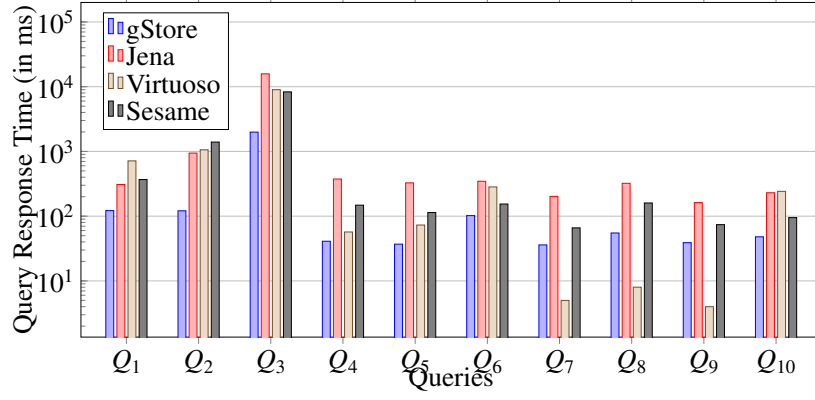
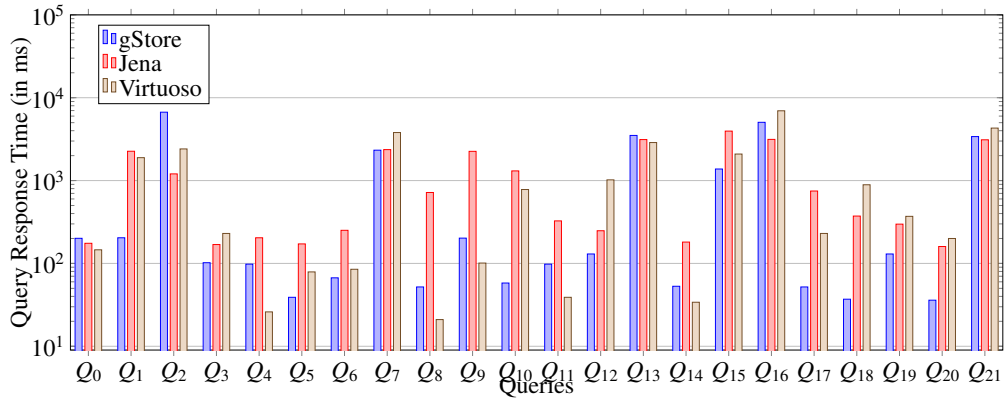
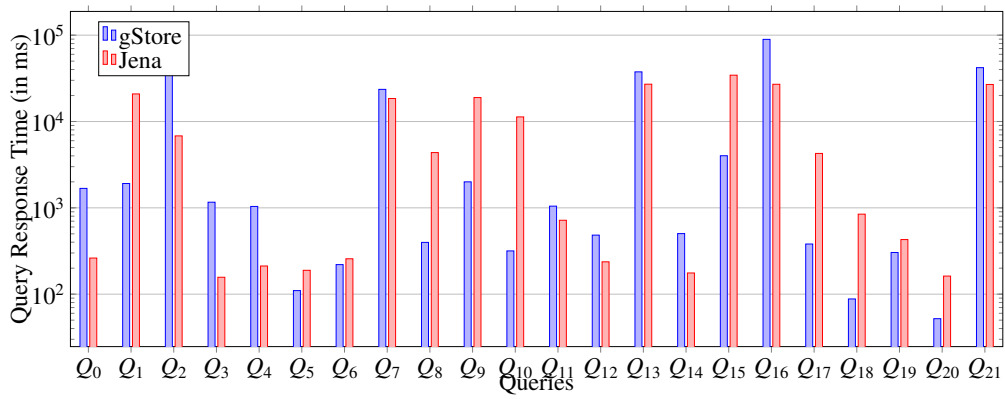


Figure 2: Query Performance over Bsbm 10000

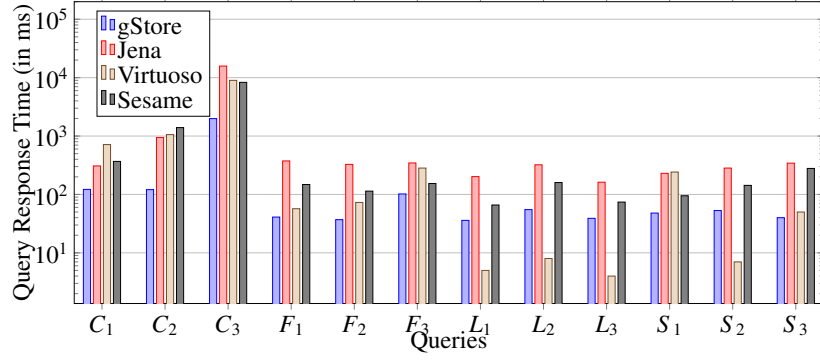


(a) LUBM 500

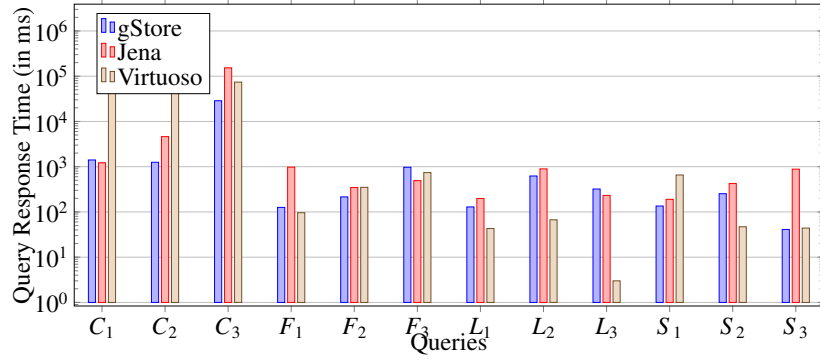


(b) LUBM 5000

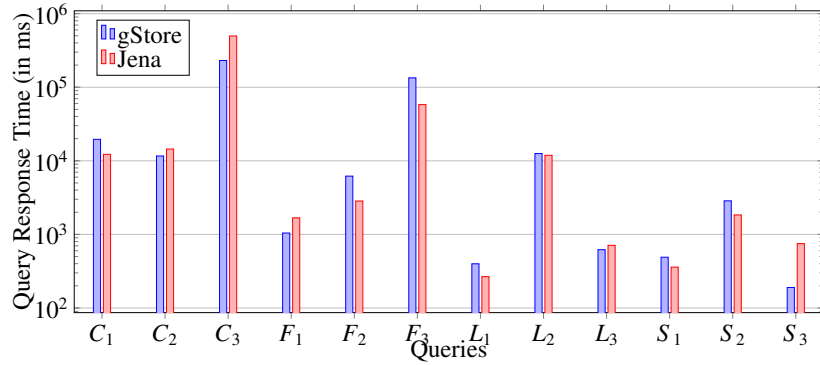
Figure 3: Query Performance over LUBM



(a) WatDiv 10M



(b) WatDiv 100M



(c) WatDiv 300M

Figure 4: Query Performance over WatDiv

4 Comparative Analysis

We can see that all query results of each database management system are matched through the result.log/, which means that the correctness of gStore is guaranteed.

Both time cost and disk cost of gStore are higher than the others when analysing the load.log/, about one order of magnitude. However, the size of the database generated by gStore can be reduced because some files are useless(for example, six_tuples).

By analysing the time.log/, we can discover that gStore performs better in very complicated SPARQL queries, for example, containing circles. However, for some queries which are in special structures(for example, star-shaped graph), the performance of gStore is worser than other RDF database management systems(for example, apache-jena). These database management systems all performs well on small datasets. (query time usually less than 1s)

The memory cost is not counted concretely, but we can claim that the memory cost of gStore is just slightly higher than the others. As for disk cost, gStore is always larger, about one order of magnitude.

All datasets and queries we used are listed in this document, to provide a more thorough understanding of the experiment results.

Below is for the WatDiv datasets, and the corresponding queries are placed in WatDiv Queries.

Dataset	Size	Triple	Predicate	Entity	Literal
watdiv_100M	15599074048	108997714	0	0	0
watdiv_10M	1542624409	10916457	0	0	0
watdiv_200	3138192889	20014680	0	0	0
watdiv_300M	47670221085	329539576	0	0	0
watdiv_500	7858764942	54905597	0	0	0

Table 2: WatDiv series

For WatDiv datasets, gStore performs worser in F3.sql. The reason is that all vertices are filtered by VSTree, but the candidate num is still very large. There are many edges in F3.sql, so the cost of join process can be very high.

Below is for the LUBM datasets, and the corresponding queries are placed in LUBM Queries.

Dataset	Size	Triple	Predicate	Entity	Literal
lubm_10	11835527	99550	28413	17	0
lubm_5000	8134671485	66718642	17	16437950	0
lubm_500	801112089	6652613	17	1648692	0

Table 3: LUBM series

For LUBM datasets, gStore performs worser in q0.sql, q13.sql, q16.sql, q21.sql, q2.sql, q3.sql, q4.sql and q7.sql. We can discover that in star-shaped query graph, the satellite vertices should not be filtered by VSTree. In addition, if there is only one triple in the query graph, none should be put into the VSTree.

Below is for the BSBM datasets, and the corresponding queries are placed in BSBM Queries.

Dataset	Size	Triple	Predicate	Entity	Literal
bsbm_100000	9100827924	34872182	0	0	0
bsbm_10000	912646084	3534773	0	0	0
bsbm_1000	95077406	371911	0	0	0
bsbm_100	10174119	40177	0	0	0
bsbm_500	48548941	190496	0	0	0

Table 4: BSBM series

For BSBM datasets, gStore performs worser in self1.sql. In this case, we had better get the result by using a p2so index, which is implemented by B+ tree. If using VSTree here, the cost of filter process is high due to large data size(more precisely, the candidate size after VSTree is very large), and the cost of join process may be higher.

Below is for the DBpedia datasets, and the corresponding queries are placed in DBpedia Queries.

Dataset	Size	Triple	Predicate	Entity	Literal
dbpedia2014	23844158944	170784508	57354	7123915	14971449

Table 5: DBpedia series

For DBpedia datasets, gStore performs worser in q3.sql, q4.sql and q5.sql. The reason is almost the same as others.

5 Conclusion

gStore can go well with RDF datasets which are in N-Triples format, while the other database management systems may come across some questions. In addition, gStore outperforms other systems on very complicated SPARQL queries. What is more, gStore is highly extensiveness because it uses graph model instead of relational model.

However, there are also some shortcomings for gStore:

1. RDF datasets in XML format are not supported
2. the memory and disk cost is high
3. only select-where clause can be used in SPARQL queries
4. unbounded predicates can not be contained in queries
5. too much warnings when compiling the project(especially redefine warning)
6. gStore is not always more efficient than other database management systems

6 Prospective

Out of question, the performance of gStore can be improved a lot later. The future work is listed below:

1. fix/add datasets and corresponding queries
2. support queries which are not in BGP(Basic Graph Pattern) efficiently
3. improve the encoding method in Signature/ and VSTree/
4. adjust the query plan, not always using VSTree as filter

7 Appendix

7.1 WatDiv queries

7.1.1 C1.sql

```
1 SELECT ?v0 ?v4 ?v6 ?v7 WHERE
2 {
3   ?v0 <http://schema.org/caption> ?v1 .
4   ?v0 <http://schema.org/text> ?v2 .
5   ?v0 <http://schema.org/contentRating> ?v3 .
6   ?v0 <http://purl.org/stuff/rev#hasReview> ?v4 .
7   ?v4 <http://purl.org/stuff/rev#title> ?v5 .
8   ?v4 <http://purl.org/stuff/rev#reviewer> ?v6 .
9   ?v7 <http://schema.org/actor> ?v6 .
10  ?v7 <http://schema.org/language> ?v8 .
11 }
```

7.1.2 C2.sql

```
1 SELECT ?v0 ?v3 ?v4 ?v8 WHERE
2 {
3   ?v0 <http://schema.org/legalName> ?v1 .
4   ?v0 <http://purl.org/goodrelations/offers> ?v2 .
5   ?v2 <http://schema.org/eligibleRegion> <http://db.uwaterloo.ca/~galuc/wsdbm/Country5> .
6   ?v2 <http://purl.org/goodrelations/includes> ?v3 .
7   ?v4 <http://schema.org/jobTitle> ?v5 .
8   ?v4 <http://xmlns.com/foaf/homepage> ?v6 .
9   ?v4 <http://db.uwaterloo.ca/~galuc/wsdbm/makesPurchase> ?v7 .
10  ?v7 <http://db.uwaterloo.ca/~galuc/wsdbm/purchaseFor> ?v3 .
11  ?v3 <http://purl.org/stuff/rev#hasReview> ?v8 .
12  ?v8 <http://purl.org/stuff/rev#totalVotes> ?v9 .
13 }
```


7.1.3 C3.sql

```
1 SELECT ?v0 WHERE
2 {
3   ?v0 <http://db.uwaterloo.ca/~galuc/wsdbm/likes> ?v1 .
4   ?v0 <http://db.uwaterloo.ca/~galuc/wsdbm/friendOf> ?v2 .
5   ?v0 <http://purl.org/dc/terms/Location> ?v3 .
6   ?v0 <http://xmlns.com/foaf/age> ?v4 .
7   ?v0 <http://db.uwaterloo.ca/~galuc/wsdbm/gender> ?v5 .
8   ?v0 <http://xmlns.com/foaf/givenName> ?v6 .
9 }
```

7.1.4 F1.sql

```
1 SELECT ?v0 ?v2 ?v3 ?v4 ?v5 WHERE
2 {
3   ?v0 <http://ogp.me/ns#tag> <http://db.uwaterloo.ca/~galuc/wsdbm/
4     Topic103> .
5   ?v0 <http://www.w3.org/1999/02/22-rdf-syntax-ns#type> ?v2 .
6   ?v3 <http://schema.org/trailer> ?v4 .
7   ?v3 <http://schema.org/keywords> ?v5 .
8   ?v3 <http://db.uwaterloo.ca/~galuc/wsdbm/hasGenre> ?v0 .
9   ?v3 <http://www.w3.org/1999/02/22-rdf-syntax-ns#type> <http://db.
    uwaterloo.ca/~galuc/wsdbm/ProductCategory2> .
10 }
```

7.1.5 F2.sql

```
1 SELECT ?v0 ?v1 ?v2 ?v4 ?v5 ?v6 ?v7 WHERE
2 {
3   ?v0 <http://xmlns.com/foaf/homepage> ?v1 .
4   ?v0 <http://ogp.me/ns#title> ?v2 .
5   ?v0 <http://www.w3.org/1999/02/22-rdf-syntax-ns#type> ?v3 .
6   ?v0 <http://schema.org/caption> ?v4 .
```

```

7   ?v0 <http://schema.org/description> ?v5 .
8   ?v1 <http://schema.org/url> ?v6 .
9   ?v1 <http://db.uwaterloo.ca/~galuc/wsdbm/hits> ?v7 .
10  ?v0 <http://db.uwaterloo.ca/~galuc/wsdbm/hasGenre> <http://db.
    uwaterloo.ca/~galuc/wsdbm/SubGenre35> .
11 }

```

7.1.6 F3.sql

```

1  SELECT ?v0 ?v1 ?v2 ?v4 ?v5 ?v6 WHERE
2  {
3    ?v0 <http://schema.org/contentRating> ?v1 .
4    ?v0 <http://schema.org/contentSize> ?v2 .
5    ?v0 <http://db.uwaterloo.ca/~galuc/wsdbm/hasGenre> <http://db.
    uwaterloo.ca/~galuc/wsdbm/SubGenre59> .
6    ?v4 <http://db.uwaterloo.ca/~galuc/wsdbm/makesPurchase> ?v5 .
7    ?v5 <http://db.uwaterloo.ca/~galuc/wsdbm/purchaseDate> ?v6 .
8    ?v5 <http://db.uwaterloo.ca/~galuc/wsdbm/purchaseFor> ?v0 .
9  }

```

7.1.7 L1.sql

```

1  SELECT ?v0 ?v2 ?v3 WHERE
2  {
3    ?v0 <http://db.uwaterloo.ca/~galuc/wsdbm/subscribes> <http://db.
    uwaterloo.ca/~galuc/wsdbm/Website38303> .
4    ?v2 <http://schema.org/caption> ?v3 .
5    ?v0 <http://db.uwaterloo.ca/~galuc/wsdbm/likes> ?v2 .
6  }

```

7.1.8 L2.sql

```

1  SELECT ?v1 ?v2 WHERE

```

```

2 {
3   <http://db.uwaterloo.ca/~galuc/wsdbm/City131> <http://www.
      geonames.org/ontology#parentCountry> ?v1 .
4   ?v2 <http://db.uwaterloo.ca/~galuc/wsdbm/likes> <http://db.
      uwaterloo.ca/~galuc/wsdbm/Product0> .
5   ?v2 <http://schema.org/nationality> ?v1 .
6 }

```

7.1.9 L3.sql

```

1 SELECT ?v0 ?v1 WHERE
2 {
3   ?v0 <http://db.uwaterloo.ca/~galuc/wsdbm/likes> ?v1 .
4   ?v0 <http://db.uwaterloo.ca/~galuc/wsdbm/subscribes> <http://db.
      uwaterloo.ca/~galuc/wsdbm/Website20769> .
5 }

```

7.1.10 S1.sql

```

1 SELECT ?v0 ?v1 ?v3 ?v4 ?v5 ?v6 ?v7 ?v8 ?v9 WHERE
2 {
3   ?v0 <http://purl.org/goodrelations/includes> ?v1 .
4   <http://db.uwaterloo.ca/~galuc/wsdbm/Retailer391> <http://purl.org
      /goodrelations/offers> ?v0 .
5   ?v0 <http://purl.org/goodrelations/price> ?v3 .
6   ?v0 <http://purl.org/goodrelations/serialNumber> ?v4 .
7   ?v0 <http://purl.org/goodrelations/validFrom> ?v5 .
8   ?v0 <http://purl.org/goodrelations/validThrough> ?v6 .
9   ?v0 <http://schema.org/eligibleQuantity> ?v7 .
10  ?v0 <http://schema.org/eligibleRegion> ?v8 .
11  ?v0 <http://schema.org/priceValidUntil> ?v9 .
12 }

```

7.1.11 S2.sql

```
1 SELECT ?v0 ?v1 ?v3 WHERE
2 {
3   ?v0 <http://purl.org/dc/terms/Location> ?v1 .
4   ?v0 <http://schema.org/nationality> <http://db.uwaterloo.ca/~galuc/
      wsdbm/Country23> .
5   ?v0 <http://db.uwaterloo.ca/~galuc/wsdbm/gender> ?v3 .
6   ?v0 <http://www.w3.org/1999/02/22-rdf-syntax-ns#type> <http://db.
      uwaterloo.ca/~galuc/wsdbm/Role2> .
7 }
```

7.1.12 S3.sql

```
1 SELECT ?v0 ?v2 ?v3 ?v4 WHERE
2 {
3   ?v0 <http://www.w3.org/1999/02/22-rdf-syntax-ns#type> <http://db.
      uwaterloo.ca/~galuc/wsdbm/ProductCategory12> .
4   ?v0 <http://schema.org/caption> ?v2 .
5   ?v0 <http://db.uwaterloo.ca/~galuc/wsdbm/hasGenre> ?v3 .
6   ?v0 <http://schema.org/publisher> ?v4 .
7 }
```

7.2 LUBM queries

7.2.1 q0.sql

```
1 select ?x where
2 {
3   ?x <ub:name> <FullProfessor0>.
4 }
```

7.2.2 q1.sql

```
1 select ?x where
2 {
3   ?x    <rdf:type>    <ub:GraduateStudent>.
4   ?y    <rdf:type>    <ub:University>.
5   ?z    <rdf:type>    <ub:Department>.
6   ?x    <ub:memberOf> ?z.
7   ?z    <ub:subOrganizationOf> ?y.
8   ?x    <ub:undergraduateDegreeFrom> ?y.
9 }
```

7.2.3 q2.sql

```
1 select ?x where
2 {
3   ?x    <rdf:type>    <ub:Course>.
4   ?x    <ub:name>     ?y.
5 }
```

7.2.4 q3.sql

```
1 select ?x where
2 {
3   ?x    <rdf:type>    <ub:UndergraduateStudent>.
4   ?y    <rdf:type>    <ub:University>.
5   ?z    <rdf:type>    <ub:Department>.
6   ?x    <ub:memberOf> ?z.
7   ?z    <ub:subOrganizationOf> ?y.
8   ?x    <b:undergraduateDegreeFrom> ?y.
9 }
```

7.2.5 q4.sql

```
1  select ?x ?y1 ?y2 ?y3 where
2  {
3    ?x      <ub:worksFor>   <http://www.Department0.University0.edu>.
4    ?x      <rdf:type>      <ub:FullProfessor>.
5    ?x      <ub:name>       ?y1.
6    ?x      <ub:emailAddress> ?y2.
7    ?x      <ub:telephone>  ?y3.
8  }
```

7.2.6 q5.sql

```
1  select ?x where
2  {
3    ?x      <ub:subOrganizationOf> <http://www.Department0.
4    University0.edu>.
5    ?x      <rdf:type>          <ub:ResearchGroup>.
6  }
```

7.2.7 q6.sql

```
1  select ?x ?y where
2  {
3    ?y      <ub:subOrganizationOf> <http://www.University0.edu>.
4    ?y      <rdf:type>            <ub:Department>.
5    ?x      <ub:worksFor>         ?y.
6    ?x      <rdf:type>            <ub:FullProfessor>.
7  }
```

7.2.8 q7.sql

```

1 select ?x ?y ?z where
2 {
3   ?x    <rdf:type>      <ub:UndergraduateStudent>.
4   ?y    <rdf:type>      <ub: FullProfessor >.
5   ?z    <rdf:type>      <ub:Course>.
6   ?x    <ub:advisor>    ?y.
7   ?x    <ub:takesCourse>    ?z.
8   ?y    <ub:teacherOf>    ?z.
9 }

```

7.2.9 q8.sql

```

1 select ?X where
2 {
3   ?X    <rdf:type>      <ub:GraduateStudent>.
4   ?X    <ub:takesCourse>    <http://www.Department0.
        University0.edu/GraduateCourse0>.
5 }

```

7.2.10 q9.sql

```

1 select ?X ?Y ?Z where
2 {
3   ?X    <rdf:type>      <ub:GraduateStudent>.
4   ?Y    <rdf:type>      <ub: University >.
5   ?Z    <rdf:type>      <ub:Department>.
6   ?X    <ub:memberOf>    ?Z.
7   ?Z    <ub:subOrganizationOf>    ?Y.
8   ?X    <ub:undergraduateDegreeFrom>    ?Y.
9 }

```

7.2.11 q10.sql

```

1 select ?X where
2 {
3   ?X      <rdf:type>      <ub: Publication >.
4   ?X      <ub:publicationAuthor> <http://www.Department0.
        University0.edu/AssistantProfessor0>.
5 }

```

7.2.12 q11.sql

```

1 select ?Y1 ?Y2 ?Y3 where
2 {
3   ?X      <rdf:type>      <ub: FullProfessor >.
4   ?X      <ub:worksFor> <http://www.Department0.University0.edu>.
5   ?X      <ub:name>      ?Y1.
6   ?X      <ub:emailAddress>      ?Y2.
7   ?X      <ub:telephone> ?Y3.
8 }

```

7.2.13 q12.sql

```

1 select ?X where
2 {
3   ?X      <ub:memberOf> <http://www.Department0.University0.edu>.
4 }

```

7.2.14 q13.sql

```

1 select ?X where
2 {
3   ?X      <rdf:type>      <ub:UndergraduateStudent>.
4 }

```


7.2.15 q14.sql

```
1  select ?X ?Y where
2  {
3    ?X    <rdf:type>      <ub:Student>.
4    ?Y    <rdf:type>      <ub:Course>.
5    ?X    <ub:takesCourse>    ?Y.
6    <http://www.Department0.University0.edu/AssociateProfessor0> <
      ub:teacherOf> ?Y.
7  }
```

7.2.16 q15.sql

```
1  select ?X where
2  {
3    ?X    <rdf:type>      <ub:UndergraduateStudent>.
4    ?Y    <rdf:type>      <ub:Department>.
5    ?X    <ub:memberOf> ?Y.
6    ?Y    <ub:subOrganizationOf> <http://www.University0.edu>.
7    ?X    <ub:emailAddress>    ?Z.
8  }
```

7.2.17 q16.sql

```
1  select ?X ?Y ?Z where
2  {
3    ?X    <rdf:type>      <ub:UndergraduateStudent>.
4    ?Z    <rdf:type>      <ub:Course>.
5    ?X    <ub:advisor>    ?Y.
6    ?Y    <ub:teacherOf> ?Z.
7    ?X    <ub:takesCourse>    ?Z.
8  }
```

7.2.18 q17.sql

```
1 select ?X where
2 {
3   ?X    <rdf:type>      <ub:GraduateStudent>.
4   ?X    <ub:takesCourse> <http://www.Department0.
        University0.edu/GraduateCourse0>.
5 }
```

7.2.19 q18.sql

```
1 select ?X where
2 {
3   ?X    <rdf:type>      <ub:ResearchGroup>.
4   ?X    <ub:subOrganizationOf> <http://www.University0.edu>.
5 }
```

7.2.20 q19.sql

```
1 select ?X ?Y where
2 {
3   ?Y    <rdf:type>      <ub:Department>.
4   ?X    <ub:worksFor>   ?Y.
5   ?Y    <ub:subOrganizationOf> <http://www.University0.edu>.
6 }
```

7.2.21 q20.sql

```
1 select ?X where
2 {
3   <http://www.University0.edu> <ub:undergraduateDegreeFrom> ?X
4   .
5 }
```

```
4 }
```

7.2.22 q21.sql

```
1 select ?X where
2 {
3   ?X      <rdf:type>      <ub:UndergraduateStudent>.
4 }
```

7.3 BSBM queries

7.3.1 self0.sql

```
1 select ?v0 where
2 {
3   ?v0 <http://www4.wiwiwiss.fu-berlin.de/bizer/bsbm/v01/vocabulary/
        rating2> "6"^^<http://www.w3.org/2001/XMLSchema#integer
        > .
4 }
```

7.3.2 self1.sql

```
1 select ?v0 ?v1 where
2 {
3   ?v0 <http://www.w3.org/1999/02/22-rdf-syntax-ns#type> ?v1 .
4 }
```

7.3.3 self2.sql

```
1 select ?v0 ?v1 where
2 {
```

```

3   ?v0 <http://www.w3.org/2000/01/rdf-schema#label> ?v1 .
4   ?v1 <http://purl.org/dc/elements/1.1/publisher> ?v2 .
5 }

```

7.3.4 self3.sql

```

1 select ?v0 ?v1 ?v2 where
2 {
3   ?v0 <http://purl.org/dc/elements/1.1/publisher> ?v1 .
4   ?v0 <http://purl.org/dc/elements/1.1/date> ?v2 .
5 }

```

7.3.5 self4.sql

```

1 select ?v0 ?v1 ?v2 where
2 {
3   ?v0 <http://www.w3.org/2000/01/rdf-schema#label> ?v2 .
4   ?v1 <http://www.w3.org/2000/01/rdf-schema#subClassOf> ?v2 .
5 }

```

7.3.6 self5.sql

```

1 select ?v0 ?v1 ?v2 ?v3 where
2 {
3   ?v0 <http://www.w3.org/2000/01/rdf-schema#label> ?v1 .
4   ?v0 <http://www.w3.org/1999/02/22-rdf-syntax-ns#type> ?v2 .
5   ?v3 <http://www.w3.org/2000/01/rdf-schema#label> ?v1 .
6   ?v3 <http://purl.org/dc/elements/1.1/publisher> <http://www4.
      wiwiss.fu-berlin.de/bizer/bsbm/v01/instances/
      StandardizationInstitution1 > .
7 }

```

7.3.7 self6.sql

```
1 select ?v0 ?v1 ?v2 ?v3 ?v4 where
2 {
3   ?v0 <http://www.w3.org/1999/02/22-rdf-syntax-ns#type> ?v1 .
4   ?v0 <http://purl.org/dc/elements/1.1/date> ?v2 .
5   ?v3 <http://www.w3.org/2000/01/rdf-schema#comment> ?v4 .
6   <http://www4.wiwiiss.fu-berlin.de/bizer/bsbm/v01/instances/
       ProductType2> <http://www.w3.org/2000/01/rdf-schema#
       comment> ?v4 .
7   ?v3 <http://www.w3.org/1999/02/22-rdf-syntax-ns#type> ?v1 .
8 }
```

7.3.8 self7.sql

```
1 select ?v0 ?v1 ?v2 ?v3 ?v4 where
2 {
3   ?v0 <http://purl.org/dc/elements/1.1/title> ?v1 .
4   ?v0 <http://purl.org/dc/elements/1.1/publisher> <http://www4.
       wiwiiss.fu-berlin.de/bizer/bsbm/v01/instances/
       dataFromRatingSite11/RatingSite11> .
5   ?v0 <http://purl.org/stuff/rev#text> ?v4 .
6   ?v2 <http://purl.org/stuff/rev#reviewer> ?v3 .
7   ?v2 <http://purl.org/dc/elements/1.1/date> "2008-04-16"^^<http
       ://www.w3.org/2001/XMLSchema#date> .
8   ?v2 <http://purl.org/stuff/rev#text> ?v4
9 }
```

7.3.9 self8.sql

```
1 select ?v0 ?v1 ?v2 ?v3 ?v4 ?v5 ?v6 where
2 {
3   ?v0 <http://www.w3.org/2000/01/rdf-schema#subClassOf> ?v1 .
4   ?v0 <http://purl.org/dc/elements/1.1/date> ?v2 .
```

```

5 ?v3 <http://purl.org/dc/elements/1.1/publisher> ?v4 .
6 ?v3 <http://www.w3.org/2000/01/rdf-schema#subClassOf> ?v1 .
7 ?v5 <http://purl.org/dc/elements/1.1/publisher> ?v6 .
8 ?v5 <http://purl.org/dc/elements/1.1/date> ?v2 .
9 }

```

7.3.10 self9.sql

```

1 select ?v0 ?v1 ?v2 ?v3 ?v4 ?v5 ?v6 ?v7 ?v8 where
2 {
3   ?v0 <http://purl.org/dc/elements/1.1/date> "2000-07-17"^^<http://www.w3.org/2001/XMLSchema#date> .
4   ?v0 <http://purl.org/dc/elements/1.1/publisher> ?v1 .
5   ?v0 <http://www.w3.org/2000/01/rdf-schema#label> ?v2 .
6   ?v0 <http://www.w3.org/2000/01/rdf-schema#comment> ?v8 .
7   ?v3 <http://www.w3.org/2000/01/rdf-schema#subClassOf> <http://www4.wiwiiss.fu-berlin.de/bizer/bsbm/v01/instances/ProductType2> .
8   ?v3 <http://purl.org/dc/elements/1.1/publisher> ?v1 .
9   ?v3 <http://www.w3.org/2000/01/rdf-schema#label> ?v4 .
10  ?v3 <http://www.w3.org/1999/02/22-rdf-syntax-ns#type> ?v7 .
11  ?v5 <http://www.w3.org/2000/01/rdf-schema#label> ?v2 .
12  ?v5 <http://purl.org/dc/elements/1.1/publisher> ?v6 .
13  ?v5 <http://www.w3.org/1999/02/22-rdf-syntax-ns#type> ?v7 .
14 }

```

7.4 DBpedia queries

7.4.1 q0.sql

```

1 select ?v0 where
2 {
3   ?v0 <http://www.w3.org/1999/02/22-rdf-syntax-ns#type> <http://dbpedia.org/class/yago/LanguagesOfBotswana> .

```

```

4   ?v0 <http://www.w3.org/1999/02/22-rdf-syntax-ns#type> <http://
      dbpedia.org/class/yago/LanguagesOfNamibia> .
5   ?v0 <http://www.w3.org/1999/02/22-rdf-syntax-ns#type> <http://
      dbpedia.org/ontology/Language> .
6 }

```

7.4.2 q1.sql

```

1 select ?v0 where
2 {
3   ?v0 <http://dbpedia.org/ontology/associatedBand> <http://dbpedia.
      org/resource/LCD_Soundsystem> .
4 }

```

7.4.3 q2.sql

```

1 select ?v2 where
2 {
3   <http://dbpedia.org/resource/!!Destroy-Oh-Boy!!> <http://dbpedia.
      org/property/title> ?v2 .
4 }

```

7.4.4 q3.sql

```

1 select ?v0 ?v2 where
2 {
3   ?v0 <http://dbpedia.org/ontology/activeYearsStartYear> ?v2 .
4 }

```

7.4.5 q4.sql

```

1 select ?v0 ?v1 ?v2 where
2 {
3   ?v0 <http://dbpedia.org/property/dateOfBirth> ?v2 .
4   ?v1 <http://dbpedia.org/property/genre> ?v2 .
5 }

```

7.4.6 q5.sql

```

1 select ?v0 ?v1 ?v2 ?v3 where
2 {
3   ?v0 <http://dbpedia.org/property/familycolor> ?v1 .
4   ?v0 <http://dbpedia.org/property/lotto> ?v2 .
5   ?v0 <http://dbpedia.org/property/lc> ?v3 .
6 }

```

7.4.7 q9.sql

```

1 select ?v0 ?v1 ?v2 ?v3 ?v4 ?v5 ?v6 ?v7 ?v8 ?v9 where
2 {
3   ?v0 <http://dbpedia.org/property/dateOfBirth> ?v1 .
4   ?v0 <http://dbpedia.org/property/genre> ?v2 .
5   ?v0 <http://dbpedia.org/property/instrument> ?v3 .
6   ?v0 <http://dbpedia.org/property/label> ?v4 .
7   ?v0 <http://dbpedia.org/property/placeOfBirth> ?v5 .
8   ?v6 <http://dbpedia.org/property/name> ?v7 .
9   ?v6 <http://dbpedia.org/property/occupation> ?v8 .
10  ?v6 <http://dbpedia.org/property/placeOfBirth> ?v5 .
11  ?v6 <http://dbpedia.org/property/instrument> ?v3 .
12  ?v6 <http://dbpedia.org/property/notableInstruments> ?v9 .
13 }

```