

数据库原理（1）期末报告

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一、 题目选择:

实验 4:Spark-SQL 分布式数据库查询-推荐系统（大数据集）

二、 实验思路:

使用两个中间表 ref_count 记录每个网站的外部标签数; common 记录任意两个网站的公共标签数量。并集 $|A \cup B| = |A| + |B| - |A \cap B|$, 最后交集 \div 并集即为两个网站之间的相似度。

三、 实验步骤:

1. 准备工作:

与实验 4 步骤基本相同，在腾讯云上租用 3 台云服务器，先搭建好基于 hadoop 的分布式文件系统，在 hadoop 目录下运行 sbin/start-all.sh，启动 hadoop，三台节点 master, slave01, slave02，查询 jps，确保 datanode 等信息出现。

2. 设置工作节点:

(1) 将 slave01, slave02 设为工作节点，master 默认作为任务调度和资源分配节点。以下给出方法：在 spark 目录下，cd conf，打开 spark-env.sh，在头部新增
export HADOOP_CONF_DIR=/usr/local/hadoop/etc/hadoop

将 hadoop 下的配置文件保存到 spark 配置文件的环境变量中，以便启动 spark-sql 时使用资源分配命令。

3. 启动 spark-sql，将 slave01, slave02 设为工作节点:

在 spark 目录下运行命令：

bin/spark-sql --master yarn --num-executors 2

该命令指明启动 spark-sql 时，选择 slave01, slave02 作为工作节点。

4. 将大数据集上传到 hdfs 上后，使用如下命令导入大数据集，并创建为 relation 表，列属性名为 referrer, referree，数据类型为 int。

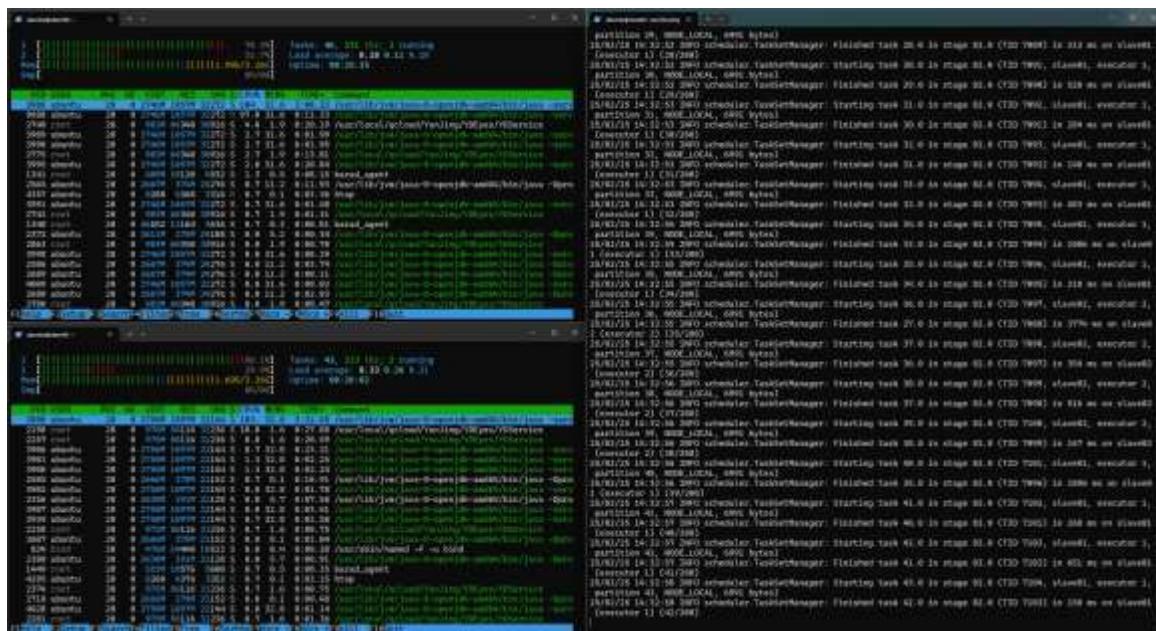
```
create table relation(
    referrer int,
    referree int
)
using csv
options(
    path "./large_relation",
    delimiter ' ',
    header 'false'
);
```

5. 使用连接方式进行查询：

语句如下，由于结果有 6400 万多行，为了节省数据打印时间，这里限制返回最多 500 行：

```
with ref_count as (select referrer, count(distinct referree) as
web_count
        from relation group by referrer),
common as (select a.referrer as web1, b.referrer as web2, count(*) as
com_cnt
        from relation a join relation b
        on a.referree = b.referree
        where a.referrer < b.referrer
        group by a.referrer, b.referrer)
select common.web1 as web1, common.web2 as web2,
case when r1.web_count + r2.web_count - common.com_cnt > 0
then common.com_cnt / (r1.web_count + r2.web_count - common.com_cnt)
else 0
end as similarity
from common join ref_count r1 on common.web1 = r1.referrer
join ref_count r2 on common.web2 = r2.referrer
order by similarity desc limit 500;
```

运行状况截图:



截图显示：在执行查询过程中，slave01, slave02 共 4 个 CPU 核心均处于工作状态，表明查询计算成功分布在两台机器上。

结果展示:

```

19298936    437136030    1.0
2603697 22817535      1.0
15108825    88863675    1.0
27377664    158592175   1.0
14467975    97742874    1.0
16884125    128953441   1.0
42437419    89894179    1.0
98809462    159570745   1.0
25988804    437136030   1.0
27889544    86525478    1.0
24889018    185639498   1.0
88228895    437136030   1.0
236425217   536055930   1.0
22558264    105639498   1.0
224849849   285949147   1.0
14467975    285949147   1.0
14851688    52659511    1.0
42880746    89894179    1.0
326386597   437136030   1.0
17455841    345999006   1.0
14768311    52659511    1.0
15387913    86376769    1.0
337414203   345999006   1.0
12742918    285949147   1.0
26479461    437136030   1.0
39381817    77816942    1.0
14637838    22299596    1.0
Time taken: 114.652 seconds, Fetched 500 row(s)
25/02/25 14:34:39 INFO CliDriver: Time taken: 114.652 seconds, Fetched 500 row(s)
spark>sql>

```

耗时 114.652 秒完成。

四、更多方式尝试

为了比较不同方式速度差异，我将实验 4 的其余几种查询语句也进行了测试，sql 语句以及结果如下：

- 嵌套相关子查询

查询语句：

```

WITH ref_count AS (
    SELECT referrer, COUNT(DISTINCT referree) AS web_count
    FROM relation
    GROUP BY referrer
),
common AS (
    SELECT
        a.referrer AS web1,
        b.referrer AS web2,
        COUNT(*) AS com_cnt,
        min((SELECT web_count FROM ref_count WHERE referrer =
a.referrer)) AS web1_count,
        min((SELECT web_count FROM ref_count WHERE referrer =
b.referrer)) AS web2_count
    FROM relation a
    JOIN relation b ON a.referree = b.referree
    WHERE a.referrer < b.referrer
    GROUP BY a.referrer, b.referrer
)
SELECT
    common.web1,
    common.web2,
    CASE

```

```

        WHEN common.web1_count + common.web2_count - common.com_cnt >
0
        THEN common.com_cnt / (common.web1_count + common.web2_count -
common.com_cnt)
        ELSE 0
    END AS similarity
FROM common ORDER BY similarity DESC LIMIT 500;

```

查询结果:

32423090	37650796	1.0
15315990	15866010	1.0
15070088	37650796	1.0
15821614	15866010	1.0
16381285	37650796	1.0
15144128	15941344	1.0
22362874	37650796	1.0
15284398	15941344	1.0
15315990	37650796	1.0
6343638	15941344	1.0
16948499	37650796	1.0
15496539	16012228	1.0
15841269	37650796	1.0
14536584	16012228	1.0
24719498	37650796	1.0
15496539	16089782	1.0
15445317	37650796	1.0
15679117	16154129	1.0
21964700	37650796	1.0
15487600	16296160	1.0
19542313	37650796	1.0
5706198	16479292	1.0
15821614	37650796	1.0
13485638	17017895	1.0
17198379	37650796	1.0
60769	17017895	1.0
15729027	37871899	1.0

Time taken: 156.646 seconds, Fetched 500 row(s)
25/02/25 14:39:47 INFO CliDriver: Time taken: 156.646 seconds, Fetched 500 row(s)
spark> |

耗时 156.646s 完成。

- 嵌套不相关子查询:

查询语句:

```

WITH ref_count AS (
    SELECT referrer, COUNT(DISTINCT referree) AS web_count
    FROM relation
    GROUP BY referrer
),
common AS (
    SELECT a.referrer AS web1, b.referrer AS web2, COUNT(*) AS com_cnt
    FROM relation a
    JOIN relation b ON a.referee = b.referee
    WHERE a.referrer < b.referrer
    GROUP BY a.referrer, b.referrer
)
SELECT common.web1, common.web2,
CASE WHEN r1.web_count + r2.web_count - common.com_cnt > 0
THEN common.com_cnt / (r1.web_count + r2.web_count - common.com_cnt)
ELSE 0 END AS similarity

```

```

FROM common JOIN (
    SELECT referrer, web_count
    FROM ref_count
    WHERE referrer IN (SELECT web1 FROM common)
) r1 ON common.web1 = r1.referrer
JOIN (
    SELECT referrer, web_count
    FROM ref_count
    WHERE referrer IN (SELECT web2 FROM common)
) r2 ON common.web2 = r2.referrer ORDER BY similarity DESC LIMIT 500;

```

查询结果:

26531267	89894179	1.0
39381817	77016942	1.0
25990595	27394633	1.0
42688746	89894179	1.0
127989625	412486871	1.0
138239358	159578745	1.0
16804125	128953441	1.0
14314752	21093061	1.0
12742918	285949147	1.0
40296131	437136630	1.0
27889544	86525478	1.0
40439102	97742874	1.0
31136356	34054226	1.0
20496152	29944159	1.0
326386597	437136630	1.0
68394221	105639498	1.0
13610348	48739890	1.0
14768311	52659511	1.0
121098486	427194818	1.0
15792401	21093061	1.0
171803433	345999006	1.0
31493162	52659511	1.0
15387913	86376769	1.0
92669544	345999006	1.0
237206932	285949147	1.0
31652187	48259437	1.0
14592440	437136630	1.0
20597466	80863675	1.0

Time taken: 202.238 seconds, Fetched 500 row(s)
25/02/25 14:44:47 INFO CliDriver: Time taken: 202.238 seconds, Fetched 500 row(s)
spark> |

耗时 202.238s 完成

- intersect 操作:

查询语句:

```

WITH ref_count AS (
    SELECT referrer, COUNT(DISTINCT referree) AS web_count
    FROM relation GROUP BY referrer),
common AS (SELECT a.referrer AS web1, b.referrer AS web2, COUNT(*) AS com_cnt
            FROM relation a JOIN relation b
            ON a.referree = b.referree
            WHERE a.referrer < b.referrer
            GROUP BY a.referrer, b.referrer)
SELECT common.web1, common.web2,
CASE WHEN r1.web_count + r2.web_count - common.com_cnt > 0
THEN common.com_cnt / (r1.web_count + r2.web_count - common.com_cnt)
ELSE 0 END AS similarity
FROM common JOIN (
    SELECT referrer, web_count FROM ref_count

```

```

    WHERE referrer IN (
        SELECT web1 FROM common
        INTERSECT
        SELECT referrer FROM ref_count)
) r1 ON common.web1 = r1.referrer
JOIN (
    SELECT referrer, web_count
    FROM ref_count
    WHERE referrer IN (
        SELECT web2 FROM common
        INTERSECT
        SELECT referrer FROM ref_count)
) r2 ON common.web2 = r2.referrer order by similarity desc limit 500;

```

查询结果:

39381817	77016942	1.0
25990595	27394033	1.0
29152253	89094179	1.0
344454081	412486871	1.0
25580358	159579745	1.0
16804125	128953441	1.0
15792401	21893061	1.0
12742918	285949147	1.0
40296131	437136030	1.0
27889544	86525478	1.0
17864133	97742874	1.0
33845600	34054226	1.0
20490152	29944159	1.0
33129732	437136030	1.0
93686448	105639498	1.0
13610348	48739090	1.0
27125224	52659511	1.0
121098486	427194018	1.0
16728776	21893061	1.0
171803433	345999006	1.0
31493182	52659511	1.0
15387913	86378769	1.0
92609584	345999006	1.0
40125679	285949147	1.0
31652187	48259437	1.0
14592440	437136030	1.0
14637838	22299596	1.0

Time taken: 205.164 seconds, Fetched 500 row(s)
25/02/25 14:56:56 INFO CliDriver: Time taken: 205.164 seconds, Fetched 500 row(s)
spark-sql> |

耗时 205.164s 完成

- exists 方式:

查询语句:

```

WITH ref_count AS (
    SELECT referrer, COUNT(DISTINCT referree) AS web_count
    FROM relation
    GROUP BY referrer),
common AS (
    SELECT a.referrer AS web1, b.referrer AS web2, COUNT(*) AS com_cnt
    FROM relation a
    JOIN relation b ON a.referree = b.referree
    WHERE a.referrer < b.referrer
    GROUP BY a.referrer, b.referrer)

```

```

SELECT
    common.web1,
    common.web2,
    CASE
        WHEN r1.web_count + r2.web_count - common.com_cnt > 0
        THEN common.com_cnt / (r1.web_count + r2.web_count -
common.com_cnt)
        ELSE 0
    END AS similarity
FROM common JOIN (
    SELECT referrer, web_count
    FROM ref_count r
    WHERE EXISTS (SELECT 1 FROM common c WHERE c.web1 = r.referrer)
) r1 ON common.web1 = r1.referrer
JOIN (
    SELECT referrer, web_count
    FROM ref_count r
    WHERE EXISTS (SELECT 1 FROM common c WHERE c.web2 = r.referrer)
) r2 ON common.web2 = r2.referrer
ORDER BY similarity DESC LIMIT 500;

```

查询结果:

69670717	89094179	1.0
39381817	77016942	1.0
2663697 22817535		1.0
33749108	89094179	1.0
14193736	15487600	1.0
18877266	41866950	1.0
16804125	128953441	1.0
14791225	21093061	1.0
14137741	17550984	1.0
14592440	437136030	1.0
27889544	86525478	1.0
27945434	97742874	1.0
28828804	34854226	1.0
21699833	29944159	1.0
378461352	437136030	1.0
19158800	105639498	1.0
8291188 17219913		1.0
27125224	52659511	1.0
121098486	427194818	1.0
7953008 21093061		1.0
337414203	345999806	1.0
27377064	52659511	1.0
15387913	86376769	1.0
92609584	345999806	1.0
5723618 41866950		1.0
31652187	48259437	1.0
22084402	437136030	1.0
14637838	22299596	1.0

Time taken: 204.174 seconds, Fetched 500 row(s)
25/02/25 14:52:40 INFO CliDriver: Time taken: 204.174 seconds, Fetched 500 row(s)
spark-sql> |

耗时 204.174s 完成。

五、 查询验证

为了方便后续查询验证，我先前将临时表 ref_count, common 保存为了中间表 tmp_ref_count, tmp_common，相似度计算结果表保存到了 result。

```

25/02/25 14:57:59 INFO scheduler.DAGScheduler: Job 42 finished: processCmd at CliDriver.java:376, took 8.021891 s
web_large      relation      false
web_large      result       false
web_large      tmp_common   false
web_large      tmp_ref_count false
Time taken: 0.036 seconds, Fetched 4 row(s)
25/02/25 14:57:59 INFO CliDriver: Time taken: 0.036 seconds, Fetched 4 row(s)
spark-sql> select count(*) from result;

```

查询 result 表数据行数：

```
25/02/25 14:59:28 INFO scheduler.DAGScheduler: Job 43 finished: processCmd at CliDriver.java:376, took 6.931805 s  
64195979  
Time taken: 7.678 seconds, Fetched 1 row(s)  
25/02/25 14:59:28 INFO CliDriver: Time taken: 7.678 seconds, Fetched 1 row(s)  
spark-sql> |
```

耗时 7678s 完成，显示结果 64195979 行，可见表及其庞大。

1. 查询相似度位于 0.72~0.73 的记录，返回最多 30 条。

```
Time taken: 19.932 seconds, Fetched 30 row(s)  
25/02/21 21:55:42 INFO CliDriver: Time taken: 19.932 seconds, Fetched 30 row(s)  
spark-sql> select * from result where similarity between 0.72 and 0.73 limit 30; |
```

```
25/02/21 21:57:46 INFO scheduler.TaskSetManager: Finished task 99.0 in stage 317.0 (TID 31346) in 227 ms on localhost (executor driver) (100/100)  
25/02/21 21:57:46 INFO scheduler.TaskSchedulerImpl: Removed TaskSet 317.0, whose tasks have all completed, from pool  
25/02/21 21:57:46 INFO scheduler.DAGScheduler: ResultStage 317 (processCmd at CliDriver.java:376) finished in 15.950 s  
25/02/21 21:57:46 INFO scheduler.DAGScheduler: Job 138 finished: processCmd at CliDriver.java:376, took 15.953909 s  
291245333 296171249 0.7297297297297297  
25227543 334462096 0.7297297297297297  
99786878 122113661 0.7297297297297297  
28539307 437057716 0.7297297297297297  
15594319 29725736 0.7297297297297297  
14667720 590021610 0.7297297297297297  
42098840 148230772 0.7297297297297297  
19040457 46970699 0.7297297297297297  
131785632 202186645 0.7297297297297297  
24033843 64058908 0.7297297297297297  
18088315 28393099 0.7297297297297297  
16987309 38211829 0.7295918367346939  
17677642 18559386 0.7295597484276729  
57846183 69306513 0.7295081967213115  
16889676 16929288 0.7295081967213115  
79378664 90433572 0.7295081967213115  
15594319 35415483 0.7294117647058823  
18359358 19040457 0.7294117647058823  
291245333 378352656 0.7294117647058823  
286481558 338614684 0.7294117647058823  
16541224 260975690 0.7294117647058823  
18359358 177761713 0.7294117647058823  
128496489 273186922 0.7294117647058823  
395472459 523832662 0.7294117647058823  
1976847 45869579 0.7293233082706767  
1976847 17023350 0.7293233082706767  
1976847 16956336 0.7293233082706767  
294854141 368829932 0.7292817679558011  
397464137 554003477 0.7292817679558011  
327129 9659998 0.7291666666666666  
Time taken: 19.945 seconds, Fetched 30 row(s)  
25/02/21 21:57:46 INFO CliDriver: Time taken: 19.945 seconds, Fetched 30 row(s)  
spark-sql> |
```

耗时 19.945s 完成查询，返回了 30 行数据。

2. 查询相似度为 0.9 的记录，最多 30 条。

```
25/02/21 21:57:46 INFO CliDriver: Time taken: 19.945 seconds, Fetched 30 row(s)  
spark-sql> select * from result where similarity=0.9 limit 30; |
```

```
25/02/21 21:59:44 INFO scheduler.TaskSetManager: Finished task 74.0 in stage 322.0 (TID 31546) in 4 ms on localhost (executor driver) (75/75)
25/02/21 21:59:44 INFO scheduler.TaskSchedulerImpl: Removed TaskSet 322.0, whose tasks have all completed, from pool
25/02/21 21:59:44 INFO scheduler.DAGScheduler: ResultStage 322 (processCommand at CliDriver.java:376) finished in 12.442 s
25/02/21 21:59:44 INFO scheduler.DAGScheduler: Job 143 finished: processCommand at CliDriver.java:376, took 12.444734 s
17084145      21764349      0.9
116225517     123854765    0.9
8168800      16955876      0.9
20216098      21624408      0.9
17084145      19662636      0.9
543643498     543723381    0.9
395829895     399644865    0.9
548633238     548738861    0.9
7265488      18324692      0.9
19424894      40977581      0.9
14880365      14882461      0.9
18324692      40977581      0.9
14799157      218588666     0.9
14683521      16929565      0.9
547878718     548738861    0.9
21624408      105508695    0.9
14268799      18324692      0.9
14268799      19424894      0.9
18324692      97388937      0.9
8168800      14603521      0.9
9557358      19424894      0.9
16929565      16955876      0.9
21624408      45922281      0.9
16956014      17081049      0.9
Time taken: 32.389 seconds, Fetched 24 row(s)
25/02/21 21:59:44 INFO CliDriver: Time taken: 32.389 seconds, Fetched 24 row(s)
spark-sql> |
```

耗时 32.389s 完成查询，返回了 24 项相似度为 0.9 的数据。

至此，实验完成。

六、实验总结

本次实验基于 Hadoop HDFS 和 Spark SQL 构建分布式数据库查询系统，我深入理解了大数据存储与处理的分布式架构。通过实验，掌握了 HDFS 的文件存储机制及 Spark SQL 的分布式查询优化技术，体验了其在海量数据下的高效查询性能。实验过程中，数据分区、并行计算和内存优化等策略显著提升了查询效率，同时也认识到集群资源调度与数据倾斜问题的挑战。总体而言，我熟悉了手动搭建 hadoop 和 spark-sql 的基本流程，学会了对大数据集查询的 sql 语句进行一定程度优化，本学期的数据库实验让我受益匪浅！