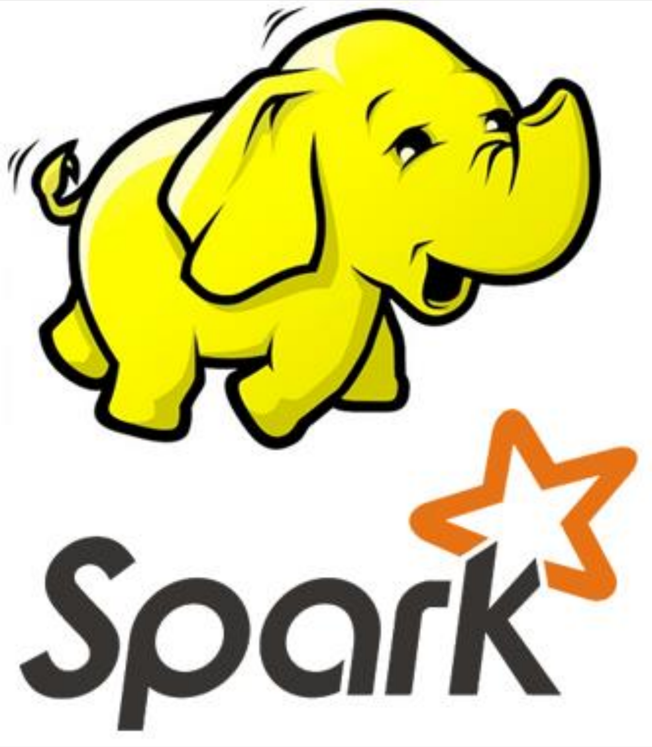
COMP9313: Big Data Management



Lecturer: Xin Cao

Course web site: http://www.cse.unsw.edu.au/~cs9313/

Chapters Required in Exam

- MapReduce (Chapters 2 and 3)
  - MapReduce Concepts and Mechanism
  - MapReduce algorithm design
- Spark (Chapters 4 and 5.1)
  - RDD operations
  - GraphX
- Mining Data Streams (Chapter 6)
  - Sampling data from a stream
  - Filtering a data stream
  - Counting distinct elements
  - Finding frequent elements
- Finding Similar Items (Chapter 7)
- NoSQL Concepts (Chapter 8.1)
- Recommender Systems (Chapter 9)

Final exam

- Final written exam (50 pts)
- Six questions in total on six topics
- Two hours + Two hours (Do not wait for the last minute to submit!)
- Online exam. Submit through Moodle
- If you are ill on the day of the exam, do not attend the exam – will not accept any medical special consideration claims from people who already attempted the exam.

Exam Questions

- Question 0: MapReduce, Spark, and NoSQL concepts
- Question 1 MapReduce algorithm design (pseudo-code only)
- Question 2 Spark algorithm design
  - Spark Core (RDD operations)
  - GraphX
- Question 3 Finding Similar Items
  - Shingling, Min Hashing, LSH
- Question 4 Mining Data Streams
  - Sampling, Bloom filter, Finding frequent items, ~~DGIM, FM-Sketch~~
- Question 5 Recommender Systems
  - Content-based and collaborative filtering (~~matrix factorization~~)

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Sample Exam Questions

Question 1 MapReduce

- Assume that you are given a data set crawled from a location-based social network, in which each line of the data is in format of (userID, a list of locations the user has visited <loc1, loc2, …>). Your task is to compute for each location the set of users who have visited it, and the users are sorted in ascending order according to their IDs.

Solution (java)

```
class Pair
    userID, locID
    int compareTo(Pair p)
        int ret = this.locID.compareTo(p.getLoc)
        if(ret == 0) ret = this.userID.compareTo(p.getUser)
        return ret

class Mapper
    method Map(userID, list of locations)
        foreach loc in the list of locations
             Emit( ((loc, userID), userID)

class Partitioner
        method int getPartition(key, value, int numPartitions)
                return key.first.hashCode() & Integer.MAX_VALUE % numPartitions

Class PairGroupingComparator extends WritableComparator
        method int compare(WritableComparable wc1, WritableComparable wc2)
                return ((Pair) wc1).getLoc().compareTo(((Pair) wc1).getLoc())

class Reducer
        method Reduce(key, userList [])
                Emit(key.getLoc(), userList)
```

Solution (python)

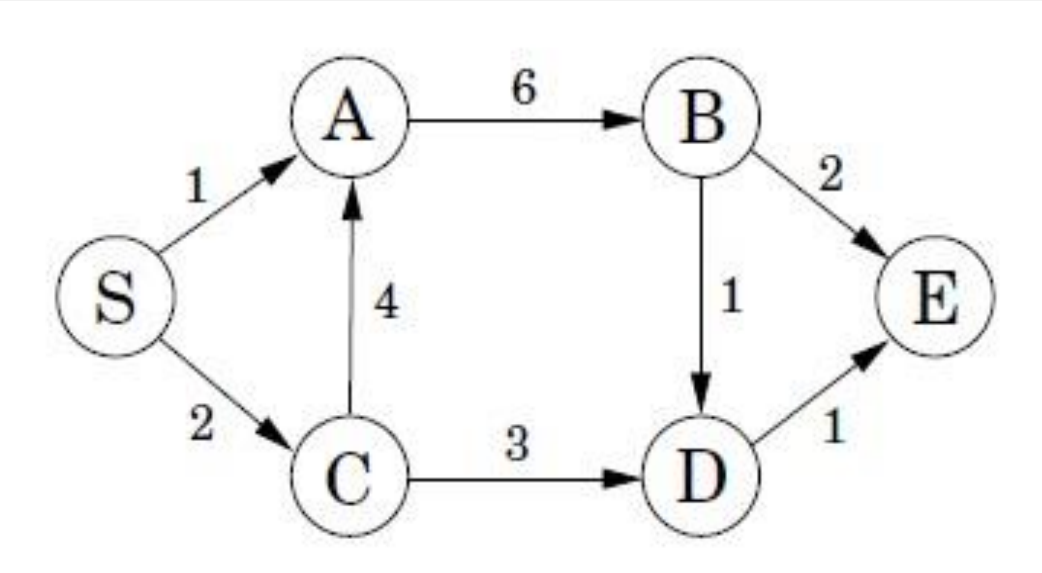
```
class Mapper
    method map(self, userID, list of locations)
        foreach loc in the list of locations
            Emit(“loc, userID”, “”)

class Reducer
    method reduce_init(self)
        current_loc = “”
        current_list = []
    method reduce(key, value)
        loc, userID = key.split(“,”)
        if loc != current_loc && current_loc!=“”
            Emit(current_loc, current_list)
            current_loc=loc
        else
            current_list.add(userID)
     method reduce_final(self)
        Emit(current_loc, current_list)

In JOBCONF, configure:
    'mapreduce.map.output.key.field.separator':’,’,
    'mapreduce.partition.keypartitioner.options':'-k1,1’,
    'mapreduce.partition.keycomparator.options':'-k1,1n -k2,2n'
```

Question 1 MapReduce

- Given the following graph, assume that you are using the single shortest path algorithm to compute the shortest path from node S to node E. Show the output of the mapper (sorted results of all mappers) and the reducer (only one reducer used) in each iteration (including both the distances and the paths).



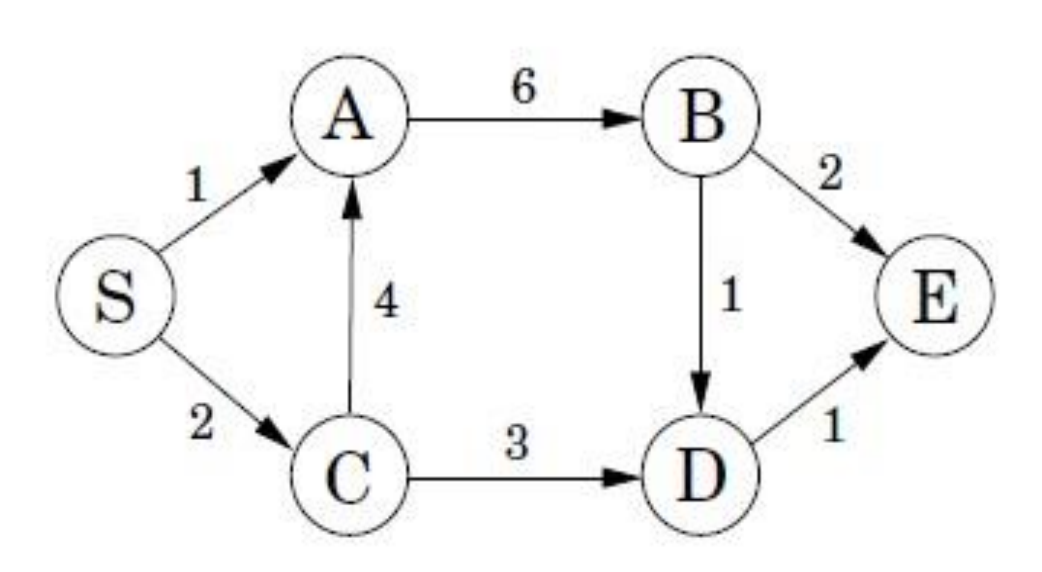
Solution

1.
Mapper:
(A, 1), (C, 2)
Reducer:
A: 1 | S->A | B:6
C: 2 | S->C | A:4, D:3

2.
Mapper:
(B, 7), (A, 6), (D, 5)
Reducer:
B: 7 | S->A->B | D:1, E:2
D: 5 | S->C->D | E:1

3.
Mapper:
(E, 9), (D, 8), (E, 6)
Reducer:
E: 6 |S->C->D->E | empty

Algorithm terminates



Question 2 Spark

- Write down the output

```
a) val lines = sc.parallelize(List("hello world", "this is a scala program", "to
create a pair RDD", "in spark"))
    val pairs = lines.map(x => (x.split(" ")(0), x))
    pairs.filter {case (key, value) => key.length <3}.foreach(println)
```

Output: (“to”, “to create a pair RDD”) (“in”, “in spark”)

```
b) val pairs = sc.parallelize(List((1, 2), (3, 4), (3, 9), (4,2)))
    val pairs1 = pairs.mapValues(x=>(x, 1)).reduceByKey((x,y) => (x._1 +
y._1,  x._2+y._2)).mapValues(x=>x._2/x._1)
    pairs1.foreach(println)
```

Output: (1, 0) (3, 0) (4, 0) (because no “.toDouble” used)

Question 2 Spark

- Given a large text file, your task is to find out the top-k most frequent co-occurring term pairs. The co-occurrence of (w, u) is defined as: u and w appear in the same line (this also means that (w, u) and (u, w) are treated equally). Your Spark program should generate a list of ***k*** key-value pairs ranked in descending order according to the frequencies, where the keys are the pair of terms and the values are the co-occurring frequencies (**Hint:** you need to define a function which takes an array of terms as input and generate all possible pairs).

```
val textFile = sc.textFile(inputFile)
val words = textFile.map(_.split(“ “).toLowerCase)

// fill your code here, and store the result in a pair RDD topk

topk.foreach(x => println(x._1, x._2))
```

Solution

```
def pairGen(wordArray: Array[String]) : ArrayBuffer[(String, Int)] = {
  val abuf = new ArrayBuffer[(String, Int)]

  for(i <- 0 to wordArray.length -1){
   val term1 = wordArray(i)
   if(term1.length()>0){
    for(j <- i+1 to wordArray.length - 1){
     val term2 = wordArray(j)
     if(term2.length()>0){
      if(term1 < term2){abuf.+=:(term1 + "," + term2, 1)}
      else {abuf.+=:(term2 + "," + term1, 1)}
     }
    }
   }
  }
  return abuf
 }


 val textFile = sc.textFile(inputFile)
 val words = textFile.map(_.split(“ “).toLowerCase)

 val pairs = words.flatMap(x => pairGen(x)).reduceByKey(_+_)
 val topk = pairs.map(_.swap).sortByKey(false).take(k).map(_.swap)

 topk.foreach(x => println(x._1, x._2))
```

Question 3 Finding Similar Items

- k-Shingles:

Consider two documents A and B. Each document's number of token is O(n). What is the runtime complexity of computing A and B's k-shingle resemblance (using Jaccard similarity)? Assume that comparison of two k-shingles to assess their equivalence is O(k). Express your answer in terms of n and k.

Answer:

Assuming n >> k,

Time to create shingles = O(n)

Time to find intersection (using brute force algorithm) = O(kn^2)

Time to find union = O(n)

Total time = (kn^2)

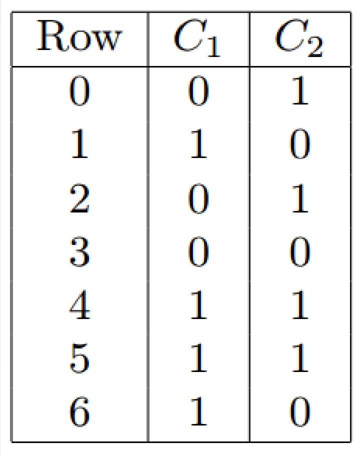
Question 3 Finding Similar Items

- MinHash:

We want to compute min-hash signature for two columns, C_1 and C_2 using two pseudo-random permutations of columns using the following function:

$h_1(n) = 3n + 2 \bmod 7$

$h_2(n) = 2n - 1 \bmod 7$

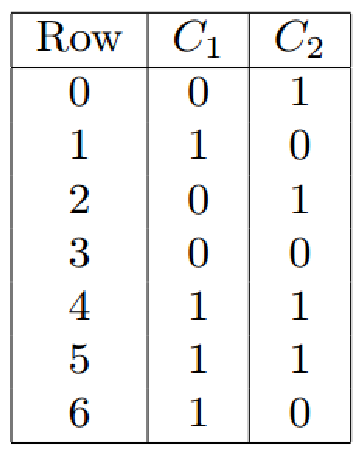


Row	C_1	C_2
0	0	1
1	1	0
2	0	1
3	0	0
4	1	1
5	1	1
6	1	0

Here, n is the row number in original ordering. Instead of explicitly reordering the columns for each hash function, we use the implementation discussed in class, in which we read each data in a column once in a sequential order, and update the min hash signatures as we pass through them.

Complete the steps of the algorithm and give the resulting signatures for C_1 and C_2.

Solution



Row	C_1	C_2
0	0	1
1	1	0
2	0	1
3	0	0
4	1	1
5	1	1
6	1	0

	Sig1	Sig2
	∞	∞
	∞	∞
$h1(0) = 2$	∞	2
$h2(0) = 6$	∞	6
$h1(1) = 5$	5	2
$h2(1) = 1$	1	6
$h1(2) = 1$	5	1
$h2(2) = 3$	1	3
$h1(4) = 0$	0	0
$h2(4) = 0$	0	0

$h_1(n) = 3n + 2 \bmod 7$
$h_2(n) = 2n - 1 \bmod 7$

Question 4 Mining Data Streams

- Sampling

Briefly explain Reservoir Sampling and describe the key steps.

- DGIM

Explain the space complexity of maintaining one bucket in the DGIM algorithm in terms of the window size N. How many buckets you need to store at most?

- DGIM

Suppose we are maintaining a count of 1s using the DGIM method. We represent a bucket by (i, t), where i is the number of 1s in the bucket and t is the bucket timestamp (time of the most recent 1).

Consider that the current time is 200, window size is 60, and the current list of buckets is: (16, 148) (8, 162) (8, 177) (4, 183) (2, 192) (1, 197) (1, 200). At the next ten clocks, 201 through 210, the stream has 0101010101. What will the sequence of buckets be at the end of these ten inputs?

Question 5 Recommender Systems

- Consider three users u_1, u_2, and u_3, and four movies m_1, m_2, m_3, and m_4. The users rated the movies using a 4-point scale: -1: bad, 1: fair, 2: good, and 3: great. A rating of 0 means that the user did not rate the movie. The three users' ratings for the four movies are: u_1 = (3, 0, 0, -1), u_2 = (2, -1, 0, 3), u_3 = (3, 0, 3, 1)
  - Which user has more similar taste to u_1 based on cosine similarity, u_2 or u_3? Show detailed calculation process.
  - User u_1 has not yet watched movies m_2 and m_3. Which movie(s) are you going to recommend to user u_1, based on the user-based collaborative filtering approach? Justify your answer.

Job/Intern Opportunity

- The AWS Relational Database Service (RDS) team has some opening positions. The job description can be accessed here. If you are interested, please submit your CV to Mr. Lei Yao (wonderyl@gmail.com).

Thank you!