Aggregating Data with Pair RDDs

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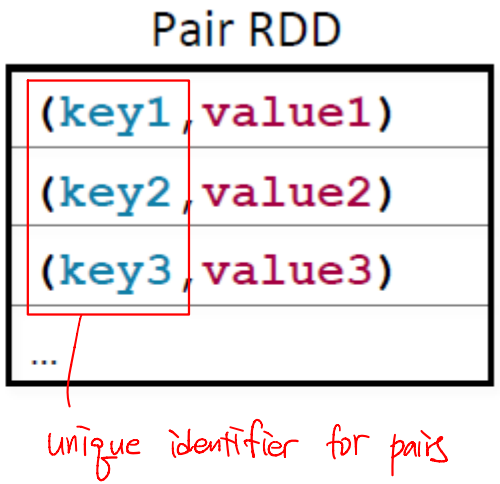
Aggregating Data with Pair RDDs

In this chapter you will learn

- How to create Pair RDDs of key-value pairs from generic RDDs
- Special operations available on Pair RDDs
- How map-reduce algorithms are implemented in Spark

Pair RDDs

- **Pair RDDs are a special form of RDD**
  - Each element must be a key-value pair (a two-element tuple)
  - Keys and values can be any type
- **Why?** Big Data ⇒ unpredictable & varied
  - Use with map-reduce algorithms
  - Many additional functions are available for common data processing needs
    - e.g., sorting, joining, grouping, counting, etc.



Creating Pair RDDs

- **The first step in most workflows is to get the data into key/value form**
  - What should the RDD should be keyed on?
  - What is the value?
- **Commonly used functions to create Pair RDDs**
  - `map`
  - `flatMap` / `flatMapValues`
  - `keyBy`

Example: A Simple Pair RDD

- Example: Create a Pair RDD from a tab-separated file

Python

```
> users = sc.textFile(file) \
    .map(lambda line: line.split('\t')) \
    .map(lambda fields: (fields[0],fields[1]))
```

Scala

```
> val users = sc.textFile(file) \
    .map(line => line.split('\t')) \
    .map(fields => (fields(0),fields(1)))
```

```
user001\tFred Flintstone
user090\tBugs Bunny
user111\tHarry Potter
...
```

(user001,Fred Flintstone)
(user090,Bugs Bunny)
(user111,Harry Potter)
...

Example: Keying Web Logs by User ID

Python

```
> sc.textFile(logfile) \
    .keyBy(lambda line: line.split(' ')[2])
```

Scala

```
> sc.textFile(logfile) \
    .keyBy(line => line.split(' ')(2))
```

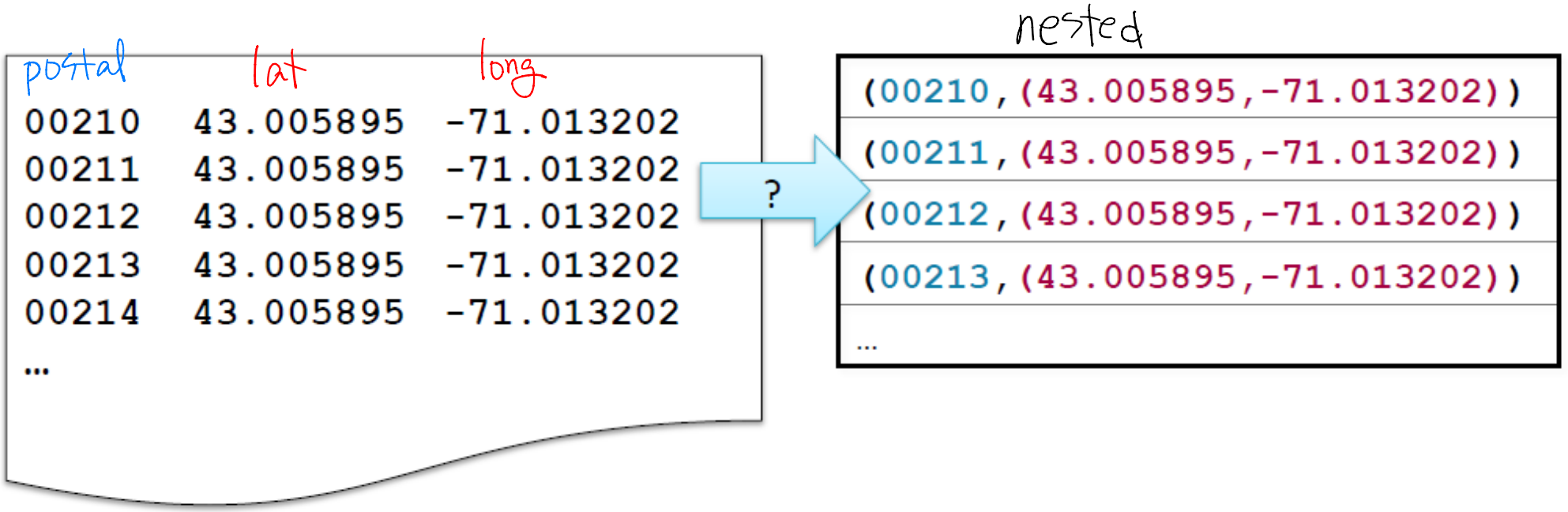
User ID

```
56.38.234.188 - 99788 "GET /KBDOC-00157.html HTTP/1.0" …
56.38.234.188 - 99788 "GET /theme.css HTTP/1.0" …
203.146.17.59 - 25254 "GET /KBDOC-00230.html HTTP/1.0" …
…
```

```
(99788,56.38.234.188 - 99788 "GET /KBDOC-00157.html…)
(99788,56.38.234.188 - 99788 "GET /theme.css…)
(25254,203.146.17.59 - 25254 "GET /KBDOC-00230.html…)
…
```

Question 1: Pairs With Complex Values

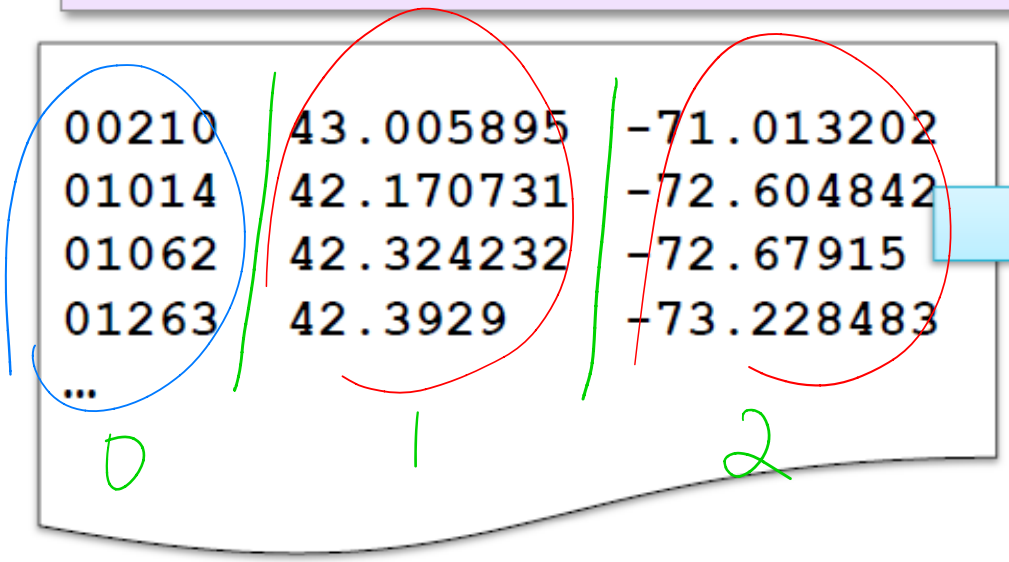
- **How would you do this?**
  - Input: a list of postal codes with latitude and longitude
  - Output: postal code (key) and lat/long pair (value)



Answer 1: Pairs With Complex Values

```
> sc.textFile(file) \
  .map(lambda line: line.split()) \
  .map(lambda fields: (fields[0],(fields[1],fields[2])))
```

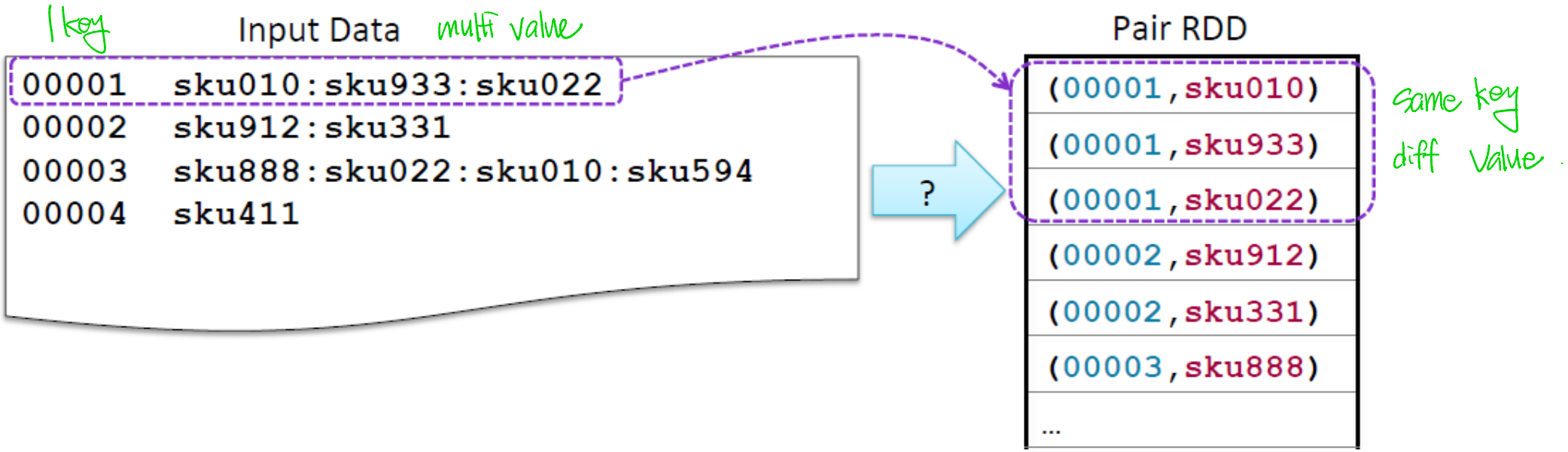
```
> sc.textFile(file).
    map(line => line.split('\t')).
    map(fields => (fields(0),(fields(1),fields(2))))
```




```
(00210,(43.005895,-71.013202))
(01014,(42.170731,-72.604842))
(01062,(42.324232,-72.67915))
(01263,(42.3929,-73.228483))
…
```

Question 2: Mapping Single Rows to Multiple Pairs (1)

- **How would you do this?**
  - Input: order numbers with a list of SKUs in the order
  - Output: order (key) and sku (value)



Question 2: Mapping Single Rows to Multiple Pairs (2)

- Hint: map alone won't work

```
00001    sku010:sku933:sku022
00002    sku912:sku331
00003    sku888:sku022:sku010:sku594
00004    sku411
```

```
(00001,(sku010,sku933,sku022))
(00002,(sku912,sku331))
(00003,(sku888,sku022,sku010,sku594))
(00004,(sku411))
```

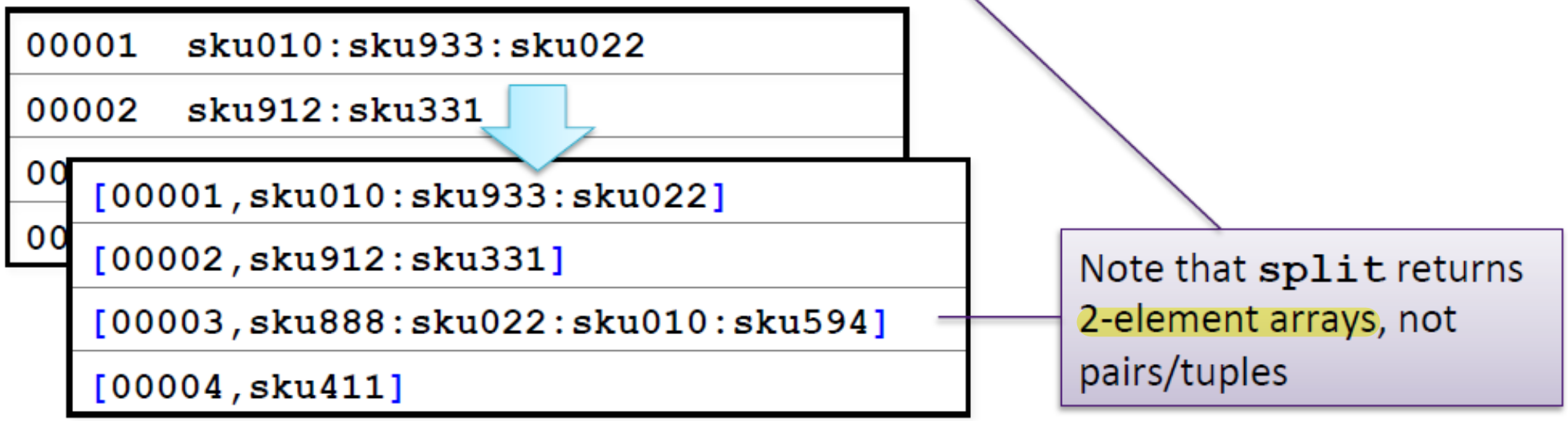
Answer 2: Mapping Single Rows to Multiple Pairs(1)

```
> sc.textFile(file)
```

00001	sku010:sku933:sku022
00002	sku912:sku331
00003	sku888:sku022:sku010:sku594
00004	sku411

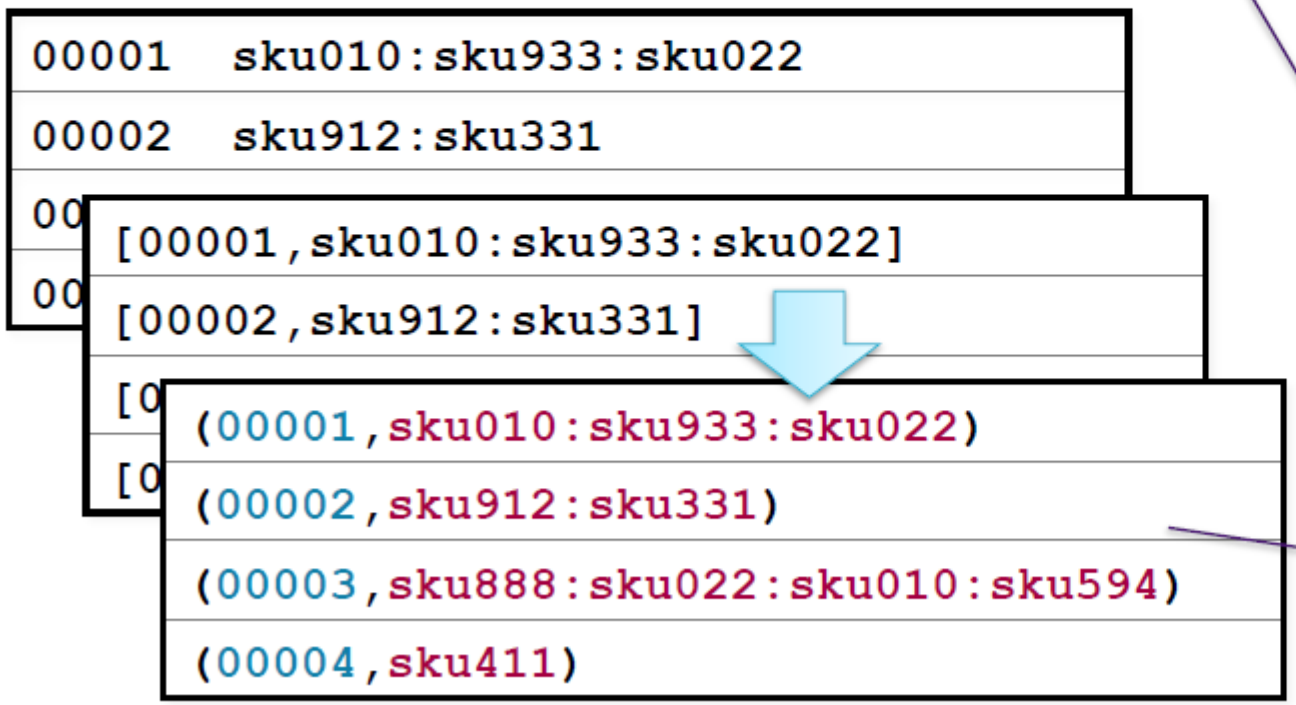
Answer 2: Mapping Single Rows to Multiple Pairs(2)

```
> sc.textFile(file) \
  .map(lambda line: line.split('\t'))
```



Answer 2: Mapping Single Rows to Multiple Pairs(3)

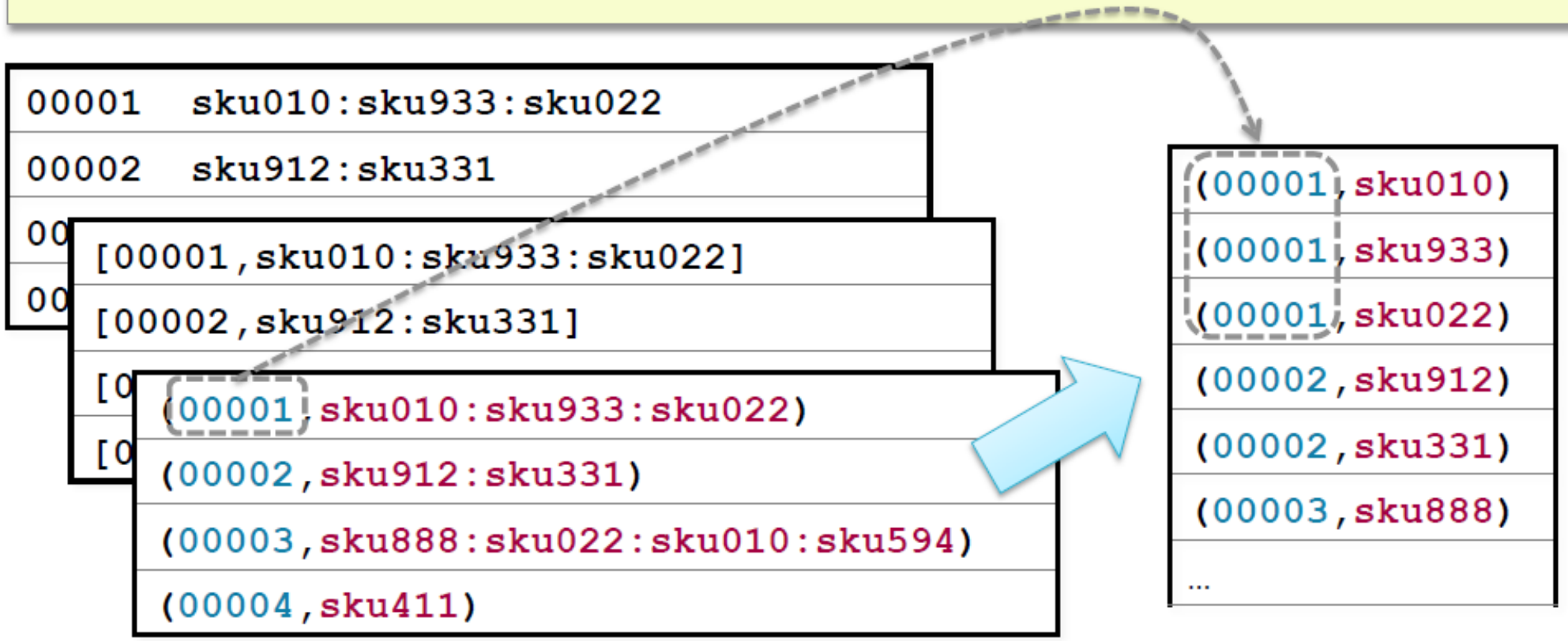
```
> sc.textFile(file) \
  .map(lambda line: line.split('\t')) \
  .map(lambda fields: (fields[0],fields[1]))
```



Map array elements to tuples to produce a Pair RDD

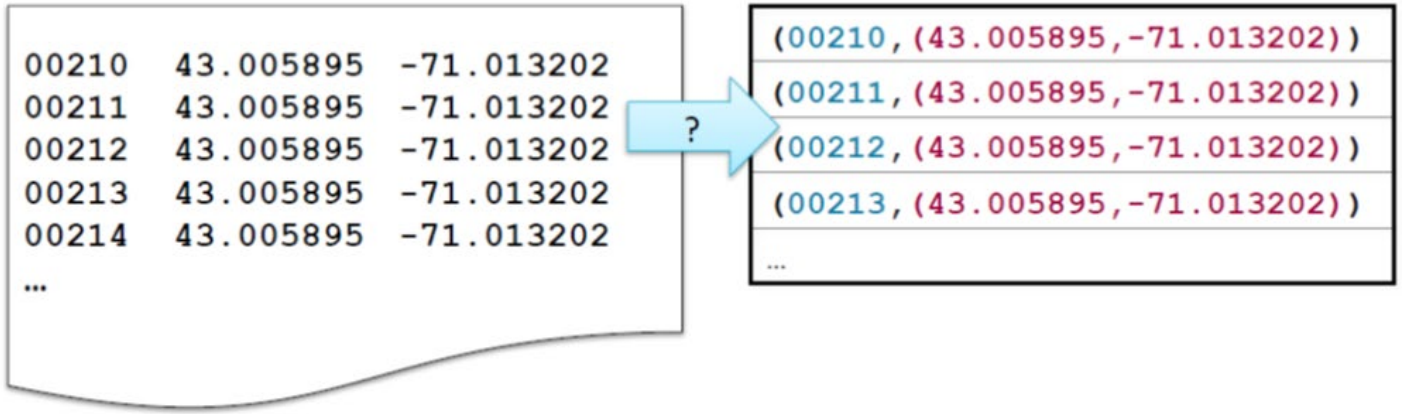
Answer 2: Mapping Single Rows to Multiple Pairs(4)

```
> sc.textFile(file) \
  .map(lambda line: line.split('\t')) \
  .map(lambda fields: (fields[0],fields[1]))
  .flatMapValues(lambda skus: skus.split(':'))
```

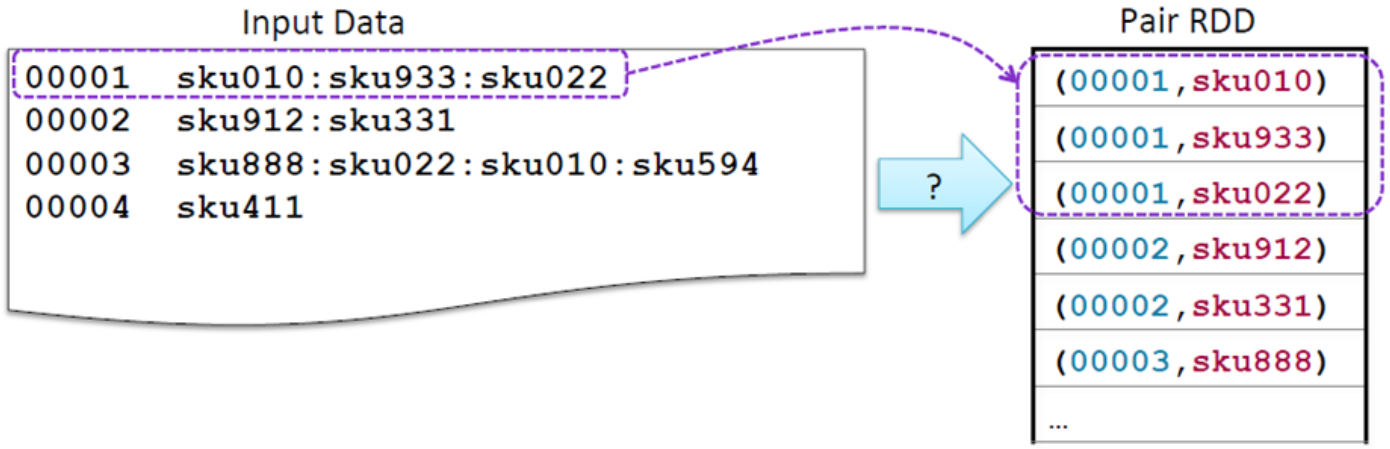


Practice

- **Practice Questions 1 and 2 using a sample data presented in the previous slides**
  - Question 1



  - Question 2



Map-Reduce

translate all operations into primitives (map, reduce)

- **Map-reduce is a common programming model**
  - Easily applicable to distributed processing of large data sets
- **Hadoop MapReduce is the major implementation**
  - Somewhat limited
    - Each job has one Map phase, one Reduce phase
    - Job output is saved to files (disk)
- **Spark implements map-reduce with much greater flexibility**
  - Map and reduce functions can be interspersed
  - Results can be stored in memory (distributed)
    - Operations can easily be chained

Map-Reduce in Spark

- **Map-reduce in Spark works on Pair RDDs**
- **Map phase**
  - Operates on one record at a time
  - "Maps" each record to one or more new records
  - e.g. **`map`**, **`flatMap`**, **`filter`**, **`keyBy`** + union, ...
- **Reduce phase**
  - Works on map output
  - Consolidates multiple records
  - e.g. **`reduceByKey`**, **`sortByKey`**, **`mean`**

Map-Reduce Example: Word Count

Input Data

```
the cat sat on the mat
the aardvark sat on the sofa
```

Result

aardvark	1
cat	1
mat	1
on	2
sat	2
sofa	1
the	4

Example: Word Count(1)

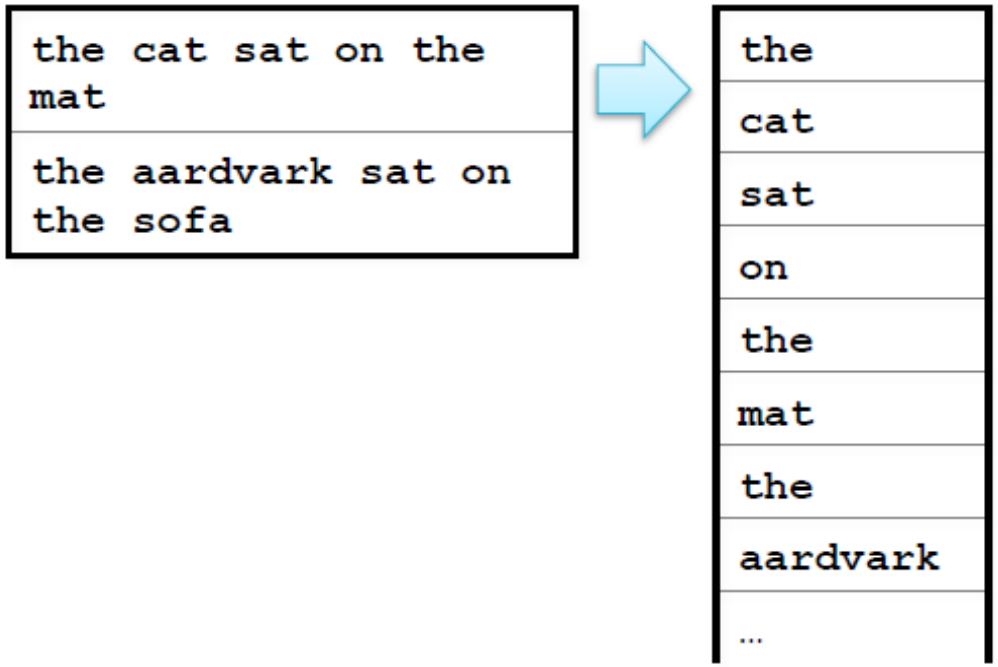
```
> counts = sc.textFile(file)
```

the cat sat on the mat
the aardvark sat on the sofa

Example: Word Count(2)

```
> counts = sc.textFile(file) \
    .flatMap(lambda line: line.split())
```

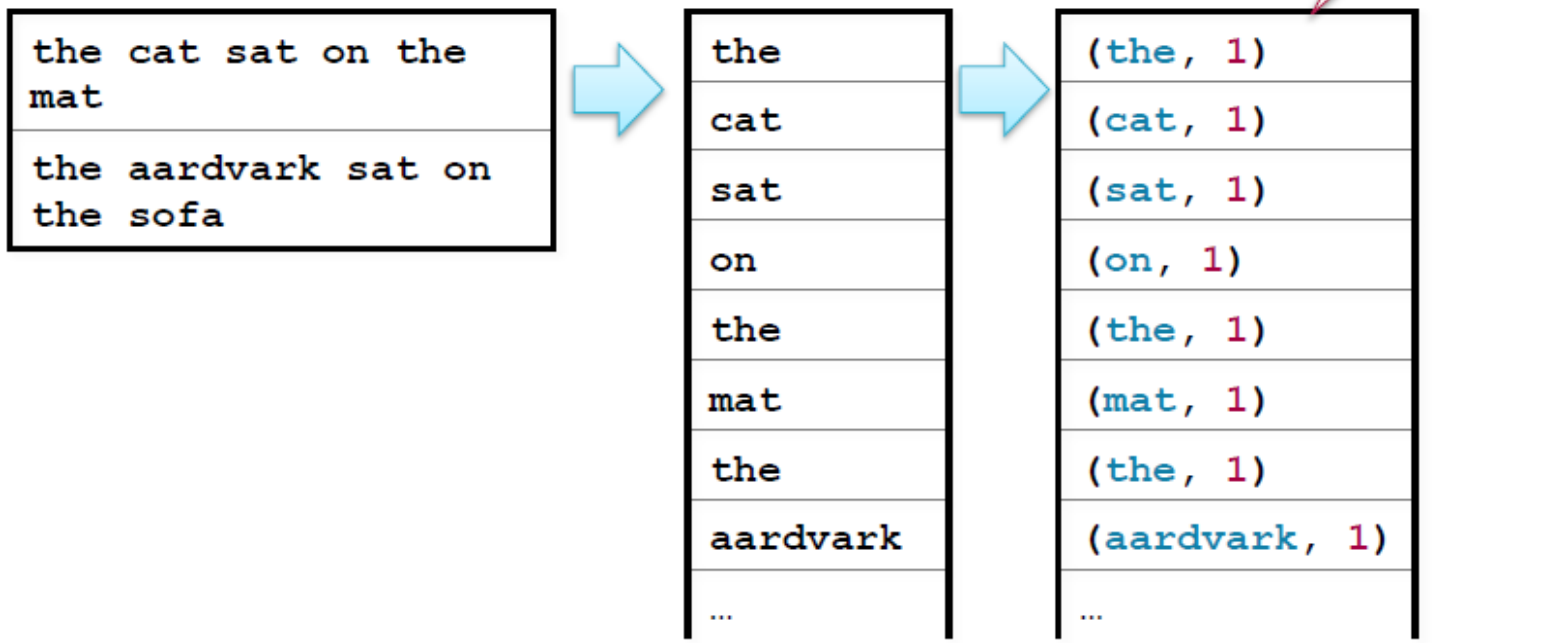
map: 1 input record => 1 output record
flatMap: 1 input record => multi output record



Example: Word Count(3)

```
> counts = sc.textFile(file) \
    .flatMap(lambda line: line.split()) \
    .map(lambda word: (word,1))
```

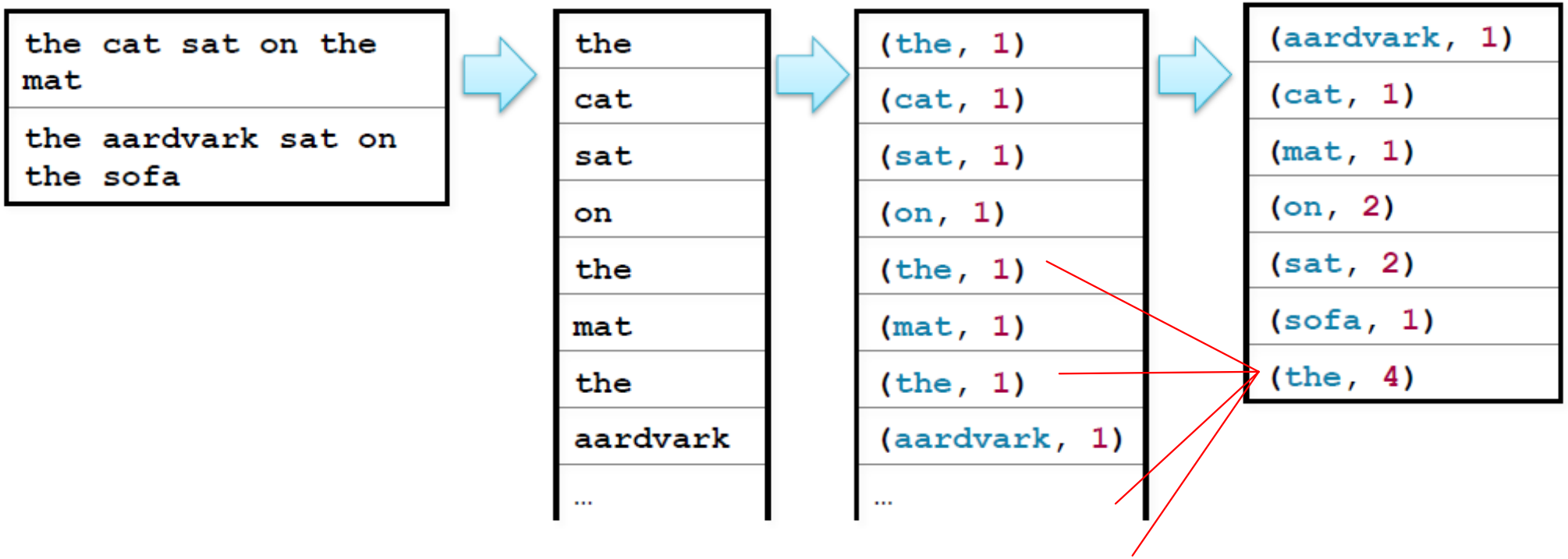
Key-Value Pairs



Example: Word Count(4)

```
> counts = sc.textFile(file) \
    .flatMap(lambda line: line.split()) \
    .map(lambda word: (word,1)) \
    .reduceByKey(lambda v1,v2: v1+v2)
```

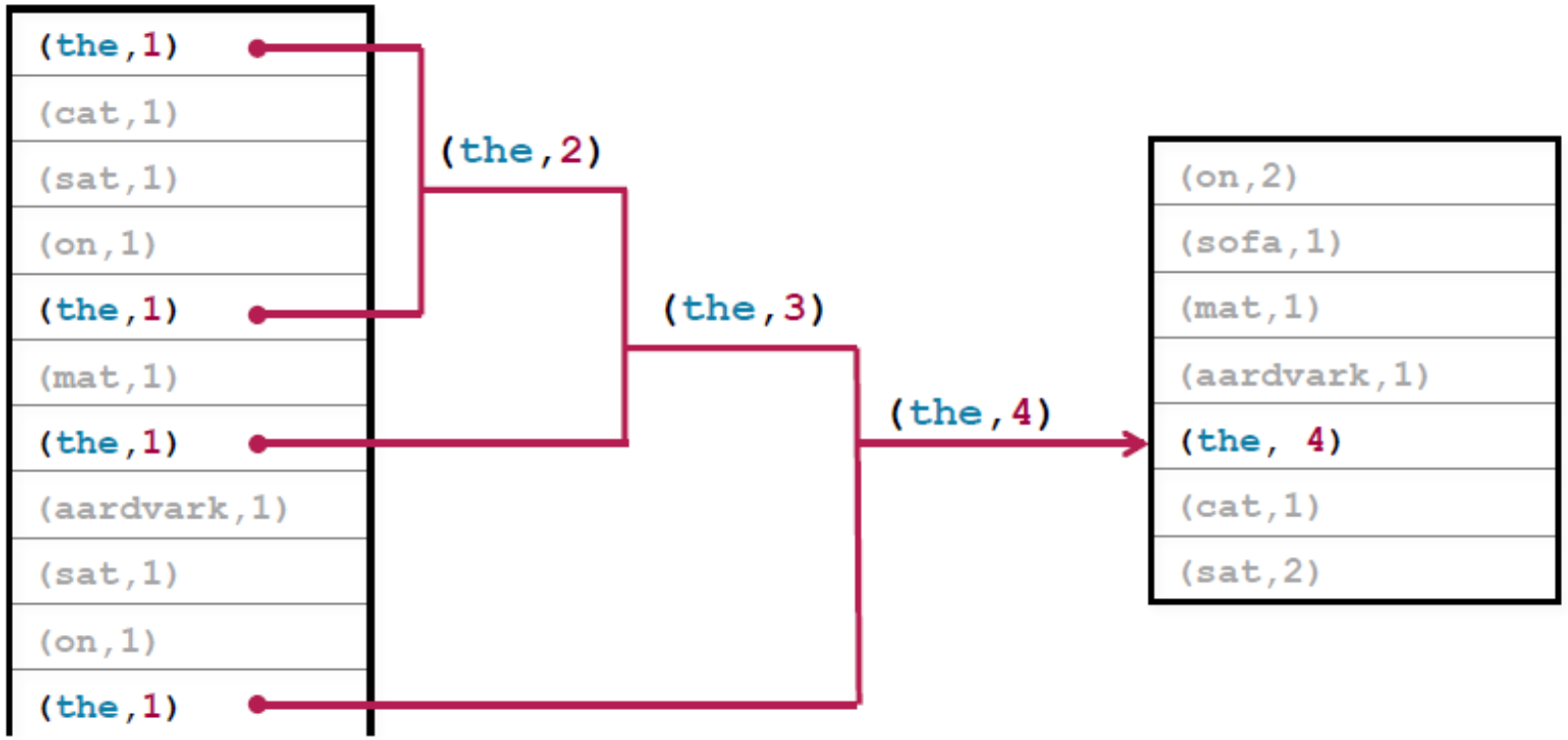
values



ReduceByKey(1)

- The function passed to `reduceByKey` combines values from two keys
  - Function must be binary

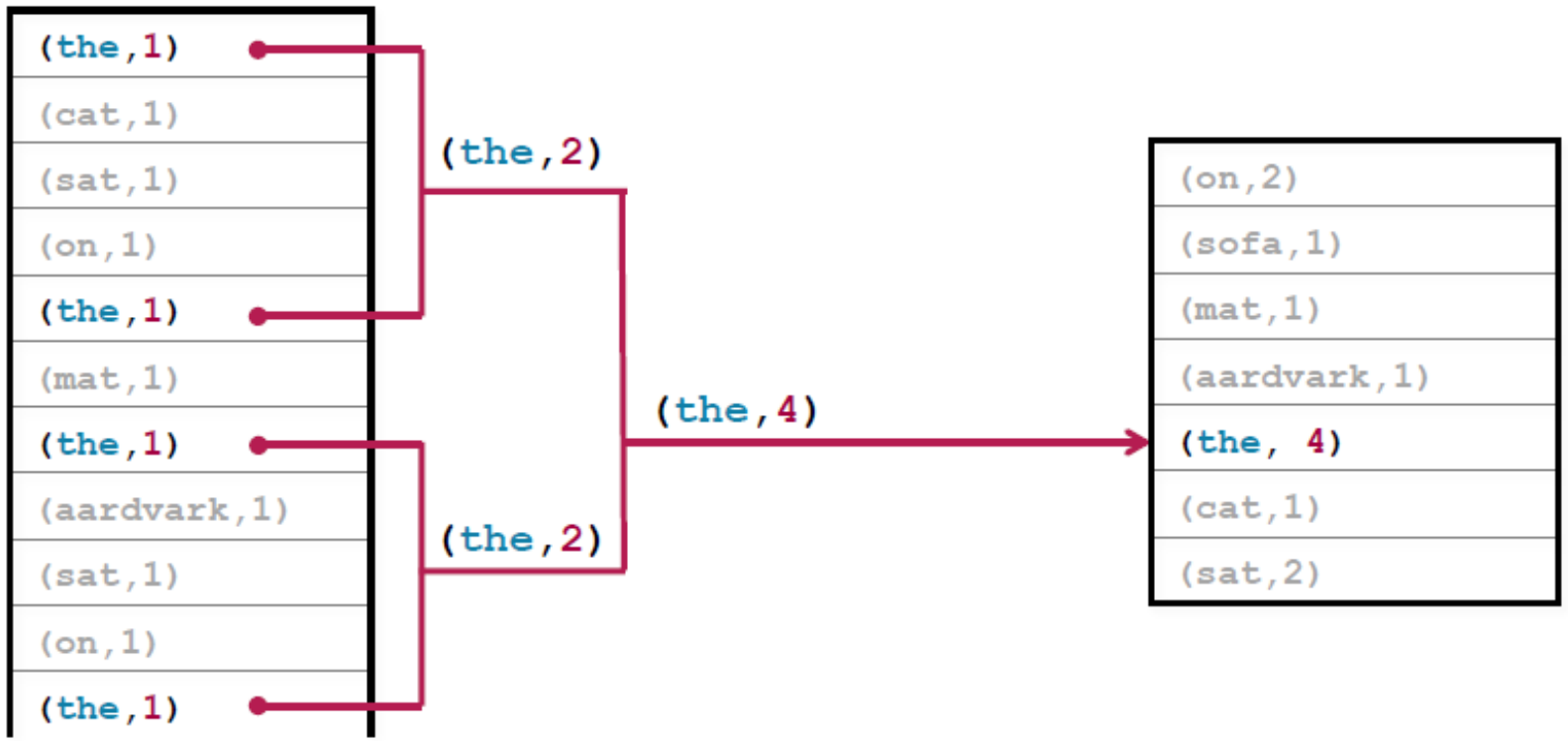
```
> counts = sc.textFile(file) \
  .flatMap(lambda line: line.split()) \
  .map(lambda word: (word,1)) \
  .reduceByKey(lambda v1,v2: v1+v2)
```



ReduceByKey(2)

- The function might be called in any order, therefore must be
  - Commutative – x+y = y+x
  - Associative – (x+y)+z = x+(y+z)

```
> counts = sc.textFile(file) \
  .flatMap(lambda line: line.split()) \
  .map(lambda word: (word,1)) \
  .reduceByKey(lambda v1,v2: v1+v2)
```



Word Count Recap (the Scala Version)

```
> val counts = sc.textFile(file).
  flatMap(line => line.split("\\W")).
  map(word => (word,1)).
  reduceByKey((v1,v2) => v1+v2)
```

OR

```
> val counts = sc.textFile(file).
  flatMap(_.split("\\W")).
  map((_,1)).
  reduceByKey(_+_)
```

Why Do We Care About Counting Words?

- **Word count is challenging over massive amounts of data**
  - Using a single compute node would be too time-consuming
  - Number of unique words could exceed available memory
- **Statistics are often simple aggregate functions**
  - Distributive in nature
  - e.g., max, min, sum, count
- **Map-reduce breaks complex tasks down into smaller elements which can be executed in parallel**
- **Many common tasks are very similar to word count**
  - e.g., log file analysis

Practice: Reduce

```
$ pyspark

> userreqs = sc.textFile("/loudacre/weblogs/*6") \
  .map(lambda line: line.split()) \
  .map(lambda words: (words[2], 1)) \
  .reduceByKey(lambda v1, v2: v1+v2)

> userreqs.take(5)
Out[]: [(u'3922', 10), (u'78723', 4), (u'31456', 4), (u'88489', 2), (u'116499', 4)]
```

- **Data sets (HDFS)**
  - /loudacre/weblogs
  - First, upload weblog data in your local file system into the HDFS

- **Using map-reduce, count the number of requests from each user.**
  - Use map to create a Pair RDD with the user ID as the key, and the integer 1 as the value. (The user ID is the third field in each line). Your data will look something like this:

(userid,1)
(userid,1)
(userid,1)
…

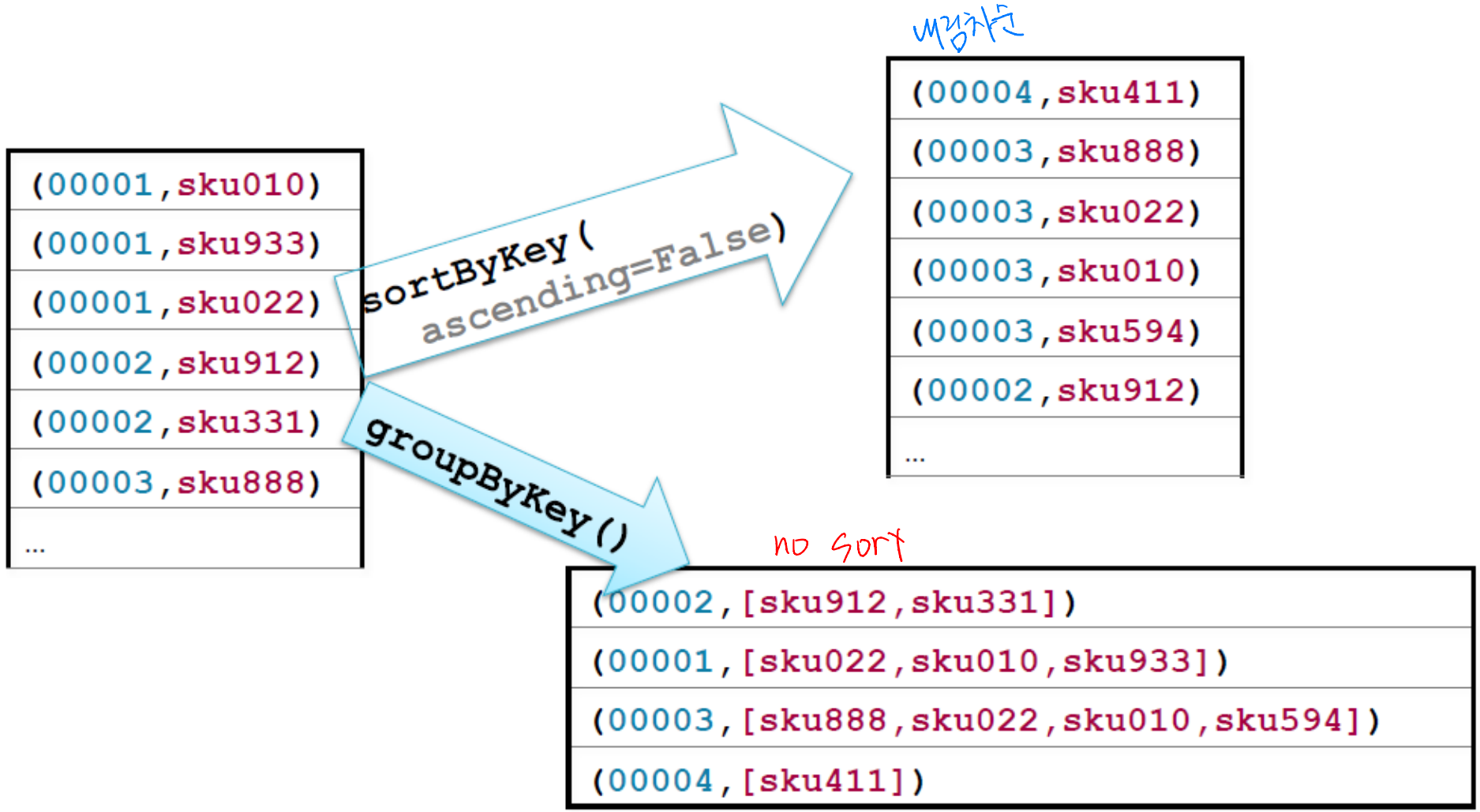
  - Use reduce to sum the values for each user ID. Your RDD data will be similar to:

(userid,5)
(userid,7)
(userid,2)
…

Pair RDD Operations

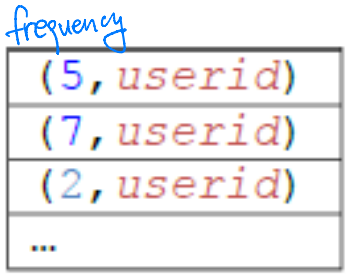
- **In addition to `map` and `reduce` functions, Spark has several operations specific to Pair RDDs**
- **Examples**
  - **`countByKey`** – return a map with the count of occurrences of each key
  - **`groupByKey`** – group all the values for each key in an RDD
  - **`sortByKey`** – sort in ascending or descending order
  - **`join`** – return an RDD containing all pairs with matching keys from two RDDs

Example: Pair RDD Operations



Practice: Count and Group

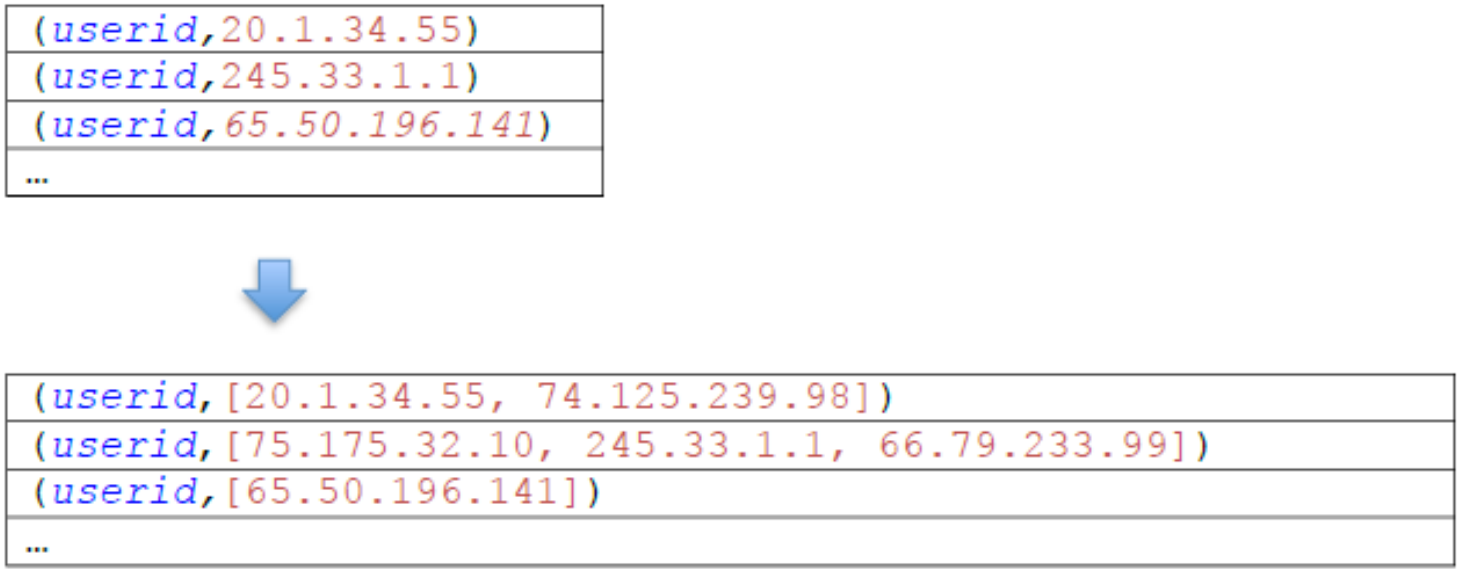
- **This practice continues to use the previous data sets**
- **Use countByKey to determine how many users visited the site for each frequency. That is, how many users visited once, twice, three times and so on.**
  - Use map to reverse the key and value, like this:




```
$ pyspark

> userreqs = sc.textFile("/loudacre/weblogs/*6") \
  .map(lambda line: line.split()) \
  .map(lambda words: (words[2], 1)) \
  .reduceByKey(lambda v1, v2: v1+v2)

> freqcount = userreqs.map(lambda (userid, freq): (freq, userid)).countByKey()

> print freqcount
defaultdict(<type 'int'>, {128: 4, 1: 4, 2: 6699, 3: 43, 4: 3784, 5: 29, 6: 2019, 7:
27, 8: 1301, 9: 17, 10: 875, 11: 22, 12: 536, 13: 9, 14: 322, 15: 5, 16: 198, 17:
10, 18: 109, 19: 3, 20: 53, 21: 1, 150: 8, 151: 1, 152: 10, 132: 10, 22: 32, 155: 1,
156: 5, 154: 9, 158: 5, 160: 4, 134: 7, 166: 6, 167: 1, 28: 1, 172: 1, 176: 2, 136:
10, 30: 2, 182: 1, 138: 10, 130: 11, 140: 3, 142: 10, 24: 18, 26: 2, 96: 1, 144: 7,
98: 1, 100: 2, 145: 1, 106: 4, 108: 3, 146: 8, 110: 3, 112: 5, 114: 2, 116: 4, 118:
4, 120: 3, 148: 15, 122: 7, 124: 7, 126: 12})
```

  - Use the countByKey action to return a Map of frequency:user-count pairs

- **Create an RDD where the user id is the key, and the value is the list of all the IP addresses that user has connected from.**
  - Hint: Map to (userid, ipaddress) and then use groupByKey

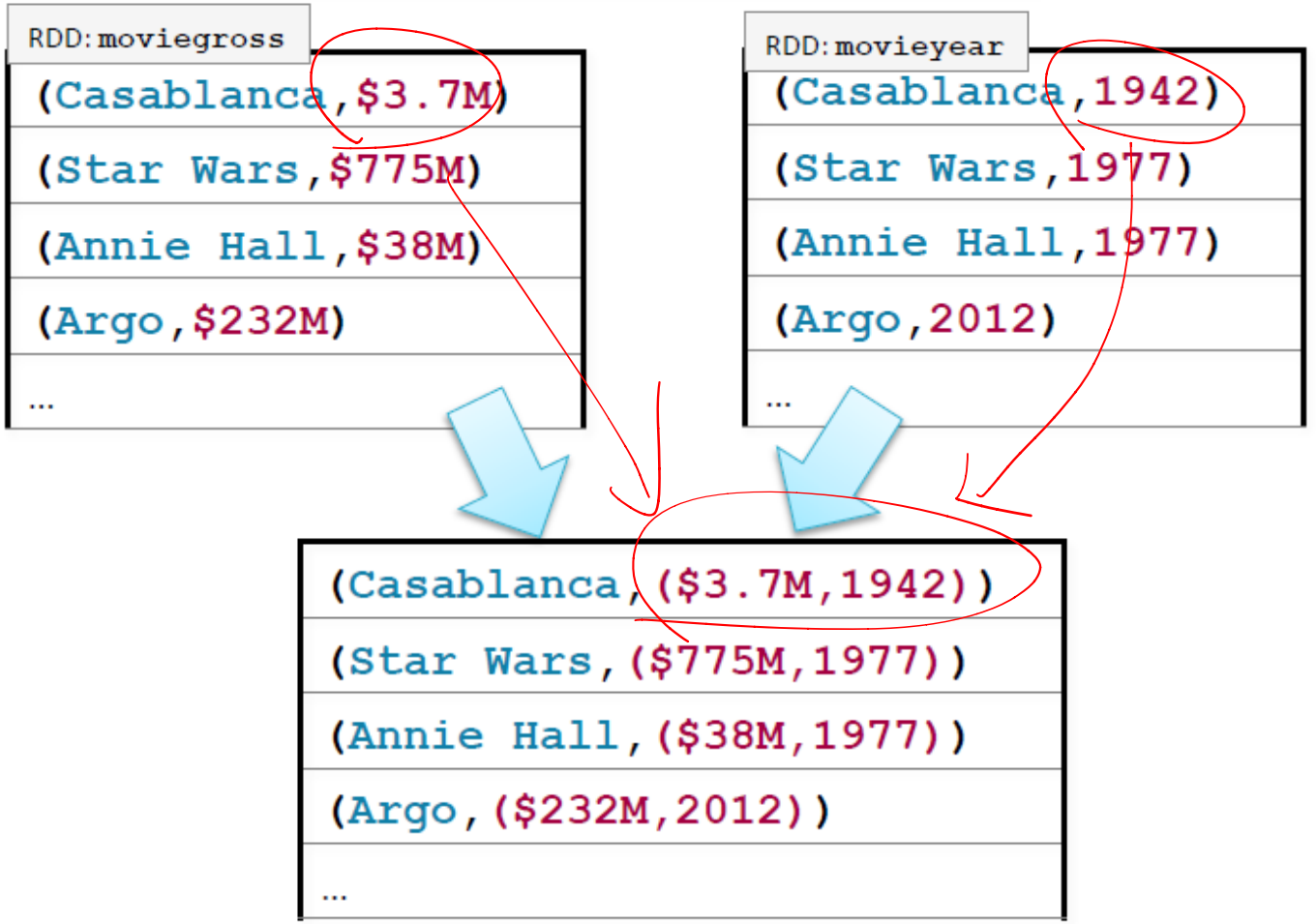



```
$ pyspark

> logs = sc.textFile("/loudacre/weblogs/*6")
> userips = logs \
  .map(lambda line: line.split()) \
  .map(lambda words: (words[2],words[0])) \
  .groupByKey()
> for (userid,ips) in userips.take(10):
  print userid, ":"
  for ip in ips: print "\t", ip
3922 :
  43.108.104.45
  43.108.104.45
  210.143.144.171
  210.143.144.171
  60.173.128.104
  60.173.128.104
  49.196.226.160
  49.196.226.160
  13.44.32.65
  13.44.32.65
78723 :
  31.73.66.73
  31.73.66.73
  31.73.66.73
  31.73.66.73
…
```

Example: Joining by Key ⇒ tuple

```
> movies = moviegross.join(movieyear)
```

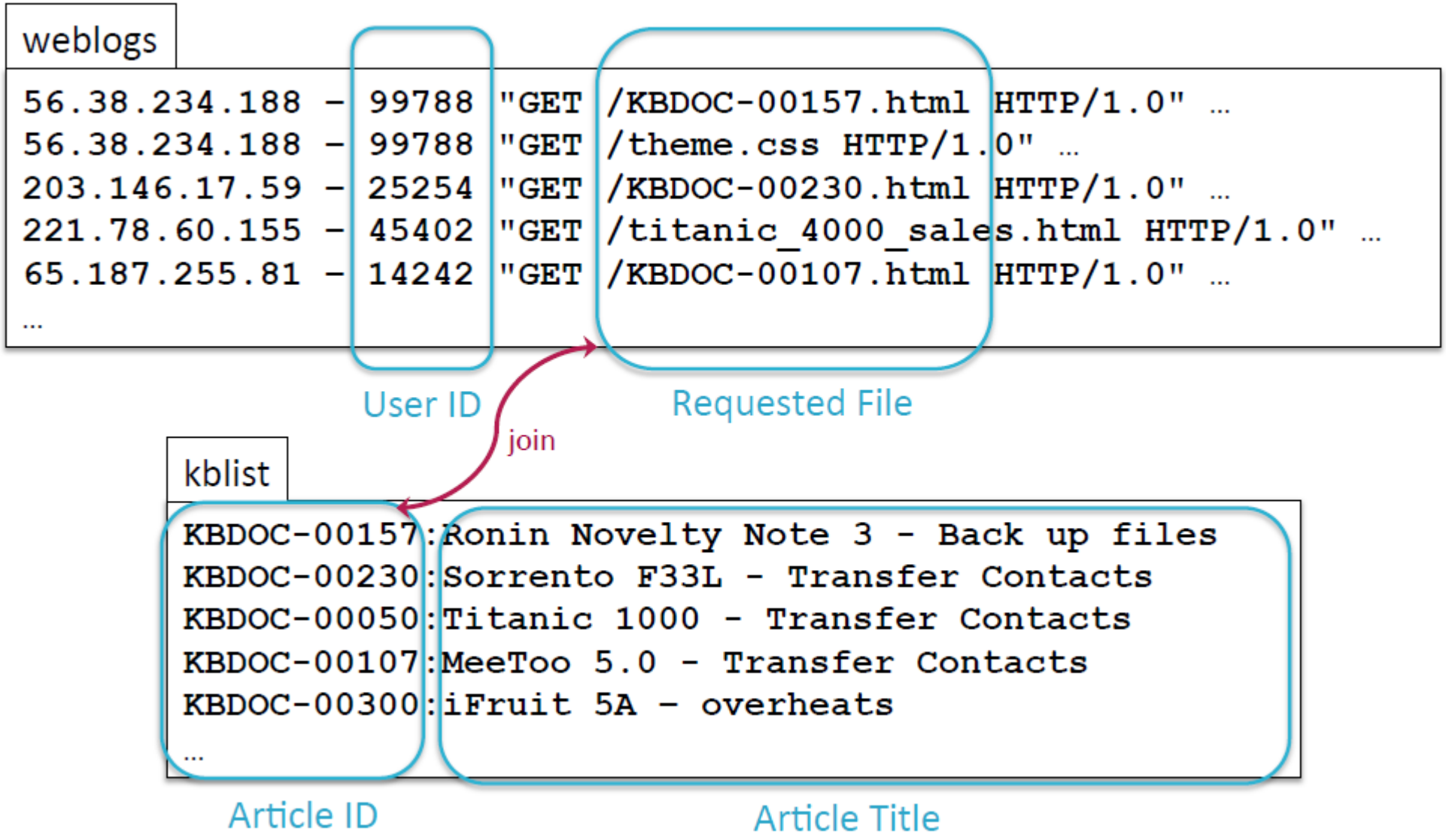
left
right
full
) outer join also supported



Using Join

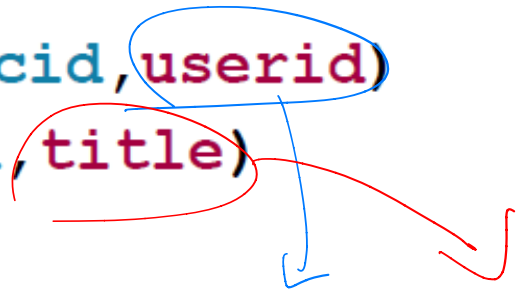
- **A common programming pattern**
  1. Map separate datasets into key-value Pair RDDs
  2. Join by key
  3. Map joined data into the desired format
  4. Save, display, or continue processing…

Example: Join Web Log With Knowledge Base Articles (1)



Example: Join Web Log With Knowledge Base Articles (2)

- **Steps**
  1. Map separate datasets into key-value Pair RDDs
     a. Map web log requests to `(docid, userid)`
     b. Map KB Doc index to `(docid, title)`
  2. Join by key: `docid`
  3. Map joined data into the desired format: `(userid, title)`
  4. Further processing: group titles by User ID



Step 1a: Map Web Log Requests to (docid, userid)

regular expression

```
> import re
> def getRequestDoc(s):
    return re.search(r'KBDOC-[0-9]*',s).group()

> kbreqs = sc.textFile(logfile) \
    .filter(lambda line: 'KBDOC-' in line) \
    .map(lambda line: (getRequestDoc(line),line.split(' ')[2])) \
    .distinct()
```

```
56.38.234.188 - 99788 "GET /KBDOC-00157.html HTTP/1.0" …
56.38.234.188 - 99788 "GET /theme.css HTTP/1.0" …
203.146.17.59 - 25254 "GET /KBDOC-00230.html HTTP/1.0" …
221.78.60.155 - 45402 "GET /titanic_4000_sales.html …
65.187.255.81 - 14242 "GET /KBDOC-00107.html HTTP/1.…
…
```

kbreqs

(KBDOC-00157,99788)
(KBDOC-00203,25254)
(KBDOC-00107,14242)
…

Step1b: Map KB Index to (docid, title)

```
> kblist = sc.textFile(kblistfile) \
  .map(lambda line: line.split(':')) \
  .map(lambda fields: (fields[0],fields[1]))
```

```
KBDOC-00157:Ronin Novelty Note 3 - Back up files
KBDOC-00230:Sorrento F33L - Transfer Contacts
KBDOC-00050:Titanic 1000 - Transfer Contacts
KBDOC-00107:MeeToo 5.0 - Transfer Contacts
KBDOC-00206:iFruit 5A - overheats
…
```

kblist

(KBDOC-00157,Ronin Novelty Note 3 - Back up files)
(KBDOC-00230,Sorrento F33L - Transfer Contacts)
(KBDOC-00050,Titanic 1000 - Transfer Contacts)
(KBDOC-00107,MeeToo 5.0 - Transfer Contacts)
…

Step 2: Join By Key docid

```
> titlereqs = kbreqs.join(kblist)
```

kbreqs

(KBDOC-00157,99788)
(KBDOC-00230,25254)
(KBDOC-00107,14242)
…

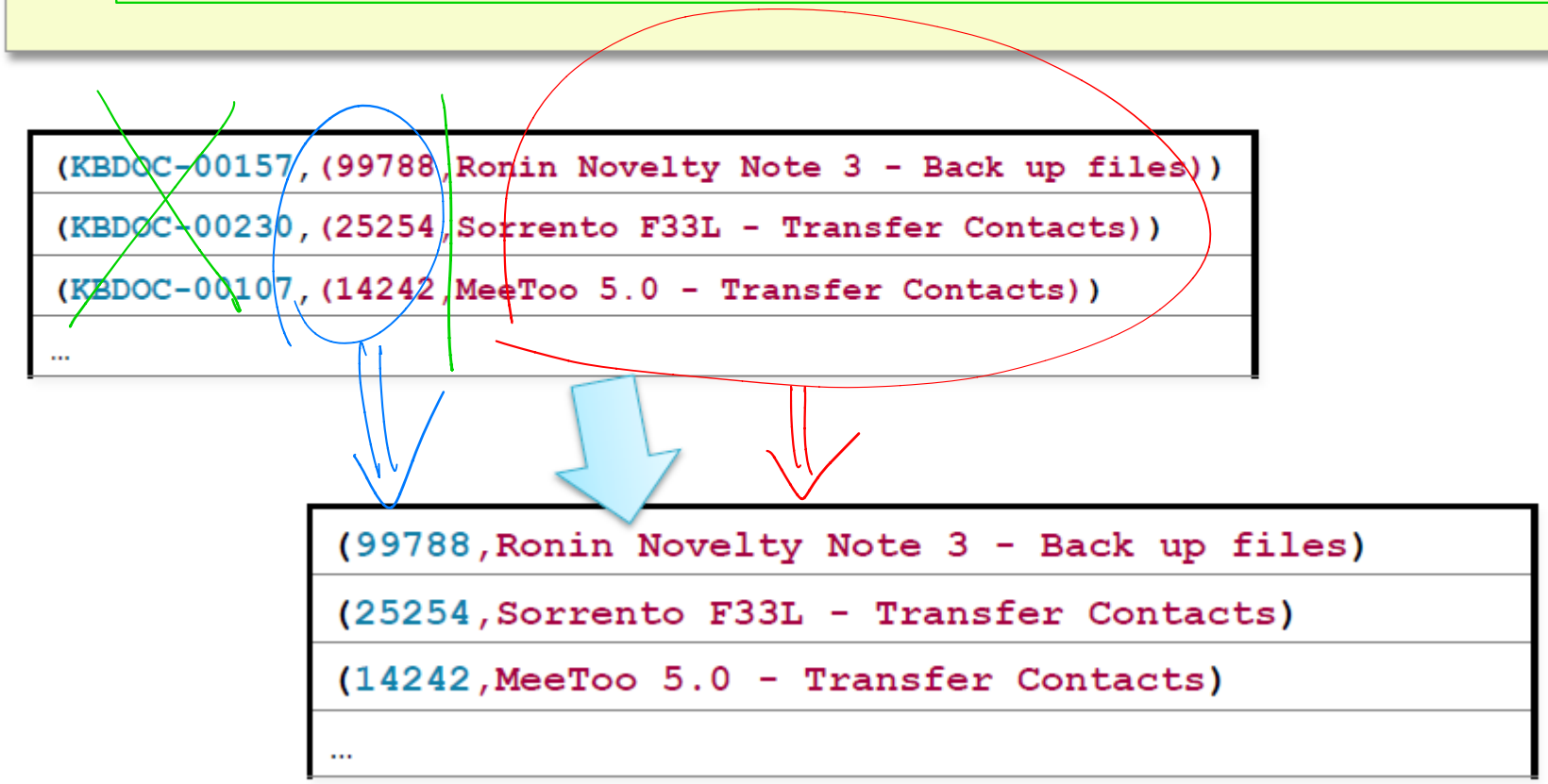
kblist

(KBDOC-00157,Ronin Novelty Note 3 - Back up files)
(KBDOC-00230,Sorrento F33L - Transfer Contacts)
(KBDOC-00050,Titanic 1000 - Transfer Contacts)
(KBDOC-00107,MeeToo 5.0 - Transfer Contacts)
…

(KBDOC-00157,(99788,Ronin Novelty Note 3 - Back up files))
(KBDOC-00230,(25254,Sorrento F33L - Transfer Contacts))
(KBDOC-00107,(14242,MeeToo 5.0 - Transfer Contacts))
…

Step 3: Map Result to Desired Format (userid, title)

```
> titlereqs = kbreqs.join(kblist) \
  .map(lambda (docid,(userid,title)): (userid,title))
```



Step 4: Continue Processing – Group Titles by User ID

```
> titlereqs = kbreqs.join(kblist) \
  .map(lambda (docid,(userid,title)): (userid,title)) \
  .groupByKey()
```

(99788,Ronin Novelty Note 3 - Back up files)
(25254,Sorrento F33L - Transfer Contacts)
(14242,MeeToo 5.0 - Transfer Contacts)
…

(99788,[Ronin Novelty Note 3 - Back up files, Ronin S3 - overheating])
(25254,[Sorrento F33L - Transfer Contacts])
(14242,[MeeToo 5.0 - Transfer Contacts, MeeToo 5.1 - Back up files, iFruit 1 - Back up files, MeeToo 3.1 - Transfer Contacts])
…

Note: values are grouped into Iterables

Example Output

```
> for (userid,titles) in titlereqs.take(10):
    print 'user id: ',userid
    for title in titles: print '\t',title

user id: 99788
  Ronin Novelty Note 3 - Back up files
  Ronin S3 - overheating
user id: 25254
  Sorrento F33L - Transfer Cont
user id: 14242
  MeeToo 5.0 - Transfer Contact
  MeeToo 5.1 - Back up files
  iFruit 1 - Back up files
  MeeToo 3.1 - Transfer Contacts
...
```

```
(99788,[Ronin Novelty Note 3 - Back up files,
        Ronin S3 - overheating])

(25254,[Sorrento F33L - Transfer Contacts])

(14242,[MeeToo 5.0 - Transfer Contacts,
        MeeToo 5.1 - Back up files,
        iFruit 1 - Back up files,
        MeeToo 3.1 - Transfer Contacts])

...
```

Practice: Join Web Log Data with Account Data

- **Data files (HDFS)**
  - /loudacre/weblogs
  - /loudacre/accounts
- **Join the accounts data with the weblog data to produce a dataset keyed by user ID which contains the user account information and the number of website hits for that user.**
  - Create an RDD based on the accounts data consisting of key/value-array pairs: (userid, [values …])

```
(userid1,[userid1,2008-11-24 10:04:08,\N,Cheryl,West,4905
Olive Street,San Francisco,CA,…])
(userid2,[ userid2,2008-11-23
14:05:07,\N,Elizabeth,Kerns,4703 Eva Pearl
Street,Richmond,CA,…])
(userid3,[ userid3,2008-11-02 17:12:12,2013-07-18
16:42:36,Melissa,Roman,3539 James Martin
Circle,Oakland,CA,…])
…
```

- Join the Pair RDD with the set of user-id/hit-count pairs calculated in the first step

```
(userid1,([userid1,2008-11-24
10:04:08,\N,Cheryl,West,4905 Olive Street,San
Francisco,CA,…],4))
(userid2,([ userid2,2008-11-23
14:05:07,\N,Elizabeth,Kerns,4703 Eva Pearl
Street,Richmond,CA,…],8))
(userid3,([ userid3,2008-11-02 17:12:12,2013-07-18
16:42:36,Melissa,Roman,3539 James Martin
Circle,Oakland,CA,…],1))
…
```

- Display the user ID, hit count, and first name (3rd value), and last name (4th value) for the first 5 elements, e.g.,:

```
userid1 4 Cheryl West
userid2 8 Elizabeth Kerns
userid3 1 Melissa Roman
…
```

```
$ pyspark

> logs = sc.textFile("/loudacre/weblogs/*6")
> userreqs = logs \
  .map(lambda line: line.split()) \
  .map(lambda words: (words[2], 1)) \
  .reduceByKey(lambda count1, count2: count1 + count2)
> accounts = sc.textFile("/loudacre/accounts") \
  .map(lambda s: s.split(',')) \
  .map(lambda account: (account[0], account))
> accounthits = accounts.join(userreqs)
>  for (userid, (values, count)) in accounthits.take(5) :
  print userid, count, values[3], values[4]
```

Other Pair Operations

- **Some other pair operations**
  - **`keys`** – return an RDD of just the keys, without the values
  - **`values`** – return an RDD of just the values, without keys
  - **`lookup(`*`key`*`)`** – return the value(s) for a key
  - **`leftOuterJoin`**, **`rightOuterJoin`** , **`fullOuterJoin`** – join, including keys defined in the left, right or either RDD respectively
  - **`mapValues`**, **`flatMapValues`** – execute a function on just the values, keeping the key the same
- **See the `PairRDDFunctions` class Scaladoc for a full list**

Essential Points

- **Pair RDDs are a special form of RDD consisting of Key-Value pairs (tuples)**
- **Spark provides several operations for working with Pair RDDs**
- **Map-reduce is a generic programming model for distributed processing**
  - Spark implements map-reduce with Pair RDDs
  - Hadoop MapReduce and other implementations are limited to a single map and single reduce phase per job
  - Spark allows flexible chaining of map and reduce operations
  - Spark provides operations to easily perform common map-reduce algorithms like joining, sorting, and grouping