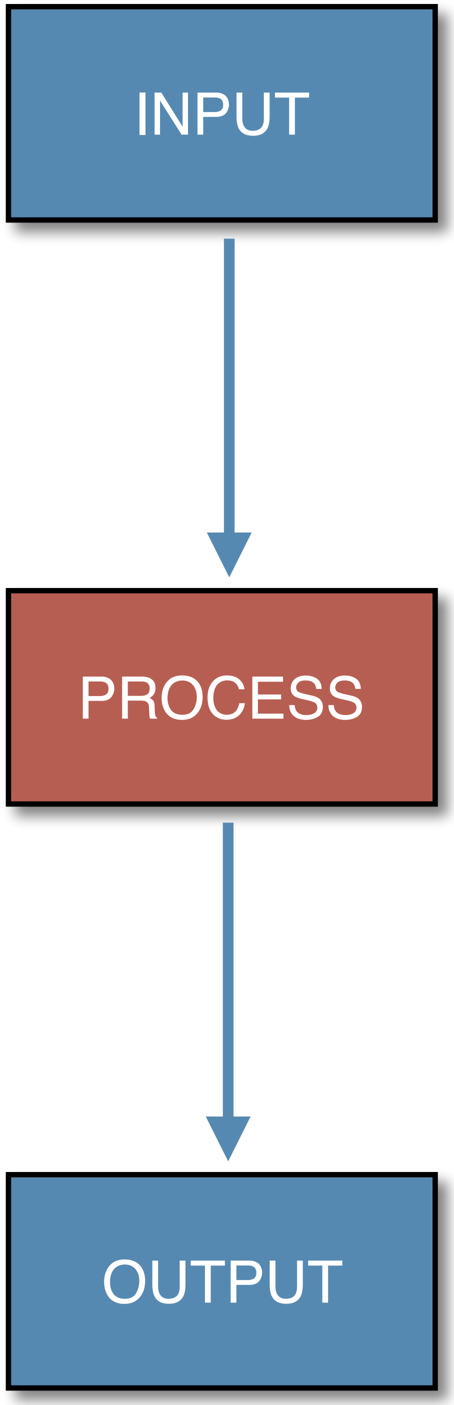
Map Reduce

MapReduce inside Google

Googlers' hammer for 80% of our data crunching

- Large-scale web search indexing
- Clustering problems for Google News
- Produce reports for popular queries, e.g. Google Trend
- Processing of satellite imagery data
- Language model processing for statistical machine translation
- Large-scale machine learning problems
- Just a plain tool to reliably spawn large number of tasks
  - e.g. parallel data backup and restore

Typical Application



What if...

INPUT

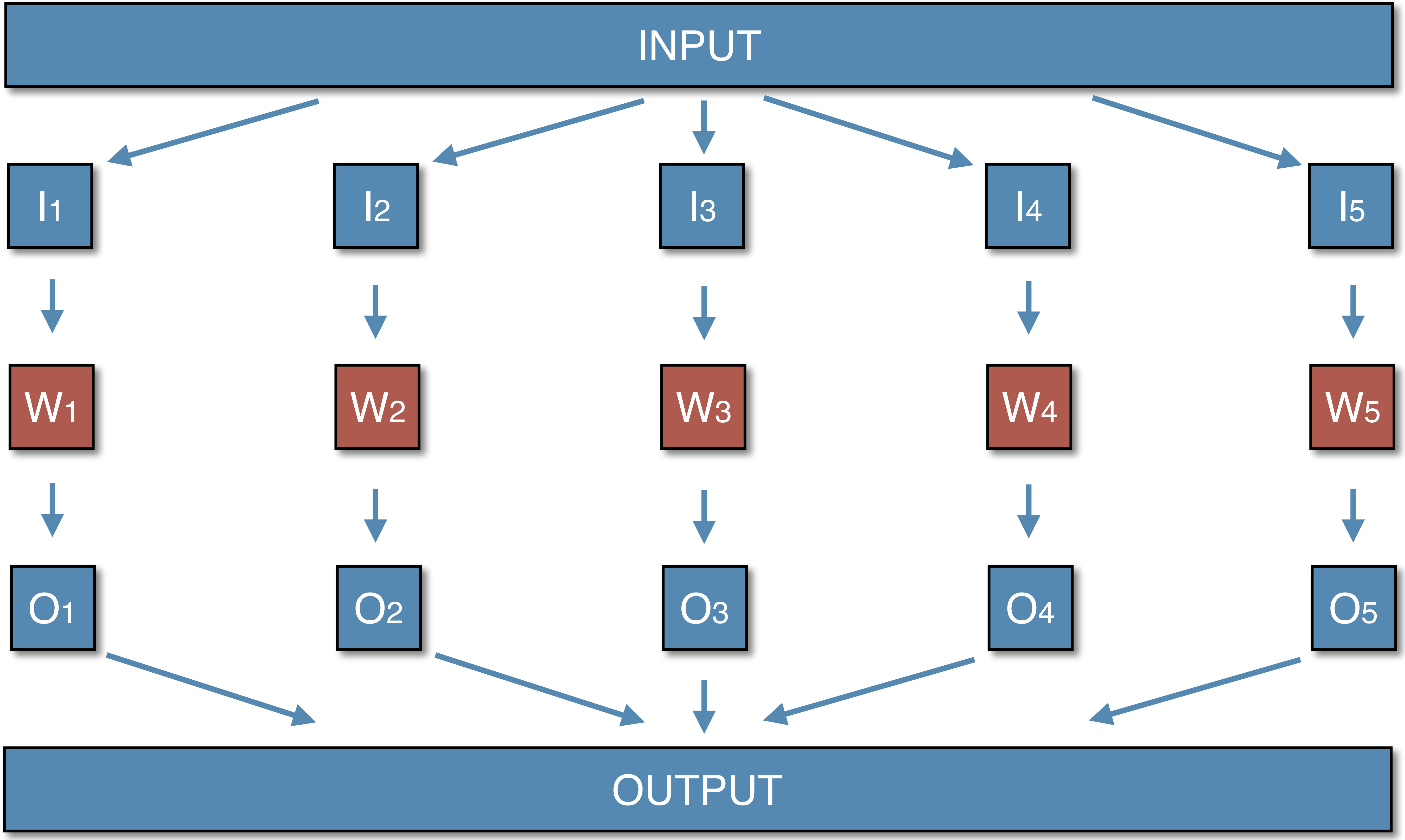
↓

PROCESS

↓

OUTPUT

Divide and Conquer



Challenges

- How do we split the input?
- How do we distribute the input splits?
- How do we collect the output splits?
- How do we aggregate the output?
- How do we coordinate the work?
- What if input splits > num workers?
- What if workers need to share input/output splits?
- What if a worker dies?
- What if we have a new input?

Difficulties

- We don’t know the order in which workers run…
- We don’t know when workers interrupt each other…
- We don’t know when workers need to communicate partial results…
- We don’t know the order in which workers access shared resources…

Common Problems

- Communication between workers (e.g., to exchange state)
- Access to shared resources (e.g., data)

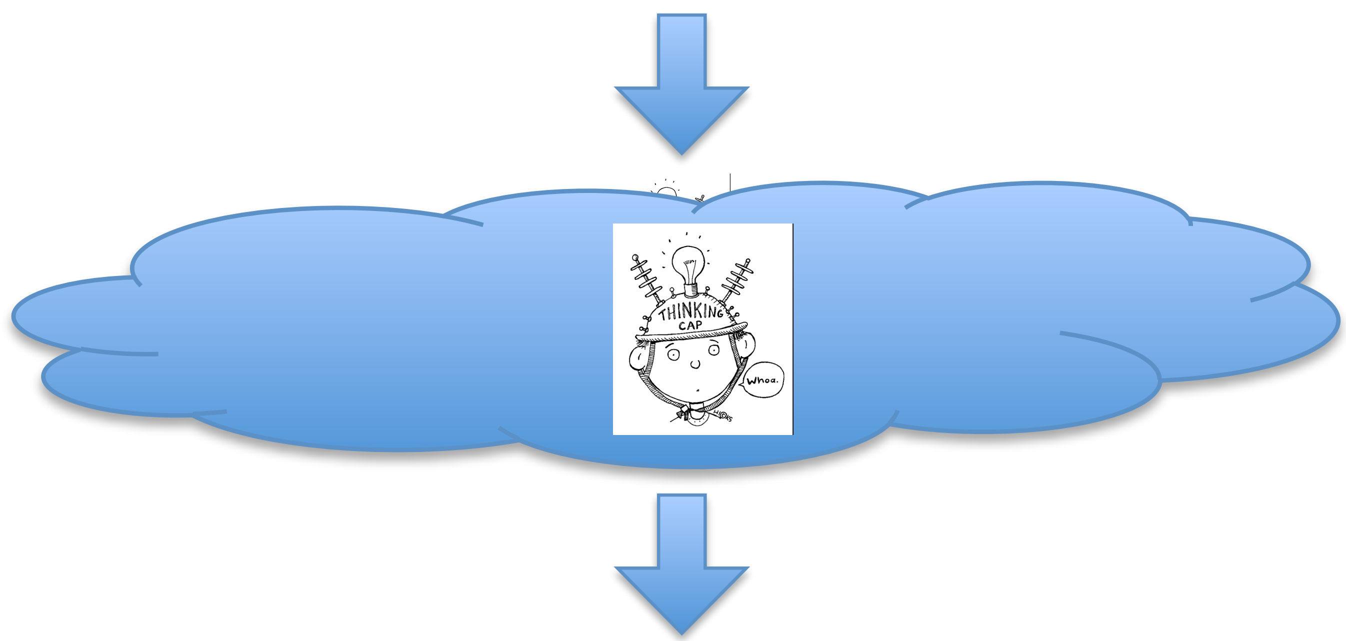

http://www.duiops.net/seresvivos

Design Ideas

- **Scale “out”, not “up”**
  - Low end machines
- **Move processing to the data**
  - Network bandwidth bottleneck
- **Process data sequentially, avoid random access**
  - Huge data files
  - Write once, read many
- **Seamless scalability**
  - Strive for the unobtainable
- **Right level of abstraction**
  - Hide implementation details from applications development

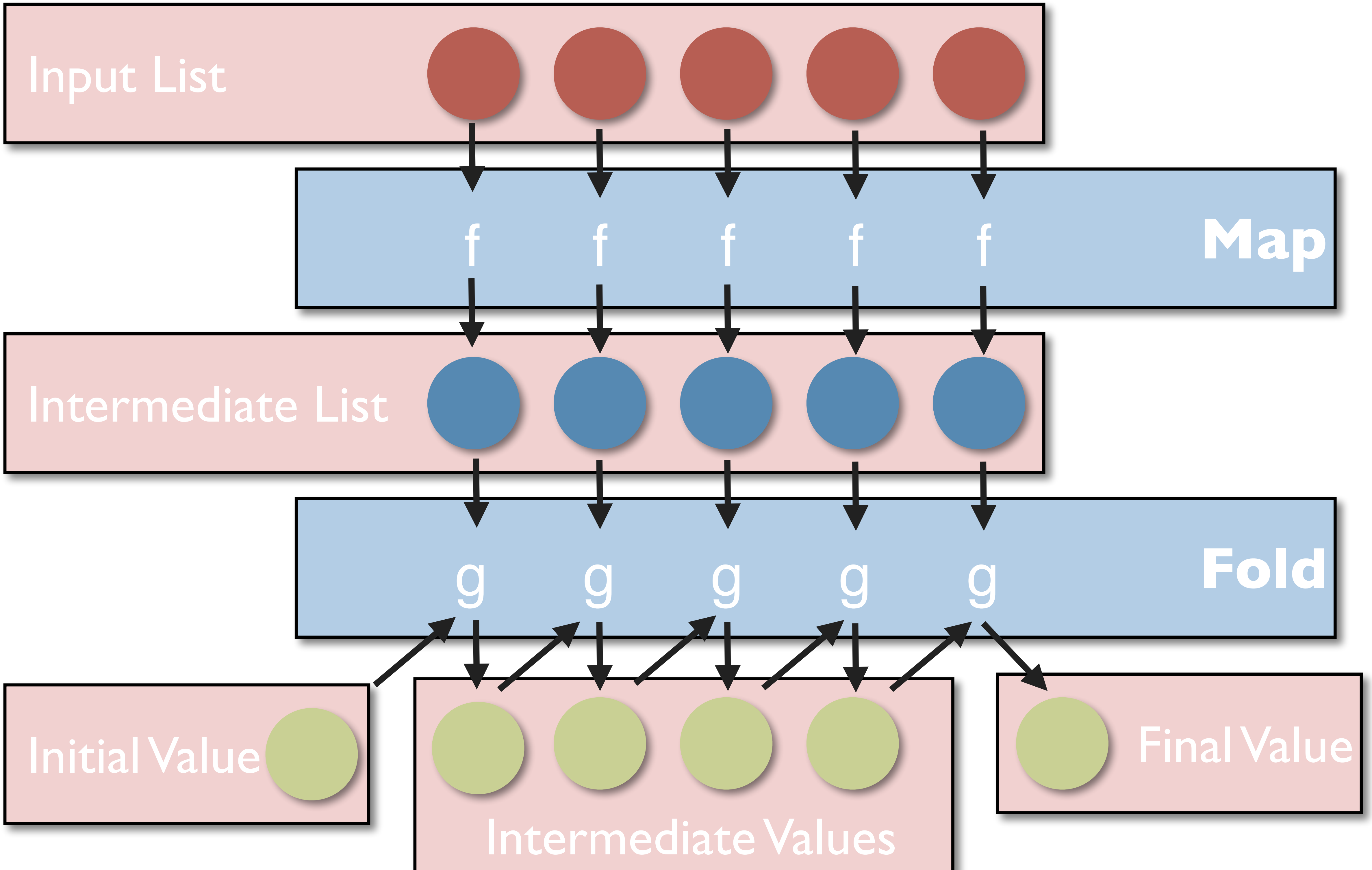
Typical Large-Data Problem

- Iterate over a large number of records
- Extract something of interest from each
- Shuffle and sort intermediate results
- Aggregate intermediate results
- Generate final output



MapReduce
Programming Model

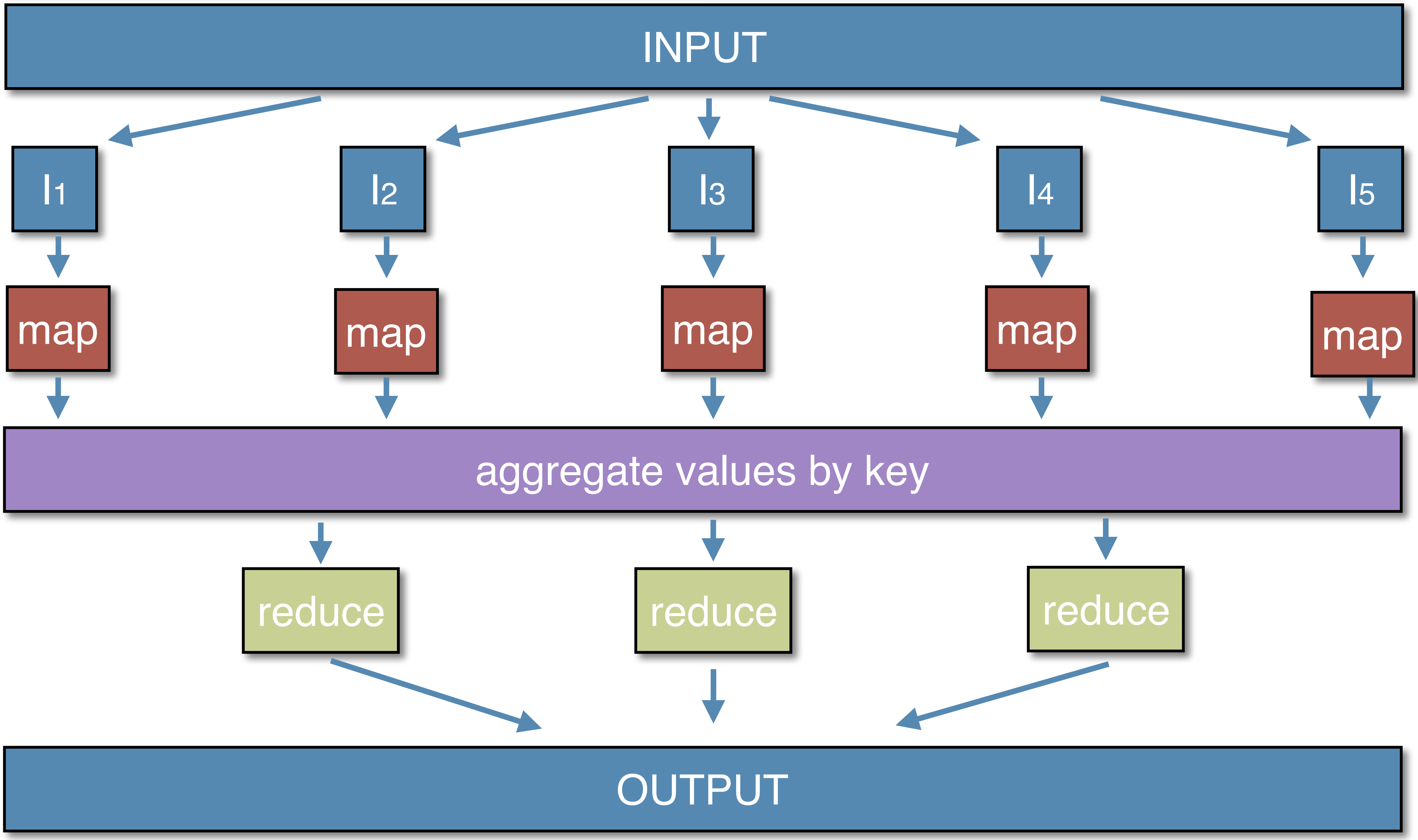
From functional programming...



...to Map Reduce

- **Programmers specify two functions**
  - **map** (k_1,v_1) --> $[(k_2,v_2)]$
  - **reduce** $(k_2,[v_2])$ --> $[(k_3,v_3)]$
- **Map**
  - Receives as input a key-value pair
  - Produces as output a list of key-value pairs
- **Reduce**
  - Receives as input a key-list of values pair
  - Produces as output a list of key-value pairs (typically just one)
- **The runtime support handles everything else...**

Programming Model (simple)



Wordcount Example (I)

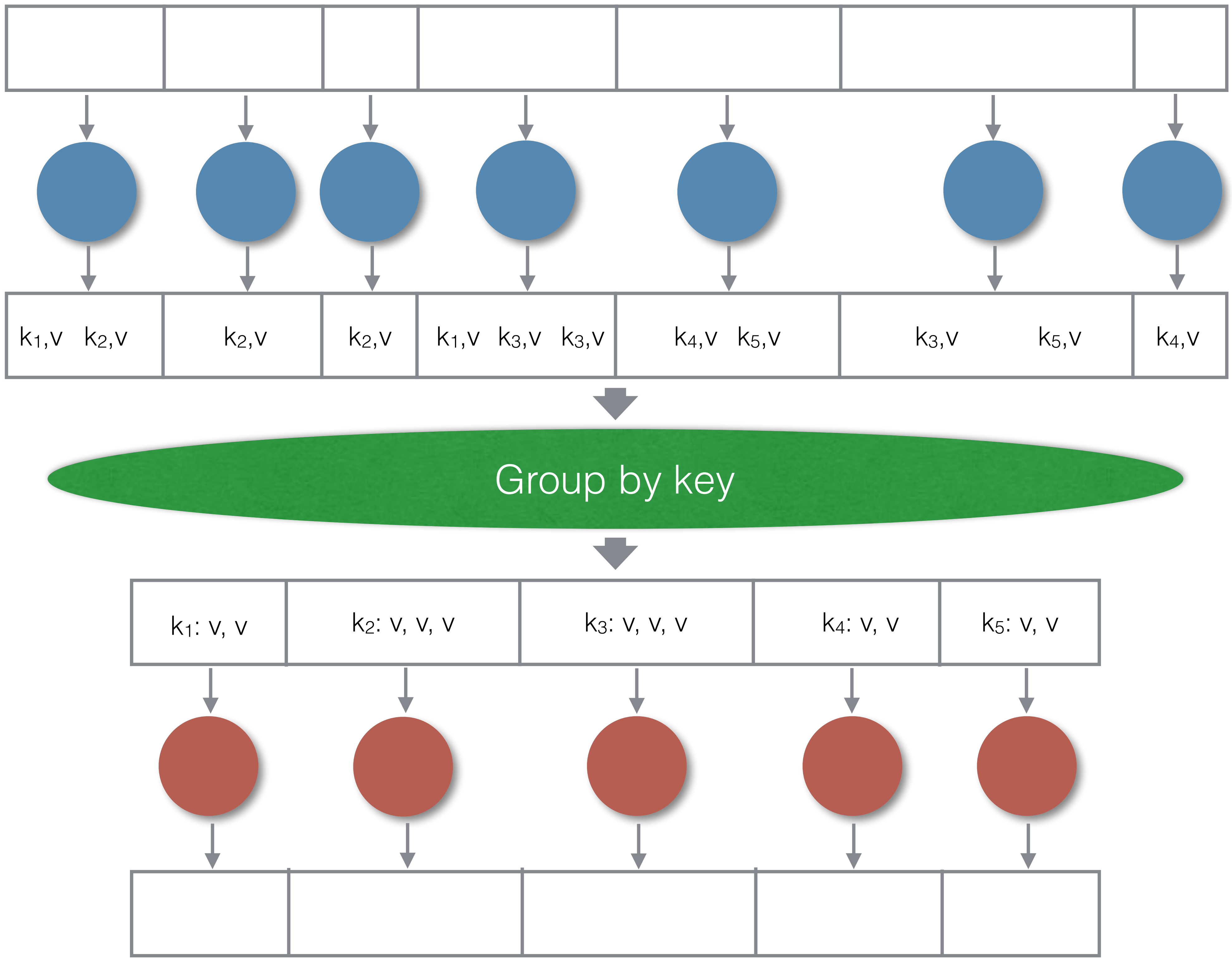
```
class Mapper
    method Map(docid a, doc d)
        for all term t ∈ doc d do
            Emit(term t, count 1)

class Reducer
    method Reduce(term t, counts [c1, c2, ...])
        sum ← 0
        for all count c ∈ counts [c1, c2, ...] do
            sum ← sum + c
        Emit(term t, count sum)
```

Diagram

MAP: reads input and produces a set of key value pairs

GROUP BY KEY: collects all pairs with the same key

REDUCE: collects all values belonging to the key and outputs



Word Frequency Exercise

- What if we want to compute the word **frequency** instead of the word **count**?

- **Input**: large number of text documents
- **Output**: the word frequency of each word across all documents

- **Note**: Frequency is calculated using the **total word count**

- **Hint 1**: We know how to compute the total word count
- **Hint 2**: Can we use the word count output as input?

- **Solution**: Use two MapReduce tasks
  - MR1: count number of all words in the documents
  - MR2: count number of each word and divide it by the total count from MR1