dataArtisans

Apache Flink® Training

DataStream API Basic

December 10, 2015

DataStream API

- Stream Processing
- Java and Scala
- All examples here in Java for Flink 0.10
- Documentation available at
  flink.apache.org

DataStream API by Example

Window WordCount: main Method

```
public static void main(String[] args) throws Exception {
    // set up the execution environment
    final StreamExecutionEnvironment env =
        StreamExecutionEnvironment.getExecutionEnvironment();
    // configure event time
    env.setStreamTimeCharacteristic(TimeCharacteristic.EventTime);

    DataStream<Tuple2<String, Integer>> counts = env
            // read stream of words from socket
            .socketTextStream("localhost", 9999)
            // split up the lines in tuples containing: (word,1)
            .flatMap(new Splitter())
            // key stream by the tuple field "0"
            .keyBy(0)
            // compute counts every 5 minutes
            .timeWindow(Time.minutes(5))
            //sum up tuple field "1"
            .sum(1);

    // print result in command line
    counts.print();
    // execute program
    env.execute("Socket WordCount Example");
}
```

Stream Execution Environment

```
public static void main(String[] args) throws Exception {
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Data Sources

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Data types

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```

Transformations

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    counts.print();
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    env.execute("Socket WordCount Example");
}
```

User functions

```
public static void main(String[] args) throws Exception {
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    counts.print();
    // execute program
    env.execute("Socket WordCount Example");
}
```

DataSinks

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            // read stream of words from socket
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            .timeWindow(Time.minutes(5))
            //sum up tuple field "1"
            .sum(1);

    // print result in command line
    counts.print();
    // execute program
    env.execute("Socket WordCount Example");
}
```

Execute!

```
public static void main(String[] args) throws Exception {
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            .sum(1);

    // print result in command line
    counts.print();
    // execute program
    env.execute("Socket WordCount Example");
}
```

Window WordCount: FlatMap

```
public static class Splitter
  implements FlatMapFunction<String, Tuple2<String, Integer>> {

  @Override
  public void flatMap(String value,
                      Collector<Tuple2<String, Integer>> out)
    throws Exception {
        // normalize and split the line
        String[] tokens = value.toLowerCase().split("\\W+");

        // emit the pairs
        for (String token : tokens) {
            if (token.length() > 0) {
                out.collect(
                    new Tuple2<String, Integer>(token, 1));
            }
        }
    }
}
```

WordCount: Map: Interface

```
public static class Splitter
  implements FlatMapFunction<String, Tuple2<String, Integer>> {

  @Override
  public void flatMap(String value,
                      Collector<Tuple2<String, Integer>> out)
    throws Exception {
        // normalize and split the line
        String[] tokens = value.toLowerCase().split("\\W+");

        // emit the pairs
        for (String token : tokens) {
            if (token.length() > 0) {
                out.collect(
                    new Tuple2<String, Integer>(token, 1));
            }
        }
    }
}
```

WordCount: Map: Types

```
public static class Splitter
  implements FlatMapFunction<String, Tuple2<String, Integer>> {

  @Override
  public void flatMap(String value,
                      Collector<Tuple2<String, Integer>> out)
    throws Exception {
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        for (String token : tokens) {
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                out.collect(
                    new Tuple2<String, Integer>(token, 1));
            }
        }
    }
}
```

WordCount: Map: Collector

```
public static class Splitter
  implements FlatMapFunction<String, Tuple2<String, Integer>> {

  @Override
  public void flatMap(String value,
                      Collector<Tuple2<String, Integer>> out)
    throws Exception {
        // normalize and split the line
        String[] tokens = value.toLowerCase().split("\\W+");

        // emit the pairs
        for (String token : tokens) {
            if (token.length() > 0) {
                out.collect(
                    new Tuple2<String, Integer>(token, 1));
            }
        }
    }
}
```

DataStream API Concepts

(Selected) Data Types

- Basic Java Types
  - String, Long, Integer, Boolean,…
  - Arrays
- Composite Types
  - Tuples
  - Many more (covered in the advanced slides)

Tuples

- The easiest and most lightweight way of encapsulating data in Flink
- Tuple1 up to Tuple25

```
Tuple2<String, String> person = new Tuple2<>("Max", "Mustermann”);

Tuple3<String, String, Integer> person = new Tuple3<>("Max", "Mustermann", 42);

Tuple4<String, String, Integer, Boolean> person =
  new Tuple4<>("Max", "Mustermann", 42, true);

// zero based index!
String firstName = person.f0;
String secondName = person.f1;
Integer age = person.f2;
Boolean fired = person.f3;
```

Transformations: Map

```
DataStream<Integer> integers = env.fromElements(1, 2, 3, 4);

// Regular Map - Takes one element and produces one element
DataStream<Integer> doubleIntegers =
     integers.map(new MapFunction<Integer, Integer>() {
     @Override
          public Integer map(Integer value) {
            return value * 2;
          }
     });

doubleIntegers.print();
> 2, 4, 6, 8


// Flat Map - Takes one element and produces zero, one, or more elements.
DataStream<Integer> doubleIntegers2 =

     integers.flatMap(new FlatMapFunction<Integer, Integer>() {
          @Override
          public void flatMap(Integer value, Collector<Integer> out) {
               out.collect(value * 2);
          }
     });

doubleIntegers2.print();
> 2, 4, 6, 8
```

Transformations: Filter

```
// The DataStream
DataStream<Integer> integers = env.fromElements(1, 2, 3, 4);

DataStream<Integer> filtered =

    integers.filter(new FilterFunction<Integer>() {
        @Override
        public boolean filter(Integer value) {
            return value != 3;
        }
    });

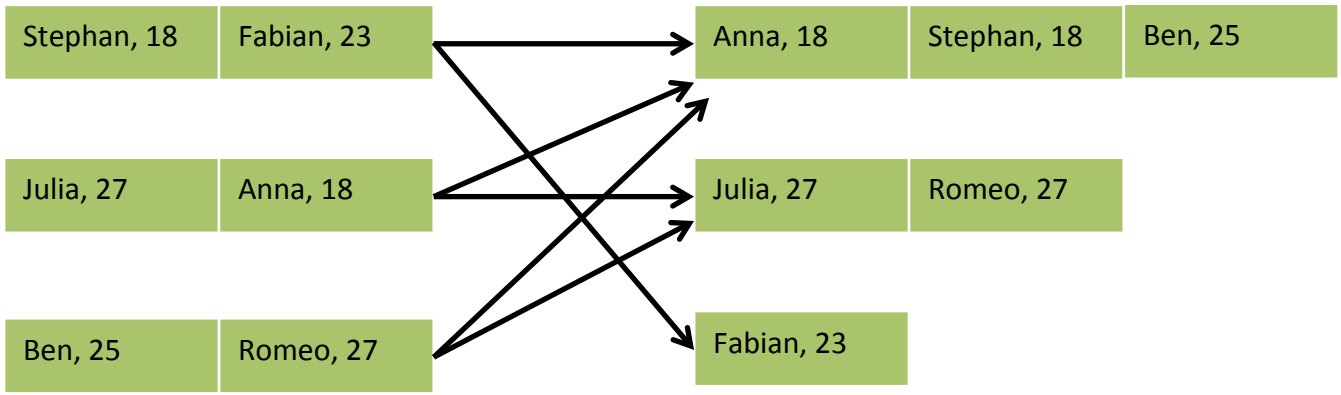
filtered.print();
> 1, 2, 4
```

Transformations: KeyBy

- A DataStream can be organized by a key
  - Partitions the data (all elements with the same key are processed by the same operator)
  - Certain operators are key-aware
  - Operator state can be partitioned by key

```
// (name, age) of employees
DataStream<Tuple2<String, Integer>> passengers = …

// group by second field (age)
DataStream<Integer, Integer> grouped = passengers.keyBy(1)
```



Data Shipping Strategies

- Optionally, you can specify how data is shipped between two transformations
- Forward: `stream.forward()`
  - Only local communication
- Rebalance: `stream.rebalance()`
  - Round-robin partitioning
- Partition by hash: `stream.partitionByHash(...)`
- Custom partitioning: `stream.partitionCustom(...)`
- Broadcast: `stream.broadcast()`
  - Broadcast to all nodes

Rich Functions

RichFunctions

- Function interfaces have only one method
  - Single abstract method (SAM)
  - Support for Java8 Lambda functions

- There is a “Rich” variant for each function.
  - `RichFlatMapFunction`, …
  - Additional methods
    - `open(Configuration c)`
    - `close()`
    - `getRuntimeContext()`

RichFunctions & RuntimeContext

- RuntimeContext has useful methods:
  - `getIndexOfThisSubtask ()`
  - `getNumberOfParallelSubtasks()`
  - `getExecutionConfig()`

- Hands out partitioned state (later discussed)
  - `getKeyValueState()`

Data Sources

Data Sources: Collections

```
StreamExecutionEnvironment env =
    StreamExecutionEnvironment.getExecutionEnvironment();

// read from elements
DataStream<String> names = env.fromElements("Some", "Example",
"Strings");

// read from Java collection
List<String> list = new ArrayList<String>();
list.add("Some");
list.add("Example");
list.add("Strings");

DataStream<String> names = env.fromCollection(list);
```

Data Sources: Files & Sockets

```
StreamExecutionEnvironment env =
    StreamExecutionEnvironment.getExecutionEnvironment();


// read text socket from port
DataStream<String> socketLines = env
    .socketTextStream("localhost", 9999);


// read a text file ingesting new elements every 100 milliseconds
DataStream<String> localLines = env
    .readFileStream("/path/to/file", 100,
     WatchType.PROCESS_ONLY_APPENDED);
```

Custom SourceFunctions & Connectors

```
StreamExecutionEnvironment env =
    StreamExecutionEnvironment.getExecutionEnvironment();

// read data stream from custom source function
DataStream<<Tuple2<Long, String> stream = env
    .addSource(new MySourceFunction());
```

Flink has connectors for many stream serving systems

- Apache Kafka
- RabbitMQ
- …

Data Sinks

Data Sinks

Write as text file using toString()

- `stream.writeAsText("/path/to/file")`

Write as CSV file

- `stream.writeAsCsv("/path/to/file")`

Print to the standard output

- `stream.print()`

Emit to socket

- ```
  stream
    .writeToSocket(host,port,SerializationSchema)
  ```
  ```

Custom Sinks & Connectors

Emit data with a custom sink function

- `stream.addSink(new MySinkFunction());`

Several connectors

- Apache Kafka
- Elasticsearch
- Rolling Files (HDFS, S3, …)

Execution

- Programs are lazily executed when `execute()` is called

```
DataStream<T> result;

// nothing happens
result.writeToSocket(...);

// nothing happens
result.writeAsText("/path/to/file", "\n", "|");

// Execution really starts here
env.execute();
```

Fault-Tolerance and Operator State

Fault Tolerance in Flink

- Flink takes a checkpoint of an application every *N* milliseconds and rolls back to the checkpointed state in case of a failure
- Enable exactly-once consistency (checkpoint every 5 seconds)

```
env.enableCheckpointing(5000)
```

- Enable at-least-once consistency (for lower latency)

```
env.enableCheckpointing(5000, CheckpointingMode.AT_LEAST_ONCE)
```

- Setting the interval to few seconds should be good for most application
- If checkpointing is not enabled, no recovery guarantees are provided
- See documentation for details: https://ci.apache.org/projects/flink/flink-docs-master/internals/stream_checkpointing.html

Stateful Functions

- All DataStream functions can be stateful
  - State is checkpointed and recovered in case of a failure (if checkpointing is enabled).
- You can define two types of state
  - *Local State*: Functions can register local variables to be checkpointed.
  - *Key-Partitioned State*: Functions on a keyed stream can access and update state scoped to the current key.

Defining Local State

```
DataStream<String> aStream;
DataStream<Long> lengths = aStream.map(new MapWithCounter());

public static class MapWithCounter
     implements MapFunction<String, Long>, Checkpointed<Long> {

     private long totalLength = 0;

     @Override
     public Long map (String value) {
          totalLength += value.length();
          return totalLength;
     }

     @Override
     public Long snapshotState(long cpId, long cpTimestamp) throws Exception {
          return totalLength;
     }

     @Override
     public void restoreState(Long state) throws Exception {
          totalLength = state;
     }
}
```

Defining Key-Partitioned State

```
DataStream<Tuple2<String, String>> aStream;
KeyedStream<Tuple2<String, String>, Tuple> keyedStream = aStream.keyBy(0);
DataStream<Long> lengths = keyedStream.map(new MapWithCounter());

public static class MapWithCounter
     extends RichMapFunction<Tuple2<String, String>,Long> {

     private OperatorState<Long> totalLengthByKey;

    @Override
     public void open (Configuration conf) {
          totalLengthByKey = getRuntimeContext()
                    .getKeyValueState("totalLengthByKey", Long.class, 0L);
     }

     @Override
     public Long map (Tuple2<String,String> value) throws Exception {
          long newTotalLength = totalLengthByKey.value() + value.f1.length();
          totalLengthByKey.update(newTotalLength);
          return totalLengthByKey.value();
     }
}
```

Best Practices

Some advice

- Use `env.fromElements(..)` or `env.fromCollection(..)` to quickly get a DataStream to experiment with

- Use `print()` to print a DataStream