# BigSem: Big Data Analytics for Semantic Data Tutorial

## Module 3: Semantic data analytic engines and frameworks

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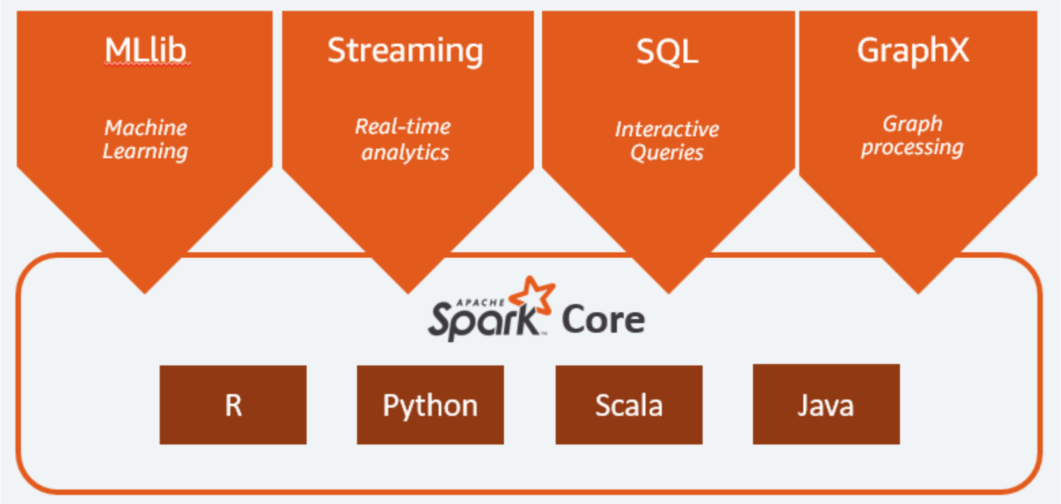
*ISWC 2024*

goo.gl/6Nrc1r

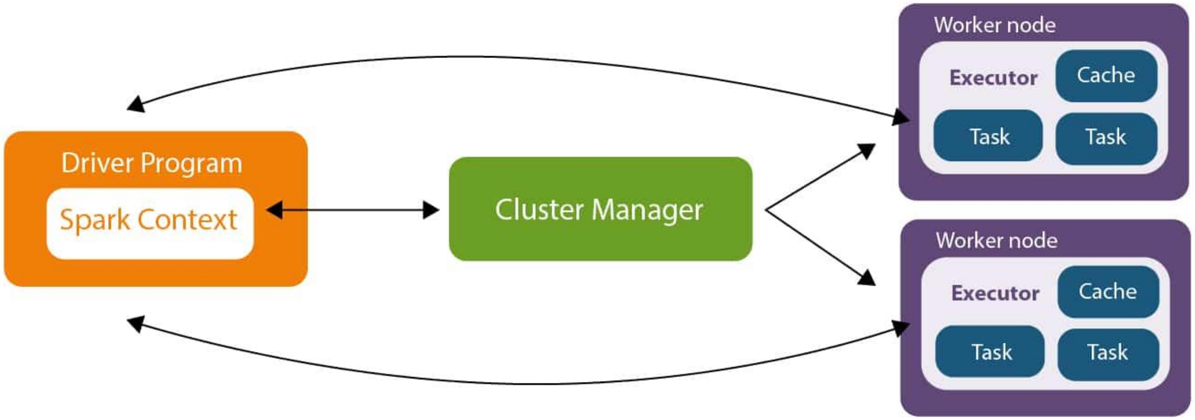
# Apache Spark

- Apache Spark is an open-source cluster computing system that provides high-level API in Java, Scala, Python.



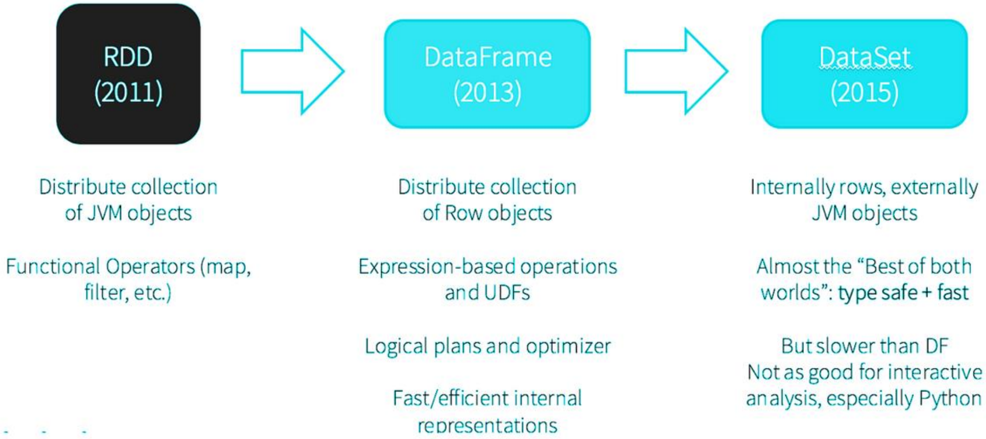
# Apache Spark: Architecture

- **Driver Program:** The Spark Context manages job execution and distributes tasks to the worker nodes.
- **Cluster Manager:** Allocates resources across the cluster. It communicates with both the driver program and the worker nodes to manage resource allocation.
- **Worker Nodes:** where the actual execution of tasks happens. Each worker node contains executors, which are responsible for running the tasks.



# Apache Spark: RDD

- An RDD (Resilient Distributed Dataset) in Apache Spark is a fundamental data structure that represents an immutable, distributed collection of objects that can be processed in parallel across a cluster.



RDD (2011)

Distribute collection of JVM objects

Functional Operators (map, filter, etc.)

DataFrame (2013)

Distribute collection of Row objects

Expression-based operations and UDFs

Logical plans and optimizer

Fast/efficient internal representations

DataSet (2015)

Internally rows, externally JVM objects

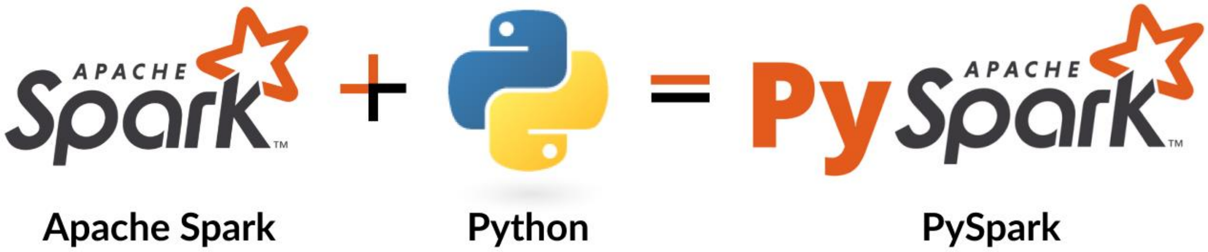
Almost the "Best of both worlds": type safe + fast

But slower than DF

Not as good for interactive analysis, especially Python

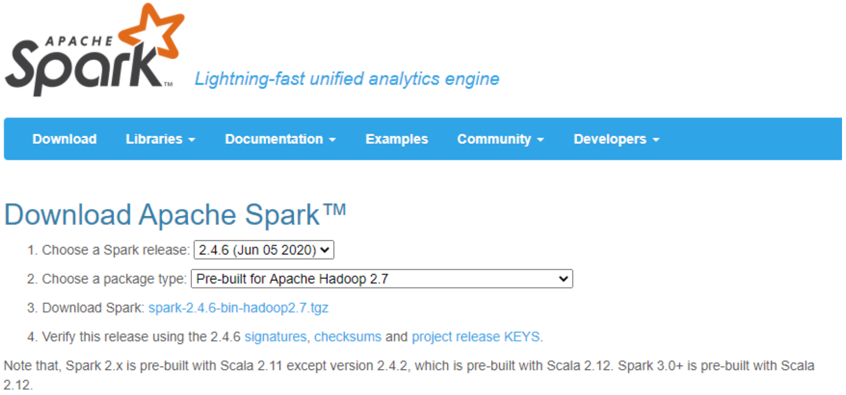
# Apache Spark in Python: PySpark

- PySpark is the Python API for Apache Spark. It enables you to perform real-time, large-scale data processing in a distributed environment using Python.



# Installing Spark

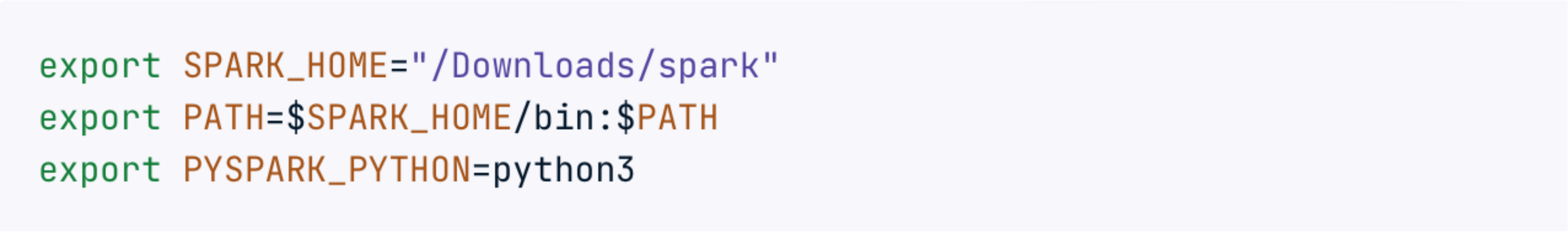
- Head over to the Spark homepage.
- Select the Spark release and package type as following and download the .tgz file.
- Configure Environment Variable for Apache Spark and Python



Download Apache Spark™

1. Choose a Spark release: 2.4.6 (Jun 05 2020)
2. Choose a package type: Pre-built for Apache Hadoop 2.7
3. Download Spark: spark-2.4.6-bin-hadoop2.7.tgz
4. Verify this release using the 2.4.6 signatures, checksums and project release KEYS.

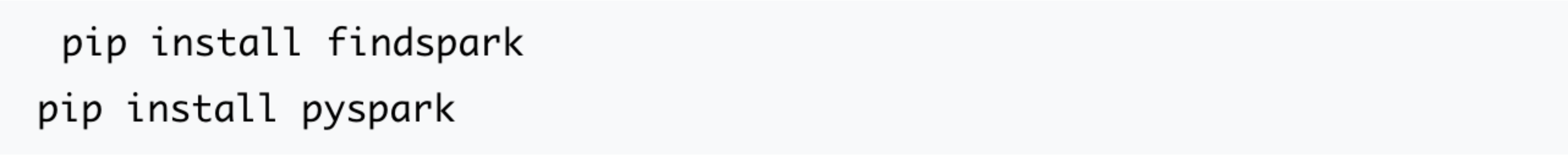
Note that, Spark 2.x is pre-built with Scala 2.11 except version 2.4.2, which is pre-built with Scala 2.12. Spark 3.0+ is pre-built with Scala 2.12.



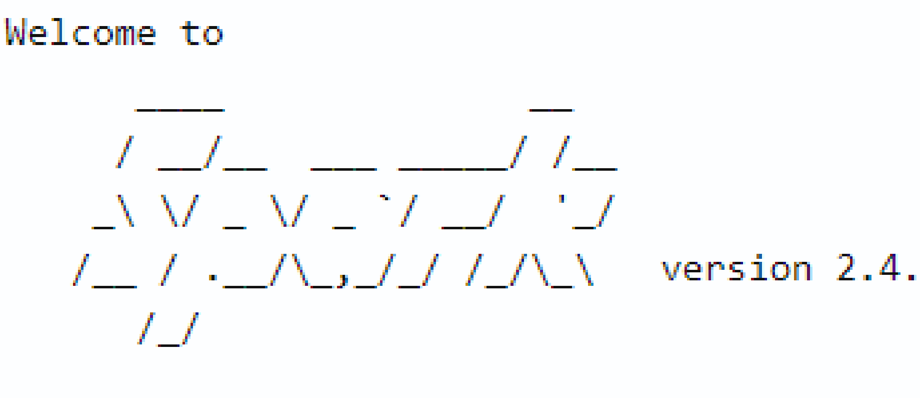
```
export SPARK_HOME="/Downloads/spark"
export PATH=$SPARK_HOME/bin:$PATH
export PYSPARK_PYTHON=python3
```

# Install PySpark

- Install PySpark using pip



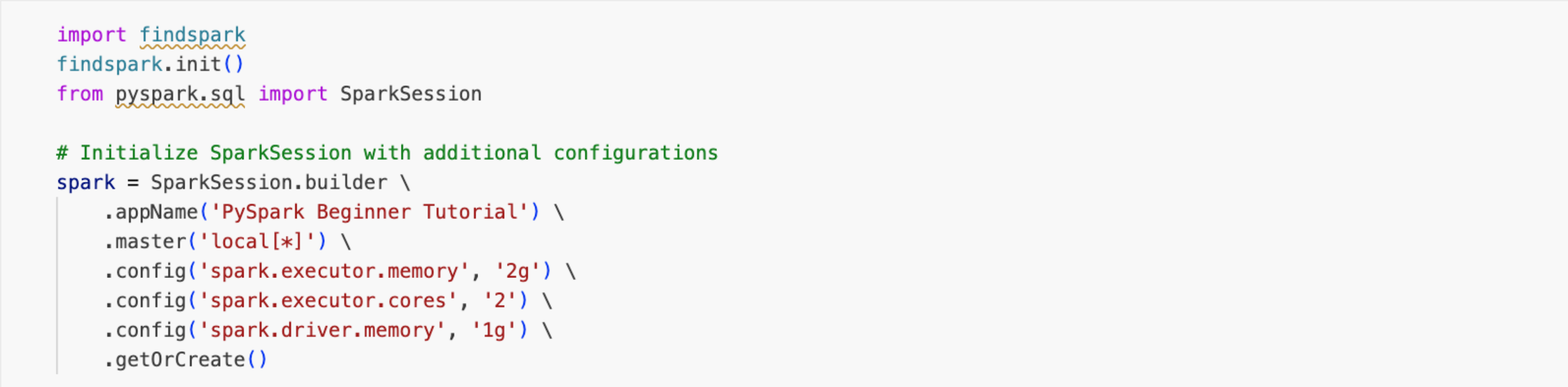
```
 pip install findspark
pip install pyspark
```



```
Welcome to
      ____              __
     / __/__  ___ _____/ /__
    _\ \/ _ \/ _ `/ __/  '_/
   /__ / .__/\_,_/_/ /_/\_\   version 2.4.
      /_/
```

# PySpark: SparkSession

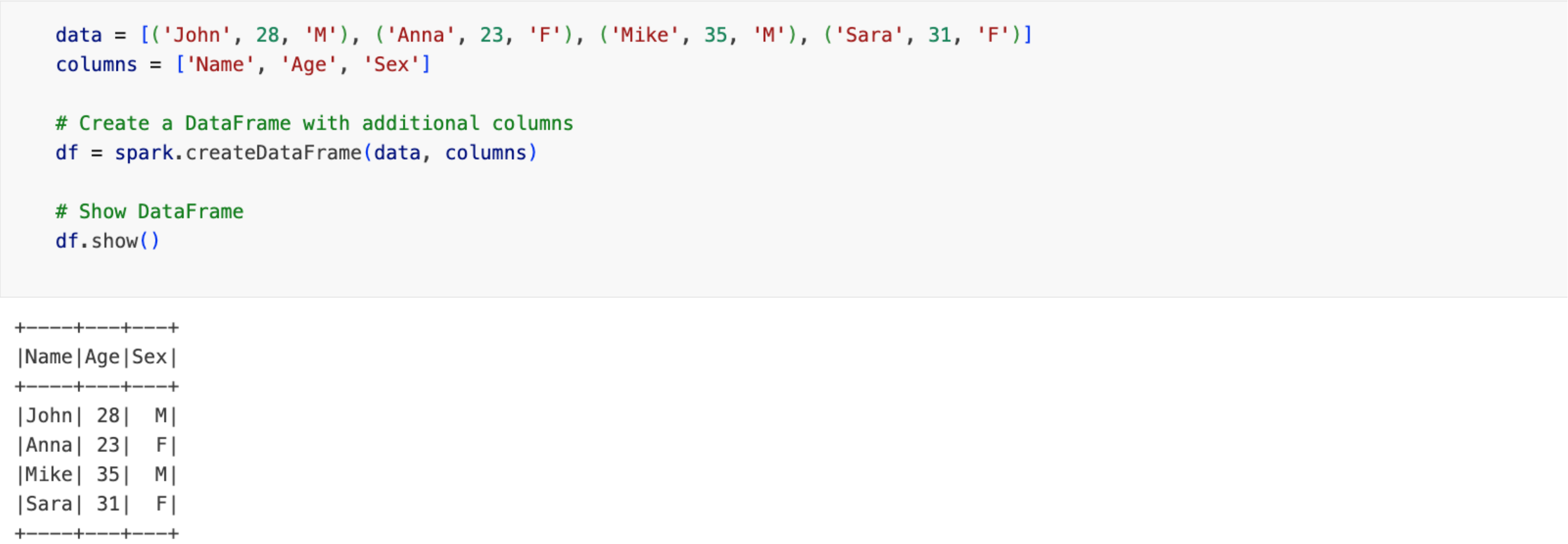
- **config**: This allows users to specify additional Spark configuration settings to customize the application further.
- **spark.executor.memory**: This parameter specifies the amount of memory allocated per executor process, such as 2g for 2 gigabytes.
- **spark.executor.cores**: This defines the number of CPU cores allocated to each executor, impacting the parallelism and speed of the application.
- **spark.driver.memory**: This indicates the amount of memory reserved for the driver process, with a common setting being 1g.



```
import findspark
findspark.init()
from pyspark.sql import SparkSession

# Initialize SparkSession with additional configurations
spark = SparkSession.builder \
    .appName('PySpark Beginner Tutorial') \
    .master('local[*]') \
    .config('spark.executor.memory', '2g') \
    .config('spark.executor.cores', '2') \
    .config('spark.driver.memory', '1g') \
    .getOrCreate()
```

# PySpark: Creating Dataframe

- Creating spark dataframe manually.

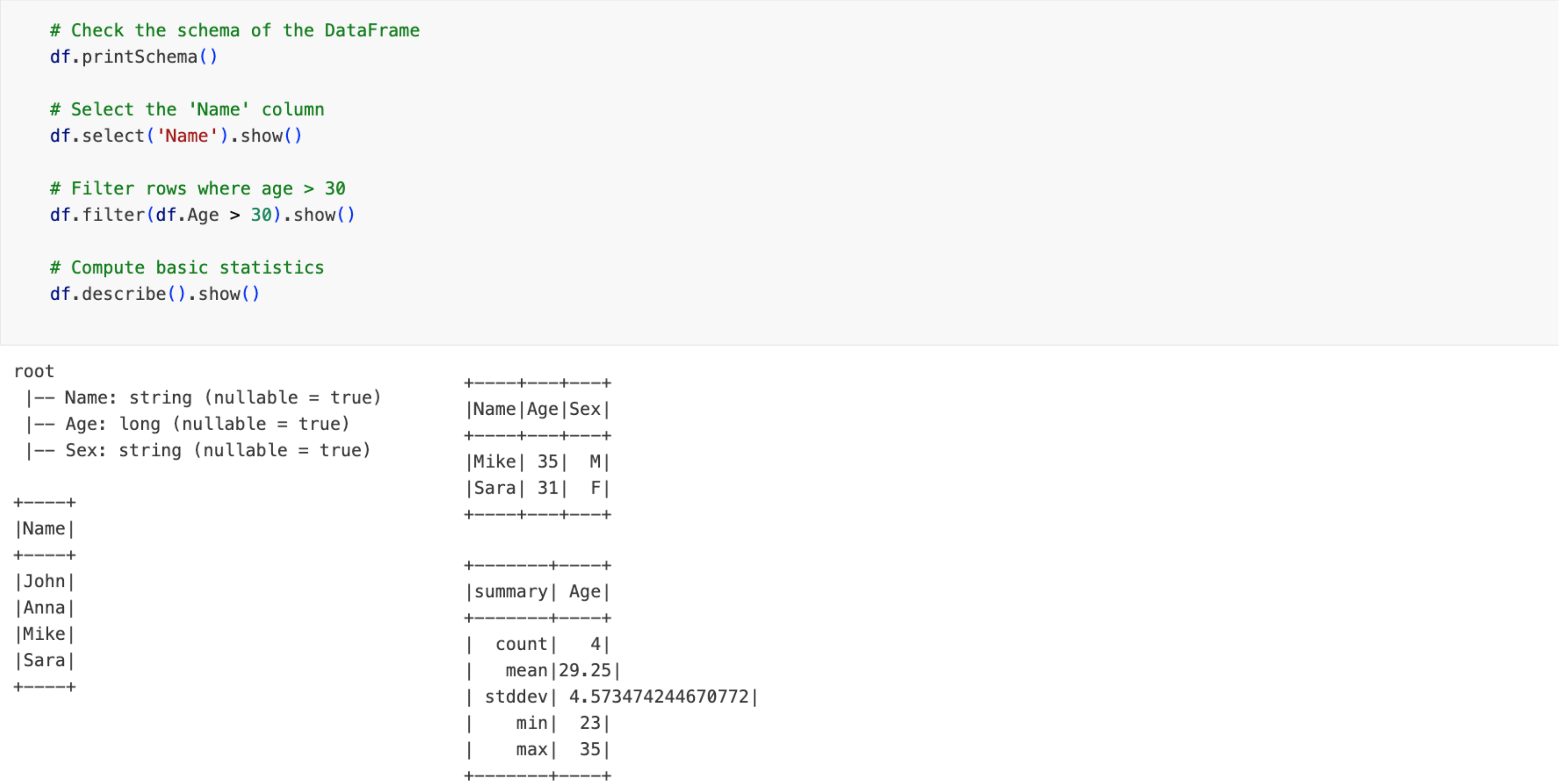


```
data = [('John', 28, 'M'), ('Anna', 23, 'F'), ('Mike', 35, 'M'), ('Sara', 31, 'F')]
columns = ['Name', 'Age', 'Sex']

# Create a DataFrame with additional columns
df = spark.createDataFrame(data, columns)

# Show DataFrame
df.show()
```

```
+----+---+---+
|Name|Age|Sex|
+----+---+---+
|John| 28|  M|
|Anna| 23|  F|
|Mike| 35|  M|
|Sara| 31|  F|
+----+---+---+
```

# PySpark: Dataframe Operations

- Here are some common DataFrame operations such as checking schema, selecting columns, filtering rows, and computing basic statistics.



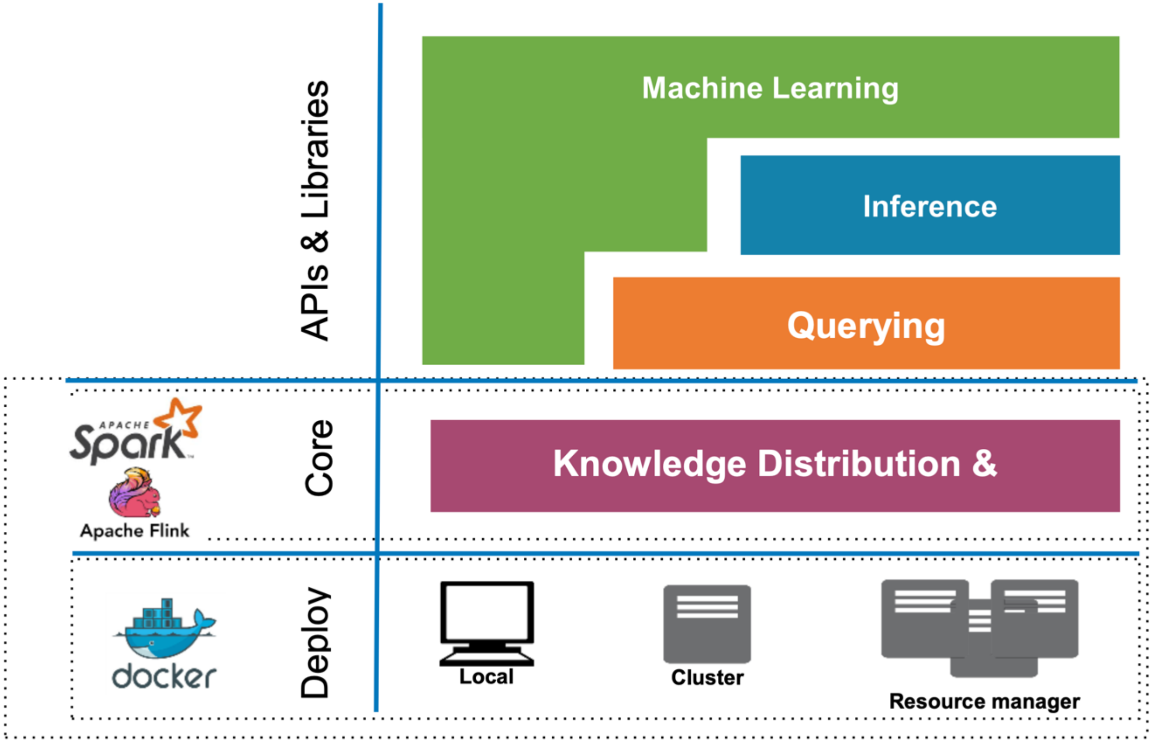
```python
# Check the schema of the DataFrame
df.printSchema()

# Select the 'Name' column
df.select('Name').show()

# Filter rows where age > 30
df.filter(df.Age > 30).show()

# Compute basic statistics
df.describe().show()
```

```
root
 |-- Name: string (nullable = true)
 |-- Age: long (nullable = true)
 |-- Sex: string (nullable = true)

+----+
|Name|
+----+
|John|
|Anna|
|Mike|
|Sara|
+----+
```

```
+----+---+---+
|Name|Age|Sex|
+----+---+---+
|Mike| 35|  M|
|Sara| 31|  F|
+----+---+---+

+-------+-----+
|summary|  Age|
+-------+-----+
|  count|    4|
|   mean|29.25|
| stddev| 4.573474244670772|
|    min|   23|
|    max|   35|
+-------+-----+
```

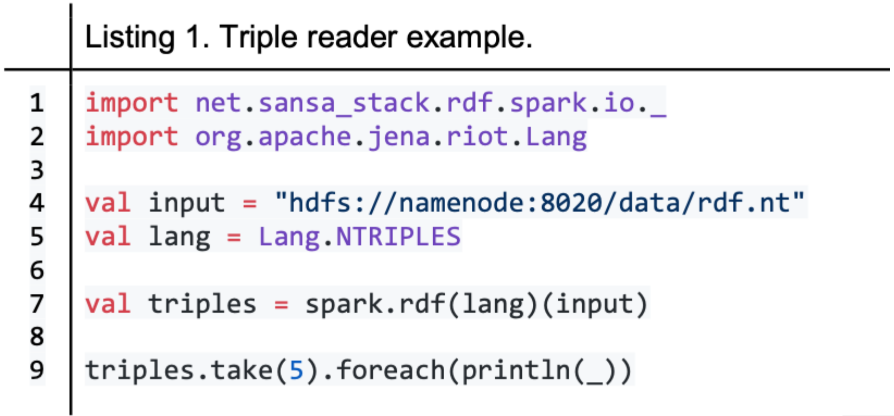
# SANSA Stack

- Scalable Semantic Analytic Stack (SANSA) framework is an open-source distributed data flow engine which allows scalable analysis of large-scale RDF datasets.



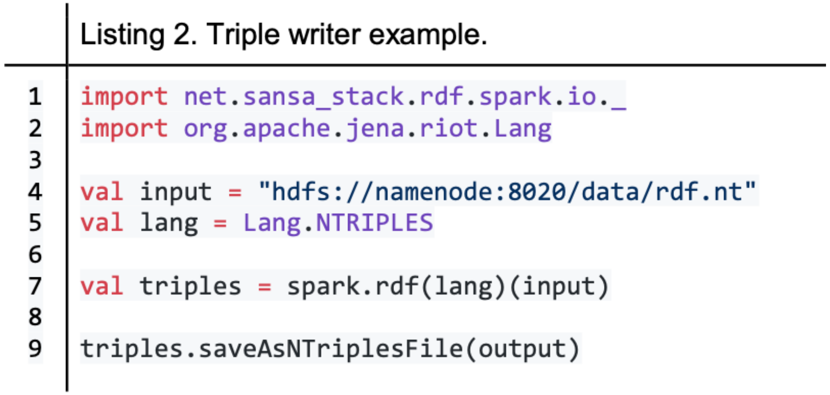
# SANSA Stack – RDF Processing Layer

- SANSA provide mechanism of reading RDF model in the format of RDD/DataFrame/Dataset of triples.



Listing 1. Triple reader example.

```
import net.sansa_stack.rdf.spark.io._
import org.apache.jena.riot.Lang

val input = "hdfs://namenode:8020/data/rdf.nt"
val lang = Lang.NTRIPLES

val triples = spark.rdf(lang)(input)

triples.take(5).foreach(println(_))
```

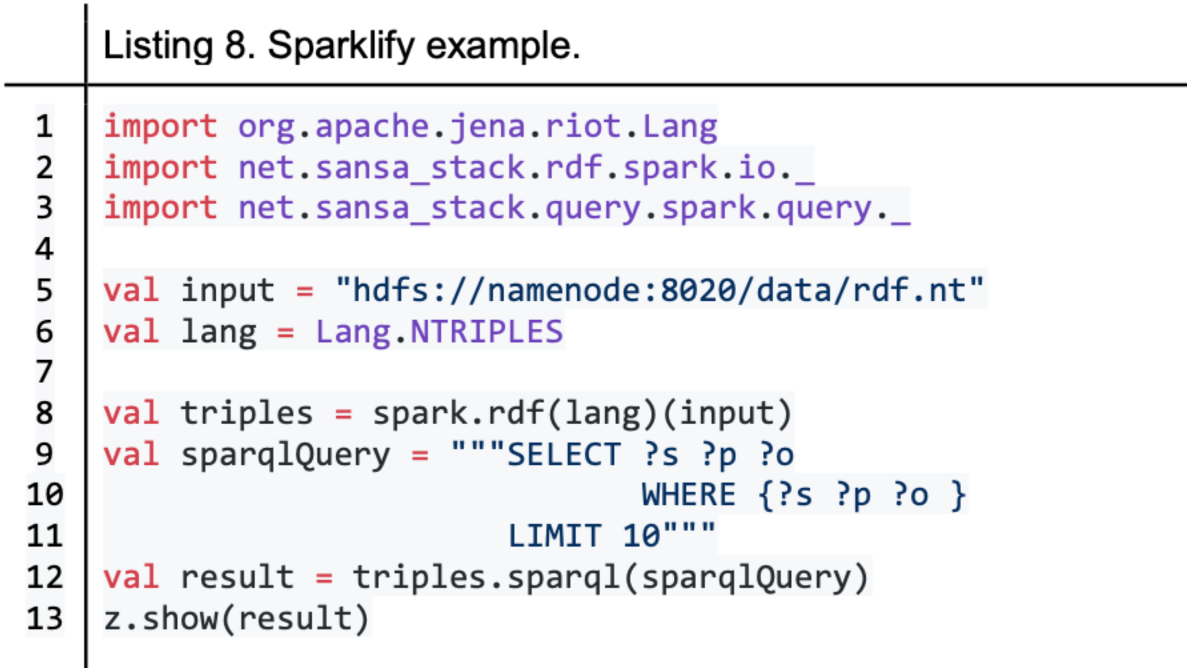


Listing 2. Triple writer example.

```
import net.sansa_stack.rdf.spark.io._
import org.apache.jena.riot.Lang

val input = "hdfs://namenode:8020/data/rdf.nt"
val lang = Lang.NTRIPLES

val triples = spark.rdf(lang)(input)

triples.saveAsNTriplesFile(output)
```

# SANSA Stack – Querying Layer

- The default approach for querying RDF data in SANSA is based on SPARQL-to-SQL. It uses a flexible triple-based partitioning strategy on top of RDF (such as predicate tables with sub partitioning by data types).

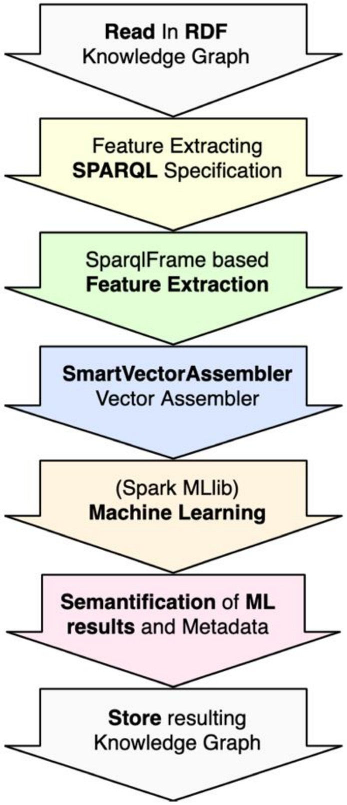


Listing 8. Sparklify example.

```scala
import org.apache.jena.riot.Lang
import net.sansa_stack.rdf.spark.io._
import net.sansa_stack.query.spark.query._

val input = "hdfs://namenode:8020/data/rdf.nt"
val lang = Lang.NTRIPLES

val triples = spark.rdf(lang)(input)
val sparqlQuery = """SELECT ?s ?p ?o
                            WHERE {?s ?p ?o }
                     LIMIT 10"""
val result = triples.sparql(sparqlQuery)
z.show(result)
```

# SANSA Stack – ML Layer (DistRDF2ML)

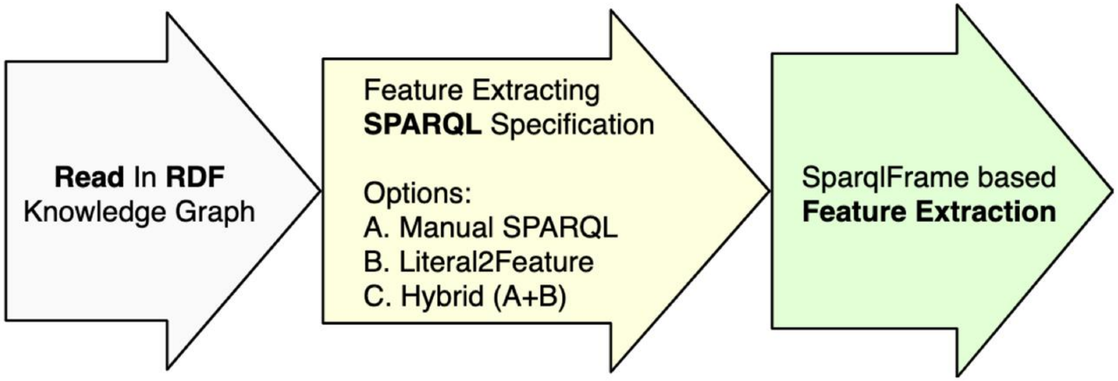
- Introduces software modules that transform large-scale RDF data into ML-ready fixed-length numeric feature vectors



**Read** In **RDF** Knowledge Graph
Feature Extracting **SPARQL** Specification
SparqlFrame based **Feature Extraction**
**SmartVectorAssembler** Vector Assembler
(Spark MLlib) **Machine Learning**
**Semantification** of **ML results** and Metadata
**Store** resulting Knowledge Graph

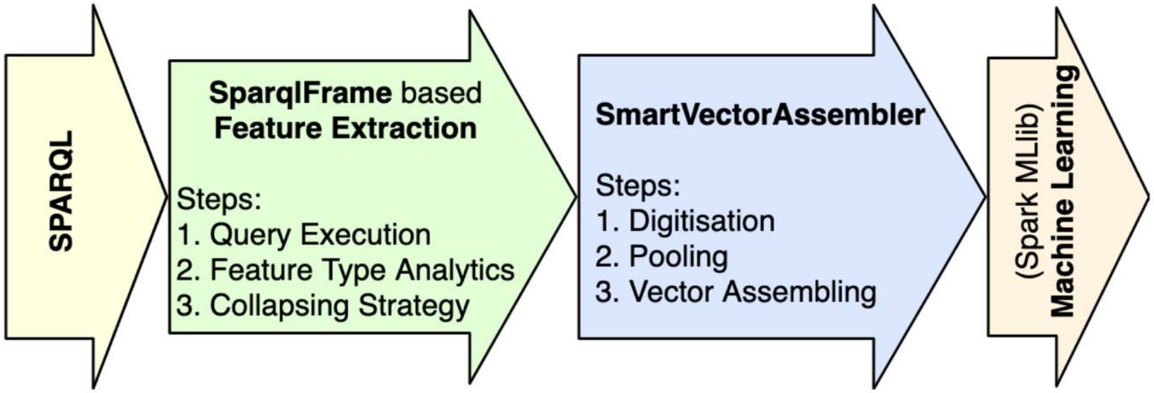
# SANSA Stack – DistRDF2ML (SparqlFrame)

- **Manual SPARQL creation:** A knowledge graph expert manually crafts the SPARQL query to extract relevant features.
- **Literal2Feature:** automatically generates a SPARQL query by deep traversing the RDF graph and extracting literals.
- **Hybrid approach:** Literal2Feature generates a query, which is then manually refined, balancing automation with manual control to create a clean and focused SPARQL query.



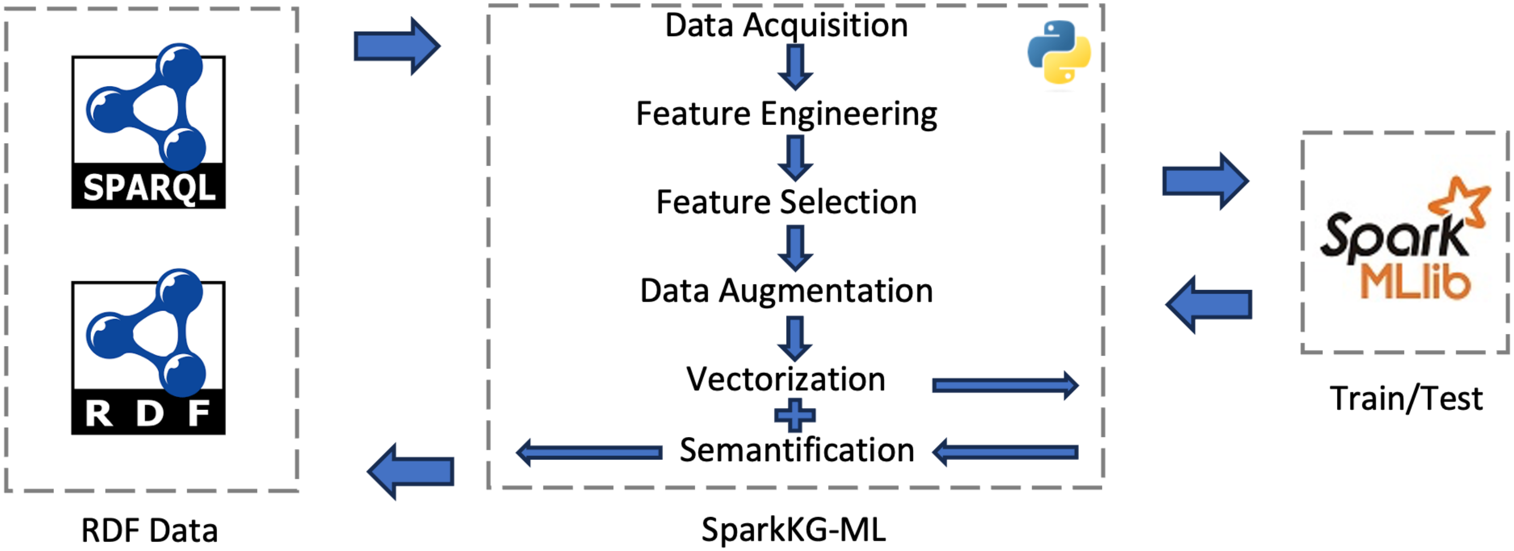
# SANSA Stack – DistRDF2ML (SmartVectorAssembler)

- **SparqlFrame**: Convert SPARQL query results into Spark DataFrames.
- **SmartVectorAssembler**: Features are converted into numeric representations based on their type (e.g., Word2Vec for strings, indices for categorical lists, and datetime transformations for timestamps).



# SparkKG-ML

- A Library to Facilitate end–to–end Large–scale Machine Learning over Knowledge Graphs in Python.



# SparkKG-ML

**Data Acquisition:** Transform RDF data into the tabular format that Spark can process.

**Feature Eng.:** Gathers feature characteristics and a collapsed DataFrame is created.

**Feature Selection:** Focuses on identifying and retaining attributes while discarding redundant

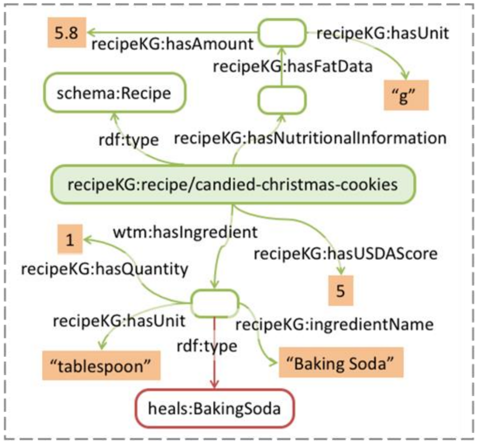
**Data Augmentation:** Enables augmenting a given KG with data from public KGs, allowing the extraction of additional features from these KGs.

**Vectorization:** Produces a ML-ready DataFrame by transforming all features according to feature type into numeric representations.

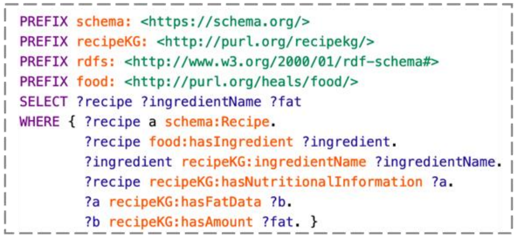
**Semantification:** Transform ML results into RDF data.

# SparkKG-ML: Data Acquisiton

- Transform RDF data into the tabular format that Spark can process.

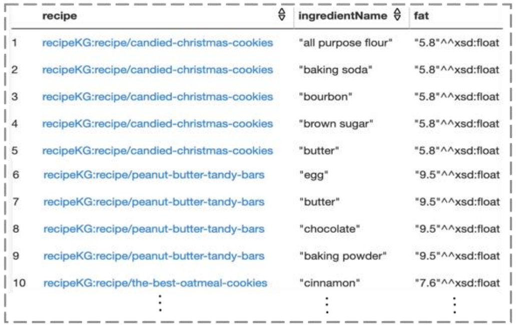


a. Knowledge Graph



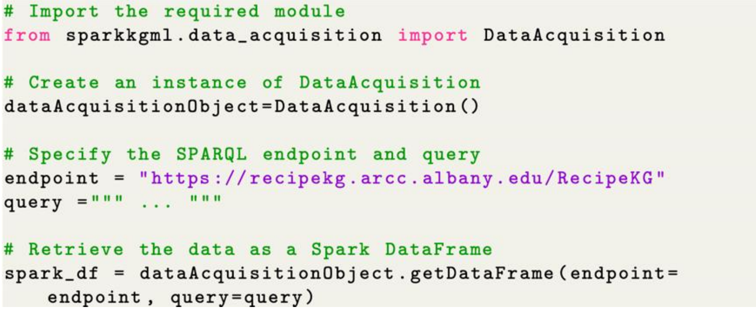
```
PREFIX schema: <https://schema.org/>
PREFIX recipeKG: <http://purl.org/recipekg/>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX food: <http://purl.org/heals/food/>
SELECT ?recipe ?ingredientName ?fat
WHERE { ?recipe a schema:Recipe.
        ?recipe food:hasIngredient ?ingredient.
        ?ingredient recipeKG:ingredientName ?ingredientName.
        ?recipe recipeKG:hasNutritionalInformation ?a.
        ?a recipeKG:hasFatData ?b.
        ?b recipeKG:hasAmount ?fat. }
```

b. SPARQL Query

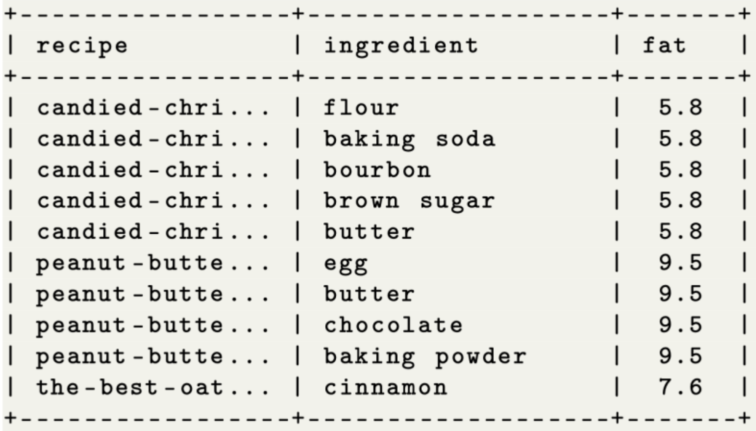


| | recipe | ingredientName | fat |
|---|---|---|---|
| 1 | recipeKG:recipe/candied-christmas-cookies | "all purpose flour" | "5.8"^^xsd:float |
| 2 | recipeKG:recipe/candied-christmas-cookies | "baking soda" | "5.8"^^xsd:float |
| 3 | recipeKG:recipe/candied-christmas-cookies | "bourbon" | "5.8"^^xsd:float |
| 4 | recipeKG:recipe/candied-christmas-cookies | "brown sugar" | "5.8"^^xsd:float |
| 5 | recipeKG:recipe/candied-christmas-cookies | "butter" | "5.8"^^xsd:float |
| 6 | recipeKG:recipe/peanut-butter-tandy-bars | "egg" | "9.5"^^xsd:float |
| 7 | recipeKG:recipe/peanut-butter-tandy-bars | "butter" | "9.5"^^xsd:float |
| 8 | recipeKG:recipe/peanut-butter-tandy-bars | "chocolate" | "9.5"^^xsd:float |
| 9 | recipeKG:recipe/peanut-butter-tandy-bars | "baking powder" | "9.5"^^xsd:float |
| 10 | recipeKG:recipe/the-best-oatmeal-cookies | "cinnamon" | "7.6"^^xsd:float |
| | ⋮ | ⋮ | ⋮ |

c. Query Result



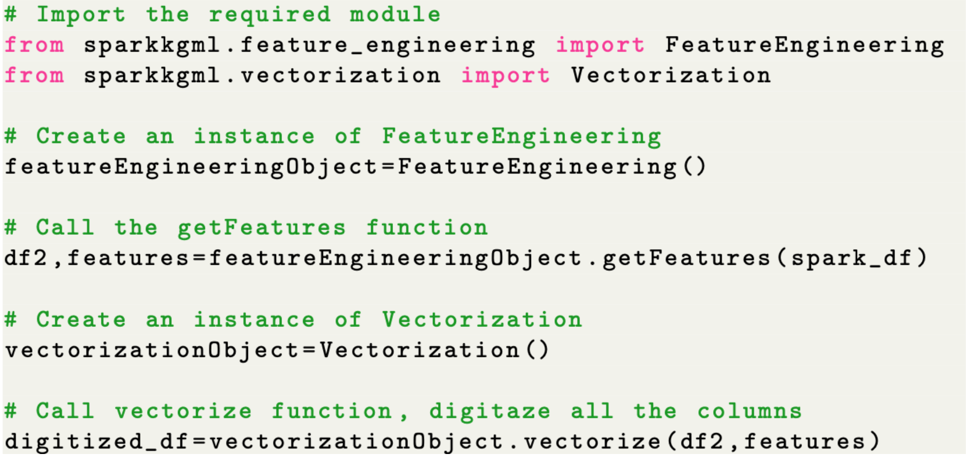
```python
# Import the required module
from sparkkgml.data_acquisition import DataAcquisition

# Create an instance of DataAcquisition
dataAcquisitionObject=DataAcquisition()

# Specify the SPARQL endpoint and query
endpoint = "https://recipekg.arcc.albany.edu/RecipeKG"
query ="""  ...  """

# Retrieve the data as a Spark DataFrame
spark_df = dataAcquisitionObject.getDataFrame(endpoint=
    endpoint, query=query)
```



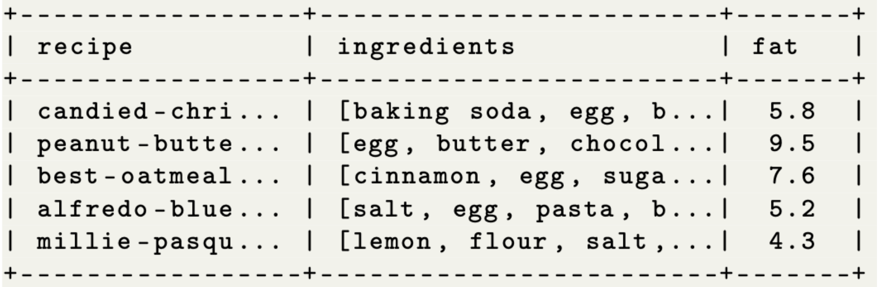
```
+----------------+-------------------+-------+
| recipe         | ingredient        | fat   |
+----------------+-------------------+-------+
| candied-chri...| flour             |  5.8  |
| candied-chri...| baking soda       |  5.8  |
| candied-chri...| bourbon           |  5.8  |
| candied-chri...| brown sugar       |  5.8  |
| candied-chri...| butter            |  5.8  |
| peanut-butte...| egg               |  9.5  |
| peanut-butte...| butter            |  9.5  |
| peanut-butte...| chocolate         |  9.5  |
| peanut-butte...| baking powder     |  9.5  |
| the-best-oat...| cinnamon          |  7.6  |
+----------------+-------------------+-------+
```

# SparkKG-ML: Feature Engineering

- Gathers feature characteristics and a collapsed DataFrame is created.
    - **datatype**: The data type of the feature column.
    - **numberDistinctValues**: The number of distinct values in the feature column.
    - **isListOfEntries**: Flag indicating if the feature is a list of entries.
    - **isCategorical**: The ratio of distinct values and overall dataset size
    - **featureType**: Combine features based on whether they consist of a list or a single value, categorical or non-categorical, and data type.



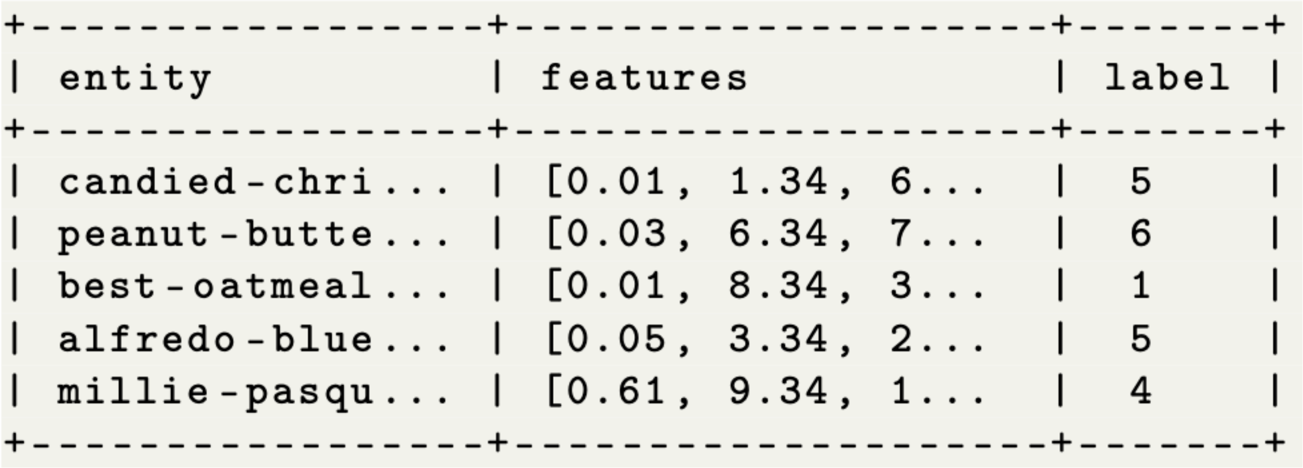
```python
# Import the required module
from sparkkgml.feature_engineering import FeatureEngineering
from sparkkgml.vectorization import Vectorization

# Create an instance of FeatureEngineering
featureEngineeringObject=FeatureEngineering()

# Call the getFeatures function
df2,features=featureEngineeringObject.getFeatures(spark_df)

# Create an instance of Vectorization
vectorizationObject=Vectorization()

# Call vectorize function, digitaze all the columns
digitized_df=vectorizationObject.vectorize(df2,features)
```



```
+-----------------+-----------------------+-------+
| recipe          | ingredients           | fat   |
+-----------------+-----------------------+-------+
| candied-chri... | [baking soda, egg, b...|  5.8  |
| peanut-butte... | [egg, butter, chocol...|  9.5  |
| best-oatmeal... | [cinnamon, egg, suga...|  7.6  |
| alfredo-blue... | [salt, egg, pasta, b...|  5.2  |
| millie-pasqu... | [lemon, flour, salt,...|  4.3  |
+-----------------+-----------------------+-------+
```

# SparkKG-ML: Vectorization

- Gathers feature characteristics and a collapsed DataFrame is created.
  - **Single Categorical String:** indexing or hashing
  - **List of Categorical Strings:** explodes the list and applies string indexing or hashing
  - **Single Non–Categorical String:** Word2Vec (optional stop word removal)
  - **List of Non–Categorical Strings:** the list elements are combined, tokenized, stop words are removed. Embeddings are then calculated using Word2Vec.
  - **Numeric Type :** (i.e., integer, long, float, double)
  - **Boolean Type:** cast to integers (0 or 1).



```
+-----------------+--------------------+-------+
| entity          | features           | label |
+-----------------+--------------------+-------+
| candied-chri... | [0.01, 1.34, 6...  |  5    |
| peanut-butte... | [0.03, 6.34, 7...  |  6    |
| best-oatmeal... | [0.01, 8.34, 3...  |  1    |
| alfredo-blue... | [0.05, 3.34, 2...  |  5    |
| millie-pasqu... | [0.61, 9.34, 1...  |  4    |
+-----------------+--------------------+-------+
```