Open for Innovation
KNIME

[L4-BD] Introduction to Big Data with KNIME Analytics Platform

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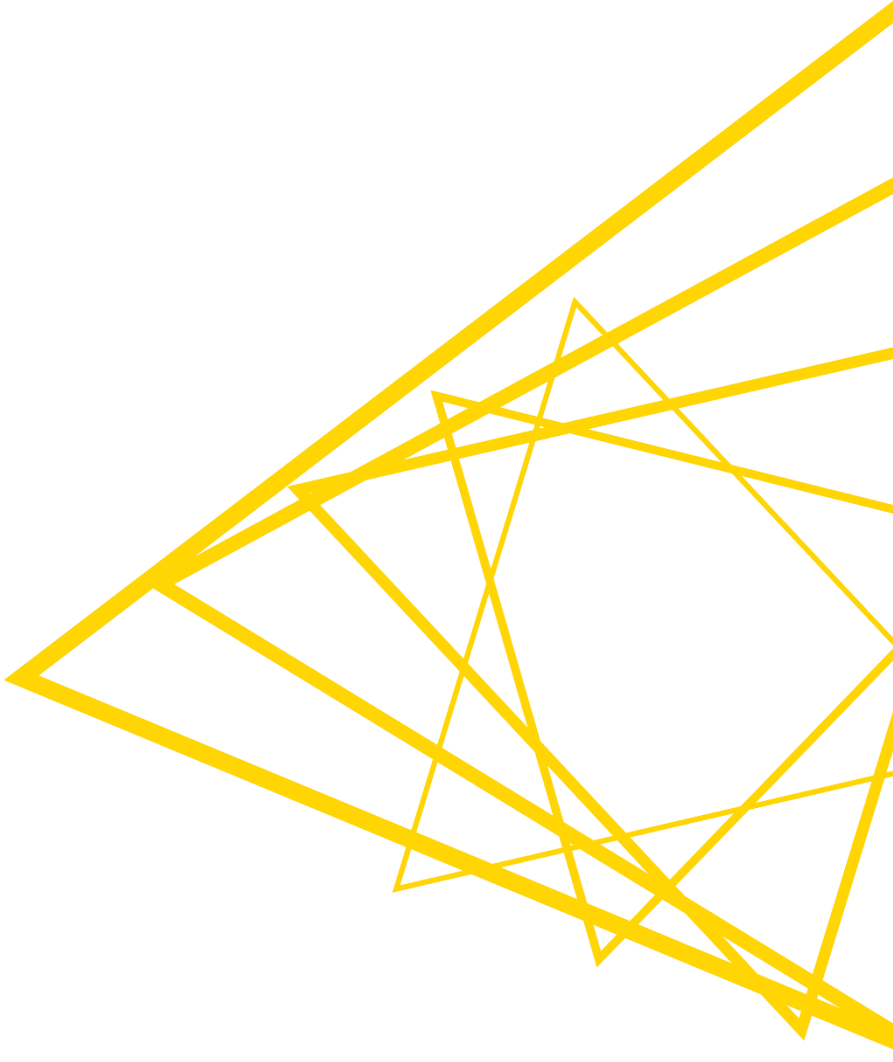
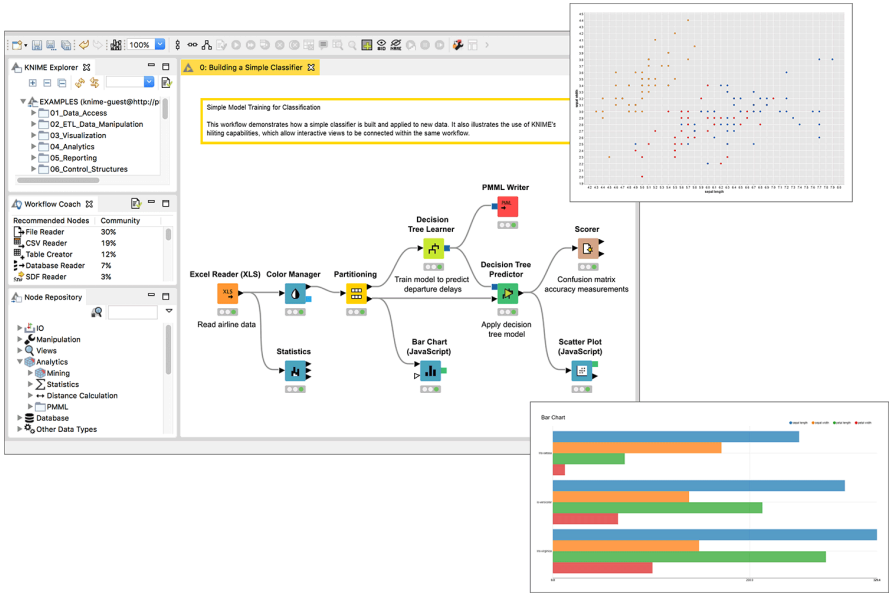
Overview
KNIME Analytics Platform



What is KNIME Analytics Platform?

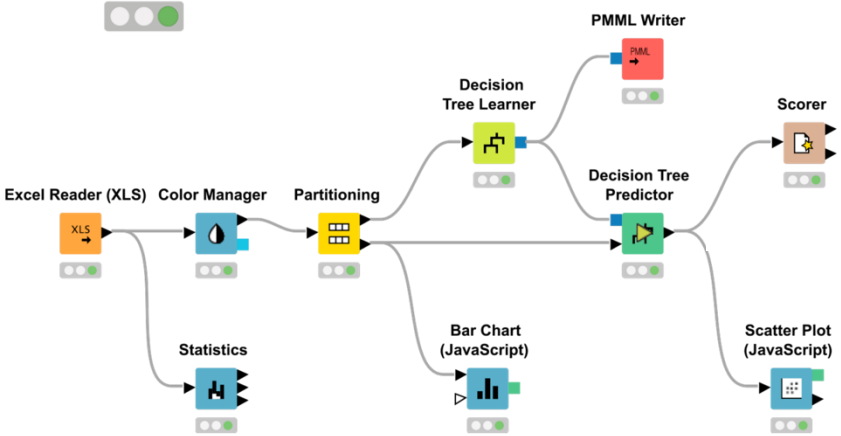
- A tool for data analysis, manipulation, visualization, and reporting
- Based on the graphical programming paradigm
- Provides a diverse array of extensions:
  - Text Mining
  - Network Mining
  - Cheminformatics
  - Many integrations,
    such as Java, R, Python,
    Weka, Keras, Plotly, H2O, etc.



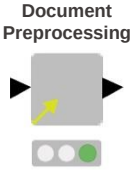
Visual KNIME Workflows

Nodes
perform tasks on data

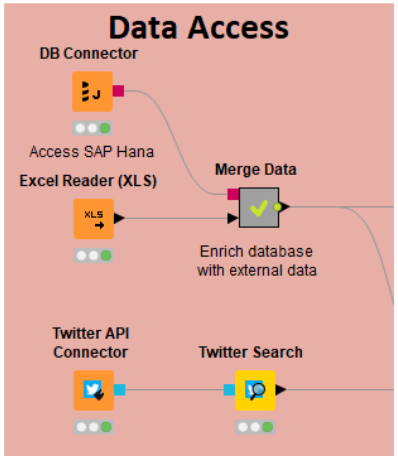
Workflows
combine nodes to model data flow



Components
encapsulate complexity & expertise

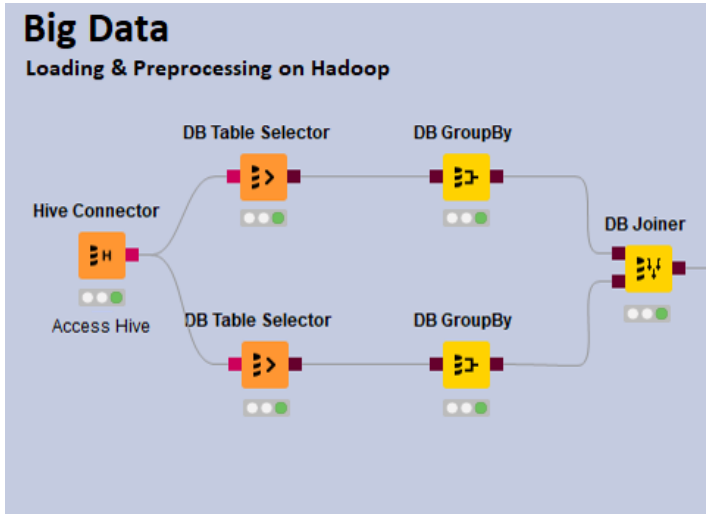


Data Access



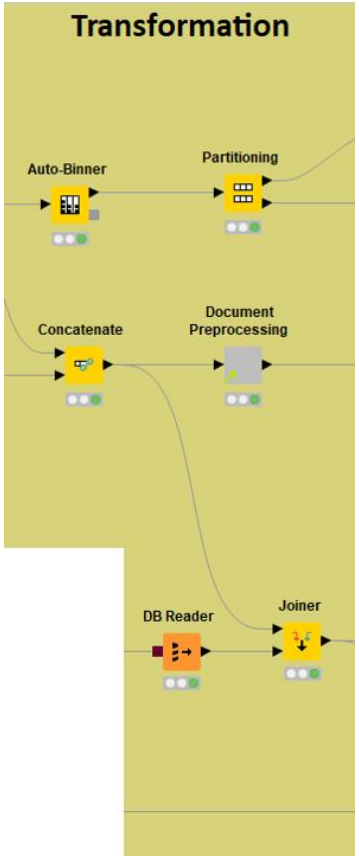
- Databases
  - MySQL, PostgreSQL, Oracle
  - Theobald
  - any JDBC (DB2, MS SQL Server)
  - Amazon DynamoDB
- Files
  - CSV, txt, Excel, Word, PDF
  - SAS, SPSS
  - XML, JSON, PMML
  - Images, texts, networks
- Other
  - Twitter, Google
  - Amazon S3, Azure Blob Store
  - Sharepoint, Salesforce
  - Kafka
  - REST, Web services

Big Data



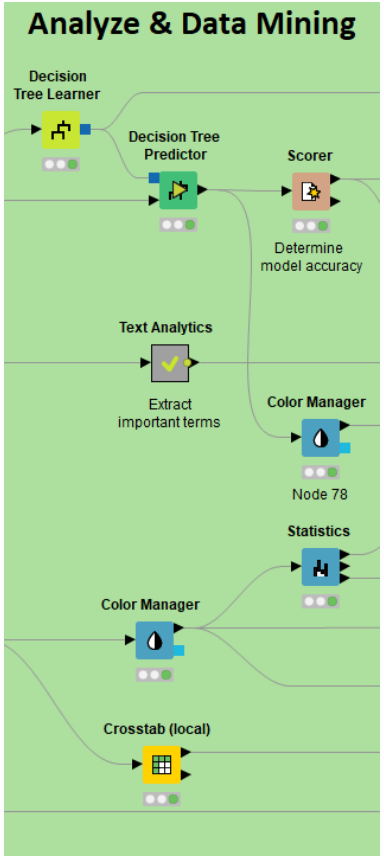
- Spark & Databricks
- HDFS support
- Hive
- Impala
- In-database processing

Transformation



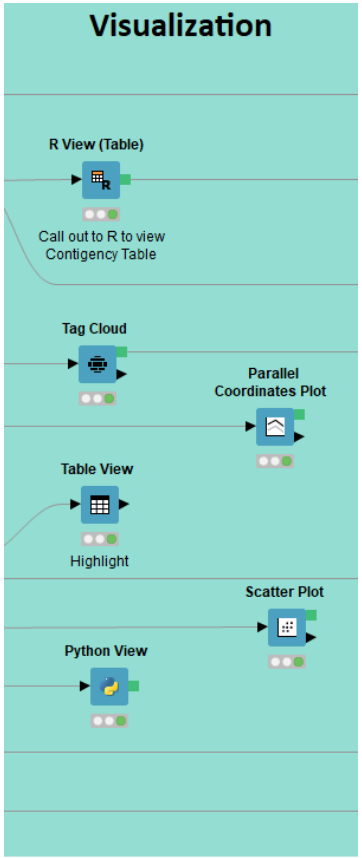
- Preprocessing
  - Row, column, matrix based
- Data blending
  - Join, concatenate, append
- Aggregation
  - Grouping, pivoting, binning
- Feature Creation and Selection

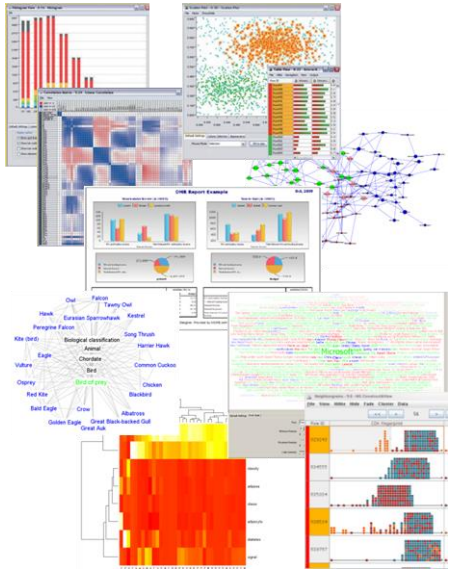
Analysis & Data Mining



- Regression
  - Linear, logistic
- Classification
  - Decision tree, ensembles, SVM, MLP, Naïve Bayes
- Clustering
  - k-means, DBSCAN, hierarchical
- Validation
  - Cross-validation, scoring, ROC
- Deep Learning
  - Keras, DL4J
- External
  - R, Python, Weka, H2O, Keras

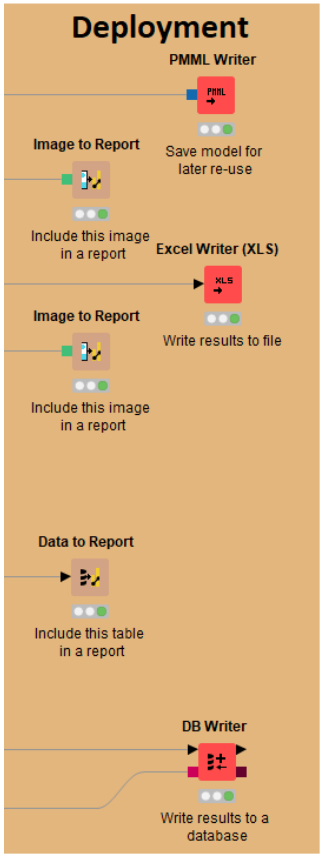
Visualization





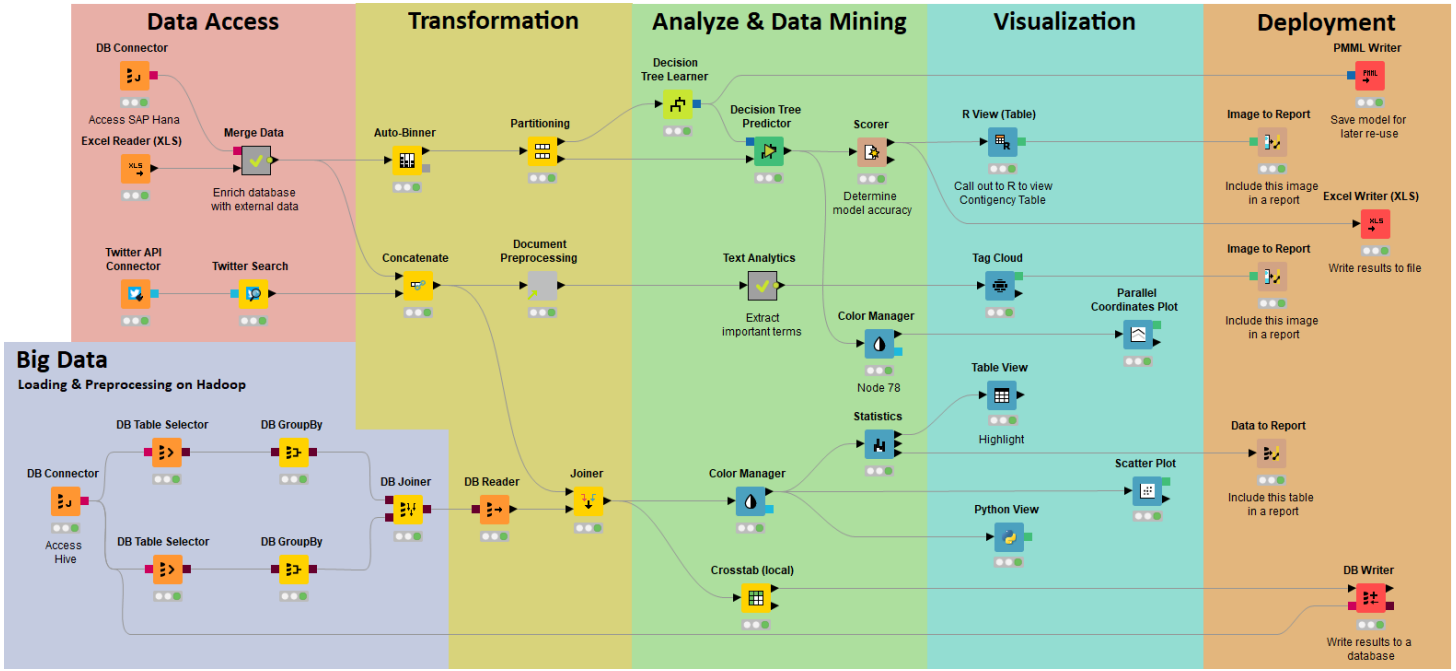
- Interactive Visualizations
- JavaScript-based nodes
  - Scatter Plot, Box Plot, Line Plot
  - Networks, ROC Curve, Decision Tree
  - Plotly Integration
  - Adding more with each release!
- Misc
  - Tag cloud, open street map, molecules
- Script-based visualizations
  - R, Python

Deployment



- Database
- Files
  - Excel, CSV, txt
  - XML
  - PMML
  - to: local, KNIME Server, Amazon S3, Azure Blob Store
- BIRT Reporting

Over 2000 Native and Embedded Nodes Included:



Data Access
MySQL, Oracle, ...
SAS, SPSS, ...
Excel, Flat, ...
Hive, Impala, ...
XML, JSON, PMML
Text, Doc, Image, ...
Web Crawlers
Industry Specific
Community / 3rd

Transformation
Row
Column
Matrix
Text, Image
Time Series
Java
Python
Community / 3rd

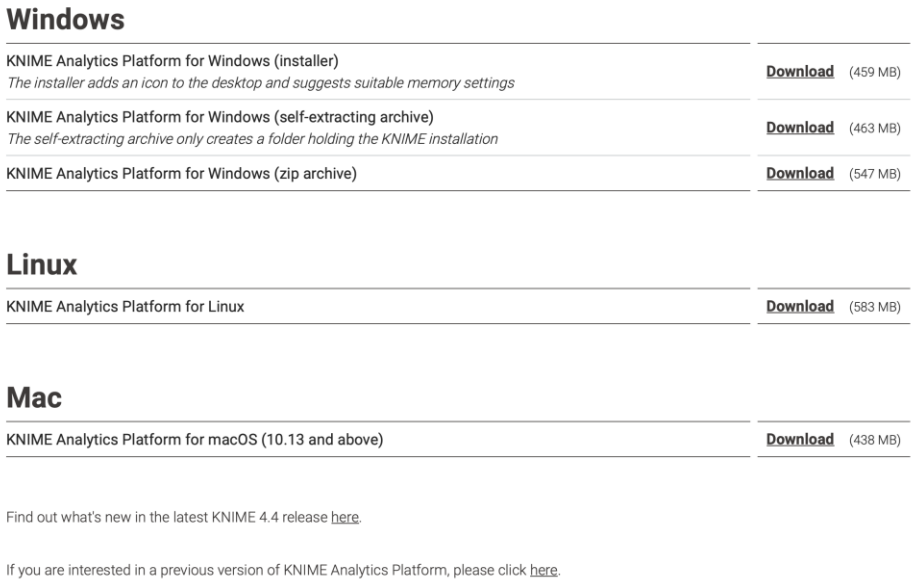
Analysis & Mining
Statistics
Data Mining
Machine Learning
Web Analytics
Text Mining
Network Analysis
Social Media Analysis
R, Weka, Python
Community / 3rd

Visualization
R
JFreeChart
JavaScript
Plotly
Community / 3rd

Deployment
via BIRT
PMML
XML, JSON
Databases
Excel, Flat, etc.
Text, Doc, Image
Industry Specific
Community / 3rd

Install KNIME Analytics Platform

- Select the KNIME version for your computer:
  - Mac
  - Windows – 32 or 64 bit
  - Linux
- Download the archive and extract the file, or download installer package and run it



Windows

KNIME Analytics Platform for Windows (installer) *The installer adds an icon to the desktop and suggests suitable memory settings*	Download (459 MB)
KNIME Analytics Platform for Windows (self-extracting archive) *The self-extracting archive only creates a folder holding the KNIME installation*	Download (463 MB)
KNIME Analytics Platform for Windows (zip archive)	Download (547 MB)

Linux

KNIME Analytics Platform for Linux	Download (583 MB)

Mac

KNIME Analytics Platform for macOS (10.13 and above)	Download (438 MB)

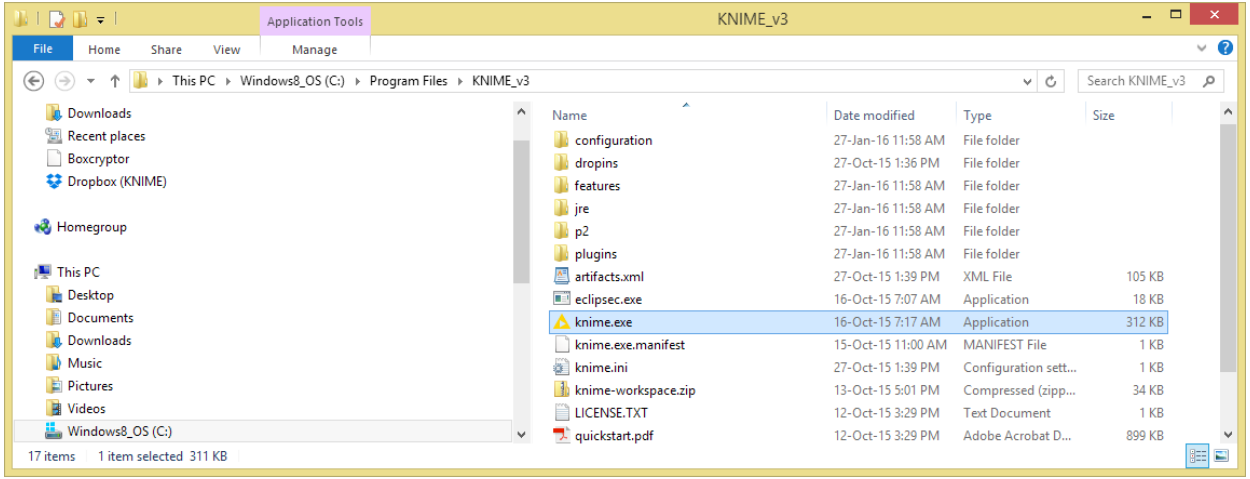
Find out what's new in the latest KNIME 4.4 release here.

If you are interested in a previous version of KNIME Analytics Platform, please click here.

Start KNIME Analytics Platform

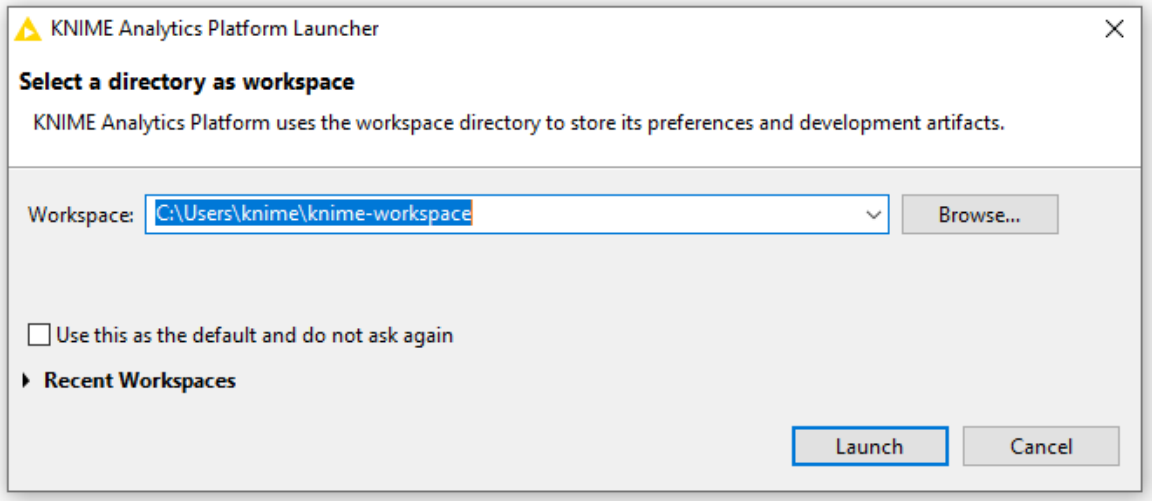
- Use the shortcut created by the installer

- Or go to the installation directory and launch KNIME via the knime.exe

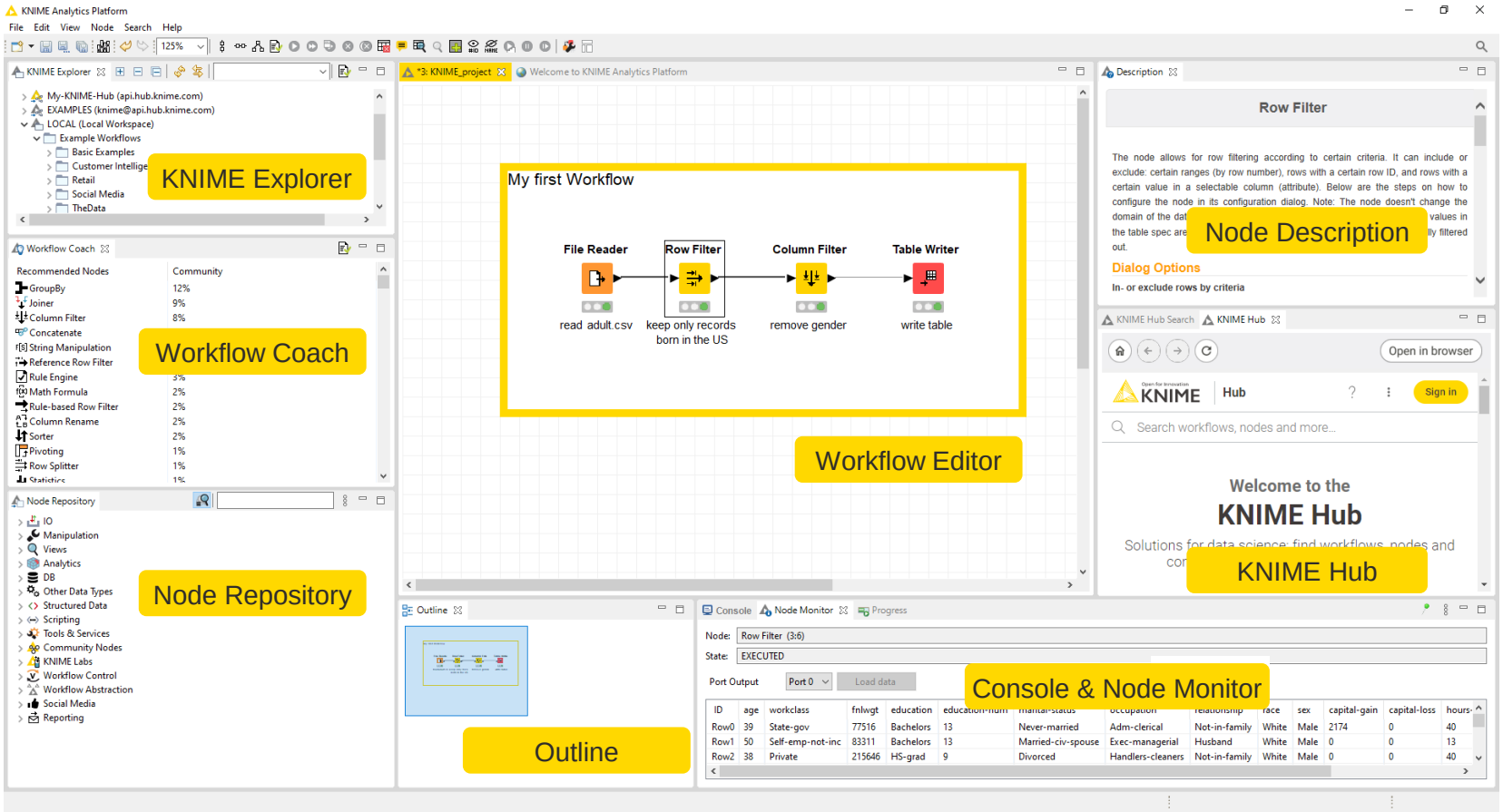


The KNIME Workspace

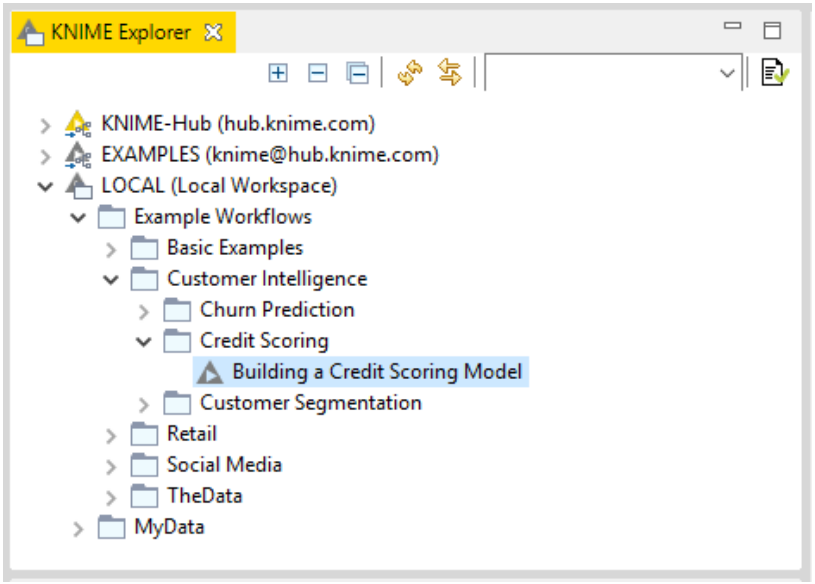
- The workspace is the **folder/directory** in which workflows (and potentially data files) are stored for the current KNIME session
- Workspaces are portable (just like KNIME)



The KNIME Analytics Platform Workbench



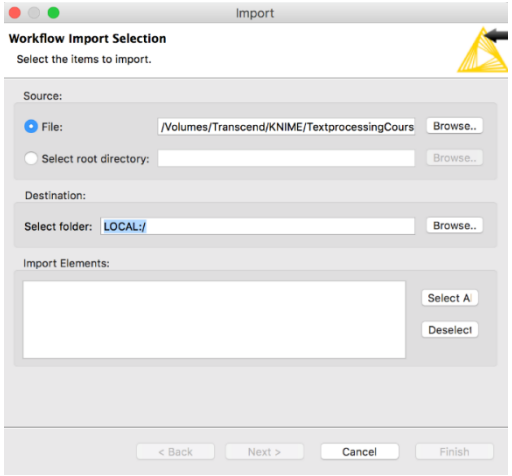
KNIME Explorer

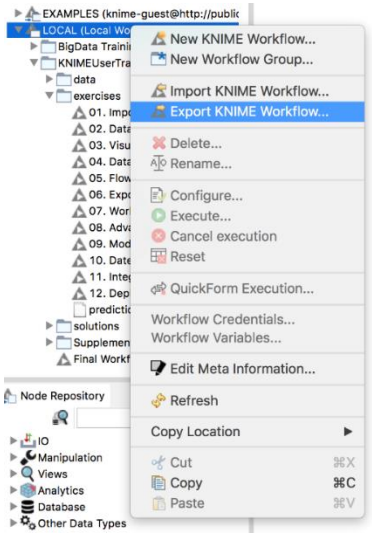


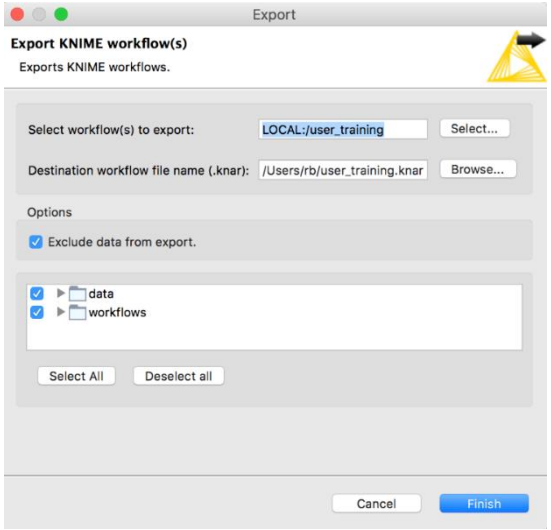
- In LOCAL you can access your own workflow projects.
- Other mountpoints allow you to connect to
  - EXAMPLE Server
  - KNIME Hub
  - KNIME Server
- The Explorer toolbar on the top has a search box and buttons to
  - select the workflow displayed in the active editor
  - refresh the view
- The KNIME Explorer can contain 4 types of content:
  - Workflows
  - Workflow groups
  - Data files
  - Shared Components

Creating New Workflows, Importing, and Exporting

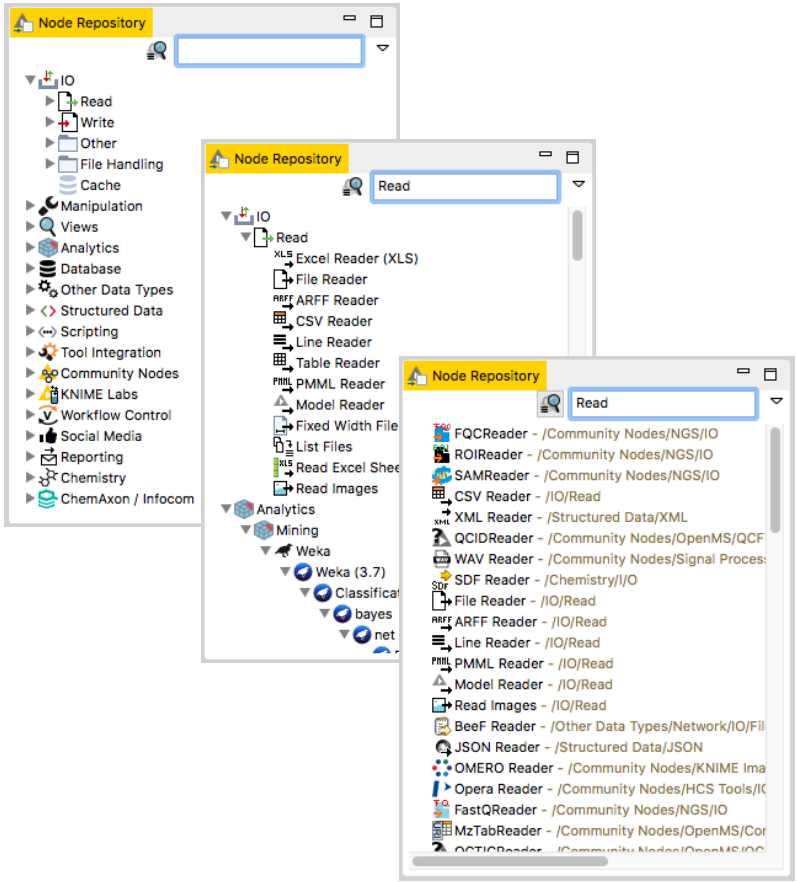
- Right-click inside the KNIME Explorer to create a new workflow or a workflow group, or to import a workflow
- Right-click the workflow or workflow group to export





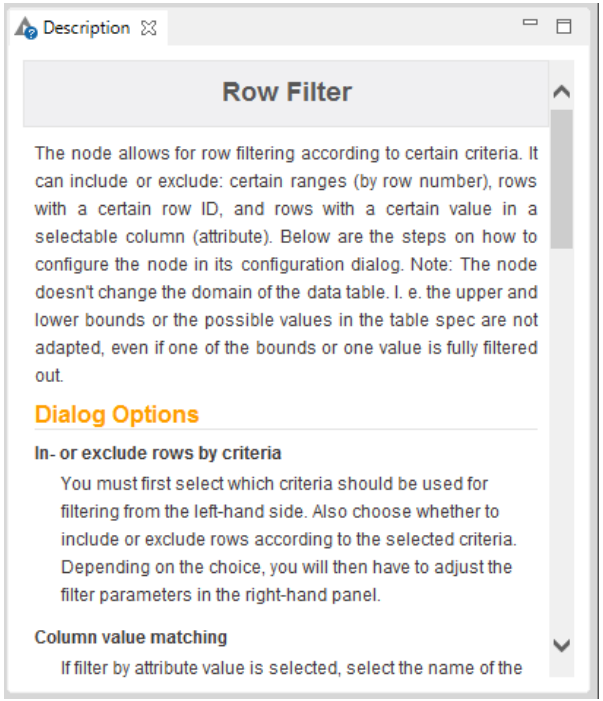


Node Repository



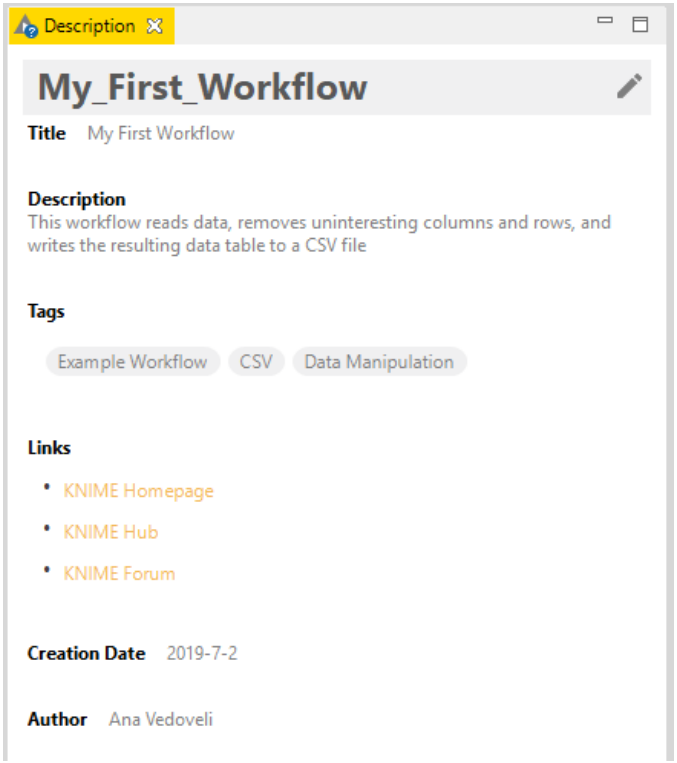
- The Node Repository lists all KNIME nodes
- The search box has 2 modes
  - Standard Search – exact match of node name
  - Fuzzy Search – finds the most similar node name

Description



- The Description view provides information about:
  - Node functionality
  - Input & output
  - Node settings
  - Ports
  - References to literature

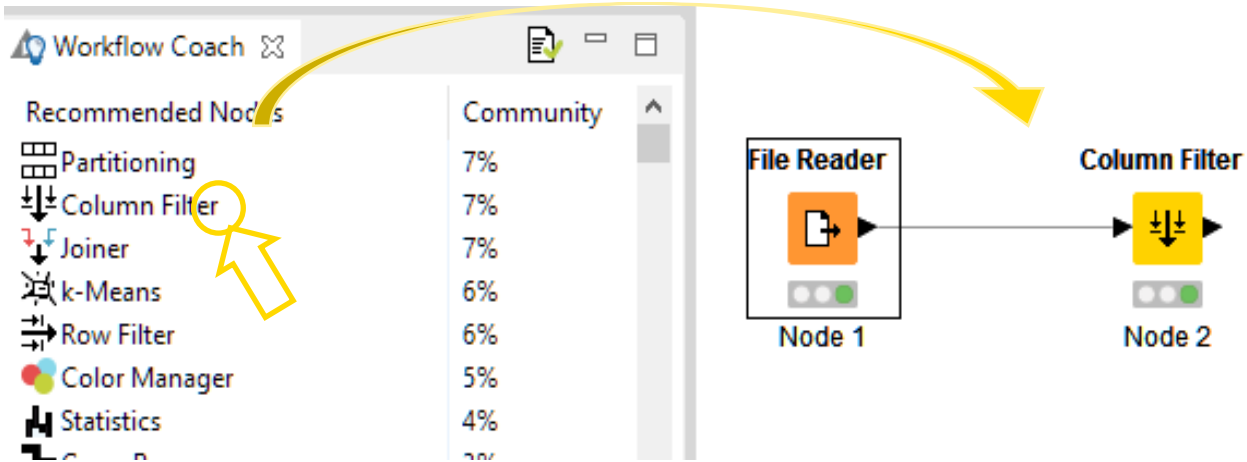
Workflow Description



- When selecting the workflow, the Description view gives you information about the workflow:
  - Title
  - Description
  - Associated tags and links
  - Creation date
  - Author

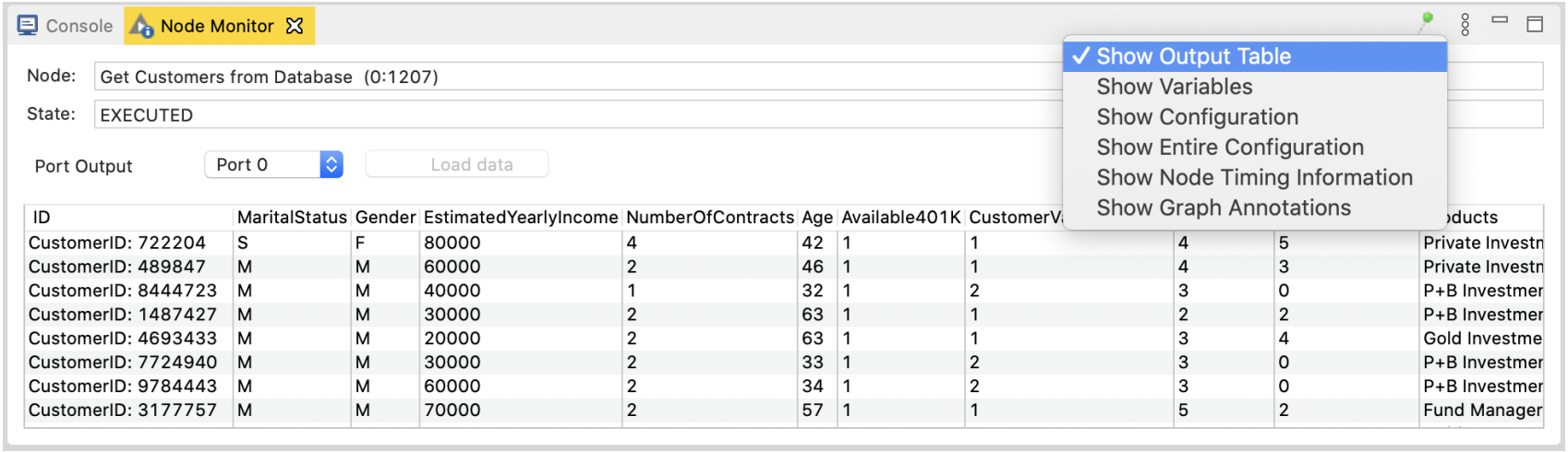
Workflow Coach

- Node recommendation engine
  - Gives hints about which node to use next in the workflow
  - Based on KNIME communities' usage statistics
  - Based on own KNIME workflows



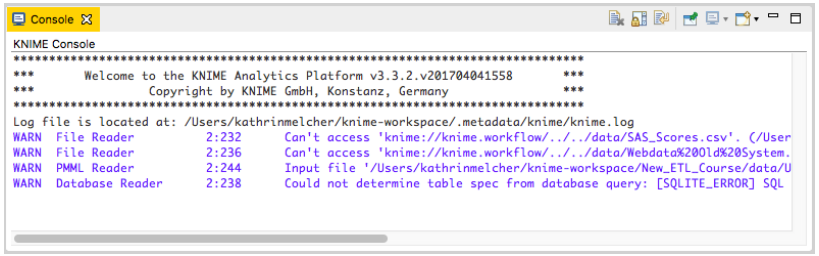
Node Monitor

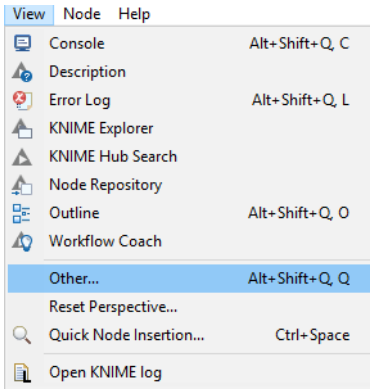
- By default the Node Monitor shows you the output table of the node selected in the workflow editor
- Click on the three dots on the upper right to show the flow variables, configuration, etc.

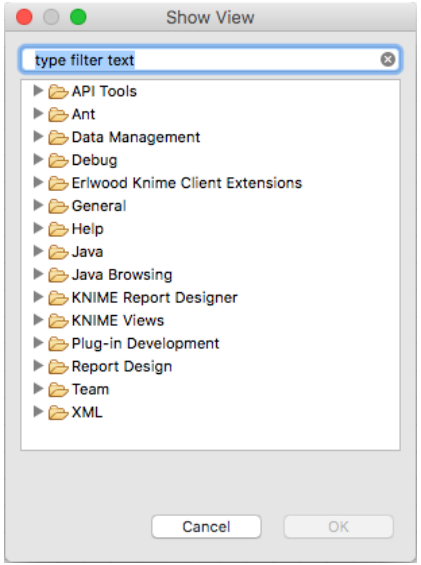


ID	MaritalStatus	Gender	EstimatedYearlyIncome	NumberOfContracts	Age	Available401K	CustomerV			oducts
CustomerID: 722204	S	F	80000	4	42	1	1	4	5	Private Investn
CustomerID: 489847	M	M	60000	2	46	1	1	4	3	Private Investn
CustomerID: 8444723	M	M	40000	1	32	1	2	3	0	P+B Investmer
CustomerID: 1487427	M	M	30000	2	63	1	1	2	2	P+B Investmer
CustomerID: 4693433	M	M	20000	2	63	1	1	3	4	Gold Investme
CustomerID: 7724940	M	M	30000	2	33	1	2	3	0	P+B Investmer
CustomerID: 9784443	M	M	60000	2	34	1	2	3	0	P+B Investmer
CustomerID: 3177757	M	M	70000	2	57	1	1	5	2	Fund Manager

Console and Other Views



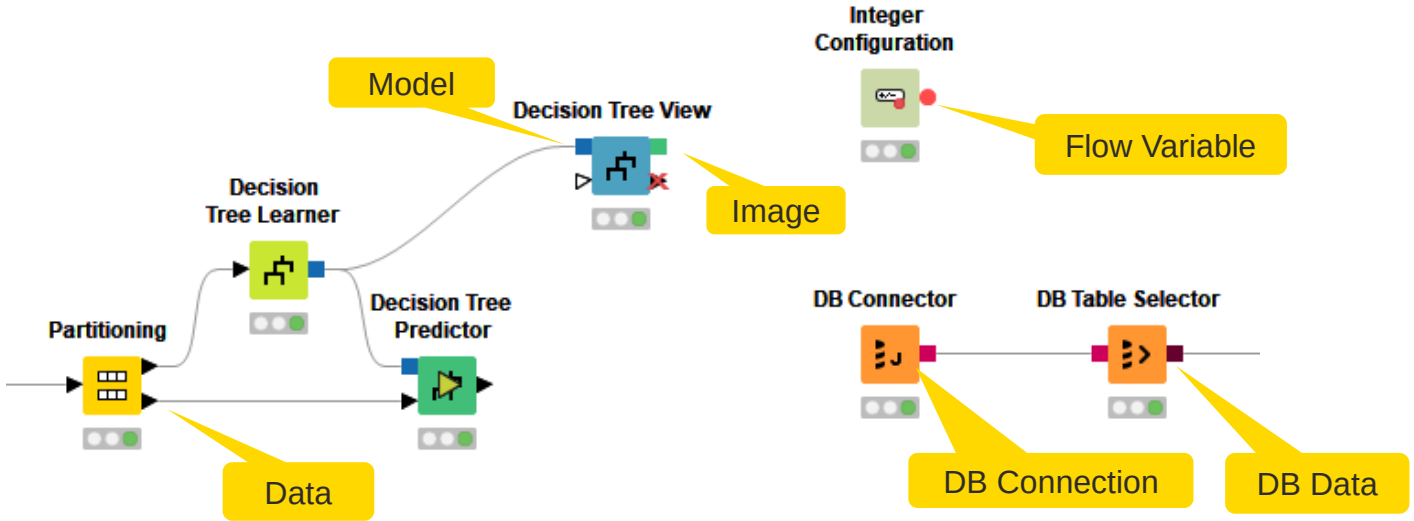




- Console view prints out error and warning messages about what is going on under the hood
- Click View and select Other… to add different views
  - Node Monitor, Licenses, etc.

Inserting and Connecting Nodes

- Insert nodes into workspace by dragging them from the Node Repository or by double-clicking in the Node Repository
- Connect nodes by left-clicking the output port of Node A and dragging the cursor to the (matching) input port of Node B
- Common port types:

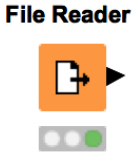


More on Nodes…

- A node can have 4 states:

Not Configured:
The node is waiting for configuration or incoming data.

Configured:
The node has been configured correctly, and can be executed.

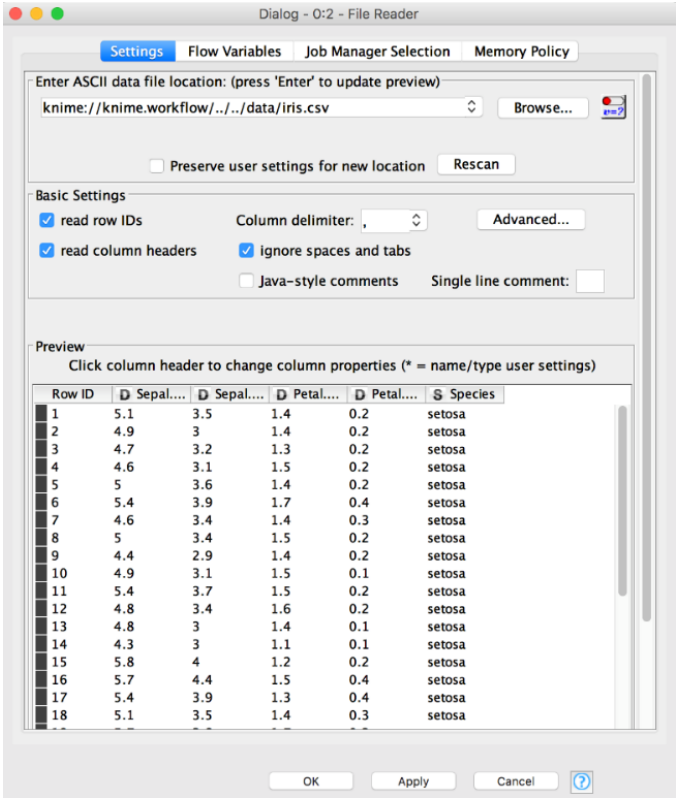


Executed:
The node has been successfully executed. Results may be viewed and used in downstream nodes.

Error:
The node has encountered an error during execution.

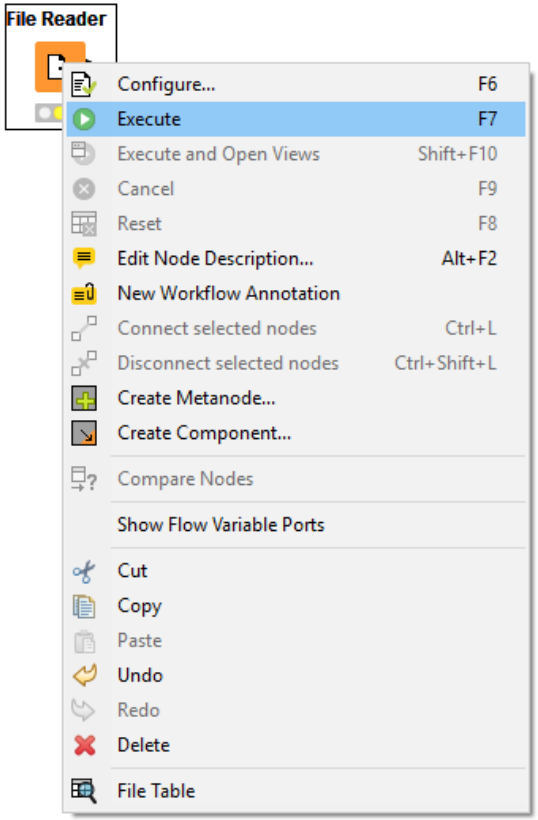
Node Configuration

- Most nodes need to be configured
- To access a node configuration dialog:
  - Double-click the node
  - Right-click -> Configure



Node Execution

- Right-click node
- Select Execute in the context menu
- If execution is successful, status shows green light
- If execution encounters errors, status shows red light



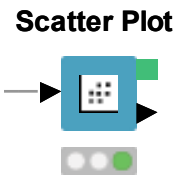
Tool Bar

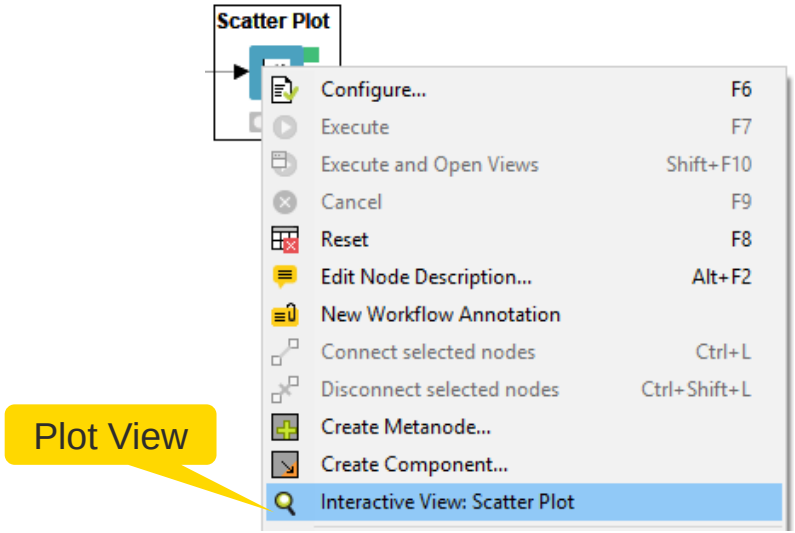
The buttons in the toolbar can be used for the active workflow. The most important buttons are:

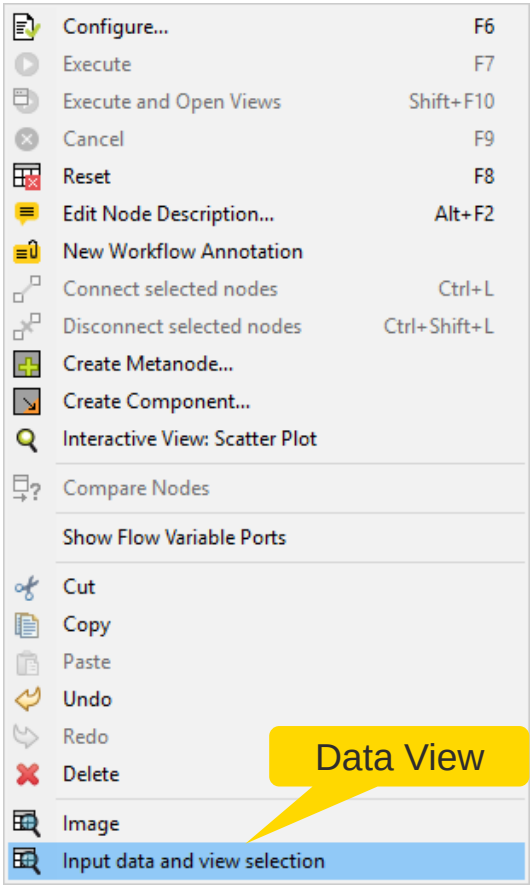
- Execute selected and executable nodes (F7)
- Execute all executable nodes
- Execute selected nodes and open first view
- Cancel all selected, running nodes (F9)
- Cancel all running nodes

Node Views

- Right-click node to inspect the execution results by
  - selecting output ports (last option in the context menu) to inspect tables, images, etc.
  - selecting Interactive View to open visualization results in a browser







KNIME File Extensions

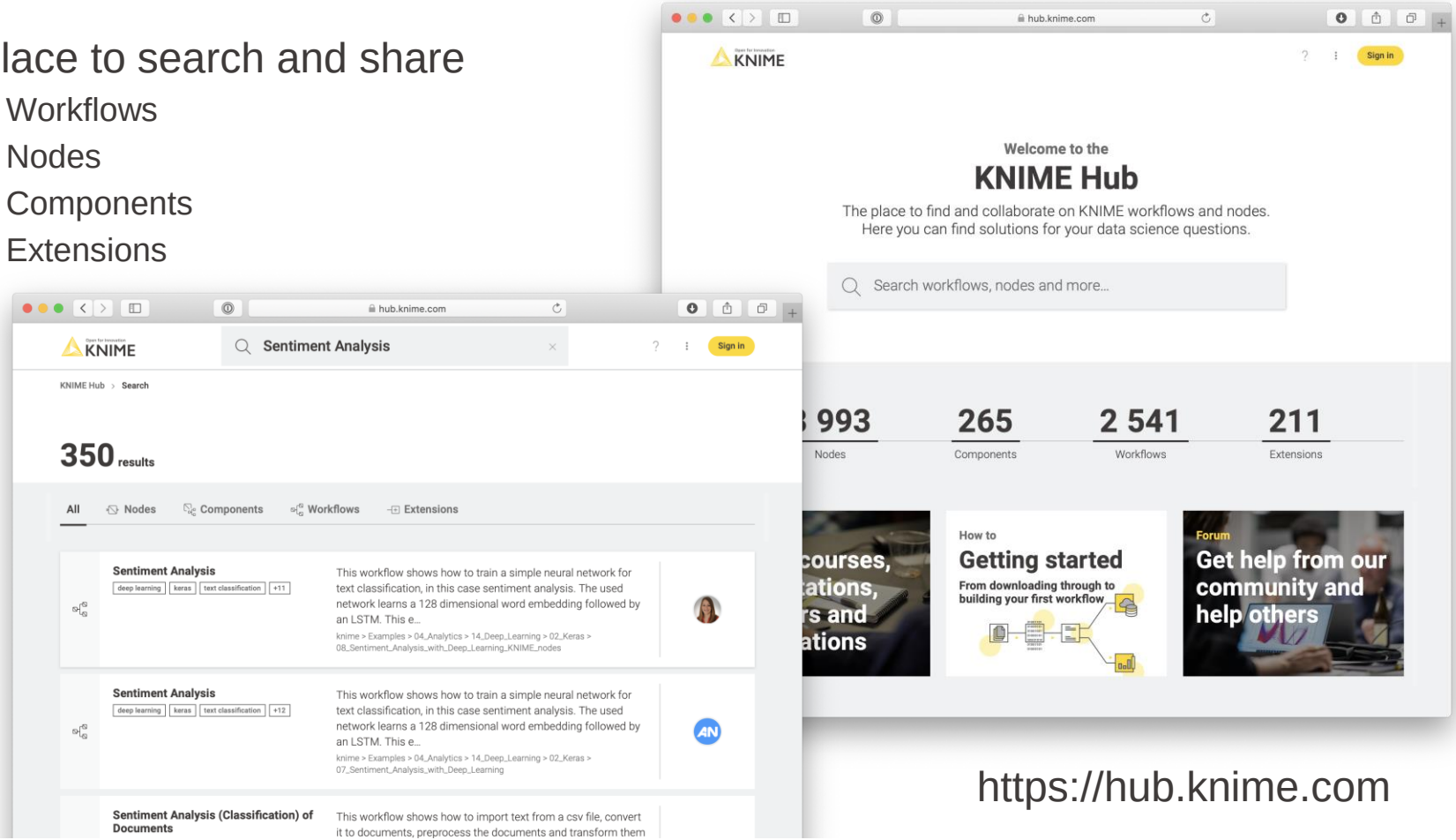
Dedicated file extensions for workflows and workflow groups associated with KNIME Analytics Platform

- ***.knwf** for KNIME Workflow Files

- ***.knar** for KNIME Archive Files

Getting Started: KNIME Hub

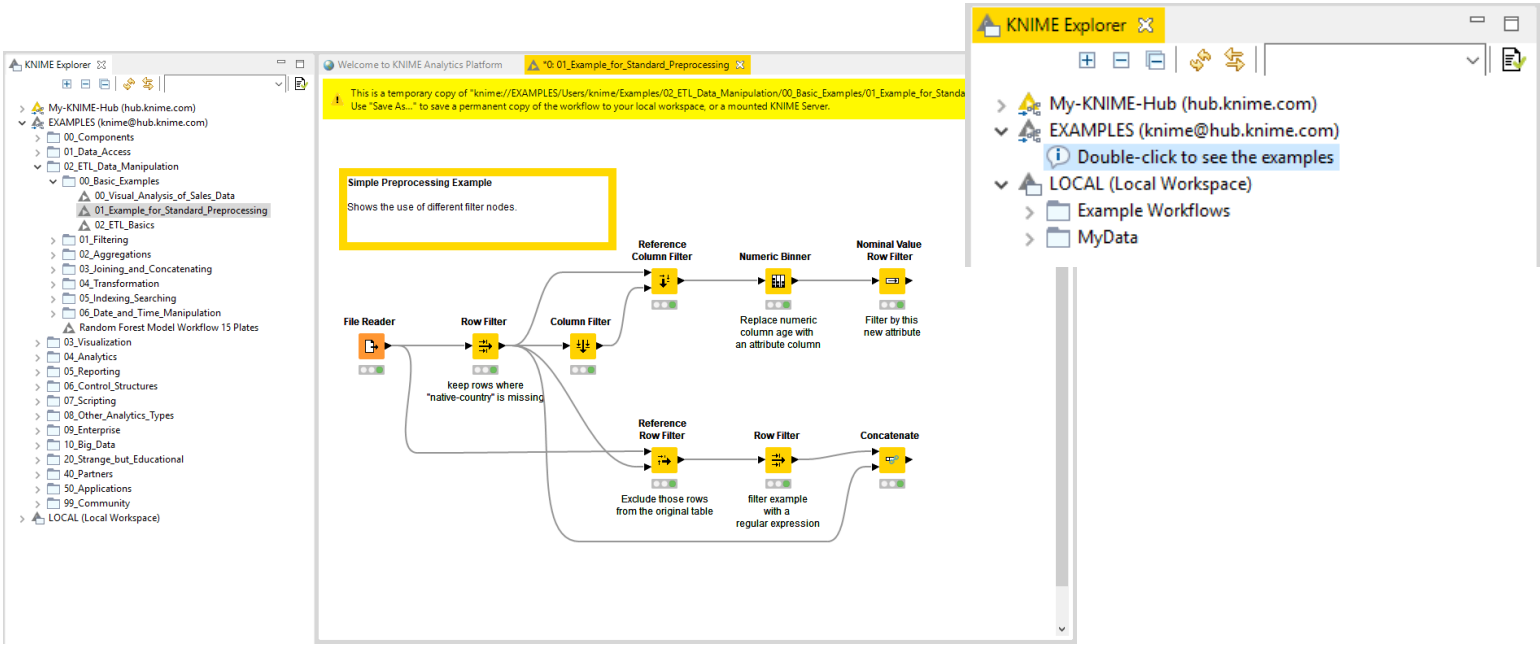
- Place to search and share
  - Workflows
  - Nodes
  - Components
  - Extensions



https://hub.knime.com

Getting Started: KNIME Example Server

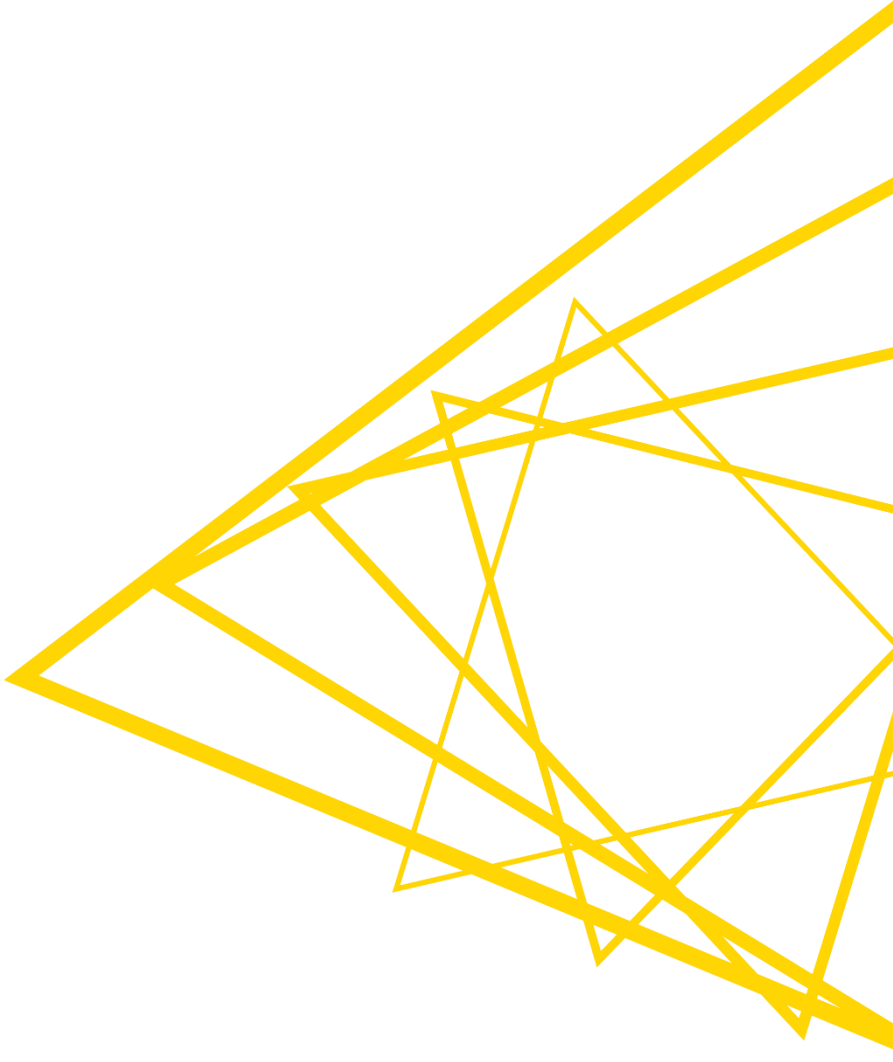
- Connect via KNIME Explorer to a public repository with large selection of example workflows for many, many applications



Hot Keys (for Future Reference)

Task	Hot key	Description
Node Configuration	F6	opens the configuration window of the selected node
Node Execution	F7	executes selected configured nodes
	Shift + F7	executes all configured nodes
	Shift + F10	executes all configured nodes and opens all views
	F9	cancels selected running nodes
	Shift + F9	cancels all running nodes
Node Connections	Ctrl + L	connects selected nodes
	Ctrl + Shift + L	disconnects selected nodes
Move Nodes and Annotations	Ctrl + Shift + Arrow	moves the selected node in the arrow direction
	Ctrl + Shift + PgUp/PgDown	moves the selected annotation in the front or in the back of all overlapping annotations
Workflow Operations	F8	resets selected nodes
	Ctrl + S	saves the workflow
	Ctrl + Shift + S	saves all open workflows
	Ctrl + Shift + W	closes all open workflows
Metanode	Shift + F12	opens metanode wizard

Introduction to the Big Data Course



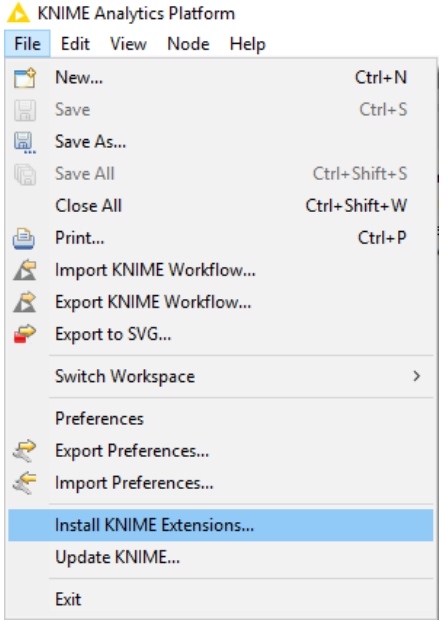
Goal of this Course

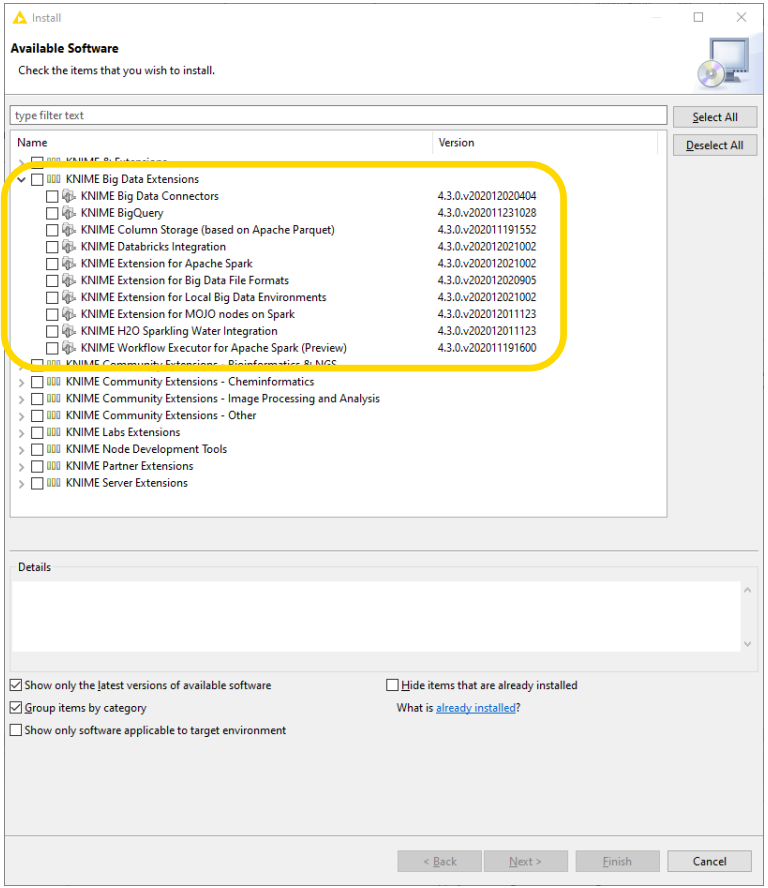
Become familiar with the **Hadoop Ecosystem** and the **KNIME Big Data Extensions**

What you need:

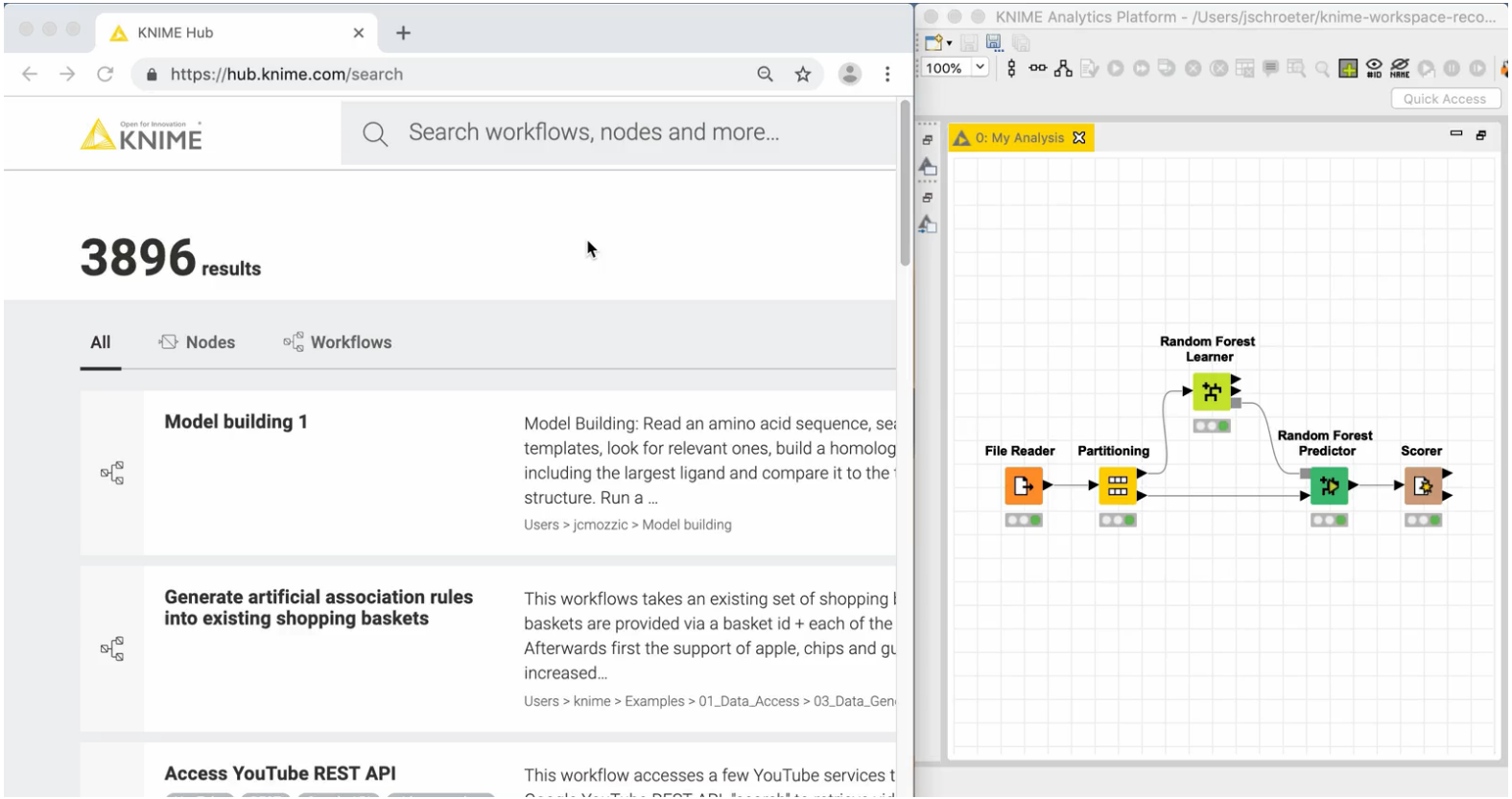
- KNIME Analytics Platform with
  - KNIME Big Data Extensions
    - KNIME Big Data Connectors
    - KNIME Extension for Apache Spark
    - KNIME Extension for Local Big Data Environment
  - KNIME File Handling Nodes

Installation of Big Data Extensions





…or install via drag-and-drop from the KNIME Hub



Big Data Resources (1)

- SQL Syntax and Examples
  https://www.w3schools.com

- Apache Spark MLlib
  https://spark.apache.org/docs/latest/ml-guide.html

- KNIME Big Data Extensions (Hadoop + Spark)
  https://www.knime.com/knime-big-data-extensions

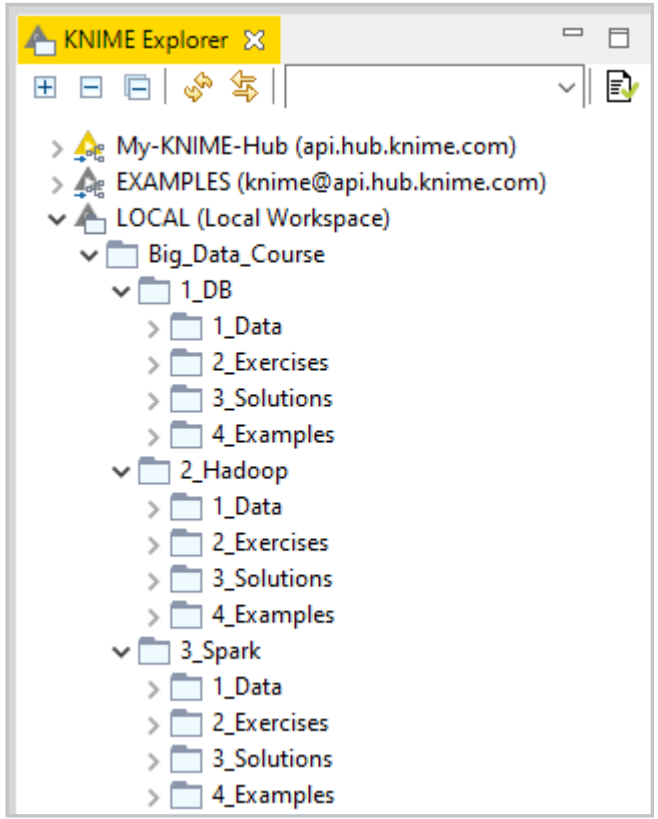
- Example workflows on KNIME Hub
  https://www.knime.com/nodeguide/big-data

Big Data Resources (2)

- Whitepaper “KNIME opens the Doors to Big Data”
  https://www.knime.com/sites/default/files/inline-images/big_data_in_knime_1.pdf
- Blog Posts
  - https://www.knime.org/blog/Hadoop-Hive-meets-Excel
  - https://www.knime.com/blog/SparkSQL-meets-HiveSQL
  - https://www.knime.com/blog/speaking-kerberos-with-knime-big-data-extensions
  - https://www.knime.com/blog/new-file-handling-out-of-labs-and-into-production
- Video
  - https://www.knime.com/blog/scaling-analytics-with-knime-big-data-extensions

Overview

1. Use a traditional Database, and KNIME Analytics Platform native Machine Learning Nodes
2. Moving In-Database Processing to Hadoop Hive
3. Moving In-Database Processing and Machine Learning to Spark



Today's Example: Missing Values Strategy

- Missing Values are a big problem in Data Science!
- Many strategies to deal with the problem (see "How to deal with missing values" KNIME Blog https://www.knime.com/blog/how-to-deal-with-missing-values?)
- We adopt the strategy that predicts the missing values based on the other attributes on the same data row
- CENSUS Data Set with missing COW values from http://www.census.gov/programs-surveys/acs/data/pums.html

  https://www.census.gov/programs-surveys/acs/microdata/documentation.html

CENSUS Data Set

- CENSUS data contains questions to a sample of US residents (1%) over 10 years
- CENSUS data set description: http://www2.census.gov/programs-surveys/acs/tech_docs/pums/data_dict/PUMSDataDict15.pdf
- *ss13hme* (60K rows) -> questions about housing to Maine residents
- *ss13pme* (60K rows) -> questions about themselves to Maine residents
- *ss13hus* (31M rows) -> questions about housing to all US residents in the sample
- *ss13pus* (31M rows) -> questions about themselves to all US residents in the sample

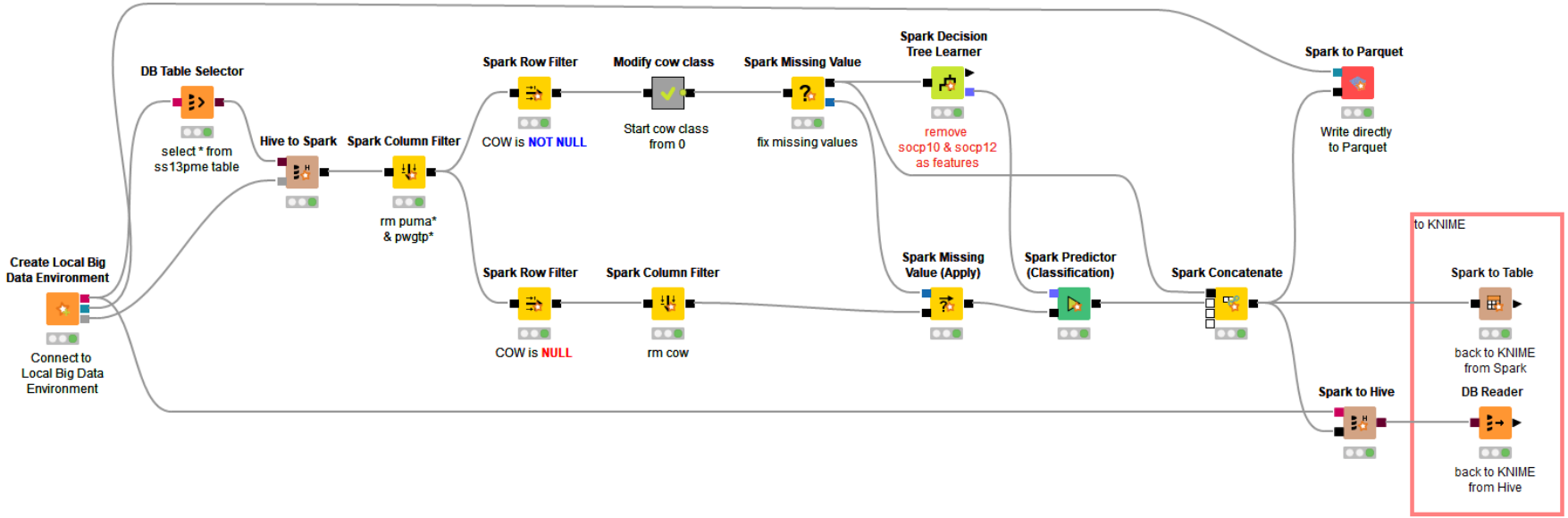
https://www2.census.gov/programs-surveys/acs/tech_docs/pums/data_dict/PUMS_Data_Dictionary_2021.pdf

Missing Values Strategy Implementation

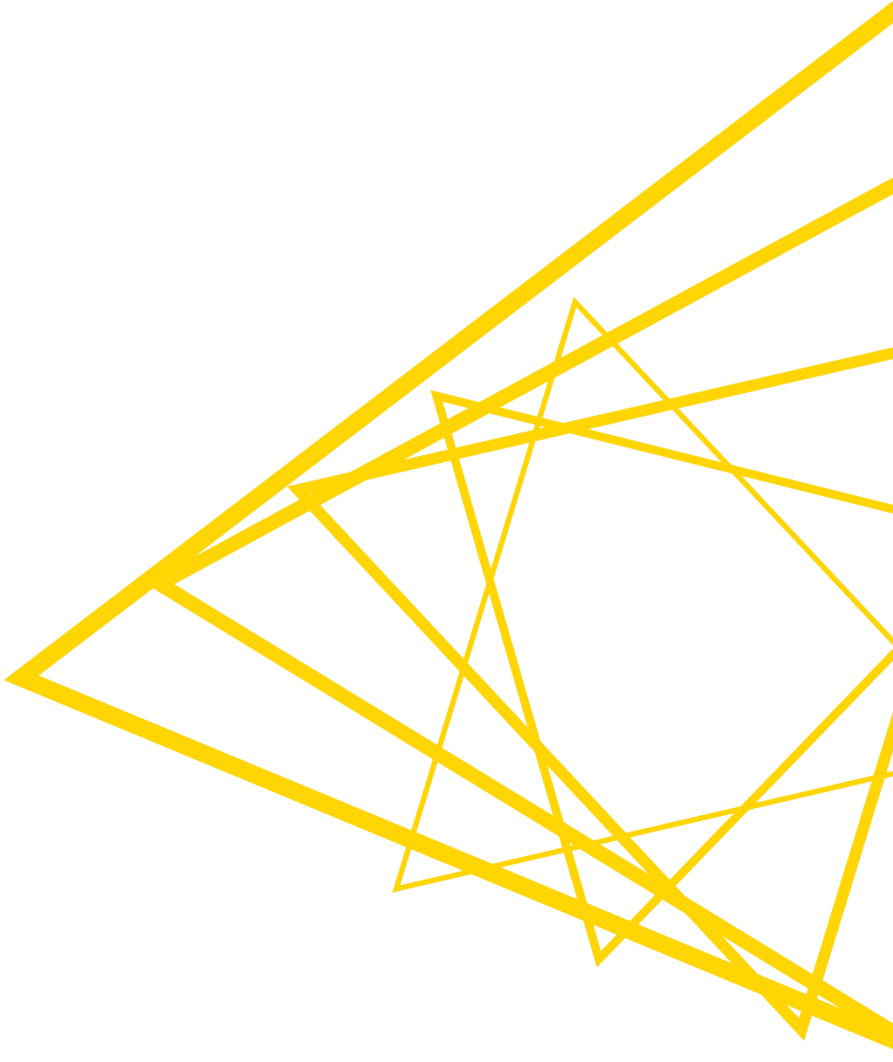
- Connect to the CENSUS data set
- Separate data rows with COW from data rows with missing COW
- Train a decision tree to predict COW (obviously only on data rows with COW)
- Apply decision tree to predict COW where COW is missing
- Update original data set with new predicted COW values

COW... Class of Worker - tipo de vínculo empregatício

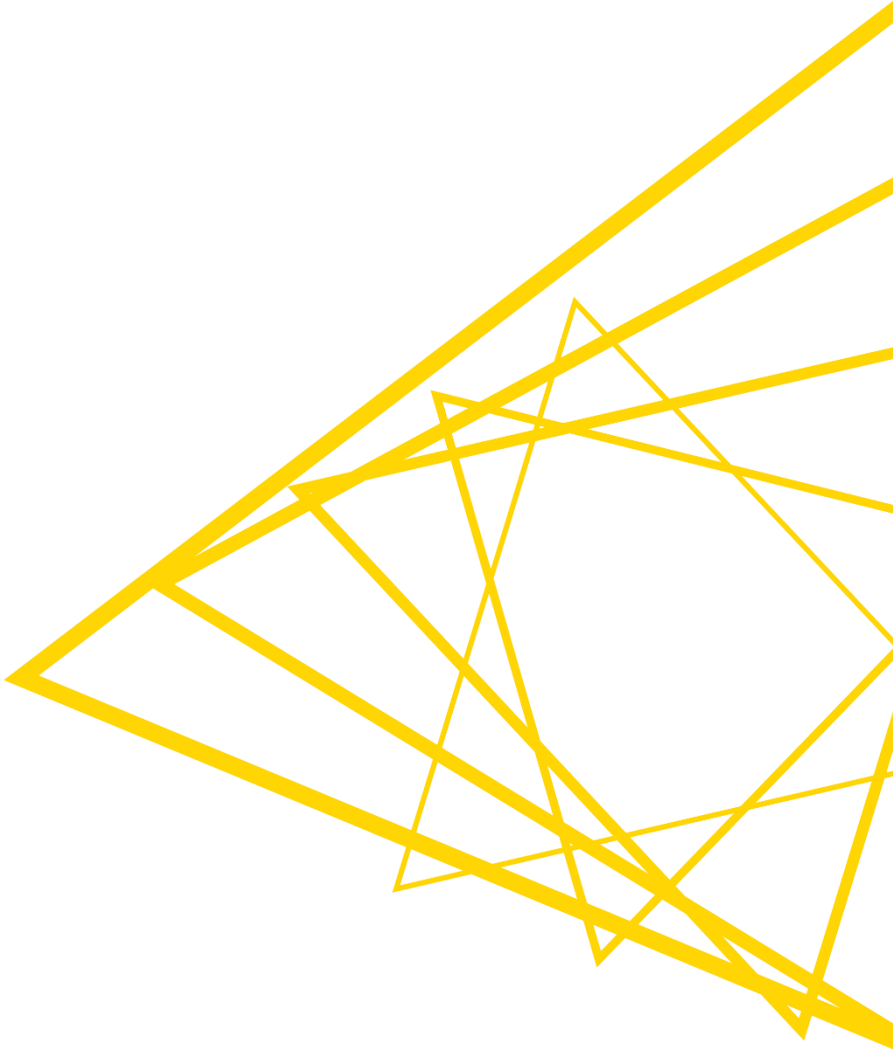
Today's Example: Missing Values Strategy



Let’s Practice First on a Traditional Database

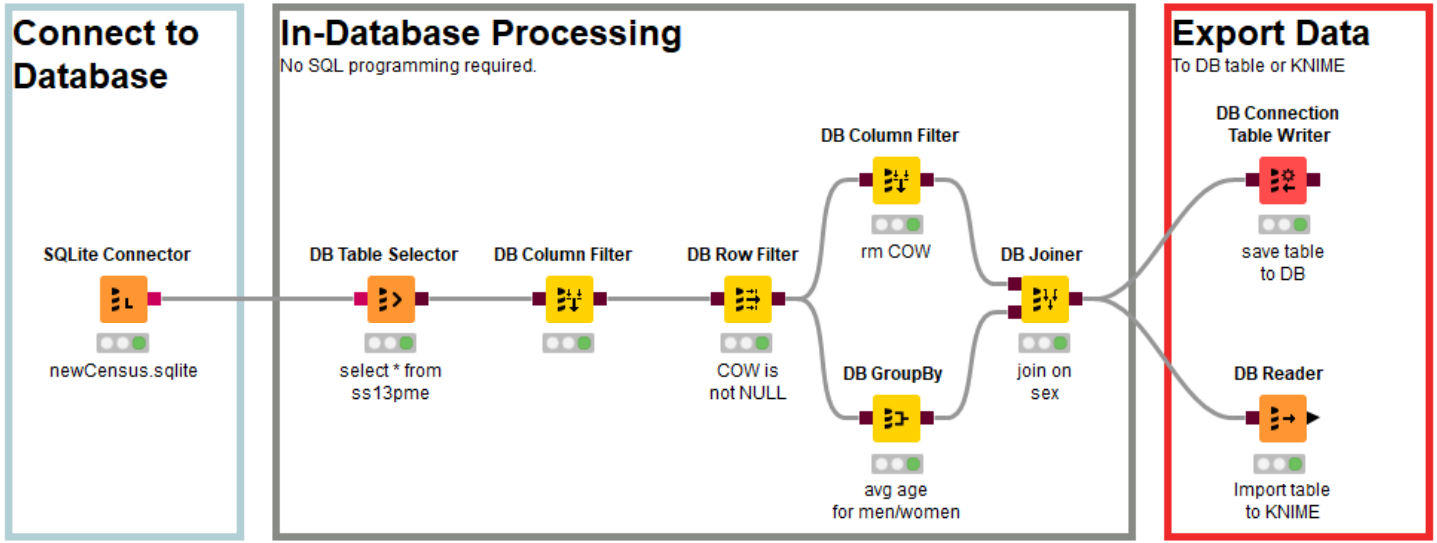


Database Extension



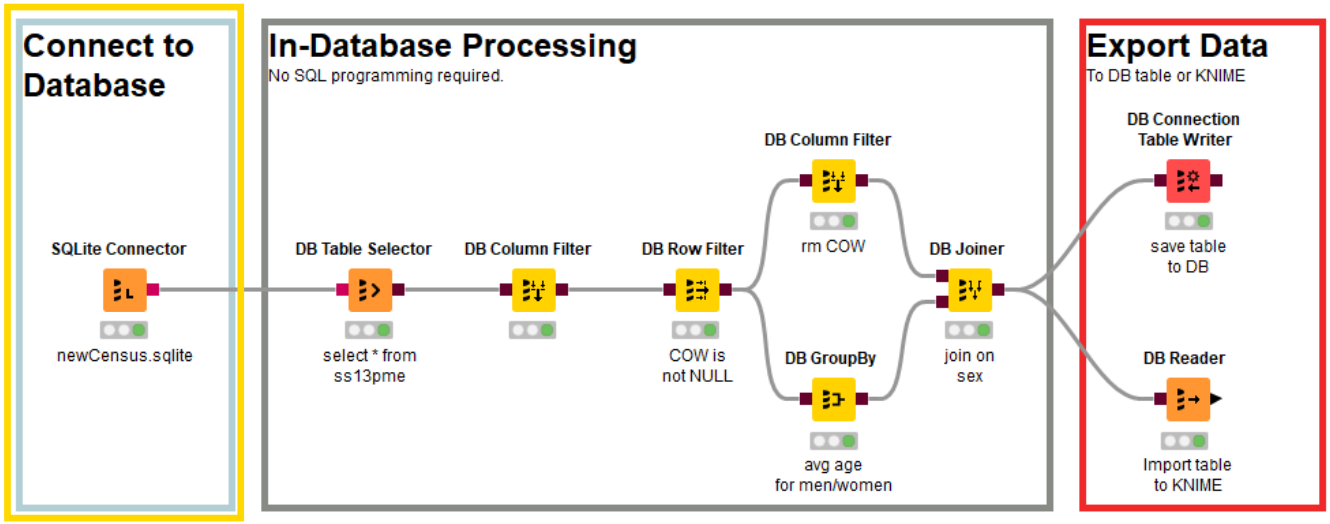
Database Extension

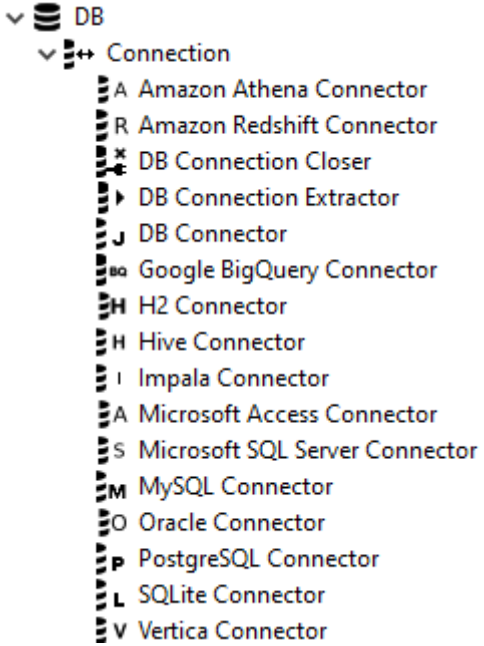
- Visually assemble complex SQL statements (no SQL coding needed)
- Connect to all JDBC-compliant databases
- Harness the power of your database within KNIME



Database Connectors

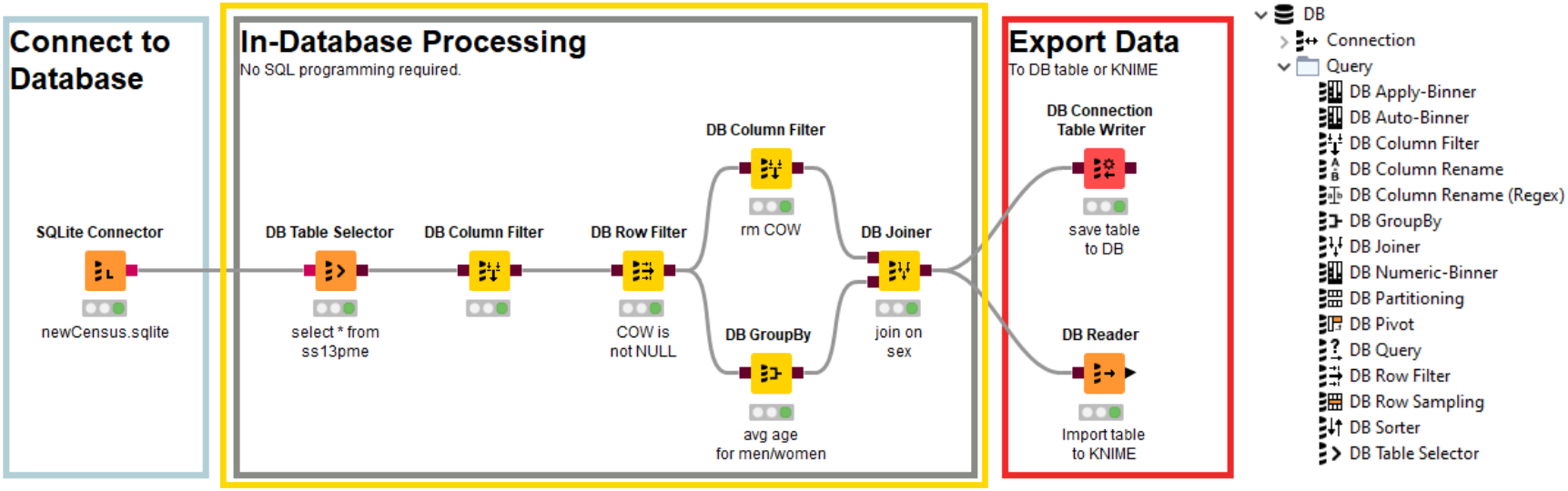
- Many dedicated DB Connector nodes available
- If connector node missing, use DB Connector node with JDBC driver





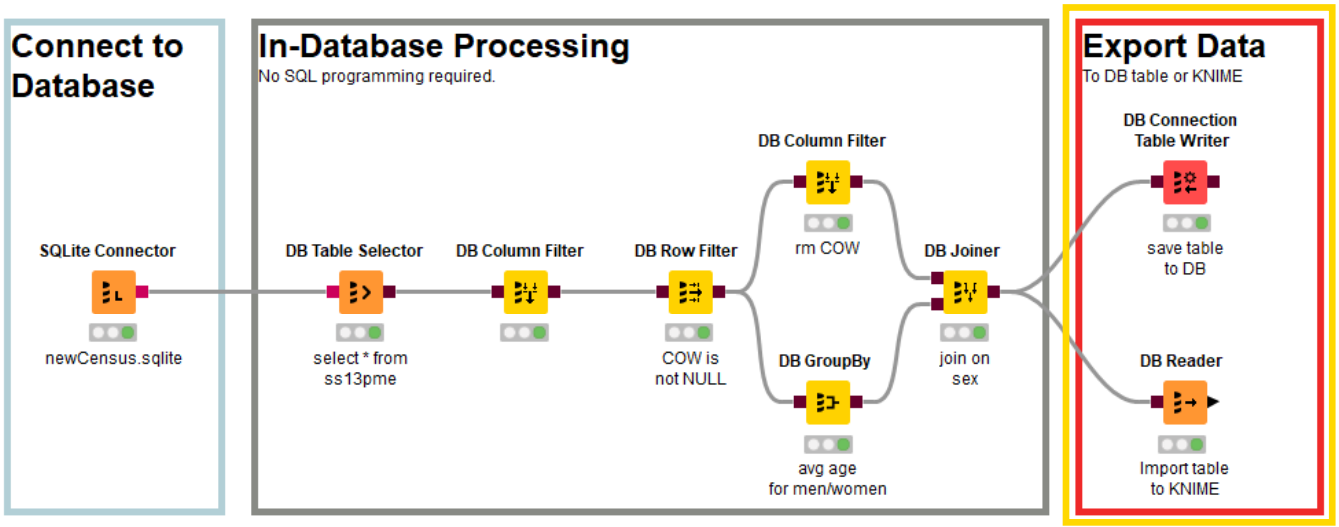
In-Database Processing

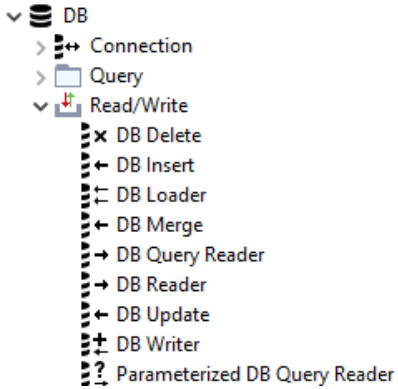
- Database Manipulation nodes generate SQL query on top of the input SQL query (brown square port)
- SQL operations are executed on the database!



Export Data

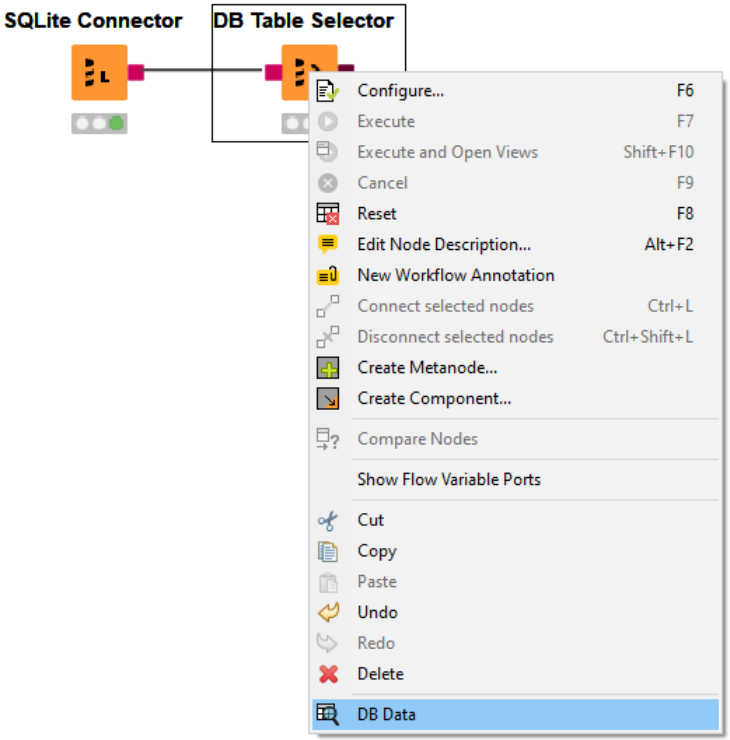
- Writing data back into database
- Exporting data into KNIME

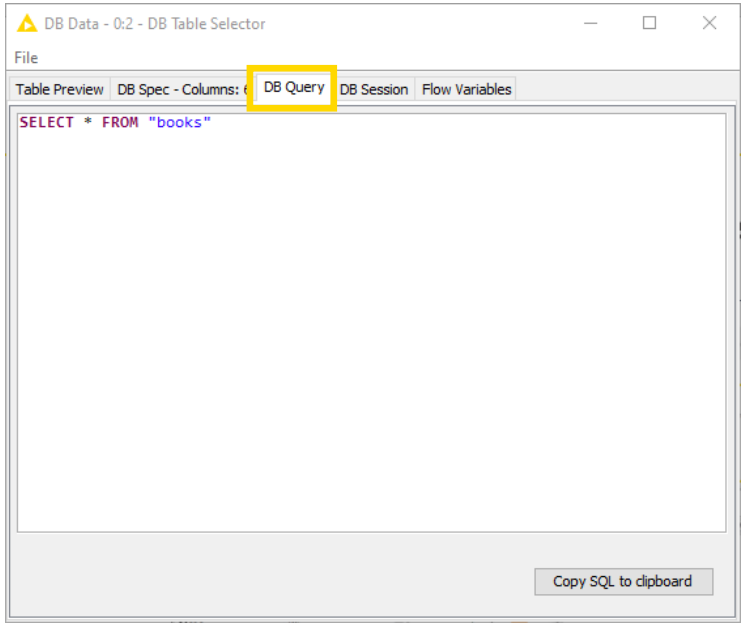




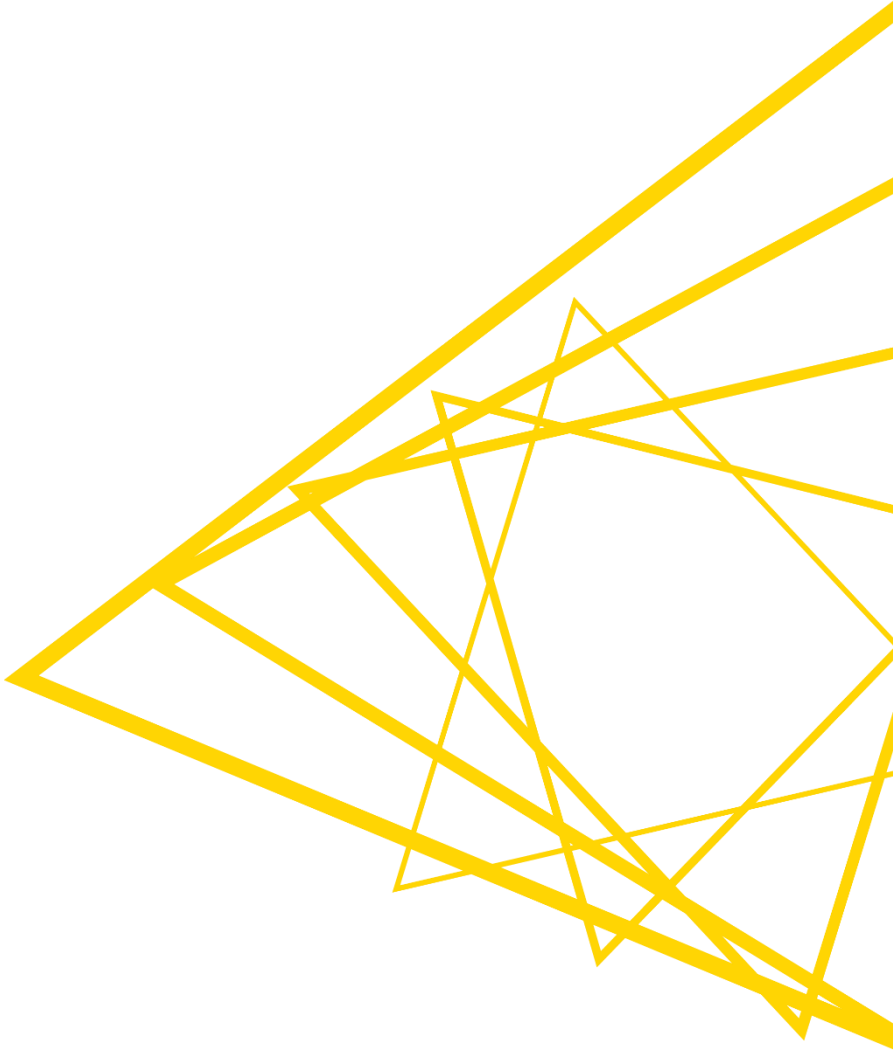
Tip

- SQL statements can be easily viewed from the DB node output ports.

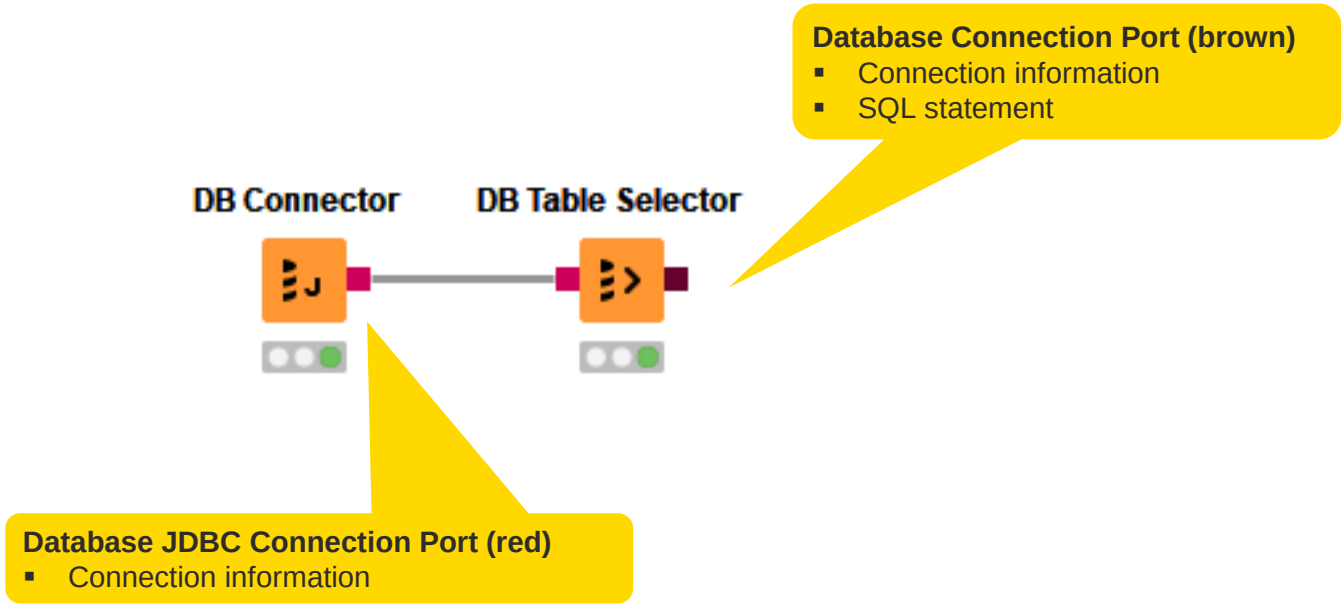




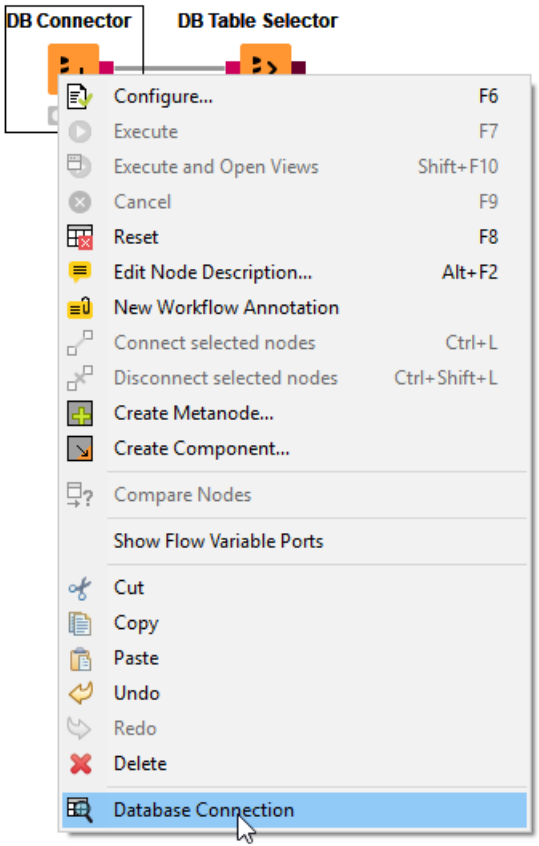
Database Port Types



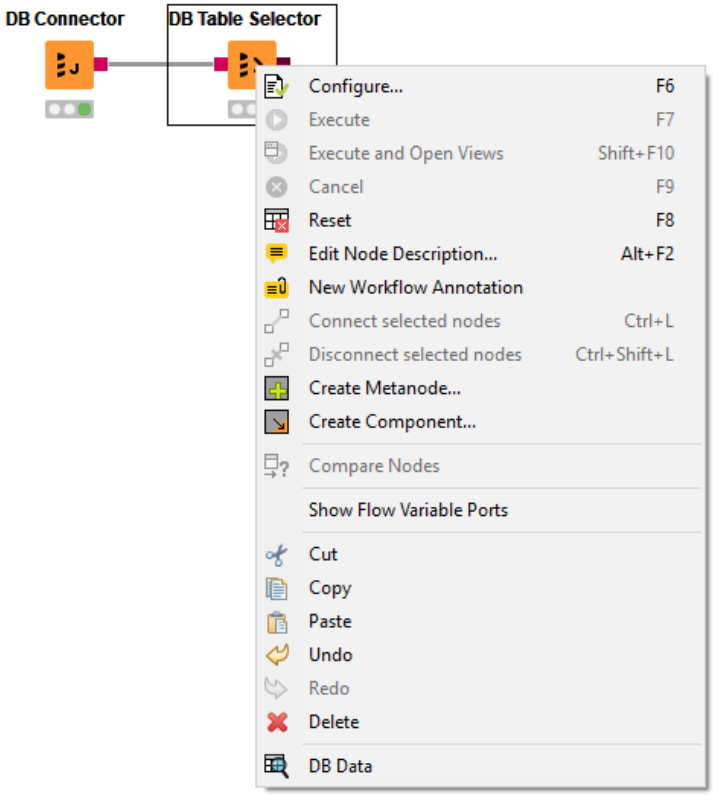
Database Port Types

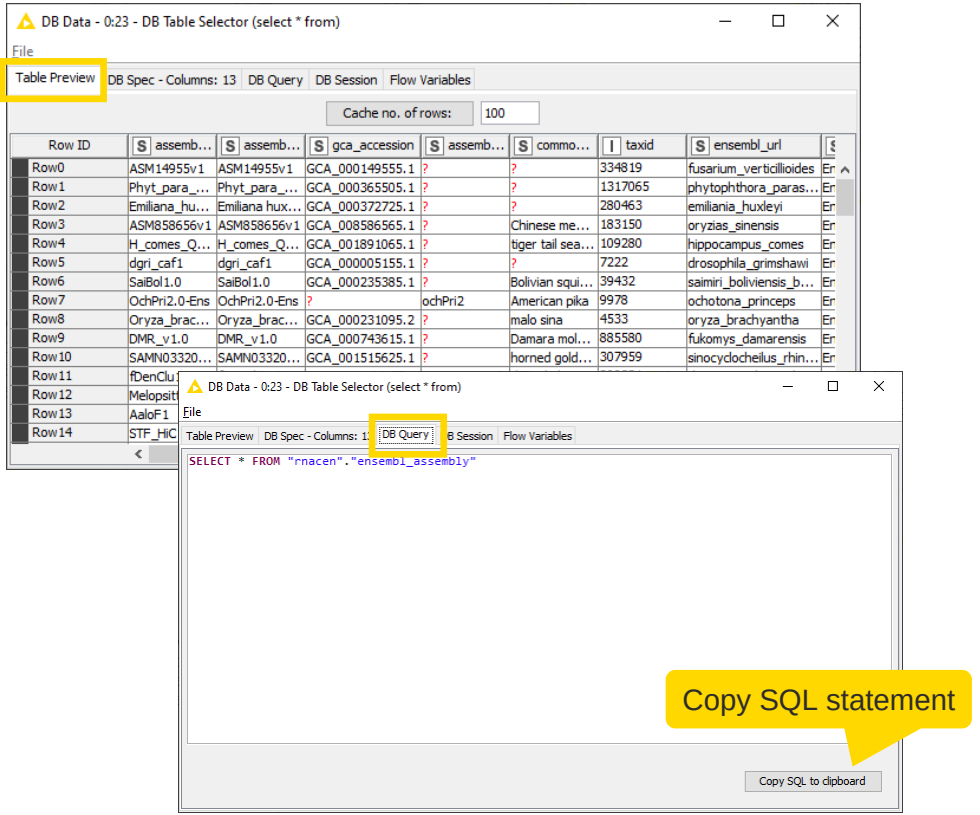


DB Connection Port View

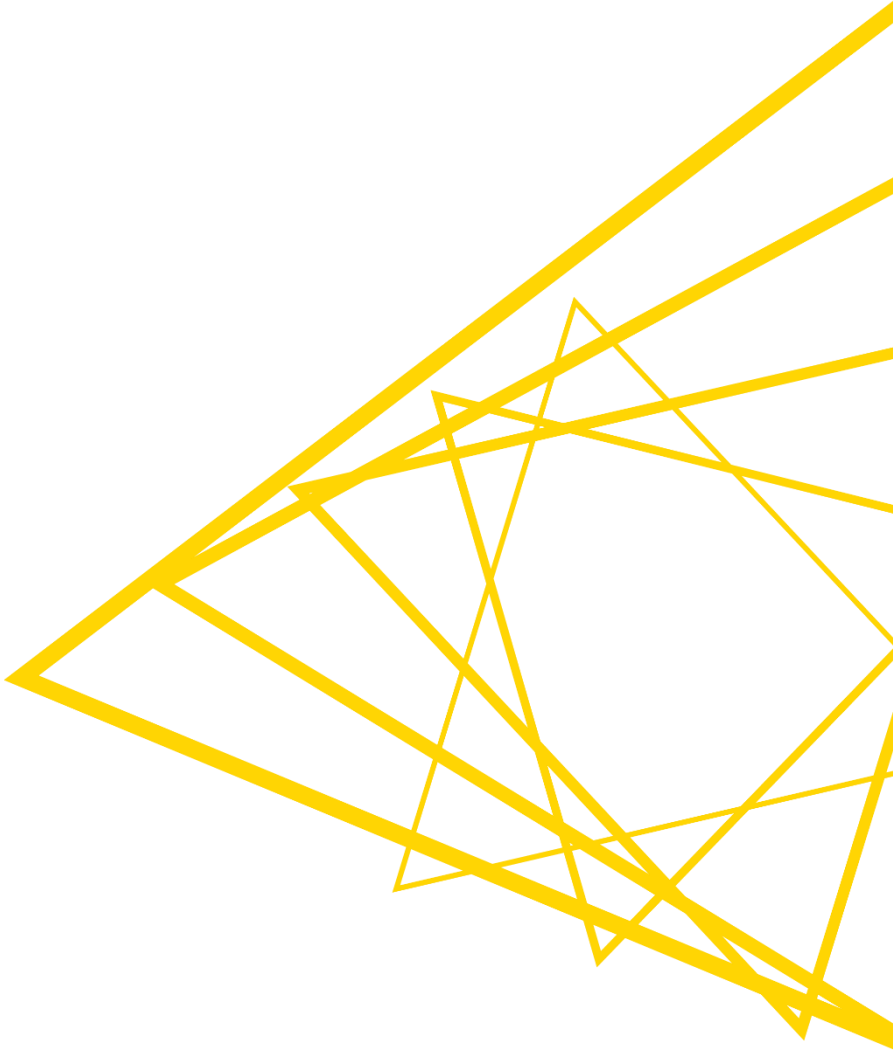


DB Data Port View



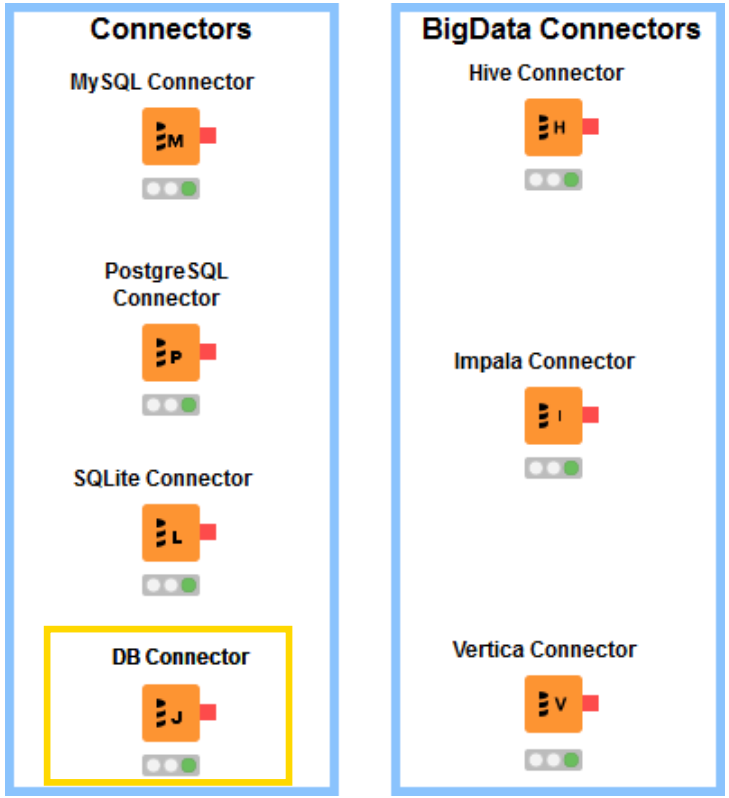


Connect to Database and Import Data

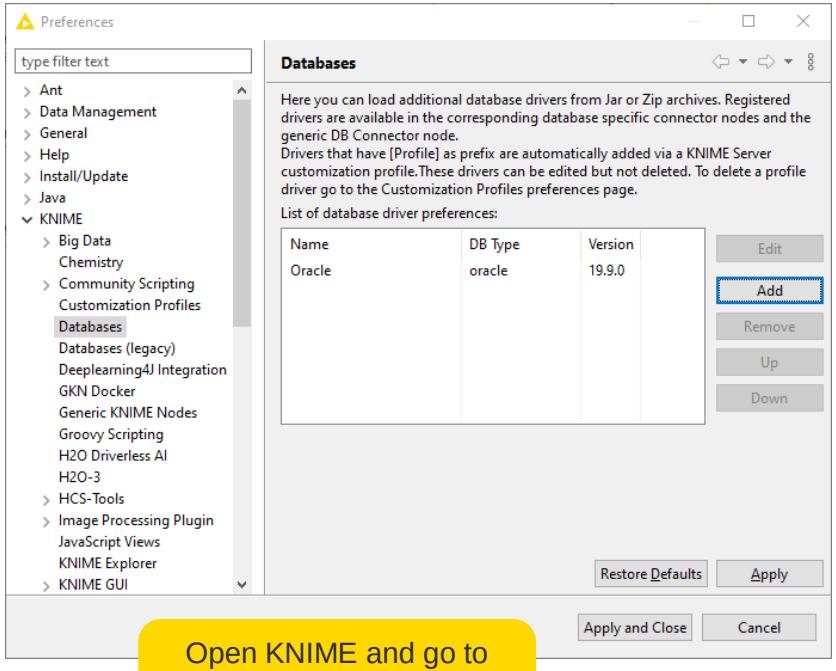


Database Connectors

- Dedicated nodes to connect to specific Databases
  - Necessary JDBC driver included
  - Easy to use
  - Import DB specific behavior/capability
- Hive and Impala connector part of the KNIME Big Data Connectors extension
- General Database Connector
  - Can connect to any JDBC source
  - Register new JDBC driver via File -> Preferences -> KNIME -> Databases



Register JDBC Driver

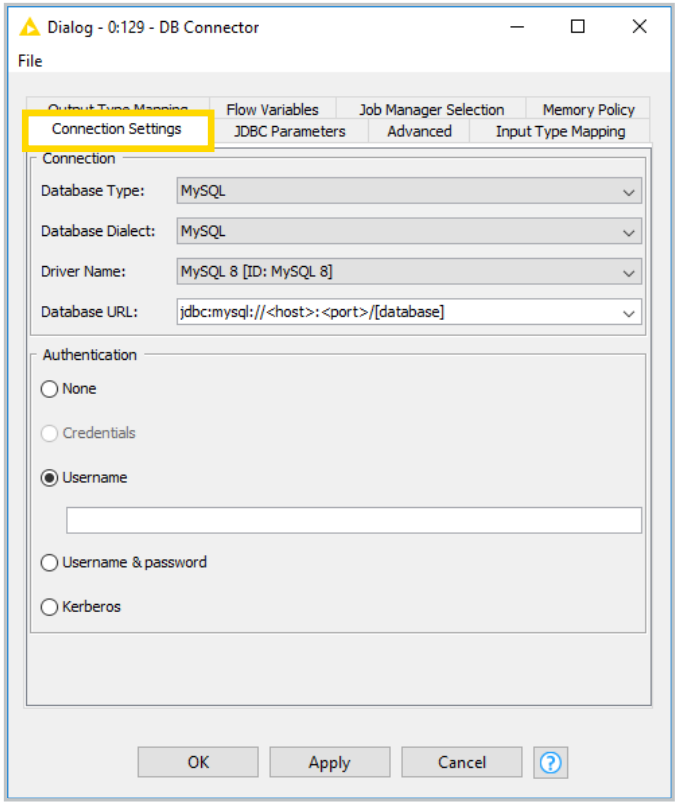


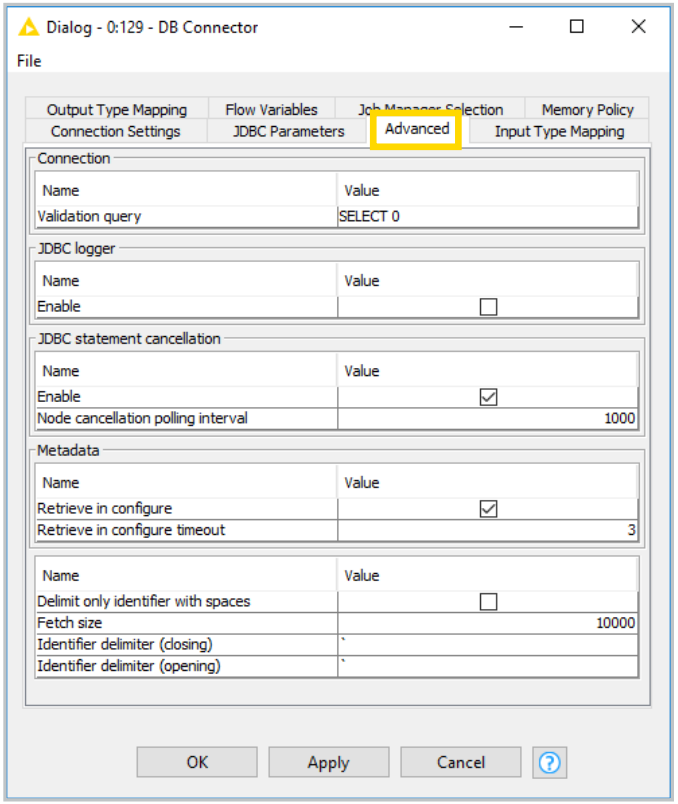
Open KNIME and go to File -> Preferences, then KNIME -> Databases

Register single jar file JDBC drivers

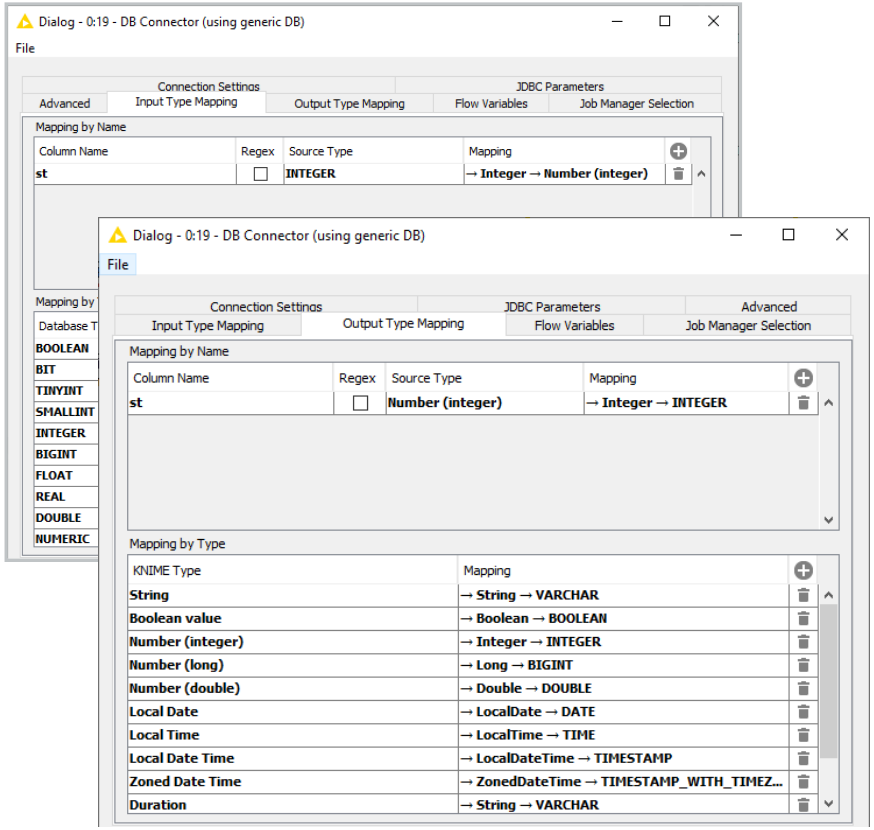
Register new JDBC driver with companion files

DB Connector Node





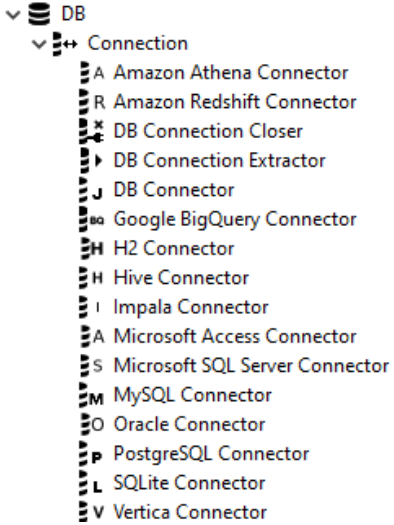
DB Connector Node – Type Mapping

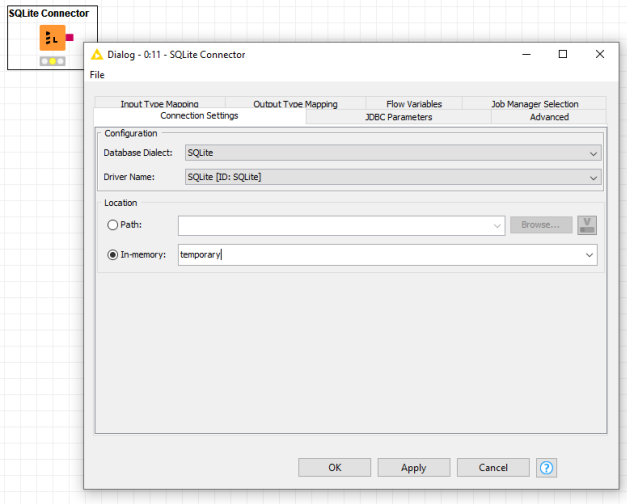


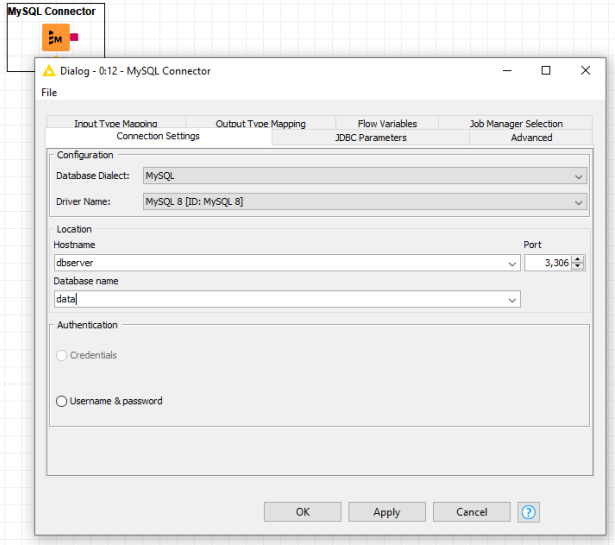
- KNIME will do its best to guess what type mappings are appropriate based on what it knows about your database
- If you need more control, you can specify type mappings manually in two ways
  - By name, for individual fields – or groups of fields using RegEx
  - By type
- Two separate tabs to govern input and output type mappings

Dedicated Database Connectors

- MS SQL Server, MySQL, Postgres, SQLite, …
- Propagate connection information to other DB nodes

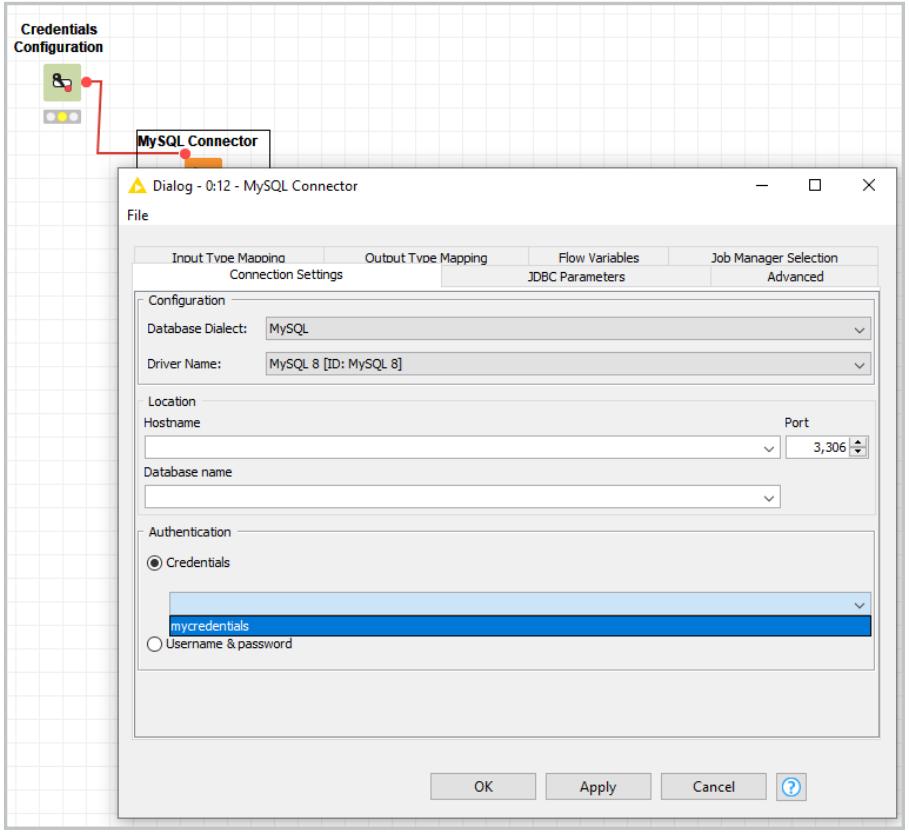






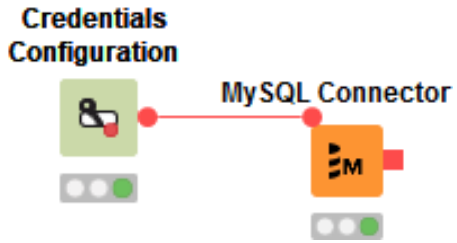
Workflow Credentials – Usage

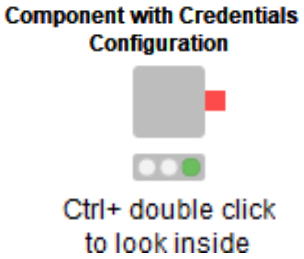
- Replaces username and password fields
- Supported by several nodes that require login credentials
  - DB connectors
  - Remote file system connectors
  - Send mail
  - …

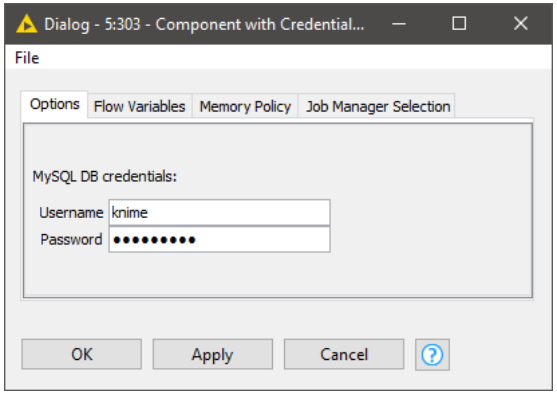


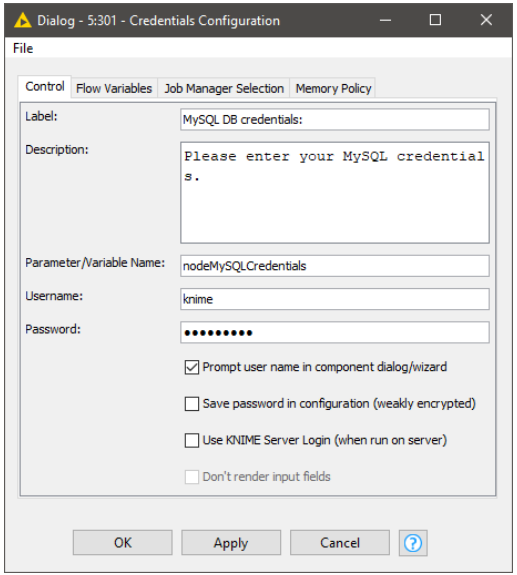
Credentials Configuration Node

- Works together with all nodes that support workflow credentials



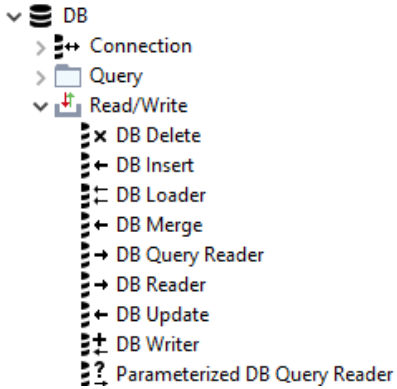


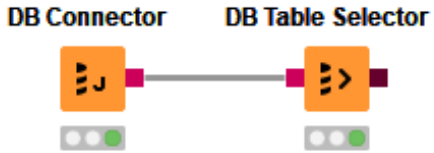


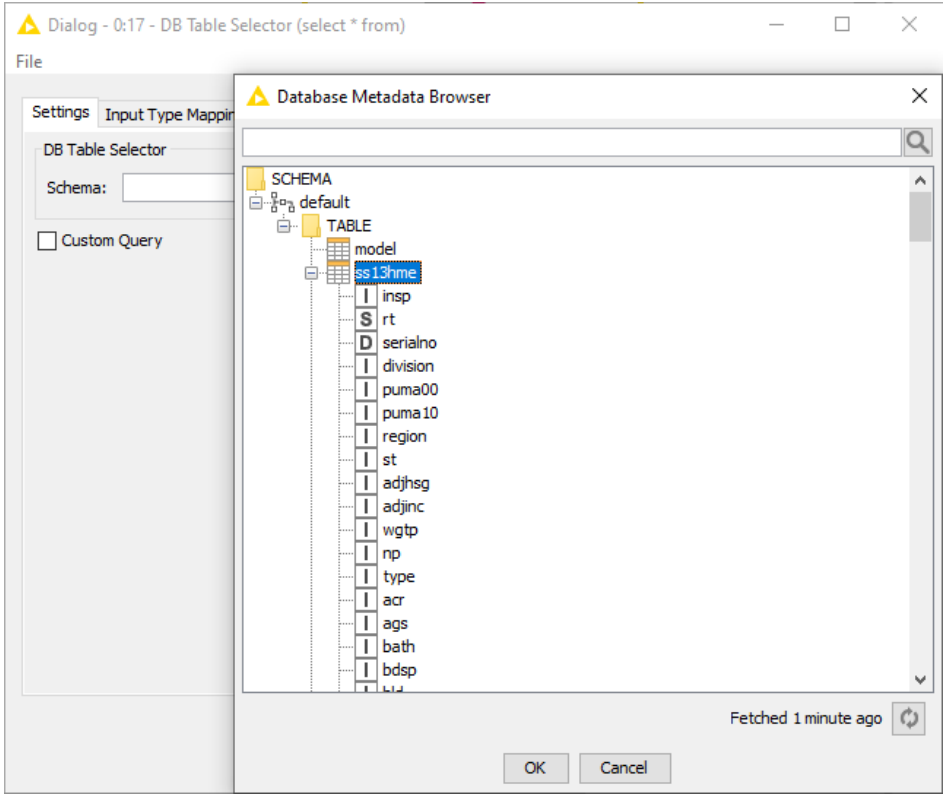


DB Table Selector Node

- Takes connection information and constructs a query
- Explore DB metadata
- Outputs a SQL query

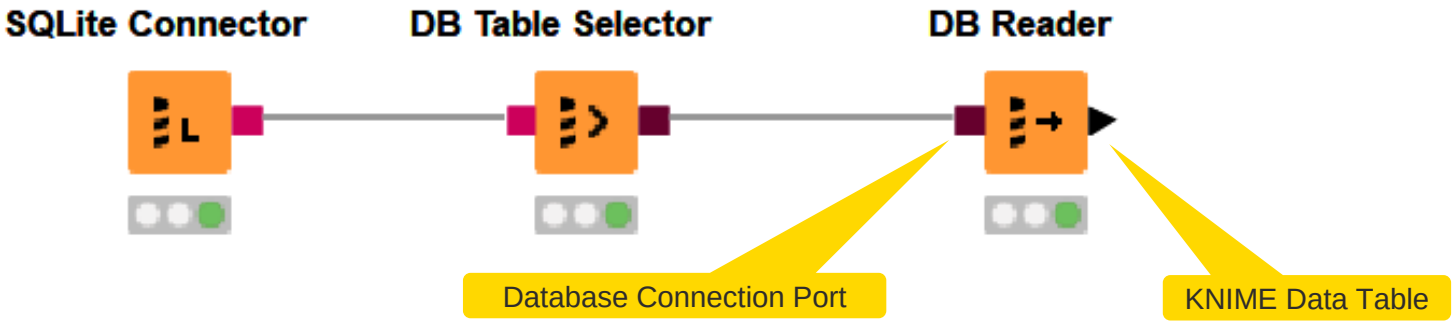






DB Reader node

- Executes incoming SQL Query on Database
- Reads results into a KNIME data table



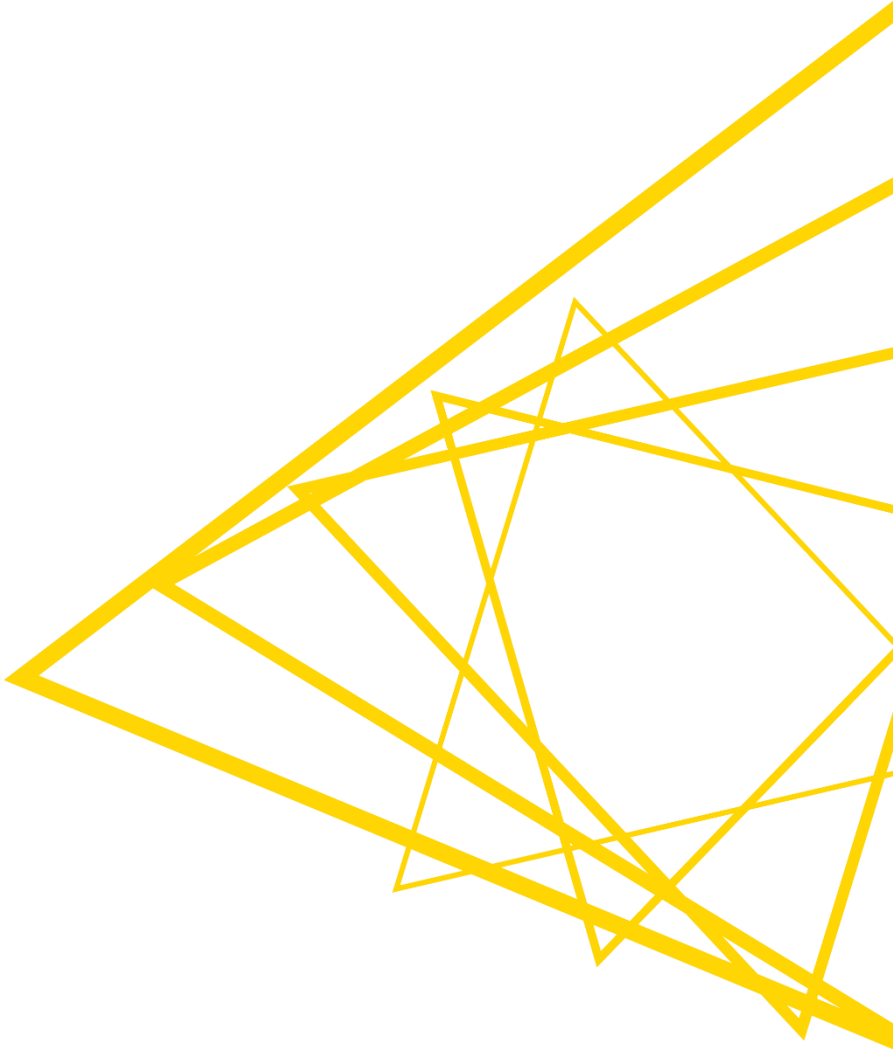
Section Exercise – 01_DB_Connect

- Connect to the database (SQLite) newCensus.sqlite in folder 1_Data
  - Use SQLite Connector (Note: SQLite Connector supports knime:// protocol)
- Explore DB metadata
- Select table ss13pme (person data in Maine)
- Import the data into a KNIME data table

Optional: Create a Credentials Input node and use it in a MySQL Connector instead of user name and password.

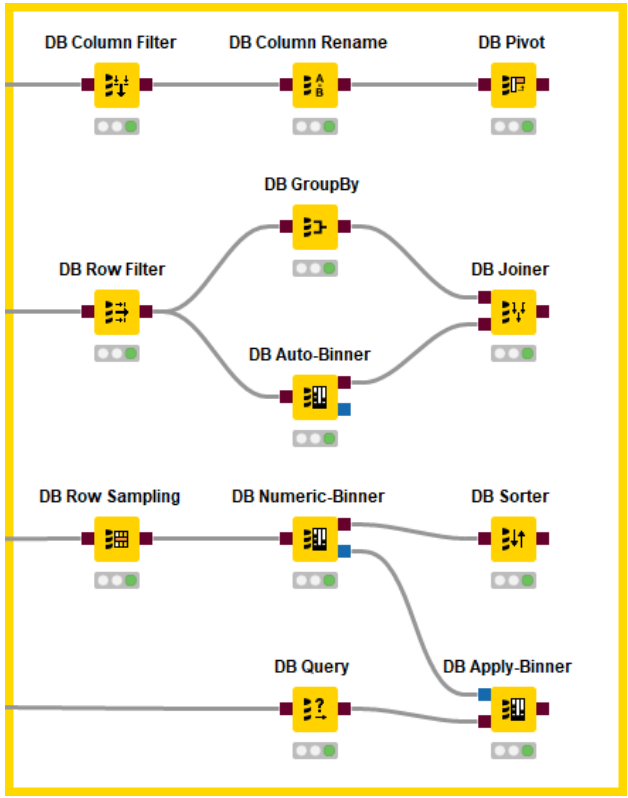
You can download the training workflows from the KNIME Hub:
https://hub.knime.com/knime/spaces/Education/latest/Courses/

In-Database Processing



Query Nodes

- Filter rows and columns
- Join tables/queries
- Extract samples
- Bin numeric columns
- Sort your data
- Write your own query
- Aggregate your data



Data Aggregation

RowID	Group	Value
r1	m	2
r2	f	3
r3	m	1
r4	f	5
r5	f	7
r6	m	5

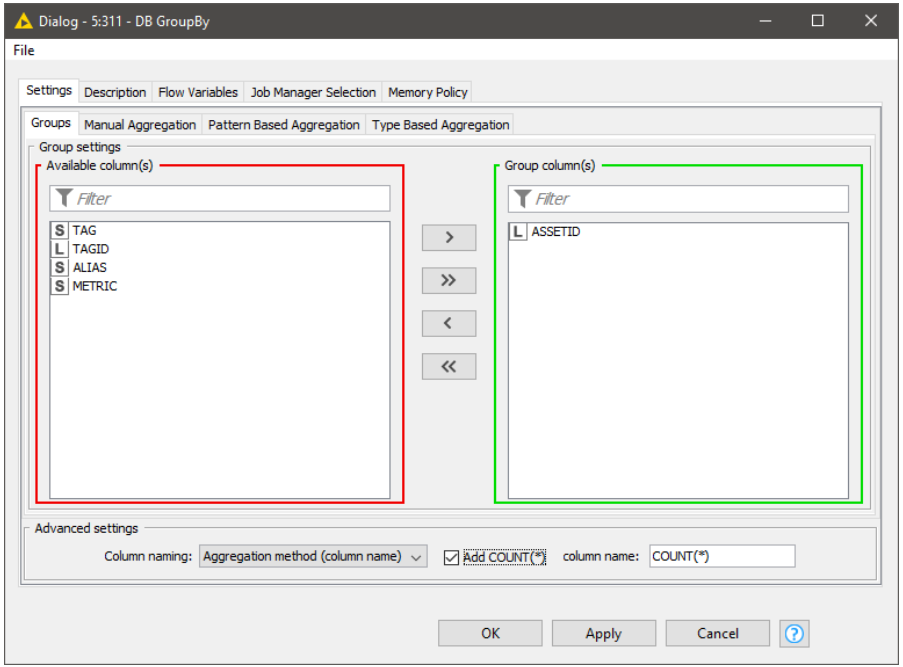
RowID	Group	Sum(Value)
r1+r3+r6	m	8
r2+r4+r5	f	15

Aggregated on “Group” by method:

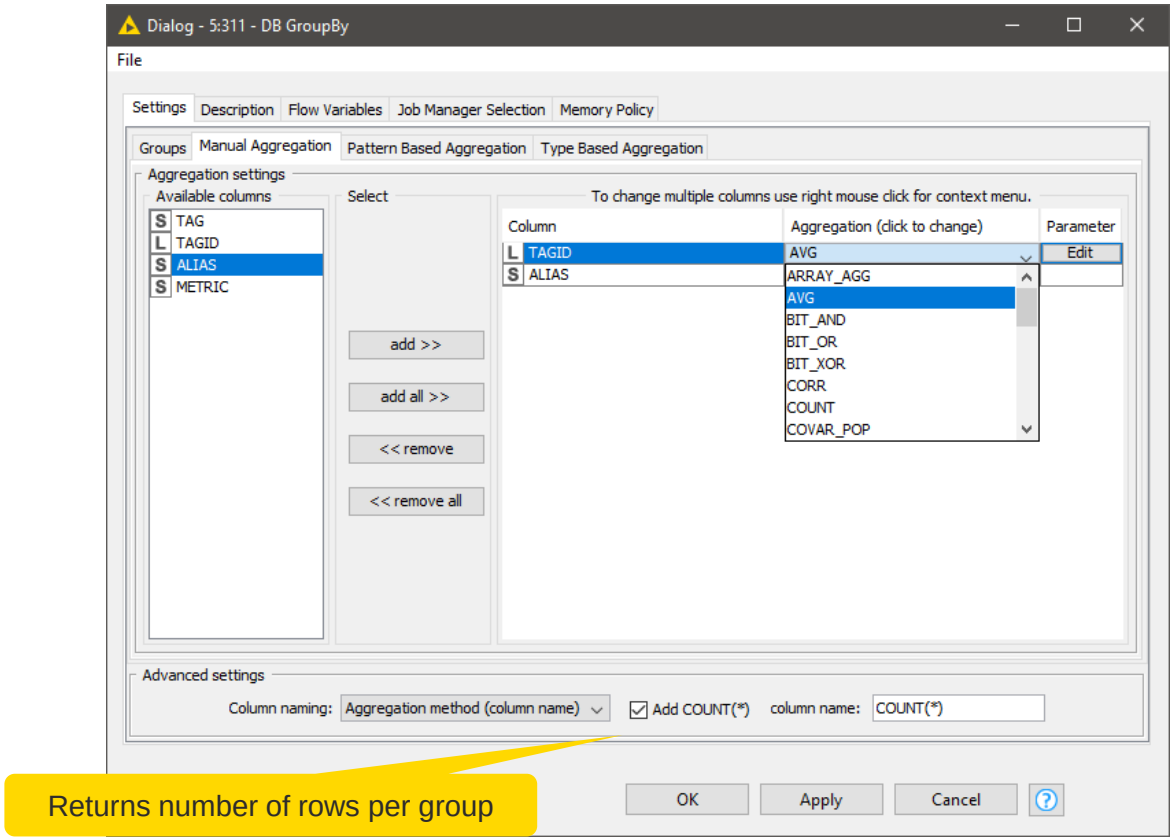
sum(“Value”)

Database GroupBy Node

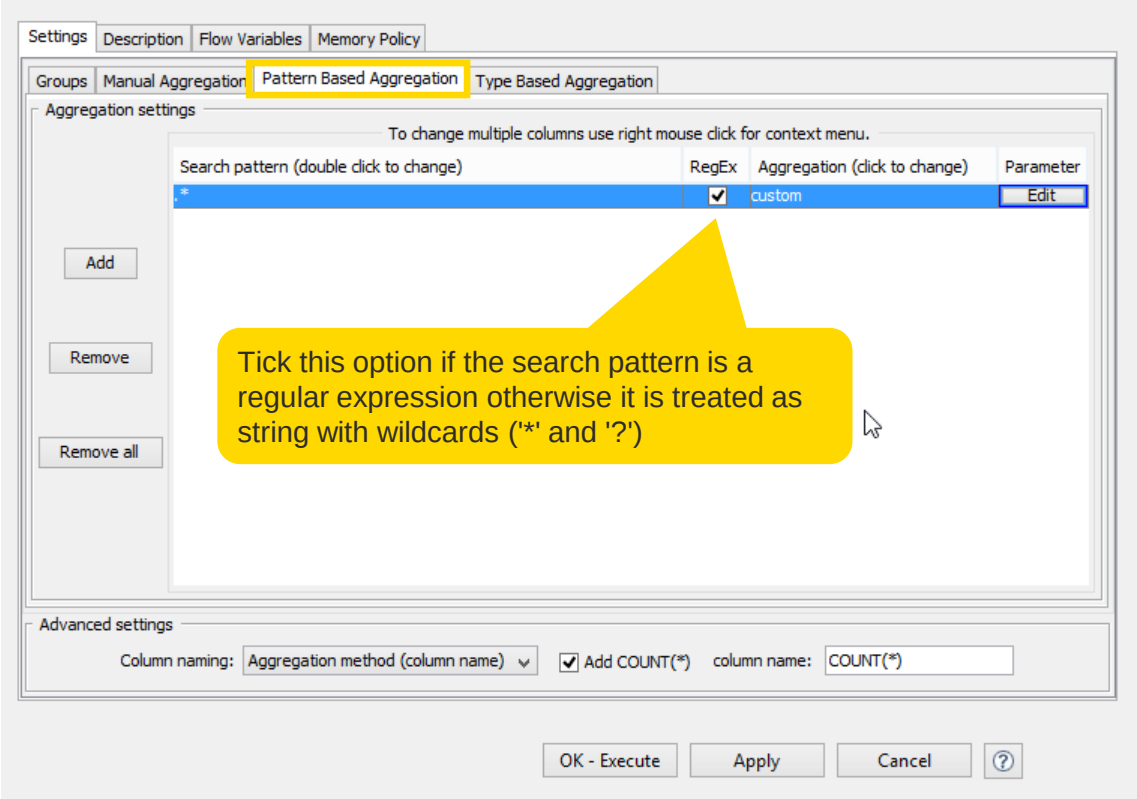
- Aggregate to summarize data



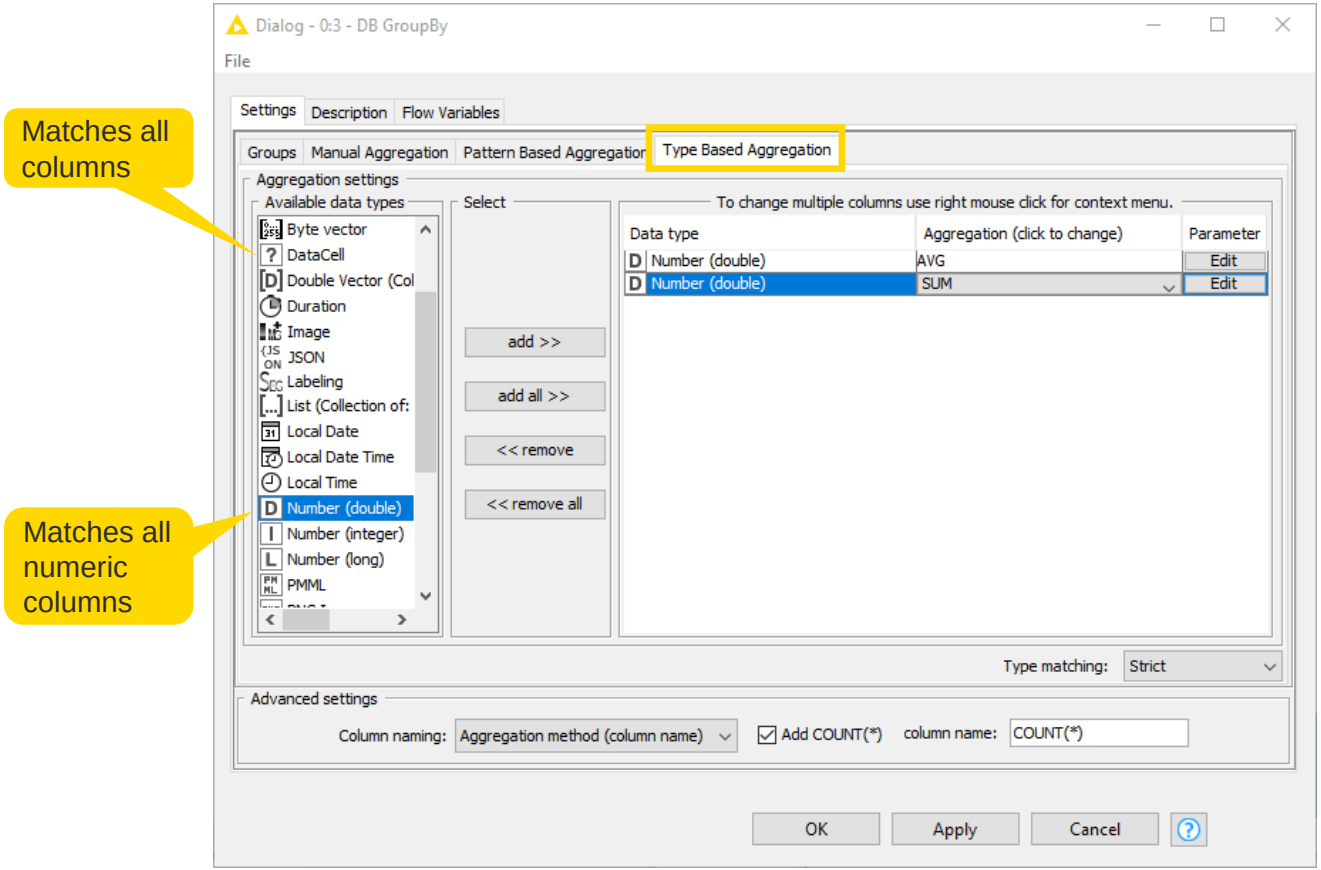
DB GroupBy Node – Manual Aggregation



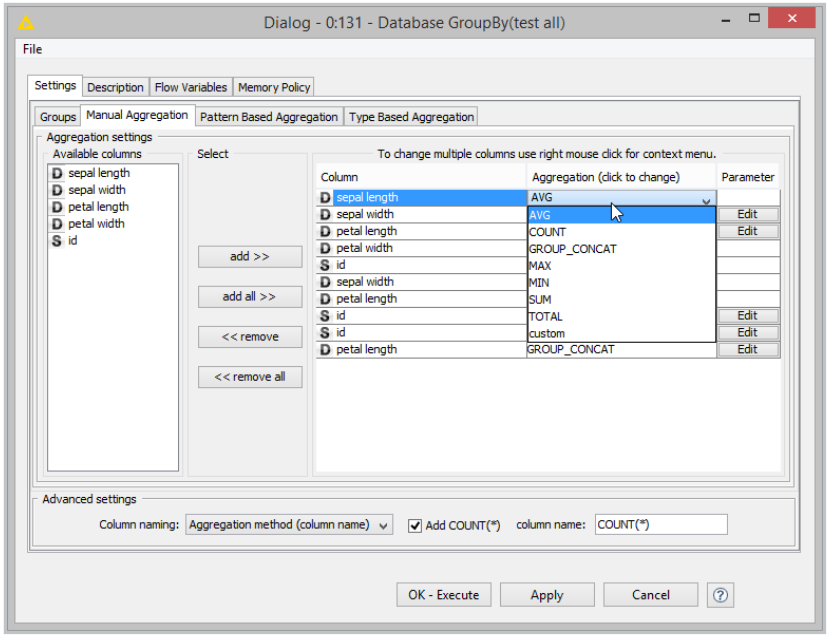
Database GroupBy Node – Pattern Based Aggregation



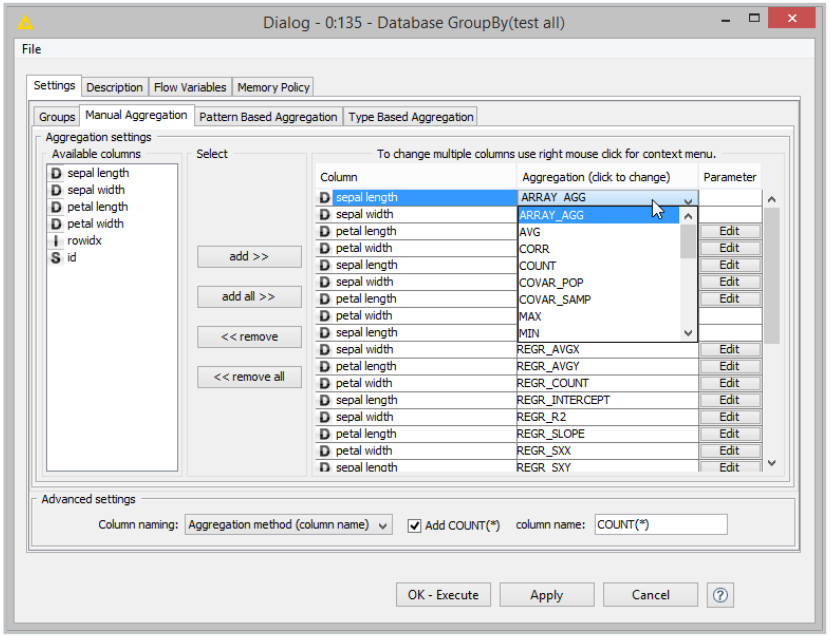
Database GroupBy Node – Type Based Aggregation



Database GroupBy Node – DB Specific Aggregation Methods

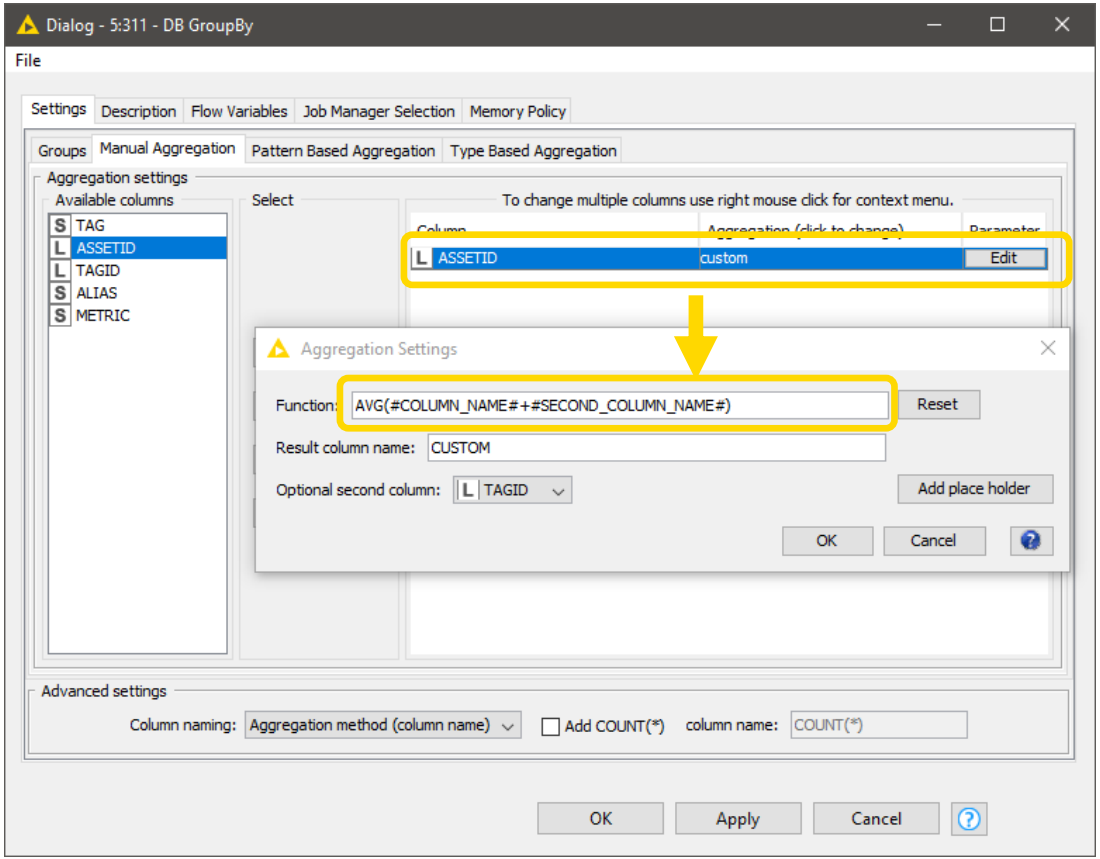


SQLite: 7 aggregation functions



PostgreSQL: 25 aggregation functions

DB GroupBy Node – Custom Aggregation Function



Joining Columns of Data

Left Table

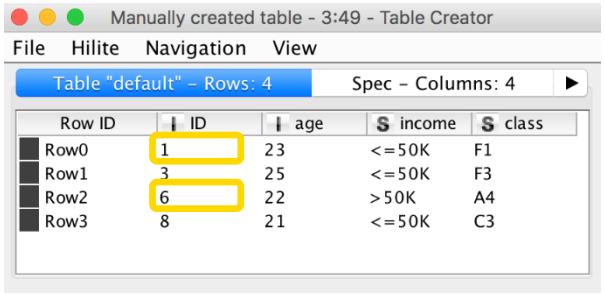
Right Table

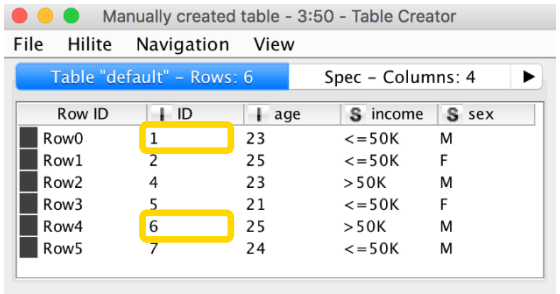
Join by ID

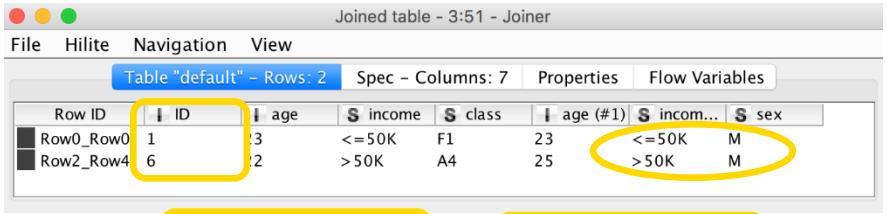
Inner Join

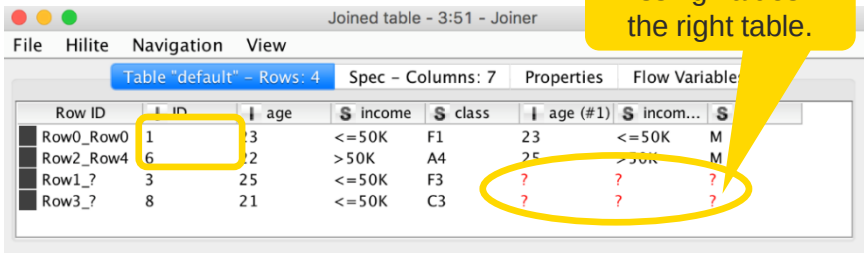
Left Outer Join

Right Outer Join

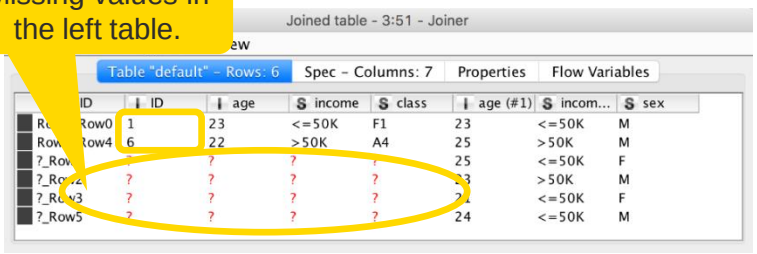








Missing values in the right table.



Missing values in the left table.

Joining Columns of Data

Left Table

Right Table

Join by ID

Full Outer Join

Manually created table - 3:49 - Table Creator

File Hilite Navigation View

Table "default" – Rows: 4 Spec – Columns: 4

Row ID	ID	age	income	class
Row0	1	23	<=50K	F1
Row1	3	25	<=50K	F3
Row2	6	22	>50K	A4
Row3	8	21	<=50K	C3

Manually created table - 3:50 - Table Creator

File Hilite Navigation View

Table "default" – Rows: 6 Spec – Columns: 4

Row ID	ID	age	income	sex
Row0	1	23	<=50K	M
Row1	2	25	<=50K	F
Row2	4	23	>50K	M
Row3	5	21	<=50K	F
Row4	6	25	>50K	M
Row5	7	24	<=50K	M

Joined table - 3:51 - Joiner

File Hilite Navigation View

Table "default" – Rows: 8 Spec – Columns: 7 Properties Flow Variables

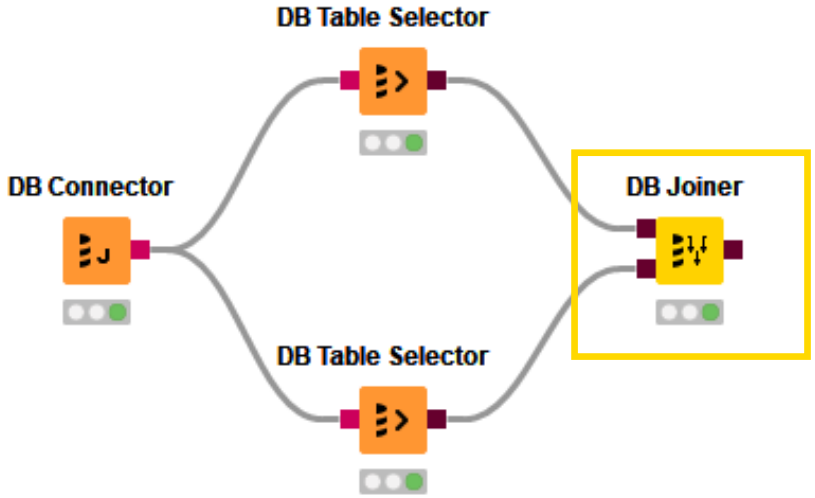
Row ID	ID	age	income	class	age (#1)	incom...	sex
Row0_Row0	1	23	<=50K	F1	23	<=50K	M
Row2_Row4	6	22	>50K	A4	25	>50K	M
Row1_?	3	25	<=50K	F3	?	?	?
Row3_?	8	21	<=50K	C3	?	?	?
?_Row1	?	?	?	?	25	<=50K	F
?_Row2	?	?	?	?	23	>50K	M
?_Row3	?	?	?	?	21	<=50K	F
?_Row5	?	?	?	?	24	<=50K	M

Missing values in the left table

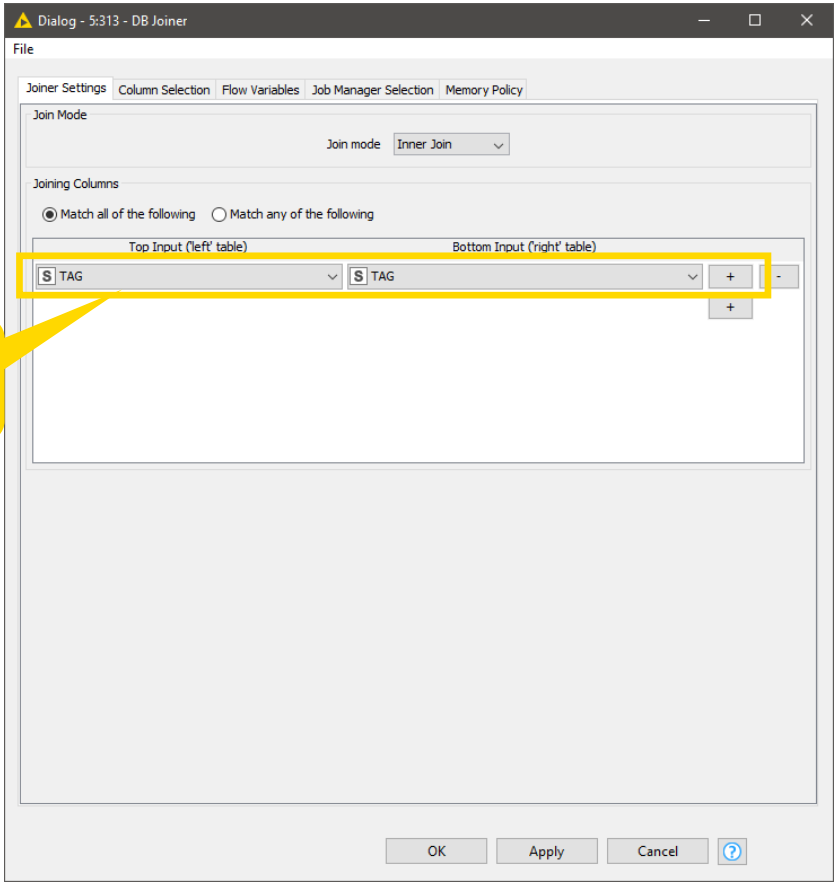
Missing values in the right table

Database Joiner Node

- Combines columns from 2 different tables
- Top port contains “Left” data table
- Bottom port contains the “Right” data table

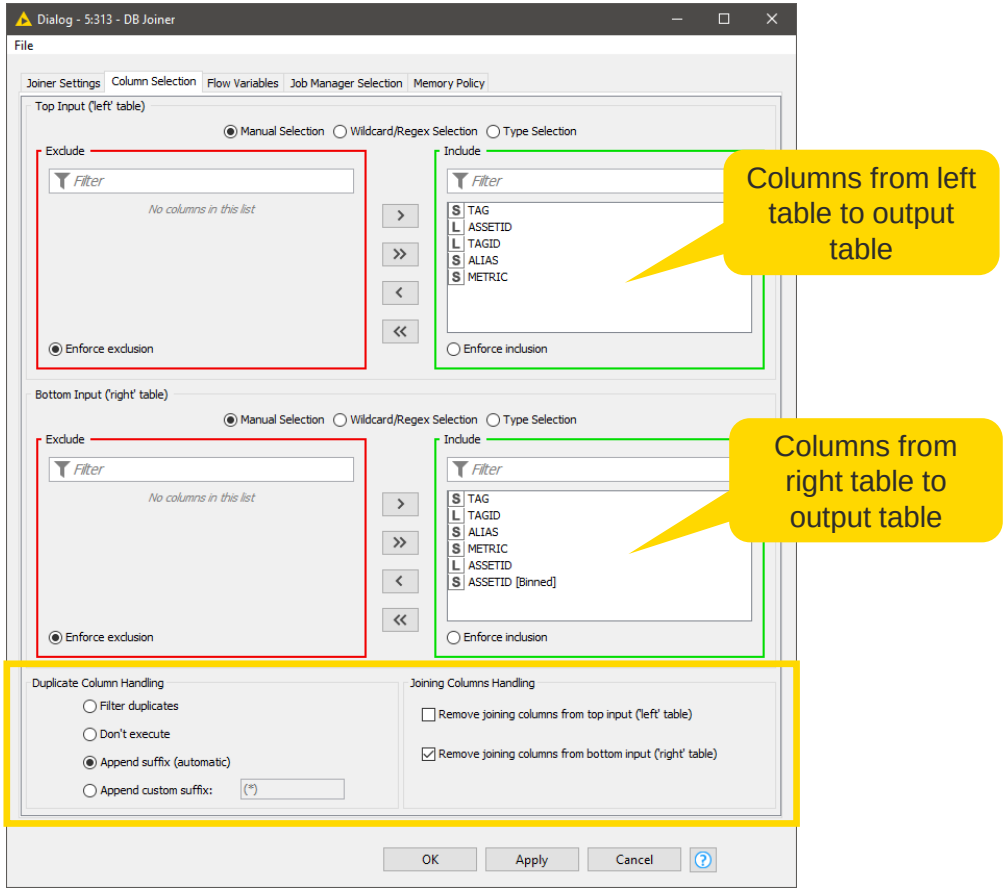


Joiner Configuration – Linking Rows



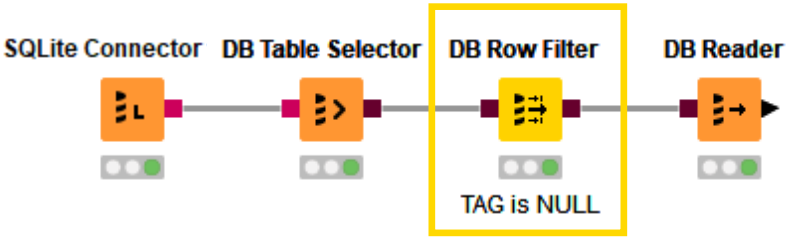
Values to join on. Multiple joining columns are allowed.

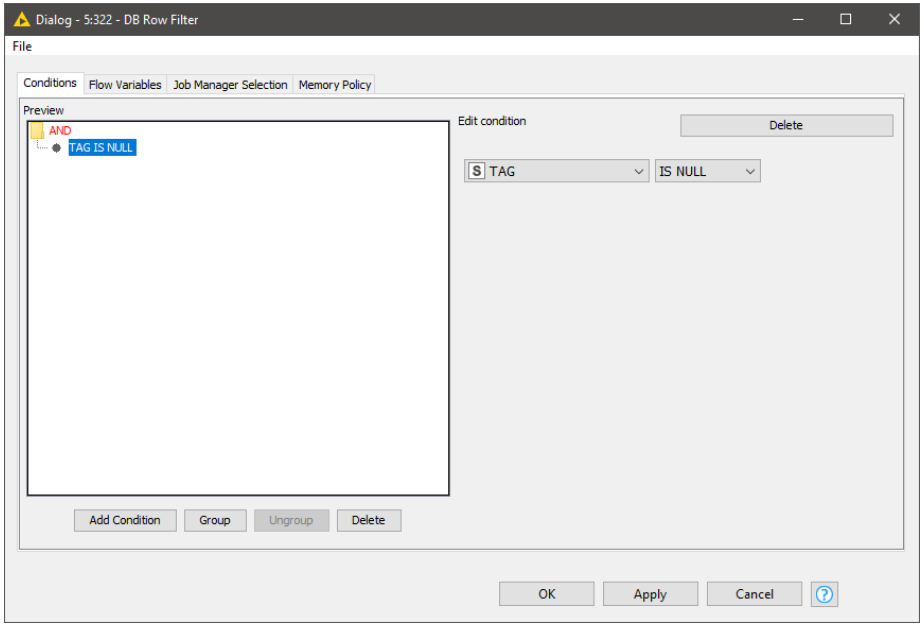
Joiner Configuration – Column Selection



Database Row Filter Node

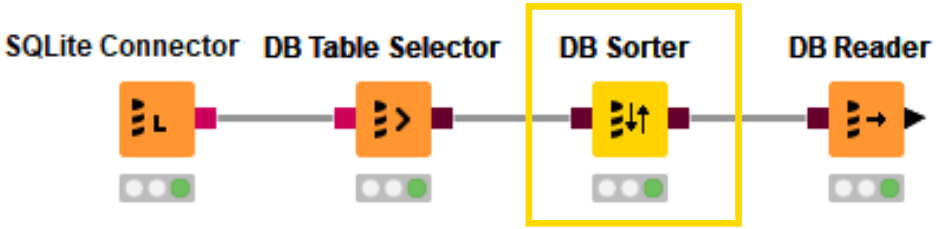
- Filters rows that do not match the filter criteria
- Use the *IS NULL* or *IS NOT NULL* operator to filter missing values

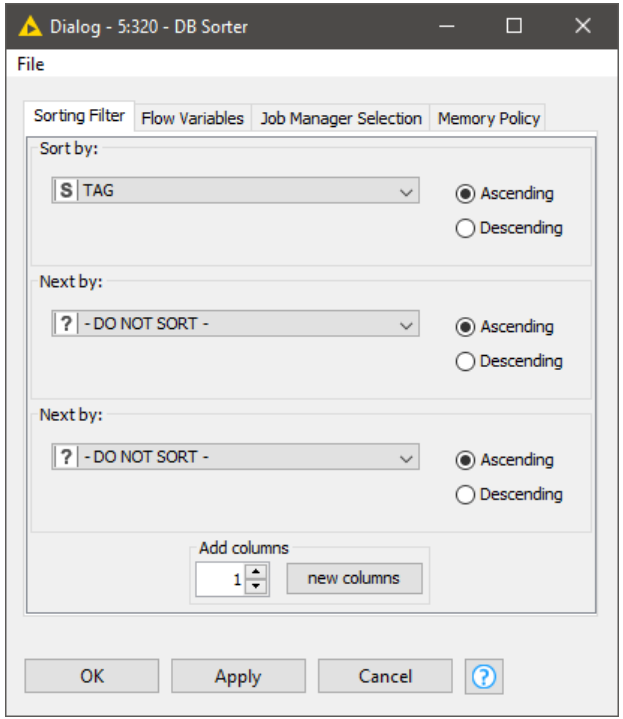




Database Sorter Node

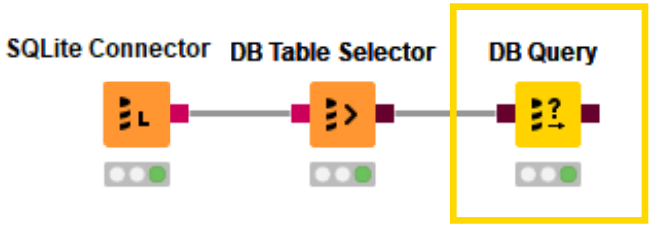
- Sorts the input data by one or multiple columns

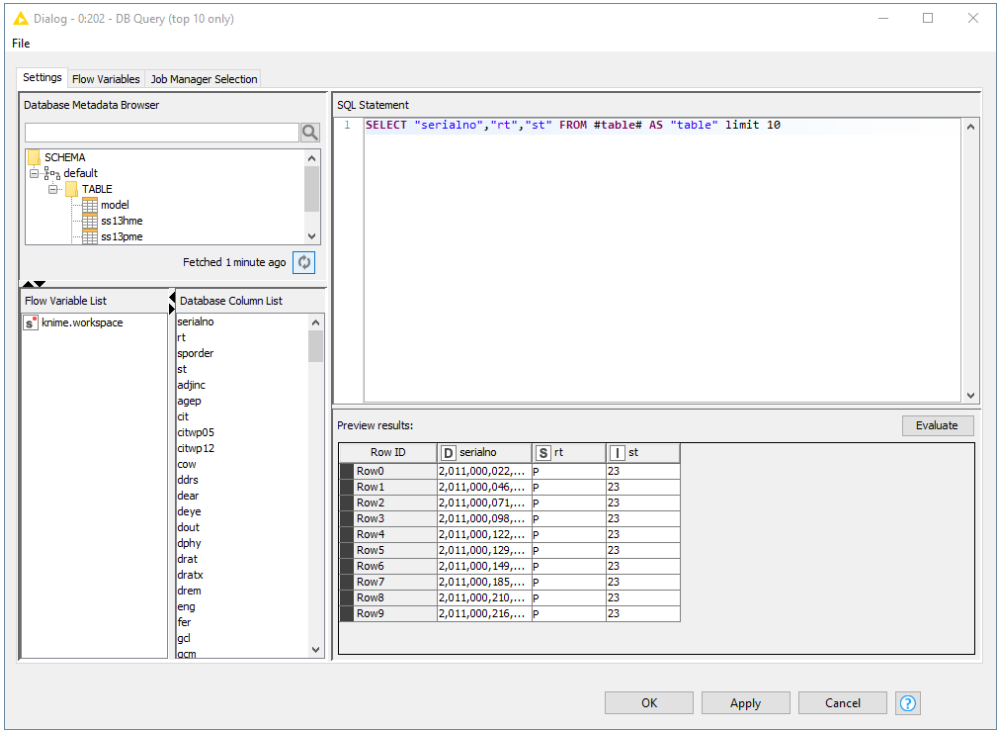




Database Query Node

- Executes arbitrary SQL queries
- #table# is replaced with input query





Section Exercise – 02_DB_InDB_Processing

From tables ss13hme (house data) and ss13pme (person data) in database newCensus.sqlite create 4 tables

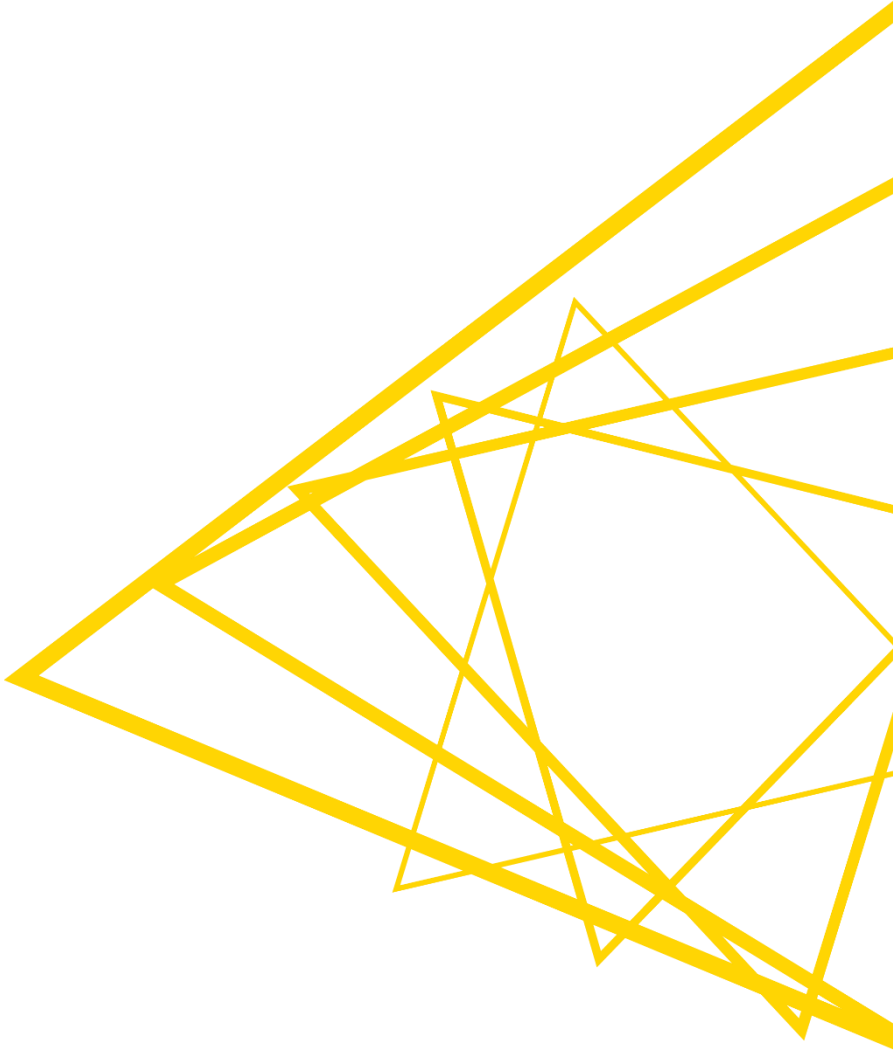
1. Join ss13hme and ss13pme on SERIALNO. Remove all columns named PUMA* and PWGTP* from both tables.
2. Filter all rows from ss13pme where COW is NULL.
3. Filter all rows from ss13pme where COW is NOT NULL.
4. Calculate average AGEP for the different SEX groups.

For all 4 tasks, at the end load data into KNIME.

Optional. Sort the data rows by descending AGEP and extract top 10 only.

Hint: Use LIMIT to restrict the number of rows returned by the db.

Predicting COW Values with KNIME

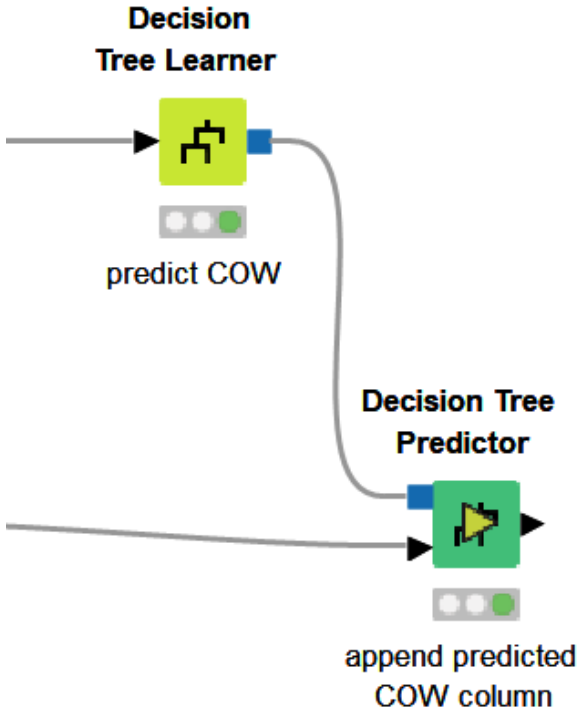


Missing Value Implementation Approach

- Remember that after we perform some in-database ETL on the data, a key task is to fill in missing values for the COW field in our dataset

- We could try to do this by applying some simple business rules, but a more sophisticated approach is to build a model to predict COW

- Therefore, we will train and apply a decision tree model for COW



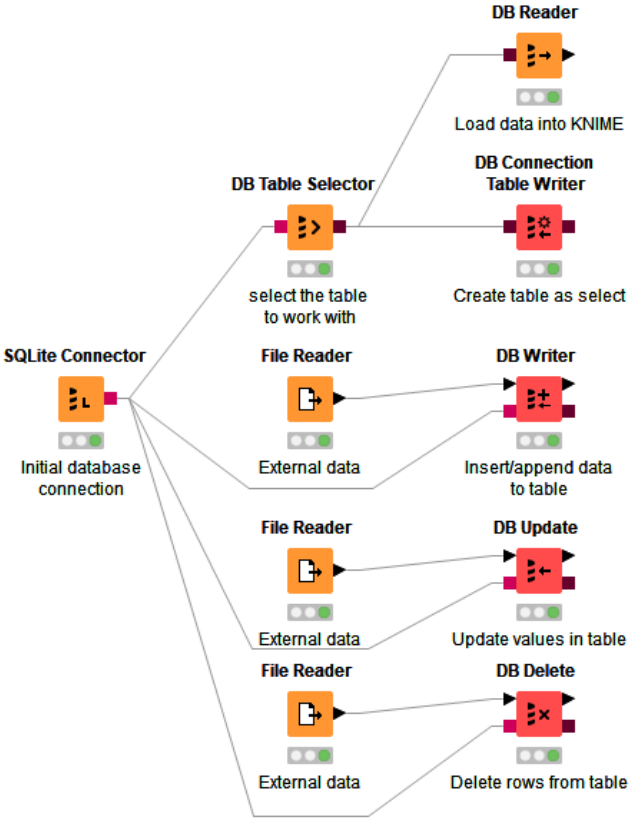
Section Exercise – 03_DB_Modelling

- Train a Decision Tree to predict the COW where COW is not null
- Apply Decision Tree Model to predict COW where COW is missing (null)

Write/Load Data into a Database

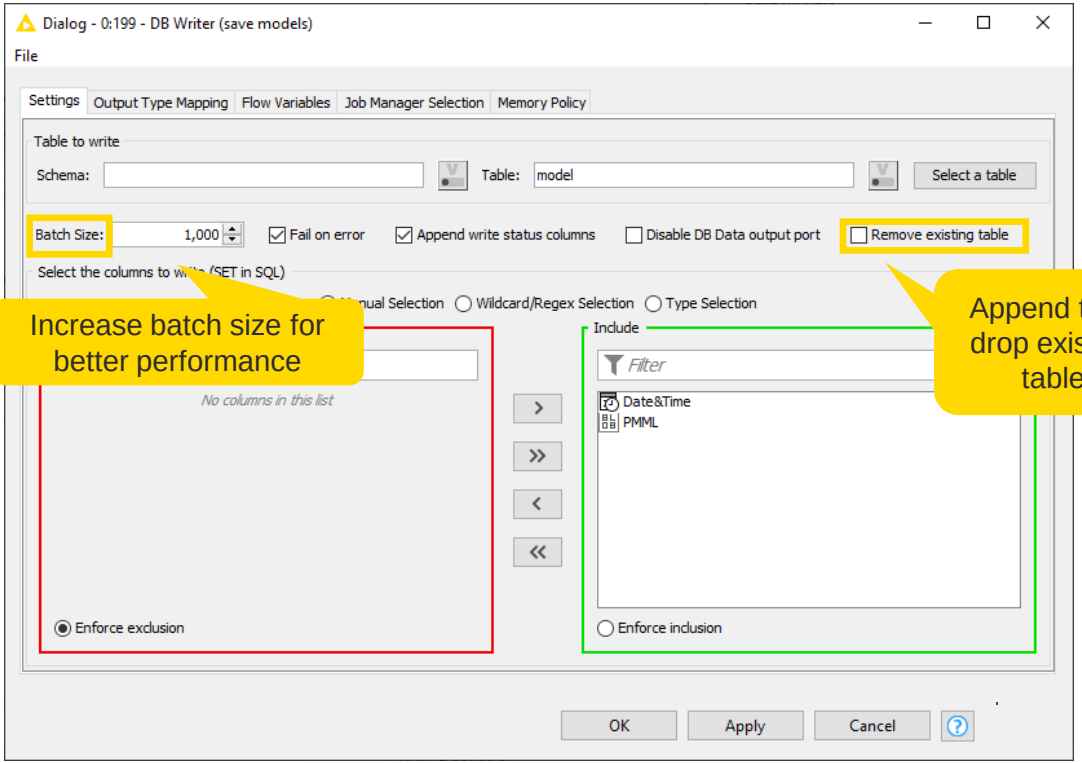
Database Writing Nodes

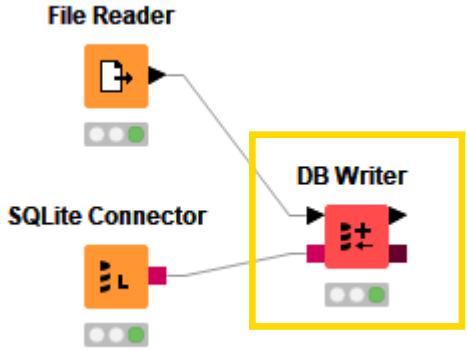
- Create table as select
- Insert/append data
- Update values in table
- Delete rows from table



DB Writer Node

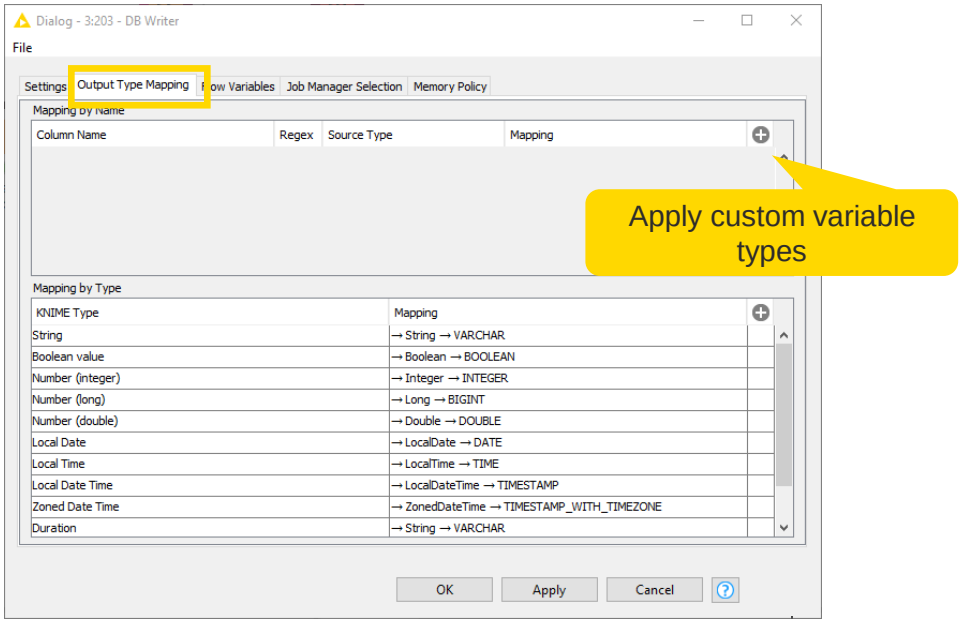
- Writes data from a KNIME data table **directly** into a database table

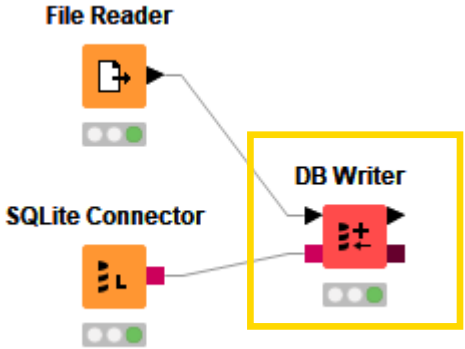




DB Writer Node (continued)

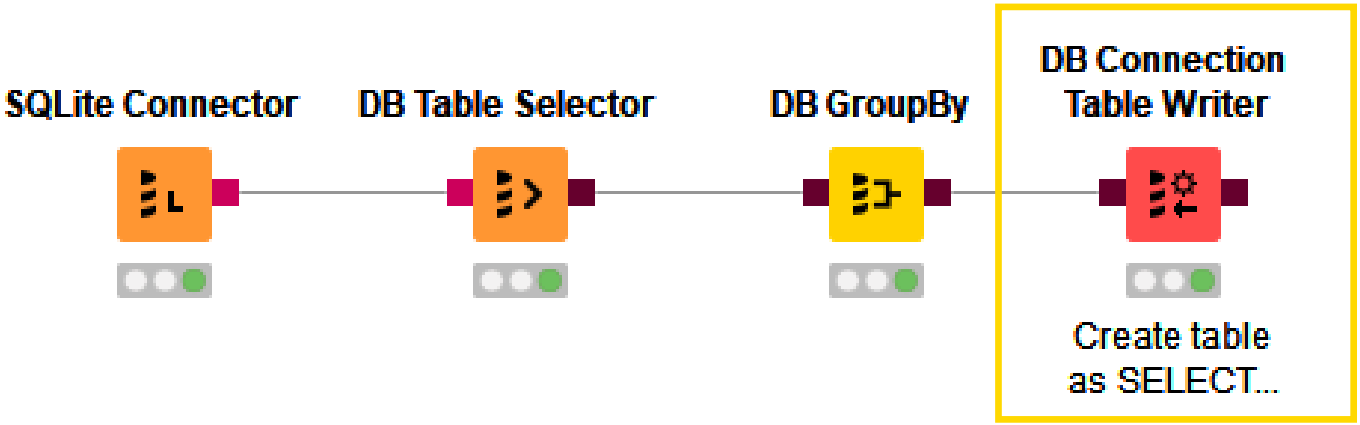
- Writes data from a KNIME data table **directly** into a database table





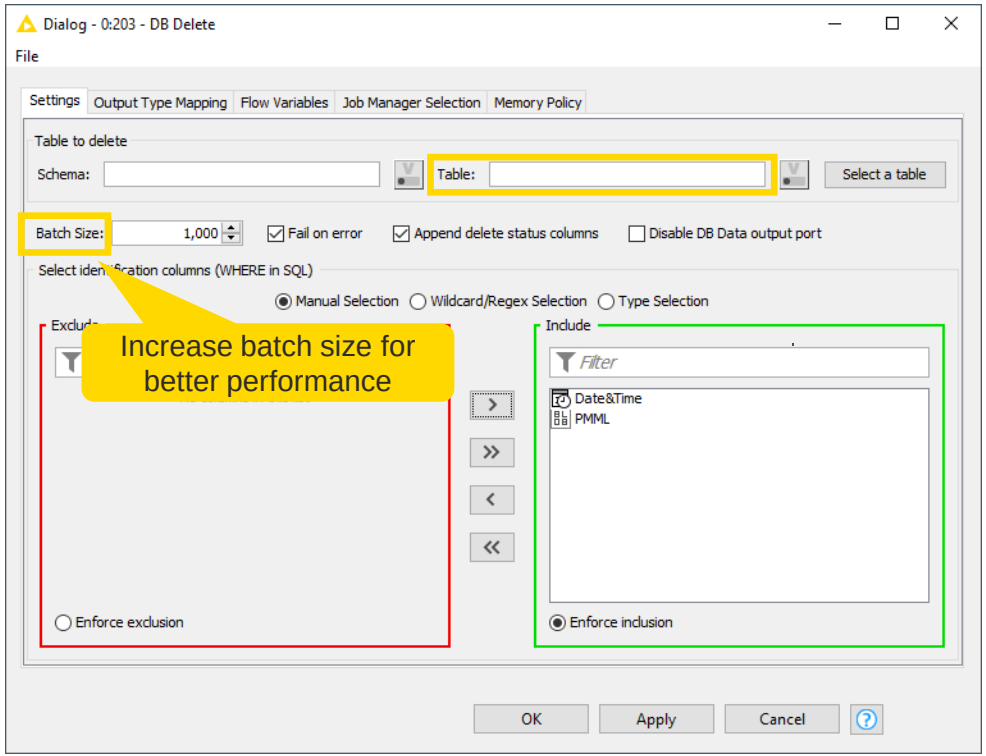
DB Connection Table Writer Node

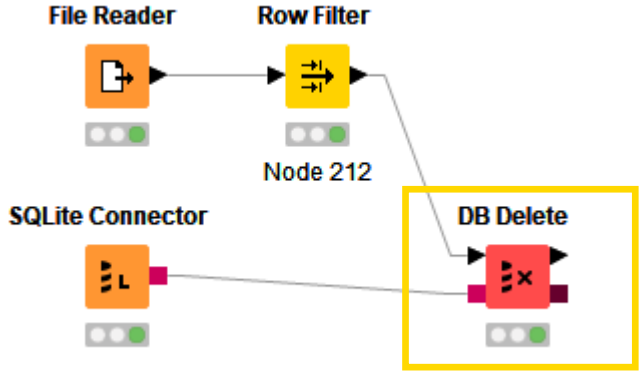
- Creates a new database table **based on the input SQL query**



DB Delete Node

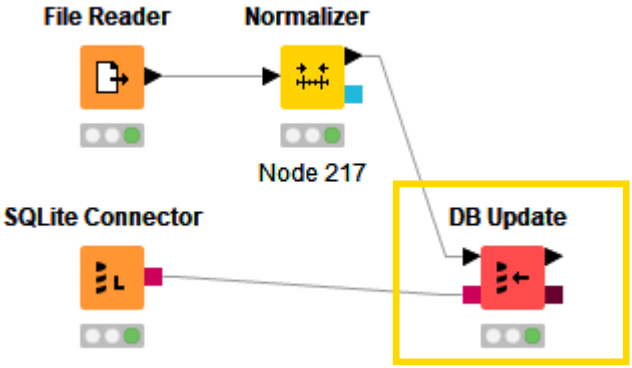
- Deletes all database records that match the values of the selected columns

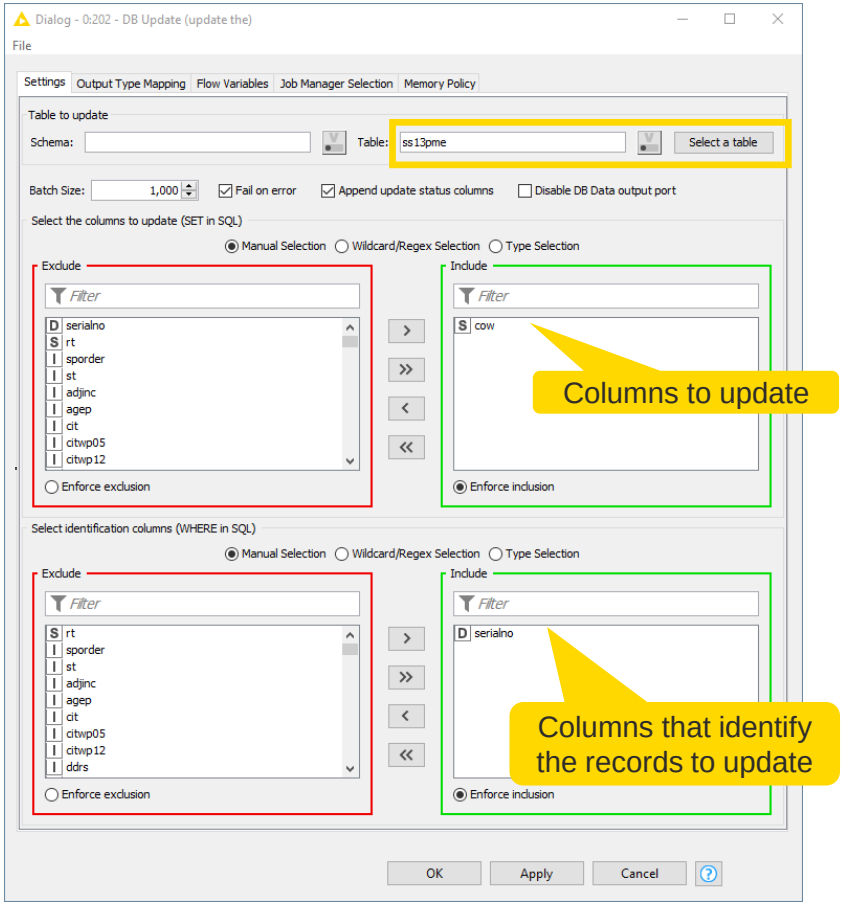




Database Update Node

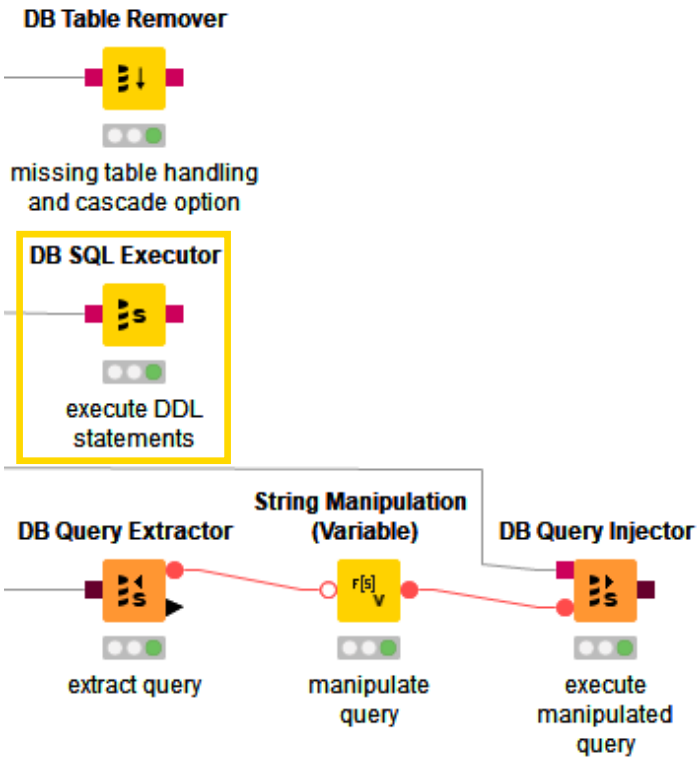
- Updates all database records that match the update criteria





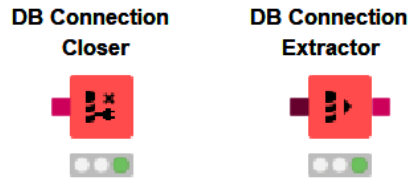
Utility

- Drop table
  - missing table handling
  - cascade option
- Execute any SQL statement e.g. DDL
- Manipulate existing queries

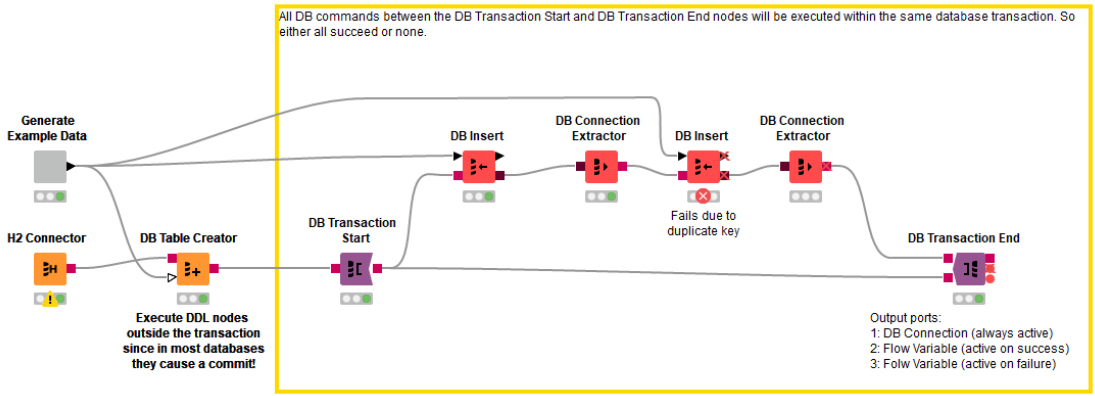


More Utility Nodes and Transaction Support

- DB Connection Extractor
- DB Connection Closer



- DB Transaction Start/End
  - Take advantage of these nodes to group several database data manipulation operations into a single unit of work
  - This transaction either completes entirely or not at all.
  - Uses the default isolation level of the connected database.



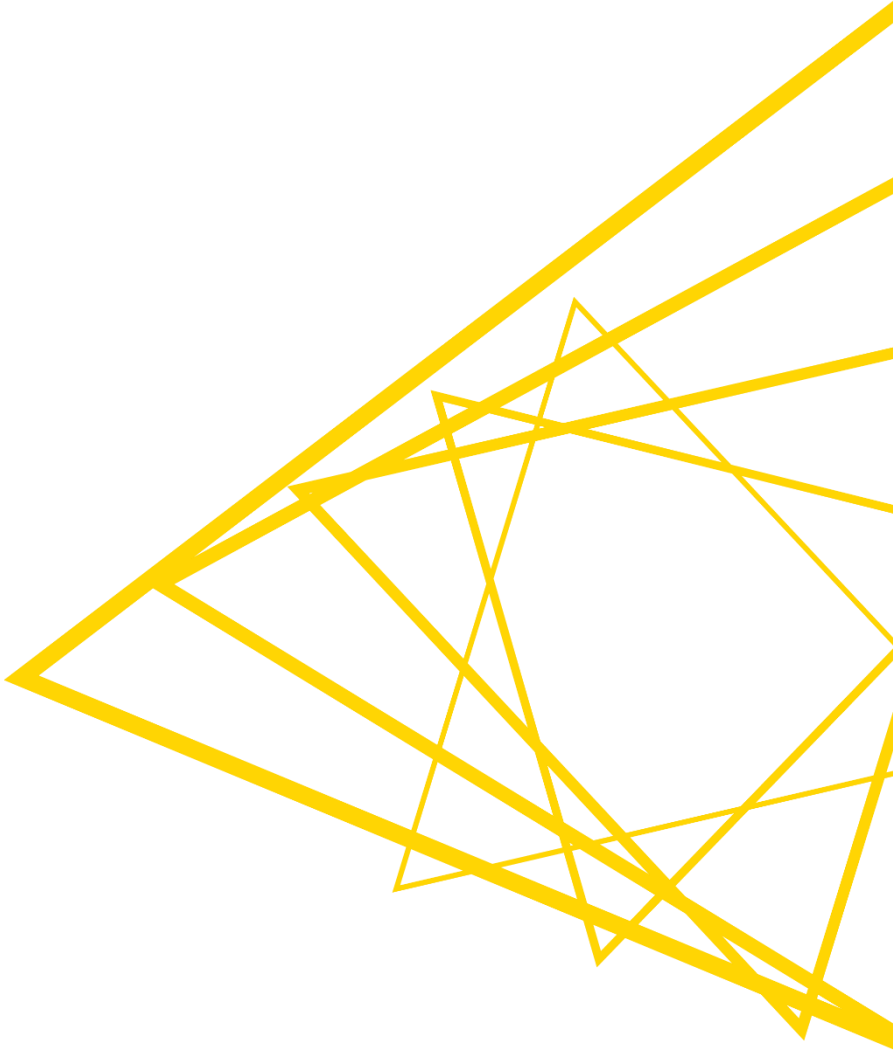
Workflow is available on the KNIME Hub:
https://kni.me/w/kWP1OhaY4DXK444n

Section Exercise – 04_DB_WritingToDB

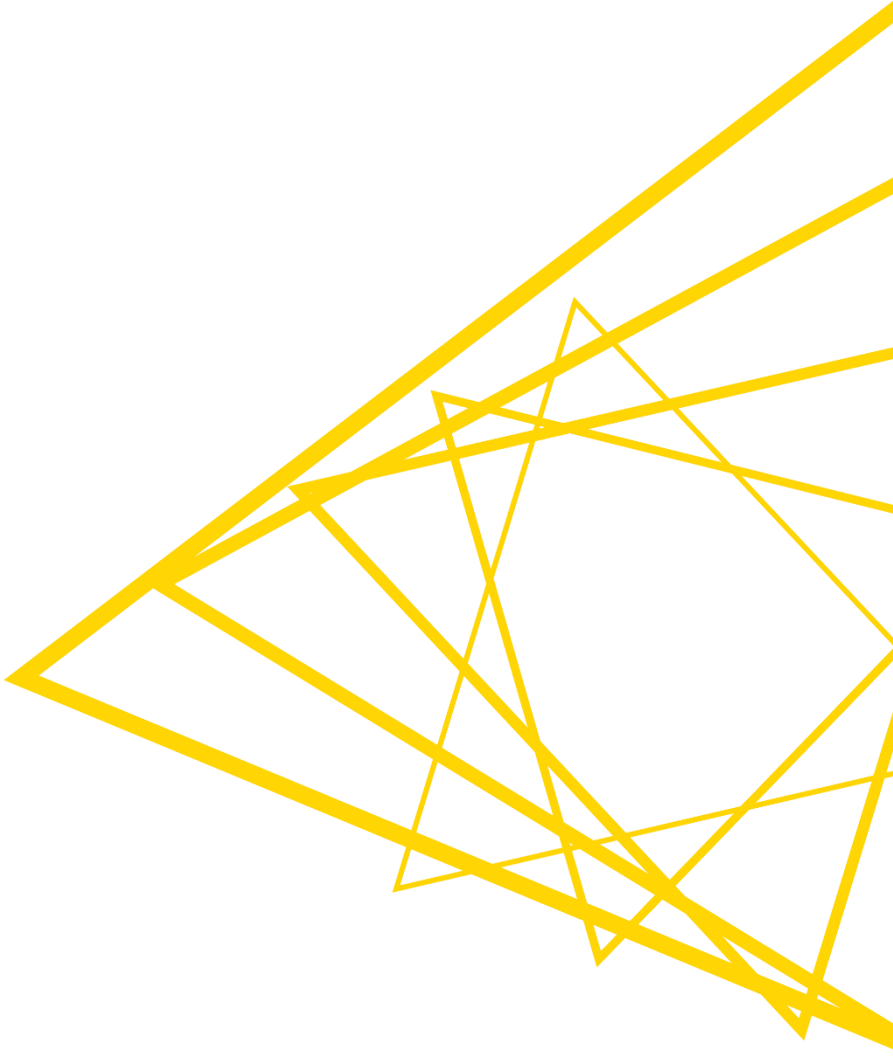
- Write the original table to ss13pme_original table with a Database Connection Table Writer node ... just in case we mess up with the updates in the next step.
- Update all rows in ss13pme table with the output of the predictor node. That is all rows with missing COW value with the predicted COW value, using column SERIALNO for WHERE condition (SERIALNO uniquely identifies each person). Check the UpdateStatus column for success.

Optional: Write the learned Decision Tree Model and the timestamp into a new table named "model"

Let’s Now Try the Same with Hadoop



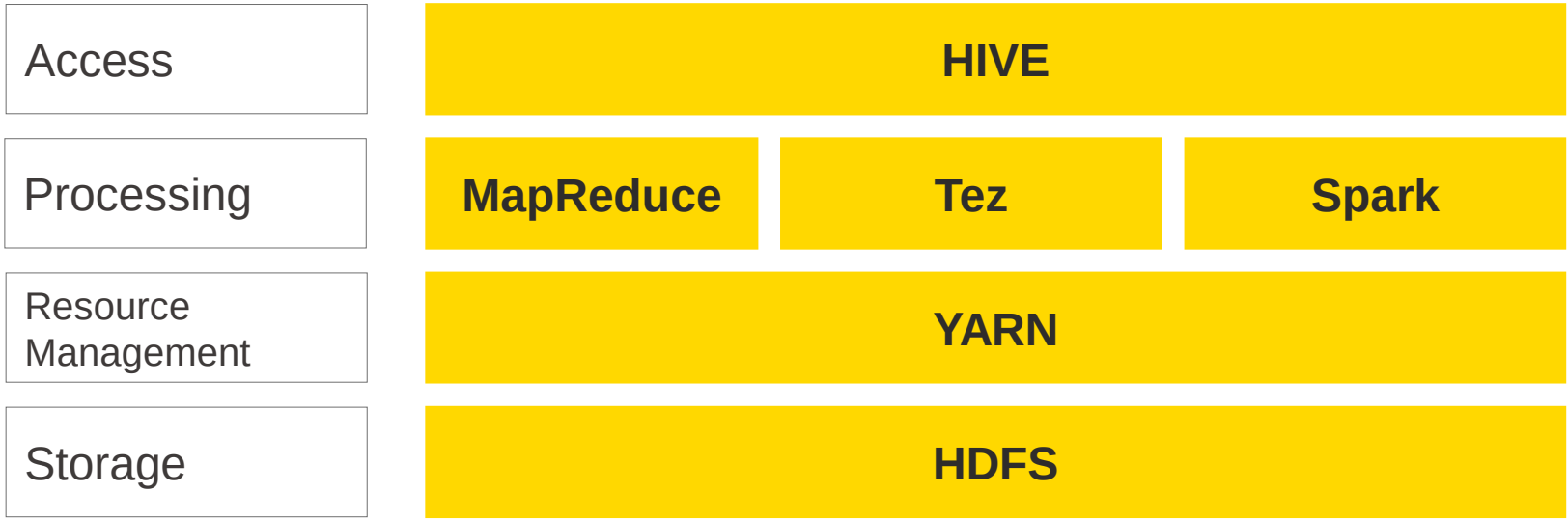
A Quick Intro to Hadoop



Apache Hadoop

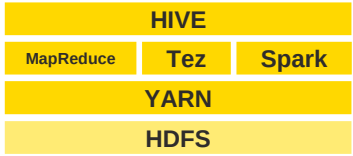
- Open-source framework for distributed storage and processing of large data sets
- Designed to scale up to thousands of machines
- Does not rely on hardware to provide high availability
  - Handles failures at application layer instead
- First release in 2006
  - Rapid adoption, promoted to top level Apache project in 2008
  - Inspired by Google File System (2003) paper
- Spawned diverse ecosystem of products

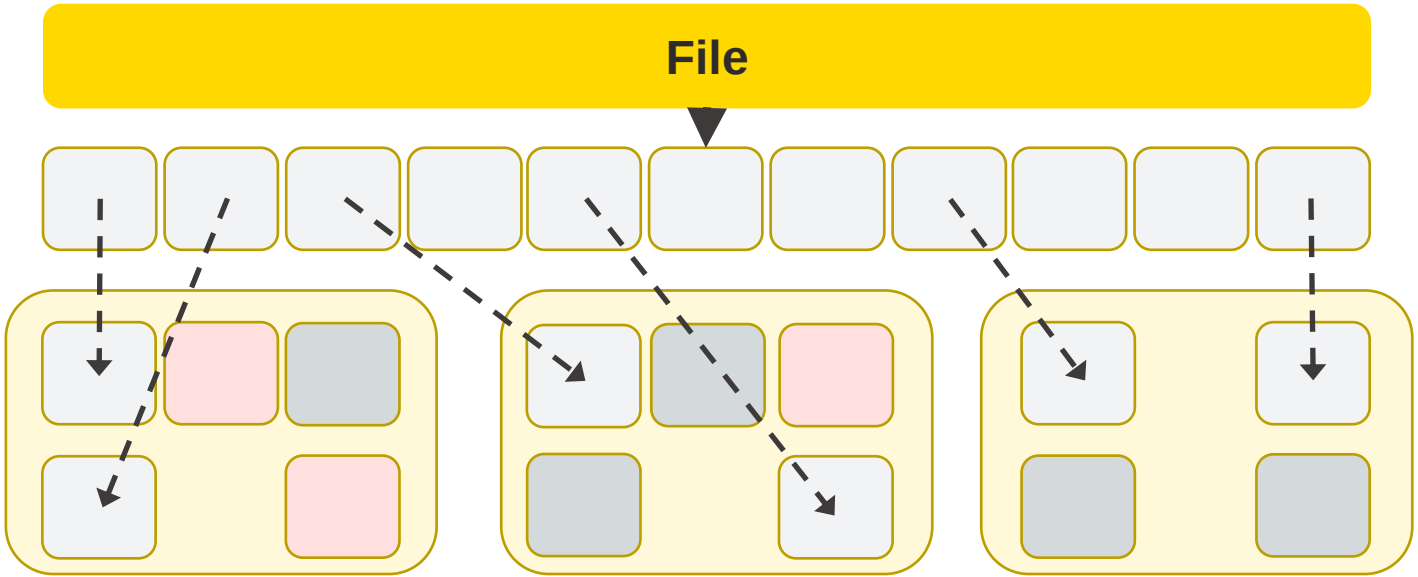
Hadoop Ecosystem



HDFS

- Hadoop distributed file system
- Stores large files across multiple machines





File (large!)

Blocks (default: 64MB)

DataNodes

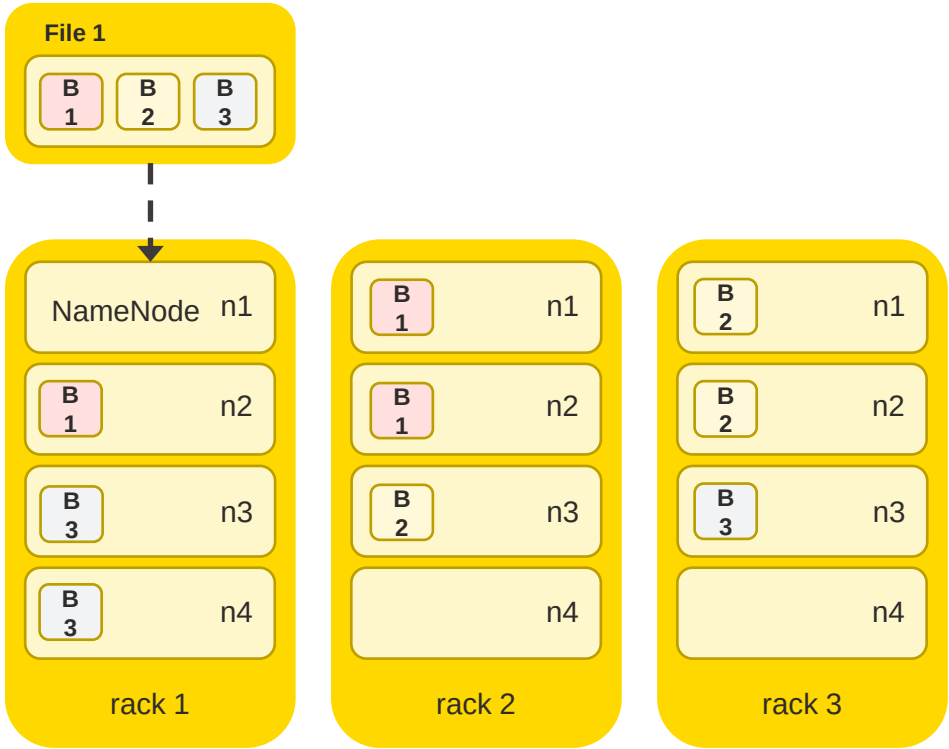
HDFS – NameNode and DataNode

- NameNode
  - Master service that manages file system namespace
    - Maintains metadata for all files and directories in filesystem tree
    - Knows on which datanode blocks of a given file are located
  - Whole system depends on availability of NameNode
- DataNodes
  - Workers, store and retrieve blocks per request of client or namenode
  - Periodically report to namenode that they are running and which blocks they are storing

HDFS – Data Replication and File Size

Data Replication

- All blocks of a file are stored as sequence of blocks
- Blocks of a file are replicated for fault tolerance (usually 3 replicas)
  - Aims: improve data reliability, availability, and network bandwidth utilization



HDFS – Access and File Size

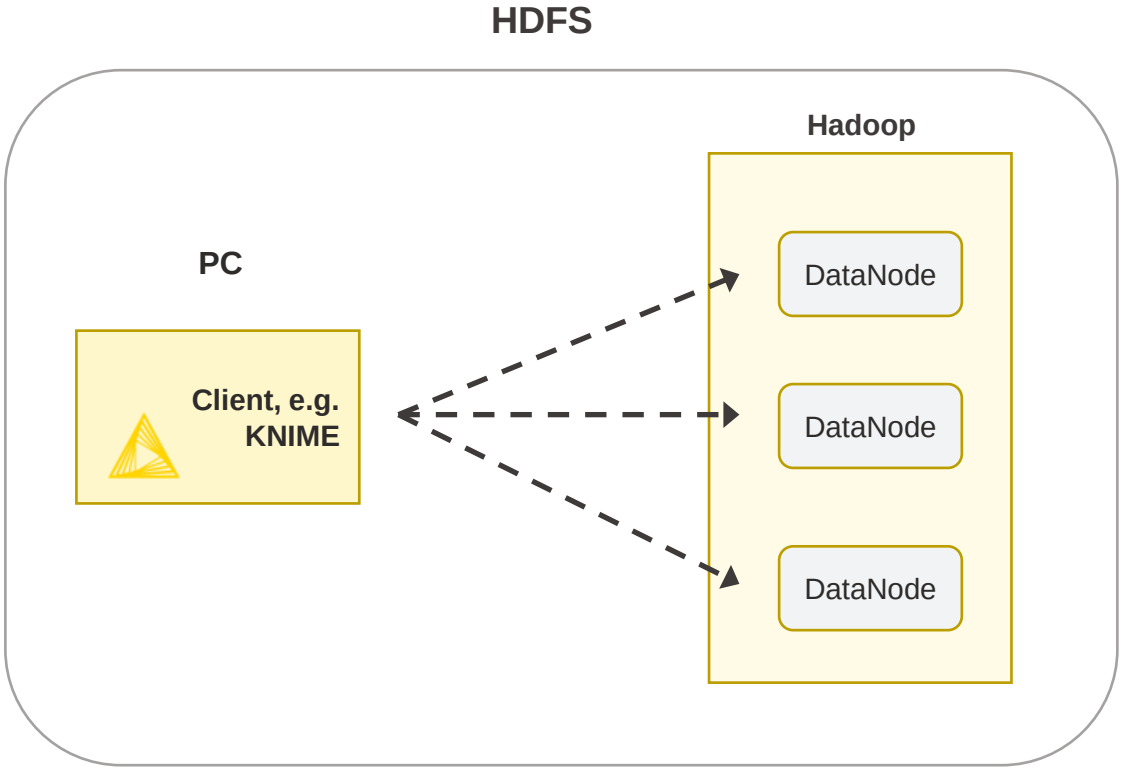
- Several ways to access HDFS data
  - HDFS
    - Direct transmission of data from nodes to client
    - Needs access to all nodes in cluster
  - WebHDFS
    - Direct transmission of data from nodes to client via HTTP
    - Needs access to all nodes in cluster
  - HttpFS
    - All data is transmitted to client via one single gateway node -> HttpFS service

File Size:

- Hadoop is designed to handle fewer large files instead of lots of small files
- Small file: File significantly smaller than Hadoop block size
- Problems:
  - Namenode memory
  - MapReduce performance

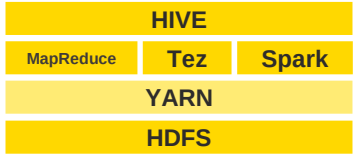
HDFS – Access

HDFS Connector

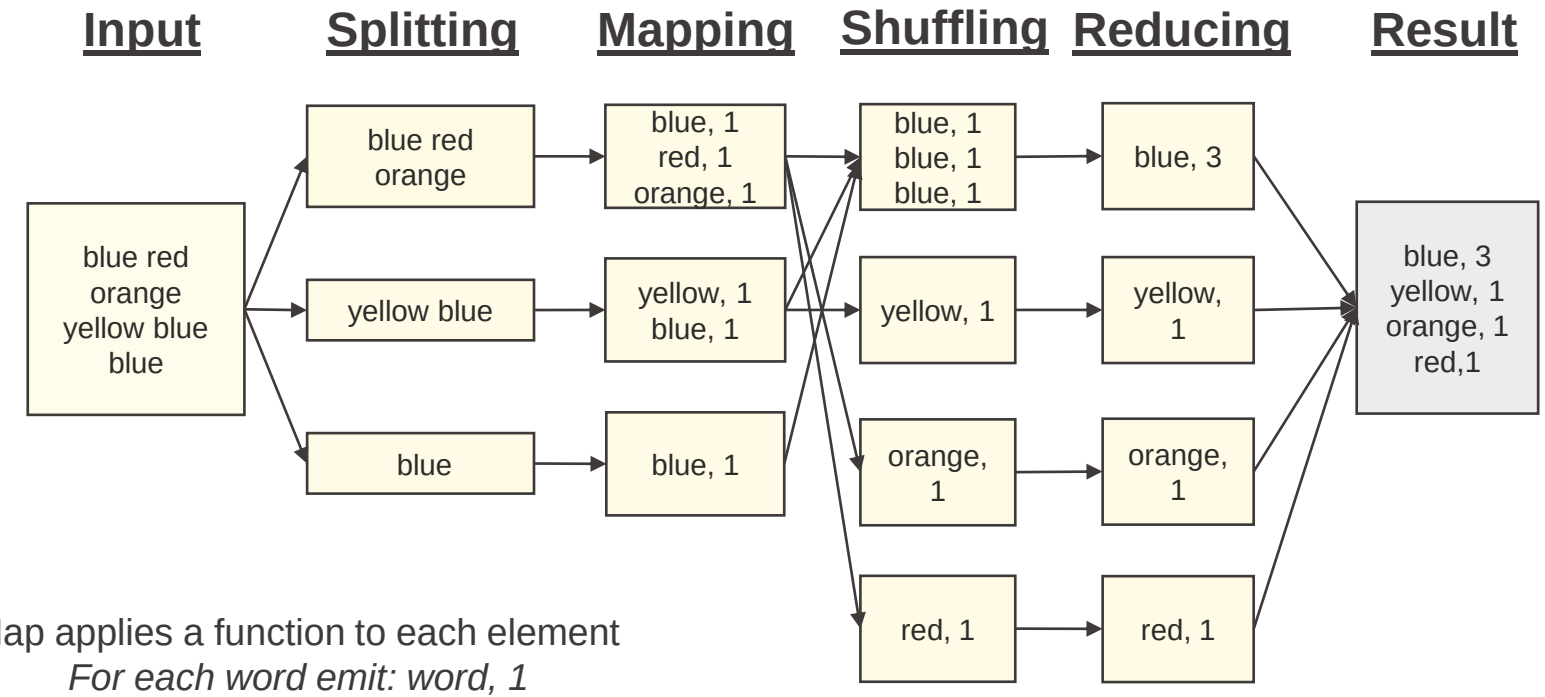


YARN

- Cluster resource management system
- Two elements
  - Resource manager (one per cluster):
    - Knows where worker nodes are located and how many resources they have
    - Scheduler: Decides how to allocate resources to applications
  - Node manager (many per cluster):
    - Launches application containers
    - Monitor resource usage and report to Resource Manager



MapReduce

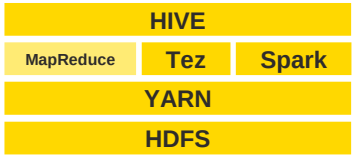


Map applies a function to each element

For each word emit: word, 1

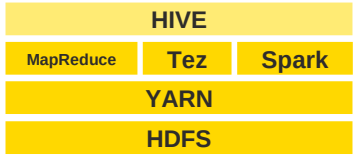
Reduce aggregates a list of values to one result

For all equal words sum up count

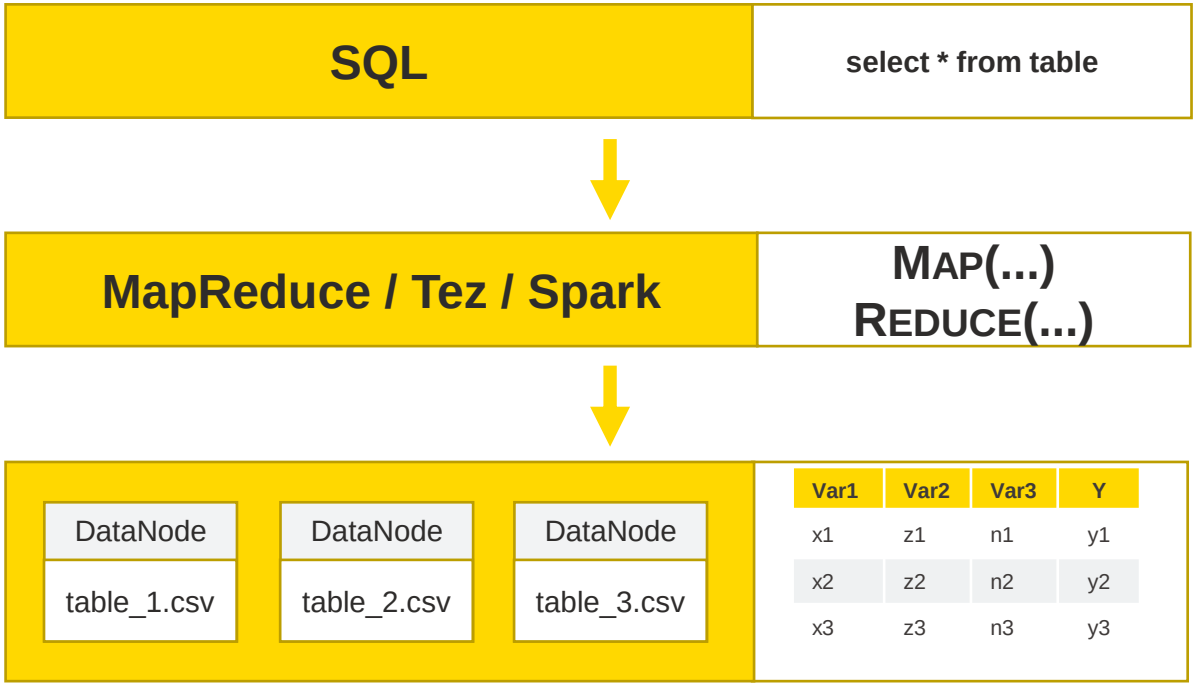


Hive

- **SQL-like database** on top of files in HDFS
- Provides data summarization, query, and analysis
- Interprets a set of files as a database table (schema information to be provided)
- Translates SQL queries to MapReduce, Tez, or Spark jobs
- Supports various file formats:
  - Text/CSV
  - SequenceFile
  - Avro
  - ORC
  - Parquet

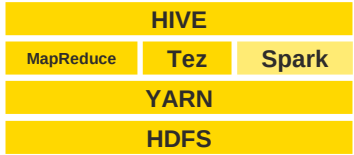


Hive



Spark

- Cluster computing framework for large-scale data processing
- Keeps large working datasets in memory between jobs
  - No need to always load data from disk -> much (!) faster than MapReduce
- Programmatic interface
  - Scala, Java, Python, R
  - Functional programming paradigm: map, flatmap, filter, reduce, fold, …
- Great for:
  - Iterative algorithms
  - Interactive analysis



Spark – Data Representation

DataFrame:

- *Table-like*: Collection of rows, organized in columns with names and types

Name	Surname	Age
John	Doe	35
Jane	Roe	29
…	…	…

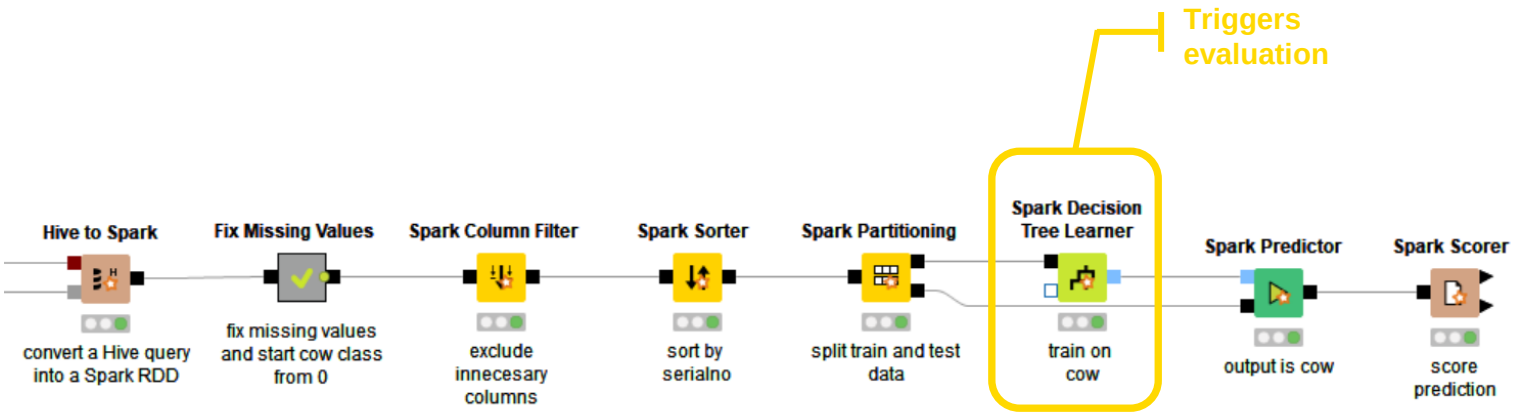
- *Immutable*:
  - Data manipulation = creating new DataFrame from an existing one by applying a *function* on it
- *Lazily evaluated*:
  - Functions are not executed until an *action* is triggered, that requests to actually see the row data
- *Distributed:*
  - Each row belongs to exactly one *partition*
  - Each partition is held by a Spark Executor

Note:

• Earlier versions of KNIME and Spark used *RDDs* (resilient distributed datasets)
• In KNIME, DataFrames are always used in Spark 2 and later.

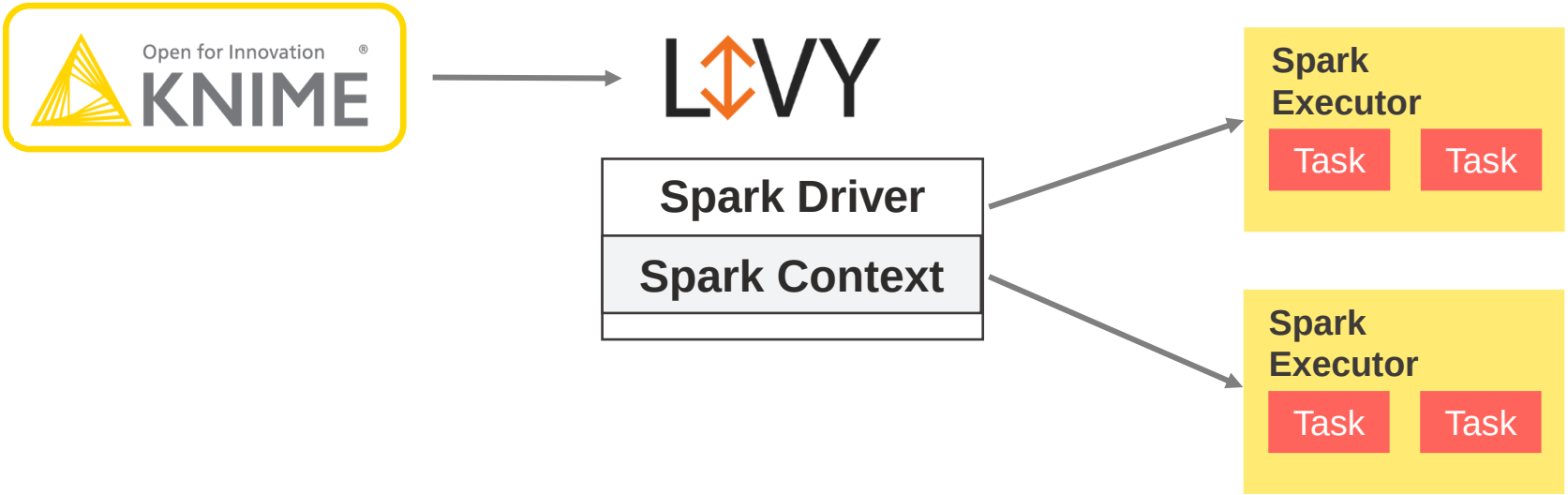
Spark – Lazy Evaluation

- Functions ("*transformations*") on DataFrames are not executed immediately
- Spark keeps record of the transformations for each DataFrame
- The actual execution is only triggered once the data is needed
- Offers the possibility to optimize the transformation steps

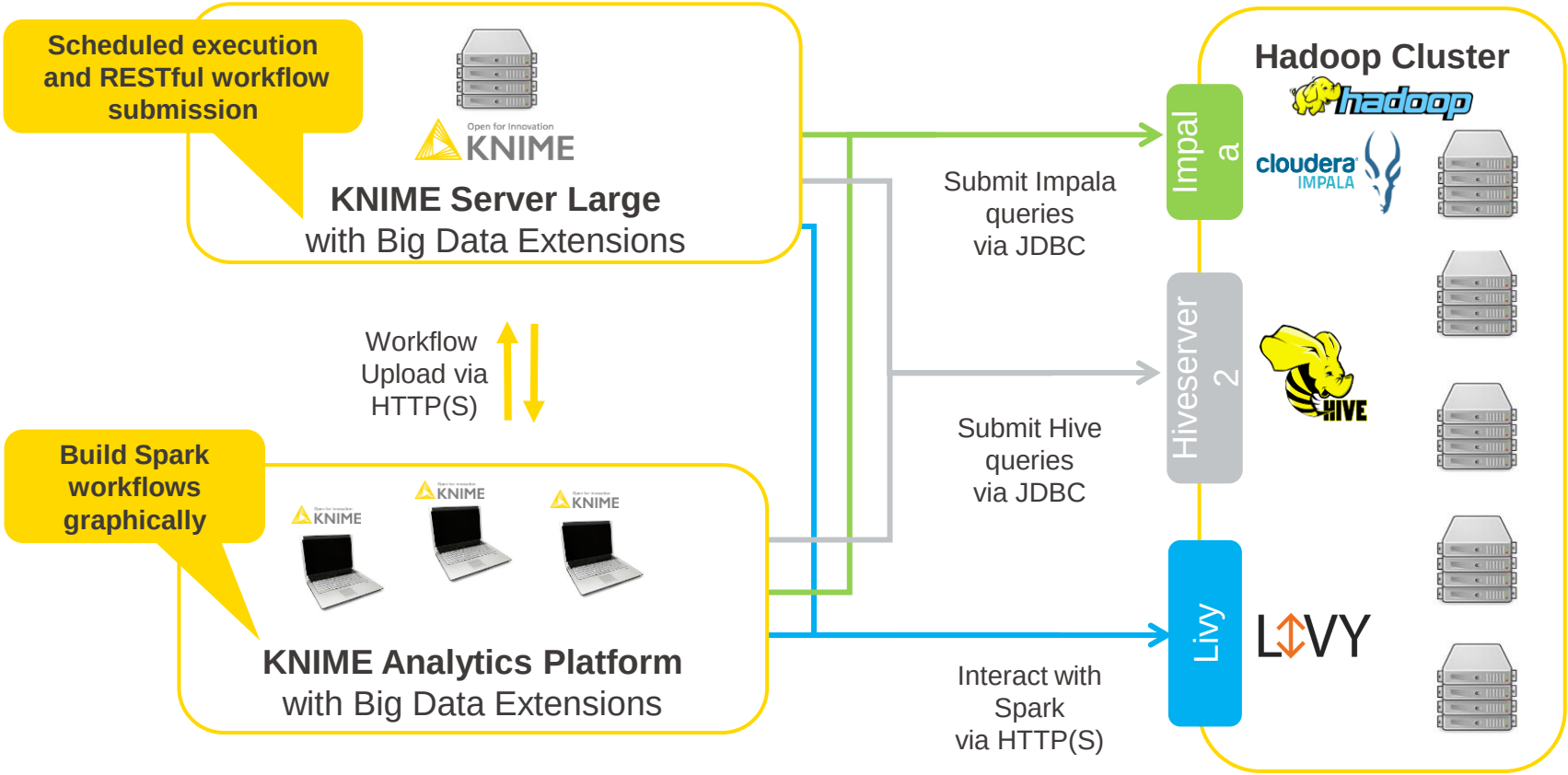


Spark Context

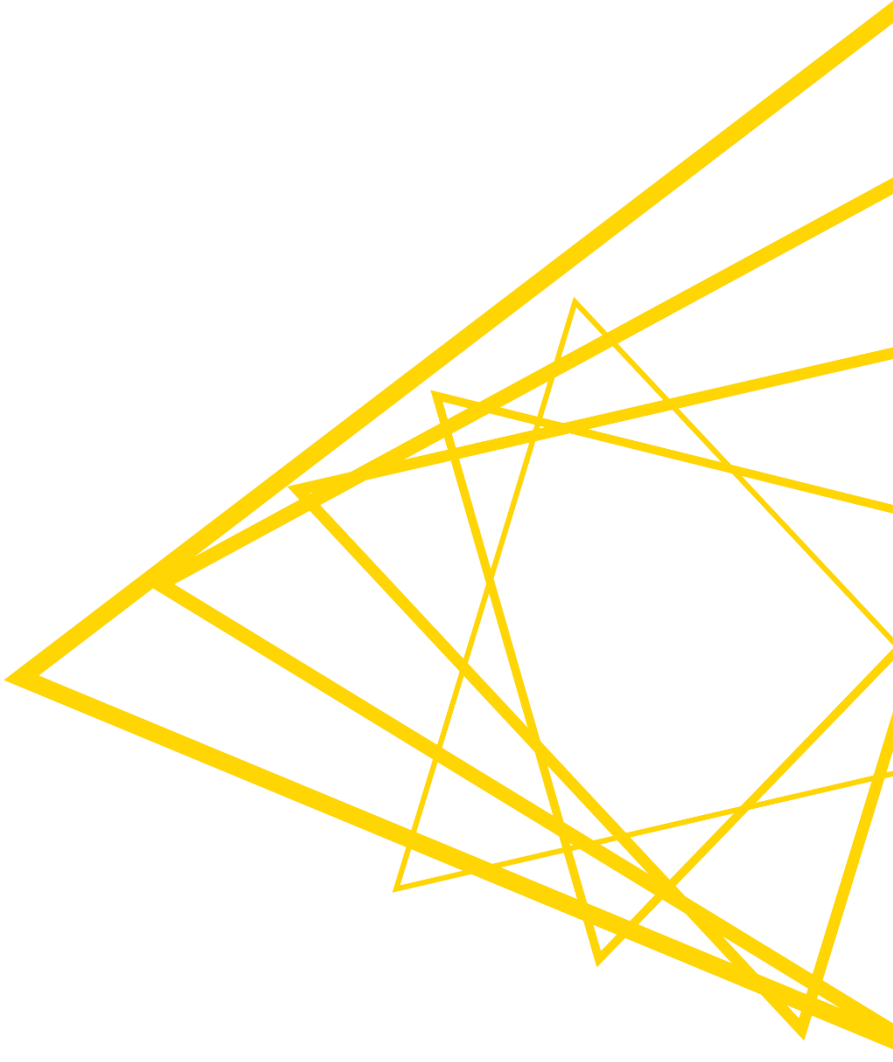
- Spark Context
  - Main entry point for Spark functionality
  - Represents connection to a Spark cluster
  - Allocates resources on the cluster



Big Data Architecture with KNIME

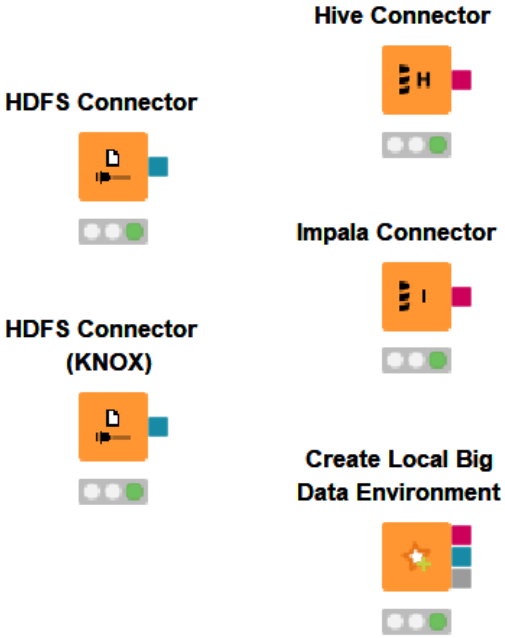


In-Database Processing on Hadoop



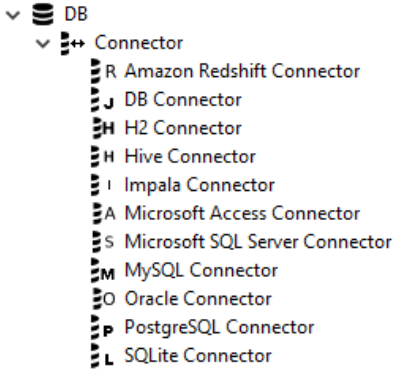
KNIME Big Data Connectors

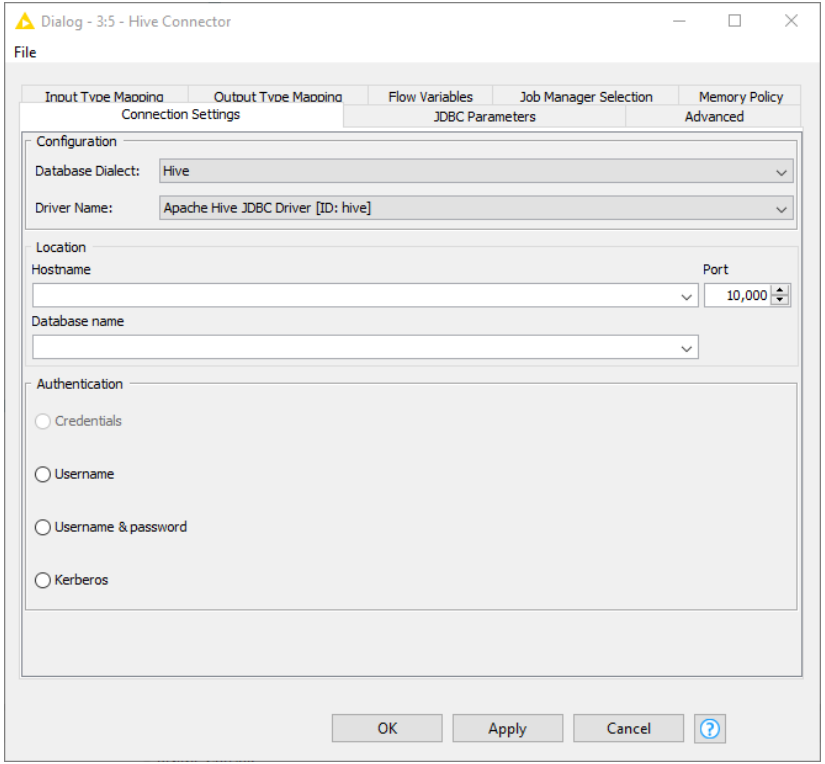
- Package required drivers/libraries for HDFS, Hive, Impala access
- Preconfigured database connectors
  - Hive
  - Impala



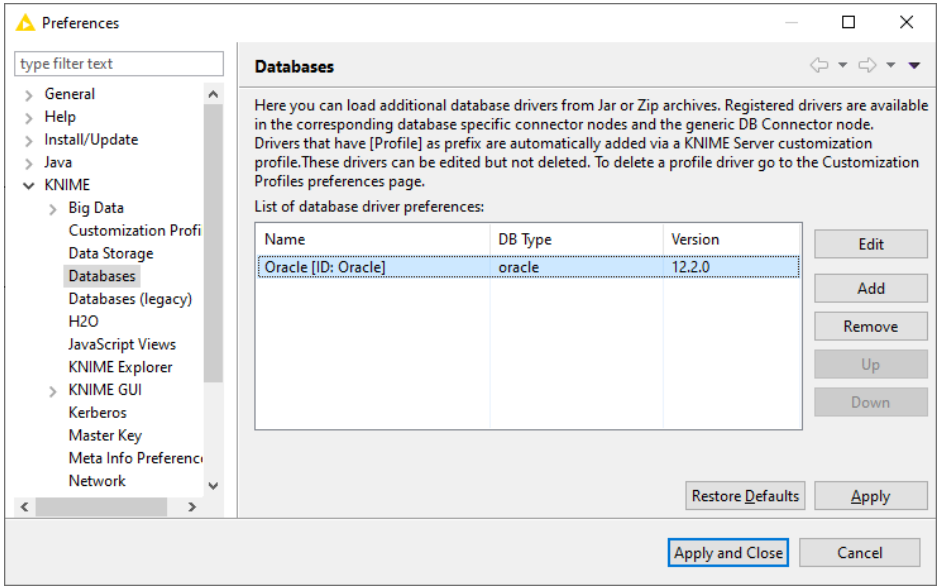
Hive Connector

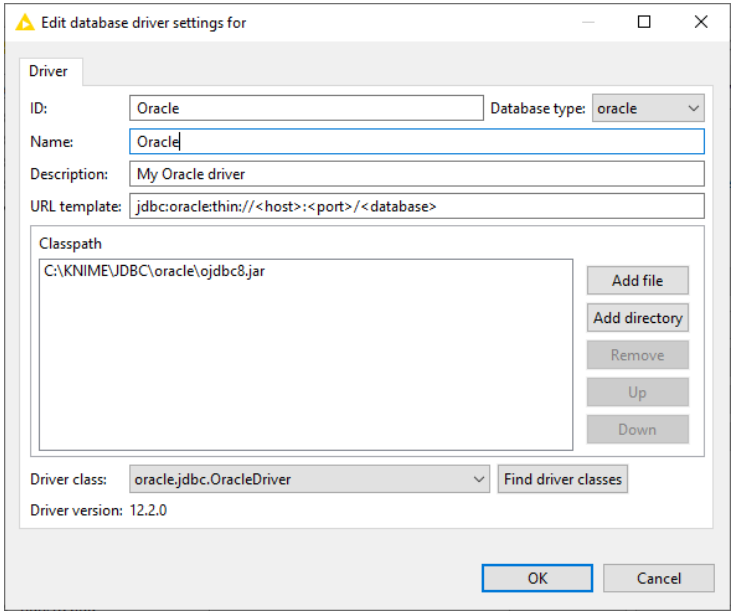
- Creates JDBC connection to Hive
- On unsecured clusters no password required





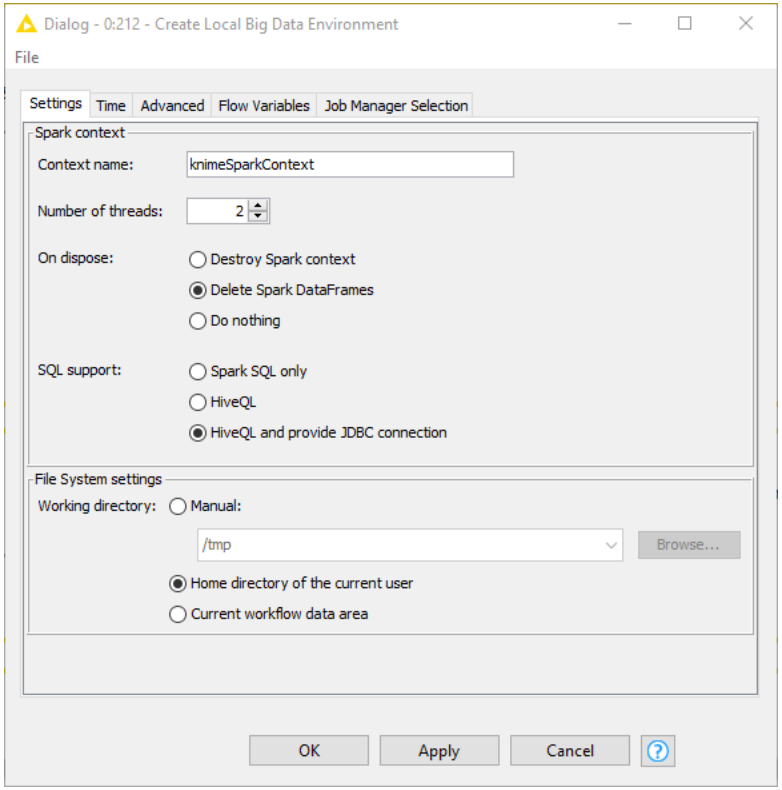
Preferences





Create Local Big Data Environment Node

- Creates a fully functional big data environment
  on your local machine with
  - Apache Hive
  - HDFS
  - Apache Spark
- Try out Big Data nodes without Hadoop cluster
- Build and test workflows locally on sample data



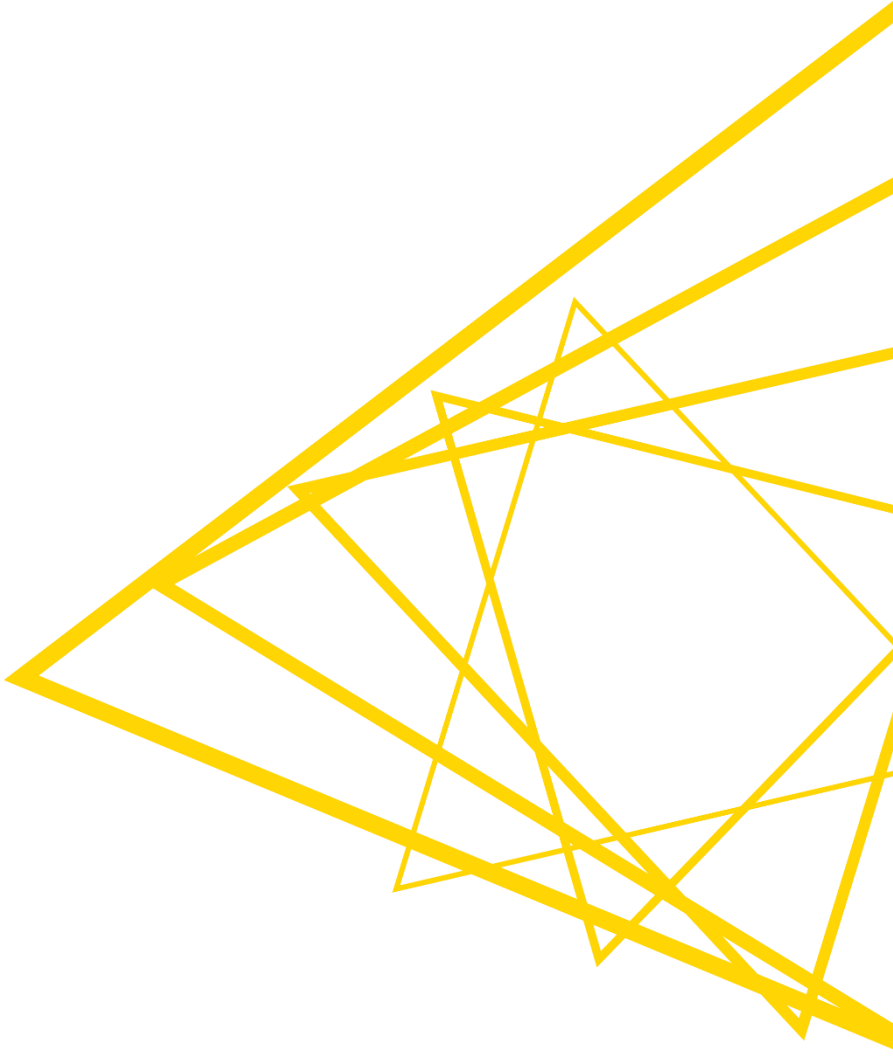
Section Exercise – 01_Hive_Connect

Execute the workflow 00_Setup_Hive_Table to create a local big data environment with the data used in this training.

On the workflow implemented in the previous section to predict missing COW values, move execution from database to Hive. That means:

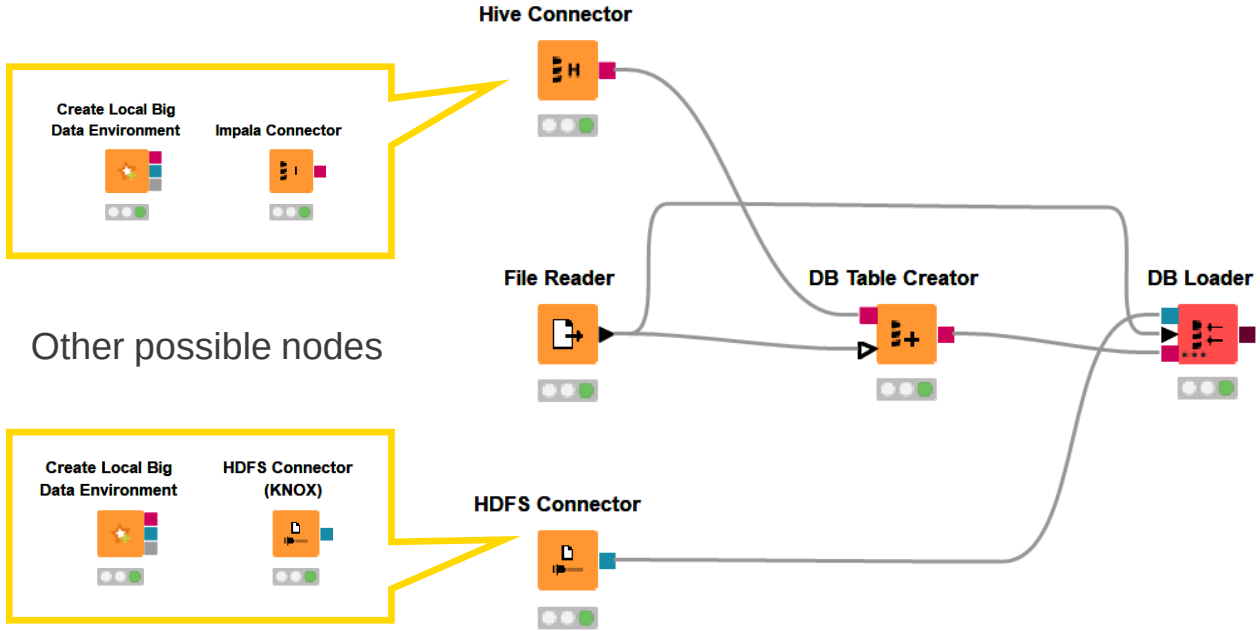
- change this workflow to run on the ss13pme table on the Hive database in your local big data environment.

Write/Load Data into Hadoop

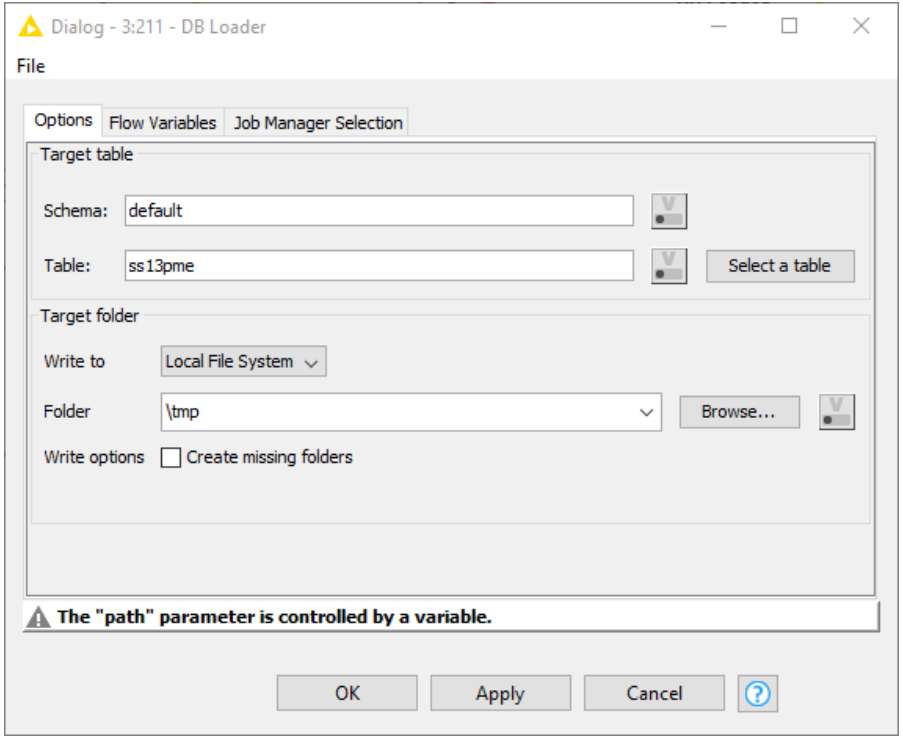


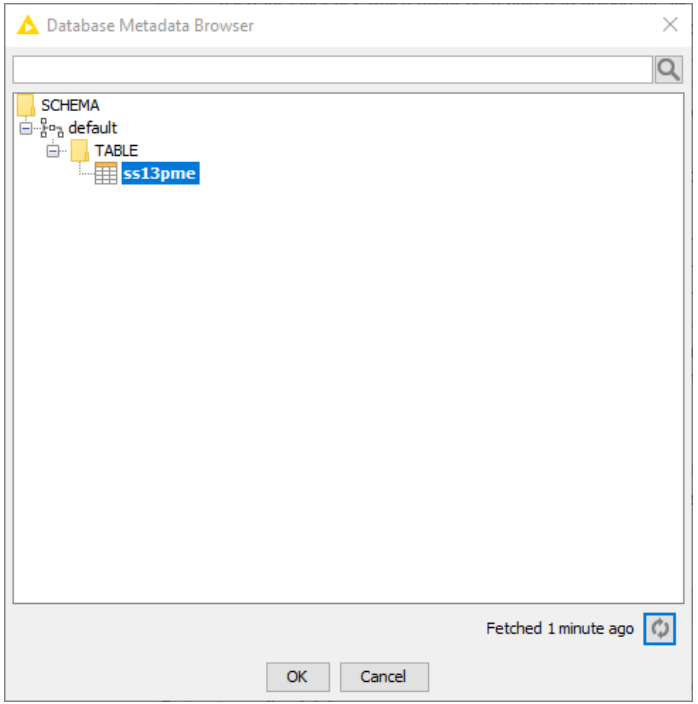
Loading Data into Hive/Impala

- Connectors are from KNIME Big Data Connectors Extension
- Use DB Table Creator and DB Loader from regular DB framework

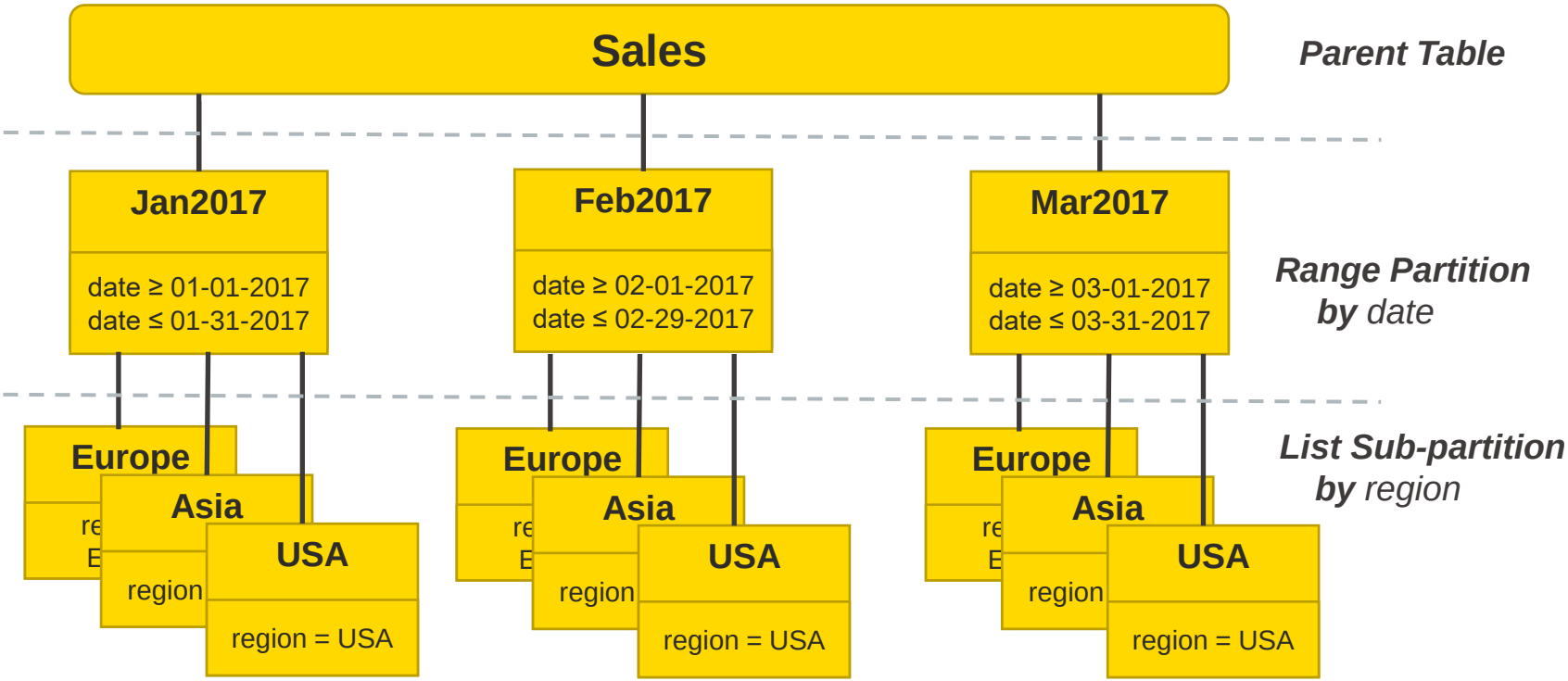


DB Loader





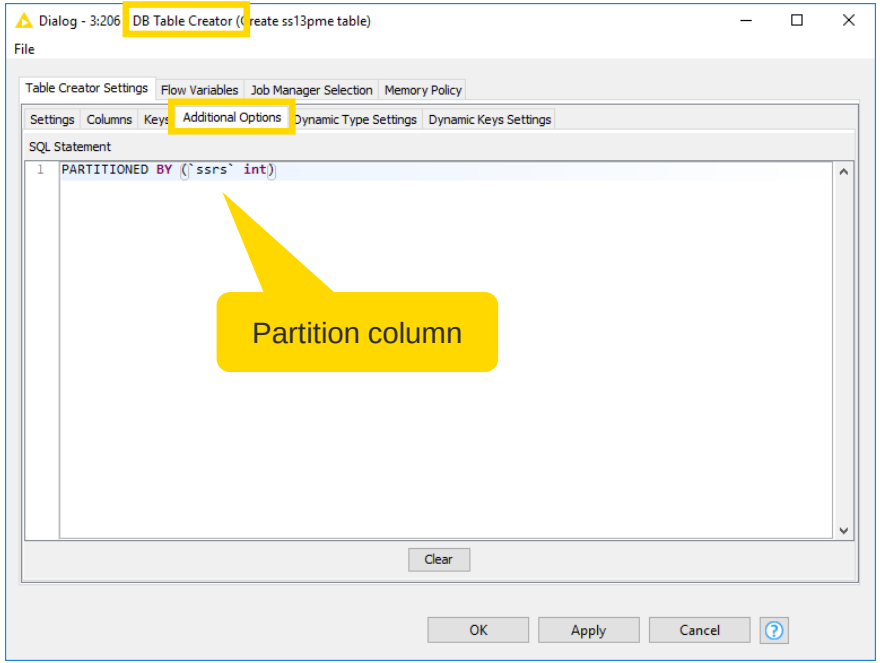
Hive Partitioning



Partitioning

About partition columns:

- Optional (!) performance optimization
- Use columns that are often used in WHERE clauses
- Use only categorical columns with suitable value range, i.e. not too few distinct values (e.g. 2) and not too many distinct values (e.g. 10 million)
- Partition columns should not contain missing values

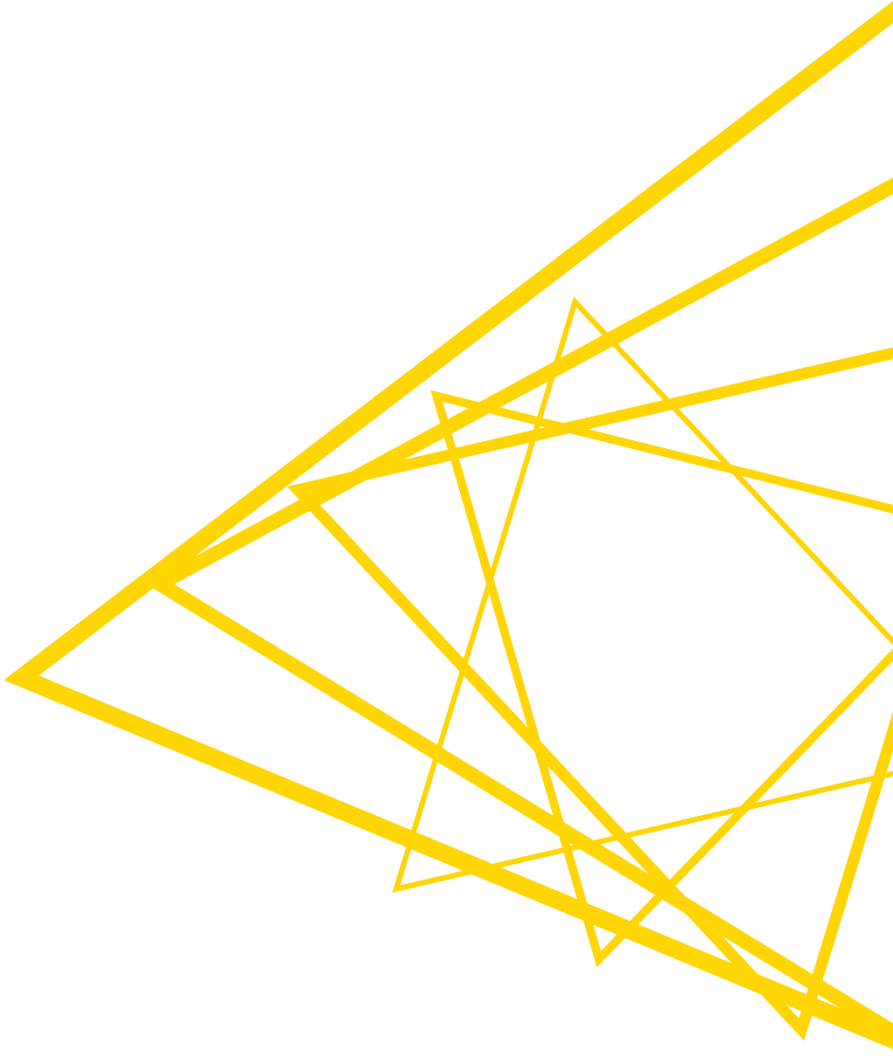


Section Exercise – 02_Hive_WritingToDB

Start from the workflow that implements the missing value strategy and write the results back into Hive. That is:

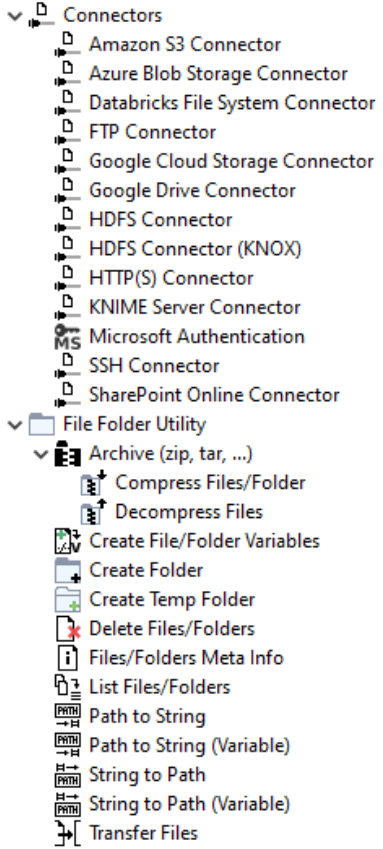
- write the results onto a new table named "newTable" in Hive using the HDFS Connection of the Local Big Data Environment along with both DB Table Creator and DB Loader nodes.

HDFS File Handling

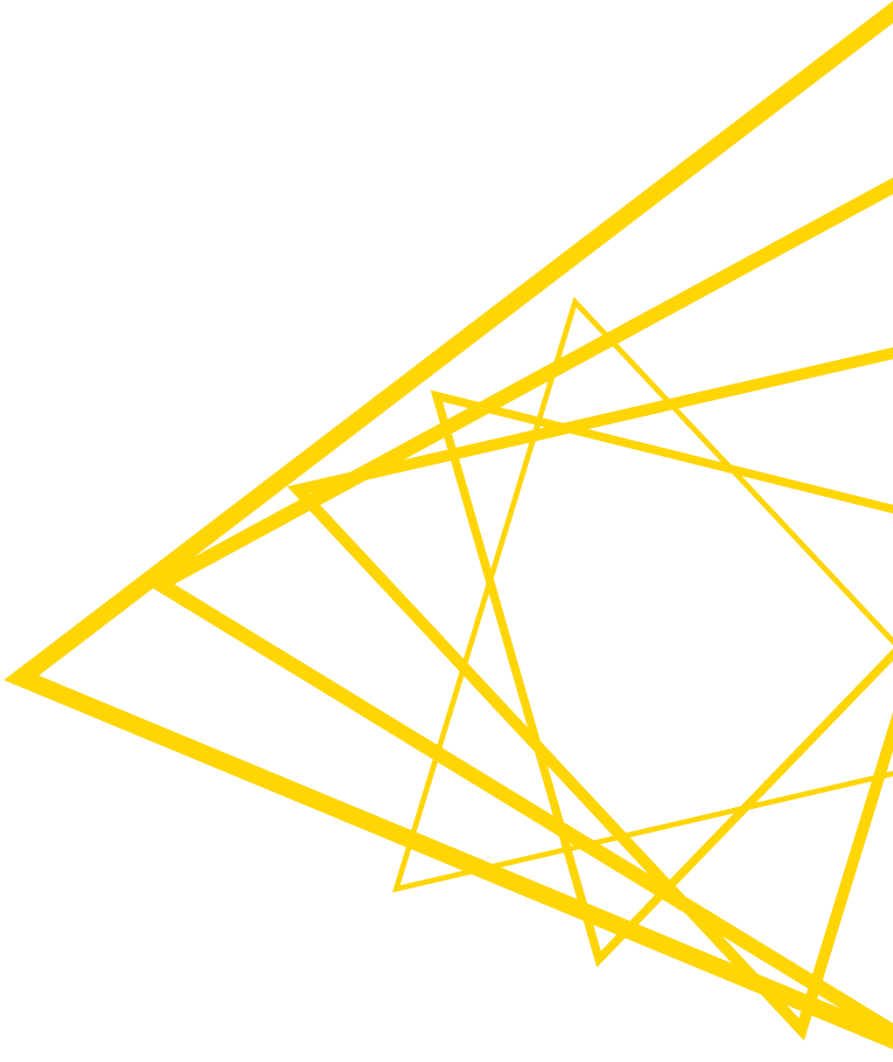


File Handling Nodes

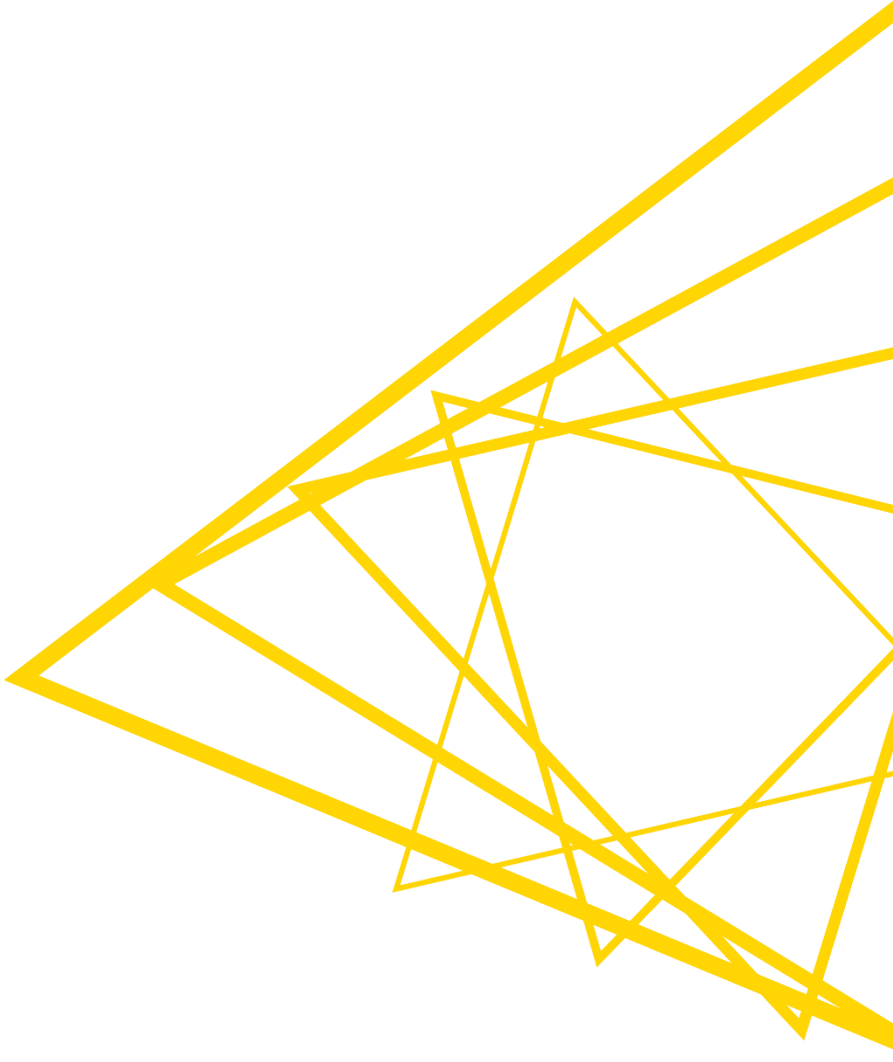
- Connection/Administration
  - HDFS Connection
  - HDFS File Permission
- Utilize the existing remote file handling nodes
  - Transfer Files
  - Create Folders
  - Delete Files/Folders
  - Compress and Decompress
  - Full documentation available



Ready for Spark?



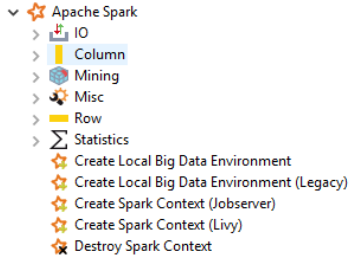
KNIME Extension for Apache Spark

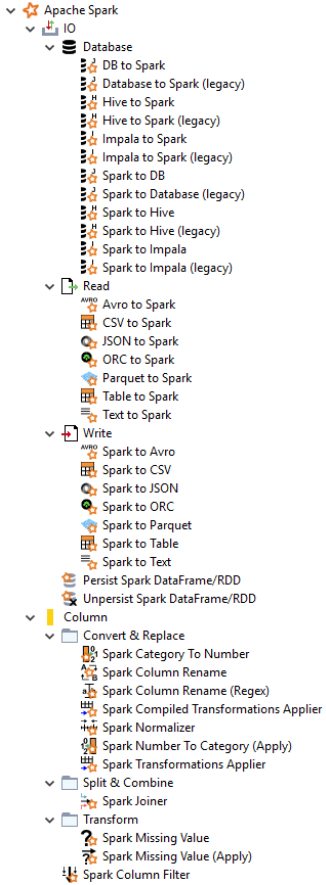


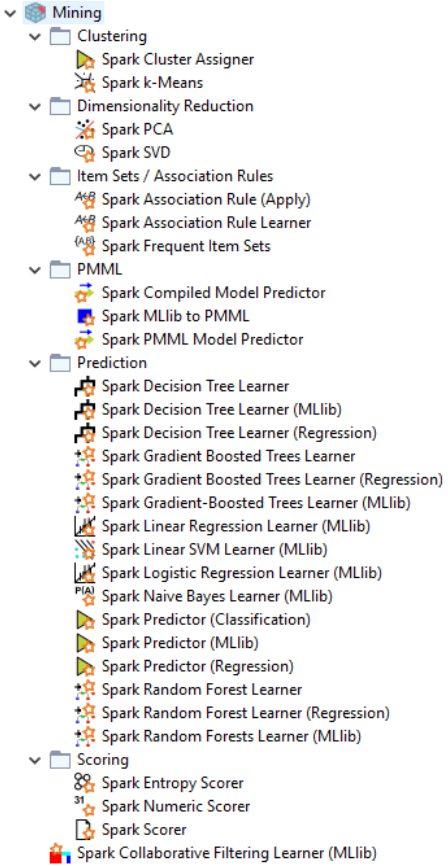
Spark: Machine Learning on Hadoop

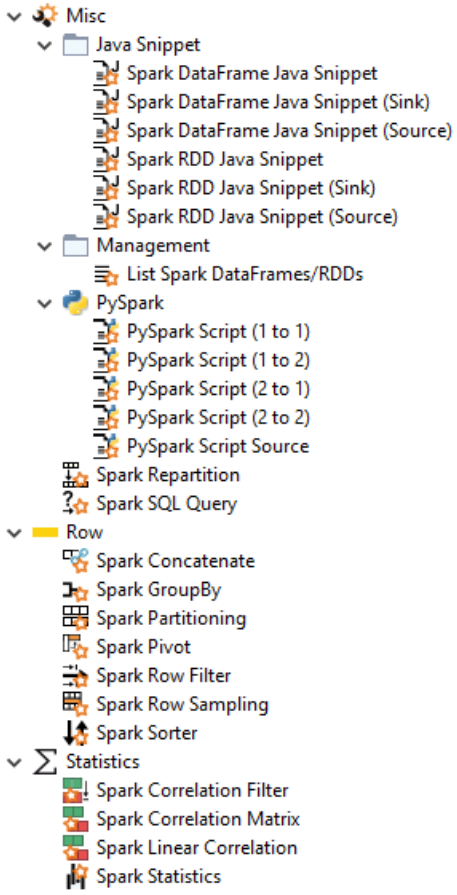
- Runs on Hadoop
- Supported Spark Versions
  - 1.2, 1.3, 1.5, 1.6, 2.x
- One KNIME extension for all Spark versions
- Scalable machine learning library (Spark MLlib and spark.ml)
- Algorithms for
  - Classification (decision tree, naïve Bayes, logistic regression, …)
  - Regression (linear regression, …)
  - Clustering (k-means)
  - Collaborative filtering (ALS)
  - Dimensionality reduction (SVD, PCA)
  - Item sets / Association rules

Spark Integration in KNIME







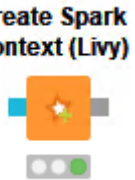


Spark Contexts: Creating

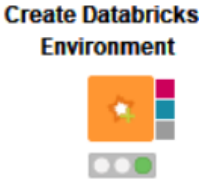
Three nodes to create a Spark context:

- Create Local Big Data Environment
  - Runs Spark locally on your machine (no cluster required)
  - Good for workflow prototyping

- Create Spark Context (Livy)
  - Requires a cluster that provides the Livy service
  - Good for production use

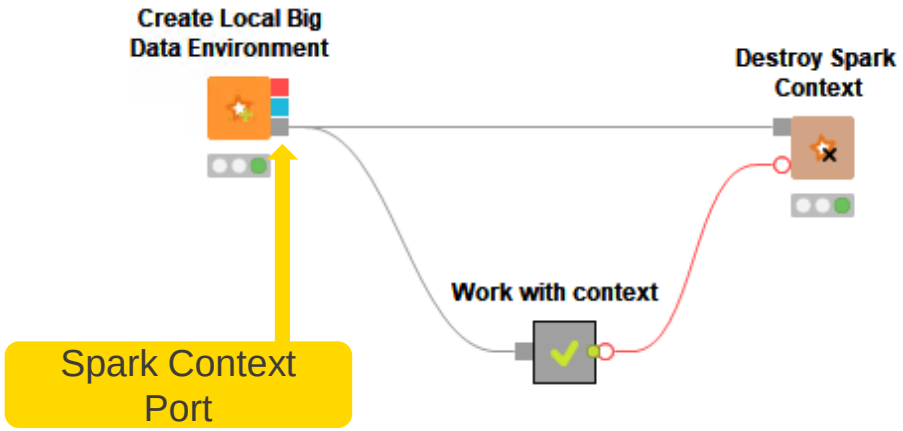


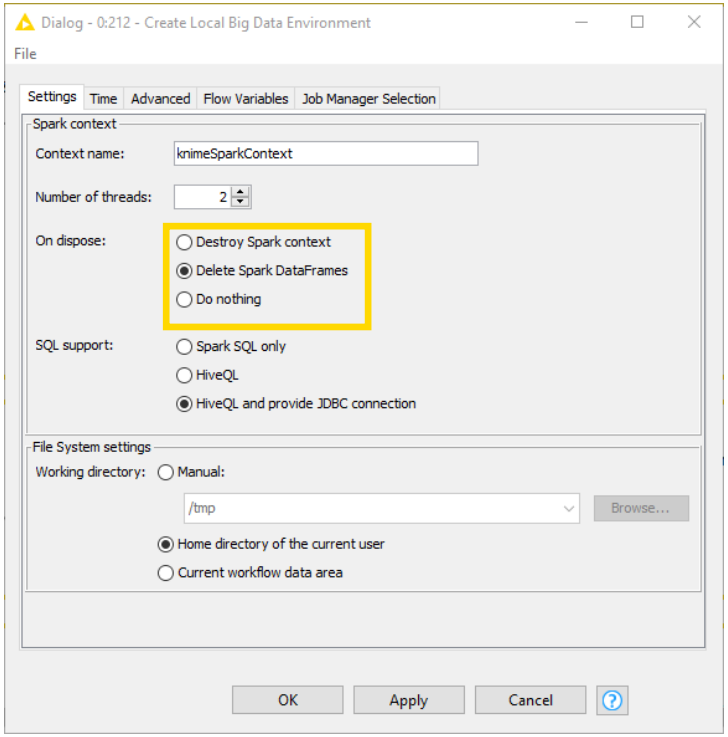
- Create Databricks Environment
  - Runs Spark on a remote Databricks cluster
  - Good for large-scale production use



Spark Contexts: Using, Destroying

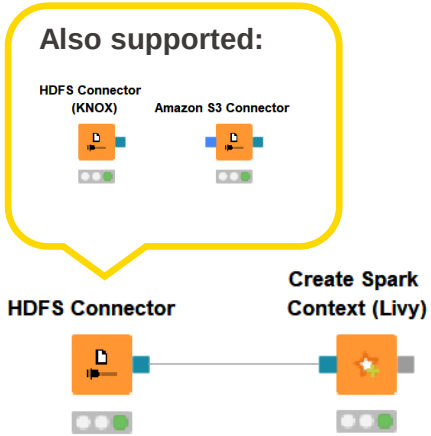
- Spark Context port is required by all Spark nodes
- Destroying a Spark Context destroys all Spark DataFrames within the context

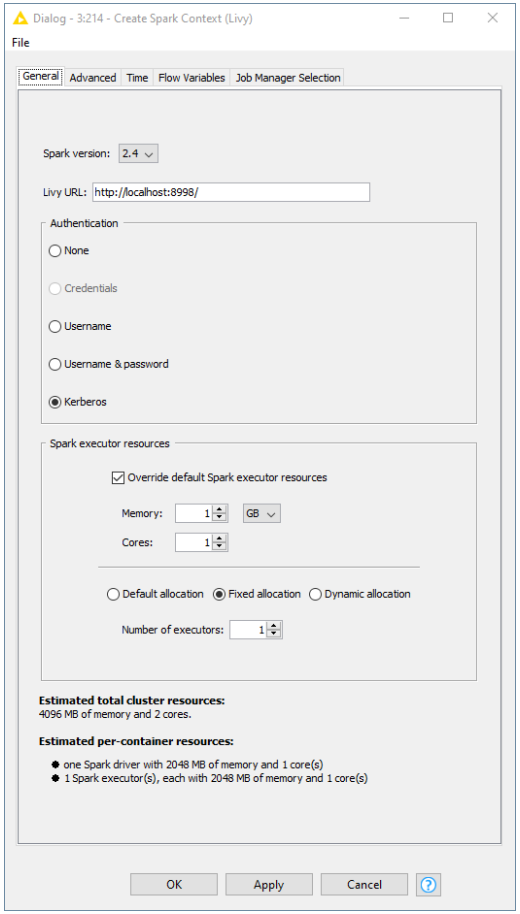




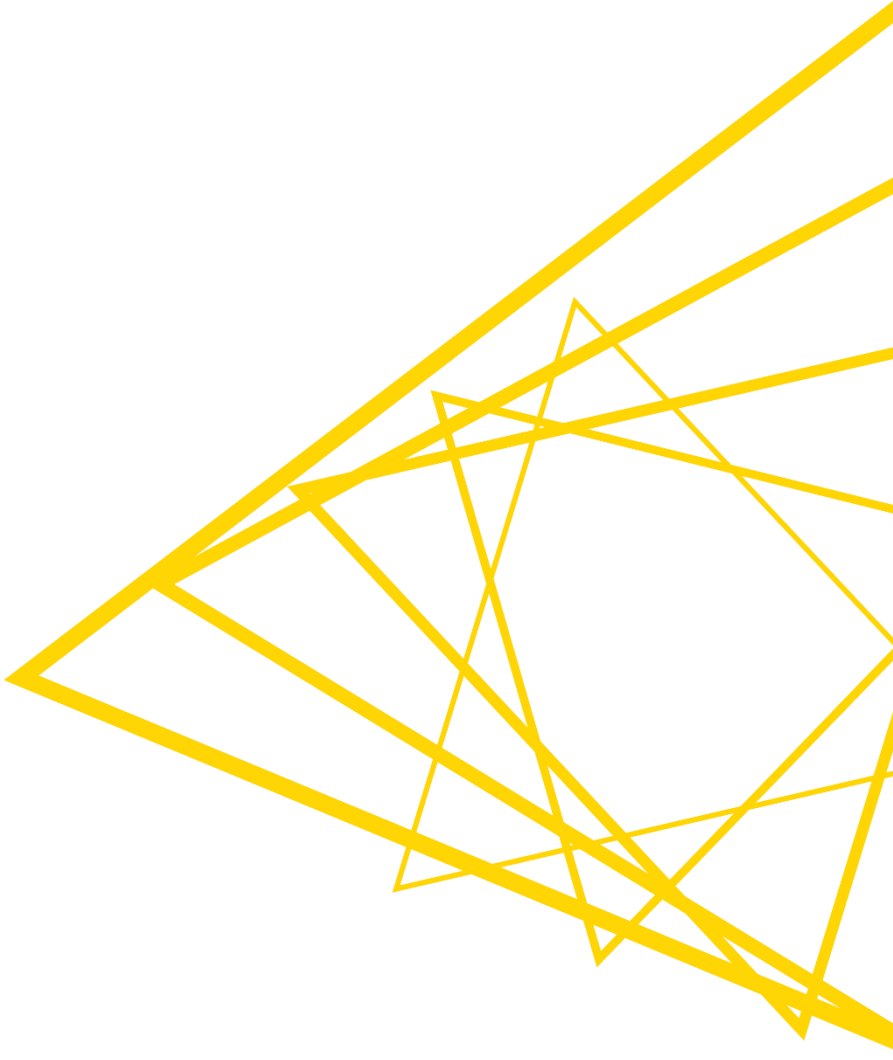
Create Spark Context (Livy)

- Allows to use Spark nodes on clusters with Apache Livy
- Out-of-the-box compatibility with:
  - Hortonworks (v2.6.3 and higher)
  - Amazon EMR (v5.9.0 and higher)
  - Azure HDInsight (v3.6 and higher)

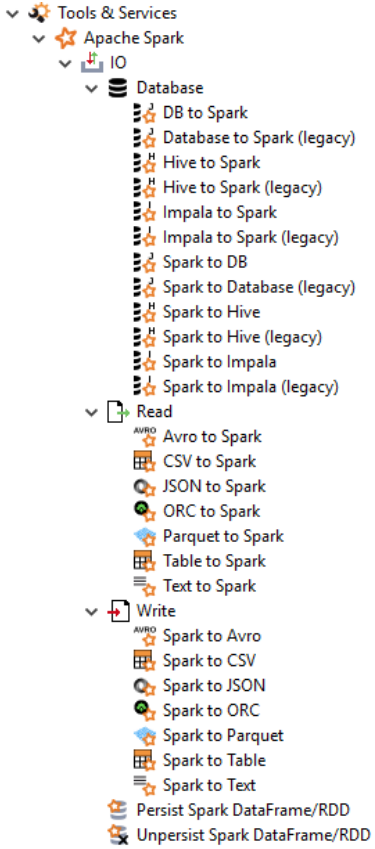




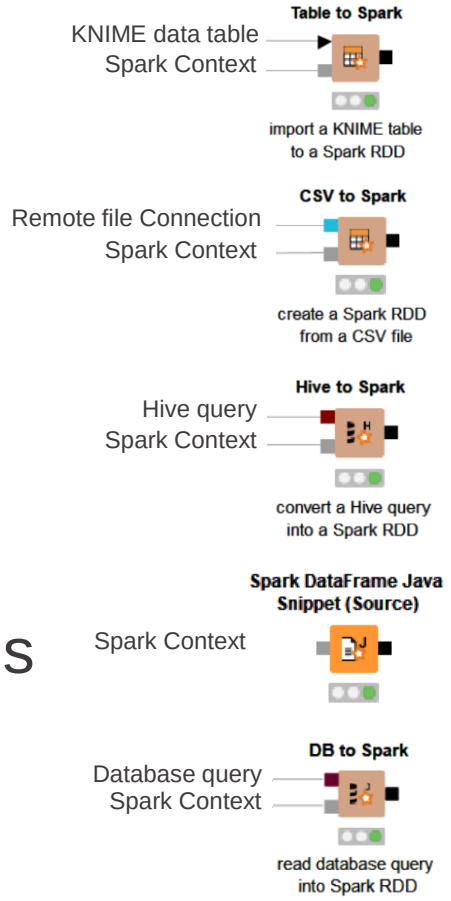
Import Data from KNIME or Hadoop



Import Data to Spark



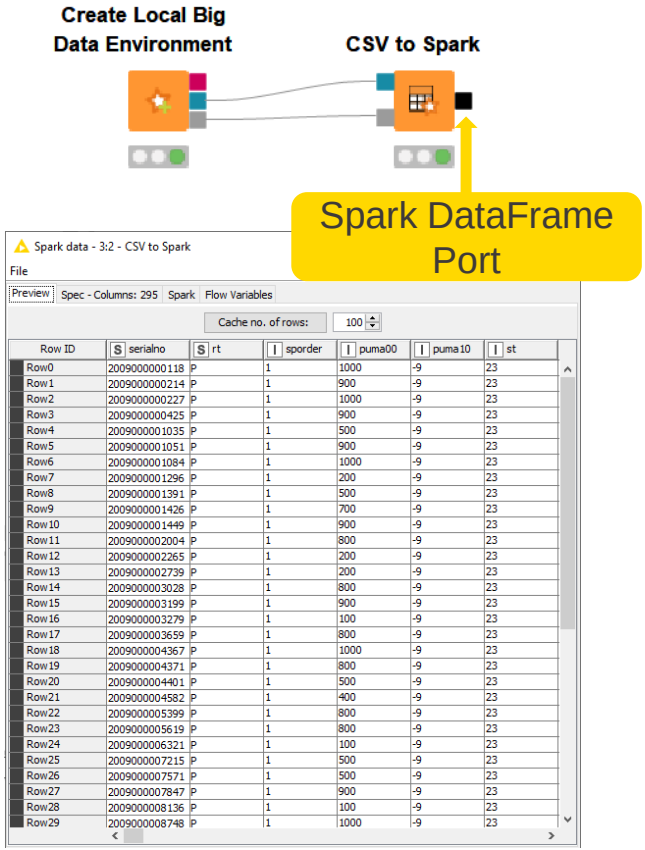
- From KNIME
- From CSV file in HDFS
- From Hive
- From other sources
- From Database



Open for Innovation KNIME

Spark DataFrame Ports

- Spark DataFrame port *points to* a DataFrame in Spark cluster
- Data stays within Spark
  - Output port provides data preview and column information
- Reminder: Lazy Evaluation
  - A green node status does not always mean that computation has been performed!



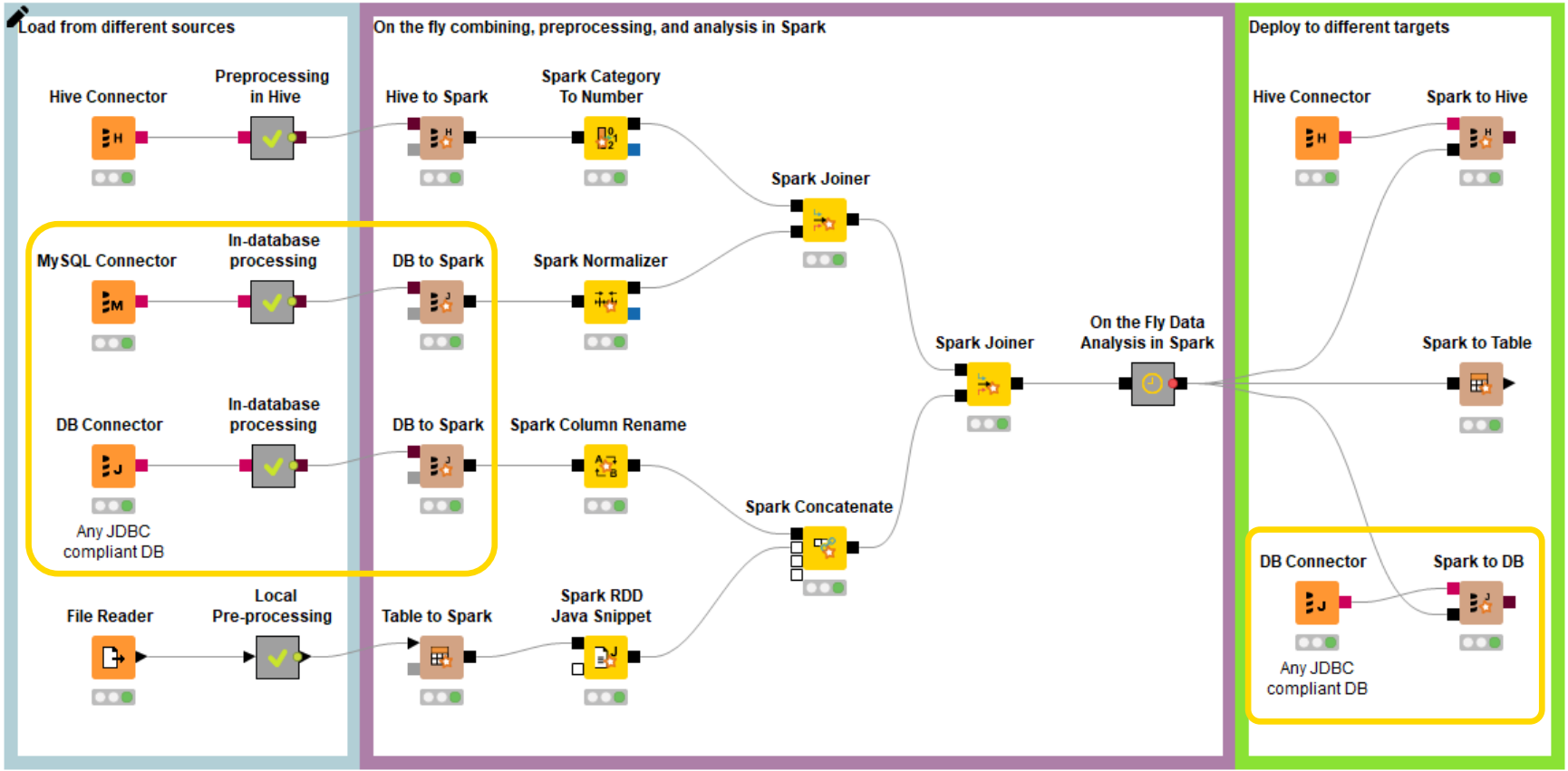
Row ID	serialno	rt	sporder	puma00	puma10	st
Row0	2009000000118	P	1	1000	-9	23
Row1	2009000000214	P	1	900	-9	23
Row2	2009000000227	P	1	1000	-9	23
Row3	2009000000425	P	1	900	-9	23
Row4	2009000001035	P	1	500	-9	23
Row5	2009000001051	P	1	900	-9	23
Row6	2009000001084	P	1	1000	-9	23
Row7	2009000001296	P	1	200	-9	23
Row8	2009000001391	P	1	500	-9	23
Row9	2009000001426	P	1	700	-9	23
Row10	2009000001449	P	1	900	-9	23
Row11	2009000002004	P	1	800	-9	23
Row12	2009000002265	P	1	200	-9	23
Row13	2009000002739	P	1	200	-9	23
Row14	2009000003028	P	1	800	-9	23
Row15	2009000003199	P	1	900	-9	23
Row16	2009000003279	P	1	100	-9	23
Row17	2009000003659	P	1	800	-9	23
Row18	2009000004367	P	1	1000	-9	23
Row19	2009000004371	P	1	800	-9	23
Row20	2009000004401	P	1	500	-9	23
Row21	2009000004582	P	1	400	-9	23
Row22	2009000005399	P	1	800	-9	23
Row23	2009000005619	P	1	800	-9	23
Row24	2009000006321	P	1	100	-9	23
Row25	2009000007215	P	1	500	-9	23
Row26	2009000007571	P	1	500	-9	23
Row27	2009000007847	P	1	900	-9	23
Row28	2009000008136	P	1	100	-9	23
Row29	2009000008748	P	1	1000	-9	23

Section Exercise – 01_Spark_Connect

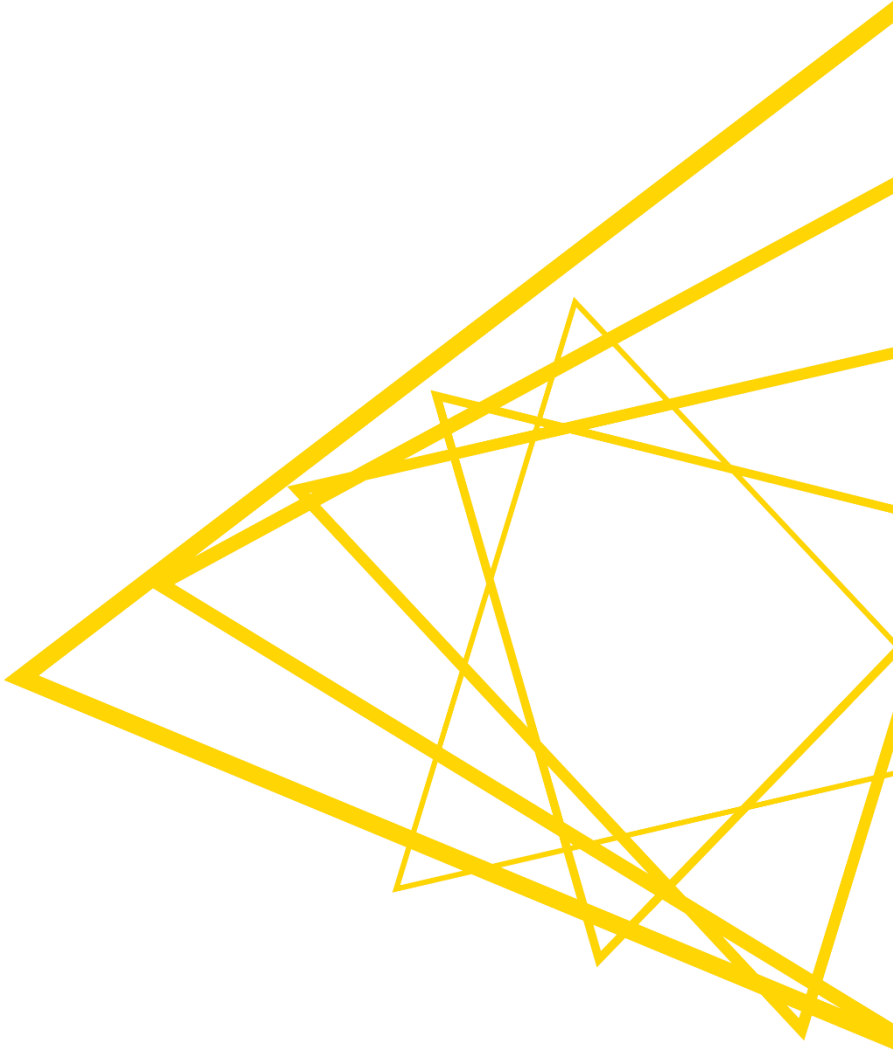
To do:

- Connect to Spark via the Create Local Big Data Environment node
- Import the ss13pme table from Hive into Spark

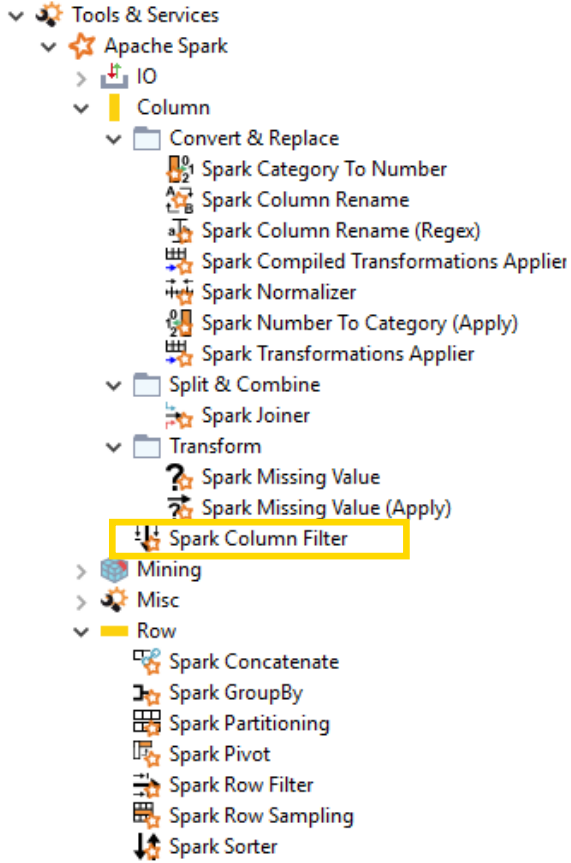
Virtual Data Warehouse

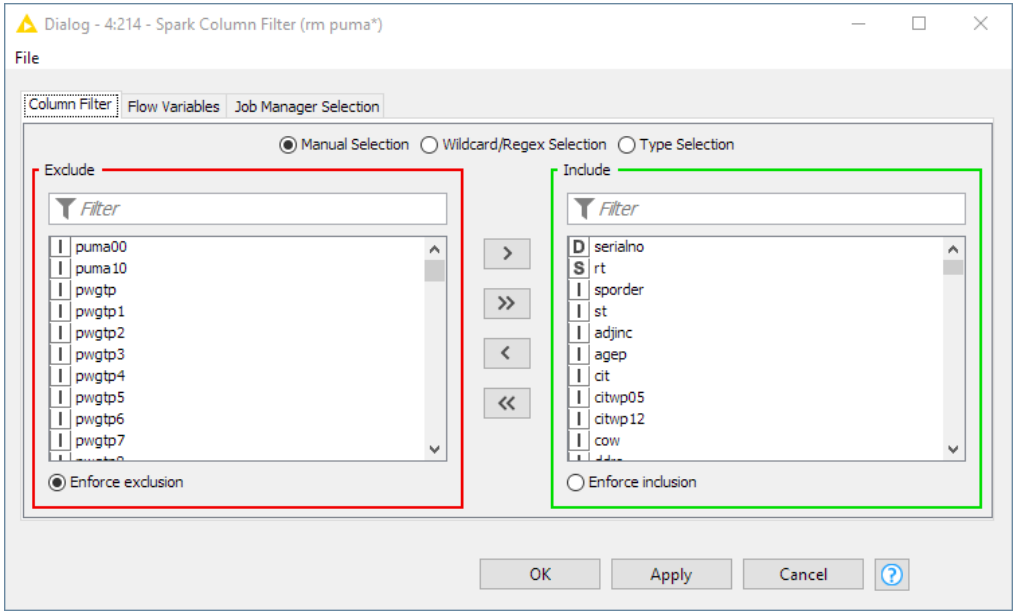


Pre-Processing with Spark

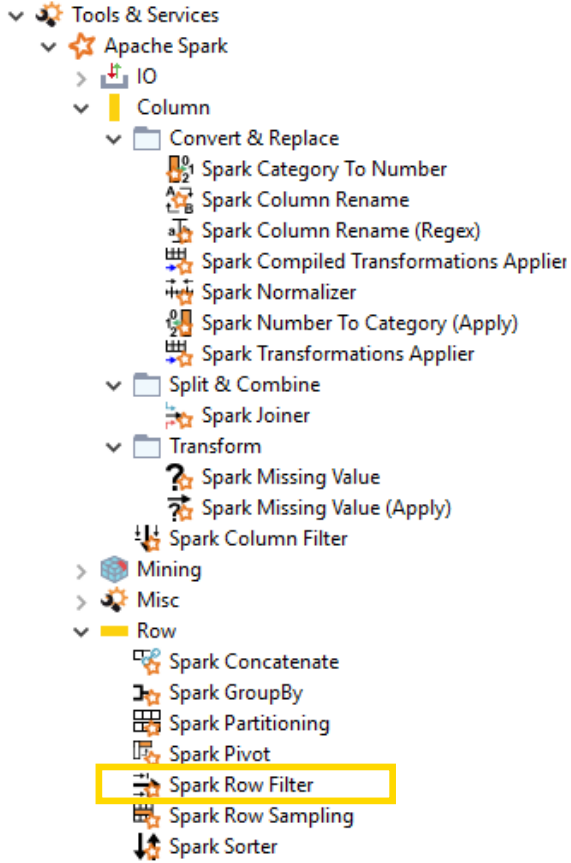


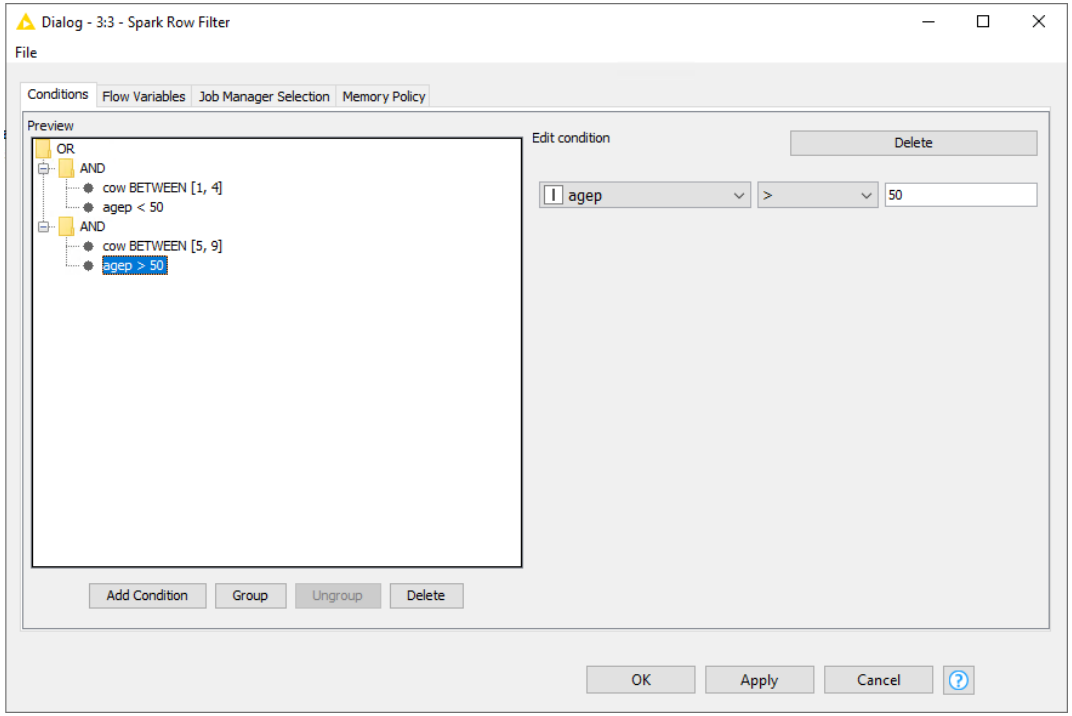
Spark Column Filter Node



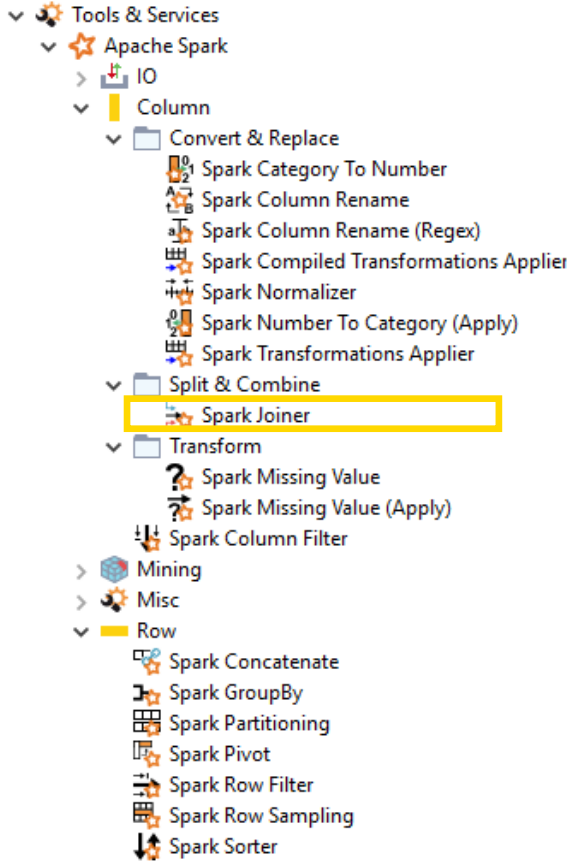


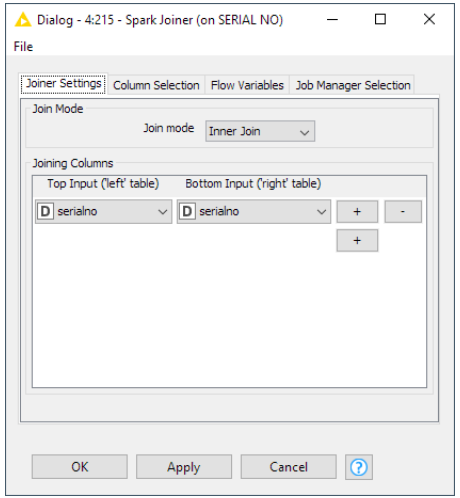
Spark Row Filter Node

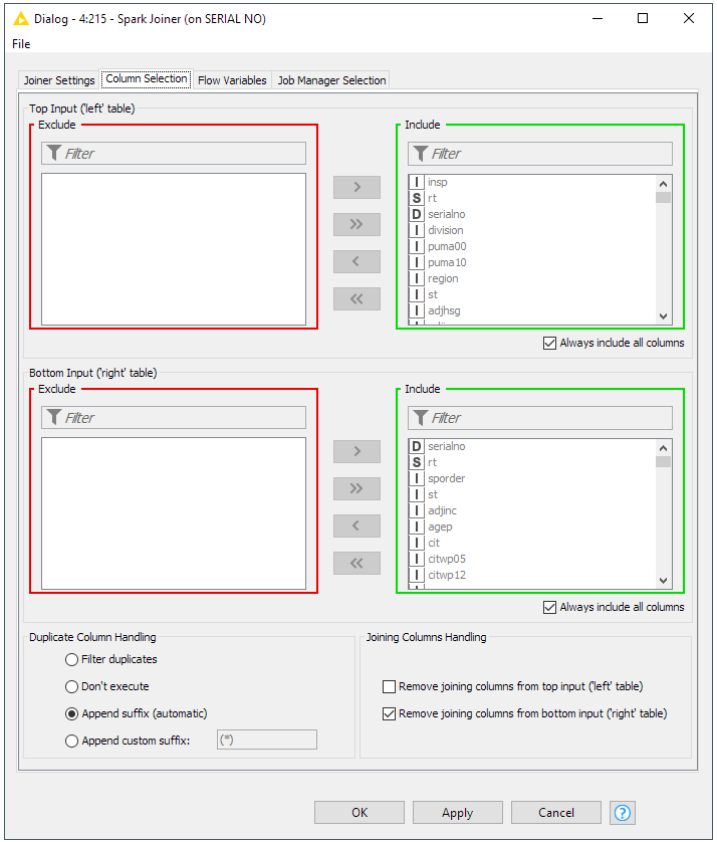




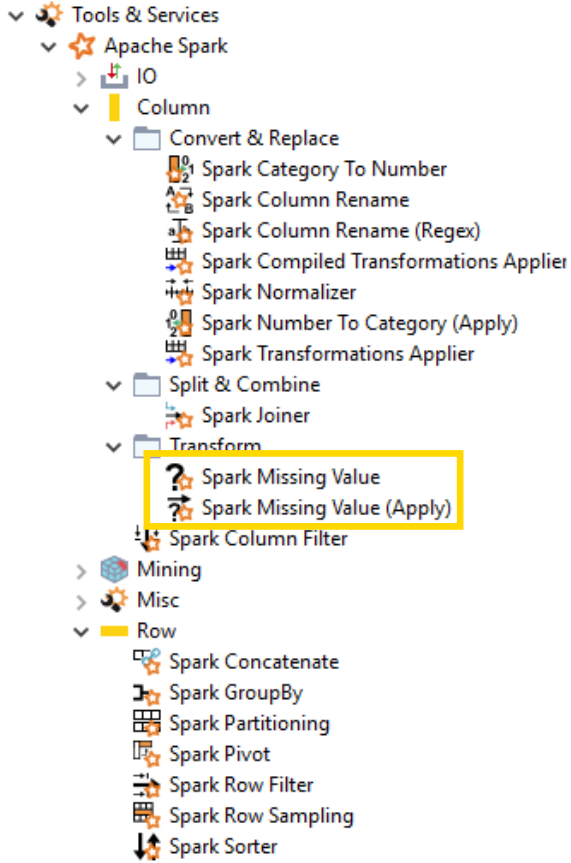
Spark Joiner Node

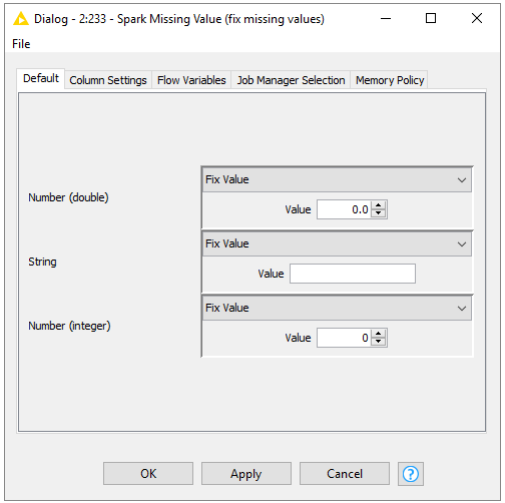


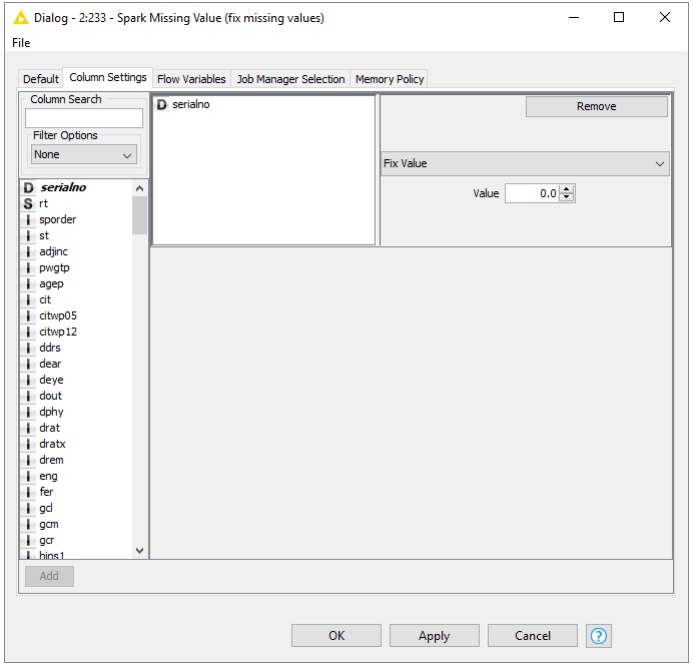




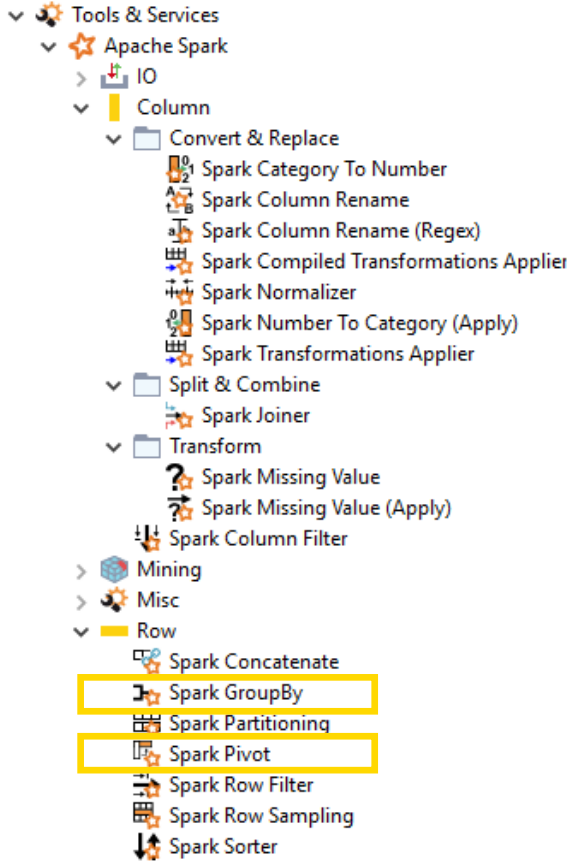
Spark Missing Value Node

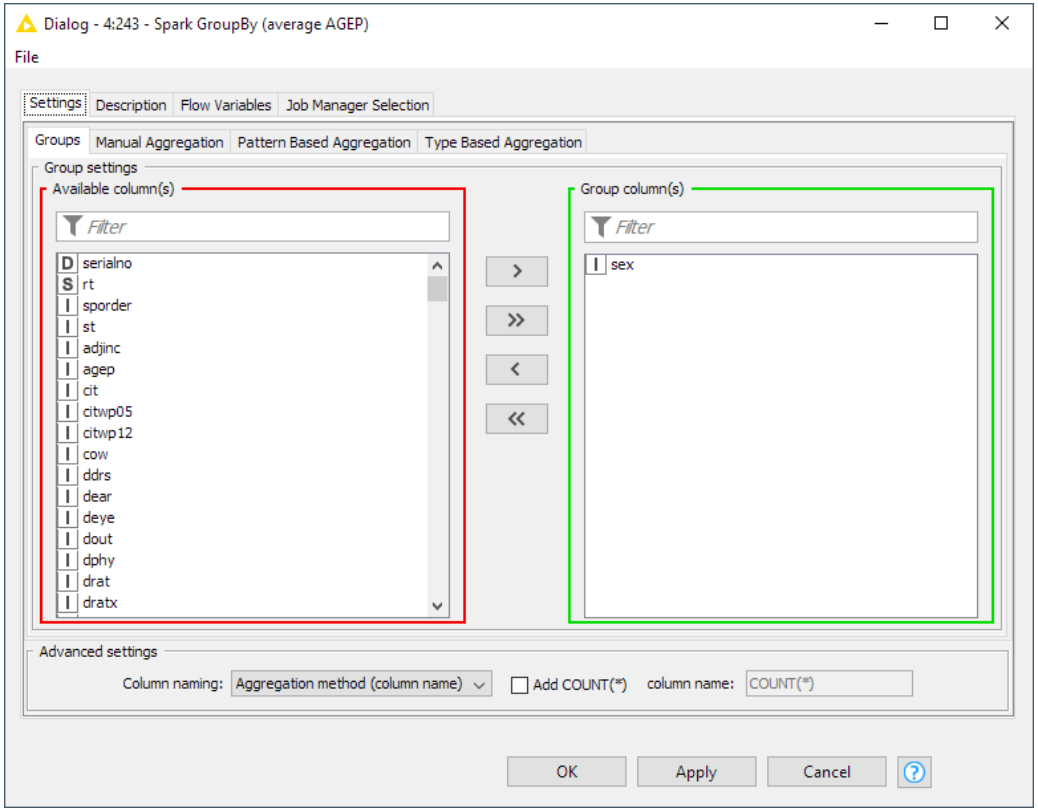




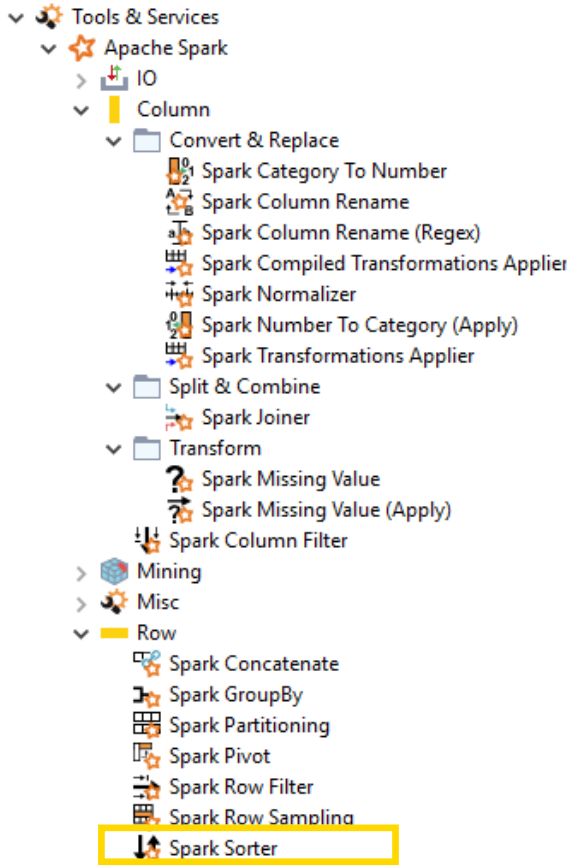


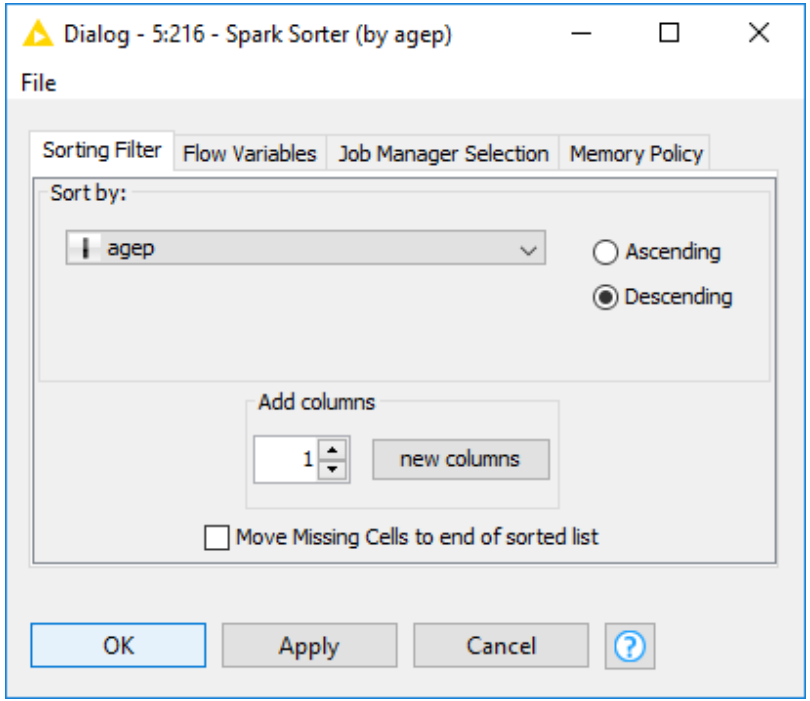
Spark GroupBy and Spark Pivot Nodes



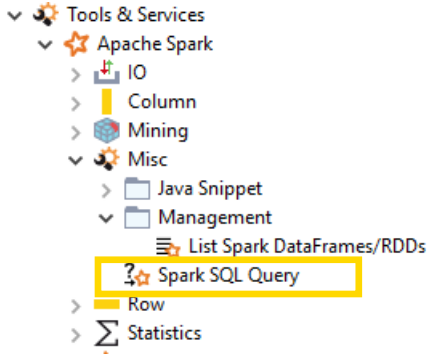


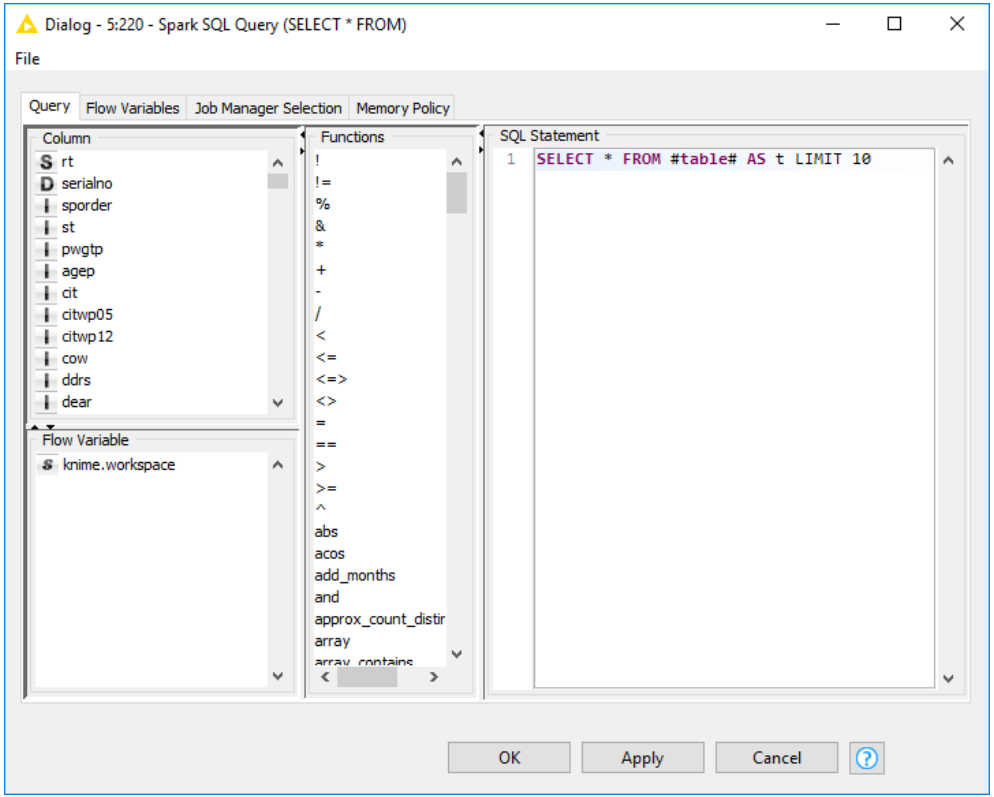
Spark Sorter Node





Spark SQL Query Node





Section Exercise – 02_Spark_Preprocessing

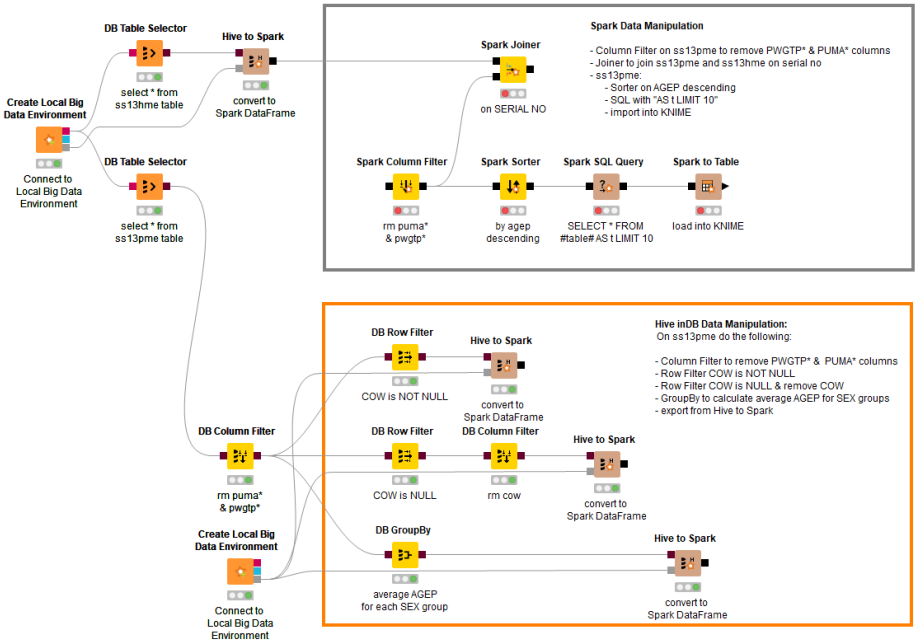
This exercise will demonstrate some data manipulation operations in Spark.
It initially imports the ss13pme and ss13hme tables from Hive.

To do:

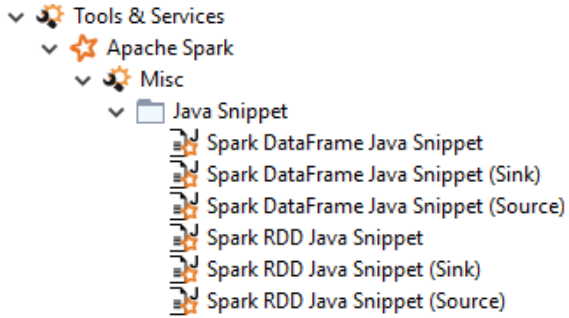
- Column Filter to remove PWGTP* and PUMA* columns
- Join with ss13hme on SERIAL NO
- Find rows with top ten AGEP in dataset and import them into KNIME
- Calculate average average AGEP per SEX group
- Split the dataset into two:
  - One where COW is null
  - One where COW is not null

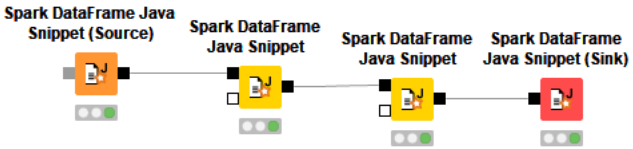
Mix & Match

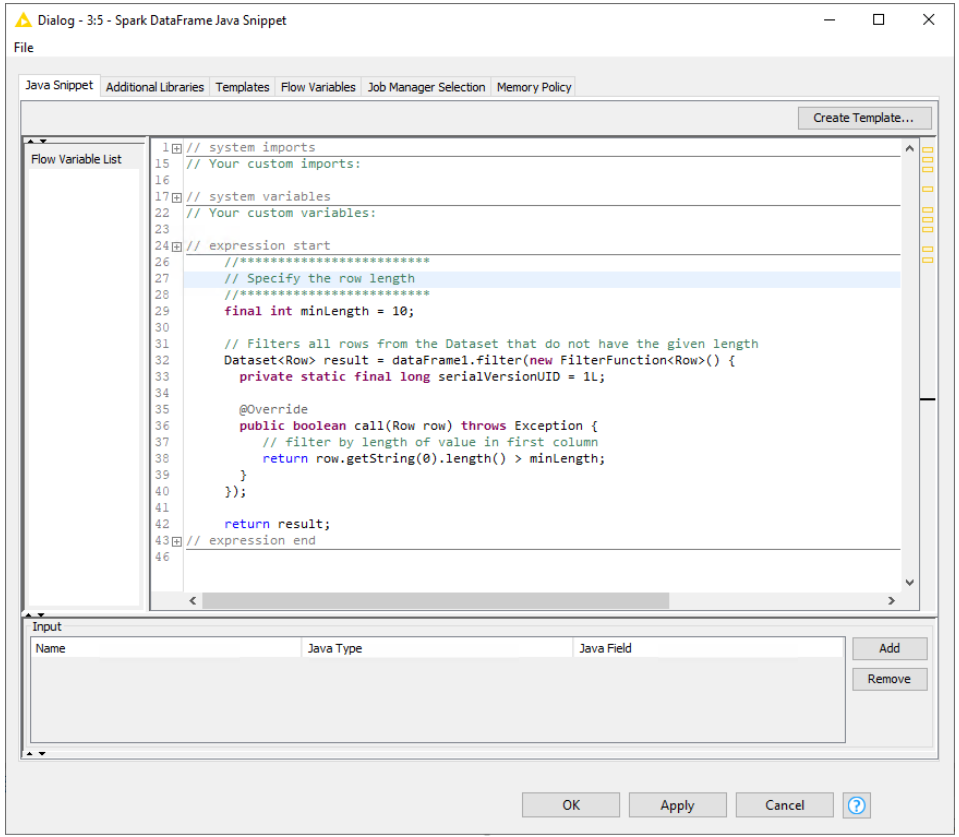
Thanks to the transferring nodes (Hive to Spark and Spark to Hive, Table to Spark and Spark to Table) you can mix and match in-database processing operations



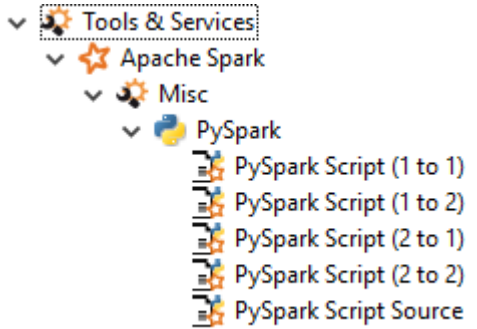
Modularize and Execute Your Own Spark Code: Java Snippets

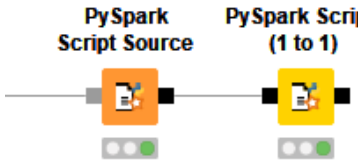


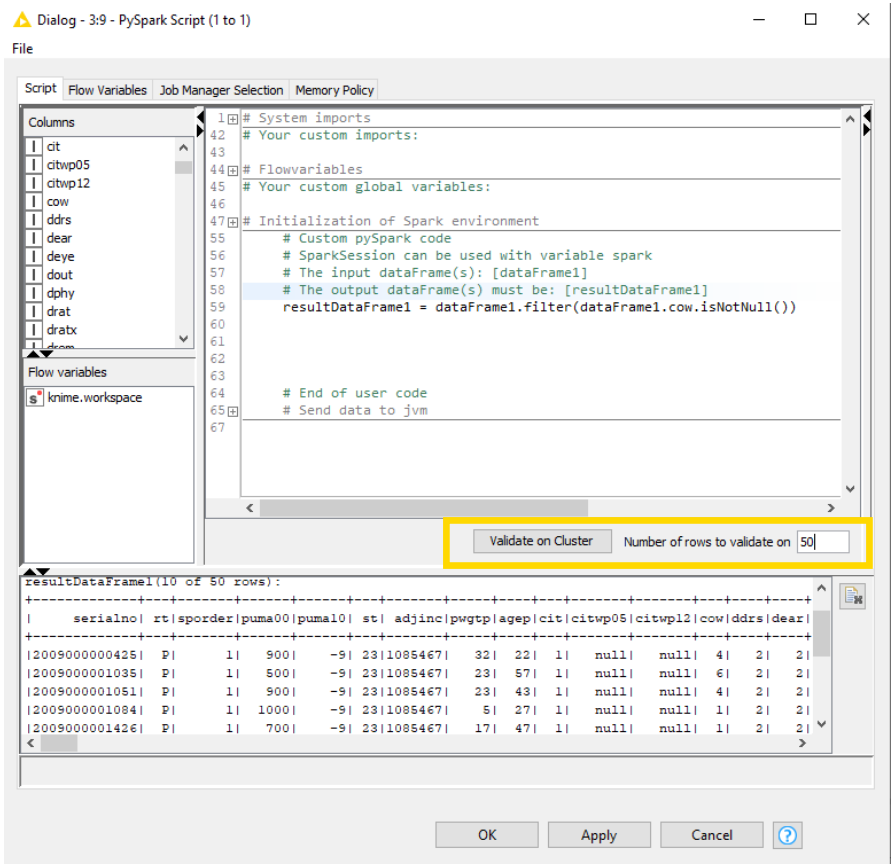




Modularize and Execute Your Own Spark Code: PySpark Script



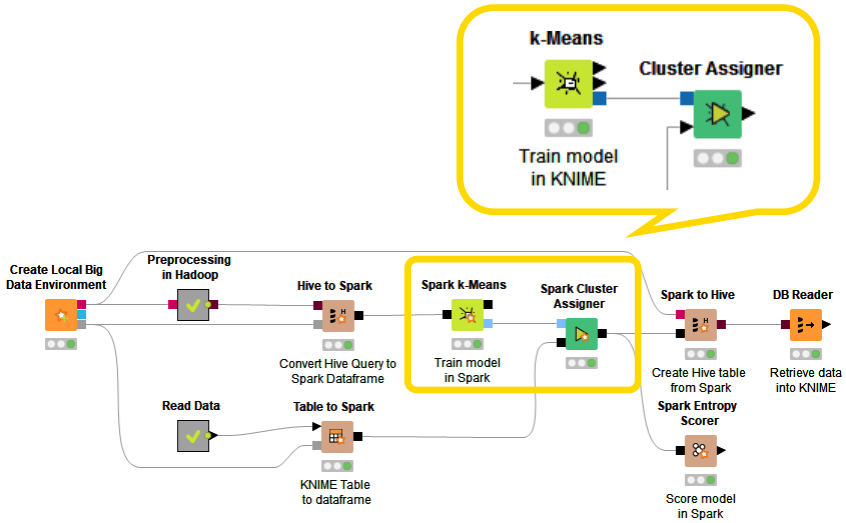


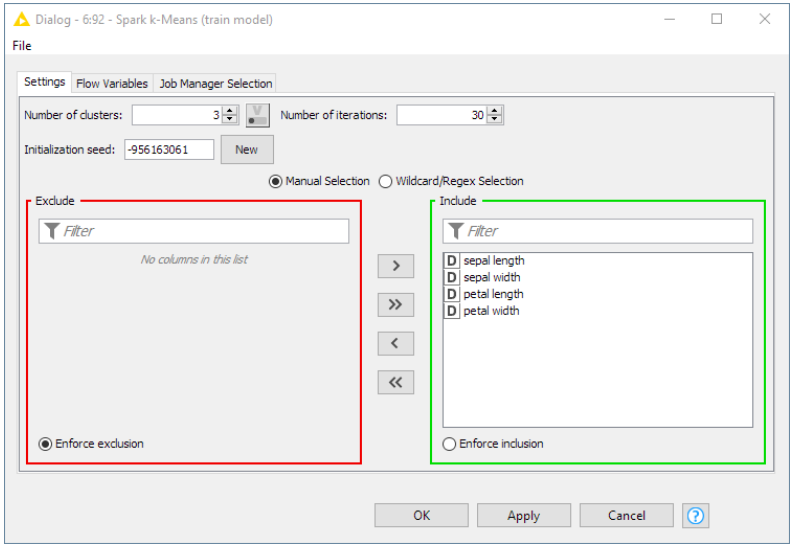


Machine Learning with Spark

MLlib Integration: Familiar Usage Model

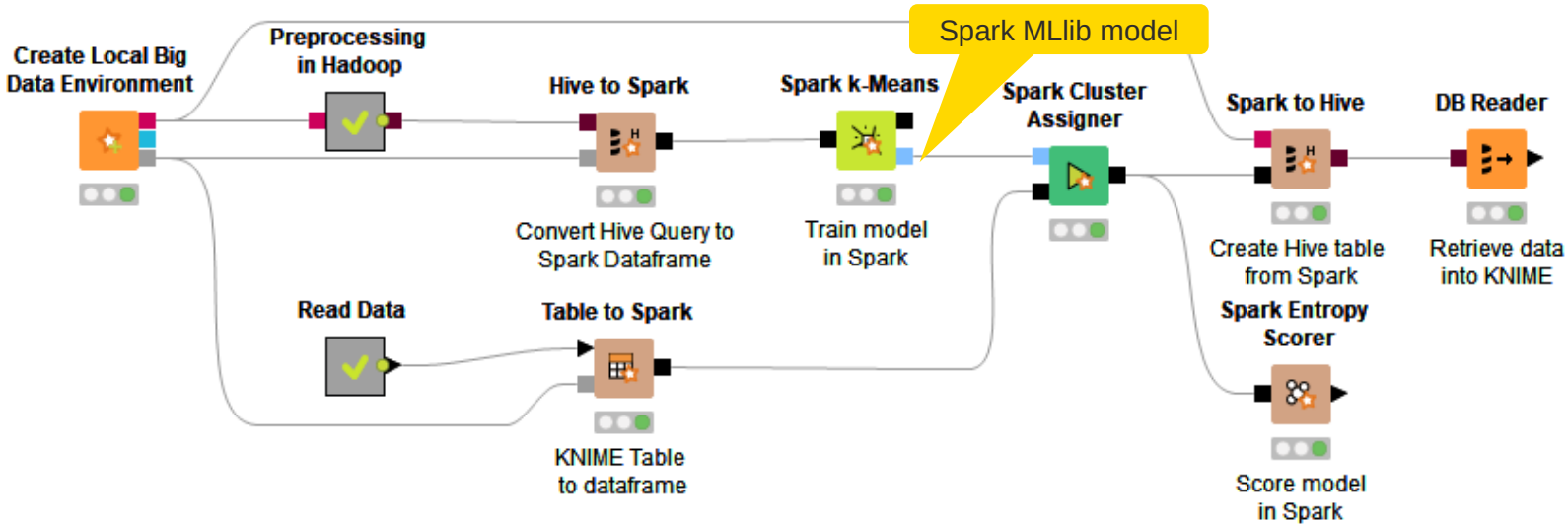
- Usage model and dialogs like existing nodes
- No coding required
- Various algorithms for classification, regression and clustering supported



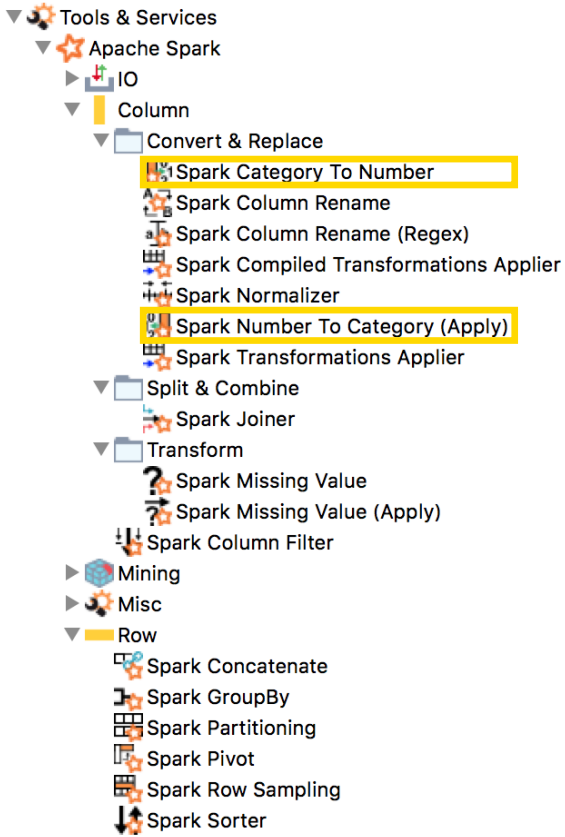


MLlib Integration: Spark MLlib Model Port

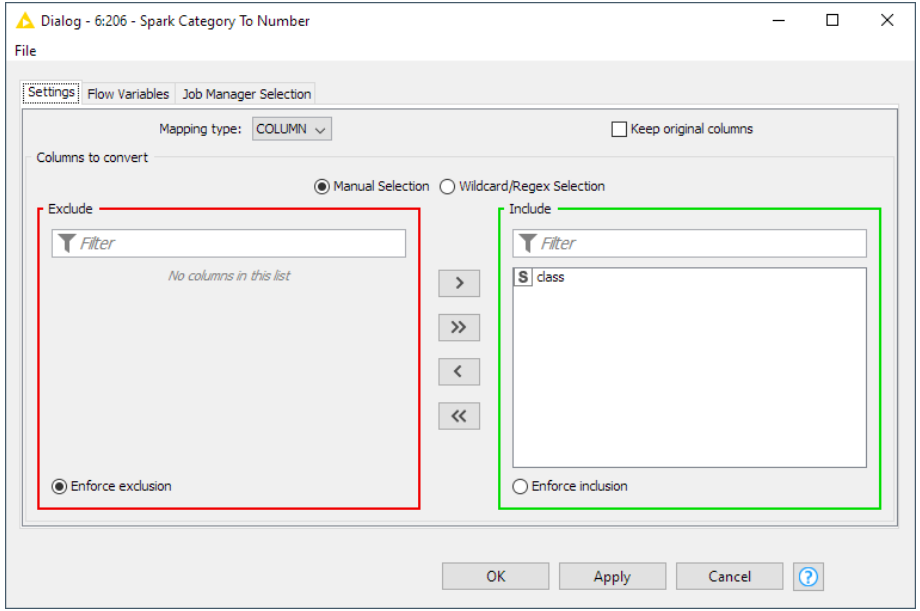
- MLlib model ports for model transfer
- Model ports provide more information about the model itself



MLlib Integration: Categorical features

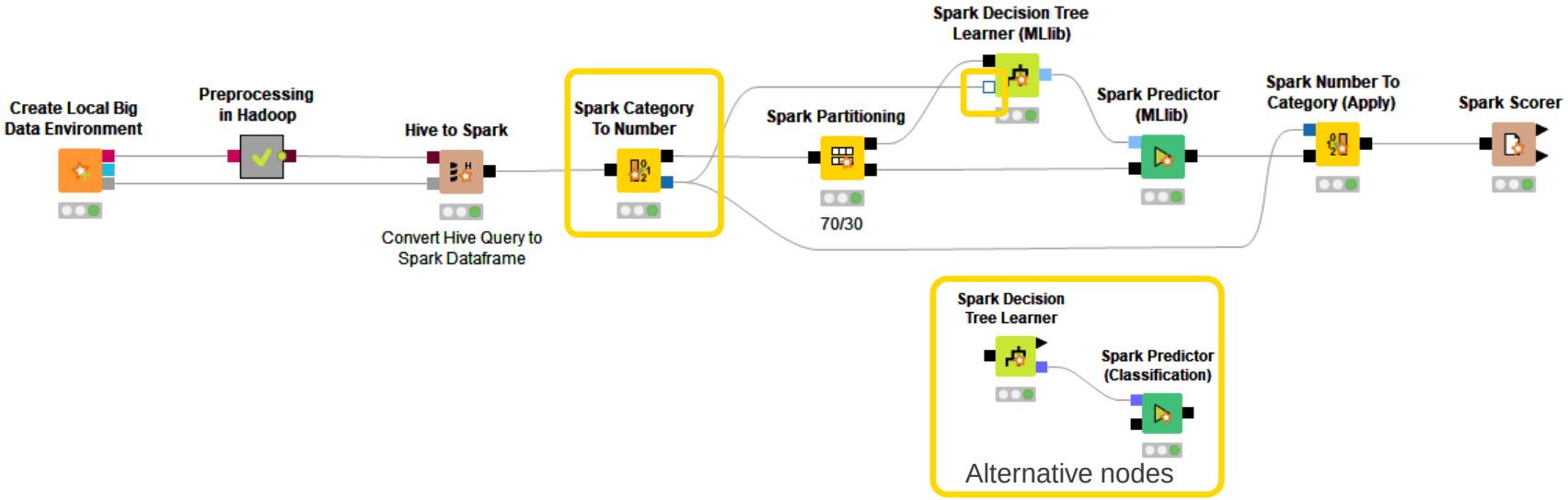


- MLLib learner nodes only support numeric features and labels
- String columns (with categorical values) need to be mapped to numeric first



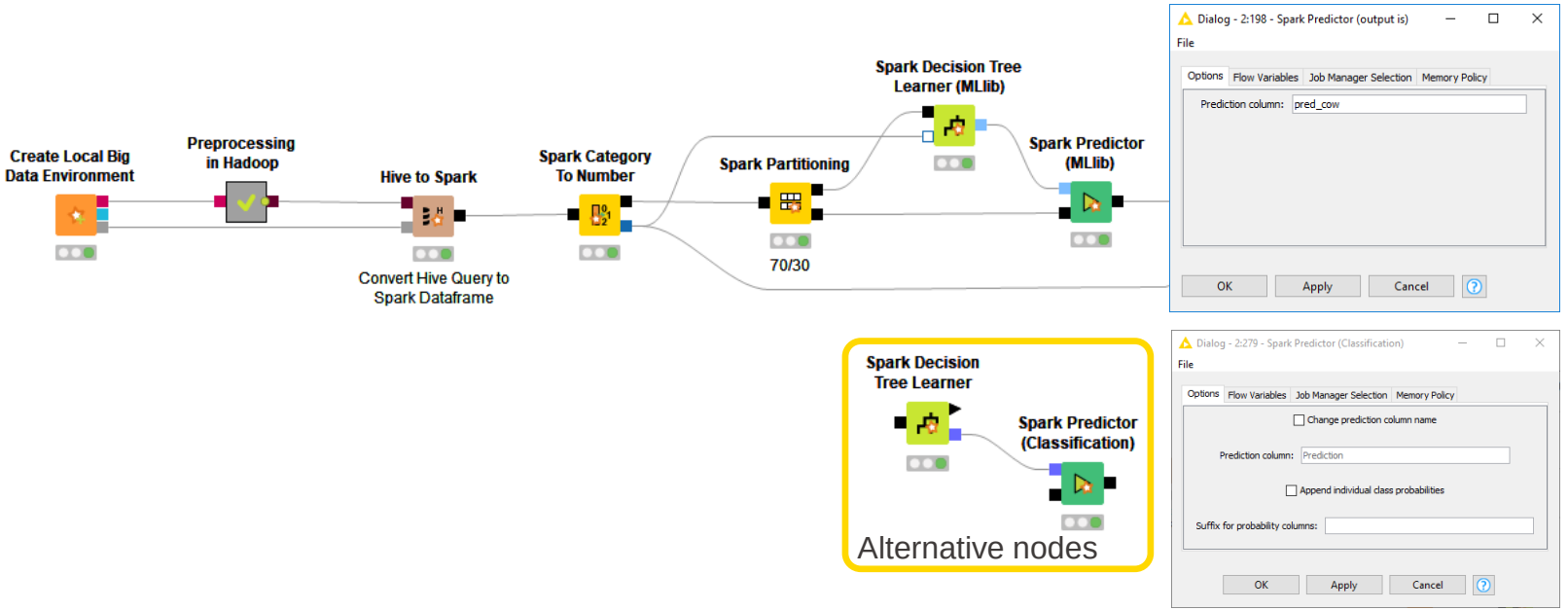
MLlib Integration: Categorical Values for Decision Tree Algorithms

- MLlib tree algorithms have optional PMML input port
  - If connected, hints to Decision Tree algorithm which numeric columns are categorical in nature
  - Improves performance in some cases



Spark Predictor Node

- Spark Predictor (Mllib) assigns labels based on an MLlib model
- Supports all **supervised** classification & regression MLlib models
- Spark.ml models have a separate learner/predictor



Section Exercise – 03_Spark_Modelling

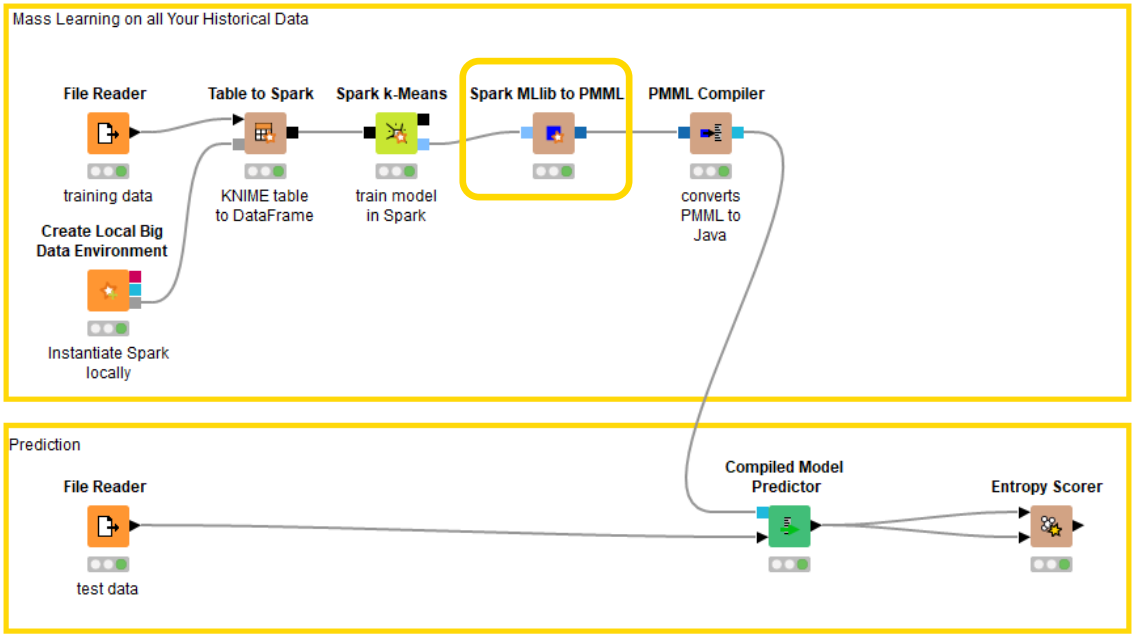
On the ss13pme table, the current workflow separates the rows where COW is null, from those where COW is not null, and then modifies COW to be zero-based.

To do:

- Where COW is not null:
  - Fix missing values in feature columns
  - Train a decision tree on COW on data rows
- Where COW is null:
  - Remove COW column
  - Apply the decision tree model to predict COW

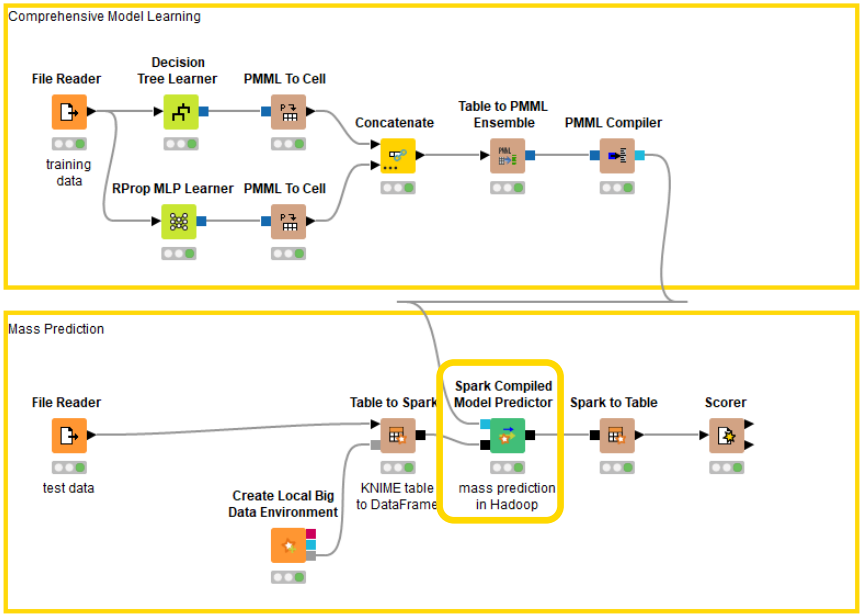
Mass Learning in Spark – Conversion to PMML

- Mass learning on Hadoop
- Convert supported MLlib models to PMML

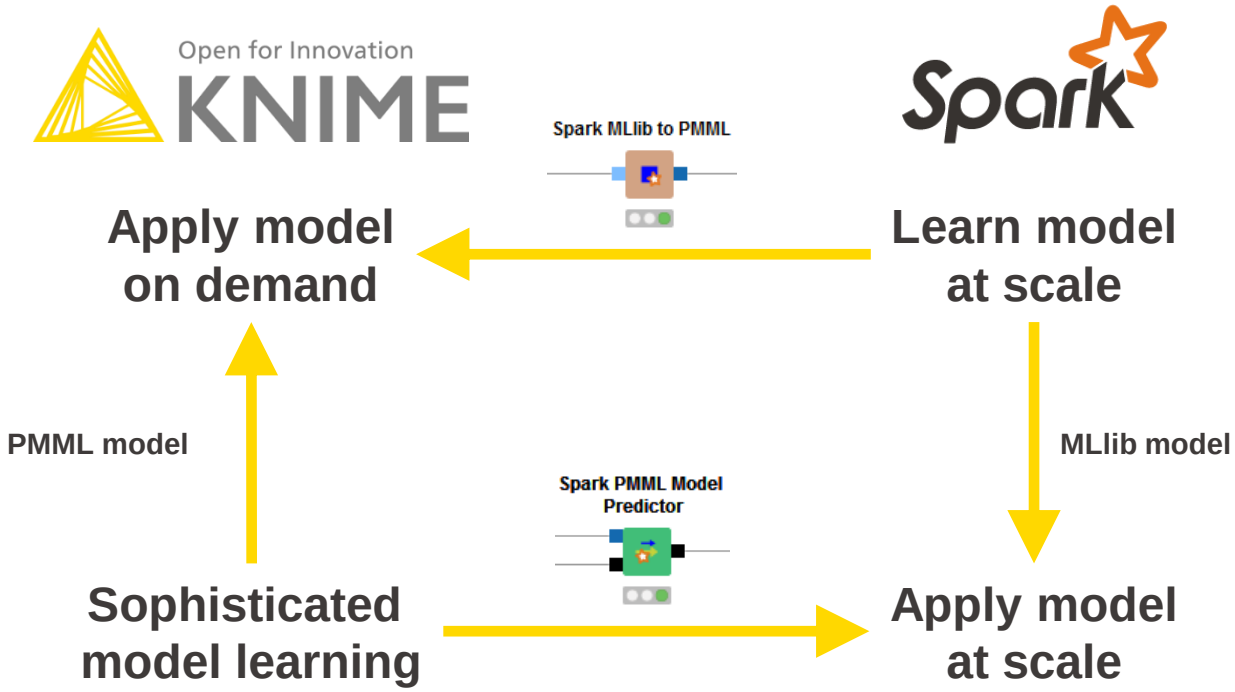


Sophisticated Model Learning in KNIME - Mass Prediction in Spark

- Supports KNIME models and pre-processing steps
- Sophisticated model learning in KNIME
- Mass prediction in Spark using Spark PMML Model Predictor

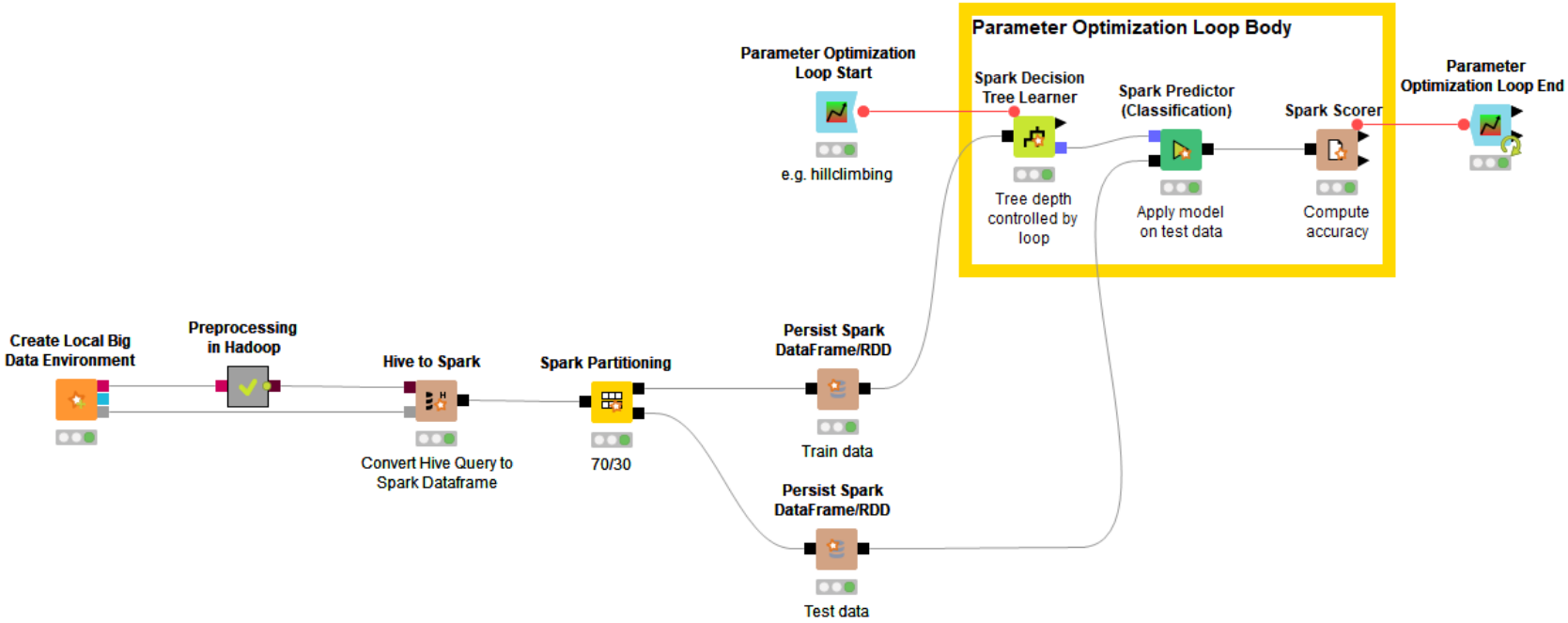


Closing the Loop

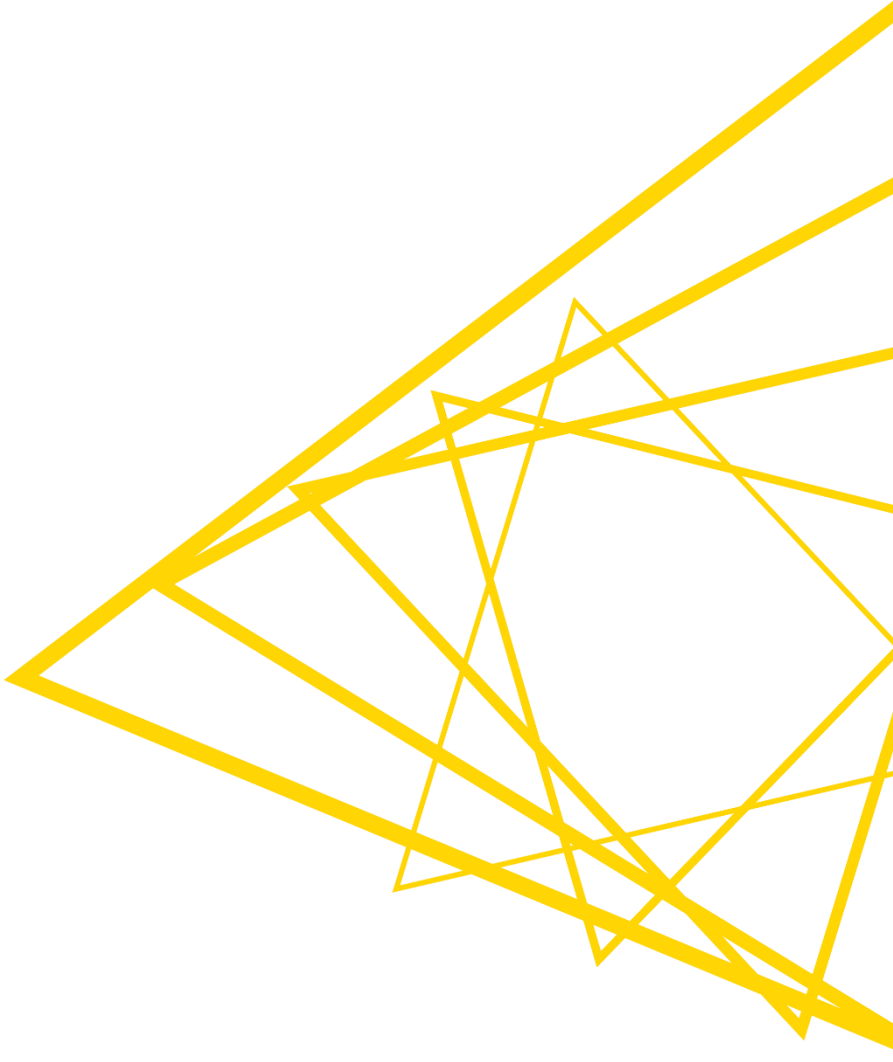


Mix and Match

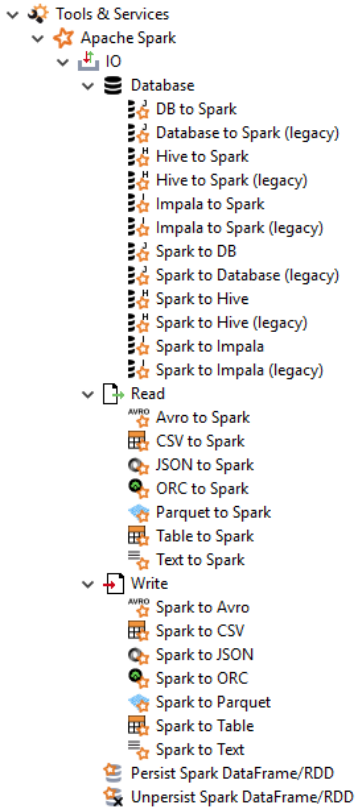
- KNIME <-> Hive <-> Spark



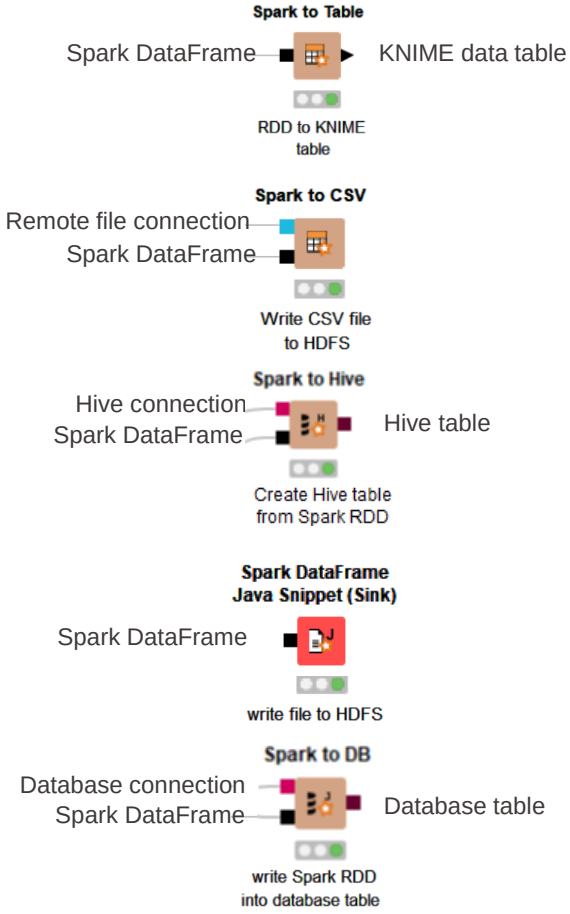
Export Data back into KNIME/Hadoop



Export Data from Spark



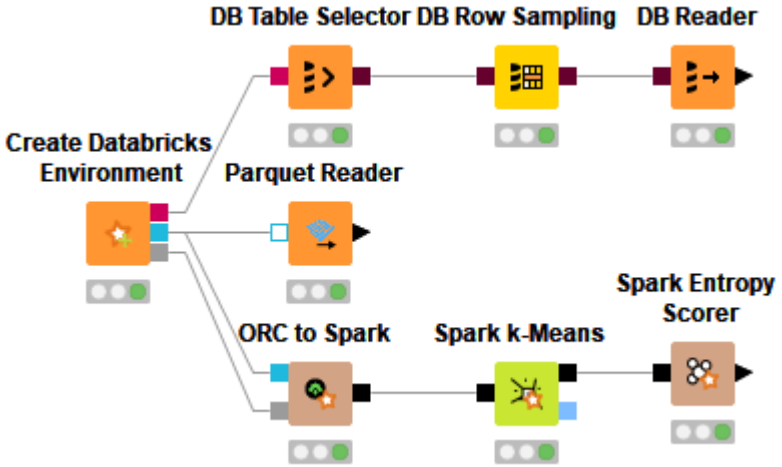
- To KNIME
- To CSV file in HDFS
- To Hive
- To Other Storages
- To Database



Open for Innovation KNIME

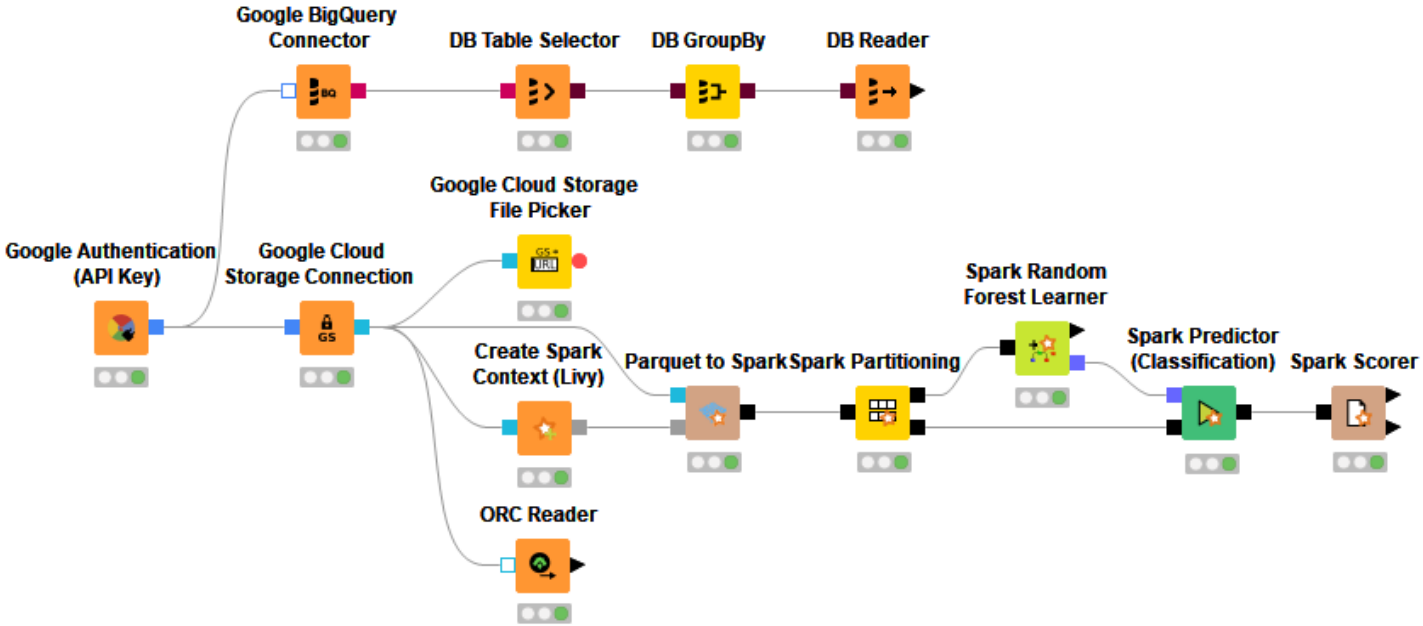
Cloud & Big Data Connectivity: Databricks

- Create Databricks Environment: connect to your Databricks cluster
  - Azure or AWS
- Databricks Delta, Databricks File System, or Apache Spark



Cloud & Big Data Connectivity: Google

- Connectivity to
  - Google Cloud Storage
  - Google Big Query (via DB Nodes)
  - Google Cloud Dataproc



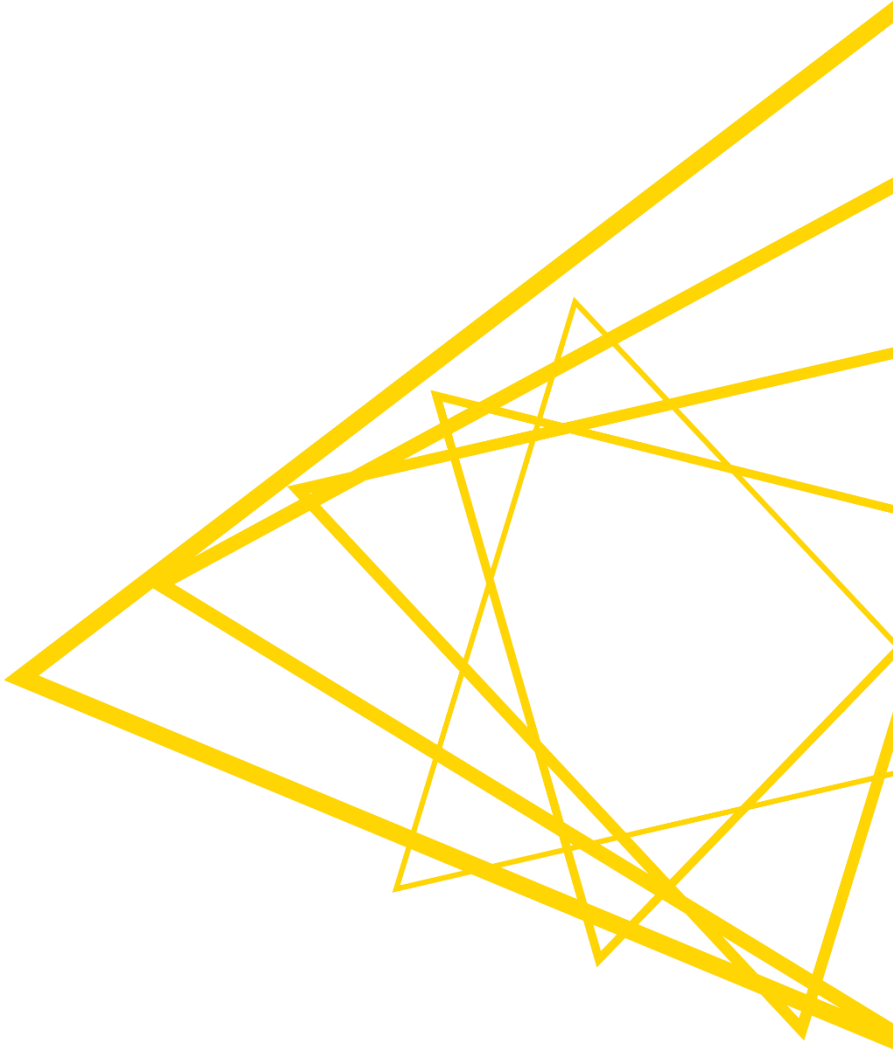
Section Exercise – 04_Spark_WritingToDB

This workflow provides a Spark predictor to predict COW values for the ss13pme data set. The model is applied to predict COW values where they are missing.

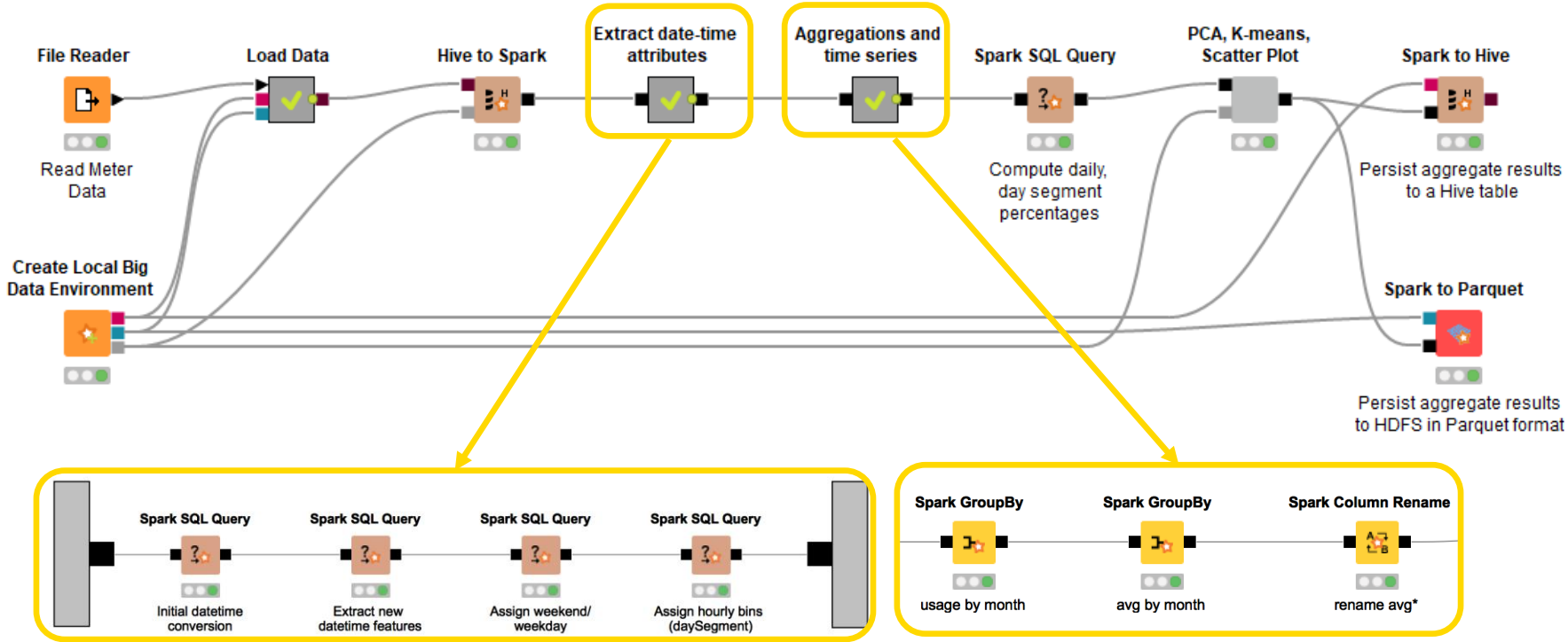
Now export the new data set without missing values to:

- A KNIME table
- A Parquet file in HDFS
- A Hive table

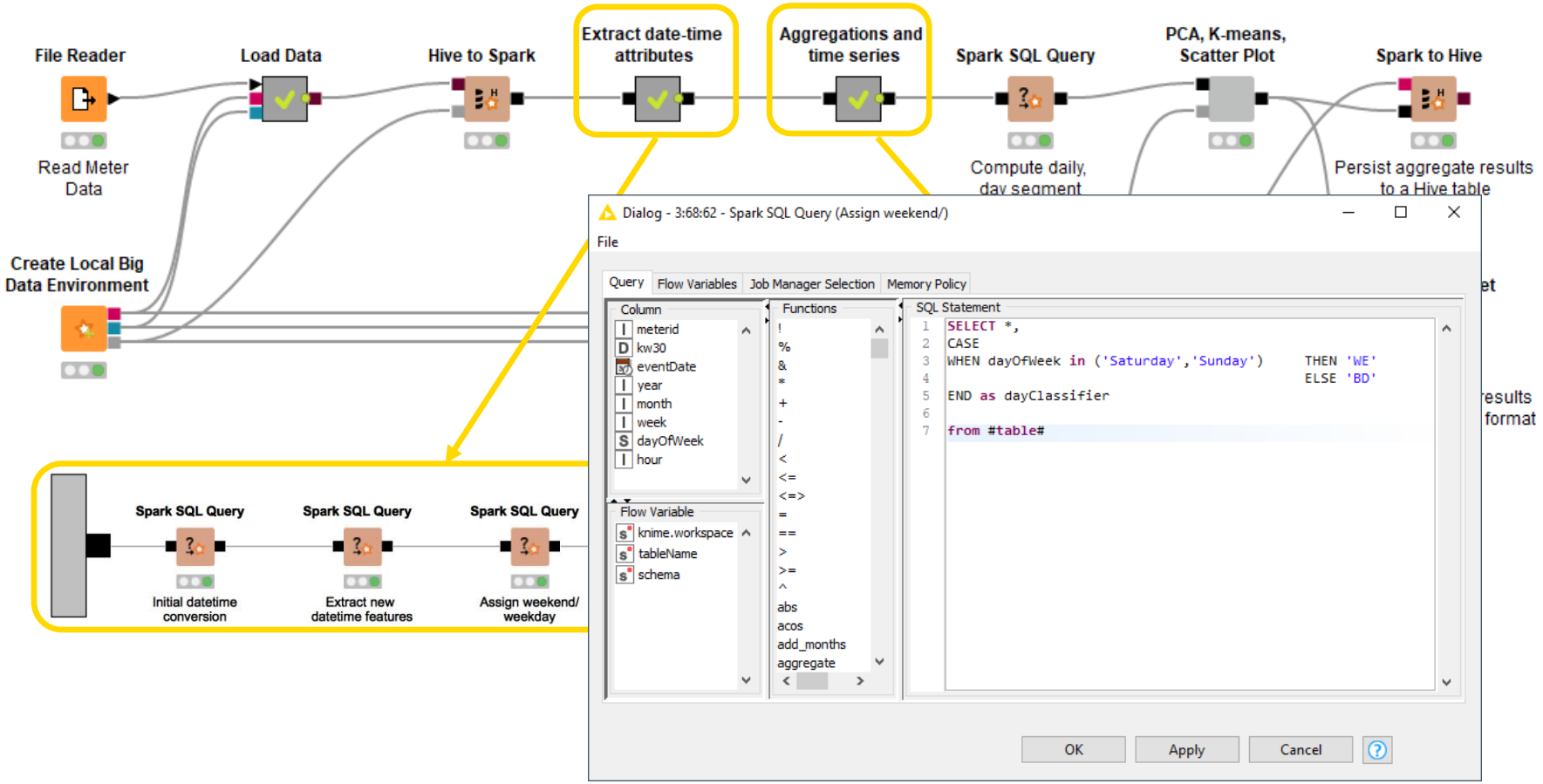
Examples



Analyzing the Irish Meter Dataset Using Spark SQL



Analyzing the Irish Meter Dataset Using Spark SQL



Columnar File Formats

- Available in KNIME Analytics Platform: ORC and Parquet

- Benefits:
  - **Efficient compression**: Stored as columns and compressed, which leads to smaller disk reads.
  - **Fast reads**: Data is split into multiple files. Files include a built-in index, min/max values, and other aggregates. In addition, predicate pushdown pushes filters into reads so that minimal rows are read.
  - **Proven in large-scale deployments**: Facebook uses the ORC file format for a 300+ PB deployment.

- Improves performance when Hive is reading, writing, and processing data in HDFS

Example: Columnar File Formats

ID	Gender	Age
1	female	45
2	male	20
⋮	⋮	⋮
3333	male	42

Metainformation
ID: min = 1 ; max = 3333
Gender: female; male
Age: min = 20; max = 45

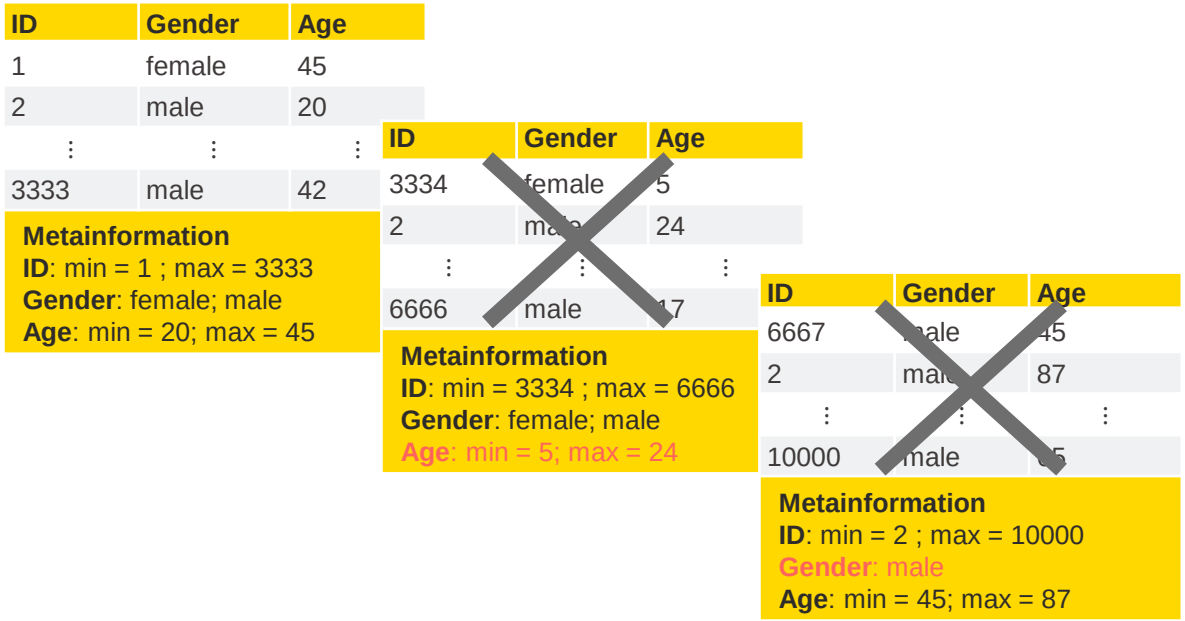
ID	Gender	Age
3334	female	45
2	male	20
⋮	⋮	⋮
6666	male	42

Metainformation
ID: min = 3334 ; max = 6666
Gender: female; male
Age: min = 5; max = 24

ID	Gender	Age
6667	female	45
2	male	20
⋮	⋮	⋮
10000	male	42

Metainformation
ID: min = 6667 ; max = 10000
Gender: female; male
Age: min = 45; max = 87

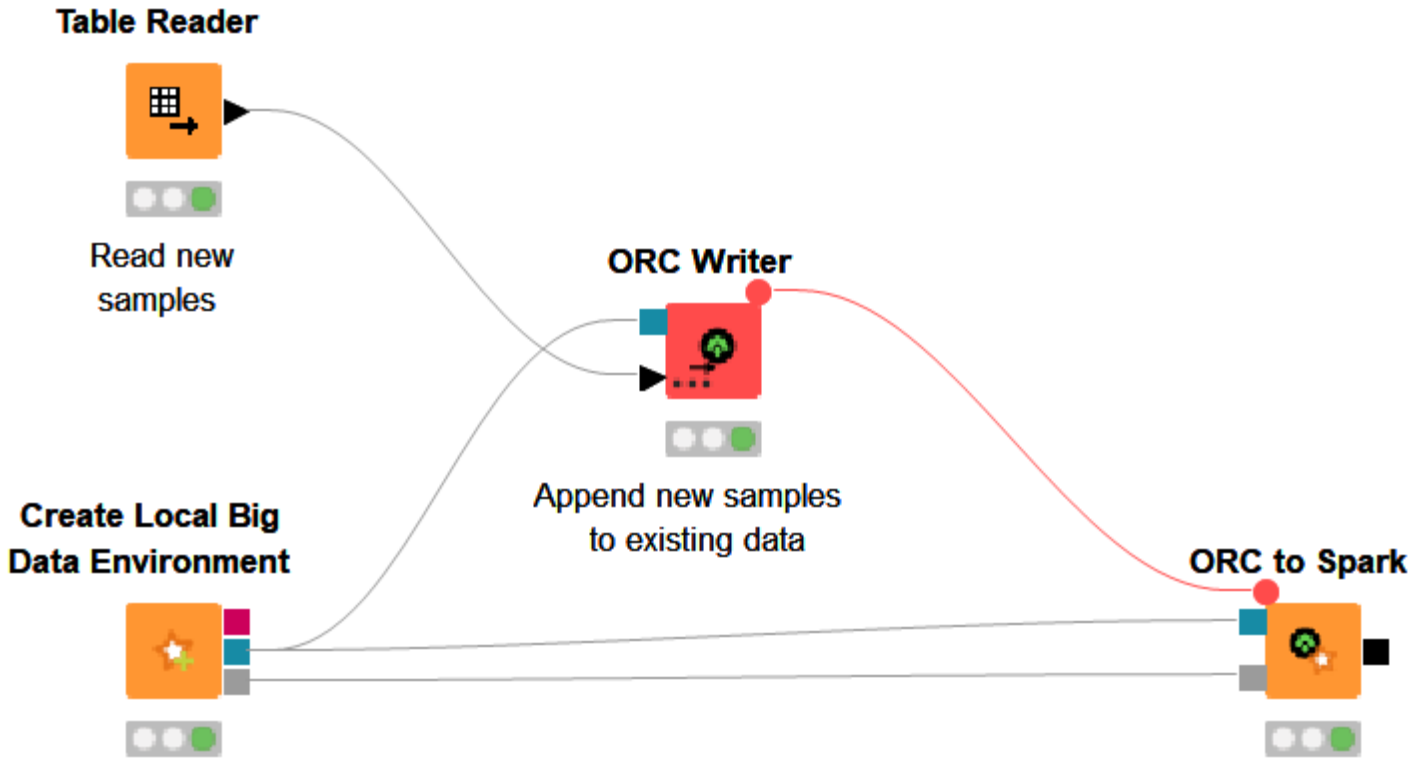
Example: Columnar File Formats



Select **ID** from table where

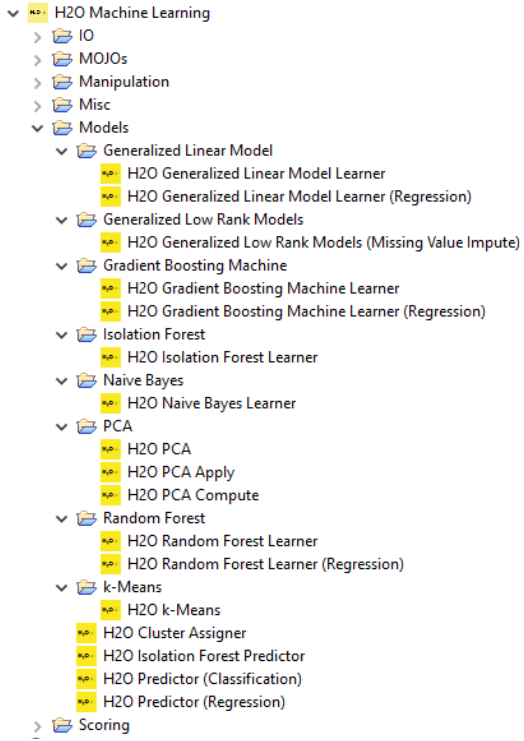
Age > 30 and Gender = female

Example: Write an ORC File

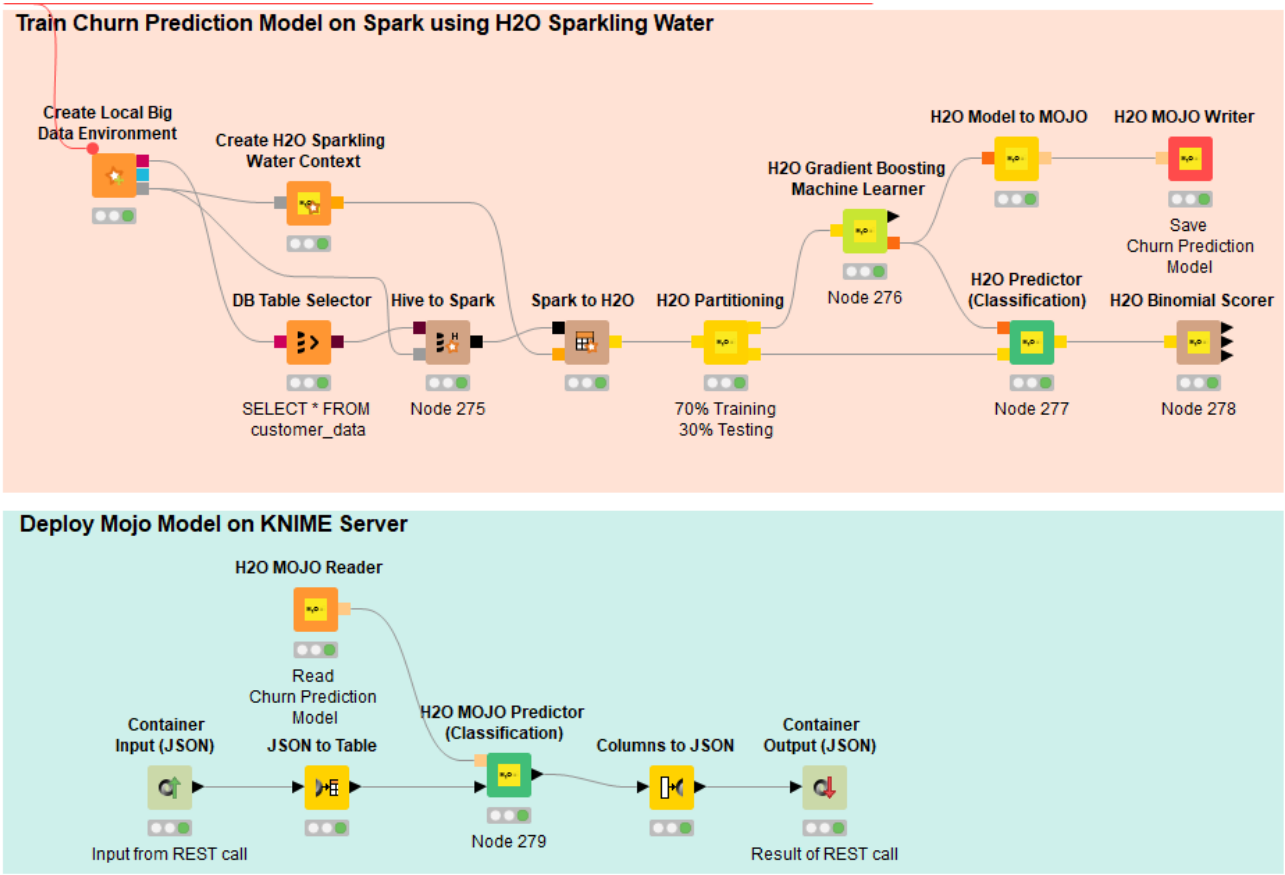


H2O Integration

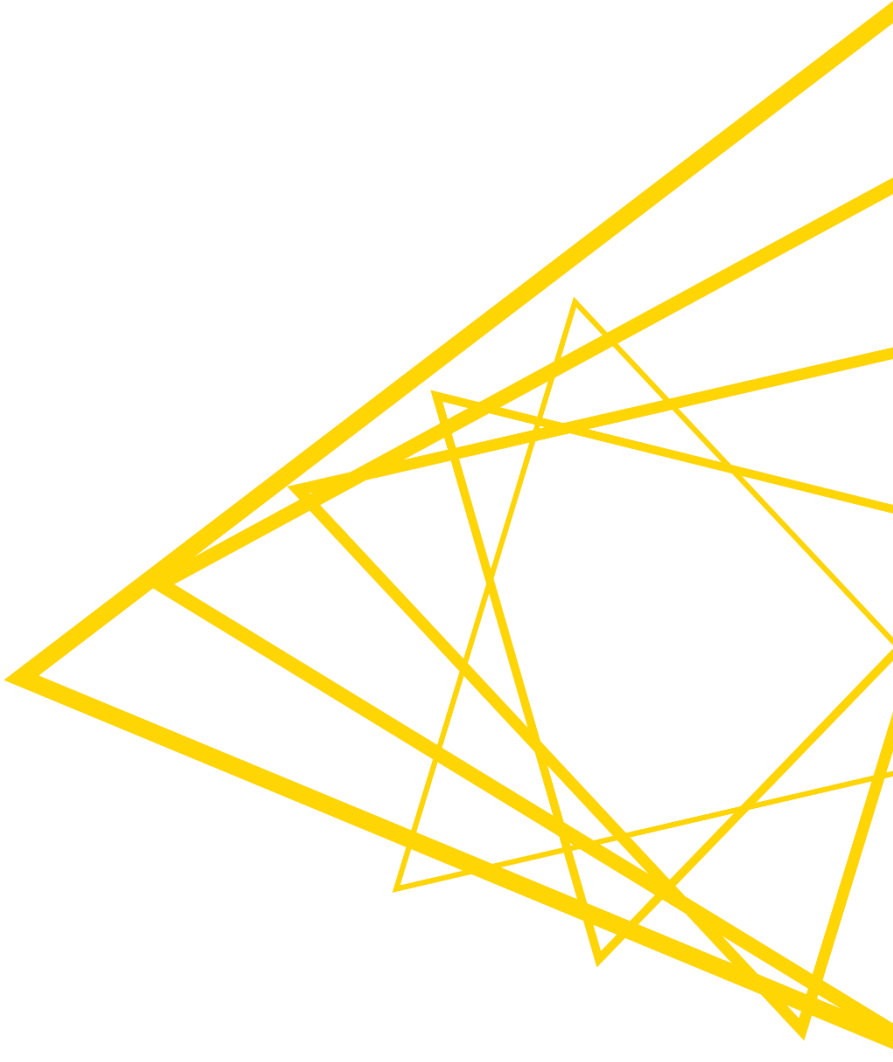
- KNIME integrates the H2O machine learning library
- H2O: Open source, focus on scalability and performance
- Supports many different models
  - Generalized Linear Model
  - Gradient Boosting Machine
  - Random Forest
  - k-Means, PCA, Naive Bayes, etc. and more to come!
- Includes support for MOJO model objects for deployment
- Sparkling water = H2O on Spark



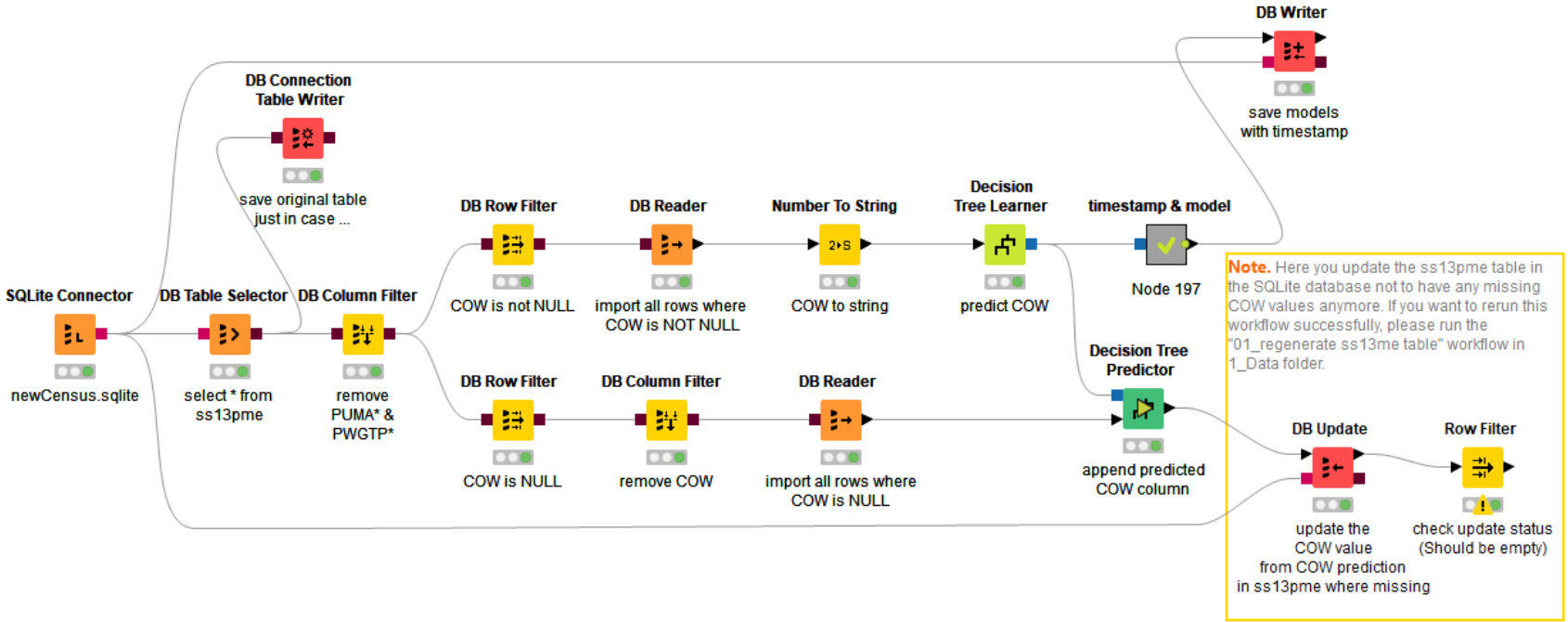
The H2O Sparkling Water Integration



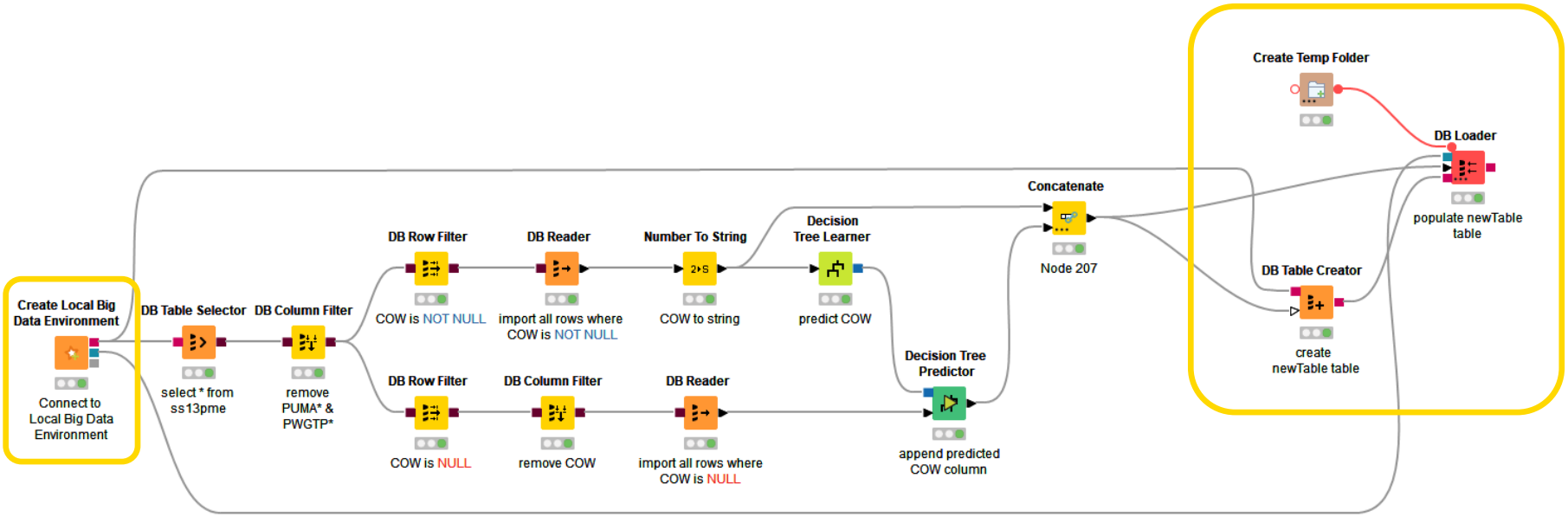
Conclusions



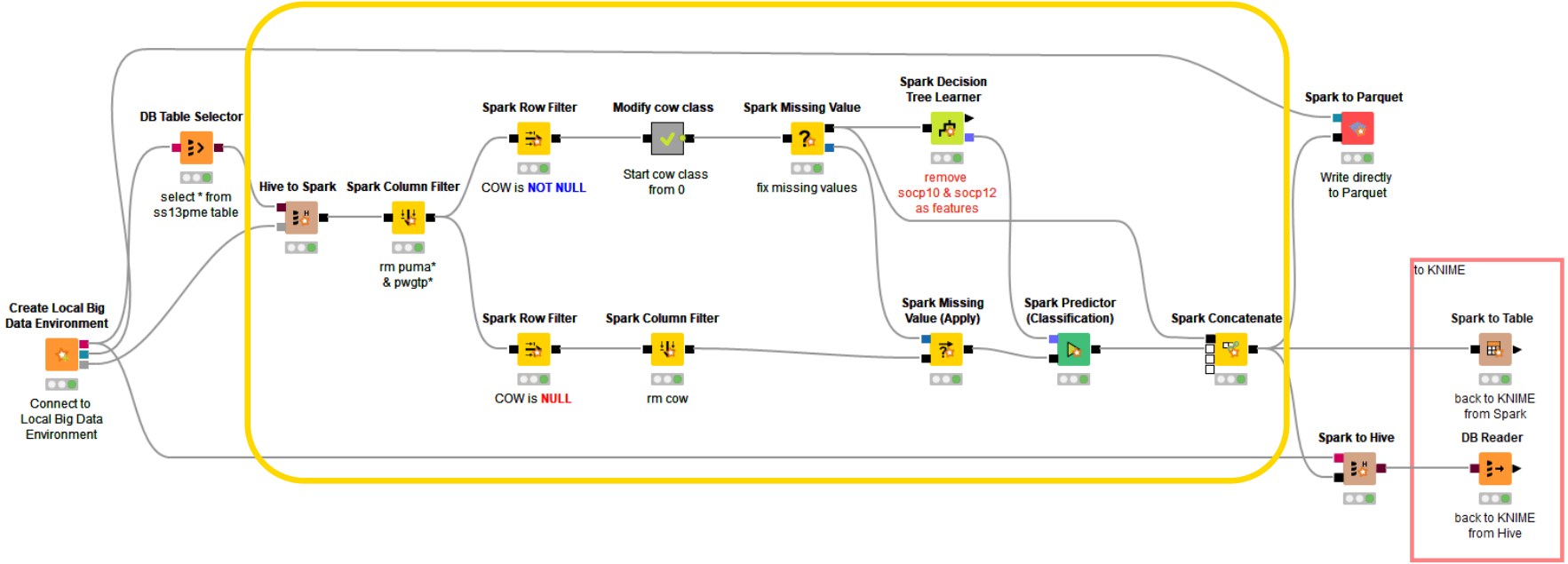
SQLite



Hadoop Hive



Spark

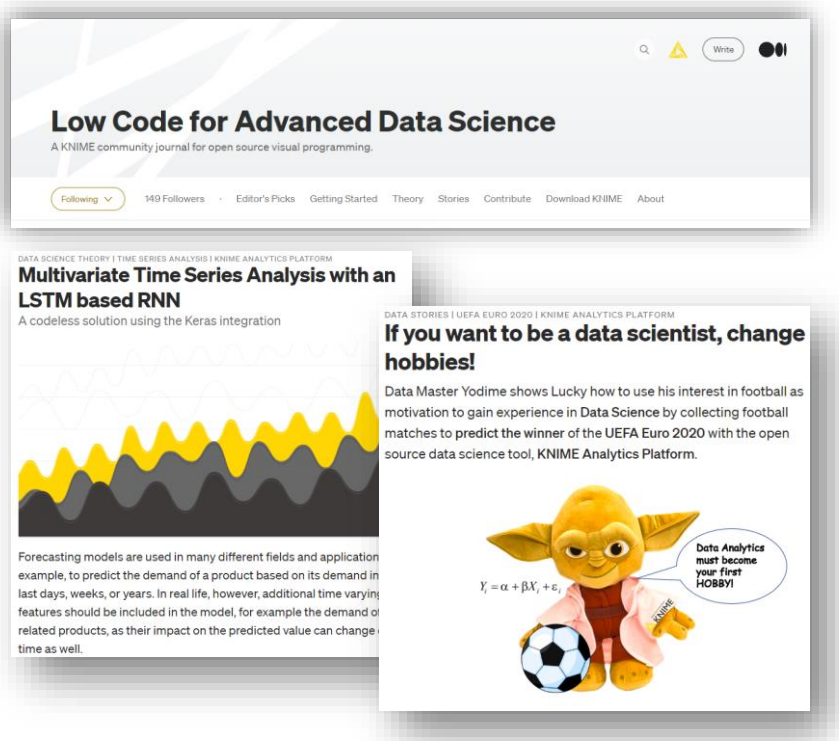


Stay Up-To-Date and Contribute

- Follow the KNIME Community Journal on Medium
  [Low Code for Advanced Data Science]

- Daily content on data stories, data science theory, getting started with KNIME and more
  for the community by the community

- Would you like to share your data story
  with the KNIME community?



Contributions are always welcome!

Open for Innovation
KNIME

The End

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