

Deployment



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*„Data Scientist is just a sexed up word for Statistician“
-Nate Silver*

How do we move the models to production?

Content of this Lesson

- Deployment
- Model Deployment
- Model Management
- Practical Example

Deployment

The Data Science Process

— SEMMA

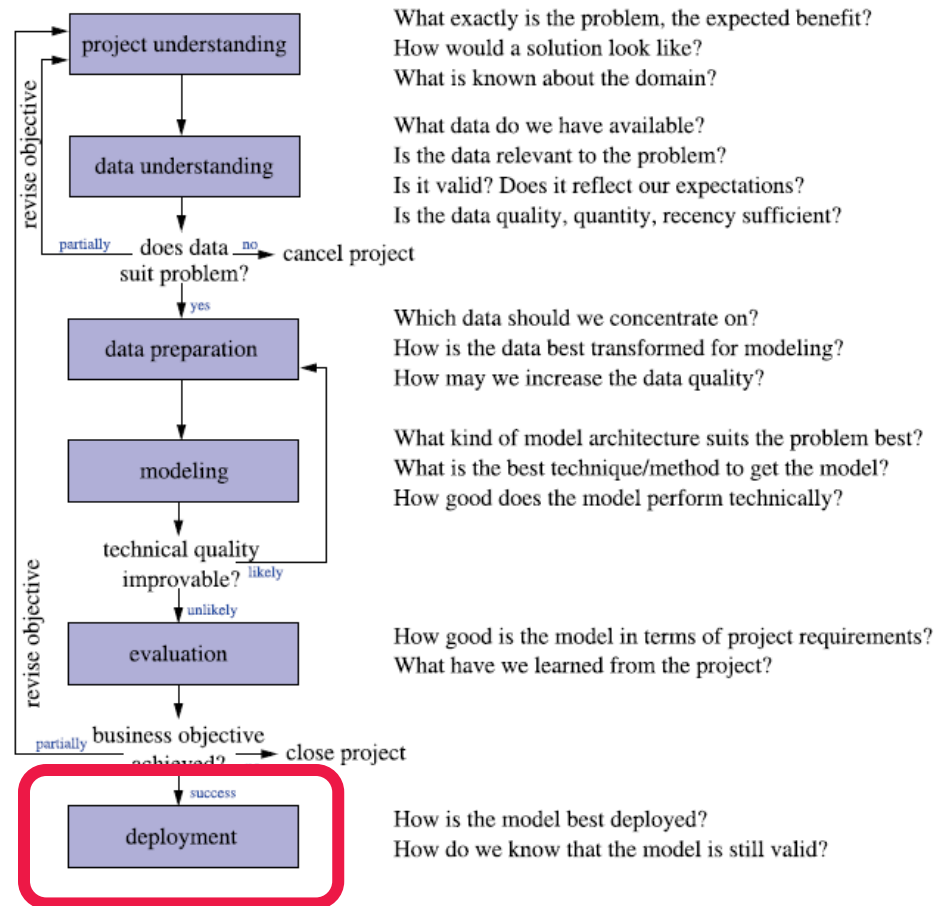
- Sample, Explore, Modify, Model, Assess

— CRISP-DM

- Cross Industry Standard Process for Data Mining

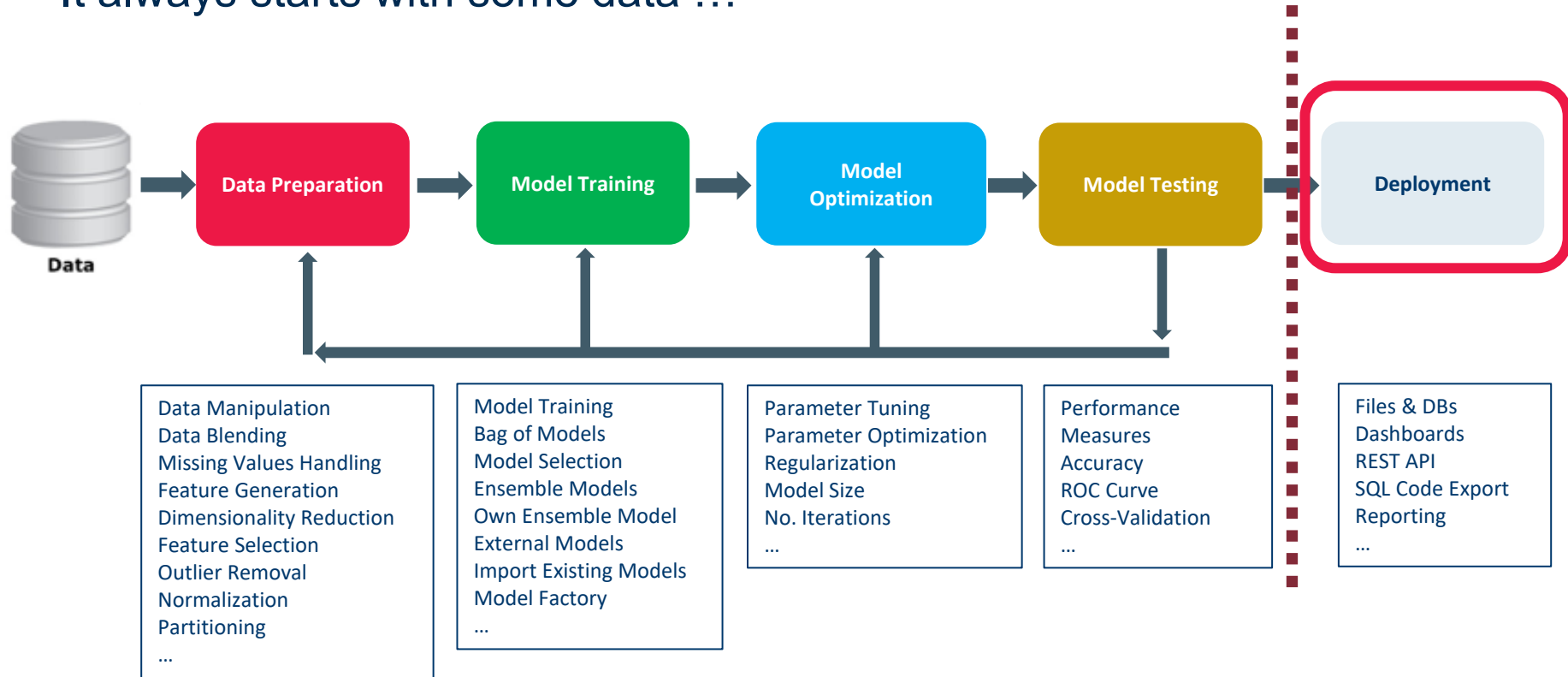
— KDD

- Knowledge Discovery in Databases

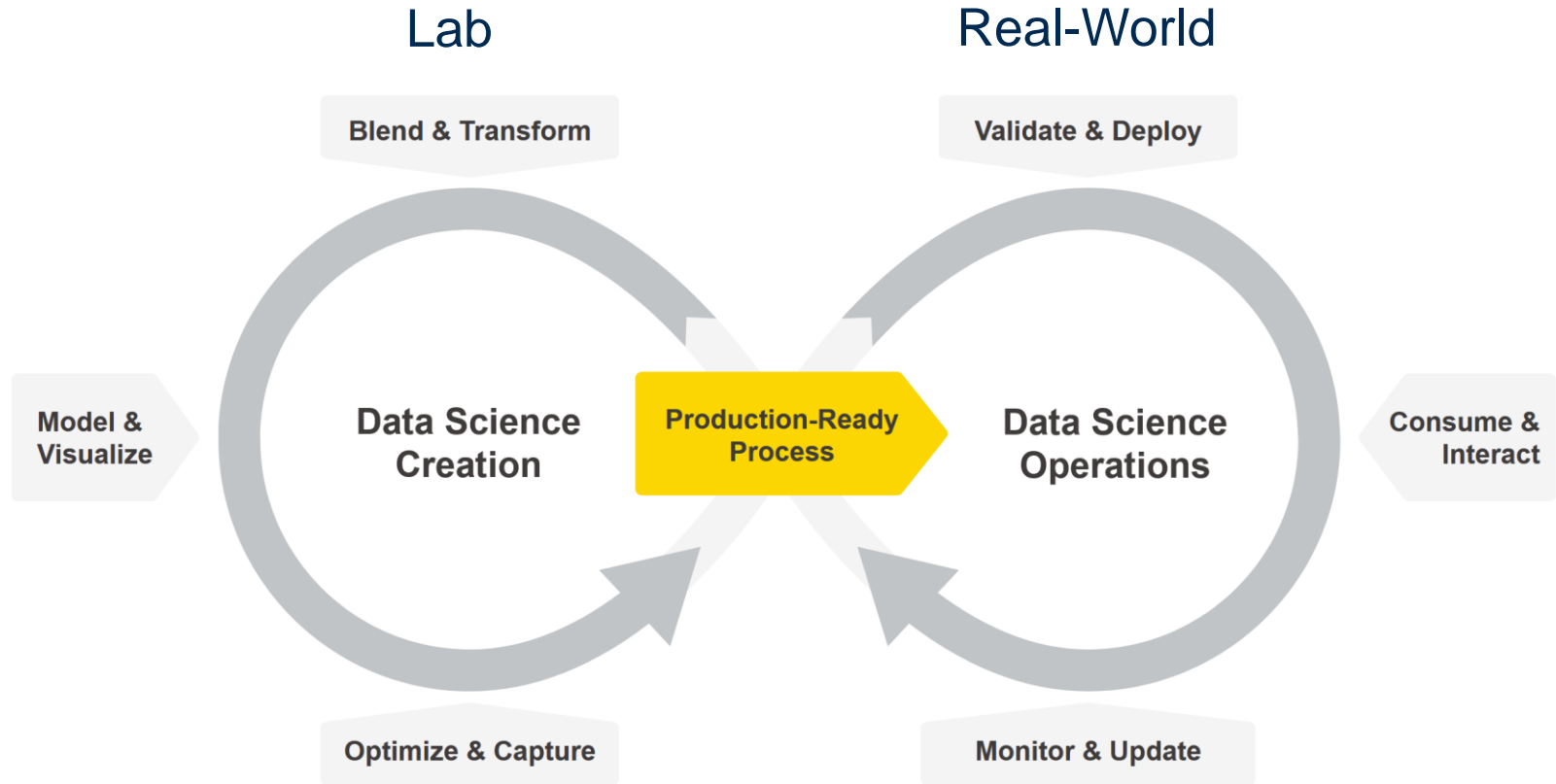


A Classic Data Science Project

- It always starts with some data ...



What comes after Deployment?



What is model deployment?

- Notice the dashed line between model testing and model deployment?
- This is where the jump **from the lab to the real world** happens
- Eventually a trained model must be included in a final application to be used **by external applications and/or end users**
- The final application is the deployment application
- The step of building the application around the trained model is called **deployment**
- Notice that the deployment application must be developed and finally put into production like all pieces of software
- When the deployment application is moved into production, so is the trained model

Deployment requirements

– Easy

- It must be easy for the application developer to include the trained model into the deployment application
- Easy to use for end users
- Easy to integrate in a Service Oriented Architecture

– Safe

- At the same time it must be correct. For example, it must include the whole data preparation part.
- Most reasons of deployment failures are in the not faithful export of the pre-processing and post-processing steps from the training application into the deployment application.
- Think of a model trained on normalized data and of a deployment application where normalization has been forgotten.

Once in the real world, the deployment application and the trained model must oblige to the laws of IT

- **Automation**
 - On demand & scheduled execution
 - Monitoring and Updating
- **Auditing**
 - Justify decisions
 - Store previous executions
 - Reproducibility
- **Security**
 - Protection of sensitive data
 - Protection of sensitive applications
 - Versioning & Disaster Recovery

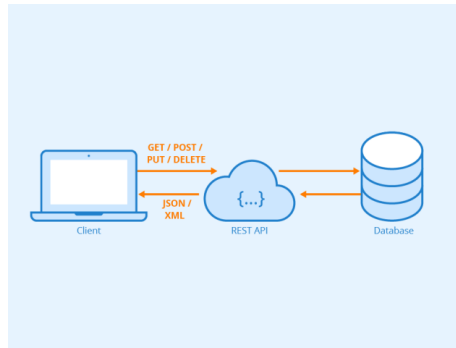
Deployment Options

Deployment

Usage of a trained model in an application to provide answers for a real-world use case

- In its own application
 - Easy to use for end users (as a web application)
 - Easy to integrate in a Service Oriented Architecture (as a web service)
- Consumed by external Applications
 - As a file in standard format
 - As a software library

Deploying the ML Model



Inside its own application

In a web service

in a web application



ML model

as a file in a standard format

as a software library

Consumed by external applications



```
<?xml version="1.0"
encoding="iso-8859-1" ?>
<languages>
  <language id="fr">
    <name lang="fr">Français</name>
    <name lang="en">French</name>
    <name lang="es">Frances</name>
    <name lang="de">Französisch</name>
    <name lang="eo">Franca</name>
  </language>
```



- Easy to use for end users

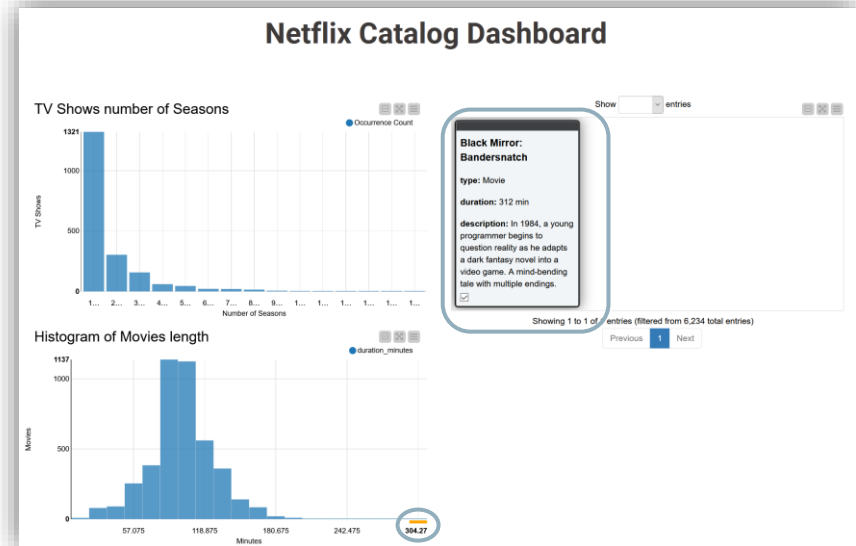
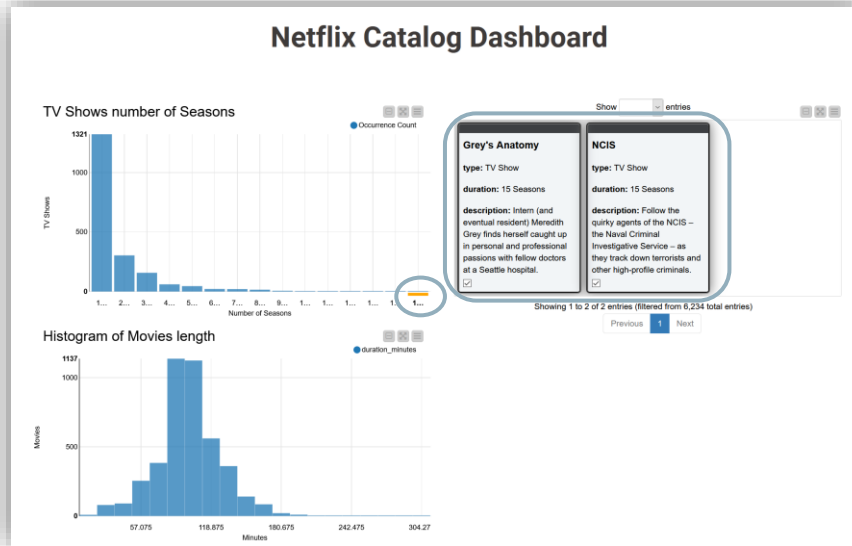
- If the model has been deployed into an application for end users, it must be easy to use also for non-experts and non-data-scientists kind of users
- As a web application from a web browser
- Hide model complexity
- Offer touchpoints for exposed parameters

- Easy to integrate in a Service Oriented Architecture

- As a web service
- Via standard interfaces for web services

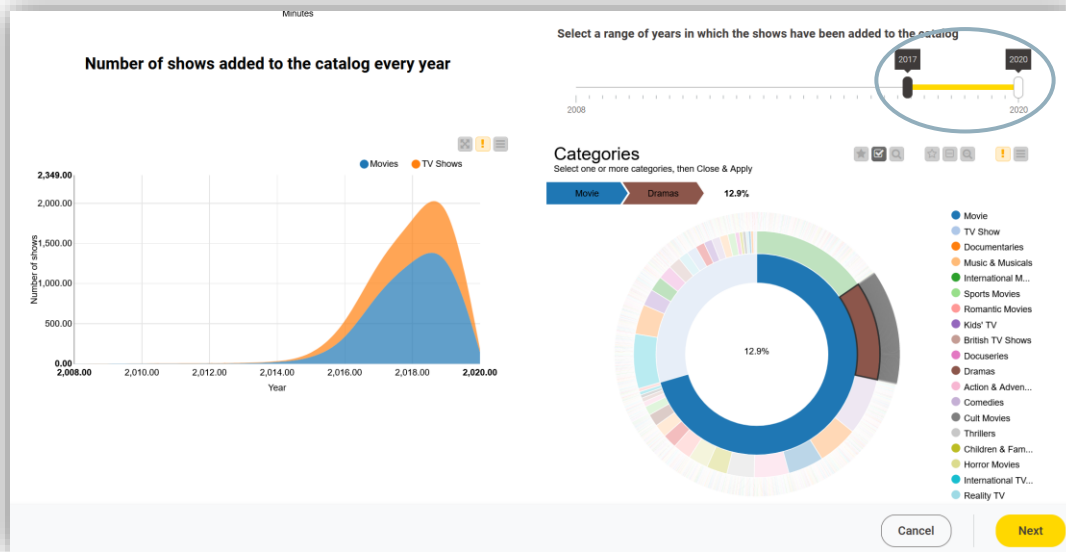
Deployment in a web application

- One page usually includes an Interactive Dashboard to show the results
- Fast and intuitive decision support even for non expert users
- Can show model prediction and more complex interactive data visualization



Deployment in a web application

- Interactive plots and charts
- Data selection across plots, charts, and tables
- Items such as: range slider, selection bullets, menus, ...

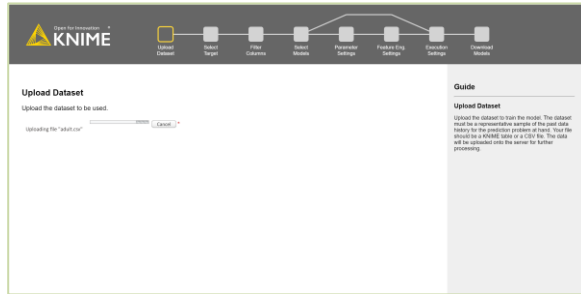


- One final dashboard page → to show results
- What about having touchpoints that require end user interaction?
- Hide complexity in automated snippets
- Expose parameters interesting to the end users via touchpoints
- Example: Guided Automation.
 - Train a number of models on the selected training set
 - Sequence of Touchpoints could be:



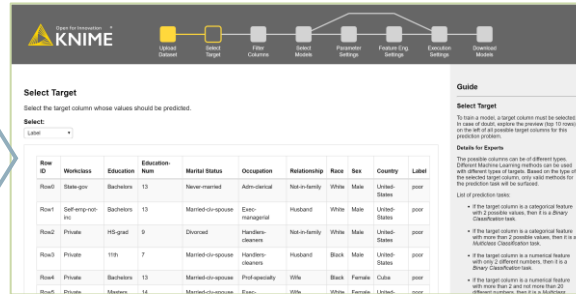
Guided Automation: An example

1. Load Data



The screenshot shows the 'Upload Dataset' workflow in KNIME. The workflow bar at the top includes 'Upload Dataset', 'Select Target', 'Filter Columns', 'Select Models', 'Parameter Settings', 'Feature Eng. Settings', 'Execution Settings', and 'Download Models'. The 'Upload Dataset' node is active, showing a guide that explains how to upload a dataset to the KNIME Server. A 'Select' button is visible next to the 'uploading the "adult.csv"' text.

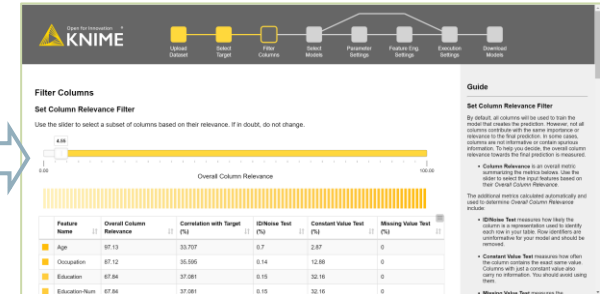
2. Select Target



The screenshot shows the 'Select Target' workflow in KNIME. The 'Select Target' node is active, displaying a table of features and their types. The 'Label' column is selected as the target. A guide explains the importance of selecting a target column and provides details for experts.

Row ID	Workclass	Education	Num	Marital Status	Occupation	Relationship	Race	Sex	Country	Label
Row#1	Self-emp-inc	Bachelors	13	Never-married	Adm-clerical	Not-in-family	White	Male	United-States	poor
Row#1	State-gov	Bachelors	13	Married-in-spouse	Exec-managerial	Husband	White	Male	United-States	poor
Row#2	Private	HSGrad	9	Divorced	Handwritten-clerical	Not-in-family	White	Male	United-States	poor
Row#3	Private	11th	7	Married-in-spouse	Handwritten-clerical	Husband	Black	Male	United-States	poor
Row#4	Private	Bachelors	13	Married-in-spouse	Prof-specialty	Wife	Black	Female	Cuba	poor
Row#5	Private	Masters	14	Married-in-spouse	Exec-managerial	Wife	White	Female	United-States	poor

3. Filter Columns



The screenshot shows the 'Filter Columns' workflow in KNIME. The 'Filter Columns' node is active, displaying a bar chart of 'Overall Column Relevance'. A guide explains the importance of selecting relevant columns and provides details for experts.

Feature	Overall Column Relevance	Correlation with Target	Efficiency Test	Constant Value Test	Missing Value Test
Age	87.13	33.707	0.7	2.87	0
Occupation	87.12	35.595	0.14	12.69	0
Education	87.84	37.081	0.15	32.16	0
Education-Hum	87.84	37.081	0.15	32.16	0

4. Select Models



The screenshot shows the 'Select Models' workflow in KNIME. The 'Select Models' node is active, displaying a list of available models. A guide explains the importance of selecting the right model and provides details for experts.

Select Models

Choose one or more machine learning models to train for your prediction task.

Simple models

- Naive Bayes
- Decision Tree
- Logistic Regression

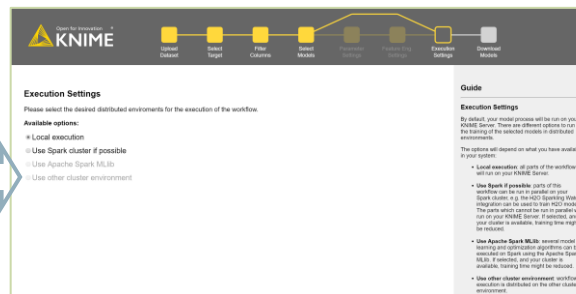
Complex models

- Support Vector Machine
- Random Forest
- Generalized Linear Models
- Gradient Boosted Trees
- Deep Learning

Fine-tune Model Parameters

Choose one or more machine learning models to train for your prediction task.

5. Select Execution Engine



The screenshot shows the 'Execution Settings' workflow in KNIME. The 'Execution Settings' node is active, displaying a list of available execution engines. A guide explains the importance of selecting the right execution engine and provides details for experts.

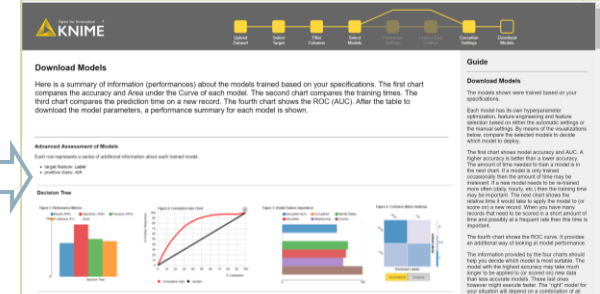
Execution Settings

Please select the desired distributed environments for the execution of the workflow.

Available options:

- Local execution
- Use Spark cluster if possible
- Use Apache Spark MLlib
- Use other cluster environment

6. Show Results



The screenshot shows the 'Download Models' workflow in KNIME. The 'Download Models' node is active, displaying a list of available models. A guide explains the importance of selecting the right model and provides details for experts.

Download Models

Here is a summary of information (performances) about the models trained based on your specifications. The first chart compares the accuracy and Area under the Curve of each model. The second chart compares the training time. The third chart shows the prediction time on a new record. The fourth chart shows the ROC (AUC). After the table to download the model parameters, a performance summary for each model is shown.

Advanced Assessment of Models

Quickly represents a series of additional information about each trained model.

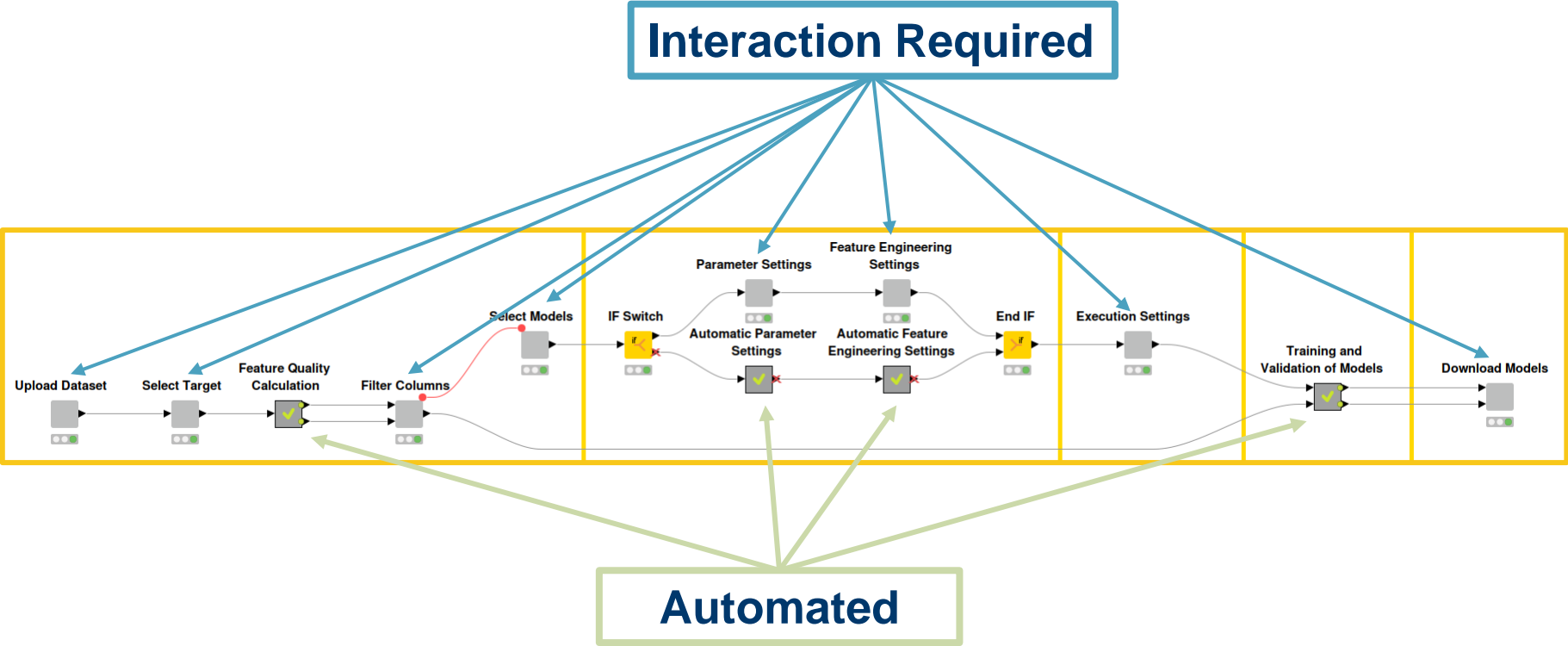
Decision Tree

The first chart shows model accuracy and AUC. A higher accuracy is better than a lower accuracy. The amount of time needed to train a model is in the second chart. The third chart shows the prediction time on a new record. The fourth chart shows the ROC (AUC). After the table to download the model parameters, a performance summary for each model is shown.

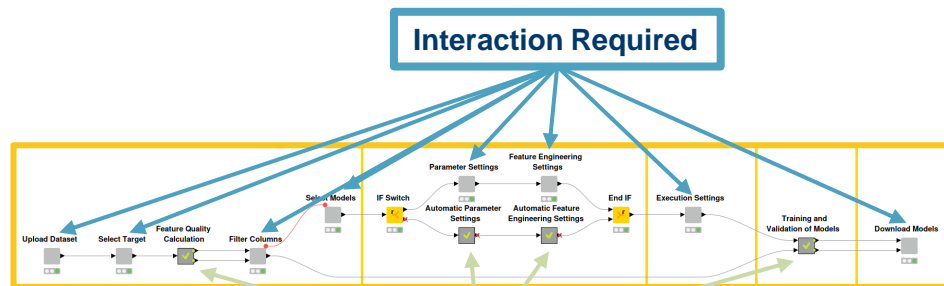
Gradient Boosted Trees

The first chart shows model accuracy and AUC. A higher accuracy is better than a lower accuracy. The amount of time needed to train a model is in the second chart. The third chart shows the prediction time on a new record. The fourth chart shows the ROC (AUC). After the table to download the model parameters, a performance summary for each model is shown.

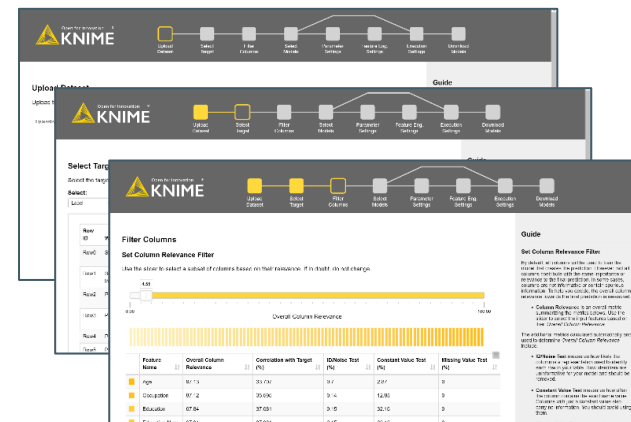
Building a Guided Automation Workflow



KNIME's Guided Automation: Automation + Interaction



<http://myhub.com>



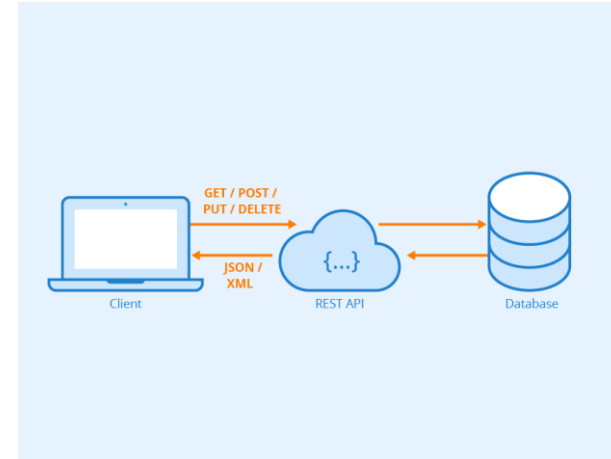
KNIME Business Hub

**analytical application
for business users
from web browser**

- A web service provides interoperability between computer systems
 - over the internet
 - through a web technology, such as HTTP
 - to transfer machine-readable file formats such as XML and JSON.
- Web Services with REST architecture are the current state of the art
- What is a REST architecture
 - **Representational State Transfer (REST)** is a software architectural style introducing a set of constraints for web services.
 - Web services that conform to the REST architectural style, are called *RESTful* (REST) web services.
 - **REST services** allow the requesting systems to access and manipulate representations of web resources by using a **uniform** and **predefined** set of stateless operations. You cannot make up your own arbitrary set of operations, as in SOAP web services.
 - Stateless protocol and standard operations => fast execution, easy to manage

– Operations in a REST web service (over HTTP)

- GET
- HEAD
- POST
- PUT
- PATCH
- DELETE
- CONNECT
- OPTIONS
- TRACE

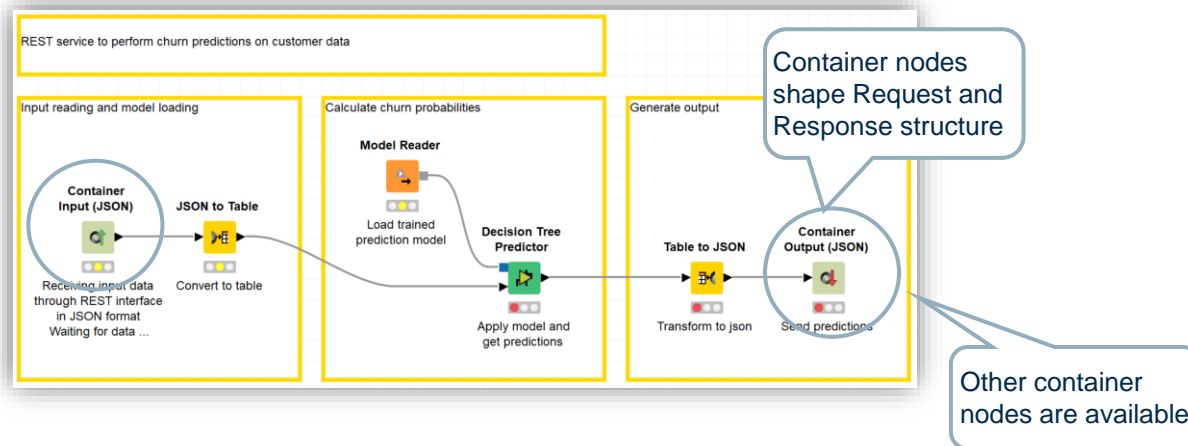


– The Request and Response objects

- Data is exchanged via a Request object and a Response object
- The **Request object** sends data to the REST service, together with the required operation
- The **Response object** passes the result back to the calling system

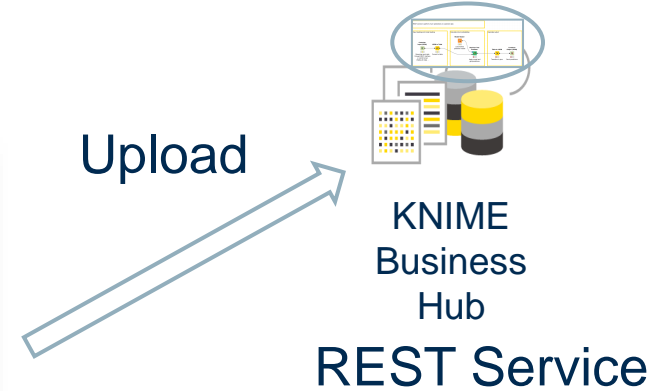
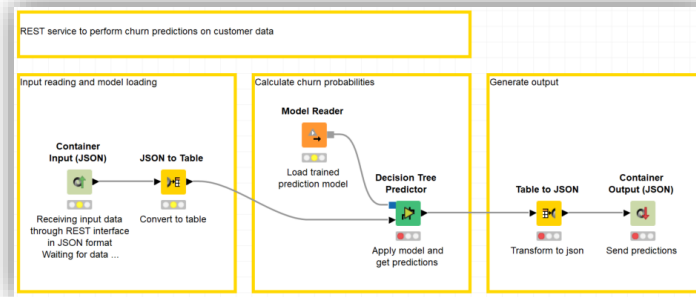
Building a web service

- Building a REST service requires:
 - To shape the structures of the Request and Response objects
 - To enable the REST API
- Solutions:
 - Container nodes shape the Request and Response objects
 - All workflows uploaded on the KNIME Server are available as REST services



Building a web service

1



2

REST Service



Deployment as a file in standard format

- Standard formats allow for external applications to consume the network/model
- **PMML**
 - **Predictive Model Markup Language (PMML)** is based on XML
 - Embeds a wide range of predictive models along with aspects of the required pre-processing
 - Can be directly loaded into database systems and applied to data tables
 - PMML works well with standard ML models (decision tree, logistic regression)
 - Representation of new complex models (ensemble, deep learning...) is problematic, either because a standard representation has not been defined or because the size of the resulting file is too large
 - Less and less used
- **ONNX**
 - ONNX = Open Neural Network for eXchange
 - Open **standard** dedicated to represent **neural networks** and **deep learning networks**
 - ONNX represented networks can then be stored into files
 - Standard ensures the portability of the represented network across systems

Note: Data processing (transformation/integration) must be part of the deployed model in production

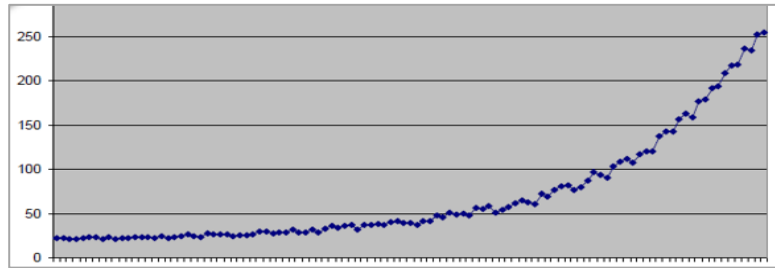
- Data Science projects often fail in deployment. Why?
- Common reasons:
 - **Bad project design:** consequences can appear only in deployment phase. For example, a feature, transformation, or a data source that is not available in production.
 - **Data leakage:** data in the test set mixes up with data in the training set. Model scores do not reflect the performances in the real-world.
 - **Dynamic domains:** Features and target variable end up having different domains in the training data vs. the real-world. New values are not handled properly.
 - **Change in Business Objectives:** During or after deployment the business objectives of the project have changed for some reason. For example, the business strategy of the company has changed.
 - **Invalidated assumptions.** What we thought it was true about the data, it is not. Maybe we did not extract a representative sample from the world data.
 - **Shift from inter- to extrapolation:** atypical data (i.e. data not used during training). What to do? Shall we stop everything?
 - **The world changes:** e.g. if new products offered or customers change habits, the data used to build and optimize the model are no longer representative of the reality

Model Management

- The world change, the business requirement change
- **Model Management** puts in place some mechanisms to ensure that the model keeps performing as expected
- Model Management includes:
 - Model Monitoring
 - Model Update & Retraining
 - Model Factories

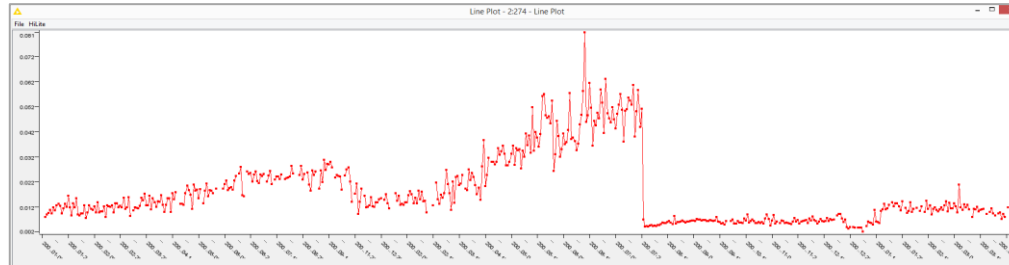
Data Drifts and Data Jumps

- The world changes, the data change
- Data Drift (data changing slowly over time)



The state of a mechanical piece, the temperature going towards winter, the price of items due to inflation, etc ...

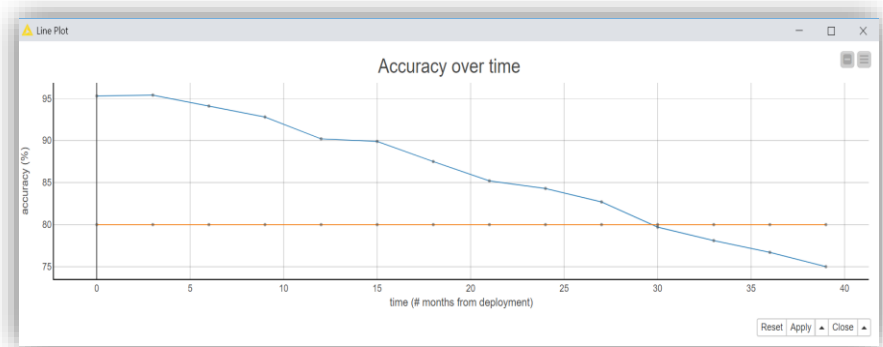
- Data Jump (Data changing suddenly at some point)



The breaking of a mechanical piece, the crash of the stock market, etc ...

Model Drift

- A model with an accuracy of 90% in the past can slowly (or suddenly) degrade to a much lower accuracy over time.
- This is called **Model Drift**



- Periodically check model performance
 - On which data?
 - How often is periodically?
- If model performance below threshold, retrain
 - What threshold value?

- To spot the Model Drift (due to an outdated model), you should use **recent data**
- It is of course useless to test the model on data acquired at the time when the training data were collected.
- At every run, production data are stored for monitoring purposes, till a sufficiently large dataset is collected.
- Manually annotated data are also added to test **border cases**
- The model is then tested again on this newly collected dataset.
- No action is taken if performance drops within an acceptable interval. Contrarily, actions for model retraining must be taken, if performance goes below the acceptance threshold.

- What does “periodically” mean?
- Shall I test my model performance once a week, once a month, or once a year?
- It depends on the data and on the business case:
 - Stock prices change every minute → model re-evaluation every few days
 - The taste of a customer segment will be the same for a few weeks
→ model re-evaluation every few months
- Same for the evaluation threshold: the value depends on the data and on the business case

– (Automatic) Model Updating

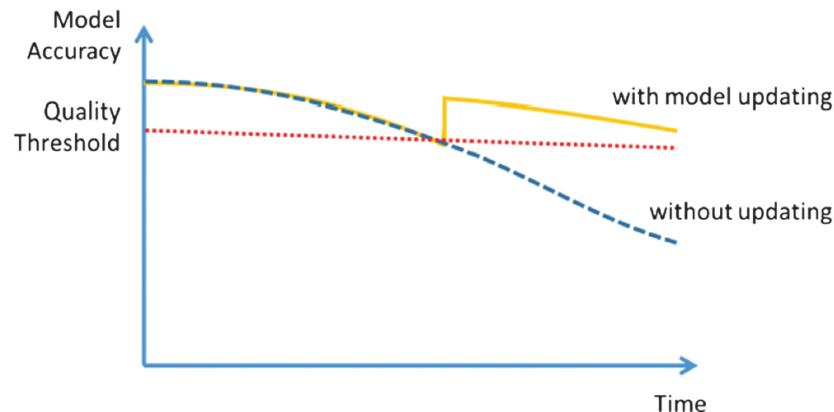
- Feed new data points to be incorporated into the model
- In this way old data are less important (are forgotten)

– Retraining

- Use sampling to provide the right mix of past and more recent data

– Caveats:

- Seasonality can be a problem. Specialized models or season knowledge manually injected
- Pre-existing knowledge (e.g. border case handling) better incorporated using a separate rule model instead of manual knowledge injection



– **Model Replacement**

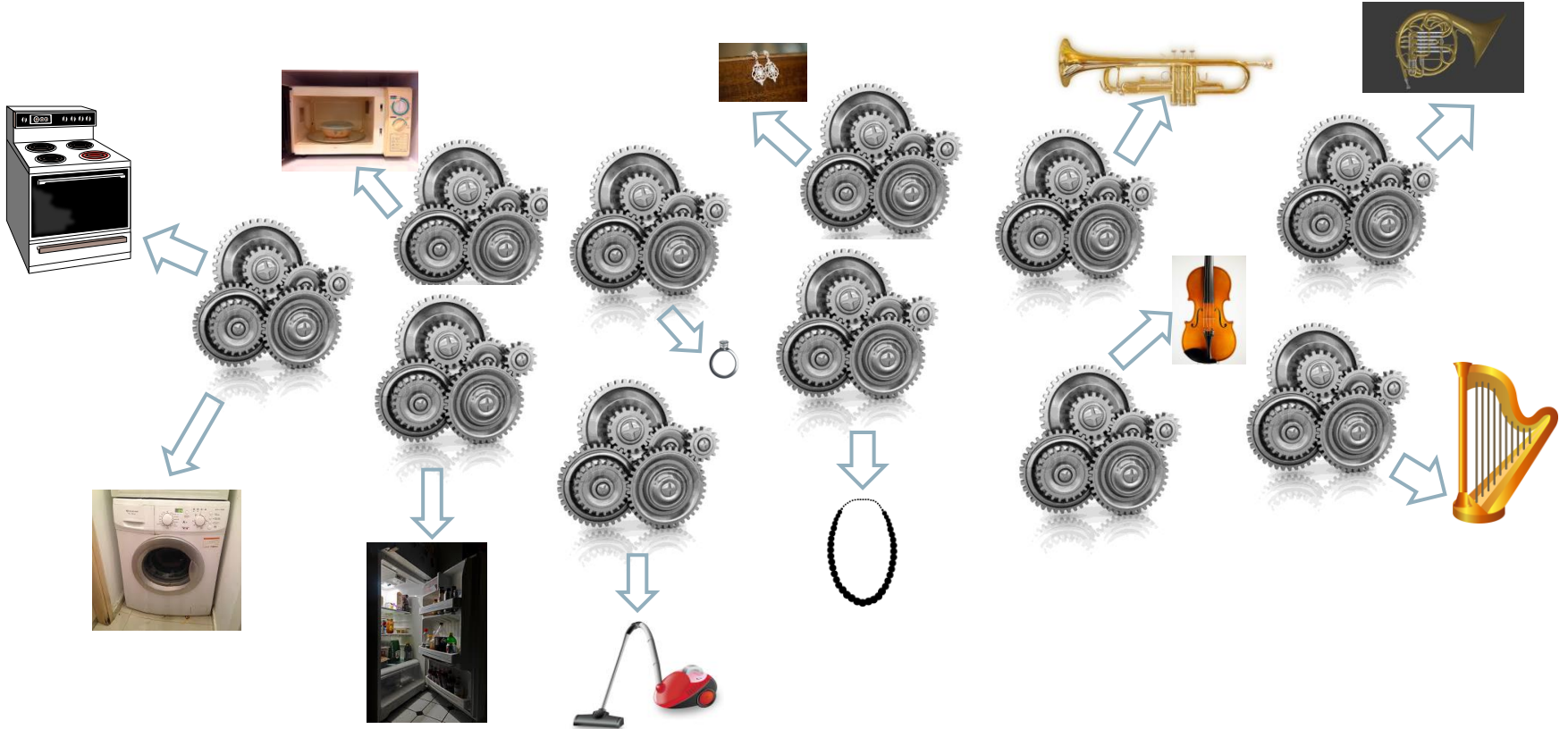
- We have retrained a new model. Are we sure it is better than the previous one?
- New model is the ***challenger***
- Former model is the ***champion***

IF challenger's performance > champion's performance THEN replace
OTHERWISE keep champion model

– **Caveats:**

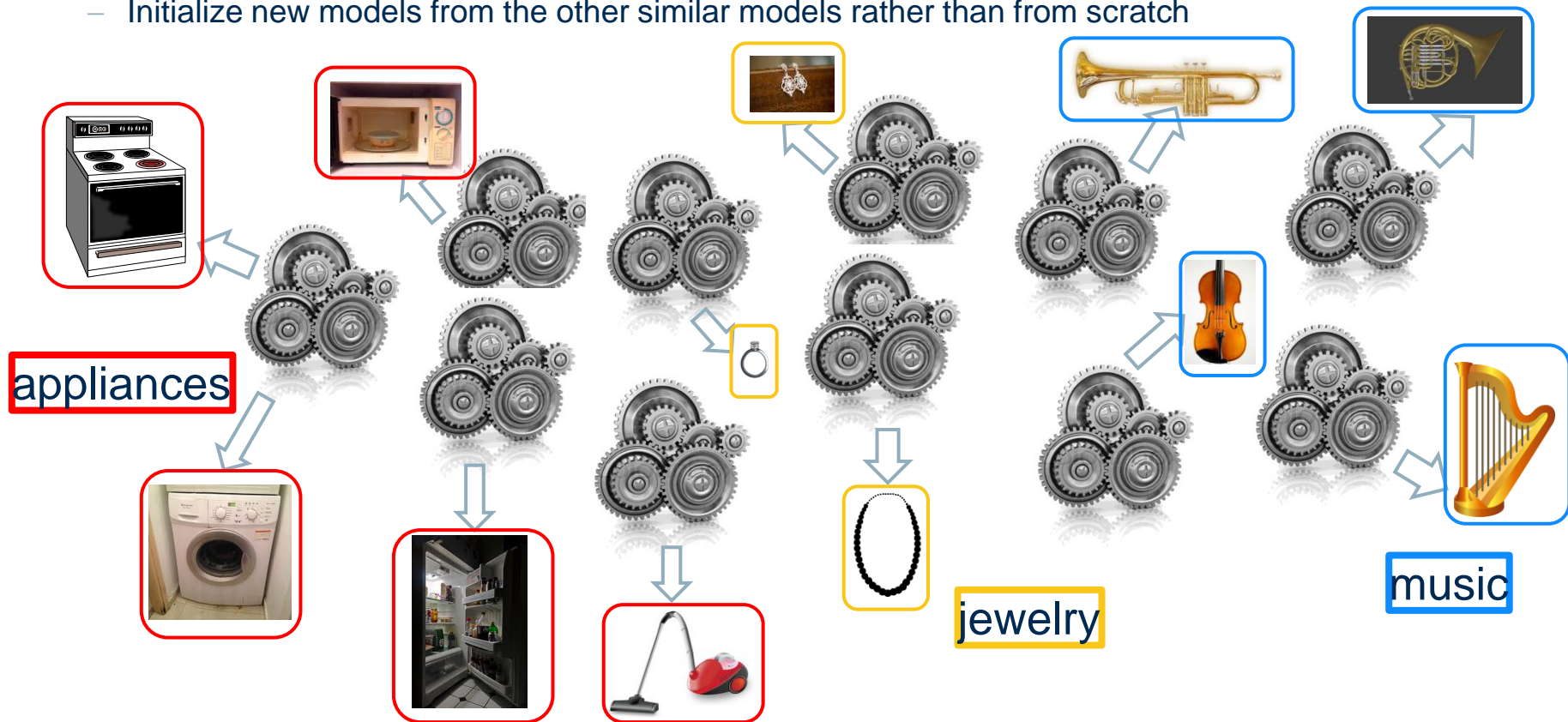
- Resources and time demanded

- Orchestration of a set of models – e.g. predicting prices



– How to manage a set of models?

- Exploit grouping (families of similar models rather than single ones)
- Initialize new models from the other similar models rather than from scratch



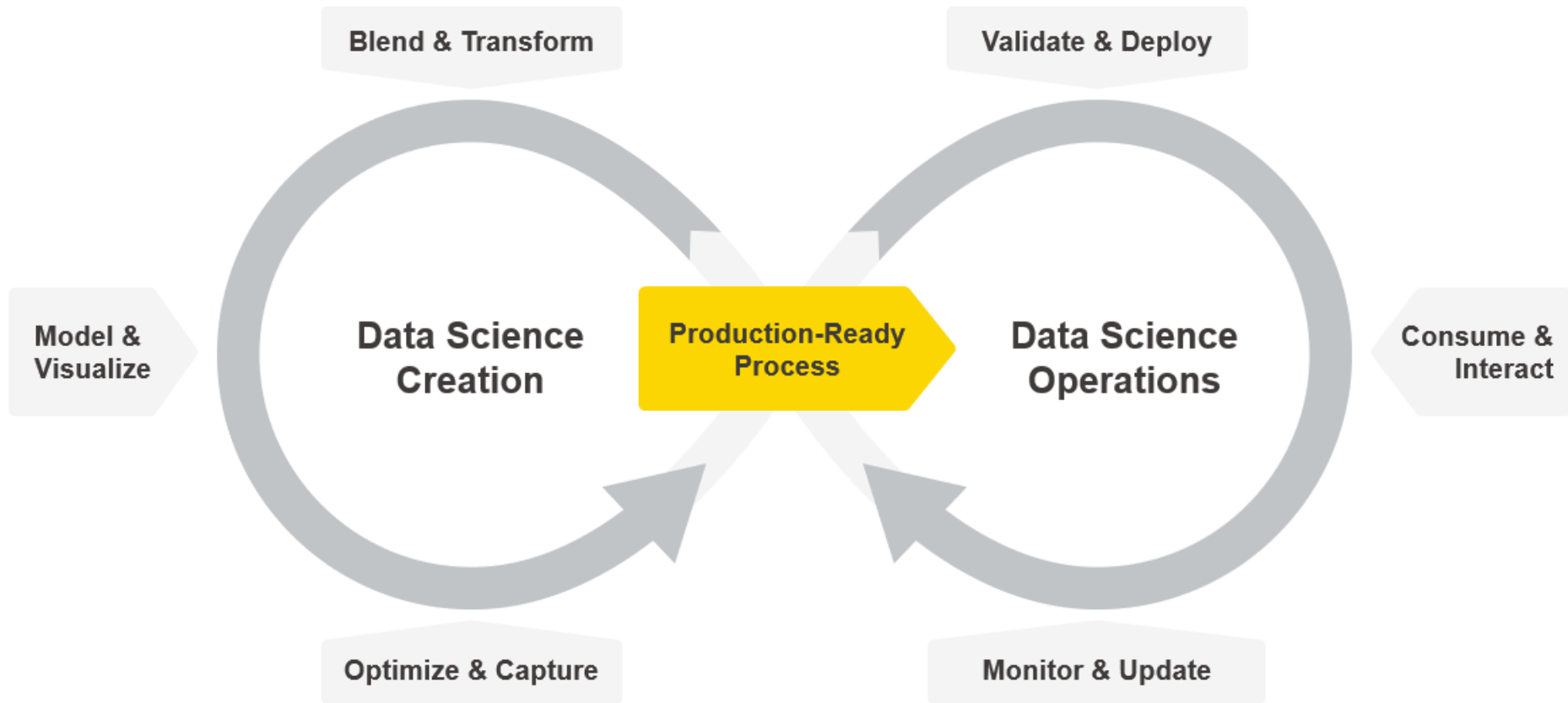
- How to communicate to the user the status of thousands of models?
 - An application for the frontend
- Who controls the process and the dependencies?
 - A separate program that handles the management process in the correct order

category	music				jewelry			appliances				
item	horn	trumpet	violin	harp	ring	Ear-rings	Neck-lace	fridge	wash. mach.	micro wave	stove	Vacuum cleaner
Threshold on accuracy	0.75	0.90	0.85	0.85	0.9	0.9	0.85	0.7	0.8	0.75	0.75	0.8
retrain	If 3 out of 4 perform below threshold				If all perform below threshold			If one performs below threshold				

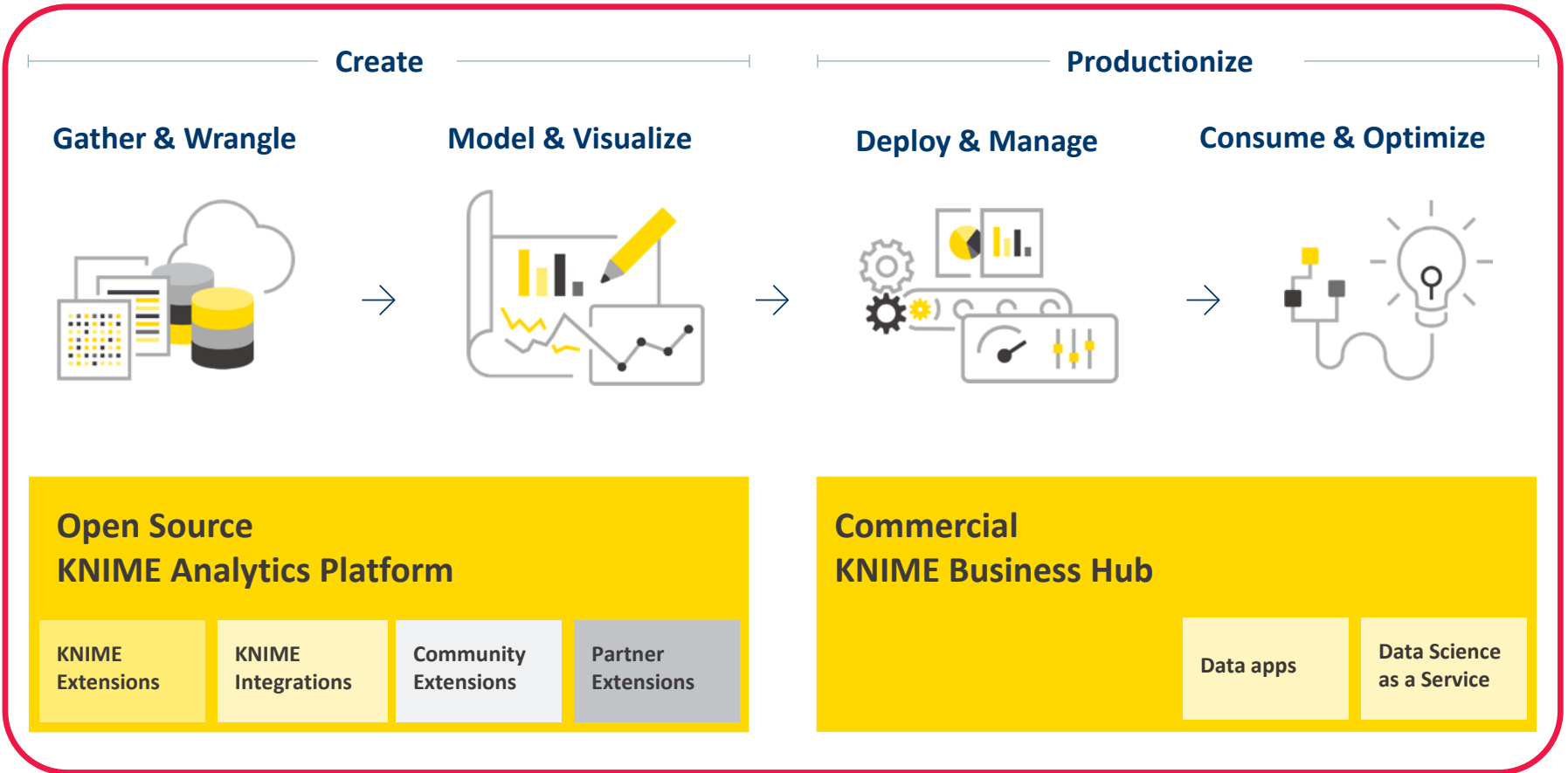
- The term **MLOps** (or **DataOps** or **DSOps**) refers to all those operations required to deploy, monitor, update/retrain a model and comply with the general company rules for auditing and data protection.
- In a sense they are similar to DevOps for software applications in a production environment, only that they deal with Machine Learning models and data science operations in general.
- MLOps Examples
 - Deployment and moving into production
 - Monitoring of Model Performance
 - Triggering of Retraining[s]
 - Storage of Information for Auditing Purposes

Model Deployment and Management in Practice with KAP and KNIME Business Hub

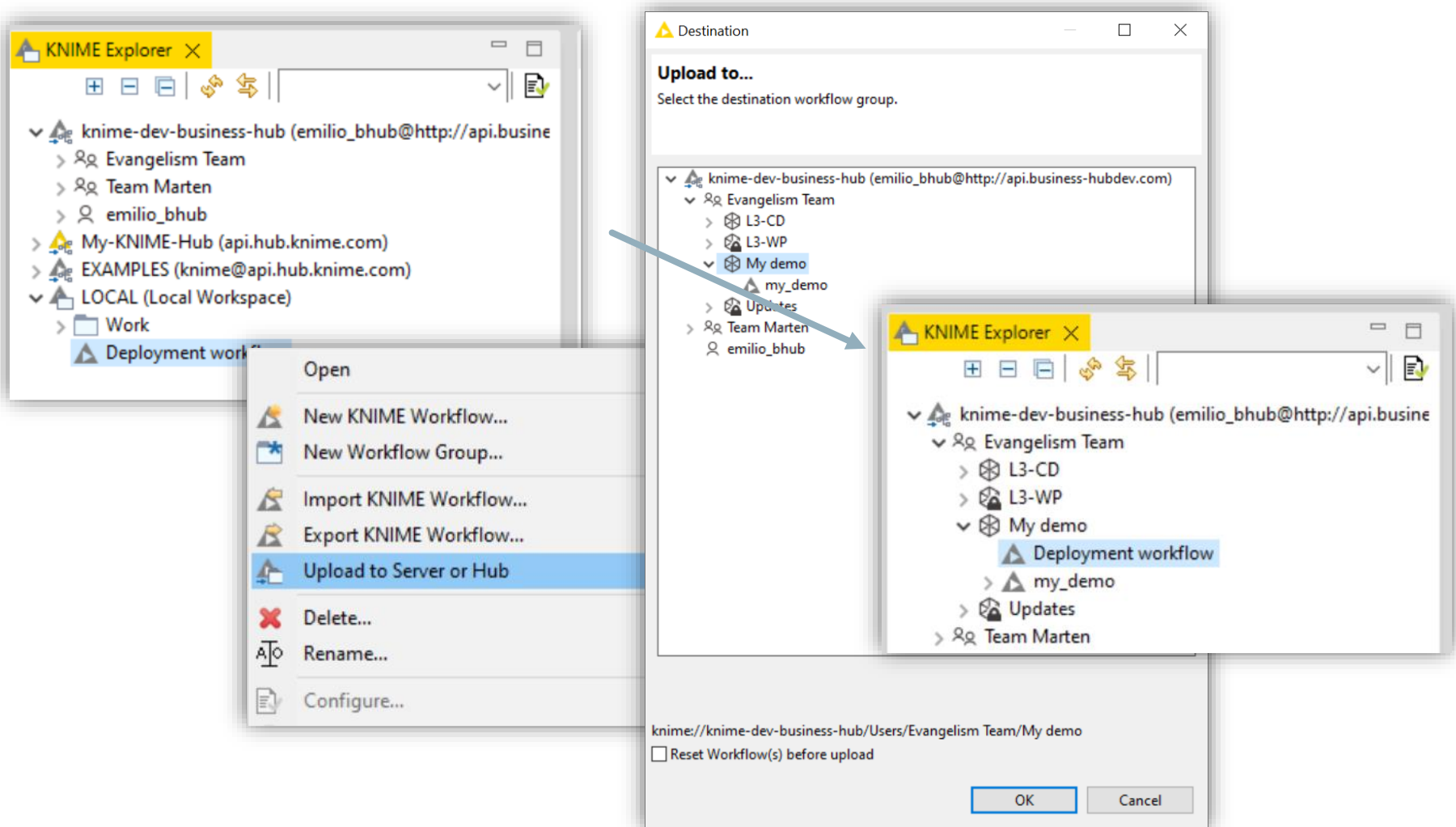
Creating and Productionizing Data Science



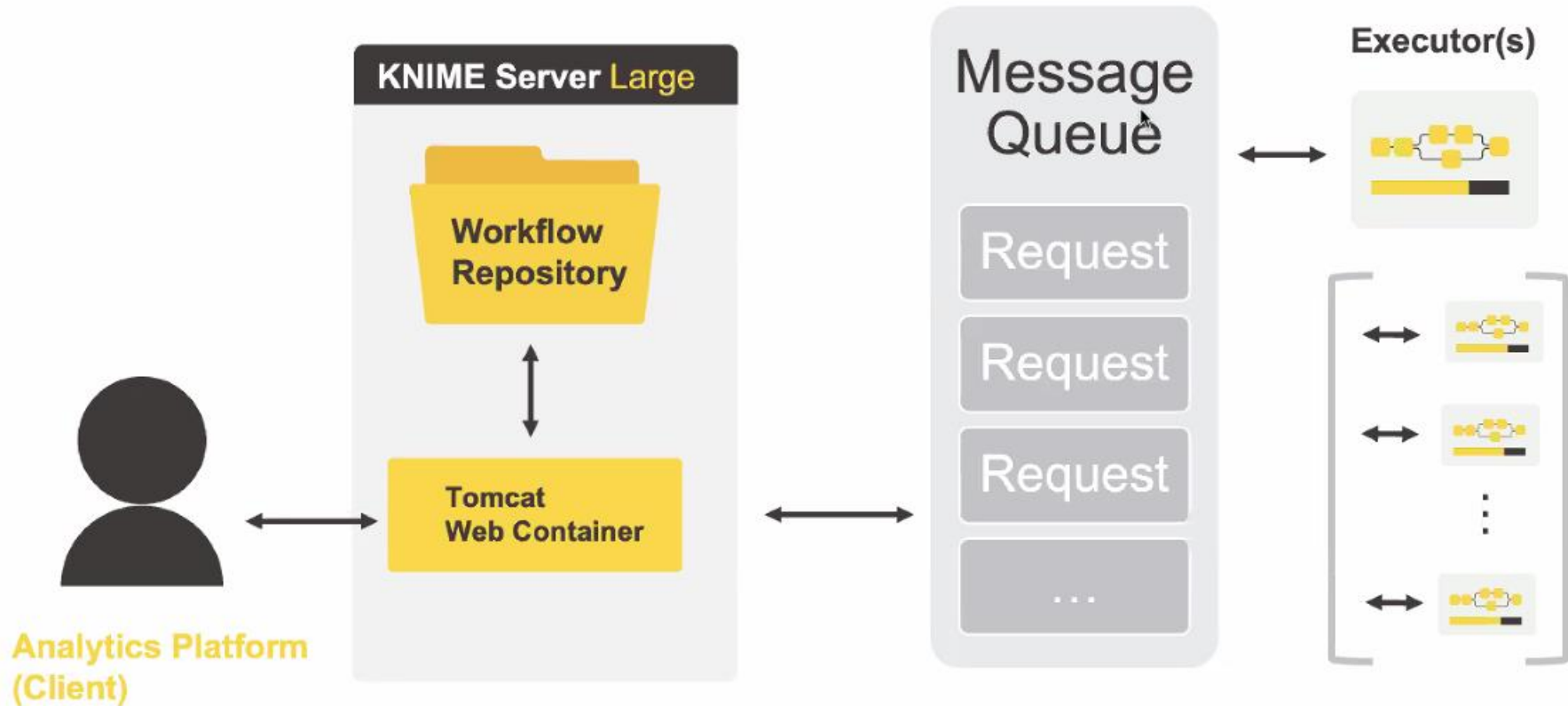
KNIME Software – One Ecosystem




How does deployment actually look like in KNIME?



KNIME Server Architecture




Usual ways to deploy a workflow on KNIME Business Hub

 **Data app** ✕


Create a data app to interact with the workflow via a user interface.

Create data app

 **Schedule**

Schedule your workflow to run automatically at selected times.

Create schedule

 **Service**

Create a service to use the workflow as an API endpoint.

Create service

Deployment to Data App

KNIME Dev Business Hub > Evangelism Team > Spaces > Updates > 01_Deploy_on_Dashboard

Workflow

Deployment to a Dashboard

The GuideBook | Deployment | Dashboard | GIS

Last edited: Jan 12, 2023 Workflow history

Prediction dashboard. The visualization component shows prediction accuracy and data insights

Model Reader

Load trained model

Data upload

Decision Tree Predictor

Predict churn

Visuali

Create data app

Create a data app to interact with the workflow via a user interface.

Deployment name

Data app - Deployment to a Dashboard

Version

demo - Jan 12, 2023 10:21 AM

Execution context

Evangelism Execution Context (Default)

Workflow actions

Control basic actions of the workflow execution.

☐ Enable workflow actions

Advanced settings

Change job lifecycle behaviour, timeouts, ...

Set >

Cancel

Create

Predictor accuracy

Confusion Matrix

	No (Predicted)	Yes (Predicted)	
No (Actual)	1229	59	95.42%
Yes (Actual)	63	149	70.28%
	95.12%	71.63%	

ROC Curve

True Positive Rate

False Positive Rate

P (class=Yes) (0.808)

● P (class=Yes) ● random

Multiple features relations

Parallel Coordinates Plot

account_l... internatio... voice_ma... total_day... number_... P (class=...

Two features visualization

Scatter Plot

account_length

total_day_charge

Show 10 entries

Search:

RowID	state	account_length	area_code	phone_number	international_plan	voice_mail_plan	number_vmai
Row2	39	74	415	916	0	0	0
Row3	12	168	408	1854	0	0	0
Row5	45	76	510	1530	0	1	33

Deployment by Scheduling Automation

The screenshot displays the KNIME Hub interface. The main area shows a workflow named **my_demo** with the following steps: **CSV Reader** → **Component** → **Automated Visualization**. The workflow was last edited on Jan 6, 2023. Below the workflow, there are tabs for **Extensions** and **Nodes**, and a note that it was created with KNIME Analytics Platform version 4.7.0.

On the right, a **Create schedule** dialog box is open. It contains the following fields and options:

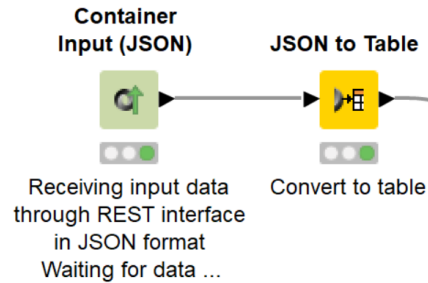
- Deployment name:** A text input field containing "Schedule - my_demo".
- Version:** A dropdown menu showing "version1 - Jan 6, 2023 5:33 PM".
- Execution context:** A dropdown menu showing "Evangelism Execution Context".
- Schedule options:** A section with the instruction "Define when the workflow should be executed." and an **Initial execution** section.
- Initial execution:** A date and time picker showing "2023-01-12" at "10:18:00".
- Repeat every:** A checkbox that is currently unchecked.
- Workflow actions:** A section with the instruction "Control basic actions of the workflow execution." and an **Enable workflow actions** checkbox that is currently unchecked.

At the bottom of the dialog box, there are **Cancel** and **Create** buttons.

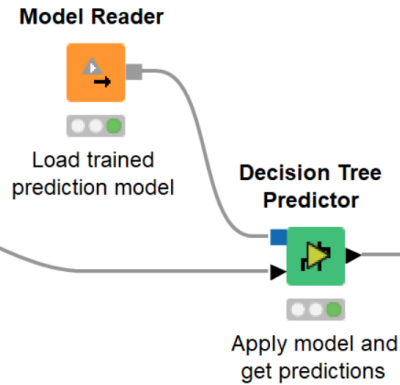
Deployment as a REST Service

REST service to perform churn predictions on customer data

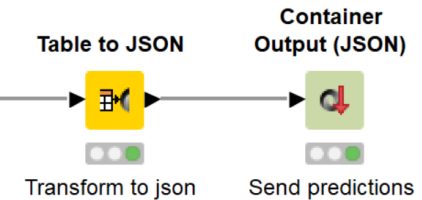
Input reading and model loading



Calculate churn probabilities



Generate output



manually

- Deployment to Data App
 - Deployment by Scheduling Automation
 - Deployment as a REST Service
-
- Integrated Deployment

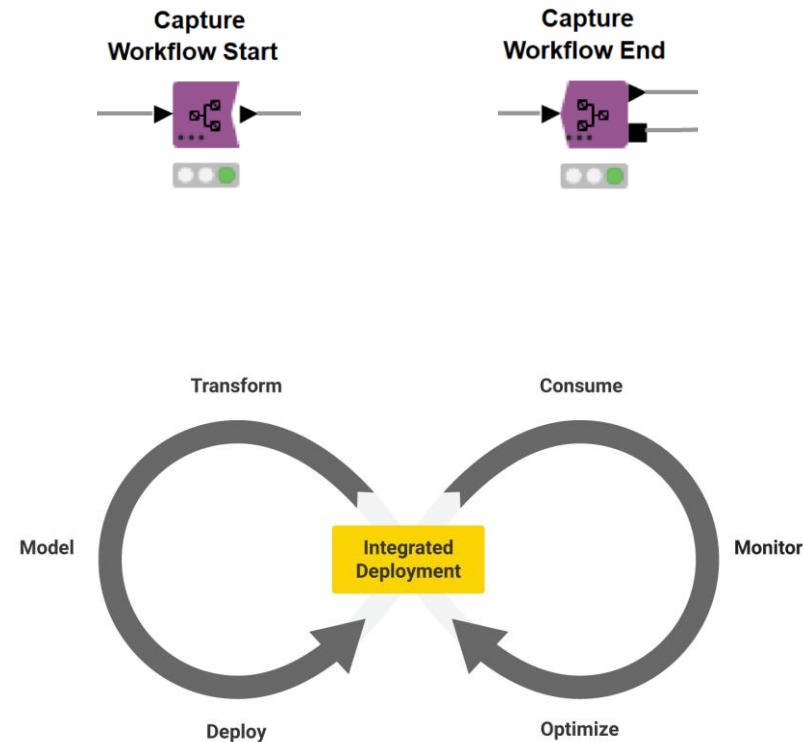
Deployment can be a repetitive task:

- *Monitor & Update*
(from cycle)

Automating deployment
of any of the above,
especially **REST Service**

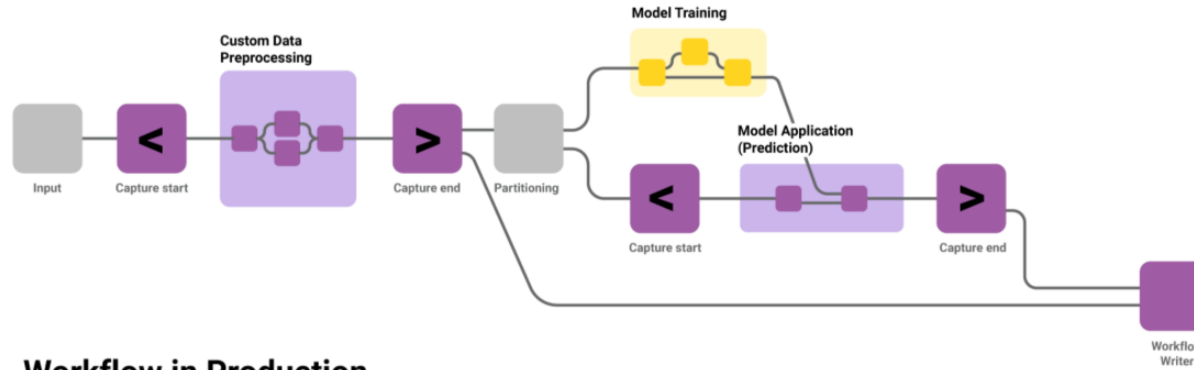
Integrated Deployment

- Build an optimal model
- Isolate core parts of the workflow (preprocessing, model building...) with the special nodes *Capture Workflow Start* and *Capture Workflow End* from the training workflow
- Export the extracted pieces to build the deployment workflow

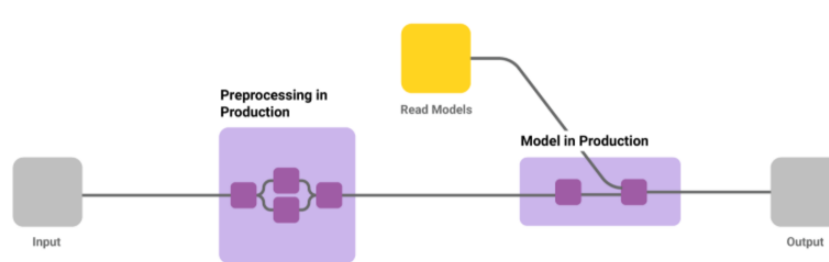


Integrated Deployment

Creating Prediction Model



Workflow in Production



- Automatically build and deploy deployment workflows
- Mostly used to automatically capture and deploy a model as REST API from the workflow which trains and validates the model

Thank you