# Open standards for machine learning model deployment

IBM **Developer**

**Svetlana Levitan, PhD**
Senior Developer Advocate
Center for Open Data and AI Technologies (CODAIT)
IBM Cognitive Applications

***@SvetaLevitan***

# Who is Svetlana Levitan?

Originally from Moscow, Russia

PhD in Applied Mathematics and MS in Computer Science from University of Maryland, College Park

Software Engineer for SPSS Analytic components (2000-2018)

Working on PMML since 2001, ONNX recently

IBM acquired SPSS in 2009

Developer Advocate with IBM Center for Open Data and AI Technologies (since June 2018)

Meetup organizer: Big Data Developers in Chicago, Open Source Analytics, IBM Cloud, Chicago ML

Two daughters love programming





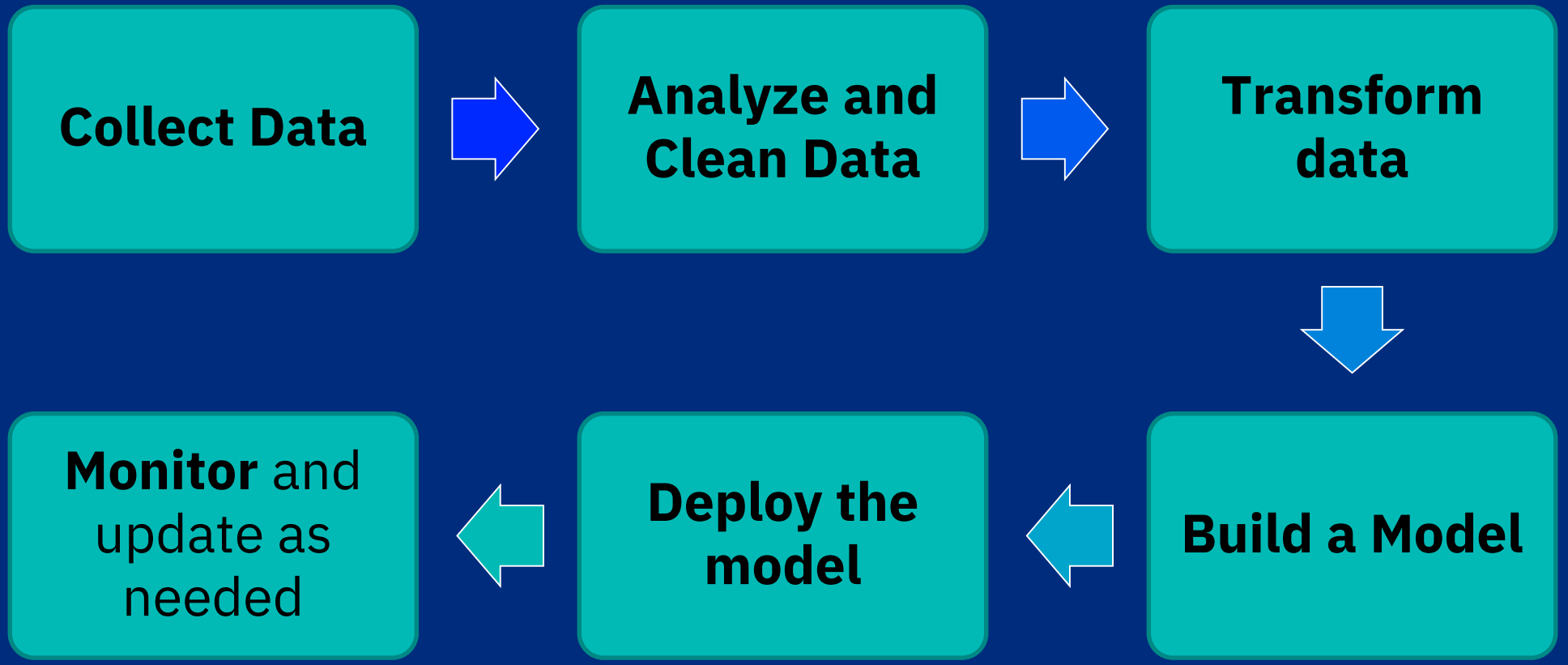
***@SvetaLevitan***

# Agenda

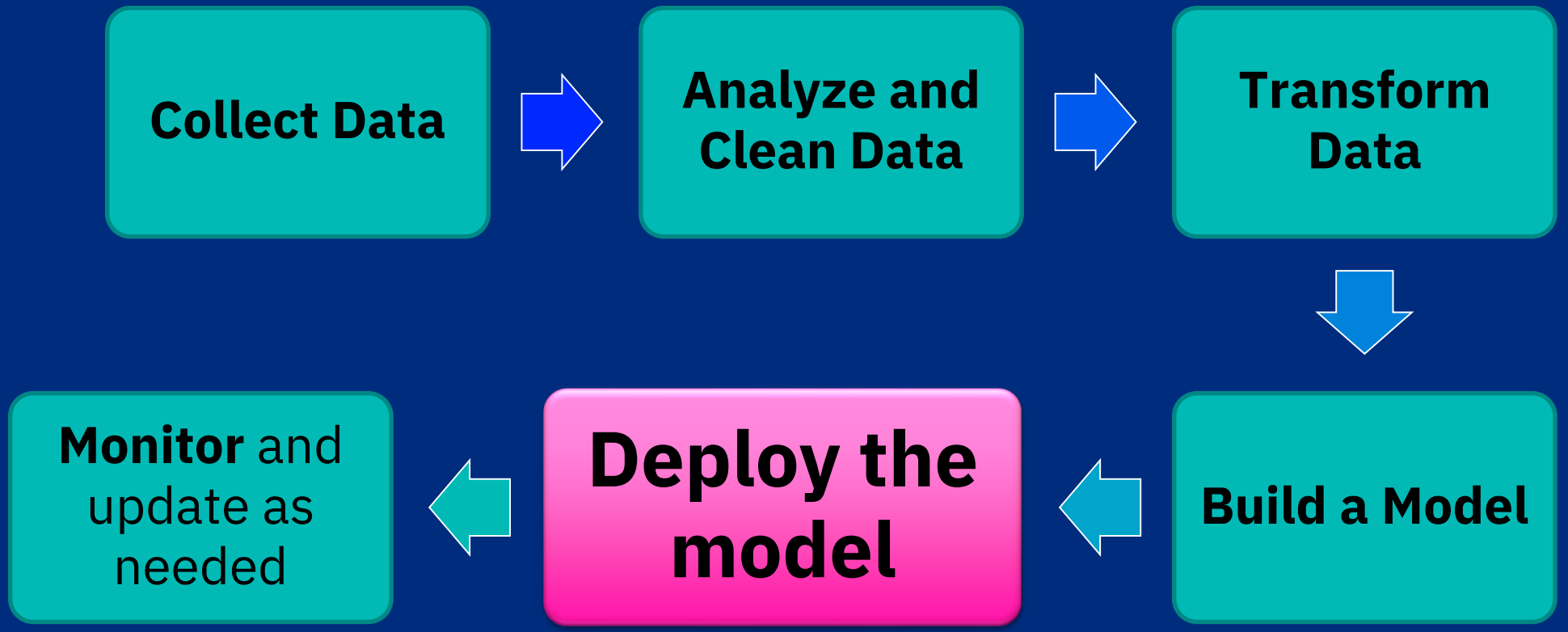
- Deployment challenges
- PMML Internals
- PMML in Python and R
- PMML in IBM products
- PFA
- ONNX

# Typical Stages in Machine Learning



# Typical Stages in Machine Learning



# Model Deployment Challenges

**Teams**

- Data Scientists and statisticians
- Application developers and IT

**Environments**

- OS and File Systems
- Databases, desktop, cloud

**Languages**

- Python or R, various packages, C++ or Java or Scala, Dependencies and versions

**Data Preparation**

- Aggregation and joins
- Normalization, Category Encoding, Binning, Missing value replacement

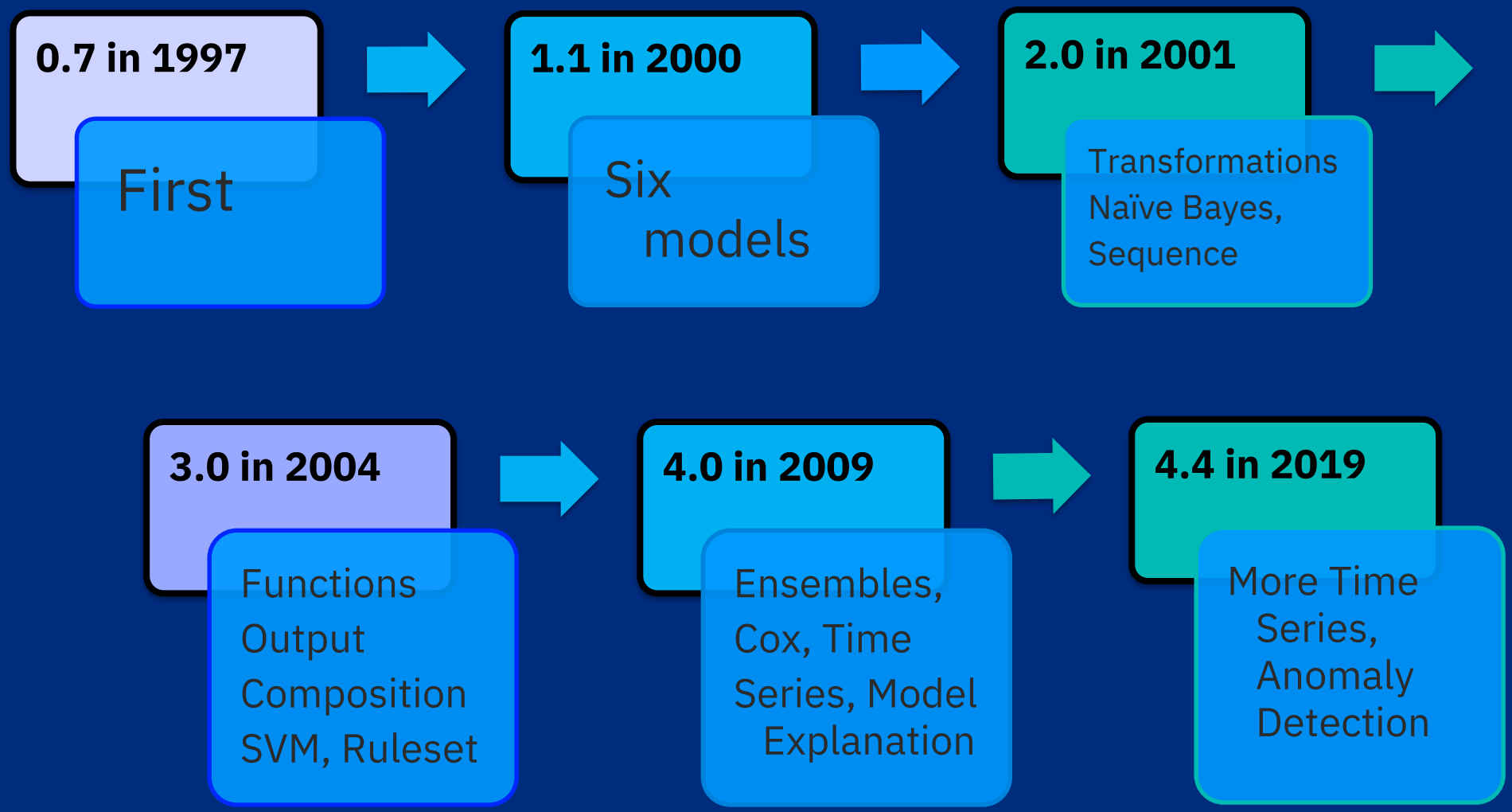
# DMG to the rescue!


Data Mining Group since 1990’s dmg.org

## Predictive Model Markup Language

- An Open Standard for **XML** Representation
- Over 30 vendors and organizations
- PMML 4.4 Release manager: Svetlana Levitan

# Brief History of PMML versions



# Main Components of PMML

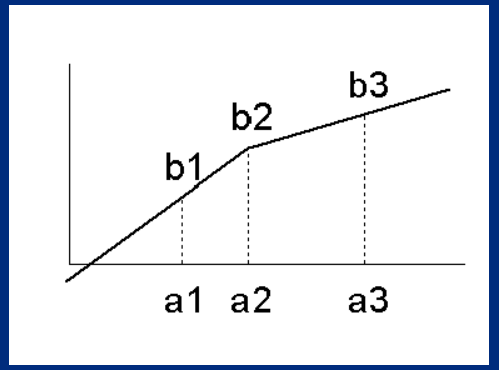

- Header
- Data Dictionary
- Transformation Dictionary
- Model(s)



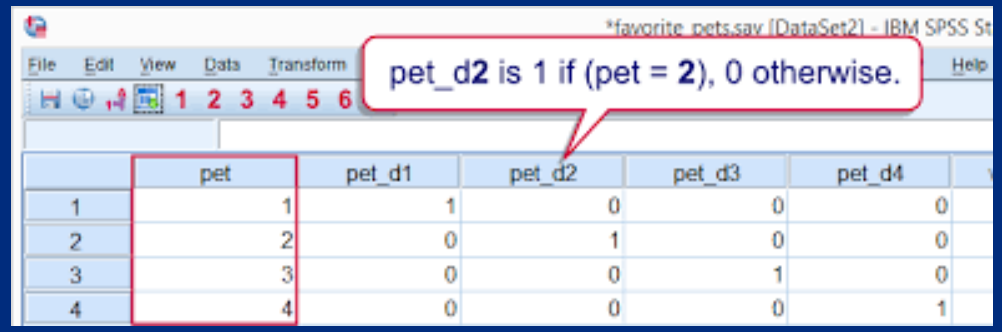
 

# Transformations

- **NormContinuous:** piece-wise linear transform




- **NormDiscrete:** map a categorical field to a set of dummy fields




| | pet | pet_d1 | pet_d2 | pet_d3 | pet_d4 |
|---|---|---|---|---|---|
| 1 | 1 | 1 | 0 | 0 | 0 |
| 2 | 2 | 0 | 1 | 0 | 0 |
| 3 | 3 | 0 | 0 | 1 | 0 |
| 4 | 4 | 0 | 0 | 0 | 1 |

- **Discretize:** binning
- **MapValues:** map one or more categorical fields into another categorical one
- **Functions:** built-in and user-defined
- Other transformations

# PMML 4.4 Models


- Anomaly Detection (new)
- Association Rules Model
- Clustering Model
- General Regression
- Naïve Bayes
- Nearest Neighbor Model
- Neural Network
- Regression
- Tree Model

- **Mining Model:** composition or ensemble (or both) of models

- Baseline Model
- Bayesian Network
- Gaussian Process
- Ruleset
- Scorecard
- Sequence Model
- Support Vector Machine
- Time Series



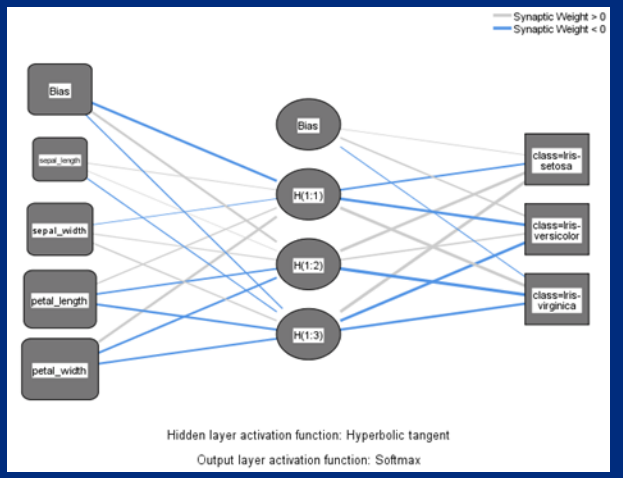
 

# Contents of a PMML Model

- **Mining Schema**: target and predictors, importance, missing value treatment, invalid value treatment, outlier treatment
- **Output**: what to report, post-processing
- **Model Stats**: description of input data
- **Model Explanation**: model diagnostics, useful for visualization
- **Targets**: target category info and prior probabilities
- **Local Transformations**: predictor transformations local to the model
- *…<Specific model contents>…*
- **Model Verification**: expected results for some cases

# An example PMML – Data Dictionary, Transformations

```
<DataDictionary numberOfFields="5">
 <DataField name="class" optype="categorical" dataType="string">
   <Value value="Iris-setosa"/>
   <Value value="Iris-versicolor"/>
   <Value value="Iris-virginica"/>
 </DataField>
 <DataField name="sepal_length" optype="continuous" dataType="double"/>
 <DataField name="sepal_width" optype="continuous" dataType="double"/>
 <DataField name="petal_length" optype="continuous" dataType="double"/>
 <DataField name="petal_width" optype="continuous" dataType="double"/>
</DataDictionary>
```

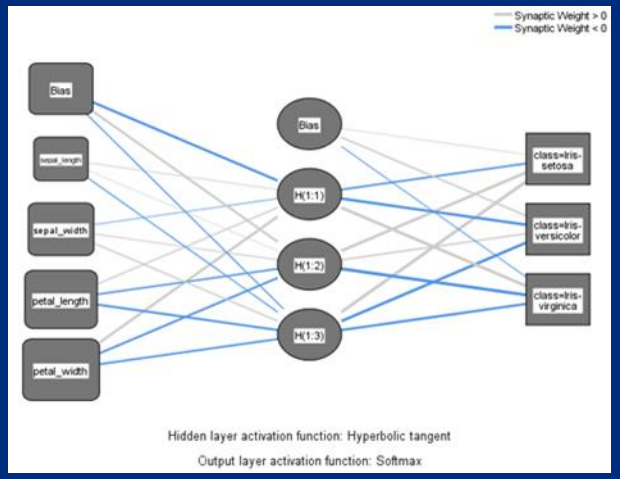



```
<DerivedField optype="categorical" dataType="double" name="classValue2">
   <NormDiscrete field="class" value="Iris-virginica"/>
 </DerivedField>
<DerivedField optype="continuous" dataType="double" name="sepal_lengthNorm">
 <NormContinuous field="sepal_length">
    <LinearNorm orig="4.3" norm="-1.84285714285714"/>
    <LinearNorm orig="7.7" norm="2.3204081632653"/>
  </NormContinuous>
 </DerivedField>
<DerivedField optype="continuous" dataType="double" name="sepal_widthNorm">
 <NormContinuous field="sepal_width">
    <LinearNorm orig="2" norm="-2.48539690378995"/>
    <LinearNorm orig="4.4" norm="3.13131926296699"/>
  </NormContinuous>
```

# Example PMML – Neural Network MiningSchema and inputs

```
<NeuralNetwork functionName="classification" activationFunction="tanh">
  <MiningSchema>
    <MiningField name="sepal_length"/>
    <MiningField name="sepal_width"/>
    <MiningField name="petal_length"/>
    <MiningField name="petal_width"/>
    <MiningField name="class" usageType="predicted"/>
  </MiningSchema>
  <NeuralInputs>
    <NeuralInput id="0">
      <DerivedField optype="continuous" dataType="double">
        <FieldRef field="sepal_lengthNorm"/>
      </DerivedField>
    </NeuralInput>
    <NeuralInput id="1">
      <DerivedField optype="continuous" dataType="double">
        <FieldRef field="sepal_widthNorm"/>
      </DerivedField>
    </NeuralInput>
```

***Predictors***



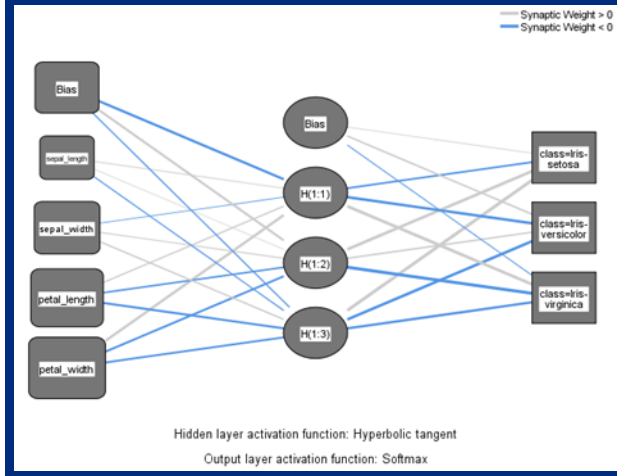
# Example PMML - Neural Network hidden layer and outputs

```
      <Neuron id="6" bias="-0.69138649428932">
        <Con from="0" weight="-0.57324998362272"/>
        <Con from="1" weight="0.892806772564007"/>
        <Con from="2" weight="-1.23192787546061"/>
        <Con from="3" weight="-1.19705013526962"/>
      </Neuron>
    </NeuralLayer>
    <NeuralLayer numberOfNeurons="3" activationFunction="identity" normalizationMethod="softmax">
      <Neuron id="7" bias="0.101922887283541">
        <Con from="4" weight="-1.05690948855012"/>
        <Con from="5" weight="2.00228899161664"/>
        <Con from="6" weight="3.31278374396491"/>
      </Neuron>
      <Neuron id="8" bias="0.917636281284728">
        <Con from="4" weight="-1.47230776836775"/>
        <Con from="5" weight="0.905795272070893"/>
        <Con from="6" weight="-1.60793177845373"/>
      </Neuron>
      <Neuron id="9" bias="-0.2772471777484">
        <Con from="4" weight="2.22290439134024"/>
        <Con from="5" weight="-2.43960637239511"/>
        <Con from="6" weight="-1.32214182019044"/>
      </Neuron>
    </NeuralLayer>
    <NeuralOutputs>
      <NeuralOutput outputNeuron="7">
        <DerivedField optype="categorical" dataType="double">
          <FieldRef field="classValue0"/>
        </DerivedField>
      </NeuralOutput>
```

***Hidden layer neuron***

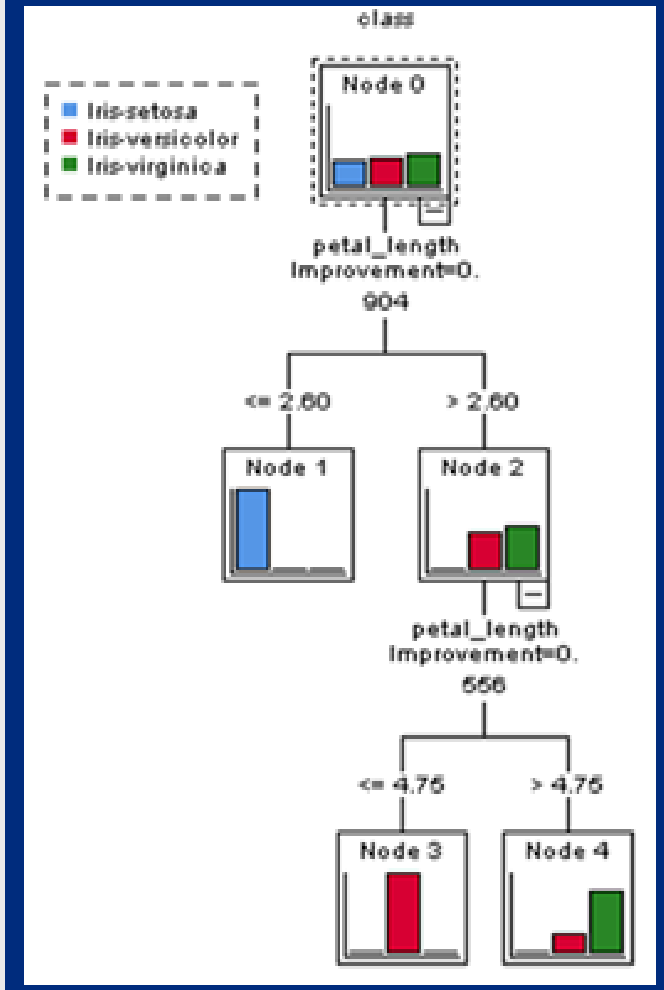
***Output Layer Neurons***

***Connecting target to the neurons***



# Example PMML for a Tree Model

```
<Node id="0"> <True/>
  <Node id="1" score="Iris-setosa" recordCount="50.0">
      <SimplePredicate field="petal_length" operator="lessOrEqual"
                       value="2.6"/>
      <ScoreDistribution value="Iris-setosa" recordCount="50.0"/>
      <ScoreDistribution value="Iris-versicolor" recordCount="0.0"/>
      <ScoreDistribution value="Iris-virginica" recordCount="0.0"/>
   </Node>
   <Node id="2">
      <SimplePredicate field="petal_length" operator="greaterThan"
                       value="2.6"/>
      <Node id="3"score="Iris-versicolor" recordCount="40.0">
         <SimplePredicate field="petal_length"
                          operator="lessOrEqual" value="4.75"/>
```



# PMML Powered

From http://dmg.org/pmml/products.html:

Alpine Data

Angoss

BigML

Equifax

Experian

FICO

Fiserv

Frontline Solvers

GDS Link

IBM (Includes SPSS)

JPMML

KNIME

KXEN

Liga Data

Microsoft

MicroStrategy

NG Data

Open Data

Opera

Pega

Pervasive Data Rush

Predixion Software

Rapid I

R

Salford Systems (Minitab)

SAND

SAS

Software AG (incl. Zementis)

Spark

Sparkling Logic

Teradata

TIBCO

WEKA

# Agenda

- Challenges
- PMML Internals
- PMML in Python and R
- PMML in IBM products
- PFA
- ONNX

# PMML in Python

JPMML package is created and maintained by Villu Ruusmann in Estonia.

From https://stackoverflow.com/questions/33221331/export-python-scikit-learn-models-into-pmml

```
pip install git+https://github.com/jpmml/sklearn2pmml.git
```

***Example of how to export a classifier tree to PMML.*** *First grow the tree:*

```
# example tree & viz from http://scikit-learn.org/stable/modules/tree.html
from sklearn import datasets, tree
iris = datasets.load_iris()
clf = tree.DecisionTreeClassifier()
clf = clf.fit(iris.data, iris.target)
```

*SkLearn2PMML conversion takes 2 arguments: an estimator (our `clf`) and a mapper for preprocessing. Our mapper is pretty basic, since no transformations.*

```
from sklearn_pandas import DataFrameMapper
default_mapper = DataFrameMapper([(i, None) for i in iris.feature_names + ['Species']])
from sklearn2pmml import sklearn2pmml
sklearn2pmml(estimator=clf, mapper=default_mapper, pmml="IrisClassificationTree.pmml")
```

# PMML in R

**R packages “pmml” and “`pmmlTransformations`”**

https://cran.r-project.org/package=pmml

Supports a number of R models: **`ada, amap, arules, caret, clue, data.table, gbm, glmnet, neighbr, nnet, rpart, randomForest, kernlab, e1071, testthat, survival, xgboost, knitr, rmarkdown`**

Maintained by Dmitriy Bolotov and others from Software AG

JPMML also has package “**r2pmml**” that augments “pmml” and provides PMML export for additional R models

**Build and save a decision tree (C&RT) model predicting Species class:**

```
> irisTree <- rpart( Species~., iris )
> saveXML( pmml( irisTree ), "IrisTree.xml" )
```

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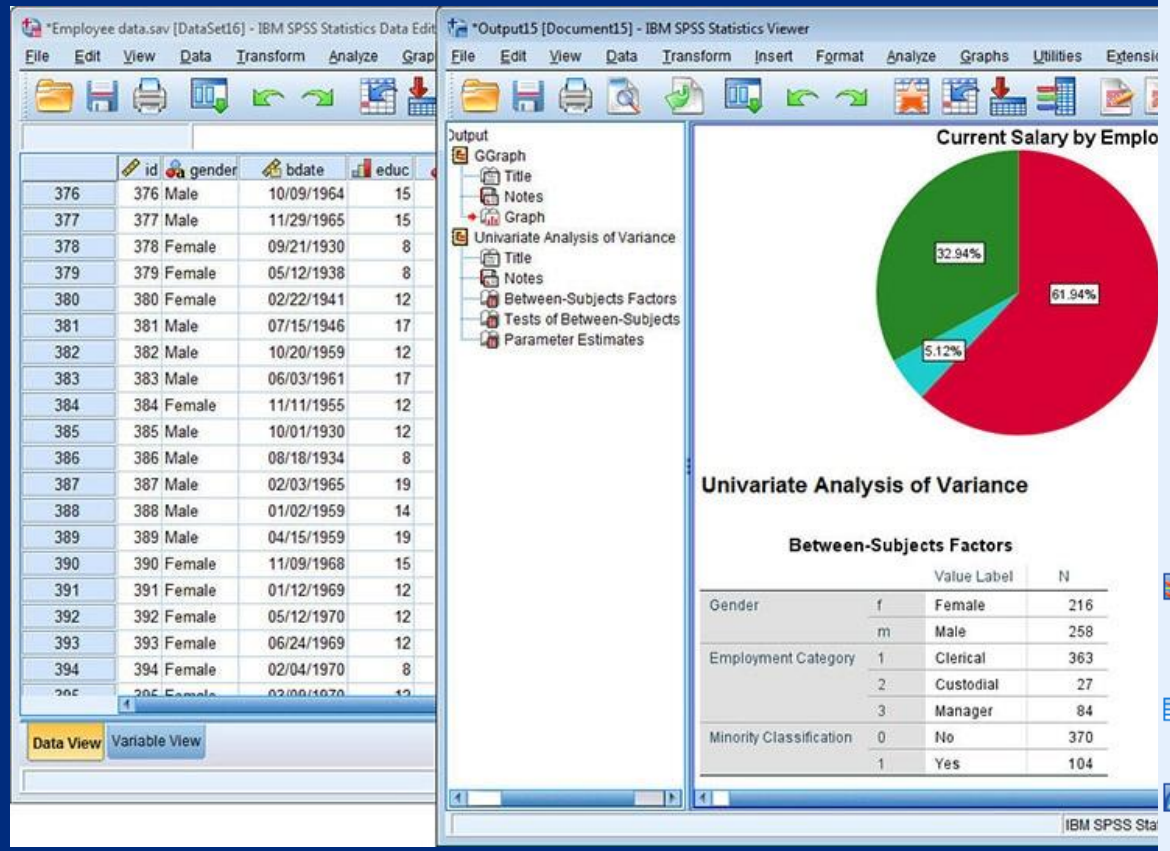
# IBM SPSS Statistics

**1968**
**Statistical Package for Social Sciences**

Acquired by IBM in 2009

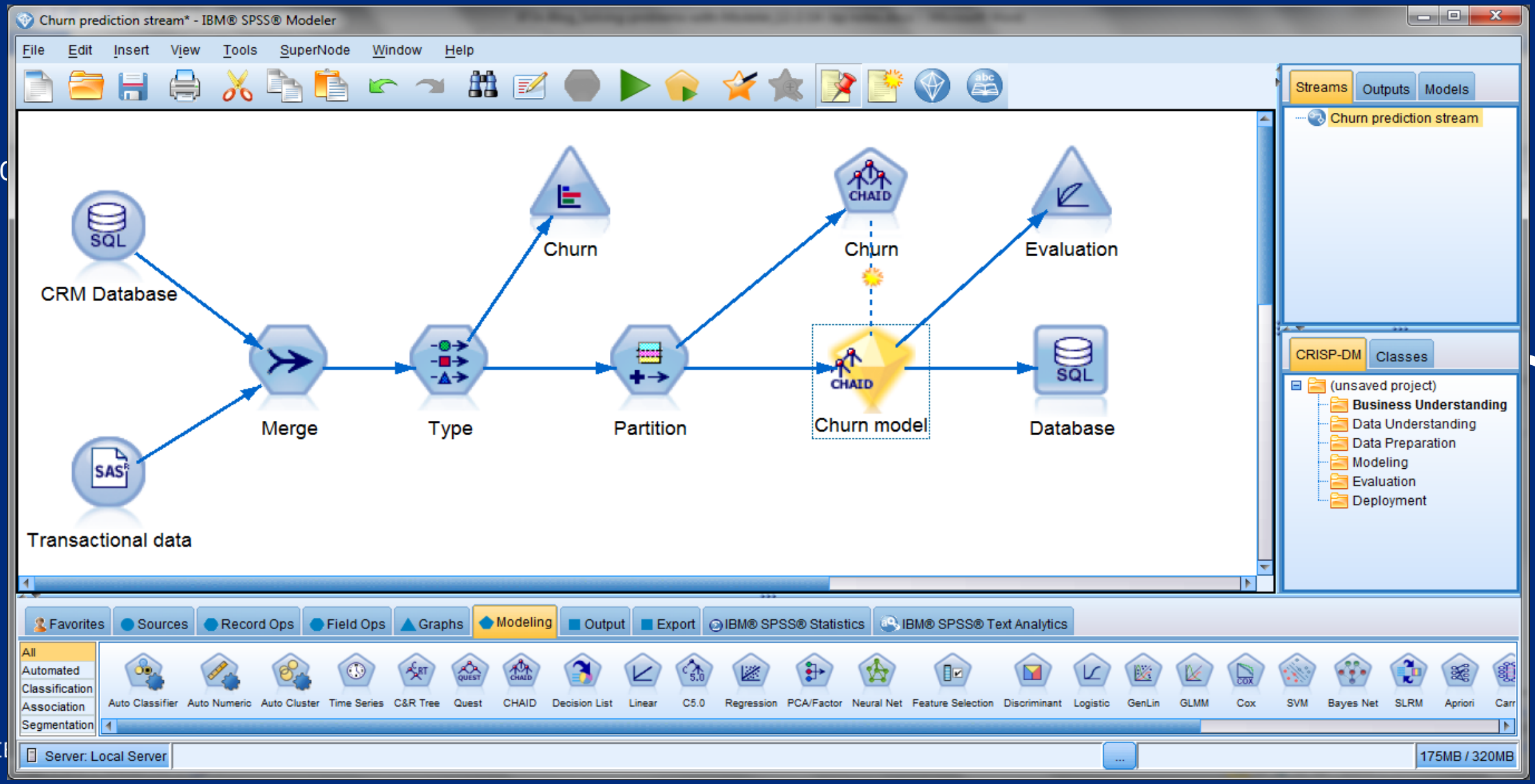
Release 25 in August 2017,
26 in Spring 2019.
Subscription option

Integration with
Python and R




IBM **Developer**

# IBM SPSS Modeler



# IBM SPSS Statistics

*Transformation PMML from:*
ADP (Automatic Data Preparation)
TMS Begin/TMS End

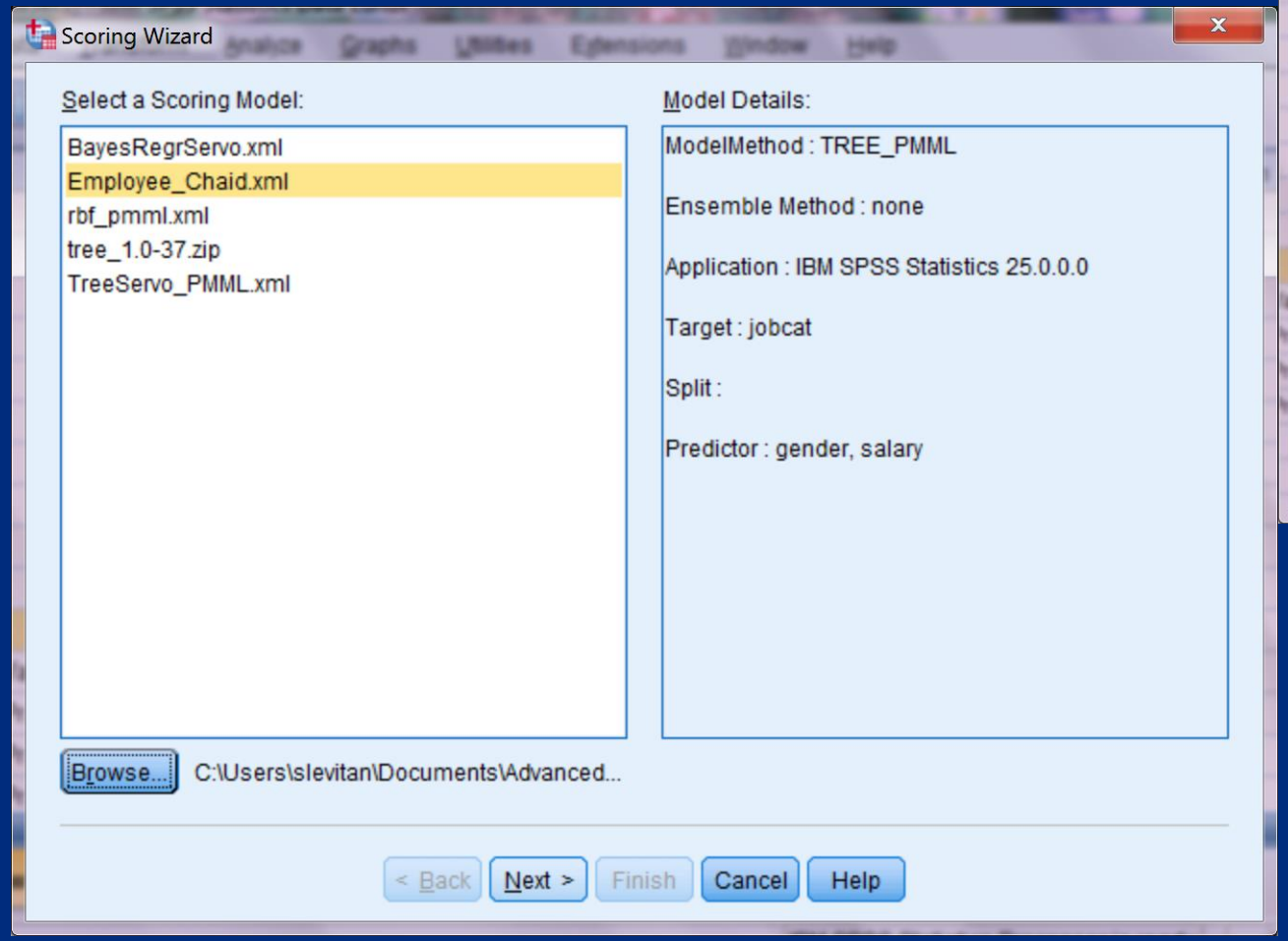
*Model PMML from:*
COXREG, CSCOXREG
CSGLM, CSLOGISTIC, CSORDINAL
GENLIN, Logistic regression, NOMREG
GENLINMIXED
LINEAR, KNN
MLP, RBF neural networks
NAÏVE BAYES
REGRESSION
TREE, TSMODEL
TWOSTEP CLUSTER

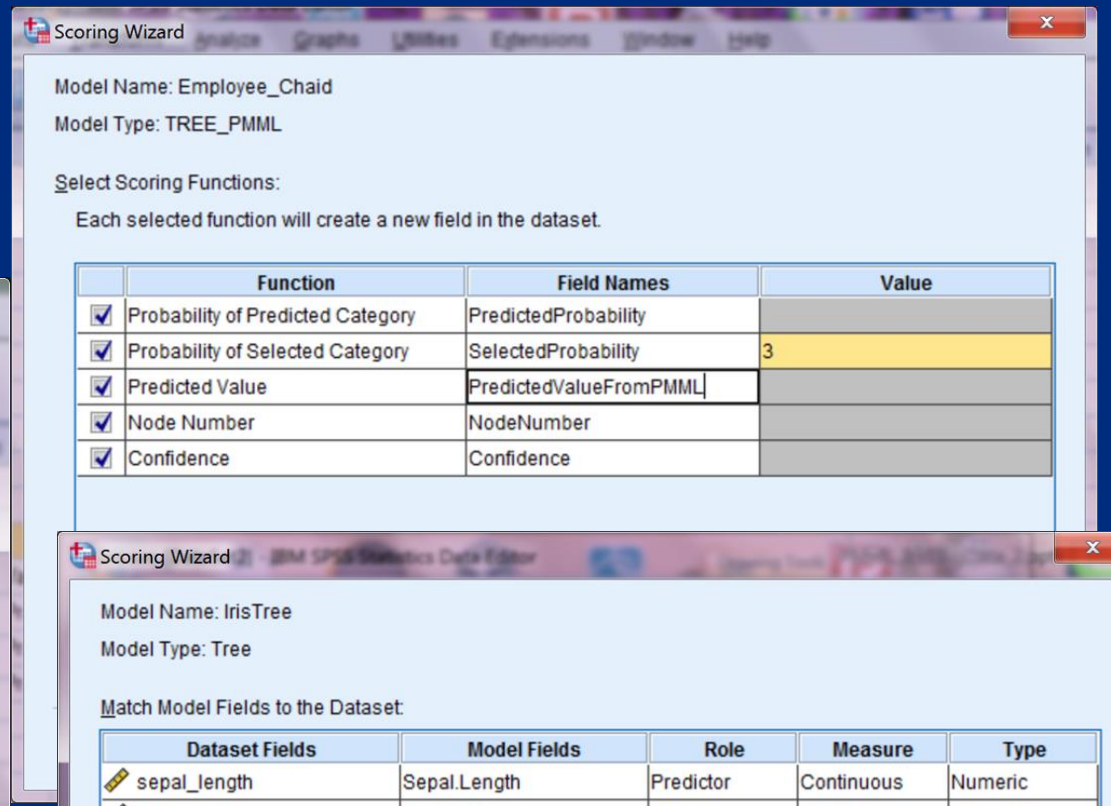
# IBM SPSS Modeler

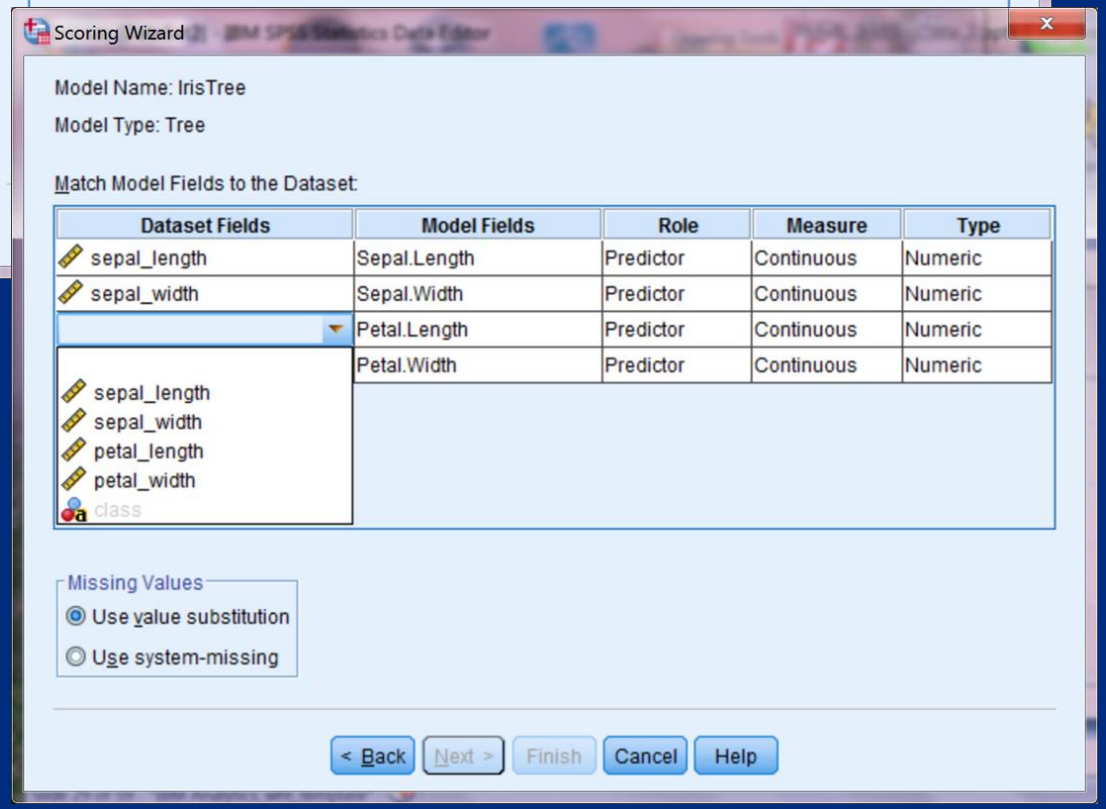
Apriori, CARMA, Association Rules
C5, CART, Chaid decision trees
Cox regression
GENLIN
Decision List
K-Means Cluster
KNN
LINEAR, Regression
Logistic Regression
MLP and RBF
NOMREG
Random Trees
Regression
Two Step Cluster

# Score PMML in IBM SPSS Statistics

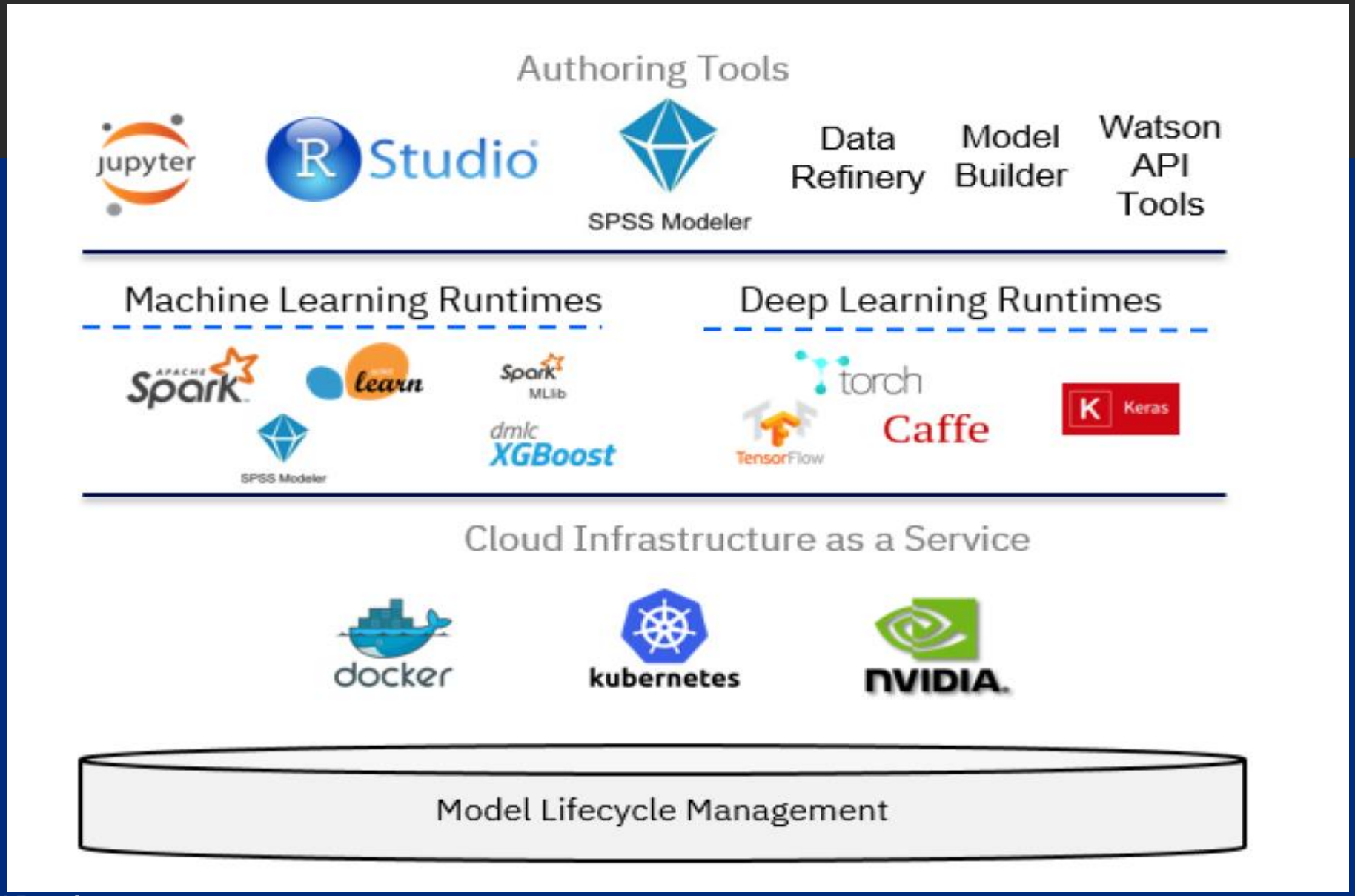
Utilities->Scoring Wizard



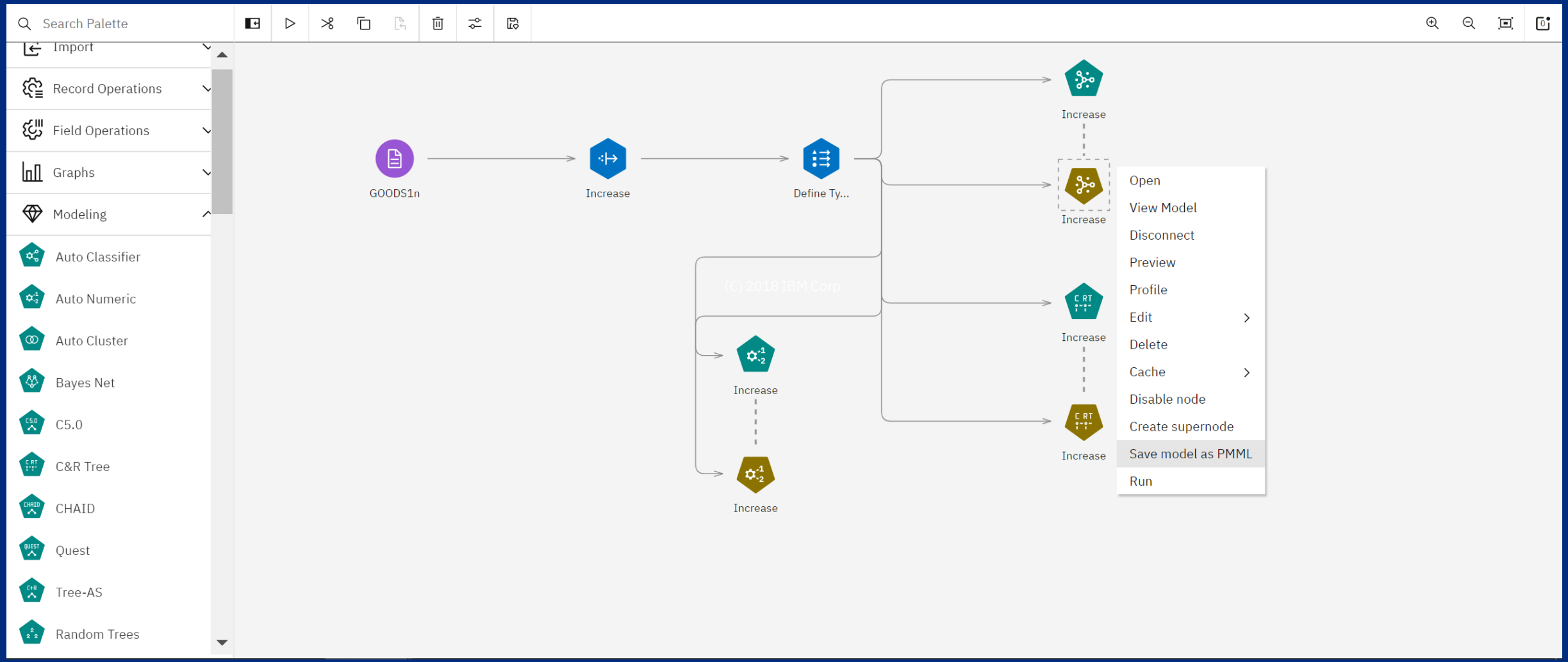



# Watson Studio (formerly Data Science Experience)

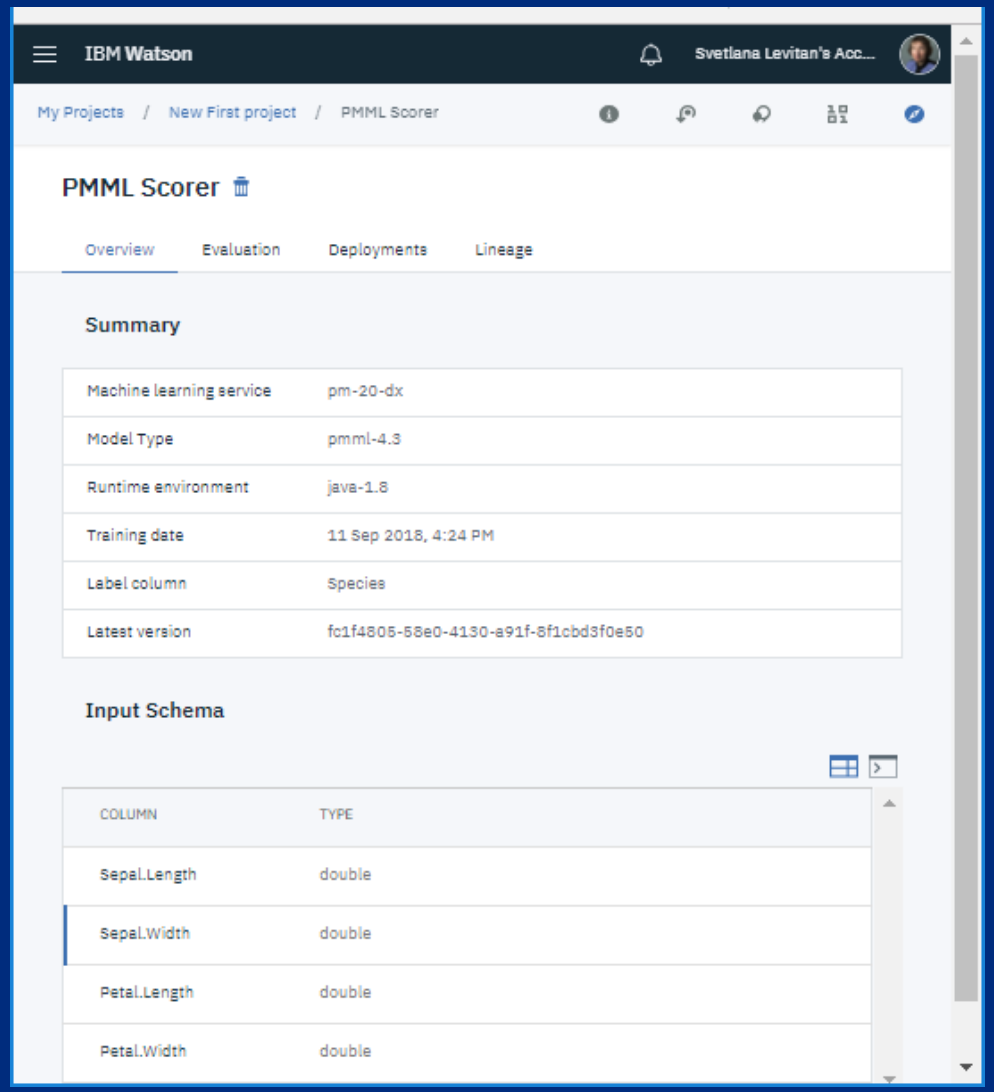


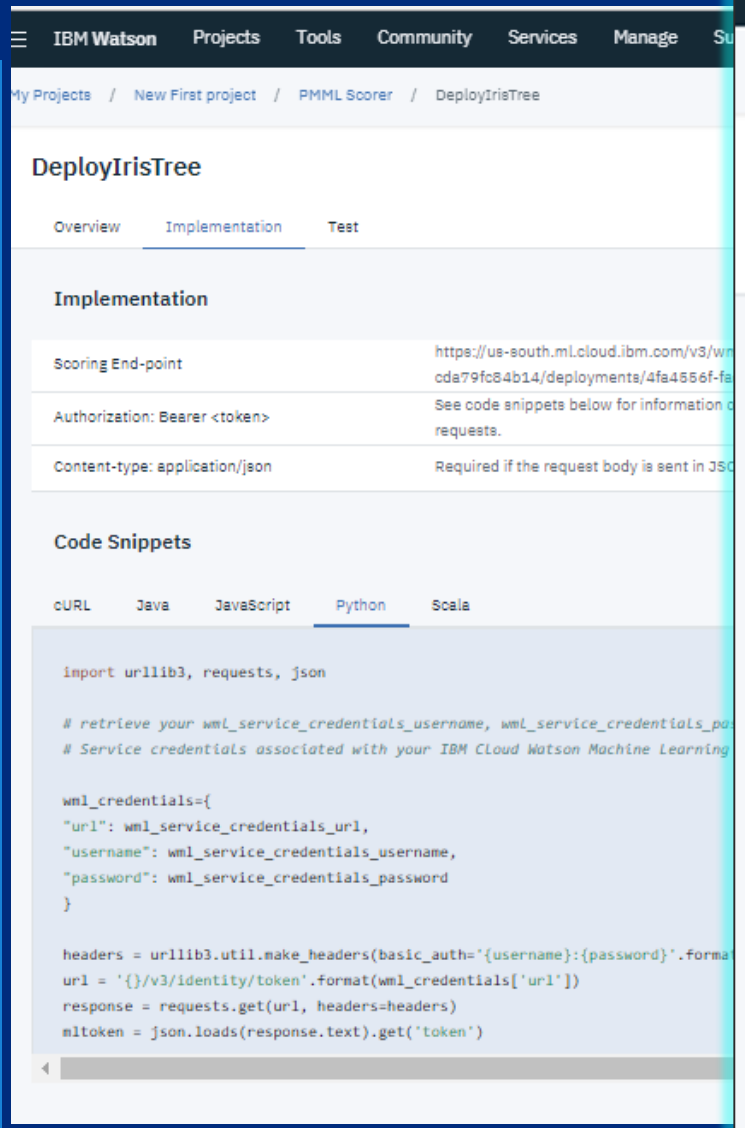

PMML export possible in Jupyter notebooks, Modeler flows, R Studio.
PMML scoring can be done in Flows, notebooks, Watson Machine Learning.

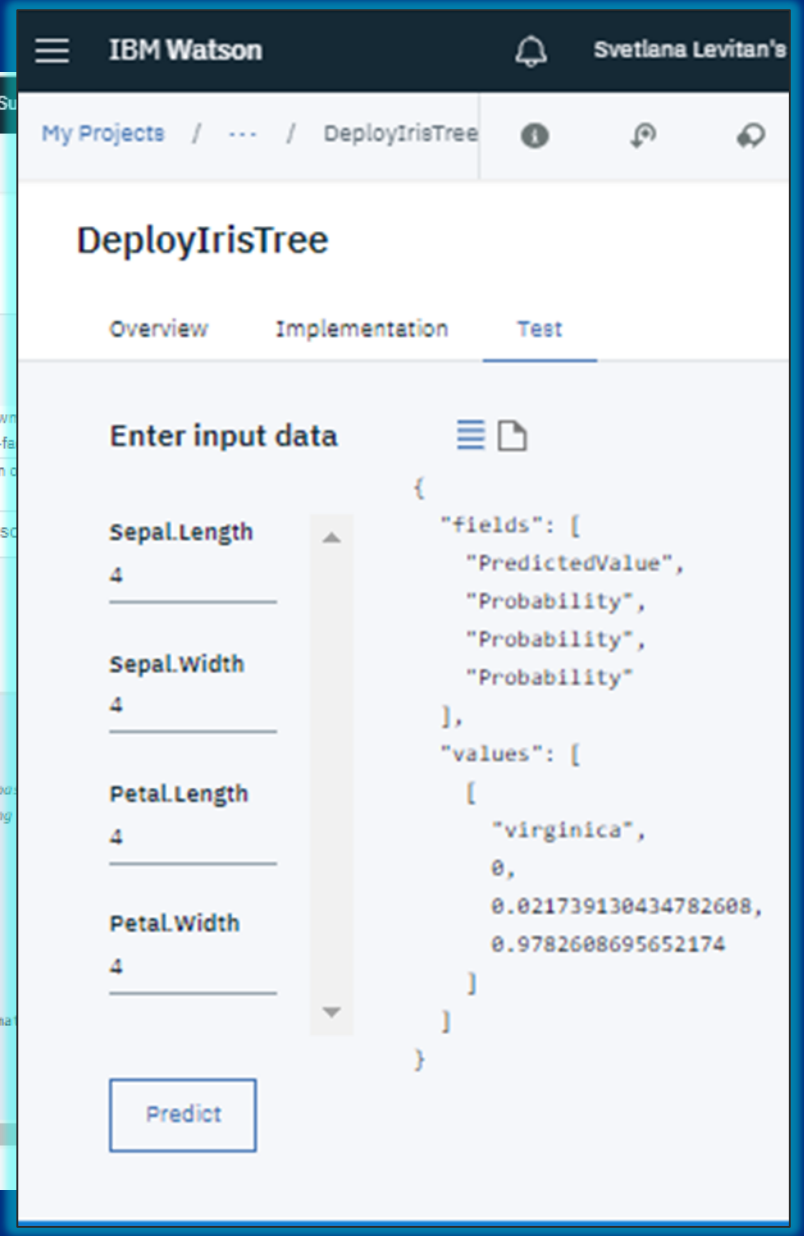
# Watson Studio Flows on IBM Cloud. Free account: https://ibm.biz/Bdqie5



# Scoring PMML in Watson Machine Learning



# Benefits of PMML


Allows seamless deployment and model exchange

Transparency: human and machine-readable

Fosters best practices in model building and deployment



# Agenda

- Challenges
- PMML Internals
- PMML in Python and R
- PMML in IBM products
- PFA
- ONNX

# Portable Format for Analytics - PFA

PMML is great, except when a model or feature is not supported

PFA to overcome this

JSON format, AVRO schemas for data types

A mini functional math language + schema specification

Built-in functions and simple models.

Info: dmg.org/pfa

Jim Pivarski

# A Simple Example of PFA (copied from Nick Pentreath's presentation)

- Example – multi-class logistic regression
- Specify input and output types using Avro schemas

```
{
  "name":"logistic-regression-model",
  "input":{
    "type":{
      "type":"array",
      "items":"double"
    }
  },
  "output":{
    "type":"double"
  },
```

- Specify the *action* to perform (typically on input)

```
"action":[
  {
    "a.argmax": [
      {
        "m.link.softmax": [
          {
            "model.reg.linear": [
              "input",
              {
                "cell": "model"
              }
            ]
          }
        ]
      }
    ]
  }
],
```

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# Known Support for PFA

**Hadrian** (PFA export and scoring engine)
from Open Data Group (Chicago, IL)

**Aardpfark** (PFA export in SparkML)
by Nick Pentreath, IBM CODAIT, South Africa

**Woken** (PFA export and validation)
by Ludovic Claude, CHUV, Lausanne, Switzerland

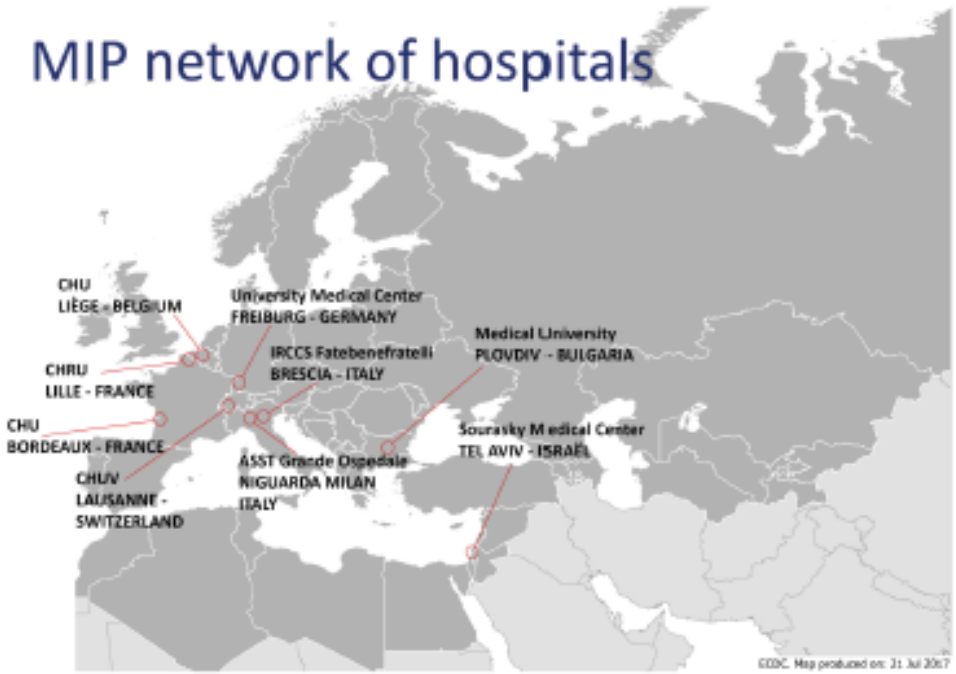
There was a lot of interest in PFA.

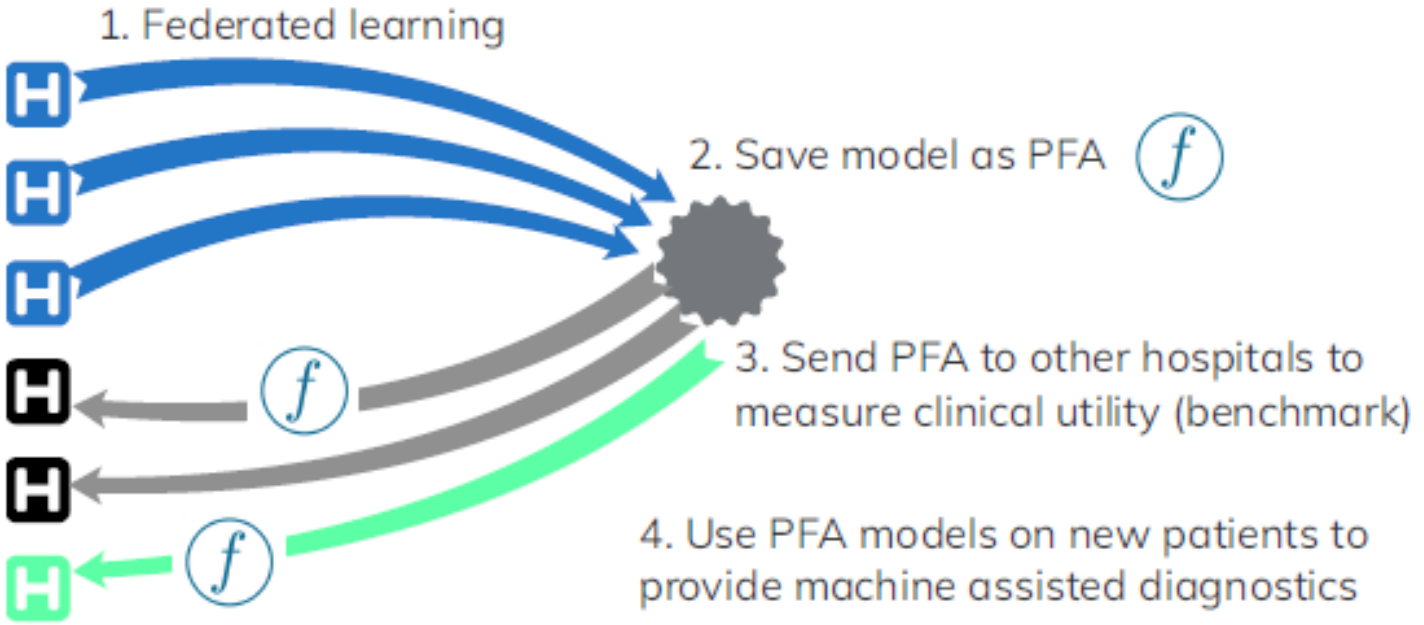
Many opportunities for open source contributions.

# Use of PMML and PFA in medical applications

Human Brain Project

Ludovic Claude,
CHUV
Lausanne,
Switzerland



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# ONNX: Open Neural Network eXchange


Since Sep. 2017. Protobuf

Covers DL and traditional ML

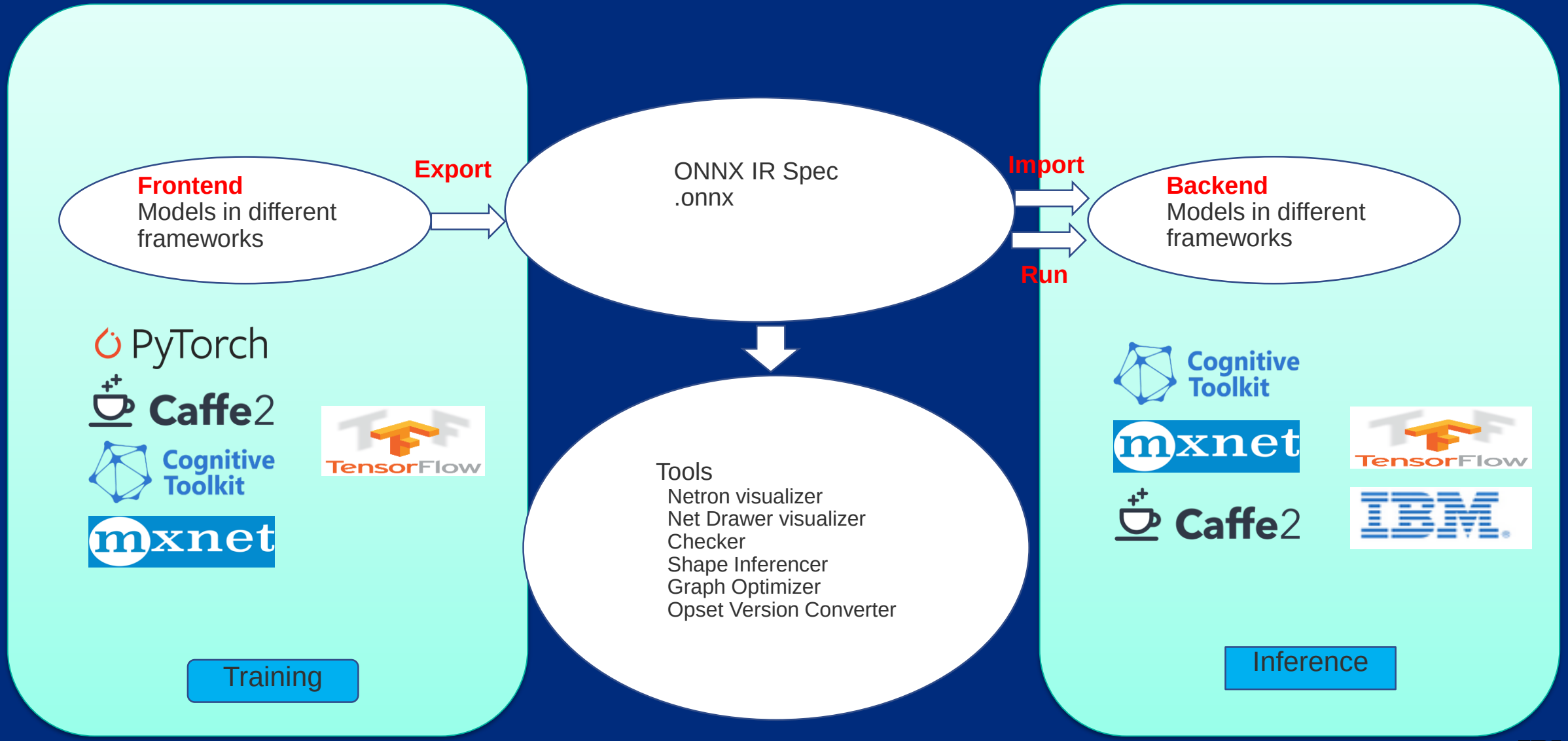
Active work by many companies

Alibaba Group 阿里巴巴集团 · AMD · arm · aws · Baidu 百度 · BITMAIN · CEVA · Facebook Open Source · habana · Hewlett Packard Enterprise · HUAWEI · IBM · intel AI · MathWorks · MEDIATEK · Microsoft · Neural Network Libraries · mi · NVIDIA · NXP · Oath: · Preferred Networks · Qualcomm · sas · skymizer · SYNOPSYS · Tencent · unity

# ONNX Background


- Initial goal: make it easier to exchange trained models between DL frameworks.
- ONNX github has 24 repos, onnx is the core. Others are tutorials, model zoo, importers and exporters for frameworks.
- Onnx/onnx currently has 14 releases, 154 contributors, 8.1K stars.
- Release 1.7 expected March 31, 2020
- Core is in C++ with Python API and tools.
- Supported frameworks: Caffe2, Chainer, Cognitive Toolkit (CNTK), Core ML, MXNet, PyTorch, PaddlePaddle; TF in progress

# ONNX use pattern (diagram by Chin Huang)





# ONNX tutorials: import and export from frameworks

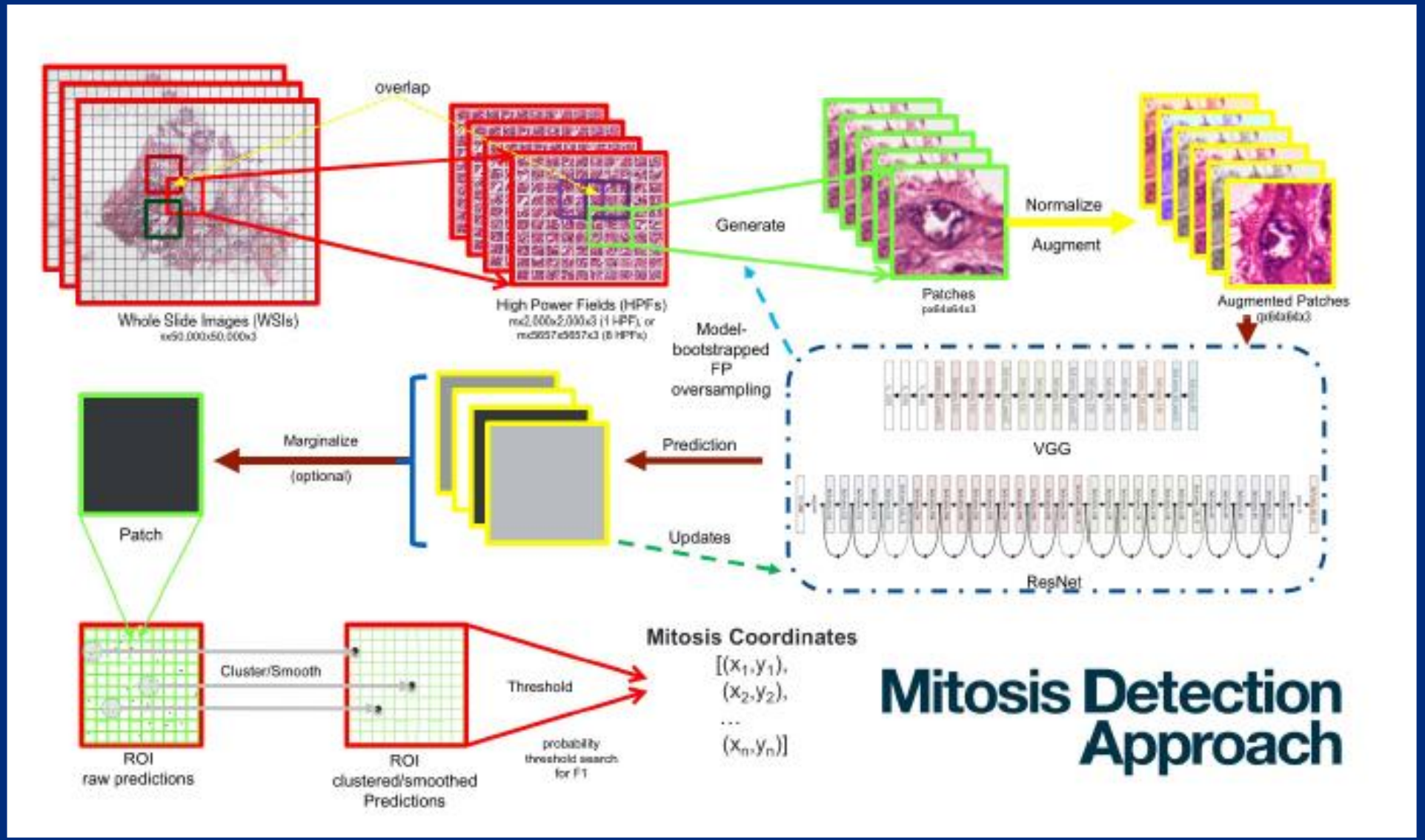
IBM

| Framework / tool | Installation | Exporting to ONNX (frontend) | Importing ONNX models (backend) |
|---|---|---|---|
| Caffe | apple/coremltools and onnx/onnxmltools | Exporting | n/a |
| Caffe2 | part of caffe2 package | Exporting | Importing |
| Chainer | chainer/onnx-chainer | Exporting | coming soon |
| Cognitive Toolkit (CNTK) | built-in | Exporting | Importing |
| Apple CoreML | onnx/onnx-coreml and onnx/onnxmltools | Exporting | Importing |
| Keras | onnx/keras-onnx | Exporting | n/a |
| LibSVM | onnx/onnxmltools | Exporting | n/a |
| LightGBM | onnx/onnxmltools | Exporting | n/a |
| MATLAB | onnx converter on matlab central file exchange | Exporting | Importing |
| Menoh | pfnet-research/menoh | n/a | Importing |
| ML.NET | built-in | Exporting | Importing |
| Apache MXNet | part of mxnet package docs github | Exporting | Importing |
| PyTorch | part of pytorch package | Exporting, Extending support | coming soon |
| SciKit-Learn | onnx/sklearn-onnx | Exporting | n/a |
| TensorFlow | onnx/onnx-tensorflow and onnx/tensorflow-onnx | Exporting - ONNX-Tensorflow Exporting - Tensorflow-ONNX | Importing [experimental] |
| TensorRT | onnx/onnx-tensorrt | n/a | Importing |

# Using ONNX in medical image processing: potential applications

MAX = Model Asset eXchange

ibm.biz/ model-exchange



# Conclusions



Model deployment is an important part of ML lifecycle

DMG works on open standards for model deployment

PMML eases deployment for supported models and data prep

ONNX is a de-facto standard for Deep Learning

Many opportunities for open source contributions

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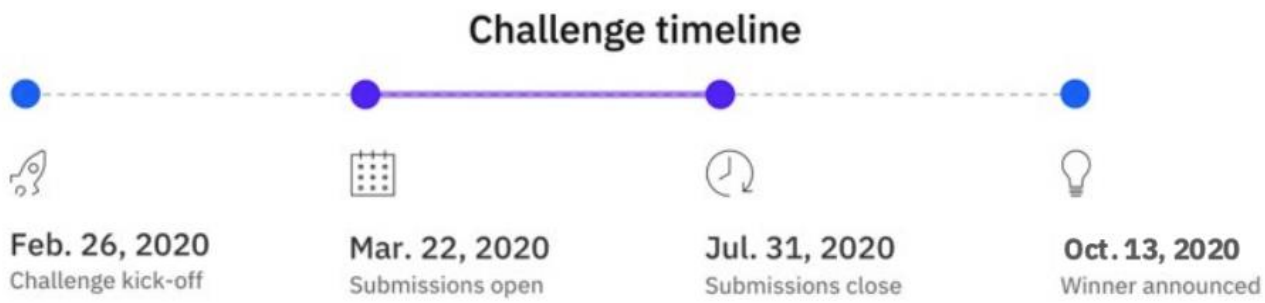
- Meetings with **mentors** & potential **investors**
- **Solution implementation** support through **Code and Response™**




ibm.biz/callforcode

# Links and resources @SvetaLevitan

PMML dmg.org/pmml
PFA dmg.org/pfa
ONNX onnx.ai, gitter.im/onnx

Call for Code: ibm.biz/callforcode

Upcoming ONNX meeting on April 9 at 9am-12pm Pacific time:
https://events.linuxfoundation.org/lf-ai-day-onnx-community-virtual-meetup/

SPSS: https://www.ibm.com/analytics/spss-statistics-software
Watson Studio: https://www.ibm.com/cloud/watson-studio
Sign up for free IBM Cloud account: **https://ibm.biz/Bdqie5**

Join Chicago Meetups: Big Data Developers in Chicago, Chicago ML, ChiPy, …

Replays of Virtual community day “Deploy AI” from March 10:
https://ibm-deployai.bemyapp.com/

Thank you.