Before we start…

Save some time by downloading these files

- Download Orange https://orange.biolab.si/
- Download Datasets http://bit.ly/44con-ml

Orange is the new Hack

AN INTRODUCTION TO MACHINE LEARNING WITH ORANGE

44CON

Presented by Philippe Arteau

Who am I ?

- Philippe Arteau
- Security Researcher at CounterTack GoSecure
- Open-source developer
  - Find Security Bugs (SpotBugs - Static Analysis for Java)
  - Security Code Scan (Roslyn – Static Analysis for .NET)
  - Burp and ZAP Plugins (Retire.js, CSP Auditor)

- Machine Learning Enthousiast

Agenda

- Machine Learning introduction
  - Definition
  - Supervised vs Unsupervised
  - …
- Hands on exercises
  - Data visualization exercises
  - Classification exercises
  - Using/Building custom plugin
- Conclusion

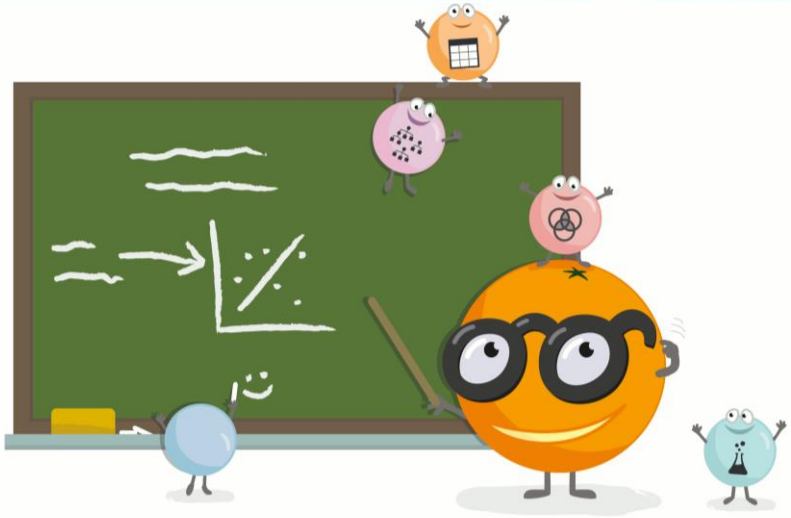
This workshop is for you

Knowledge requirement

- You don’t need prior knowledge of Machine Learning
  - I have no statistics or machine learning specialization myself !

- Machine Learning is a technique that can be applied to many fields
- Aside from learning the basic principles, the workshop might give you some ideas for future applications

Orange



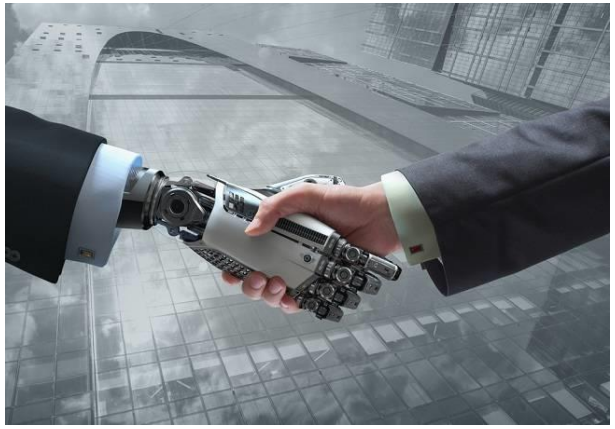
Tool used in this workshop

- Orange is a python Machine Learning library
- Orange has a powerful UI
  - No programming knowledge required
- Many framework can be used to reproduce the exercise
  - I highly encourage you to try other tools in your projects
- I find Orange extremely useful for prototyping, visualization and **training**
- It may not scale for datasets that can’t fit in RAM

Machine Learning?

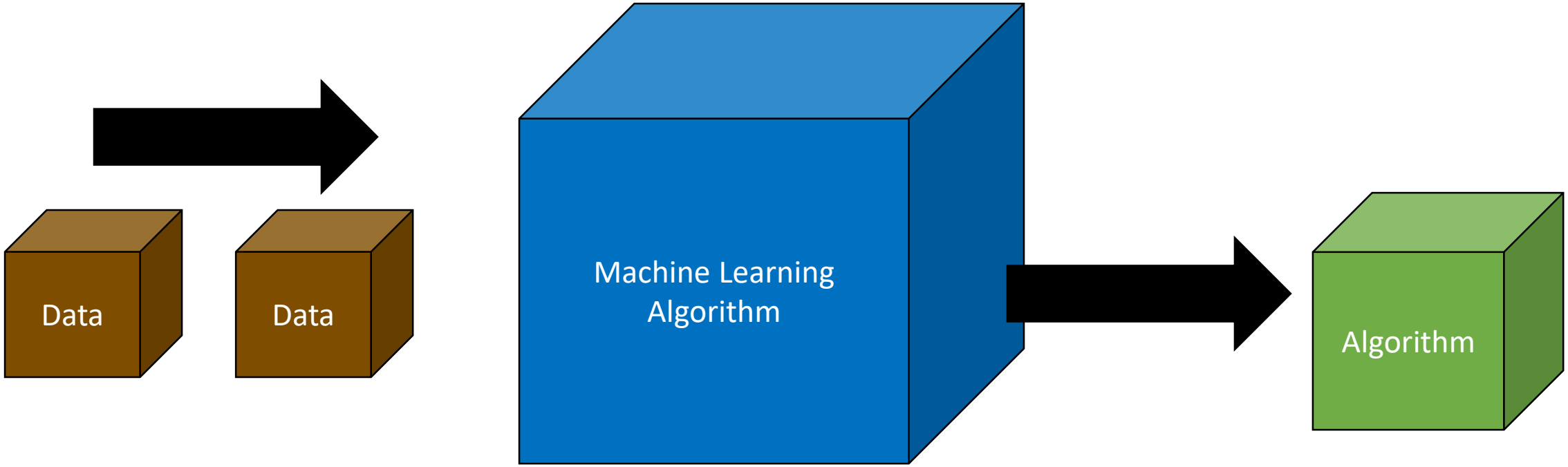
What is Machine Learning?

"Machine learning is a field of computer science that uses **statistical techniques** to give computer systems the ability to **"learn" with data**, **without** being **explicitly programmed**."



- https://en.wikipedia.org/wiki/Machine_learning

“without being explicitly programmed”



Data-driven algorithm

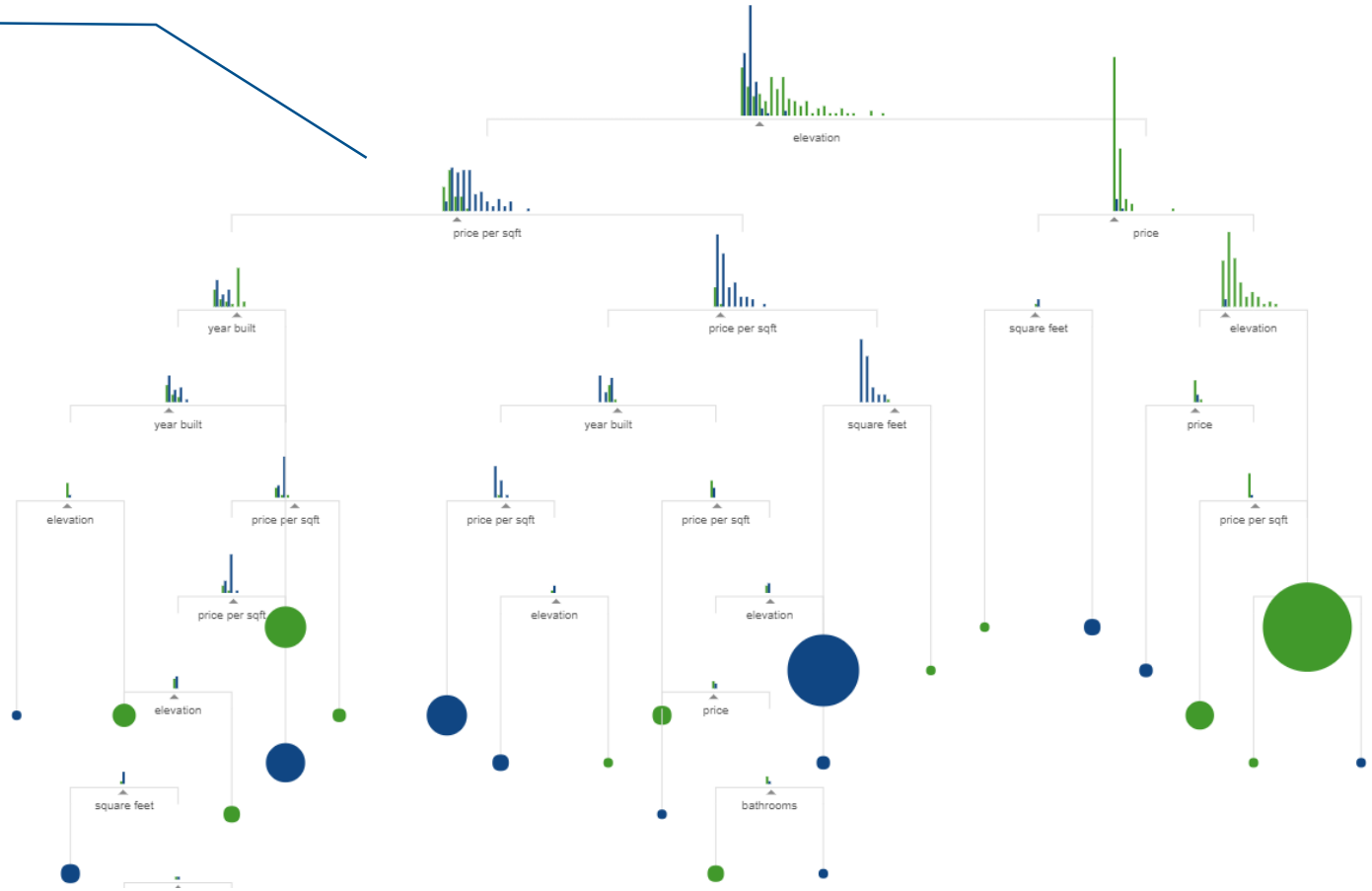
```
def calc_price_house(year,nb_rooms, …):

    price = nb_rooms * 50000

    if(year <= 1950):
        price += 40000

    price -= year * 500

    […]
    return price
```



http://www.r2d3.us/visual-intro-to-machine-learning-part-1/

Supervised vs Unsupervised

Supervised Classification vs Regression

Supervised learning has two variations

Supervised classification

Attempts to predict the **right answer** from a discrete number of possibilities

Prediction Features ->

- Recommend or not to user
- Types of species

Supervised regression

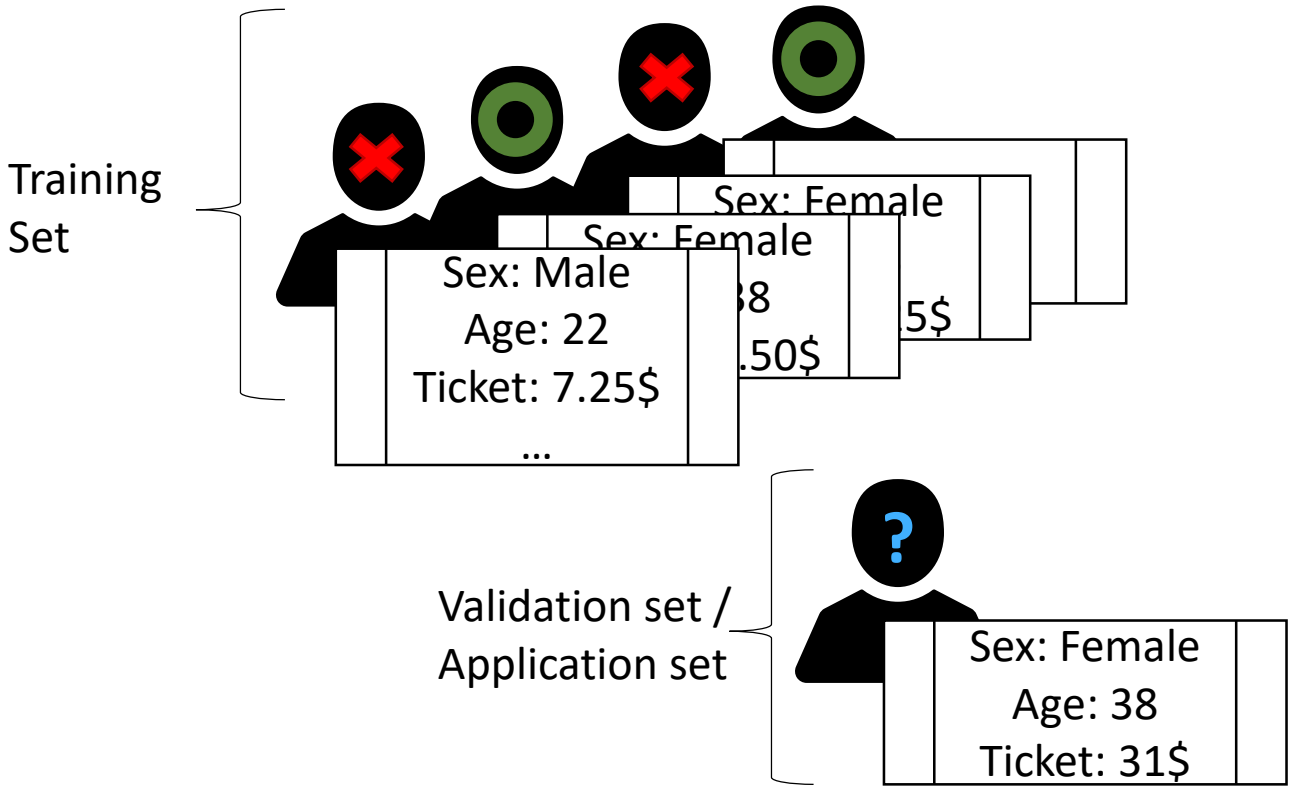
Attempts to predict a **continuous value**

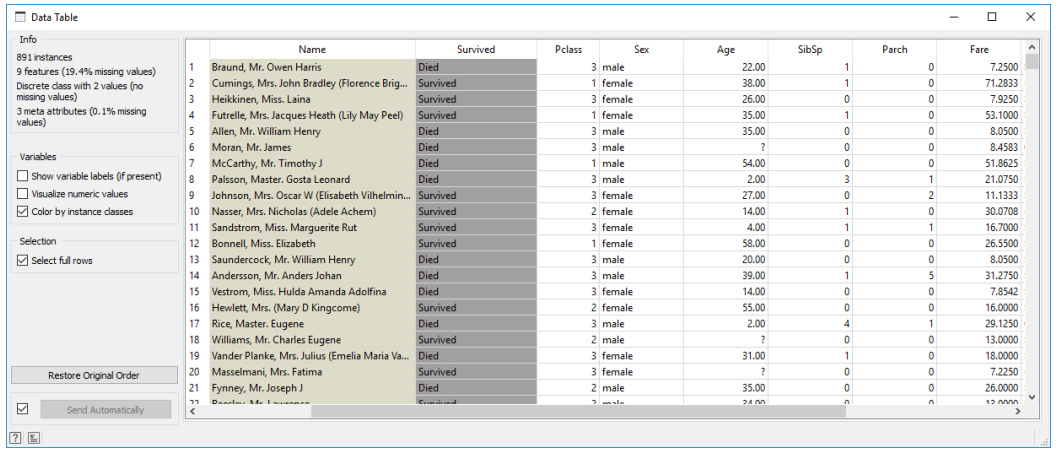
Prediction Features ->

- House pricing (10k to 10M)
- Time of recovery from an incident

Supervised Classification

- Example of prediction





Data Table

Info
891 instances
9 features (19.4% missing values)
Discrete class with 2 values (no missing values)
3 meta attributes (0.1% missing values)

Variables
Show variable labels (if present)
Visualize numeric values
Color by instance classes

Selection
Select full rows

Restore Original Order
Send Automatically

	Name	Survived	Pclass	Sex	Age	SibSp	Parch	Fare
1	Braund, Mr. Owen Harris	Died	3	male	22.00	1	0	7.2500
2	Cumings, Mrs. John Bradley (Florence Brig...	Survived	1	female	38.00	1	0	71.2833
3	Heikkinen, Miss. Laina	Survived	3	female	26.00	0	0	7.9250
4	Futrelle, Mrs. Jacques Heath (Lily May Peel)	Survived	1	female	35.00	1	0	53.1000
5	Allen, Mr. William Henry	Died	3	male	35.00	0	0	8.0500
6	Moran, Mr. James	Died	3	male	?	0	0	8.4583
7	McCarthy, Mr. Timothy J	Died	1	male	54.00	0	0	51.8625
8	Palsson, Master. Gosta Leonard	Died	3	male	2.00	3	1	21.0750
9	Johnson, Mrs. Oscar W (Elisabeth Vilhelmin...	Survived	3	female	27.00	0	2	11.1333
10	Nasser, Mrs. Nicholas (Adele Achem)	Survived	2	female	14.00	1	0	30.0708
11	Sandstrom, Miss. Marguerite Rut	Survived	3	female	4.00	1	1	16.7000
12	Bonnell, Miss. Elizabeth	Survived	1	female	58.00	0	0	26.5500
13	Saundercock, Mr. William Henry	Died	3	male	20.00	0	0	8.0500
14	Andersson, Mr. Anders Johan	Died	3	male	39.00	1	5	31.2750
15	Vestrom, Miss. Hulda Amanda Adolfina	Died	3	female	14.00	0	0	7.8542
16	Hewlett, Mrs. (Mary D Kingcome)	Survived	2	female	55.00	0	0	16.0000
17	Rice, Master. Eugene	Died	3	male	2.00	4	1	29.1250
18	Williams, Mr. Charles Eugene	Survived	2	male	?	0	0	13.0000
19	Vander Planke, Mrs. Julius (Emelia Maria Va...	Died	3	female	31.00	1	0	18.0000
20	Masselmani, Mrs. Fatima	Survived	3	female	?	0	0	7.2250
21	Fynney, Mr. Joseph J	Died	2	male	35.00	0	0	26.0000

Unsupervised Classification: Text

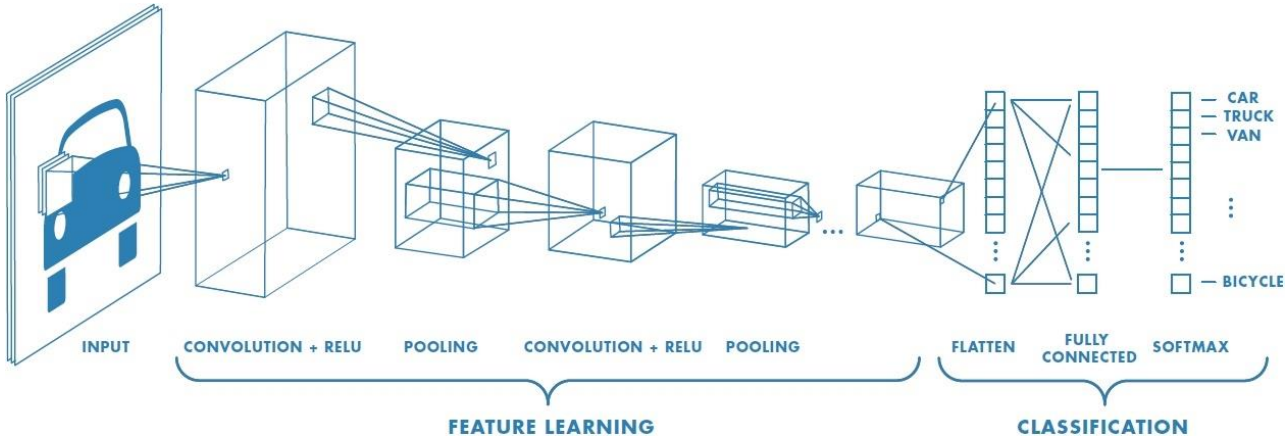
Use case : Classification of related articles

- One potential implementation would be based on the **top rare keywords from the content**
- Titles of article don't need to be similar

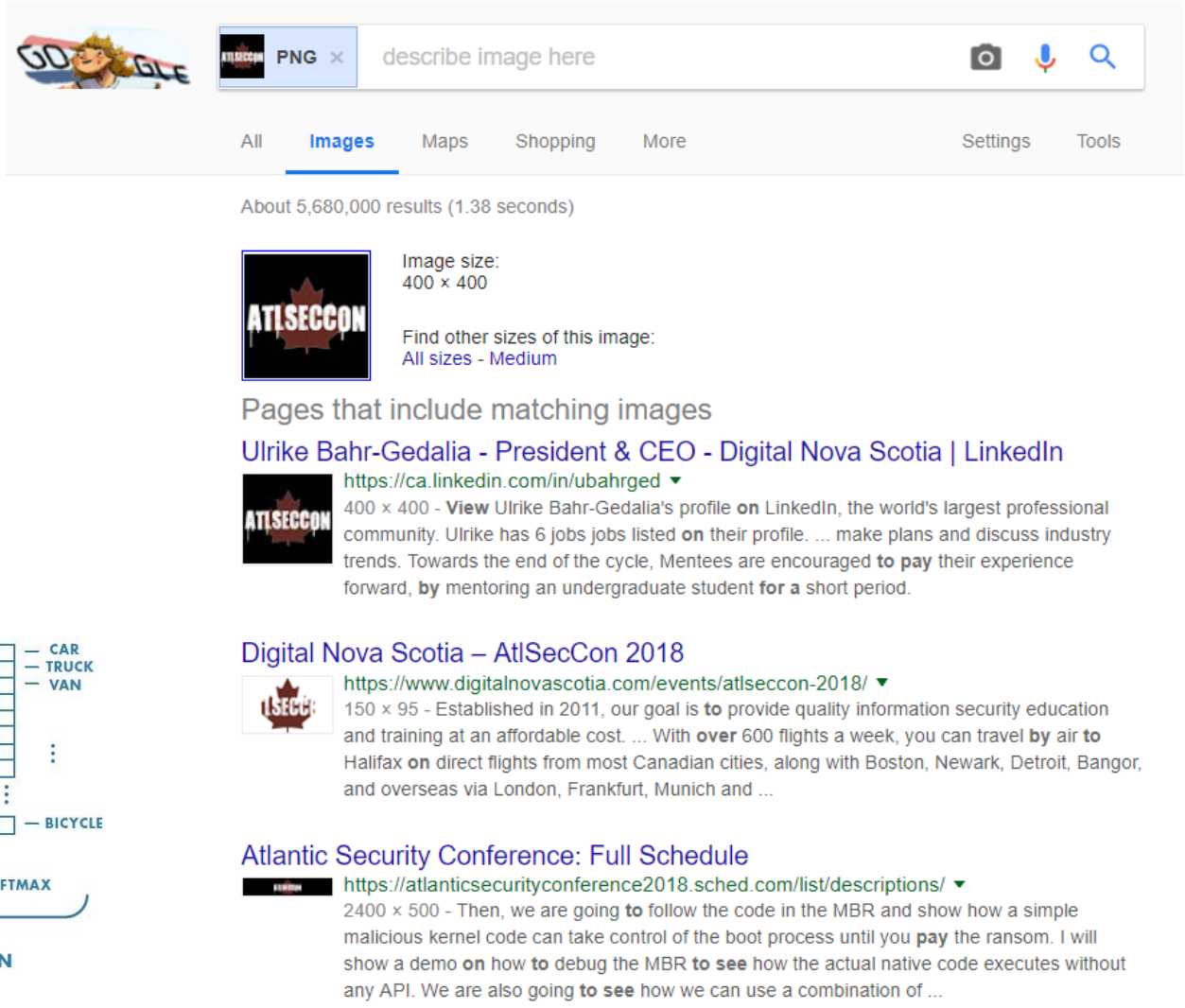
Unsupervised Classification: Images

Use case : Classification of **similar** images (mostly unlabeled)

- Convolutional neural network (CNN) could be applied



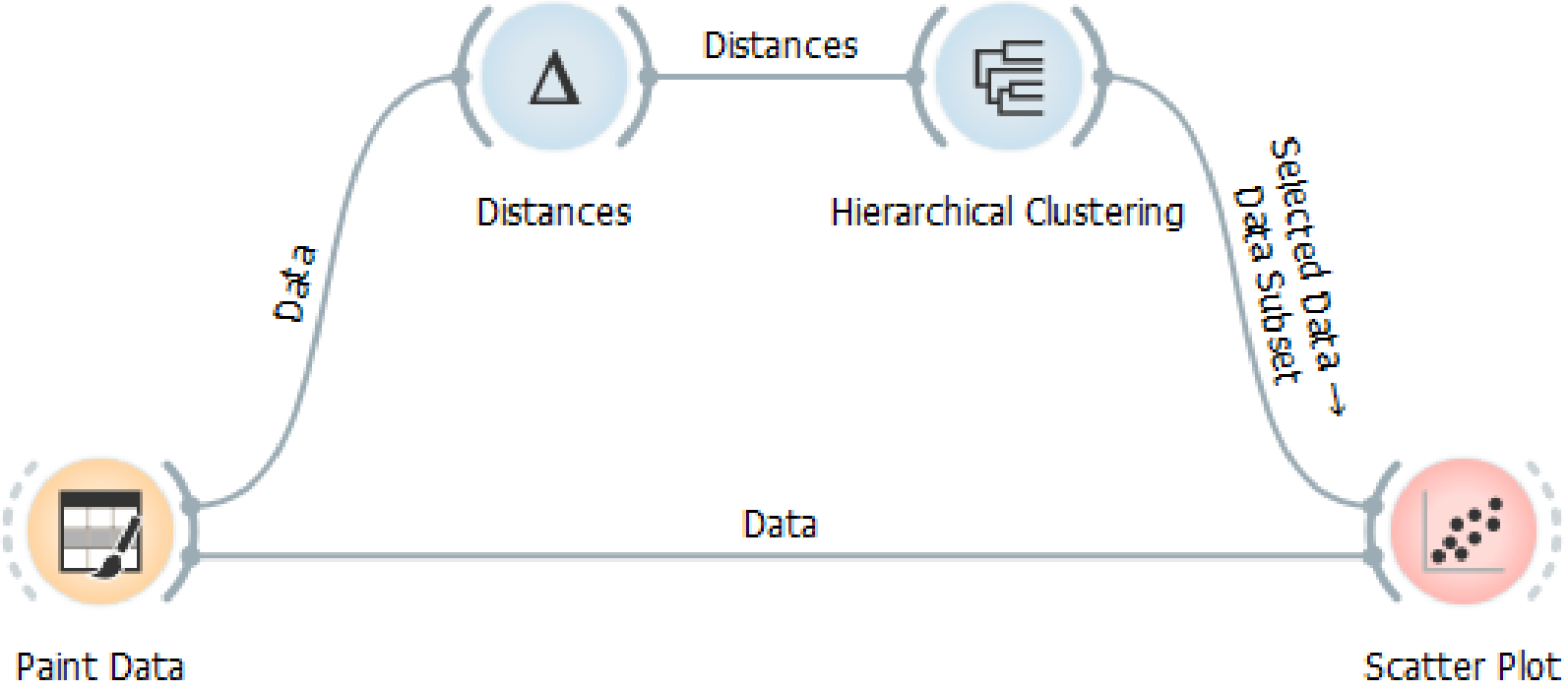
[Demo of supervised CNN : http://cs231n.stanford.edu/](http://cs231n.stanford.edu/)



Clustering
Warm-up with Orange

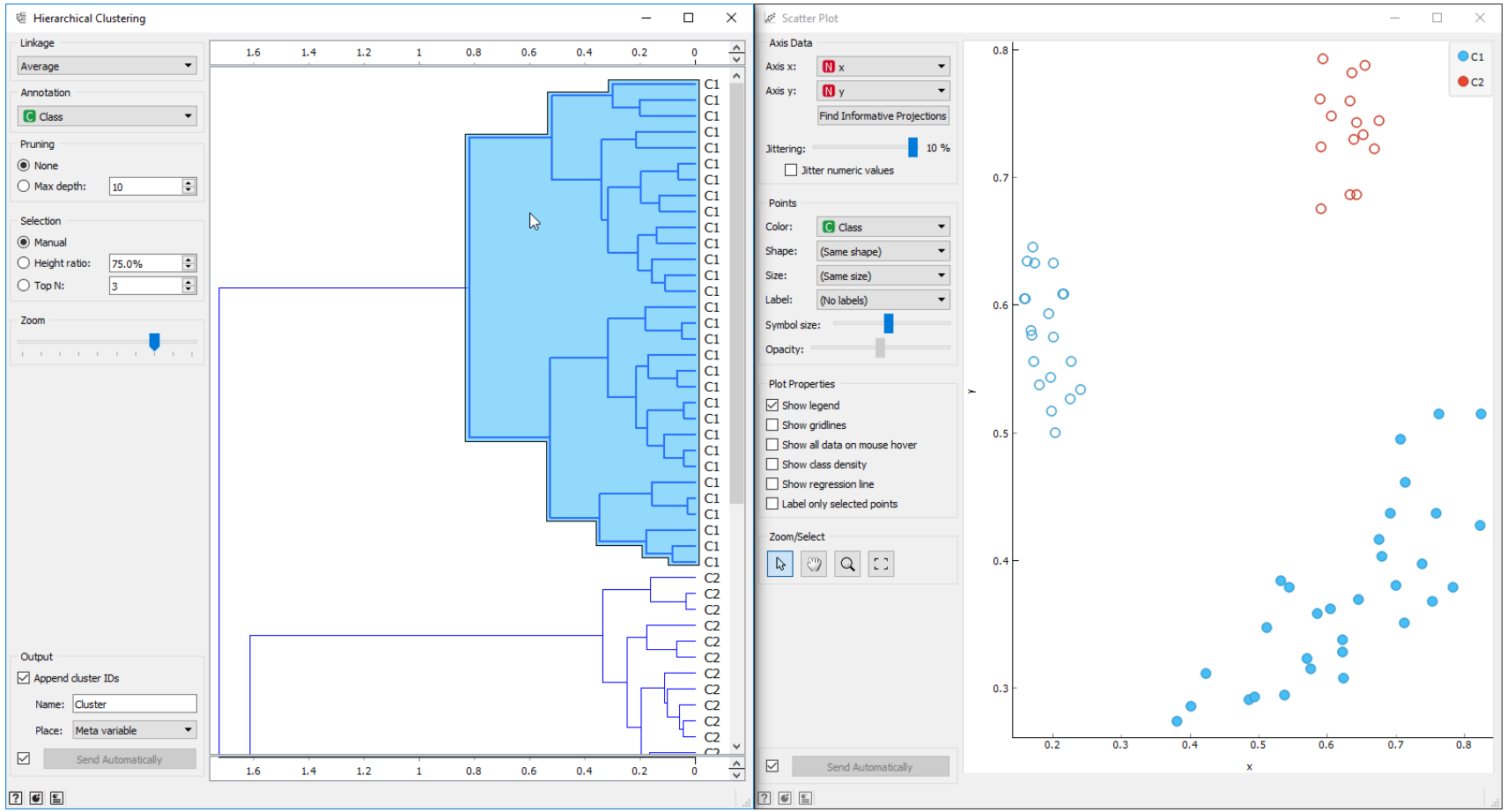
GoSecure

In order to warmup for Orange workflow, we are going to create the following clustering classifier



Hand-on !

Interactive Visualization (Selection)



Data Visualization (Titanic Dataset)

GoSecure

The Titanic Dataset

- **survival:** Survival (0 = No; 1 = Yes)
- **pclass:** Passenger Class (1 = 1st; 2 = 2nd; 3 = 3rd)
- **name:** Name
- **sex:** Sex
- **age:** Age
- **sibsp:** Number of Siblings/Spouses Aboard
- **parch:** Number of Parents/Children Aboard
- **ticket:** Ticket Number
- **fare:** Passenger Fare
- **cabin:** Cabin
- **embarked:** Port of Embarkation (C = Cherbourg; Q = Queenstown; S = Southampton)

- https://jasonicarter.github.io/survival-analysis-titanic-data/

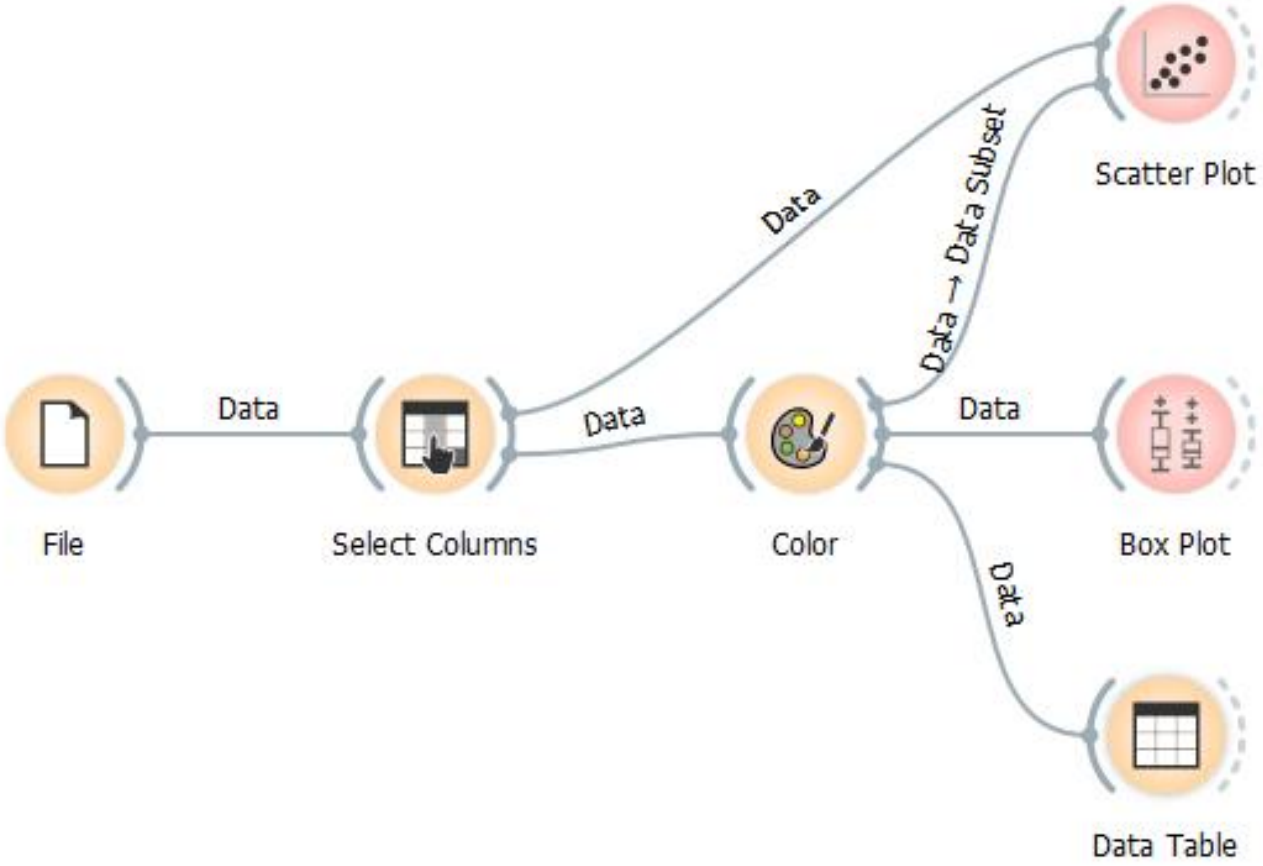
Visualization

Why visualization is important?

- The choice of algorithm is not always obvious
- Visualization can help greatly the debugging of ML algorithm
  - Quickly identify and review extreme value
  - Review misclassified entries
- Better understand how algorithm behave

Your First Orange workflow

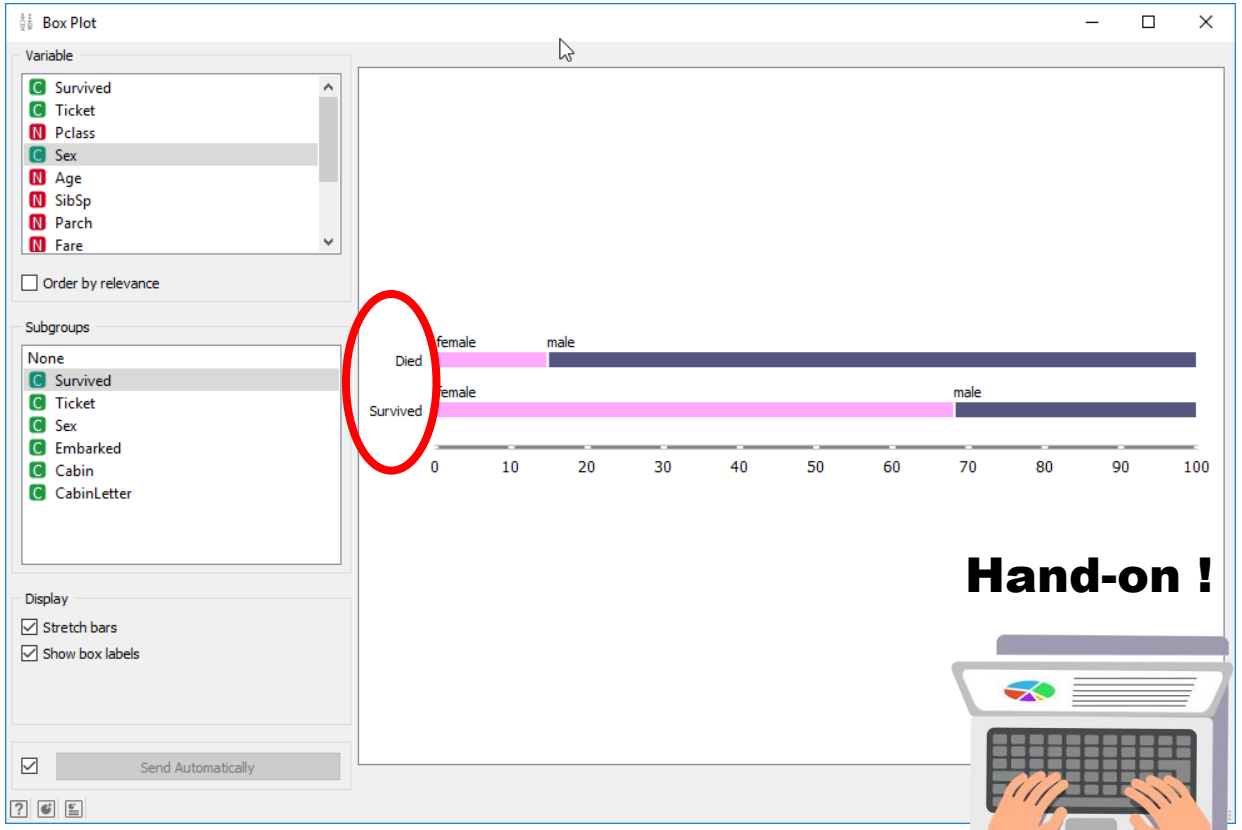
- Before doing any classification, we are going to visualize the dataset



Hand-on !

Color Change and Values Renamed

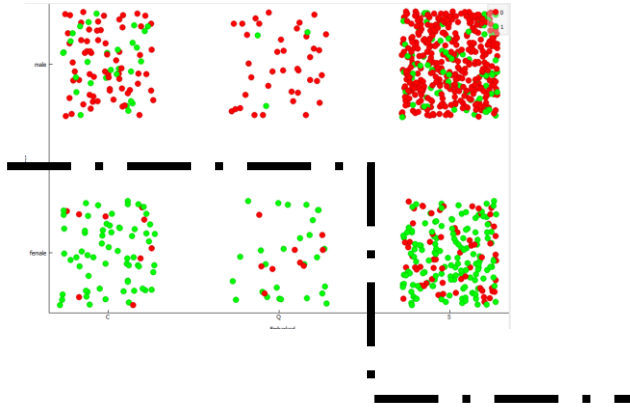
- The default colors might be counterintuitive (Red for Positive / Green for Negative)
- Some values can be primitive (True/False or 0/1)
- Configure the color component to generate the adjacent view



Hand-on !

Visualisation Exercise

- In the **Scatter Plot View**, find two attributes that would allow a good projection. You should be able to see a clear separation of class (Survived or not). It doesn't need to be perfect.

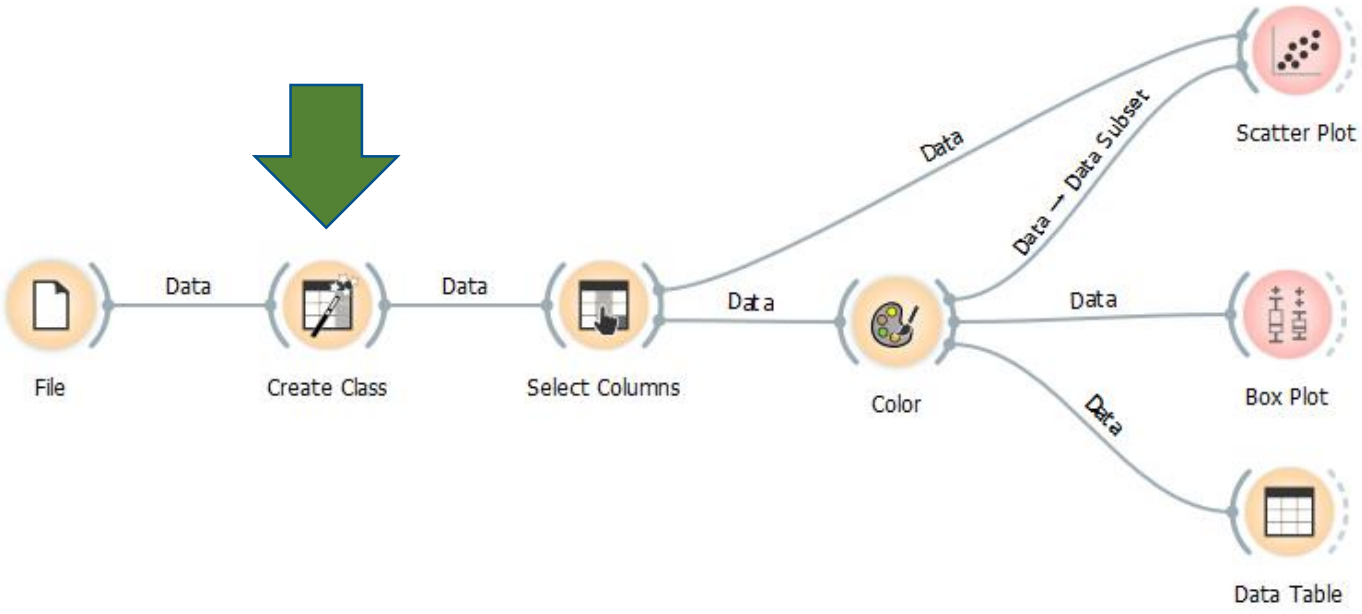


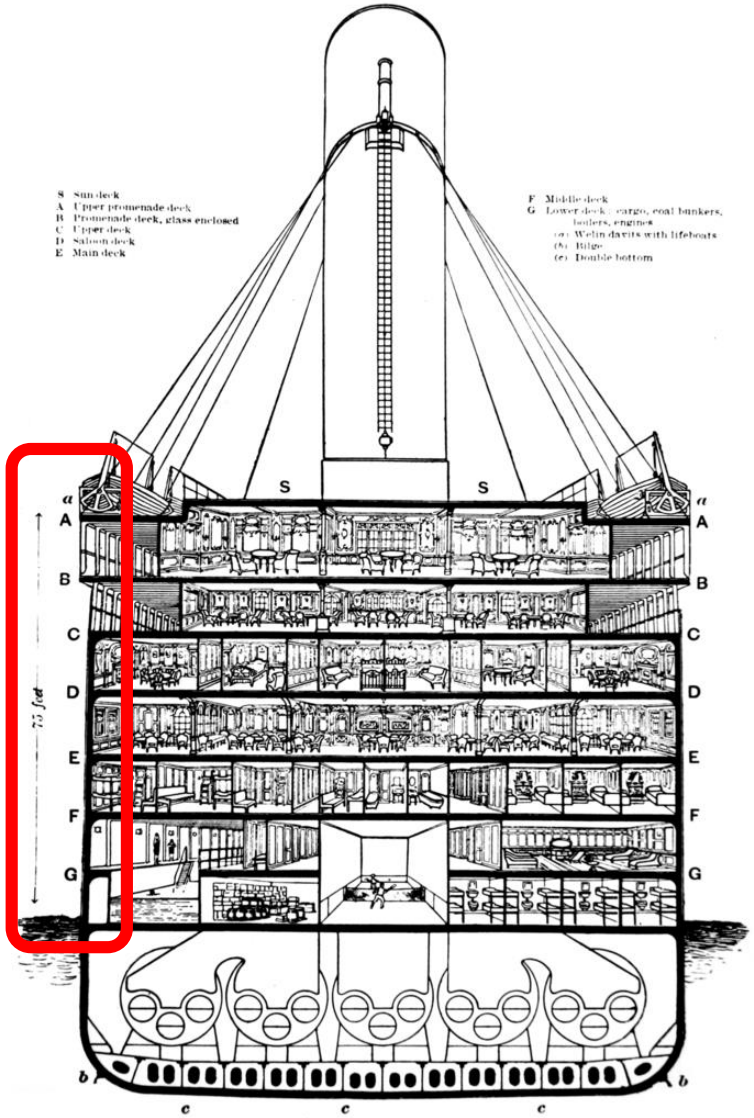
- Can you identify an abnormally precise attribute ?

- Which attribute could be improved ?

Cabin Number

- The cabin attribute contains the level (B86, C85, E46 –> B,C,E)
  - A transformation is required to allow the future classification to see this information

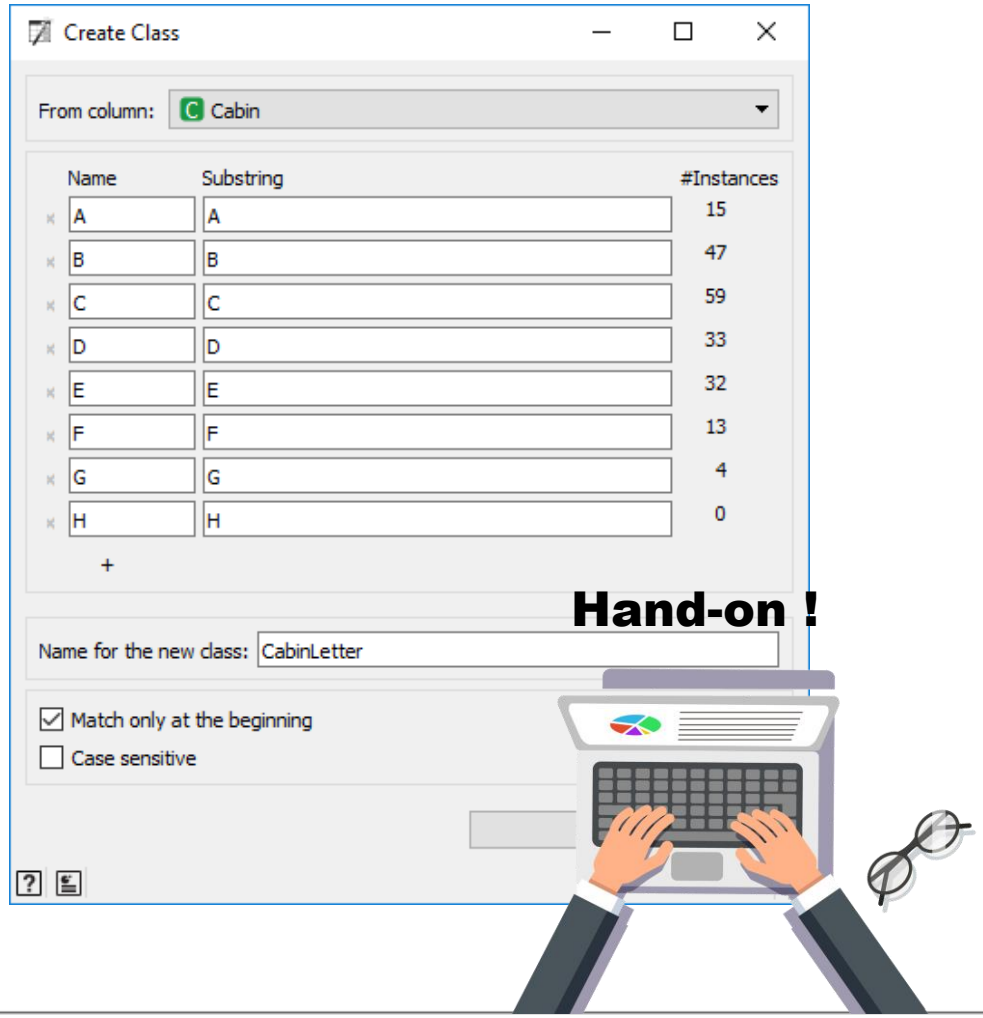




Creating the “Cabin **Letter**” Attribute

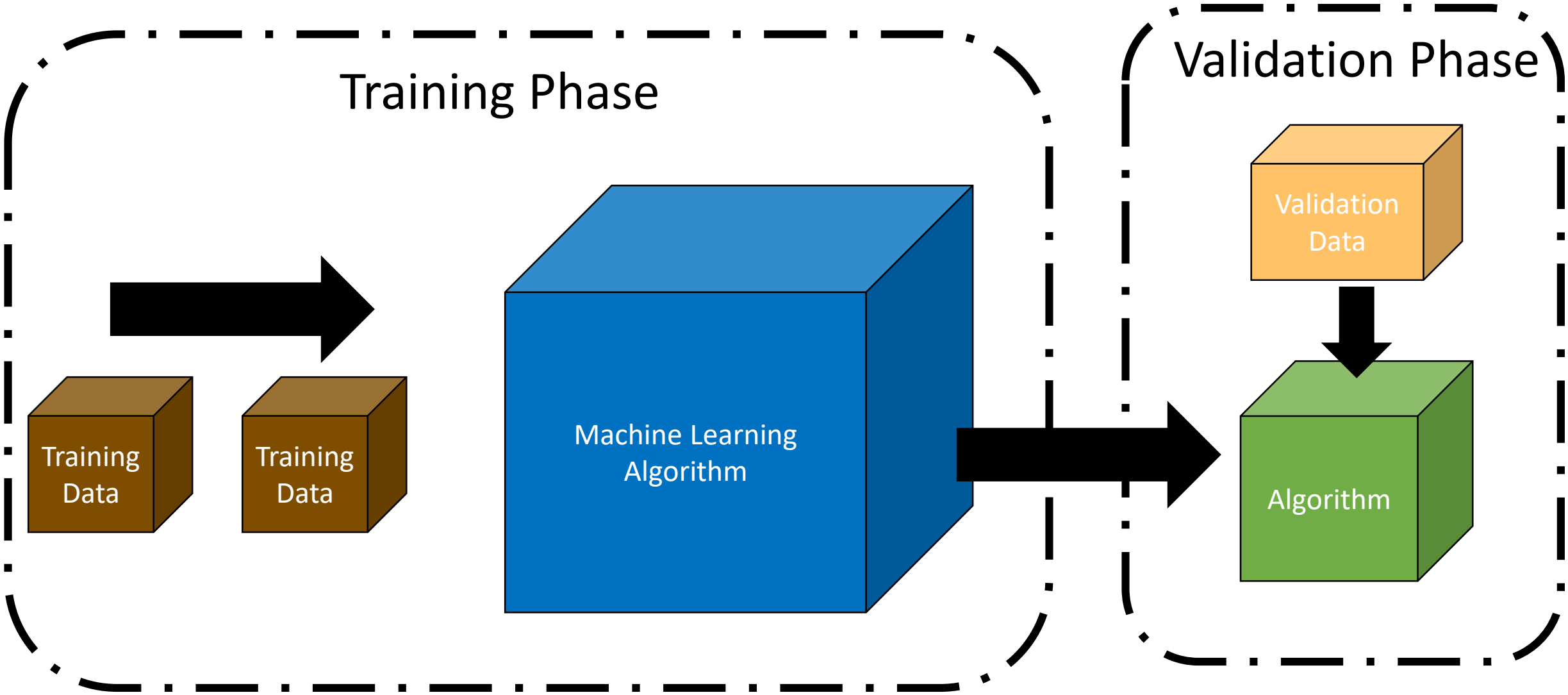
For simple features creation, two widgets are available

- **Create class (Substring operation)**
- Feature constructor (Numeric transformation)

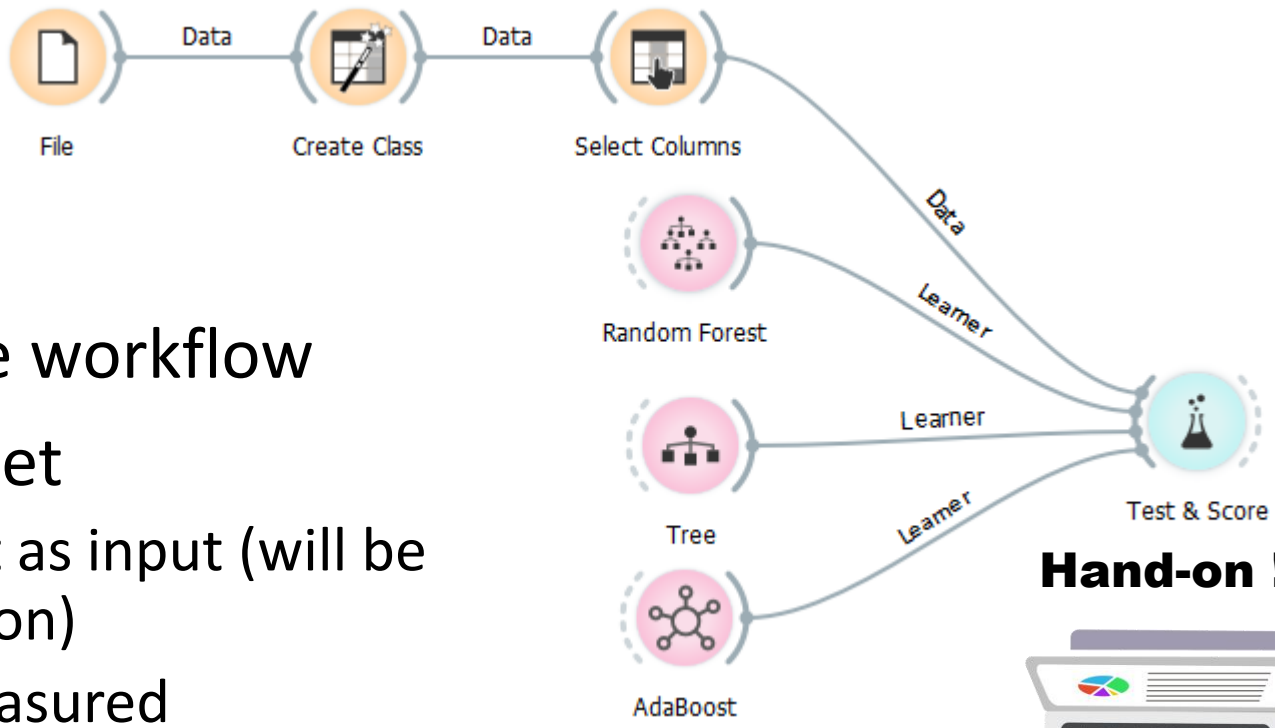


Making Prediction (Titanic Dataset)

Identifying Efficient Algorithm



Testing Algorithms



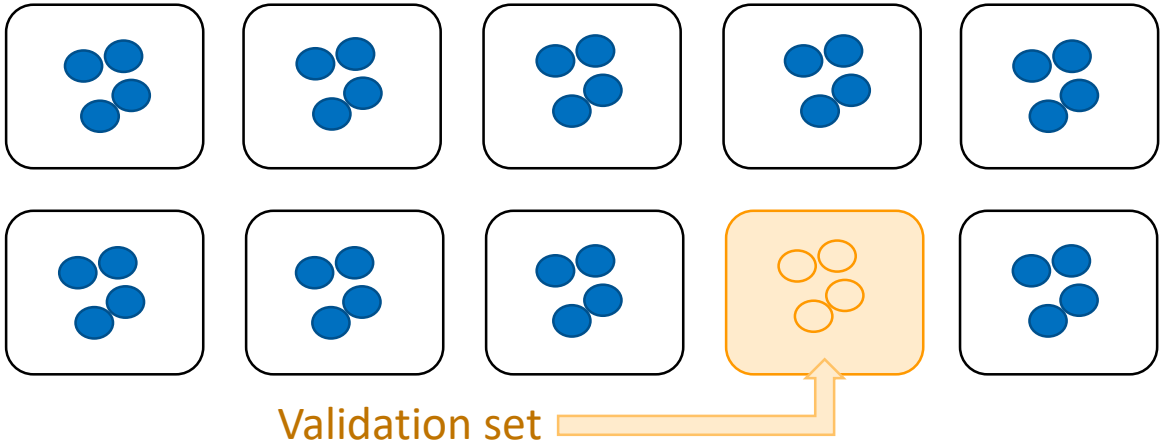
- Drag three algorithms to the workflow
- Use the “Test & Score” widget
  - It takes the complete dataset as input (will be used for training and validation)
  - All algorithms link will be measured

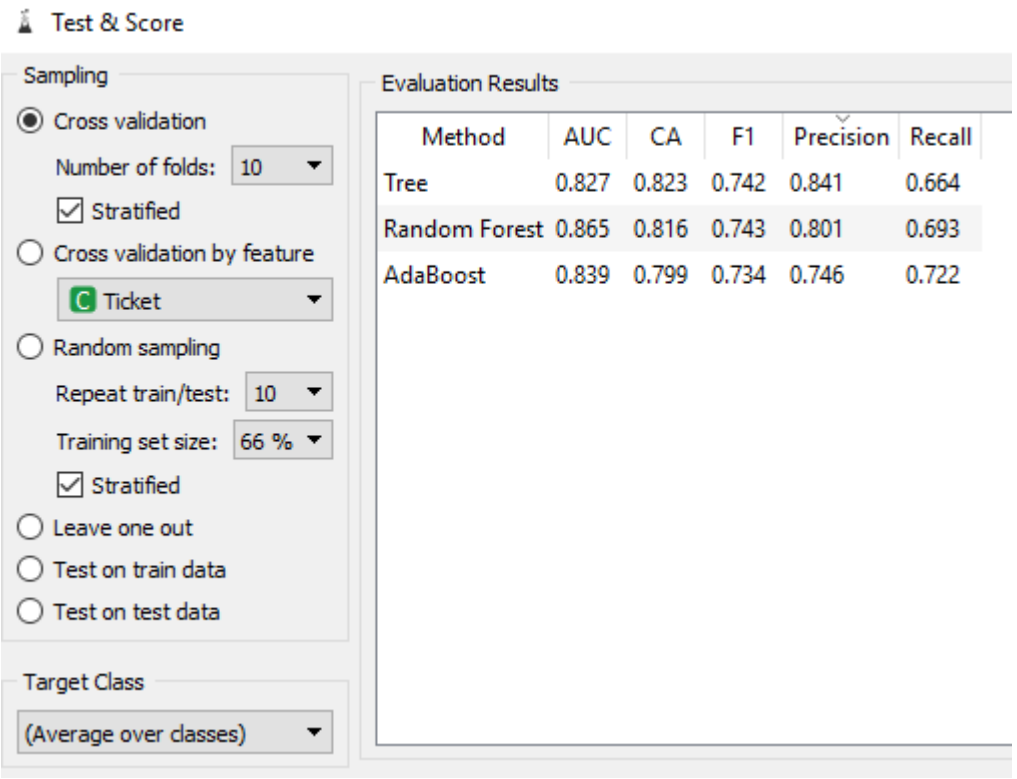
Hand-on !

Test & Score

10-fold Cross validation

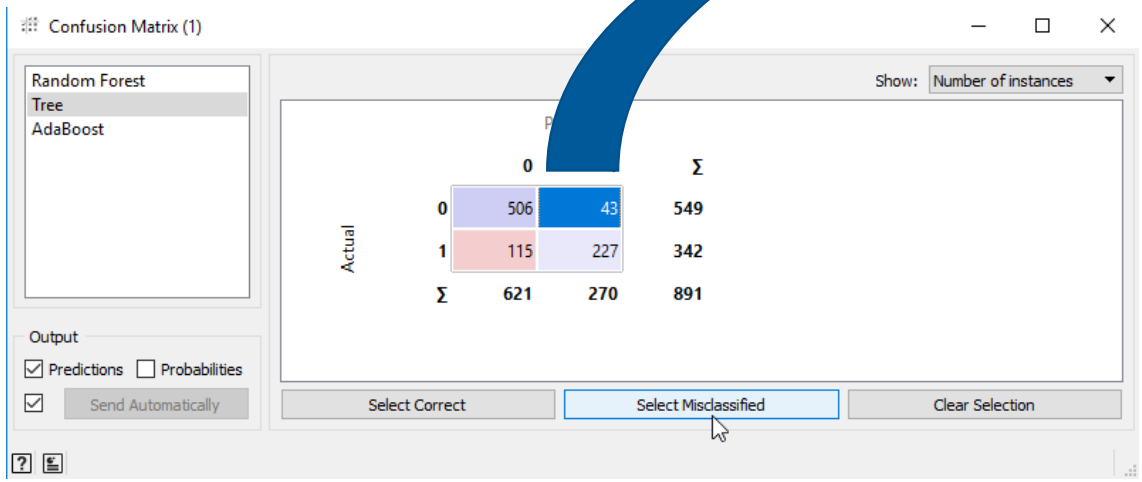
Technique to evaluate predictive models by partitioning the original sample into a training set to train the model, and a test set to evaluate it.

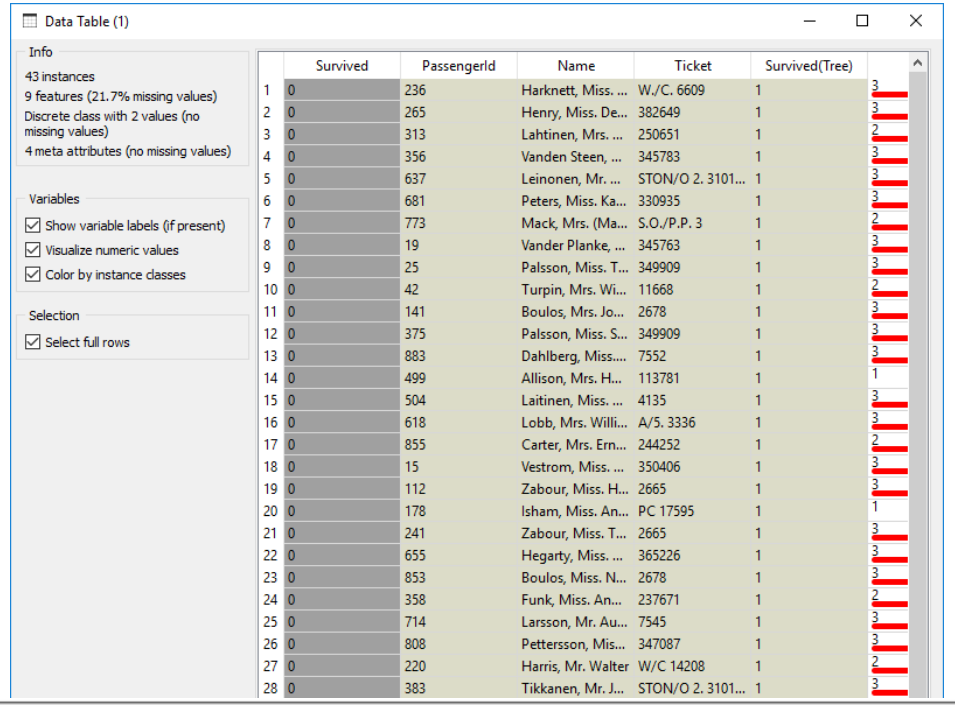




Method	AUC	CA	F1	Precision	Recall
Tree	0.827	0.823	0.742	0.841	0.664
Random Forest	0.865	0.816	0.743	0.801	0.693
AdaBoost	0.839	0.799	0.734	0.746	0.722

Analyzing Misclassified Elements

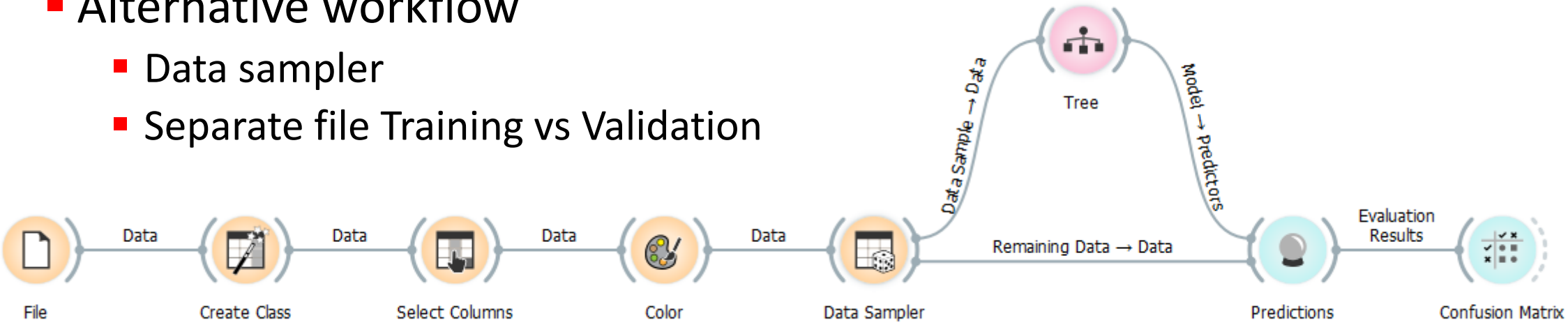


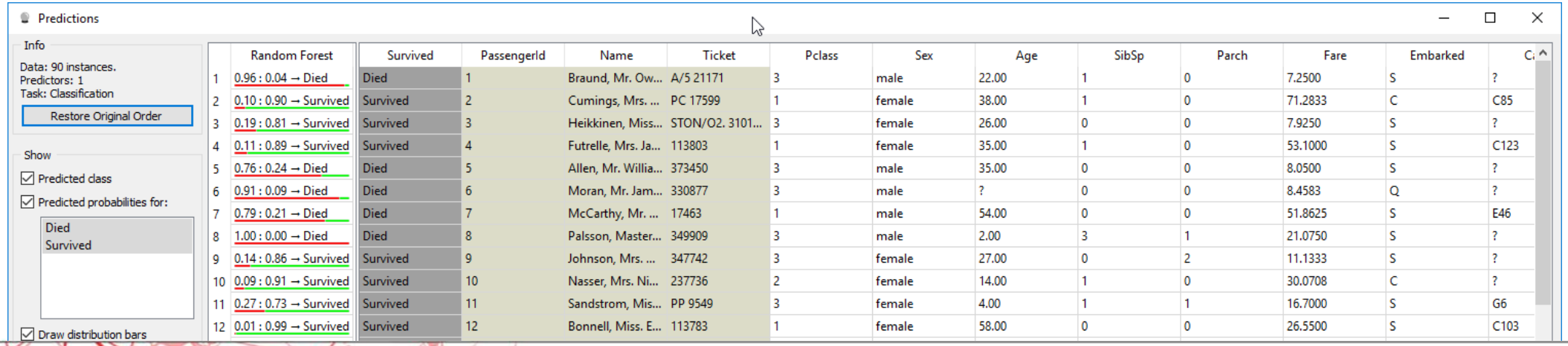


	Survived	PassengerId	Name	Ticket	Survived(Tree)	
1	0	236	Harknett, Miss. ...	W./C. 6609	1	3
2	0	265	Henry, Miss. De...	382649	1	3
3	0	313	Lahtinen, Mrs. ...	250651	1	2
4	0	356	Vanden Steen, ...	345783	1	3
5	0	637	Leinonen, Mr. ...	STON/O 2. 3101...	1	3
6	0	681	Peters, Miss. Ka...	330935	1	3
7	0	773	Mack, Mrs. (Ma...	S.O./P.P. 3	1	2
8	0	19	Vander Planke, ...	345763	1	3
9	0	25	Palsson, Miss. T...	349909	1	3
10	0	42	Turpin, Mrs. Wi...	11668	1	2
11	0	141	Boulos, Mrs. Jo...	2678	1	3
12	0	375	Palsson, Miss. S...	349909	1	3
13	0	883	Dahlberg, Miss....	7552	1	3
14	0	499	Allison, Mrs. H...	113781	1	1
15	0	504	Laitinen, Miss. ...	4135	1	3
16	0	618	Lobb, Mrs. Willi...	A/5. 3336	1	3
17	0	855	Carter, Mrs. Ern...	244252	1	2
18	0	15	Vestrom, Miss. ...	350406	1	3
19	0	112	Zabour, Miss. H...	2665	1	3
20	0	178	Isham, Miss. An...	PC 17595	1	1
21	0	241	Zabour, Miss. T...	2665	1	3
22	0	655	Hegarty, Miss. ...	365226	1	3
23	0	853	Boulos, Miss. N...	2678	1	3
24	0	358	Funk, Miss. An...	237671	1	2
25	0	714	Larsson, Mr. Au...	7545	1	3
26	0	808	Pettersson, Mis...	347087	1	3
27	0	220	Harris, Mr. Walter	W/C 14208	1	2
28	0	383	Tikkanen, Mr. J...	STON/O 2. 3101...	1	3

Data Sampler + Predictions Widget (alternative)

- Alternative workflow
  - Data sampler
  - Separate file Training vs Validation

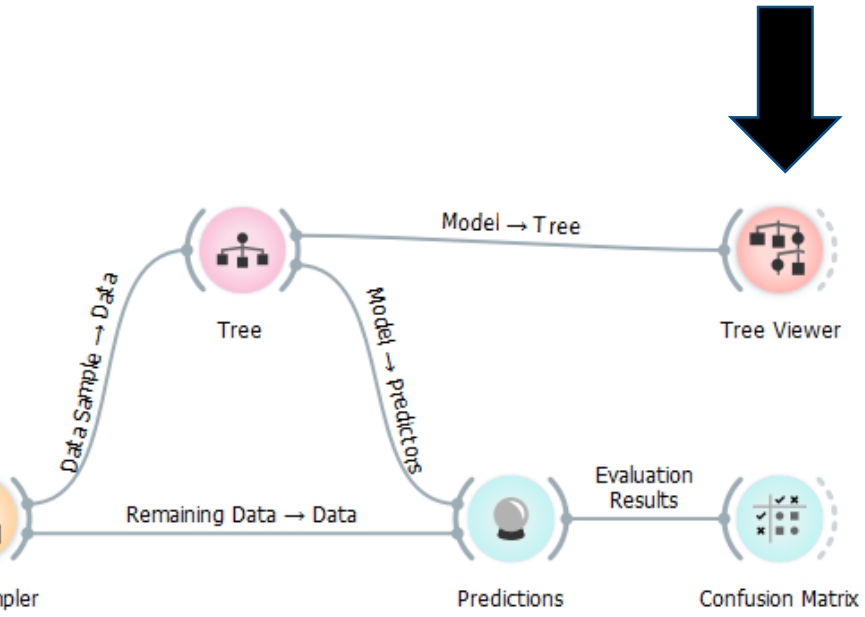


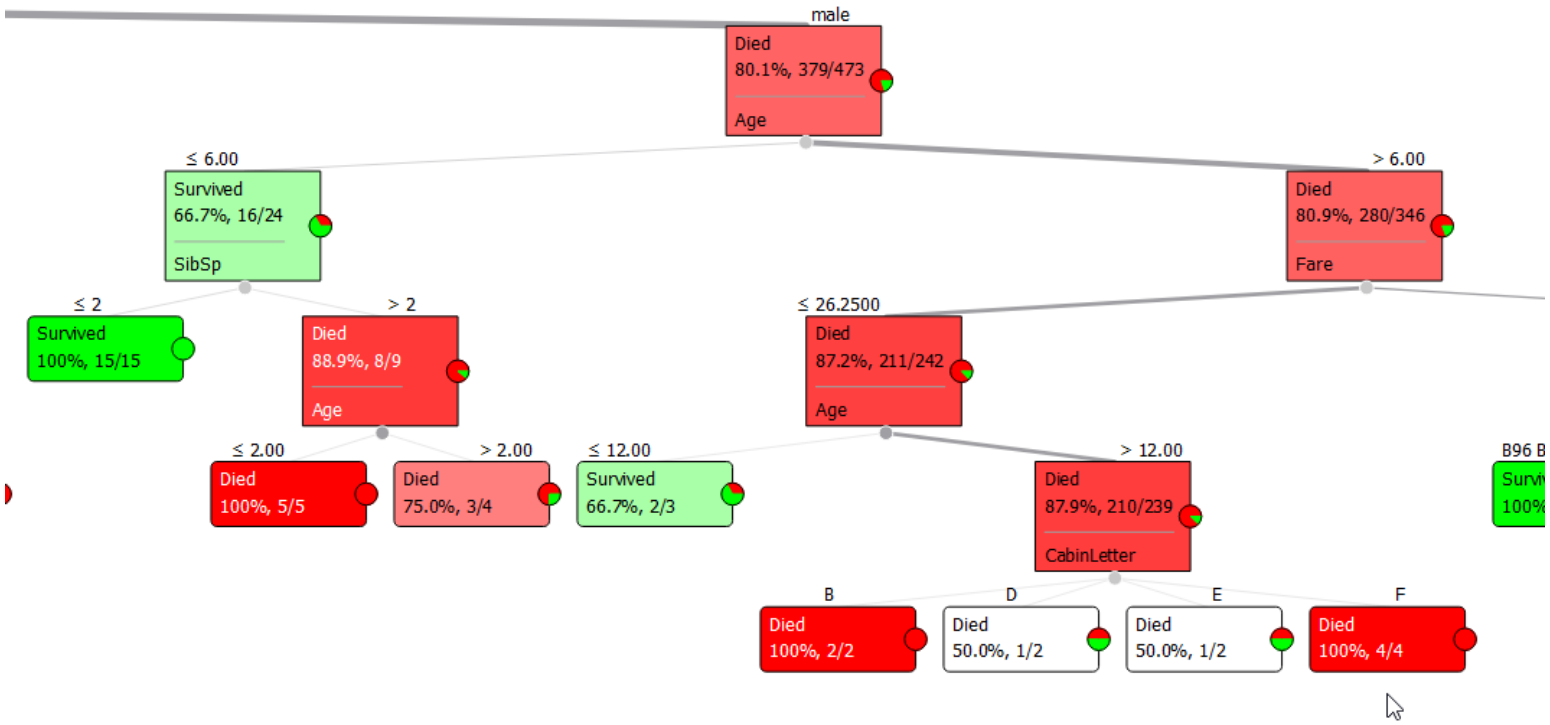


	Random Forest	Survived	PassengerId	Name	Ticket	Pclass	Sex	Age	SibSp	Parch	Fare	Embarked	C
1	0.96 : 0.04 → Died	Died	1	Braund, Mr. Ow...	A/5 21171	3	male	22.00	1	0	7.2500	S	?
2	0.10 : 0.90 → Survived	Survived	2	Cumings, Mrs. ...	PC 17599	1	female	38.00	1	0	71.2833	C	C85
3	0.19 : 0.81 → Survived	Survived	3	Heikkinen, Miss...	STON/O2. 3101...	3	female	26.00	0	0	7.9250	S	?
4	0.11 : 0.89 → Survived	Survived	4	Futrelle, Mrs. Ja...	113803	1	female	35.00	1	0	53.1000	S	C123
5	0.76 : 0.24 → Died	Died	5	Allen, Mr. Willia...	373450	3	male	35.00	0	0	8.0500	S	?
6	0.91 : 0.09 → Died	Died	6	Moran, Mr. Jam...	330877	3	male	?	0	0	8.4583	Q	?
7	0.79 : 0.21 → Died	Died	7	McCarthy, Mr. ...	17463	1	male	54.00	0	0	51.8625	S	E46
8	1.00 : 0.00 → Died	Died	8	Palsson, Master...	349909	3	male	2.00	3	1	21.0750	S	?
9	0.14 : 0.86 → Survived	Survived	9	Johnson, Mrs. ...	347742	3	female	27.00	0	2	11.1333	S	?
10	0.09 : 0.91 → Survived	Survived	10	Nasser, Mrs. Ni...	237736	2	female	14.00	1	0	30.0708	C	?
11	0.27 : 0.73 → Survived	Survived	11	Sandstrom, Mis...	PP 9549	3	female	4.00	1	1	16.7000	S	G6
12	0.01 : 0.99 → Survived	Survived	12	Bonnell, Miss. E...	113783	1	female	58.00	0	0	26.5500	S	C103

Visualizing the Model Produced

- Select the widget Tree Viewer





Testing Classification Algorithm (Static-Analysis Dataset)

GoSecure

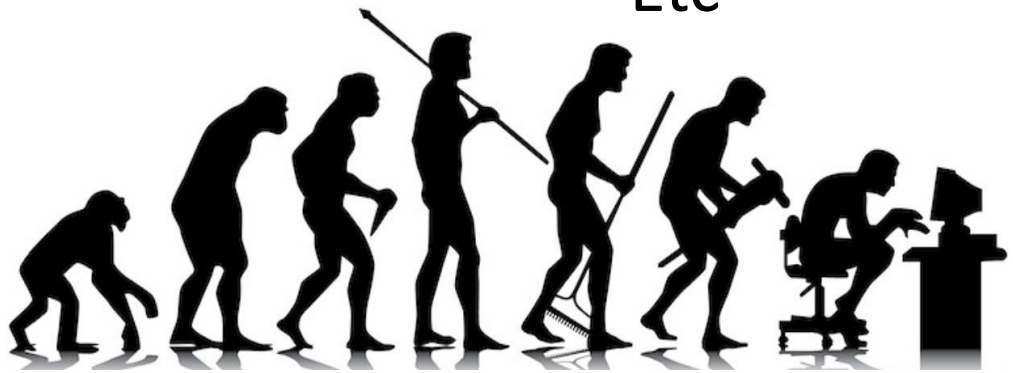
Applying ML to Static Analysis

Typical Static Code Analysis (SCA) report includes

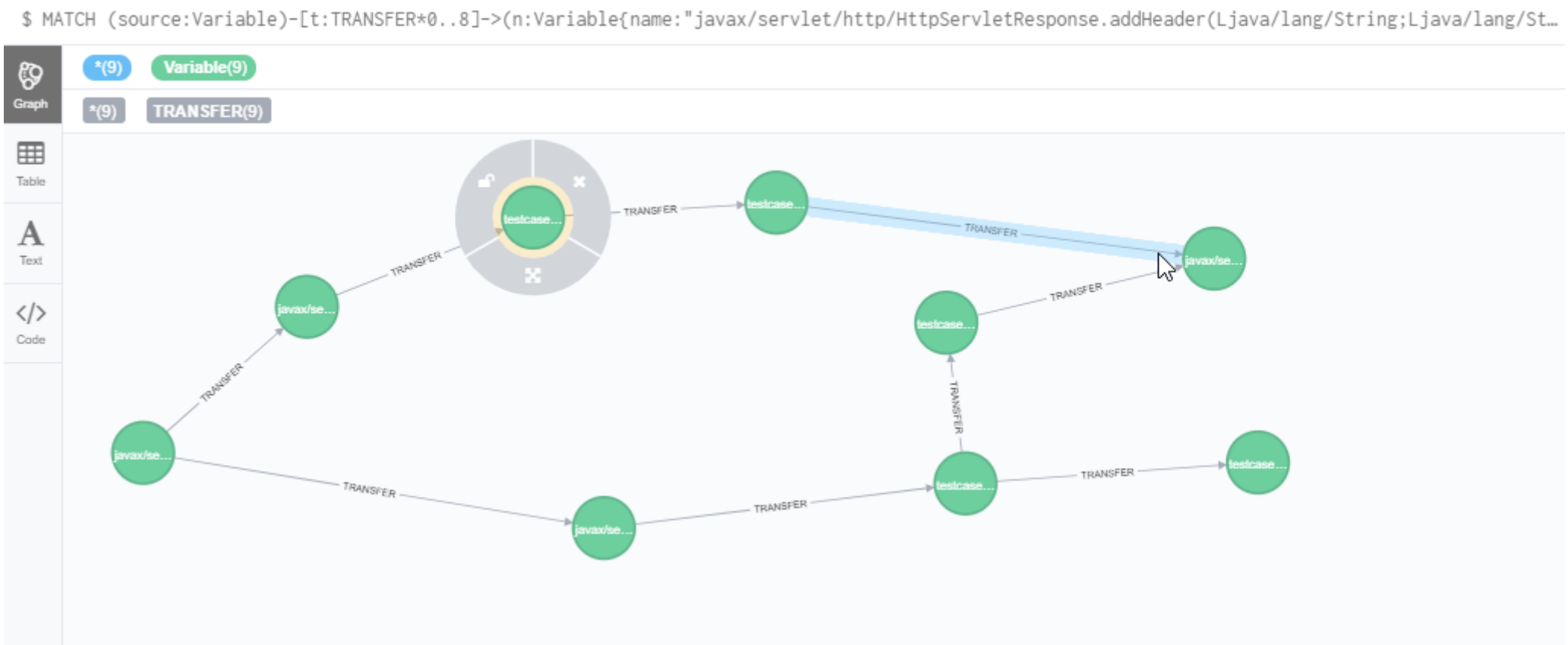
- Bug type
- Source file (or class name)
- Line number
- Description for remediation

"Enrich" Information added to the model

- Presence of Tainted variable
- Presence of Safe source
- Methods called
  - Sources and Sinks
- Etc



Where Do Those New Attributes Comes From?



- In order to do taint analysis accross the entire web application, a graph was built (The CSV is the result of this graph query on such graph).

Preview with a Subset of the Data

Data Table

Info

13 instances
12 features (26.9% missing values)
No target variable.
2 meta attributes (no missing values)

Variables

- [x] Show variable labels (if present)
- [ ] Visualize numeric values
- [x] Color by instance classes

Selection

- [x] Select full rows

Restore Original Order

	Key	GroupId	ArtifactId	Author	BugType	CWE	MethodSink	UnknownSource	SourceMethod	HasTaintedSourc	HasSafeSource	asUnknownSour	Status
1	?	gov.nist.samate	juliet-test-suite...	?	SQL_INJECTIO...	89	java/sql/Statem...	java/lang/System.gete...	testcases/CWE89_SQ...	true	true	false	?
2	?	gov.nist.samate	juliet-test-suite...	?	SQL_INJECTIO...	89	java/sql/Statem...	?	testcases/CWE89_SQ...	true	true	true	?
3	?	gov.nist.samate	juliet-test-suite...	?	LDAP_INJECTION	90	javax/naming/...	javax/servlet/http/Coo...	testcases/CWE90_LD...	true	true	false	?
4	?	gov.nist.samate	juliet-test-suite...	?	LDAP_INJECTION	90	javax/naming/...	javax/servlet/http/Http...	testcases/CWE90_LD...	true	true	false	?
5	?	gov.nist.samate	juliet-test-suite...	?	XSS_SERVLET	79	java/io/PrintWr...	java/lang/Throwable.g...	testcasesupport/Abst...	false	true	true	?
6	?	gov.nist.samate	juliet-test-suite...	?	XSS_SERVLET	79	java/io/PrintWr...	java/lang/Throwable.g...	testcasesupport/Abst...	false	true	true	?
7	?	gov.nist.samate	juliet-test-suite...	?	XSS_SERVLET	79	java/io/PrintWr...	java/lang/Throwable.g...	testcasesupport/Abst...	false	true	true	?
8	?	gov.nist.samate	juliet-test-suite...	?	XSS_SERVLET	79	java/io/PrintWr...	java/lang/Throwable.g...	testcasesupport/Abst...	false	true	true	?
9	?	gov.nist.samate	juliet-test-suite...	?	XSS_SERVLET	79	java/io/PrintWr...	java/lang/Throwable.g...	testcasesupport/Abst...	false	true	true	?
10	?	gov.nist.samate	juliet-test-suite...	?	XSS_SERVLET	79	java/io/PrintWr...	java/lang/Throwable.g...	testcasesupport/Abst...	false	true	true	?
11	?	gov.nist.samate	juliet-test-suite...	?	DMI_EMPTY_D...	259	?	?	testcasesupport/IO.g...	?	?	?	?
12	?	gov.nist.samate	juliet-test-suite...	?	HARD_CODE_P...	259	?	?	testcasesupport/IO.g...	?	?	?	?
13	?	gov.nist.samate	juliet-test-suite...	?	PREDICTABLE_...	330	?	?	testcasesupport/IO.st...	?	?	?	?

Juliet Static Analysis Dataset

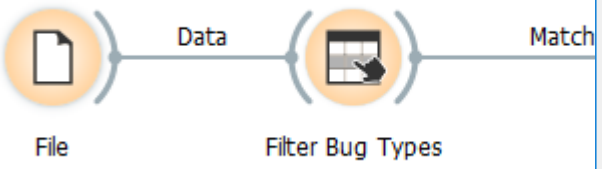
Developed by the NIST to test static code analysis tools

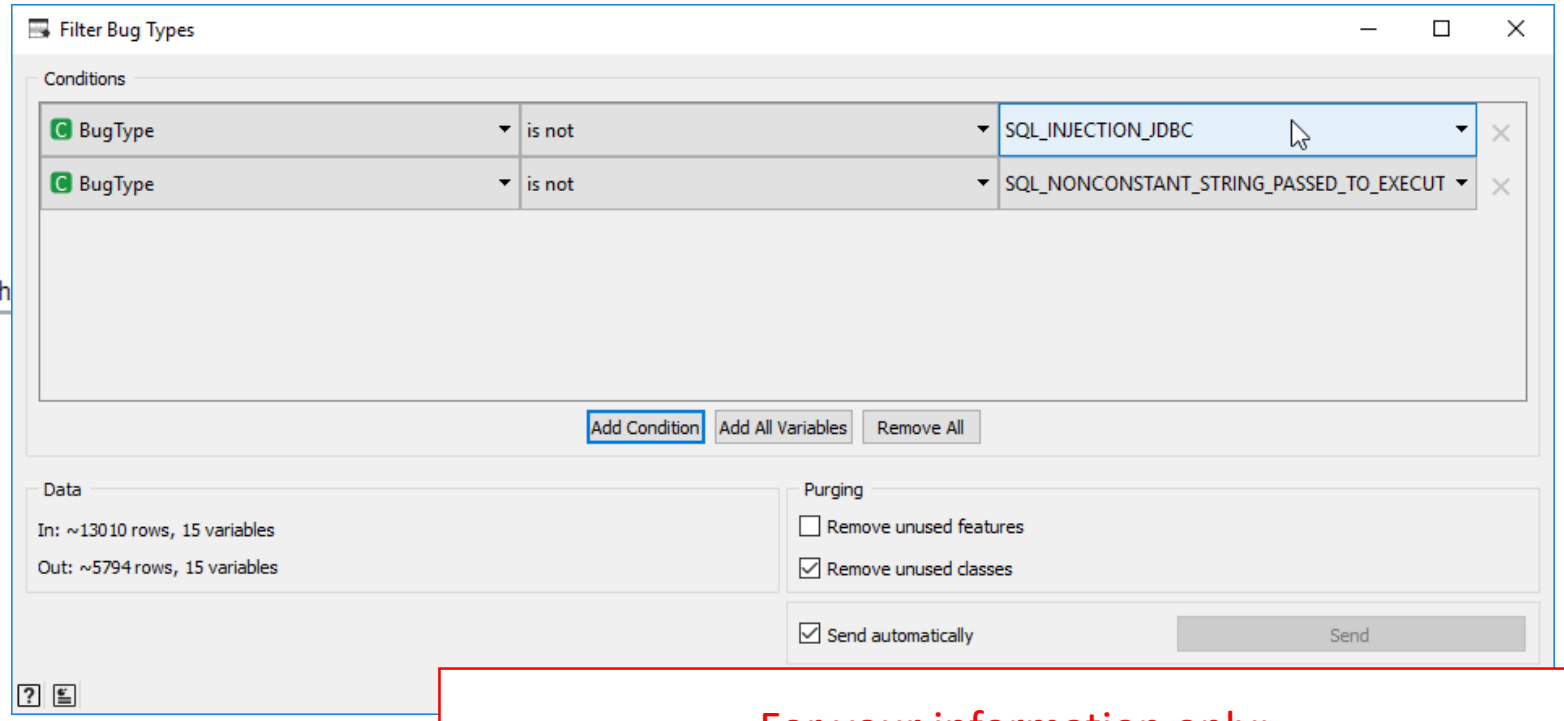
- 28881 individual test cases
- 118 CWE categories
- Language: Java

https://samate.nist.gov/SRD/testsuite.php

Filtering data (possibly noise)

- Additional filter needed “Select Rows Widget”





For your information only:
These categories have been removed from the dataset.

Objectives for the SCA datasets

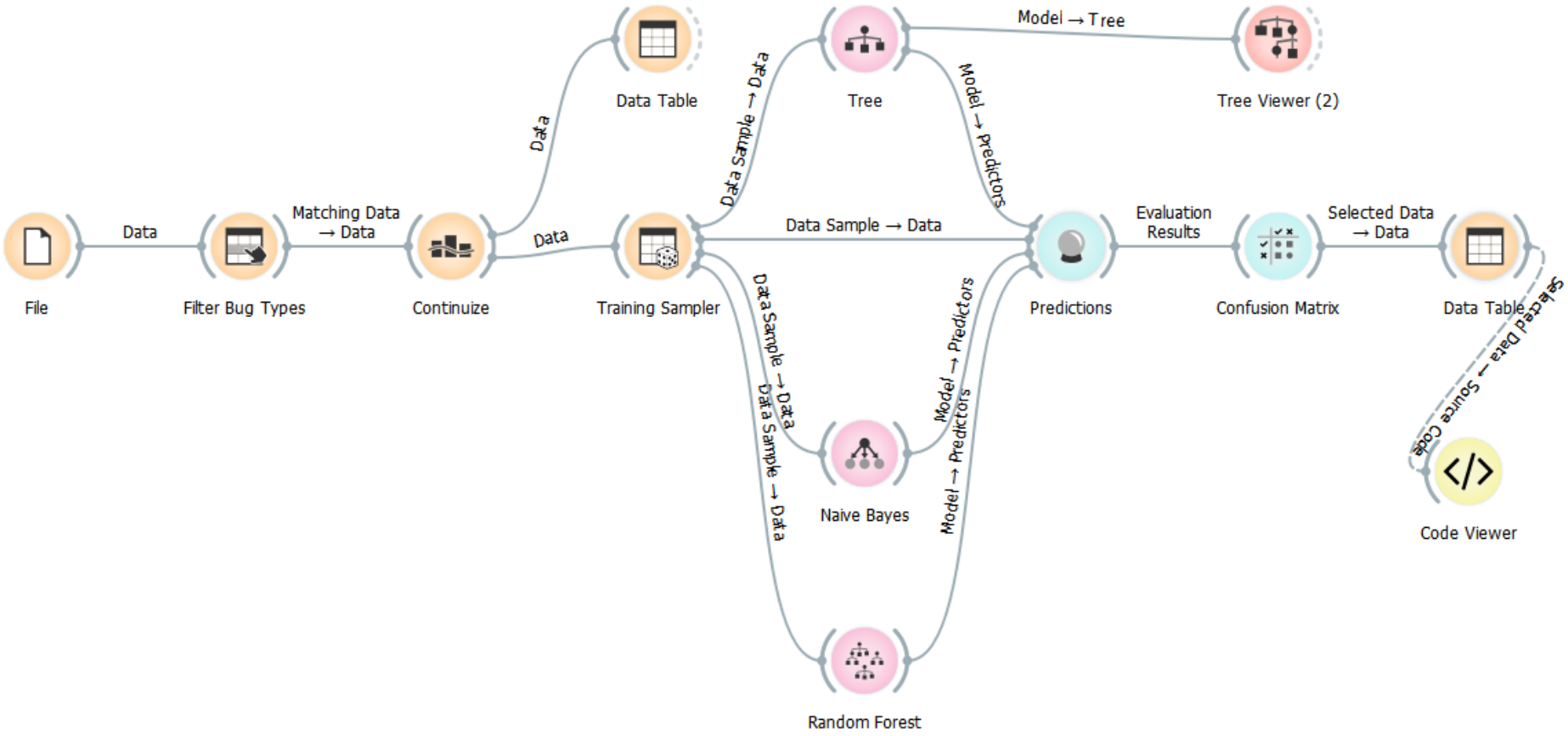
- Find the types of bugs that have low or high false positives

- Which attributes should be transfer to metadata?
  - Attributes that should be ignored
- Reproduce the same prediction workflow to this new dataset

Hand-on !

- Which algorithm perform the best?

Expected Orange Canvas



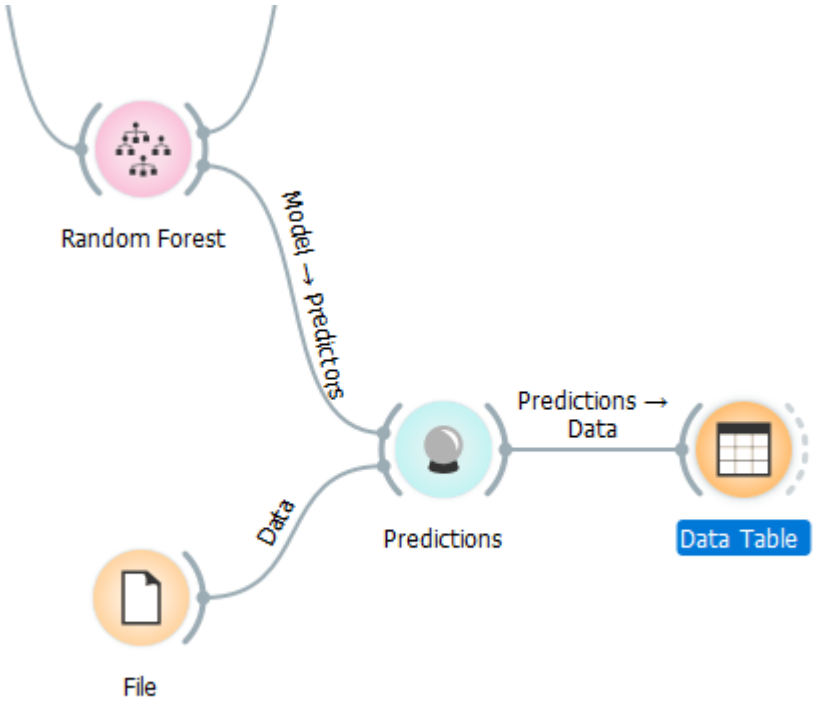
Hand-on !

Code Viewer Widget :
https://github.com/GoSecure/orange-code-widget

Can you find the vulnerability?

- Apply the "Random forest" algorithm to the dataset “03_hotel-spotbugs-results.csv”

- Use the Code Widget to explore the potential vulnerability
  - https://github.com/GoSecure/orange-code-widget



Conclusion

Potential Extensions to this Workshop

- Repeat the exercise with the **Orange API**

```
>>> import Orange
>>> data = Orange.data.Table("juliet-result.csv")
```

- Develop **custom widgets** for Orange (Python based add-on)

- Start experimenting with your **own dataset**

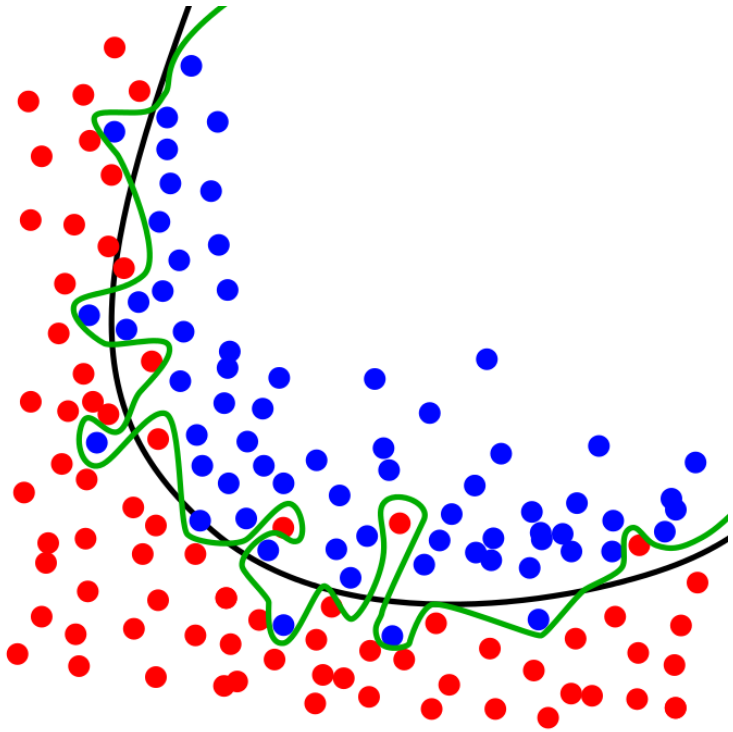
Training ML algorithm

Short documentary on Machine Learning training risks

Be careful …

- Inadequate training set (noisy, incomplete)
- Overfitting
  - Excellent results with training data
  - ..but inaccurate with application data
- Underfitting
  - Lack of attributes

- Keep skepticism regarding the validity of your data and the performance associated to your algorithm's results



Overfitting example using two dimensions (numeric attributes)

- This workshop touches only a subset of Machine Learning (Supervised-learning)
- Supervised-learning requires prior classification of a subset of values
- Machine learning will **not work** on **any data**
  - The selection of attributes is crucial
- Selection of training data and validation data is very important

References

Machine Learning Coursera

- https://www.coursera.org/learn/machine-learning

Introduction to Machine Learning

- https://developers.google.com/machine-learning/crash-course/ml-intro

- Getting Started with Orange : Tutorial Series

https://www.youtube.com/watch?v=HXjnDIgGDuI&list=PLmNPvQr9Tf-ZSDLwOzxpvY-HrE0yv-8Fy

Additional Datasets

Kaggle

- https://www.kaggle.com/datasets

Google BigQuery public datasets

- https://bigquery.cloud.google.com/publicdatasets/

OpenML

- https://www.openml.org/search?type=data

Data from your systems..

- Log files (WAF, IDS), malware samples (exe, ps, apk), network capture (pcap), etc.