AISA – Demo
Articial Intelligence for Situation Awareness
Digital Twin – Server / Client(s)
Web based user interface for test, tune & validate

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Valmet

Progress built on 220 years of industrial history

From cloth making to high-tech processes

1797 Jokioisten Verkatehdas
1841 Götaverken
1856 Tampella
1858 Beloit
1860 KMW
1868 Sunds Defibrator

1942
Rauma-Raahe

1951
Valmet

1968–1996
Several M&As:
1986 KMW

1987 Wärtsilä paper finishing machinery

1992 Tampella Papertech

1999
Metso created through merger of Valmet and Rauma

Acquisitions
2000
Beloit Technology

2006
Kvaerner Pulping
Kvaerner Power

2009
Tamfelt

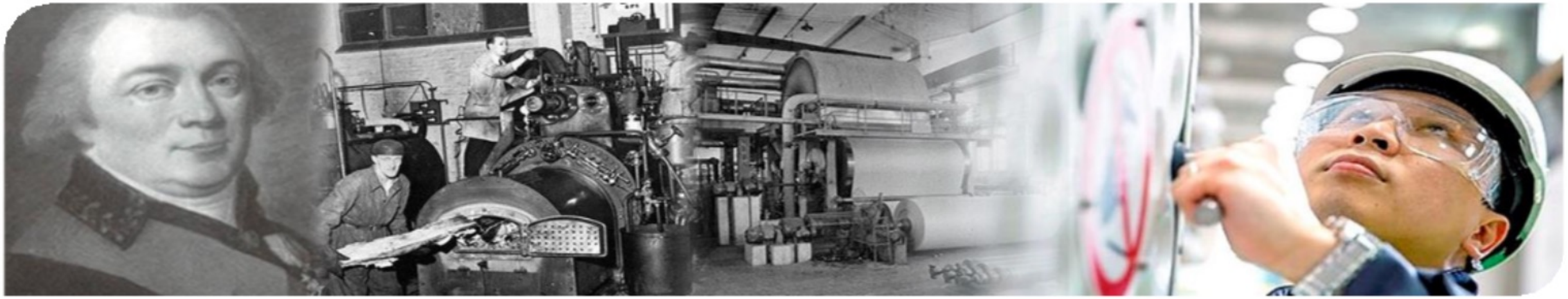
End of 2013
Demerger to Valmet and Metso

2015
Metso Process Automation Systems to Valmet

2019
Valmet acquires GL&V and J&L Fiber Services Inc

2020
Valmet acquires PMP Group

2021
Valmet acquires EWK Umwelttechnik and ECP Group



This is Valmet

Unique offering

- Market's widest offering combining process technologies, services and automation
- Research and development spend EUR 75 million in 2020

Market leadership

- Leading market position in all markets

Pulp	#1–2
Energy	#1–3
Board	#1
Tissue	#1
Paper	#1
Services	#1–2
Automation	#1–3

Strong global presence

- Approx. 100 service centers
- 98 sales offices
- 43 production units
- 16 R&D centers
- 14,000 professionals

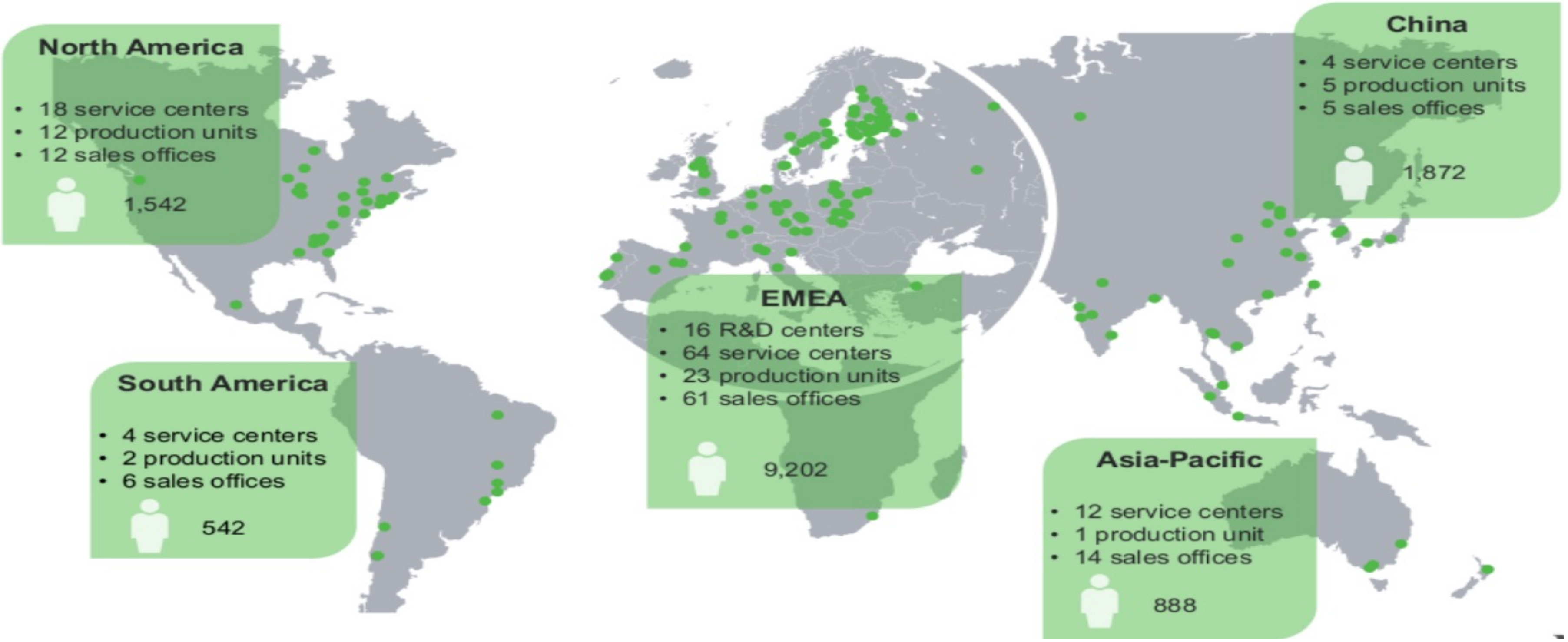
EMEA	9,200
China	1,900
North America	1,500
Asia-Pacific	900
South America	500

Leader in sustainability

- Eight consecutive years in Dow Jones Sustainability Index
- Highest ranking in Ecovadis sustainability assessment
- B rating in CDP climate program 2021

Strong global presence is a good platform for growth

100 service centers, 98 sales offices, 43 production units, 16 R&D centers



North America

- 18 service centers
- 12 production units
- 12 sales offices

1,542

South America

- 4 service centers
- 2 production units
- 6 sales offices

542

EMEA

- 16 R&D centers
- 64 service centers
- 23 production units
- 61 sales offices

9,202

China

- 4 service centers
- 5 production units
- 5 sales offices

1,872

Asia-Pacific

- 12 service centers
- 1 production unit
- 14 sales offices

888

Valmet Offerings by business lines

Paper

- Recycled fiber lines
- Tailor-made board and paper machines
- Modularized board and paper machines
- Tissue production lines
- Modernizations and grade conversions
- Standalone products

Pulp and Energy

- Complete pulp mills
- Sections and solutions for pulp production
- Multifuel boilers
- Biomass and waste gasification
- Emission control systems
- Biotechnology solutions e.g. for producing bio fuels

Process technology
Customer
Services
Automation

Services

- Spare and process parts
- Workshop and roll services
- Fabrics
- Maintenance development and outsourcing
- Field services
- Process upgrades
- Industrial internet solutions

Automation

- Distributed control systems
- Industrial applications
- Quality management
- Analyzers and measurements
- Industrial internet solutions
- Automation services

Focus in customer benefits

Digital Twin for Industry

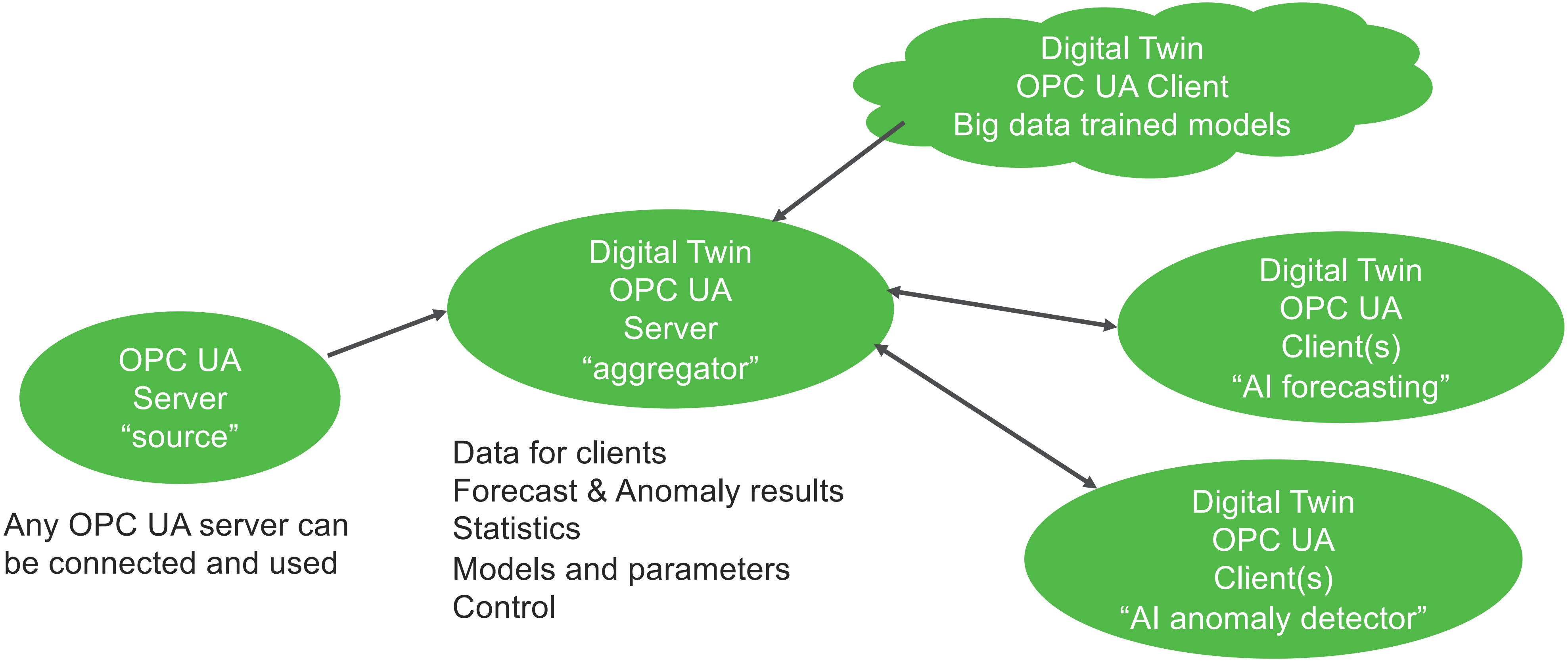
- Easy to install & configure, can be run on site or on cloud, flexible architecture

- Digital Twin Server:
  - Aggregate values
  - Provide historical access to data
  - Digital Twin Alarms for Anomalies
  - Forecast & other results will be stored to server

- Digital Twin Client for forecasting, anomaly detection & regression:
  - Run model: train/fit/predict according data from the Digital Twin Server
  - Write back forecast, accuracy & error
  - Raise: Anomaly detection alarm
  - Implementation with Python / Javascript / other suitable programming language
  - Keeps/hides algorithm/model inside client code

Digital Twin OPC UA based architecture

OPC UA as enabler: HA communication for data, A&C for anomaly & UA file for model & parameters



Any OPC UA server can
be connected and used

Data for clients
Forecast & Anomaly results
Statistics
Models and parameters
Control

AISA Demo phases

- Phase 1:
  - Server – client infrastructure working

- Phase 2:
  - Clients updating predictions / anomalies to server

- Phase 3:
  - Pretrained models for industry?
  - Federated learning
  - Template for Digital Twin client
    - Forecast
    - Anomaly detector
    - Multivariable regression

Digital Twin – RNN forecast

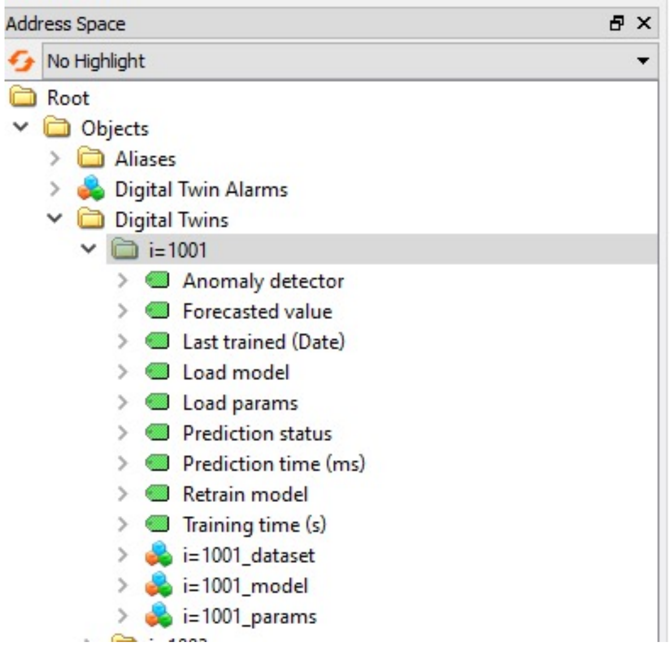
Findings: TensorFlow (JavaScript)

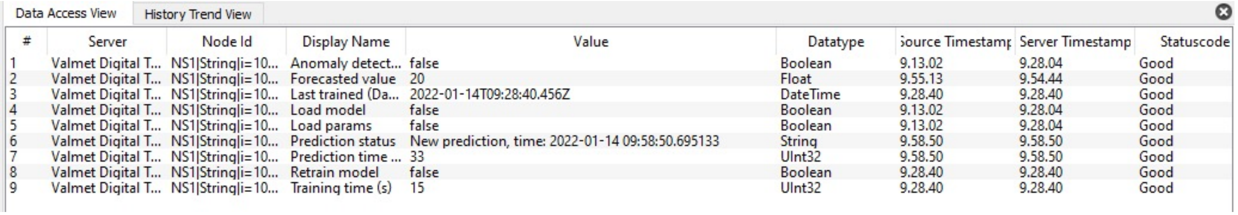
- First initial training time consuming => run predictions with created model
  - From 40s training -> less than 100ms prediction time
- Re-train model, interval 300s
  - If prediction error with real measurement too big => force re-training
  - In practice NOT USABLE
- RNN parameters needed for each instance
  - General parameters are not matching well => tuning needed for each
  - IDEA: Pre-defined parameters for specific measurements in industry
  - IDEA: Pre-trained models for industry
- TODO:
  - Anomaly detector (Autoencoder first, but it will be not enough, some classification will be needed)
  - Multi-variable regression for complex predictions

Digital Twin Server – OPC UA based management

Aggregate values from the other server

- Address space build for Digital Twin
- Constructed from the configuration
- For the Digital Twin clients variables (nodeId + suffix):
  - _detector == Anomaly detection (connected to A&C alarm object)
  - _forecast == Predicted value
  - _last_trained == Last training time
  - _load_model == Request from server to client to load model file (pkl)
  - _load_params == Request from server to client to load parameter file (jsonc)
  - _status == Client can report status
  - _prediction_time == Execution time to make new prediction
  - _training_time == Execution time to train model
  - _model == Model file
  - _params == Parameter file
  - _dataset == Dataset (csv)

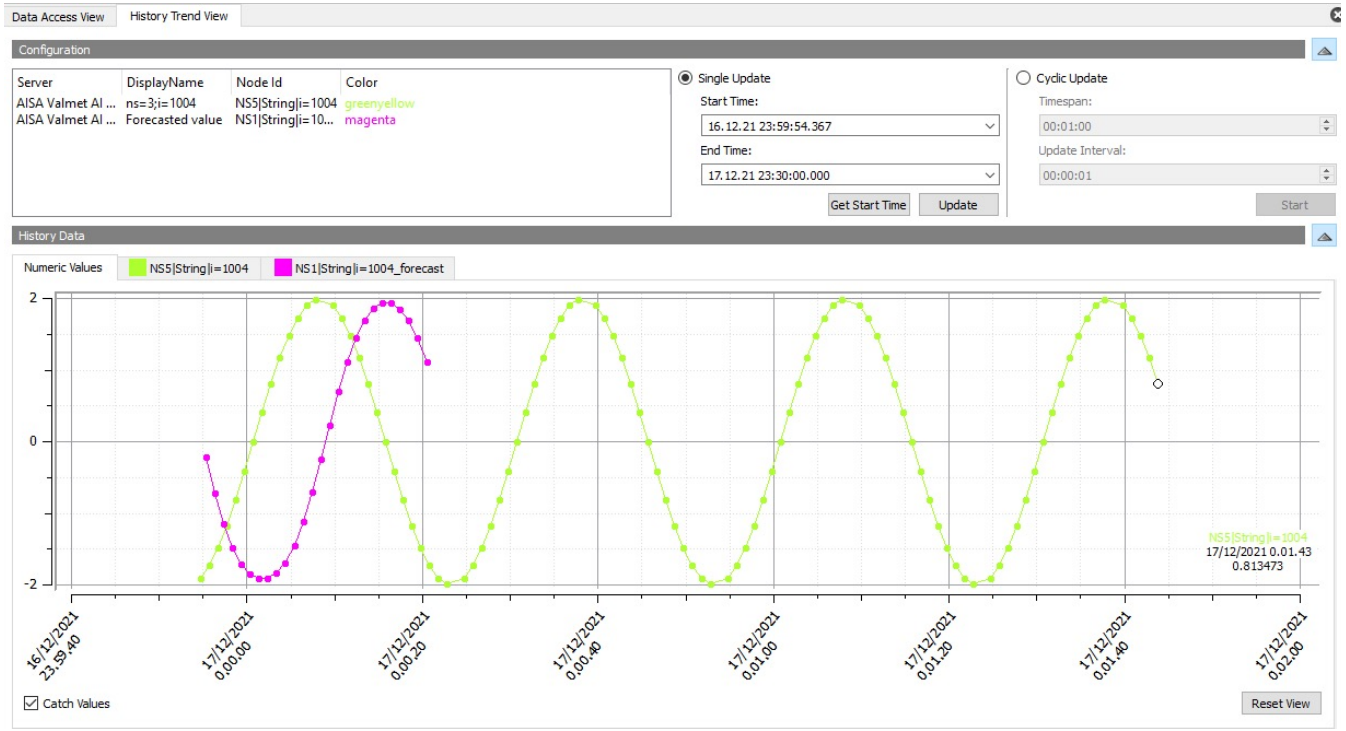




#	Server	Node Id	Display Name	Value	Datatype	Source Timestamp	Server Timestamp	Statuscode
1	Valmet Digital T...	NS1|String|i=10...	Anomaly detect...	false	Boolean	9.13.02	9.28.04	Good
2	Valmet Digital T...	NS1|String|i=10...	Forecasted value	20	Float	9.55.13	9.54.44	Good
3	Valmet Digital T...	NS1|String|i=10...	Last trained (Da...	2022-01-14T09:28:40.456Z	DateTime	9.28.40	9.28.40	Good
4	Valmet Digital T...	NS1|String|i=10...	Load model	false	Boolean	9.13.02	9.28.04	Good
5	Valmet Digital T...	NS1|String|i=10...	Load params	false	Boolean	9.13.02	9.28.04	Good
6	Valmet Digital T...	NS1|String|i=10...	Prediction status	New prediction, time: 2022-01-14 09:58:50.695133	String	9.58.50	9.58.50	Good
7	Valmet Digital T...	NS1|String|i=10...	Prediction time ...	33	UInt32	9.58.50	9.58.50	Good
8	Valmet Digital T...	NS1|String|i=10...	Retrain model	false	Boolean	9.28.40	9.28.40	Good
9	Valmet Digital T...	NS1|String|i=10...	Training time (s)	15	UInt32	9.28.40	9.28.40	Good

Forecast – First test client

Time offset – signal shape “correct”



Server	DisplayName	Node Id	Color
AISA Valmet AI ...	ns=3;i=1004	NS5|String|i=1004	greenyellow
AISA Valmet AI ...	Forecasted value	NS1|String|i=10...	magenta

● Single Update

Start Time: 16.12.21 23:59:54.367

End Time: 17.12.21 23:30:00.000

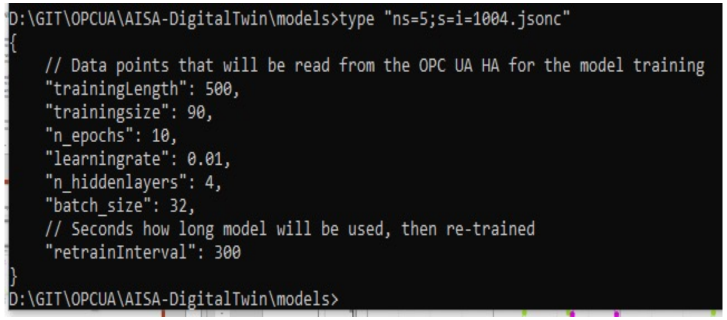
○ Cyclic Update

Timespan: 00:01:00

Update Interval: 00:00:01

☑ Catch Values

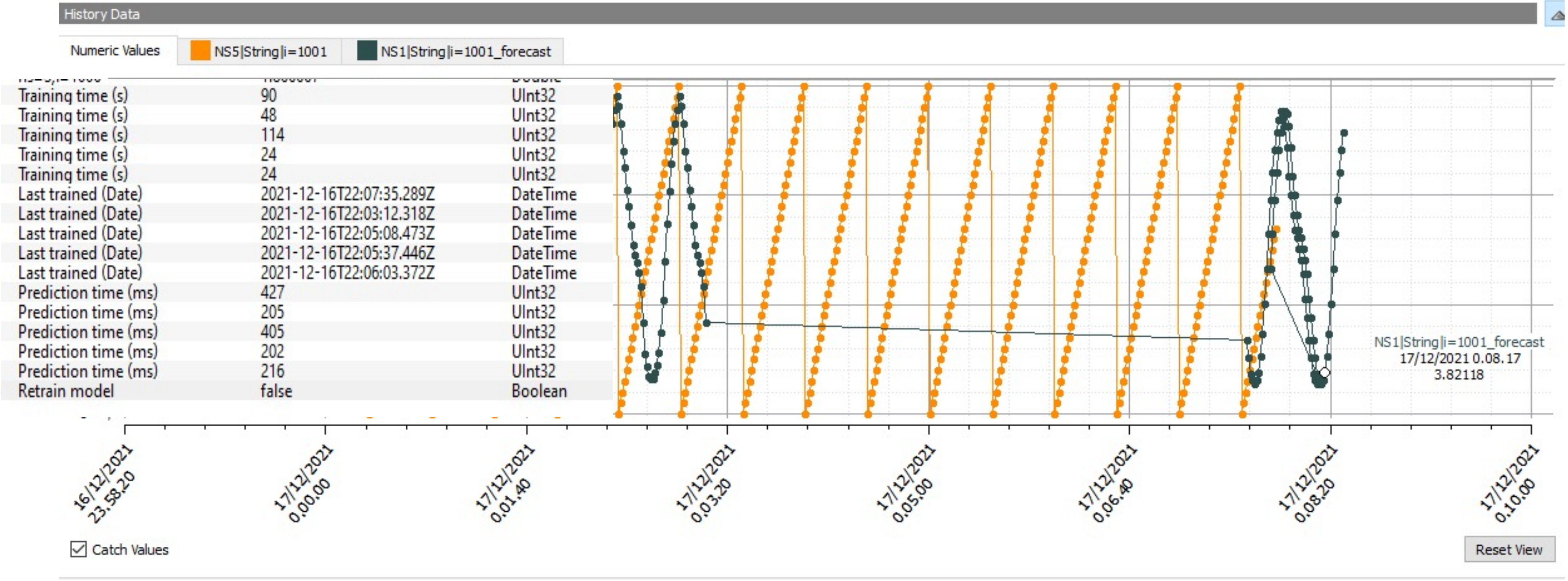
Example of model parameters:



```
D:\GIT\OPCUA\AISA-DigitalTwin\models>type "ns=5;s=i=1004.jsonc"
{
    // Data points that will be read from the OPC UA HA for the model training
    "trainingLength": 500,
    "trainingsize": 90,
    "n_epochs": 10,
    "learningrate": 0.01,
    "n_hiddenlayers": 4,
    "batch_size": 32,
    // Seconds how long model will be used, then re-trained
    "retrainInterval": 300
}
D:\GIT\OPCUA\AISA-DigitalTwin\models>
```

Retrain model – interval OR by retrain request

If model does not match to signal shape – add training data or other parameters

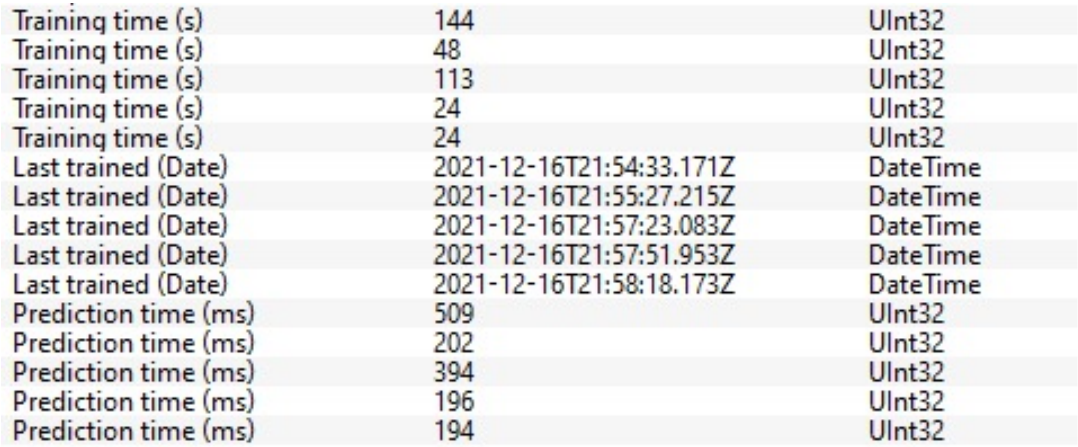


Training time (s)	90	UInt32
Training time (s)	48	UInt32
Training time (s)	114	UInt32
Training time (s)	24	UInt32
Training time (s)	24	UInt32
Last trained (Date)	2021-12-16T22:07:35.289Z	DateTime
Last trained (Date)	2021-12-16T22:03:12.318Z	DateTime
Last trained (Date)	2021-12-16T22:05:08.473Z	DateTime
Last trained (Date)	2021-12-16T22:05:37.446Z	DateTime
Last trained (Date)	2021-12-16T22:06:03.372Z	DateTime
Prediction time (ms)	427	UInt32
Prediction time (ms)	205	UInt32
Prediction time (ms)	405	UInt32
Prediction time (ms)	202	UInt32
Prediction time (ms)	216	UInt32
Retrain model	false	Boolean

☑ Catch Values

Performance – just some thousands of data points

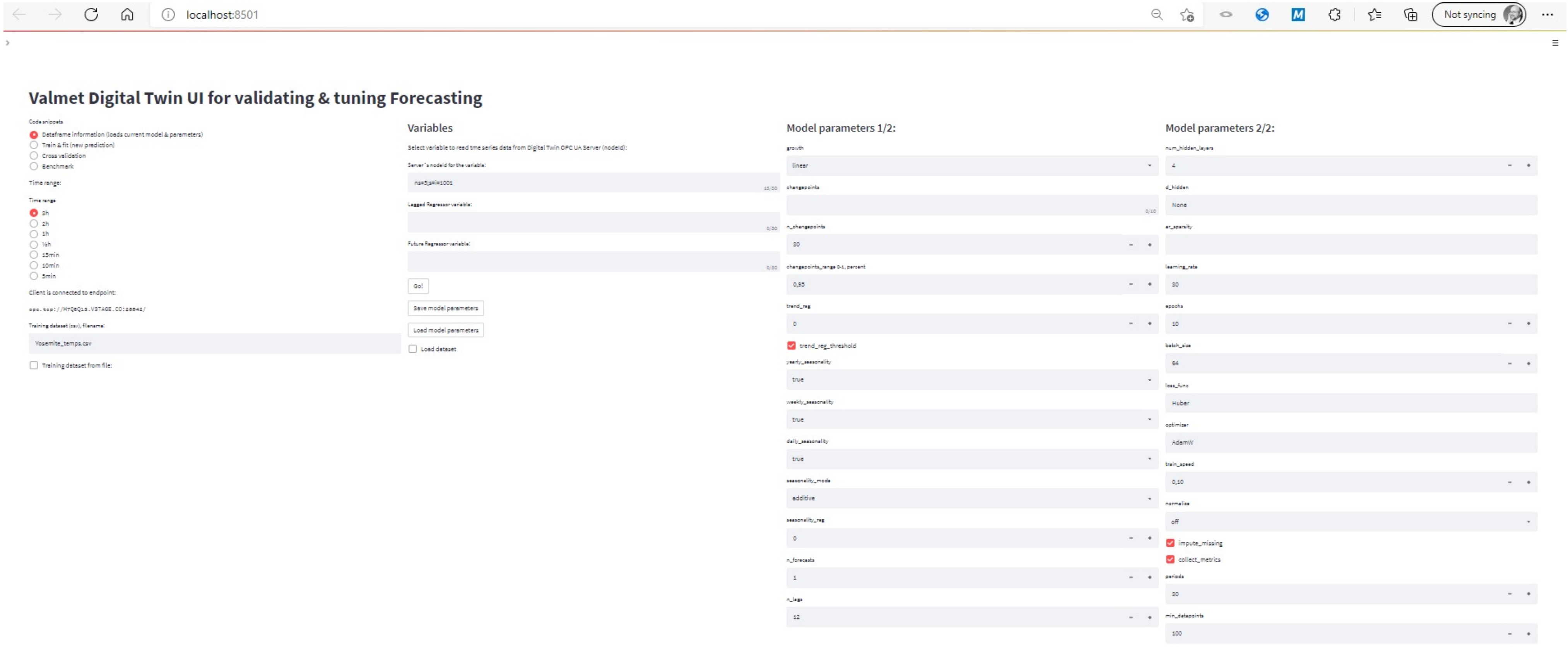
Digital Twin client will write back to server statistics



Training time (s)	144	UInt32
Training time (s)	48	UInt32
Training time (s)	113	UInt32
Training time (s)	24	UInt32
Training time (s)	24	UInt32
Last trained (Date)	2021-12-16T21:54:33.171Z	DateTime
Last trained (Date)	2021-12-16T21:55:27.215Z	DateTime
Last trained (Date)	2021-12-16T21:57:23.083Z	DateTime
Last trained (Date)	2021-12-16T21:57:51.953Z	DateTime
Last trained (Date)	2021-12-16T21:58:18.173Z	DateTime
Prediction time (ms)	509	UInt32
Prediction time (ms)	202	UInt32
Prediction time (ms)	394	UInt32
Prediction time (ms)	196	UInt32
Prediction time (ms)	194	UInt32

Tools for tuning & validating Neural Network

Overview



Valmet Digital Twin UI for validating & tuning Forecasting

Code snippets

● Dataframe information (loads current model & parameters)
○ Train & fit (new prediction)
○ Cross validation
○ Benchmark

Time range:

Time range

● 3h
○ 2h
○ 1h
○ ½h
○ 15min
○ 10min
○ 5min

Client is connected to endpoint:

`opc.tcp://H7QeQ15.VSTAGE.CO:26542/`

Training dataset (csv), filename: Yosemite_temps.csv

□ Training dataset from file:

Variables

Select variable to read tme series data from Digital Twin OPC UA Server (nodeId):

Server´s nodeId for the variable: ns=5;s=i=1001 15/50

Lagged Regressor variable: 0/50

Future Regressor variable: 0/50

□ Load dataset

Model parameters 1/2:

growth: linear

changepoints: 0/10

n_changepoints: 30

changepoints_range 0-1, percent: 0,95

trend_reg: 0

☑ trend_reg_threshold

yearly_seasonality: true

weekly_seasonality: true

daily_seasonality: true

seasonality_mode: additive

seasonality_reg: 0

n_forecasts: 1

n_lags: 12

Model parameters 2/2:

num_hidden_layers: 4

d_hidden: None

ar_sparsity:

learning_rate: 30

epochs: 10

batch_size: 64

loss_func: Huber

optimizer: AdamW

train_speed: 0,10

normalize: off

☑ impute_missing

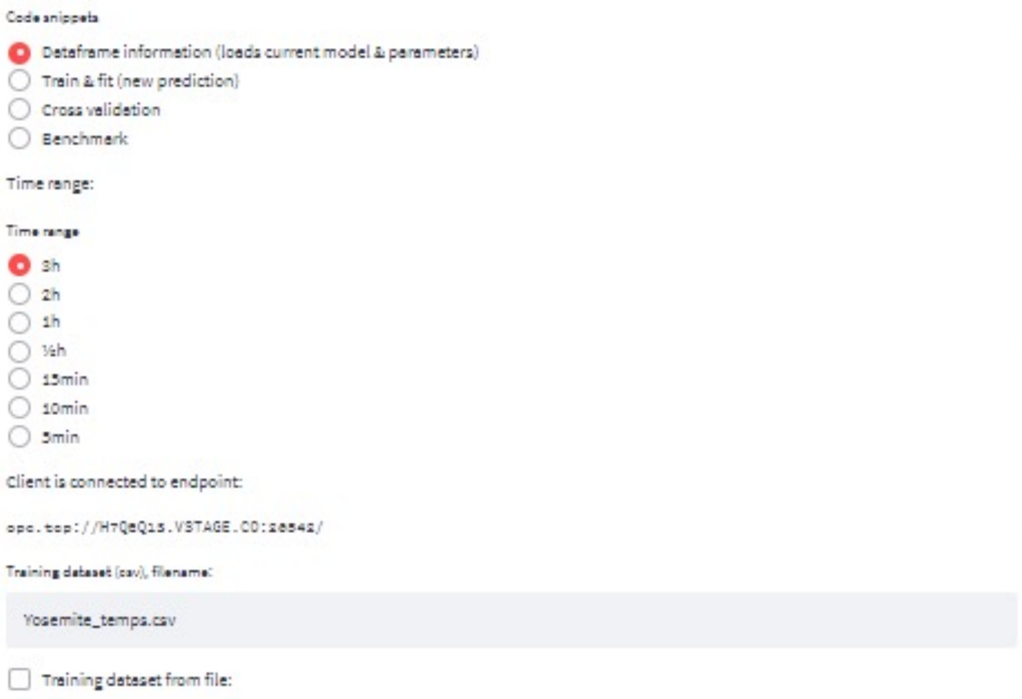
☑ collect_metrics

periods: 30

min_datapoints: 100

Tools for tuning & validating Neural Network

Actions & Variables



Code snippets

● Dataframe information (loads current model & parameters)
○ Train & fit (new prediction)
○ Cross validation
○ Benchmark

Time range:

Time range

● 3h
○ 2h
○ 1h
○ ½h
○ 15min
○ 10min
○ 5min

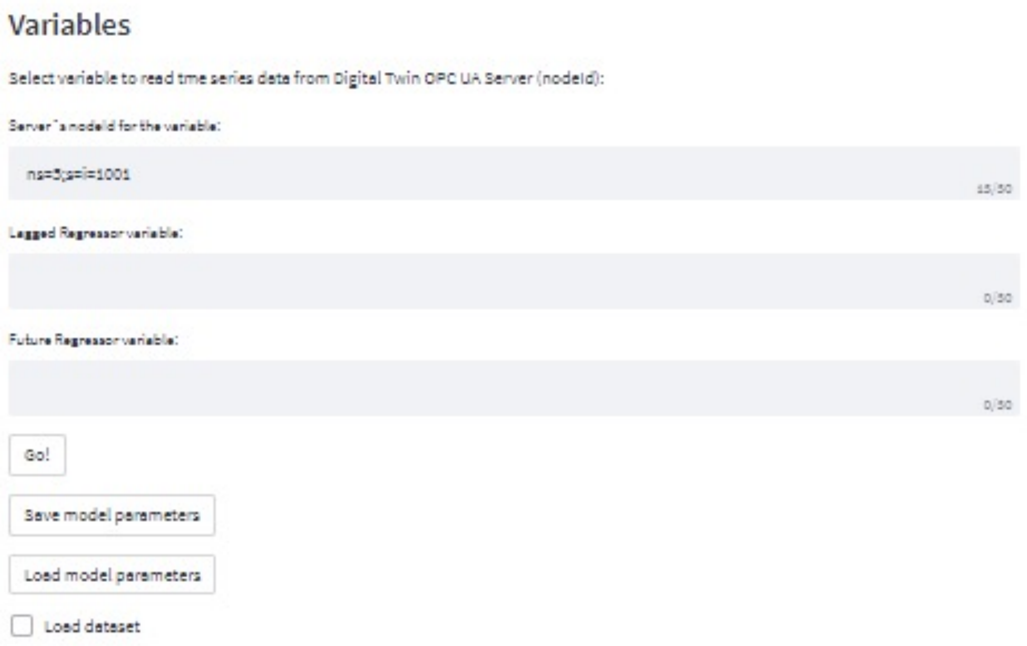
Client is connected to endpoint:

```
opc.tcp://H7QeQ1s.VSTAGE.CO:26542/
```

Training dataset (csv), filename:

Yosemite_temps.csv

□ Training dataset from file:



Variables

Select variable to read tme series data from Digital Twin OPC UA Server (nodeId):

Server´s nodeId for the variable:

ns=5;s=i=1001 15/50

Lagged Regressor variable:

0/50

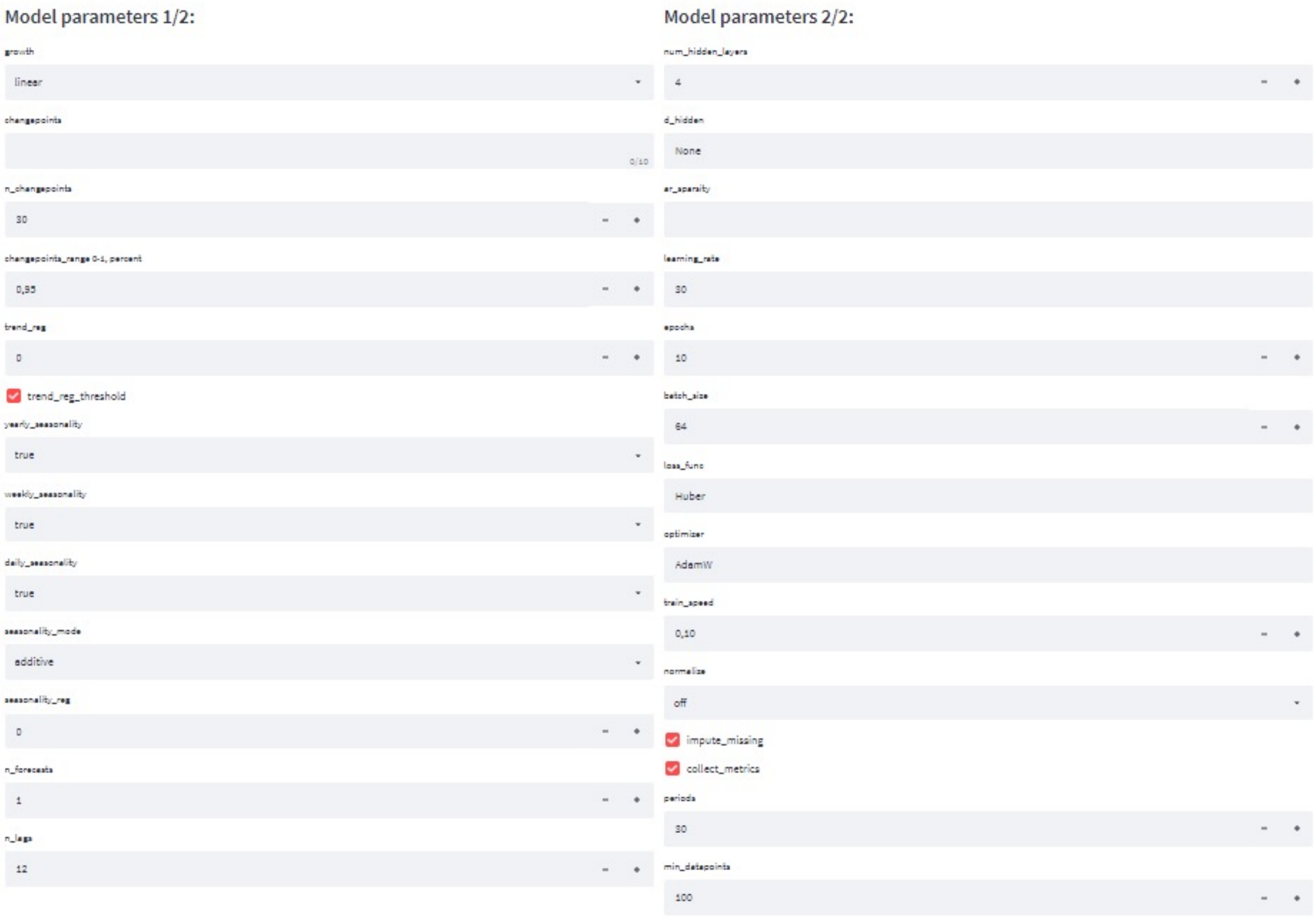
Future Regressor variable:

0/50

□ Load dataset

Tools for tuning & validating Neural Network

Model parameters



Model parameters 1/2:

growth
linear

changepoints

n_changepoints
30

changepoints_range 0-1, percent
0,95

trend_reg
0

☑ trend_reg_threshold

yearly_seasonality
true

weekly_seasonality
true

daily_seasonality
true

seasonality_mode
additive

seasonality_reg
0

n_forecasts
1

n_lags
12

Model parameters 2/2:

num_hidden_layers
4

d_hidden
None

ar_sparsity

learning_rate
30

epochs
10

batch_size
64

loss_func
Huber

optimizer
AdamW

train_speed
0,10

normalize
off

☑ impute_missing

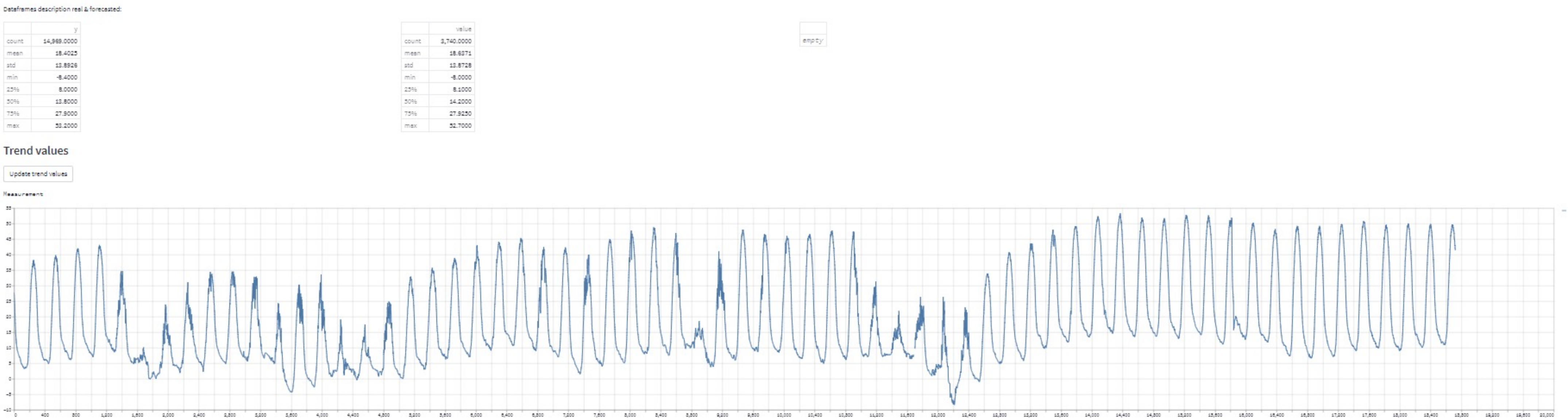
☑ collect_metrics

periods
30

min_datapoints
100

Tools for tuning & validating Neural Network

Show current measurement trend: Yosemite temperatures as example (>40k datapoints)



Dataframes description real & forecasted:

	y
count	14,969.0000
mean	18.4025
std	13.8926
min	-8.4000
25%	8.0000
50%	13.8000
75%	27.9000
max	53.2000

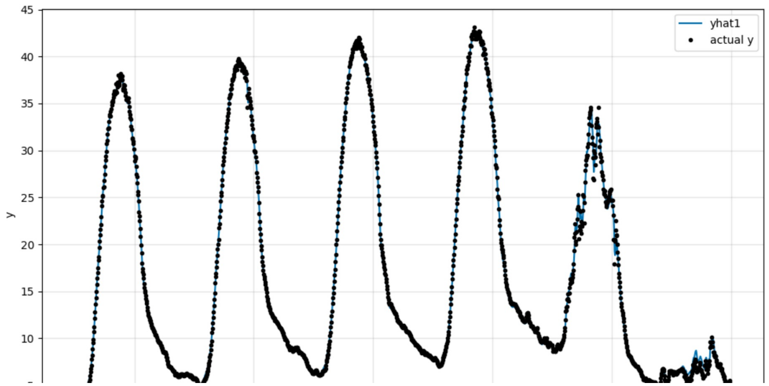
	value
count	3,740.0000
mean	18.6371
std	13.8728
min	-8.0000
25%	8.1000
50%	14.2000
75%	27.9250
max	52.7000

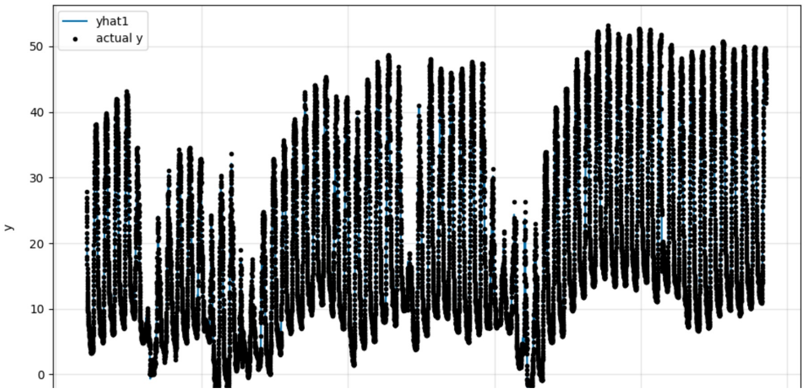
empty

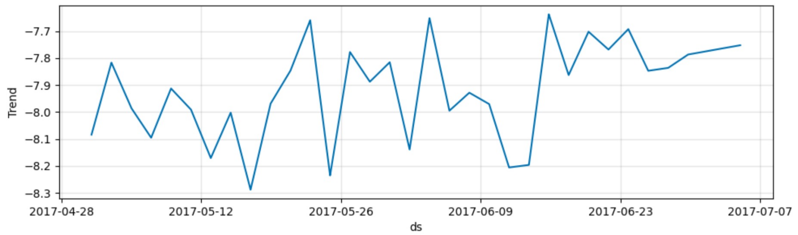
Trend values

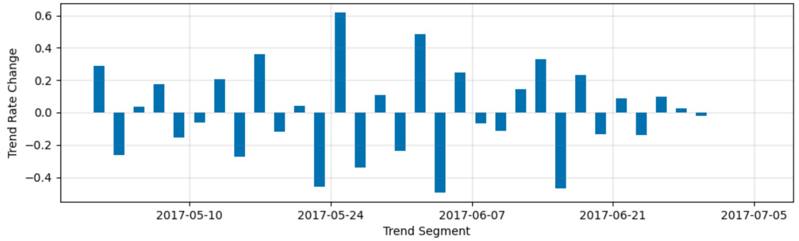
Tools for tuning & validating Neural Network

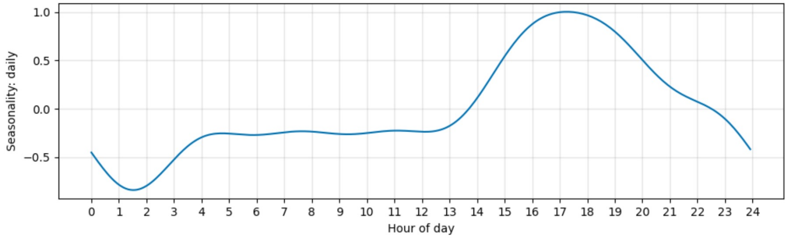
Train & fit

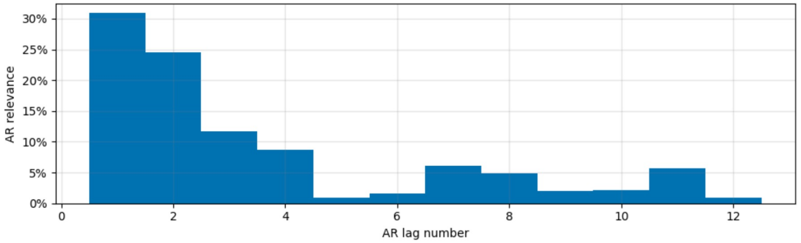






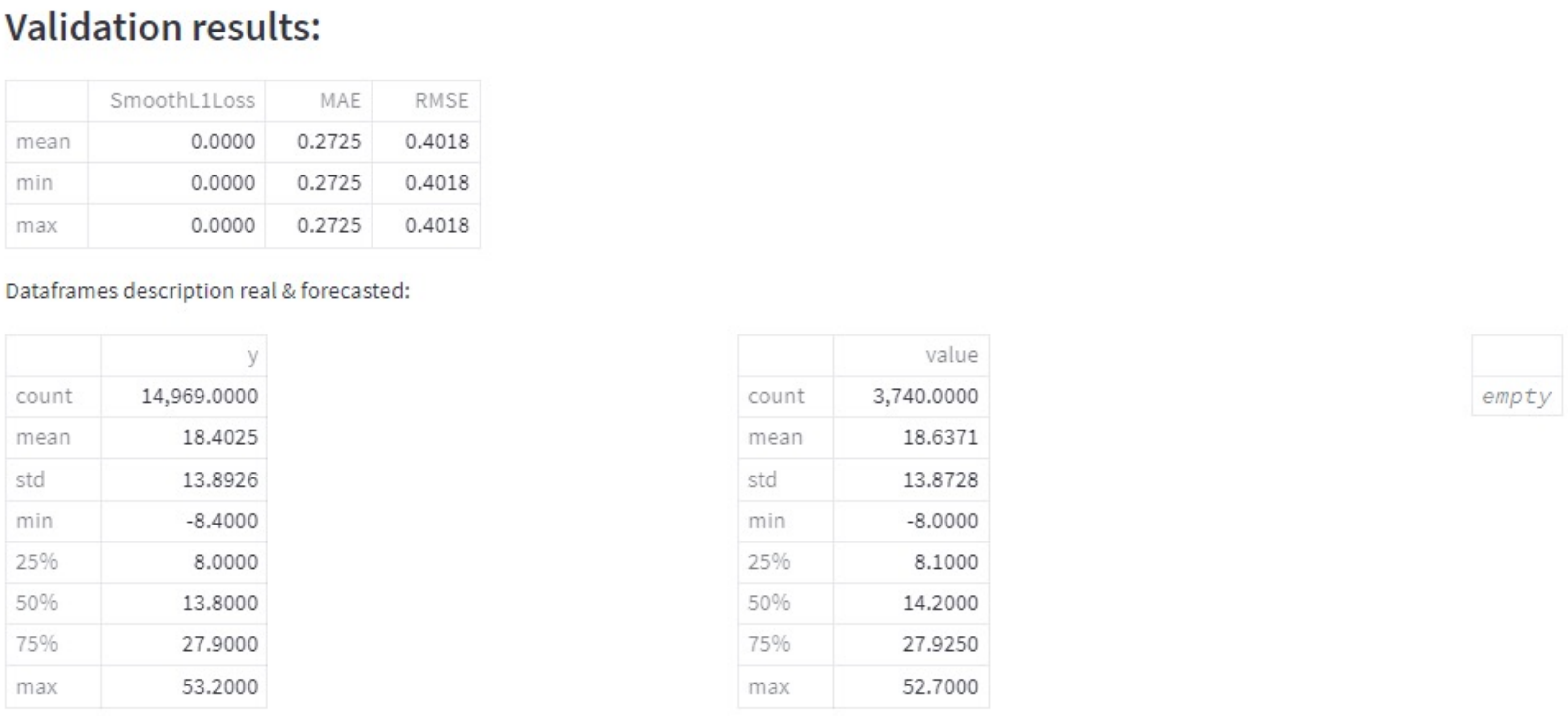






Tools for tuning & validating Neural Network

Cross validate



Validation results:

	SmoothL1Loss	MAE	RMSE
mean	0.0000	0.2725	0.4018
min	0.0000	0.2725	0.4018
max	0.0000	0.2725	0.4018

Dataframes description real & forecasted:

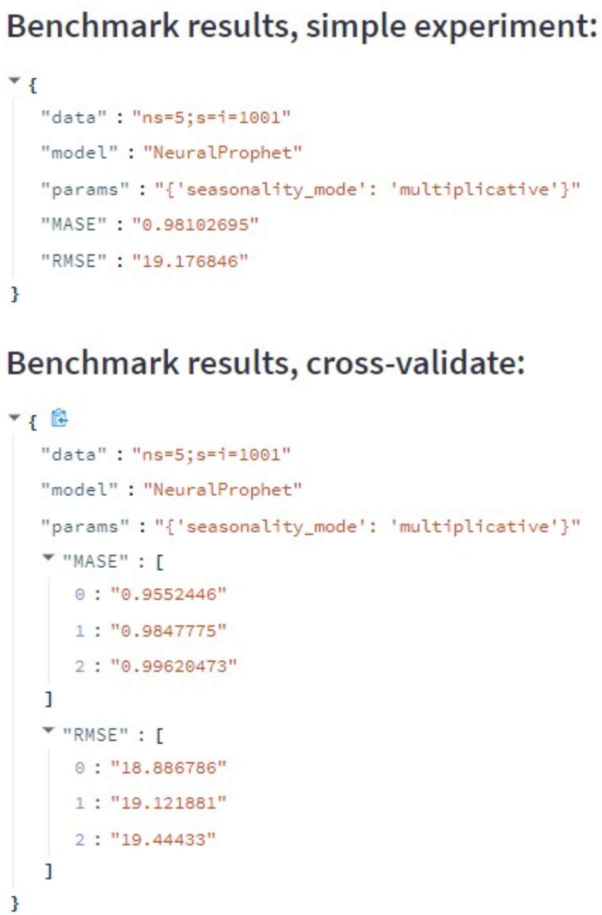
	y
count	14,969.0000
mean	18.4025
std	13.8926
min	-8.4000
25%	8.0000
50%	13.8000
75%	27.9000
max	53.2000

	value
count	3,740.0000
mean	18.6371
std	13.8728
min	-8.0000
25%	8.1000
50%	14.2000
75%	27.9250
max	52.7000

empty

Tools for tuning & validating Neural Network

Benchmark



Benchmark results, simple experiment:

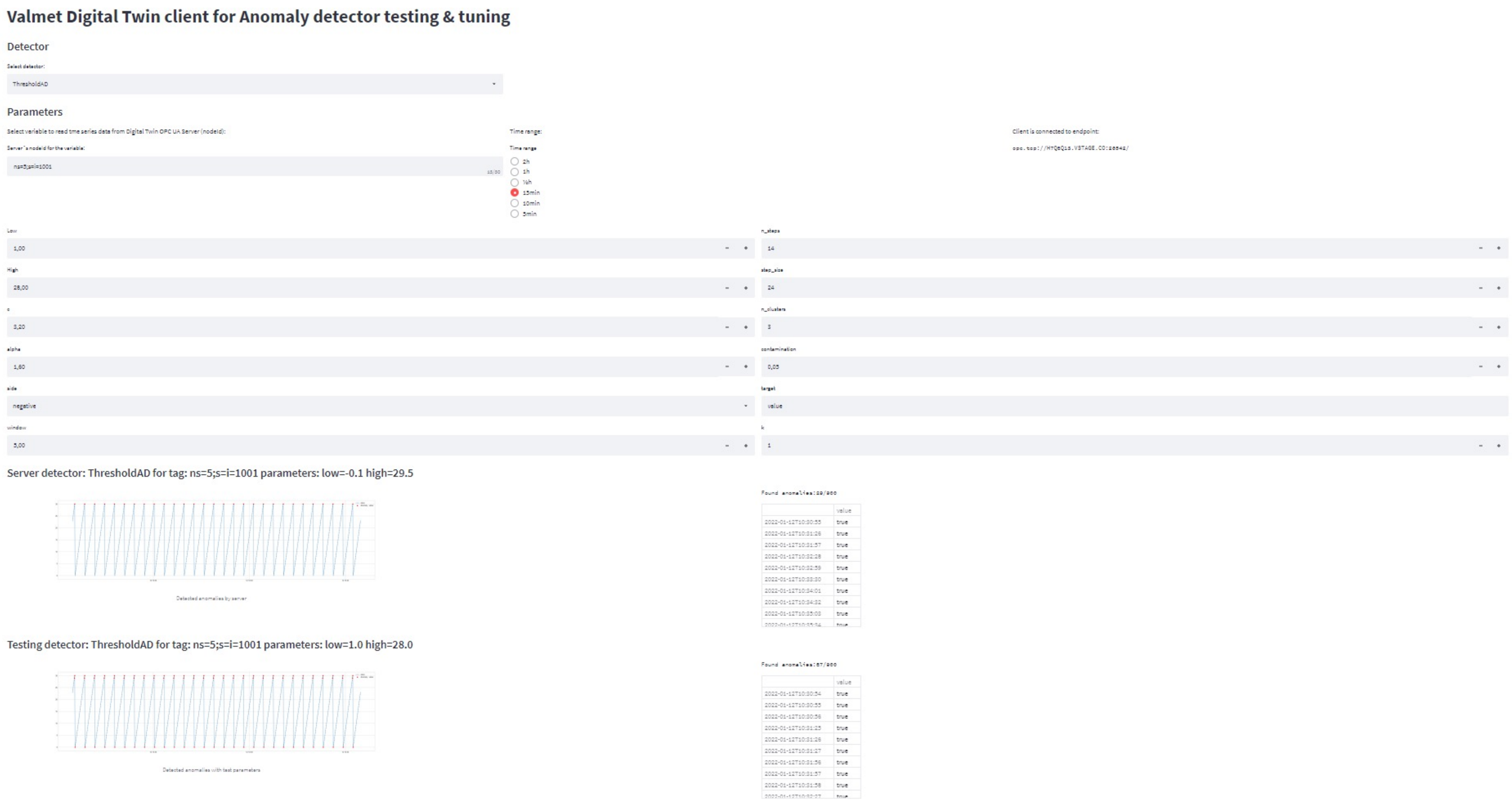
```
▾{
   "data" : "ns=5;s=i=1001"
   "model" : "NeuralProphet"
   "params" : "{'seasonality_mode': 'multiplicative'}"
   "MASE" : "0.98102695"
   "RMSE" : "19.176846"
}
```

Benchmark results, cross-validate:

```
▾{
   "data" : "ns=5;s=i=1001"
   "model" : "NeuralProphet"
   "params" : "{'seasonality_mode': 'multiplicative'}"
  ▾"MASE" : [
      0 : "0.9552446"
      1 : "0.9847775"
      2 : "0.99620473"
   ]
  ▾"RMSE" : [
      0 : "18.886786"
      1 : "19.121881"
      2 : "19.44433"
   ]
}
```

Tools for tuning & validating Anomaly detection

Overview



Valmet Digital Twin client for Anomaly detector testing & tuning

Detector

Select detector:

ThresholdAD

Parameters

Select variable to read tme series data from Digital Twin OPC UA Server (nodeId):

Server´s nodeId for the variable:

ns=5;s=i=1001 15/50

Time range:

Time range

○ 2h
○ 1h
○ ½h
● 15min
○ 10min
○ 5min

Client is connected to endpoint:

opc.tcp://H7QeQ1s.VSTAGE.CO:26542/

Low: 1,00

High: 28,00

c: 3,20

alpha: 1,60

side: negative

window: 5,00

n_steps: 14

step_size: 24

n_clusters: 3

contamination: 0,05

target: value

k: 1

Server detector: ThresholdAD for tag: ns=5;s=i=1001 parameters: low=-0.1 high=29.5

Detected anomalies by server

Found anomalies:29/960

	value
2022-01-12T10:30:55	true
2022-01-12T10:31:26	true
2022-01-12T10:31:57	true
2022-01-12T10:32:28	true
2022-01-12T10:32:59	true
2022-01-12T10:33:30	true
2022-01-12T10:34:01	true
2022-01-12T10:34:32	true
2022-01-12T10:35:03	true
2022-01-12T10:35:34	true

Testing detector: ThresholdAD for tag: ns=5;s=i=1001 parameters: low=1.0 high=28.0

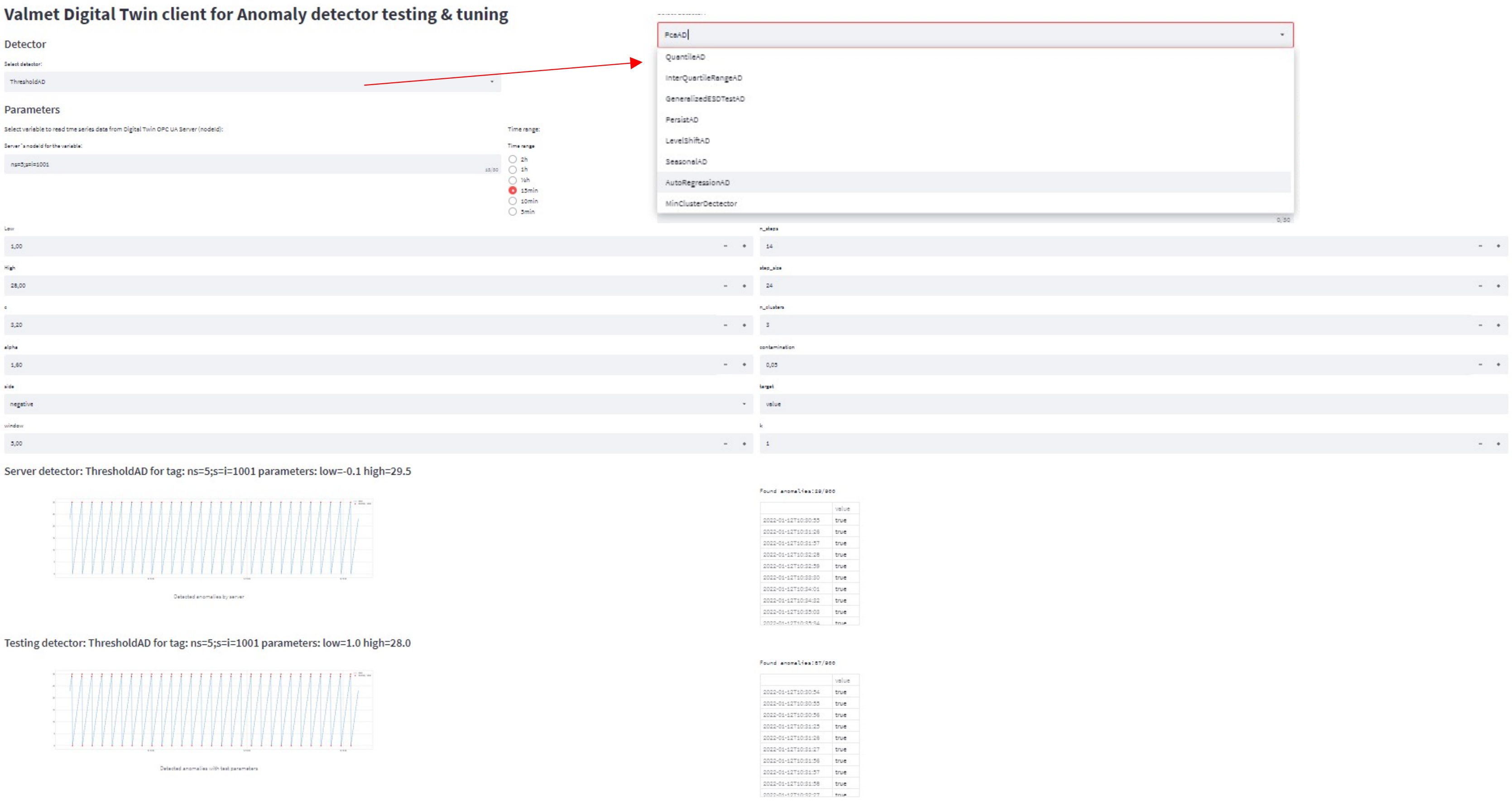
Detected anomalies with test parameters

Found anomalies:87/960

	value
2022-01-12T10:30:54	true
2022-01-12T10:30:55	true
2022-01-12T10:30:56	true
2022-01-12T10:31:25	true
2022-01-12T10:31:26	true
2022-01-12T10:31:27	true
2022-01-12T10:31:56	true
2022-01-12T10:31:57	true
2022-01-12T10:31:58	true
2022-01-12T10:32:27	true

Tools for tuning & validating Anomaly detection

Testing anomaly detection, select from available detector algorithms (14 implemented)



Valmet Digital Twin client for Anomaly detector testing & tuning

Detector

Select detector:

ThresholdAD

PcaAD

Parameters

Select variable to read tme series data from Digital Twin OPC UA Server (nodeId):

Server´s nodeId for the variable:

ns=5;s=i=1001

15/30

Time range:

Time range

○ 2h
○ 1h
○ ½h
● 15min
○ 10min
○ 5min

Low: 1,00	n_steps: 14
High: 28,00	step_size: 24
c: 3,20	n_clusters: 3
alpha: 1,60	contamination: 0,05
side: negative	target: value
window: 5,00	k: 1

Server detector: ThresholdAD for tag: ns=5;s=i=1001 parameters: low=-0.1 high=29.5

Detected anomalies by server

Found anomalies:29/960

	value
2022-01-12T10:30:55	true
2022-01-12T10:31:26	true
2022-01-12T10:31:57	true
2022-01-12T10:32:28	true
2022-01-12T10:32:59	true
2022-01-12T10:33:30	true
2022-01-12T10:34:01	true
2022-01-12T10:34:32	true
2022-01-12T10:35:03	true
2022-01-12T10:35:34	true

Testing detector: ThresholdAD for tag: ns=5;s=i=1001 parameters: low=1.0 high=28.0

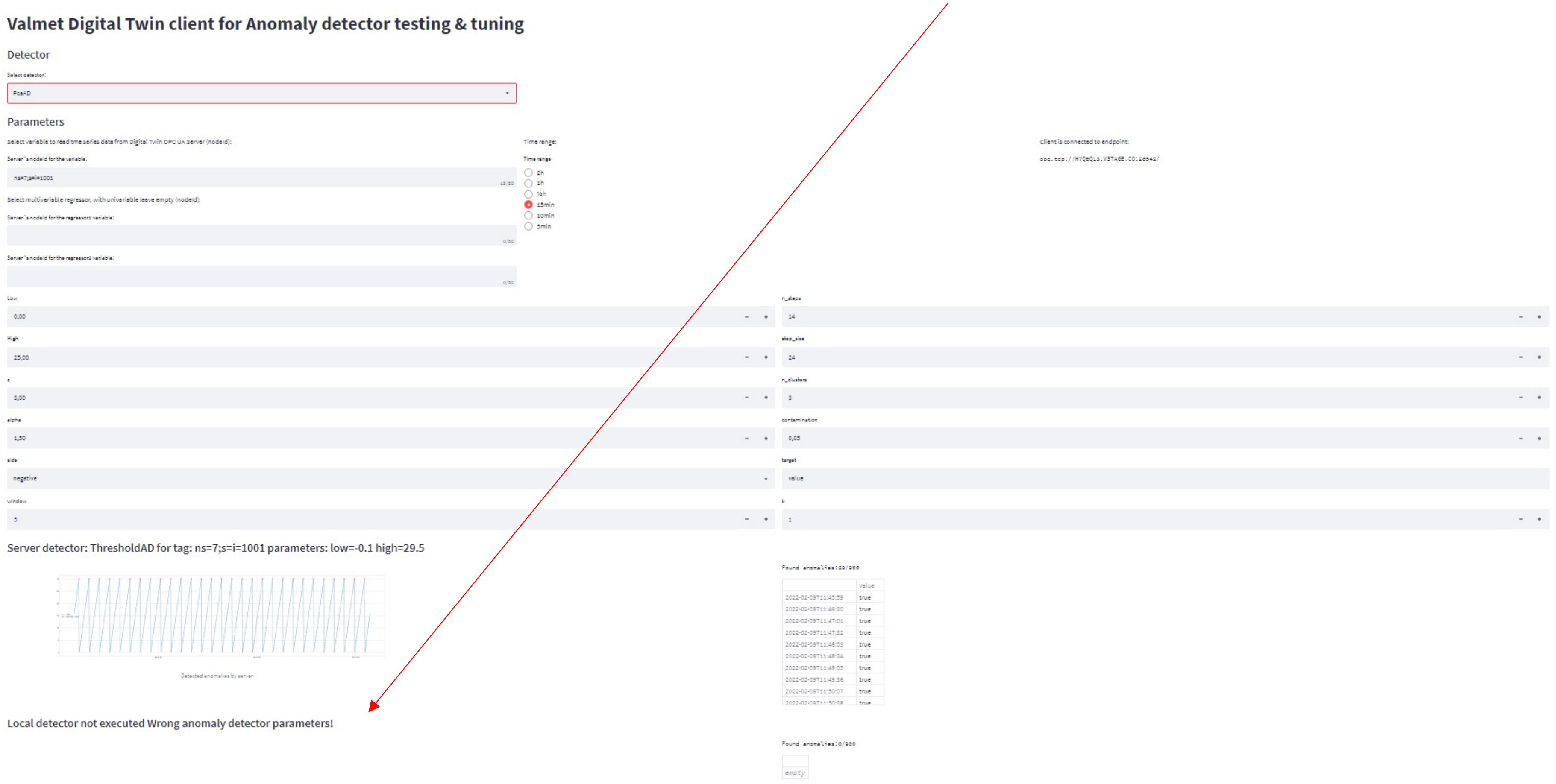
Detected anomalies with test parameters

Found anomalies:57/960

	value
2022-01-12T10:30:54	true
2022-01-12T10:30:55	true
2022-01-12T10:30:56	true
2022-01-12T10:31:25	true
2022-01-12T10:31:26	true
2022-01-12T10:31:27	true
2022-01-12T10:31:56	true
2022-01-12T10:31:57	true
2022-01-12T10:31:58	true
2022-01-12T10:32:27	true

Tools for tuning & validating Anomaly detection

Testing Pca with 5min time range – no anomalies detected



Valmet Digital Twin client for Anomaly detector testing & tuning

Detector

Select detector: PcaAD

Parameters

Select variable to read time series data from Digital Twin OPC UA Server (nodeId):

Server`s nodeId for the variable: ns=7;s=i=1001

Select multivariable regressor, with univariable leave empty (nodeId):

Server`s nodeId for the regressor1 variable:

Server`s nodeId for the regressor2 variable:

Time range:

Time range

○ 2h
○ 1h
○ ½h
● 15min
○ 10min
○ 5min

Client is connected to endpoint:

opc.tcp://H7QeQ1s.VSTAGE.CO:26542/

Low: 0,00

High: 25,00

c: 3,00

alpha: 1,50

side: negative

window: 5

n_steps: 14

step_size: 24

n_clusters: 3

contamination: 0,05

target: value

k: 1

Server detector: ThresholdAD for tag: ns=7;s=i=1001 parameters: low=-0.1 high=29.5

Detected anomalies by server

Found anomalies:29/960

	value
2022-02-09T11:45:59	true
2022-02-09T11:46:30	true
2022-02-09T11:47:01	true
2022-02-09T11:47:32	true
2022-02-09T11:48:03	true
2022-02-09T11:48:34	true
2022-02-09T11:49:05	true
2022-02-09T11:49:36	true
2022-02-09T11:50:07	true
2022-02-09T11:50:38	true

Local detector not executed Wrong anomaly detector parameters!

Found anomalies:0/960

empty

Summary

- OPC UA used as standard communication to integrate AI for industrial use
- Python Neural Prophet for forecasting and ADTK Anomaly Detection Tool-Kit anomalies
- Web application build with Streamlit
  - Parameter tuning
  - Visualize model results
  - Test & validate, repeat until satisfied with the results
  - Write new model & parameters back to server with OPC UA
  - Integrated with FreeOpcUa: opcua-asyncio
- Many steps closer to people can use artificial intelligence at industry
  - Tools are first generation, proof of concept build, architecture promising
  - Needs training for people to understand parameters, models & algorithms
  - Multivariable models needed (current solution is simple univariable implementation)

Next actions with project members

- AWS EC2 instance with Digital Twin server (Valmet)
  - Simulated data (perhaps some historical real data)
  - Some photos (TBD synthetic or augmented)
- Workshop: How to implement Digital Twin client (Python snippets)
  - Digital Twin: INSTA & TAU
- Nokia: Test setup for WebRTC & integration
  - Embedded WebRTC (HTML)
  - Field device detector (AutoML TensorFlow model: object detector)
  - TDS: Person detector
- Architecture:
  - Nokia & Valmet: real-time data & video stream/photo, secure data connection

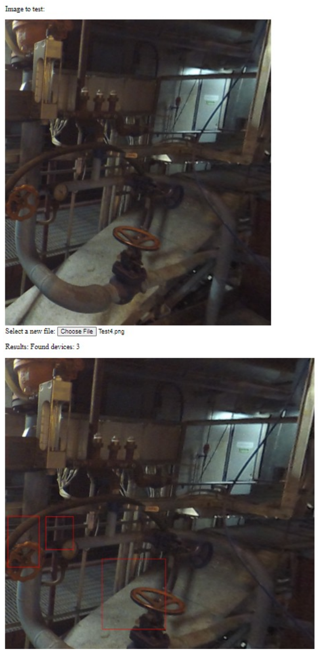
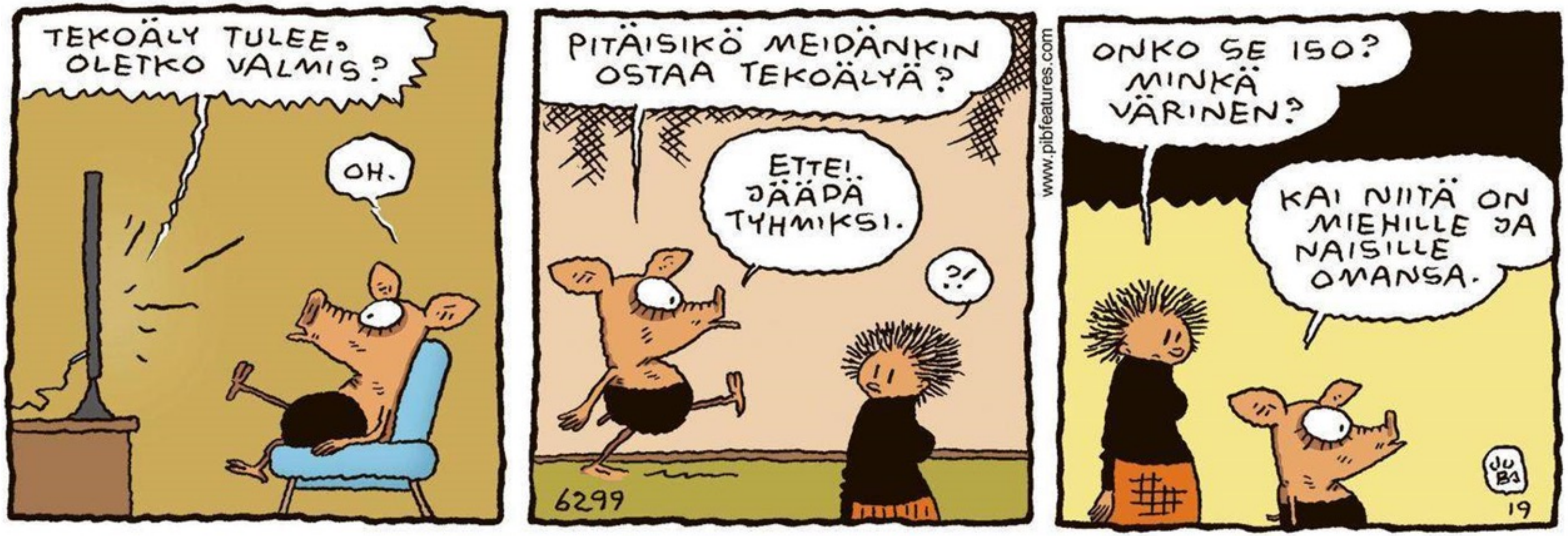


Image to test:

Select a new file: Test4.png

Results: Found devices: 3

“Loppukevennys”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Valmet

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