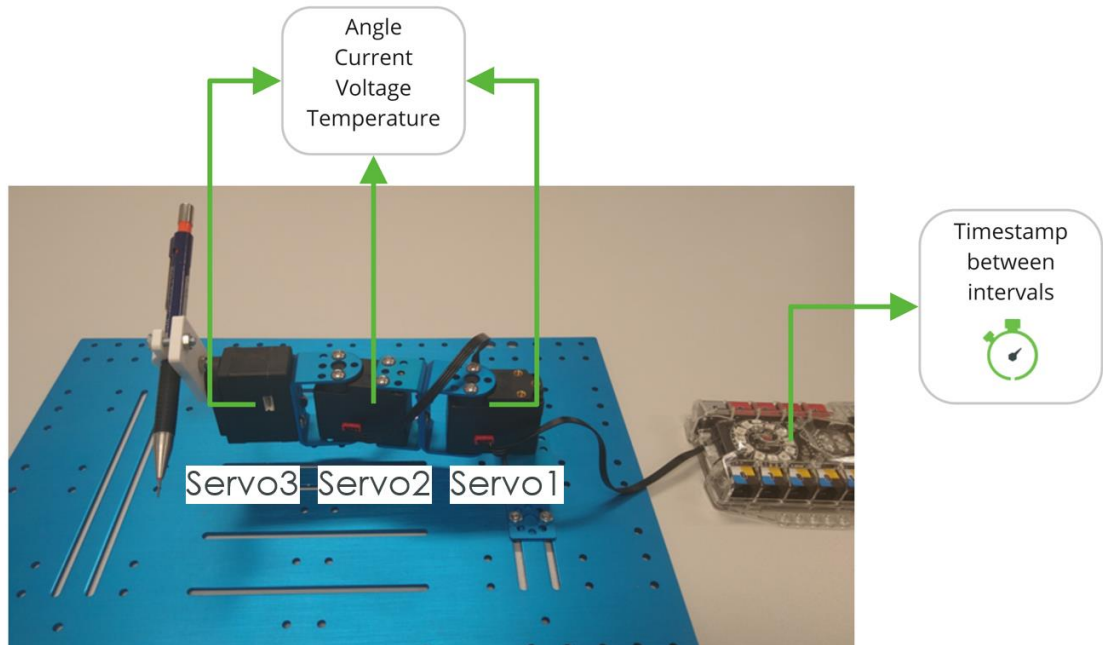
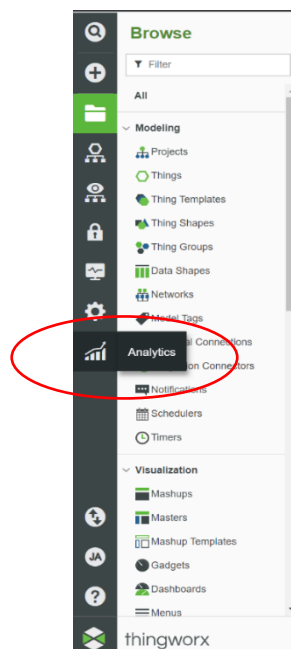


Create a predictive maintenance project using time series analytics with Thingworx Analytics

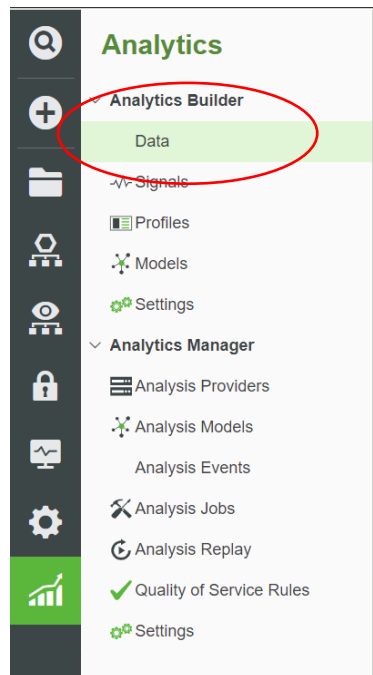
1. Demonstrator



- a. Dataset: `data/ThingworxAnalyticsTimeSeriesDataset.csv`
2. This guide serves as an introductory exercise for a predictive maintenance use case using Thingworx Analytics. This example is intended to familiarize new users with the necessary steps for a predictive maintenance project and time series Analytics with the Analytics builder. Before you start the project please read through the guideline for a predictive maintenance project before. For more information on the demonstrator and the use case please refer to the `README.md` in this subdirectory.
3. Navigate to Analytics on the menu bar on the left side of composer:



4. Select Data



5. Create New dataset

- Name: predictive_maintenance_demo
- Choose File -> navigate to the ThingworxAnalyticsTimeSeriesDataset.csv file on your PC
- Check Upload metadata, Review metadata and time series data

A screenshot of the 'New Dataset' form in the PTC Analytics Builder. The form has a header 'New Dataset' and a 'Status Messages' section on the right. The 'Dataset Name (required):' field contains 'predictive_maintenance_demo'. Below it, the 'File Containing Dataset Data (CSV format):' section has a 'Datei auswählen' button and the text 'Keine ausgewählt'. The 'File Containing Dataset Field Configuration (JSON format):' section has a 'Datei auswählen' button and the text 'ThingworxAnalyticsTimeSeriesPredictionMetadata.json'. There are three checkboxes: 'Upload metadata' (checked), 'Review uploaded metadata' (checked), and 'Time series data' (checked). At the bottom are 'Submit' and 'Cancel' buttons.

- Upload File Containing Dataset Field Configuration -> navigate to the ThingworxAnalyticsTimeSeriesPredictionMetadata.json file on your PC
- Submit

6. Check the metadata

a. It should look like this:

Asset	Entity ID	String	Integer	Double	Temporal	Boolean	Integer	Value	Actions
asset	Entity ID	String							[Icons]
smartServo1Angle	Continuous	Integer							[Icons]
smartServo1Temp	Continuous	Integer							[Icons]
smartServo1Current	Continuous	Integer							[Icons]
smartServo1Voltage	Continuous	Double							[Icons]
smartServo2Angle	Continuous	Integer							[Icons]
smartServo2Temp	Continuous	Integer							[Icons]
smartServo2Current	Continuous	Integer							[Icons]
smartServo2Voltage	Continuous	Double							[Icons]
smartServo3Angle	Continuous	Integer							[Icons]
smartServo3Temp	Continuous	Integer							[Icons]
smartServo3Current	Continuous	Integer							[Icons]
smartServo3Voltage	Continuous	Double							[Icons]
time	Temporal	Integer						60	[Icons]
cycle	Continuous	Integer							[Icons]
isDrawing	Boolean	Boolean							[Icons]
RUL	Continuous	Integer							[Icons]

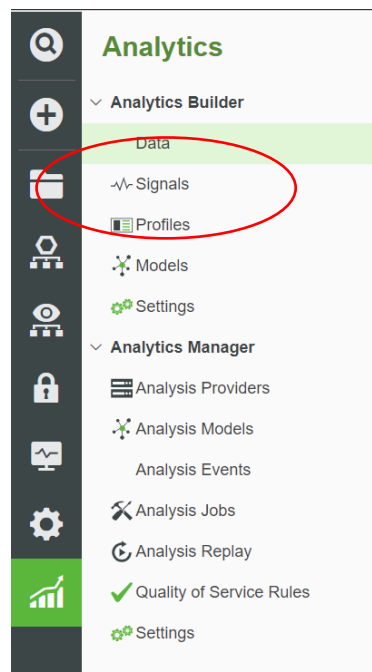
Buttons: Restore Defaults, Download As JSON, Create Dataset, Cancel

b. Click Create Dataset

c. For detailed information on data types please refer to: [Review and Edit Metadata](#)

7. Navigate to Signals

a. Create a new signal



8. Enter Signal settings

- Name: predictive_maintenance_demo_signals
- Dataset: Select your previously created Dataset
- Goal: Select RUL (Abbreviation for Remaining Useful Life)
- Filter: all_data

- e. Exclude Features -> exclude isDrawing
This feature was manually labeled during the data collection (see scripts/time_series_log.py) and is not available for live predictions.
- f. Change all other settings to match with the image below:

New Signals

Signal Name (required): predictive_maintenance_demo_signals

☒ Redundancy Filter

Excluded Fields from Signal: isDrawing

Data from Existing Dataset

Dataset (required): predictive_maintenance_demo

Goal (required): RUL

Filter (required): all_data

Create Filter

-- OR --

Exclude Features Upload New Data

Timeseries Data Only

Lookback Size: 64

Lookahead Size: 1

☐ Use Goal History

Submit Cancel

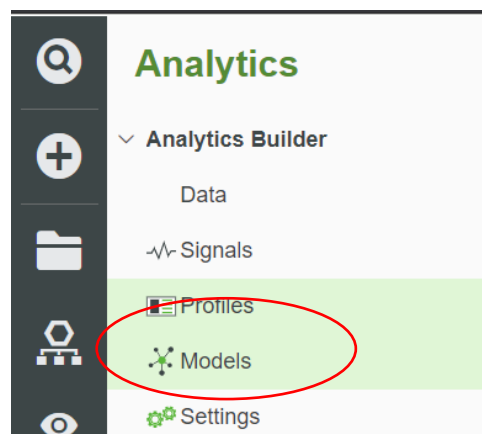
- g. Submit

9. Review Signal results

- a. On the left side you can see the Feature Name and how much information it provides for the value of RUL (from 0 to 1), 0 means no mutual information
- b. For more information to Signals please refer to [Working with Signals](#)
- c. For more information on feature engineering please refer to [Feature Engineering Community Post](#)

10. Navigate to Models

- a. For more information please refer to [Predictive Models](#)



11. For this guide time series analytics is used, for information about this please see [Time Series Prediction](#)

12. Create new Model

- a. Name: predictive_maintenance_demo_model
- b. Dataset: name of the previously created dataset
- c. Goal: RUL
- d. Exclude Fields: (right side of the window)

Fields To Be Excluded From Job

Available Fields

[Select All](#)

- ☐ asset
- ☐ cycle
- ☐ smartServo1Current
- ☐ smartServo1Voltage
- ☐ time

Fields to Exclude

[Select All](#)

- ☐ isDrawing
- ☐ smartServo1Angle
- ☐ smartServo1Temp
- ☐ smartServo2Angle
- ☐ smartServo2Current
- ☐ smartServo2Temp
- ☐ smartServo2Voltage
- ☐ smartServo3Angle
- ☐ smartServo3Current
- ☐ smartServo3Temp
- ☐ smartServo3Voltage

Save **Cancel**

Save

e. Exclude following values:

Create A Filter

Filter Name (required): Copy Definition from Existing Filter

Find Features

Available Fields:

- asset
- cycle
- isDrawing**
- smartServo1Angle
- smartServo1Current
- smartServo1Temp
- smartServo1Voltage
- smartServo2Angle
- smartServo2Current
- smartServo2Temp
- smartServo2Voltage
- smartServo3Angle
- smartServo3Current
- smartServo3Temp
- smartServo3Voltage
- time

Field Values:

Values	# Of Records	% Of Total
true	52399	51%
false	50940	49%

Include Records Exclude Records

Include/Exclude Records with these values:

Field Name	Values	# Of Records	% Of Total	Included/Excluded
isDrawing	false	50940	49%	EXCLUDE

Remove Feature Values

Create Filter Cancel

Those values need to be excluded in order to not have too many samples with cycle 0 in the dataset. This would bias the model output.

- Enter a filter name and create the filter, after that you need to select your filter from the filter dropdown menu
- Make sure your settings match with the following image:

New Predictive Model

Model Name (required): Model Description:

Data Selection Advanced Model Configuration

Dataset (required): ☒ This dataset contains Time Series Configuration. Check to create Time Series Model.

Goal (required):

Filter (required): Create Filter

Filter Details

This filter contains 52,399 rows, representing 51% of all the rows in the dataset

Field	Value	Included / Excluded	SQL Clause
isDrawing	'false'	EXCLUDE	((isDrawing) != 'false')

Excluded Fields from Model: Exclude Fields

- isDrawing
- smartServo1Angle
- smartServo1Temp
- smartServo2Angle
- smartServo2Current
- smartServo2Temp
- smartServo2Voltage
- smartServo3Angle
- smartServo3Current
- smartServo3Temp
- smartServo3Voltage

Submit Cancel

- Click on Advanced Model Configuration (refer to step 10 for more information on the settings)
- Please enter following details:

New Predictive Model

Model Name (required): predictive_maintenance_demo_model

Model Description:

Data Selection **Advanced Model Configuration**

Model Settings

Validation Holdout %: 20

Max Fields: 12

☒ Redundancy Filter

☒ Validate on Training Data

Confidence Model

☐ Create Confidence Model

Confidence Level %: 80

Sampling Strategy

Only available for Boolean goals.

Confusion Matrix Weights

Only available for Boolean goals.

Time Series Parameters

Lookback Size (required): 64

Lookahead: 1

☐ Use Goal History

Learning Techniques

Add Learner **Remove Learners**

Name	Layer Count	Hidden Unit %	Max Depth	# Of Trees	Hidden Activation	Layer With Loss	Number Iterations
LINEAR_REGRESSION							

Ensemble Technique: Soloist

Reset Configuration

Submit **Cancel**

Validation holdout: For time series analytics the last 20% (if you select 20%) of data samples in your dataset are used to test the trained model to ensure the data integrity. Non time series models use 20% random samples.

Max Fields: Limit how many features should be used for training (Thingworx Analytics creates features, so if your dataset only contains 4 features this limit still applies, because averages, derivatives, ... are calculated and used as additional features)

Lookback size: 64 is the limit with Thingworx Analytics and those samples contain an entire cycle of the robot-program

Learning Techniques: Remove all learners except Linear_Regression, you can experiment with different learners later and compare them

j. Submit

13. Wait until the model state changes to Completed

14. Double click on created model

- Review the results for the training and test data
- For more information on the model results please refer to [View Model Results](#)

15. Congratulations, you have done your first time series analysis. Now you can either work on your own projects or continue experimenting with this dataset. The following points will show you how to create a new feature from your dataset, how to label the RUL and use the hardware for data collection.

- For more information on feature engineering please refer to [Feature Engineering Community Post](#)
- If you want to use real time predictions please refer to the ThingworxAnalyticsIntroduction-guide (starting at step 14) and the thingworx_analytics_scripts in this git.

16. The current version of the scripts are customized for following workflow:
 - a. Collect data from the hardware
One run includes drawing with the robot and approximately the same amount of cycles after the pencil does not draw a complete line anymore
 - b. Calculate the RUL for the small dataset
 - c. (Optional) calculate the average values for the SmartServo1Current
 - d. Merging the individual runs into one large data set
The “asset” column indicates the number of the run (JA_Demonstrator_1 to JA_Demonstrator_30)
if you want to try the scripts, please only use them on one run (split the dataset and don’t forget to copy the header in the first row) or edit the script to work on the full dataset -> create a loop
17. To start the data collection with the hardware run the `predictive_maintenance_data_collection.ino` code on the Arduino (you can find the script in the `physical_demonstrator` directory in this git) and afterwards run the `time_series_log.py` script. If you want to collect multiple datasets please look at line 30 and change the number after each run. Follow the instructions on the command line. If the pencil tip is not drawing a full line on the paper anymore (move the paper a little bit to check) press `ctrl+c`. From this point on the data will be labeled as “`isDrawing = false`”. If you have approximately the same amount of cycles drawing on the paper and not drawing press `ctrl+c` again. This is done to get the same number of samples for each state of the variable `isDrawing`. The data set for boolean goals should contain 50% true and 50% false values. For continuous goals it is important to ensure an equal number per value.
18. Now you can run the `calculate_RUL.py` script for any individual run. Make sure to use the correct csv name in line 6 (if you changed the output name of the data collection script). The script will count the number of cycles until the `isDrawing` variable switched to false.
19. (Optional) If you want to experiment with feature engineering you can use `current_feature_engineering.py` script. For each run you can execute the script. During each cycle of the robot arm, data points are taken when the robot is drawing and which ones when the pen is in the air and returns to the starting point. This script sums the values for the current of the SmartServo1 during the drawing process and outputs a new csv file containing those values. If you want to use these for training, make sure to only include following features:
 - a. asset
 - b. time
 - c. AVG
 - d. RULSelect RUL as goal again and the only input will be the AVG value.
20. Merge the datasets. Attention: only use one header on top of the merged file and remove the headers from the other runs.
21. Upload the dataset and go through the Analytics process again.