# Webinar
# TMat-SynDat
# A Synthetic Data Generator

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# TMat-SynDat

Today's Special

Breakfast Menu Item

on

**DigiPro Breakfast Webinar**

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## OUTLINE

- What is TMat-SynDat?
- Why is TMat-SynDat used?
- Challenges faced in TMat-SynDat development
- Uses Cases for TMat-SynDat
- A Case on use of TMat-SynDat
- Next Steps regarding TMat-SynDat

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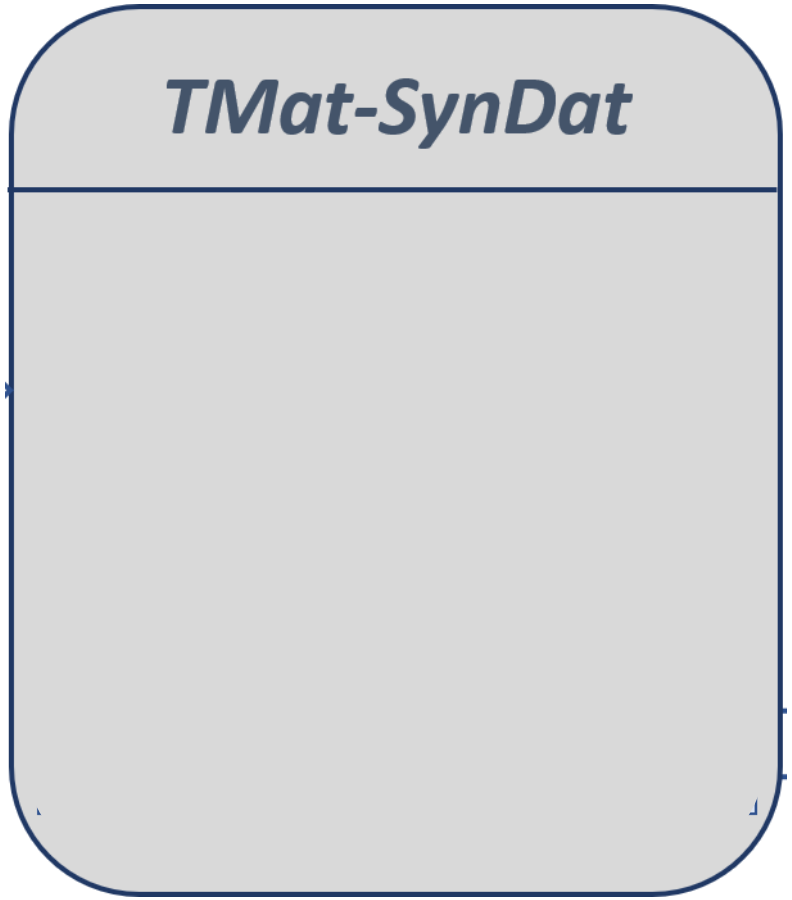
# What is TMat-SynDat?

- TMat-SynDat is a **synthetic data generator** for **electro mechanical parts**.
- TMat-SynDat works with **MATLAB Simulink.**


- The **output** of TMat-SynDat is a supervised and annotated dataset .mat format.

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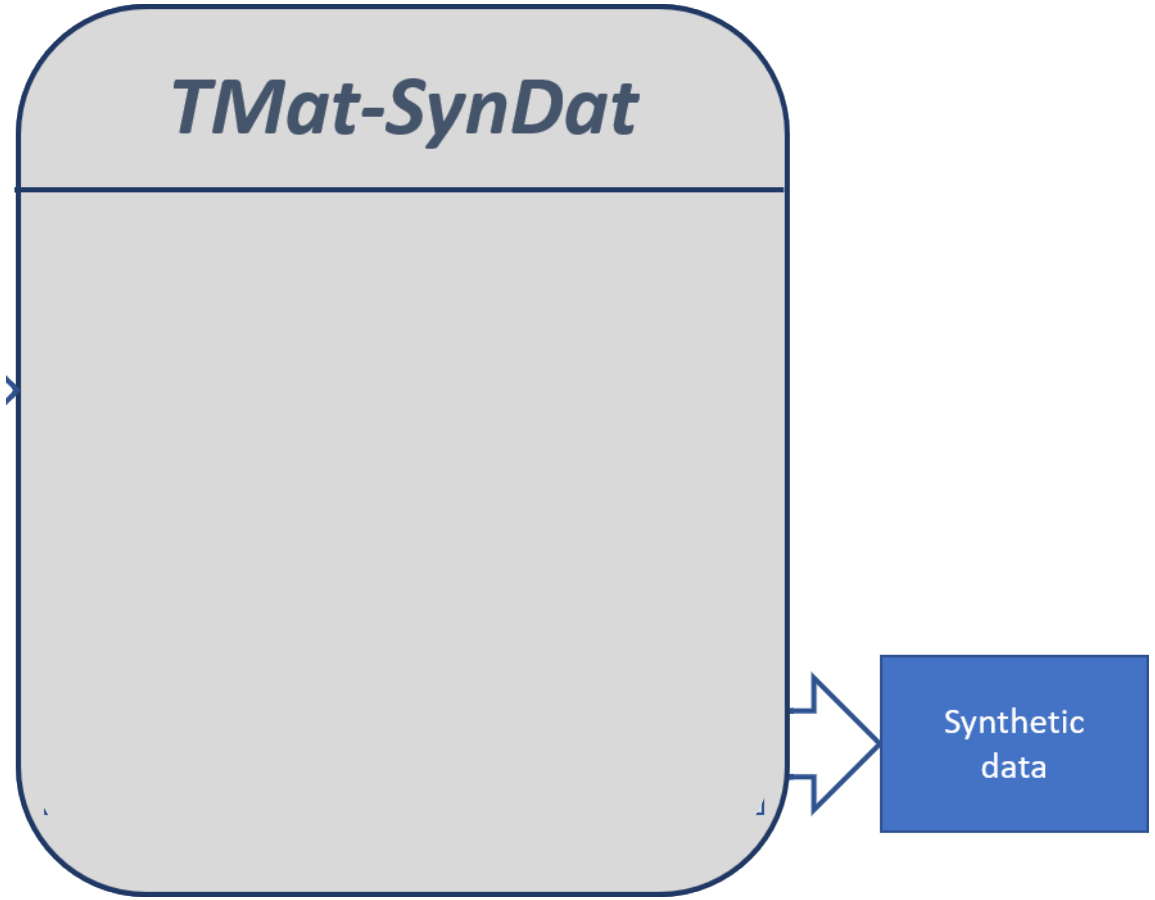
# What is TMat-SynDat?

- TMat-SynDat generates **synthetic data** from the model elements for
  - common electro mechanical parts,
  - electric DC motors and
  - a hydraulic press.

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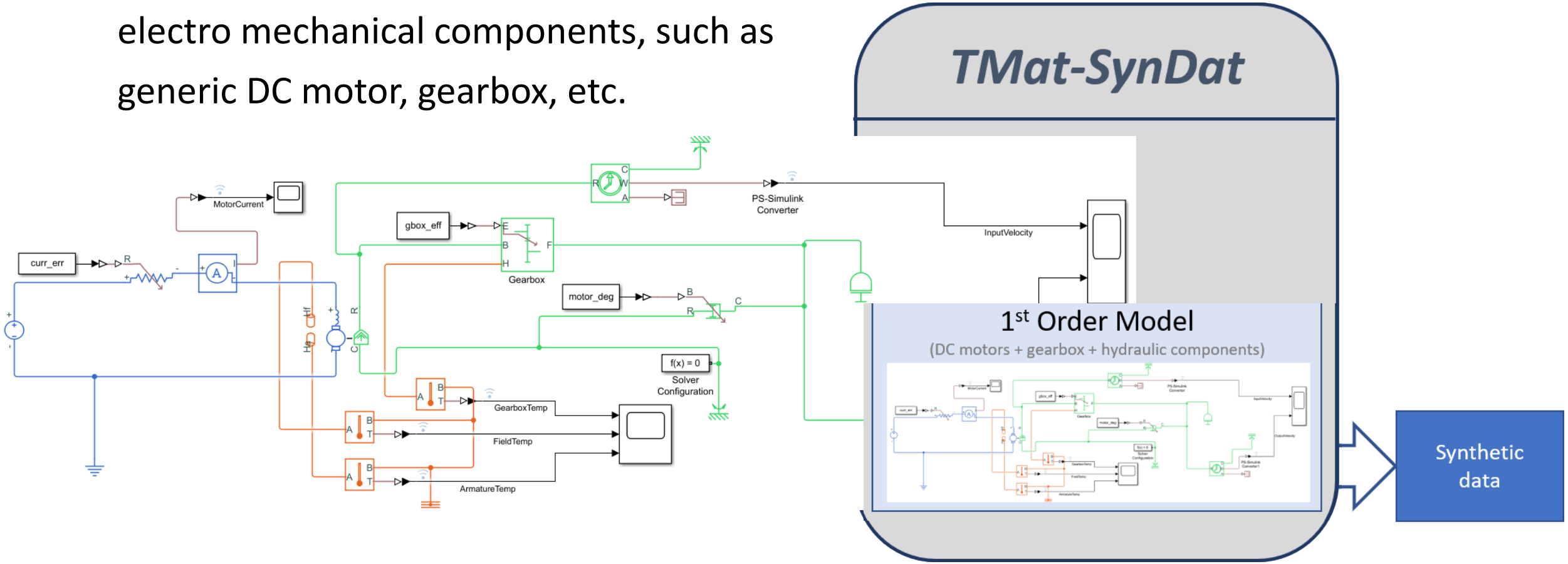
# What is TMat-SynDat?

- TMat-SynDat utilizes **1st order models** for electro mechanical components, such as generic DC motor, gearbox, etc.

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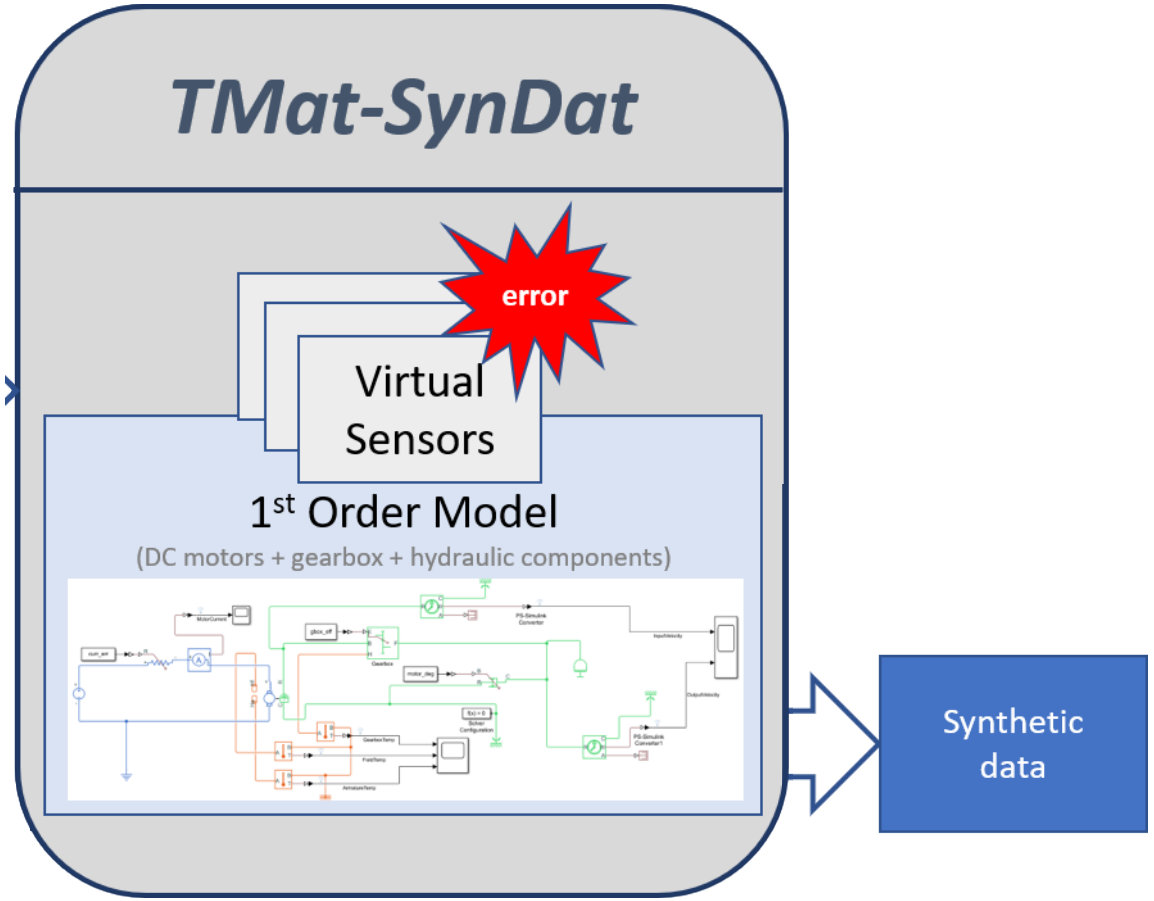
# What is TMat-SynDat?

- Random realistic **error sources** are generated such as:
  - degradation of the components
  - and measurement errors.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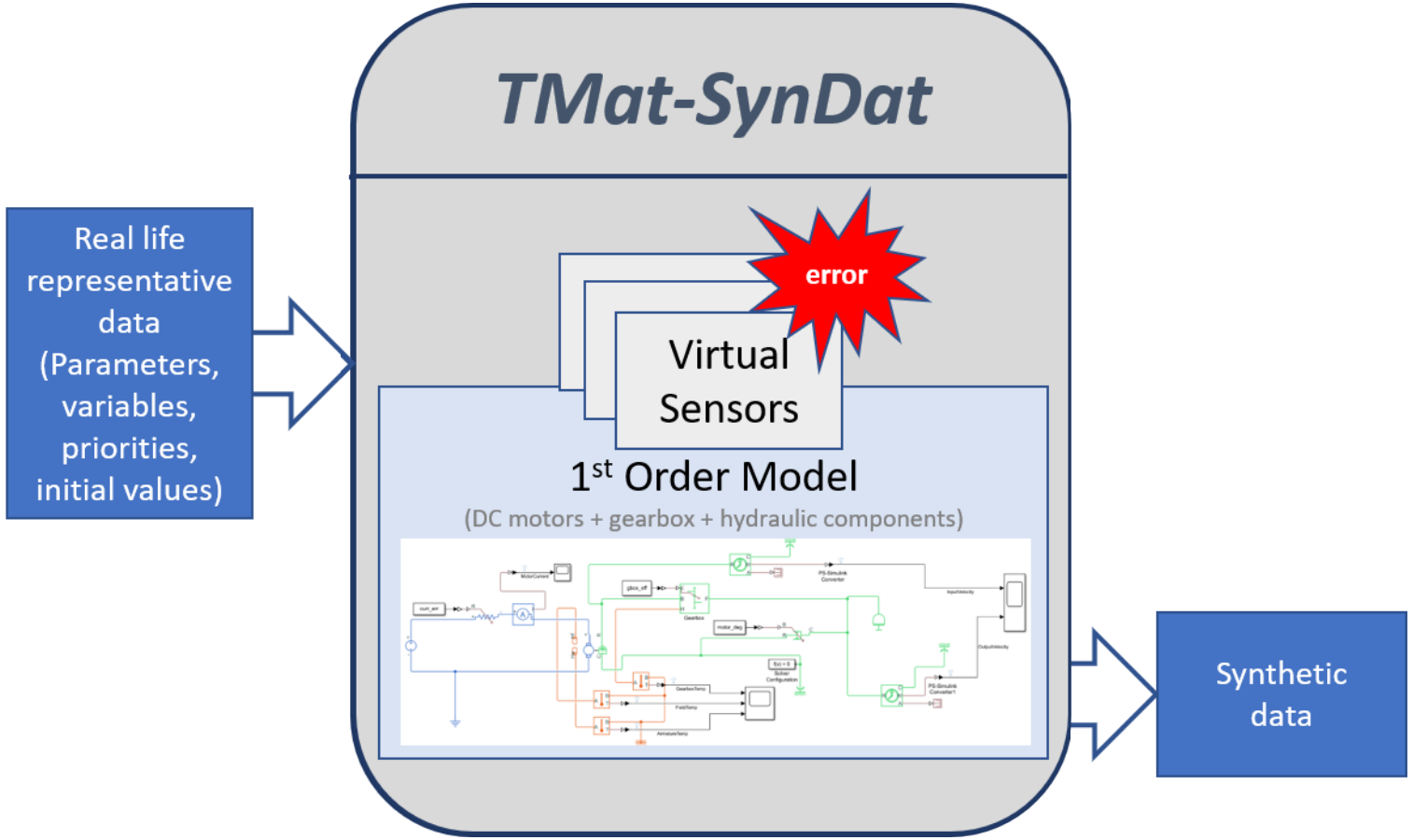
# What is TMat-SynDat?

- As **input**, TMat-SynDat takes real life representative data such as;
  - parameters,
  - variables,
  - priorities,
  - initial values…



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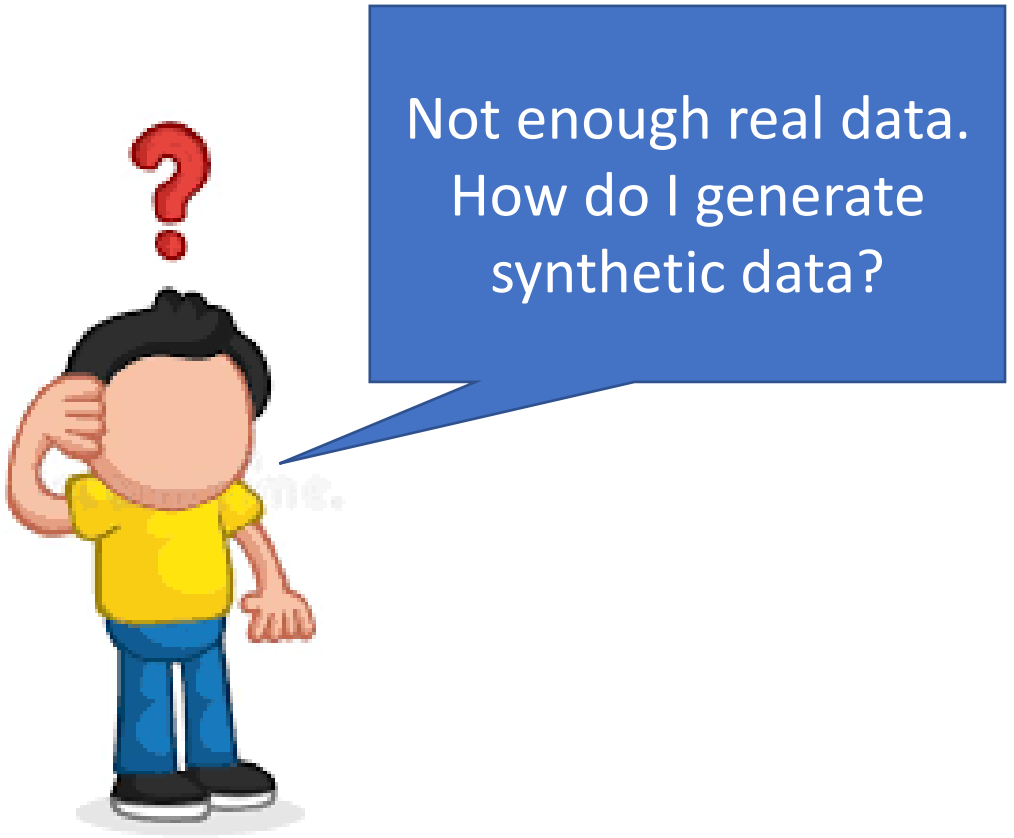
# Why is TMat-SynDat used for?

- In cases where **real data is missing** for machine learning algorithms, models are generated using synthetic data.
- TMat-SynDat aims to generate such data to fulfil the **data requirements of the artificial intelligence/ machine learning algorithms**.
- The **generated data is labeled** because of the boundaries that determine the error condition for an error source variable, meaning that **the error variable is labeled as faulty if the randomly assigned value is within faulty condition boundaries.** This enables the usage of supervised machine learning.

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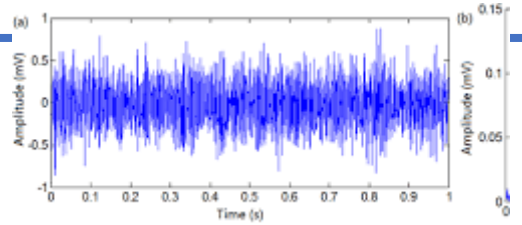
# Challenges met in TMat-SynDat development

Viable and accurate vibration signal generation




Suitable consistency tolerance

10^(-6)

determining the threshold levels for the error source variables

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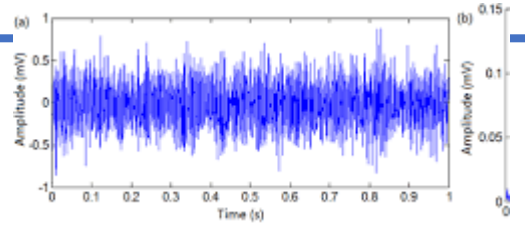
# Challenges met in TMat-SynDat development

- The biggest challenge encountered was obtaining a **reliable and accurate vibration output signal**, that is compatible with the digital twin model.
- With the initial version of the twin model, adding a subsystem that directly generates a vibration signal did not yield desired results due to the operation mechanisms of the existing fault models.
- In order to gather a satisfactory vibration output, the digital model was renovated with the removal of several obsolete fault models and sensors, and implementation of new fault subsytems, as well as a subsystem to generate a vibration signal, which led to having more accurate vibrations from the digital twin.

Viable and accurate vibration signal generation

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# Challenges met in TMat-SynDat development

- Another challenge was to **find a suitable consistency tolerance for the solver configuration** of the model.
- Default value for the consistency tolerance (10^(-8)) provided by Simulink caused some of the simulations to raise error flags, which led to whole simulation process being halted, due to calculational insensitivities of the motor current signals.
- This **consistency tolerance was alleviated to 10^(-6)** in order to get rid of false error flags and obtain a smoother simulation process.

Suitable consistency tolerance

10^(-6)

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# Challenges met in TMat-SynDat development

- Lastly, **determining the threshold levels for the error source variables**, which indicates whether a simulation condition is healthy or faulty, was another challenge faced during the synthetic data generation process.
- As the values for the error variables are randomly given from a specified interval, **choosing very small healthy condition boundaries resulted in domination of the sampling of faulty conditions**.
- This sampling domination of faulty conditions lowered the accuracy of determining the healthy conditions in the classifier model training step, as healthy condition class was undersampled.
- In order to overcome this issue of sampling inequality, the **threshold values specifying the healthy conditions was broadened**, leading to a better overall accuracy of the classifier.

determining the threshold levels for the error source variables

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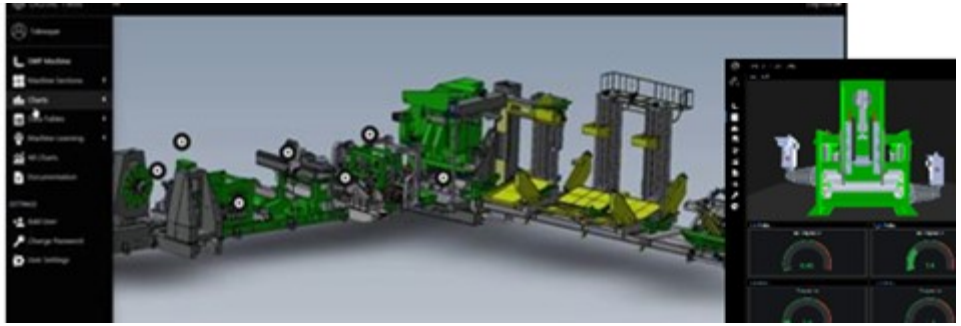
# Use Cases for TMat-SynDat

- TMat-SynDat can be applied to typical use cases in which failure data need to be generated for a machine that is composed of DC motors, hydraulic press and gearbox, where different sensors are installed on the machine.
- The component **has been tested and used for the NOKSEL case of the COGNITWIN project,** where both healthy and faulty data was generated in order to be used in **predictive maintenance** purposes.
- Following the predictive maintenance steps, the generated synthetic data can also be used for estimation of **remaining useful time** of a machine if needed.



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# A Case on: TMat-SynDat Use for Predictive Maintenance

information

MDPI

*Article*

## Synthetic data generation and predictive maintenance for vibration data – a proposed workflow

**Şahan Selçuk[1], Perin Ünal[2], Özlem Albayrak[3] and Moez Jomâa[4]**

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# A Case Study: TMat-SynDat Use for Predictive Maintenance

- a high-fidelity physical model of the real-life physical object or system is modelled for a motor, and a gearbox
- For motor the circuit is designed based on
  - Kicrhhoff's voltage law
- For mechanical components
  - Newton's second law of motion

  are used.

Vibration signal is measured from the spring-damper chain in the subsystem.

Sensors are added and modeled.

- Two types of faults are modeled:
  - gearbox tooth faults and
  - vibration sensor errors
- Tooth fault is modelled by inserting an undesired faulty torque at a fixed position (an error in a fixed tooth) in the turn of the gearbox shaft.
- to represent both the measurement errors and the intrinsic mechanical errors of these sensors, a simple offset is inflicted in the measurement of the vibration sensors; and if the value of this offset is 0, it means that there is no error in the measurement of vibration signals.
- The parameters (such as electrical power inertia, rated speed of the universal DC motor, voltage of supply what drives the motor,…) were taken from NOKSEL experts.

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# Next Steps for TMat-SynDat

- The model calibration will be finalized by using the real data collected in the NOKSEL pilot, and the 1st order model developed for the NOKSEL's machinery component.
- Data fusion and state estimation techniques, using estimation filters such as Kalman filters and particle filters, will be investigated as next steps.

The name of the component is planned to be changed into

**TIA DATA-GEN**

**T**eknopar **I**ndustrial **A**utomation **Data Gen**erator

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# Thanks for your attention


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