MODEL-BASED VIRTUAL FORCE MEASUREMENTS ON TWO INDUSTRIAL CASES

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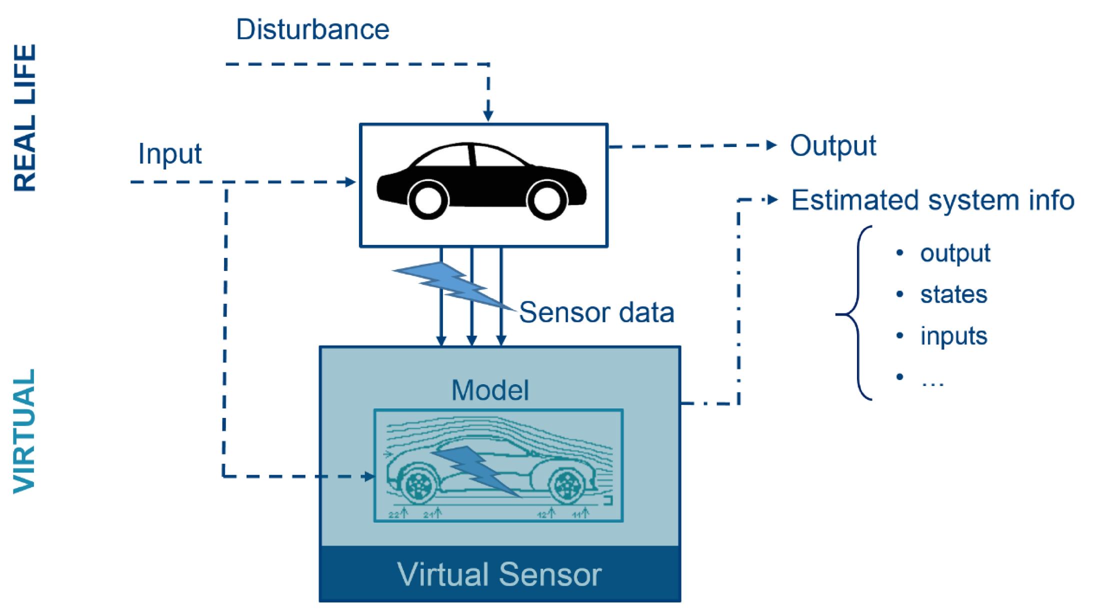
INTRODUCTION

During the last decades, increase of performance, reduction of development cost and time-to-market have been the key focus points of the automotive industry. These conflicting requirements have led to model-based design approaches which reduce the effort spent in prototyping and on measurement campaigns during a vehicle's design. Meanwhile, the advent of new technologies, such as electric drivelines, has complicated the development.
The developed methodology to estimate input force with a virtual sensor aims to reduce the measurement time and cost. The methodology also has applications in monitoring and control during the operational life of the vehicle.
This poster describes the methodology qualitatively and presents its application on two automotive cases.

METHODOLOGY

The developed methodology is shown schematically in figure 1. It reveals a-priori hidden information, embedded in measurement data, through fusion with physical system models.



Important Aspects

- Measurements
  - Observability
  - Sensor noise
  - Sampling rate
- Model
  - Process noise

Figure 1: Schematic overview virtual sensor.
(- - -) possibly unknown, (- · -) estimated

The estimation performance grows together with the amount of knowledge included in the system models throughout the vehicle's design phase. High fidelity models are nowadays already used to virtually test component, subsystem and system designs. The next step is to extend this trend towards virtual sensors.

TORQUE ESTIMATION ON A MECHATRONIC DRIVETRAIN

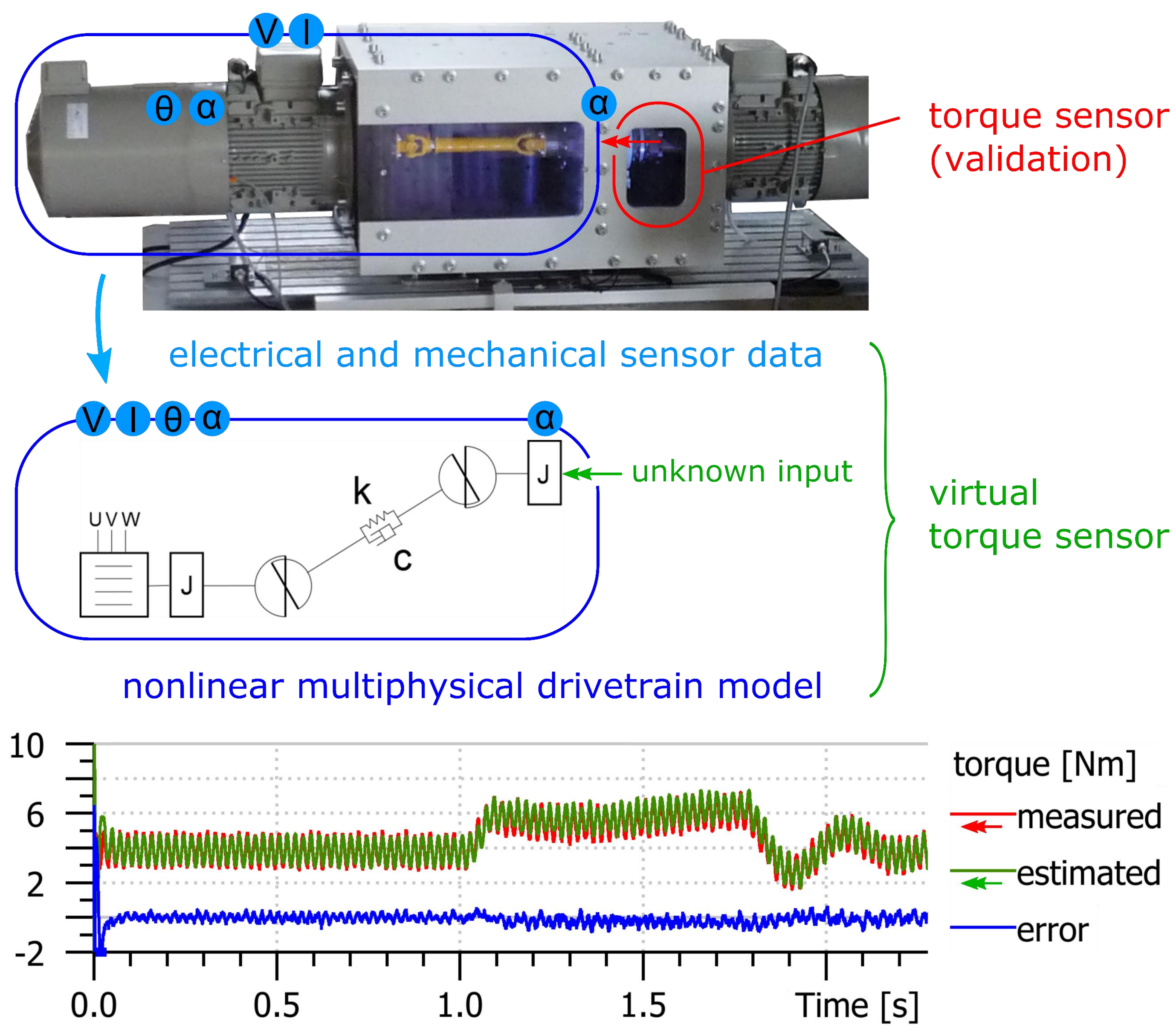


Figure 2: Input torque estimation on a mechatronic drivetrain.

To assess operational loading of a drivetrain, torque measurements are often desired but unfeasible due to their intrusive character. A virtual torque sensor is therefore developed for drivetrains like those in electric vehicles. It employs terminal voltage and current readings, angle and acceleration data. These measurements are combined with a nonlinear electro-mechanical torsional model of the drivetrain in an Unscented Kalman Filter scheme. Through coupled state and input estimation, the load torque becomes online available. The virtual sensor is validated for both slow and fast-transient loads on a purpose-built test setup with nonlinear drivetrain dynamics.

FORCE INPUT ESTIMATION ON A REAR SUSPENSION TWISTBEAM

The force is measured and estimated in the application point of figure 3.

Measurements

- Estimation
  - Accelerometers
  - Position
  - Strain
- Validation
  - Force

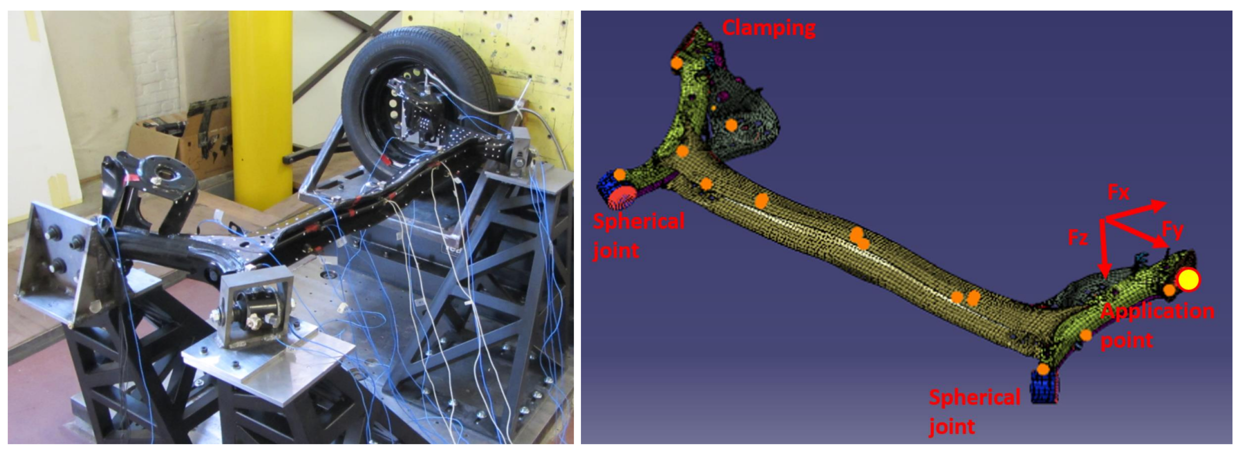
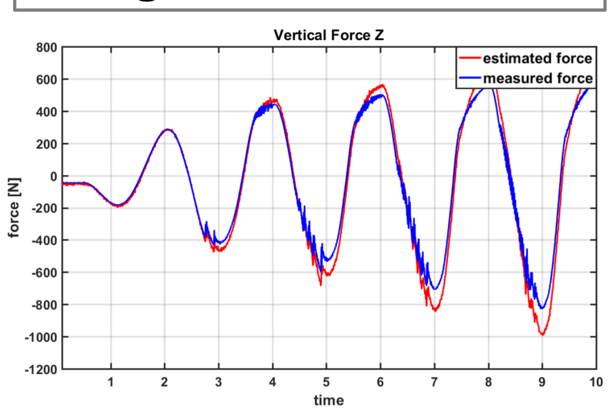
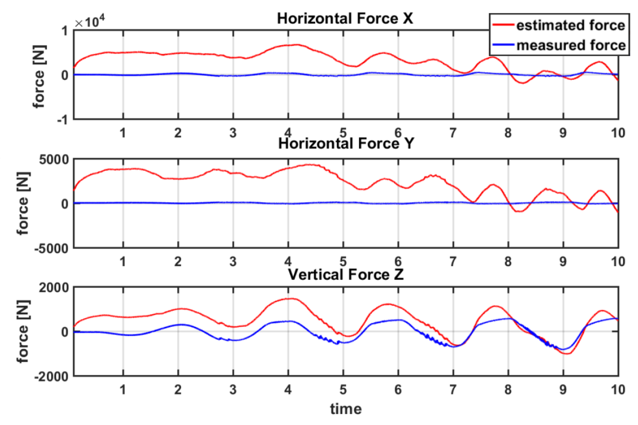


Figure 3: Twistbeam test-rig and FE model.

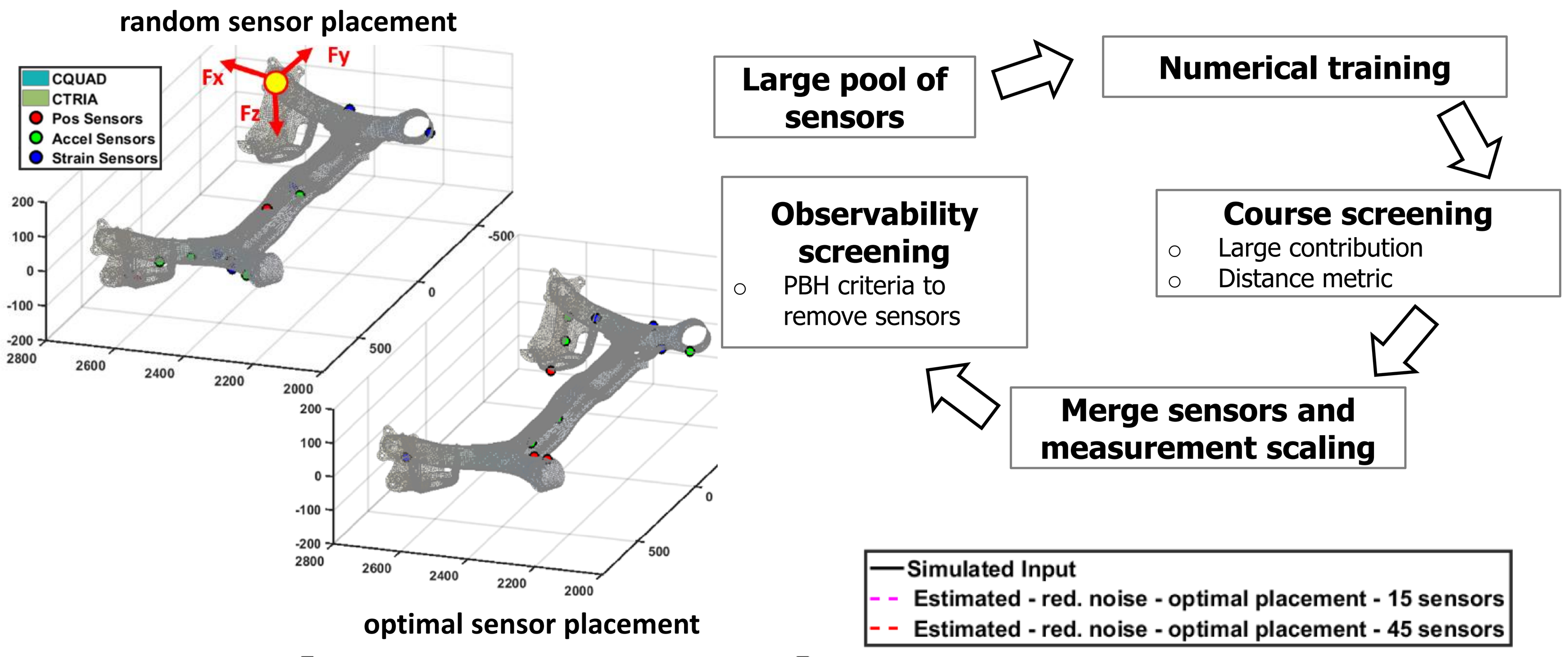
Single force estimation ⟺ **Multiple force estimation**

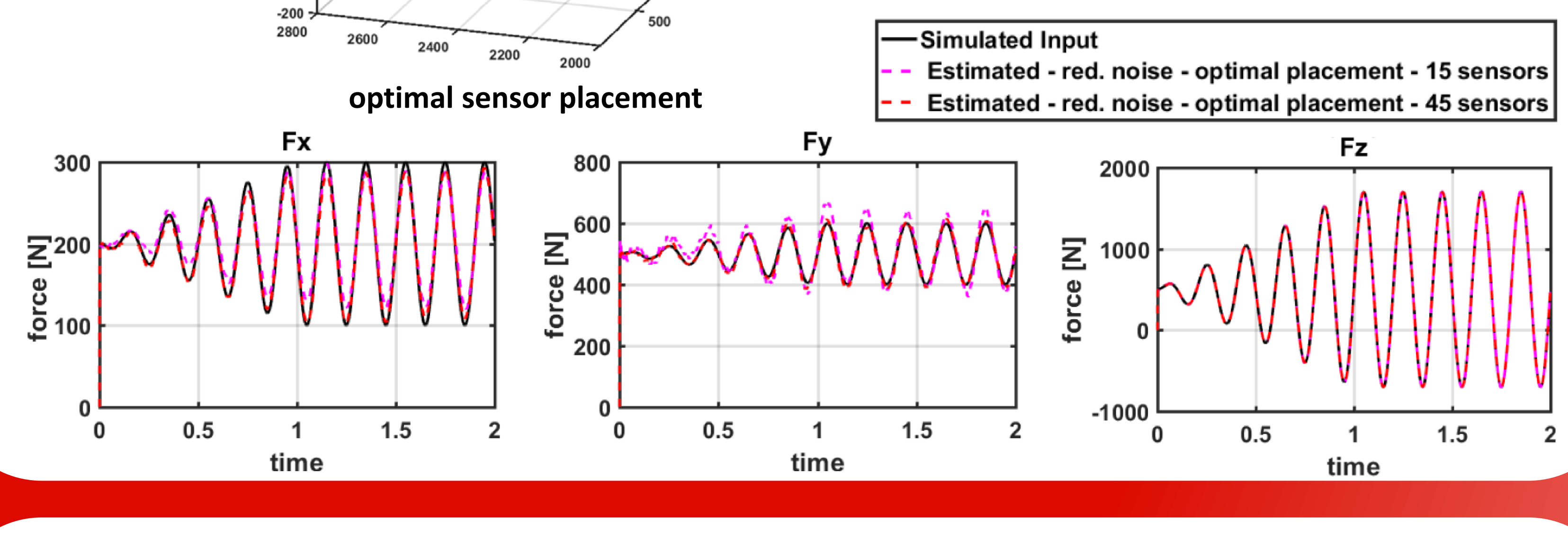


- **Ill-conditioning:** Stiffness $\frac{K_y}{K_z} \gg 1$
- **Ill-posedness:**
  - Loads along x and z direction lead to almost the same (scaled) deformations and strains
- **State versus input estimation**
  - States (e.g. position) are better estimated than the input (force)
  - Input → well updated model required
  - State → less strict requirements



Optimal sensor placement





CONCLUSIONS

- Both a well-suited model and a well-chosen sensor set are in-dispensable for accurate input force/torque estimation.
- The demands on model fidelity are less strict in the context of pure state estimation.
- The fusion of multi-domain information improves the accuracy of a virtual load torque sensor on a mechatronic drivetrain.

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