Simulating Defects in Environmental Sensor Networks Using Stochastic Sensor Models

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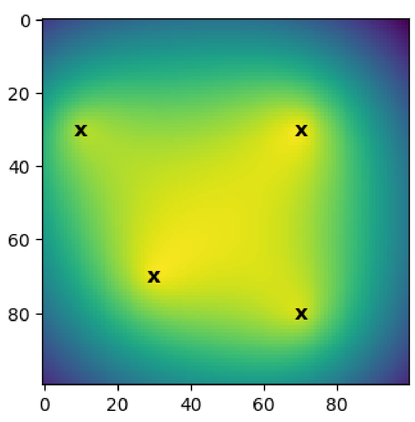
Abstract

Chemiresistive gas sensors are an important tool for monitoring air quality in cities and large areas due to their low cost, low power and, hence, the ability to densely distribute them. Unfortunately, such sensor systems are prone to defects and faults over time such as sensitivity loss of the sensing material, less effective heating of the surface due to battery loss, or random output errors in the sensor electronics, which can lead to signal jumps or sensor stopping. Although these defects usually can be compensated, either algorithmically or physically, this requires an accurate screening of the entire sensor system for such defects. In order to properly develop, test, and benchmark corresponding screening algorithms, however, methods for simulating gas sensor networks and their defects are essential. In this work, we propose such a simulation method based on a stochastic sensor model for chemiresistive sensor systems. The proposed method rests on the idea of simulating the defect-causing processes directly on the sensor surface as a stochastic process and is capable of simulating various defects which can occur in low-cost sensor technologies. The work aims to show the scope and principles of the proposed simulator as well as to demonstrate its applicability using exemplary use cases.

Framework

Concentration Simulation

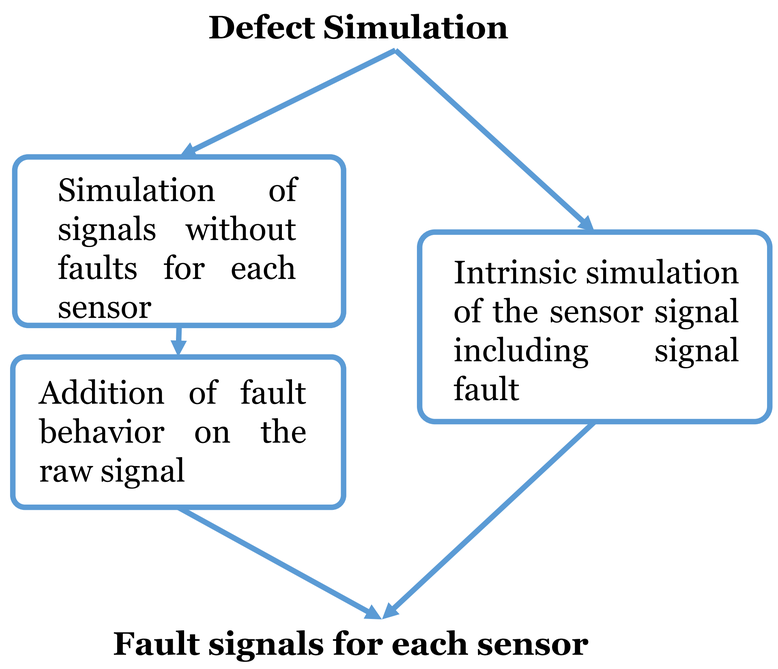
- Group of several source locations with different time-dependent concentrations distributed on the simulation grid
- Calculation of the spread of the gases emitted by the sources over time



Simulation Example

Sensor Simulation

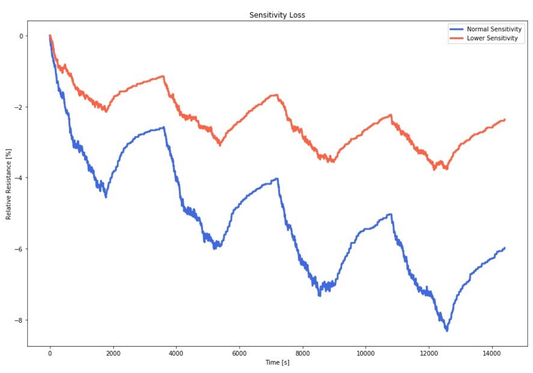
- Stochastic model simulating the adsorption/desorption behavior on the graphene surface based on simulated concentrations at the sensor.
- Simulation of the defect sensor behavior either intrinsically or after the sensor simulation.
- Faults that are simulated:
  - Sensitivity Loss
  - Signal Jumps
  - Signal Stopping
  - Battery Loss



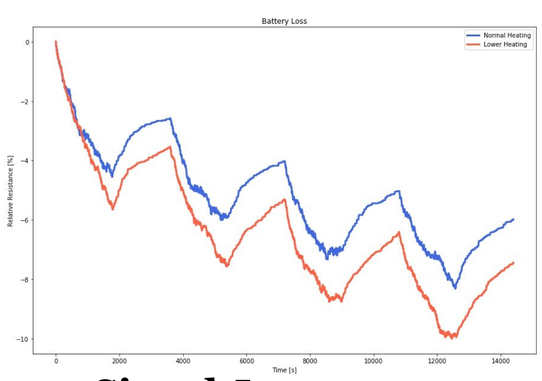
Results

- Simulation of different fault types and their impact on the signal behavior (red) based on several input concentration pulses.
- Comparison to the simulated signal without faults (blue).

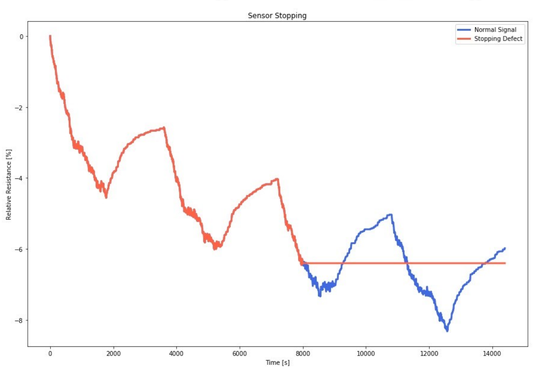
Sensitivity Loss



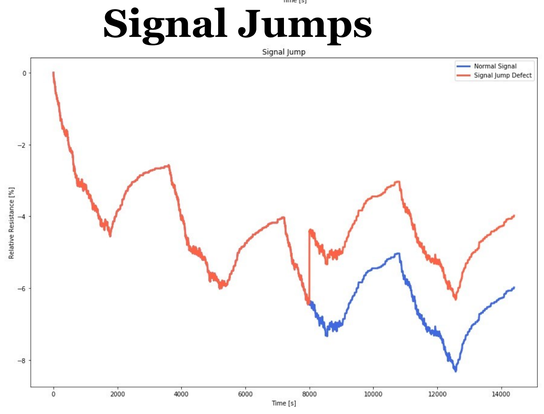
Battery Loss



Signal Stopping



Signal Jumps



Conclusions and Outlook

- Fault simulation model can be used to synthetically generate sensor signal scenarios which might occur during sensor deployment.
- Simulating battery loss leads to a slower recovery of the signal whereas sensitivity loss leads to less pronounced signals.
- Faults may be inserted in the signal in two different ways: Intrinsically as part of the simulation model or post-simulation after the signal was simulated without faults.
- Additional faults concerning environmental sensors may be added in the framework.