

# Sensitivity analysis

Sajad Sabzi  
Mohammadreza Ahmadi Teshnizi

December 4, 2023

## What is Sensitivity Analysis in Machine Learning Models?

Sensitivity analysis in the context of machine learning models involves assessing how the output of a model is affected by changes in input variables. It's a technique used to determine how "sensitive" a model is to variations in its input features. This analysis can help in understanding the behavior of the model under different conditions and in identifying which inputs have the most significant impact on the model's predictions.

## Purpose of Sensitivity Analysis

The primary purpose of sensitivity analysis is to gauge the robustness and reliability of machine learning models. It helps in identifying which input variables are the most influential, understanding the model's behavior in different scenarios, and in debugging the model by revealing unexpected dependencies or anomalies in model responses.

## When is Sensitivity Analysis Used?

Sensitivity analysis is used:

- During the model development phase, to understand and improve model performance.
- In the model validation stage, to assess the model's robustness to variations in input data.
- Before deploying the model, to ensure it performs well under a range of realistic conditions.

## Advantages and Disadvantages

### Advantages

- **Enhanced Understanding of Model Behavior:** Sensitivity analysis allows you to understand how different inputs affect the outputs of your model. This is crucial for complex models where the relationship between input and output is not straightforward.
- **Identification of Key Features:** It helps in identifying the most influential features that have a significant impact on the model's predictions. This is especially useful in feature selection and in understanding which variables are worth focusing on for model improvement.
- **Model Robustness and Reliability:** By examining how changes in input affect the output, you can assess the robustness of your model. It helps in ensuring that the model performs consistently across a range of input values and is not overly sensitive to small changes.
- **Facilitates Model Tuning and Improvement:** Sensitivity analysis can reveal model weaknesses or biases, guiding developers in refining and improving the model's architecture or training process.
- **Aids in Model Validation and Verification:** It is an essential tool in the model validation process, ensuring that the model behaves as expected under various conditions and input scenarios.
- **Supports Regulatory Compliance and Risk Management:** In sectors like finance or healthcare, understanding how a model reacts to different inputs is crucial for risk management and meeting regulatory requirements.

## Disadvantages

- **Computational Complexity:** For large and complex models, sensitivity analysis can be computationally expensive and time-consuming, requiring extensive resources to evaluate the model under various scenarios.
- **Limitations in Capturing Complex Interactions:** Some sensitivity analysis methods may not effectively capture complex, non-linear interactions between variables, especially in highly intricate models like deep neural networks.
- **Potential for Misinterpretation:** The results of sensitivity analysis can be misinterpreted, especially if the underlying assumptions of the model or the analysis method are not properly considered.
- **Dependency on Quality and Range of Data:** The effectiveness of sensitivity analysis is highly dependent on the quality and range of input data used. If the data does not represent the full spectrum of possible scenarios, the analysis may not be fully reliable.
- **Challenges in High-Dimensional Spaces:** In models with a very large number of features (high-dimensional spaces), conducting comprehensive sensitivity analysis becomes more challenging and the results harder to interpret.
- **Bias Amplification:** If the model or the data is biased, sensitivity analysis might inadvertently amplify these biases, especially if not carefully conducted and interpreted.

## Additional Aspects

- **Applications:** Sensitivity analysis is widely used in fields like finance, healthcare, and climate modeling, where understanding the impact of input variables is crucial.
- **Methods:** Techniques like the Sobol method, variance-based sensitivity analysis, or simpler approaches like perturbation analysis are commonly used.
- **Integration with Explainable AI (XAI):** Sensitivity analysis is often a component of XAI, helping in making the model's decisions more transparent and understandable.
- **Data Preprocessing Impact:** The results of sensitivity analysis can be influenced by how the input data is preprocessed and normalized, highlighting the importance of careful data preparation.

## PyTorch Codes for Sensitivity Analysis on GitHub

### sensitivity\_torch

- **Description:** This package is designed for taking first- and second-order derivatives through optimization or other fixed-point processes, building on top of PyTorch.
- **URL:** [https://github.com/rdyro/sensitivity\\_torch](https://github.com/rdyro/sensitivity_torch)
- **Installation:** Install using pip with the command `pip install git+https://github.com/rdyro/sensitivity_torch.git` or from the source.
- **Testing:** Run all unit tests using `python3 setup.py test`.

### SA\_DNN: Sensitivity Analysis of Deep Neural Networks

- **Description:** Provides Python scripts for the CIFAR10 and MNIST datasets, including implementation for networks like ResNet50 and DenseNet121.
- **URL:** [https://github.com/shu-hai/SA\\_DNN](https://github.com/shu-hai/SA_DNN)
- **Usage:** Includes various Python scripts for handling different datasets and network architectures, such as `CIFAR10_DenseNet121.py` and `MNIST_ResNet50.py`.

## **torchsde: Differentiable SDE Solvers with GPU Support and Efficient Sensitivity Analysis**

- **Description:** PyTorch implementation of differentiable Stochastic Differential Equation solvers, with GPU support and efficient sensitivity analysis.
- **URL:** <https://github.com/google-research/torchsde>
- **Installation:** Install via pip using `pip install torchsde`. Requires Python  $\geq 3.8$  and PyTorch  $\geq 1.6.0$ .