Machine Learning in Remote Sensing

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Introduction
In remote sensing, the quantities of interest can often not be directly measured themselves but instead only some related variables. For example, the state of the earth’s atmosphere can be inferred by the emitted spectra. This is usually referred to as an inverse problem. In order to solve these kinds of problems, mathematical algorithms are usually used, that rely on physical models, in order to reproduce the observed measurements as good as possible and thus obtaining the quantities of interest.

Overview
For the quality of the results obtained with this approach the accuracy of the physical model (also called forward model) is crucial. Higher accuracy however implies higher complexity which in turn usually leads to a higher computational cost. In the context of remote sensing of the atmosphere, there exist a number of very accurate models (e.g. VLIDORT, RJD Spurr 2006) with the price of being computationally expensive. However for an operational processor of satellite data with near real time requirements (like the UPAS processor developed by DLR, Kiemle et al 2004) the use of such models is often not feasible.

The main objective of this thesis is therefore to investigate current machine learning techniques in order to either approximate the forward model or to replace the common inversion process altogether. The goal is to achieve a faster retrieval with a comparable quality of the results.

Objectives
The usefulness of machine learning techniques in the context of remote sensing problems has already been proven, e.g. by the ROCINN (Retrieval of Cloud Information using Neural Networks) (Loyola et al. 2018) algorithm. This algorithm retrieves cloud
information by using neural networks as a forward model which were trained to approximate spectra computed by VLIDORT for different states of the atmosphere. Based on this work, it is first planned to investigate how the use of neural networks can be optimized, e.g. by using different network topologies, as well as examine recent developments in the field like deep learning. Additionally, also other promising methods like Gaussian processes shall be tested.

Another approach is to not just use machine learning techniques to approximate the forward model, but to use them to perform the entire retrieval. That means for example, that a neural network would get observations as an input and immediately calculates the quantities of interest as output. A neural network like this would be trained for a vast variety of different input/output cases and thus be optimized globally - whereas in the classical approach the optimization is performed locally, as it is done for each measurement independently. However, one problem with machine learning techniques used in this way is usually that it is very hard to estimate the quality of the solution.

In summary the work can roughly be separated in the following steps:

- Investigate machine learning techniques to approximate forward models in the classical approach to inversion problems
- Investigate machine learning techniques to perform the retrieval completely (full inversion)
- Compare and evaluate all tested methods

References


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