Commercial Microwave Links in Sri Lanka as a precipitation source using Deep Transfer Learning

Ludo Diender

MSc thesis proposal
Hydrology and Quantitative Water Management Group, Wageningen University

1 Problem description

In short, without references yet. In the past 25 years, Commercial Microwave Links (CML) have been recognized as a valuable opportunistic method to measure rainfall (Leijnse, Uijlenhoet, & Stricker, 2007) (Ruf, Aydin, Mathur, & Bobak, 1996). The links' signals get attenuated by rainfall by means of scattering and absorption. This attenuation is measured and stored by telecompanies and can be used to retrieve rainfall rates. Especially in data scarce areas, where little precipitation is measured, CML's have proven to be an excellent addition to precipitation data (Overeem et al., 2021; Doumounia, Gosset, Cazenave, Kacou, & Zougmore, 2014; Diba, Samad, Ghimire, & Choi, 2021). Their density in populated areas makes them especially useful for urban hydrology where high spatial and temporal resolution of precipitation data is required (Overeem, Leijnse, & Uijlenhoet, 2011). In general, having ample and correct precipitation data is important for flood warnings, agriculture, river systems, shipping routes and many more (Chwala & Kunstmann, 2019).

The first studies on the use of CML signals to retrieve rainfall rates were done by using a specific Power-Law (PL) to relate the attenuation of the signal and the rainfall rate. This method, which includes a wet-dry classification, baseline estimation, wet antenna attenuation estimation and finally a rainfall rate retrieval, has yielded good results in multiple studies (de Vos, Overeem, Leijnse, & Uijlenhoet, 2019; Graf, Chwala, Polz, & Kunstmann, 2020; Fencl, Dohnal, Rieckermann, & Bareš, 2017). Recent methods have shifted away from this PL algorithm and used a more data-driven approach in the form of neural networks of different kinds. Studies have been performed in Sweden, Israel (Habi, 2019), Germany (Polz, Chwala, Graf, & Kunstmann, 2020), South Korea and Ethiopia (Diba et al., 2021) on the use of such data-driven networks in relating CML signals to rainfall rates. In general, the time needed for the algorithm, the ease of implementing and the transferability of the methods are mentioned as main advantages of data-drive neural networks in comparison to the traditional PL method.

One of the disadvantages of using data-driven methods like neural networks, is the dependency on a large training data set. In areas with less or little available training data, transfer learning provides the opportunity to adapt an already existing model with a certain structure to do a sligthly different task (Tan et al., 2018). The technique exploits the availability of data in the source domain and is able to transfer the knowledge to the target domain. It does so by relaxing the underlying assumption that training and test data for a Machine Learning model should be independent and identically distributed (Weiss, Khoshgoftaar, & Wang, 2016). Although used quite often in different Machine Learning applications (Zhuang et al., 2021), the concept of transfer learning has not yet been used to improve the precipitation estimation using CML's in data-scarce areas.

Part on the use of Sri Lanka and Netherlands? Part on NN?

2 Research objectives

State objectives clearly. What is the point of this research? The aim should follow directly from the problem description. The objectives of this research are to 1) train, test and validate a neural network on CML data in the Netherlands to obtain precipitation rates, 2) apply the concept of transfer learning to make the model able to obtain precipitation rates for Sri Lanka, and 3) create 2D interpolated rainfall maps using the neural network.

3 Research questions

Which questions do you want to answer in order to reach the objectives? Divide into sub-questions for clarity.

- How does a neural network perform on Dutch data?
- How does transfer learning improve the use of CML's in Sri Lanka as precipitation measurements?

- What is the potential of the use of NN for 2D interpolation of rainfall maps

4 Field site and data

Are you going to use other people's data or collect data yourself? What are the considered locations, instruments, resolutions? You can also include the data in the methods. Making use of Aart's dataset of the Netherlands and the provided data for Sri Lanka. Combination makes the research come together. **To what extent do I need to explain the data here? Frequency, number, type of measurements (interval or continuous, min/max or 1 min), time period (probably yes), metadata like average height and frequency.**

5 Methods

Explain neural networks shortly. Neural networks are part of deep learning. An input signal is transfered through different layers of the model. Every layer consists of different neurons that are able to extract features from the input signal. The subsequent layers extract combinations out of the previous layer, until finally the network ends up with a prediction with a certain probability. By applying a loss function, the network can learn how to improve, by changing the different parameters in all neurons. As a part of Machine Learning, the to-be-extracted features are unknown beforehand to the researcher. The network itself learns which features are interesting, seperable and help in classifying the specific signal.

To answer my research questions, I will use a neural network set up to infer rainfall rates from CML data. Picking the type of neural network will be part of the research as well, as there is a plethora of different architectures available, all of which serve specific purposes. Pick RNN as proposed by Habi, specifically LSTM. The main architectural types that will be considered are one-dimensional convolutional neural networks (CNN), Long Short Term Memory (LSTM) and Gated Recurrent Unit (GRU). The final two are both different types of Recurrent Neural Networks.

6 Timetable

Adapt the Table below to make it specific for your project (or make your own). Set deadlines for the products. Be as specific as possible: mention when you will collect which data /do which model runs / write which parts of the report. It often helps to link activities and products to your sub-questions. A specific planning can help later on to see if you are on schedule or that you should e.g. shorten a certain data-processing step or stop calibrating your model, so you have enough time to do the analyses and answer your research questions. It often helps to link the tasks to the methodology (and therefore to the research questions). Specify special conditions: are you planning to take courses, vacation, etc.

References

Chwala, C., & Kunstmann, H. (2019). Commercial microwave link networks for rainfall observation: Assessment of the current status and future challenges [Journal Article]. *WIREs Water*, *6*(2), e1337. Retrieved from https://wires.onlinelibrary.wiley.com/doi/pdfdirect/ doi: https://doi.org/10.1002/wat2.1337

de Vos, L. W., Overeem, A., Leijnse, H., & Uijlenhoet, R. (2019). Rainfall estimation accuracy of a nationwide instantaneously sampling commercial microwave link network: Error dependency on known characteristics [Journal Article]. *Journal of Atmospheric and Oceanic Technology*, *36*(7), 1267-1283. Retrieved from https://journals.ametsoc.org/downloadpdf/journals/a doi: 10.1175/JTECH-D-18-0197.1

Diba, F., Samad, M., Ghimire, J., & Choi, D. (2021). Wireless telecommunication links for rainfall monitoring: Deep learning approach and experimental results [Journal Article]. *IEEE*, *9*, 11. doi: 10.1109/ACCESS.2021.3076781

Doumounia, A., Gosset, M., Cazenave, F., Kacou, M., & Zougmore, F. (2014). Rainfall monitoring based on microwave links from cellular telecommunication networks: First results from a west african test bed [Journal Article]. *Geophysical Research Letters*, *41*(16), 6016-6022. Retrieved from https://agupubs.onlinelibrary.wiley.com/doi/pdfdire doi: https://doi.org/10.1002/2014GL060724

Fencl, M., Dohnal, M., Rieckermann, J., & Bareš, V. (2017). Gauge-adjusted rainfall estimates from commercial microwave links [Journal Article]. *Hydrol. Earth Syst. Sci.*, *21*(1), 617-634. Retrieved from https://hess.copernicus.org/articles/21/617/2017/he (HESS) doi: 10.5194/hess-21-617-2017

Graf, M., Chwala, C., Polz, J., & Kunstmann, H. (2020). Rainfall estimation from a german-wide commercial microwave link network: optimized processing and validation for 1 year of data [Journal Article]. *Hydrol. Earth Syst. Sci.*, *24*(6), 2931-2950. Retrieved from https://hess.copernicus.org/articles/24/2931/2020/h (HESS) doi: 10.5194/hess-24-2931-2020

Table 1: Schedule of the project.

Habi, V. (2019). *Rain detection and estimation using recurrent neural network and commercial microwave link* (Thesis).

Leijnse, H., Uijlenhoet, R., & Stricker, J. N. M. (2007). Hydrometeorological application of a microwave link: 2. precipitation [Journal Article]. *Water Resources Research*, *43*(4). Retrieved from https://agupubs.onlinelibrary.wiley.com/doi/pdfdirect/10.1029/2006WR004989?download=true doi: https://doi.org/10.1029/2006WR004989

Overeem, A., Leijnse, H., Leth, T., Bogerd, L., Priebe, J., Tricarico, D., ... Uijlenhoet, R. (2021). Tropical rainfall monitoring with commercial microwave links in sri lanka [Journal Article]. *Environmental Research Letters*, *16*. Retrieved from https://iopscience.iop.org/article/10.1088/1748-9326/ac0fa6 doi: 10.1088/1748-9326/ac0fa6

Overeem, A., Leijnse, H., & Uijlenhoet, R. (2011). Measuring urban rainfall using microwave links from commercial cellular communication networks [Journal Article]. *Water Resources Research*, *47*(12). Retrieved from https://agupubs.onlinelibrary.wiley.com/doi/pdfdirect/10.1029/2010WR010350?download=true doi: https://doi.org/10.1029/2010WR010350

Polz, J., Chwala, C., Graf, M., & Kunstmann, H. (2020). Rain event detection in commercial microwave link attenuation data using convolutional neural networks [Journal Article]. *Atmos. Meas. Tech.*, *13*, 18.

Ruf, C. S., Aydin, K., Mathur, S., & Bobak, J. P. (1996). 35-ghz dual-polarization propagation link for rain-rate estimation [Journal Article]. *Journal of Atmospheric and Oceanic Technology*, *13*(2), 419-425. doi: 10.1175/1520-0426(1996)013<0419:Gdpplf>2.0.Co;2

Tan, C., Sun, F., Kong, T., Zhang, W., Yang, C., & Liu, C. (2018). A survey on deep transfer learning [Conference Proceedings]. In (p. 270-279). Springer International Publishing.

Weiss, K., Khoshgoftaar, T. M., & Wang, D. (2016). A survey of transfer learning [Journal Article]. *Journal of Big Data*, *3*(1), 9. Retrieved from https://doi.org/10.1186/s40537-016-0043-6 doi: 10.1186/s40537-016-0043-6

Zhuang, F., Qi, Z., Duan, K., Xi, D., Zhu, Y., Zhu, H., ... He, Q. (2021). A comprehensive survey on transfer learning [Journal Article]. *Proceedings of the IEEE*, *109*(1), 43-76. doi: 10.1109/JPROC.2020.3004555