Deep Learning for Analysis of Time-Series in Smart Home Environments

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I would like to dedicate this thesis to my loving parents, my beautiful sisters, and the memory of my brother who passed away.

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Declaration

I hereby certify that the work embodied in the thesis is my own work, conducted under normal supervision. The thesis contains no material which has been accepted, or is being examined, for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made. I give consent to the final version of my thesis being made available worldwide when deposited in the University's Digital Repository, subject to the provisions of the Copyright Act 1968 and any approved embargo.

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Acknowledgement of Authorship

I hereby certify that the work embodied in this thesis contains material of the following two published papers and manuscript under review of which I am a joint author:

- Submitted Paper : M. Mobasher-Kashani, N. Noman and S. Chalup, "Relating Dataset Complexity and Deep Learning Models in the Context of the Non-Intrusive Load Monitoring"
- M. Mobasher-Kashani, J. Li and S. Luo, "Light-Weight Recurrent Deep Learning Algorithm for Non-Intrusive Load Monitoring," 2019 IEEE 2nd International Conference on Electronic Information and Communication Technology (ICEICT), 2019, pp. 572-575, doi: 10.1109/ICEICT.2019.8846263.
- M. Mobasher-Kashani, N. Noman and S. Chalup, "Parallel LSTM Architectures for Non-Intrusive Load Monitoring in Smart Homes," 2020 IEEE Symposium Series on Computational Intelligence (SSCI), 2020, pp. 1272-1279,
doi: 10.1109/SSCI47803.2020.9308592.

I have contributed to these papers by contributing to each study's conception and design, developing analysis plans, developing research material and collecting data, performing both quantitative and qualitative analyses, writing code and executing programs, interpreting data, and leading the writing of the manuscripts.

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Abstract

Electrical energy wastage is a major problem in residential areas in modern societies. Energy production costs our environment a great deal and wasting such valuable assets will bring enormous consequences for future generations. Hence, it is a vital priority for researchers in all areas to tackle this problem. Computer science, alongside other disciplines, provides approaches to abate the overconsumption of electrical energy using a modern computation algorithm called deep learning. Deep learning models are powerful tools for the computation of complex problems, namely energy disaggregation problems. Non-Intrusive Load Monitoring (NILM) is becoming popular as an approach for extracting detailed power consumption information related to different appliances used in a household. NILM utilizes time-series analysis methods to disaggregate the signals of operating appliances from a single point in houses and, based on that, can provide advice to households about how to reduce their energy consumption. NILM is known to be a challenging task from a computational perspective, and previous solutions have not demonstrated sufficient accuracy. This thesis aims to achieve solutions with higher accuracy by utilizing deep neural network models with a Parallel Long Short Term Memory Topology (PLT) and Deep Transformer Networks. To implement machine learning techniques on low-cost devices with limited computation power, the Deep Transformer Networks are enhanced to adapt to these criteria, and then, in order to tackle the imbalance in appliances in the current datasets, a synthetic dataset is proposed and the models are applied to the synthetic dataset with the transfer learning method. The proposed method to create a synthetic dataset improves the accuracy and reduces the training time for the deep learning models in this study. To create the proposed synthetic data generator, the common time-series features of different appliances have been modelled with mathematical formulas. Since maintaining the privacy of users is vital in our design, the solution is optimized for implementation on edge devices, and all computation related to residents' data will be performed locally. The thesis describes the main structure of the deep learning models that are introduced and the proposed synthetic data generation method, then evaluates them on publicly available datasets.

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