Master in Data Science and Advanced Analytics

Uncovering Urban Mobility Patterns: Analyzing Travel Diaries with Non-negative Tensor Factorization

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Context: The rise of large-scale mobility data, such as travel diaries, provides the potential for urban planners to gain valuable insights into human movement patterns. However, traditional methods struggle to capture the full complexity of mobility data across spatial, temporal, and behavioral dimensions. Non-negative tensor factorization (NNTF) offers a solution by decomposing such data into interpretable components, revealing hidden mobility trends. This thesis applies NNTF to a travel diary dataset to find key mobility patterns.

Research Gap and Objectives: NNTF has been rarely used for analyzing mobility patterns, especially using travel diaries. While NNTF has shown promise in areas such as topic modeling, its use in mobility pattern mining remains relatively underexplored. Additionally, most studies analyze mode-specific datasets like bike-sharing or taxi rides, leaving a gap in a more holistic understanding of individual travel behaviors, which can be addressed by leveraging travel diary data. This thesis seeks to answer the question: *How can Non-negative Tensor Factorization be used to extract and analyze meaningful mobility patterns from a travel diaries dataset?* To achieve this, the following objectives are pursued:

1. Extract spatial and temporal patterns from the travel diaries dataset using NNTF.
2. Interpret the discovered mobility patterns using the factors extracted from NNTF.
3. Validate the patterns by comparing them to existing mobility trends from literature or similar datasets (e.g., bike-sharing, taxi data).

Methodological approach: The methodology involves transforming raw travel diaries data into a three-way tensor (origin, destination, time) and applying NNTF for decomposition. Interpretability metrics will assess the extracted components, which will then be compared to existing mobility models.

Expected results and contribution: This thesis will contribute methodologically by providing a framework for applying NNTF to travel diary data, enabling the extraction of meaningful mobility patterns. It will help validate and discover these patterns by identifying both universal trends and user-specific travel behaviors. Additionally, the findings are anticipated to offer broader insights that can support urban planning and transportation systems beyond the original dataset, demonstrating the adaptability and utility of the method across various contexts.

Bibliographical references:

Asif, M. T., Kannan, S., Dauwels, J., & Jaillet, P. (2013). Data compression techniques for urban traffic data. *2013 IEEE Symposium on Computational Intelligence in Vehicles and Transportation Systems (CIVTS)*, 44–49. https://doi.org/10.1109/CIVTS.2013.6612288

Cichocki A., Zdunek R., Phan A. H., & 甘利俊一. (2009). *Nonnegative matrix and tensor factorizations: Applications to exploratory multi-way data analysis and blind source separation*. John Wiley & Sons. https://ci.nii.ac.jp/ncid/BA91456611

Eslami Nosratabadi, H., Fanaee-T, H., & Gama, J. (2017). Mobility Mining Using Nonnegative Tensor Factorization. In E. Oliveira, J. Gama, Z. Vale, & H. Lopes Cardoso (Eds.), *Progress in Artificial Intelligence* (Vol. 10423, pp. 321–330). Springer International Publishing. https://doi.org/10.1007/978-3-319-65340-2_27

Espín Noboa, L., Lemmerich, F., Singer, P., & Strohmaier, M. (2016). Discovering and Characterizing Mobility Patterns in Urban Spaces: A Study of Manhattan Taxi Data. *Proceedings of the 25th International Conference Companion on World Wide Web - WWW ′16 Companion*, 537–542. https://doi.org/10.1145/2872518.2890468

Han, Y., & Moutarde, F. (2016). Analysis of Large-Scale Traffic Dynamics in an Urban Transportation Network Using Non-Negative Tensor Factorization. *International Journal of Intelligent Transportation Systems Research*, *14*(1), 36–49. https://doi.org/10.1007/s13177-014-0099-7

Soltani Naveh, K., & Kim, J. (2019). Urban Trajectory Analytics: Day-of-Week Movement Pattern Mining Using Tensor Factorization. *IEEE Transactions on Intelligent Transportation Systems*, *20*(7), 2540–2549. https://doi.org/10.1109/TITS.2018.2868122

Takeuchi, K., Tomioka, R., Ishiguro, K., Kimura, A., & Sawada, H. (2013). Non-negative Multiple Tensor Factorization. *2013 IEEE 13th International Conference on Data Mining*, 1199–1204. https://doi.org/10.1109/ICDM.2013.83

Toch, E., Lerner, B., Ben-Zion, E., & Ben-Gal, I. (2019). Analyzing large-scale human mobility data: A survey of machine learning methods and applications. *Knowledge and Information Systems*, *58*(3), 501–523. https://doi.org/10.1007/s10115-018-1186-x