Understanding Mobility of Aalborg Commuters: A case study with a Floating Car Dataset

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Abstract. This research focuses on investigating human commuting patterns within the GeoVisual Analytics (GVA) environment using Floating Car Datasets (FCD) collected in Aalborg municipality between years 2012 – 2014. According to studies in the transportation domain, physical commuting remains an actual routine in the everyday lifestyle of modern society. And yet, insufficient number of studies have been conducted in this direction nor presented from the GVA analytics perspective that would provide a more in-depth understanding. To contribute to the existing studies, we investigate the spatio-temporal distribution of the travel behaviour of Aalborg commuters from location-to-location during peak and off-peak hours throughout working days and weekends with morning and afternoon rush hours. Accordingly, we propose an interactive GVA environment as an essential tool for the extensive analysis of human mobility data to ensure effective exploratory interpretation of the commuters' travel behaviour while following the analysis workflow provided by the traffic experts. The GVA reveals ongoing dynamic processes in traffic flow over space and time to help local authorities for a better decision-making process in traffic management.

Keywords. GeoVisual Analytics, Floating Car Dataset, Commuting

1. Introduction

According to the studies conducted by the Confederation of Danish Industry (DI), on average in Denmark, people commute 40 – 45 km between work and home places. However, these numbers can differ in some parts of the country

LBS 2021
16th Conference on Location Based Services
24-25 November 2021 Online

Published in "Proceedings of the 16th International Conference on Location Based Services (LBS 2021)", edited by Anahid Basiri, Georg Gartner and Haosheng Huang, LBS 2021, 24-25 November 2021, Glasgow, UK/online.

https://doi.org/10.34726/1781

due to significant distances between municipalities. For instance, in the northern part of Denmark, some workplaces require employees to commute on average 53 – 56 km between home to work depending on whether they are full-time or half-time employed (Dansk Industri 2018). Besides the morning and afternoon rush hours, traffic congestion causes adverse ecological and health outcomes, plus a significant time burden and fuel consumption (Bopp et al. 2018, Novaco 2015). From an environmental and health perspective, long time commuting results in a more extensive exposure to air pollution, traffic noise and possible mental health associated with stress and fatigue (Bopp et al. 2018b). The study provided by Dansk Industri (2018) gives an overall understanding of the commuting behaviour of Danes across the country. However, more in detail investigations are needed for individual regions. Therefore, to comprehend Aalborg commuters' spatial behaviour and mobility patterns during rush and off rush hours over the weekdays, we investigate their spatial distribution and temporal variation over space and time using FCD. The FCD contains valuable information on commuters' whereabouts. One of the effective ways to get better insight into the human mobility characteristics from a visual exploration perspective is a flow map (Kraak 2014, Verbeek et al. 2011). According to the literature in transportation research, traditional micro and macro simulation and modelling approaches focus on providing tools to support planning challenges by determining travel needs for origin and destination (Saeedi 2018). Therefore, differing from those traditional methods, we propose a GVA environment for the interactive visual investigation of commuting patterns, where the focal representation of a flow map is supported by various graphs for a profound analysis of the origin-destination data. The GVA will help the users to answer the following questions: What variations exist in commuting patterns, and how did they change over space and time? How far and how often do people commute between work and living places? How does commuting affect traffic congestion, the environment and commuters' health?

Thus, this study will be interesting for the local municipality representatives due to the increased traffic problems during morning and afternoon rush hours that causes some health and ecological issues.

2. Related Work

Over the years, various Origin-Destination (OD) flow map visualizations have been introduced in the scientific literature. For instance, Dewulf et al. (2015) introduced OD matrices to study commuting time differences between cars and public transport during rush hours based on FCD. To overcome overlapping problems, Wood et al. (2013) proposed to map OD as cells rather than flows. Differing from them, Zhou et al. (2019) presented an interactive visualization interface focusing on the OD flow wheel supported by graphs to reveal human mobility characteristics through a mobile phone location dataset. These authors used different techniques to avoid visual overclutter. However, studies on usability issues indicate the importance of the cartographic design of OD flow maps (Koylu & Guo 2017). For instance, Purchase et al. (2012) and Xu et al. (2012) found that the users performed better with straight edges than curved edges due to considerable visual clutter. Ware et al. (2002) and Huang et al. (2005) revealed that reducing the number of crossings between edges improves the effectiveness and efficiency of flow maps. The above studies tackle visual clutter issues and focus on understanding commuting patterns through interactive interfaces. Differing from them, we suggest an interactive GVA environment as a visual solution space to allow the users data filtering and selection on demand options. This will facilitate visual clutter and increase the effectiveness and efficiency of the visual communication for knowledge extraction. To do so, the proposed GVA incorporates a flow map with various graphs to enhance in-depth data analysis. This will lead to understand the dynamic processes in the mobility of Aalborg commuters on micro and macro geographical scales.

3. Data and Methodology

3.1. Study area

Aalborg Municipality is situated in the Northern Jutland region of Denmark and covers approximately 1,144 km2 with a population of 215,312. The center of municipality, Aalborg city is the 4th largest city in Denmark and plays an essential role in the social and economic development of the Northern region.

Figure 1. Location of the Aalborg municipality in Denmark.

3.2. Data collection and processing

The Floating Car Datasets (FCD) was collected from 425 vehicles registered in Aalborg Municipality over three years. The data were gathered for a Danish big data project focusing on the Intelligent Transportation System (ITS) platform. The information about vehicle whereabouts and technical conditions was transmitted and stored in the database based on the installed onboard tracking devices. After data collection, FCD was map-matched to the real-world traffic network and anonymized. And after the anonymization, only data recordings gathered from 389 vehicles with 0,74 billion positions covering 9.7 million km have been published as an open source for data sharing (Figure 2a) (Gøeg et al. 2019).

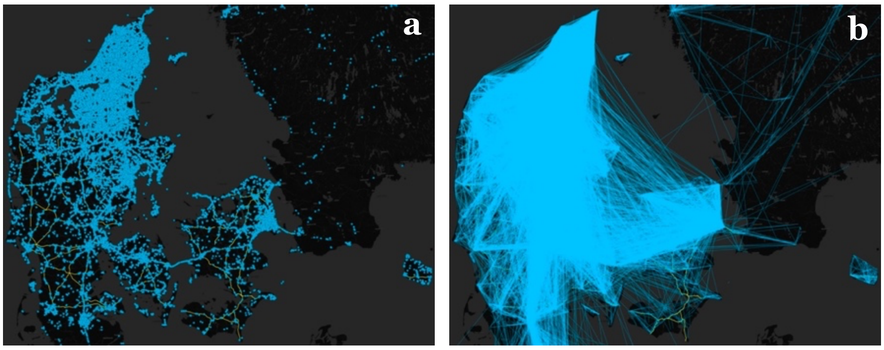

Figure 2. a) Row FCD and b) trips extracted with Origin-Destination (OD).

The anonymized FCD dataset was further processed for this research to extract relevant data characteristics and geographic knowledge with Origin-Destination (OD) trips for the GVA application. The extracted origin-destination points were again processed to separate weekdays from weekends and then connected to the municipality centres.

3.3. Designing the GeoVisual analytics environment

To gain an in-depth understanding of the mobility of Aalborg commuters, a user-friendly interface that allows enhanced characteristic analysis of human mobility from a spatio-temporal perspective was designed. The developed GVA environment aims to provide comprehensive information on the connectivity and volume of the Aalborg commuters across the country. Thus, flow maps can aggregate large streams of movements into flows to avoid visual over-clutter and reveal movement intensity between pairs of Origin and Destination locations (OD). OD flow maps require a careful cartographic design approach to overcome occlusions on the representation, for instance, between vectors and their arrowheads (Jenny et al. 2016). A graph drawing criterion of a flow map could be grouped in edge geometry, arrangement of edges, and direction indication categories. The origin-destination node positions on the flow map are fixed to the centre of the municipality. At the same time, their thickness indicates the volume of the traffic flow within particular time windows. To follow some temporal uniformity, those time windows were generated based on the typical 24-hour traffic rhythm of the Danish Road network. The other important aspect was to define commuting distance in terms of space and time between home and work locations. However, according to traffic experts, it cannot be represented accurately as it depends on the different modes of transport. Therefore, trips with more than 5km were considered consistent. A large portion of the analytical environment consists of the geographical map view that specifically was designed in Mapbox and linked via API to the GVA. While the implementation of the flow map partially relies on the solutions described in Graser et al. (2019) and Koylu & Guo (2017). To operate displayed context on the map view, selection and filtering options are integrated into the system. This should allow a better visual perception of the flow map and information extraction. For better analysis and interpretation of commuter movements, graph views of time graph and parallel coordinate plot were also embedded in the GVA. The graphs and flow map are being constructed based on the user requirements and design recommendations gathered from the literature.

4. Results

Origin Destination (OD) flow maps are one of the interesting forms to visualize human mobility. Accordingly, the spatial view of the flow map allows interactive exploratory analysis on Aalborg commuters' distribution over space and time. The primary results show different trends in travelling distance and time behaviour over the weekdays. According to Danish Industry (DI) (Dansk Industri 2018), the length of the trips between work and home places for mobile Danes can vary across Denmark, and the average commuting is 42,5 km per day. Besides, there is a trend that the majority of the commuters prefer an early trip to the workplace to avoid morning rush hours. Alternatively, they will commute to the workplace late and accordingly return home late. Of course, family obligations have a crucial role to play in the commuting behavioural pattern. Therefore, the proposed GVA environment, reveals and answers a diversity of the complex questions for a profound understanding of commuters' mobility patterns In Aalborg municipality.

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