Retail Centre Footfall: Planning and Forecasting Using Time Series Modelling

Yang Zhou[1], Huanfa Chen[1] and Christian Tonge[2]
[1]University College London, [2] Movement Strategies

Project Background

Recent advancements in sensor technology enable the development of many new applications to embed into the urban infrastructures. Smart cameras, one example of this innovation, are rapidly finding their way into Intelligent Surveillance Systems. Equipped with a vision system that can extract information from videos or images and generate specific information, smart cameras possess the capability of creating essential insights for business, especially for the retail industry to explore the customer counts, queue lengths and customer preference. Specifically, people counting is a crucial and challenging problem in visual surveillance, which can provide additional value to security and safety applications, as well as give valuable insights for retail managers.

Data and Methods

This thesis studies the footfall count records collected by the Springboard cameras installed at ten streets of Bath city, ranging from 1 March 2017 to 20 May 2019. Each street is given a unique ID by numbers 1 through 10. The Dynamic Time Warping algorithm is applied to generate the distance matrix to compare the similarity of temporal footfall sequence among different spatial locations. Besides, the performance of Seasonal Autoregressive Integrated Moving Average with External Variables (SARIMAX), Facebook Prophet, eXtreme Gradient Boosting (XG Boost) and Long short-term memory (LSTM) is evaluated and compared to explore the most suitable time series model that can be adapted to data with hour granularity. Finally, while combining the exogenous variables to forecast footfall, including the footfall counts in the prior time steps, weather conditions and holiday effects, the feature importance of the explanatory variables is also investigated to explore which inputs contribute the most to the footfall counts.

Key Findings

Firstly, a large proportion of pairs of sequences reveals high similarities, whereas the footfall level on HoF Milsom Street illustrates relatively low similarity degree to that on all other streets, which might cause by its insufficient temporal length of footfall sequence. To sum up, ten footfall sequences generally show high similarity to each other even if the footfall data obtained from different spatial locations.

Secondly, all four models are applied to fit the dataset for each street separately; additionally, the XG Boost and LSTM models trained on each street are also applied and tested to the rest of streets to investigate the generalisation of constructed models. On the one hand, the results of prediction accuracy illustrate that the XG Boost models have the highest performance, followed by the LSTM, Prophet and SARIMAX for predicting with hourly granularity. On the other hand, construct separate model for each street equips with lower error scores than the generalisation of constructed models on one street. Generally, id7-based XG Boost model and id3-based LSTM model perform the best on other streets, as they equip with the high degree of similarities to other streets.

Thirdly, the feature importance of the explanatory variables is investigated by XG Boost model (see Figure 3). It is found that the temporal features like the footfall counts in different prior time steps represent the greatest importance. Meanwhile, the weather conditions include humidity, wind speed and temperature also influence the footfall counts greatly. Sunday and Saturday also reveal greater influence on footfall than other days of a week. Additionally, the holiday events illustrate relatively less significance.

Value of the Research

There has been limited visible research on modelling the pedestrian counts given camera sensors data, especially in the retail area, as the highly spatial-temporal granularity of footfall makes it challenging to study pedestrian behaviour comprehensively. This research develops and compares time series models, including traditional statistical model, machine learning model and deep learning model, with footfall counts to generate retail insights. Additionally, the constructed prediction models in this study are based on hourly granularity dataset, whereas previous time series modellings mainly focus on daily, weekly or monthly forecasting.

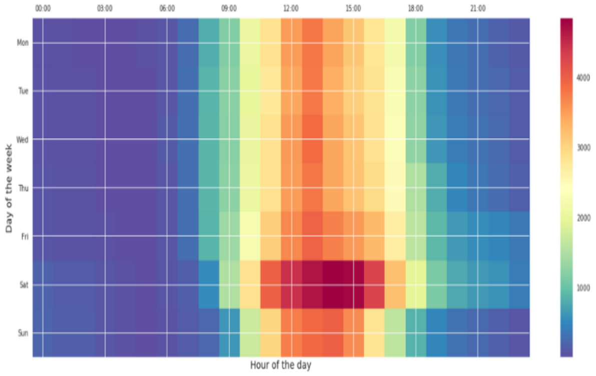

Figure 1 - Heat map to represent the changing trend of footfall count each hour for a week (24*7)