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A Spatio-temporal Schedule-fused Neural Network for Urban Taxi Waiting Time Prediction

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Abstract: Taxi waiting times are important criteria for taxi passengers to choose appropriate pick-up locations in urban environments. The research developed in this paper introduces a taxi waiting time prediction model based on a behavioral neural network. The approach integrates a series of multi-source data from taxi trajectories to city points of interest and different time frames and human behaviors in the city. We apply a grid-based and functional structuration of an urban space that provides a lower-level representation of these different data. Overall, the neural network model can dynamically predict the waiting time of taxi passengers in real time under certain spatio-temporal constraints. The experimental results show that the granular-based grids and spatio-temporal neural network can effectively predict and optimize the accuracy of taxi waiting time's prediction. This work provides a sort of scientific decision support for intelligent travel predictions of taxi waiting time in a smart city.

Keywords: spatio-temporal big data; spatio-temporal characteristics; neural network; urban computing; mul-ti-source data

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1. Introduction

Over the past few years, with the rapid development of smart cities that provide many high-tech opportunities and novel services to human beings and decision-makers, transportation systems have also gradually evolved toward the concept of "smart travel". Smart cities have the potential to offer novel interactive applications for either optimizing routes at the local level or transportation planning schemas at the city level [1]. As one of the major means of transportation in the city, taxis have the advantage of flexibility and convenience, and can often meet residents' travel demands [2]. However, there is often an imbalance between taxi supplies and demands, this leading in many cases to long waiting times and thus an urgent need for reasonable and effective automated solutions [3].

With the aim of bridging the gap between taxi demands and supplies with smart travels, the research introduces a neural network approach whose objective is to predict passengers' taxi waiting times and provide passengers with optimized waiting places. Our approach is based on a combination of an optimized neural network, a grid-based spatio-temporal and functional structure of urban space and integration of multi-source data. Different spatio-temporal and semantic data compose the input of our modelling approach, from a selection of urban points of interest, historical taxi trajectory data including waiting times at specific locations and weather data. The whole approach is experimented in the Wuchang District of Wuhan in China using a set of real taxi trajectories recorded over a significant enough period of time, and illustrated by a case study application that shows the interest of the whole modelling approach.

The remainder of the paper is organized as follows. Section 2 summarizes the related work. Section 3 describes the principles behind our behavioral model and develops the neural network modelling approach. Experimental results and analysis are provided in Section 4. Finally, the conclusions and future work are summarized in Section 5.

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5. Conclusion and future work

Over the past few years, the emergence of many sensor-based applications in urban environments progressively favor the emergence of the concept of smart cities. Amongst a wide range of novel services offered to urban residents and decision-makers, transportation on demand has radically changed the way operations are distributed amongst potential passengers and delivery companies. When considering and modelling taxi demand and supplies, many factors impact the waiting times of taxi passengers, from the efficiency of the urban network infrastructure and functional organization of the city, to the optimization of taxi resources and passenger pickup locations, to traffic flows to mention a few examples [40].

The research developed in this paper introduced an experimental neural network model whose objective is to predict and optimize taxi allocation times to passenger demands in an urban environment. The approach is based on a close integration of multi-dimensional data, from historical taxi trajectories, to a spatio-temporal distribution of human behaviors in the city according to different functional, temporal constraints and weathers. The applicability, accuracy and effectiveness of the proposed model are primarily compared with actual historical taxi trajectory data and a spatio-temporal behavioral model of urban residents. Lastly the whole neural network approach is compared to a few alternative modelling approaches, the results show that our modelling approach performs relatively well in terms of accuracy and efficiency.

The advantage of this modelling approach is twofold: it can help taxi drivers to reduce the no-load rate while reducing waste of energy resources, and it can improve the balance between the supply and demand of taxis and passengers to some extent this being a key issue in taxi demand allocation tasks [39]. For passengers, predicting the waiting time in advance can also improve the success rate of taking a taxi and help passengers arrange their journey appropriately.

Although the research has made some preliminary progress, additional issues need to be further developed. Subsequent work will continue around the following two points: first by further optimizing the time-space modeling, such as different holidays and area without function category identification, secondly based on predicted taxi waiting times, optimization of allocation pickup points might be still explored with further algorithmic approaches.