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Real-Time Parking Lot Guidance

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Abstract

This paper describes a system that would suggest parking choices to a user based on a destination selected and information previously extracted from regularly gathered aerial and/or street-level imagery. The system provides information on the expected occupancy of the suggested parking options at the estimated time of user arrival. Further, this system would be able to provide information on which parking options are free and which ones are commercial and the pricing information, also sensitive to the time of the user arrival. The occupancy is predicted via the application of machine learning models to the regularly gathered imagery. The imagery can be analyzed with machine learning models specialized to look for ground level parking lots with or without vehicles in them to find the locations of any open-air parking or multi-level parking lots with the roof level available for parking.

Introduction

Typical navigation systems do not provide navigation help to nearby parking lots or complete information on parking availability and pricing. Rather, in most cases, the driver has to inquire in advance about parking with a business or facility that they are going to visit, or hope to find metered or unmetered street parking nearby. Oftentimes drivers spend a decent amount of time driving streets around their destination while looking for commercial parking lots or streetside parking, which can be frustrating in addition to time consuming.

Summary

A system is described herein, where real-time parking information is provided to users. For example, a navigation system may direct the user to a parking spot that is most likely available. The user may define parameters for the spot, such as price considerations, distance from the user's destination, restrictions such as time limits, etc. The parking information may be provided when the user inputs a destination into the navigation system. Further, the parking information may be updated as the user travels along a route to the destination.

Data used to compute such parking information may be collected from one or more sources, such as aerial imaging, street-level imaging, reporting mechanisms, or the like. According to some examples, unmanned aerial vehicles (UAVs), such as drones or the like, may be dispatched periodically to collect intel on parking availability. The timing or frequency with which such UAVs are dispatched may be varied depending on factors such as a number of requests for parking information received for a particular area. Moreover, machine learning may be used to predict, with a high level of accuracy, availability of parking at particular locations at future points in time.

Details

The parking availability information system described herein suggests parking choices to a user based on a destination selected and information previously extracted from regularly gathered intel. The regularly gathered intel may include, for example, aerial and/or street-level imagery. The system may further provide information on the expected occupancy of the suggested parking options at the estimated time of user arrival. Further, this system is able to provide information on which parking options are free and which ones are commercial. For the commercial parking options, pricing information may also be provided, which is sensitive to the time of the user arrival.

User Interface

The parking availability information system may be implemented in various types of applications, such as map applications, navigation applications, parking applications, etc. The system may be automatically triggered, such as when a user enters a destination, or manually turned on by the user. The user may set various parameters for the system, such as pricing parameters, parking range indicating how far from the user's destination they are willing to park, anticipated times of travel, etc. In response, the user may be provided with information indicating likely availability at one or more parking lots or availability of on-street parking on particular streets for a time at which the user is expected to arrive at the destination.

Parking Information Collection

The parking information used to calculate the predicted availability can be regularly gathered through one or more methods, such as aerial imagery, street-level imagery, sensors, etc. Aerial imagery may be obtained and analyzed to look for open on-street parking spots, ground level parking lots with or without vehicles, open-air parking or multi-level parking lots with the roof level available for parking, etc. The aerial imagery may be collected by UAVs, which may have a predetermined schedule and flight pattern. The schedule and flight pattern may be designed for the purpose of identifying available parking. In other examples, however, images may be collected from other types of aerial vehicles flown for other purposes, such as commercial blimps with cameras attached.

The UAVs or other aerial vehicles may be coupled to a server, and automatically stream the aerial images to the server as the images are collected. The images may be sent with metadata identifying a location and time corresponding with the images. For example, the images may be time-stamped and/or transmitted along with GPS coordinates or other location information.

The collected aerial imagery may be analyzed using machine learning models, and used to predict parking availability at future times, as described in further detail below. For example, patterns may be recognized in a number or percentage of available parking spaces in a given location over time.

Street-level imagery may additionally or alternatively be collected, such as by cameras mounted on street vehicles, businesses, utility poles, parking structures, etc. Street-level imagery may also be collected from user-contributed content, such as user uploads of images, text, or voice information related to parking availability. In addition to open parking spaces, the street-level imagery may provide information indicating parking restrictions, such as signs limiting parking hours or prohibiting parking altogether, streetside parking meters, curb markings, etc. Figures 1 and 2 below provide examples of such parking restrictions identified by street-level imagery.

Fig. 1: Street-level imagery identifying a pay-to-park zone.

Fig. 2: Street-level imagery identifying a parking meter.

It is possible to extract parking pricing and policy information from street-level imagery with sign detections and text transcription models. For example, image recognition techniques may identify signs or parking meters, and text recognition techniques can be employed to extract sign information (e.g., no parking on Tuesdays because of street sweeping, parking free on Sundays, etc.).

The collected aerial and street-level imagery need not be limited to RGB imagery. Other types of sensors, such as LiDAR, may be mounted to aerial or street-level vehicles and used to collect the parking availability information. LiDAR may produce improved results during the evenings and night time, as compared to RGB imagery, even if parking lots are reasonably well lit by street lights. Other types of sensors which may indicate parking availability may include motion sensors detecting entry or exit from a parking lot, or any of a variety of other types of sensors.

Determining Real-time Parking Occupancy

This accumulation of actual information about any specific parking lot occupancy serves as the foundation of a predictive occupancy model indicating availability at the specific lot at specific times. The algorithm can be a mathematical regression or probability distribution model fitted to some initial data and then refined over time as new data is gathered. The algorithm can be used to update regression parameters or probability means at the same time resolution that UAV flights occur. As a result the model can predict, for a specific lot, the percentage of open parking spaces at a particular time of day on a particular day of the week during a particular time of year, such as 4-6pm on a June Monday. Then, a user query for parking occupancy for a specific arrival time, such as 5:31pm, can be answered via a computation that involves most recently gathered data at time X and a term that uses the predictive occupancy model to estimate the occupancy dynamics since that time X when the last image had been taken and processed. The user may be informed through a user interface of the predicted availability. Just as an example, the notification may indicate "At your arrival, the parking lot is likely to be approximately 83% full." Furthermore, the map interface can show pins for nearby parking lot choices and label these with the predicted percentage occupancy at arrival time.

To compute the predicted availability, once the image information is collected, image analysis and machine learning models are used to identify patterns in parking availability. These patterns may be used to predict parking availability at future times. The image analysis may include, for example, image content analysis (ICA) or specialized segmentation models. In some instances, the data may be segmented by a machine learning model into individual vehicle detections.

The predictive model can be utilized at different time resolutions and also with respect to different parking lot sizes, including individual parking spots. This may be particularly advantageous in identifying and predicting street side parking. Accordingly, the predictive model results can allow the user to be informed about the likelihood of finding an available parking spot within a given range. The given range may be input by the user, such as by how many minutes it would take to walk to their final destination or within a particular number of miles, kilometers, etc. from their destination.

The machine learning models, run on the collected aerial and street-level imagery, yield information about the more stable properties of parking lots. Such stable properties can include location, pricing, policies, etc. The information from the collected imagery may be regularly updated, for example, as new imagery is collected.

In some examples, a frequency at which the images are collected over a particular geographical area or route may be adjusted based on a number of requests for parking availability within the particular geographical area. For example, if image collection is scheduled for every several months, but a significant increase in requests for the area is received, it is possible that the likelihood of finding parking for the particular area provided in response to the requests will be out of date and therefore possibly inaccurate. Accordingly, additional image collection may be scheduled to keep the machine learning models accurate.

A tasking system can be set up to fly drones or blimps or other UAVs on regular routes over potential parking locations. In some examples, the UAVs may hover over a given area during the day, to observe changes in parking occupancy over a period of time. The number of drones/blimps and the routes they would fly each day can be computed given some target visit frequency, such as hourly, N times per day, weekly, etc. The target frequency can vary from one parking location to the next, for example, based on the importance/density of nearby businesses, facilities, user navigation queries, etc. In dense urban areas, when flying at a certain altitude, a UAV may be able to image multiple parking lots at the same time, thus the visit locations may be considerably less than one per each parking lot, making routing easier.

According to some examples, the UAVs may limit the reporting of information, such as to save power, memory, bandwidth, or other communication costs. For example, the UAVs may share updates in parking availability or occupancy only if particular thresholds are reached. For example, a lot having 50 total spaces and only 2-3 cars occupying the spaces may be reported as completely empty at the time. This may also serve to protect the privacy of occasional users of the lot.

The machine learning models can provide the user with near real-time expected occupancy information about each prospective parking location, including nearby lots as well as streetside parking spots. During each visit, the UAVs can take one or more snapshots and run machine learning model inference on these snapshots to compute the number of occupied parking spaces. For example, a percentage of open space in a lot as compared to space occupied by cars may be extracted from the image. Given the known parking lot size, this percentage can be translated to available parking spaces. Such computations can be done on the UAV without sending any data back to the server, or they can be performed on a remote server. Likewise, the UAV and/or the server can keep track of periodic occupancy averages, such as hourly, daily, weekly, etc. occupancy averages.