Context-Aware Parking Systems in Urban Areas: A Survey and Early Experiments

Hafiz Mahfooz Ul Haque[1(✉)], Haidar Zulfiqar[2], Sajid Ullah Khan[2], and Muneeb Ul Haque[3]

[1] Department of Software Engineering, The University of Lahore, Lahore, Pakistan
mahfoozul.haque@se.uol.edu.pk
[2] Department of Computer Science, The University of Lahore, Lahore, Pakistan
haidarmalik@live.com, sajid.ullah@cs.uol.edu.pk
[3] SBE, University of Management and Technology, Lahore, Pakistan
hhmuneeb@gmail.com

Abstract. Parking spaces have been considered as vital resources in urban areas. Finding parking spaces in jam-packed areas are often challenging, stressful and uncertain for the drivers that cause traffic congestion with a consequent of wastage of time, fuel and increase of pollution. These problems can be addressed using smart parking systems if drivers reserve parking slots in advance. With the proliferation of smart devices in a pervasive computing environment, real-time monitoring of the traffic situation and parking areas is often trivial using context-awareness. Context-awareness has the capability to occupy parking slots dynamically at any time and in any place. However, it is often challenging in busy parking areas because vehicles occupy and leave parking slots very frequently. This paper presents a brief survey on context-aware smart parking systems theoretically as well as practically. We propose a context-aware parking application to assist drivers in finding parking slots dynamically while moving and/or arriving at the destination.

Keywords: Context-aware · Smart parking · Distributed reasoning
Sensor · Embedded system

1 Introduction

In recent years, transportation has become one of the most essential parts of people's daily lives across the globe. In urban areas, people often prefer to travel using their personal vehicles. These vehicles provide ease, comfort to humans with stress-free driving, discourage public transport services and reduce the risks of getting late. Due to heavy work pressure and anxiety, people usually rush in driving and finding parking slots. Although, it is a fact that traffic is increasing day by day, however, the number of accidents is also increasing accordingly. Accidents are always unplanned events that occur unexpectedly at any time and in any place. In recent years, accidents ratio has been terribly increasing day

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by day. According to the World Health Organization (WHO), it is estimated that around 1.7 million people die in the road accidents every year and around five hundred million people get serious and/or mild injuries [1]. More than 80% of victims can be saved if they are treated within a limited span of time. The core intention is to save the lives of victims and make traffic flow faster and smoother. With the advent of smart technologies and pervasiveness, smart parking, road safety, and route planning and management have been rapidly evolving since the last decade. Thanks to the context-aware vehicular frameworks and applications, that provides a wide range of services to vehicle drivers such as traffic management, smart parking, route planning, collision avoidance controls, suitable assistance, etc. In context-aware computing, smart devices are equipped with various embedded/un-embedded sensors. These devices have the capability to sense and detect, interpret and respond according to the environmental situation. A prime example of this type of application is SFPark [23]. Srikanth et al. proposed a framework that uses sensors embedded in the streets of the city of San Francisco, which shows vacant parking slots. When a user intends to find a parking slot in some area of the city, the application shows a map with marked locations of the vacant parking slots in the designated area. However, the user has to explicitly choose the vacant marked parking slot. To the best of our knowledge, no systematic theoretical frameworks, as well as applications, have been developed yet that assign and maintain the parking slots dynamically at run-time. In this paper, a prototypal context-aware parking application is being developed to assist drivers in finding parking slots dynamically. In particular, when a user registers himself/herself with the application and enters the destination, the system starts acquiring user contextual information (location) while the user is traveling and reserve parking slot automatically on the estimated time of arrival. On arrival at the parking area, the system directs the driver to the reserved parking slots using a guided map. The system calculates the parking duration, and the fee is automatically deducted as the user leaves the parking space.

The rest of the paper is organized as follows. In Sect. 2, we briefly introduce the core notion of context-awareness. In Sect. 3, context-aware vehicular systems have been described. In Sect. 4, we briefly survey smart paring systems with the incorporation of context-awareness. In Sect. 5, we present our proposed context-aware parking application framework and conclude in Sect. 6.

2 Context and Context-Awareness

A context is any information that describes the state of an entity like a person, place or object. Context can be a location, weight, people around, time, user activity, social interactions, and these factors may have also other attributes like the weight of an object according to location. The context-awareness relies on context and provides the relevant information or services according to that context [9]. Context-aware applications usually sense the contextual information from the physical environment or grab a particular situation, respond

intelligently in such environment and have the ability to build the understanding of the current execution and provide services accordingly [13].

The Context-aware systems are those systems that gather the context of a particular environment or situation and deliver it to the interested entities connected with ubiquitous computing. Context-aware systems provide different devices integrated with multiple sensors that are used to monitor physical environment and individuals to measure their current situations without human involvement and respond accordingly [5,25]. These systems assist the users at any time, anywhere by taking intelligent decisions without human intervention.

3 Context-Aware Vehicular System

In recent years, intelligent transportation systems have significantly influenced by context-aware systems. Intelligent transportation systems are incorporating a variety of context-awareness features to facilitate drivers in personalized services ubiquitously such as road safety, the comfort of drivers, analyze traffic condition and suggest appropriate actions accordingly [2,4,10,16–18,24]. Context-aware vehicular applications acquire contextual information related to drivers, vehicle's current state (personalized information such as speed, acceleration, etc), traffic regulations and take appropriate action according to the current situation. Due to rapid technological advancements in the intelligent transportation system, vehicle manufacturers are providing latest features like camera, cruise control, sensors, airbags, GPS, etc. in their vehicles to provide secure, comfortable and hassle-free journey.

Context-aware applications of the transportation system use the driving context information such as information related to the driver, the vehicle state, traffic regulations, available parking lots in different areas etc. and provide assisted support according to the current situation. Context-aware vehicular systems allow the vehicles to communicate with other vehicles and road infrastructure by measuring speed and distance. These systems detect hazardous situation and take decisions intelligently. Majority of these applications are based on a Vehicular Ad-hoc Network (VANET) that collects context data of driving by using the different sensors, cameras and provides inter-vehicular communication capabilities. VANET is a wireless technology for ITS (Intelligent Transportation system) that provides DSRC (Dedicated Short Range Communication) to inter-vehicular communication (vehicle to vehicle) and roadside static infrastructure (vehicle to infrastructure) [12]. VANET has two types of nodes, vehicles OBUs (On-board Units) and RSUs (Road Side Units). The vehicular OBU is used to communicate with other vehicles and RSU. The RSU has multiple network interfaces to connect with other RSUs, vehicles and ISPs (Internet Service Providers). RSU allows OBU to connect using the internet. In VANET, nodes communicate through single-hop and each node can be treated as a router to enable multi-hop communication between the other nodes. VANET uses IEEE 802.11p and IEEE 1609 standards/topology for inter-vehicular communication [20]. In literature, a significant amount of work has been done on Context-aware vehicular systems including Accident detection system [17], smart parking [7,18,26], driver

assistance [6], driver behaviour [4], route planning and optimization [24], traffic congestion estimation [16], etc.

4 Context-Aware Smart Parking Systems

Since the last decade, traffic congestion is becoming one of the major issues in urban cities. Finding a parking place in urban areas is one of the most challenging and stressful task for the drivers. Drivers often spend their time, suffer stress and waste fuel to find a parking place and thus the waste production of tons of carbon dioxide which is dangerous for human life. There are many smart parking methods that have been proposed by different researchers. In [8], Biondi et al. proposed a smart parking android application that uses GPS to locate the nearest parking areas and BLE (Blue tooth low energy advertising) to provide the contextual information about the adjacent passenger in the vehicle. In this framework, users have to register in the smart parking system and when a user starts driving to the designated place, the application sends GPS position to the remote server after certain intervals until it reaches to the destination and store paths by joining all GPS points. The server stores the maps of designated areas in the database and the paths are compared through an algorithm to estimate the available parking slots. The system architecture consists of smartphones that contain GPS and BLE to gather the contextual information like adjacent users, position, path, and activities of the users. This application presents the result originated by the engine and sends contextual and location information to the engine and provides the nearest parking area. Although the use of Bluetooth technology is a well-suited approach to interconnect devices, however, it may trigger another issue related to heterogeneity, data security, and battery life, which may cause unreliability issue. Adhatarao et al. [3] proposed a smart parking method that sense the vehicle at the entry node and generates parking ID to broadcast over the network. When the vehicle reaches the parking lot, the parking lot sensor detects the presence of a vehicle and the system assigns the ID generated at the entry node to the vehicle parking ID. While leaving the parking lot, the sensor detects free space and the system makes the calculation for easy payment. Though all the smart parking systems are proposed to easily discover and maintain the parking slots in the parking areas. However, users have to do manual requests for discovering and reserving the parking lots every time, even in the same parking area and the slots are not assigned systematically to the users. This may cause inefficiency and inefficacy of the system in maintaining quick response time, light and temperature sensitivity due to high voltage requirements.

In [7], a context-aware on-street parking system was developed by De Montfort University. This project was specifically designed to facilitate the drivers to park their vehicles by automatically locating the freely available and reserved parking places. This context-aware Information system was developed with the incorporation of Vehicular Ad-hoc Networks with the intention of providing more convenient and efficient parking spaces to save fuels and time of the people.

In this system, the parking zones and streets are given the specific identity. So whenever a vehicle sends a request to park the car based on their preferences, the information system automatically locates the desired parking space and reserve the parking space based on the user's preference. In [18], an effort has been made to facilitate the drivers by providing available/reserved parking spaces using contextual knowledge generated. The system has four different parking states including freely available parking spaces to be used by the drivers, reserved parking spaces for pre-booking of parking places, occupied parking spaces and load/unload parking spaces for the quick delivery of goods. These parking states are utilized according to the user's preferences and privileges. To suitably utilize the parking space, the system has two main interfaces; one for the driver and other for the traffic monitoring authorities. In this paper, authors took the advantage of cloud-computing to suitably implement the complex functionalities using smart server. Context-awareness services have been incorporated in the smart server to make its adaptive behavior. Another approach proposed in [26], which describes a PhonePark application to detect the availability of on-street parking places. The architecture is composed of smartphone sensors like GPS, Bluetooth and accelerometer sensors along with the algorithms that can automatically detect the real-time parking/deparking conditions. A parking status detector runs on the smartphone and when it detects the parking/unparking activity of a specific area, it sends the status of parking to the parking availability estimator that is known as the aggregates of parking status detectors (PSD's) notifications. To overcome the false detection of parking places historical availability profile(HAP) construction algorithm is proposed along with the PSD and parking availability estimator(PAE). In [19], Rinne et al. investigates a mobile crowdsourcing approach that describes how smartphone sensors are capable of obtaining contextual information of available parking places without using external infrastructure and discussed the pros and cons of the investigated approach. To detect the available and occupied status of parking places, Google API's activity recognition (in the vehicle, on foot) and Geofencing is used to detect the exit and entrance in the parking area. An Android application has developed to acquire the run-time data from the GPS and API's and automatically send to the server. The server shows real time parking status to the requested drivers according to their preferences and this can be updated either automatically or manually using smartphones.

Kamble et al. [11] presents a prototype of Android centered smart parking application that assists the users in reserving or pre-booking the parking space. In the presented architecture, the user can view and select the parking lot for booking by specifying the parking duration through the application. The system will mark the parking space and provide One Time Password (OTP) to the user to make sure that the specific parking lot is not available for others. The user has to enter the OTP through the keypad in order to open the gate while going in or out from the parking area. In [22] Satre et al. presents an RFID tag based digital parking system. The system architecture consists of GPS, RFID kit, Android and desktop applications, and database. The user can search for

the parking lot near to his current location through an Android app. When the user selects the parking lot from the available lots, the app directs the user to the parking lot. The RFID tags contain the user's information and used to allocate and deallocate the parking lots through RFID readers installed at the parking gate. The desktop application assists the administration to keep track of available and unavailable parking lots.

5 Proposed Context-Aware Parking Application Framework

Recent years have witnessed the parking problem is one of the crucial issues, more specifically in urban areas that cause road accidents, traffic congestion, time and fuel wastage, environment pollution and driver's stress. Drivers are often unaware of the parking status to their destinations. Literature has revealed a significant amount of work on the smart parking system considering VANET [7,15], cloud computing [14], IoT [21], etc. However, there is a number of quite few frameworks available for context-aware smart parking systems, and these works have not been implemented yet with the intelligent reasoning formalisms to provide fully automated parking support. In addition, to the best of our knowledge, the existing context-aware approaches do not assign parking slots to users dynamically. Users have to explicitly search the parking slots in the specific parking area even if there are many vacant parking places available. Our approach is novel in a sense that we propose a framework that will provide the parking services on the basis of user's preferences automatically. We intend to provide a cost effective context-aware smart parking system for personal vehicles using the smartphone application. The proposed context-aware parking application is being developed to assist drivers in finding a parking slot on real-time, reaching the destination and also allows user to inquire the available parking slots while the user is at home, in office or on the way to the specific parking area.

The application is twofold: one for the user end (client) and other for the service providers (i.e., Parking Bays). Initially, a user has to register through the parking application once using a smartphone only. However, the service provider end needs to fulfill the context-aware smart parking system requirements such as parking area, an entrance sensor, a database system, vehicle presence detection sensor in the designated parking slots and an exit sensor. The proposed application will help three types of users: Registered User with Planned Destination ($RUPD$), Registered User with Unplanned Destination ($RUUD$), and Unregistered User (UU). $RUPD$ users need to enter destination prior starting their journey in order to avail parking with fully automated support, $RUUD$ users do not require the destination, however, they can avail parking with semi-automated support, and unregistered users can avail parking with limited automated support. Whenever a registered user with planned destination arrives at the destination, the system assigns a pre-booked parking slot (which is allocated on the estimated time of arrival) to the driver with a directed map to the assigned parking slot through a unique auto-generated One Time

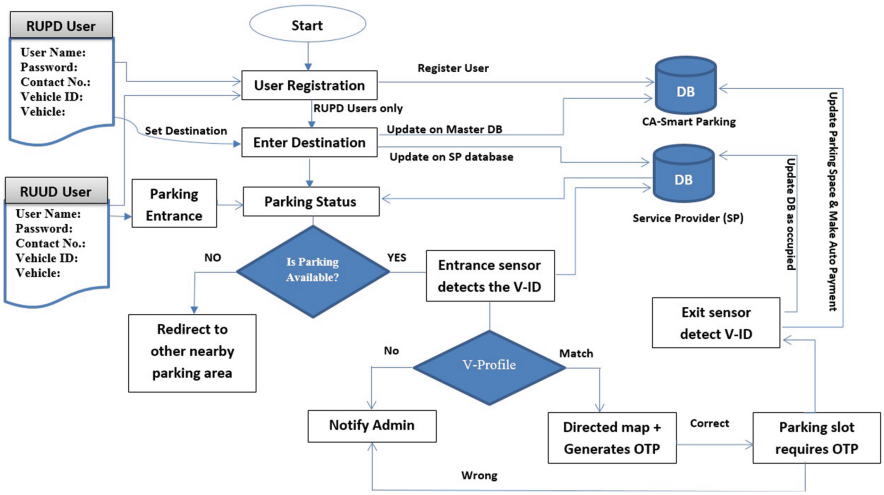

Fig. 1. Context-aware parking system activity diagram

Password (OTP). When the vehicle occupies the assigned parking slot, the system requires the OTP through vehicle presence detection sensor from the user and the user will automatically receive SMS about parking slot including slot's occupancy starting time. As the vehicle leaves the reserved parking slot, the system automatically calculates the parking duration and parking fee will be deducted from the user account through the automatic payment method. Whenever *RUUD* user arrives at the destination, the system automatically allocates parking slot to the driver with a map directed to the assigned parking slot that will save the user's time. Note that the registered vehicle numbers are matched with the database in the system at the entrance gate to make the process faster and secure. In case if an unregistered user is willing to park in a smart parking area, then the system automatically captures the car number using the entrance sensor and allocates parking slot at run-time. Un-registered users are provided parking cards at the entrance gate, and these users pay parking fee on exit gate using Auto Paying Machine. If there is no free parking space, then the user will be redirected to the nearby parking areas from the destination. The system activity diagram is shown in Fig. 1 whereas the system architecture can be seen in Fig. 2.

5.1 Framework Development Mechanism

To suitably implement the proposed framework, we choose Xcode IDE to develop the smart parking application using Swift 4 programming language. As the system is two-fold in nature, so both kinds of systems (service-provider-end and client-end) are developed using iOS version 11. The application is being connected to the firebase database which usually operates on smartphones. The system consists of a master database (i.e., Context-aware Smart Parking database)

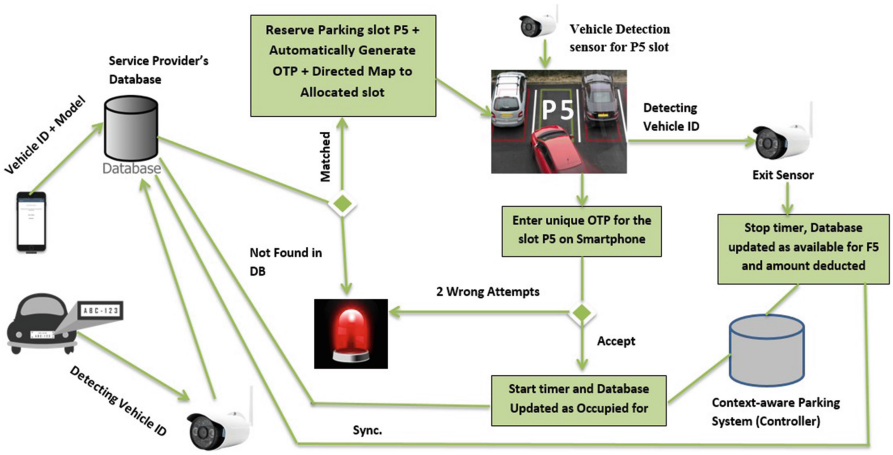

Fig. 2. System architecture

and service provider's database. These databases provide different levels of privileges and access grants. The master database keeps records of drivers, vehicles and parking bays along with vacant slots information, whereas service provider's database contains records of its parking slots as well as client's information. The application uses Google maps for route planning, optimization, time and distance calculation. Both firebase and Google maps are third party libraries that have been integrated into the iOS using Pods. As the system is heterogeneous in nature, so users from different localities can register to the application. Whenever a user intends to find the parking slot at the specific parking area, the system lets the user to interconnect to corresponding service provider's database. To suitably implement the complexity and decisiveness of context-aware parking system, we use rule-based reasoning in order to make efficient and correct flow of the system. As the system runs on smartphones, the service-providers-end's smart devices acquire low-level contextual information from surrounding environment regarding parking allocation and client's information and then infers high-level contextual information in order to fulfill the complete parking process. The system consists of hardware components including a server computer, sensors at the entrance and exit of the parking area to detect the number plate of the vehicle through image processing. The vehicle presence detector notifies the system about the presence and absence of the vehicle in the parking slot. Each slot has its own sensor to timely update the system about the status of the parking slot. The server controls all the sensors, database and payment method.

5.2 Proposed Application User Interface

The proposed application user interfaces show the design of the user application and processes through which user can request for a parking slot while reaching on the parking area and inquire about the available parking slot in advance.

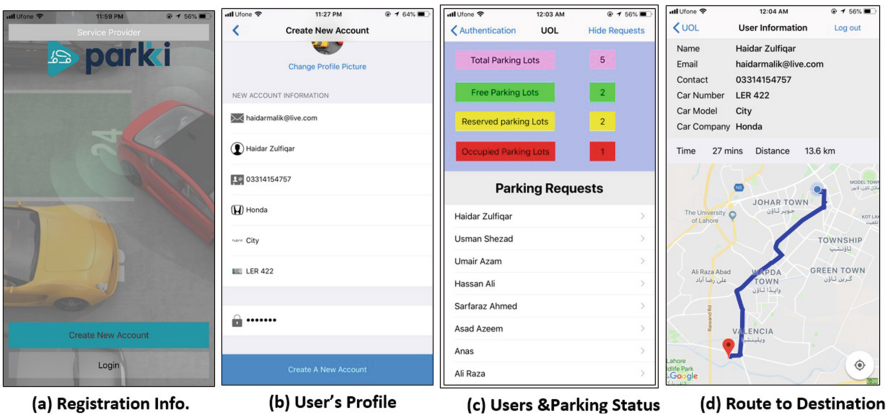

Fig. 3. Proposed context-aware application user interfaces

The Fig. 3 depicts four different screens. Figure 3(a) is a service provider's home screen where a user can register or login to the application. The purpose of this login screen is to book a parking slot. Figure 3(b) shows the user's profile. In Fig. 3(c), the service provider can see the available, requested and occupied parking slots. Figure 3(d) shows the screen of the RUPD user who is about to arrive at the parking area. Due to space constraint, we illustrate few screenshots of the application only and omit further technicalities.

6 Conclusion

In this paper, we first briefly surveyed context-aware smart parking systems and then proposed a prototype of context-aware parking application that assists drivers in finding a parking slot on real-time dynamically while the user intends to arrive at the destination. This system allows registered users to reserve parking slots at the estimated time of arrival in the specified location while the user is at home, in the office or on the way to the destination. In the future work, we will implement the system in a real-time environment. In addition, we upgrade this application for Android devices.

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