Designing an IoT Smart Parking Prototype System

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Abstract

To take advantage of modern wireless connectivity, we designed and developed a new parking system based on (USP CCTV camera) which provides drivers with a simple parking service. This design solution for any car park in any busy city does not require extensive, if any, infrastructural adjustments. Our approach is based on User Centered Design (UCD); The prototype design process started by involving the stakeholders. Several approaches were planned, with in-depth interviews and diaries to collect data from stakeholders. As the participants (stakeholders) where 15 people, each five represent as category as mentioned above, staff, students and visitors worked together to develop the prototype. The investigation sheds light on users' challenges and issues experienced in everyday parking in practice. It offers a description and reflection on methods to better understand their role and the role of the participant in developing IT tools. Also, it provides discussion on the practical aspects of UCD while organising and conducting co-design with stakeholders.

Keywords: HCI, Smart Parking, IoT, Video processing, user-centered design

Introduction

The rapid development of information and communications technology (ICT) offers opportunities to many societal services, providing users with technology to access different types of systems. This study has designed a system that facilitates the availability of parking spaces to stakeholders. In the field of smart parking systems, different technologies have emerged over the past twenty years. Installing a parking system at any car park may be expensive. Furthermore, increasing volume of motor traffic leads to increased fuel consumption, pollution and driving time, along with unwanted traffic jams and accidents. At the end points of a journey, there is always a requirement to access parking spaces, an increasingly expensive resource in the urban landscape.

Since this problem exists in all urban areas, many different car-parking systems have been proposed to alleviate such problems.

As the Internet of Things technology (IoT) evolves, further possibilities to provide services have emerged. Moreover, as Internet of Things (IoT) applications leverage ubiquitous connectivity, big data and analytics are enabling Smart City initiatives all over the world. We propose a non-invasive prototype, as otherwise some parking structures would need extensive infrastructure investment, for example digging holes in the ground at each parking spot to install a sensor. We are proposing an approach that can utilise an existing system instead, i.e. CCTV coverage. The proposed system has some advantages. It is cost efficient as it is using the existing CCTV cameras and no infrastructure changes are needed. In our case, USB CCTV-cameras were used as CCTVs nodes in outdoor environment. This paper presents a prototype of a low-cost and flexible smart parking monitoring system using an embedded system micro-controller (Intel Galileo board- Gen 2), with IP connectivity for accessing and controlling devices and appliances remotely.

Background Literature and Related Work

In this section, we review some smart parking systems that fulfil the same purpose with a different technology. Zheng et al (2006) developed a system using crossbow motes, which have a low unit cost, to enable a car detecting entry to the car park and efficiently guiding the driver to an empty parking space through signs displayed to the driver. Funck et al (2004) proposed a system that uses CCTV cameras that are fitted in car-parks to automatically detect car parking spaces. Also Fraifer and Fernström (2014) proposed smart car parking prototype using camera nodes and OpenCV algorithm to detect the parked cars to facilitate the service to the users. Panayappan et al (2007) described a parking system in VANET that locates available parking spaces; this system depends on roadside units deployed to relay parking messages and GPS to locate parking positions. Pala and Nihat (2007) used RFID technology. Kianpisheh et al (2012) presented a smart parking system using an ultrasonic detector, with one sensor fixed in the ceiling above each parking space. Mathur et al (2009) discussed the research challenges relating to parking technology and proposed some possible solutions. In a centralized solution, cars are equipped with ultrasonic sensors, and when driving past parking spaces they collect occupancy data and upload the data to the centralized database. The cars that want to park query the centralized database. Hazrin et al (2010) proposed a smart parking system using SMS, A parking reservation system was developed so that users could book their parking spots via SMS and using GPS. Bong at el (2008) developed a system to acquire car-park occupancy information using an integrated approach of image processing algorithms, called Car-Park Occupancy Information System (COINS). Klappenecker et al (2014) modelled a parking lot as a continuous-time Markov chain. The parking area was modelled as a grid, and schemes for information aggregation and dissemination over the grid were proposed. Jian et al (2008) proposed a system containing a Gate-PC Controller and Embedded Gate Hardware, an RFID System and a Modular Parking Management Platform. Most systems in the Modular RFID Parking Management System could be substituted for any other similar subsystem. Lee et al (2016) proposed the use of a combination of magnetic and ultrasonic sensors for accurate and reliable detection of vehicles in a parking lot, and also described a modified version of the min-max algorithm for the detection of vehicles using magnetometers. Many different forms of communication technologies have been used in smart parking systems, e.g. WSNs, ZIGBEE, IEEE802.15.4, RFID, NFC, Bluetooth.
For an overview of the reviewed systems, see Table 1.

Table 1. Overview of smart parking systems based on different techniques

Technology Base	*Reliability*	*Circuit Complexity*	*Detection Accuracy*
RFID	High	Complex	Accurate
CCTVs	High	Simple	False detection may occur
Light sensor	High	Complex	Accurate at day time Cannot be used at night
Acoustic sensor	High	Complex	Seriously influenced by environmental noise

Optical sensor	High	Complex	Very accurate
Ultra-sound	High	Simple	Accurate
SMS	High	Simple	Accurate
Magnetic sensors	High	Simple	Accurate
Infrared IR	High	Simple	Too sensitive (Maximum accurate daytime)

Table 1. smart parking systems and different techniques

Research Methodology

Our approach is based on User Centered Design (UCD). It involves designing an Interactive Technology (IT) smart parking system with stakeholders and utilizing the infrastructure of a car park of any organisation. This is carried out in parallel with technical probes. Also, motivations through UCD design observation and survey and in depth interviews with stakeholders are outlined. In this paper, we are monitoring actual parking spaces and explore the desired services informed and shaped by our user groups (stakeholders), using open source software as much as possible.

The prototype design process started by involving stakeholders. Several iterations are being planned. This also illustrates how the different methods help to inform the design. We are designing from the users' perspective (UCD), while having the users included in the design phase of the mobile app (PD), and for the ethnographic approach we are making observations (UCD). This design framework focusses on the needs, desires, and limitations of stakeholders at each stage of the design of a product or service. This method has been applied to design a system prototype (IoTcam and server). While focusing on the user's active involvement and participation in design process, several iterations are being planned to redesign and evaluate the prototype, as following:

i. In-depth interviews with stakeholders were conducted in The Interaction Design Centre (IDC). These in-depth interviews are a qualitative method of analysis, a semi-structured conversation between the interviewer and respondent.
ii. Diary Studies, a longitudinal technique used in Anthropology and User Experience research to capture data from stakeholders, were carried out. Some diaries have been completed while some are still in use by stakeholders.
iii. Design Workshop Sessions will present an informal space for sharing skills and ideas, exploring processes to evaluate the performance of the prototype.

User-Centred Design and Its Influence on Our Prototype

This research study is carried out to explore the approach of user-centred design, with a focus on stakeholders' involvement in the development of a smart parking technology prototype. It has become usual for a driver to spend a large part of his time just minutes looking for a place to stop his car and stand in unwanted place, which is a fee parking place, which would be avoided by the students usually. Include stress and anger, in addition to the greater consumption of fuel while idling. Which many drivers do not care and do not aware too. The societal and economic costs of this scourge are vast and increasing rapidly. We tried to alleviate this everyday issue through the proposed prototype. Although it is only in the early stages there is no need to change the infrastructure, although some stakeholders suggested a few things may involve some costs. The stakeholders have been identified and a thorough investigation of their needs has been conducted. By performing tasks and needs analyses, designers can develop alternative design solutions to be evaluated by users. The data analysis was based on a qualitative content analysis from a human-computer interaction perspective.

(UCD) methodology in this process is used as a framework of processes in which the needs of stakeholders of a product or service are given extensive attention at each stage of the design process. It begins by defining the problem, which in our case is congestion during peak times and it is the effect on the drivers as it appears as difficult to find a parking spot for the driver accordingly. Information is then collected from the stakeholders to get more ideas about the problem and how they feel about it (in our case we deliver some information about the phenomena and how should react to it.) and then build a test model and for each time go back to stakeholders to evaluate the porotype until improve the service and the prototype.

System Contribution and Design Goals

Based on our literature review and having access to the existing infrastructure on campus, we set out to explore a smart parking system based on camera nodes that can provide drivers with a parking information service. It should provide real-time navigation support to the driver. It should provide a friendly parking information service to both the parking user and the parking facility's operator/owner. Using CCTV camera nodes for this purpose as well as for security purposes is an economical option.

Based on our literature review and having access to the existing infrastructure on campus, we set out to explore a smart parking system based on camera nodes that can provide drivers with a parking information service. It should provide real-time navigation support to the driver, for example by utilising Google maps. It should provide a friendly parking information service to both the parking user and the parking facility's operator/owner. Using CCTV camera nodes for this purpose as well as for security purposes is an economical option.

Moreover, through the usage of the (UCD); we have been able to include features that the stakeholders deemed important and that would drive them to use the system, as the main function the system is to gather information about parking status in real time, and help drivers to navigate directly to vacant parking spaces. In this scenario, we develop a prototype inspired by ourselves (authors) as the first cornerstone and then, following the methodology of UCD, use stakeholders for each stage as many ideas were inspired by them when build a model. For each stage, we go back to the stakeholders to get feedback about the prototype and to test the prototype in different aspects such as usability and feasibility and to get more ideas about improving the prototype to help us to improve the service and of course to solve the issue of making the driver turn around to find the best parking space or at least let them know that there's no need for searching for parking spaces.
This approach was used for listening to stakeholders to discuss an alternative design which can enhance designers' understanding of the intended purpose(s) of the prototype and may provide information that does not come out of initial interviews, observations, and needs analysis. It is only through feedback collected in an interactive iterative process involving users that products can be refined. The lesson we learned is that the most valuable form of feedback is through evaluating design solutions with stakeholders, as we got several ideas on how to improve the prototype, which at least alleviates the issue of unnecessary idling when searching for a parking spot.

Ideas from Stakeholders Used to Improve the Prototype:

. Some suggested letting all the drivers know about the fully equipped parking spots via large information screens.
. Use small screens at each parking (space/area) to help to avoid crowding and congestion.
. Use large screens at each entrance to the university to provide information to the drivers.
. The user should be able to click on a button to confirm that he/she has arrived through applying human-computer interaction's principles.
. Parking is free but all the spaces are occupied, so you have to cruise until you find a space.
. Some suggested applying rules about carpooling to convince the students and staff to come in one car (A website would be created to support this).
. Design a simple app to check and maybe book a specific parking spot.
. Most participants do not involve utilising a specific technique to identify the parking status.
. Some suggested only to use the system to covering entire parking spaces to let the driver know about the parking status.
. Some stakeholders advised strongly against using the reservation option in the app. (It should be used to get information about the status of parking spaces, they believe they only need it to go directly to the less occupied ones).
. A suggestion from stakeholders to improve the system and its feasibility is to make the security staff (Buildings and Estates department) a part of the system, to intervene in cases where a driver finds someone had taken his/her place (from a human-computer interaction perspective). Assistance could be requested through a button in the app if needed.

Prototype of The Proposed System and Requirements

There are three main components.

- An application installed on the user's smartphone that connects the user with a parking server (PS).
- An IoT cam (in our prototype, a USB-Camera) that is connected to a microcontroller Intel Galileo (gen 2).
- A PS hosting a database. When the user installs the app on their Smartphone, they are given unique ID. The app can also hold a user's profile including all the information entered by the user during the registration with the system and the server.

Figure 9 shows the general perception of our proposed porotype

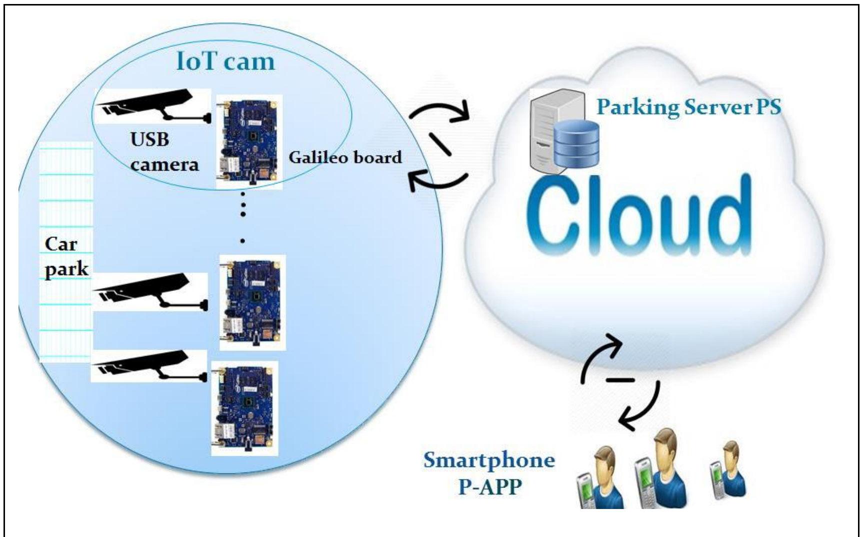

Figure 1. General outline of Prototype

Parking is available in several areas on the UL campus. Most are openly accessible to staff, students and visitors. Most areas don't have any entry/exit barriers. There are two car parks on campus with controlled entry/exit, including payment on exit. Regarding the openly accessible areas, each parking lot divided into areas that are covered by CCTV camera. In our prototype, the IoT-cam can be set to report changes to the scene, as a grid of polygons. At the same time, the user can interact with the system through the p-app. The IoT-cam uses a DHCP connection to connect the PS, which tunnels back to the IOT-cam. A simple blob-detection algorithm using Intel's OpenCV library monitors and reports changes (if parking spaces are made vacant or occupied). IoT-cams connect via the Internet to the PS, which aggregates the data and updates a database of available car parking spaces, close to real-time. Status information regarding parking areas within the coverage of any IoT-cam is continuous.
All information is live, using a centralised database system, which potentially can be cloud-based. Each parking lot is divided into areas that are covered by IoT-cams, as shown in Figure 1.

Hardware (USB-camera and Intel Galileo board - Gen 2 Platform)

The Intel Galileo board used, which is the first in a family of Arduino certified development and prototyping boards based on Intel architecture and specifically designed for researchers and developers. The system is connected to a USB camera. Video is processed, analyzing live streaming of data and changes communicated to the PS. In this prototype we used a C270 Logitech USB camera, with HD 720p (1280x720).

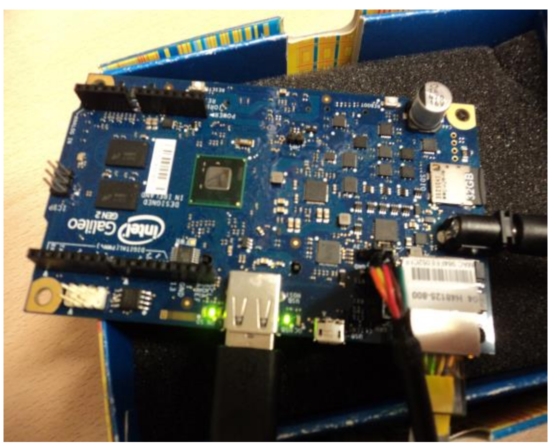

Figure 2. Galileo board using FTDI cable during cross compilation of Java OpenCV code on the board

Figure 3. Galileo board with Wi-Fi shield configured

OpenCV Algorithm technique

The IoT-cam is positioned with an angled view of the parking space, acquiring a fixed scene. The code retrieves the frames from the streaming video using a prospective transform matrix. We have used the ISODATA method for thresholding to get a high degree of accuracy, and to consistently find the contours for each rectangle (car).

The IoT-cam, in a simulated environment, fixed in position at height 2.5 meter with a side view of the parking as in Figure 4.a.

	
Figure 4.a Shows the testing scenario of our prototype system outdoor	**Figure 4.b Shows the testing scenario of our prototype system outdoor**

· The main body of the code fully depends on the OpenCV library which has been used for video processing, to detect vacant parking spaces. Image pre-processing steps, including erosion, smoothing, noise reduction, blurring, contrast fix and brightness are applied to the uploaded images to get a uniform output from the camera input image. Then, edge detection and conversion of the image into a vector format is completed.
· One layer of the algorithm has been applied to detect vacant spaces in the parking lot using a contour method (rectangular detection) to identify the number of cars in the parking lot. The findRect method matches the detected shapes to the shape of a parked car, detecting the cars as rectangles. This data will be sent to the MySQL database through a MySQL connector, with a listing of all parking areas, number of possible spaces, etc., so the system can count how many parking spots are available. Using the marked parking spaces as bearings, the code can identify the center position of a car (see pseudocode below in Figure 3).

```
// variables are for checking car on part. If there is a car on parking spot 1, "occupied"
is true. If there is no car "occupied" is false

boolean occupied1 = false, occupied2 = false,... occupied20 = false;
// If a contour existed or detected (in the parking spot the contour is a parked car)
if(contours.size() != 0 )
{
// checking each contour
for(int idx = 0; idx < contours.size(); idx++)
          {
//To get bounders of rectangular of contour.
Rect contourRect=Imgproc.boundingRect(contours.get(idx));

// If bounding rect is between the two aspect ratio x,y.
if((contourRect.width < min_x)||(contourRect.height < min_y)||(contourRect.width
> max_x)||(contourRect.height > max_y))
                              continue;
// Get aspect ratio.
double ratio = [(double)contourRect.height /(double)contourRect.width];
          if((ratio < x)||(ratio > y))
                              continue;
If (The detected contour is a car)
    {
   // Draw rectangle of the car.
     R = rectangle of car,
   // Get the position of each car.
    Pi = center position of car(i),
   // Give each occupied parking spot an ID.
     ParkID(i) = occupied_parking_spot(i),
         }
```

Interaction with the Database

We are using a LAMP1 server as software platform. The system has real-time communication between the mobile app and the server, using a RESTful API. Each car park can be identified with labels, for instance (Park A, Space 1, 2, 3, 4 etc., so when a driver enters the parking area, they can easily identify each parking space. The main technique of the system is to monitor the system through IoT cams, while the video is processed by analyzing live streaming data and changes stored in a MySQL database. Figure 4 illustrates the UML use-case diagram for the interaction of the prototype.

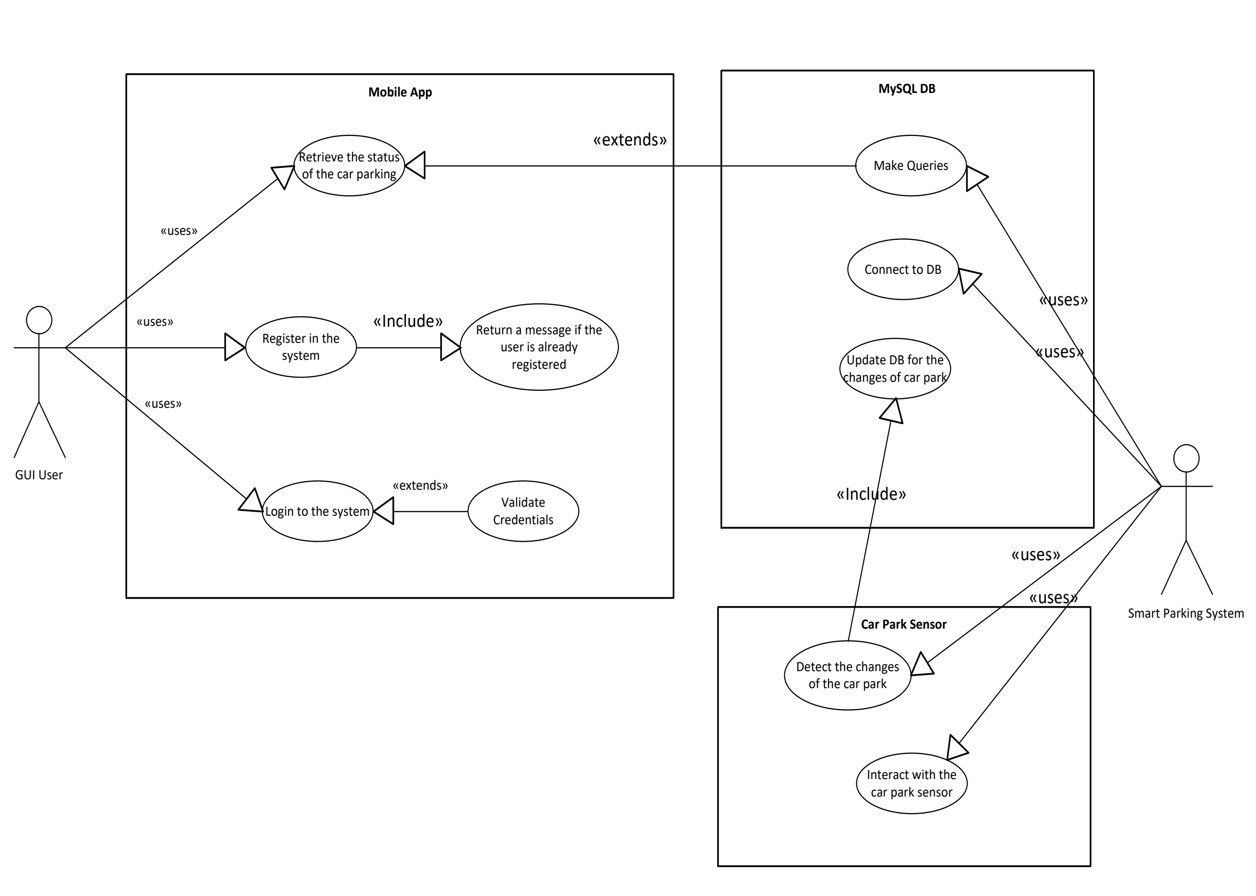

Figure 6 . UML use case diagram

Mobile App GUI

The mobile app is a key component, with a normal user interface for everyday use. Through the app, car parking information and services can be delivered to the user in a simple way. When users register with the system they are given unique IDs. Also the system is currently able to allocate another parking space to the user in the case of someone deliberately (or by mistake) taking a pre-booked space by clicking in the complaint button as it is illustrated below in the Figure 7. The proposed architecture utilizes RESTful based Web services as an interoperable application layer for communicating between the remote user and the system itself.

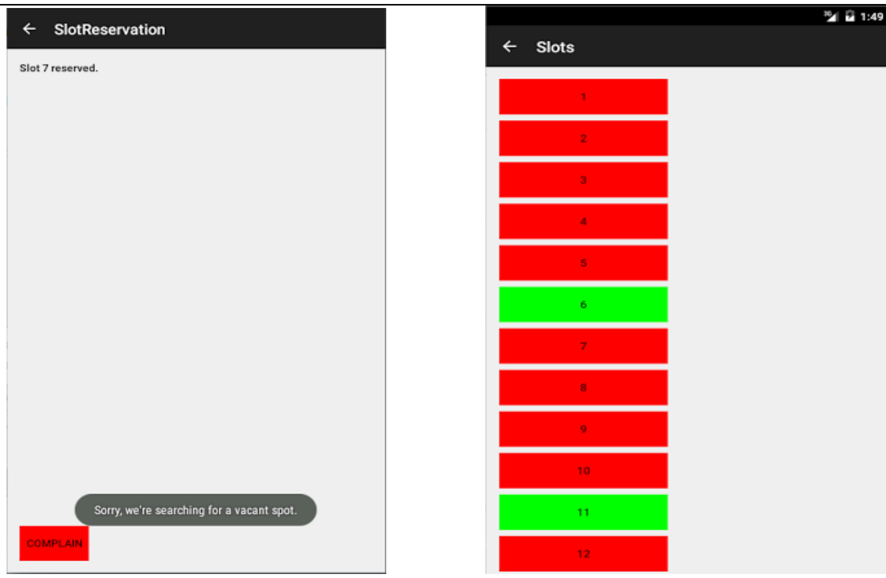

Figure 7. snapshots of different scenario from GUI

System Evaluation

A smart parking system based on CCTV (USB camera) have been proposed and tested in this paper. There are two codes written in Java, one called *SmartParkingSystemApp* (OpenCV Library) and the other called *SmartPrkingMobileApp* (GUI). The interaction between them is through MySQL database. The main purpose of the first code is to detect the statue or changes of the car park and send it periodically to the database real-time. At the same time, the GUI retrieves these changes to the user, Figure 3 shows the implementation of the system, shows red and green bottoms where the user can reserve the park space. The testing cases used to evaluate the functionalities of the system are listed in Table 1.

Table 1. Table 1 the testing cases of our prototype system

Test scenario	Result
MySQL connector can make a database update record according to status change.	Pass
Can the user reserve a specific parking space? as illustrate if Figure 9	Pass
Parking area status will update info to Parking Server (PS) when a car leaves the car park. as illustrate in Figure 9	Pass
Able the user to register in the system using GUI as illustrate if Figure 9	Pass

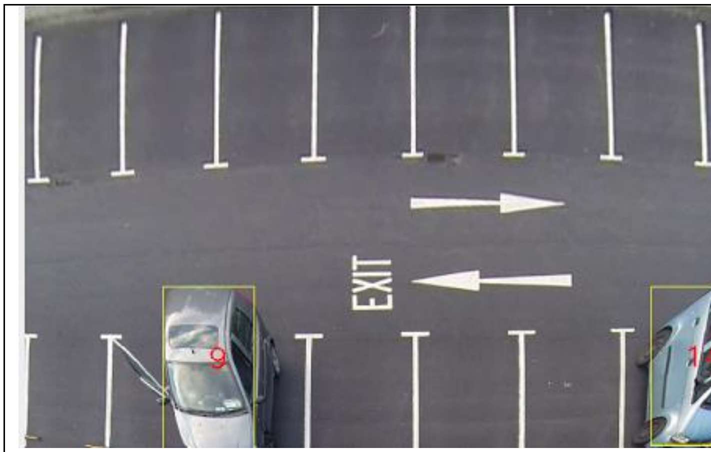

Figure 8. System outdoor deployment -snapshot from the parking server (PS) during implementation

Challenges and Discussion

As society increasingly relies on computer-based information systems to improve efficiency, smart parking systems are rapidly increasing in number. Smart parking systems may have become a necessity, especially in densely populated centres. While designing with a user-cantered design approach, some issues emerged regarding operational and other specific technical challenges. These challenges must be addressed from the very beginning to ensure that the system will work efficiently in situ. Another challenge before the UCD process began was the criteria to choose the stakeholders; in our case we chose from our background a driving (students, staff, and visitors) for visitors specifically we enlisted some friends to encourage them to engage in the process. As UCD need not be extensive or expensive, a few simple workshops early in development will significantly reduce the cost and increase the usability of an adequate prototype.

Regarding our prototype, we faced some challenges and problems during and after the first design iteration. The prototype's initial design was based on discussions with stakeholders (including the authors themselves), asking them to write short diaries, including a mini-questionnaire, to explain their parking experiences on a daily basis. All 15 stakeholders suggested designing a system which used smartphones or "a big board on the street" to give information about the vacant parking spaces. A few suggested using the CCTV cameras to monitor the status of parking spaces. After that, we started building our indoor prototype using a camera to monitor miniature model parking spaces. In our original simulation test, we used 10 parking spots and 15 cars. Our challenge was that the system would have no physical barriers to guarantee the pre-booked spot, so the users would have to trust each other and the system itself, although the management could make rules and apply fines for those not following the rules. The prototype is designed to eliminate the need to search for a parking space by driving around. When there is no parking space, the user is informed of this when they check in. The system may help the user save both fuel and time, while reducing emissions. To conclude; Our prototype system is a novel service in terms of being a cost and budget-efficient solution by enabling the existing infrastructure to become a smart system, and to become a part of the Internet of Things and designed upon suggestions from stakeholders from HCI point view.

A critical review of technology for smart parking systems as reported in the relevant literature was carried out. A major goal of this review was to gain clarity on the evolutionary patterns of smart parking. Previous research undertaken in this field was presented, highlighting how their results influenced the development of the smart parking field. The main contributions will be in the field of Internet of things and HCI. Facilitating the parking systems process by enable a camera (thing) to be a smarter thing using Galileo board (microprocessor) by providing a solution by links smart objects to the Internet. It can enable an exchange of data never available before, and bring users information by present an algorithm which aims to detect the vacant parking space.

Conclusion

Although much work has been done on smart parking, the work reported in this paper is almost exclusively based upon IoT cams. We propose a novel architecture for low cost and flexible smart parking using CCTV and smart phones. The system is intended to use previously installed CCTV cameras at any parking space instead of using dedicated systems, which would be more expensive.
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