14/04/2023

Applied research document

Fontys University of Applied Sciences | ICT

Fabiënne Leidekker
S3 SOFTWARE | VERSION 0.3

Version history

Version	Date	Author(s)	Changes
0.1	22-03-2023	Fabiënne Leidekker	Added document structure and research questions
0.2	09-04-2023	Fabiënne Leidekker	Introduction, problem definition
0.3	14-04-2023	Fabiënne Leidekker	Sub questions, Results, Conclusion, References

Contents

1 Introduction

Sioux Technologies is a strategic high-tech solutions provider that develops, innovates, and assembles complex high-tech systems globally. They have all kinds of competences, like electronics, mechatronics, embedded software, application software. They have multiple location, where their main location is in Eindhoven.

At their location in Eindhoven, they have a special car parking for guests when they meet with Sioux. The only problem is, is that it has limited spots and no way to keep track of the availability of the parking. So when a guest meets with Sioux and comes across a full parking lot, they will have to go to another parking that will take them at least an extra 10 minutes. This would cause confusing and give a bad first impression to the Sioux employee, because they have no notion of the late arrival due to the guest having to go to another parking. If there was a sensor system in place that would keep track of the parking lot, and that would also notify the guest of the availability, the guest could manage their time better and arrive on time so there wouldn’t be any confusing between the guest and Sioux.

But how can a system using sensors be created that keeps track of how many parking spots are still available? This paper sets out to be find an answer to the question: “Which sensor would be most suitable for Sioux to use and why?”. It first discusses the main and sub questions and list the research methods used, then goes on to answer each sub question. Then the results will be explained and lastly a conclusion to answer the main question will be given.

2 Problem definition

To answer and solve the main question, it will be divided into sub questions. Each sub question will contribute to answering the main question. Then a conclusion can be drawn that answers the main question.

2.1 Main question

What type of sensor would be most suitable and plausible for Sioux' parking situation?

There are a couple requirements to take into consideration, while answering these questions. Mainly, no budget has been set for the use of these sensors. Also, the guest parking at Sioux is an outside parking without a roof, that has between 20 to 30 parking spots.

2.2 Sub questions

A brief summary of Smart Parking

The research methods **literature study** and **SWOT analysis** will be used. I'll give an explanation of what smart parking is and how it originated. After that, a couple benefits of smart parking will be discussed.

What kind of parking sensors are used in practice?

This sub question will use the research methods: **Available product analysis** and **literature study**. I'll look at an existing product and describe how this type of sensor works. Other sensors could be explained by less specific sources.

What are the pros of the previous mentioned sensors?

When listing all the pros of each sensor, I'm basically searching for the strengths and opportunities, meaning I'm using the **SWOT analysis** research method.

What are the cons of the previous mentioned sensors?

When listing all the cons of each sensor, I'm basically searching for the threats and weaknesses, meaning I'm using the **SWOT analysis** research method.

How to mock the most suitable car detection sensor for the context?

When trying to mock out the scenario, I'll need to use **domain modelling** to sketch out the flow. And before **prototyping**, it's smart to look if other people have tried to mock a similar scenario by using the **available product analysis**.

3 A brief summary of Smart Parking

According to Karsten (2018) smart parking could be described as the following, “in a nutshell, Smart Parking is a parking solution that can include in-ground Smart Parking sensors, cameras or counting sensors. These devices are usually embedded in to parking spots or positioned next to them to detect whether parking bays are free or occupied”. The use of smart parking can be traced back to the early 2000. The first smart parking system was invented through a collaboration between 2 companies (Smart parking systems, n.d.). As the years went by, different types of sensors have come on the market, all with the mission to make the flow of looking for a parking spot more efficient.

This flow can be described more in-depth. It starts of by installing sensors near/on parking spots that collect real time data about the occupancy or even the time of stay. This data gets sent to a server and processes it. After that, the output can be communicated to the user via a mobile app or website. This informs the user of the availability of the parking (see figure 1).

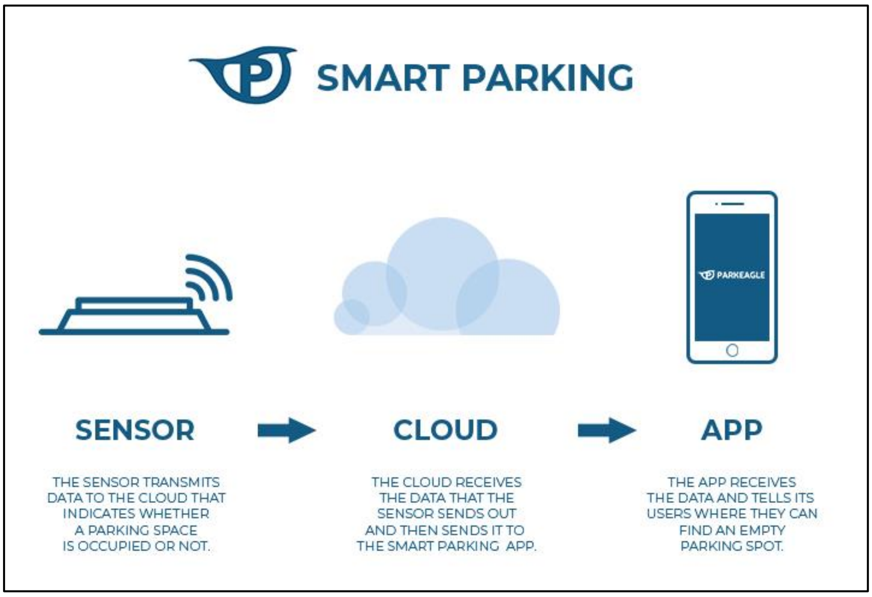

Figure 1: Flow of smart parking (Parkeagle)

There are also a number of benefits that smart parking has brought with it. Beside it just being more efficient and faster, it also contributes to a cleaner environment. Reducing the amount of traffic and time it takes to find a parking spot will reduce the amount of fuel that is being used. It also creates a safer environment. With the use of smart parking sensors, drivers can keep their attention, instead of having to look around stressed for an available parking spot. Lastly, the real-time data can be utilized for analysing metrics, like peak-times. All that data can be collected and used to make forecasting and predictions for possible future trends.

4 What kind of car parking sensors are used in practice?

In practice, different sensors are used. But to understand what kind of sensors there are, it is important to make a distinguish between the different categories. There are 2 categories in which the sensors can be classified and where each category has multiple different type of sensors.

1. Overhead/camera sensors
2. In/on ground sensors

4.1 Overhead / camera sensors

There are 2 types of overhead parking sensors. The ultrasonic sensor and the camera-based sensor. Camera-based parking monitoring uses image/video processing to identity if any cars are on the parking lot. So, it technically doesn't use a sensor, but instead a camera. Depending if the camera is indoor or outdoor, it could be connected to an LED display that shows the parking status (free or occupied) via colours to incoming drivers.

Another sensor that is used for indoor and outdoor use is the ultrasonic sensor. This type of sensor uses sound waves to detect objects. The sensor discharges sound waves that reflects on nearby objects. If it detects an object, a system controller processes the data and – if present – can send the status to an LED display.

4.2 In/on ground sensors

There are 3 types of sensors that can be in ground, on ground or used on both in and on ground. The magnetometer is one that can be used both on and below the ground. When mounted on the ground, withstanding the weight of a car is important. The LW009 sensor created by Moko Smart tackles this problem by making it out of "an impact-resistant shell with thickness and an external structure to ensure that the vehicle will not break even if it is run over". By nature, the earth has a magnetic field surrounding its surface. With an magnetometer, it's possible to detect distortions in that magnetic field caused by a ferrous object, like a car. The sensor can then send that information to a management system in real time, in order to decrease /increase the amount of available parking spots.

Another type of sensor is the optical infrared (ranging) sensor. This sensor can not be installed underground and consists of 2 parts: an emitter and a receiver. The emitter emits light and the receiver receives the light. There are 2 ways this sensor can be implemented, by placing the 2 parts on the same side of the wall and placing them across from each other, e.g. the ceiling and the floor. The first way uses a reflective approach. The emitter emits a light beam forward and the receiver does not yet receive anything. As soon an object, like a car comes into contact with the light beam, the beam gets reflected to the receiver (see figure 2). Now the receiver knows that a car has occupied this spot and can send the information to the management system. The second method start of with an uninterrupted beam between the emitter and receiver. When a car drives up to the parking spot and “breaks” the beam, the sensor knows that something is now occupying that spot and sends that information to the system.

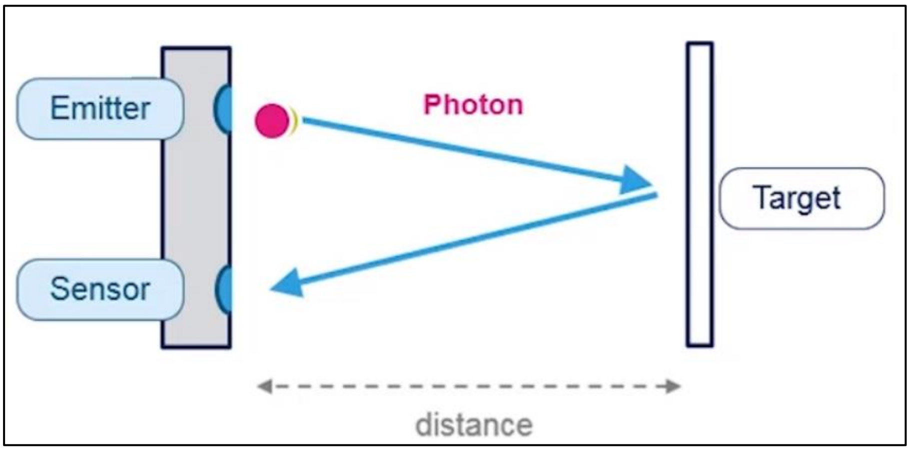

Figure 2: Infrared sensor method 1 (Farnell)

Lastly, there is the radar sensor. This sensor can be mounted on the ground or semi in ground. It uses a similar principle as method one of the infrared sensor. But instead of using light it uses reflecting radio waves. It can not be mounted fully under ground, otherwise it won’t be able to detect the reflected waves.

5 What are the pros of the previous mentioned sensors?

Now that the working of each sensor is clear, let's see what the pros of each sensor is.

Camera-based sensor:

- Can detect multiple spots at the same time, on a smaller parking lot, only one could be necessary
- Can often times also detect cars' license plate
- Could analyse if people park their cars correctly in between the lines
- 99% accurate and very dependable
- Can be used in indoor and outdoor parking garages
- Can be operated using renewable energy

Ultrasonic sensor:

- It is one of the cheaper ones
- It is powered by a battery, so no constant power connection necessary
- Works well inside a parking garage, but could also be used outside
- It has temperature compensation, which makes it insensitive to temperature changes
- Can be used in combination with infrared sensor

Magnetic sensor:

- It is cost effective
- Can be used wire and wireless
- Can be installed below and on ground
- Can be used indoors and outdoors
- It has accurate and repeatable responses
- Impermeable, even in severe weather conditions
- Detection rate is very high
- Often uses removeable battery, which lasts up to 5 years
- Can be used in combination with radar sensor
- Low current drain

Optical infrared (ranging) sensor:

- Very fast detection
- Very accurate
- Can "burn" through mist and steam, making it a reliable choice for environments with high water temperatures, such as car wash bays

- Often only used indoors
- Has ambient light rejection
- Not sensitive to material of target object

Radar sensor:

- Great for outdoor usage, but can also be used indoors
- Can detect moving and stationary vehicles
- Not impacted by environmental factors such as rain, wind, fog, humidity and air temperature
- Can detect vehicles from a distance (some from 7 meters already)

6 What are the cons of the previous mentioned sensors?

Each sensor also has its own drawbacks. In order to pass judgement to pick a suitable sensor, the disadvantages must also be considered.

Camera-based sensor:

- Can be quite costly (money and processing wise), so can't really be used in scalable manner
- Even though it can detect multiple spaces, there could still be an undetectable blind spot
- It needs a continuous power supply

Ultrasonic sensor:

- Battery + shell would take half a century to degrade
- It's less accurate (compared to the radar sensor)
- Knows less details about the parked vehicle, only if the space is occupied or not
- Can't make distinction between objects, so anything that passes between will be detected by the sensor
- Extremely power hungry

Magnetic sensor:

- Vulnerable to electromagnetic interference, when used near high-voltage power lines
- High-clearance vehicles such as trucks and vans are difficult to detect due to creating a stronger magnetic field deviation
- Electric vehicles of non-ferrous metals and carbon fibre may be much harder to detect

Optical infrared (ranging) sensor:

- It needs 2 mounting, for the emitter and receiver
- Can be affected by outside environment
- Has a much higher current drain (20x more compared to the magnetometer)
- More expensive (costs approximately 3x more than the magnetometer)

Radar sensor:

- More on the expensive side
- The use of the equipment may require specialized knowledge of high-frequency circuit design
- Radar signal processing requires much more motor control unit (MCU) horsepower

7 How to mock the most suitable car detection sensor for the context?

In order to create a prototype and look at other peoples' examples, it's good to know what kind of flow I need to create for my context. With the help of diagram.net I created a flowchart (see figure 3).

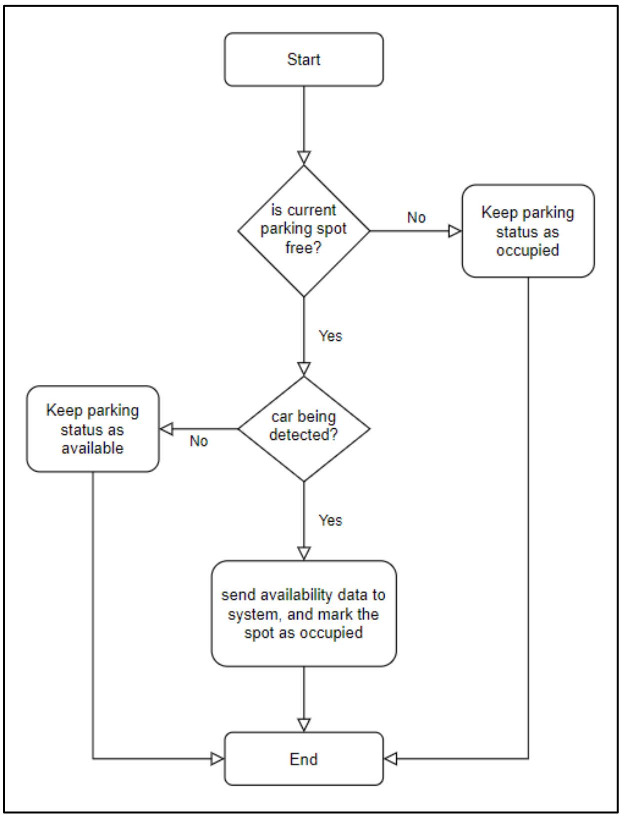

Figure 3: Flow of vehicle detection

Basically, when the sensor detects that the space is occupied it sends the status to the parking management system, otherwise the status will marked as available. As there isn't a budget, it would be the easiest to create a virtual prototype. One website that is able to do that, is Tinkercad. Tinkercad is a free web application that can be used for 3d design, electronics and coding. It's also possible to look at other peoples' work, so it's really easy to find examples. By doing that I can create my own circuit and prototype the flow. For creating the scenarios, a ultrasonic sensor was used. Out of the previously mentioned sensors, the ultrasonic one was the easiest to use. Some sensor also weren't available on Tinkercad. The images below show 2 scenarios, the car (green dot) has not entered the detection region, so the parking spot is still available (see image 1). The car has been detected, so the parking space is currently occupied (see image 2).

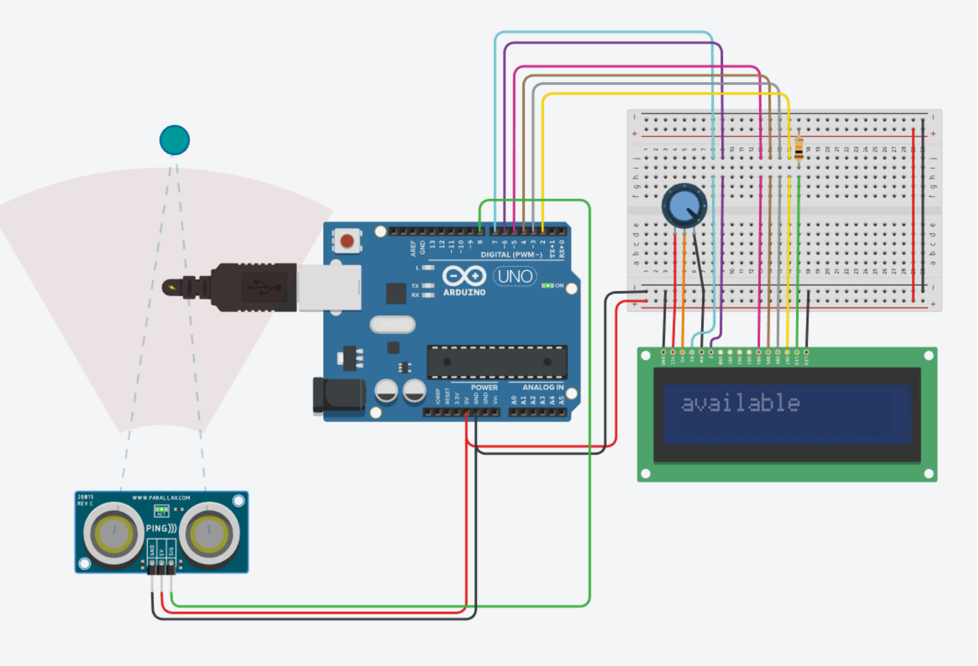

Image 1: Parking spot available

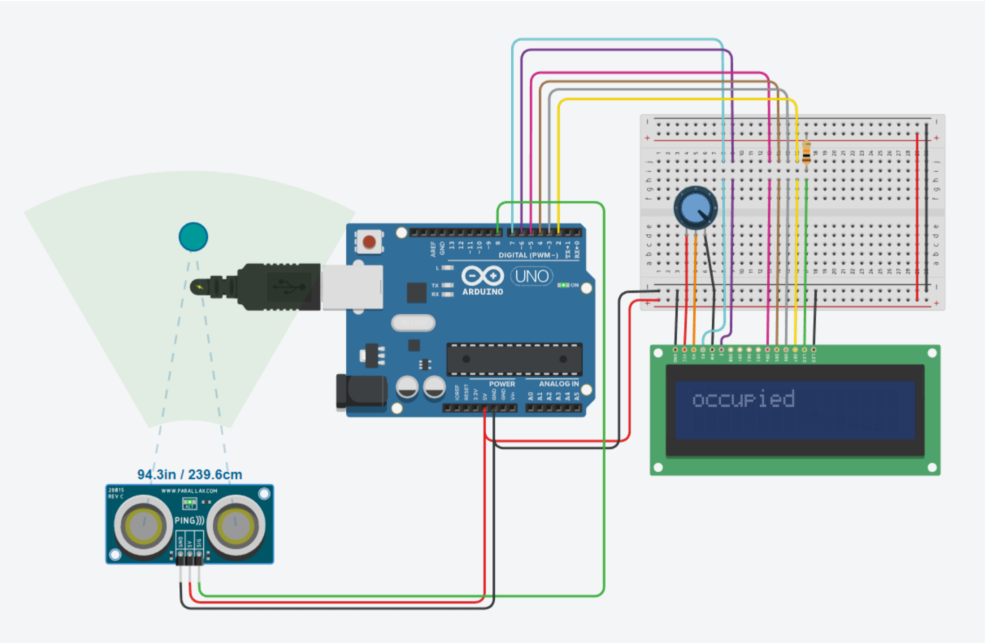

Image 2: Parking spot occupied

8 Results

After explaining and comparing all the sensors, there are a couple sensors that would work for the context. To repeat the specifications: there isn't a budget, so "cheaper would be better", the parking is outside in the open air and it has around 20 to 30 parking spots. The first sensor that wouldn't work is the optical infrared (ranging) sensor. Even though the detection isn't sensitive to the material of the object, and it has fast and accurate detection, it would be too affected by the outside environment and too expensive (money and current wise). The ultrasonic and the radar sensors also wouldn't be a good match. The ultrasonic sensor is one of the cheaper kinds, but it's also less accurate and extremely power hungry, which in turn would increase the costs. The radar sensor is great for outdoor and isn't affective by any outside environment, but it is more on the expensive side and requires a lot of MCU horsepower. The 2 possible matches are the magnetometer and the camera-based sensor. Even though the camera isn't technically a 'normal' sensor, it has the possibility to succeed in this scenario. It is on the more expensive side, but knowing it can detect multiple spaces (when positioned correctly) compared to the other sensors where each parking spot needs their own separate sensor could decrease the costs by quite a bit. It could very well be that only one camera would be required for the whole parking. In addition, it also has a high accuracy and it can do more than just detecting the availability. The other option is the magnetometer. One big pro is that it's cost effective, so the production costs wouldn't be to high. Also the current drain is low and the detection rate is high. But it should be noted that the detection rate could drop when non-ferrous cars or high-clearance vehicles would enter a parking space.

9 Conclusion

As Sioux wanted to know what sensor would be most suitable for increasing their parking/visiting experience, it is important to look at the possible sensors that are used in practice. By explaining, comparing the pros and cons and by mocking the sensor implementation, there is an even tie between 2 sensors. The magnetometer and the camera-based sensor. The tie could be resolved by knowing more about the actual implementation. If one camera would be enough for the whole parking lot, it would be more beneficial to use the camera, but if there are only a dozen or so parking spots, investing in separate magnetometers would probably be more beneficial. Maybe Sioux would want to know more information than just the occupancy, e.g. a license plate detection, then again the camera would be a better option. So depending on a couple more specifications, a clear line can be drawn.

10 References

Karsten, J. (2018, May 12). *What is Smart Parking?* Parkeagle.

https://www.parkeagle.com/2018/05/12/what-is-smart-parking/

About us > Smart Parking Systems - Intercomp Innovation. (n.d.). Smart Parking Systems - Intercomp Innovation. Retrieved April 12, 2023, from

https://smartparkingsystems.com/en/about-us/

Smart Parking Systems® > Smart Parking Systems – Intercomp Innovation. (n.d.). Smart Parking Systems - Intercomp Innovation. Retrieved April 12, 2023, from

https://smartparkingsystems.com/en/smart-parking-system/

Hughes, J. (2019, July 25). *10x Benefits of Smart Parking Technology (IoT).* Manx Technology Group.

https://www.manxtechgroup.com/10-x-benefits-of-smart-parking-technology-iot/

Nieves, J.M. (2021, September 9). *How to choose a Smart Parking sensor?* ThingPark Market

https://market.thingpark.com/blog/post/how-to-choose-smart-parking-sensor

Mohammed, B. (2022, August 9). *What Are The 3 Types of Vehicle Detection Sensors for Parking?* Precise ParkLink.

https://www.preciseparklink.com/news/what-are-the-3-types-of-vehicle-detection-sensors-for-parking?locale=en

Ultrasonic sensor. (n.d.). Parksol. Retrieved April 13, 2023, from

https://parksol.lt/solutions/ultrasonic-sensor/

Lee, N. (2022, November 10). *Why choose magnetic parking sensor as your wireless vehicle detection solution.* Moko Smart.

https://www.mokosmart.com/magnetic-parking-sensor/

Birchenko, Y. (n.d.). *Smart Parking Solutions – IoT sensors space race.* Farnell. Retrieved April 13, 2023, from

https://nl.farnell.com/smart-parking-solutions-the-iot-sensors-space-race

Why choose camera-based technology over others? (n.d.). Quercus. Retrieved April 13, 2023, from

https://www.quercus-technologies.com/news/why-choose-a-camera-based-guidance-system-over-other-parking-solutions

Parking Space Detection: Sensors vs Camera | Comparison Review. (n.d.). Parklio. Retrieved April 13, 2023, from

https://parklio.com/en/blog/parking-space-detection-sensors-vs-camera-comparison-review

Imran, M. (2022, July 4). *10 Best Vehicle Detection Sensors in 2022.* Folio3 AI.

https://www.folio3.ai/blog/best-vehicle-detection-sensors/#:~:text=It%20works%20by%20measuring%20the,flux%20due%20to%20vehicle%20passage

Infrared Optical Sensors for Vehicle Detection. (n.d.). Banner Engineering. Retrieved April 13, 2023, from

https://www.bannerengineering.com/th/en/company/expert-insights/infrared-photoelectric-sensor-vehicle-detection.html

Vehicle detection in parking lot. (n.d.). Sensor Partners. Retrieved April 13, 2023, from

https://sensorpartners.com/en/applications/voertuigdetectie-op-parkeerplaats/