UDC 004.89: 004.3
DOI: 10.31891/CSIT-2021-3-7

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NEURAL NETWORK BASED IMAGE RECOGNITION METHOD FOR SMART PARKING

Currently, the issue of creating smart parking lots is extremely important due to the rapid growth of number of cars, especially in big cities. Thus the need for parking spaces and search facilities still remains an urgent problem. Assuming that every day the average motorist spends 20 minutes searching for such a place, this is about 120 hours a year, which could be spent on something more useful. Today, there are many projects of "smart" parking, but practical examples can be counted on the fingers, and information about the cost-effective aspect of their implementation is generally very limited. The paper provides analysis of the most common methods and tools for smart parking and proves the advantages of camera-based method. The research in general is aimed at image recognition for camera-based smart parking using convolutional neural network.

Keywords: Video-Image processing, Smart Parking, Smart City, Deep Learning, Convolutional Neural Network, Machine learning

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МЕТОД РОЗПІЗНАВАННЯ ЗОБРАЖЕНЬ ДЛЯ РОЗУМНОГО ПАРКІНГУ НА ОСНОВІ НЕЙРОННОЇ МЕРЕЖІ

Наразі питання створення розумних парковок є надзвичайно актуальним, особливо у великих містах. Зі зростанням кількості автомобілів збільшується потреба у кількості паркувальних місць та засобах їх пошуку. Якщо припустити, що кожен день середньостатистичний автомобіліст витрачає 20 хвилин на пошук такого місця, в рік це близько 120 годин, які можна було б витратити на щось більш корисне. А якщо взяти до уваги той факт, що "нарізаючи" коло за колом в пошуках вільного місця збільшується й вірогідність потрапити у ДТП - інформація про вільне місце може бути безцінна. На сьогодні існує безліч проектів "розумних" парковок, але практично реалізовані приклади можна перерахувати на пальцях, а про економічно-вигідний аспект їх реалізації інформація взагалі дуже обмежена.

Сьогодні існує багато проектів розумного паркування, але приклади готових до використання можна перерахувати на пальцях, а інформація про економічно вигідний аспект їх реалізації, як правило, дуже обмежена. Слід мати на увазі, що при розробці таких інструментів найбільшу фінансову частину розвитку породжує програмне, а не апаратне забезпечення. Навіть у відносно дорогих сенсорних системах на основі магнітних, радіо та інфрачервоних датчиків головне - це взаємодія користувача з апаратними компонентами, описаними вище. В ідеалі інтерфейс повинен бути у вигляді сітки паркувальних місць, яка повинна чітко і без зайвих рухів показувати користувачеві, вільні вони чи ні.

Тому проблема пошуку вільного місця для паркування на громадській автостоянці актуальна в наш час. Оскільки уряд активно розробляє систему розумного міста, розумна громадська автостоянка з низькою вартістю та високою доступністю для всіх мешканців міста має стати невід'ємною частиною цієї системи.

Ключові слова: обробка відео, розумні парковки, розумне місто, глибинне навчання, згорткова нейронна мережа, машинне навчання.

Introduction

Currently, the issue of creating smart parking is extremely important, especially in large cities. As the number of cars increases, so does the need for parking spaces and search facilities. Assuming that every day the average driver spends 20 minutes searching for such a place, this is about 120 hours a year, which could be spent on something more useful. And if take into account the fact that driving circle after circle in search of a free place increases the probability of getting into an accident - the information about a free place can be invaluable.

Today there are many smart parking projects, but ready for use examples can be counted on the fingers, and information about the cost-effective aspect of their implementation is generally very limited. It should be born in mind that when designing such tools, the largest financial part of the development is born by the software, not hardware. Even in relatively expensive sensor systems based on magnetic, radio and infrared sensors, the main thing is the user interaction with the hardware components described above. The interface should ideally be in the form of a grid of parking spaces, which should clearly and without unnecessary movements show the user whether they are vacant or not.

Therefore, the problem of finding a vacant parking spot on public parking is relevant nowadays. Since the government is actively developing a smart city system, smart public parking with the low cost and high accessibility for all the city dwellers should be an integral part of this system.

State-of-the-art

With the growing level of urbanization and the increasing number of cars in large cities, the problem of parking has become interesting not only from an applied point of view, but also from a scientific point of view, since it was necessary to find new rational ways to park cars, such as the concept of a smart city.

This problem has been considered in the works of many scientists around the world. Lookmuang et al. [10] propose and develop a prototype using an embedded controller, Raspberry Pi 3, ultrasonic sensor, and a camera, with the aim of localizing vacant parking spots. Similar approaches are contributed by Vakula et al. [11] and Grodi et al. [12]. In particular, Grodi et. al. discuss the advantages and disadvantages of multiple sensor types, such as induction proximity, RFID, light/ranging detection, and camera. In both cases, the authors chose to use an ultrasonic sensor for detecting when a vehicle was parked on a parking spot. Maine et al. [13] present another smart parking system, which combines different IoT technologies, such as ultra-high frequency RFID (UHF RFID), Wireless Sensor Network (WSN) and Near Field Communication (NFC).The work done by Patane et al. [14] is an example of a vacant parking spot detection system that makes use of a vision-based system. A similar approach was contributed by Amato et al. [5], where a collection of approximately 150 000 images were trained for classifying vacant parking spot.

But the above mentioned works do not present any ready-to-use solution for a smart parking system which provides fasr and easy acces for the user with the low installation and maintanence cost. Therefore research of smart parking solution methods still remains an urgent issue.

Research of known methods and solutions in the smart parking domain

Today, there are multiple proposed systems that are being utilized for finding vacant parking spots, where small sensors are placed on each parking spot or cameras are positioned next to them, keeping track of vacant parking spots [1] [2]. However, these solutions require a power source and often maintenance of each of the sensors. Each solution has some benefits and drawbacks based on the sensor technology that is used to determine the state of the parking spots.

1. Ultrasonic Sensors

Today ultrasonic sensors are commonly used for a wide variety of applications, such as noncontact presence, motion detection, proximity, or distance measuring. Some of the main application areas for ultrasonic sensors are water and wastewater, mining, general industry, chemistry, and petrochemistry [3]. Ultrasonic technology is among the most preferred technologies for smart parking systems.

2. RFID

The RFID technology has been widely used in industry, electronic commerce, credit-cards, IDcards and so on. Today, RFID is one of the key core technologies for the development of the Internet of Things solutions [4]. In particular, one of the application areas for RFID technology is parking solutions.[9]

3. Magnetic Sensors

The use of magnetic sensors can be very useful when developing a system for detecting vacant parking spots. Since the magnetic sensors rely on the magnetic field of the Earth, it can detect when there are some anomaly changes, such as when a car is parked over the magnetic sensor.[9]

4. Camera

Although sensors are widely used for vehicle detection they have some drawbacks. One of the main drawbacks is scalability, since the need to use one sensor per parking spot may be an expensive solution. To overcome this issue, vision-based systems can be used for vehicle detection [2]. This type of systems can provide a more scalable solution than a sensor-based system. A camera, which is placed in a location that covers a wide view of a parking area can be used to determine the status of several parking spots.

In order to evaluate the smart parking techniques, a summary of the common characteristics of smart parking solutions are derived in Table 1. The estimated characteristics presented in the table below may vary depending on the number of parking places that the smart parking system covers.

Table 1

Comparison of different parking detection techniques

	Ultrasonic sensors	RFID	Magnetic sensors	Camera
Installation Cost	HIGH	HIGH	HIGH	LOW
Maintenance Cost	HIGH	HIGH	HIGH	LOW
Hardware Cost (Per unit)	LOW	LOW	LOW	MEDIUM
Power Consumption	LOW	VARYING	VARYING	HIGH
Relocation Possible	HARD	HARD	HARD	EASY
Hardware Complexity	HIGH	HIGH	HIGH	LOW
Software Complexity	LOW	LOW	LOW	HIGH
Scalability	LOW	LOW	LOW	HIGH
Reliability	HIGH	HIGH	HIGH	HIGH
Vehicle identification	NO	YES	NO	YES
Obstacle Recognition	YES	NO	VARYING	YES
Vehicle Recognition	NO	YES	YES	YES
Additional Requirements	-	Privacy & all vehicles need to have an RFID tag	-	Privacy and Security issues

Thus, from the above table a conclusion can be made that the method of smart parking using camera is much more effective than others, taking into account most of the factors considered. In addition, since most of the parking lots are usually located in public places, privacy and security factors also should be taken into account.

Neural network based method for image recognition

Let us consider the smart parking system which consists of the following hardware and software components (Fig.1).

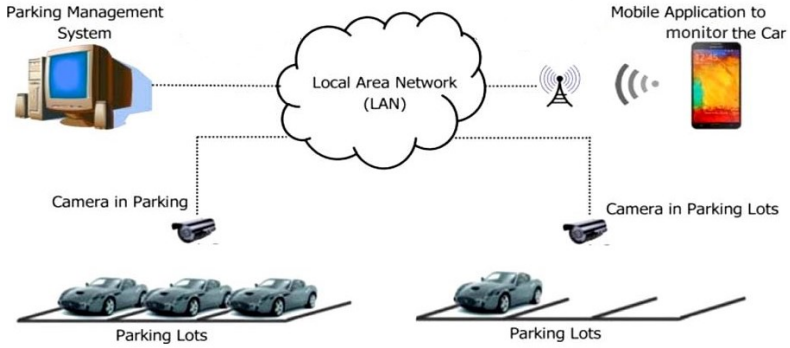

Fig.1. Model of the proposed Smart Parking System [8]

As it can be seen from the model, camera is the main tool that performs the analysis of the parking spot state. Therefore detecting a vacant or occupied spots is an important issue for such Smart Parking System development.

Object detection using deep learning

Deep learning is a subset of Machine learning (ML), where it uses neural networks with multiple layers to learn from patterns.

Despite the recent advances of deep learning, there is still much more to contribute and improve in this area. The use of deep learning in vision-based solutions has in the past years been widely used for recognizing objects. Deep learning works in a way that requires a trained model before being able to classify the objects [6].

The neural network in deep learning consists of three main layers: the input layer, the hidden layer, and the output layer. The input layer consumes the information, in the case of image recognition this would be the image data. In the next step, the nodes are weighted in the hidden layer and then processed in the output layer, which return the classiffication result based on the weights [6]. A representation of a neural network can be seen in the Figure 2 below.

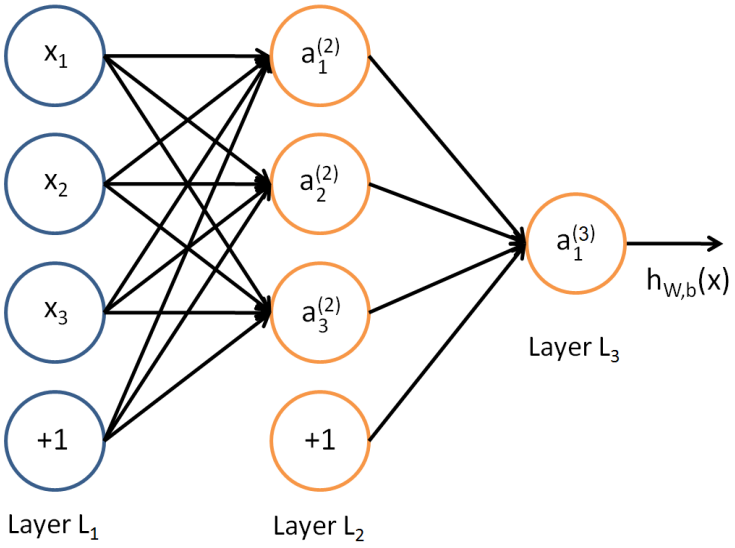

Fig.2. Representation of a Neural Network [6]

Convolutional Neural Network

When handling a vision-based solution, where recognition is needed of an object, convolutional neural network (CNN) can help to effectively recognize patterns in the image. Amato et al. [5] describe that the huge amount of hidden layers in CNN are used in order to handle the input and provide a result as an output. A large number of hidden layers improve the detection accuracy when deciding what the recognized objects are, resulting in the output.

Convolutional Neural Network (CNN) is a deep learning algorithm, which is a subclass of the neural network. The CNN architecture is used mostly for detecting objects in images, due to it is constructed to handle large sized images, which the ordinary neural network does not handle.

This is possible due to that the CNN architecture handles the images as volumes, consisting of depth, width, and height. When the data transfers between the input layer to the hidden layers, data is being processed and filtered between the layers by using neurons, which try to find patterns in these images.

Data training is an important requirement for the CNN approach. Before starting the object detection, a data-set that contains images of the desired object must be collected. The objects in images should be defined by labelling each object separately. After the labelling process, the data-set is ready to be trained. During the training, the data is filtered in the hidden layers in order to find and specify what similar patterns all the images share together. These patterns are parameters that provide a specific description of the object/objects; the parameters which helps to learn how the specific object looks like.

Nevertheless training a model for object classiffcation it can be very expensive from a computational and time perspective. This is due to the number of iterations needed for the network to find and understand the layers in the neural network, requiring a decent graphics unit to perform the training. [9]

Clustering

Clustering is commonly used within ML, and it is useful for classifying objects that are unlabeled.

Clustering is an unsupervised learning method, i.e., data that is not labelled, thus the clustering algorithm labels the data by adding similar data together in the same cluster. This is possible by calculating the distance between the different data points and afterwards associate similar data together. Moreover, clustering is useful for detecting anomalies in the data, preventing the clusters from being affected by outliers in the data that might have been collected due to a measurable error [6].

Image Processing

The idea with image processing is to interpret an image in order to extract essential information needed for the desired purpose. This can be compared to the human eye and the perception, which help the human to get a visual image of the world and understand the state of an environment.

The aim with image processing is to replicate the same function, but instead use it in machines. Today, image processing is widely used in different areas, such as inspecting faults in electronic circuits, medical diagnosis or object tracking for surveillance purposes [7].

Fig.3. The Three Basic Steps in Image Processing [9]

Thus the proposed system will be based on a CNN deep learning technique which will be used to create a software for recognition the image of the parking spot and detecting whether it is vacant or occupied.

Therefore, the proposed method of Image Recognition based on Neural Network consists of the following steps:

- Capture the images of the parking area using camera;
- Divide each frame into patches where each of the patches contains a single parking space;
- Classify each patch using a trained CNN in order to decide if the parking spot is occupied or not.

Discussion and directions of further work

In order to develop our smart parking prototype, the first step is to investigate the needed functionalities and requirements that are important for this type of system. Investigating these functionalities and requirements would enable to understand the development process of the complete system.

Installing a camera in a publicly available area requires a permit form camera surveillance. An important factor that should be taken into the account is this privacy issue that comes with vision-based solutions.

Sending images to a server or cloud through the Internet comes with security issues as well. In order to handle this security issue, some encryption process may be used. All of these limitations may affect the usability of the system in a negative way. Performing image processing tasks in the place, where the images are captured without storing or sending any image data through the Internet may help to avert these issues mentioned above. Hence, the privacy and security aspect should be considered as a requirement of a smart parking solution.

As a result, the following requirements diagram was developed based on the above mentioned factors:

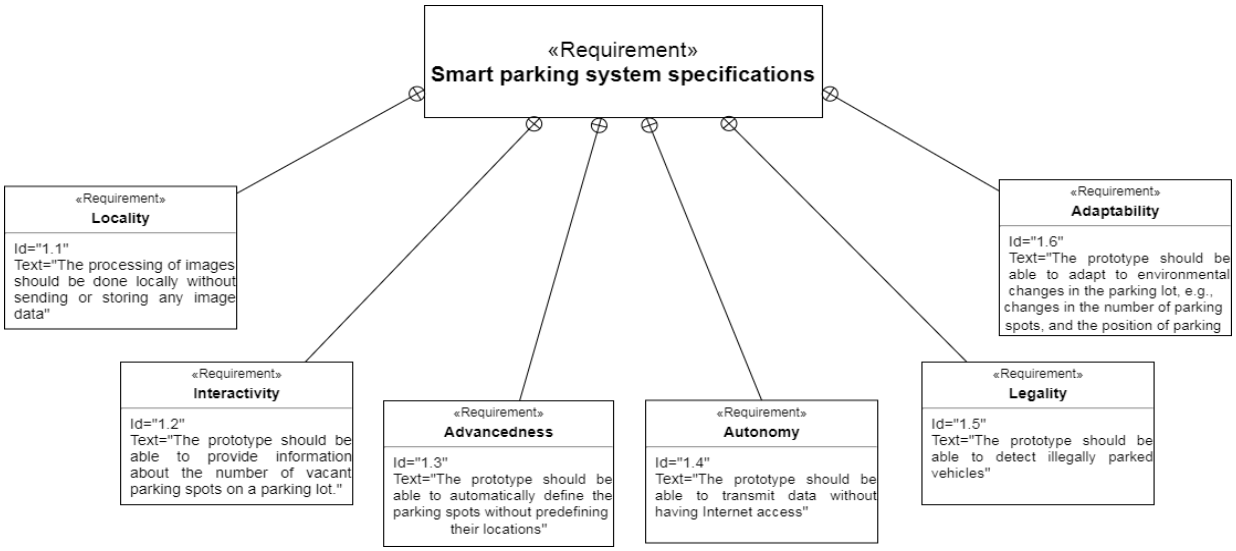

Fig.4. Smart Parking System Requirements Diagram

A vision-based smart parking system may include different subsystems, e.g., cloud, visualization platform, and database. The focus of this study is to build a prototype that is responsible for capturing images, extracting the parking occupancy information from those images and sending this small sized information to a platform. Choosing the best data transmission technology, visualization platform and data storage are out of scope for our study.

Based on the requirements diagram presented above, the problem breakdown flow was developed in order to get a general overview of the different subproblems of the system. Each subproblem contains a set of tasks that are needed in order to solve the subproblem. To solve the main problem, four subproblems were derived: parking spot detection, data transmission, hardware choice and configuration, and integration. The main focus of this study is to solve the subproblem parking spot detection. The problem breakdown flow is illustrated in the Fig.5.

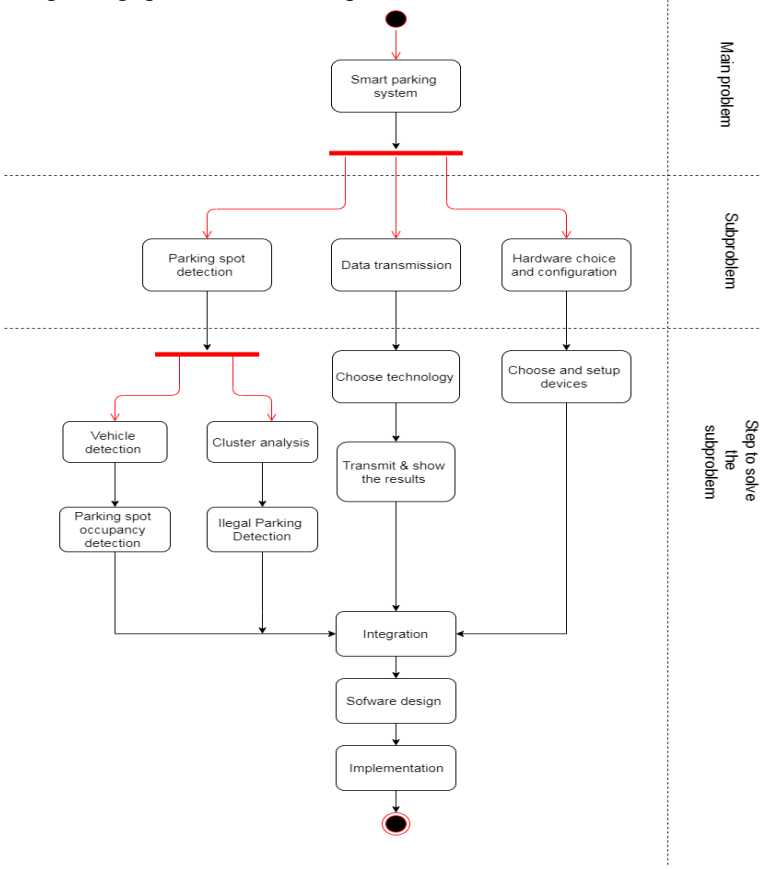

Fig.5. Problem Breakdown Flow

According to the Fig.5, the main steps of the research are the subproblems, highlighted with red arrows.

Parking spot detection

In order to build a dynamic smart parking system, parking spots should be detected automatically. This task can be performed by using an object detection algorithm. The chosen approach for detecting the parking spots is vehicle detection using deep learning technology. The chosen approach is based on its simplicity of detecting the parking spots on a parking lot.

Another approach that can be used for detecting parking spots is line detection. However, this approach has some drawbacks, i.e., that lines may be erased or blurred over time or may be simply covered with snow.

Data transmission

The purpose of data transmission in the system is to transmit the data to a server where the parking information can be registered. The transmitted data aims to give information about the status of a parking lot, i.e., how many parking spots are available and how many of these parking spots are unoccupied.

Hardware choice and configuration

The hardware that can be used in this system consists of three different parts: the camera part, the computer part, and the user interface part. The camera's purpose is to capture images of the parking lot and send them to a single board computer. The computer's purpose is to perform the calculations and image processing on the images that is received from the camera in order to detect the parking spots. A transmission device is used to transmit information about the parking lot to a server, e.g., parking lot id, how many available spots, and how many are unoccupied. The user interface part may be developed in the form of mobile application.

Integration

Once the parking spot detection, implementation of the chosen data transmission technique and hardware selection are done, these different parts need to be integrated into one system.

Conclusions

Currently, the issue of creating smart parking is extremely important, especially in large cities. Since the number of cars increases, there is steel the need for parking spaces and search tools which allow user to find the parking space remotely, using mobile phone, for instance. Therefore, finding the best technology for smart parking today is an urgent task.

In this paper the known tools and technologies for smart parking have been considered, taking into account installation cost, maintenance cost, hardware cost, power consumption, hardware and software complexity and other criterias. Thus, from the above mentioned facts a conclusion can be made that the method of smart parking using camera is much more effective than others. In addition, since most of the parking lots are usually located in public places, privacy and security factors also should be taken into account.

Problem breakdown flow and requirements diagram have been created, and it has been concluded that the neural network image recognition method will best cope with the above mentioned tasks.

Thus, work on all the above mentioned subproblems and development of smart parking system using image processing method is the aim of further research of the authors.

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