UNIVERSITY OF NAIROBI

SCHOOL OF COMPUTING AND INFORMATICS

AUTOMATED CAR PARKING SPACE DETECTION USING DEEP LEARNING

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Aug, 2021

Declaration

I hereby declare that this thesis is my own work and has, to the best of my knowledge, not been submitted to any other institution of higher learning.

Signature: .... **... Date: ...25 –AUG-2021............**

Name: Samuel Ndiva Murani **Registration Number: P52/34358/2019**

This research project has been submitted for examination towards the fulfillment for the award of the degree of Masters in Computational Intelligence with my approval as the supervisor.

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School of Computing and Informatics

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Signature: .... **Date**: 1st Sept 2021

Dedication

This research project is dedicated to my Parents, Wife and Daughter Eliana Samora Njoki for their support during my Master's project.

Acknowledgement

I would like to acknowledge God above all for giving me the opportunity and resources required to pursue my Master's degree from the University of Nairobi. Secondly, I would like to thank my Parents Mr. & Mrs. Murani, my wife and daughter Eliana, and my siblings for always believing in me and encouraging me to keep moving despite the tough academic journey. I would also like to thank my classmates, Robert Kegunya and Kennedy Njoroge for the wonderful learning discussions we had and encouragements throughout this journey. Most importantly, I would like to thank Dr. Lawrence Muchemi and the entire panel of Prof. Peter Waiganjo and Dr. Samuel Ruhiu for their patience and guidance during the project research journey.

Abstract

Parking space detection is a major challenge in our cities and drivers waste time when moving from one place to another in search of a free parking space. The current parking space detection systems available are based on sensors which are costly to install and maintain. The sensor systems cannot also be used outdoor environments such as in cities as the sensors can be stolen or vandalized. This study compared the performance of M-RCNN and YOLO algorithm which are a deep learning algorithms used to classify images. YOLO was seen to be the best to use in this study because it was able to run under low comping resources and give accurate predictions. It was thus used to develop a prototype that was used for detecting the status of parking slots as either empty or occupied.

The solution was verified by feeding it with a parking area video stream that had vehicles coming and leaving the parking area and monitoring how well its able to identify the vehicle objects from other objects and how well it is able to predict the status of a parking area as either vacant or occupied. The model achieved an accuracy of 92.6% in parking space status detection. Our experiments showed that the model proposed can be used to achieve automated parking space status detection in any marked parking area.

Definition of Terms

- **Parking Slot**: An area designated for parking vehicles.
- **Deep Learning**: Form of machine learning where human brain functions are mimicked in terms of processing information and drawing patters for decision making.
- **Automated Parking**: Process devoid of human control.
- **CNNN**: Convolution Neural Network
- **M-RCNN**: Mask Region Based Convolution Neural Network
- **YOLO**: You Only Look Once

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Chapter One: Introduction

1.1 Background

Identification of parking spots in cities is a challenge especially during peak hours when people are reporting to work. An average of 7-8 minutes is spent by people cruising for a parking spot in the city which contributes to 30% of the traffic in the cities (D.Azshwanth, 2019). Most Motorists who park their vehicles in Nairobi Central Business District are forced to wake up early so that they can find uncopied parking spots (Musulin, 2017). To alleviate this problem, suggestions on how to solve city parking spots have been given but majority have not been effective. An example, in Nairobi City, it had been suggested that parking fee should be doubled so as to make people leave their cars at home but the proposal was rejected by the courts (Mediamax Network Limited, 2019). Other suggestions such as increasing the number of parking spots have also been suggested but the solution is not sustainable due to the increasing urbanization.

Computer Vision and deep learning algorithms can be applied to solve the parking spot detection in cities and shopping malls. This will involve training a model to be able to recognize parking spaces from other spaces, and vehicle detection. When parking spots and vehicles are detected, classification can then be applied to distinguish between a parking spot that has been occupied by a vehicle from one that is not occupied. This information can then be mapped to a user interface which drivers can use to check for parking spots in the city and in shopping malls. Drivers with thus be empowered with knowledge on where to locate a vacant parking area thus saving on time and preventing traffic congestion in the city.

Suggestions to use Bluetooth technologies and sensors have been recommended, however this is an expensive as it requires the existing parking slots be revamped and it is not applicable in open parking areas due to vandalism of the materials. This thus makes computer vision a good approach as it involves use of a camera which is strategically position to view the parking spots. The training and recognition of empty and occupied parking spots is done using machine learning algorithms such as convolution neural network which has enhanced object detection capabilities (Girshick R, 2015).

Computer Vision Parking spot detection System using deep learning can be based on two approaches, i.e. Object detection and Image classification (Rivano & Mouël, 2017). Image classification, an image if first captured by a camera and parking spaces are identified and segmented into individual parking slots where Convolution Neural Network (CNN) is used to predict each individual parking spot as empty or occupied. With Object detection technique, a neural network functions as a car detector which keeps a count of all cars that have been detected.

1.2 Problem Statement

With the growing economy and immigration of people from rural areas to urban areas, the number of vehicles coming in the cities has increased. According to (Musulin, 2017), most drivers get frustrated when trying to look for parking space in major cities in the world. In a survey conducted by IBM, Nairobi City was listed as the eight most difficult city for one to find parking space (Armonk, 2011). This is due to the time that one has to spend trying to look for parking space which is always not guaranteed. The time one spends looking for parking space does not only affect the person alone but it also leads to increased traffic in the city.

Suggestions such as increasing parking fees in cities and malls have been proposed as the solution to end the parking problem but this has not worked (Musulin, 2017). This was seen as a measure to force people to use public transport and thus leave their cars at home, however the proposal was not adopted by the court. Increasing the number of parking spaces in the city could help solve the parking space problem, however as a city develops this measure becomes unsustainable. To solve the parking problem in our cities, computer vision and deep learning technologies can be adopted to provide drivers with information about where to find free parking spaces in the city.

1.3 Research Objectives

The objectives of this research are:

i. To investigate the application of computer vision technologies in parking space detection.
ii. To investigate features of machine learning algorithms such as Region Based Convolution Neural Network, Faster R-CNN and YOLO algorithms on accurate detection of cars and parking spaces.
iii. Design a model for detecting parking spaces based on an optimized machine learning algorithm.
iv. Implement a prototype based on the above model for automated and real time parking spot detection.
v. Evaluate the performance and accuracy of the model using independent data.

1.4 Research Questions

The research questions that guided this study are:

i. How can parking spaces be detected using computer vision and machine learning?
ii. How to distinguish a parking space that has been occupied from one that has not been occupied?
iii. How to distinguish between cars parked in a parking space and other objects.

1.5 Scope

The scope of this study was limited to development of an efficient machine learning model that can detect and distinguish vehicles from other objects in a parking area under different lighting areas and weather conditions.

1.6 Significance of the Study

Application of an efficient machine learning and computer vision in developing an automated parking space will aid:

i. Better planning

This being a real time tool, drivers will be able to check in advance the state of parking spaces the city or malls and decide whether they will leave their vehicles or they can look for parking in areas that the system will show are less busy. City and mall managers will also have data to guide them when increasing or reducing parking spaces.

ii. Better Traffic Control

(Musulin, 2017), says that vehicles that stop to look for parking spaces are the major causes of traffic in the cities. Through having a parking space detection system, drivers will not be moving round the city looking for parking space thus aiding in traffic control.

iii. Improved Revenue Projection

Through the parking space detection system, approximation about the number of vehicles which park in the city can easily and accurately be achieved. This can then be used to project the expected revenue based on the number of cars parking and the time spent by each car. Accurate revenue projection will lead to increased developments in the cities.

Chapter Two: Literature Review

2.1 Background

According to (Mediamax Network Limited, 2019), parking spot identification is a major issue in the city which has been the cause of traffic. There have been suggestions on how to decongest the city through restriction of the number of cars that enter the city but these suggestions have not worked. Technological enhancements in computer vision field have provided solutions which have been assisted in automated parking slot detection through machine learning. This section looks at the existing solutions and enhancements of the computer vision algorithms that have been developed.

According to (A. Al-Dweik, 2017), parking solutions can be divided into four categories: Counter Based Systems, Sensor based Systems and Image Based Systems.

2.1.0 Counter Based Systems

The counter based systems work by having sensors at the entry and exit places of parking areas. These systems count the availability of parking spaces by getting the difference between the cars counted at the entrance and the cars counted at the exit place of the parking place. The difference gotten is then subtracted from the total parking space which gives the count of available parking spaces in the parking area. In case the count of available spaces is zero, then the entrance does not open until there are available parking slots. This method however cannot be applied on street parking spot detection.

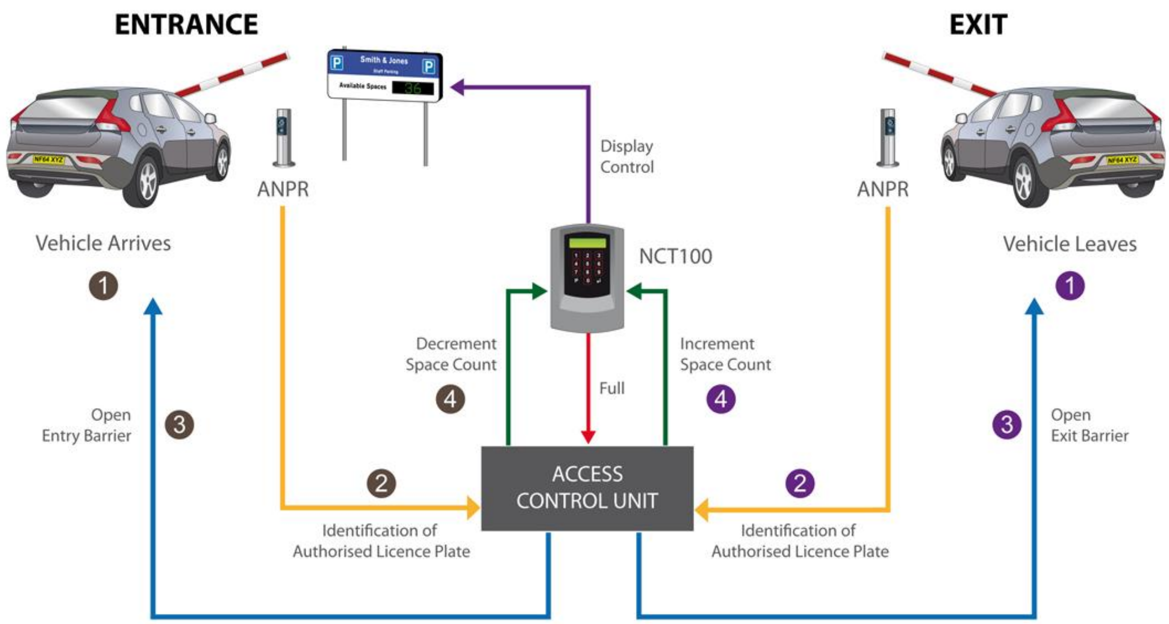

Figure 1: Counter Based Systems for Parking Slots

(https://www.nortechcontrol.com/media/77182/anpr-with-counting-web.jpg)

2.1.1 Sensor Based Systems

Sensor based systems (Wireless sensor and wireless magnetic sensor based systems) use infrared light, ultrasonic or wireless magnetic sensors that are deployed on every parking space (Ichihashi, 2016). This technology has worked well in shopping malls and private parking spaces; however, the technology is expensive due the high cost of the sensors installations required. The technology is not also applicable in street parking as the sensors can be vandalized or stolen.

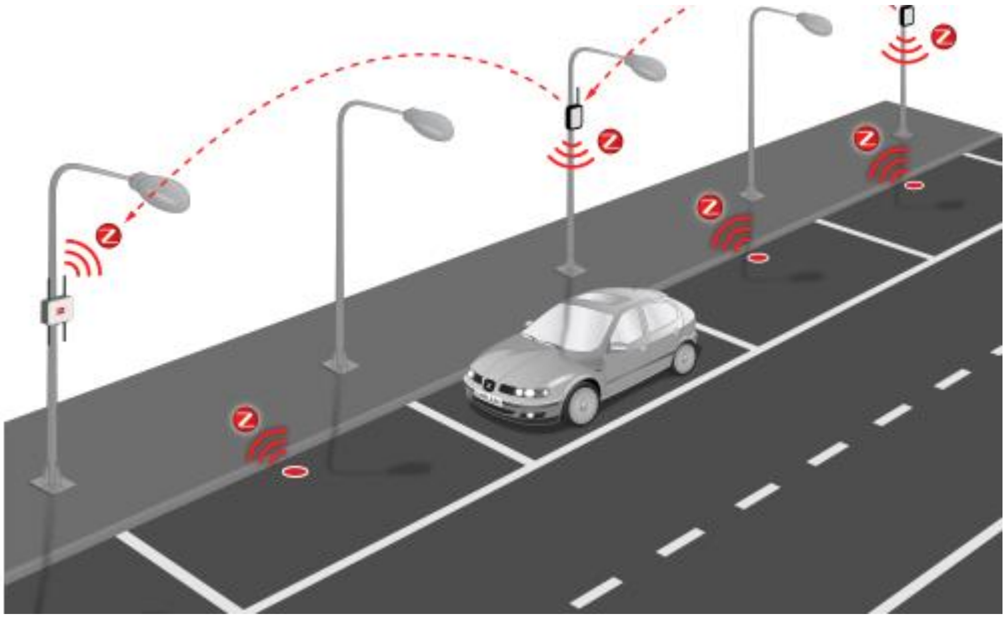

Figure 2: Sensor Based Parking System

(https://www.libelium.com/libelium-images/generico2/smart_parking_sensor_board-recortada-med.png)

2.1.2 Vision Based Systems

Vision based systems rely on the use of cameras to detect images and deep learning to train the models to be able to detect parking spaces which are empty and which have been occupied. According to (Girshick & Donahue, 2015), research has been done on object detection and model training to enable accurate detection of objects. There is also more data on objects which allows better training of models for better prediction (Girshick & Donahue, 2015).

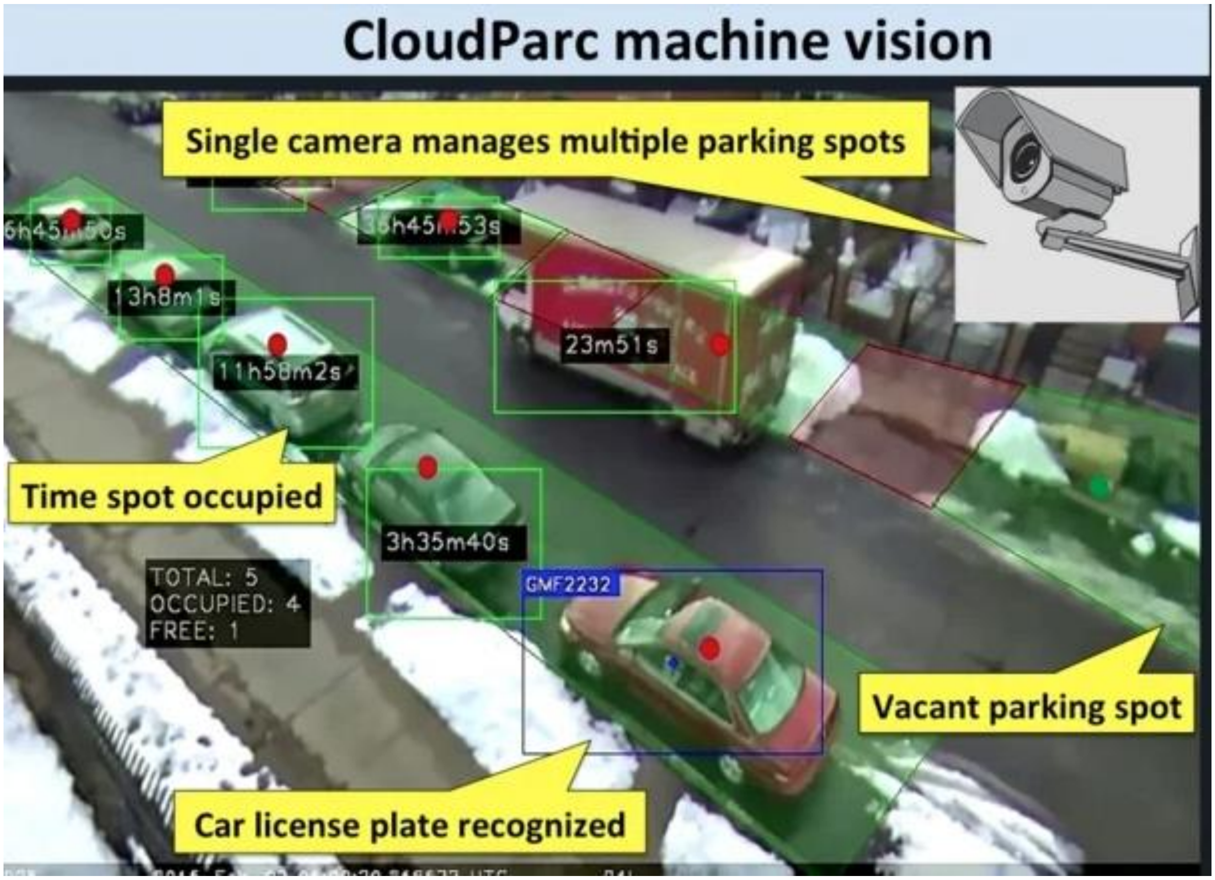

Figure 3: Vision Based Parking Systems

(https://www.allaboutcircuits.com/uploads/articles/Fig1m1116.jpg)

2.2 Related Research

Previous research has been done on this area to aid in coming up with a good parking spot detection model that is efficient, accurate and easy to deploy. Some of the previous research done on this area has improves significantly the aspect of vehicle detection and parking space classification.

(Boda, et al., 2012), in his paper proposed the use of ultrasonic and magnetic sensors for parking space detection in cars parked in a parking area. The proposed model had high accuracy in detecting occupied and vacant parking spaces and required less human intervention in maintaining the model. The proposed research work is however expensive to implement as each parking slot required a sensor. Changes of vandalism are also high in such a model which is deployed in an open space parking environment.

A research by (Girshick & Donahue, 2015) proposed the use of Markov Random and Support Vector machines for object detection in a parking area. This model relied on the use of visual images which were subjected to a trained model which could detect cars in the video stream. This model was proposed to be implemented at the entrance and exit of parking spaces where its able to keep a count of vehicles that come in and vehicles that leave the parking area.

A research by (D.Azshwanth, 2019) , proposed to use convolution neural networks to detect open and occupied parking spaces using Adaboost classifier. The algorithm took too much time (90) seconds to process one image thus making it unsustainable to work with large datasets. The author thus recommended further research to be carried out in this area to provide a more effacement method.

K. Simonyan and A. Zisserman (Simonyan, K., Zisserman, A. (2014)) proposed the use of a very deep convolution network (CNN) which was able to accurately detect a parking spot. The use of CNN networks made a huge achievement to this area as parking spot detection speed improved and the detection accuracy was also improved compared to the previous research. The researcher however recommended more research to be carried out in the algorithm developed to ensure it was efficient in terms or resource utilization and accuracy.

Xiang et al. (2017) proposed to use Haar-AdaBoosting cascade classifier to predict cars in petrol stations and predict the empty parking areas with a deep CNN and he reported an accuracy of 73%. The approach by Xiang has aided in showing that CNN can be used to provide better prediction of open parking slots.

(Rivano & Mouël, 2017) proposed use of YOLO (You Only Look Once) algorithm for image detection. According to the researcher, YOLO algorithm improved efficiency in terms of car parking space location as the algorithm only looks once then does the classification. This had a high accuracy of 87%. The model was also affected by changes in weather conditions. The researcher used CNRPark dataset which has classified vehicle objects to test the data.

2.3 Computer Vision and Machine Learning Algorithms for Automated Parking Space Detection

Computer vision is a field of study in computer science that aims at developing techniques that can help computers view and understand concepts presented in photos and videos (Ren, 2015). In the recent years, computer vision field has gained a lot of popularity due to the capabilities that have identified in as image processing and the application areas such as in automotive industry, security, medical industry and in electronics. (Girshick R, 2015) describes two main pillars of computer vision which are:

Image Formation

This is the basic step in computer vision which aims at capturing the image in question, signal acquisition and lightning aspects of the environment in computers. An image is represented by matrix values of each pixel in the image which captures values equivalent to the color intensity of the pixel. Images can be captured in their colored state or they can be transformed to their gray scale equivalent whose matrix hold values from 0 to 255.

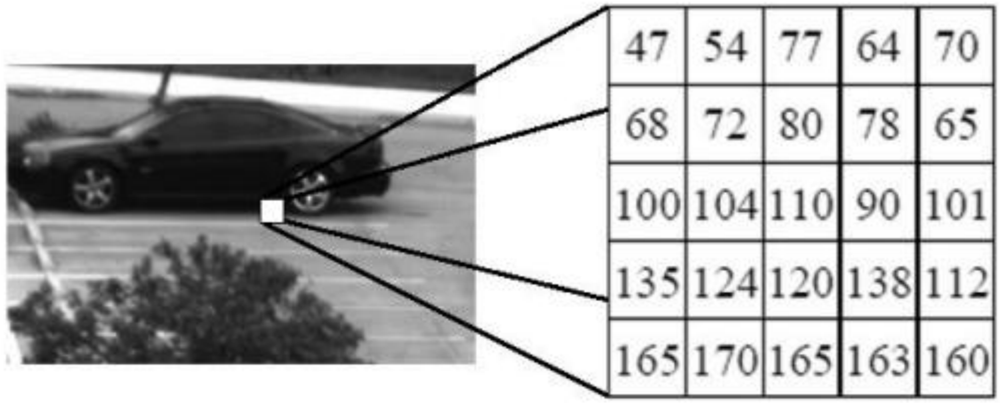

Figure 4: Gray Scale Image representation in a Matrix

Figure 1: Gray Scale Image representation in a Matrix

Image Processing

This refers to the process of object manipulation so as to extract areas with objects in the image. Different techniques are used in image processing and they include

Image Difference: This is the process of comparing two images so as to determine the differences in the images. This is however affected by changes in lighting conditions and environment climate change. This technique will be important in the parking slot system as it will help to train the model on parking spaces which have been occupied and those which have not been occupied.

Image Binarization: This is the process of transforming grayscale imaged to their binary equivalent where pixels have either black or red color intensity values. This is achieved through thresholding the gray scale image.

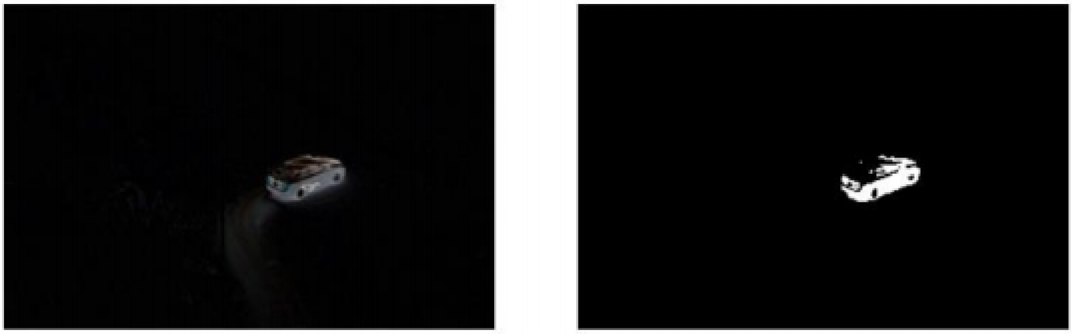

Figure 5: Conversion of a Gray Scale image to a Binary Image

Morphology Operations: These are techniques used to clean up an image after binarization has been applied. This can be achieved through application o techniques such as 3*3 edge modification techniques which assist in improving the image contrast and edge enhancement. Algorithms used in computer vision include

2.3.1 Neural Networks

A neural network is a collection of connected neurons which pass information forward to the next neuron. Each neuron does computations on the information received then it passed it to the next neurons in the network. In computing, this is done through application of weights on each neuron which is then used to train the network.

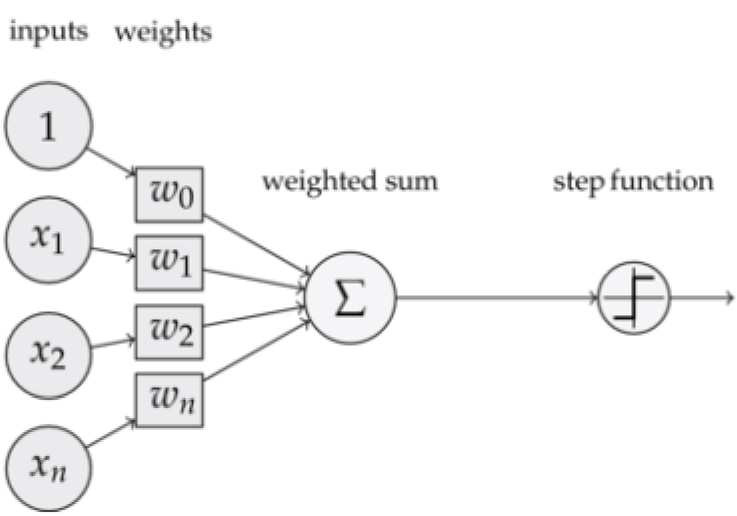

Figure 6: Perceptron Neural Network

2.3.2 Convolution Neural Networks

This is a class of deep learning networks which take image as an input and assign various weights on the image so as to be able to differentiate it from another image (Nielsen, 2015). With proper training, convolution neural networks are capable of doing the learning themselves. The network is divided into neuron layers where each layer passes information to the next layer in a process known as feed-forward process. Network training is done through giving the network a large input of the same image so that it can be able to correctly categorize the image. If the network gives a wrong prediction, supervised learning is applied to train the network. This the results in adjusting the neural network weights thus making them able to make accurate predictions the next time an image is given. Through proper training, the network is capable of extracting unique features in an image and be able to classify the image correctly. The image below shows a visualization of the CNN.

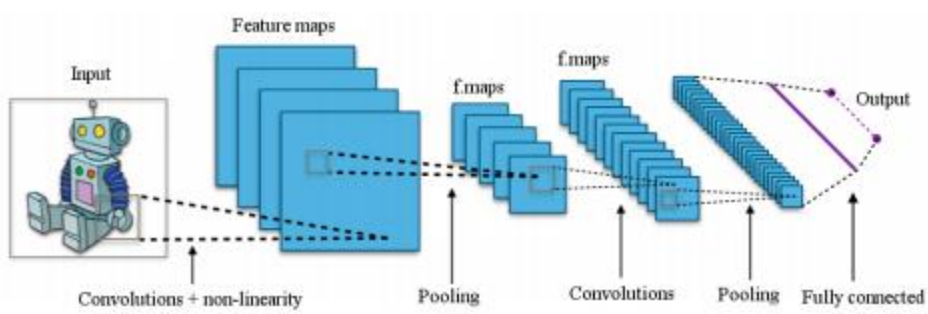

Figure 7 Convolution Neural Network

2.3.3 Region Based CNN (R-CNN)

This is an improved CNN algorithm that is concerned with selecting the areas that one is interested with on an image (Malik, 2016) and trying do classification on those areas and not the whole image.

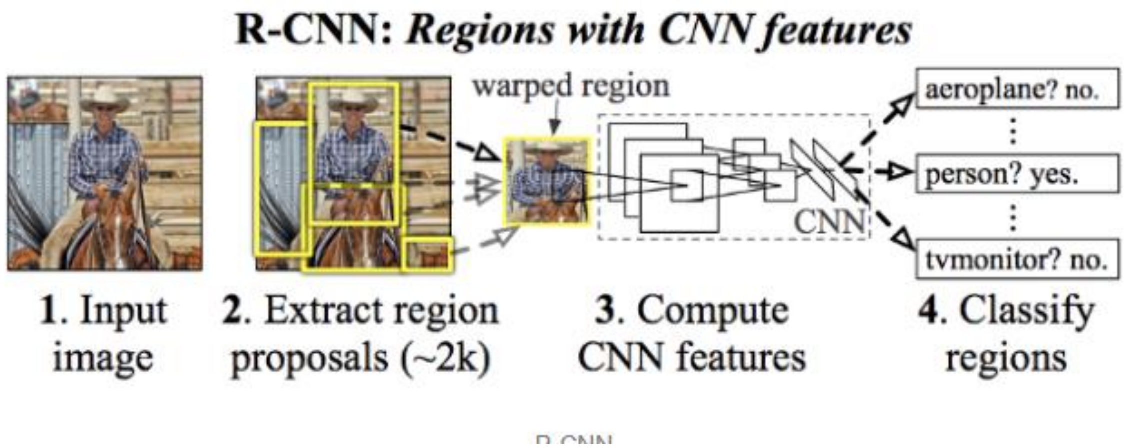

Figure 8 Region Based CNN

This has provided better predictions compared to using only CNN however it has some drawbacks which limit its use. The main disadvantage of this algorithm is that it takes too much time, approximately 47 seconds to process an image. This algorithm will thus not be suitable to use in the parking space detection model as it will present performance issues to the model to be developed.

2.3.4 Faster R-CNN

Fast Region based Convolution Neural Network (Fast R-CNN) is an improvement of RCNN which offers improved image speed processing. It works by first reading an image frame to the CNN algorithms so as to produce a convolutional feature map of the image. Areas of proposal are recognized from the convolutional feature map where they are wrapped into square and a softmax layer is used to classify the class of the marked region (Malik, 2016). The improved processing time in the R-CNN algorithm is attributed to the single calculation done per image where a feature map is generated instead of feeding the neural network with 2000 proposal region to the neural network each time as it is the case with R-CNN.

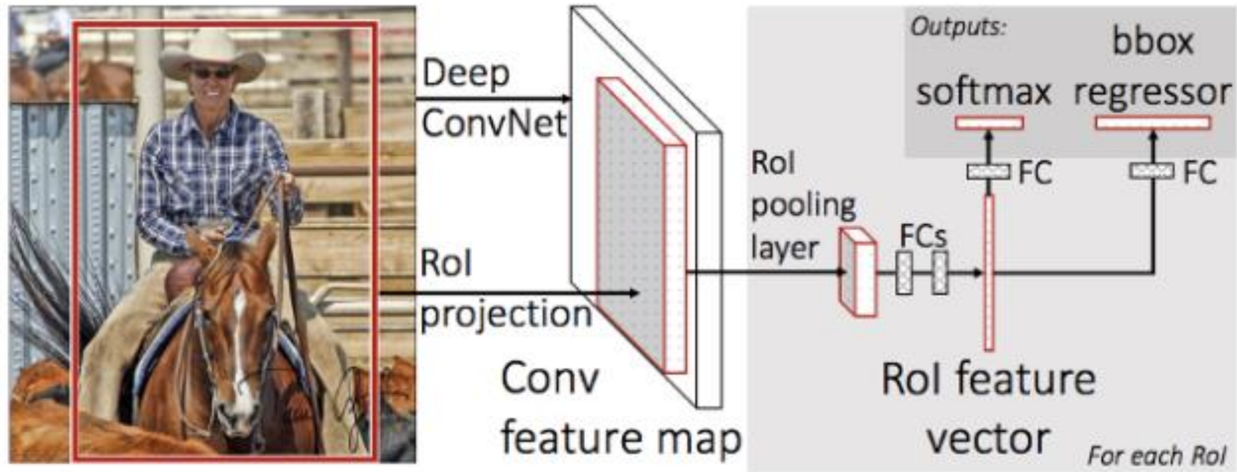

Figure 9 Faster R-CNN

2.3.5 Mask RCNN

(Rahul K. Kher, 2017) describes Mask RCNN as a deep neural network algorithm that achieves object detection through segmenting objects in an image or video. The algorithm detects the bounding boxes, masks and image classes of objects in an image frame. Generation of proposals on area where images might be in an image frame is the first step on how the algorithms works. Class prediction of objects identified in an image follows as the second process, where it refines the bounding boxes and masks are generated in pixel level of the detected object.

2.3.6 YOLO

YOLO technique (You Only Look Once) is an object detection algorithm that is based on the use of a single convolutional network to determine the bounding boxed and the classes of the boxes in an image (Malik, 2016).

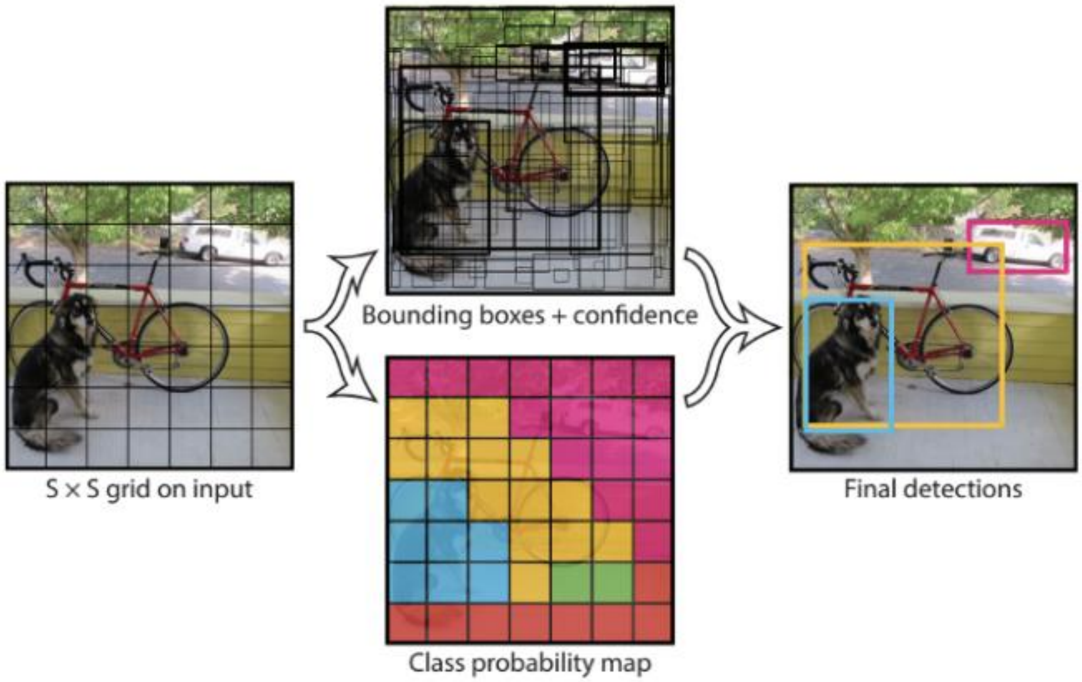

Figure 10 YOLO Algorithm

The algorithm works by splitting an image into S*S grid, where each bounding boxes is taken in each grid. The network gives a class and an offset probability of each bounding box and boxes that have a class probability more than a given threshold are selected an used to locate the objects within the image (Malik, 2016).

2.4 Research Gap

Based on the previous research work that has been done on this area, sensor based technologies have high accuracy and require less computing resources to run on. The use of wireless sensor networks and wireless magnetic sensors is however limited to parking slots in restricted areas and they are also expensive to install (Rivano & Mouël, 2017). Research on vision based systems shows that its well suited for searching for vehicles in a large parking area and its easily adaptable in both open and enclosed parking spaces. The vision based systems however are affected by lighting conditions if the models are not well trained, it's based on rules and not intelligence and require high computing resources to rain and run. This research aims at improving accuracy on detection of cars and parking spaces in a more efficient way which is not affected by environmental changes by using YOLO and M-RCNN algorithm for object detection and a classifier for predicting whether a parking spot is empty or occupied.

2.5 Process Model

The diagram below shows the proposed process model on how the solution was developed.

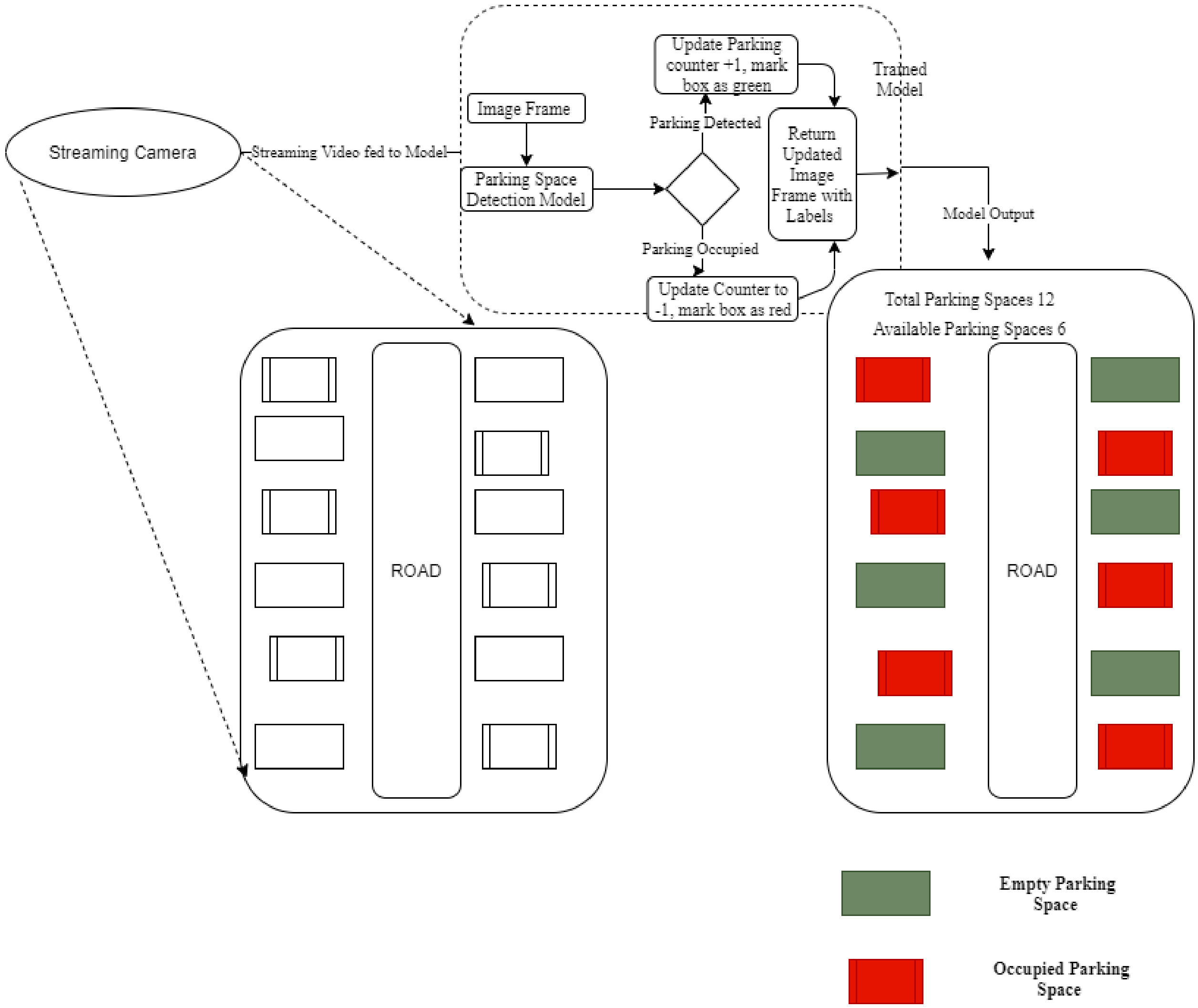

Figure 11: Process Model for Automated Parking Spot Detection

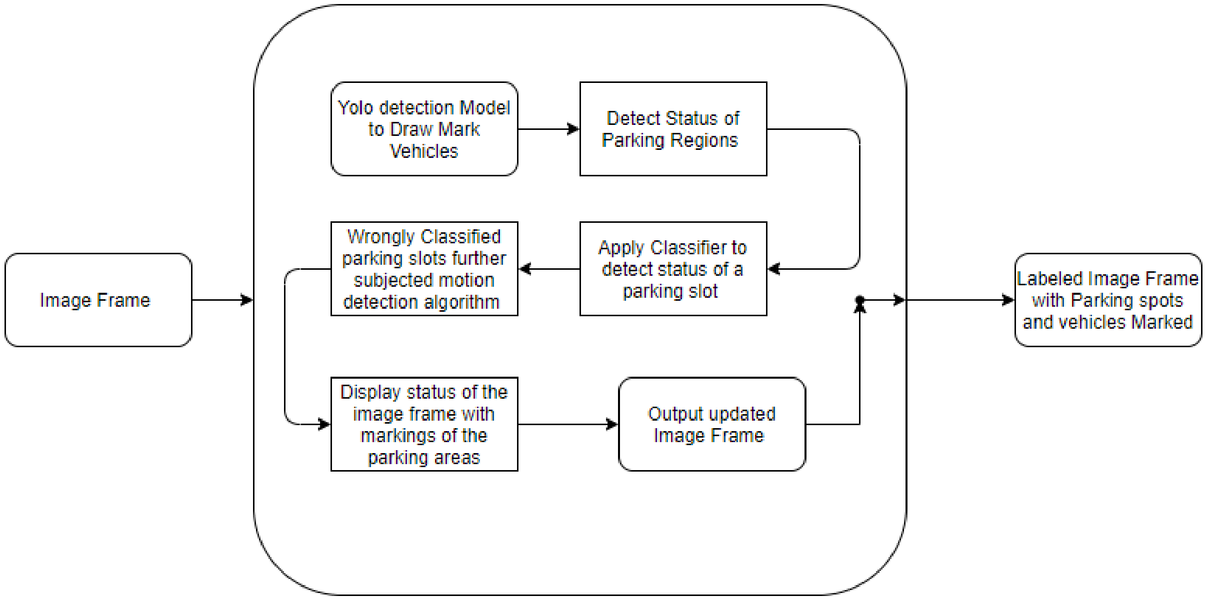

Figure 12: Model Classification Process

Chapter Three: Methodology

3.0 Introduction

The research intended to develop a prototype for automated parking spot detection in parking areas. Publicly available data (Giuseppe Amato, 2015), was thus used to train and test the model to be able to identify and classify parking slots as either vacant or occupied. YOLO algorithm was used for object detection which provided means of identifying objects such as cars in the parking area. A classifier was added to aid in the classification of the parking spaces as either vacant or occupied. Evaluation was achieved through subjecting the model to different parking areas videos and seeing how it's able to predict and identify vacant and occupied parking areas.

3.1 Research Design

(Uma Sekaran, 2016) describes research design as a blueprint for collection and analysis of data that is created to answer questions that guide the research. It articulates the data that is required, the methods that will be used to gather the data and how the research questions will be answered by the data collected.

The general approach used was to train YOLO and M-RCNN algorithms to detect vehicle objects and marking of parking spaces in a parking area. The status of each parking area was determined and the objects in the parking area were classified as either vehicles or other objects and thus the status of the parking area established as either vacant or empty. CRISP-DM methodology (Cross Industry Standard Process for Data Mining) was used in the entire lifecycle of the prototype development. The methodology consists of six phases namely: business understanding, data understanding, data preparation, modelling, evaluation and deployment.

3.2 Business Understanding

A parking space is an area that has been designated for parking cars. The parking areas are aimed at ensuring cars are well parked and other activities are not hindered by the cars that park in the cities or other places. To ensure better management of parking spaces, most parking spaces are normally marked to indicate where a driver should park his car and avoid double parking. Thus, if a parking space is well labelled, drivers will be able to park their cars well and the higher the number of vehicles that can be accommodated in a parking area. In line with this, well labelled parking spaces make it easy to train a model to determine the status of a parking space. Well labelled parking slots also in our study, ensure that we can accurately mark them when training our classification model.

3.3 Data Understanding

Parking areas provide two types of data, number of parking spots that have been occupied by vehicles and count of empty parking slots. The information above is critical in aiding in the automated identification of the status of parking spaces which is critical for this project. Due to the huge parking space data required for this project to train a model to accurately identify the status of a parking area, the researcher opted to train YOLO and M-RCNN algorithms for vehicle object detection and use the optimal algorithm to develop a prototype that can be used to classify a parking area as either vacant or occupied.

3.4 Data Collection and Preparation

This phase involved all activities that transform the row data captured to standard acceptable formats. This was to ensure that model training reads from all the data collected. Screenshots of the parking area were taken which were to be used to mark the slots which would be used to classify the parking areas as either occupied or not. Window's snipping tool was used to take the screenshots of the parking areas in the videos.

Training images of cars were downloaded from Pascal VOC dataset (Pascal2, 2014) which contains thousands of images which were used for training the vehicle detection model. Pascal VOC dataset has standardized image class data which are used for image classification. The researcher found this to be a good source of data to be used to train the detection model as the source provided testing, training and validation data.

3.5 Modelling

YOLO and Mask RCNN algorithms were trained for object detection using the VOC images. The training images were divided as follows: 25494 images were used in training the algorithms and 10926 images used in testing the model accuracy. After successful training, time taken to train and object classification accuracy parameters were taken so as to see which algorithm was efficient in object detection. Weights of the efficient model were created to be used for vehicle and car parking space classification the parking space detection prototype.

A flow chart for detecting objects using the efficient algorithm was developed which was guided on the implementation on how the prototype worked. A program that assisted in marking parking areas was also developed which provided an easier way to mark parking areas in the parking photos that were taken.

3.6 Evaluation

The model was evaluated by subjecting it to a video stream of the parking area and observing how accurate it classifies parking spots when vehicles come and leave the parking area, accurate detection of objects in a parking area. The model was also evaluated on the basis on the projects objectives alignment to determine whether there were ways to improve it in future works.

3.7 Deployment

The model was deployed in Raspberry pi where Raspberry pi and streaming video image of parking area fed in the model. The model was able to classify parking spaces as either vacant or occupied and the information displayed.

CHAPTER 4: ANALYSIS, DESIGN AND IMPLEMENTATION

4.1 Introduction

This chapter describes the analysis of the parking data, design of the model, training and the implementation of the prototype.

4.2 Attribute Selection

The research focused on training the model on vehicle objects and non-vehicle objects. This was to ensure that the model is well trained to be able to identify the various objects in a parking area and distinguish the ones which are vehicles from the ones which are not. Thus, images of various vehicles which were in different positions and areas were used to train the model. For the parking slot area, attributed selected were the coordinates of each of the four coordinates of the parking area. The parking slot coordinates were used to show the location of each parking, thus aiding the model to keep track of the no of empty and occupied parking areas whenever a video stream image was fed in the model.

4.3 Analysis of Testing Data

VOC testing data consisted of images which were a combination of vehicles and other images. The testing data was fed into the trained model and observations made on the results on how well is was able to classify vehicles objects from non-vehicle objects. The testing data had similar image size, no of images in a picture as the training data, the difference was only the labelling where we labelled one with positive vehicle images as the training data and the one with the various images as the testing data which.

A video stream of vehicles parked in a parking area, vehicles leaving the parking area and vehicles coming to the parking area was used to test the model accuracy. This video stream contained all parking area scenarios, i.e. vehicles coming, vehicle leaving and vehicles parked in a parking area. A count on the number of empty and occupied parking slots was taken manually each time a vehicle came or left the parking area. This count was compared with the parking space count that was provided by the model.

3.5 Modelling

YOLO and Mask R-CNN algorithms were trained on the VOC dataset which contained images of cars and other images. This involved feeding the model with images having cars and the coordinates of where the vehicle images were in the images, where this data was stored in the algorithms deep network to be used for classification when a new image is presented to it. After successful training of the model, the next process that followed was to test the accuracy of the algorithms so as to determine the algorithm to proceed with in the parking spot detection prototype. In the testing phase, the algorithms were tested using the testing data which was also gotten from the VOC dataset.

Parking spot labelling followed as the next phase which involved taking coordinates of all parking areas and saving them in a file. To train the model to detect the vacant and occupied parking area, an image of the parking area was taken to be used to train the classifier.

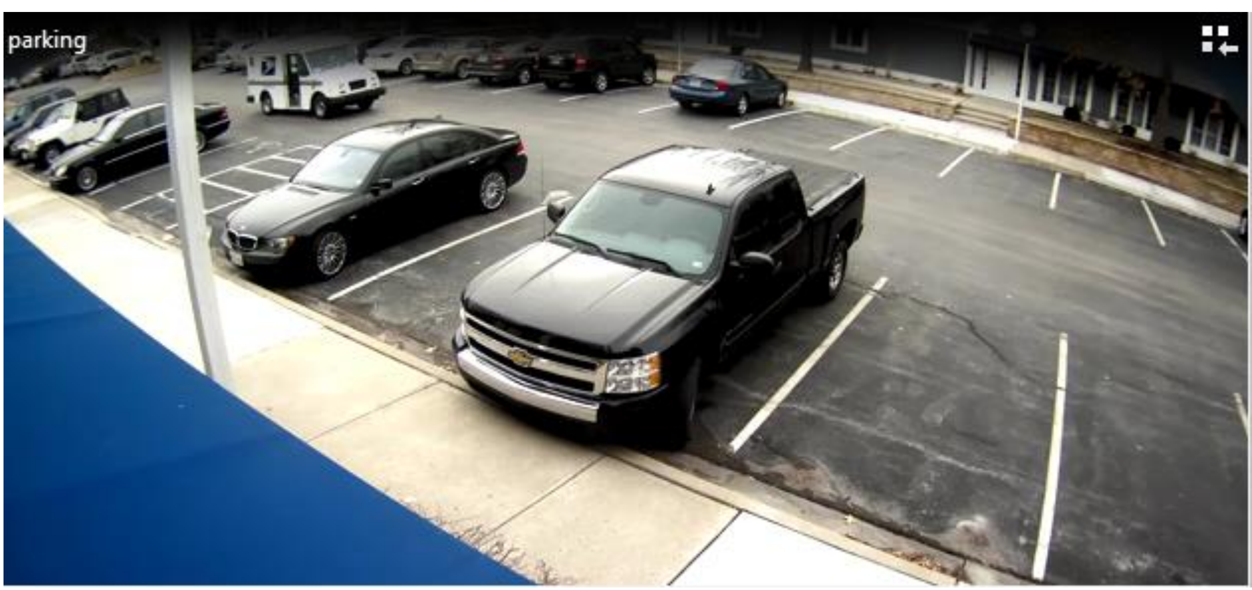

Figure 13: Image of the Parking Area

In order to ensure automated and faster marking of the parking spots, we developed a small program in python which read the image and allowed a user to mark the parking polygon areas by double-clicking on the parking areas coordinates.

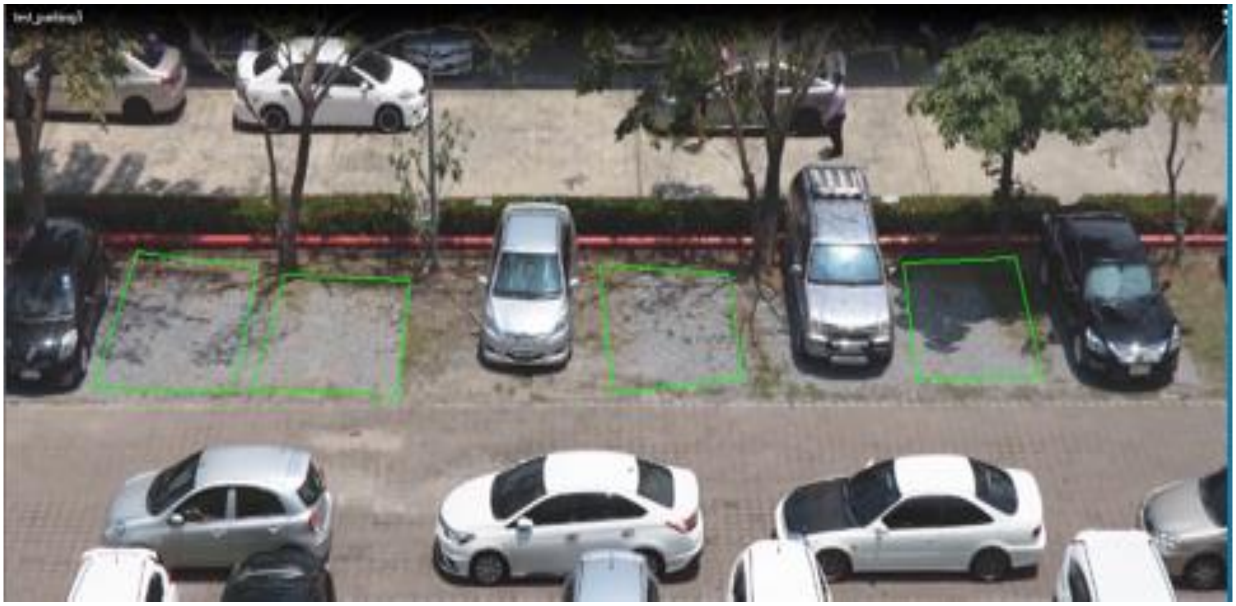

Figure 14: Parking areas Marked

From the above image, the marked parking areas are the ones which are the model keeps track of, when checking the status of the parking spaces as either occupied or vacant. Count on the parking area begins from the first parking slot which is clicked and after four successful double clicks, the parking slot coordinates in the image are saved on a format which can be easily be read by humans and computers. YAML is used to represent the parking spaces in a readable format and **PyYAML** parser utility for Python was used to make the slots.

After successful marking of the parking spaces, the coordinates were stored in a yaml file which was used to hold information about the parking areas. An extract of how the parking coordinates looked like is shown below;

```yaml
- id: 0
  points:
  - - 140
    - 207
  - - 54
    - 205
  - - 81
    - 133
  - - 155
    - 141
```

Figure 15: Parking Slot Coordinates

The point represented the parking coordinates in terms of their location in the x and y axis, where points with two – represented the x coordinates of a point and – represented the y coordinates of the point. The Id element was used as the parking location which was used as the parking counter in the model.

Model Flow Chart

The flow chart representing the testing and training of the model used the below chart.

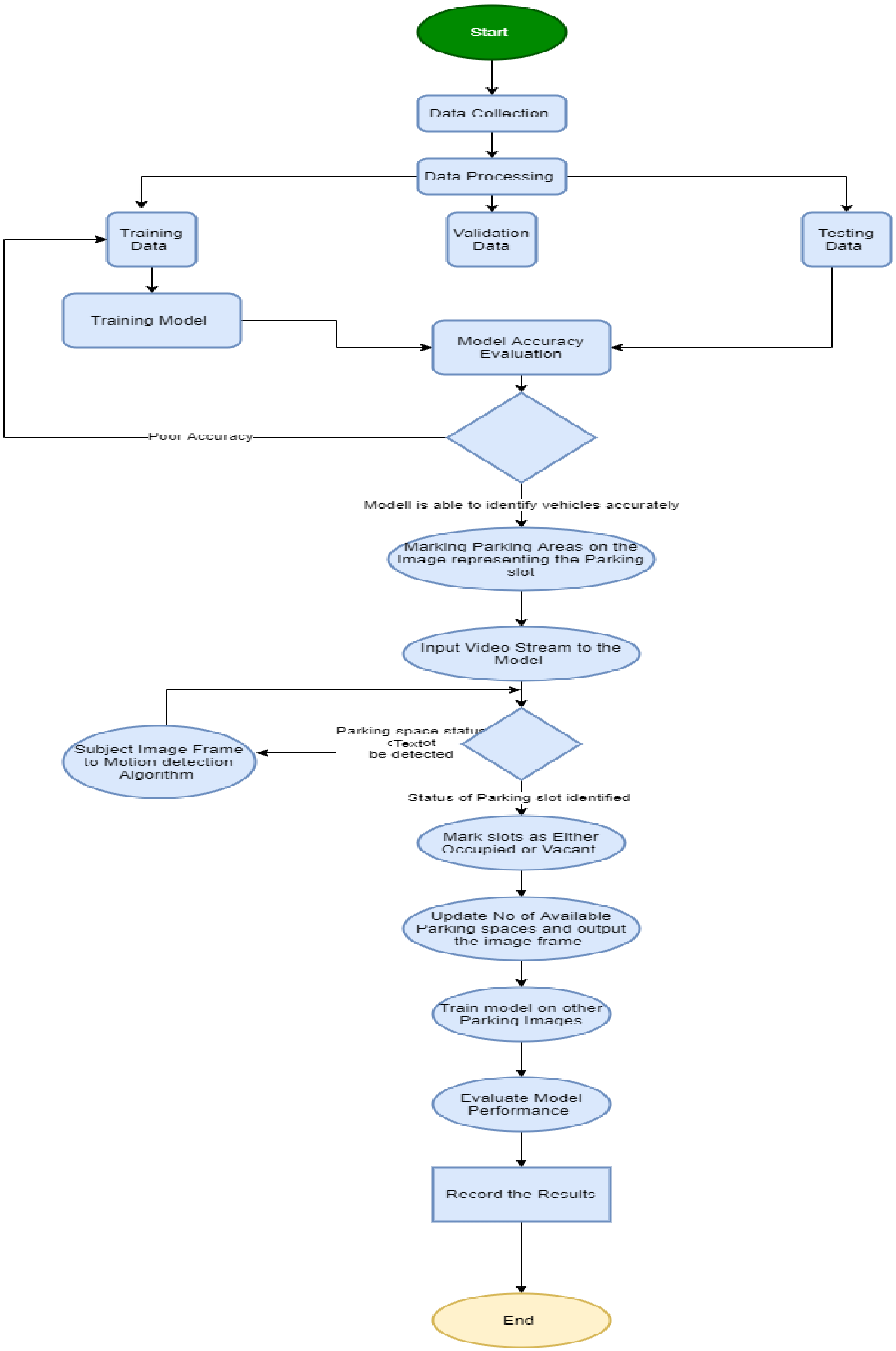
Start
Data Collection
Data Processing
Training Data
Validation Data
Testing Data
Training Model
Model Accuracy Evaluation
Poor Accuracy
Modell is able to identify vehicles accurately
Marking Parking Areas on the Image representing the Parking slot
Input Video Stream to the Model
Subject Image Frame to Motion detection Algorithm
Parking space status cTextot be detected
Status of Parking slot identified
Mark slots as Either Occupied or Vacant
Update No of Available Parking spaces and output the image frame
Train model on other Parking Images
Evaluate Model Performance
Record the Results
End

Figure 16: Model Flow Chart

4.6 Implementation

The model was implemented in Python as the main programming language where the model receives a video input stream of a parking area and it classified the parking slots as either vacant or occupied. The model also showed the count of parking areas which changes when a parking spot is occupied or when a vehicle leaves the parking slot.

Figure 17: Video Stream of the Parking Area

Figure 18: Image of Video Stream Output of detected parking spots, vacant spots and parking count

4.7 Prototype Evaluation

The prototype was evaluated against the objectives that had been identified at the introduction part of the research. It was evaluated on its accuracy to detect a vacant and an occupied parking slot from a parking area. The model was evaluated through feeding it streaming parking slot data which had cars coming in and out of the parking area. The output of the model was a video stream image which showed whether parking slots had been classified an empty of full.

CHAPTER 5: RESULTS AND DISCUSSIONS

5.0 Introduction

This chapter explains the performance results of the developed model when subjected to various testing scenarios. The model performance was evaluated on speed of detection, accuracy of detection and impact of changing the edge detection method on the model accuracy of detecting vacant and occupied parking slots.

5.1 Model Performance

5.1.1 YOLO Algorithm for object detection and classification

YOLO algorithm was used to classify cars in the parking area, and below are the results obtained when a video an image tested. The model was able to identify the cars, however the accuracy of detection of the model has is an average of 82% where the lowest detection was at 50% and the highest detection was at 88%.

Figure 19: YOLO Car Detection

The results below show the performance of YOLO when used to identify cars.

```
class confidence score here is ::::::::::::S  car 0.50
class confidence score here is ::::::::::::S  car 0.62
class confidence score here is ::::::::::::S  car 0.88
class confidence score here is ::::::::::::S  car 0.58
class confidence score here is ::::::::::::S  car 0.65
class confidence score here is ::::::::::::S  car 0.55
class confidence score here is ::::::::::::S  car 0.62
```

Figure 20: YOLO Performance in Object detection

5.1.2 Mask R-CNN for Object detection and Classification

Mask RCNN algorithm was also used to detect objects in a video stream and it had the highest accuracy of 100% accuracy in detecting cars in a video and the lowest detection of 94%. The algorithm however took more time to detect vehicle objects in a video compared to YOLO algorithm, thus making it not suitable to be used in the prototype setup.

Based on the above result, YOLO was used for object detection on our automated car parking prototype. The model was tested on five video streams of different parking areas which contained vehicles coming and leaving the parking area where it was able to detect vehicles, cars and the status of the parking areas. Two tests were done, one where motion detection of objects coming into the parking area was enabled and the other one where motion detection was disabled. Below are results obtained when motion detection had been enabled:

#	Video File Name	With Motion Detection	Actual Empty	Predicted Empty	Actual Occupied	Predicted Occupied	Wrong Predictions	Model Accuracy
1.	Parking Slot	Yes	4	4	1	1	0	100%
2.	Parking slot 2	Yes	3	3	1	1	0	100%
3	Parking Slot 3	Yes	6	5	5	5	1	83%
4	Parking Slot 4	Yes	5	4	0	0	1	80%
5	Parking Slot 4	Yes	3	3	2	2	0	100%
							Average Accuracy	**92.6%**

Table 1: Model Performance with Motion Detection Results

The table below shows the summary of the findings gotten when motion detection was had been turned off.

#	Video File Name	With Motion Detected	Actual Empty	Predicted Empty	Actual Occupied	Predicted Occupied	Wrong Predictions	Model Accuracy
1.	Parking Slot	No	4	4	1	1	0	100%
2.	Parking slot 2	No	3	3	1	1	0	100%
3	Parking Slot 3	No	6	6	5	4	1	80%
4	Parking Slot 4	No	5	4	0	0	1	80%
5	Parking Slot 5	No	3	3	2	2	0	100
							Average Accuracy:	**92%**

Table 2: Model Performance with No Motion Detection Results

5.2 Discussions

Based on the above results, YOLO and M-RCNN algorithms are able to detect and classify vehicle objects in a video stream when fed into the model. The differences between the two models is the time taken and accuracy when detecting vehicle objects in a video. YOLO algorithms is able to detect cars from other objects in video input in using minimal time compared to Mask R-CNN. When the same video input was fed to a model using M-RCNN algorithm, high accuracy was achieved in detection of vehicle objects, the time taken to detect vehicle objects was however long compared to the other algorithm. M-RCNN algorithm also required high computing resources to be able to do the detection. The M-RCNN algorithm works by masking out all detected images and trying to predict the classes of the detected images. Due to the high processing power required for M-RCNN algorithm, the researcher found it not a suitable algorithm to be used in the processing environment which the research was based on.

The below image shows the detection results achieved when using M-RCNN model.

Figure 21: Mask-RCNN Vehicle Detection

A comparison of the same image detected with YOLO algorithm is shown below

Figure 22: YOLO Image detection

From the above comparison, M-RCNN algorithm has more accuracy in detecting vehicles compared to use of YOLO. In terms of resources needed, M-RCNN required more resources to do the prediction than YOLO algorithm.

On edge detection, two edge detection matrices were evaluated, Laplacian and Sobel edge detection models. Sobel detects edge by first order derivatives by calculating the first derivatives of the image frame of the x and y axis individually through a 3 *3 kernel which are convolved with the initial image to calculate the derivatives for both the x and y axis. The image below shows the results of the image after applying Sobel edge detection matrix.

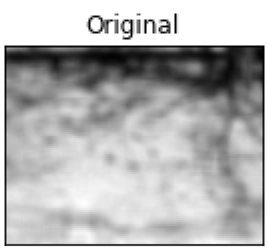

Figure 23:Original Parking spot Image

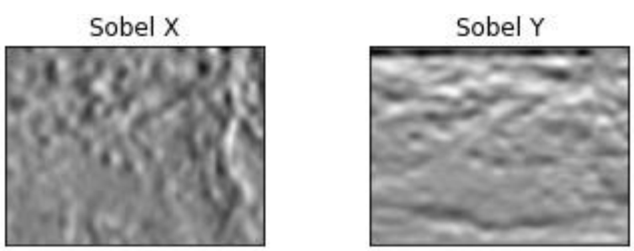

Figure 24: Sobel Edge detection

Laplacian edge detection matrix, which uses a single kernel, calculates the second order derivatives in a single pass, which provided the below results.

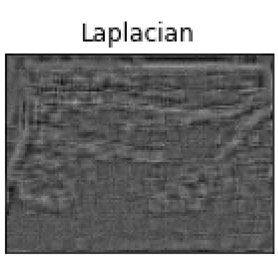

Figure 24: Laplacian Edge detection

```
Laplacian detected is ::::::::::
 [[  8.   7.   6. ...  -6. -15. -14.]
 [-15. -16. -17. ...   2.   2.  -1.]
 [-12. -14. -15. ...   5.   2.   9.]
 ...
 [ -1.   5.  -1. ...   1.   1.  -1.]
 [ -2.   0.   2. ...  -4.  -8.  -4.]
 [ -6.   2.   0. ...  -2.   3.  -2.]]
Laplacian Mean computed is ::::::: 2.7780632411067194
```

Figure 25: Computed Laplacian Matrix and Mean

From the above two edege detection matrices, luplacian edge detection performed better than the Sobel edge, thus the choice of using it in detecting the edges of the parking area. When luplacian was changed, there was an imact in the number of miscalculated cars in the parking area, thus an optimum threshold of 2.7 was used.

CHAPTER 6 CONCLUSION AND RECOMMENTATIONS

6.1 Conclusion

The research focused on evaluating the current algorithms used in car parking detection, design of a model and testing its accuracy in predicting parking spaces. Pascal VOC, an open source dataset of standardized objects was used to train a YOLO and M-RCNN algorithm to detect vehicle objects in a parking area. Parking slots in the parking area were marked using a small program which was developed in this research to aid in marking the coordinates of each of the parking slots in the parking area. This coordinates were fed in a classifier which was used to classify the parking area as either empty or parked. Video stream image was fed in the model where object detection was the first thing to take place, then classification of the parking slot status followed. In order to enhance the accuracy of the parking slot detection model, parking spaces whose status could not be known were subjected to a motion detection algorithm which was used to detect motion of objects coming to the parking slots and try to retest the parking slot status after two seconds. This approach aided in improving the performance of the model as parking space status could easily be updated once vehicles leave or come to a parking area.

The model can be used in real life parking space detection in areas such as shopping malls, cities and airport where we have vehicles coming and leaving the parking areas. In the current real life situation, drivers have to drive round the parking areas in search of empty parking spots which contributes to waste of time and causes congestion of vehicles. If the developed model used in these places, drivers will have prior information on the status of the parking zones allowing them to know whether to enter the parking area or look for an alternative parking area.

Further research is proposed to ensure accurate prediction of parking areas in all weather conditions, and automation of processes such as detection of number plates of the vehicles and predicting whether a vehicle has paid its parking fees or not. This will give more value to the parking spaces managers as they will not have to hire personnel who keep monitoring vehicles which have not paid for parking in the cities. Research on ways of improving the perofrmance of M-RCNN algorithm so that it can use low computing resources can also be expored as the algorithm showed a high accuracy in object detection compared to YOLO algorithm.

6.2 Contributions

The research contributes to the body of knowledge by showing how deep learning algorithms such as YOLO and M-RCNN can be combined with a classifier to aid in the detection of the status of a parking slot, whether empty or occupied and whether the object in the parking area is a vehicle or another object. The prototype developed further shows how machine learning and computer vision can be used to properly manage parking areas so as to avoid unnecessary congestion, wastage of time when drivers are looking for parking areas and improved revenue collection in commercial parking areas due to transparency on parking space data. The developed prototype had an average accuracy of 92.6% in parkign space status detection.

6.3 Future Work

The developed model had an accuracy of 92.6%, further research on the subject area should focus on improving the accuracy of the model prediction of empty and occupied parking areas. Automated lighting systems in parking areas can be added to the model to ensure the model is able to predict the parking spaces even at night when vehicles are approaching the parking areas.

Design on the model can be improved to provide notifications to users who would wish to be informed whenever a parking spot is detected.

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