DRONE PARKING SPOT FINDER

Ionut COJOCIA FLINTOACA[1]

With the constantly growing number of vehicles ownership, especially in the densely populated cities, parking places have become one of the major problems for both councils and drivers. This paper aims to solve the problem of non-intelligent or non-managed car parks by combining aspects of existing technologies. A personal on-demand video image processing system connected to a personal video surveillance drone will lead the owner of such a system to the most desirable free parking spot. The idea of combining drone technology and image processing in the automotive domain is an original and unique contribution. The sequence of algorithm steps and chosen mathematical approach also bring an original aspect to the paper. Computing parking spaces from drone camera broadcast using Radon transform and Canny algorithm. A unique method of pixel matrix count will be detailed to differentiate between free and occupied parking spaces.

Keywords: Drone, surveillance, parking, automotive, image processing

1. Introduction

With the growing population, the already huge number of vehicles which are being used is, increasing, adding up to the statistics of parking spaces, traffic jams, emissions, and driver anxiety. Not all public and private parking lots are managed correctly or monitored using a CCTV surveillance system. Due to these facts finding a free parking spot becomes a daily challenge, especially for 9 to 5 working class. Not all companies with a large number of employees, nor all universities or supermarkets provide transport. In the given situations and for increased comfort employees, students or shoppers must use their own vehicles to get themselves to work, to school or go shopping. With traffic jams occurring all the time and overcrowded parking lots, finding a parking spot adds up to the daily stress intake. In the highly stressful environments like corporations, every bit matters for working individual when it comes to stress or anxiety factors. Imagine working in such an environment, having to commute to work using a personal vehicle, driving a couple of runs through the car park, ending up parking in an odd place very far from the building and spotting a better place when walking towards the office building. This paper aims to overcome this stress factor, reduce

[1] PhD Student, Dept. of Transports, University POLITEHNICA of Bucharest, Romania, e-mail: cojocia@gmail.com

emissions and vehicle usage little by little every day and give owners of such a system the satisfaction of getting the best available parking space on the spot.

Based on the statistics [1] performed in the central business areas of ten cities on four continents, estimates show that 34% of the cars driving in the city are cruising for finding parking spots. The traffic congestion created by vehicles searching for an available parking space, in turn, has a significant impact on carbon emissions through fuel consumption. Paper studies from [2] mention that almost half of the fuel consumed in big cities like San Francisco is due to vehicles searching for vacant spaces.

Research papers on parking assistance systems have become a highlight in the field of intelligent vehicles. J. D. Power’s 2001 Emerging Technology Study shows that over 66% of urban drivers are likely to purchase automatic parking systems or parking assistance systems [3].

The current paper brings together drone technology, image processing and road vehicles creating a unique sub-category of usability and adding to the current state-of-the-art in the domain of the drones. The vehicle parking assistance system proposed by this paper consists of having a drone capable of video surveillance as a mobile device and a computer installed in the road vehicle for image processing. This way the drone will take off on demand, rise up to desired altitude and broadcast live images of the parking lot. Figs. fig. 1(a) and fig.1(b) show a comparison between a car park shown from the street level and the same car park seen from a 10m altitude. This comparison alone can highlight the usefulness of such a system alone, even before getting to use any image processing.

Fig. 1 (a) parking lot drone view (b) parking lot street level view
(Right-side picture source before Simulink processing: https://www.newgeography.com/)
(Left-side picture source before Simulink processing:
https://www.epi-group.com/systems/trafficvloeren-en/epi-parking-decks-trafficvloeren/)

Generally, a well-managed outdoor, ground level, parking lot consists of a visual parking management system consists of CCTV camera for a live image, big outdoor screen or monitor to display the live image. The personal assistance parking system proposed in this paper will have all the abilities described above, but using smaller, portable devices paired with the car and an image processing computer to detect the marking and highlight the available parking spots as shown in fig. 2

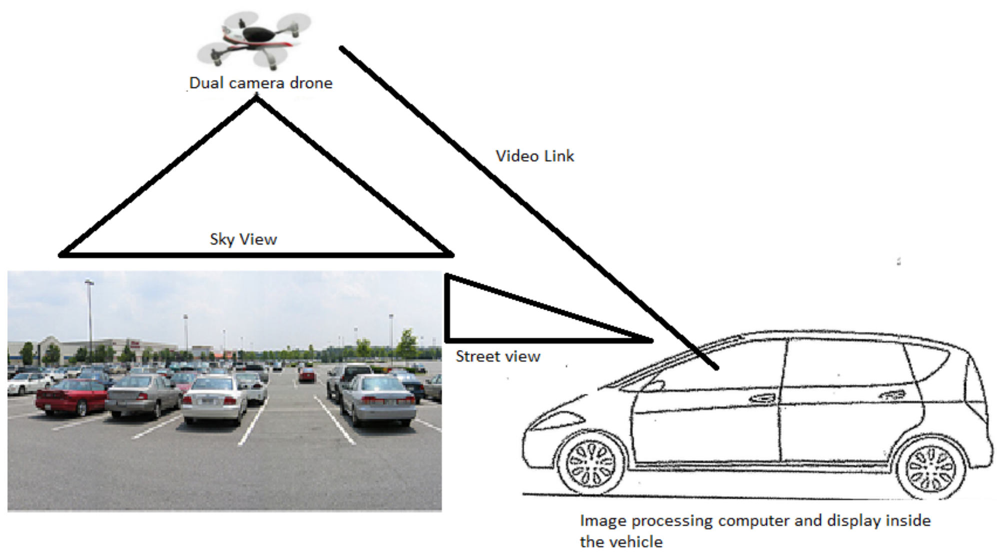


Fig. 2 System overview
(Left-side picture source before Simulink processing and integrating in overview block: https://www.newgeography.com/)

There are other methods of scanning and detecting spaces already occupied by vehicles like microwave radar, ultrasonic or laser as demonstrated in [8] and [9]. This paper implies using a wide-angle camera installed on the drone. Using non-intrusive devices as cameras prove both cost efficiency and technological performance as demonstrated in [4], [5], [6] and [7]. Drone flight and image transmission are not going to be the main focus of this paper, so only a short description of operations and input data will be given. In most counties parking lots marking are painted with contrasting colors in the RGB space. As the human eye has a biological performance of spotting green color given the number of receptors, this paper is going to use the green channel for edge detection for better visualization of the Canny edge intermediary images. Image processing will be done using Canny algorithm for edge detection, Hough transform, and Radon transform for extracting the line markings from the parking lot image and make the difference between an empty space and an occupied space.

2. Live Image acquisition

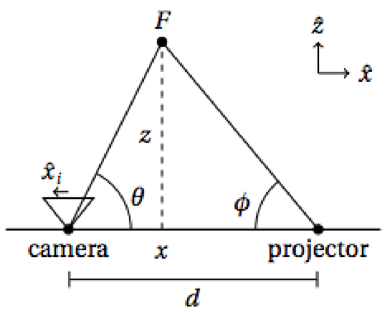
For this particular step of the concept, the images are going to be provided through a live stream from an infrared camera mounted on the drone. The quadcopter is located in the vehicle trunk on a charging station. When arriving near the parking lot the driver will command the system to open up the car trunk and the drone will take off.

The infrared camera is a cheap solution, provides a good enough resolution and it can come in light packaging for lift purposes. The live image is going to be broadcasted over the air towards the image-processing computer in the vehicle. An infrared camera was chosen due to its capability to measure depth. The principle behind depth imagers is the timing of the interval in which light travels an unknown distance. Infrared cameras operate by transmitting a light pulse at known time t_1 and measuring the return time t_2 of the first reflection. Since the speed of light c is known, the radial distance r to the object that generated the reflection, which is the nearest object along the pulse's ray, is given by:

$$r = \frac{t_2 - t_1}{2c} = \frac{\Delta t}{2c} \qquad (1)$$

Processing this distance measurement with the light pulse's angle provides enough information to compute the three-dimensional. Looking at a single point of the parking surface we can define that point by projecting an infrared beam at angle φ and imaged at angle θ given the distance d between the camera and projector, the associated depth in the x-z plane is:

$$z = \frac{d}{cot\theta + cot\varphi} \qquad (2)$$



Further on we can compute the position of point F like in [10]. For any depth, the image coordinate of feature F in Fig. above is:

$$x_i = -a\frac{x}{z} + c_x \qquad (3)$$
$$= -a_x cot\theta + c_x$$

To get the whole parking lot picture for the whole x-z plane the angle θ varies.

$$x_i = -a_x\left(\frac{d}{z} - cot\emptyset\right) + c_x \qquad (4)$$

Thus, if x_{i0} and z_0 satisfy Eq. 4 for feature F, then subtracting x_{i0} from x_i for feature F yields:

$$\delta x_i = x_i - x_{i0} = -a_x\left(\frac{d}{z} - cot\emptyset\right) + c_x + a_x\left(\frac{d}{z_0} - cot\emptyset\right) - c_x \qquad (5)$$
$$\delta x_i = a_x d\left(\frac{1}{z_0} - \frac{1}{z}\right)$$

This result relates the change in feature depth from known z_0 to unknown z with the associated change in image coordinate
from x_{i0} to x_i. Solving Eq. 5 for z in terms of δx_i yields

$$z = \left(\frac{1}{z_0} - \frac{\delta x_i}{a_x d}\right)^{-1} = \frac{1}{a\delta x_i + b} \qquad (6)$$

where. $a = -\frac{1}{\alpha x d}$ and $b = \frac{1}{z_0}$.

Equations (6) and (2) are sufficient to compute the three-dimensional position of the point F with respect to the drone's aerial position. This type of image acquisition will be saved as a matrix of depths, which will support differentiating between an occupied spot and an empty spot.

3. Computing the parking spaces

The image processing will be done on the computer located on the vehicle. Now that the computer has the image in both infrared and RGB, that last one can be used for computing the markings and parking spaces pattern. For this, we have to select between the Hough transform and the Radon transform (named after the Austrian mathematician Johann Karl August Radon (December 16, 1887–May 25, 1956)). Following the analysis made in [12] the advantage of Hough transform is that pixels lying on one line need not all be contiguous. This can be very useful when trying to detect lines with short breaks in them due to noise. One of the disadvantages of the Hough transform is that it can give misleading results when object happens to be aligned by chance. Another disadvantage is that detected lines are infinite lines described by their (m, c) values, rather than finite lines with defined endpoints. Before commencing any calculation, we can have a glance at a MATLAB processing of a parking image by using Hough in comparison to Radon as below in Fig. 3.

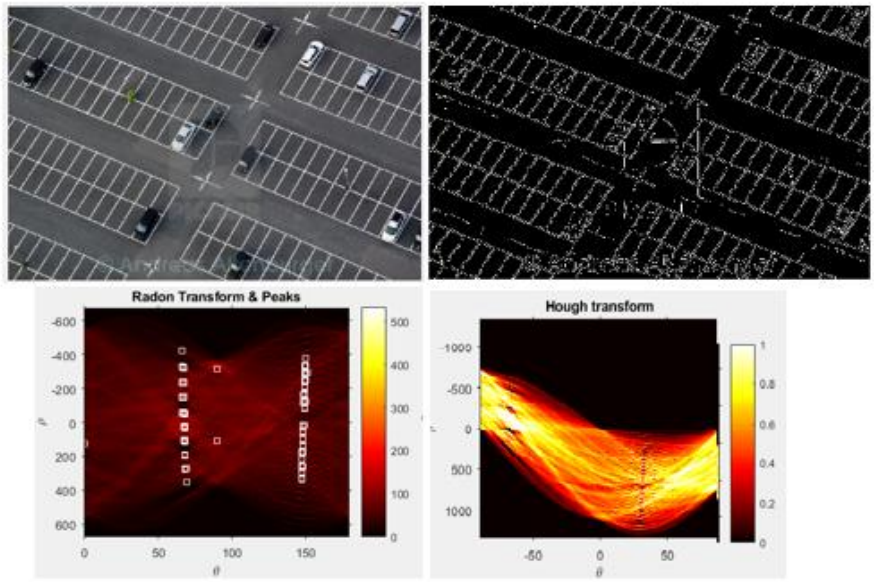


Fig. 3 Radon transform vs. Hough Transform
(top-left picture source:
https://www.epi-group.com/systems/trafficvloeren-en/epi-parking-decks-trafficvloeren/,
top-right picture and graphs: Matlab Simulink processed data for this experiment)

Given this study the Radon transform is going to be preferred.

$$\rho = x\ cos\theta + y\ sin\ \theta \tag{7}$$

$$R(\theta, \rho) = \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} I(x, y)\, \delta(\rho - xcos\theta - ysin\theta) dxdy$$

where δ is the Dirac Delta function. (θ, ρ) is the parameter space about the Radon space. $R\ (\theta, \rho)$ is the value of Radon space at (θ, ρ) points. Radon transform, and Hough transform both transform the two-dimensional image plane $(u$, V) to the parameter space, defined by (θ, ρ). The Radon transform is going to be applied to our image $I\ (x, y)$ for a given set of angles. The resultant projection $R\ (\theta, \rho)$ will a line integral which is the sum of the intensities of the pixels in each direction. In other words, the liner integral value $R\ (\theta, \rho)$ is the projection of the geometry image along the direction θ, as shown in Fig. 4 below.

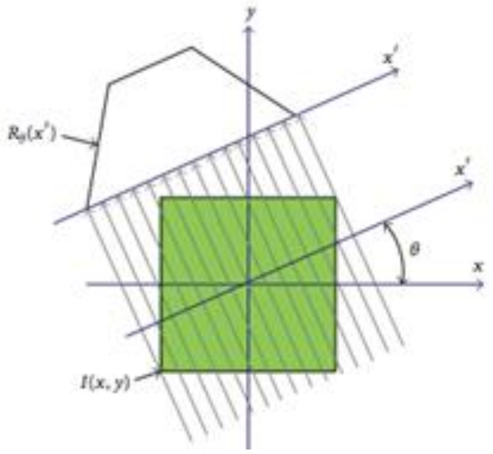


Fig. 4 Radon Transform (adaptation for experiment of picture source: https://www.mathworks.com/help/images/radon-transform.html)

Further on, for implementing the Radon transform in a software application we need to go through the following steps:

- The threshold value used has to be fine-tuned manually for detecting lines in the initial phase.
- The gray image can either be direct from the infrared camera or from selecting only one channel from the RGB picture (in our case the green channel).
- Edge detection is going to be done using the Canny algorithm from the gray image. Considering the influence of noises, clutters, and vehicles in the edge image, it is necessary to take the area around the BS as the region of interest. The detector structure is shown in Fig. 5.

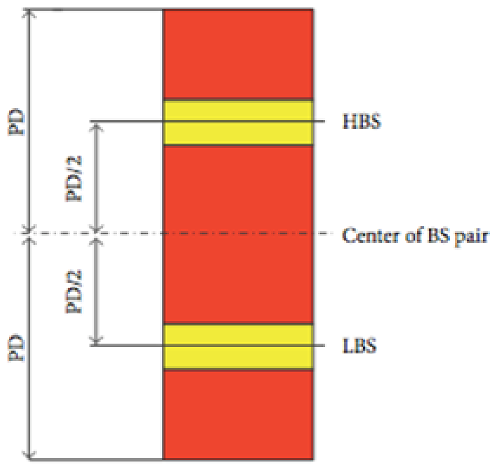


Fig. 5 Parallel line pairs

- Computing the accumulator matrix using the Radon transform. By construction, parking space markings have several fixed widths and white (or colored) parallel pairs of line segments. According to the Radon transform, the lines are mapped to the brighter spots in the Radon space. Parallel line segment pairs in the Canny edge image will produce bright spot pairs in the Radon space. The two BS points in one pair have the same value θ and a fixed width.

$$V(\theta,\rho) = R_{HBS} + R_{LBS} - K_s\,R(\theta,\rho) - R(\theta,\rho+PD) - R(\theta,\rho - PD) \quad (8)$$

Where $V(\theta,\rho)$ is the temporary value of the detector. $R(\theta,\rho)$ is the line interval in the Radon space. R_{HBS}, $R_{LBS}, R(\theta,\rho+PD), R(\theta,\rho-PD)$ are the line integral values in the radon space, respectively K_s is a factor related by the extent of the difference between R_{HBS} and R_{LBS}. The value is defined as follows:

$$K_s = \frac{max(R_{HBS}, R_{LBS})}{min(R_{HBS} + R_{LBS})} \quad (9)$$

- The maximum value from the accumulator matrix is a candidate for parameters of a line (the threshold can be used for sensitivity fine-tuning). Finally, in order to extract the center of the bright spot pair, we limited the temporary value $V(\theta,\rho)$ to be between 0 and 1.

$$P(\theta,\rho) = \frac{V(\theta,\rho)}{R_{HBS} + R_{LBS}} \cdot \frac{min(R_{HBS} + R_{LBS})}{max(R)} \quad (10)$$

where $P(\theta,\rho)$ is probability set of the center about the BS pairs and R is the whole Radon space. The higher the probability of $P(\theta,\rho)$ is, the more likely the parking space exists. With known parking space orientation, the set C can be obtained by series candidate feature points about the possible parking space line segment pairs. The detection result is shown in Fig. 6.

- Compute the coordinates for each detected line.

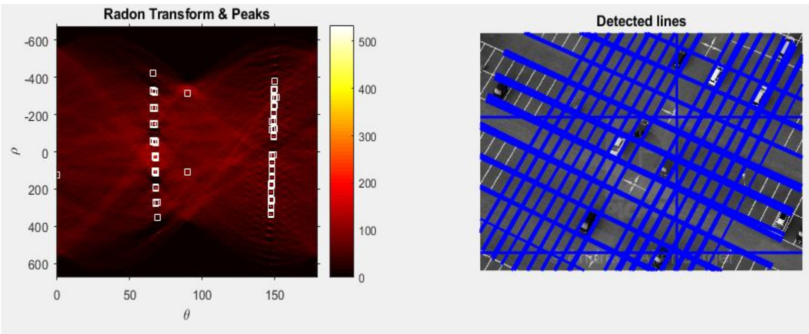


Fig. 6 Radon line detection (print screen of Simulink experiment after processing picture at: https://www.epi-group.com/systems/trafficvloeren-en/epi-parking-decks-trafficvloeren/)

4. Extracting the free parking spaces

Parking spaces can be defined from the result of the previous result by selecting regions of interest delimited by the lines perpendicular to the vehicle delimitation markings using the same method, but a smaller region of the parking lot. For this we are going to use and original approach of counting pixels in order to highlight the differences between an occupied parking space and a free parking space. For extracting the empty parking space, we are going to compare a small portion of the road R with smaller portions of the defined parking space P_i with i= [1,8]. This way the parking space is going to be split into eight equal surfaces. R will have the same surface as any P_i . For each surface we will consider the sum of all the pixel, S_{P_i}, respectively S_r. For tuning it, a threshold value x is going to be considered. If more than four of the $|S_{P_i} - S_r| < x$, the space will be considered empty. Another method could be defined by using a matrix of depths as a result of using an infrared camera. This way we will consider similar surfaces like described above, but instead of comparing pixel values, depth values will be used. A free parking space will be defined as a space with the same depth as the road in front of it.

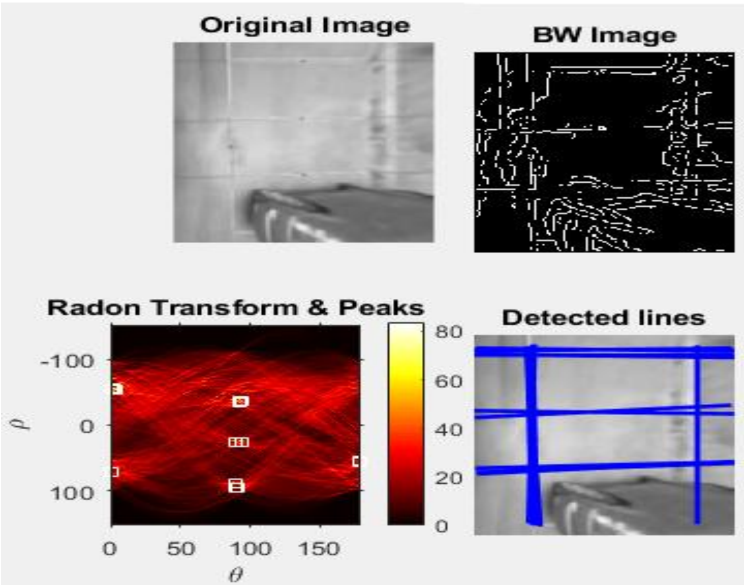


Fig. 7 Extracting Spaces (top-left picture crop from source image at: https://travel.zeelo.co/top-5-tips-to-save-money-on-your-parking-space/,

top-right, bottom-left Graph and bottom-right: print screen from Matlab Simulink experiment)

5. Conclusions

The system can map (Fig. 6) and detect free parking space (Fig. 7) without the need for a managed parking area as shown in the introduction of this paper.

The concept of the system brings lower cost and ease of implementation, as demonstrated in chapter 2 in comparison to other methods of scanning and detecting spaces already occupied by vehicles like microwave radar, ultrasonic, or laser as demonstrated in [8] and [9].

Choosing the Radon transform proved to be the right choice for the system following the analysis in chapter 3. To back up the experiment Fig. 3, it is to mention that the Hough transform can give misleading results when the object happens to be aligned by chance and detected lines are infinite lines described by their (m, c) values, rather than finite lines with defined endpoints.

The system presented is original and unique by concept of using a drone as an accessory for a public road vehicle for the purpose of aerial live image view as shown in chapter 2.

6. Future research and original contribution

The last decade witnessed a rapid augmentation of automotive solutions from intelligent vehicles that can offer driver assistance to intelligent roads that can accommodate high traffic while minimizing the risk for all traffic participants.

The original contribution consists of bringing together drone technology, image processing, automotive technology for solving the global problem of overcrowded parking lots. The main advantages of implementing the concept of this paper in a real-world automotive may save a small amount of fuel per vehicle, but extending it to the number of vehicles looking for a parking spot, every minute, every day, around the world we can conclude that this can lead to representative savings. Besides fuel, there are also benefits in vehicle maintenance reduction, lower mileage, and reduction of driver stress and anxiety. By using well-known methods like Canny for edge detection and Radon or Hough for line detection we demonstrated the possibility of mapping a parking lot from the sky without the need of a managed CCTV system. Another original contribution is information systematization and the step by step approach and logic of selecting the appropriate methods for computing parking spaces from a moving drone live broadcast. Using Radon algorithm in the detriment of Hough due to pixels lying on one line not having to be all contiguous. The pixel-count mathematical model to extract empty parking spaces is also original contribution. The current paper brings together drone technology, image processing and road vehicles creating a unique sub-category of usability and adding to the current state-of-the-art in the domain of the drones.

This system will encourage more daring concepts in the automotive world using the existing pallet of technologies and mathematical models. Also, it will generate new ideas and approaches towards autonomous driving, automatic parking component and will support new ADAS features.

REFERENCES

[1] R. P. Loce and E. Saber, “Fuel consumption in San Francisco,” http:// spie.org/x1816.xml (March 2013).

[2] Bulan, Orhan & Loce, Robert & Wu, Wencheng & Wang, YaoRong & Bernal, Edgar & Fan, Zhigang. (2013). Video-based real-time on-street parking occupancy detection system. Journal of Electronic Imaging. 22. 041109. 10.1117/1.JEI.22.4.041109;

[3] R. Frank, “Sensing in the ultimately safe vehicle,” in Proceedings of the Convergence Conference and Exhibition, 2004;

[4] Abdallah, L., Stratigopoulos, H.-G., Mir, S. and Kelma, C. (2012) Experiences With Non-Intrusive Sensors For RF Built-In Test. 2012 IEEE International Test Conference (ITC), Anaheim, 5-8 November 2012, 1-8.

[5] D. Kim and W. Chung (2008) Motion Planning for Car-Parking Using the Slice Projection Technique. IEEE/RSJ International Conference on Intelligent Robots and Systems, Nice, 22-26 September 2008, 1050-1055.

[6] Zhang, B., Jiang, D.L., Wang, F. and Wan, T.T. (2009) A Design of Parking Space Detector Based on Video Image. The Ninth International Conference on Electronic Measurement & Instruments, Beijing, 16-19 August 2009, 253-256.

[7] Sreedevi, A.P. and Nair, B.S.S. (2011) Image Processing Based Real Time Vehicle Theft Detection and Prevention System. 2011 International Conference on Process Automation, Control and Computing (PACC), Coimbatore, 20-22 July 2011, 1-6.

[8] Yu, H.M., Pang, Z. F. and Ruan, D.R. (2008) The Design of the Embedded Wireless Vehicles Monitoring Management System Based on GPRS: Evidence from China. International conference on Intelligent Information Technology, Shanghai, 21-22 December 2008, 677-680.

[9] Wang, L.F., Chen, H. and Li, Y. (2009) Integrating Mobile Agent with Multi-agent System for Intelligent Parking Negotiation and Guidance. 4th IEEE Conference on Industrial Electronics and Applications, 25-27 May 2009, Xi’an, 1704-1707.

[10] Draelos, Mark & Deshpande, Nikhil & Grant, Edward. (2012). The Kinect up close: Adaptations for short-range imaging. 251-256. 10.1109/MFI.2012.6343067.

[11] Gajulla Nagaraja, Chaitra & Khare, Nayan. (2015). Feature extraction of clothing texture patterns for classification. Recent and Emerging Trends in Computer and Computational Sciences, RETCOMP 2015. 6-9. 10.1109/RETCOMP.2015.7090796.

[12] Abbas, Haider & Ali Hussein, Hussein. (2010). Line Detection Using Radon Transform. Engineering & Technology Journal. 28. 1267-1280.