PARKING LOT DETECTION USING TUNABLE TWO-MODE REGION OF INTEREST

NAJMI HAFIZI BIN ZABAWI

MASTER OF ENGINEERING (ELECTRONICS)

UNIVERSITI MALAYSIA PAHANG
SUPERVISOR’S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Master of Engineering (Electronics).

_______________________________
(Supervisor’s Signature)

Full Name : 
Position : 
Date : 
STUDENT’S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

____________________________
(Student’s Signature)

Full Name : NAJMI HAFIZI BIN ZABAWI
ID Number : MEL11001
Date : 22 December 2016
PARKING LOT DETECTION USING
TUNABLE TWO-MODE REGION OF INTEREST

NAJMI HAFIZI BIN ZABAWI

Thesis submitted in fulfillment of the requirements
for the award of the degree of
Master of Engineering (Electronics)

Faculty of Electrical and Electronics Engineering
UNIVERSITI MALAYSIA PAHANG

DECEMBER 2016
ACKNOWLEDGEMENTS

Alhamdulillah. My praise be only to Allah SWT the Almighty, the Most Gracious, and the Most Merciful, whose blessing and guidance have helped me to complete this thesis. In particular, I wish to convey my gratitude to my supervisors, Dr. Sunardi, Dr. Md. Rizal Bin Othman and Associate Professor Dr. Kamarul Hawari Bin Ghazali for guidance, encouragement, advice, ideas, and motivation. Without their help, of course, this thesis would not have been the same as presented here.

I also would like to express my appreciation to my family especially my beloved mother, father, wife, daughter and son for their understanding, support and pray for me to carry out and finish this research. My appreciation also goes to my fellows Mr. Azrul Bin Mahfurdz, Mrs. Sharmiza Binti Kamaruddin, Miss Norfarhana Binti Mohd Hashim, Miss Noramira Binti Mohd Rodzi and other friends for their idea and guidance that help me a lot in finishing this research.

I also would like to thank the Ministry of Education Malaysia and Department of Polytechnic Education for providing direct and indirect support during this study. My sincere appreciation also extends to all my colleagues either involved directly or indirectly in the success of this study. Only Allah SWT will bless you all.
# TABLE OF CONTENT

DECLARATION

TITLE PAGE

ACKNOWLEDGEMENTS ii

ABSTRAK iii

ABSTRACT iv

TABLE OF CONTENT v

LIST OF TABLES ix

LIST OF FIGURES x

LIST OF SYMBOLS xiv

LIST OF ABBREVIATIONS xv

CHAPTER 1 INTRODUCTION 1

1.1 Research Background 1

1.2 Problem Statements 2

1.3 Research Objectives 3

1.4 Scope of Study 3

1.5 Thesis Overview 4

CHAPTER 2 LITERATURE REVIEW 5

2.1 Introduction 5

2.2 Sensor-Based Method 6

2.3 Vision-Based Method 11

2.3.1 Machine Learning Approach 11
CHAPTER 3 RESEARCH METHODOLOGY

3.1 Introduction 23

3.2 Experimental Framework 23

3.3 Research Materials and Parking Lot Sites 25
   3.3.1 Main Site of Research 25
   3.3.2 Other Parking Lot Sites 28
   3.3.3 Image Acquisition Device 29
   3.3.4 Processing Computer 30

3.4 GUI Program 31
   3.4.1 Image Acquisition Module 33
   3.4.2 Image Preprocessing Module 34
   3.4.3 ROI and Threshold Setting Module 35
   3.4.4 Colour Detection Module 36
   3.4.5 GUI’s Other Functions 37

3.5 Image Acquisition Stage 38
   3.5.1 Real Situation Image Acquisition Technique 39
   3.5.2 Traffic-type Image Acquisition Technique 39
   3.5.3 Recorded Video Acquisition Technique 41
   3.5.4 Viewing Angle 41

3.6 Image Preprocessing Stage 42
   3.6.1 Image Filtering 42
   3.6.2 Colour Space 43
3.7 ROI and Threshold Setting Stage 44
  3.7.1 ROI Size 44
  3.7.2 ROI Number 45
  3.7.3 Range Threshold Setting 46
3.8 Colour Detection Stage 49
  3.8.1 Boolean Logical Operators 53
  3.8.2 Timer Function 54
  3.8.3 Control ROI 55
  3.8.4 Shadow Filter 57
3.9 Summary 59

CHAPTER 4 RESULT AND DISCUSSION 60

4.1 Introduction 60
4.2 Image Acquisition 60
4.3 Image Preprocessing 62
  4.3.1 Image Filtering 62
  4.3.2 Colour Space 64
4.4 ROI and Threshold Setting 66
  4.4.1 ROI Size 66
  4.4.2 Single ROI Mode 70
  4.4.3 Two-mode ROI 75
  4.4.4 Range Threshold Setting 76
4.5 Colour Detection 80
  4.5.1 Logical Operators 80
  4.5.2 Timer Function 87
  4.5.3 Control ROI Function 91
4.5.4 Shadow Filter

4.6 Summary

CHAPTER 5 CONCLUSION AND FUTURE WORKS

5.1 Conclusion

5.2 Future Works

5.3 Contributions

REFERENCES

APPENDIX A LIST OF PUBLICATIONS

APPENDIX B IMAGE ACQUISITION ACTIVITIES

APPENDIX C DETECTOR’S GUI

APPENDIX D SOURCE CODES

APPENDIX E RESEARCH FLOWCHART

APPENDIX F RAW DATA
| Table 4.1 | The effect of different view angles to the result of the detection process | 61 |
| Table 4.2 | The effect of using filters to parking lot image | 64 |
| Table 4.3 | Comparison of the detection performance between BGR, HSV and YUV colour space using single ROI mode | 65 |
| Table 4.4 | Comparison of the detection performance between BGR, HSV and YUV colour space using twin ROI mode | 65 |
| Table 4.5 | The effect of ROI size compared to the size of vehicle | 68 |
| Table 4.6 | The detection result using BGR colour space and single ROI mode | 70 |
| Table 4.7 | The detection result using different range values set with double ROI mode and OR logical operator with timer and control ROI function | 78 |
| Table 4.8 | The detection result using double ROI mode with AND logical operator | 82 |
| Table 4.9 | The detection result using double ROI mode with OR logical operator | 86 |
| Table 4.10 | The detection result using double ROI mode with OR logical operator and timer function | 89 |
| Table 4.11 | Raw data for Table 4.10 | 90 |
| Table 4.12 | The detection result using double ROI mode with OR logical operator, with timer and control ROI function | 92 |
| Table 4.13 | Raw data for Table 4.12 | 93 |
| Table 4.14 | The detection result using double ROI mode with OR logical operator, with timer, control ROI and shadow filtering function | 96 |
### LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>An illustration of an induction loop sensor being buried under the road surface</td>
<td>7</td>
</tr>
<tr>
<td>2.2</td>
<td>Parking space sensor and indicator lamp</td>
<td>8</td>
</tr>
<tr>
<td>2.3</td>
<td>An AMR sensor used along an excitation coil in an experiment</td>
<td>9</td>
</tr>
<tr>
<td>2.4</td>
<td>RFID sensor is used at a parking lot’s entry</td>
<td>10</td>
</tr>
<tr>
<td>2.5</td>
<td>The position of short range radars to detect parking space vacancy</td>
<td>12</td>
</tr>
<tr>
<td>2.6</td>
<td>GUI for semi-manually specifying parking lot layout</td>
<td>13</td>
</tr>
<tr>
<td>2.7</td>
<td>Flowchart of the multi-classifier image-based parking detection system</td>
<td>14</td>
</tr>
<tr>
<td>2.8</td>
<td>Winter weather performance</td>
<td>16</td>
</tr>
<tr>
<td>2.9</td>
<td>Scene merging from four cameras</td>
<td>16</td>
</tr>
<tr>
<td>2.10</td>
<td>Models of a vehicle template</td>
<td>17</td>
</tr>
<tr>
<td>2.11</td>
<td>The occupancy of parking space by the blockage of the brown round patches</td>
<td>17</td>
</tr>
<tr>
<td>2.12</td>
<td>The process of shadow removal procedure</td>
<td>19</td>
</tr>
<tr>
<td>2.13</td>
<td>Feature-based tracking approach is used to track moving vehicle</td>
<td>21</td>
</tr>
<tr>
<td>3.1</td>
<td>The experimental framework</td>
<td>24</td>
</tr>
<tr>
<td>3.2</td>
<td>Parking lot area at Electrical Engineering Department, POLISAS</td>
<td>25</td>
</tr>
<tr>
<td>3.3</td>
<td>Different height points of possible camera position</td>
<td>26</td>
</tr>
<tr>
<td>3.4</td>
<td>Camera view angle related to the orientation of the parking vehicle</td>
<td>27</td>
</tr>
<tr>
<td>3.5</td>
<td>Uniform angle of parking spaces in a parking lot site</td>
<td>27</td>
</tr>
<tr>
<td>3.6</td>
<td>Mixed angles of parking spaces in a parking lot site</td>
<td>28</td>
</tr>
<tr>
<td>3.7</td>
<td>The improved view of occluded parking spaces</td>
<td>28</td>
</tr>
<tr>
<td>3.8</td>
<td>Parking lot at Electrical and Electronics Engineering Faculty, Universiti Malaysia Pahang</td>
<td>29</td>
</tr>
<tr>
<td>3.9</td>
<td>Student parking area near Food Technology Department, POLISAS</td>
<td>29</td>
</tr>
<tr>
<td>3.10</td>
<td>Parking lot area near De Palma Hotel Ampang in Kuala Lumpur</td>
<td>30</td>
</tr>
<tr>
<td>3.11</td>
<td>Logitech C170 USB web camera</td>
<td>30</td>
</tr>
<tr>
<td>3.12</td>
<td>Acer Aspire 4736 notebook used during data collection process</td>
<td>31</td>
</tr>
<tr>
<td>3.13</td>
<td>The architecture of the GUI development</td>
<td>32</td>
</tr>
<tr>
<td>3.14</td>
<td>The screenshot of detector program</td>
<td>32</td>
</tr>
<tr>
<td>3.15</td>
<td>‘File’ and selector button to switch acquisition mode and select image file on the detector’s GUI</td>
<td>33</td>
</tr>
</tbody>
</table>
Figure 3.16  The ‘Smooth’ and selector buttons that are used to apply the image filtering function on the GUI  

Figure 3.17  The buttons used to switch the raw video image into BGR, HSV and YUV during image preprocessing stage  

Figure 3.18  The individual buttons used to select colour space and colour component for each of parking space  

Figure 3.19  The selector button to select the size of ROI window  

Figure 3.20  The buttons and radio buttons used to set the ROI and perform colour range threshold setting on the GUI  

Figure 3.21  The on-screen display function allows the current status of parking space detection to be displayed on the screen  

Figure 3.22  The outline of involved parking space detection procedures  

Figure 3.23  The screenshot of real situation test type procedure  

Figure 3.24  The example of traffic-type experiment technique  

Figure 3.25  The example when a vehicle blocked the other’s ROI  

Figure 3.26  The more appropriate view angle to prevent false detection  

Figure 3.27  Multiple sizes of ROI boxes depending to the distance of the camera’s view and the parking space  

Figure 3.28  Small size of ROIs used for distant view of captured image  

Figure 3.29  ‘Blind areas’ or the spots that has BGR value in the range of road surface area’s colour  

Figure 3.30  The use of twin ROI mode or two ROIs per parking space  

Figure 3.31  The procedure in setting up the colour range threshold of an ROI  

Figure 3.32  Origin point of image pixels and scanning direction in a 640×480 frame size in OpenCV  

Figure 3.33  A 12×12 ROI pixels scanning direction  

Figure 3.34  The example of successful colour detection process  

Figure 3.35  The example of ‘no detection’ case  

Figure 3.36  The use of twin ROI mode with OR function solved the no detection problem  

Figure 3.37  A case where a vehicle parked ‘too deep’ inside parking space  

Figure 3.38  Cases where ROI is partially blocked by passing vehicle  

Figure 3.39  The parking lot area point set with control ROI in different lighting conditions
Figure 3.40  The use of control ROI  57
Figure 3.41  The effect of shadow filtering method  58
Figure 3.42  The way of shadow filtering method works  59
Figure 4.1  Camera height effect to the view of parking vehicle  62
Figure 4.2  The effect of not using any filter to parking lot image  63
Figure 4.3  The effect of using erosion and dilation filter to parking lot image  63
Figure 4.4  The effect of using Gaussian blur filter to parking lot image  63
Figure 4.5  Parking lot site used in the colour space test  66
Figure 4.6  The example of a 90 and 230 pixel wide vehicle image  67
Figure 4.7  The effect of ROI size compared to the size of vehicle  69
Figure 4.8  The oversize ROI detects vehicle outside the parking space area creating false detection possibilities  70
Figure 4.9  The detection result using BGR colour space and single ROI mode  71
Figure 4.10  The colour of the vehicle has the similar colour value to the parking space surface colour value  71
Figure 4.11  The part of the vehicle has the similar colour value to the road surface colour value  72
Figure 4.12  The vehicle parked missed the ROI inside the parking space  72
Figure 4.13  The example where a false detection to the neighbour’s parking space is created when an ROI is positioned too much inside  73
Figure 4.14  BGR value at two spots with different lighting conditions  73
Figure 4.15  The situation where a passing pedestrian fills the ROI  73
Figure 4.16  The situation where a passing vehicle fills the ROI  74
Figure 4.17  False detection caused by shadows  74
Figure 4.18  The example of twin mode ROI solves the no detection caused by similarity of the vehicle colour to the parking space background colour  75
Figure 4.19  The twin ROI mode has higher chance to be filled by vehicle’s part colour  76
Figure 4.20  Modified range of threshold value  77
Figure 4.21  The detection result using different range values set with double ROI mode and OR logical operator with timer and control ROI function  79
Figure 4.22  The use of AND operator compared to OR operator  80
Figure 4.23  The detection result using double ROI mode with AND logical operator 83
Figure 4.24  Original image of parking lot area 83
Figure 4.25  Parking lot area from the detector’s point of view 84
Figure 4.26  The steps in setting colour range to the ROI 84
Figure 4.27  The effect of using twin ROI mode 85
Figure 4.28  The detection result using double ROI mode with OR logical operator 86
Figure 4.29  The effect of using timer function 88
Figure 4.30  The detection result using double ROI mode with OR logical operator and timer function 89
Figure 4.31  The example of the use of control ROI to compensate the change of the surrounding lighting 91
Figure 4.32  The detection result using double ROI mode with OR logical operator, with timer and control ROI function filtering function 94
Figure 4.33  Shadow filtering mode on the detector’s GUI method 95
Figure 4.34  Shadow filtering method solves the false detection problem caused by the cast of the shadows 95
Figure 4.35  The detection result using double ROI mode with OR logical operator, with timer, control ROI and shadow filtering function 97
Figure 4.36  The no detection problem caused by the use of shadow filtering method 98
LIST OF SYMBOLS

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \sigma )</td>
<td>standard deviation</td>
</tr>
<tr>
<td>( \in )</td>
<td>element of</td>
</tr>
<tr>
<td>( \cos^{-1} )</td>
<td>inverse cosine</td>
</tr>
<tr>
<td>min</td>
<td>minimum</td>
</tr>
<tr>
<td>max</td>
<td>maximum</td>
</tr>
<tr>
<td>( x' )</td>
<td>x prime – first derivative of x</td>
</tr>
</tbody>
</table>
## LIST OF ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMR</td>
<td>Anisotropic Magneto Resistance</td>
</tr>
<tr>
<td>FLTK</td>
<td>Fast, Light Toolkit</td>
</tr>
<tr>
<td>GPS</td>
<td>Global Positioning System</td>
</tr>
<tr>
<td>GUI</td>
<td>Graphical User Interface</td>
</tr>
<tr>
<td>HSV</td>
<td>Hue, Saturation, Value</td>
</tr>
<tr>
<td>LBP</td>
<td>Local Binary Pattern</td>
</tr>
<tr>
<td>LBQ</td>
<td>Local Phase Quantization</td>
</tr>
<tr>
<td>LIDAR</td>
<td>Light Detection and Ranging</td>
</tr>
<tr>
<td>OpenCV</td>
<td>Open source Computer Vision</td>
</tr>
<tr>
<td>POLISAS</td>
<td>Politeknik Sultan Haji Ahmad Shah</td>
</tr>
<tr>
<td>RAM</td>
<td>Random Access Memory</td>
</tr>
<tr>
<td>RANSAC</td>
<td>Random Sample Consensus</td>
</tr>
<tr>
<td>REA</td>
<td>Relative Extremum Algorithm</td>
</tr>
<tr>
<td>RFID</td>
<td>Radio Frequency Identification</td>
</tr>
<tr>
<td>RGB</td>
<td>Red, Green, Blue</td>
</tr>
<tr>
<td>ROI</td>
<td>Region of Interest</td>
</tr>
<tr>
<td>SfM</td>
<td>Structure from Motion</td>
</tr>
<tr>
<td>SVM</td>
<td>Support Vector Machine</td>
</tr>
<tr>
<td>TB</td>
<td>Texton Boost</td>
</tr>
<tr>
<td>UMP</td>
<td>Universiti Malaysia Pahang</td>
</tr>
<tr>
<td>WSN</td>
<td>Wireless Sensor Networks</td>
</tr>
<tr>
<td>YUV</td>
<td>Y - Luminance, U and V - Chrominance</td>
</tr>
</tbody>
</table>