Contents

1 Introduction **1**
- 1.1 Computer vision systems . . . 1
- 1.2 Image segmentation . . . 2
- 1.3 Motivation . . . 3
- 1.4 Goals . . . 4
- 1.5 Contributions . . . 5
- 1.6 Organization . . . 6

2 Image segmentation **7**
- 2.1 Introduction . . . 7
- 2.2 Notation and definitions . . . 8
- 2.3 Preprocessing techniques . . . 10
  - 2.3.1 Sobel operator. . . . 10
  - 2.3.2 Top-hat transform. . . . 11
- 2.4 Segmentation algorithms . . . 12
  - 2.4.1 Global thresholding . . . 12
  - 2.4.2 Otsu's method . . . 14
  - 2.4.3 Local Adaptive Thresholding (LAT) . . . 14
  - 2.4.4 Watershed . . . 15
  - 2.4.5 Local variation . . . 16
- 2.5 Conclusions . . . 17

3 Background modelling and motion segmentation **19**
- 3.1 Introduction . . . 19
- 3.2 Notation and definitions . . . 20
- 3.3 Background modelling . . . 22
  - 3.3.1 Adjacent frame differencing . . . 25
  - 3.3.2 Running Gaussian average . . . 25
  - 3.3.3 Mixture of Gaussians (MoG) . . . 26
  - 3.3.4 Kernel density estimation (KDE) . . . 28
  - 3.3.5 Sequential kernel density approximation . . . 28
  - 3.3.6 Temporal median filter . . . 29
  - 3.3.7 Eigenbackgrounds . . . 29
  - 3.3.8 Coocurrence of image variations . . . 30
  - 3.3.9 Local Binary Patterns . . . 31
  - 3.3.10 Wallflower . . . 33
  - 3.3.11 Edges histograms . . . 34
  - 3.3.12 Salient motion . . . 35

3.4 Motion segmentation algorithms . . . 36
3.4.1 Temporal differencing . . . 36
3.4.2 Background subtraction . . . 37
3.4.3 Optical flow . . . 39
3.4.4 Other methods . . . 39
3.5 Shadow removal techniques . . . 39
3.5.1 Non-model deterministic methods . . . 40
3.6 Conclusions . . . 41

4 Character identification in containers **43**
4.1 Introduction . . . 43
4.1.1 Related work . . . 44
4.1.2 Goals and constraints . . . 45
4.2 Proposed schema . . . 46
4.3 Preprocessing . . . 47
4.4 Testing different segmentation approaches . . . 47
4.4.1 A new version for local variation algorithm . . . 48
4.4.2 Data set . . . 48
4.4.3 Parameter set . . . 50
4.4.4 Evaluation criterion . . . 51
4.4.5 Experiments . . . 51
4.5 Filters proposed for noise reduction . . . 55
4.5.1 Size filter . . . 56
4.5.2 Contrast filter . . . 56
4.5.3 Classification . . . 57
4.5.4 Confidence filter . . . 57
4.5.5 Fusion filter . . . 57
4.5.6 Position filter . . . 58
4.5.7 Decision of the tone of the characters . . . 58
4.5.8 Code extraction . . . 59
4.5.9 Filtering segmentation results . . . 59
4.5.10 Code extraction results . . . 60
4.6 Use of sequences of images . . . 64
4.6.1 Clustering objects . . . 64
4.6.2 Processing a sequence . . . 66
4.6.3 Experiments . . . 66
4.7 Conclusions . . . 68

5 Low level vision developments for SENSE **69**
5.1 Introduction . . . 69
5.1.1 Goals and constraints . . . 70
5.1.2 SENSE project . . . 70
5.2 Proposed processing for video modality . . . 72
5.3 Background modelling . . . 74
5.4 Segmentation . . . 75
5.5 Filters . . . 75
5.6 Feature selection . . . 76
5.6.1 Geometric features . . . 76
5.6.2 Foreground pixel density . . . 77
5.6.3 Number of heads . . . 78

5.7 Object tracking 79
5.8 Blob dataset 83
5.8.1 Evaluation of features with blob dataset 84
5.8.2 Experiments with geometric features 85
5.8.3 Experiments with foreground pixel density features 86
5.8.4 Foreground density with different granularity 90
5.8.5 Experiments with head detection algorithm 92
5.9 Experiments with sequences 96
5.10 Conclusions 97

6 Background modelling and object detection **99**
6.1 Introduction 99
6.1.1 Goals and constraints 100
6.2 Background adaptive with confidence (BAC) 101
6.2.1 Similarity criteria between two grey pixels 101
6.2.2 Motion and similarity with the background 102
6.2.3 Segmentation process 102
6.2.4 Model update 104
6.2.5 Segmentation confidence 106
6.2.6 Corrupt model 106
6.2.7 Results obtained with a particular sequence 108
6.3 BAC with colour coordinates 109
6.3.1 Extension to RGB 109
6.4 MBAC 110
6.4.1 Segmentation process with MBAC 110
6.4.2 Corrupt model 112
6.4.3 Model update 112
6.5 Fuzzy background subtraction (FBS) 113
6.5.1 Empirical results 114
6.5.2 Computation of membership functions 115
6.5.3 Pixel level processing 122
6.5.4 Foreground recovery 123
6.5.5 Model corruption detection 123
6.5.6 Model update 124
6.6 Experiments 125
6.6.1 The Wallflower benchmark 127
6.6.2 Analysis of BAC and MBAC parameters 127
6.6.3 Analysis of FBS parameters 132
6.6.4 The FBS algorithm versus the BAC, MBAC algorithms 133
6.6.5 Our proposal compared to the literature algorithms 134
6.6.6 Temporal analysis of algorithms 135
6.6.7 Space complexity of the algorithms 136
6.6.8 Combining BAC and the FBS algorithm 137
6.6.9 Combining the algorithms with a classifier 140
6.7 Conclusions 141

7 Conclusions and future works **143**
7.1 Conclusions 143
7.2 Future works 146

A Morphological operators **147**

B Object classification **149**
B.1 Feature sets for characters recognition 150
B.1.1 Database preprocessing 150
B.1.2 Equalization 151
B.1.3 Cropping 151
B.1.4 Scaling 152
B.1.5 PCA 152
B.2 Training 153
B.3 k-NN confidence computation 153