

List of Figures

| Figure | Title | page |
|--------|---|------|
| 1.1 | Structural Diversities Among Documents | 3 |
| 1.2 | Unconstrained Annotations for Non-controlled Environment. Writing within the margins, between the paragraphs, multi-oriented text-lines, overlapping with the printed text, and presence of symbolic annotations like arrows, underlines, cuts, and encirclement are the examples of the unconstrained annotations. | 4 |
| 1.3 | Organization of the Thesis | 6 |
| 2.1 | Examples of such documents [warrelics.eu, 2010; Japanese Military Postcards, 1931] in real environment where the text is broken to characters and encourages segmentation of handwritten and printed content at character level. | 11 |
| 2.2 | Examples of such documents in real environment where large chunks of text persists and encourages segmentation of handwritten and printed content at Block Level. | 13 |
| 2.3 | Examples of such documents [Genealogy Photos, 2010; Birth Certificate, 2018] in real environment where mixed types of text persists and encourages segmentation of handwritten and printed content at word/connected component Level. | 15 |
| 2.4 | Multi-oriented Handwritten Dataset used by the work [Pandey and Harit, 2015]. | 20 |
| 2.5 | Examples of such documents [Peng et al., 2013; Pandey and Harit, 2015] in real environment where the text is of overlapping nature and encourages segmentation of handwritten and printed content at Pixel Level. | 22 |
| 2.6 | Examples of such documents [Lin Yangchen, 2015; Nathan Raab, 2017] where long independent text-lines of single category persist and encourages segmentation of handwritten and printed content at text-line Level. | 24 |
| 3.1 | Discriminating Elements in Handwriting. | 30 |
| 4.1 | Kinds of Handwritten Annotations. | 56 |
| 4.2 | Contrast among Controlled and Non-controlled Annotation Documents. | 57 |
| 4.3 | Type of documents processed/included in Our Dataset for extracting annotations. The blue bounding boxes represent hand annotated pseudo words while the red bounding boxes represent the printed pseudo-words. | 59 |
| 4.4 | Schematic diagram of the proposed scheme for Handwritten and Printed Segmentation | 61 |
| 4.5 | Extraction of pseudo-words by morphological analysis. At first the boundaries of foreground (dark) regions in the original image is enlarged by dilation mechanism using a structuring element. Then the foreground region of the dilated image is shrunk by erosion mechanism using the same structuring element. The resulting image is then smoothed by a median filter and finally connected blocks of pixels are boxed as patches using boundary extraction algorithm. | 61 |
| 4.6 | Maximum Horizontal Runlength for Printed and Handwritten Pseudo-word. | 62 |
| 4.7 | Maximum Height of the Connected Components within a Printed and Handwritten Pseudo-word. | 62 |
| 4.8 | Overlap-area of the connected components within a pseudo-word/patch. | 63 |
| 4.9 | Vertical Projection Profile is drawn by Counting the Foreground Pixels column wise. | 63 |
| 4.10 | Selection of Sample Points. | 64 |
| 4.11 | Envelop Straightness Feature Value Computation. | 64 |
| 4.12 | Envelop Straightness | 65 |

| | | |
|------|---|-----|
| 4.13 | Sample result of annotations and printed text extraction with Graph Cuts framework on one(two) image(s) from our dataset | 68 |
| 4.14 | Sample result of annotations and printed text extraction with Graph Cuts framework on one(two) image(s) from IAM dataset . | 69 |
| 4.15 | Results of Feature Sets mentioned by [Peng <i>et al.</i> , 2013] and [Benjlaiel <i>et al.</i> , 2014] in contrast to proposed Feature Set on Our Dataset using the Graph Cut Framework. | 70 |
| 4.16 | Results of Feature Sets mentioned by [Peng <i>et al.</i> , 2013] and [Benjlaiel <i>et al.</i> , 2014] in contrast to proposed Feature Set on IAM Dataset using the Graph Cut Framework. | 70 |
| 5.1 | Salient object and its Neighborhood. | 72 |
| 5.2 | Types of visual saliency. | 72 |
| 5.3 | Types of annotations used in our work. | 76 |
| 5.4 | Set 1: All kinds of annotation localization in documents using CRF. | 83 |
| 5.5 | Set 2: Underlined region localization in multi-annotated images using CRF | 85 |
| 5.6 | Set 2: Marginal annotation region localization in multi-annotated images using CRF. | 86 |
| 5.7 | Set 2: Encircled region localization in multi-annotated images using CRF | 87 |
| 5.8 | Set 2: Inline annotation region localization in multi-annotated images using CRF | 88 |
| 5.9 | Set 3: Textual region localization in documents comprising both Textual and Symbolic annotations using CRF | 88 |
| 5.10 | Set 3: Symbolic Region Localization in Documents comprising both Textual and Symbolic Annotations using CRF | 89 |
| 5.11 | Set 4: Underlined annotation localization in single-class annotated images using CRF | 90 |
| 5.12 | Set 4: Marginal annotation localization in single-class annotated images using CRF | 91 |
| 5.13 | Set 4: Encircled annotation localization in single-class annotated images using CRF | 91 |
| 5.14 | Set 4: Inline annotation localization in single-class annotated images using CRF. | 92 |
| 5.15 | Textual region localization in IAM images using CRF. | 93 |
| 5.16 | Textual region localization in PRImA images using CRF. | 93 |
| 5.17 | All kinds of annotation localization in documents using SVM. | 94 |
| 6.1 | Set 1: All kinds of Annotation Localization in Documents using DS. | 104 |
| 6.2 | Set 2: Underlined Region Localization in Multi-annotated Images using DS | 105 |
| 6.3 | Set 2: Marginal Annotation Region Localization in Multi-annotated Images using DS. | 106 |
| 6.4 | Set 2: Encircled Region Localization in Multi-annotated Images using DS | 107 |
| 6.5 | Set 2: Inline Annotation Region Localization in multi-annotated Images using DS | 108 |
| 6.6 | Set 3: Textual Region Localization in Documents comprising both Textual and Symbolic Annotations using DS | 109 |
| 6.7 | Set 3: Symbolic Region Localization in Documents comprising both Textual and Symbolic Annotations using DS | 110 |
| 6.8 | Set 4: Underlined region localization in single-class annotated images using DS | 111 |
| 6.9 | Set 4: Marginal annotations localization in single-class annotated images using DS | 112 |
| 6.10 | Set 4: Encircled annotation localization in single-class annotated images using DS | 113 |
| 6.11 | Set 4: Inline annotation localization in single-class annotated images using DS | 114 |
| 6.12 | Textual region localization in IAM images using DS. | 115 |
| 6.13 | Textual region localization in PRImA images using DS. | 115 |
| 7.1 | Variety of handwriting challenges for core-region extraction. | 117 |
| 7.2 | A word divided into its corresponding zones. | 118 |
| 7.3 | Zoning by using Horizontal Projection Profile Method | 119 |
| 7.4 | Erroneous detection of reference lines due to longer horizontal strokes by Horizontal Projection Profile method. | 119 |
| 7.5 | The peaks of the horizontal stroke are discarded in the HPP derivative while the peaks of the core-region are preserved [Bozinovic and Srihari, 1989]. | 119 |

| | | |
|------|---|-----|
| 7.6 | Contiguous set of pixels are drawn on the upper envelop. The pixel marked as U belongs to the upper envelop. | 122 |
| 7.7 | The pixels numbered from 1 --- 8 represents the sampled sequence of pixels on the upper envelop. | 122 |
| 7.9 | The pixels 2, 4, 5 and 7 are the maximal points selected when matched with the Topological Patterns for the upper reference line. | 123 |
| 7.11 | Partitioning the computed maxima points into two sets of core and non-core region maximal points. The first and the last maximal points i.e. 1 and 8 are also included. | 124 |
| 7.12 | Histogram indicating the percentage of word images having core-region area mismatch with its corresponding ground truth core-region for specified percentage of pixels mismatch. | 125 |
| 7.13 | A few sample results of our proposed method to identify core regions in handwritten words. The region between blue lines indicates the core region obtained by our proposed method while the region between red lines indicates the core region marked as ground truth. | 127 |
| 8.1 | The three types of handwritten Word Allographs from CVL Dataset | 130 |
| 8.2 | The four topological masks with P as the central pixel, the dark region as the foreground pixel and the filled pattern as <i>do not care</i> care region. | 134 |
| 8.3 | Results for grapheme based features with non overlapping and overlapping window. | 136 |
| 8.4 | Results for Character based features with non overlapping and overlapping window. | 137 |
| 8.5 | Performance comparison between grapheme and character feature clusters. | 137 |
| 8.6 | Identification rate improvement between [Slimane and Margner, 2014] and our method using graphemes. | 138 |

