Direct Processing of Run-Length Compressed Document Image for Segmentation and Characterization of a Specified Block

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ABSTRACT

Extracting a block of interest referred to as segmenting a specified block in an image and studying its characteristics is of general research interest, and could be a challenging if such a segmentation task has to be carried out directly in a compressed image. This is the objective of the present research work. The proposal is to evolve a method which would segment and extract a specified block, and carry out its characterization without decompressing a compressed image, for two major reasons that most of the image archives contain images in compressed format and ‘decompressing’ an image incurs additional computing time and space. Specifically in this research work, the proposal is to work on run-length compressed document images.

General Terms:
Compressed Document, Direct processing

Keywords:
Compressed data, Document Block Extraction, Document Characterization, Entropy, Density

1. INTRODUCTION

Segmentation and characterization of a specified block in a document image finds many applications in the area of Document Image Analysis (DIA) and Pattern Recognition (PR) systems, particularly in applications like signature extraction from official documents [1], logo extraction and detection [12] and document text, photo and line extraction [6]. In addition to this, the concept of block segmentation has been applied for text extraction from layout-aware [18] and 2D plot [12] image documents. Another interesting work uses extracted text blocks from postal images for classification using wavelet coefficients [24]. However, all these methods have major limitation of working only with uncompressed or decompressed documents, although in real life documents are made available in compressed form to provide better transmission and storage efficiency. While dealing with compressed documents, they need to decompress the compressed document and then operate over them. Thus decompression has become an unavoidable pre-requisite which incurs extra computation time and buffer space. Therefore, it is novel to think of developing intelligent algorithms to extract specified document blocks for document image analysis straight from corresponding compressed formats directly. The specified block to be extracted is conventionally assumed to be rectangular. A sample document showing the real life applications of logo, date and signature extraction by binding them in rectangular blocks is demonstrated in Fig. 1.

Fig. 1: Block-segments of Logo, Date and Signature used in document image analysis

The second issue is characterization of the segmented/extracted block. Generally absolute characterization of the block may suffice, but there are instances where it is required to express the block characterization contrasted to characterization of the entire document. This is relative characterization of the extracted segment with reference to the entire document. This implies that not only characterization of the extracted version, also for relative characterization the process has got to be done on the entire document but directly in its compressed version. Working with compressed version of documents directly for applications in image analysis and pattern recognition, is a challenging goal. The initial idea of working with compressed data was first demonstrated in early 1980’s [8][23]. Run-Length Encoding (RLE), a simple compression method was first used for coding pictures [3].
and television signals [14]. There are several efforts in the direction of directly operating on document images in compressed domain. Operations like image rotation [11], connected component extraction [19], skew detection [21], page layout analysis [22] are reported in the literature related to run-length information processing. There are also some initiatives in finding document similarity [13], equivalence [9] and retrieval [15]. One of the recent work using run-length information is to perform morphological related operations [2]. In most of these works, they use either run-length information from the uncompressed image or do some partial decoding to perform the operations. To our best knowledge in the literature, there has been no effort seen in extracting document blocks directly from the TIFF compressed binary text-documents for document characterization. However there is an initiative to show the feasibility of performing segmentation without decompression using JPEG documents by [4,5], which may not be suitable for direct processing of TIFF compressed documents.

Therefore in this backdrop, a novel idea of segmenting a document block straight from the run-length data of TIFF compressed documents, without going through the stage of decompression is proposed. Some of the recent works related to feature extraction and text-document segmentation directly from run-length compressed data can be found in [11,10,16]. Rest of the paper is organized as follows: section-2 describes the problem, related issues and terminologies, section-3 discusses the proposed model for segmenting a block, section-4 shows the experimental analysis with the proposed methods, section-5 brings out absolute and relative characterization of the segmented block using density and entropy values and finally section-6 concludes the paper with a brief summary.

2. UNDERSTANDING THE PROBLEM AND TERMINOLOGIES

Segmenting and analyzing or characterizing a specified block from documents is more frequently used in document image analysis, which usually means extracting the contents of a document bound in some rectangular segment. Such a segmentation involves extraction of horizontal and vertical boundaries which can be performed easily in a decompressed image without much effort using the specified rows and columns of the block as shown in Fig-2a. However, when this image is subjected to run-length compression, the specified block does not visibly appear rectangular shaped. Therefore automatically tracing the block becomes challenging. While tracing the contents of the specified block of Fig-2a within the compressed data, it is observed to be located within the enclosed boundary of runs shown in Fig-2b. This boundary can be located inside the compressed data with the help of start (y1) and end (y2) columns of the specified block. For example, at line number 5 of the Fig-2b, the start-column (y1 = 3) and end-column (y2 = 6) of the specified block of Fig-2a is located within the run columns of 1 (start-run) and 2 (end-run) respectively and hence, the position of the specified block inside the compressed data is tabulated respectively as P1 and P2 in Fig-2b. Once the boundary of the specified block is approximately located inside the compressed data as in Fig-2b, it is necessary to do further refinement of the runs specifically at the runs of start and end locations of the block to get exact boundary of the specified block as in Fig-2a. The schematic view of these exact locations of the specified block in the compressed data is given in Fig-3. It is observed that the start and end boundaries of the specified block is located in between the runs pointed by P1(4) and P2(4). Therefore, the extraction of exact block warrants the removal of excess runs from the both ends. These extra runs at both ends are coined as residue runs which are correspondingly tabulated as R1(2) and R2(2) in Fig-2b. These residue runs have to be eliminated from the enclosed boundary of specified block in compressed data of Fig-2b and the updated compressed data is shown in Fig-4a. The resulting compressed data when decompressed gives the exact specified block as shown in Fig-4b.

Another important aspect in this research work is the absolute and relative characterization of the specified block from the compressed data. The method of analyzing the contents of the segmented block independently is absolute characterization, whereas the analysis with respect to source document is relative characterization. In this research study, the entropy [16,17] and density features are used for characterizing the specified block which will be discussed in section-5.

3. PROPOSED MODEL

In this section, a novel method for extracting specified document blocks straight from run-length compressed document data is proposed. The different stages involved in segmenting a document block is shown in Fig-5.

The proposed model works on the run-length compressed data extracted using Huffman decoding from the TIFF compressed binary
documents. Using the specified rows \((x_1\) and \(x_2\)) of the document block, the segmentation of horizontal boundaries is done in the compressed data. The next stage is to trace the vertical boundary positions and corresponding residue runs from each row in the compressed data using columns \((y_1\) and \(y_2\)) of the specified block. The strategy to be used in locating the boundary position and the corresponding residues is summarized in Table-1 and Table-2, where \(j\) indicates the column position of runs in the compressed data. For every row of runs in compressed data, the cumulative sum of runs \((\text{runSum})\) is calculated until one of the following cases described in Table-1 is encountered, which gives the position of \(y_1\) in the compressed data. Similarly continue the row scan to find the position of \(y_2\) based on the condition specified in Table-2. Tabulate these positions of \(y_1\) and \(y_2\) traced from the compressed data as \(P_1\) and \(P_2\) and their corresponding residues \(R1\) and \(R2\) in position table shown in Fig-2. Now using the position table extract the compressed data matrix of the specified block. As it is known that, this compressed data approximately represents the specified block and hence requires removal of residue runs using the residue values tabulated previously. Once the residue runs are removed from the compressed data of the specified block using the strategy specified in Table-3, the updated compressed data is obtained which is shown with an example in Fig-4. The resulting compressed data of the specified block is utilized for further document analysis such as for absolute and relative characterization using the density and entropy features which will be discussed in the next section.
Table 3.: Strategy for residue run modifications from the compressed data

| For all the rows \( i \) | Updated Start Run | Updated End Run |
|--------------------------|------------------|-----------------|
| Case 1: \( \text{if} P_1 = P_2 \& R_1 \neq 0 \& R_2 \neq 0 \) | \( M(i, P_1) = R_1 - R_2 \) | \( M(i, P_2) = M(i, P_1) - R_1 \) |
| Case 2: \( \text{if} P_1 = P_2 \& R_1 \neq 0 \& R_2 = 0 \) | \( M(i, P_1) = M(i, P_1) - R_1 \) | \( M(i, P_2) = M(i, P_1) - R_2 \) |
| Case 3: \( \text{if} P_1 = P_2 \& R_1 = 0 \& R_2 \neq 0 \) | \( M(i, P_1) = M(i, P_2) - R_1 \) | \( M(i, P_2) = M(i, P_1) - R_2 \) |
| Case 4: \( \text{if} P_1 = P_2 \& R_1 = 0 \& R_2 = 0 \) | \( M(i, P_1) = M(i, P_1) - R_1 \) | \( M(i, P_2) = M(i, P_1) - R_2 \) |
| Case 5: \( \text{if} P_1 \neq P_2 \& R_1 = 0 \& R_2 \neq 0 \) | \( M(i, P_1) = M(i, P_1) - R_1 \) | \( M(i, P_2) = M(i, P_1) - R_2 \) |
| Case 6: \( \text{if} P_1 \neq P_2 \& R_1 = 0 \& R_2 = 0 \) | \( M(i, P_1) = M(i, P_1) - R_1 \) | \( M(i, P_2) = M(i, P_1) - R_2 \) |
| Case 7: \( \text{if} P_1 \neq P_2 \& R_1 \neq 0 \& R_2 = 0 \) | \( M(i, P_1) = M(i, P_1) - R_1 \) | \( M(i, P_2) = M(i, P_1) - R_2 \) |
| Case 8: \( \text{if} P_1 \neq P_2 \& R_1 \neq 0 \& R_2 \neq 0 \) | \( M(i, P_1) = M(i, P_1) - R_1 \) | \( M(i, P_2) = M(i, P_1) - R_2 \) |

Table 4.: Accuracy of the extracted blocks

| Sample | Accuracy-1 (%) | Accuracy-2 (%) |
|--------|----------------|----------------|
| Block-Segment-1 | 100 | 100 |
| Block-Segment-2 | 100 | 100 |
| Block-Segment-3 | 100 | 100 |
| Block-Segment-4 | 100 | 100 |

Where \( m \) and \( n' \) are the rows and columns of the specified block in the compressed data, where \( n' < n \). The accuracy of 4 segmented blocks in Fig 6 using both the methods described is tabulated in Table 4.

5. BLOCK CHARACTERIZATION

In this section, the absolute and relative characterization of the specified block extracted directly from the compressed data is demonstrated. The density and entropy features \([11, 16, 7]\) computed from Conventional Entropy Quantifiers (CEQ) and Sequential Entropy Quantifiers (SEQ) are used for characterizing the extracted document block. CEQ measures the energy contribution of each row by considering the probable occurrence of +ve and -ve transitions among the total number of pixels in that row and SEQ analyzes the component by measuring the entropy at the position of occurrence of the transitions. The detailed presentation is available in [7].

The mathematical formula for CEQ is as follows,

\[
E(t) = p \star \log \left( \frac{1}{p} \right) + (1 - p) \star \log \left( \frac{1}{1-p} \right)
\]

where \( t \) is the transition from 0 to 1 and 1 to 0, \( E(t) \) is the entropy, \( p \) is the probable occurrence of transition in each row, then \( 1 - p \) is the probable non-occurrence of transition. For SEQ, if the transition occurs between two columns \( c_{3a} \) and \( c_{3b} \) in row \( r_n \) then corresponding row entropy is formulated as:

\[
E(\beta) = \frac{(m - c_{3a}) \star \log \frac{m}{m-p} + (m - c_{3b}) \star \log \frac{m}{m-p}}{m}
\]

where \( \beta = 1, \ldots, m \) and the position parameter \( pos \), which indicates the position of transition point in horizontal direction.

The absolute characterization of the extracted block is done considering only the features of the block. The parameters \( p' \) for CEQ and SEQ is computed as the ratio of total number of (0-1) Or (1-0) transitions in each row of the block and total number of probable transitions possible in each row of the block, and parameter \( 'p' \) indicates the column position of transition in each row of the block. On the other hand, the relative characterization of the specified block is done taking into account the features of source document. The parameters \( 'p' \) for CEQ and SEQ is computed as the ratio of total number of (0-1) Or (1-0) transitions in each row of the block and total number of probable transitions possible in a row of block with respect to source document, and the parameter
On the similar line, the absolute and relative characterization using density feature is given as follows,

\[ \text{Absolute Density} = \frac{\text{Total sum of foreground pixel runs}}{\text{Size of the block}} \]

\[ \text{Relative Density} = \frac{\text{Total sum of foreground pixel runs}}{\text{Size of the Document}} \]

The absolute and relative characterization using density and entropy features for different blocks extracted in Fig-6 is tabulated in Tables 5 and 6, respectively. From these tables it is observed that the extracted block in Fig-6c is a case for low density and low entropy. Fig-6d is an example for low density and high entropy. On the other hand Fig-6e shows high density and low entropy. Fig-6b shows high density and low entropy.

In this research work, the study is limited to extracting and characterizing the document blocks in rectangular segments from the compressed data. However, there is a scope for research in extracting document blocks of different shapes and also considering skew as shown in Fig-7, which could be taken as an extension to this research work.

6. CONCLUSION

In this research work, a novel method for extracting the specified document block in rectangular segments directly from the run-length compressed data without going through the stage of decompression is proposed. Further, the absolute and relative characterization of the extracted blocks using density and entropy features are demonstrated. This research study also demonstrates that document analysis is possible using compressed data without decompression and also opens up the gateway for plenty of research issues using compressed documents in compressed domain.
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