An Object-Based, Multiresolution Approach for Coding of MRI Data

Habibollah Danyali
University of Kurdistan
hdanyali@ieee.org

Abstract: This paper proposes an object-based, highly scalable, lossless coding approach for MRI data. The proposed approach, called OBHS-SPIHT, encodes each slice of the input MRI data set separately in a multiresolution fashion from low resolution to full resolution without losing any information. To achieve more compression efficiency, the algorithm only encodes the main object of interest in the input data set, and ignores the unnecessary background. The experimental results on some test MR image sets show the efficiency of the proposed algorithm for multiresolution lossless coding. OBHS-SPIHT, is a very attractive coding approach for medical image information archiving and transmission applications.

Keywords: Medical image compression, HS-SPIHT, object-based coding, progressive transmission, scalability, wavelet coding.

1 Introduction

Over the past decade, wavelet-based image compression schemes have become increasingly important and gained widespread acceptance. An example is the new JPEG2000 still image compression standard [1, 2]. Due to the multiresolution signal representation offered by the wavelet transform, wavelet based coding schemes have a great potential to support scalability features. Among the state-of-the-art embedded wavelet coding approaches the Set Partitioning in Hierarchical Trees (SPIHT) algorithm [3] is well known as a benchmark for its compression efficiency, full SNR scalability support and very low complexity. These features have made SPIHT very attractive for medical image coding as well [4–6]. As shown in [4], an object-based version of SPIHT (OB-SPIHT) exhibits a very competitive PSNR performance for the compression of medical images. On the other hand, research conducted by Pearlman [7] showed a very significant complexity reduction of SPIHT over JPEG2000. Although the SPIHT bitstream is tailored for full SNR scalability and is progressive (by quality) coding, it does not support spatial scalability to provide a bitstream that can be parsed for multiresolution decoding by different clients with different capabilities. Thus a full scalable coding approach which support both quality and resolution scalability is highly required. For a full-featured coding algorithm for an efficient medical image archiving and transmission system, lossless compression and object-based coding support are also highly demanded. A lossless compression facilitate more accurate diagnosis, of course at the expense of lower com-
pressions (i.e. higher bit rates) in comparison to the lossy coding methods. An object-based coding makes it possible to only encode the object of interest, which can have any arbitrary shape, regardless of the rest the image.

This research proposes an object-based medical image coding system based on the highly scalable set partitioning in hierarchical trees (HS-SPIHT) algorithm. The HS-SPIHT, introduced by the author in his previous works [8, 9], is a modification of the SPIHT algorithm [3] that adds spatial scalability features to the SPIHT algorithm without sacrificing the interesting features of the original algorithm. The coding system proposed in this paper, called OBHS-SPIHT, extends the 2D HS-SPIHT algorithm for object-based lossless coding of MR image data. The OBHS-SPIHT algorithm fulfills all requirements for medical image information archiving and transmission systems.

The rest of this paper is organized as follows. In Section 2, the OBHS-SPIHT coding algorithm is presented. The scalable structure of the OBHS-SPIHT bitstream is explained in Section 3. In Section 4, some details about the simulation of the coding system are given and experimental results for multiresolution lossless coding are presented, and finally, Section 5 concludes the paper.

2 Object-based HS-SPIHT

Figure 1 depicts the proposed OBHS-SPIHT encoder system. The input MR slice is first segmented to extract the object of interest from the background. The extracted object is decomposed by a shape adaptive integer DWT (SA-IDWT) approach which maps integer object voxels to integer wavelet coefficients. The decomposed object coefficients and the decomposed shape mask are then consigned to the OBHS-SPIHT encoder. The encoder only encodes the coefficients that belong to the decomposed object. The bitstreams from the shape coding and object coding algorithms are assembled in the bitstream organizer to generate the final encoder output bitstream.

The SPIHT algorithm of [3] considers sets of coefficients that are related through the parent-offspring dependency depicted in Figure 2. In its bitplane coding process, the algorithm deals with the wavelet coefficients as either members of insignificant sets, individual insignificant pixels, or significant pixels. It sorts these coefficients in three ordered lists: the list of insignificant sets (LIS), the list of insignificant pixels (LIP), and the list of significant pixels (LSP). The main concept of the algorithm is managing these lists in order to efficiently extract insignificant sets in a hierarchical structure and identify significant coefficients, which is the core of its high compression performance. The SPIHT algorithm provides a progressive (by quality) bitstream which is fully SNR scalable, however its bitstream does not support spatial scalability.

In [8, 9] we proposed a scalable modification of SPIHT for image coding, called highly scalable SPIHT (HS-SPIHT), through the introduction of multiple resolution-dependent lists and a resolution-dependent sorting pass. The HS-SPIHT algorithm encodes the different resolution subbands in the wavelet decomposed image separately, allowing a parser or a decoder to directly access the data needed for reconstruction of a desired spatial resolution and/or quality. To manage the scalable coding process, for each resolution subband set, the algorithm defines a set of LIP, LSP and LIS lists, therefore there are LIP_k, LSP_k, and LIS_k for k = s_{max}, s_{max} - 1, ..., 1.
where $s_{\text{max}}$ is the maximum number of spatial resolution levels supported by the encoder. To improve the algorithm to be used for coding of medical images which contain objects with any arbitrary shape, we only consider and process those coefficients that belong to the decomposed object (see Figure 3) and those sets that are at least partially located inside the decomposed object, similar to the SA-SPIHT algorithms in [10]. To recognize these coefficients and sets, the improved algorithm, OBHS-SPIHT, needs the decomposed shape mask information.

### 3 Bitstream Structure

Figure 4 shows the structure of the bitstream generated by the OBHS-SPIHT encoder for a slice. The slice bitstream contains the mask and object bitstreams. The object bitstream is fully resolution scalable and constructed of different codeparts ($P_k$), each part belong to a spatial resolution. To support bitstream parsing, some markers are put in the bitstream to provide the information required for identifying the different resolution in the parsing process.

The encoder needs to encode the input object only once at a lossless rate. Different bitstreams for different spatial resolutions can be easily generated from the encoded bitstream by selecting the related resolution codeparts. The parsing process is a simple codeparts selection procedure and can be carried out by a server that stores the encoded medical data sets or by an individual parser as a part of an active network. The parser does not need to decode any part of the bitstream. Note that the markers in the main bitstream are only used by the parser and do not need to be sent to the decoder.

### 4 Experimental Results

#### 4.1 Simulation Details

The OBHS-SPIHT coding system were fully software implemented. Four gray-scale (8 bits per voxel) MR data sets were chosen as test data sets. These data sets were also used in [5, 6, 11]. A description of these MR sets is given in Table 1. To extract the objects from the unimportant, very low magnitude background voxels, a two-stage threshold-based segmentation scheme was used. In the first stage, each MR set was compared with a threshold and all voxels that exceeded the threshold were considered to belong to the object. In a second stage, all background areas that were surrounded by the object were reclassified to belong to the object. The first slice of one of the MR test set, MR_sag_head, and its appropriate segmentation mask is shown in Figure 5. For the object-based wavelet decomposition, an efficient, non-expansive SA-DWT approach, based on the method introduced in [12] was implemented. The integer I(2,2) wavelet filter bank [13] was implemented in a lifting scheme and used for object decompositions with symmetric extension at the boundaries of the object in each slice.

The OBHS-SPIHT encoder was set to encode the decomposed objects of all slices of each MR test set to lossless rate with three levels of spatial scalability support. The binary mask information for each slice was encoded by an arithmetic binary coding scheme [14].
Table 1: Description of the MR data sets used in this paper.

<table>
<thead>
<tr>
<th>History</th>
<th>Age</th>
<th>sex</th>
<th>File name</th>
<th>Voxel size (mm)</th>
<th>Volume size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Congenital heart disease</td>
<td>1</td>
<td>M</td>
<td>MR_ped_chest</td>
<td>0.78 × 0.78 × 5</td>
<td>256 × 256 × 77</td>
</tr>
<tr>
<td>Normal</td>
<td>38</td>
<td>F</td>
<td>MR_liver_t</td>
<td>1.45 × 1.45 × 5</td>
<td>256 × 256 × 58</td>
</tr>
<tr>
<td>Normal</td>
<td>38</td>
<td>F</td>
<td>MR_liver_2e1</td>
<td>1.37 × 1.37 × 5</td>
<td>256 × 256 × 58</td>
</tr>
<tr>
<td>Left exopthalmos</td>
<td>42</td>
<td>M</td>
<td>MR_sag_head</td>
<td>0.98 × 0.98 × 3</td>
<td>256 × 256 × 58</td>
</tr>
</tbody>
</table>

Figure 5: The first slice of (a) MR\_sag\_head data set. (b) extracted mask for MR\_sag\_head data set.

### 4.2 Results

Table 2 provides the average bits per voxel (bpv) obtained by OBHS-SPIHT for multiresolution lossless coding of the four MR object sets. As the results show for both cases, a lossless version of the lower resolutions can be obtained at very small rates. Figure 6 shows the lossless reconstruction of slice 9 of MR\_sag\_head data set at three different resolutions (full, half and quarter). The average rate consumed for coding of the binary mask information of the MR sets lies between 0.016 bpv to 0.02 bpv and therefore is negligible.

In Table 3 the OBHS-SPIHT results for lossless coding at full resolution are compared with HS-SPIHT, SPIHT, JPEG2000 and WinZip coding approaches. For the HS-SPIHT, SPIHT, JPEG2000 and WinZip cases the object background in all slices was set to zero to have a fair comparison with OBHS-SPIHT. A very small difference between the lossless compression rates of HS-SPIHT and SPIHT is due to the extra budget consumed by HS-SPIHT for markers in the bitstream which are required for the parsing process. The results reported here for SPIHT and HS-SPIHT for both object-based and non object-based coding cases were obtained without extra arithmetic coding of the encoder output bitstreams. As shown in [3], an improved coding performance for SPIHT and consequently for HS-SPIHT can be achieved by further compressing the binary bitstreams with an arithmetic coder. Despite this fact the OBHS-SPIHT algorithm provides comparable results to JPEG2000 while it has much less complexity and consequently is faster than JPEG2000 [7]. The OBHS-SPIHT shows significantly better performance than all the other 2D coding approaches in the table.

### 5 Conclusions

An object-based, highly scalable wavelet coding system, OBHS-SPIHT, for lossless coding of MR data sets was presented. The object of interest in each slice of MR data set were segmented from the background. A reversible shape-adaptive in-
Table 2: Average bits per voxel obtained for lossless encoding of the MR data sets by OBHS-SPIHT.

<table>
<thead>
<tr>
<th>Spatial resolution</th>
<th>MR_ped_chest</th>
<th>MR_liver_t1</th>
<th>MR_liver_t2e1</th>
<th>MR_sag_head</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quarter</td>
<td>0.1419</td>
<td>0.2722</td>
<td>0.2605</td>
<td>0.1727</td>
</tr>
<tr>
<td>Half</td>
<td>0.4339</td>
<td>0.8320</td>
<td>0.8378</td>
<td>0.5435</td>
</tr>
<tr>
<td>Full</td>
<td>1.2550</td>
<td>2.3420</td>
<td>2.4955</td>
<td>1.7440</td>
</tr>
</tbody>
</table>

Figure 6: Original slice 9 of MR\_sag\_head at full, half and quarter resolution.

Table 3: Comparison of average bits per voxel obtained for lossless encoding of the MR data sets at full resolution with different coding methods.

<table>
<thead>
<tr>
<th>Method</th>
<th>MR_ped_chest</th>
<th>MR_liver_t1</th>
<th>MR_liver_t2e1</th>
<th>MR_sag_head</th>
</tr>
</thead>
<tbody>
<tr>
<td>OBHS-SPIHT</td>
<td>1.2550</td>
<td>2.3420</td>
<td>2.4955</td>
<td>1.7440</td>
</tr>
<tr>
<td>HS-SPIHT</td>
<td>1.5921</td>
<td>2.6354</td>
<td>2.7781</td>
<td>2.1772</td>
</tr>
<tr>
<td>SPIHT</td>
<td>1.5818</td>
<td>2.6247</td>
<td>2.7677</td>
<td>2.1660</td>
</tr>
<tr>
<td>WinZip</td>
<td>1.8900</td>
<td>3.7261</td>
<td>3.7512</td>
<td>2.3571</td>
</tr>
</tbody>
</table>
integer DWT was used to decompose the input objects. Each slice of the data set was encoded separately. This not only facilitates more efficient random access to the slices, but also requires less memory from the coding system. The OBHS-SPiHT bitstream is easily reorderable by a simple parser for multiresolution decoding. The experimental results on some MR image sets at various spatial resolution levels showed the excellent performance of the proposed algorithm. Possessing important features such as arbitrarily shaped object coding and resolution scalability functionality makes the proposed approach attractive for medical image information archiving and transmission applications.

References


