Diagnostically-Preserving Compression of Ultrasound Images based on Adaptive Quantization

Shira Nemirovsky-Rotman[1], Zvi Friedman[2] and Moshe Porat[1]
[1]Dept. of Electrical Engineering, Technion, [2]Dept. of Biomedical Engineering, Technion

Background:

- Medical image compression is essential in order to meet storage and transmission requirements.
- The main challenge in medical image compression is to preserve the image diagnostic information.
- Current coding methods achieve compression ratios of 20:1 – 30:1 with acceptable medical image quality.
- We propose a novel coding scheme for ultrasound images, which focuses on the diagnostic image areas.

Adaptive Quantization:

- Our coding scheme is based on partition of the image into blocks and their classification into ROIs (Regions-of-Interest), BG (background) and Hybrid, according to their diagnostic value.
- For each block class, an optimal quantization table is computed according to a Rate-Distortion criterion.
- Each block is coded using the appropriate table.

Optimal Quantization Algorithm:

Input: Target compression ratio, CR_{target}.
Image f, to be optimally coded.
Quantization step size S.

Output: Quantization table Q.

Step 1: Initialize quantization table Q.

Step 2: Calculate the compression ratio using the current Q. If it is smaller than the target compression ratio, then for each table entry, find the change in the PSNR (Peak-Signal-to-Noise Ratio) and CR if that entry is increased by S. Then, select the entry that yields the smallest $\frac{\Delta(PSNR)}{\Delta(CR)}$ ratio and increase that entry with S. Denote the corresponding ratio (or slope) as

$$R_{min} = -\frac{\Delta(PSNR)}{\Delta(CR)}$$

Step 3: Calculate the compression ratio using the current Q. If it is larger than the target compression ratio, then for each table entry, find the change in the PSNR and CR if that entry is decreased by S. Then, select the entry that yields the largest $\frac{\Delta(PSNR)}{\Delta(CR)}$ ratio and decrease that entry with S. Denote the corresponding ratio (or slope) as

$$R_{max} = -\frac{\Delta(PSNR)}{\Delta(CR)}$$

Step 4: Repeat Steps 2, 3 until $R_{max} \le R_{min}$ (see Fig. 1).

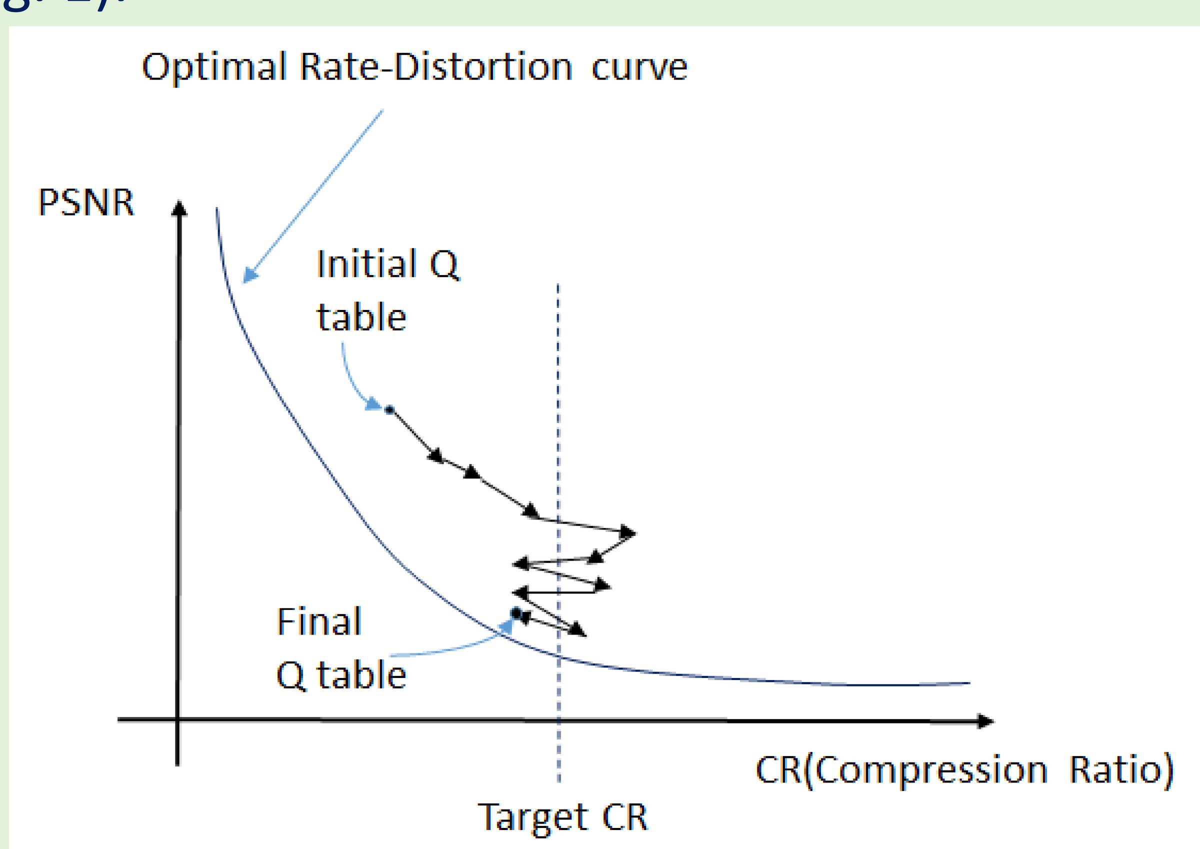


Figure 1 – Convergence of the iterative algorithm for optimization of the Q-table.

Proposed Coding Algorithm: (Fig. 2)

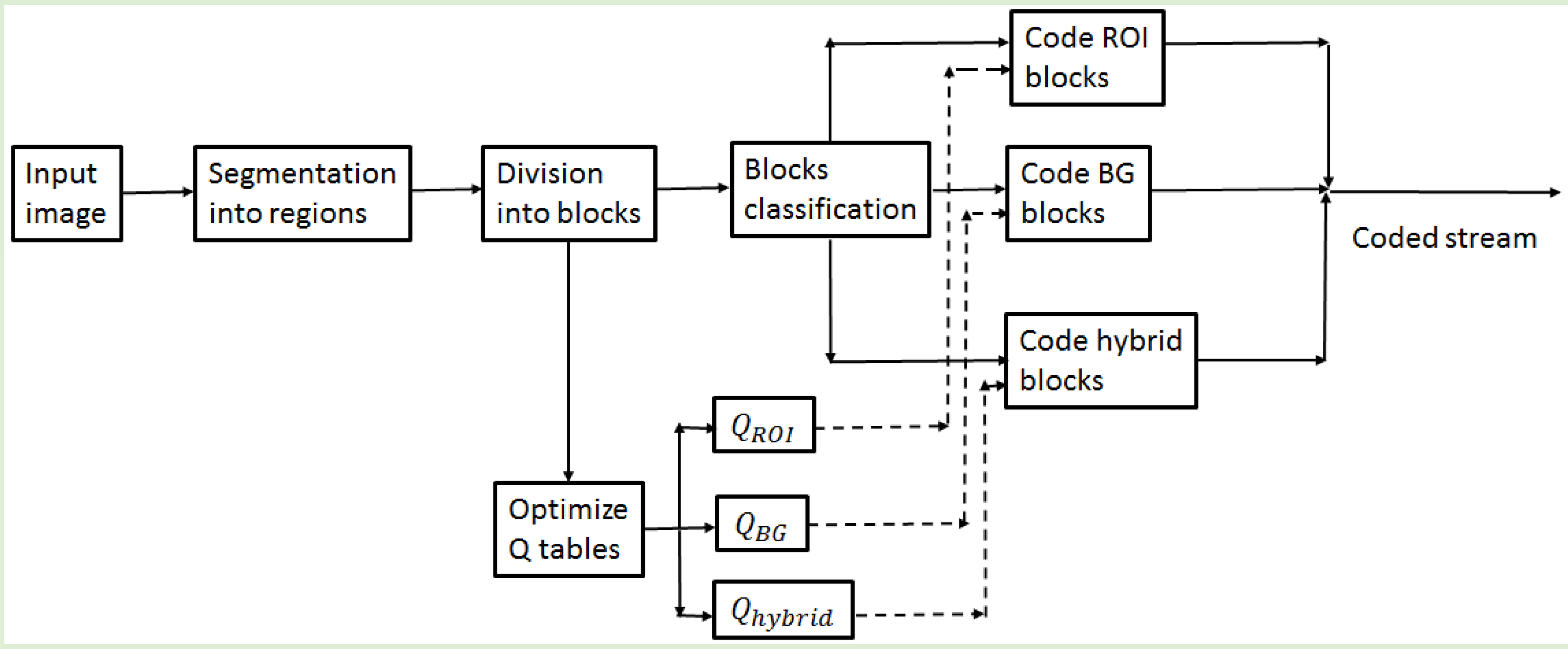


Figure 2 – Block diagram for the proposed coding algorithm.

Step 1: Identification of the ROI pixels.
For example, for echo-cardiac images (see Fig. 3) the ROI pixels satisfy: $p_i > \mu + th \cdot \sigma$
p_i - ROI pixel's gray level; μ - global mean gray level in the image;
σ - standard deviation of gray levels in the image; th - threshold.
Step 2: Division of the image into blocks.
Step 3: Classification of blocks into ROI, Background and Hybrid blocks.
Step 4: Optimization of the Q-tables for each block type.
Step 5: Coding of each block using the appropriate Q-table.

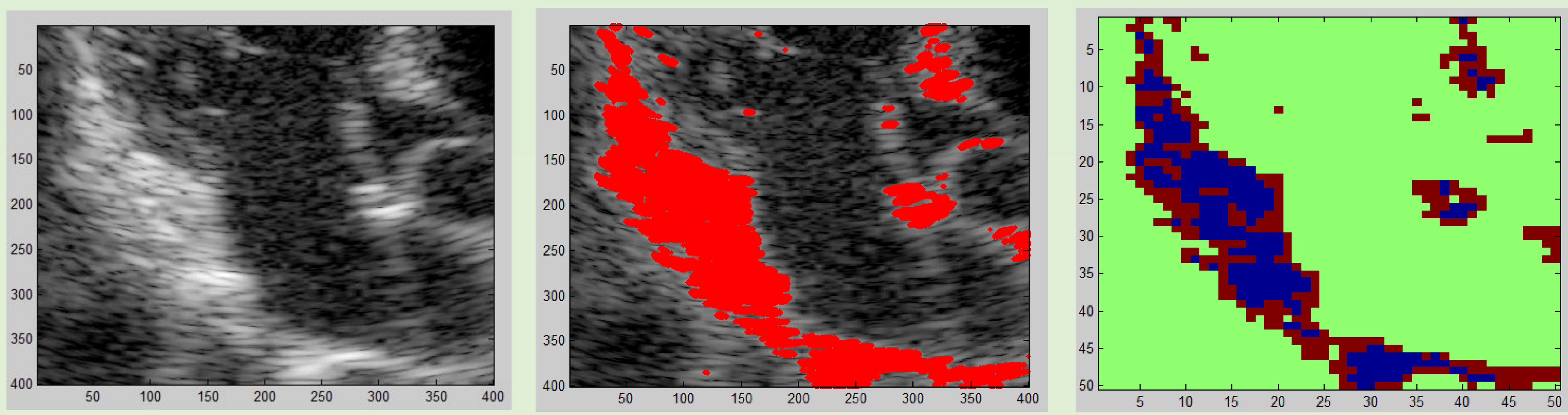


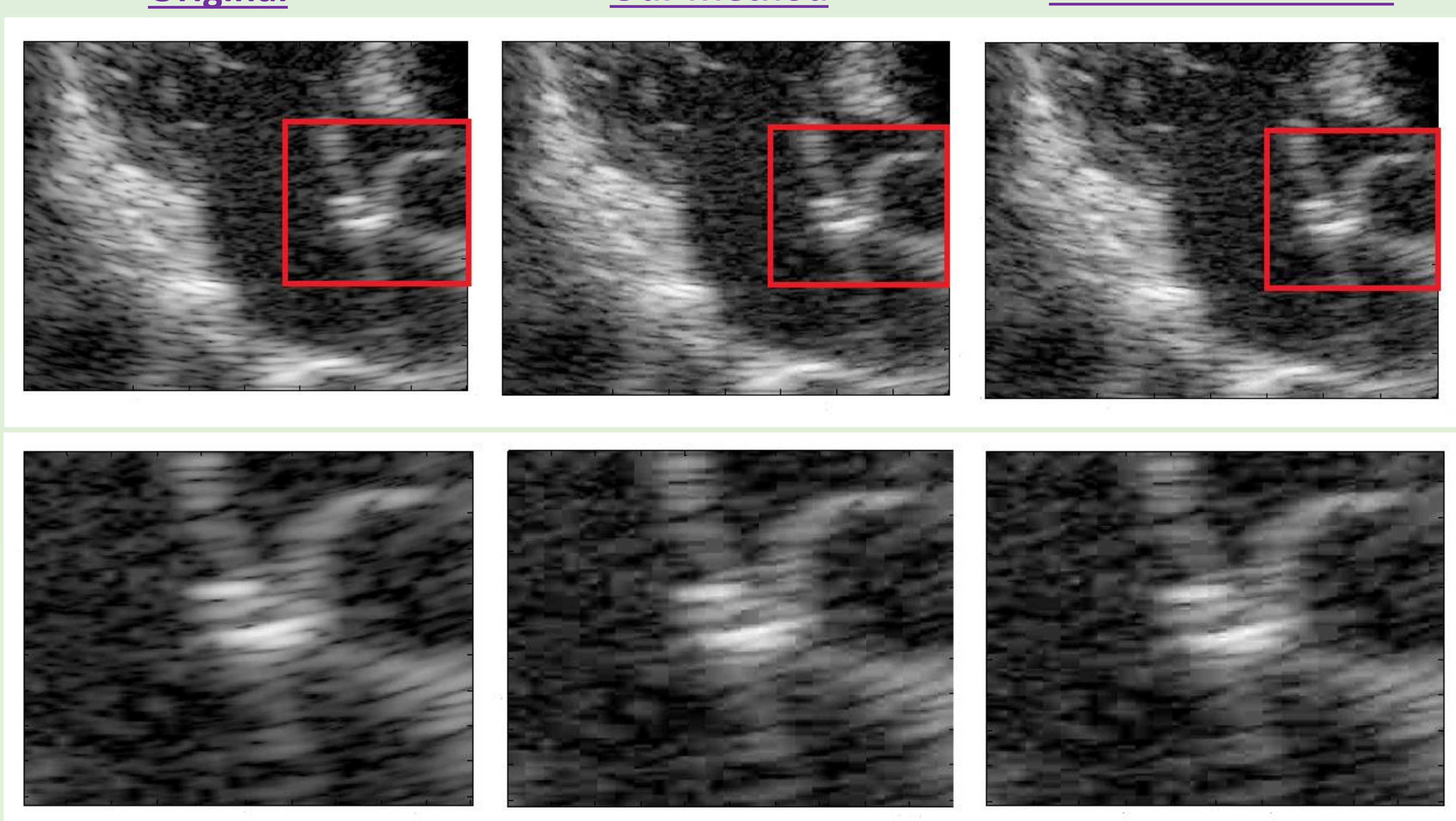
Figure 3 – Left: original echo-cardiac image; middle – identification of ROI pixels (marked in red); right – division into blocks and their classification according to their diagnostic importance (i.e., ROI pixels contents): green – background; blue – ROI; red – Hybrid.

Experimental Results:

The proposed algorithm was tested on echo-cardiac images (see Fig. 4), for CR(compression ratio) = 15.

- The reconstructed images obtained using the proposed algorithm were compared to standard DCT (Discrete Cosine Transform) coding using the default JPEG Q-tables.
- The proposed algorithm achieved improved PSNR values, on the entire image and particularly over the ROI pixels, as well as reduced blockiness.

Original | Our Method | Default JPEG Tables



PSNR(entire image)=31dB | PSNR(entire image)=30.4dB
PSNR(ROI) = 33.3dB | PSNR(ROI) = 32.5dB

Figure 4 – Results for an echo-cardiac image. Top row: whole image; bottom row – zoom-in over the red rectangles.

Summary:

- A coding method for ultrasound images, which optimally compresses each image block according to its classification, is proposed.
- Experimental results for echo-cardiac images demonstrate that the proposed method is able to achieve improved PSNRs on the entire image, as well as reduced blockiness over the diagnostically important ROIs.