Fast Codec Design and Implementation using WHT and R-D Optimization in Wireless Handset

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Abstract. An image compression codec based on WHT is proposed and implemented in wireless handset. Considering the low processing power of wireless handset, fast decoding codec is proposed and implemented. The proposed codec consists of RCT, WHT transform, quantization using R-D optimization and lossless coding. The test results for wireless handsets show that the proposed codec has a better performance than the IJG JPEG codec.

1 Introduction

Wireless internet services using handset have been developed fast in recent years. The portability and mobility, which are the main characteristics of wireless handset, have provided the users with convenience. However, the wireless internet has several limitations such as low processing power, limited memory and narrow bandwidth. To provide multimedia service in wireless handset, the implemented codec should be optimized in the sense of memory, CPU and network bandwidth. Though ARM 9 based handsets are released nowadays, many handsets have low processing power CPU with 20-40 MHz clock speed. In these handsets, the S/W decoding speed of JPEG codec [1] is about 300-1000 ms for 128×128 size images and it may not be used for handset with slow CPU. In this paper, a fast image codec using WHT (Walsh-Hadamard Transform) is designed and implemented for the wireless handsets with 20-40MHz CPU clock speed. The WHT [2] has a simple structure which consists of ± 1, and has faster speed than DCT which is used in JPEG [3]. Considering these characteristics, WHT has been utilized for fast image codec implementations. Comparing to DCT or KLT, the codec efficiency of WHT is lower than DCT or KLT. To make up for that, the R-D optimization [4] and ARM assembly implementation [5] are also applied to the design.

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2 Fast codec design using WHT

In some wireless internet services such as wall-paper download services, the encoding is done off-line. That is, the contents are made not from handset but from PC or server. In these services, fast decoder design is required. In this paper, the decoder design is mainly considered. Fig. 1 and Fig. 2 show the structures of the proposed encoder and decoder respectively. The proposed codec mainly consists of 4 parts such as color transformation (RCT), 8×8 block transformation (WHT), quantization and entropy coding. In the block transformation, WHT is used. In the color transformation, RCT is adapted instead of ICT. To compensate for the usage of WHT in the sense of quality and file size, R-D optimization is used for the design of quantization table. Since R-D optimization consumes much time, only the decoder is implemented in the handset. The encoding is done in PC and the decoding is done in handset.

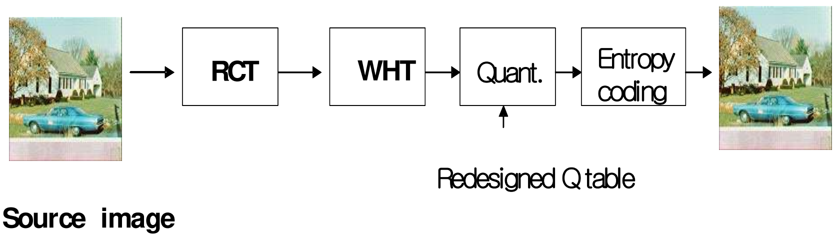

Fig. 1. The structure of encoder in PC or server

2.1 Color Transformation

In JPEG, color space conversion transforms RGB pixels into YCbCr. In IJG implementation [1], ICT (Irreversible Component Transformation) has been used. There is another transformation called RCT (Reversible Component Transformation). RCT approximates the ICT and the implementation can be done using only shift and addition. The inverse RCT is defined as

$$Y` = 0.25R + 0.5G + 0.5B\,,\ Cr` = B - G\,, Cb` = R - G$$
$$G = Y` - 0.25Cb` - 0.25Cr`\,, R = Cr` + G\,, B = Cb` + G \tag{1}$$

Using RCT, the color transformation can be made faster than ICT.

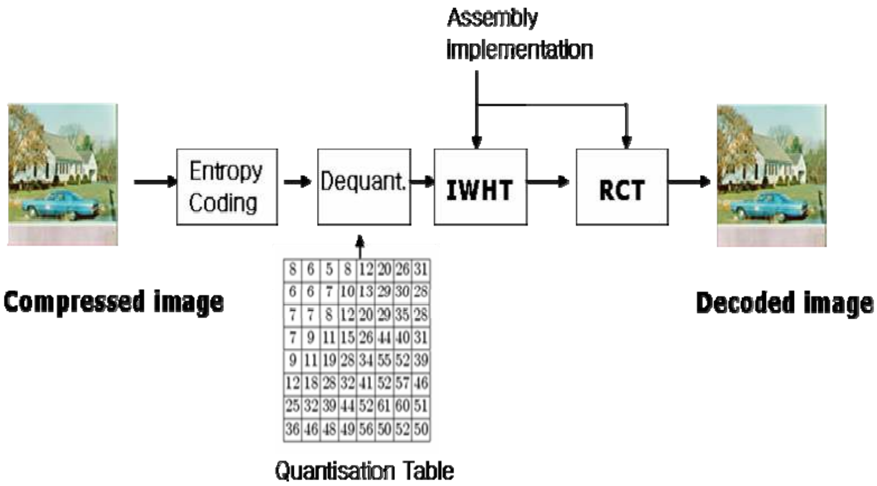

Fig. 2. The structure of decoder in handset

2.2 WHT Implementation

Table 1 shows the 8×8 transformation matrix of WHT. WHT can be implemented using 24 additions. Comparing to WHT, DCT consists of cos() and sin() functions and consumes more time than WHT. In fact, there are various fast DCT implementations [6][7]. Especially, the fast DCT algorithm in [6] is used for IJG JPEG and has 5 multiplications and 29 summations. For ARM core [5], multiplication consumes about 4 more times than addition and WHT can be implemented faster than the DCT algorithm in IJG JPEG.

Table 1. WHT transformation matrix

1	1	1	1	1	1	1	1
1	1	1	1	-1	-1	-1	-1
1	1	-1	-1	-1	-1	1	1
1	1	-1	-1	1	1	-1	-1
1	-1	-1	1	1	-1	-1	1
1	-1	-1	1	-1	1	1	-1
1	-1	1	-1	-1	1	-1	1
1	-1	1	-1	1	-1	1	-1

2.3 R-D optimization

Though WHT is faster transformation than KLT or DCT, it is inferior to them in the sense of compression gain. In this paper, to compensate WHT, R-D optimization based method is adopted. R-D optimization [4] is an algorithm to efficiently optimize rate-quality. In R-D optimization, objective function is given as $D(Q) + l R(Q)$, where l is an Lagrange multiplier, D, R, Q denote the distortion, rate and quantization table, respectively. The objective function is minimized according to l and quantization table Q. In wireless handset, it would be better to make the file size small since the memory of handset and bandwidth of network are limited.
Using R-D optimization, the file size and image quality can be compensated. In this paper, quantization table is re-designed for each image. If the frequency distribution of the images is similar to each other, the methods in [8] can be applied.

2.4 Assembly Coding Implementation

To make the decoding faster, IWHT part of the decoder is implemented using ARM assembly. (The RCT part is also implemented using assembly but its affect can be neglected.) ARM core has two modes such as ARM mode with 16 bit operation and THUMB mode with 8 bit operation. The two modes have different characteristics for the speed. If the operation is repetitive such as IWHT, THUMB mode implementation has a better performance. The optimisation of WHT is done as follows: First, C sources are compiled with -O2 option. Second, from the assembly code using ARM compiler, stack operation is preferred to heap operation and data register operation is preferred to stack operation. Also, the order of operation is changed in order to have a minimum move of data register. These are done manually. After assembly implementation, the processing time for IWHT becomes 30-40% faster than C implementation.

Table 2. System Settings

Settings	
Network	CDMA 1x EVDO
Baseband chipset	MSM 5500 (ARM 7 core up to 36 MHz)
Image size	128×128
LCD size	128×160
LCD bit depth	16 bit
Memory size	1M bytes
Heap Memory size	200K bytes
Porting environment	Qualcomm BREW [9]

3 Implementation Results

Table 2 shows the test environment. The proposed codec is implemented in MSM 5500 CDMA handset.
Fig. 3 shows the test images and Table 3 shows the test results. The file size and image quality are slightly better that IJG JPEG. However, the average decoding time is 45% faster than that of IJG JPEG in handset.

Fig. 3. Test images

Table 3. System Settings

	IJG JPEG			Proposed method		
Test images	Quality (dB)	Size (bytes)	Decoding Time (ms)	Quality (dB)	Size (bytes)	Decoding Time (ms)
Image 1	26.394	4810	396	26.398	4612	211
Image 2	25.004	5809	426	25.241	5668	235
Image 3	27.507	4156	372	27.753	4044	201
Image 4	24.691	5871	438	24.751	5776	238
Image 5	24.190	8030	492	24.548	7913	275
Image 6	27.667	3992	366	27.798	3820	197

4 Conclusion

In this paper, a fast codec implementation has been discussed in wireless handset. Since WHT can be implemented using 24 additions and multiplication consumes 4 times more than addition in ARM core, the codec is designed based on WHT. Also, R-D optimization is applied to compensate for WHT. To save the decoding time, IWHT part is implemented using ARM assembly. The test of the proposed codec is performed in BREW handset with MSM 5500 CPU. The test results show that the proposed codec has a better performance than the IJG JPEG codec.

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