# Run Time Performance of JPEG 2000 Codec

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## Project Overview

The focus of our project is to improve run-time of the JPEG-2000 Codec. We wish to hand-optimize sections of the codec using loop transformations (hand-optimization) and the x86 SSE instruction set. We will use a C based implementation of JPEG 2000 called JasPer as a starting point for our optimizations and compare the original with our optimized version.

## Motivation

The JasPer software [1] is one of the first software implementations of JPEG 2000, which is a new image compression standard [2]. The software implements both the encoder and decoder processes specified in the JPEG 2000 standard. The encoding and decoding processes are inverses of each other. The encoding process involves the following [1,3]:

1) Preprocessing: This stage involves component decomposition, tiling (partitioning input image into rectangular non-overlapping tiles of equal size), DC shifting, and image mapping from RGB color space to YCrCb color space.

2) Discrete Wavelet Transform: A wavelet transform based on 1-D 2-channel filter banks. Through the wavelet transform an image signal is split into numerous frequency bands (i.e. subbands).The transform is applied on each tile and yields four subbands: horizontal and vertical lowpass (LL), horizontal lowpass and vertical highpass (LH), horizontal highpass and vertical lowpass (HL), horizontal and vertical highpass (HH),

3) Quantization: The transformed coefficients are quantized using deadzone scalar quantization.

4) Tier 1 encoder: The quantized indices associated with each subband partitioned into fixed-size code blocks. Then an embedded code stream is produced for each block independently using bit-plane coding. There are a total of three passes (significance, refinement, and cleanup pass per bit plane) and each pass is associated with a particular component, resolution level, subband, and code block.

5) Tier 2 encoder: The output from Tier 1 coding i.e. the set of bit-plane coding passes is given to Tier-2 encoder for organizing compressed data from code blocks into packets and layers.

The authors of the JasPer software analyze the run-time complexity of the implentation [1] and find that most amount of time spent in the encoding process is in wavelet transform and Tier 1 encoding. Thus in our project we wish to exploit both the wavelet transform and Tier1 encoder code and leverage algorithm transformation and parallel processing techniques to improve the execution time of the software implemented JPEG 2000 codec.

**Prior Work**

Discrete Wavelet Transform (DWT) on a 2-D image is performed by 1-D wavelet transformation on the rows and followed by columns. This allows the algorithm to be exploited using SIMD and vector processing. There are various studies focusing on SIMD implementations of 2D DWT. The authors in [5,6] present parallelized 2-D wavelet following a single-loop approach i.e. a loop fusion of the lifting steps of horizontal filtering, and interleaving horizontal and vertical filtering for temporal locality. Other techniques such as loop interchange and array padding are also applied.

**Approach & Planning**

Our first step is to identify sections of the C based code in JasPer that take long execution time. We have done this using a profiling tool called GNU Profiler (gprof) [4]. Based on the information we discovered the time spent in each sections of the program. The time spent in the most functions (top 4 entries) is provided in Table 1, for encoding a 1792x1200 bitmap image.

| % of Total Time | Cumulative time (itself+others above it) (ms) | Time spent executing this function (ms) | Total calls to this function | Average Time spent /call | Avg. Time spent (itself +descenden) (ms) | Function Name |
|---|---|---|---|---|---|---|
| 26.94 | 11.23 | 11.23 | 30 | 0.37 | 0.65 | jpc_ft_analyze |
| 20.01 | 19.57 | 8.34 | 17391 | 0.00 | 0.00 | jpc_qmfb1d_split |
| 10.96 | 24.14 | 4.57 | 6041 | 0.00 | 0.00 | jpc_encsigpass |
| 10.60 | 28.56 | 4.42 | 7772 | 0.00 | 0.00 | jpc_encclnpass |

**Table 1: GNU profile for JasPer**

From Table 1 we notice that these four functions take up over 50% total execution time. On further investigation of these functions we found that jpc_ft_analyze and jpc_qmfb1d_split are functions involved in DWT. The DWT uses a subband encoding technique called Quadrature Mirror-Image Filter Bank (jpc_qmfb.c). The other two functions jpc_encsigpass and jpc_encclnpass are components of Tier1 encoder (jpc_t1enc.c) that for bit-plane coding.

We noticed that all the four functions perform some form of loop operation. So, our next step will be to understand these functions and perform loop optimization techniques such

as loop unrolling, loop fusion, and function inlining. The latter will also enable us to apply SIMD extensions. For SIMD extensions, we will use the SSE instruction set.

**Expected Results**

We hope to achieve some degree of speedup by hand-optimization of the original code using optimization techniques and SIMD extensions.

**References**


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