Explore the Performance of the ARM Processor Using JPEG

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***Abstract*: Recently, the evolution of embedded systems has shown a strong trend towards application-specific, single- chip solutions. The ARM processor core is a leading RISC processor architecture in the embedded domain. The ARM family of processors supports a unique feature of code size reduction. In this paper it is illustrated using an embedded platform trying to design an image encoder, more specifically a JPEG encoder using ARM7TDMI processor. Here gray scale image is used and it is coded by using keil software and same procedure is repeated by using MATLAB software for compare the results with standard one. Successfully putting a new application of JPEG on ARM7 processor.**

I. INTRODUCTION

Real-time embedded systems are a challenge to implement. An embedded environment constrains the energy consumption, the memory space, and the execution time of an application. On the other hand, the complexity of the applications running on an embedded platform keeps increasing. Examples include next-generation cell phones, portable game-boys and digital assistants, smartcards, and medical monitoring devices.

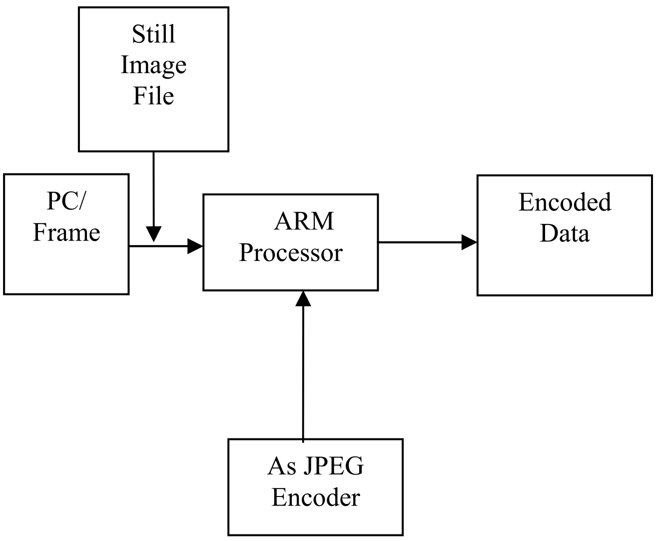


Figure 1. Generalized Block Diagram

Looking forward to new era of image processing, modernized and fastest ways to compress the images by using JPEG , in the world of photography and its best outputs in terms of image compression ,world is definitely in need of new approaches. To achieve this we need to evaluate the performance of ARM PROCESSOR by using JPEG as one of the application. This is an embedded approach for the compression which can be useful and suitable for the application like digital camera. Now a days Digital camera has become fastest and best means in the world of photography, and so as the images created by it. Figure 1 shows generalized block diagram of ARM based JPEG encoder. As any Images file created by digital is to be compressed by using JPEG standard and then further this file will be processed through serial communication by using ARM processor. JPEG acts as a JPEG encoder for the ARM processor. In this paper, evaluating the performance of ARM processor family with JPEG. Here, image file is taken from windows and then converted into grayscale image by using MATLAB then is process through ARM.

II. ARM PROCESSOR

An Embedded Processors is simply a micro Processors that has been “Embedded” into a device. It is software programmable but interacts with different pieces of hardware. The three most important design criteria for embedded processors are performance, power, and cost. Performance is a function of the parallelism, instruction encoding efficiency, and cycle time. Power is approximately a function of the voltage, area, and switching frequency also a function of execution time. cost is a function of both area (how many fit on a die) and the complexity of use (in terms of engineering cost).ARM seems to be leading the way in this field of processing. The processor has found this as one of its greatest markets, mainly because of the steps the company has taken to fit into the embedded market and the architecture it has adopted. Other embedded applications that take advantage of such processors are: disc drive controllers, automotive engine control and management systems, digital auto surround sound, TV-top boxes and internet appliances. Other products are still being modified to take advantage of it: toys, watches, etc. The possible applications are almost endless. ARM can offer low cost, high performance and low power consumption, each of which is required to make a portable embedded item marketable in today's world. Not to mention the fact that a whole sub-group of ARM architecture has been dedicated to function strictly to signal processors.

2.1 FEATURES OF ARM PROCESSOR

FOLLOWING ARE THE FEATURES OF THE ARM PROCESSOR.

a) On-chip integrated oscillator operates with external crystal in range of 1 MHz to30 MHz or with external oscillator from 1 MHz to 50 MHz.
b) Power saving modes include idle and Power-down.
c) Individual enable/disable of peripheral functions as well as peripheral clock scaling down for additional power optimization.
d) Two 32-bit timers/external event counters (with four captures and four compare channels each), PWM unit (six outputs) and watchdog.
e) Low power Real-time clock with independent power and dedicated 32 kHz clock input.
f) Multiple serial interfaces including two UARTs (16C550), two Fast I2C (400 kbit/s), SPI™ and SSP with buffering and variable data length capabilities
g) Vectored interrupt controller with configurable priorities and vector addresses.
h) Up to 47 of 5 V tolerant general purpose I/O pins in tiny LQFP64 package.
i) Processor wake-up from Power-down mode via external interrupt or Real-time Clock.
j) Single power supply chip with Power-On Reset (POR) and Brown-Out Detection (BOD) circuits:– CPU operating voltage range of 3.0 V to 3.6 V (3.3 V ± 10 %) with 5 V tolerant I/O pads.

III. JOINT PHOTOGRAPHY EXPERT GROUPS

For the past few years, a joint ISO/CCITT committee known as JPEG (Joint- Photographic Experts Group) has been working to establish the first international compression standard for continuous tone still images, both grayscale and color. JPEG's proposed standard aims to be generic, to support a wide variety of applications for continuous tone images. To meet the differing needs of many applications, the JPEG standard includes two basic compression methods, each with various modes of operation. A DCT based method is specified for "lossy'' compression, and a predictive method for "lossless'' compression. JPEG features a simple lossy technique known as the Baseline method, a subset of the other DCT based modes of operation. The Baseline method has been by far the most widely implemented JPEG method to date, and is sufficient in its own right for a large number of applications. JPEG has following modes of operation:

Sequential encoding: each image component is encoded in a single left to right top to bottom scan.

Progressive encoding: the image is encoded in multiple scans for applications in which transmission time is long, and the viewer prefers to watch the image build up in multiple coarse to clear passes.

c) Lossless encoding: the image is encoded to guarantee exact recovery of every source image sample value (even though the result is low compression compared to the lossy modes).

d) Hierarchical encoding: the image is encoded at multiple resolutions so that lower resolution versions may be accessed without first having to decompress the image at its full resolution.

3.1 BLOCK DIAGRAM DESCRIPTION OF JPEG

Figure2 shows the key processing steps which are the heart of the DCT Based modes of operation. These figures illustrate the special case of Single component (grayscale) image compression. Color image compression can then be approximately regarded as compression of multiple grayscale images, which are either compressed entirely one at a time, or are compressed by alternately interleaving 8x8 sample blocks from each in turn. For DCT sequential mode codecs, which include the Baseline sequential codec, the simplified diagrams indicate how, single component compression works in a fairly complete way. Each 8x8 block is input, makes its way through each processing step, and yields output in compressed form into the data stream.

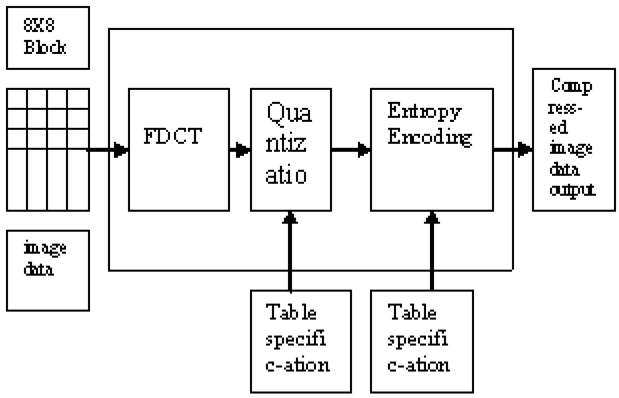


Figure 2. DCT Based Encoder Processing Steps 8 X 8 DCT

DCT progressive mode codecs, an image buffer exists prior to the entropy coding step, so that an image can be stored and then parceled out in multiple scans with successively improving quality. For the hierarchical mode of operation, the steps shown are used as building blocks within a larger framework. The DCT coefficient values can thus be regarded as the relative amount of the 2D spatial frequencies contained in the 64point input signal. The coefficient with zero frequency in both dimensions is called the "DC coefficient" and the remaining 63 coefficients are called the "AC coefficients.'' . Figure 4 shows that DCT operation and related equation. For ARM Processor, Floating-point arithmetic is a more flexible and general Mechanism than fixed-point. With floating-point, system designers have access to wider *dynamic range* (the ratio between the largest and smallest numbers that can be represented). As a result, floating-point are generally easier to program than their fixed point but usually are also more expensive and have higher power consumption. The increased cost and power consumption result from the more complex circuitry required within the floating-point which implies a larger silicon die.

F(I,j)
f(u,v)

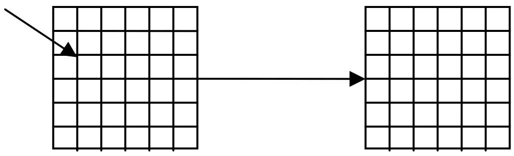


Figure 3. Spatial domain to frequency domain

$$C(u,v) = \alpha(u)\alpha(v) \sum_{x=0}^{N-1} \sum_{y=0}^{N-1} f(x,y) \cos\left[\frac{\pi(2x+1)u}{2N}\right] \cos\left[\frac{\pi(2y+1)v}{2N}\right] \quad \text{- - -(1.4)}$$

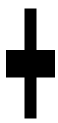


Figure 4. Sample bmp image 8X8

Fig 4 shows the sample 8X8 bmp image, here image is somewhat expanded so tat clear image can be seen. This image has some color coefficients, first converting this color coefficient into gray scale by using command from MATLAB gray2ind converting all color components into gray coefficients table 1 shows image coefficients and table 2 shows gray image coefficients.

TABLE I. SAMPLE IMAGE COEFFICIENTS

255	255	255	255	255	255	255	255
255	255	255	255	255	255	255	255
255	255	0	0	0	0	255	255
255	255	0	0	0	0	255	255
255	255	0	0	0	0	255	255
255	255	0	0	0	0	255	255
255	255	255	255	0	0	255	255
255	255	255	255	255	255	255	255

TABLE II. CONVERTING ALL COLOR COEFFICIENTS INTO GRAY

15	15	15	15	15	15	15	15
15	15	15	15	15	15	15	15
15	15	0	0	0	0	15	15
15	15	0	0	0	0	15	15
15	15	0	0	0	0	15	15
15	15	0	0	0	0	15	15
15	15	15	15	0	0	15	15
15	15	15	15	15	15	15	15

These coefficients are directly used in Keil software for embedded version. Since we can use JTAG for this but it increases C code, so directly taking image coefficients to process for DCT. Table 3 shows DCT values for sample image and its is perfectly matched with ARM. This DCT code is written as per R [1]. In 'C' code all the last values are get divided by 65535 because when we are converting sample image into gray we are using index 16 and in MATLAB it is index 16 is for 65535.

TABLE III. DCT RESULT FOR SAMPLE IMAGE.

86.2500	1.9905	31.1809	-4.0739	0	2.7221	-12.9156	-0.3959
4.4095	-2.3406	-4.0739	4.7904	0	-3.2008	1.6875	0.4656
25.6869	1.0772	-23.7316	-2.2048	0	1.4732	9.8300	-0.2143
-1.0346	0.5492	0.9559	-1.1240	0	0.7510	-0.3959	-0.1092
3.7500	-1.9905	-3.4645	4.0739	0	-2.7221	1.4351	0.3959
-5.2014	2.7609	4.8055	-5.6506	0	3.7756	-1.9905	-0.5492
-6.5809	-2.6007	6.0800	5.3228	0	-3.5566	-2.5184	0.5173
-2.9464	1.5639	2.7221	-3.2008	0	2.1387	-1.1275	-0.3111

3.2 Quantization

After output from the DCT, each of the 64 DCT coefficients is uniformly quantized in conjunction with a 64element Quantization Table, which must be specified by the application (or user) as an input to the Encoder. Each element can be any integer value from 1 to 255, which specifies the step size of the quantizes for its corresponding DCT coefficient. The purpose of quantization is to achieve further compression by representing DCT coefficients with no greater precision than is necessary to achieve the desired image quality. Stated another way, the goal of this processing step is to discard information, which is not visually significant. Quantization is a many to one mapping, and therefore is fundamentally lossy. It is the principal source of lossiness in DCT based encoders. Quantization is defined as division of each DCT coefficient by its corresponding quantized step size, followed by rounding to the nearest integer:

F‘ [u, v] = round (F [u, v] / q [u, v]).

Why? -- To reduce number of bits per sample

Example: 101101 = 45 (6 bits).

Q [u, v] = 4 --> Truncate to 4 bits: 1011 = 11.

For the ARM Processor, we are quantizing File i.e. reducing file size length. Memory required, execution time, speed required will be less for this block. Here four table specifications are required for quantization. Each table has 64 byte, so total 256 bytes are required. For quantization Luminous table for color image is used because it is same for gray image. Table 4 shows quantization table for gray scale image and Table 5 shows keil output of quantization and it is again is perfectly matched with MATLAB.

TABLE IV. QUANTIZATION TABLE USED FOR GRAY SCALE IMAGE.

Quant= [16 11 10 16 24 40 51 61;
12 12 14 19 26 58 60 55;
14 13 16 24 40 57 69 56;
14 17 22 29 51 87 80 62;
18 22 37 56 68 109 103 77;
24 35 55 64 81 104 113 92;
49 64 78 87 103 121 120 101;
72 92 95 98 112 100 103 99].

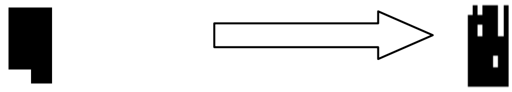
Equation for quantization is as follows:

Q=DCT (x,y) /quant. ---- (1.5)

TABLE V. OUTPUT OF KEIL FOR QUANTIZATION

11.5530	-12.8668	10.8411	-6.1552	-20.2332	-26.2163	71.2116	-34.8024
0.2988	-0.4504	0.8666	-0.7943	0.4546	-0.9377	1.0041	-0.4286
0.2956	-0.8732	3.9475	-1.5304	0.5620	-4.3798	4.0433	-1.4656
-0.0701	0.1057	-0.2033	0.1864	-0.1067	0.2200	-0.2356	0.1006
0.2541	-0.3830	0.7370	-0.6755	0.3866	-0.7974	0.8539	-0.3645
-0.3525	0.5312	-1.0222	0.9369	-0.5363	1.1061	-1.1844	0.5056
0.1526	-0.0529	-0.8374	-0.0972	0.1857	0.9510	-0.7505	0.2125
-0.1997	0.3009	-0.5790	0.5307	-0.3038	0.6265	-0.6709	0.2864

Here, all the results of DCT and quantization of Keil and MATLAB are perfectly matched. Here, we have used MATLAB only for verification of keil output. Since, algorithm used for JPEG for embedded platform should be matched with standard tool that’s why we have used MATLAB. Up to quantization we can see the output of the image after that image coefficients are scanned or prepared for entropy encoding. Fig 5 shows quantized output and image size.



Sample image file Quantized image file
1.1.KB 368 bytes

Figure 5. Quantized output

3.3 DC Coding and Zig -Zag Sequence

After quantization, the DC coefficient is treated separately from the 63 AC coefficients. The DC coefficient is a measure of the average value of the 64 image samples. Because there is usually strong correlation between the DC coefficients of adjacent 8x8 blocks, the quantized DC coefficient is encoded as the difference from the DC term of the previous block in the encoding order. Figure 6 shows zigzag scanning of an image.

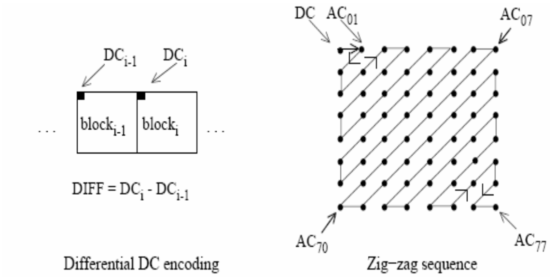


Figure 6. Preparation of Quantized Coefficients for Entropy Coding

All of the quantized coefficients are ordered into the “zigzag” sequence. This ordering helps to facilitate entropy coding by placing low frequency coefficients (which are more likely to be non zero) before high frequency coefficients.Here,2D to 1D is converted and then again it is converted image coefficients are same but is zig-zag sanned.

3.4 Entropy Coding

The final DCT based encoder processing step is entropy coding. This step achieves additional compression losslessly by encoding the quantized DCT coefficients more compactly based on their Statistical characteristics. The JPEG proposal specifies two entropy. Coding methods by Huffman coding and arithmetic coding. The Baseline .Sequential codec Uses Huffman coding, but codecs with both methods are specified for all modes of operation. It is useful to consider entropy coding as a 2step Process. The first step converts the zigzag sequence of quantized coefficients into an intermediate sequence of symbols. The second step converts the symbols to a data stream in which the symbols no longer have externally identifiable boundaries. The form and definition of the intermediate symbols is dependent on both the DCT based mode of operation and the entropy coding method. Huffman coding requires that one or more sets of Huffman code tables be specified by the application. The same tables used to compress an image are needed to decompress it. Huffman tables may be predefined and used within an application as defaults, or computed specifically for a given image in an initial statistics gathering. Pass prior to compression. Such choices are the business of the applications which use JPEG; the JPEG proposal specifies no required Huffman tables. Huffman table needs 64 bytes for encoder and 64 bytes for decoder. Table specification is different for color and grayscale image. The final image and output after zig-zag is as shown in fig3.10 and 3.11. Fig3.10 shows the output of zig-zag scanning its values are fixed to near zero by suing MATLAB n same id done with the help of keil embedded software. Fig 3.11 shows output codeword of sample image.For keil we have to intialize serial port and through hyper terminal output is shown.fig 7 shows that out of 64 coefficients 47 coefficients are zeros,hence image is successfully compressed because we are using JPEG lossy mode.

TABLE VI. OUTPUT OF ZIG-ZAG SCANNING.

11	-12	10	-6	-20	-26	71	-34
0	0	0	0	0	0	1	0
0	0	3	-1	0	-4	4	-1
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	-1	0	0	1	-1	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

1*01000*01000*01000*01000*01000*01000*010
00*01000*01000*100*01000*01000*01000*

Figure 7. Huffman codeword output of hyper terminal.

IV. SELECTION OF THE ARM 7TDMI PROCESSOR

Table1 shows comparison of ARM&TDMI family.

Device	No.of Pins	On-chip SRAM	End Point USB RAM	On-chip FLASH
LPC2141	64	8KB	2KB	32KB
LPC2142	64	16KB	2KB	64KB
LPC2144	64	16KB	2KB	128KB
LPC2146	64	16KB	2KB	256KB
LPC2148	64	32KB+8KB	2KB	512KB

Table 1:Device Information of ARM Processor

LPC2148 has 32KB in addition with 8KB memory and 512KB on chip FLASH memory. So selecting LPC2148 for future work related to color images.

Conclusion

JPEG is not the application of ARM7 processor since this processor is not in the area of image compression. In this work, after successful experimentation on JPEG lossy technique, code word is obtained using Huffman coding. Outcome of this work shows that code word is generated by scanning quantization matrix. Using this technique, JPEG lossy technique is successfully implemented on keil platform to assert the Uart signal of LPC2148 processor, so as to show the output on hyper terminal. Image compression is nearly about 90% to 95%.

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