

Power Optimization for Mobile multimedia

Ms. Sonali A. Deshpande

Sipna's C.O.E.T, Amravati

sonali21.deshpande@gmail.com

Ms. Archana N. Boob

Sipna's C.O.E.T, Amravati

archanaboob7@gmail.com

Prof. D. M. Dakhane

Asst. Professor, Dept. of CSE,

Sipna's C.O.E.T, Amravati

ddakhane@gmail.com

ABSTRACT

A mobile device is a very powerful to support increasing multimedia functions. To support these high computing and high bandwidth operations on a mobile device with limited energy, the power-aware design concept is expected to be introduced for further power optimization. A power-aware system is a design that can adaptively adjust its power consumption to specific conditions, such as different battery status, signal content, user preferences, and operating environments. In this paper, we focus on the introduction of power-aware concepts and considerations to the architecture design of a video coder, followed by discussions of exiting power aware Motion Estimation and Discrete Cosine Transform designs.

Keywords:

Video Codec Design, Discrete Cosine Transform, Motion Estimation

1. INTRODUCTION

“A power-aware system is not only a conventional low power design, but also a design that can adaptively adjust its power consumption to specific conditions.”

Digital audio/video entertainment and services colorize our life today. With the rapid advances of semiconductor and communication technologies, the mobile multimedia environment is more and more mature. We can now enjoy multimedia content not only at home but everywhere and anytime in our daily life. To support these high computing and high bandwidth operations on a mobile device with limited energy, the power-aware design concept is expected to be introduced for further power optimization. A powerful processor does not work without power. Different from a non-mobile device with a power line, a mobile appliance depends on batteries with limited energy. While more and more multimedia functions are integrated into a portable device, the growth of power capacity still falls behind the huge requirements.

A power-aware device is a smart design that is aware of the limiting power, and it can utilize the available energy in a smart and efficient way by dynamically adjusting the power consumption [1]. The idea behind the power-aware concept is analogous to our daily life behaviors. With limited time and energy, we have to prioritize the jobs at hand, and give more efforts to important things, while skipping less important ones.

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This concept provides an overview of power aware video codec design concepts and approaches. Design perspectives and examples on power aware Motion Estimation (ME) and Discrete Cosine Transform (DCT) will be discussed.

2. VIDEO CODEC DESIGN

2.1 Video coding algorithms and standards

The goal of video coding is to remove the data redundancy. There is temporal, spatial, statistical and perceptual redundancy in digital video data. Video coding is to represent the data in a more compact format. Most video coding algorithms adopt transform and motion compensation (MC), based on hybrid video coding. Figure 1 shows a basic video coding framework. The temporal redundancy is effectively

removed by motion compensation, which is realized by block-based motion estimation (ME) to search for a

similar block in reference frame(s) for a current block. As for the spatial and statistical redundancy, Discrete Cosine Transform (DCT) and entropy coding such as Huffman Coding algorithm is adopted. Quantization is a scheme to control the compression ratio. The less important information is discarded by quantization scheme, which is basically based on the characteristics of human visual system.

2.2 Framework for video codec design

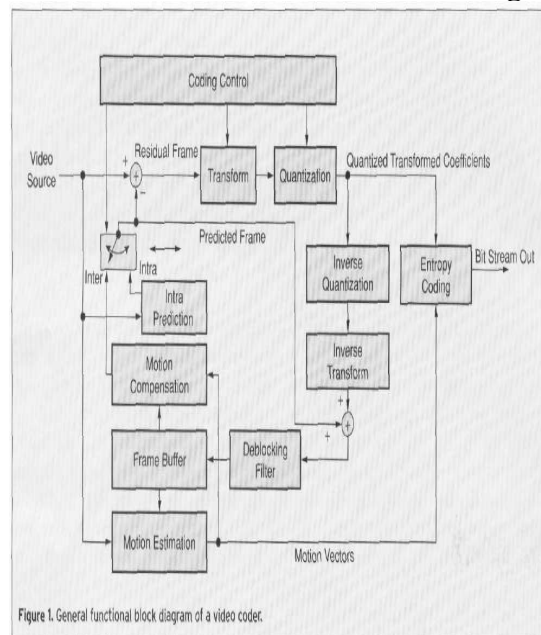


Figure 1. General functional block diagram of a video codec.

Video coding (compression) is a core technology that enables the storage and transmission of a large amount of digital video data. Figure 1 shows a typical video-coding framework. It is a hybrid coding architecture based on Discrete Cosine Transform (DCT) and Motion Estimation/ Motion Compensation (ME/MC). The technique of ME/MC is to remove the temporal redundancy between frames, while DCT followed by entropy coding is to remove the spatial and statistical redundancy of video data.

Many widely used video coding standards, such as MPEG-1/-2/-4, H.26x, and H.264/AVC, are mainly based on this framework. In a situation where power is very critical, video quality can be sacrificed to some extent to lower the power consumption and to sustain longer the encoding or decoding of a video. In a video codec, there are various parameters that can be adjusted to lower the power consumption. The goal is to find a good configuration that has optimal visual quality under the rate and power constraints. Figure 2 shows a conceptual example that illustrates the power-aware video coding.

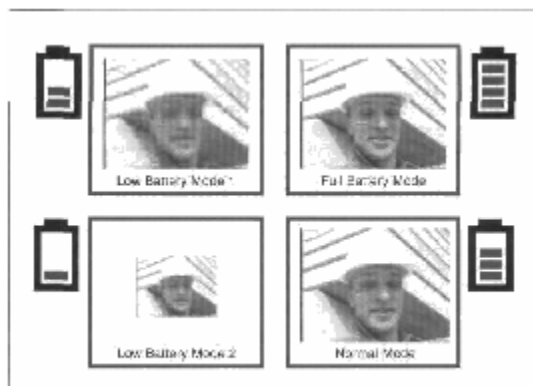


Fig 2: Example of power aware multimedia.

Steps involve in video codec design:

- Dividing each video frame into blocks of pixels so that processing of the video frame can be conducted at the block level.
- Exploiting the spatial redundancies that exist within the video frame by coding some of the original blocks through transform, quantization and entropy coding (or variable-length coding).
- Exploiting the temporal dependencies that exist between blocks in successive frames, so that only changes between successive frames need to be encoded. This is accomplished by using motion estimation and compensation.
- Exploiting any remaining spatial redundancies that exist within the video frame by coding the residual blocks, i.e., the difference between the original blocks and the corresponding predicted blocks—again, through transform, quantization and entropy coding.

Two modules of video codec design are:

- 1) Power aware ME
- 2) Power aware DCT

1) Power aware ME:

Motion estimation is an effective but high-complexity technique to remove the temporal redundancy for video compression. For inter-frame prediction, a current frame is first partitioned into Macro Blocks (MBs), where each MB is a 16 x 16 block. To code an MB, the process is to search for the most similar MB (best matched MB) in previously coded frames, code the motion vector, which points to the previous coded MB, and then code the difference (residue) of the two MBs. Figure 3 illustrates the block matching ME[2].

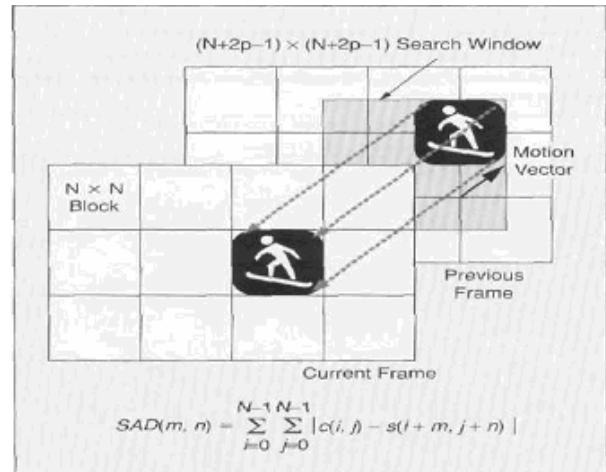


Fig 3: Block Matching Motion Estimation

The computational complexity of ME is very high. It is seen from the run time profiling of a processor-based implementation of a video codec that ME always occupies over half of the computing time. The ME is, the most critical module in a video codec not only because of the real-time performance requirements but also because of the power issue considerations.

Block based ME technique is adopted in video coding standard, but how to search for a motion vector is beyond the scope of the standardization. The impact of the ME performance is that when a more similar MB is found, the residue (difference between the two MBs) is smaller, and then the compression performance can be better. If we ask for better ME search quality, we need to spend more power. To search for the best matched MB, Three Step Search (TSS) ME, which search for all possible candidates in a search range and it searches for the best motion vectors in a coarse to fine search pattern, These three-step search (3SS) is as follows.

Three Step Search (TSS) It became very popular because of its simplicity and also robust and near optimal performance. It searches for the best motion vectors in a coarse to fine search pattern. The algorithm may be described as:

Step 1: An initial step size is picked. Eight blocks at a distance of step size from the center (around the center block) are picked for comparison.

Step 2: The step size is halved. The center is moved to the point with the minimum distortion.

Steps 1 and 2 are repeated till the step size becomes smaller than 1. A particular path for the convergence of this algorithm is shown below.

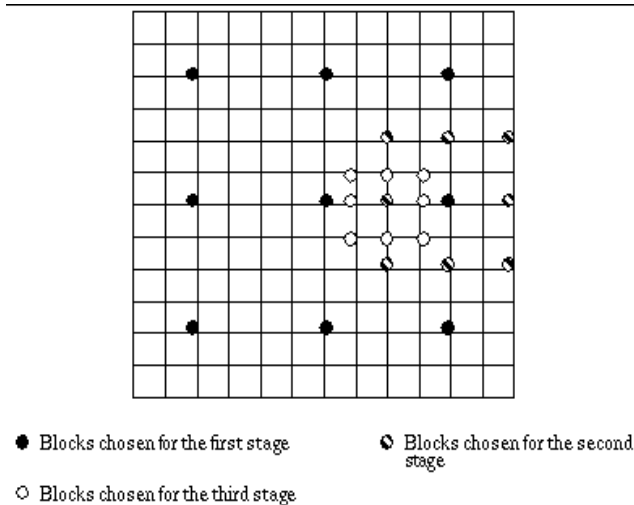


Fig 4: Example path for convergence of Three Step Search

2) Power aware DCT:

DCT and inverse DCT (IDCT) are also computationally intensive modules in a video codec. For an MPEG-4 Simple Profile encoder with full search ME, the DCT, Quantization (Q), Inverse Quantization (IQ), and IDCT occupies about 16% of overall complexity. As for an encoder with fast ME algorithm, DCT/Q/IQ/IDCT can occupy up to 29% of overall complexity.

For a module that is mainly composed of arithmetic computations, such as additions, subtractions and multiplications, there are basically two ways for the considerations of power-awareness. One is to reduce the number of data that has to be processed, and the other is to reduce the bit-width (precision) of the data path. The idea is to approximate the original computing results by sacrificing some precision at the less significant or less visible part[4].

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When the data signals have large content variations, these data are potential to be utilized for low power and power aware design. The data signals in the DCT, Q, IQ, and IDCT modules in a video codec are one of the good examples to show the power awareness through content-aware detection. For the coding of natural images, after the 8×8 2D DCT, the magnitudes of lower-frequency DCT coefficients in a block are usually larger than those of higher-frequency ones. Since the human visual system is less sensitive to higher frequency signals, high frequency components are usually quantized more. As we increase the compression ratio by raising the quantization steps, more and more high

frequency coefficients are quantized to zero. Besides a single 8×8 block, the percentage of non-zero occurrence of quantized DCT coefficients between frames and sequences also has large variations, depending on the complexity of the scene[5].

For the IDCT, the computational precision has to meet the IEEE Standard 1180-1990 so that the drift error in the video coding loop can be controlled to some extent. As for the DCT, there are no constraints on it, since it is an encoder issue and the scope of a video standard is only the decoding part. Therefore, the precision of DCT implementation is a better candidate for power-aware design. Feasible methods are to jointly consider the quantization effect and the DCT, to design a content-aware DCT module by exploiting the video data characteristics, or to directly reduce the precision or operations at some cost of quality.

3. CONCLUSION

Low power and power aware video codec design is a key to successful multimedia application. It always a challenging task providing a more powerful processing engine but at the same time asking for less power consumption. The design of reconfigurable architecture for power awareness will be the key to power-aware multimedia.

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Author Biography



Prof. Dhananjay M. Dakhane is working as a Associate Professor in Department of Computer Sci & Engineering, Sipna College of Engineering and Technology, Amravati, Sant Gadge baba Amravati University. He has Published 17 papers in National and International Conferences. He has Guided 8 M.E. Students and 35 BE students. Presently he is doing its research at Sant Gadge baba Amravati University. His area of interest is open source security, network security and information and web security.



Ms. Archana N. Boob is a student of Sipna College of Engineering and Technology, M.E.[CE] Amravati, Sant Gadge baba Amravati University and working as a lecturer in H.V.P.M's College of Engg in CSE Dept. She has published 2 papers in National Conferences. Her area of interest is multimedia technology.



Ms. Sonali A. Deshpande is a student of Sipna College of Engineering and Technology, M.E.[IT] Amravati, Sant Gadge Baba Amravati University and working as a lecturer in H.V.P.M's College of Engg in CSE Dept. She has published 2 papers in National Conferences. Her area of interest is multimedia technology.