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碩士論文

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在嵌入式系統上的多媒體視訊之電力效率分析

Energy Efficiency Analysis of Multimedia Video Decoding on Embedded System

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摘要

手持裝置的電源管理正日益嚴苛、困難，理由是其應用功能仍在持續高度擴展，過去手機沒有 MP3 功能、沒有照相功能，如今不僅幾乎快成必備，還要附有收音機功能、閃光燈功能；其中，影音應用因需要高複雜的影音解碼運算能力，其在手持裝置上的耗電就勢必成為一嚴苛挑戰。近幾年，視頻編碼器非常多樣，在這篇論文上，我們試著從在嵌入式系統下的電力測試分析找出最佳節能的視頻壓縮編碼器，並針對各種不同的 File Type、File Format、Codec 參數作調整，以研究其對電力耗用的影響。

關鍵詞：編碼器、電力消耗、嵌入式系統

Abstract

There are more and more applications provided and played by embedded systems, such as radio, camera functions, audio and video media. Due to the complex computing characteristic of video decoding, the video applications consumes large amount of energy and demands an efficient strategy for power management. Codecs are used to encode video media from original sources of films; lots of new compression codecs are released in recent years.

In this thesis, we aim to find the optimal video codecs on embedded systems from analyses of energy consumptions. Experiments have been done to investigate the effects of various codecs, file formats, and parameters of codecs.

Keywords: codec, energy consumption, embedded system

致謝

本篇論文得以順利完成，仰賴許多人的指導與協助，要感謝的人著實很多，在此僅以此文來表達我的誠摯感謝。首要感謝的為我的指導老師 林祝興教授，於兩年來悉心的指導我；我的獲益不僅在學術研究有所成長，期間也獲得老師的幫助為自己實作能力作提升，在處事之道理上透過了尊師也獲益匪淺。另外，感謝 劉榮春博士在實驗上的多番指導，本文乃得以順利完成，僅向兩位讓我獲益良多的恩師致上最高的敬意與謝意，也感謝口試委員們撥冗指正論文中的錯誤並提供許多寶貴意見，使本篇論文得以更加完整。

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兩年研究生生涯讓我成長了許多，磨勵了耐心與毅力也學會互相忍讓與包容，家人的支持讓我無後顧之憂為自己的理想去前進去努力，僅將此篇論文獻給我最愛的父母與姐妹，是他們無私的支持讓我有足夠的動力一步步完成自己的目標。今日，終於完成碩士學位。在此，致上我最誠摯的祝福與感謝予所有曾經協助過我的師長、家人、同學、親友，願目前研究能為未來研究者有所幫助，提供未來應用的一個深入延續。

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Chapter 1
Introduction

The technological growth of batter capacity of is not able to catch up the fast demand arising from constantly increasing applications on hand-held devices; the energy density of batteries grows too slow to keep up with the rapidly increasing requirements for all kinds of applications nowadays [1]. Along with the progress of mobile technology, more and more applications on desktop computers also appear on hand-held devices. People are in favor of light and convenient electronic products and pervasive applications of amusements, especially, the video application. Owing to the highly complex characteristic of video decoding, large amount of energy is consumed for video applications.

In recent years, many compression codecs are issued for two major video code standards: MPEG [2][3] and ITU-T [4]. What codecs are suitable choices for encoding films into video codes that will consume less energy when decoding? How to produce optimal video codes to play on hand-devices? These are the typical and confusing questions on minds of users. Experiments of energy analysis have been done on PDA hand-held devices [5][6]. Since PDAs have their optimal powers set by manufacturers, the energy analyses of them have limited applications. The embedded system is a development environment for mobile hand-held devices. In this thesis, based on energy analyses, we attempt to find the optimal video codecs that consumes less energy on embedded systems.

We use the same software environment as described in [7] but different hardware environment, that is, an embedded system instead of a hand-held device. The embedded system consists of a TFT LCD with a resolution of 320x240. We first analyze the upper energy consumption limit of this embedded system and then set up experiments to measure consumptions of energy, which are required to be well below the upper energy consumption limit to be meaningful for interpretation. Finally, optimal choices of encoding parameters are suggested to have efficient power management on embedded systems.

This thesis is organized as follows: Section 2 introduces the popular video codecs. Section 3 describes the experimental environments and setups. Experimental results as well as energy analyses will be shown in Section 4. Conclusions will be given in Section 5.

Chapter 2
Codecs

A codec is a device or program capable of encoding and decoding a digital data stream or signal. The word codec may be a combination of any of the following: ‘compressor-decompressor’, ‘coder-decoder’, or ‘compression/decompression algorithm’. In the recent software sense, codecs encode a data stream or signal for transmission, storage or encryption, or decode it for viewing or editing.

Most codecs are lossy, which due to the reduced size of the resulting data stream achieve higher network transmission rates. Additionally, smaller data sets ease the strain on relatively expensive storage sub-systems such as non-volatile memory and hard disk, as well as write-once-read-many formats such as CD-ROM, DVD and Blu-ray Disc.

However, The widely spread notion of AVI being a codec is incorrect as AVI is a container format, which many codecs might use (although not to ISO standard). There are other well-known alternative containers such as Ogg, ASF, QuickTime, RealMedia, Matroska, DivX, and MP4.

2.1. MPEG-4

MPEG-4 is an encoding standard used primarily to compress audio and visual digital data. Introduced in late 1998, it is the designation for a group of audio and video coding standards and related technology agreed upon by the ISO/IEC[9] Moving Picture Experts Group (MPEG) under the formal standard ISO/IEC 14496.

The uses for the MPEG-4 standard are webs (streaming media), CD distributions, conversations (video phones), and broadcast televisions, all of them benefit from compressing the audio and visual stream.

MPEG-4 absorbs many of the features of MPEG-1 and MPEG-2 and other related standards, adds new features such as the extended VRML support for 3D rendering, object-oriented composite files (including audio, video and VRML objects), supports for externally-specified Digital Rights Management and various types of interactivity.

MPEG-4 is still a developing standard and is divided into a number of parts. Unfortunately the companies promoting MPEG-4 compatibility do not always clearly state which "part" level compatibility. The key parts to be aware of are MPEG-4 part 2 (MPEG-4 SP/ASP, used by codecs such as DivX, Xvid, Nero Digital and 3ivx and by Quicktime 6) and MPEG-4 part 10 (MPEG-4 AVC/H.264, used by the x264 codec, by Nero Digital AVC, by Quicktime 7, and by next-gen DVD formats like HD-DVD[10] and Blu-ray Disc[11]).

Most of the features included in MPEG-4 are left to individual developers to decide whether to implement them. This means that there are probably no complete implementations of the entire MPEG-4 set of standards. To deal with this, the standard includes the concept of "profiles" and "levels", allowing a specific set of capabilities to be defined in a manner appropriate for a subset of applications[12].

2.2. DivX

DivX is a brand name of products created by DivX, Inc. (formerly DivXNetworks, Inc.), including the DivX Codec which has become popular due to its ability to compress lengthy video segments into small sizes while maintaining relatively high visual quality. The DivX codec uses lossy MPEG-4 Part 2 compression, also known as MPEG-4 ASP, where quality is balanced against file size for utility. It is one of several codecs commonly associated with "ripping", whereby audio and video multimedia are transferred to a hard disk and transcoded. Many newer "DivX Certified" DVD players are able to play DivX encoded movies, although the Qpel and global motion compensation features are often omitted to reduce processing requirements. They are also excluded from the base DivX encoding profiles for compatibility reasons.

We adopted DivX3 and DivX5 [13] in our experiment.

2.3. XviD

Xvid (formerly "XviD") is a video codec library following the MPEG-4 standard. Xvid features MPEG-4 Advanced Simple Profile features such as b-frames, global and quarter pixel motion compensation, lumi masking, trellis quantization, and H.263, MPEG and custom quantization matrices.

Xvid is a primary competitor of the DivX Pro Codec (Xvid being DivX spelled backwards). In contrast with the DivX codec, which is proprietary software developed by DivX, Inc., Xvid is free software distributed under the terms of the GNU General Public License. This also means that unlike the DivX codec, which is only available for a limited number of platforms, Xvid can be used on all platforms and operating systems for which the source code can be compiled.

As an implementation of MPEG-4 part 2 Xvid utilizes many patented technologies.[5] For this reason, Xvid 0.9.x versions were not licensed in countries where these software patents are enforceable. With the 1.0.x releases, a GNU GPL v2 license is used with no explicit geographical restriction. However, the legal usage of Xvid may still be restricted by local laws.[14].

2.4. H.263

H.263 was a video codec originally designed by the ITU-T [4] in 1995/1996 as a low bit rate compressing format standard for videoconferencing. It is one member of the H.26x family of video coding standards in the domain of the ITU-T Video Coding Experts Group (VCEG).

The codec is first designed to be utilized in H.324 based systems (PSTN and other circuit-switched network videoconferencing and video telephony), but has since also found use in H.323 (RTP/IP-based videoconferencing), H.320 (ISDN-based videoconferencing), RTSP (streaming media) and SIP (Internet conferencing) solutions.

H.263 is developed as an evolutionary improvement based on experiences from H.261, the previous ITU-T standard for video compression, and the MPEG-1 and MPEG-2 standards. Its first version was completed in 1995 and provides a suitable replacement for H.261 at all bit rates. It is further enhanced in projects known as H.263v2 (also known as H.263+ or H.263 1998) and H.263v3 (also known as H.263++ or H.263 2000).

The next enhanced codec developed by ITU-T VCEG (in partnership with MPEG) after H.263 is the H.264 standard, also known as AVC and MPEG-4 part 10.

We adopted H.263v2 [15] in this experiment.

2.5. WMV

Windows Media Video (WMV) is a generic name for the set of video codec technologies developed by Microsoft. It is part of the framework of Microsoft Windows Media.

Windows Media Video (WMV), a popular codec for distributing video on the Internet, competes with other codecs such as RealVideo, DivX, Xvid, and H.264, etc. Generally speaking, common usage of the term WMV refers to this codec only. WMV supports variable bit rate, average bit rate, and constant bit rate encoding.

The first version of the WMV codec, WMV 7, was released in 1999. It is originally developed as a proprietary codec for low bit rate streaming applications. It is believed that WMV 7 is built upon Microsoft's own non-standard version of MPEG-4 Part 2, and has received continued proprietary development from Microsoft. The second version of the codec, WMV 8, was released in 2001 along with Windows Media Player 8.

The current version of the codec, WMV 9, was released in 2003 as part of the Windows Media 9 Series. This version introduces interlaced video encoding and video smoothing. It has been slightly revised to improve encoding speed and quality, and fixes the issue of frame-dropping problems with ABR encoding for high-resolution video.

WMV (*.wmv) files can be played by Windows Media Player and other players such as MPlayer, VLC media player or Media Player Classic. Many third-party players exist for various platforms such as Linux that use the FFmpeg implementation of the WMV codecs.

Although WMV is generally packed into an Advanced Systems Format (ASF) container format, it can also be put into AVI or Matroska containers. The resulting files will be named .AVI, or .MKV respectively. WMV can be stored in an AVI file when using the WMV 9 Video Compression Manager (VCM) codec implementation. One common way to encode WMV in AVI is to use the VirtualDub encoder. Microsoft's Windows Media Player for Mac does not support all WMV encoded files since it supports only the ASF file container. Other files can be played with Flip4Mac and QuickTime or MPlayer for Mac OS X.

When encapsulated in ASF file format, WMV can support DRM protected content.

We adopted WMV7 and WMV8 [16] in our experiment.

Chapter 3
Experiment Setting

3.1. Experiment Environment

We used Xvid, DivX5, DivX3 (open source edition), MPEG-4, MS MPEG-4 V2 (Microsoft MPEG-4 version 2), H.263+, WMV1 (Windows Media Video V7) and WMV2(Windows Media Video V8) as compression encoders on SUPER© [17] (Simplified Universal Player Encoder & Renderer) (Figure 3.1). SUPER© is free software developed by eRightSoft and supports many media formats, such as 3GP, 3G2, ASF, AVI, MOV, MP4, WMV, etc.

Figure 3.1 shows SUPER© (Simplified Universal Player Encoder & Renderer). We can choose output format on Red circle 1, choose the video encoder, for example DivX, XviD, WMV, H.263+, etc. on red circle 2, choose video resolution on Red circle 3, and determine movie frame numbers per second on Red circle 4, and choose the bit-rate of output video on Red circle 5.

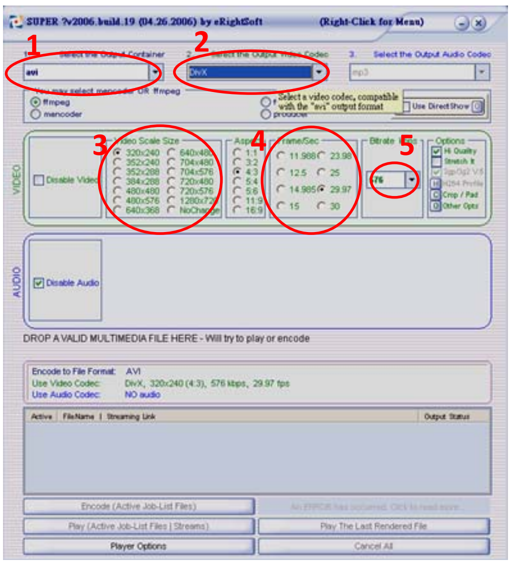


Figure 3.1 SUPER©

We used TCPMP (The Core Pocket Media Player) shown in Figure 3.2 as media's player procedure [18]. TCPMP is free software and Open Source Code which can be used on mobile hand-held devices, either Palm OS-based or Windows CE / Windows Mobile-based. Besides, it can play files of many media formats.

We set up the environment of a compiler by Embedded C++ of Microsoft, recompiled TCPMP into a procedure that can be run on the embedded system, and loaded it into the embedded system environment through ActiveSync.

Figure 3.2 TCPMP

The process of encoding and decoding is shown in Figure 3.3 We encoded the source film (DVD) into a video file by SUPER©, loaded this video file to the embedded system, and decoded it with TCPMP. We measured the consumption of electricity when decoding it.

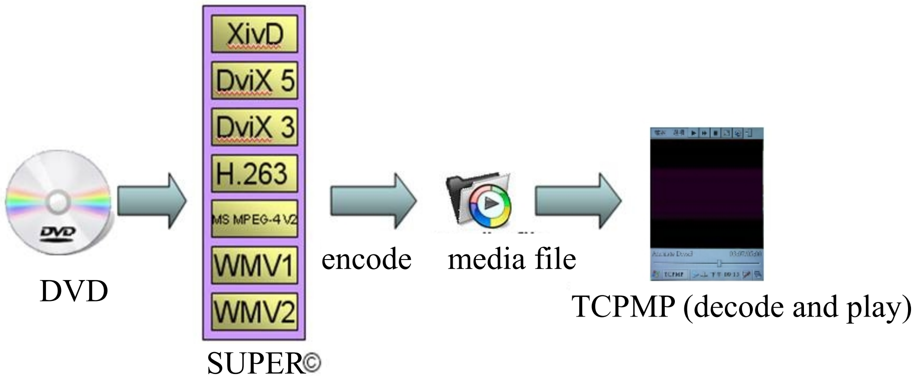


Figure 3.3 The process of encoding and decoding

3.2. Experiment Setup

The experiment setup is shown in Figure 3.4 We used a DMATEK ARM9 DMA-2410 Embedded System with a 266 MHz Samsung S3C2410 processor, a 64MB NAND Flash, a 32MB SDRAM, and Microsoft® Windows Mobile™ Version 4.2 as its operating system[19]. A power supply of DC 12 Volts was series-connected with a 1 Ohm resistor [20][21]. We used a National Instruments PCI DAQ data acquisition board [22] to sample the voltage across the resistor to calculate the electric current at 1000 samples/sec[23][24]. The energy measurement was done by using LabVIEW 8. According to the Joule's law, we calculated the instantaneous power consumption and the total energy consumption using following equations (1) (2):

$$P_{Inst} = \frac{V_R}{R} \times V_{Embedded\_System} \qquad (1)$$

$$E = \sum P_{Inst} \times T \qquad (2)$$

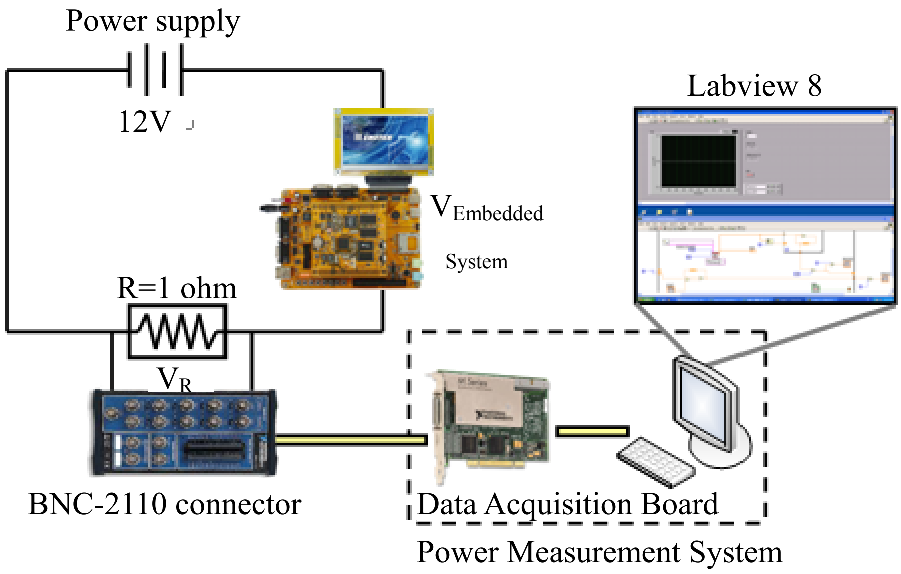


Figure 3.4 Experimental Setup

We first considered the extreme case when the CPU of the embedded system runs at full speed and data keeps swapping in and out of SD Card and RAM all the time.

We designed a test to measure the consumption of energy with the embedded system running at full speed. A procedure with infinite iterations was compiled to run on the embedded system for a test time of 5 minutes and the consumption of energy was measured to be about 193.3 joules. Furthermore, we encoded a film with a resolution of 640x480 and a frame rate of 30 frames/sec, and a bit rate of 576kbp. We loaded the film into the SD Card and played the film in TCPMP for 5 minutes and obtained the consumption of energy, which was 233.2 joules and was the energy spent at the extreme case when CPU runs at full speed and the data swaps in and out of SD Card and RAM all the time. So, when doing the experiments, we have to control the experiment setup to obtain credible data by keeping the consumption of energy for playing a 5 minutes film well under 233.2 joules.

In experiment 1 and 2, we measured the consumption of energy for three kinds of films: animation, action thriller, and romance. We tested five different films for each genre (listed in Table 3.1), all with resolution of 160×120, frame rate of 30 frames per second, bit rate of 144 kbps. Each film was played for 5 minutes.

In experiment 3, we analyzed the trend of the consumption of energy for films encoded with parameters of codec. We designed two setups for this experiment: experiment module 1 and experiment module 2 according to the relative size of the resolution of the encoded film and the screen of TFT LCD. Two kinds of parameters were tuned: the bit rate and the resolution. The film using in this experiment was "The Simpson's"; the film's playing time was 5 minutes. The experimental result will tell us the optimal combination of these two parameters to economize the consumption of energy when playing videos on embedded systems.

Table 3.1 Films tested in experiments

Type of video	List of video
Cartoon	The Simpson's Family
	The Lion King
	Aladdin's
	The little mermaid
	Tarzan
Action	Spider-Man 3
	The Rock
	X-Men: The Last Stand
	Die Hard: With a Vengeance
	Blade II
Romance	Now, I want to see you
	You've Got Mail
	Sleepless In Seattle
	Serendipity
	Ghost

Chapter 4
Experiment Result

4.1. Experiment 1

We used Xvid, DivX3, DivX5, H.263+, MPEG, MS MPEG4 V2, WMV1, WMV2 codec to encode five films for each of the three genres. The file format was in AVI. The results for energy consumption are shown in Figure 4.1 for animation films, in Figure 4.2 for action thrillers, in Figure 4.3 for romance films.

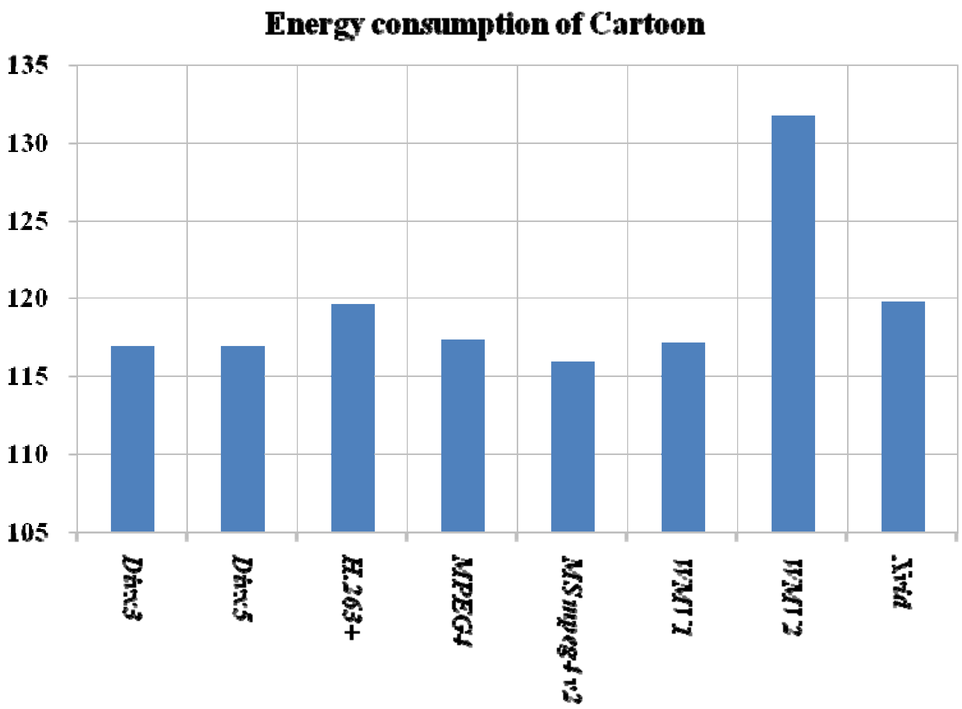


Figure 4.1 Energy consumption of Cartoon (unit in Joules)

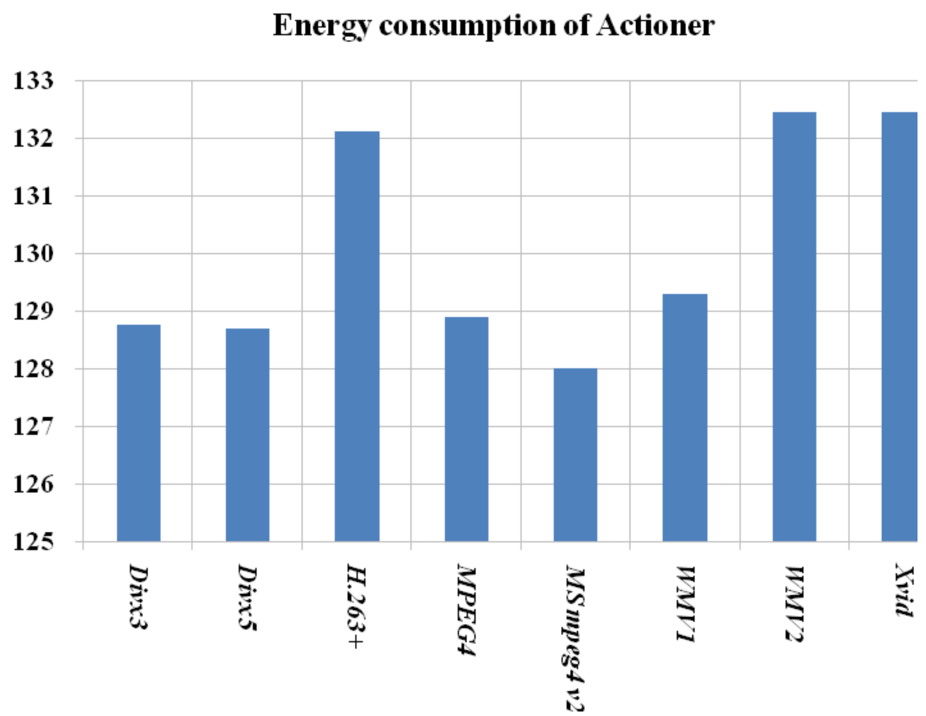


Figure 4.2 Energy consumption of Actioner (unit in Joules)

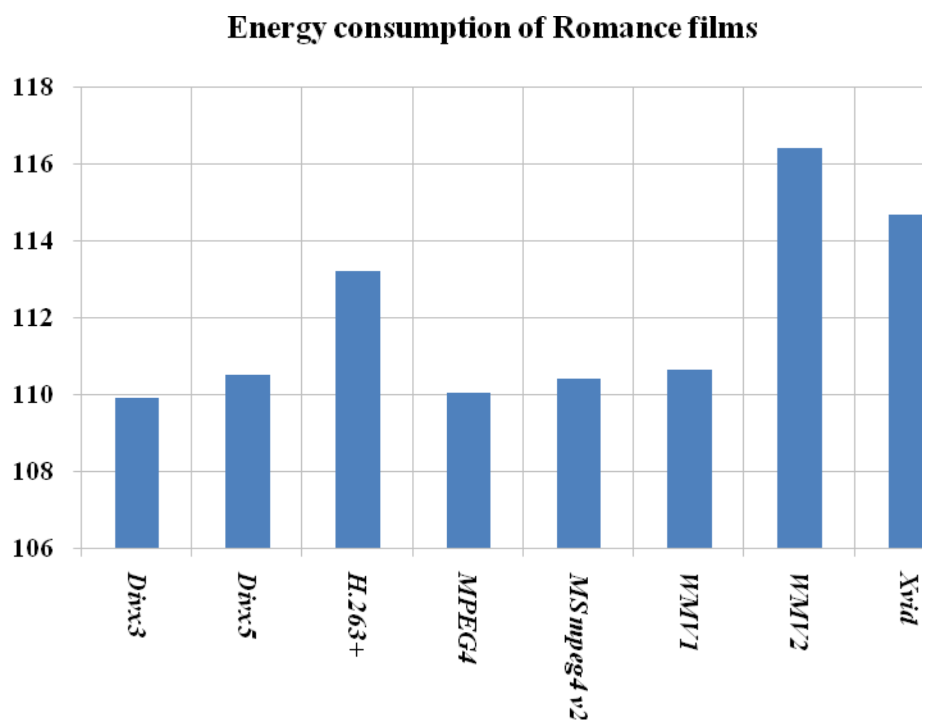


Figure 4.3 Energy consumption of Romance films (unit in Joules)

From Fig. 4.1, Fig. 4.2 and Fig. 4.3 three trends are observed:

1. Films encoded by adopting DivX3, DivX5, MPEG-4, and MS MPEG-4 v2 consumed less electricity than those encoded by adopting H.263+, WMV2, XviD.
2. The amounts of energy consumption of films adopting DivX3, DivX5, MPEG-4, and MS MPEG-4 v2 were close to each other, and those of films adopting H.263+, WMV2, and XviD were close.
3. The energy consumption of the actioner is greater than the cartoon, and the cartoon is greater than the romance movie.

4.2. Experiment 2

In experiment 2, we encoded films in popular file formats, such as ASF, AVI, MOV, MP4, WMV, and measured the consumption of energy for films encoded by Dvix 3, Dvix 5 , H.263+, MPEG-4,MS MPEG-4 V2 (Microsoft MPEG-4 version2), WMV1, WMV2, and Xivd codecs. The experimental results are tabulated in Table 4.1, Table 4.2, and Table 4.3.

Table 4.1 Energy consumptions of animation films of various file formats (unit in Joules)

	DivX3	DivX5	H.263+	MPEG4	MS MP4v2	WMV1	WMV2	Xvid
ASF	NA	NA	NA	NA	118.27	120.62	133.50	NA
AVI	116.94	116.99	119.70	117.35	115.99	117.23	131.75	119.86
MOV	119.84	NA	NA	120.35	NA	NA	NA	122.98
MP4	120.05	NA	NA	119.86	NA	NA	NA	122.90
WMV	NA	NA	NA	NA	119.86	121.67	133.87	NA

Table 4.2 Energy consumptions of action thrillers of various file formats (unit in Joules)

	DivX3	DivX5	H.263+	MPEG4	MS MP4v2	WMV1	WMV2	Xvid
ASF	NA	NA	NA	NA	131.63	132.43	135.03	NA
AVI	128.76	128.69	132.11	128.90	128.01	129.29	132.44	132.45
MOV	131.87	NA	NA	132.29	NA	NA	NA	135.31
MP4	132.10	NA	NA	132.30	NA	NA	NA	135.92
WMV	NA	NA	NA	NA	131.20	132.51	135.25	NA

Table 4.3 Energy consumptions of romance films of various file formats (unit in Joules)

	DivX3	DivX5	H.263+	MPEG4	MS MP4v2	WMV1	WMV2	Xvid
ASF	NA	NA	NA	NA	113.86	114.39	120.16	NA
AVI	109.92	110.52	113.23	110.05	110.42	110.65	116.41	114.69
MOV	112.84	NA	NA	113.98	NA	NA	NA	118.22
MP4	113.44	NA	NA	113.37	NA	NA	NA	118.22
WMV	NA	NA	NA	NA	114.56	114.73	121.01	NA

From Table 4.1, Table 4.2, Table 4.3, we observe that films encoded by the same codec have very close consumptions of energy irrespective to the file formats.

4.3. Experiment 3

In experiment 3, we investigated the effects of changing the two parameters: the resolution and the bit rate of films.

We adjust these two parameters to observe the influence of them on the electric power consumption and find which parameter has the greatest influence on electricity consumption. As shown in Fig. 4.4, there are three parameters in red circles to be selected when encoded film using SUPER© (Simplified Universal Player Encoder & Renderer).

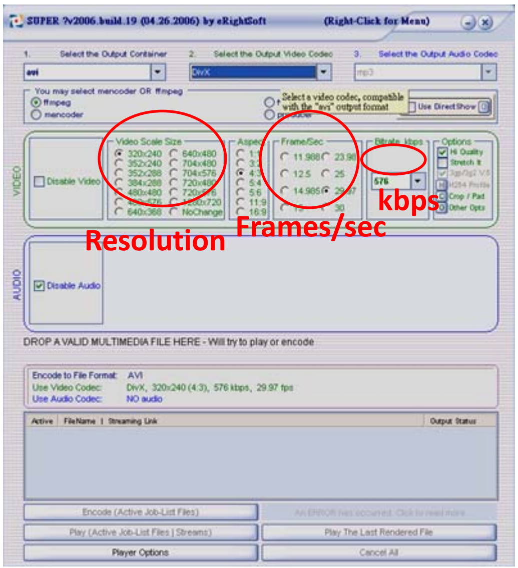


Figure 4.4 SUPER©

4.3.1 Experiment Module 1

In Module 1, the resolution of the film was set to be smaller than the actual resolution on TFT LCD as shown in Fig. 4.5.

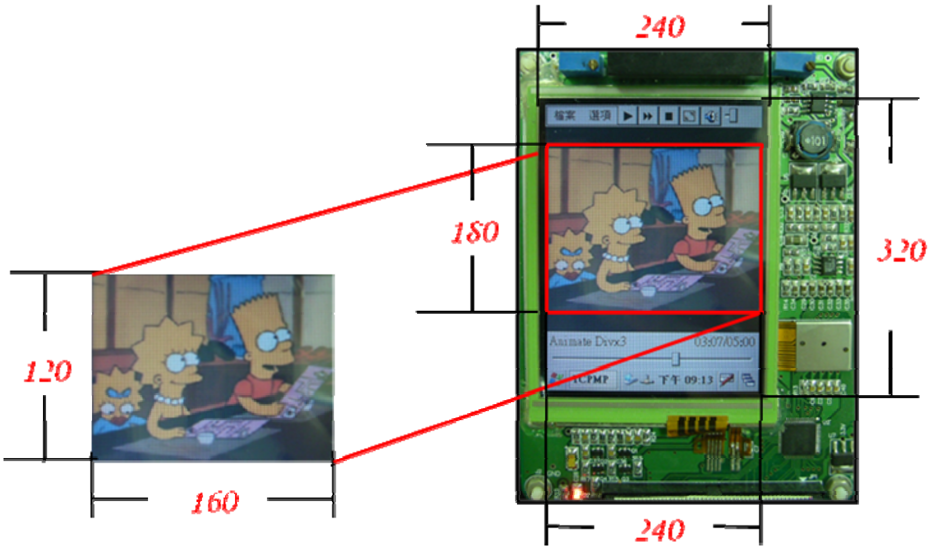


Figure 4.5 Embedded system playing films of smaller resolution than its frame

Since the TFT LCD screen has a resolution of 180x240 and the film has resolution of 160×120, an enlarged version of the film was played.

Table 4.4 shows the energy consumption of the film with various bit rates. Table 4.5 shows growth rate of energy consumption when bit rates of the film is doubled. For example, the energy consumed is 62.04 Joules when bit rate is 144kbps, with the film encoded by DivX3, and it is 71.18 Joules when bit rate is changed to 288kbps.

The growth rate of electric energy consumption formula the following:

$$\frac{\text{latter's energy} - \text{former's}}{\text{former's}} \times 100\% \qquad (3)$$

The growth rate of electric energy consumption is calculated to be 7.77% when bit rate is adjusted from 72kbps to 144kbps. The arithmetic average of growth rate of energy consumption when the bit rate is doubled is found to be 9.91%.

Table 4.4 Energy consumption of films with various bit rates

	72kbps	144kbps	288kbps	576kbps
Divx3	108.51	116.94	131.26	144.10
Divx5	108.42	116.99	131.54	143.44
MPEG4	108.54	117.35	131.58	143.59
MS mpeg4 v2	107.68	115.99	132.10	143.02
WMV1	108.51	117.23	133.21	144.54

Table 4.5 Growth rate of energy consumption when bit rate is doubled

	72→144kbps	144→288kbps	288→576kbps
Divx3	7.77%	12.25%	9.78%
Divx5	7.90%	12.44%	9.04%
MPEG4	8.12%	12.13%	9.13%
MS mpeg4 v2	7.72%	13.89%	8.27%
WMV1	8.04%	13.63%	8.51%

Table 4.6 lists the energy consumptions of films encoded with resolution of 160 × 120, frame rate of 30 frames per second, while Table 4.7 lists those with resolution of 192 × 144, frame rate of 30 frames per second. Table 4.8 shows the growth rate of energy consumption by changing the resolution from 160 × 120 to 192 × 144. We find the average growth rate of the energy consumption is 15.46% when the resolution of the film is changed from 160x120 to 192x144.

Table 4.6 The energy consumption of films with resolution of 160×120 and 30 frames/sec

	72kbps	144kbps	288kbps	576kbps
Divx3	108.51	116.94	131.26	144.10
Divx5	108.42	116.99	131.54	143.44
MPEG4	108.54	117.35	131.58	143.59
MS mpeg4 v2	107.68	115.99	132.10	143.02
WMV1	108.51	117.23	133.21	144.54

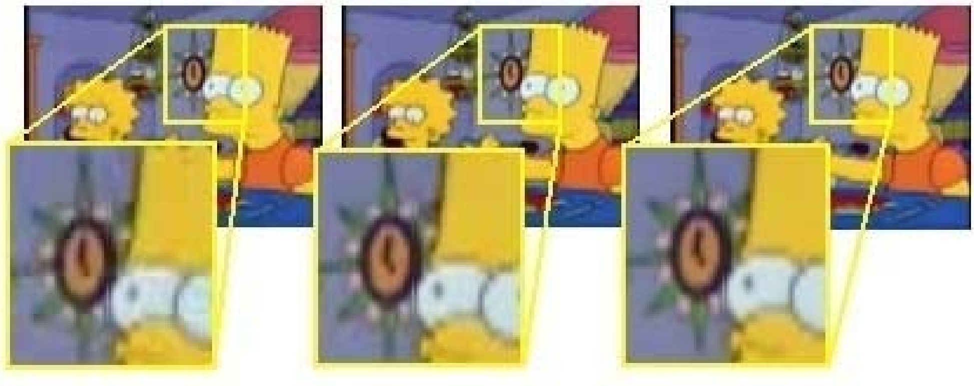
Table 4.7 The energy consumption of films with resolution of 192×144 and 30 frames/sec

	72kbps	144kbps	288kbps	576kbps
Divx3	123.98	133.28	150.20	167.52
Divx5	123.60	133.31	150.46	167.62
MPEG4	123.32	133.25	153.02	167.60
MS mpeg4 v2	122.07	132.32	149.93	167.50
WMV1	123.04	132.71	161.49	180.77

Table 4.8 Growth rate of energy consumption of films when frame rate is changed

	72kbps	144kbps	288kbps	576kbps
Divx3	14.26%	13.98%	14.43%	16.25%
Divx5	14.00%	13.96%	14.38%	16.86%
MPEG4	13.62%	13.56%	16.29%	16.72%
MS mpeg4 v2	13.37%	14.07%	13.50%	17.11%
WMV1	13.39%	13.20%	21.23%	25.07%

We observe that when the bit rate is doubled, the average growth rate of energy consumption (9.91%) is smaller than the average growth rate of energy consumption (15.46%) when the resolution is changed from 160×120 to 192 × 144. In other words, with the same percentage of increase, the resolution instead of the bit rate consumes more energy. In order to have better image quality and lesser increase of the consumption of energy, we can encode the film with a larger bit rate but the same resolution.



(a) (b) (c)

Figure 4.6 Films of various bit rates (a) 72Kbps (b) 144Kbps (c) 288Kbps

4.3.2 Experiment Module 2

In Module 2, the resolution of the film was set to be larger than the actual resolution on TFT LCD as shown in Fig. 4.7.

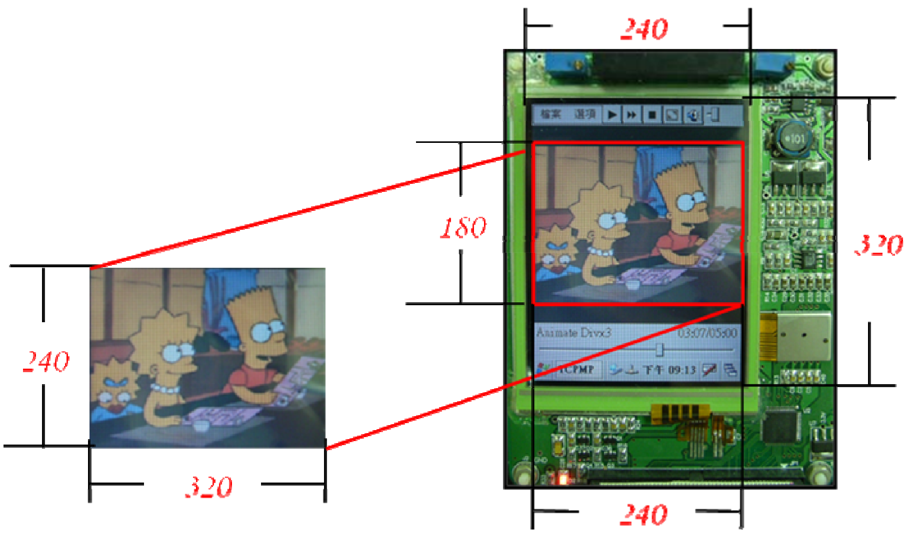


Figure 4.7 Embedded system playing films of larger resolution than its frame

Since the TFT LCD screen has a resolution of 180x240 and the film has resolution of 240×320, a reduced version of the film was played.

Table 4.9 shows the energy consumption of the film with various bit rates. Table 4.10 shows the growth rate of energy consumption when bit rates of the film is doubled.

Since the energy consumptions of films with 576 kbps and 1152 kbps in Table 4.9 are too close to the upper energy consumption limit, the growth rate of the energy consumption from 576 kbps to 1152 kbps is not meaningful.

After taking off entries under 576→1152kbps, the average growth rate of energy consumption when the bit rate is doubled is found to be 13.72%.

Table 4.9 Energy consumption of films with various bit rates

	144kbps	288kbps	576kbps	1152kbps
Divx3	177.91	202.83	229.68	228.88
Divx5	178.11	203.17	230.15	227.91
MPEG4	178.07	202.72	229.49	227.55
MS mpeg4 v2	175.04	199.94	228.77	227.44
WMV1	178.09	203.65	229.21	228.60

Table 4.10 Growth rate of energy consumption when bit rate is doubled

	144→288kbps	288→576kbps	576→1152kbps
Divx3	14.00%	13.24%	-0.35%
Divx5	14.07%	13.28%	-0.97%
MPEG4	13.85%	13.20%	-0.85%
MS mpeg4 v2	14.22%	14.42%	-0.58%
WMV1	14.35%	12.55%	-0.27%

Table 4.11 lists the energy consumptions of films encoded with resolution of 320x240, and 30 frames per second, while Table 4.12 lists those with resolution of 384x288, and 30 frames per second. Table 4.13 shows the growth rate of energy

consumption when the resolution is changed from 320x240 to 384x288.

Since the energy consumptions of films with 576 kbps and 1152 kbps in Table 4.13 are too close to the upper energy consumption limit, the growth rate of the energy consumption from 576 kbps to 1152 kbps is not meaningful.

After taking off entries under 576→1152kbps, the average growth rate of the energy consumption is found to be 7.32% when the resolution of the film is changed from 320x240 to 384x288.

Table 4.11 The energy consumption of films with resolution of 320×240 and 30 frames/sec

	144kbps	288kbps	576kbps	1152kbps
Divx3	177.91	202.83	229.68	228.88
Divx5	178.11	203.17	230.15	227.91
MPEG4	178.07	202.72	229.49	227.55
MS mpeg4 v2	175.04	199.94	228.77	227.44
WMV1	178.09	203.65	229.21	228.60

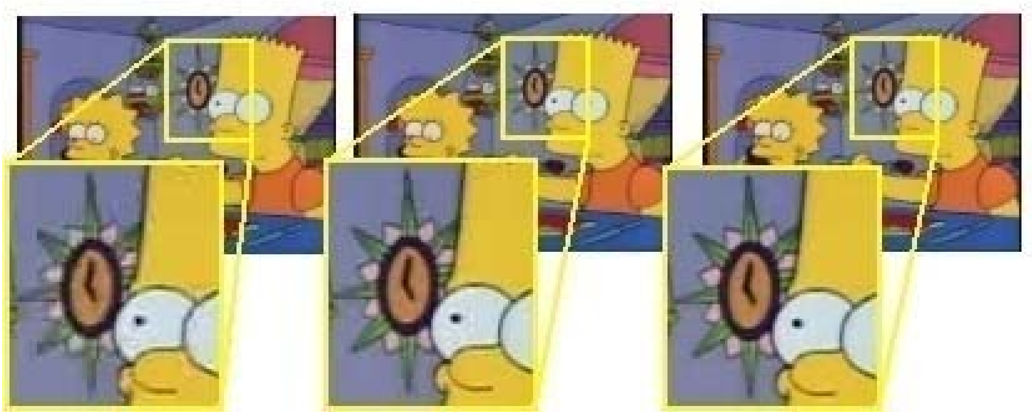
Table 4.12 The energy consumption of films with resolution of 384×288 and 30 frames/sec

	144kbps	288kbps	576kbps	1152kbps
Divx3	192.15	219.92	233.51	227.24
Divx5	191.26	218.58	233.08	226.61
MPEG4	191.62	218.15	233.54	226.96
MS mpeg4 v2	185.70	213.27	233.39	226.73
WMV1	190.98	217.13	232.74	227.85

Table 4.13 Growth rate of energy consumption of films when resolution is changed from 320x240 to 384x288

	144kbps	288kbps	576kbps	1152kbps
Divx3	8.00%	8.42%	1.67%	-0.72%
Divx5	7.39%	7.58%	1.28%	-0.57%
MPEG4	7.61%	7.61%	1.77%	-0.26%
MS mpeg4 v2	6.09%	6.67%	2.02%	-0.31%
WMV1	7.24%	6.62%	1.54%	-0.33%

We observe that when the bit rate is doubled, the average growth rate of energy consumption (13.72%) is larger than the average growth rate of energy consumption (7.32%) when the resolution is changed from 320×240 to 384 × 288. As shown in Figure 4.7, the picture qualities of high resolution films of various bit rates are negligibly different. So, when playing high resolution films, we can save the electricity greatly by reducing the bit rate without influencing the picture quality too much.



(a) (b) (c)

Figure 4.7 Films of various bit rates (a) 144Kbps (b) 288Kbps (c) 576Kbps

Chapter 5
Conclusions

In this thesis, we encode films by several kinds of most common codecs, and investigate various film codes by adjusting the parameters of codecs. Energy consumptions of these films are analyzed to find optimal codec settings on the embedded system.

From the experimental results we find that playing films encoded of one group of video codecs, including DivX3, DivX5, MPEG4, MS MPEG4 V2, and WMV1, the energy consumption is lesser than playing films encoded of the other group of video codecs, including H.263+, WMV2, and XviD. Codecs that produce video codes consuming less power when decoding are recommended to use on mobile device to obtain a longer battery life.

The experimental results also demonstrate that file formats do not have much effect on energy consumption. Different file formats of the same codec have very close energy consumption.

The bit rate plays a very important part in both low and high resolution films in saving of the consumption of energy. When making low resolution films, in order to have better image quality and lesser increase of the consumption of energy, we can encode the film with a larger bit rate but the same resolution. When making high resolution films, we can reduce the bit rate other than the resolution to cut down energy consumptions and still enjoy the high visual quality.

Chapter 6
Future Work

Video Streaming is one kind to dial the technology of showing the video file via the network. In recent years, the topic that Video Streaming applies to the online TV is very popular. At the same time the Mobile Device doing the complicated download and decoding of video, and it must be make the Mobile Device's power continual consume. The Mobile device's management of power will be more difficult day by day.

At present, we carry on the relevant research and discussion[25][26] to different wireless transfer way efficiency already; Future work, we will focus on and consume and make and combine studying with the electricity, expect to find out and have relatively higher wireless transfer efficiency and energy consumption relatively lower wireless transfer way, make further experiment conclusion and suggestion.

Bibliography

[1] K. Lahiri, A. Raghunathan, S. Dey, and D. Panigrahi, “Battery driven system design: a new frontier in low power design,” In Proc. ASP-DAC/VLSI Design 2002, Bangalore, India, January 2002, pp. 261-267.

[2] MPEG Industry Forum. [Online]. Available: http://www.m4if.org/

[3] Overview of the MPEG-4 Standard: http://www.chiariglione.org/mpeg/standards/mpeg-4/mpeg-4.htm

[4] International Telecommunication Union, ITU. [Online]. Available: http://www.itu.int/

[5] Chu-Hsing Lin, Jung-Chun Liu, Chun-Wei Liao, "Energy Analysis of Multimedia Video Decoding on Mobile Handheld Devices,” 2007 International Conference on Multimedia and Ubiquitous Engineering (MUE07), Seoul, Korea, April 26-28, 2007, pp.120 – 125.

[6] Chu-Hsing Lin, Jung-Chun Liu, Chun-Wei Liao, “Energy Consumption Analysis of Audio Applications on Mobile Handheld Devices,” Proceedings of IEEE TENCON 2007, Intelligent Information Communication Technologies for Better Human Life, Taipei, Taiwan, Oct. 31-Nov. 3, 2007. (EI)

[7] Chu-Hsing Lin, J. C. Liu, M. H. Cheng, “Energy Analysis of Multimedia Video Decoding on Embedded Systems,” accepted and to present in The International Conference on Information Networking 2008 (ICOIN2008), Paradise Hotel, Busan, Korea, January 23 - January 25, 2008.

[8] Chu-Hsing Lin, C. S. Shih, J. C. Liu, M. H. Cheng, and Y. W. Lee, “Energy Efficiency Measurement for Multimedia Audio Decoding on Embedded

Systems," accepted and to present in The Second International Conference on Ubiquitous Information Management and Communication (ACM ICUIMC 2008) to be held in Suwon, Korea, Jan. 31 – Feb. 1, 2008.

[9] International Electrotechnical Commission，IEC. [Online]. Available: http://www.iec.ch/

[10] HD-DVD Promotion Group. [Online]. Available: http://www.hddvdprg.com/

[11] Blu-ray Disc Association. [Online]. Available: http://www.blu-raydisc.com/

[12] Applications and Requirements for Scalable Video Coding, MPEG-document ISO/IEC JTC1/SC29/WG11 N5540, Mar. 2003.

[13] DivXNetworks, Inc. [Online]. Available: http://www.divx.com/divx/

[14] XviD Software Package [Online]. Available: http://www.xvid.org/

[15] G. Cote, B. Erol, M. Gallant, F. Kossentini, "H.263+: Video Coding at Low Bit Rates," IEEE Trans. on Circuits and Systems for Video Technology, Nov. 1998, pp. 849-866.

[16] W. Ashmawi, R. Guerin, S. Wolf, and M. Pinson, "On the impact of policing and rate guarantees in DiffServ networks: A video streaming application perspective," Proceedings of the 2001 conference on Applications, Technologies, Architectures, and Protocols for Computer Communications, California, United States, Aug. 2001, pp. 83-95.

[17] SUPER©: http://www.erightsoft.com/SUPER.html

[18] TCPMP: http://tcpmp.corecodec.org/

[19] DMATEK Corp. http://www.dmatek.com.tw

[20] N. R. Potlapally, S. R., A. Raghunathan, and N. K. Jha, "A Study of the Energy Consumption Characteristics of Cryptographic Algorithms and Security Protocols," IEEE Transactions on Mobile Computing, Issue 2, Volume 5, Feb. 2006, pp.128 – 143.

[21] T. K. Tan, A. Raghunathan, and N. K. Jha., “A simulation framework for energy-consumption analysis of OS-driven embedded applications,” IEEE Trans. on Computer-Aided Design of Integrated Circuits and Systems, Sept. 2003, pp. 1284-1294.

[22] National Instruments, Optimizing LabVIEW Embedded Applications (search keyword), http://www.ni.com

[23] National Instruments Corp. http://www.ni.com

[24] M. L. Higa, D. M. Tawy, S. M. Lord, “An introduction to LabVIEW exercise for an electronics class” The 32nd ASEE/IEEE Frontiers in Education Conference, Boston, MA, Volume 1, 6-9 Nov. 2002 pp.T1D-13 - T1D-16 vol.1

[25] K.-M. Ho, W.-F. Poon, and K.-T. Lo, “Performance Study of Large-Scale Video Streaming Services in Highly Heterogeneous Environment” IEEE Trans. on Broadcasting, vol. 53, no. 4, Dec. 2007

[26] K.M. Ho, W.F. Poon and K.T. Lo, “Investigating the Performance of Hierarchical Video-on-Demand System in Heterogeneous Environment” The 2nd international conference on ubiquitous information Management and Communication, Jan. 2008

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碩士論文

Energy Efficiency Analysis of Multimedia Video Decoding on Embedded Systems

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