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Performance of commercial multimedia workloads on the Intel Pentium 4: A case study

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ABSTRACT

In this paper, we present a case study of the execution time characteristics of several popular commercial audio and video applications on a state of the art microprocessor, the Intel Pentium 4. The on-chip performance counters on the Pentium 4 processor are used to perform this study using actual real-world workloads. While the Pentium 4 is capable of executing 3–4 instructions in one cycle, it was observed that commercial audio and video applications take between 1.4 and 3.5 cycles (per instruction) to execute. Despite using large caches and sophisticated out of ordering techniques, the average cycles per instruction is higher than a predecessor like Pentium II. This indicates that while clock frequency has improved, real speedups are not scaling. The performance of multimedia programs is compared with execution characteristics of SPEC CPU 2000 programs. Performance impact of branch predictors, caches and trace caches on the Pentium 4 are analyzed for multimedia and SPEC CPU applications.

1. Introduction

In the past few years, the computer industry has undergone tremendous changes in the application domain. Multimedia applications are becoming an increasingly common computer workload. The computer is no longer a business tool but it also has become a popular form of entertainment. While the home user still uses the typical applications from word processing, email, spreadsheets, and Internet surfing, the amount of multimedia being used has increased significantly.

The Internet has played a huge role in changing the workload of the computer. With the use of peer-to-peer media sharing, the typical users now have a huge collection of media at their fingertips. Digitized audio and video is becoming the norm to store music, pictures and motion. State of the art computers, especially personal computers are spending a large part of their cycles on workloads performing audio and video encoding and decoding. By observing the computer usage trends of different demographic spectrum, including college and school age users, one can observe that the computers are widely used to perform a wide variety of multimedia tasks including, music playback, DVD playback, video playback, and video games. Since the workload is focused on real-time applications, the performance of common applications needs to be investigated in order to understand current CPUs and to design next generation computers.

For more than a decade, microprocessor designers have realized the importance of media processing workloads and have made instruction set and microarchitectural enhancements to improve performance of multimedia applications. In the instruction set domain, the most notable enhancement has been the introduction of SIMD (Single Instruction Multiple Data) instruction set extensions such as Intel's MMX/SSE, Sun Microsystems' VIS, AMD's 3Dnow!, Motolora's AltiVec, DEC's MVI, HP's MAX2, and MIPS' MDMX. In the microarchitectural domain, the improvements such as larger caches, larger block sizes,

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branch predictors, etc have helped to make use of the locality and predictability in media programs. The abundance of functional units is also helpful to take advantage of the data parallelism and address generation computation requirements in these applications.

In this paper, we present a case study of the execution time characteristics of several popular commercial audio and video applications on a state of the art microprocessor, the Intel Pentium 4. The on-chip performance counters on the Pentium 4 processor was used to perform this study using actual real-world workloads. By monitoring the performance counters of the Pentium 4, important information on how the different features in the CPU are responding to the demands of contemporary multimedia workloads are obtained. The information presented in this paper can be utilized by computer architects in the design of future micro-architectures. It can also be used by compiler writers and application developers to optimize emerging and future media applications.

The rest of the paper is organized as follows. Section 2 provides background information on what work has been done in the area. Section 3 discusses our experiment methodology, describing the workloads, the platform and the experimental tools. The performance of audio and video, decoding and encoding are examined in Section 4. Section 5 offers concluding remarks.

2. Related work

Multimedia workloads have been extensively studied in past research [2,3,5,6,8,10,11,13,14,16], however, many of the papers focused on kernels or algorithms, rather than entire commercial applications. There has been a large amount of work investigating the performance of multimedia benchmarks or the important parts of the algorithms [3,11,13]. Many past studies use kernel-type benchmarks, but full application benchmarks are normally preferred to kernel benchmarks because they perform the actual task of interest in the same manner as the real workload [14]. Even if several kernels are used in a full application, the characteristics of each of those kernels cannot accurately predict the features of the entire application. While these types of research show the performance on certain parts of multimedia, it does not show the overall performance. The benchmarks only test a certain part of the algorithm. In this research we investigate the performance of the processor on commonly used commercial audio and video applications, such as *Real Player*, *iTunes* and *MPEG4.*

Talla et al. [16] studied the execution of multimedia applications on the Pentium 2 processor. They give some insight into the CPI, branching, and MMX execution, but it was on the Pentium 2, and with applications that existed in the 90s. Our research focuses on modern audio and video applications such as *iTunes* for the *iPod* or the *Windows MediaPlayer* on the Pentium 4 architecture. Also, our study almost a decade after the introduction of MMX gives us the opportunity to evaluate the impact of extensions such as MMX. Chen et al. [4] studied media applications on the Pentium 4. However, this study only includes MPEG and Video watermarking. In this paper we present a more extensive set of applications, in conjunction with popular personal computer applications.

3. Experimental environment

To fulfill our objective of understanding how commercial multimedia applications in the real-world take advantage of high performance hardware, we perform an experiment with several contemporary audio and video applications on a state of the art computer system with a high performance microprocessor. In this section, we describe the different audio and video workloads that we have used, the platform on which the experiments were performed and the performance monitoring mechanism and metrics. To offer a baseline to compare the multimedia applications against some standard benchmarks, several programs from the SPEC CPU2000 integer benchmarks were also studied. Since computer architects and programmers are familiar with these benchmarks, it offers them an insight into how these applications compare with each other. The SPEC2000 results are given in the various sections to enable a comparison on performance of various structures including the branch predictor and the caches. Fourteen SPEC CPU2000 benchmarks including two floating point benchmarks were used. The SPEC benchmarks were compiled with the make files provided by SPEC [15].

3.1. Multimedia workloads

The workloads that this paper examines are the most commonly used multimedia applications used today. The applications we used belong to audio and video encoding and decoding. The various applications and instruction counts are summarized in Table 1.

3.1.1. Audio

In audio encoding, the application takes the original uncompressed audio file and applies an algorithm to map the file to a model perceivable by the human ear. The mapping into the model will remove all the sounds that the ear cannot perceive. Audio decoding will take the compressed data and extract into the standard pulse code modulated (PCM) format to be sent out to the sound card. Different applications are used to test the encoding of audio because the codec defines only the way the bit stream should look. Therefore each application will have its own way of encoding by choosing different levels of detail and type of hearing models.