**Performance Analysis and Optimization of a Real-Time Video Processing Application on Different Hardware Configurations**

**A PROJECT REPORT**

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**By**

**soujanya (192211752)**

COURSE FACULTY

**Dr B.GEETHA**

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**SAVEETHA SCHOOL OF ENGINEERING, SIMATS,**

**CHENNAI - 602105**

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Abstract:

This project analyses and optimizes the performance of a real-time video processing application on various hardware configurations. The project investigates the impact of cache size, clock speed, memory bandwidth, and instruction-level parallelism on system performance. A performance analysis of a simple vector addition algorithm implemented using SIMD instructions in C are presented, demonstrating the potential performance improvement achieved through instruction-level parallelism. Additionally, the project evaluates the trade-offs between power consumption and system performance by monitoring energy usage across various hardware setups. The project's findings and recommendations will be valuable for developers and researchers working on real-time video processing applications, enabling them to make informed decisions regarding hardware configurations and performance optimization strategies.

**Introduction**

In this assignment, we will analyze and optimize the performance of a real-time video processing application on various hardware configurations. We will investigate the impact of cache size, clock speed, memory bandwidth, and instruction-level parallelism on system performance. By monitoring energy usage across different hardware setups, we will evaluate the trade-offs between power consumption and system performance. This information will enable developers and researchers to make informed decisions regarding hardware configurations and performance optimization strategies for real-time video processing applications.

Throughout this assignment, we will focus on a simple vector addition algorithm implemented using SIMD instructions in C. We will present a performance analysis of this algorithm, demonstrating the potential performance improvement achieved through instruction-level parallelism. By understanding the factors that influence system performance and power consumption, we can optimize the video processing application for better realtime performance and energy efficiency.

In the following sections, we will discuss the impact of cache size, clock speed, memory bandwidth, and instruction-level parallelism on system performance. We will also provide a code example implementing SIMD instructions in C for a simple vector addition and analyze the performance improvement and power consumption trade-offs.

1. **Impact of Cache Size on System Performance**

Cache size is a critical factor in system performance, especially for applications that require frequent access to data. A larger cache allows more data to be stored closer to the CPU, reducing the time it takes to fetch data from main memory. This is particularly important for real-time video processing applications, which often involve processing large streams of data that benefit from quick access to previously accessed frames or computations.

• With a 4MB Cache: The system may experience more cache misses, leading to frequent accesses to the slower main memory, which can significantly slow down processing speeds. • With an 8MB Cache: The increased cache size would likely reduce the number of cache misses, leading to improved performance as more data can be kept close to the CPU.

• With a 16MB Cache: An even larger cache would further decrease the reliance on main memory, potentially leading to more consistent performance with fewer bottlenecks during data-intensive operations.

1. **Role of Clock Speed in Processor Performance**

Clock speed, measured in gigahertz (GHz), determines how many cycles a processor can execute per second. Higher clock speeds generally translate to faster processing capabilities, as more instructions can be processed in a given time frame.

• At 2.4GHz: A processor with this clock speed will execute 2.4 billion cycles per second, which is suitable for many tasks but may not be optimal for realtime video processing that requires high throughput.

• At 4.2GHz: A higher clock speed like this would allow for more instructions to be processed per second, potentially doubling the performance for tasks that are not limited by other factors such as I/O or memory bandwidth.

1. **Influence of Memory Bandwidth on Overall System Speed**

Memory bandwidth refers to the amount of data that can be transferred between the RAM and the CPU per unit of time. It is crucial for applications that continuously move large amounts of data, such as video processing.

• DDR4 2400MHz RAM: This configuration provides a baseline level of memory bandwidth. It may be sufficient for moderate video processing tasks but could become a bottleneck for high-resolution or high-frame-rate video processing.

• DDR4 3200MHz RAM: Increasing the memory frequency to 3200MHz would provide higher bandwidth, allowing for faster data transfer rates. This would likely result in smoother video processing and higher frame rates, especially when dealing with highdefinition content.

1. **Impact of Instruction-Level Parallelism on CPU Performance**

Instruction-level parallelism (ILP) refers to the ability of a CPU to execute multiple instructions simultaneously. Techniques such as Single Instruction, Multiple Data (SIMD) allow for parallel processing of data elements, which is highly beneficial for video processing tasks that often involve the same operation applied to multiple pixels or data points.

• Implementing SIMD Instructions: By leveraging SIMD instructions, the CPU can process multiple data points with a single instruction, significantly reducing the number of instructions required and thereby improving performance. This can lead to a substantial decrease in processing time for video frames, as the computations can be vectored and executed in parallel.

1. **Trade-offs Between Power Consumption and System Performance**

Increasing hardware performance often comes with increased power consumption. Highperformance CPUs with large caches and high clock speeds, as well as fast memory, consume more power, which can lead to higher temperatures and the need for better cooling solutions. For real-time video processing applications, it is essential to find a balance between 5 performance and power consumption, especially in environments where energy efficiency is crucial, such as mobile or embedded systems.

• Monitoring Energy Usage: Throughout the project, it is important to monitor the power consumption of different hardware configurations. This data will help in making informed decisions about the optimal balance between performance and energy efficiency. For instance, a slight decrease in clock speed or cache size might lead to a significant reduction in power usage without a substantial loss in processing speed.

Implementing instruction-level parallelism using SIMD instructions in C for a simple vector addition. This example uses the \_\_m128 type and the \_mm\_add\_ps intrinsic function from the SSE (Streaming SIMD Extensions) instruction set.

Materials and Methods:

Hardware Platform: A modern CPU with SIMD instruction support, such as Intel's SSE or AVX, or AMD's AVX2.

Software Tools: A C compiler that supports SIMD intrinsics, such as GCC or Clang.

Algorithm: A video processing algorithm that can be parallelized using SIMD instructions. For example, a simple algorithm that adds two arrays element-wise can be parallelized using SIMD instructions.

**Code**:

#include<stdio.h>

#include<xmmintrin.h>

void add\_vectors\_simd(float \*a, float \*b, float \*result, int n) {

for (int i = 0; i < n; i += 4) {

\_\_m128 va = \_mm\_loadu\_ps(a + i);

\_\_m128 vb = \_mm\_loadu\_ps(b + i);

\_\_m128 vc = \_mm\_add\_ps(va, vb);

\_mm\_storeu\_ps(result + i, vc);

}

}

int main() {

const int n = 16;

float a[n] = {1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16};

float b[n] = {1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16};

float result[n];

add\_vectors\_simd(a, b, result, n);

for (int i = 0; i < n; i++) {

printf("result[%d] = %f\n", i, result[i]);

}

return 0;

}

**OUTPUT:**

**Result and Discussion**

The output shows the result of adding the corresponding elements of two arrays a and b using the add\_vectors\_simd function with SIMD instructions. The function takes the arrays a, b, and result as input, along with the number of elements n, which is 16 in this case.

The output displays the elements of the result array, which are the sum of the corresponding elements of the a and b arrays. For example, result[0] is the sum of a[0] and b[0], which is 1 + 1 = 2. Similarly, result[1] is the sum of a[1] and b[1], which is 2 + 2 = 4, and so on.

The last line of the output shows the time taken by the program to execute, which is 0.3892 seconds. This time includes the time taken to load the arrays, call the add\_vectors\_simd function, and print the results.

The performance improvement achieved by using SIMD instructions in the add\_vectors\_simd function depends on the size of the input arrays and the hardware platform. For large arrays, the performance improvement can be significant due to the ability of SIMD instructions to perform multiple operations in parallel. However, for small arrays, the overhead of loading and storing data in SIMD registers may outweigh the benefits of parallelism, resulting in little or no performance improvement.

In summary, the output shows the correct results of adding the corresponding elements of two arrays using the add\_vectors\_simd function with SIMD instructions, and the time taken by the program to execute. The performance improvement achieved by using SIMD instructions depends on the size of the input arrays and the hardware platform.

To evaluate the trade-offs between power consumption and system performance, you can monitor energy usage across various hardware setups using power monitoring tools or built-in hardware sensors. Here are some steps to follow:

**Identify the hardware platforms to be tested**

In this step, you should identify the different hardware platforms that you want to test. This can include different CPUs, GPUs, and memory configurations. For example, you can test a range of CPUs with different clock speeds, cache sizes, and core counts. You can also test different GPUs with varying memory sizes and processing capabilities. Additionally, you can test different memory configurations, such as varying the amount of RAM or using different types of memory, such as DDR4 or GDDR6.

**Set up a power monitoring system**

In this step, you should set up a power monitoring system to measure the power consumption of each hardware platform. This can be a hardware power meter that connects to the power supply or a software tool that measures power consumption at the system or component level. You should ensure that the power monitoring system is accurate and can capture power consumption data at regular intervals, such as every second.

**Run benchmark tests on each hardware platform**

In this step, you should run benchmark tests on each hardware platform. These tests should include video processing tasks that stress the CPU, GPU, and memory subsystems. For example, you can test the performance of each hardware platform when encoding or decoding video, applying filters or effects, or scaling or cropping video. You should ensure that the 9 benchmark tests are representative of the real-world workloads that the hardware platform will encounter.

**Measure the power consumption during each benchmark test**

In this step, you should measure the power consumption during each benchmark test. You should record the power consumption at regular intervals, such as every second, to capture changes in power usage over time. This will allow you to see how power consumption varies during different stages of the video processing task.

**Calculate the average power consumption for each benchmark test**

In this step, you should calculate the average power consumption for each benchmark test. This can be done by dividing the total energy used during the test by the duration of the test. This will give you an average power consumption value that you can use to compare the power efficiency of each hardware platform.

**Analyze the performance metrics and power consumption data**

In this step, you should analyze the performance metrics and power consumption data. You should identify any trends or correlations between performance and power consumption. For example, you may find that a hardware platform with a higher clock speed consumes more power but also provides better performance. You should also consider other factors, such as memory efficiency and thermal throttling, that can affect the overall performance and power consumption of the hardware platform.

E**valuate the trade-offs between performance and power consumption**

In this step, you should evaluate the trade-offs between performance and power consumption. You should consider the performance gains achieved by each hardware platform and the associated power consumption costs. For example, you may find that a hardware platform with a higher clock speed provides better performance but also consumes more power, resulting in a higher overall energy cost. You should aim to find a balance between 10 performance and power consumption that provides optimal real-time video processing performance.

**Make recommendations for hardware configurations**

In this step, you should make recommendations for hardware configurations that balance processing speed, memory efficiency, and power consumption for optimal real-time video processing performance. You should provide a detailed analysis of the performance metrics and power consumption data, along with recommendations for hardware configurations that provide the best trade-offs between performance and power consumption. You should also consider other factors, such as cost and availability, that can affect the selection of hardware configurations.

By following these steps, you can evaluate the trade-offs between power consumption and system performance and make informed recommendations for hardware configurations that balance processing speed, memory efficiency, and power consumption for optimal real-time video processing performance.

**Conclusion**

In conclusion, evaluating the trade-offs between power consumption and system performance is crucial when analyzing and optimizing a real-time video processing application on different hardware configurations. By monitoring energy usage across various setups, one can identify the optimal balance between processing speed, memory efficiency, and power consumption for optimal real-time video processing performance. The project includes investigating the impact of cache size, clock speed, memory bandwidth, and instruction-level parallelism on system performance. Implementing SIMD instructions in C for a simple vector addition demonstrates the potential performance improvement achieved through instructionlevel parallelism. By following the outlined steps and considering the trade-offs, developers and researchers can make informed decisions regarding hardware configurations and performance optimization strategies.

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