CSCI 4717 – Computer Architecture — *Project 2: Analyzing Cache Performance*

Due: Software is due on Monday, October 9, 2006 at 11:59 PM
Graphed results is due in class on Tuesday, October 10, 2006

What to submit: You will be submitting a text file containing two C functions, ***requestMemoryAddress()*** and ***getPercentageOfHits()*** in addition to a graph showing the results of your simlulation using different block sizes and a discussion of those results. Submit your project functions using the digital dropbox on Blackboard. Name your file cache_username where your z-account name is substituted for the word "username". I will try to notify you when I receive your file. You will be turning in your results discussion by hand on Tuesday in class.

Introduction

Your assignment is to simulate a 4K ***direct mapping cache*** using C++. The memory of this system is divided into 2-, 4-, 8-, 16-, or 32-word blocks, which means that the 4K cache has 4K/2 = 2048 lines, 4K/4 = 1024 lines, 4K/8 = 512 lines, 4K/16 = 256 lines, or 4K/32 = 128 lines. I've given you some significant code which I will try to describe below.

You will first need to write two functions, ***requestMemoryAddress()*** and ***getPercentageOfHits()***. requestMemoryAddress() will simulate a processor request to the cache while getPercentageOfHits() will return the performance of the cache. You are to run your completed simulator on a set of sample address sequences and plot your results on a graph which you will hand in on paper in class on Tuesday, October 10th.

Class DirectCache

The class Direct Cache will be used to define the cache. First, let's look at its functions.

```
    DirectCache(int number_of_word_bits);
    bool requestMemoryAddress(unsigned int address);
    unsigned int getPercentageOfHits(void);
```

The first function, DirectCache(int number_of_word_bits), is the constructor. Since we are looking to test the cache with different numbers of lines, we need to pass an argument to the constructor to indicate the number of lines. The cache is a fixed size, 4096 words. If we know the block size, i.e., the number of words per block, and since one block is stored per line, we can determine the number of lines by knowing the number of word id bits. I have already written this function for you.

The second function, ***bool requestMemoryAddress(unsigned int address)***, is used to simulate a memory request from the processor. You will be writing this function. An address is passed to this function as its argument. You will need to determine the block, load it from a memory array (to be discussed later), and set the appropriate tag in the cache. Note that the address isn't a pointer! It is an integer between 0 and 65,535 that is supposed to represent the address of the desired data. Assume that the cache is empty to start with, so your very first call to this function will require a figurative "loading of the cache". requestMemoryAddress() will return a bool true if the data was found in the cache or a bool false if the data was not found and the block had to be loaded from memory. In other words, true indicates a "hit" and false indicates a "miss".

The second function, ***unsigned int getPercentageOfHits(void)***, is called to see how well the cache performed. You will use this data to compare the different block sizes. The result of getPercentageOfHits() should be an integer from 0 to 100 representing the percentage of successful hits in the cache. The equation should be something like:

```
                               number of hits
    Percentage of hits = -------------------------- X 100%
                         number of memory requests
```

Each time a request is made to requestMemoryAddress(), increment number_of_memory_requests, and each time one of those requests results in a "true" returned, increment number_of_hits. These values will be used in getPercentageOfHits().

There are a number of private variables declared in DirectCache too.

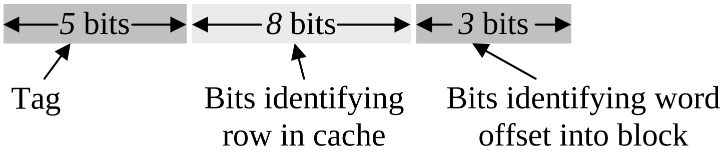
```
     int *tags;
     int *blocks;
     int number_of_hits;
     int number_of_memory_requests;
     int number_of_lines_in_cache;
     int number_of_words_in_block;
     unsigned int tag_mask;
     unsigned int line_mask;
     unsigned int word_mask;
```

Since the number of lines varies depending on the declared number of words per block, we need to dynamically declare an array to hold the tags and the blocks for each line. The arrays ***tags*** uses a line number as its index. The array ***blocks*** also uses a line number as its index, but it has a second index which identifies the word positions. Both of these arrays are declared in the constructor for DirectCache.

The integers ***number_of_hits*** and ***number_of_memory_requests*** are to be incremented as needed by requestMemoryAddress(), then used to calculate the output from getPercentageOfHits().

number_of_words_in_block can be calculated from the number of bits that define a word id and is simply included so that you don't have to keep calculating it throughout your code.

The last three integers are also included for your convenience. They are bit masks that you can use to isolate the bits in the address that identify the tag, the line number, and the word id. They are created in the DirectCache constructor. For example, assume we have a 16 bit address with blocks defined using 3 word id bits and a 256 line cache. The partitioning of our address would look like that shown below.


5 bits
8 bits
3 bits
Tag
Bits identifying row in cache
Bits identifying word offset into block

The masks would then be defined like the following.

```
tag_mask = 1111100000000000;
line_mask = 0000011111111000;
word_mask = 0000000000000111;
```

Function powerOfTwo()

Microsoft indicates that there are some bugs in their function templates (http://support.microsoft.com/default.aspx?scid=kb;en-us;240869). This includes the pow function which is part of the <cmath> library. Therefore, I have written a short function int powerOfTwo(int exponent) to return powers of 2. powerOfTwo() returns the value of two raised to the power exponent. It only allows for positive exponents because of the return value. If exponent is less than zero, an error condition of -1 is returned. I have included this function in the source code I've given you.

main()

I have also included in the code a short "incomplete" main(). It declares and initializes memory as an array of char based on the number of bits in the address. It also prompts the user through the console for the number of word id bits so that you don't have to recompile in order to test different cache configurations. It then creates the instance of the cache.

Sample Address Sequences

In order to test your cache and take measurements of its performance, I will give you some sample sequences of address requests. These will be given to you in an array called ***memory_request_sequence[]***. There will be more than one in an effort to simulate loops, sequential code, and other types of program constructs.

Have fun! Don't hesitate to read the book or my notes. There's a great deal of useful information in there including examples and descriptions of the different mapping functions.