CacheLab
Recitation 7

10/8/2012

Outline

- Memory organization
- Caching
  - Different types of locality
  - Cache organization
- Cachelab
  - Tips (warnings, getopt, files)
  - Part (a) Building Cache Simulator
  - Part (b) Efficient Matrix Transpose
- Blocking

Memory Hierarchy

- Registers
- SRAM
- DRAM
- Local Secondary storage
- Remote Secondary storage

We will discuss this interaction

SRAM vs DRAM tradeoff

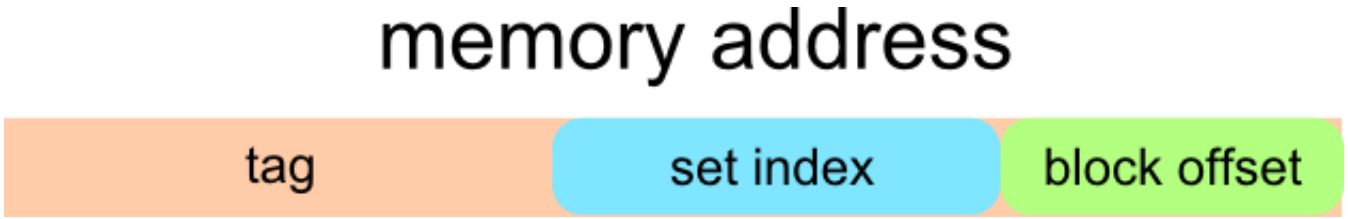
- SRAM (cache)
  - Faster (L1 cache: 1 CPU cycle)
  - Smaller (Kilobytes (L1) or Megabytes (L2))
  - More expensive and “energy-hungry”
- DRAM (main memory)
  - Relatively slower (hundreds of CPU cycles)
  - Larger (Gigabytes)
  - Cheaper

Caching

- Temporal locality
  - A memory location accessed is likely to be accessed again multiple times in the future
  - After accessing address X in memory, save the bytes in cache for future access
- Spatial locality
  - If a location is accessed, then nearby locations are likely to be accessed in the future.
  - After accessing address X, save the block of memory around X in cache for future access

Memory Address

- 64-bit on shark machines



- Block offset: b bits
- Set index: s bits

Cache

- A cache is a set of 2^s *cache sets*
- A *cache set* is a set of E *cache lines*
  - E is called associativity
  - If E=1, it is called “direct-mapped”
- Each *cache line* stores a block
  - Each block has 2^b bytes

Cachelab

- Warnings are errors!
- Include proper header files
- Part (a) Building a cache simulator
- Part (b) Optimizing matrix transpose

Warnings are Errors

- Strict compilation flags

- Reasons:
  - Avoid potential errors that are hard to debug
  - Learn good habits from the beginning

- Add “-Werror” to your compilation flags

Missing Header Files

- If function declaration is missing
  - Find corresponding header files
  - Use: man <function-name>
- Live example
  - man 3 getopt

Getopt function

```
GETOPT(3)                  Linux Programmer's Manual                 GETOPT(3)

NAME
       getopt - Parse command-line options

SYNOPSIS
       #include <unistd.h>

       int getopt(int argc, char * const argv[],
                  const char *optstring);

       extern char *optarg;
       extern int optind, opterr, optopt;

       #define _GNU_SOURCE
       #include <getopt.h>

       int getopt_long(int argc, char * const argv[],
                  const char *optstring,
                  const struct option *longopts, int *longindex);

       int getopt_long_only(int argc, char * const argv[],
                  const char *optstring,
                  const struct option *longopts, int *longindex);

DESCRIPTION
       The  getopt()  function  parses  the command-line arguments.  Its arguments argc and argv are the argument
       count and array as passed to the main() function on program invocation.  An element of  argv  that  starts
       with  '-'  (and  is  not exactly "-" or "--") is an option element.  The characters of this element (aside
```

We want you to use getopt!

- You don’t have t, but why waste time reinventing the wheel?
- Your programs MUST us the same command line arguments as the reference programs or the autograder will not work

Part (a) Cache simulator

- A cache simulator is NOT a cache!
  - Memory contents NOT stored
  - Block offsets are NOT used
  - Simply counts hits, misses, and evictions

- Your cache simulator need to work for different s, b, E, given at run time.
- Use LRU replacement policy

Files

- #include <stdio.h>
- FILE *my_fp=fopen(char * filename, char *mode)
  - Mode = “r” for read, “w+” for read/write, “w” for a new file
  - Returns NULL (or 0) if opening fails
- fscanf(fp,char *format, pointers to vars …
  - Same formats as printf
  - Returns # of items scanned
  - Returns EOF at the end of the file
  - Man fscanf for details
  - If reading a string, watch out for string length! Remember buf lab. Stops at white space
- fclose(fp) when done with the file

Cache simulator: Hints

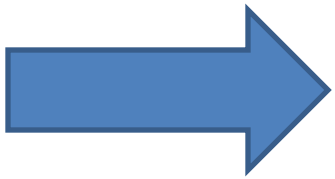
- A cache is just 2D array of *cache lines*:
  - struct cache_line cache[S][E];
  - S = 2^s, is the number of sets
  - E is associativity
- Each cache_line has:
  - Valid bit
  - Tag
  - LRU counter

Part (b) Efficient Matrix Transpose

- Matrix Transpose (A -> B)

Matrix A

1	2	3	4
5	6	7	8
9	10	11	12
13	14	15	16

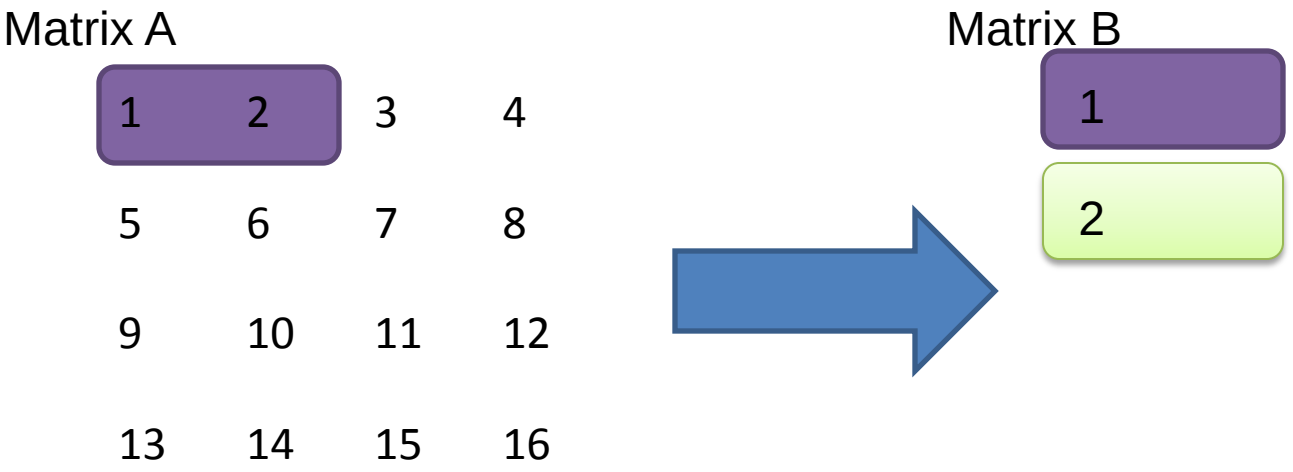


Matrix B

1	5	9	13
2	6	10	14
3	7	11	15
4	8	12	16

Part (b) Efficient Matrix Transpose

- Matrix Transpose (A -> B)
- Suppose block size is 8 bytes (2 ints)



Access A[0][0] cache miss
Access B[0][0] cache miss
Access A[0][1] cache hit
Access B[1][0] cache miss

Question: After we handle 1&2. Should we handle 3&4 first, or 5&6 first ?

Blocking

- What inspiration do you get from previous slide ?
  - Divide matrix into sub-matrices
  - This is called **blocking** (CSAPP2e p.629)
  - Size of sub-matrix depends on
    - cache block size, cache size, input matrix size
  - Try different sub-matrix sizes
- We hope you invent more tricks to reduce the number of misses !

Part (b)

- Cache:
  - You get 1 kilobytes of cache
  - Directly mapped (E=1)
  - Block size is 32 bytes (b=5)
  - There are 32 sets (s=5)
- Test Matrices:
  - 32 by 32, 64 by 64, 61 by 67