CMSC 313 Lecture 14

- Reminder: Midterm Exam next Tues (10/26)
- Project 4 Questions
- Virtual Memory on Linux/Pentium platform

Project 4: An Error-Correcting Code, Part 2 Due: Thursday October 21, 2004

Objective

The objective of this programming exercise is to practice writing assembly language programs that use the C function call conventions.

Assignment

Modify your assembly language program from Project 3 so that it can be called from a C program as a C function with the following function prototype:

```
char *encode(char *A, int n, int *mptr) ;
```

Here `A` is a pointer to a sequence of bytes in memory that should be encoded into the Hamming Code format from Project 3. The parameter `n` is the number of bytes in `A`. The result of the codewords must be stored in a memory location that is dynamically allocated. Your assembly language program must call `malloc()` to obtain a block of memory of the correct size. The address of this block of memory is the return value from `encode()`. The size of the block must be stored in the location specified by `mptr`.

Your program must work with the C main program `p4main.c` which is available in the following directory in the GL file system:

```
/afs/umbc.edu/users/c/h/chang/pub/cs313
```

This C program reads bytes from `stdin` and stores them in a dynamically allocated memory location. It then calls your `encode()` function and writes the resulting codewords to `stdout`. Thus, if your assembly language implementation of `encode()` works correctly, the program resulting from compiling it with `p4main.c` behaves exactly like the encoding program in Project 3.

If you cannot convert your assembly language program from Project 3 (e.g., if your program for Project 3 does not work), then you must implement a similar `encode()` function that copies the bytes in `A`, but inserts the byte `0xFF` after every three bytes. It must also pad the resulting memory block with `0xFF` so the total length is divisible by 4. Implementing this version of the project will incur a 10% penalty.

Implementation Notes

- Look up `malloc()` if you haven't used it in a while. Remember that calling `malloc()` from your assembly language program will clobber the EAX, ECX and EDX registers.
- You should check for the possibility that `malloc()` returns 0 because the system does not have as much memory as you have requested.
- You will most likely need to use the EBX, ESI and EDI registers. You should push them on the stack to save them. Remember that when you pop them off the stack, you must pop them off in the opposite order.
- You will need to pre-compute the size of the memory block that holds the resulting codewords. Look up the DIV instruction. Note that it does not support many addressing modes.
- Your program should not alter the sequence of bytes given to you. This might change the way you handle the "extra bytes" at the end.
- As in Project 3, you can use `decode`, `corrupt` and `diff` to check if your program produced the correct results.

Turning in your program

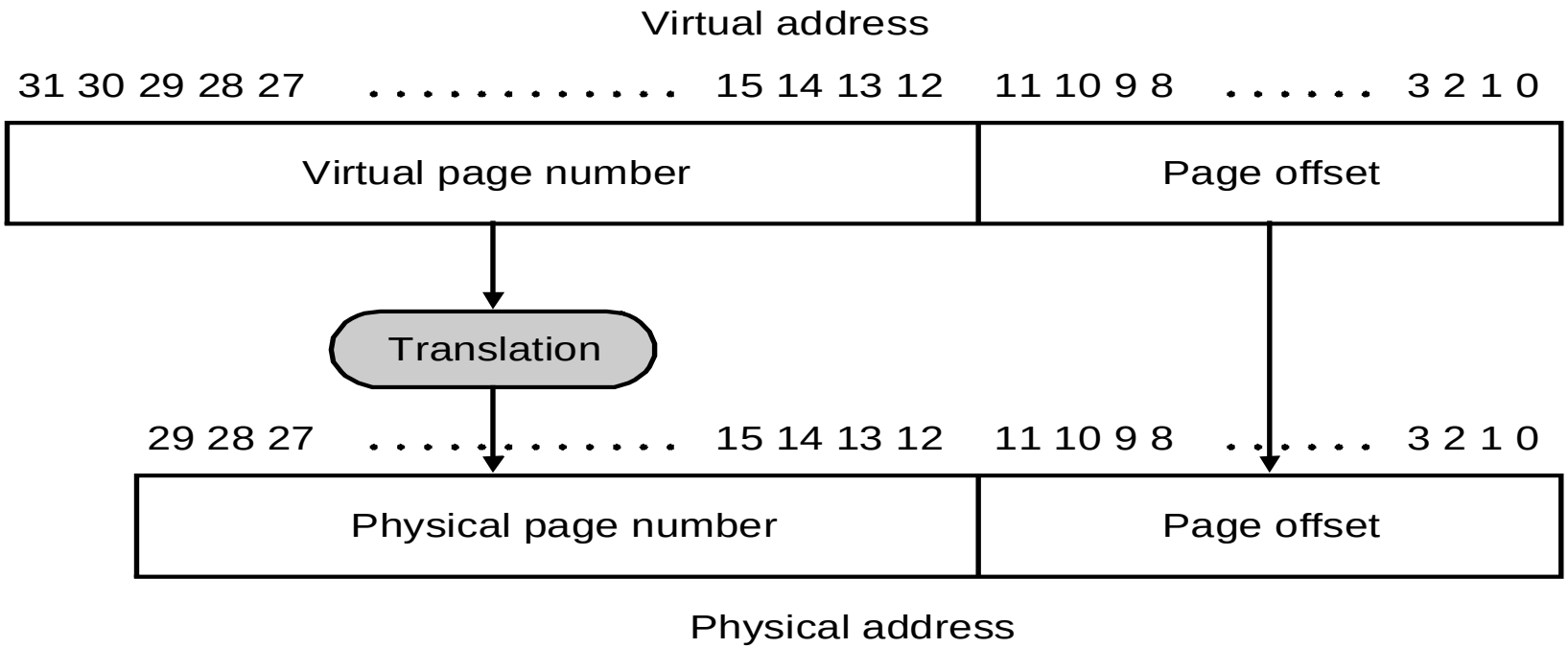
Use the UNIX `submit` command on the GL system to turn in your project. You should submit two files: 1) the assembly language program and 2) the typescript file of sample runs of your program. The class name for submit is `cs313_0101`. The name of the assignment name is `proj4`. The UNIX command to do this should look something like:

```
submit cs313_0101 proj4 p4encode.asm typescript
```

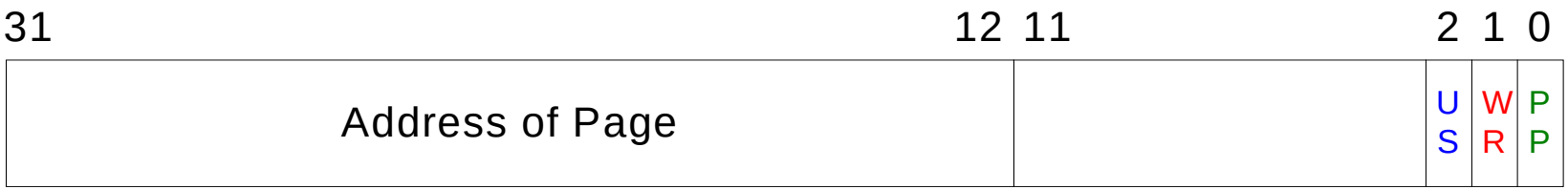
Last Time: Virtual Memory

- **Not enough physical memory**
  - Uses disk space to simulate extra memory
  - Pages not being used can be swapped out (how and when you'll learn in CMSC 421 Operating Systems)
  - Thrashing: pages constantly written to and retrieved from disk (time to buy more RAM)
- **Fragmentation**
  - Contiguous blocks of virtual memory do not have to map to contiguous sections of real memory
- **Memory protection**
  - Each process has its own page table
  - Shared pages are read-only
  - User processes cannot alter the page table (must be supervisor)

Virtual Addressing



- Page faults are costly and take millions of cycles to process (disks are slow)
- 80386 Page attributes:
  - RW: read and write permission
  - US: User mode or kernel mode only access
  - PP: present bit to indicate where the page is



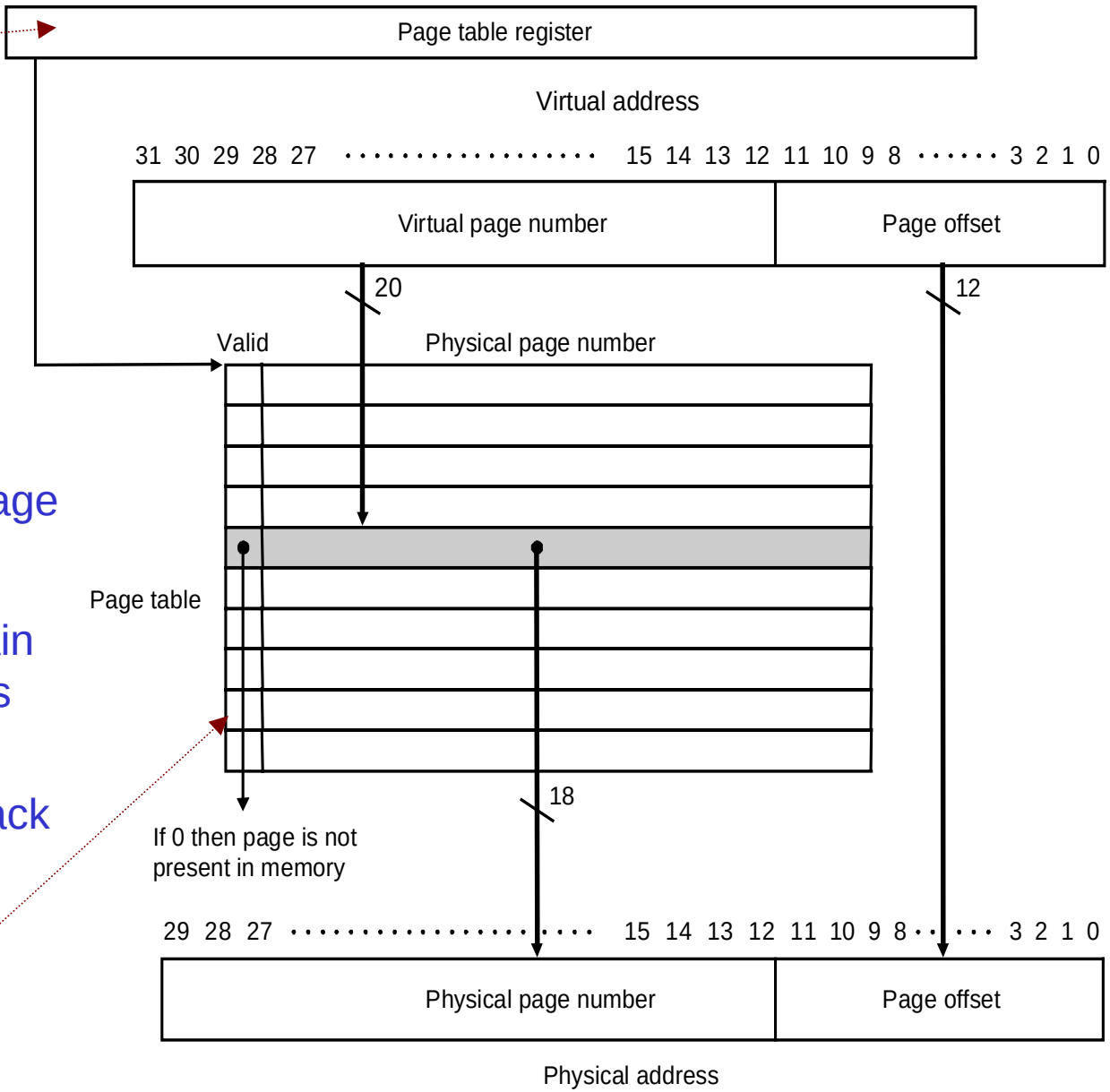
Page Table

Hardware supported

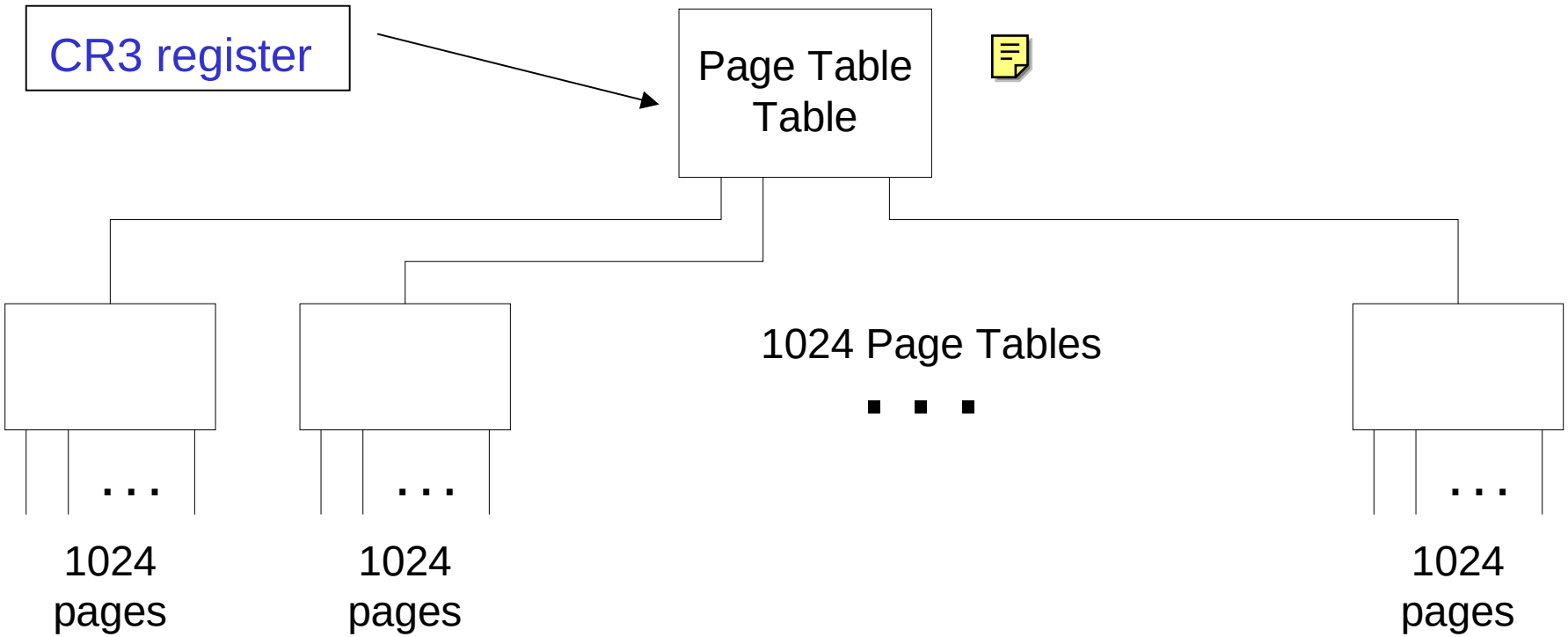
Page table:

- ★ Resides in main memory
- ★ One entry per virtual page
- ★ No tag is required since it covers all virtual pages
- ★ Point directly to physical page
- ★ Table can be very large
- ★ Operating sys. may maintain one page table per process
- ★ A dirty bit is used to track modified pages for copy back

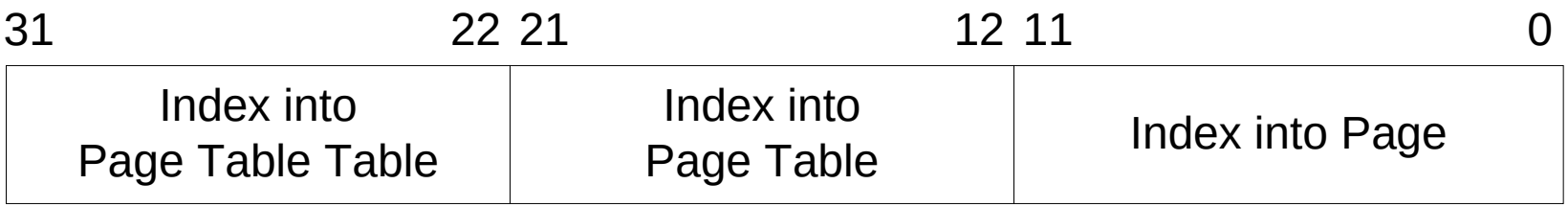
Indicates whether the virtual page is in main memory or not



Linux 2-Level Page Table



- The CR3 register is designated for pointing to the first level page table
- The CR3 is part of the task state that needs to be saved at preemption



3.7.1. Linear Address Translation (4-KByte Pages)

Figure 3-12 shows the page directory and page-table hierarchy when mapping linear addresses to 4-KByte pages. The entries in the page directory point to page tables, and the entries in a page table point to pages in physical memory. This paging method can be used to address up to 2^{20} pages, which spans a linear address space of 2^{32} bytes (4 GBytes).

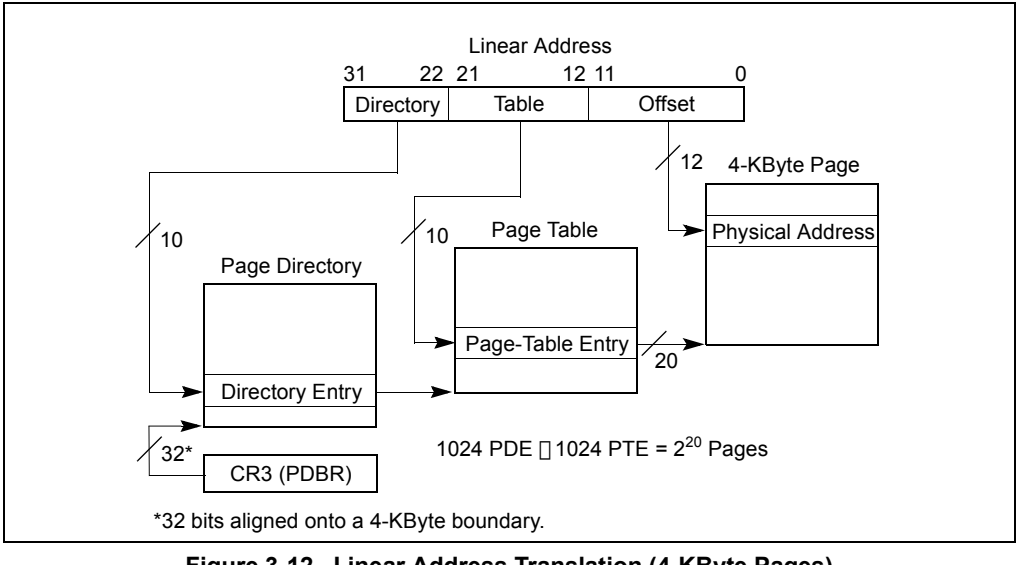


Figure 3-12. Linear Address Translation (4-KByte Pages)

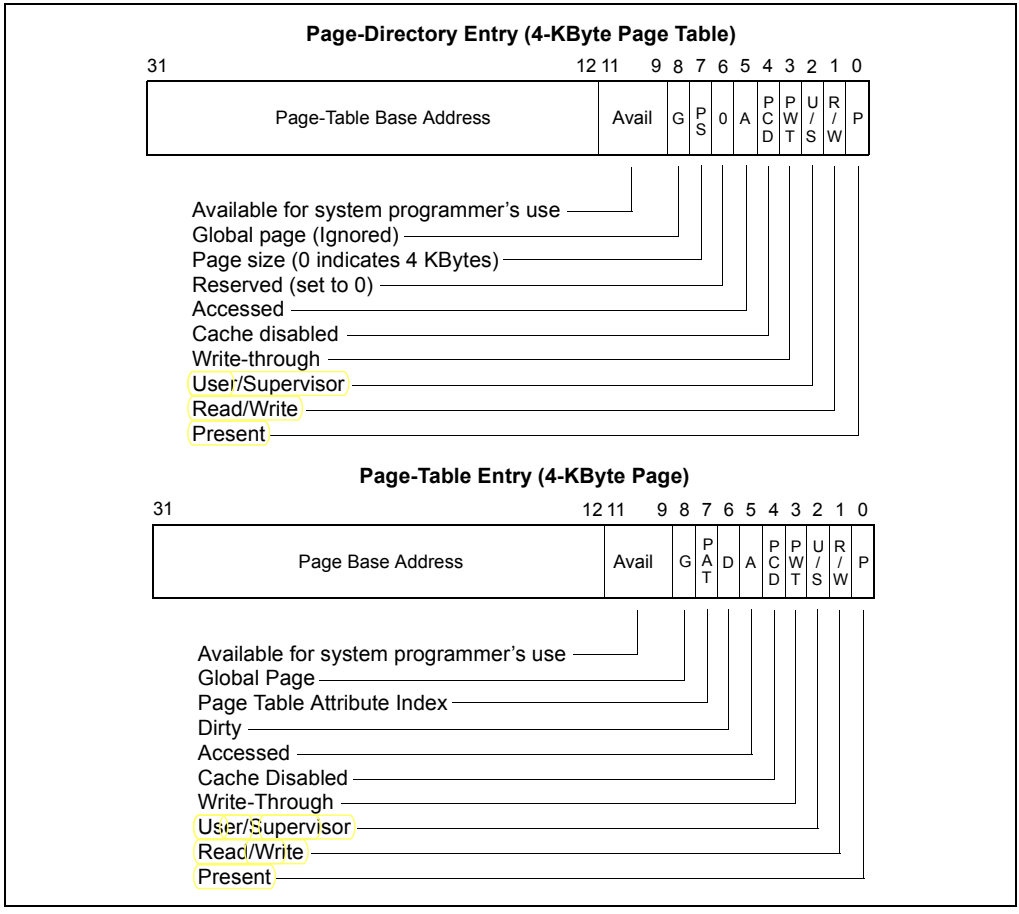
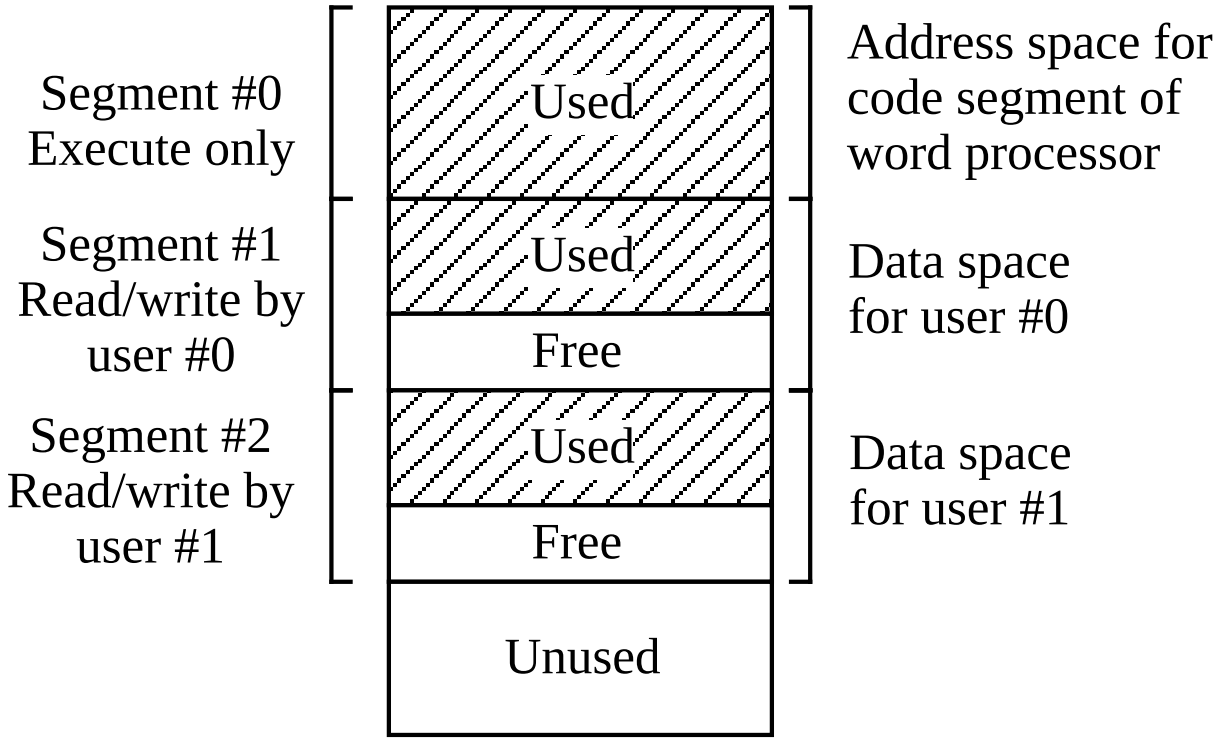


Figure 3-14. Format of Page-Directory and Page-Table Entries for 4-KByte Pages and 32-Bit Physical Addresses

Segmentation

- **A segmented memory allows two users to share the same word processor code, with different data spaces:**



Translation Lookaside Buffer

- **An example TLB holds 8 entries for a system with 32 virtual pages and 16 page frames.**

Valid	Virtual page number	Physical page number
1	0 1 0 0 1	1 1 0 0
1	1 0 1 1 1	1 0 0 1
0	- - - - -	- - - -
0	- - - - -	- - - -
1	0 1 1 1 0	0 0 0 0
0	- - - - -	- - - -
1	0 0 1 1 0	0 1 1 1
0	- - - - -	- - - -

Virtual Memory: Problems Solved

- **Not enough physical memory**
  - Uses disk space to simulate extra memory
  - Pages not being used can be swapped out (how and when you'll learn in CMSC 421 Operating Systems)
  - Thrashing: pages constantly written to and retrieved from disk (time to buy more RAM)
- **Fragmentation**
  - Contiguous blocks of virtual memory do not have to map to contiguous sections of real memory
- **Memory protection**
  - Each process has its own page table
  - Shared pages are read-only
  - User processes cannot alter the page table (must be supervisor)

Virtual Memory: too slow?

- **Address translation is done in hardware**

  In the middle of the fetch execute cycle for:

  ```
  MOV     EAX, [buffer]
  ```

  the physical address of buffer is computed in hardware.

- **Recently computed page locations are cached in the translation lookaside buffer (TLB)**
- **Page faults *are* very expensive (millions of cycles)**
- **Operating systems for personal computers have only recently added memory protection**

Next

- Interrupts
- Cache Memory