Announcements

- Project #3
  - Is out
  - Deadline is before midterm #2 (start early)
Project #3

- **What is pageable?**
  - User memory including text, data, and stack

- **Memory model**
  - Kernel memory in low memory
  - User memory in high memory

- **Paging Bits**
  - cr3 – Page Table Base Register (PTBR)
  - cr0:31 – Enable Paging bit
  - cr2 – Address causing page fault

- **Page Faults**
  - Look in errorCode fields of interrupt
Steps of Project

- **Enable Paging**
  - Map all of physical memory

- **Get separate page table for User Process**
  - Map user pages at 2GB
  - Update Segment Info
  - Context switch PTBR

- **Get page faults working**
Working Sets and Page Replacement

- **Programs usually display reference locality**
  - temporal locality
    - repeated access to the same memory location
  - spatial locality
    - consecutive memory locations access nearby memory locations
  - memory hierarchy design relies heavily on locality reference
    - sequence of nested storage media

- **Working set**
  - set of pages referenced in the last delta references

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**Working Set Size**

- Small: Very Fast
- Large: Very Slow
Preventing Threashing

- Need to ensure that we can keep the working set in memory
  - if the working sets of the processes in memory exceed total page frames, then we need to swap a process out
- How do we compute the working set?
  - can approximate it using a reference bit
Implementation Issues

- **How big should a page be?**
  - want to trade cost of fault vs. fragmentation
    • cost of fault is: trap + seek + latency + transfer
  - Does the OS page size have to equal the HW page size?
    • no, just needs to be a multiple of it

- **How does I/O relate to paging**
  - if we request I/O for a process, need to lock the page
    • if not, the I/O device can overwrite the page

- **Can the kernel be paged?**
  - most of it can be.
  - what about the code for the page fault handler?
Segmentation

- Segmentation is used to give each program several independent protected address spaces
  - each segment is an independent protected address space
  - access to segments is controlled by data which describes size, privilege level required to access, protection (whether segment is read-only etc)
  - segments may or may not overlap
    - disjoint segments can be used to protect against programming errors
    - separate code, data stack segments
- Disjoint Segments can be used to exploit expanded address space
  - In 16 bit architectures e.g. (8086 and 80x86 in V86 mode) each segment has only 16 bits of address space
  - In distributed networks consisting of multiple 32 bit machines, segmentation can be used to support single huge address space
- Segments can span identical regions of address space - flat model
  - Windows NT and Windows ‘95 use 4 Gbyte code segments, stack segments, data segments
X86 Segmentation + Paging

Stored in Segment Register

Virtual Address

Page Directory

Page Table

Page Frame