Lab 3 Details

CSE 451 20au
● Lab 3 Design Doc due tonight
  ○ Please submit the Canvas assignment when you’ve finished it
Today’s Agenda

- More detail on vspace and vspace functions
- Some discussion questions on lab 3
- Hopefully, some time at the end for open questions
vspace Visual Diagram

```
struct proc
<table>
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<tbody>
<tr>
<td>struct vspace</td>
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<tr>
<td>vregion</td>
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Machine dependent page table in RAM/TLB

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<tbody>
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<td>struct vpi_page</td>
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<tr>
<td>vregion</td>
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<tbody>
<tr>
<td>struct vpage_info</td>
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<tr>
<td>used</td>
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<td>ppn</td>
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<tr>
<td>present</td>
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<tr>
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<tr>
<td>writeable</td>
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</table>

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```
vregions vs Page Tables

- Both have virtual to physical address mappings

  - `vspace.pgtbl`
    - Used by hardware to translate virtual addresses to physical addresses
    - CR3 register holds the top level page table (i.e. `vspace.pgtbl`)
    - TLB caches virtual -> physical mappings

  - `vspace.regions`
    - Portable architecture independent software representation of the address space
    - Used by kernel to track/update mappings without affecting hardware page table lookups
    - May be incomplete at times (e.g. mappings in exec())

- How do we update the page table to reflect the vspace regions?
vspaceinvalidate(vs)

- “Transforms a vspace into the architecture dependent page table”
  - I.e. virtual mappings in vs.regions are reflected in vs.pgtbl
  - Git analogy: commit vspace changes to the page table
- Call when you’ve changed a mapping in vs.

Pop Quiz: When will you be calling vspaceinvalidate in Lab 3?
vspaceinstall(p)

- “Installs the page table into the page table register”
  - i.e. CR3 = vs.pgtbl
  - In x86, this flushes the TLB!
  - Git analogy: pushes your committed changes to the TLB/CR3
- If there were changes in the vspace, call after invalidating

Pop Quiz: When will you be calling vspaceinstall in Lab3? Can you ever get away without calling vspaceinstall?
Handling Page Faults in x86-64

- CR2 register holds the faulting linear address (but since virtual paging is turned on, this is the virtual address)
  - How do you read or load a control register?
  - (look in trap.c in the default case)
- tf->err holds the exception error code
  - You can use this to determine the type of fault
- More info: https://wiki.osdev.org/Exceptions#Page_Fault
More on Error codes

- `rcr2()` returns address attempted to be accessed on page fault
- Last 3 bits of `tf->err`
  - B2 is set if fault occurred in usermode
  - B1 is set if fault occurred on a write
  - B0 is set if it was a page protection issue. This is not set if the page is not present

- What will the error code be if the page fault was from touching the stack region of memory?

- From touching a copy-on-write page?
Copy-on-write Fork FAQ

- How do we keep track of physical pages and refcounts?
  - Coremap!

- What vspace functions need to behave differently to support COW fork, and how?
  - vspacecopy()

- Synchronization in modifying the vspace in page fault in COW fork?
  - Not needed – current process has exclusive access to its own vspace
  - However, the refcount on the physical page could be concurrently modified
More COW

- What do the fields of a page (struct `vpage_info`) need to be after a copy-on-write fork?
  - (fields for reference) used, ppn, present, writeable

- What needs to be changed in the `core_map_entry` to support COW fork?
  - Ref count, (and a lock for the core map)

- Can the kernel cause a copy-on-write page fault?
  - Sure! While not a protection fault, a write to a read-only page will induce a page fault

- What can happen if a copy-on-write fork is not synchronized?
Any questions?