6.S081: Q&A Labs

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Agenda

- Review lab assignments
- Main focus: Page table lab

Page table lab

- Traditionally a difficult lab
- Debugging can be challenging
  - Bugs in page tables can change code and data layout
- New version this year focuses more on features enabled by page tables, less on xv6 VM layout

Part 1: USYSCALL

- Problem: Kernel transitions have overheads
- Could we speed up some system calls through shared memory between process and kernel
- Which system calls can be sped up?
  - Must have no side-effects
  - Returns constant value while process runs
  - But value can change after entering kernel (e.g., ticks)

Q: Which system calls in xv6?

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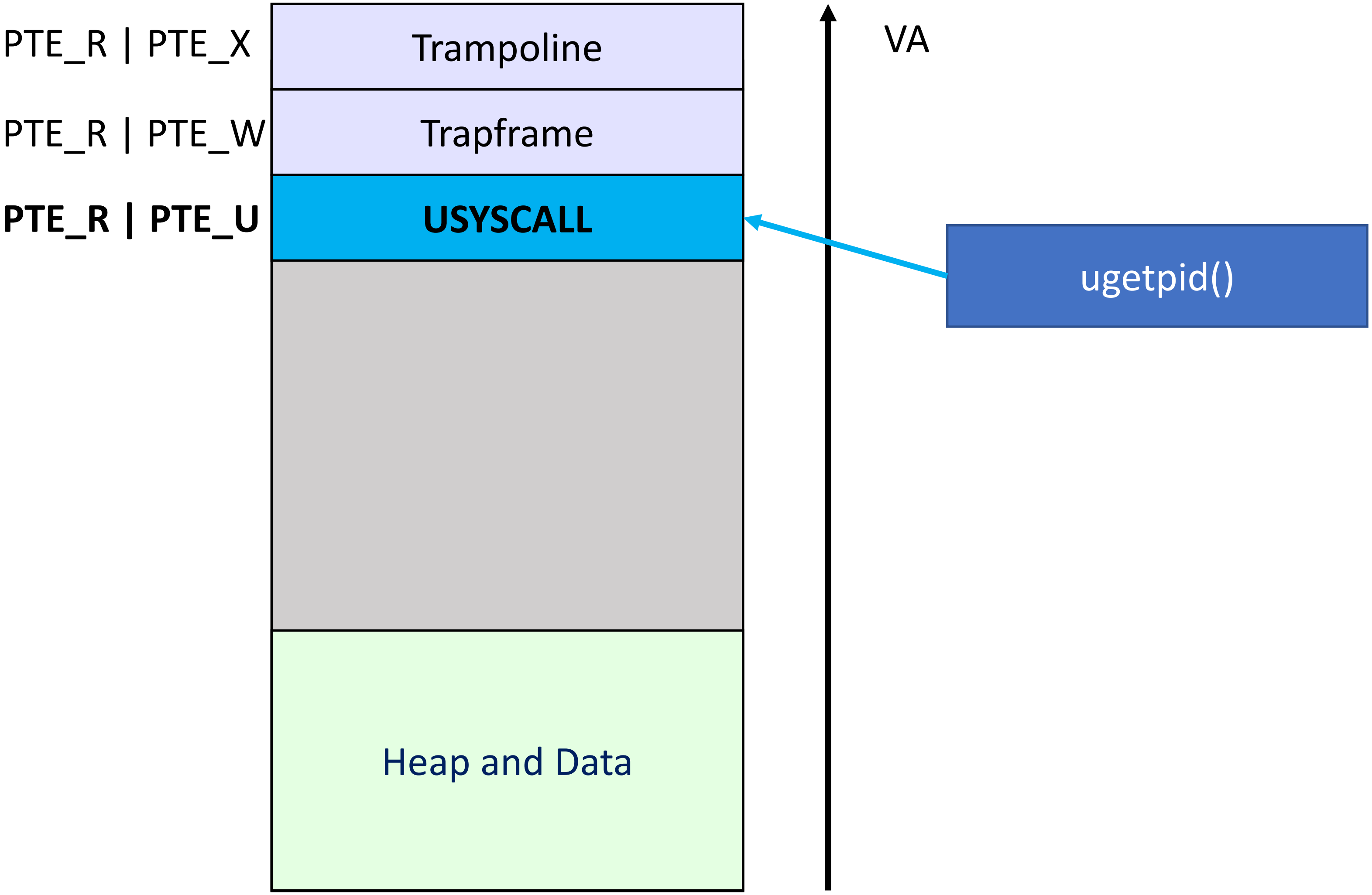
- Getpid() – constant value, doesn’t change
- Uptime() – constant until next tick
  - Each tick triggers a kernel interrupt, can update value

- Fstat() – maybe possible, not likely worth it, too much state

USYSCALL Mapping



Code walkthrough

How does Linux use USYSCALL?

- A more sophisticated mechanism called **VDSO**
- Idea: Read-only, shared memory region
  - Exactly the same as the lab
- Idea #2: Kernel ships code into user program
  - Code interprets the data in the shared region

Powerful: makes time measurement more efficient

- 1: Kernel posts time to shared region on user enter
- 2: VDSO code adds TSC to latest time

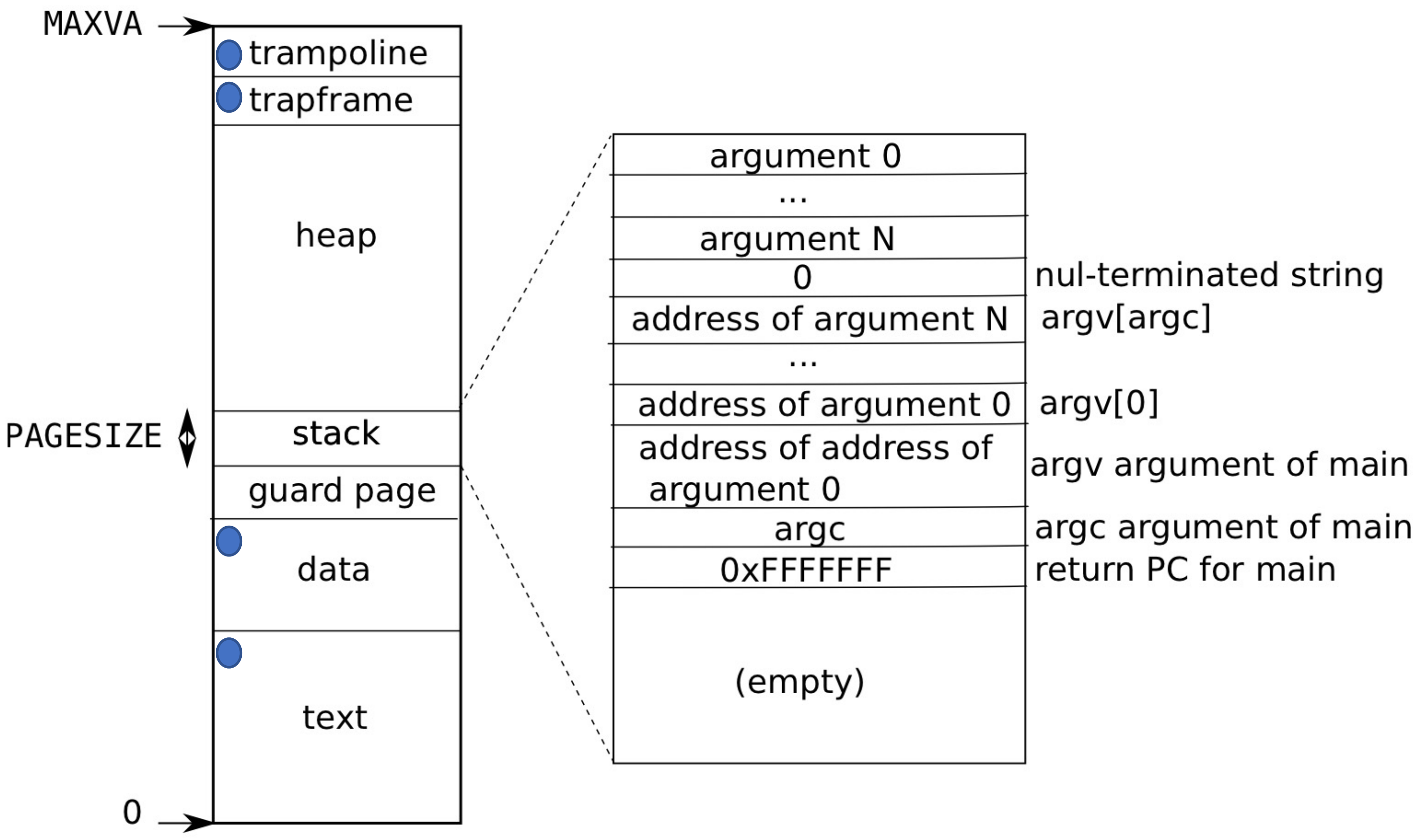
Linux VDSO methods

- clock_gettime()
- getcpu()
- getpid()
- getppid()
- gettimeofday()
- set_tid_address()

Part 2: Printing a page table

- Goal: Print the contents of the user page table
- Save your code! Useful for debugging future labs

Recall user address layout (fig 3.4)



User page table output

LVL0 LVL1 PTE

```
page table 0x0000000087f6e000
 ..0: pte 0x0000000021fda801 pa 0x0000000087f6a000
 .. ..0: pte 0x0000000021fda401 pa 0x0000000087f69000
 .. .. ..0: pte 0x0000000021fdac1f pa 0x0000000087f6b000 Code + data
 .. .. ..1: pte 0x0000000021fda00f pa 0x0000000087f68000 Guard page
 .. .. ..2: pte 0x0000000021fd9c1f pa 0x0000000087f67000 Stack
 ..255: pte 0x0000000021fdb401 pa 0x0000000087f6d000
 .. ..511: pte 0x0000000021fdb001 pa 0x0000000087f6c000
 .. .. ..509: pte 0x0000000021fdd813 pa 0x0000000087f76000 USYSCALL
 .. .. ..510: pte 0x0000000021fddc07 pa 0x0000000087f77000 TRAPFRAME
 .. .. ..511: pte 0x0000000020001c0b pa 0x0000000080007000 TRAMPOLINE
```

Permission bits

Code walkthrough

Part 3: Access bits

- Goal: Efficiently tell userspace which pages were accessed
- Hardware page walker accelerates this:
  - PTE_A: Was the page accessed (read or write)
  - PTE_D: Is the page dirty (only write)
  - HW marks these bits when walking page table
- In this lab, provide a bitmask indicating which pages were accessed (PTE_A)

Code walkthrough

How does Linux use access bits?

- Used for swapping pages to disk
- CLOCK algorithm: Scan pages, which were accessed (PTE_A marked) since last interval?
- Least accessed pages moved to disk
- PTE_D used to detect if copy on disk is stale
- Linux does not expose this info to userspace!

Q: How could you detect page accesses without access bits?

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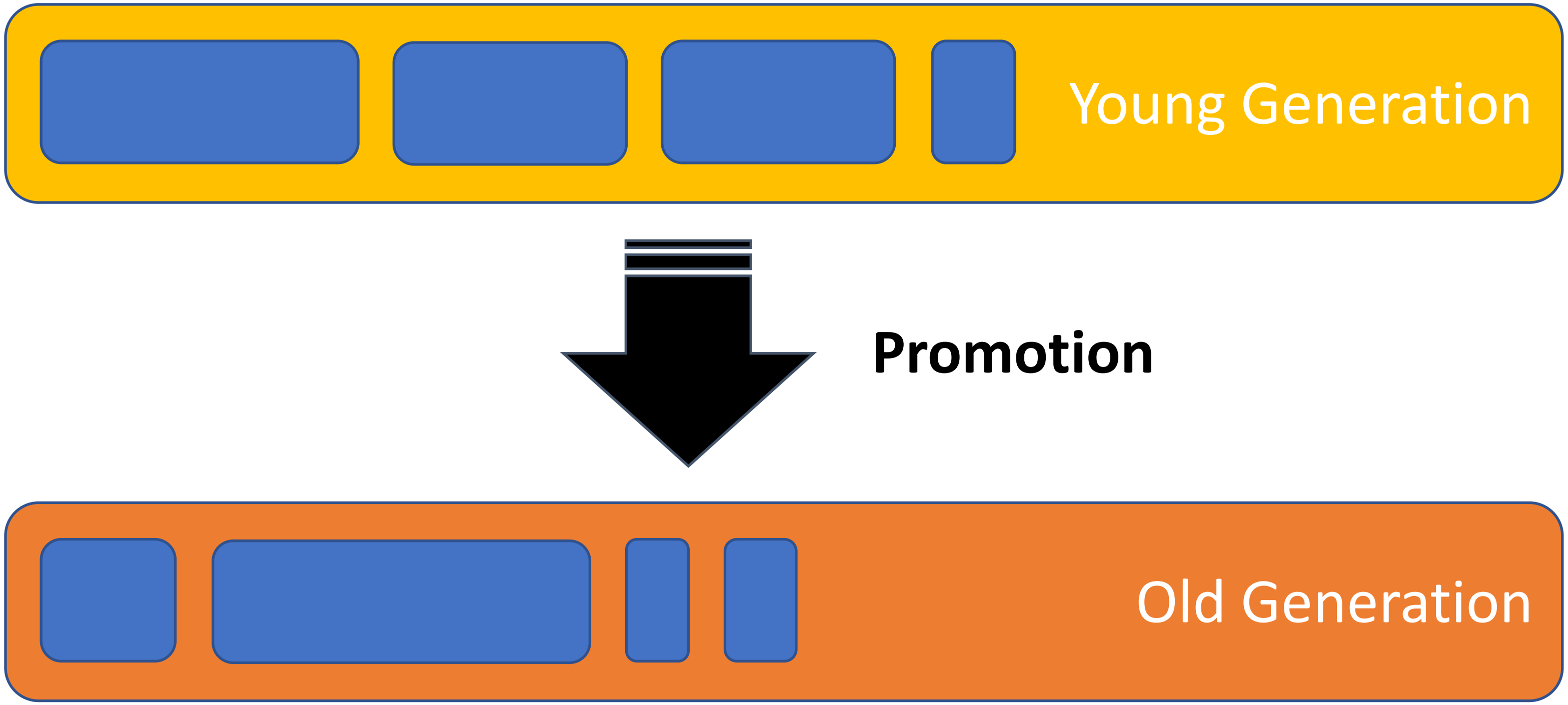
- Use page faults!
- Clear PTE_V, wait for faults
- In fault handler, record fault, then set PTE_V
- Slow!

Use Case: Generational GC

- Observation: Most objects die young
- Idea: Maintain separate regions for young and old objects
- Plan: Collect young objects independently and more often
- Performance impact: Avoids tracing overhead of old generation

Generational GC

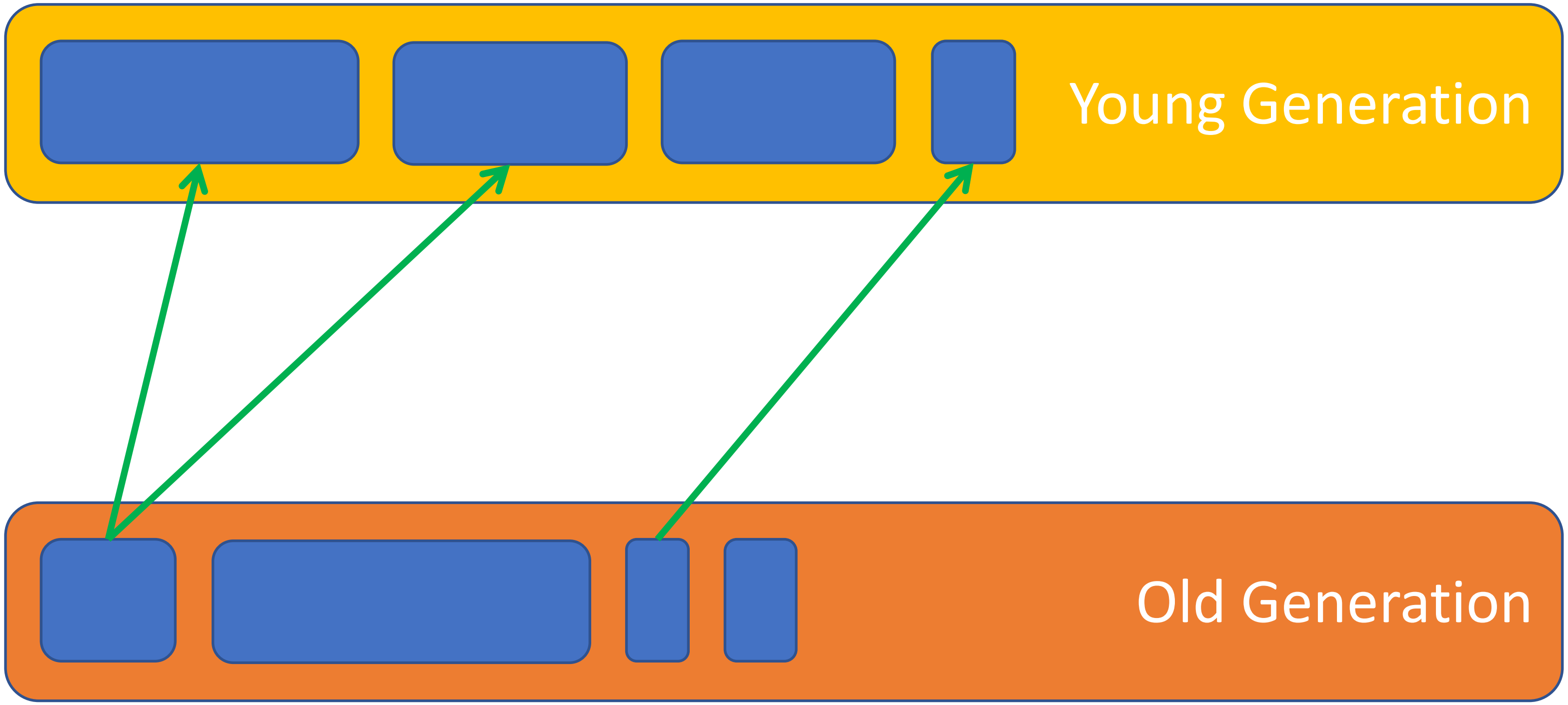


Challenge: How to find live objects in young gen?

- Easy part: Start with roots like registers, stack, and global pointers
- Hard part: What if an old gen object points to a young gen object?
    - We can’t trace the old gen or no speedup!

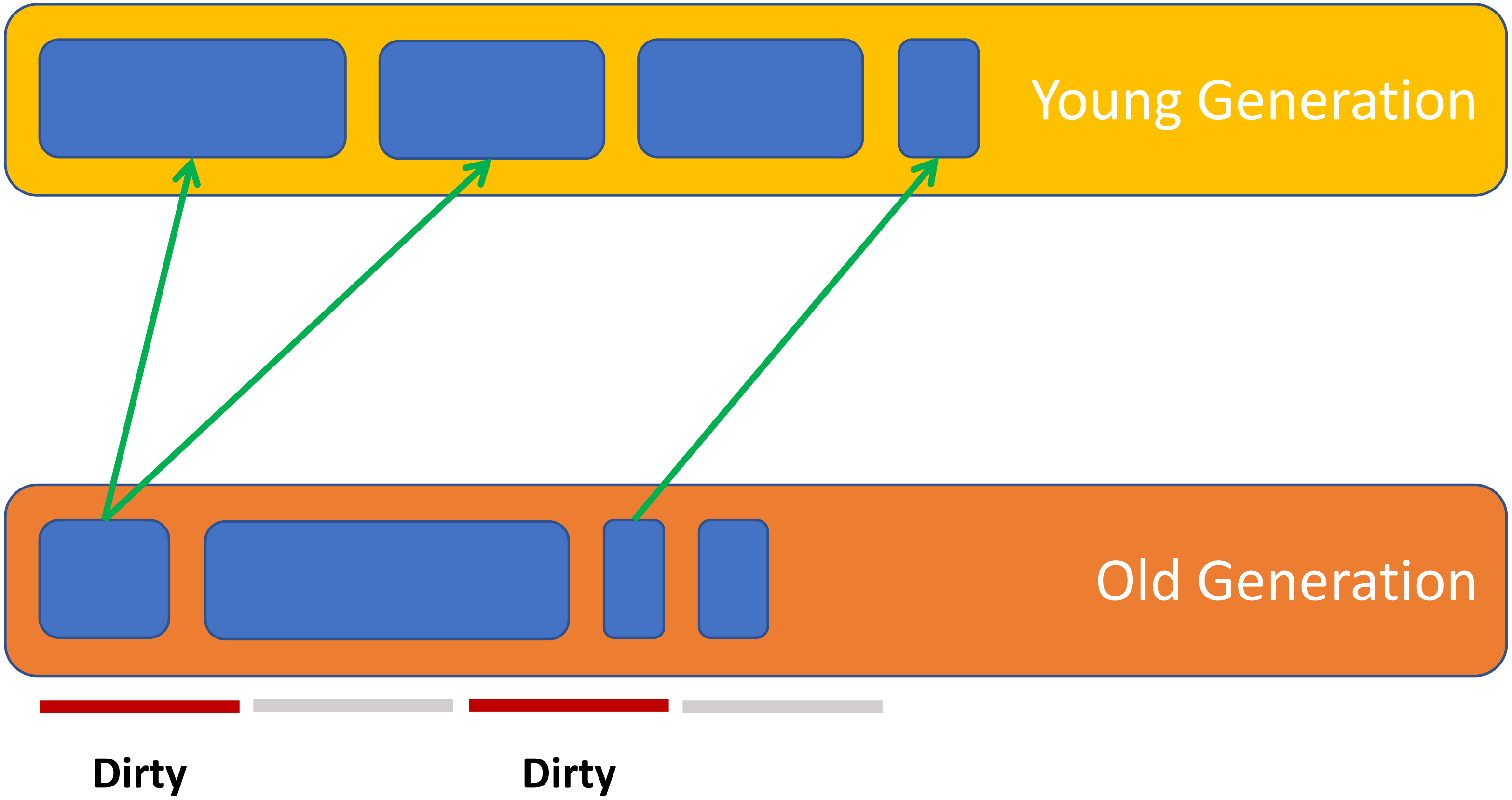
Challenge: How to quickly find live objects in young gen?

- Old gen may have references to young gen!



Solution: Use virtual memory!

- Paging HW tracks which pages were modified (DIRTY)



Other questions?