CS 444/544 OS II
Lab Tutorial #8

Copy-on-Write Fork

(Lab4 – Part B)

Acknowledgement: Slides drawn heavily from Yeongjin Jiang

Part-A Result

```
dumbfork: OK (1.0s)
Part A score: 5/5
```

- You should get this OK before start exercise 8

- FAQ
  - What if dumbfork halts?
    - Check if your sched_yield()/env_run() is implemented correctly
    - curenv must set as ENV_RUNNABLE state if it is scheduled out…
  - What if I have a syscall error?
    - Check if your implementation returns the return value of the syscall correctly
    - Check syscall arguments and orders
    - There always be syscalls to SYS_getenvid and SYS_cputs

CAUTION:
You Will See LOTS of Page Faults in Part B

- What should I do if I see a page fault?

```
set_pgfault_handler(handler);
cprintf("%s\n", (char*)0xDeadBeef);
cprintf("%s\n", (char*)0xCafeBffe);
```

- Check information related to the fault
  - Check tf_eip (the origin of the fault)
  - Check fault_va (read cr2, rcr2())
    - You can reason a lot from this address, e.g., 0xcafebffe?
    - If it is 0, a null pointer dereference, check your impl!!!
  - Check error code (user/kernel, read/write, present?)

- Think about why this fault happens???

How Can I Get the Code for User Exec?

- Read obj/user/xxxx.asm
- E.g., dumbfork:
  - You can match eip and the source code

```
void
duppage(envid_t dstenv, void *addr)
{
  800040:   55                      push   %ebp
  800041:   89 e5                   mov    %esp,%ebp
  800043:   56                      push   %esi
  800044:   53                      push   %ebx
  800045:   83 ec 20                sub    $0x20,%esp
  800048:   8b 75 08                mov    0x8(%ebp),%esi
  80004b:   8b 5d 0c                mov    0xc(%ebp),%ebx
    int r;

    // This is NOT what you should do in your fork.
    if ((r = sys_page_alloc(dstenv, addr, PTE_P|PTE_U|PTE_W)) < 0)
  80004e:   c7 44 24 08 07 00 00    movl   $0x7,0x8(%esp)
  800055:   00
  800056:   89 5c 24 04             mov    %ebx,0x4(%esp)
  80005a:   89 34 24                mov    %esi,(%esp)
  80005d:   e8 81 0d 00 00          call   800de3 <sys_page_alloc>
  800062:   85 c0                   test   %eax,%eax
  800064:   79 20                   jns    800086 <duppage+0x46>
        panic("sys_page_alloc: %e", r);
  800066:   89 44 24 0c             mov    %eax,0xc(%esp)
  80006a:   c7 44 24 08 a0 12 80    movl   $0x8012a0,0x8(%esp)
  800071:   00
  800072:   c7 44 24 04 20 00 00    movl   $0x20,0x4(%esp)
  800079:   00
  80007a:   c7 04 24 b3 12 80 00    movl   $0x8012b3,(%esp)
  800081:   e8 24 02 00 00          call   8002aa <_panic>
    if ((r = sys_page_map(dstenv, addr, 0, UTEMP, PTE_P|PTE_U|PTE_W)) < 0)
  800086:   c7 44 24 10 07 00 00    movl   $0x7,0x10(%esp)
  80008d:   00
  80008e:   c7 44 24 0c 00 00 40    movl   $0x400000,0xc(%esp)
  800095:   00
```

Part B: Copy-on-Write Fork

- We will implement an efficient, copy-on-write fork
  - Purely in user-level with **user-level page fault handler**
  - Will use syscalls that we implemented in Exercise 7
    - sys_exofork, sys_env_set_status, sys_page_alloc, sys_page_map, sys_page_unmap

- DO NOT implement lib/fork.c the same as user/dumbfork.c
  - Dumbfork does not do Copy-on-write
  - fork() should not copy any of memory page
    - It only copies VA-to-PA mappings (page table entries)

Part B: Copy-on-Write Fork

- We will implement
  - User-level exception handling (page fault handler) (Exercise 8—11)
  - Copy-on-write fork() (Exercise 12)

How Page Fault Works (in Lab 3)?

- 1. User program generates a fault
  - E.g., struct Env *e = NULL;
    - e->env_id; (Null pointer dereference)
- 2. trapentry.S, _alltraps, trap(), and then trap_dispatch()
  - Will call the page_fault_handler(tf)

```
switch (tf->tf_trapno) {
    case T_PGFLT:
    {
        return page_fault_handler(tf);
    }
```

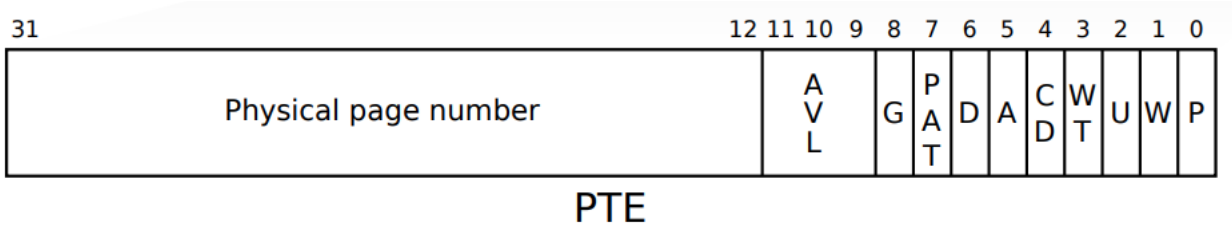
How Page Fault Works (in Lab 4)?

- 3. in page_fault_handler(tf)

- Handle user page fault in user space

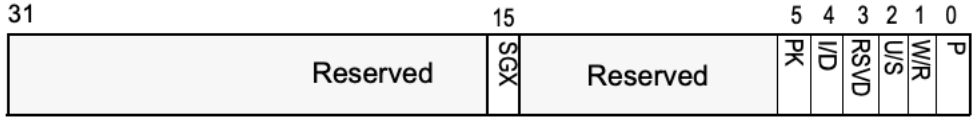
```
// We've already handled kernel-mode exceptions, so if we get here,
// the page fault happened in user mode.

// Call the environment's page fault upcall, if one exists.  Set up a
// page fault stack frame on the user exception stack (below
// UXSTACKTOP), then branch to curenv->env_pgfault_upcall.
//
// The page fault upcall might cause another page fault, in which case
// we branch to the page fault upcall recursively, pushing another
// page fault stack frame on top of the user exception stack.
//
// It is convenient for our code which returns from a page fault
// (lib/pfentry.S) to have one word of scratch space at the top of the
// trap-time stack; it allows us to more easily restore the eip/esp. In
// the non-recursive case, we don't have to worry about this because
// the top of the regular user stack is free.  In the recursive case,
// this means we have to leave an extra word between the current top of
// the exception stack and the new stack frame because the exception
// stack _is_ the trap-time stack.
//
// If there's no page fault upcall, the environment didn't allocate a
// page for its exception stack or can't write to it, or the exception
// stack overflows, then destroy the environment that caused the fault.
// Note that the grade script assumes you will first check for the page
// fault upcall and print the "user fault va" message below if there is
// none.  The remaining three checks can be combined into a single test.
//
// Hints:
//   user_mem_assert() and env_run() are useful here.
//   To change what the user environment runs, modify 'curenv->env_tf'
//   (the 'tf' variable points at 'curenv->env_tf').

// LAB 4: Your code here.
```

Page Fault



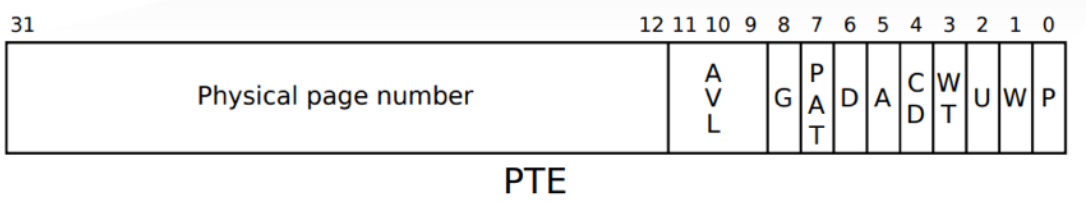
- A memory access fault caused by:
  - Having no Page Directory Entry or Page Table Entry
  - Insufficient permission to access the memory
    - PTE & PTE_U == 0, accessed by user process (Ring 3)
    - PTE & PTE_W == 0, attempted write access
    - PTE & PTE_P == 0, not available
  - Invalid physical address for PTE…
- CPU will call page fault trap handler from IDT
  - CR2 will store the fault address
  - Error code will store the cause of violation, P/U/W, etc.
- Execution resumes at the faulting address (re-execute)

```
+--------------------+ KSTACKTOP
| 0x00000 | old SS   |      " - 4
|      old ESP       |      " - 8
|     old EFLAGS     |      " - 12
| 0x00000 | old CS   |      " - 16
|      old EIP       |      " - 20
|     error code     |      " - 24 <---- ESP
+--------------------+
```

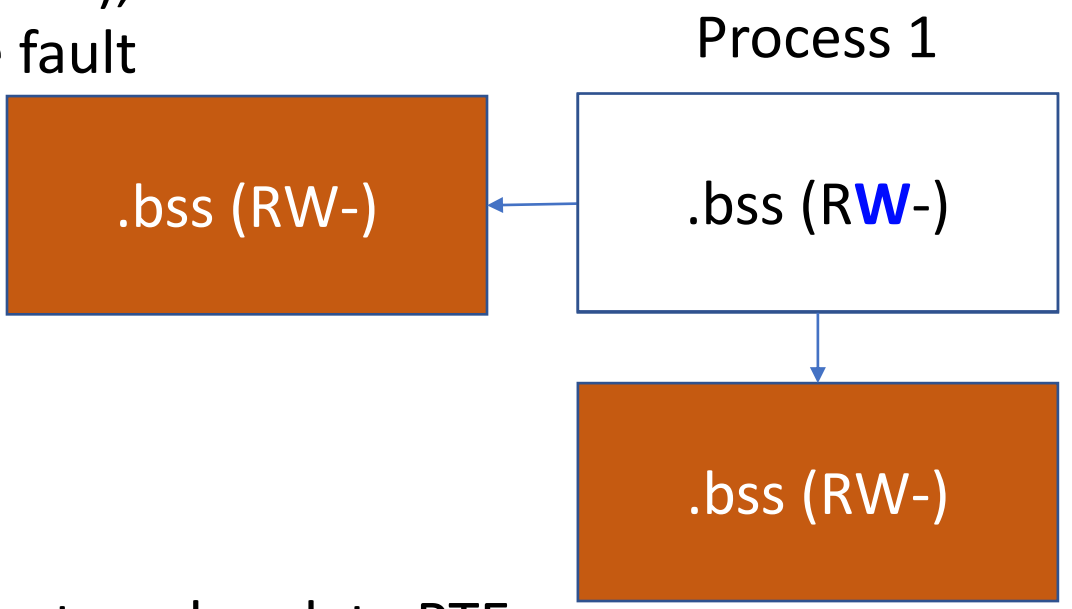


Copy-on-Write Page Fault Handler

Check PTE_COW



- Copy-on-write fork
  - Make pages read-only, mark PTE_COW (in AVL..), and share.
  - Any write to COW page will generate a page fault
- On fault
  - CR2 will store the faulting address
  - Error code will say: write on read-only page
- TODO
  - Retrieve PTE (using the value in CR2)
  - Check if PTE & PTE_COW == 1
  - Allocate a new physical page, copy the content, and update PTE
    - PTE_W!



JOS Page Fault Workflow (Kernel)

- 1. Fault (user/somewhere.c)
- 2. CPU runs trap handler
- 3. _alltraps (kern/trapentry.S)
- 4. trap (kern/trap.c)
- 5. trap_dispatch (kern/trap.c)
- 6. page_fault_handler (kern/trap.c)

JOS User Fault Handling Workflow

- 6. page_fault_handler (kern/trap.c) — Exercise 9
- 7. _pgfault_upcall (lib/pfentry.S) — Exercise 8/10
  - 7-1. _pgfault_handler (lib/pgfault.c) — Exercise 12
- 8. return to the faulting instruction — Exercise 11
- 9. Resume!

- Blue: Program execution in user
- Purple: Fault handling in user
- Red: Fault handling in kernel

Exercise 8

- Implement sys_env_set_pgfault_upcall (kern/syscall.c)
  - Kernel page fault handler will call _pgfault_upcall
    - curenv->env_pgfault_upcall

```
static int
sys_env_set_pgfault_upcall(envid_t envid, void *func)
```

  - Get the Env of envid, and set it's `env_pgfault_upcall = func`

- 6. page_fault_handler (kern/trap.c)
- 7. _pgfault_upcall (lib/pfentry.S)
  - 7-1. _pgfault_handler (lib/pgfault.c)

Exercise 9

Exercise 8/10

Exercise 8

- How can we get an Struct Env * from envid?
- Use envid2env

```
int
envid2env(envid_t envid, struct Env **env_store, bool checkperm)
```

- How?

```
struct Env *e = NULL;
if (envid2env(envid, &e, 1) < 0)
    return -E_BAD_ENV;
```

- Checkperm will check if the env is
  - Current env or
  - A child env of the current env

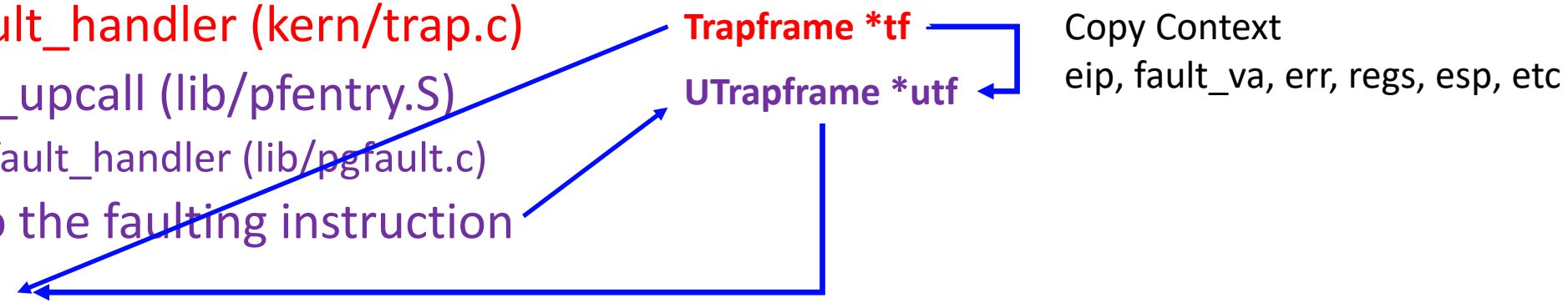
`e->env_pgfault_upcall = func`

Exercise 9: page_fault_handler (kern/trap.c)

- What should it do?
  - Execute curenv->env_pgfault_upcall (set by user via syscall)
    - 6. page_fault_handler (kern/trap.c)
    - 7. _pgfault_upcall (lib/pfentry.S)
  - `tf->tf_eip = (uintptr_t) curenv->env_pgfault_upcall;`
- Requirement?
  - Let env_pgfault_upcall returns to the faulting instruction
  - Restore all CPU context after handing the fault
    - 7. _pgfault_upcall (lib/pfentry.S)
      - 7-1. _pgfault_handler (lib/pgfault.c)
    - 8. return to the faulting instruction
    - 9. Resume!

Exercise 9: page_fault_handler (kern/trap.c)

- How can we execute kernel -> user -> user??
  - 6. page_fault_handler (kern/trap.c)
  - 7. _pgfault_upcall (lib/pfentry.S)
    - 7-1. _pgfault_handler (lib/pgfault.c)
  - 8. return to the faulting instruction
  - 9. Resume!

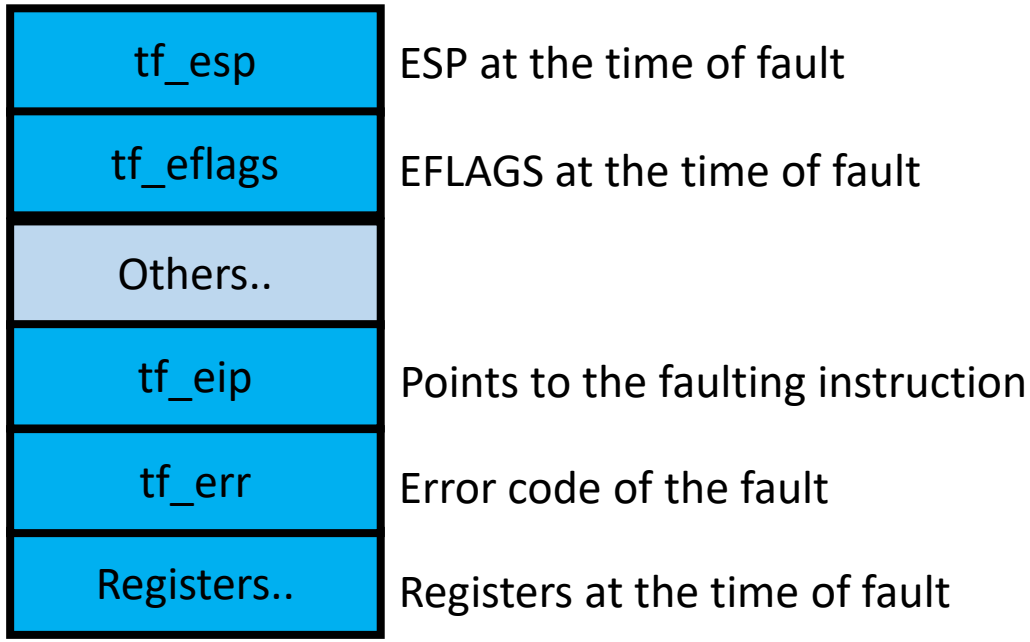


- Trapframe *tf stores the context at the time of fault
  - Create UTrapframe *utf to deliver this context to the user-level handler

Exercise 9: page_fault_handler (kern/trap.c)

Exception stack

Trapframe *tf



We want to do:

1) Copy Trapframe information as Utrapframe
2) Call curenv->env_pgfault_upcall

Exercise 9: How can we run the function curenv->env_pgfault_upcall() in Ring 3?

- Via iret, env_pop_tf()
  - Set the `tf_eip = curenv->env_pgfault_upcall;`
  - Set the `tf_esp = addr_of_UTrapframe;`

Trapframe *tf

ESP at the time of fault

EFLAGS at the time of fault

Points to the faulting instruction

Error code of the fault

Registers at the time of fault

UTrapframe?

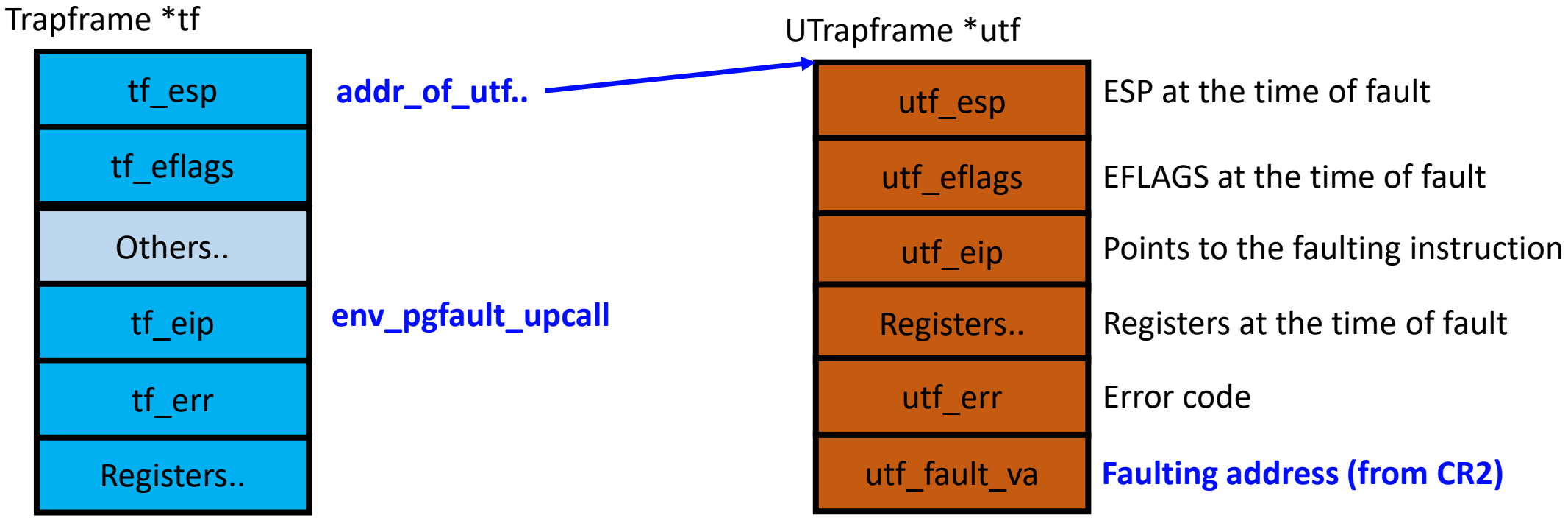
env_pgfault_upcall

We want to do:

1) Copy Trapframe information as Utrapframe
2) Call curenv->env_pgfault_upcall

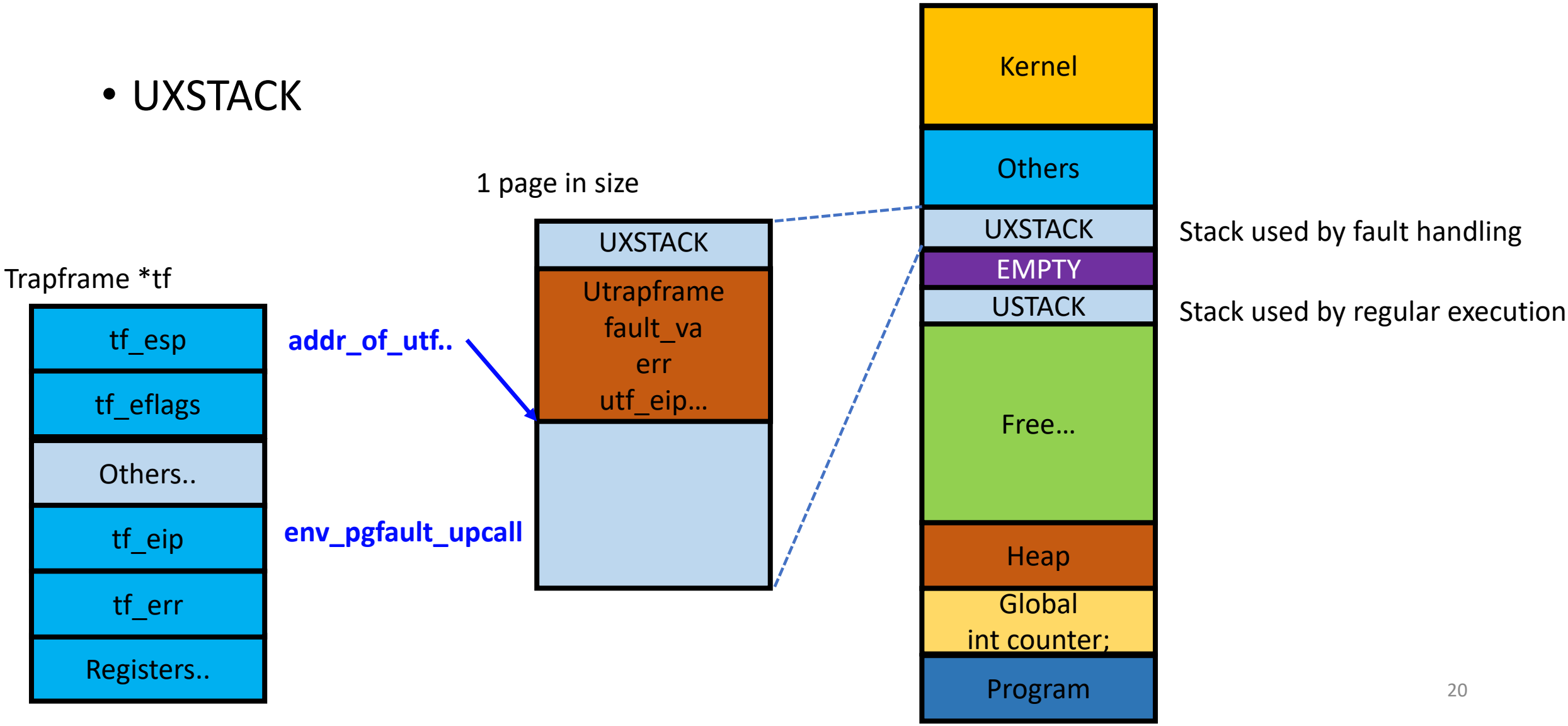
Use UTrapframe to Transfer Execution Context

- Create Utrapframe, and deliver that to env_pgfault_upcall!
  - Copy necessary information to handle the page fault and return back..



Where Do We Store UTrapframe?

- UXSTACK



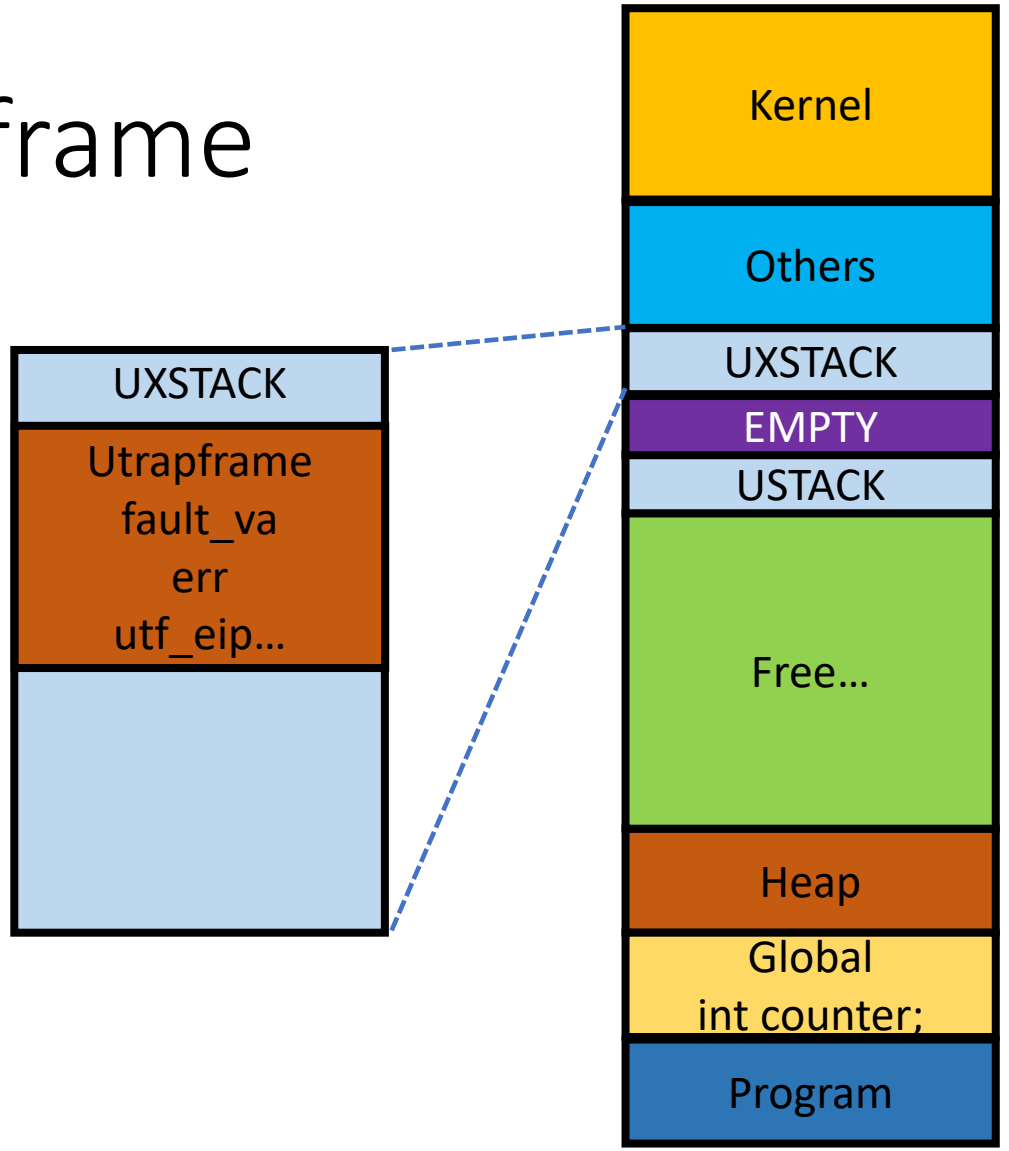
Exercise 9-1
Copy Utrapframe from Trapframe

- A) Create UTrapframe

```
struct UTrapframe utf;
utf.utf_fault_va = fault_va;
utf.utf_err = tf->tf_err;
utf.utf_regs = tf->tf_regs;
utf.utf_eip = tf->tf_eip;
utf.utf_eflags = tf->tf_eflags;
utf.utf_esp = tf->tf_esp;
```

Exercise 9-1
Copy Utrapframe from Trapframe

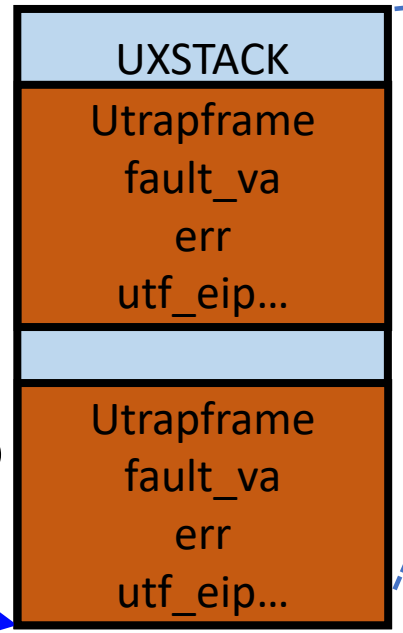
- B) Put UTrapframe in UXSTACK
- Two cases
  - If this is a new exception
  - `UXSTACKTOP-sizeof(struct UTrapframe)`

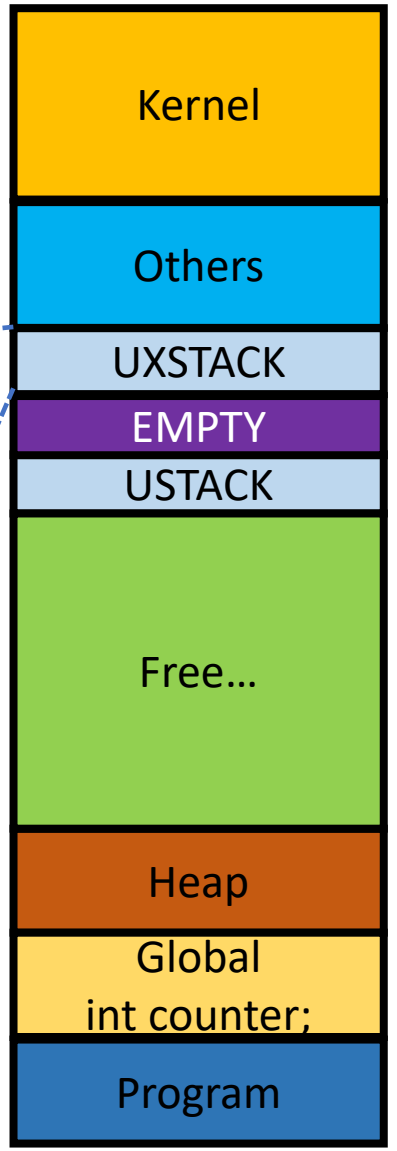


Exercise 9-1
Copy Utrapframe from Trapframe

- B) Put UTrapframe in UXSTACK
- Two cases
  - If this is a new exception
  - `UXSTACKTOP-sizeof(struct UTrapframe)`
  - If this is a nested exception
  - `utf_esp =`
    - `tf_esp-4-sizeof(struct Utrapframe)`
- How to distinguish each case?

```
if (ROUNDUP(tf->tf_esp, PGSIZE) == UXSTACKTOP) {
```



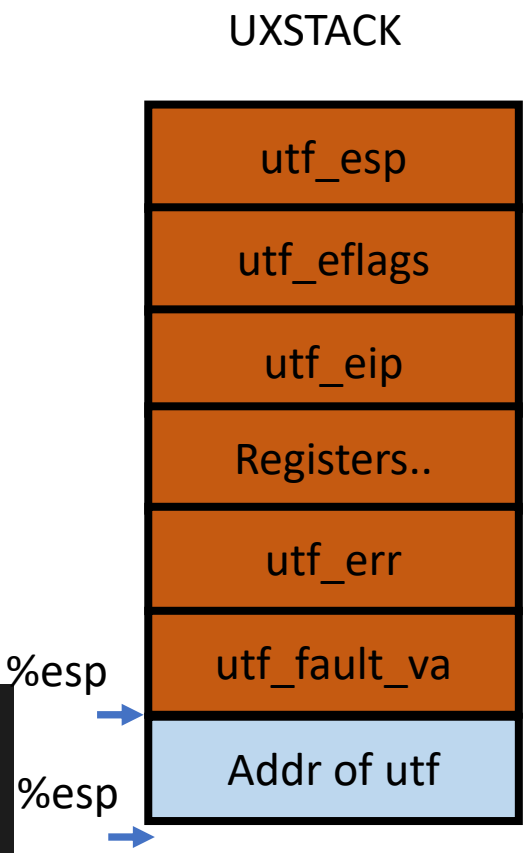


Exercise 10: _pgfault_upcall

- 1) calls _pgfault_handler(utf)
  - _pgfault upcall is called via iret (tf_eip)
  - tf_esp must point to the exception stack (near UXSTACKTOP)
  - tf_esp must point to the address of utf

```
_pgfault_upcall:
    // Call the C page fault handler.
    pushl %esp               // function argument: pointer to UTF
    movl _pgfault_handler, %eax
    call *%eax
    addl $4, %esp            // pop function argument
```

_pgfault_handler(utf)



JOS User Fault Handling Workflow

- 6. page_fault_handler (kern/trap.c)
- 7. _pgfault_upcall (lib/pfentry.S)
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- 8. return to the faulting instruction
- 9. Resume!

- Blue: Program execution in user
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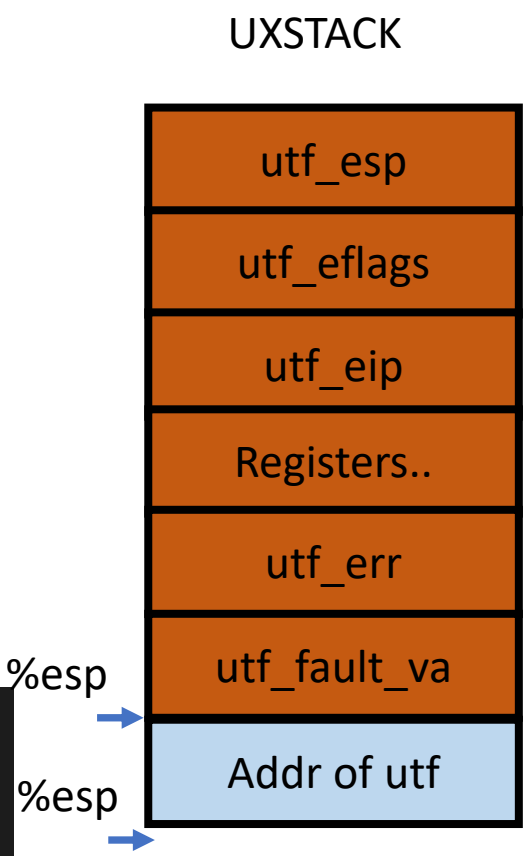
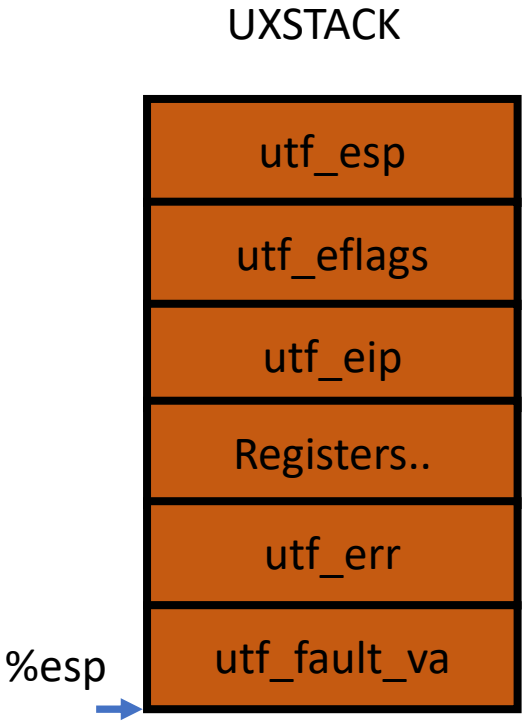


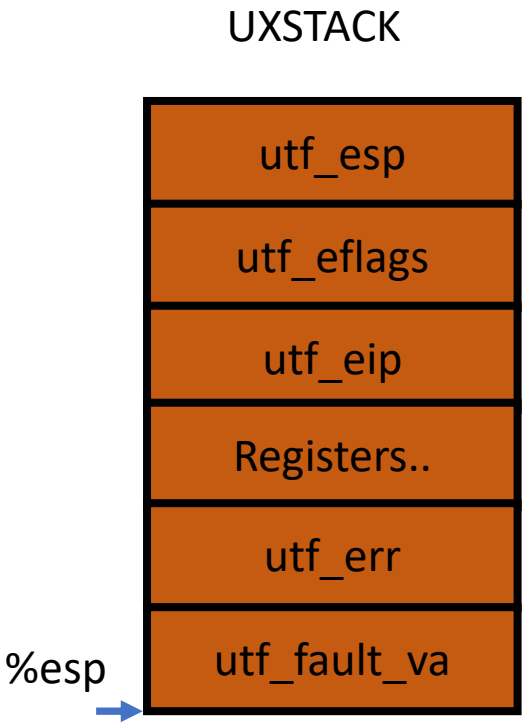
Exercise 10: Return to the Faulting Instruction

- UTrapframe stores the original execution context
- _pgfault_upcall should restore all context
  - General purpose registers (eax, edx, ecx, ebx, esi, edi, ebp)
  - EIP
  - EFLAGS
  - ESP



Restoring Context

- General purpose registers
  - popa will pop all registers…
- Assembly
  - add $8, %esp
  - popa



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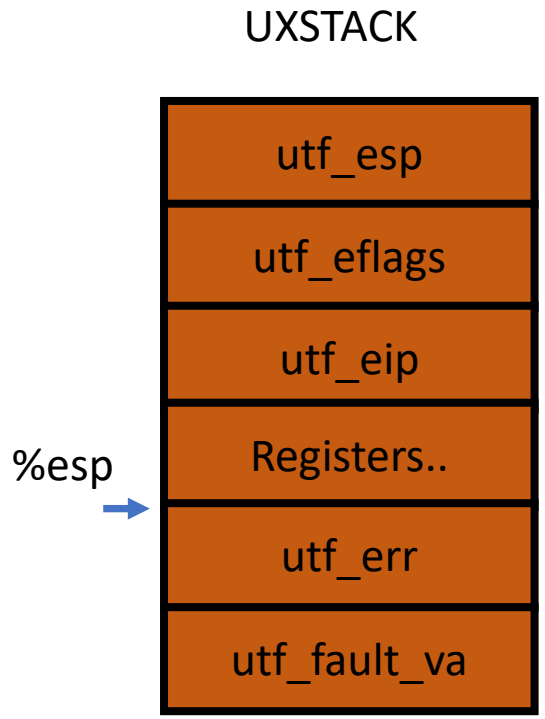
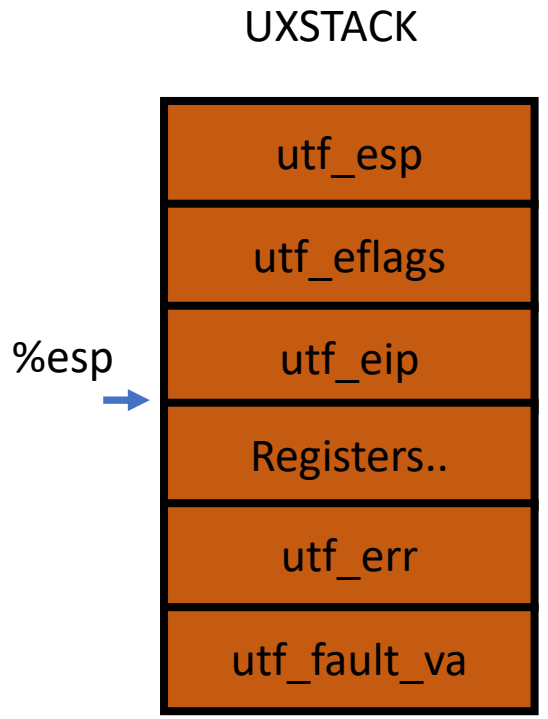


Restoring Context

- General purpose registers
  - popa will pop all registers…
  - eax, edx, ecx, ebx, esi, edi, and ebp

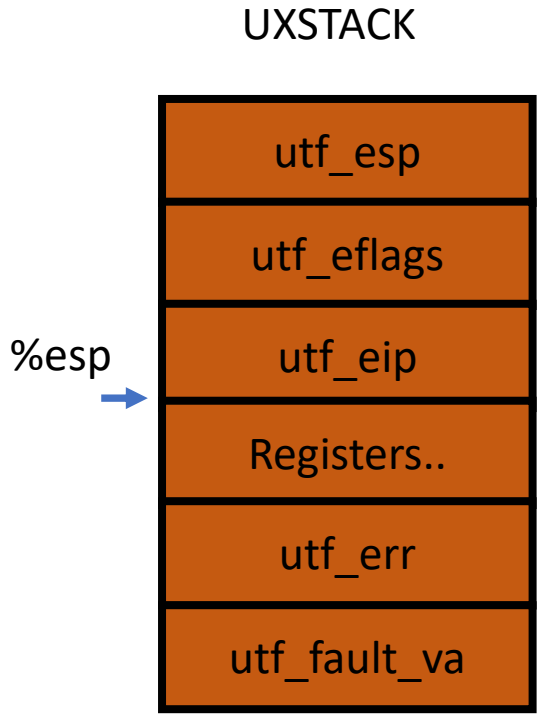
- Assembly
  - add $8, %esp
  - popa

You cannot overwrite the values in those registers after doing this…



Restoring EFLAGS

- POPF
  - add $4, %esp
  - popf



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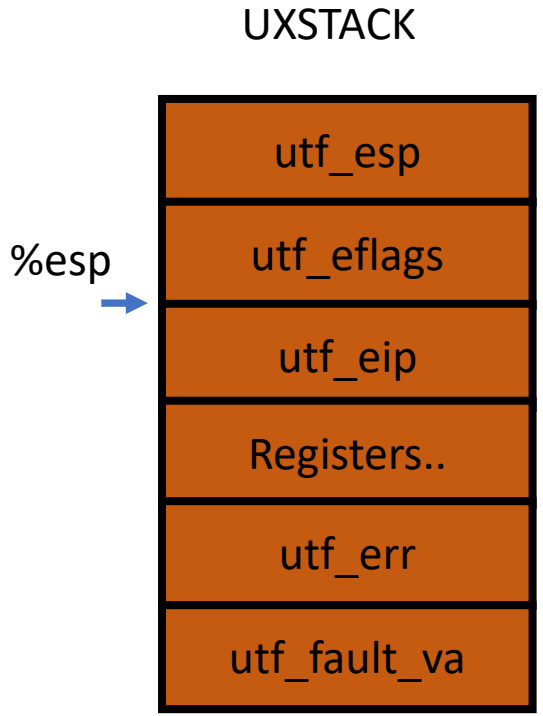

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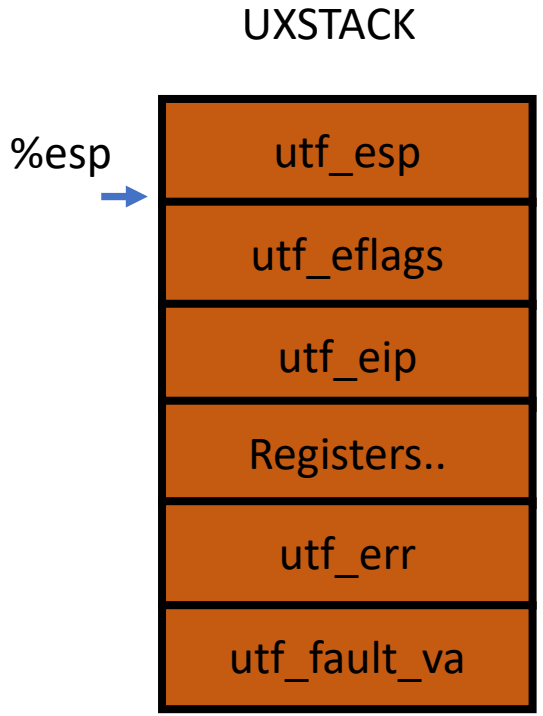
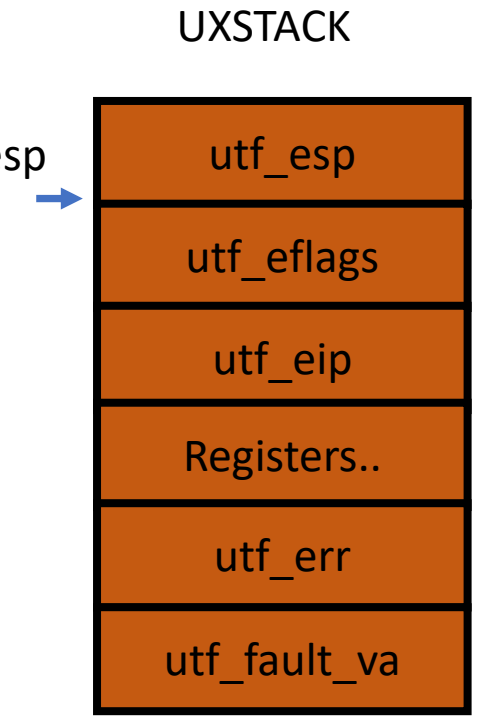


You cannot use arithmetic operations after doing this.. Because doing such will change EFLAGS!

Restoring ESP

- LEA (Load Effective Address)
  - lea 4(%esp), %esp

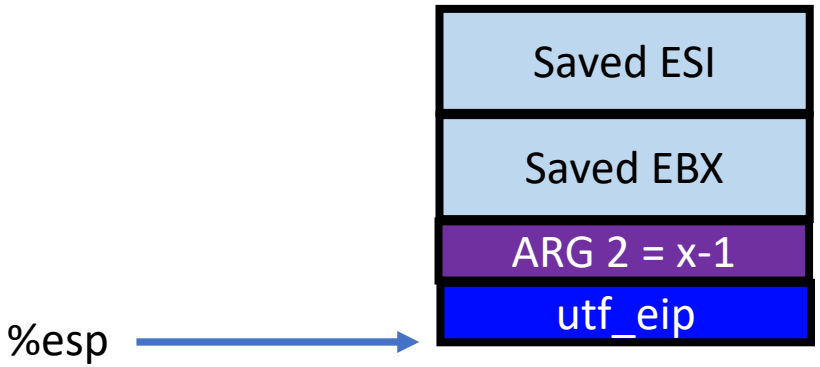
This will add esp by 4, i.e., esp += 4;



- C-style
  - esp = &(*(esp+4))
  - Interpretation
    - 4(%esp) means esp[4] or *(esp+4)
    - lea means getting the address of the operand
    - &esp[4] or &(*(esp+4))
  - Result: esp += 4
- **This will not change EFLAGS!**

How to Restore EIP?

- In x86, two ways
  - Call/jmp
    - mov $0x8048444, %eax
    - Call *%eax
    - Jmp *%eax
    - But we cannot use general purpose registers…
  - RET
    - Interpretation: ret == pop %eip
      - f = *esp
      - esp += 4
      - f();
  - We can put utf_eip right below utf_esp
  - Why???



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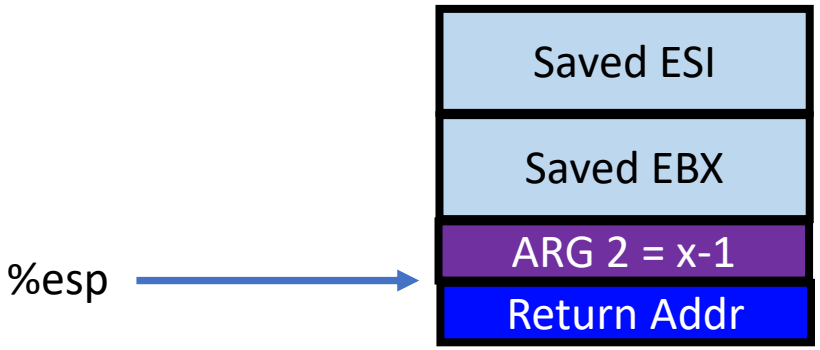
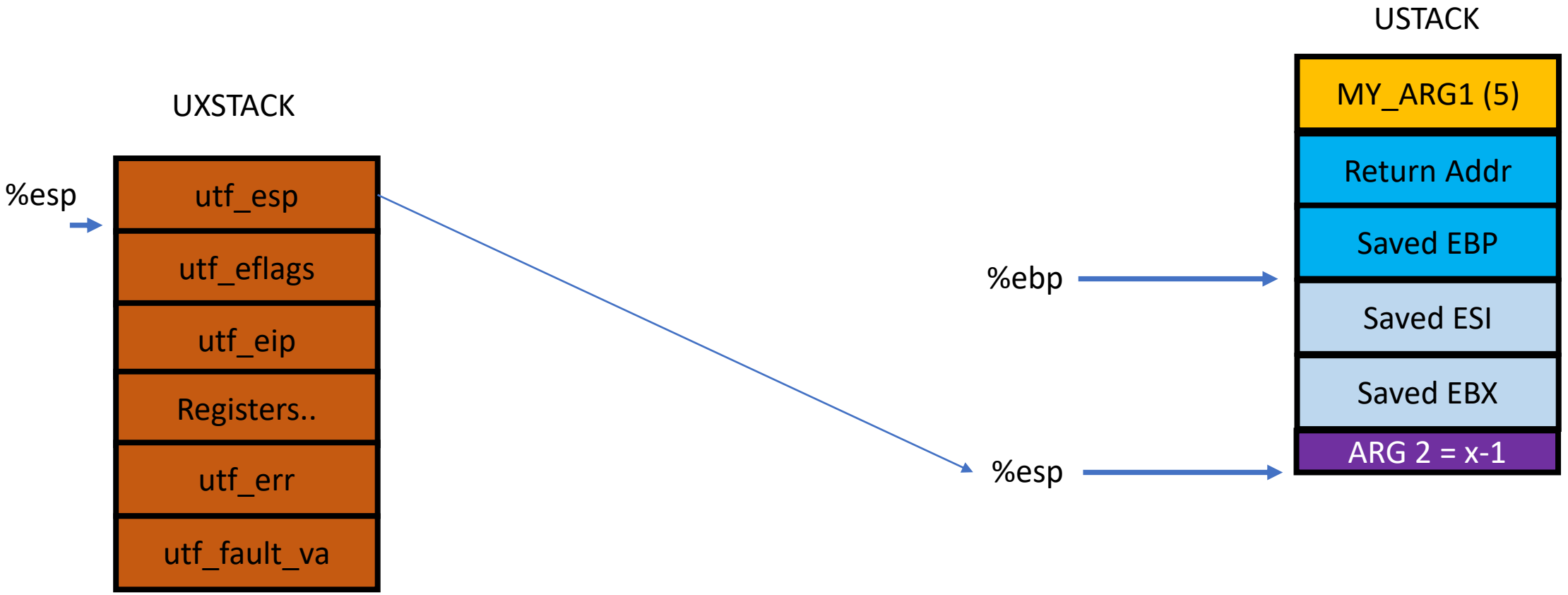
  - We can put utf_eip right below utf_esp
  - Why???

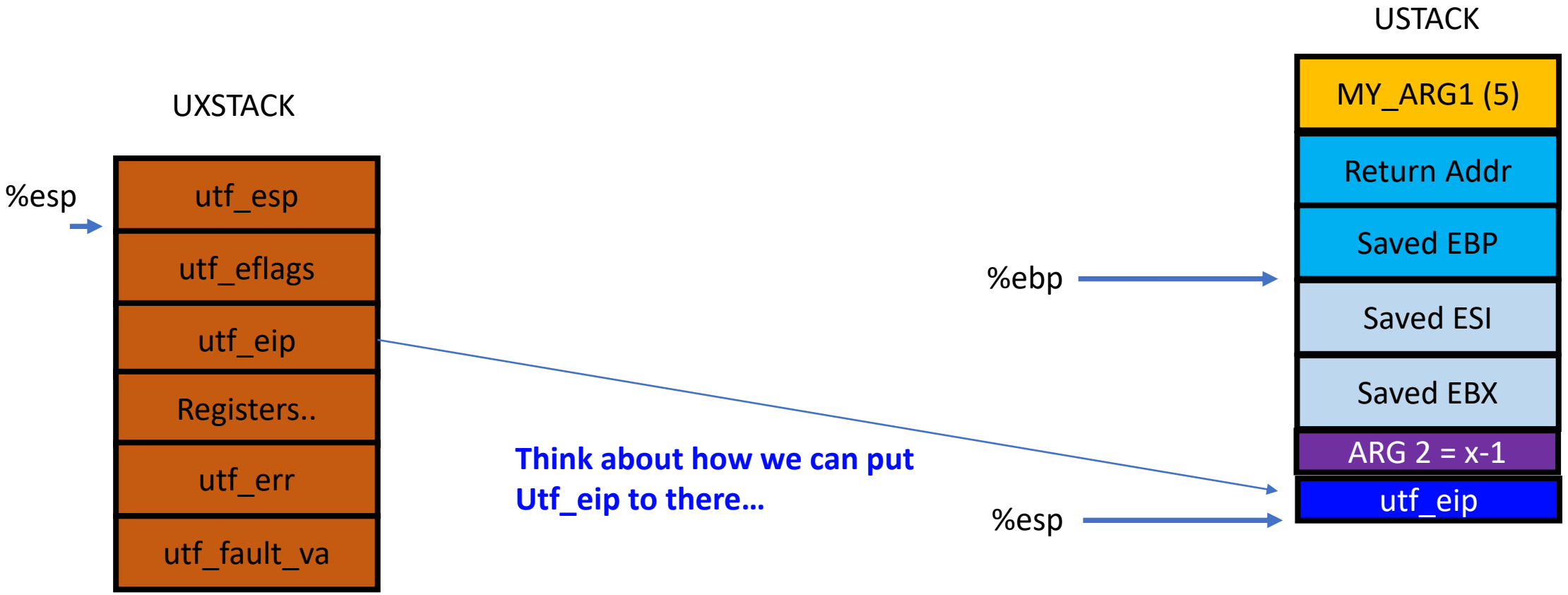


UXSTACK vs USTACK



pop %esp (esp will get the value of utf_esp)
lea -4(%esp), %esp (esp -= 4)
ret

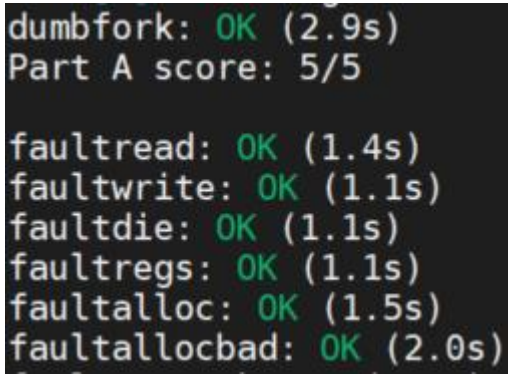
UXSTACK vs USTACK



pop %esp (esp will get the value of utf_esp)
lea -4(%esp), %esp (esp -= 4)
ret

Exercise 11: Finish set_pgfault_handler()(lib/pgfault.c)

- 1) Allocate a page at [UXSTACKTOP-PGSIZE, UXSTACKTOP)
  - To store UTrapframe!
  - Use sys_page_alloc()
- 2) Set env_pgfault_upcall
  - Via syscall, sys_env_set_pgfault_upcall!
- After finishing this (correctly), you should get OKs upto
  - faultallocbad



Some Debugging Tips

- Unexpected user_mem_check fails
  - Check your implementation for user_mem_assert

- Why are there 3 faults in faultalloc?
  - Faultalloc reads 2 bad addresses, 0xDeadBeef and 0xCafeBffe

```
void
umain(int argc, char **argv)
{
    set_pgfault_handler(handler);
    cprintf("%s\n", (char*)0xDeadBeef);
    cprintf("%s\n", (char*)0xCafeBffe);
}
```

Some Debugging Tips

- Why are there 3 faults in faultalloc?
  - Faultalloc reads 2 bad addresses, 0xDeadBeef and 0xCafeBffe

```
void
umain(int argc, char **argv)
{
    set_pgfault_handler(handler);
    cprintf("%s\n", (char*)0xDeadBeef);
    cprintf("%s\n", (char*)0xCafeBffe);
}
```

- 0xdeadbeef
  - Fault at 0xDeadBeef, allocate 0xDeadB000
  - Handler writes “this string…”

```
void
handler(struct UTrapframe *utf)
{
    int r;
    void *addr = (void*)utf->utf_fault_va;

    cprintf("fault %x\n", addr);
    if ((r = sys_page_alloc(0, ROUNDDOWN(addr, PGSIZE),
                            PTE_P|PTE_U|PTE_W)) < 0)
        panic("allocating at %x in page fault handler: %e", addr, r);
    snprintf((char*) addr, 100, "this string was faulted in at %x", addr);
}
```

Some Debugging Tips

- Why are there 3 faults in faultalloc?
  - Faultalloc reads 2 bad addresses, 0xDeadBeef and 0xCafeBffe

```
void
umain(int argc, char **argv)
{
    set_pgfault_handler(handler);
    cprintf("%s\n", (char*)0xDeadBeef);
    cprintf("%s\n", (char*)0xCafeBffe);
}
```

- 0xcafebffe
  - Fault at 0xCafeBffe, allocate 0xCafeB000
  - Handler writes “this string…”
  - Fault at 0xCafeC000
    - Why? 0xCafeBffe + 2 = 0xCafeC000
    - Not mapped…

```
void
handler(struct UTrapframe *utf)
{
    int r;
    void *addr = (void*)utf->utf_fault_va;

    cprintf("fault %x\n", addr);
    if ((r = sys_page_alloc(0, ROUNDDOWN(addr, PGSIZE),
                PTE_P|PTE_U|PTE_W)) < 0)
        panic("allocating at %x in page fault handler: %e", addr, r);
    snprintf((char*) addr, 100, "this string was faulted in at %x", addr);
}
```

Handling Multiple Faults

- Page fault can occur during handling a page fault
- In kernel: Panic
- In user:
  - 7. _pgfault_upcall (lib/pfentry.S)
    - 7-1. _pgfault_handler (lib/pgfault.c)

- How?
  - Recursively handle the fault…

JOS Page Fault Workflow (Kernel)

- A-1. Fault (user/somewhere.c)
- A-2. CPU runs trap handler
- A-3. _alltraps (kern/trapentry.S)
- A-4. trap (kern/trap.c)
- A-5. trap_dispatch (kern/trap.c)
- A-6. page_fault_handler (kern/trap.c)

JOS User Fault Handling Workflow

- A-6. page_fault_handler (kern/trap.c)
- A-7. _pgfault_upcall (lib/pfentry.S)
  - A-7-1. _pgfault_handler (lib/pgfault.c, FAULT)

JOS Page Fault Workflow (Kernel)

- B-1. Fault (user/fork.c)
- B-2. CPU runs trap handler
- B-3. _alltraps (kern/trapentry.S)
- B-4. trap (kern/trap.c)
- B-5. trap_dispatch (kern/trap.c)
- B-6. page_fault_handler (kern/trap.c)

JOS User Fault Handling Workflow

- B-6. page_fault_handler (kern/trap.c)
- B-7. _pgfault_upcall (lib/pfentry.S)
  - B-7-1. _pgfault_handler (lib/pgfault.c)
- B-8. return to the faulting instruction
- B-9. Resume to A-7

JOS User Fault Handling Workflow

- B-9. Resume to A-7
- A-7-1. _pgfault_handler (lib/pgfault.c, FAULT)
- A-8. return to the faulting instruction
- A-9. Resume!

Exercise 11

- So you must correctly handle nested page fault to pass “faultalloc”
  - Fault at 0xCafeBffe
    - While handling this fault, the handler generates another fault at 0xCafeC000
      - Handle it!

- This is the case that you need to check if Trapframe stack is in UXSTACK region or not

Exercise 12: Copy-on-Write Fork

- Using user-level page fault handler, implement CoW fork! (lib/fork.c)

- Take a look at the impl. of user/dumbfork.c
  - dumbfork()

```c
void
duppage(envid_t dstenv, void *addr)
{
    int r;

    // This is NOT what you should do in your fork.
    if ((r = sys_page_alloc(dstenv, addr, PTE_P|PTE_U|PTE_W)) < 0)
        panic("sys_page_alloc: %e", r);
    if ((r = sys_page_map(dstenv, addr, 0, UTEMP, PTE_P|PTE_U|PTE_W)) < 0)
        panic("sys_page_map: %e", r);
    memmove(UTEMP, addr, PGSIZE);
    if ((r = sys_page_unmap(0, UTEMP)) < 0)
        panic("sys_page_unmap: %e", r);
}
```

```c
envid_t
dumbfork(void)
{
    envid_t envid;
    uint8_t *addr;
    int r;
    extern unsigned char end[];

    // Allocate a new child environment.
    // The kernel will initialize it with a copy of our register state,
    // so that the child will appear to have called sys_exofork() too -
    // except that in the child, this "fake" call to sys_exofork()
    // will return 0 instead of the envid of the child.
    envid = sys_exofork();
    if (envid < 0)
        panic("sys_exofork: %e", envid);
    if (envid == 0) {
        // We're the child.
        // The copied value of the global variable 'thisenv'
        // is no longer valid (it refers to the parent!).
        // Fix it and return 0.
        thisenv = &envs[ENVX(sys_getenvid())];
        return 0;
    }

    // We're the parent.
    // Eagerly copy our entire address space into the child.
    // This is NOT what you should do in your fork implementation.
    for (addr = (uint8_t*) UTEXT; addr < end; addr += PGSIZE)
        duppage(envid, addr);

    // Also copy the stack we are currently running on.
    duppage(envid, ROUNDDOWN(&addr, PGSIZE));

    // Start the child environment running
    if ((r = sys_env_set_status(envid, ENV_RUNNABLE)) < 0)
        panic("sys_env_set_status: %e", r);

    return envid;
}
```

Exercise 12: in duppage()

- Unlike the one in dumbfork, we will not call memmove nor sys_page_alloc
  - We will only call sys_page_map
  - You need to duplicate mappings in a parent env to child env
  - No memory copy! This is copy-on-write!

- Caveat
  - For Read-only mapping, you can map the region read-only in child
  - For Writable mapping, you can map
    - The child as read-only with PTE_COW
    - The parent as read-only with PTE_COW
    - **You must change the permission of both pages as PTE_P | PTE_U | PTE_COW**

Exercise 12: in duppage()

To avoid this problem:
Map the child mapping as Copy-on-Write first. And then, change the parent mapping as Copy-on-Write. Then you will have no problem.

- Another important tip
  - Making the stack copy-on-write will generate an immediate page fault
- Why?

```
// Also copy the stack we are currently running on.
duppage(envid, ROUNDDOWN(&addr, PGSIZE));
```

- We make both parent and child to have read-only COW mapping
  - If duppage is called for a writable page
- Program stack will become read-only, and any write of stack, e.g., using local variable, will generate a page fault…

Exercise 12: in fork()

- Don’t forget to
- 1. set_page_fault_handler(&pgfault);
- 2. Allocate a new page at UXSTACKTOP – PGSIZE
  - For having a separate exception handling stack!
- 3. SYS_env_set_pgfault_upcall(envid, thisenv->env_pgfault_upcall);
  - Child must have set its page fault handler to handle CoW
- 4. SYS_env_set_status(envid, ENV_RUNNABLE);
  - Make child runnable after finishing the Copy-on-Write fork!

Exercise 12: in pgfault()

- What should we do in the page fault handler to support CoW?
  - COPY ON WRITE
- Yes, we need to copy the faulting page if
  - The access is a write attempt (read attempt is true error on unmapped page)
  - The page is set with PTE_COW == 1
    - Otherwise, it's a write fault on a true read-only page
- So copy the page if all such condition meets, otherwise, panic!

Exercise 12: in pgfault()

Now the faulted page is backed by a private, writable copy

- Then, how can we copy a page?

- 1. allocate a page at the address PFTEMP
- 2. memcpy(PFTEMP, PTE_ADDR(fault_addr), PGSIZE);
- 3. sys_page_map(0, PFTEMP, 0, PTE_ADDR(fault_addr), PTE_U | PTE_P | PTE_W);
- 4. sys_page_unmap(PFTEMP);

Debugging Tips

- Check your traps. Recommend to print out some trap information whenever you got a trap…

```
static void
trap_dispatch(struct Trapframe *tf)
{
    // Handle processor exceptions.
    // LAB 3: Your code here.

    uint32_t envid;
    if (curenv == NULL) envid = 0;
    else envid = curenv->env_id;
    if (tf->tf_trapno == T_SYSCALL) {
        cprintf("Syscall from %p %s(%p, %p, %p, %p, %p) from "
                "eip %p\n",
                envid,
                stringtbl[tf->tf_regs.reg_eax],
                tf->tf_regs.reg_edx,
                tf->tf_regs.reg_ecx,
                tf->tf_regs.reg_ebx,
                tf->tf_regs.reg_edi,
                tf->tf_regs.reg_esi,
                tf->tf_eip);
    }
    else if (tf->tf_trapno == T_PGFLT) {
        cprintf("Page fault from %p from va %p eip %p\n",
                envid,
                rcr2(), tf->tf_eip);
    }
    else {
        cprintf("Trap from %p number %d from eip %p\n",
                envid,
                tf->tf_trapno, tf->tf_eip);
    }
```

Debugging Tips

- Check your traps. Recommend to print out some trap information whenever you got a trap…

```
static void
trap_dispatch(struct Trapframe *tf)
{
    // Handle processor exceptions.
    // LAB 3: Your code here.

    uint32_t envid;
    if (curenv == NULL) envid = 0;
    else envid = curenv->env_id;
    if (tf->tf_trapno == T_SYSCALL) {
        cprintf("Syscall from %p %s(%p, %p, %p, %p, %p) from "
                "eip %p\n",
                envid,
                stringtbl[tf->tf_regs.reg_eax],
                tf->tf_regs.reg_edx,
                tf->tf_regs.reg_ecx,
```

```
[00000000] new env 00001000
Syscall from 0x1000 SYS_getenvid(0x0, 0x0, 0x0, 0x0, 0x0) from eip 0x800bdf
Syscall from 0x1000 SYS_cputs(0xeebfde88, 0x27, 0x0, 0x0, 0x0) from eip 0x800b4f
I am the parent.  Forking the child...
Syscall from 0x1000 SYS_page_alloc(0x1000, 0xeebff000, 0x7, 0x0, 0x0) from eip 0x800c23
Syscall from 0x1000 SYS_env_set_pgfault_upcall(0x0, 0x8012b9, 0x0, 0x0, 0x0) from eip 0x800d6f
Syscall from 0x1000 SYS_exofork(0x0, 0x8012b9, 0x0, 0x0, 0x0) from eip 0x800f77
[00001000] new env 00001001
Syscall from 0x1000 SYS_page_map(0x0, 0x200000, 0x1001, 0x200000, 0x805) from eip 0x800c76
Syscall from 0x1000 SYS_page_map(0x0, 0x200000, 0x0, 0x200000, 0x805) from eip 0x800c76
Trap from 0x1000 number 32 from eip 0x800c76
```

Debugging Tips

- You will get a page fault (due to Copy-on-Write) immediately after making your stack Copy-on-Write
- This is because duppage will make both virtual page in parent and child set with PTE_COW == 1

- So don’t be surprise, that’s an intended behavior

Debugging Tips

- Make sure you set env_pgfault_upcall for both parent and child

- For parent
  - Run set_pgfault_handler

- For child
  - Run sys_env_set_pgfault_upcall(envid, thisenv->env_pgfault_upcall)
  - Right after forking the child
  - Before changing the child to ENV_RUNNABLE