xv6©-rev10
(Copyright Frans Kaashoek, Robert Morris, and Russ Cox.)

First Process Creation, II

Carmi Merimovich

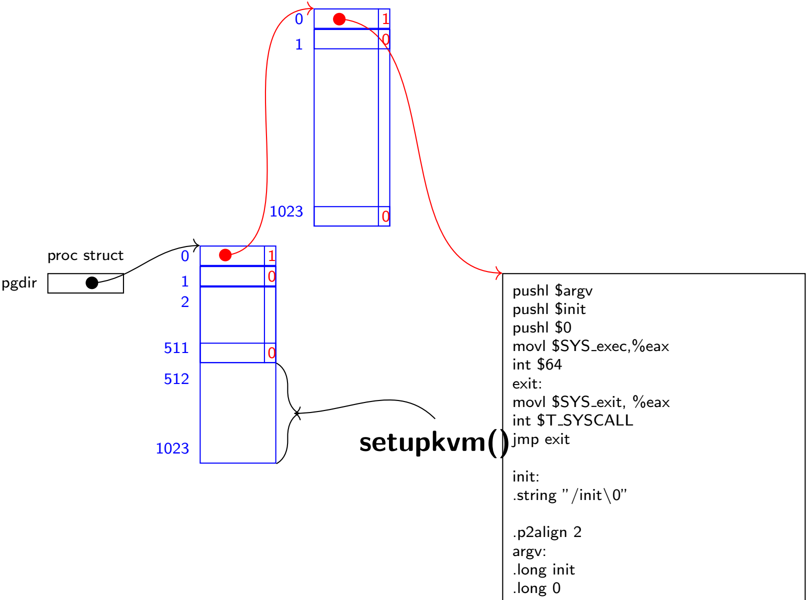
Tel-Aviv Academic College

November 20, 2017

Context

```
kinit1(end, P2V(4*1024*1024)); // phys page alloca
kvmalloc();          // kernel page table
  ⋮
seginit();           // set up segments
  ⋮
pinit();             // process table
  ⋮
  ⋮
kinit2(P2V(4*1024*1024), P2V(PHYSTOP)); // must co
userinit();          // first user process
mpmain();
```

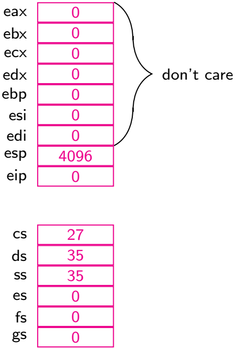
Context in **userinit()**



```
pushl $argv
pushl $init
pushl $0
movl $SYS_exec,%eax
int $64
exit:
movl $SYS_exit, %eax
int $T_SYSCALL
jmp exit

init:
.string "/init\0"

.p2align 2
argv:
.long init
.long 0
```

The Road to User Mode

Initial user mode state for first process



eax	0
ebx	0
ecx	0
edx	0
ebp	0
esi	0
edi	0
esp	4096
eip	0

don't care

cs	27
ds	35
ss	35
es	0
fs	0
gs	0

```
0     pushl $argv
      pushl $init
      pushl $0
      movl $SYS_exec,%eax
      int $64
      exit:
      movl $SYS_exit, %eax
      int $T_SYSCALL
      jmp exit

      init:
      .string "/init\0"

      .p2align 2
      argv:
      .long init
      .long 0


4095
```

The naive approach for the scheduler

```
movw $35,%ax
movw %ax, ds
movw %ax, ss  # Interrupts use the stack. We just ruined
movl  $4096,%esp

movl $0,%eax   # Much better to move eax to other regs
movl $0,%ecx
movl $0,%edx
movl $0,%ebx
movl $0,%ebp
movl $0,%esi
movl $0,%edi

movw %ax,%es
movw %ax,%fs
movw %ax,%gs

ljmp $27,$0
```

The problem

It is not possible to find a reasonable order to load:

- cs, eip.
- ss, esp.
- eflags (Containing the Interrupt flag).

What the hardware should provide us with?

- The **iret** instruction fits the bill.

iret instruction in kernel mode

Implied stack operands:

	31	9	2	1 0
esp				
ss	unused	gdt index	0	11
eflags				
cs	unused	gdt index	0	11
esp →eip				

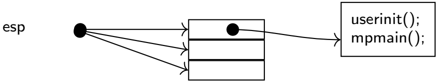
The operands are loaded into the appropriate registers and POPped of the stack.

Working Approach for the scheduler!!

```
pushl   $4096
pushl   $35
pushl   $512
pushl   $27
pushl   $0

iret
```

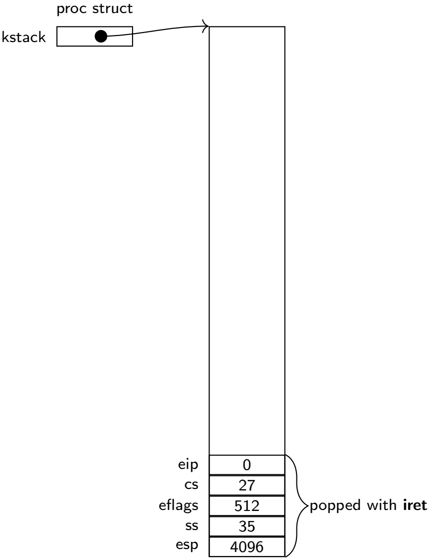
- **We are not the scheduler!**

Current stack



What do we do??

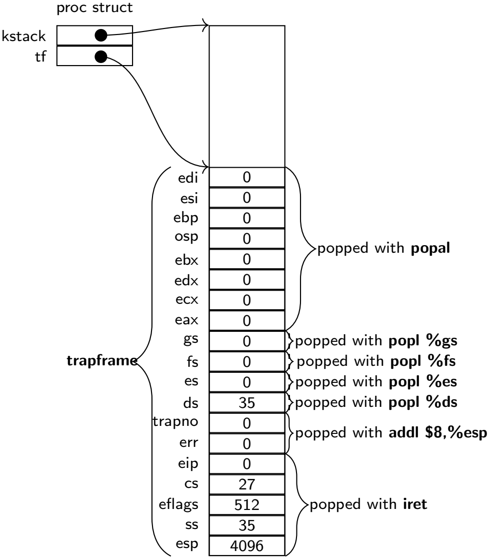
Build kernel stack for the first process



- We expect the scheduler to execute **iret** with its **esp** pointing to the **eip** field.
- We began the discussion with more registers.
- What about those other registers?
- The scheduler should load them with the prescribed values.
  - Ugly. Registers are being setup in two different places.

  OR
- We will put reigsters values on stack for all the registers!

Build kernel stack for first process



trapframe structure

```
struct trapframe {
  uint edi;
  uint esi;
  uint ebp;
  uint oesp;
  uint ebx;
  uint edx;
  uint ecx;
  uint eax;

  ushort gs;
  ushort padding1;
  ushort fs;
  ushort padding2;
  ushort es;
  ushort padding3;
  ushort ds;
  ushort padding4;
  uint trapno;

  uint err;
  uint eip;
  ushort cs;
  ushort padding5;
  uint eflags;

  uint esp;
  ushort ss;
  ushort padding6;
};
```

Building trapframe example

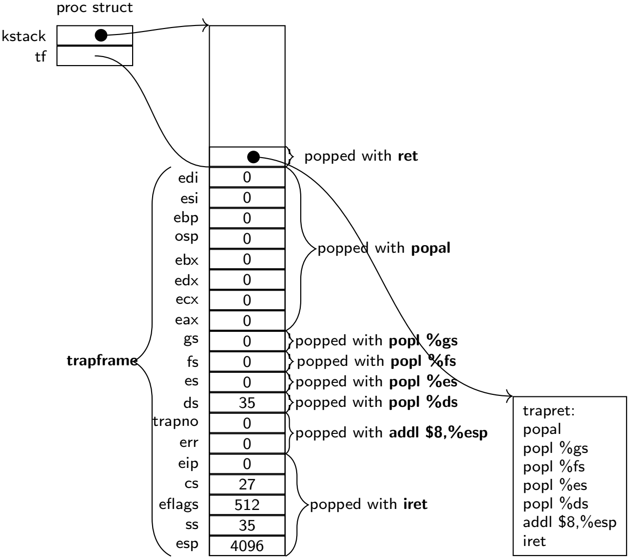
```
sp    = p->kstack + KSTACKSIZE;
sp   -= sizeof *p->tf;
p->tf = (struct trapframe*)sp;
memset(p->tf, 0, sizeof *p->tf);

p->tf->cs = (SEG_UCODE << 3) | DPL_USER;
p->tf->ds = (SEG_UDATA << 3) | DPL_USER;
p->tf->es = p->tf->ds;
p->tf->ss = p->tf->ds;
p->tf->eflags = FL_IF;
p->tf->esp = PGSIZE;
p->tf->eip = 0; // beginning of initcode.S
```

- So, the code the scheduler is supposed to execute is:

```
popal
popl %gs
popl %fs
popl %es
popl %ds
addl $8,%esp
iret
```

- For the sake of generality, we leave the address of this code on the stack.

Build kernel stack for first process



		popped with **ret**
edi	0	popped with **popal**
esi	0	
ebp	0	
osp	0	
ebx	0	
edx	0	
ecx	0	
eax	0	
gs	0	popped with **popl %gs**
fs	0	popped with **popl %fs**
es	0	popped with **popl %es**
ds	35	popped with **popl %ds**
trapno	0	popped with **addl $8,%esp**
err	0	
eip	0	popped with **iret**
cs	27	
eflags	512	
ss	35	
esp	4096	

```
trapret:
popal
popl %gs
popl %fs
popl %es
popl %ds
addl $8,%esp
iret
```

trapret pointer setting

```
sp -= 4;
*sp = trapret;
```

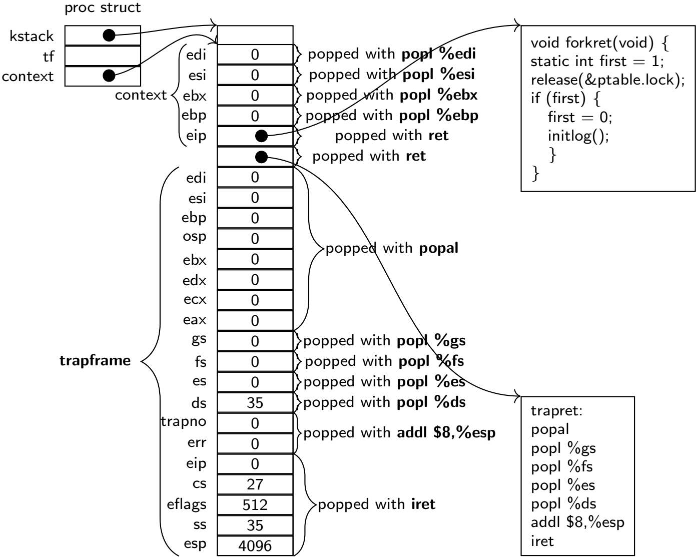
A word of caution

- The real reason behind the **trapframe** construction is the interrupt servicing code.
- Wait for the real reasoning until there.

The **context** struct

- The **xv6** machinery is more general than the above.
- The scheduler has a context of its own.
- Using just **trapframe** will cause the scheduler to loose context.
- So, a **context** struct is pushed on the stack in order to preserve context.

Build kernel stack for the first process



context	edi	0	popped with **popl %edi**
	esi	0	popped with **popl %esi**
	ebx	0	popped with **popl %ebx**
	ebp	0	popped with **popl %ebp**
	eip	●	popped with **ret**
		●	popped with **ret**
trapframe	edi	0	popped with **popal**
	esi	0	
	ebp	0	
	osp	0	
	ebx	0	
	edx	0	
	ecx	0	
	eax	0	
	gs	0	popped with **popl %gs**
	fs	0	popped with **popl %fs**
	es	0	popped with **popl %es**
	ds	35	popped with **popl %ds**
	trapno	0	popped with **addl $8,%esp**
	err	0	
	eip	0	popped with **iret**
	cs	27	
	eflags	512	
	ss	35	
	esp	4096	

```
void forkret(void) {
static int first = 1;
release(&ptable.lock);
if (first) {
   first = 0;
   initlog();
   }
}
```

```
trapret:
popal
popl %gs
popl %fs
popl %es
popl %ds
addl $8,%esp
iret
```

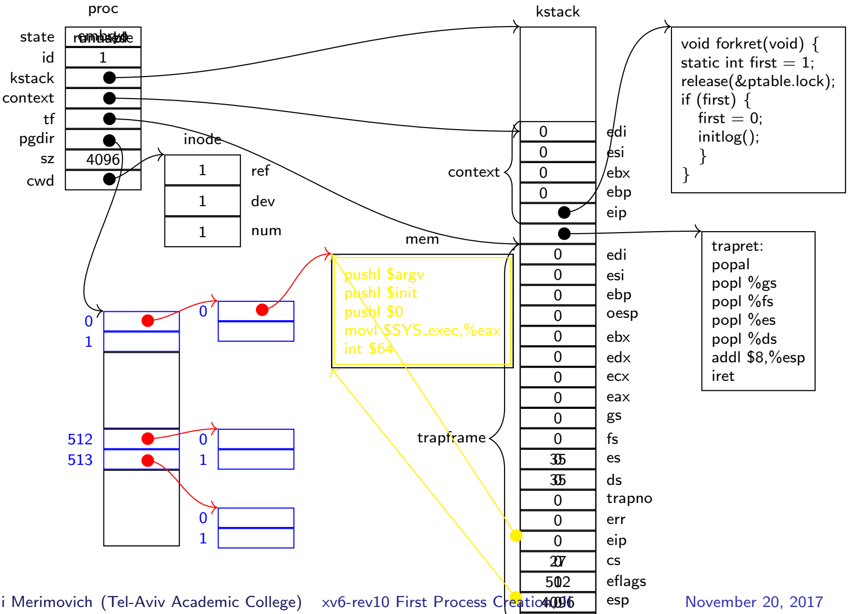
context structure

```
struct context {
 uint edi;
 uint esi;
 uint ebx;
 uint ebp;
 uint eip;
};
```

Bulding the **context** structure

```
sp -= sizeof *p->context;
p->context = sp;
memset(p->context, 0, sizeof(*p->context));
p->context->eip = forkret;
```

The whole first process creation



proc	
state	embryo runnable
id	1
kstack	●
context	●
tf	●
pgdir	●
sz	4096
cwd	●

inode	
1	ref
1	dev
1	num

kstack	
0	edi
0	esi
0	ebx
0	ebp
●	eip
●	
0	edi
0	esi
0	ebp
0	oesp
0	ebx
0	edx
0	ecx
0	eax
0	gs
0	fs
0 35	es
0 35	ds
0	trapno
0	err
0	eip
0 27	cs
0 512	eflags
0 4096	esp

```
pushl $argv
pushl $init
pushl $0
movl $SYS_exec,%eax
int $64
```

```
void forkret(void) {
static int first = 1;
release(&ptable.lock);
if (first) {
   first = 0;
   initlog();
   }
}
```

```
trapret:
popal
popl %gs
popl %fs
popl %es
popl %ds
addl $8,%esp
iret
```

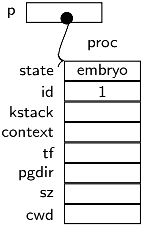
userinit()

- **allocproc()**: Allocate **proc** structure.
    - Allocate process kernel stack.
    - Leave space for a **trapframe** structure.
    - Build **context** structure on the stack.
- `setupkvm`: Create page table.
- `inituvm`: User space:
    - Allocate one page.
    - Copy user code to the allocated page.
    - Modify page table to use the allocated page.
- Set the `trapframe` so the user process will be able to run.

allocproc(): (1) Finding unused `proc` structure

```
2473 static struct proc *allocproc(void) {
      struct proc *p;
      char *sp;

      acquire(&ptable.lock);
      for(p = ptable.proc; p < &ptable.proc[NPROC]; p++)
       if (p->state == UNUSED)
        goto found;
      release(&ptable.lock);
      return 0;

     found:
      p->state = EMBRYO;
      p->pid = nextpid++;
      release(&ptable.lock);
```

allocproc(): (1) Operation



p

proc

state	embryo
id	1
kstack	
context	
tf	
pgdir	
sz	
cwd	

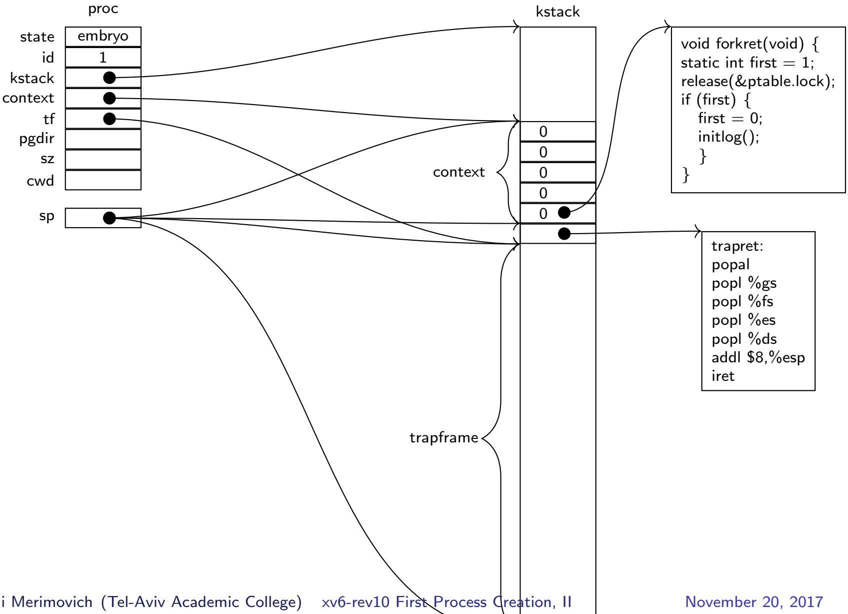
```
void forkret(void) {
static int first = 1;
release(&ptable.lock);
if (first) {
   first = 0;
   initlog();
   }
}
```

```
trapret:
popal
popl %gs
popl %fs
popl %es
popl %ds
addl $8,%esp
iret
```

allocproc: (2) Initialize process kernel stack

```
  if((p->kstack = kalloc()) == 0){
   p->state = UNUSED;
   return 0;
  }
  sp    = p->kstack + KSTACKSIZE;
  sp   -= sizeof *p->tf;
  p->tf = (struct trapframe*)sp;
  sp   -= 4;
  *(uint*)sp = (uint)trapret;
  sp   -= sizeof *p->context;
  p->context = (struct context*)sp;
  memset(p->context, 0, sizeof *p->context);
  p->context->eip = (uint)forkret;
  return p;
}
```

allocproc: (2) Operation



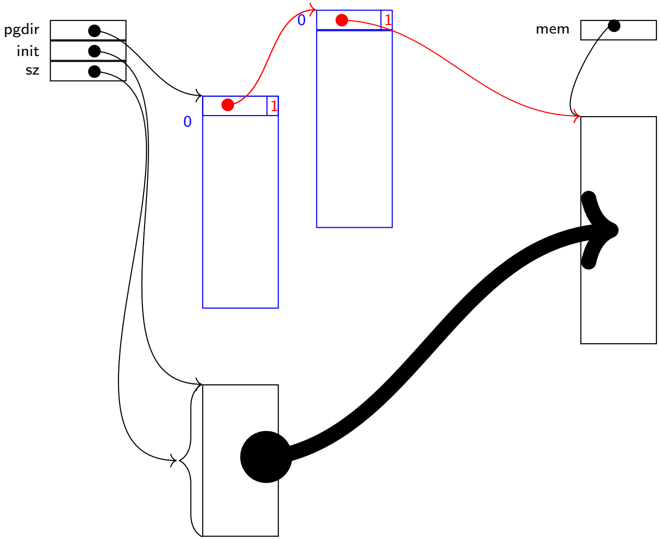
```
void forkret(void) {
static int first = 1;
release(&ptable.lock);
if (first) {
   first = 0;
   initlog();
   }
}
```

```
trapret:
popal
popl %gs
popl %fs
popl %es
popl %ds
addl $8,%esp
iret
```

inituvm

```
inituvm(pde_t *pgdir, char *init, uint sz)
{
 char *mem;

 if (sz >= PGSIZE)
  panic("inituvm:␣more␣than␣a␣page");
 mem = kalloc();
 memset(mem, 0, PGSIZE);
 mappages(pgdir, 0, PGSIZE, v2p(mem), PTE_W|PTE_U);
 memmove(mem, init, sz);
}
```

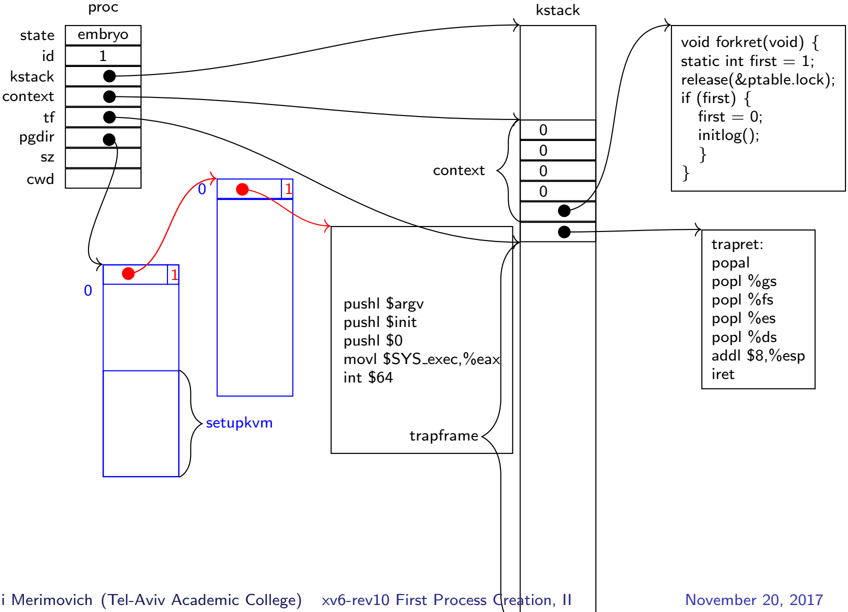
inituvm() operation



userinit(): (1) Invoking `allocproc` & `inituvm`

```
userinit(void) {
 struct proc *p;
 extern char _binary_initcode_start[],
             _binary_initcode_size[];

 p = allocproc();
 initproc = p;
 if ((p->pgdir = setupkvm()) == 0)
  panic("userinit: out of memory?");
 inituvm(p->pgdir, _binary_initcode_start,
               (int)_binary_initcode_size);
 p->sz = PGSIZE;
```

userinit(): (1) Operation



```
void forkret(void) {
static int first = 1;
release(&ptable.lock);
if (first) {
   first = 0;
   initlog();
   }
}
```

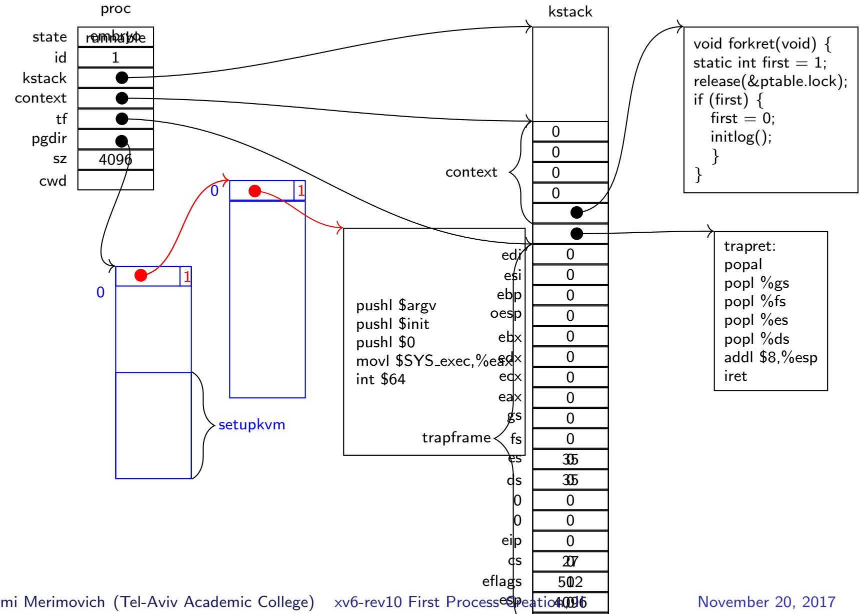
```
pushl $argv
pushl $init
pushl $0
movl $SYS_exec,%eax
int $64
```

```
trapret:
popal
popl %gs
popl %fs
popl %es
popl %ds
addl $8,%esp
iret
```

userinit(): (2) trapframe initialization

```
  memset(p->tf, 0, sizeof(*p->tf));
  p->tf->cs = (SEG_UCODE << 3) | DPL_USER;
  p->tf->ds = (SEG_UDATA << 3) | DPL_USER;
  p->tf->es = p->tf->ds;
  p->tf->ss = p->tf->ds;
  p->tf->eflags = FL_IF;
  p->tf->esp = PGSIZE;
  p->tf->eip = 0; // beginning of initcode.S
  p->cwd = namei("/");
  p->state = RUNNABLE;
}
```

userinit(): (2) Operation



```
void forkret(void) {
static int first = 1;
release(&ptable.lock);
if (first) {
   first = 0;
   initlog();
   }
}
```

```
pushl $argv
pushl $init
pushl $0
movl $SYS_exec,%eax
int $64
```

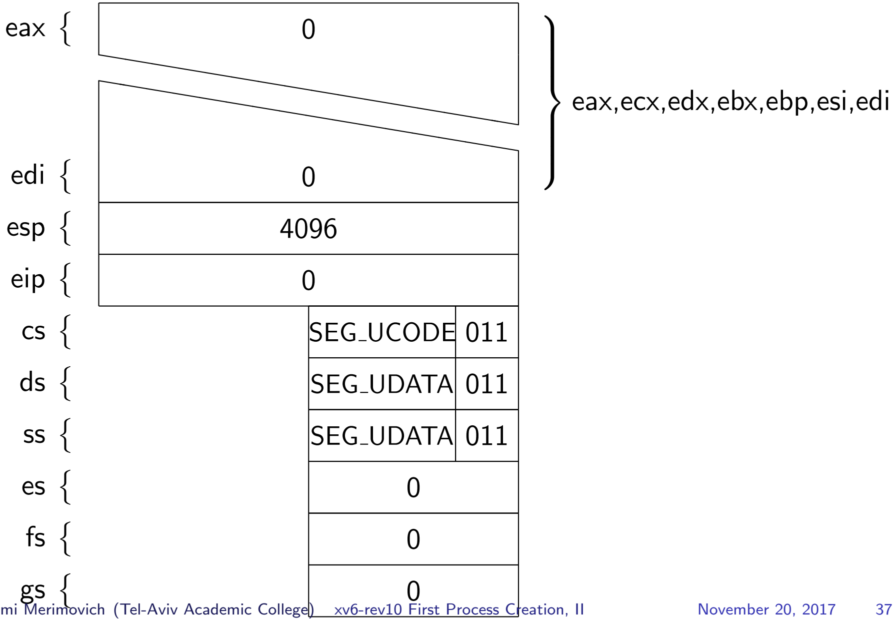
```
trapret:
popal
popl %gs
popl %fs
popl %es
popl %ds
addl $8,%esp
iret
```

trapret

```
3324 trapret:
  popal
  popl %gs
  popl %fs
  popl %es
  popl %ds
  addl $0x8, %esp # trapno and errcode
  iret
```

- What is the registers state after the `iret` instruction?

Registers after iret



eax	0	
edi	0	
esp	4096	
eip	0	
cs	SEG_UCODE	011
ds	SEG_UDATA	011
ss	SEG_UDATA	011
es	0	
fs	0	
gs	0	

Informing the CPU about safe stack

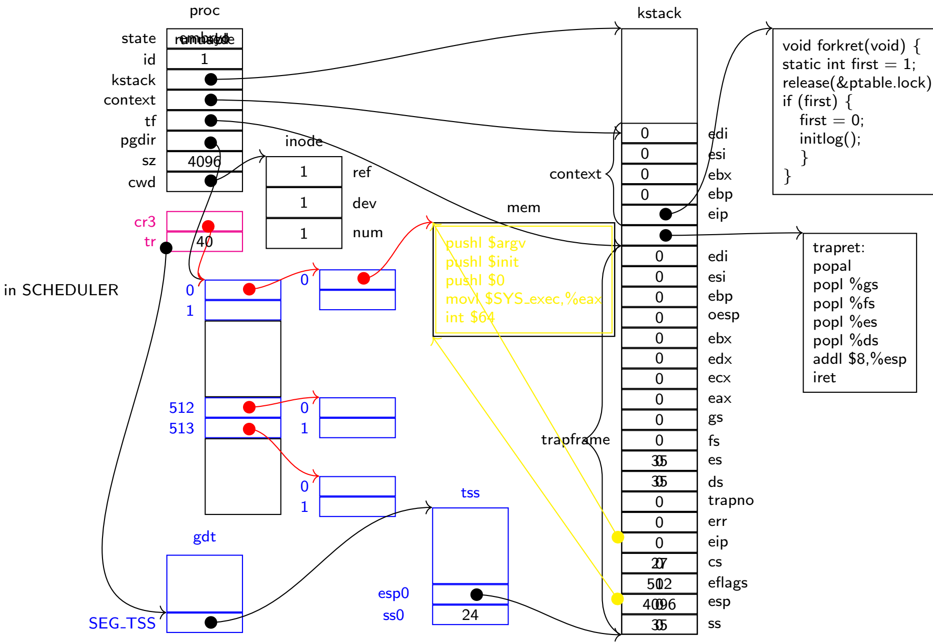
The PUSHAL/POPAL instructions

```
pushl %eax
pushl %ecx
pushl %edx
pushl %ebx
pushl %esp  !!!
pushl %ebp
pushl %esi
pushl %edi
```

```
popl %edi
popl %esi
popl %ebp
popl %esp
popl %ebx
popl %edx
popl %ecx
popl %eax
```

What now?

- How the kernel will return to run?
  - Only by interrupt service routine.
- Where is the interrupt service routine located?
  - Later topic,
- What happens to the stack when interrupt is delivered??
  - GOOD POINT.
  - Before going to user mode we set stack address for interrupts.



```
pushl $argv
pushl $init
pushl $0
movl $SYS_exec,%eax
int $64
```

```
void forkret(void) {
static int first = 1;
release(&ptable.lock);
if (first) {
   first = 0;
   initlog();
   }
}
```

```
trapret:
popal
popl %gs
popl %fs
popl %es
popl %ds
addl $8,%esp
iret
```