Operating Systems

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The Process Concept

- The OS creates number of virtual computers
- Execution of a program on one of these virtual computer is called a *sequential process*
- The virtual computer gives the illusion to each process that it is running on a dedicated CPU with a dedicated memory
- The actual CPU is switched back and forth among the processes (multiprogramming with time-sharing)
- Process memory is managed so that all the needed portions are present in the actual memory
- The virtual computer is the execution environment, the process is the executor, and the program being executed determines the process behavior

Programs and Processes

- Static object existing in a file
- A sequence of instruction
- Static existence in space & time
- Same program can be executed by different processes

- Dynamic object – program in execution
- A sequence of instruction executions
- Exists in limited span of time
- Same process may execute different program

```
main() {
   int i, prod = 1;
   for (i=0 ; i < 100; i++)
       prod = prod * i;
}
```

```
prod = prod*i;
```

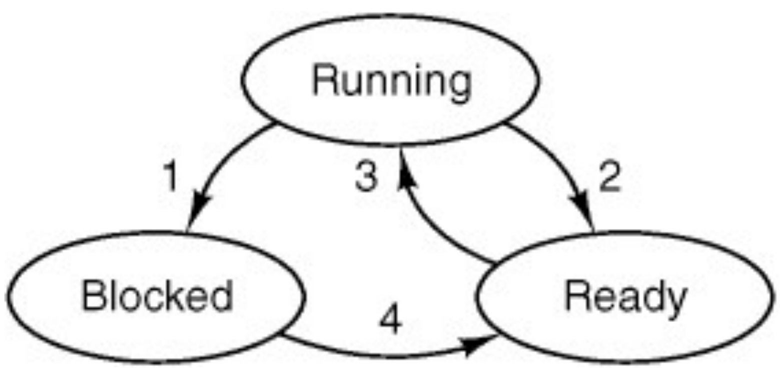
Process executes it 100 times

Process Life Cycle

- A process can be created
  - During OS initialization
    - “init” process in UNIX
  - By another process
    - fork(), or NtCreateProcess()
- A process can be terminated
  - By itself
    - exit(), or ExitProcess()
  - Because of an error
    - e.g., segmentation fault
  - By another process
    - kill(), TerminateProcess()

Process States

- Process states
  - Running (using the CPU)
  - Ready (waiting for the CPU)
  - Blocked (waiting for a resource to become available)



1. Process blocks for input
2. Scheduler picks another process
3. Scheduler picks this process
4. Input becomes available

Process States

- Process hierarchy
  - each process has a parent
  - each process can have many children
  - does not have to be like that (e.g., Windows NT)

- Parent must collect status of child processes
  - otherwise, children become *zombie* processes
  - what happens when parent dies first?

- How is signal delivery handled
  - I.e., do children receive signals of parents?

Process Implementation

- The OS maintains a *process table* with an entry for each process, called *Process Control Block* (PCB)

- The PCB contains:
  - Process ID, User ID, Group ID
  - Process state (Running, Ready, Blocked)
  - Registers (Program counter, PSW, Stack pointer, etc)
  - Pointers to memory segments (Stack, Heap, Data, Text)
  - Priority/Scheduling parameters
  - Accounting information
  - Signal management functions
  - Open file tables
  - Working directory

Process Implementation

- In Minix, different pieces of information about a process are stored in different parts of the OS

- Kernel
  - register values (PC, stack pointer, …)
  - scheduling information

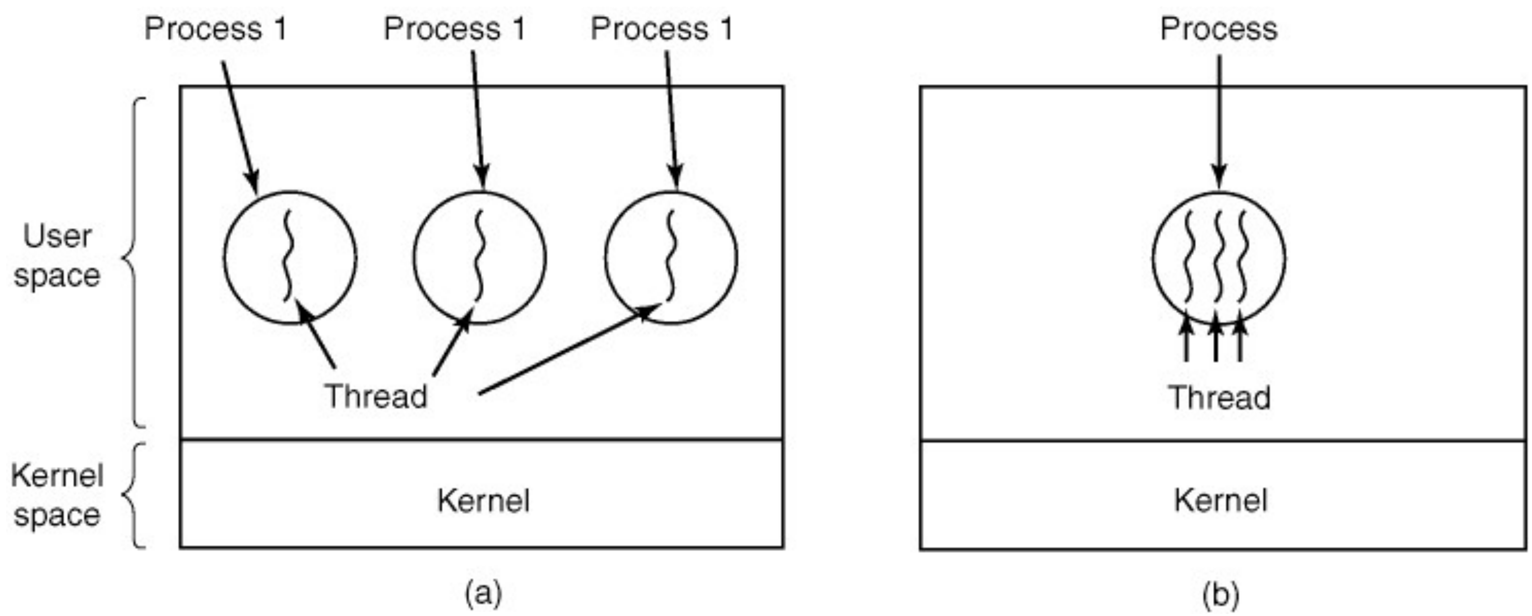
- Process management
  - memory information (pointers to text, data, bss segment)
  - IDs (UID, GID, …)

- File management
  - working directory
  - umask
  - file table

Threads

- A process is a way to
  - Group resources (memory, open files, ...)
  - Perform the execution of a program: a thread of execution (code, program counter, registers, stack)
- Multiple threads of execution can run in the same process environment
- Multiple threads share
  - Common address space (shared memory)
  - Open files
  - Process, user, and group IDs
- Each thread has its own code, program counter, set of registers, and stack

Threads


Process 1
Process 1
Process 1
User space
Thread
Kernel space
Kernel
(a)
Process
Thread
Kernel
(b)

Parallel Processes


```
1: int i;
2:
3: g()
4: {
5:     printf("Value of i is %d\n", i);
6: }
7:
8: f()
9: {
10:    g();
11: }
12:
13: int main(int argc, char **argv)
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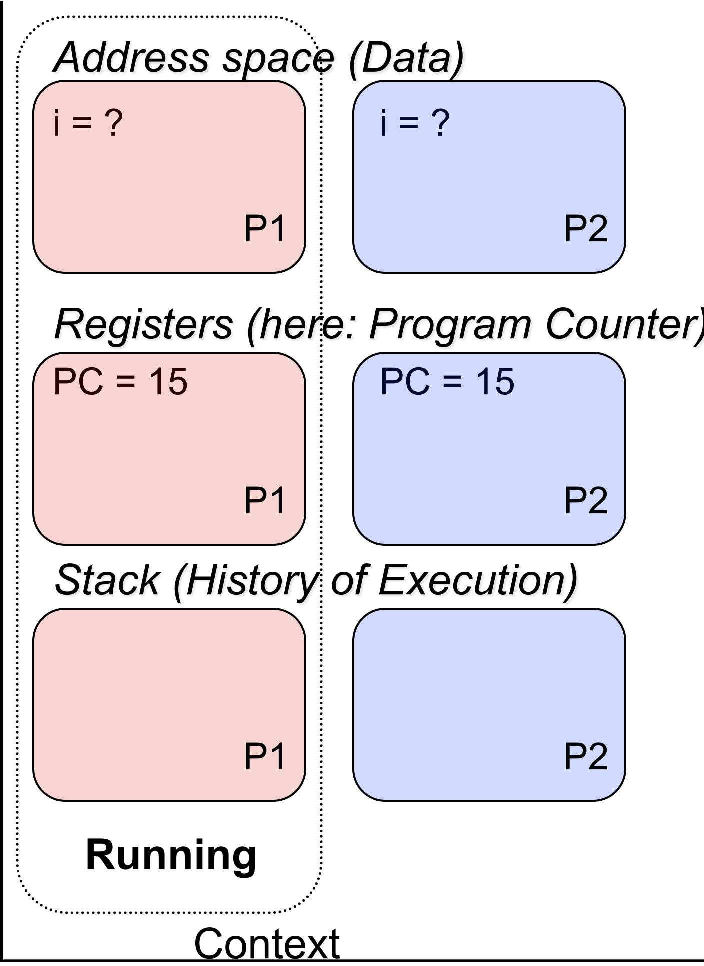

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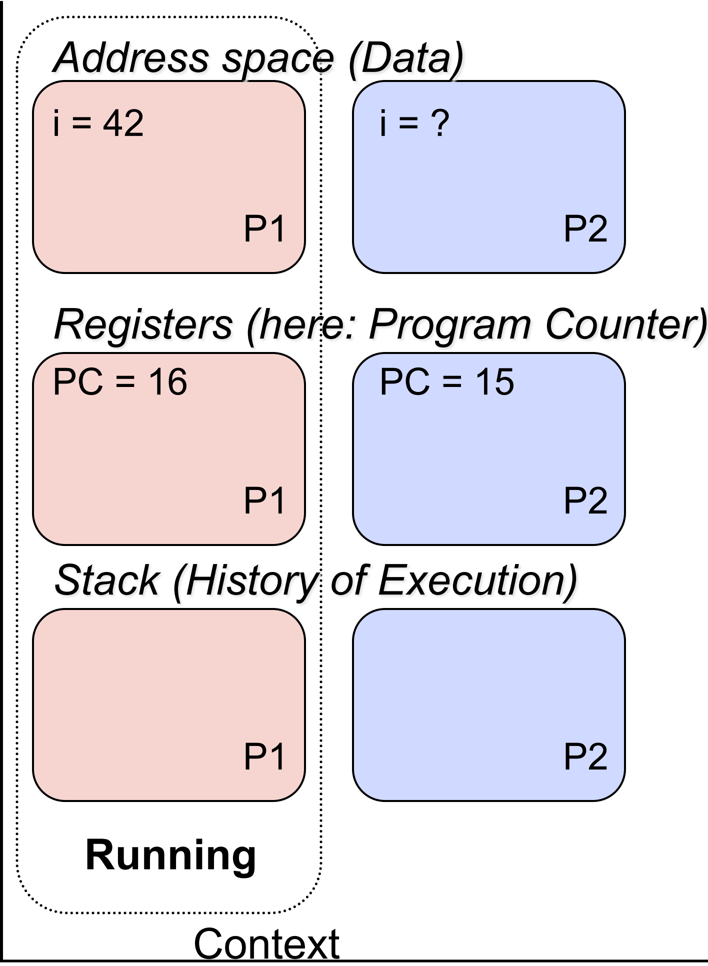

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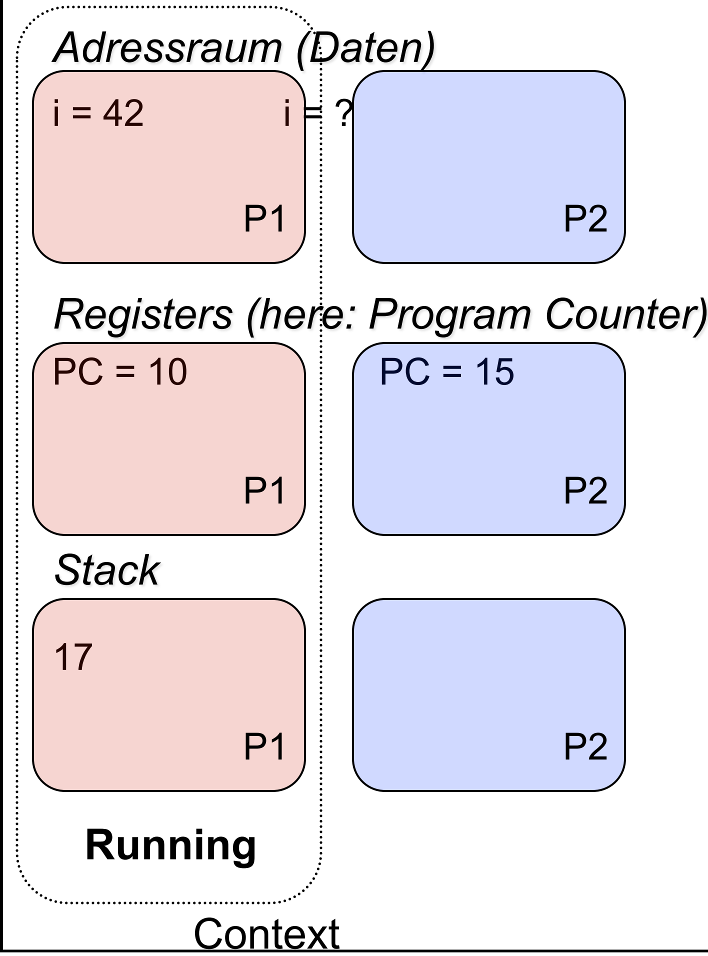

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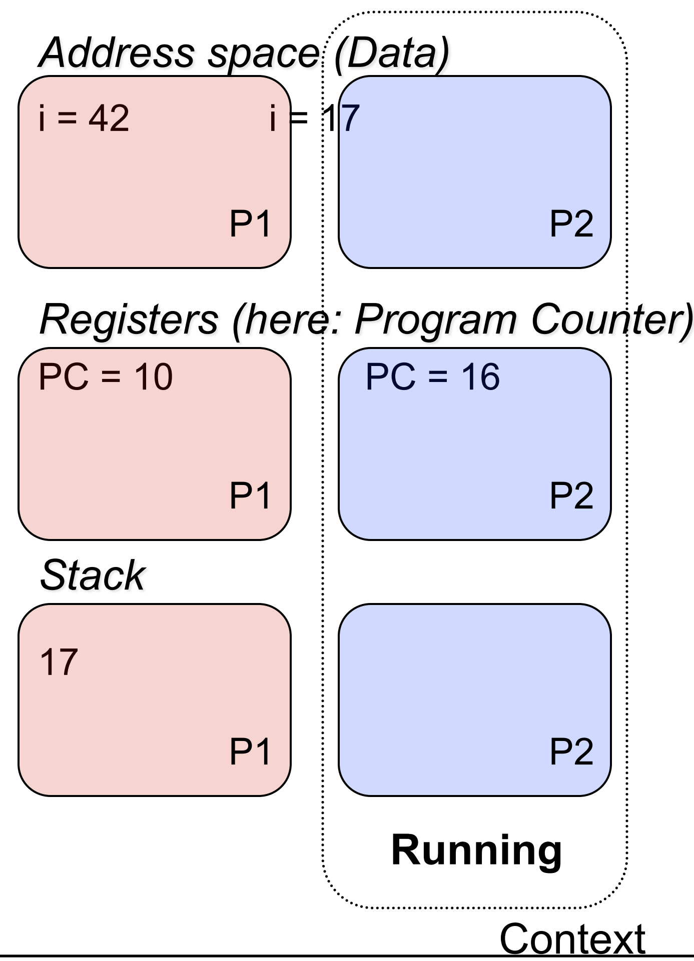

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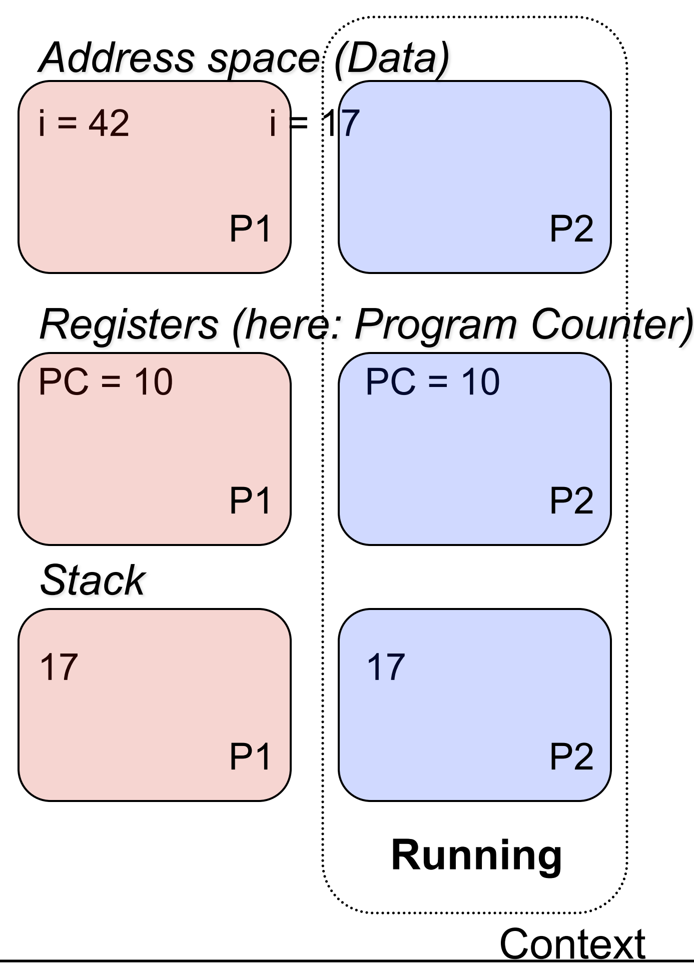

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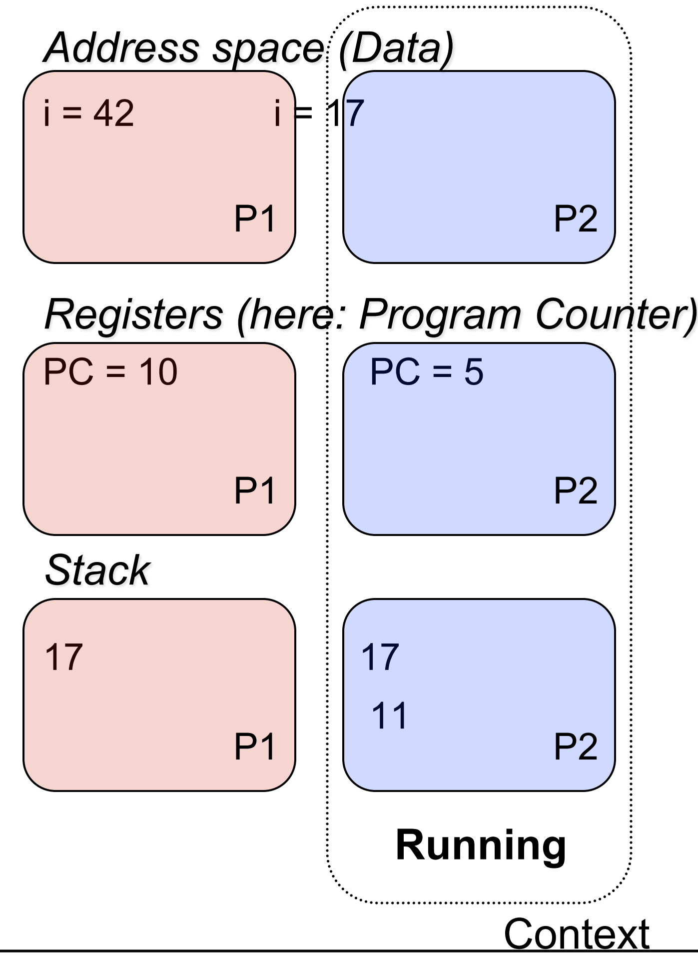

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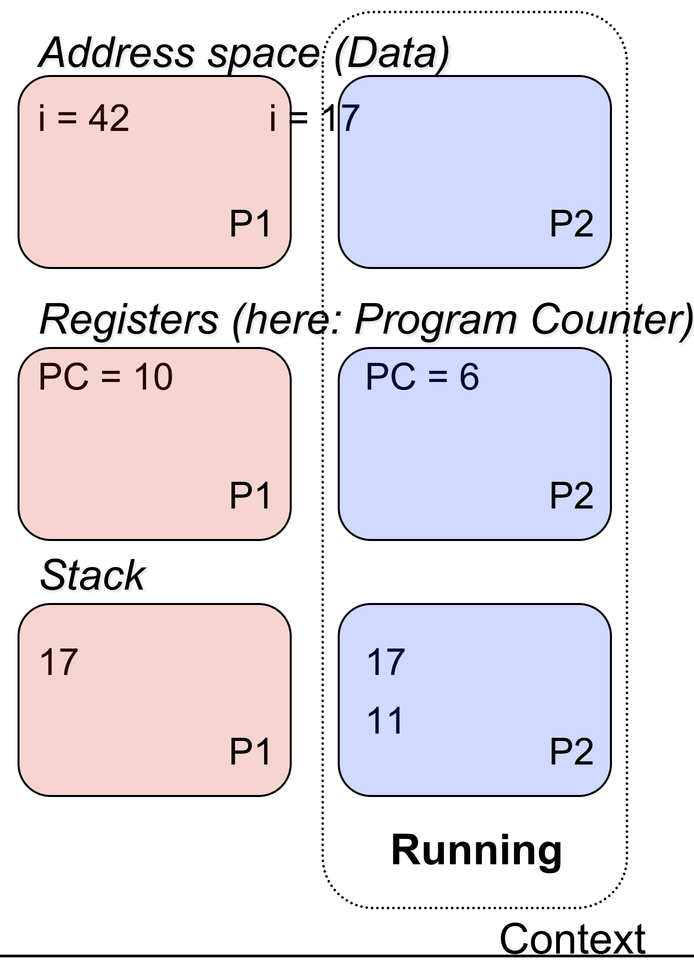
Value of i is 17



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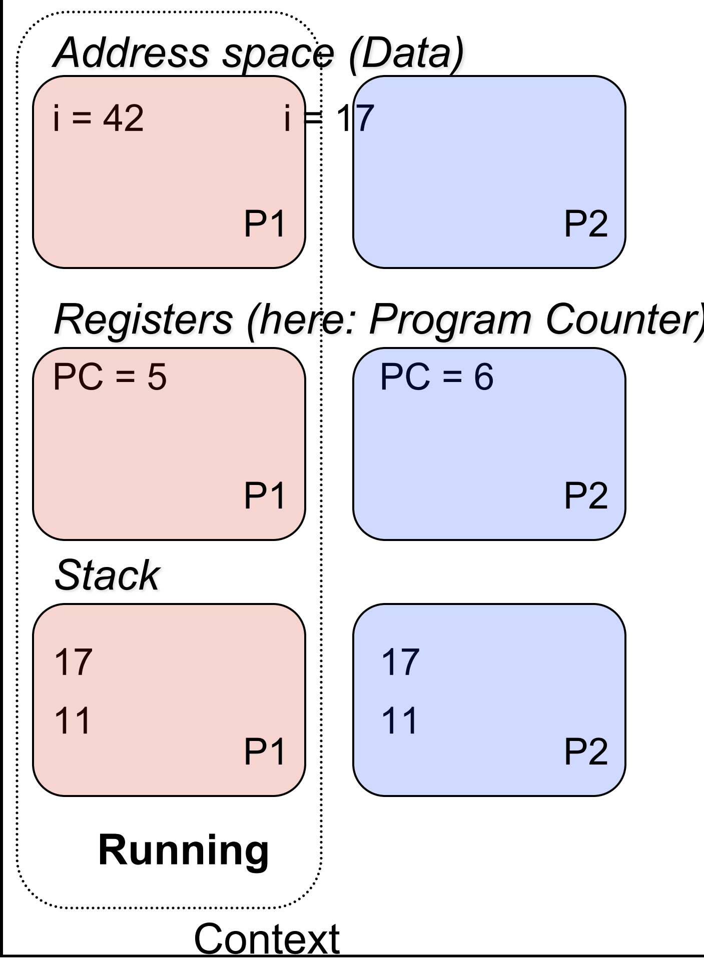

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Value of i is 42

Address space (Data)

i = 42 P1

i = 17 P2

Registers (here: Program Counter)

PC = 6 P1

PC = 6 P2

Stack

17
11
P1

17
11
P2

Running

Context

Threads


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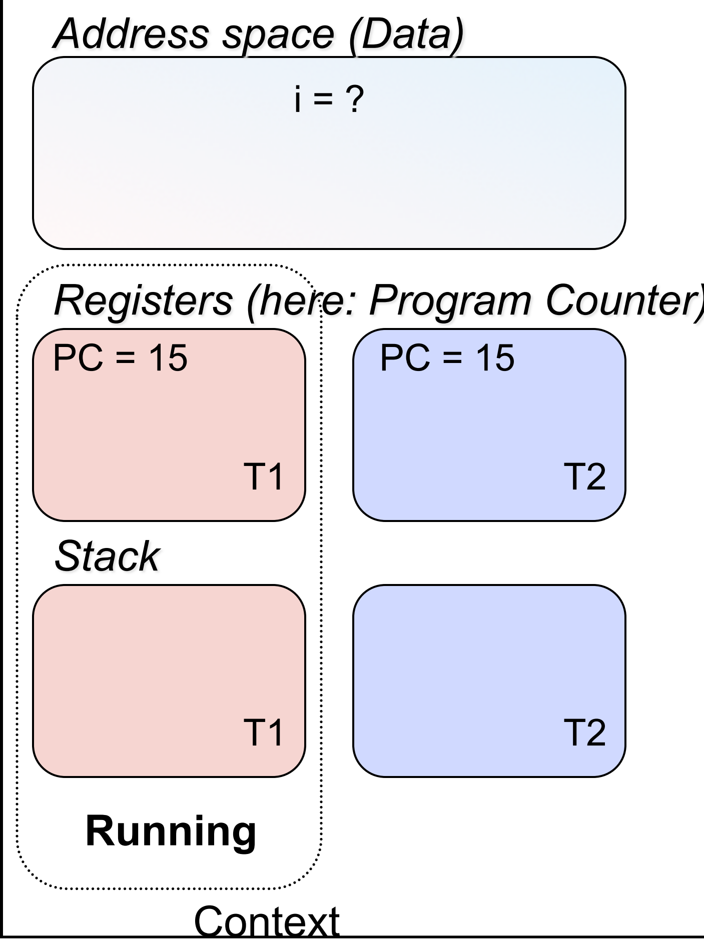

Threads

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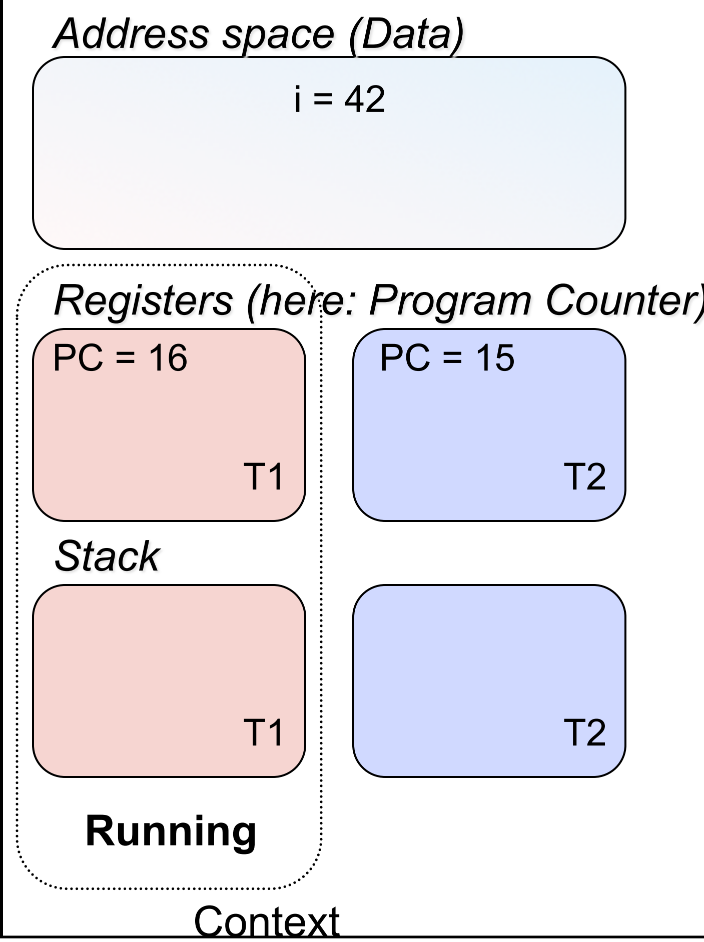

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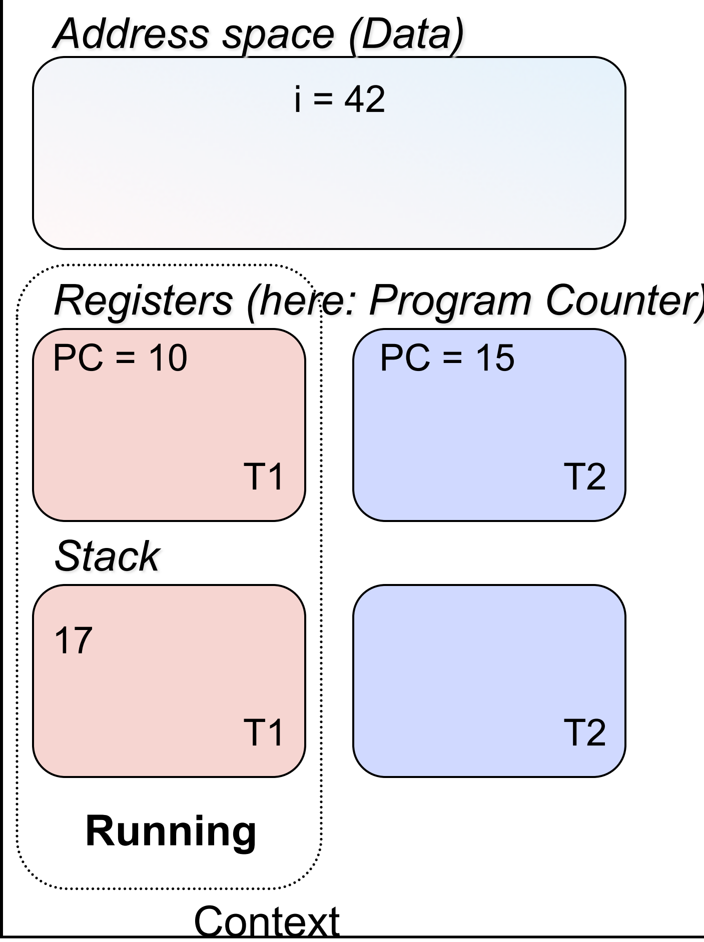

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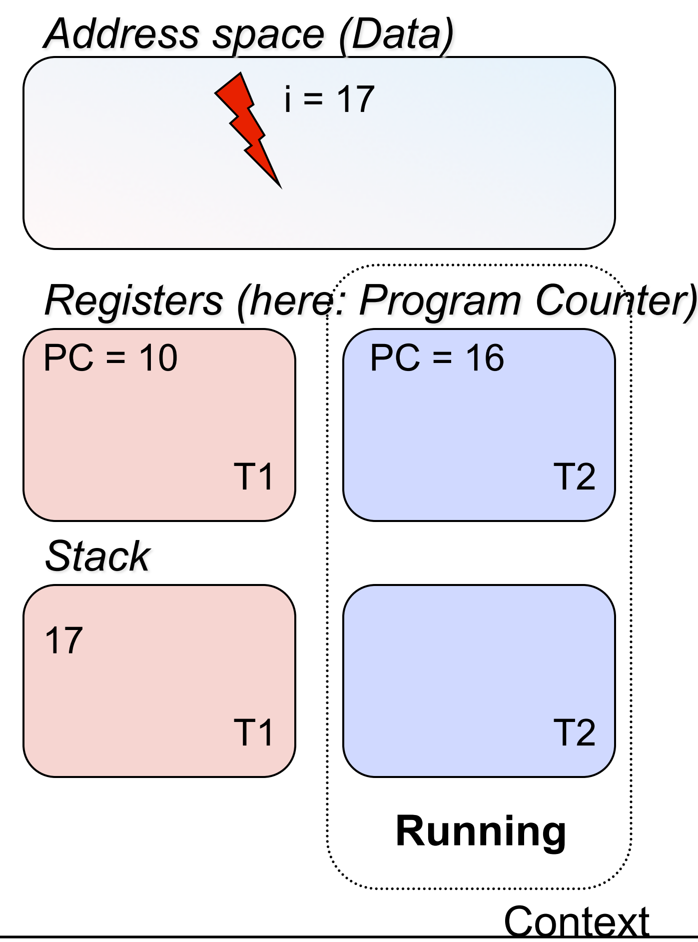

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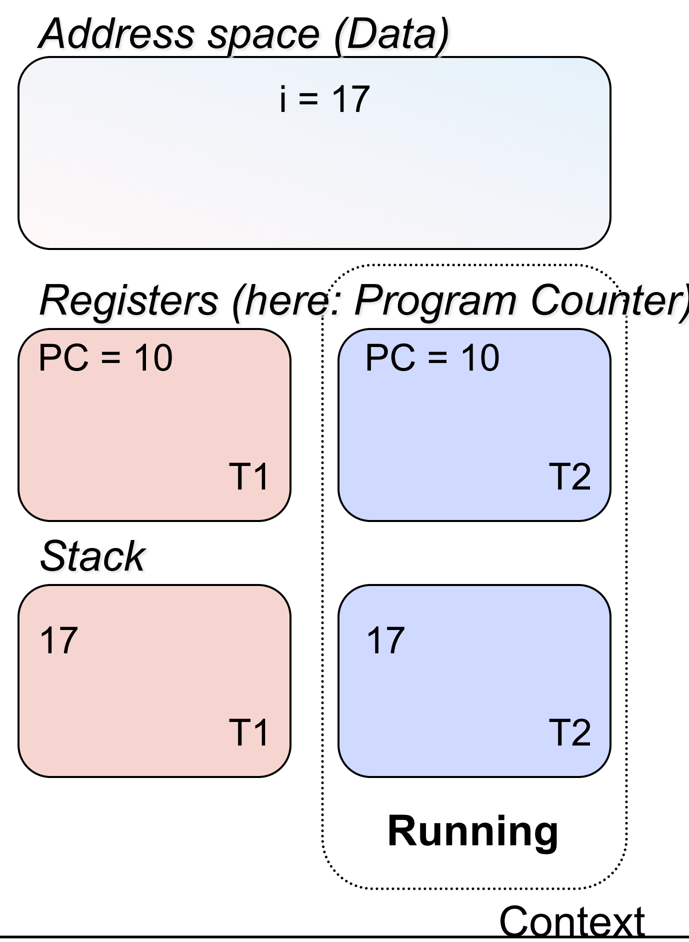

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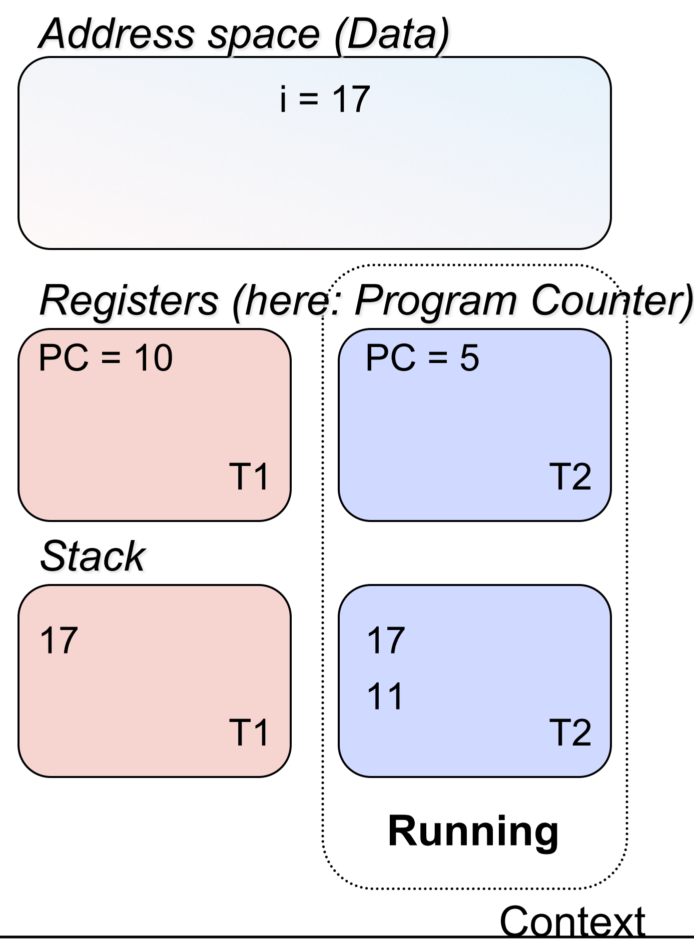

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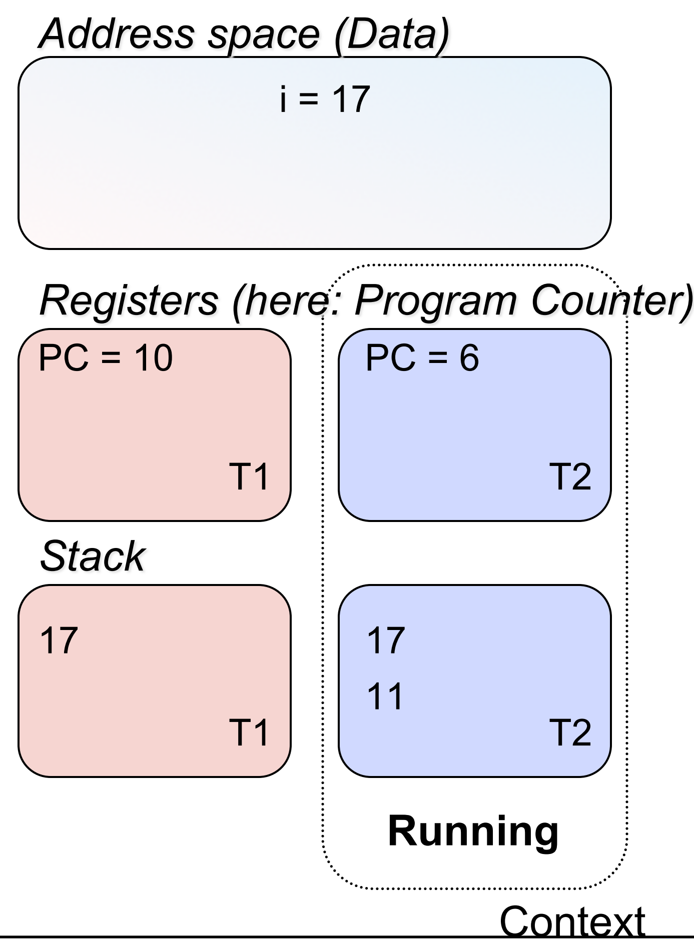

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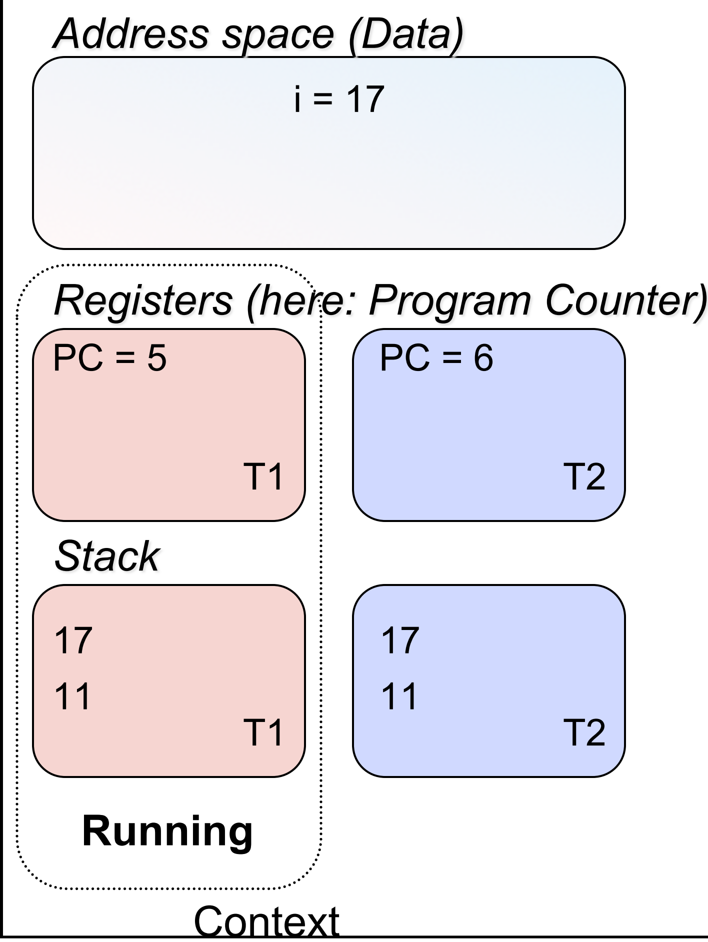

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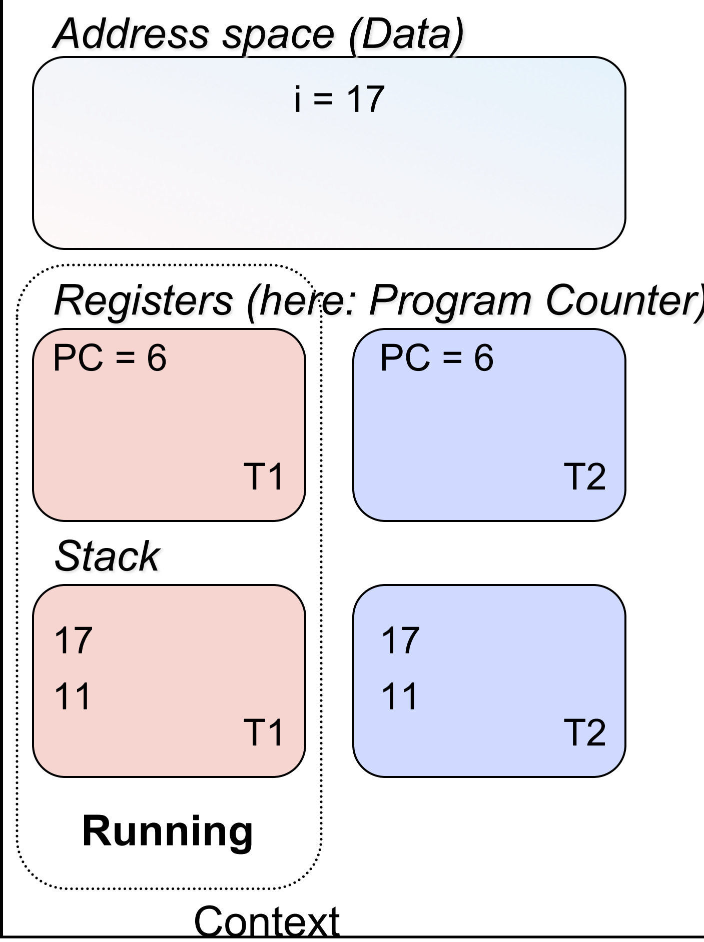

Why Threads?

- Useful to structure applications that have to do many things concurrently
  - One thread is waiting for I/O
  - Another thread *in the same process* is doing some computation
- Having threads share common address space makes it easier to coordinate activities
- Use a shared data-structure through which the processes can be coordinated:
  - Producer-Consumer interactions
  - Shared data structures/counts
- More efficient than using processes (context switch is faster)

Thread Primitives

- thread_create
- thread_exit
- thread_join
- thread_yield

(synchronization primitives)

Thread Implementation

- Threads can be implemented in user space
  - Pros
    - Performance (no kernel/user switch)
    - Portability (same primitives for every environment)
    - Flexibility (custom scheduling algorithm)
  - Cons
    - Blocking system calls block the process, not the thread
      - need to check if a system call would block before each invocation
    - Threads cannot be easily preempted (they have to *yield*)

Thread Implementation

- Threads can be implemented in the kernel
  - Pros
    - Blocking system calls suspend the calling thread only
    - Can take advantage of multiple CPUs
    - Signals can be delivered more precisely
  - Cons
    - Can be heavy, not as flexible

Threading Issues

- What happens on a fork()?
  - only a single thread is created in the child
- What happens with shared data structures and files?
  - threads need to be careful and synchronize access
- What about stack management?
  - each thread needs its own stack
- What about signal delivery?
  - complicated!
  - some signals are sent to specific thread (alarm, segfault)
  - others to the first that does not block them (termination request)

Reentrant Functions

- What about global variables in libraries?
  - functions need to be reentrant
- Some functions are not designed to be invoked concurrently
  - Use of global variables, such as *errno*
- Functions used by threads need to be *reentrant*

Portability Issues and Pthreads

- POSIX 1003.1c (a.k.a. pthreads) is an API for multi-threaded programming standardized by IEEE as part of the POSIX standards
- Most Unix vendors have endorsed the POSIX 1003.1c standard
- Implementations of 1003.1c API are available for many UNIX systems
- pthreads defines an interface
  - implementation can be done in either user or kernel space
- Thus, multithreaded programs using the 1003.1c API are likely to run unchanged on a wide variety of Unix platforms