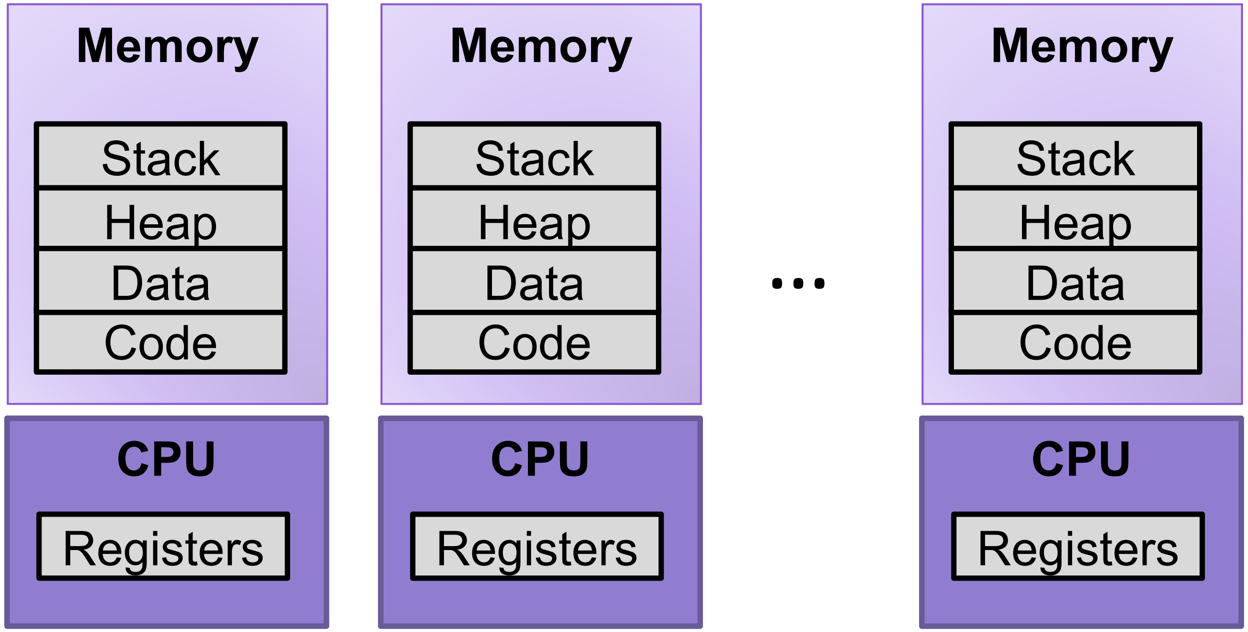
Lecture 17: Virtual Memory

CS 105

April 6, 2020

Multiprocessing: The Illusion

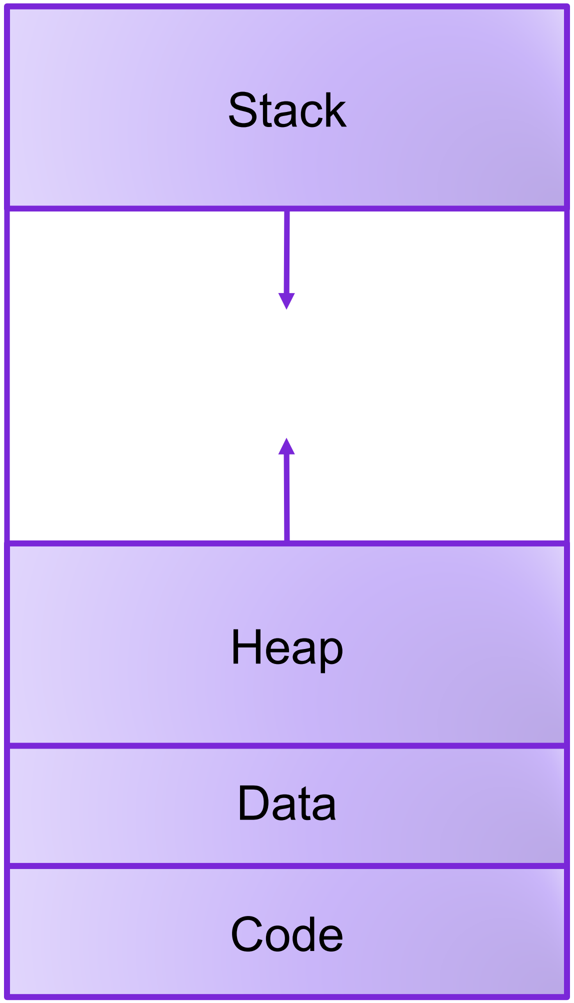


- Process provides each program with two key abstractions:
  - ***Logical control flow***
    - Each program seems to have exclusive use of the CPU
    - Provided by kernel mechanism called ***context switching***
  - ***Private address space***
    - Each program seems to have exclusive use of main memory.
    - Provided by kernel mechanism called ***virtual memory***

Multiprocessing: The Reality

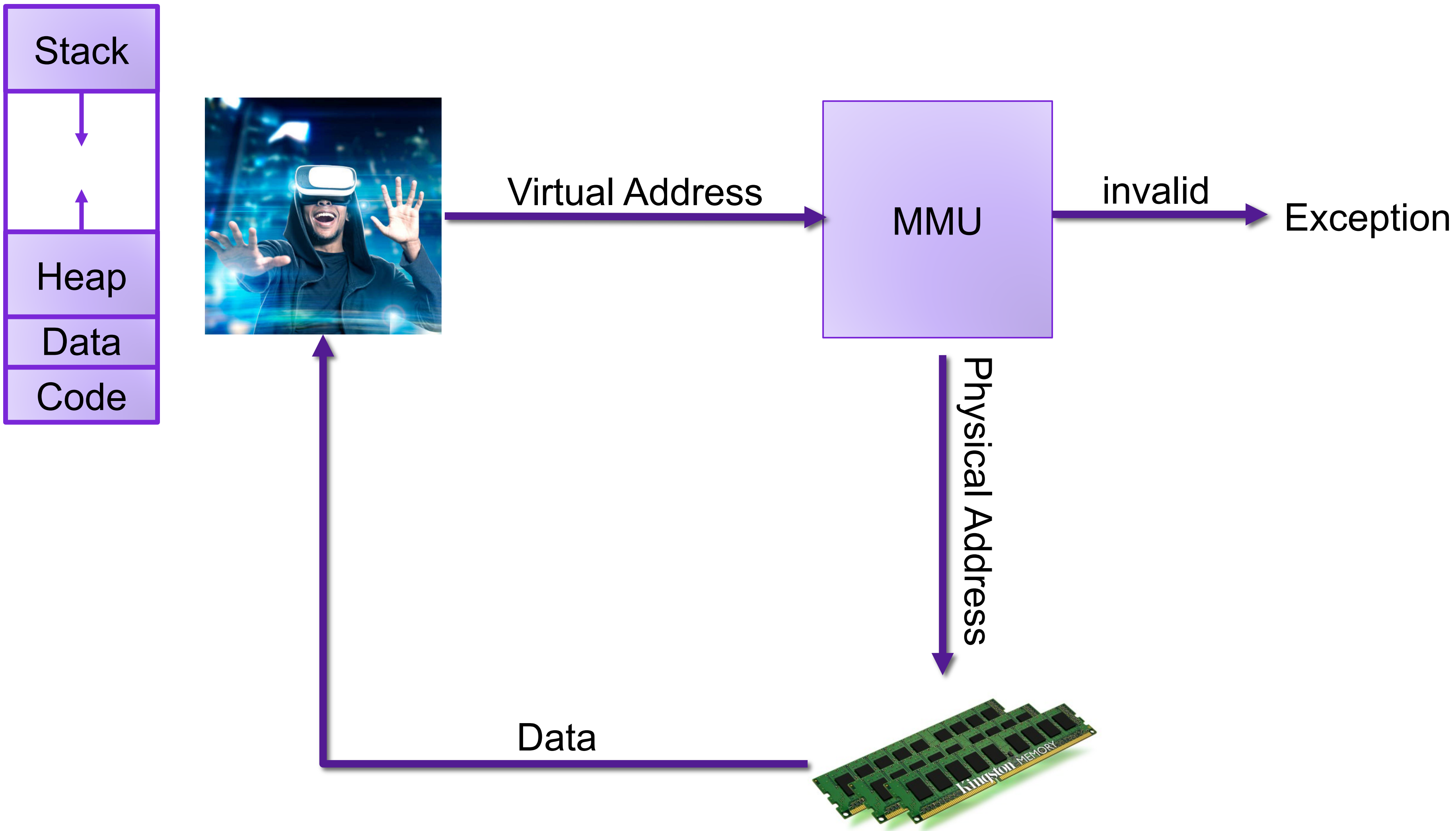
- Computer runs many processes simultaneously
- Running program “top” on Mac
  - System has 123 processes, 5 of which are active
  - Identified by Process ID (PID)

Virtual Memory Goals

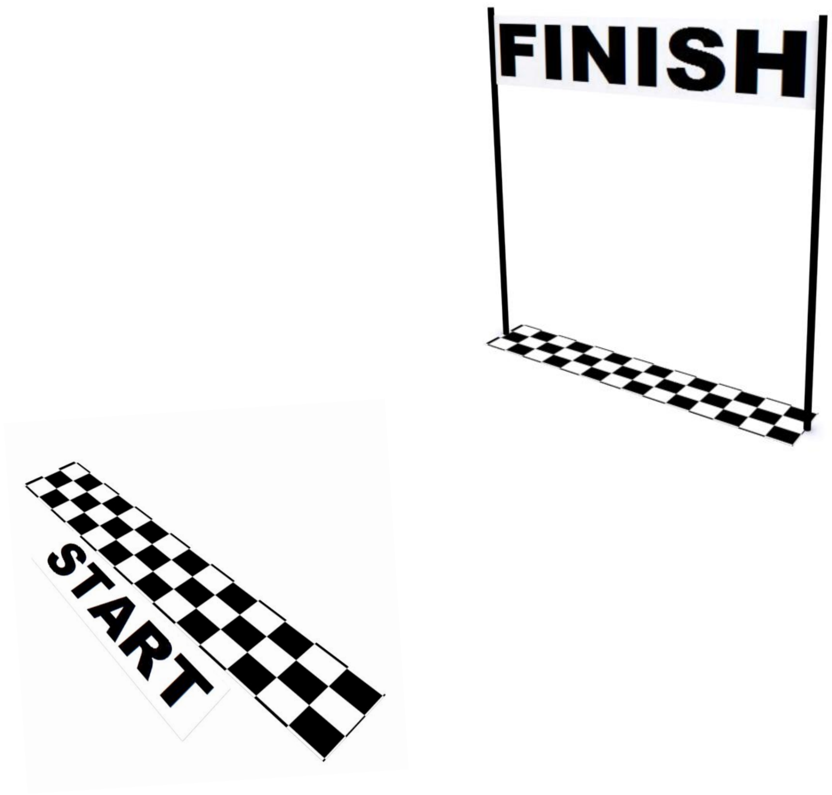


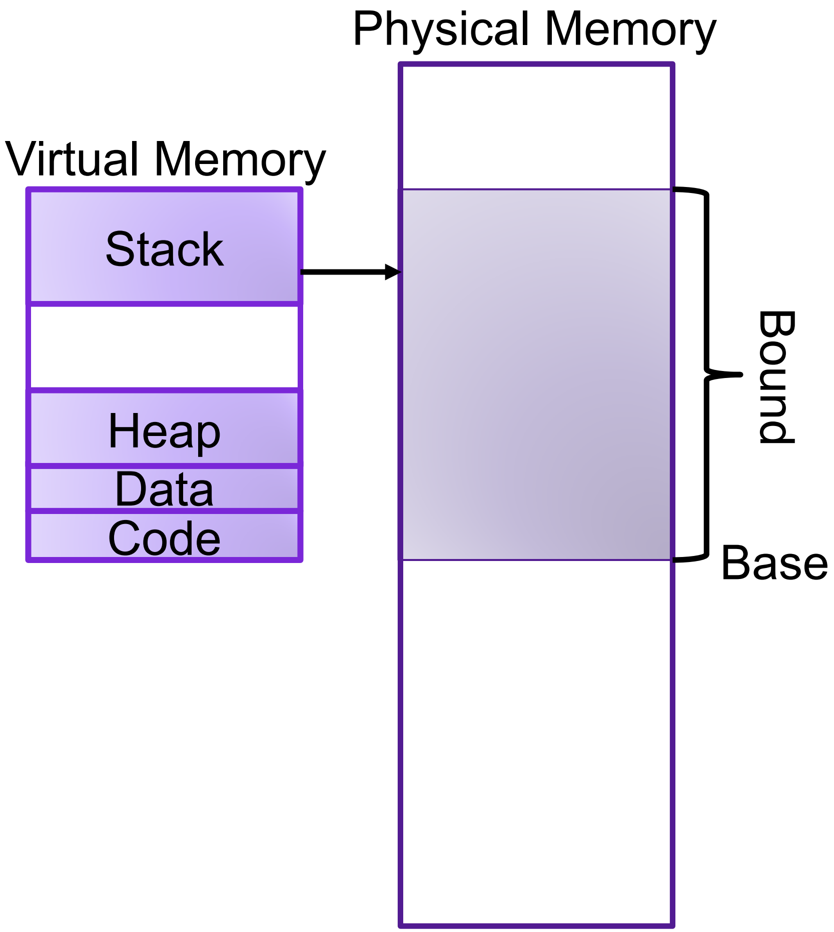
- **Isolation:** don't want different process states collided in physical memory
- **Efficiency:** want fast reads/writes to memory
- **Sharing:** want option to overlap for communication
- **Utilization:** want best use of limited resource
- **Virtualization:** want to create illusion of more resources

Address Translation

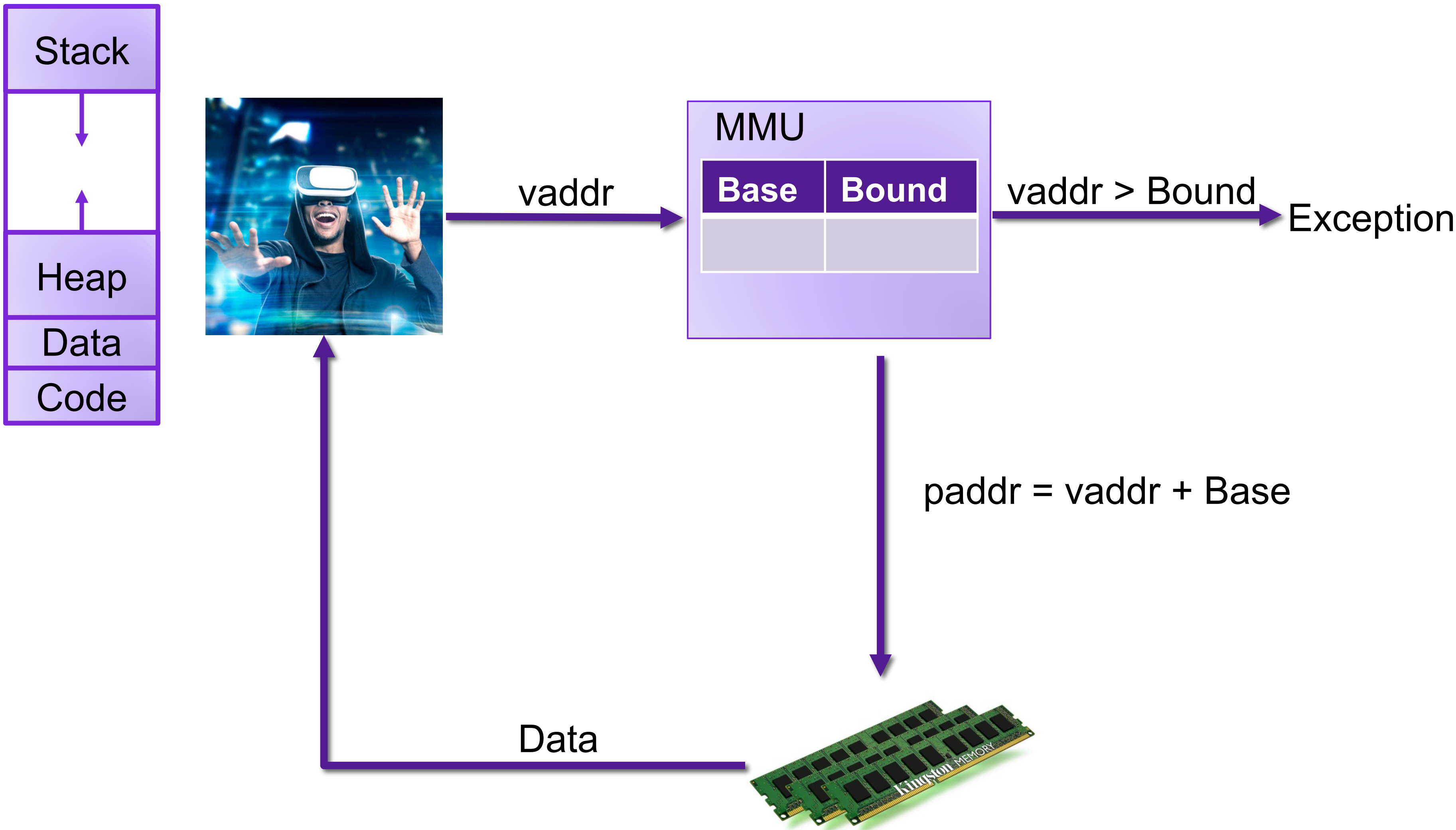


Base-and-Bound





Base-and-Bound

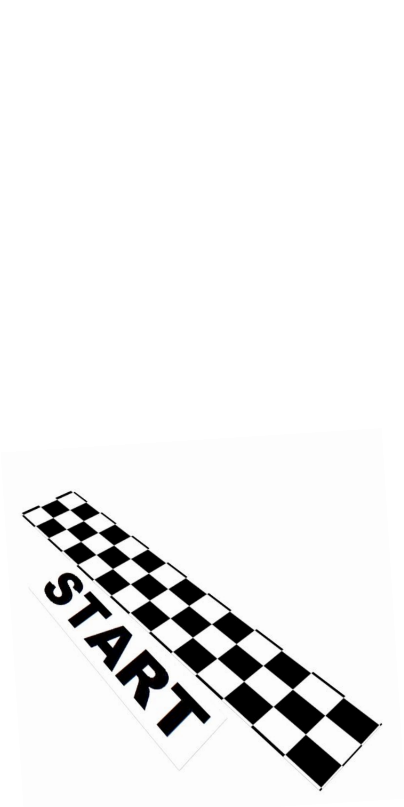


Exercise 1: Base-and-Bound

Assume that you are currently executing a process P with Base 0x1234 and Bound 0x100.

- What is the physical address that corresponds to the virtual address 0x47?
- What is the physical address that corresponds to the virtual address 0x123?

Evaluating Base-and-Bound



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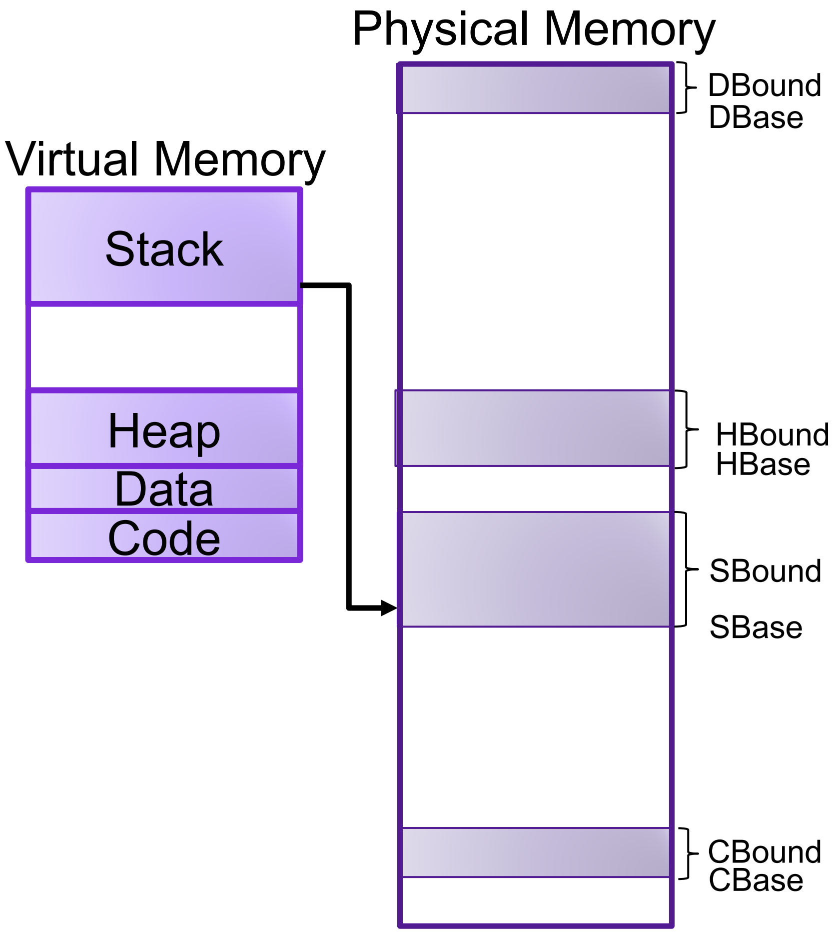
Segmentation



Segmentation

Stack

Heap

Data

Code

idx	offset

vaddr

MMU

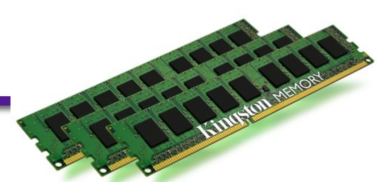
Base	Bound	Access
		R,W
		R,W
		R,W
		R,X

offset > Bound[idx]
or access not allowed

Exception

paddr = Base[idx] + offset

Data



Exercise 2: Segmentation

Assume that you are currently executing a process P with the following segment table:

Base	Bound	Access
0x4747	0x80	R,W
0x2424	0x40	R,W
0x0023	0x80	R,W
0x1000	0x100	R,X

- What is the physical address that corresponds to the virtual address 0x000?
- What is the physical address that corresponds to the virtual address 0xC47?

Evaluating Segmentation

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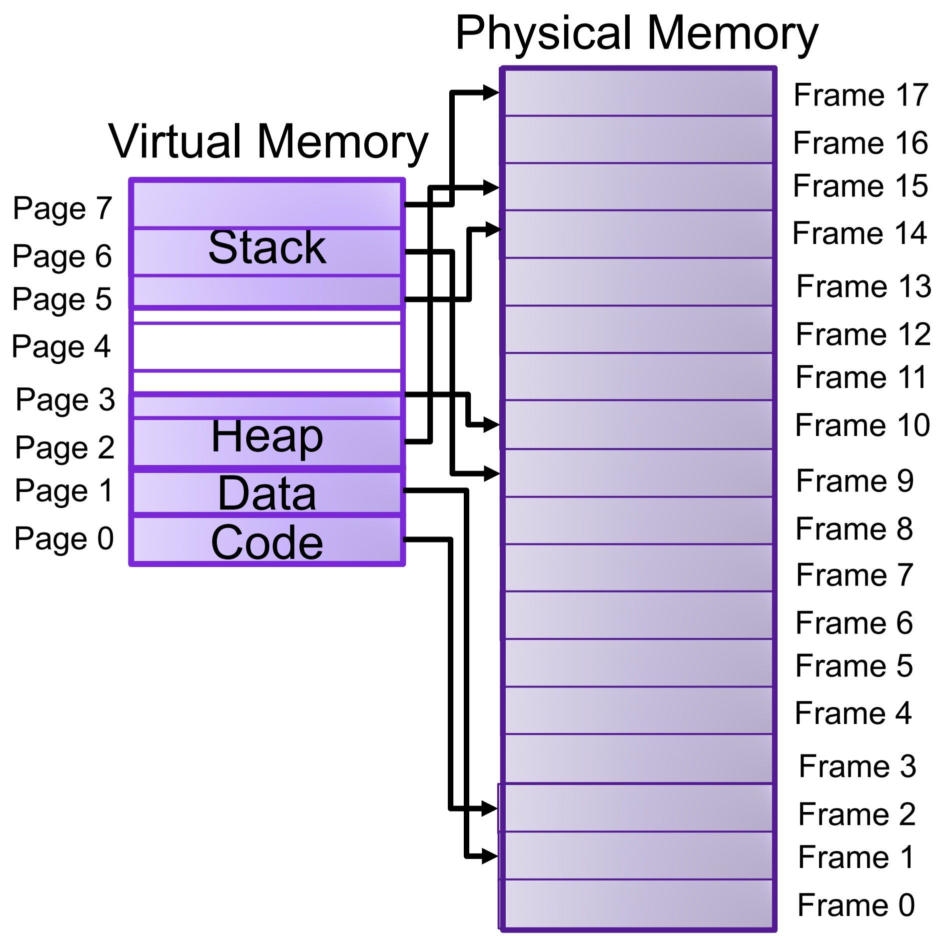
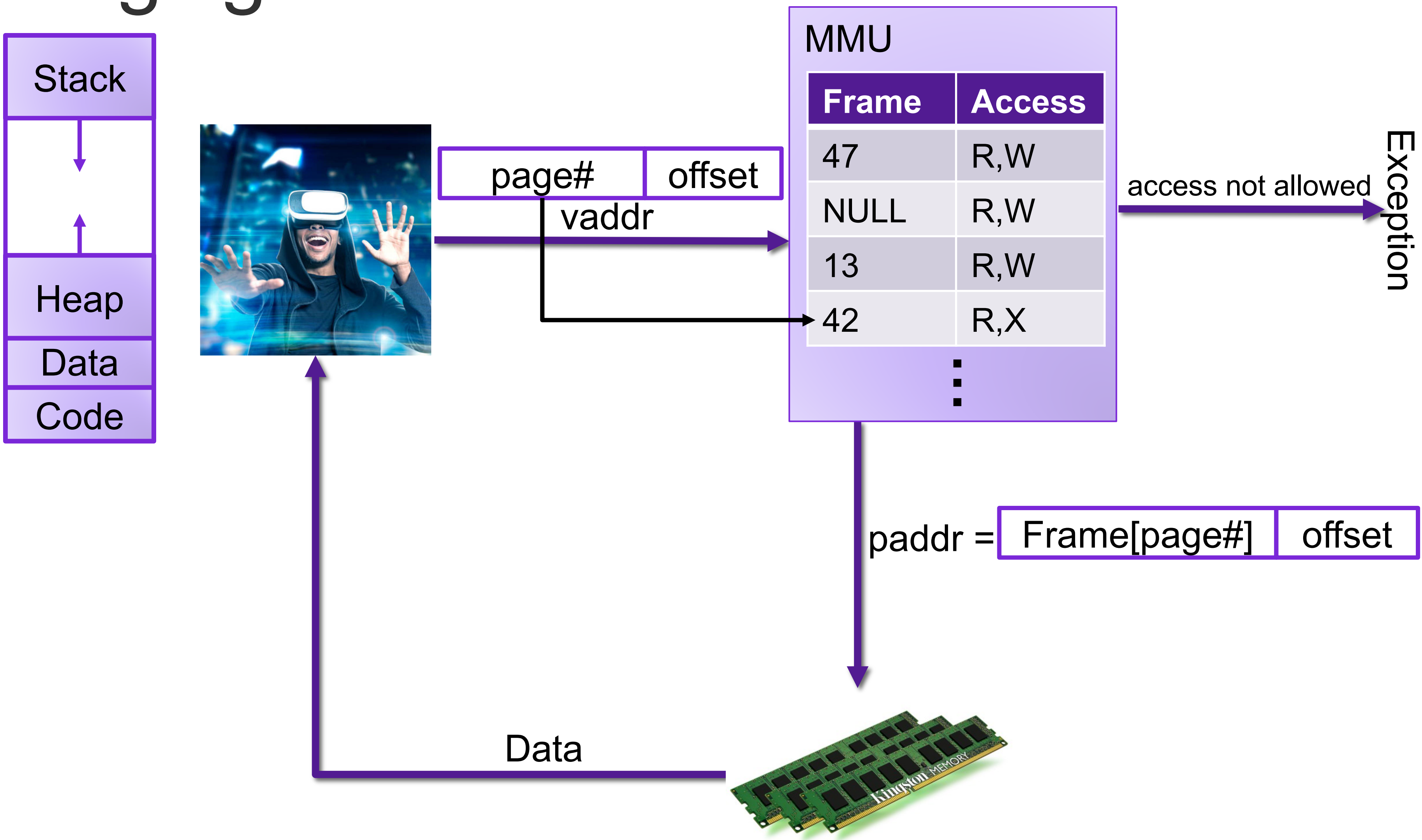
Paging


Physical Memory
Virtual Memory
Page 7
Page 6
Page 5
Page 4
Page 3
Page 2
Page 1
Page 0
Stack
Heap
Data
Code
Frame 17
Frame 16
Frame 15
Frame 14
Frame 13
Frame 12
Frame 11
Frame 10
Frame 9
Frame 8
Frame 7
Frame 6
Frame 5
Frame 4
Frame 3
Frame 2
Frame 1
Frame 0

Paging



Frame	Access
47	R,W
NULL	R,W
13	R,W
42	R,X
⋮	

Memory as a Cache

- each page table entry has a valid bit
- for valid entries, frame indicates physical address of page in memory
- a **page fault** occurs when a program requests a page that is not currently in memory
  - takes time to handle, so context switch
  - evict another page in memory to make space (which one?)

MMU

v	Frame	Access
1	47	R,W
0	NULL	R,W
0	13	R,W
1	42	R,X

⋮

Thrashing

- working set is the collection of a pages a process requires in a given time interval
- if it doesn't fit in memory, program will thrash

Exercise 3: Paging

Assume that you are currently executing a process P with the following page table on a system with 256 byte pages:

	v	Frame	Access
⋮			
250	1	0x47	R,W
249	1	0x24	R,W
248	0	NULL	R,W
247	0	0x23	R,X
⋮			

- What is the physical address that corresponds to the virtual address 0xF947?
- What is the physical address that corresponds to the virtual address 0xF700?

Evaluating Paging

- **Isolation:** don't want different process states collided in physical memory ✓
- **Efficiency:** want fast reads/writes to memory ✗
- **Sharing:** want option to overlap for communication ✓
- **Utilization:** want best use of limited resource ✓
- **Virtualization:** want to create illusion of more resources ✓

Exercise 4: Feedback

1. Rate how well you think this recorded lecture worked
    1. Better than an in-person class
    2. About as well as an in-person class
    3. Less well than an in-person class, but you still learned something
    4. Total waste of time, you didn't learn anything

2. Do you have any comments or suggestions for future classes?