



# CS 1550

Project 3-cont.

# Project 3 - Virtual Memory Simulator

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- No need to use qemu
- You will write the simulator from scratch with Java, c++,Perl, or Python
- Read from memory traces text files
- Count the number of events (pagefaults, page evictions, hits etc.)
  - Compare eviction algorithms

# Project 3 - Virtual Memory Simulator

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- Simulate memory page allocation and page eviction algorithm
  - Your program will read from a memory trace
  - You will implement how loaded pages are evicted

190a7c20 R  
3856bbe0 W  
190afc20 R  
15216f00 R  
190a7c20 R  
190a7c28 R  
190a7c28 R  
190aff38 R

# Project 3 - Virtual Memory Simulator

---

- Since it is a 32-bit address space.
  - First 20 bits is used for the address
  - The rest is used for offset

Page Address    Page offset

**190a7c20** R  
**3856bbe0** W  
**190afc20** R  
**15216f00** R  
**190a7c20** R  
**190a7c28** R  
**190a7c28** R  
**190aff38** R

# Project 3 - Virtual Memory Simulator

---

- Lets suppose you have 12KB of physical memory
  - Page has 4KB
  - Assume FIFO

0	
1	
2	

190a7c20 R  
3856bbe0 W  
190afc20 R  
15216f00 R  
190a7c20 R  
190a7c28 R  
190a7c28 R  
190aff38 R

# Project 3 - Virtual Memory Simulator

---

- Lets suppose you have 12KB of physical memory
  - Page has 4KB
  - Assume FIFO

0	
1	
2	

**Pagefault** since it is not in the process table



**190a7c20** R  
3856bbe0 W  
190afc20 R  
15216f00 R  
190a7c20 R  
190a7c28 R  
190a7c28 R  
190aff38 R

# Project 3 - Virtual Memory Simulator

---

- Lets suppose you have 12KB of physical memory
  - Page has 4KB
  - Assume FIFO

0	<b>190a7</b>
1	
2	

**Pagefault** since it is not in the process table



**190a7c20** R  
3856bbe0 W  
190afc20 R  
15216f00 R  
190a7c20 R  
190a7c28 R  
190a7c28 R  
190aff38 R

# Project 3 - Virtual Memory Simulator

---

- Lets suppose you have 12KB of physical memory
  - Page has 4KB
  - Assume **FIFO**

0	190a7
1	3856b
2	190af

We need to evict someone!!

Pagefault again

190a7c20 R  
3856bbe0 W  
190afc20 R  
15216f00 R  
190a7c20 R  
190a7c28 R  
190a7c28 R  
190aff38 R



# Project 3 - Virtual Memory Simulator

---

- Lets suppose you have 12KB of physical memory
  - Page has 4KB
  - Assume **FIFO**

0	190a7
1	3856b
2	190af

We need to evict someone!!

Pagefault again

190a7c20 R  
3856bbe0 W  
190afc20 R  
15216f00 R  
190a7c20 R  
190a7c28 R  
190a7c28 R  
190aff38 R

# Project 3 - Virtual Memory Simulator

---

- Lets suppose you have 12KB of physical memory
  - Page has 4KB
  - Assume **FIFO**

0	3856b
1	190af
2	

We need to evict someone!!

Pagefault again

190a7c20 R  
3856bbe0 W  
190afc20 R  
15216f00 R  
190a7c20 R  
190a7c28 R  
190a7c28 R  
190aff38 R

# Project 3 - Virtual Memory Simulator

---

- You have to implement:
  - Opt (Clairvoyant)
  - FIFO
  - NRU
  - Clock

# Project 3 – Optimal algorithm

---

- Evicts the page that will not be used the longest in the future.

# Project 3 – Optimal algorithm

---

- Evicts the page that will not be used the longest in the future.

0	190a7
1	3856b
2	190af

Pagefault again



190a7c20 R  
3856bbe0 W  
190afc20 R  
15216f00 R  
190a7c20 R  
190a7c28 R  
190a7c28 R  
190aff38 R  
3856bbe0 R

# Project 3 – Optimal algorithm

---

- Evicts the page that will not be used the longest in the future.

**Pagefault** again

0	<b>190a7</b>
1	<b>3856b</b>
2	<b>190af</b>

**We need to evict  
someone!!**



**190a7c20** R  
**3856bbe0** W  
**190afc20** R  
**15216f00** R  
190a7c20 R  
190a7c28 R  
190a7c28 R  
190aff38 R  
3856bbe0 R

# Project 3 – Optimal algorithm

---

- Evicts the page **that will not be used the longest in the future.**

**Pagefault** again

0	<b>190a7</b>
1	<b>3856b</b>
2	<b>190af</b>

**We need to evict  
someone!!**



**190a7c20** R  
**3856bbe0** W  
**190afc20** R  
**15216f00** R  
190a7c20 R  
190a7c28 R  
190a7c28 R  
190aff38 R  
3856bbe0 R

# Project 3 – Optimal algorithm

---

- Evicts the page **that will not be used the longest in the future.**

Let's analyze who will be needed furthest away in the trace



0	<b>190a7</b>	
1	<b>3856b</b>	
2	<b>190af</b>	

**We need to evict someone!!**

**Pagefault** again

**190a7c20** R  
**3856bbe0** W  
**190afc20** R  
**15216f00** R  
190a7c20 R  
190a7c28 R  
190a7c28 R  
190aff38 R  
3856bbe0 R



# Project 3 – Optimal algorithm

---

- Evicts the page **that will not be used the longest in the future.**

**Pagefault** again

0	<b>190a7</b>	
1	<b>3856b</b>	
2	<b>190af</b>	

**We need to evict  
someone!!**



**190a7c20** R  
**3856bbe0** W  
**190afc20** R  
**15216f00** R  
190a7c20 R  
190a7c28 R  
190a7c28 R  
190aff38 R  
3856bbe0 R

# Project 3 – Optimal algorithm

---

- Evicts the page **that will not be used the longest in the future.**

**Pagefault** again

0	<b>190a7</b>	0
1	<b>3856b</b>	
2	<b>190af</b>	

**We need to evict  
someone!!**



**190a7c20** R  
**3856bbe0** W  
**190afc20** R  
**15216f00** R  
190a7c20 R  
190a7c28 R  
190a7c28 R  
190aff38 R  
3856bbe0 R

# Project 3 – Optimal algorithm

---

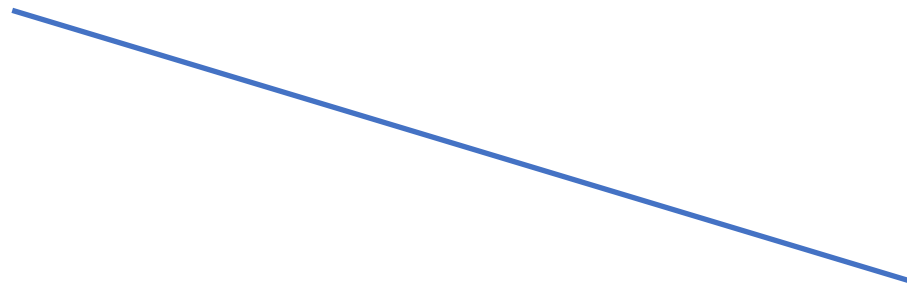
- Evicts the page **that will not be used the longest in the future.**

**Pagefault** again

0	<b>190a7</b>	0
1	<b>3856b</b>	4
2	<b>190af</b>	

**We need to evict  
someone!!**

**190a7c20** R  
**3856bbe0** W  
**190afc20** R  
**15216f00** R  
190a7c20 R  
190a7c28 R  
190a7c28 R  
190aff38 R  
3856bbe0 R



# Project 3 – Optimal algorithm

---

- Evicts the page **that will not be used the longest in the future.**

**Pagefault** again

0	<b>190a7</b>	0
1	<b>3856b</b>	4
2	<b>190af</b>	3

**We need to evict  
someone!!**

**190a7c20** R  
**3856bbe0** W  
**190afc20** R  
**15216f00** R  
190a7c20 R  
190a7c28 R  
190a7c28 R  
190aff38 R  
3856bbe0 R



# Project 3 – Optimal algorithm

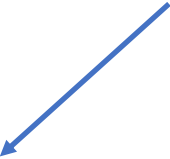
---

- Evicts the page **that will not be used the longest in the future.**

**Pagefault** again

0	190a7	0
1	3856b	4
2	190af	3

**We need to evict someone!!**



190a7c20 R  
3856bbe0 W  
190afc20 R  
15216f00 R  
190a7c20 R  
190a7c28 R  
190a7c28 R  
190aff38 R  
3856bbe0 R

# Project 3 – Optimal algorithm

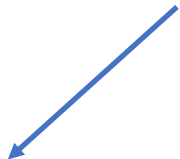
---

- Evicts the page **that will not be used the longest in the future.**

**Pagefault** again

0	190a7	0
1		
2	190af	3

**We need to evict someone!!**



190a7c20 R  
3856bbe0 W  
190afc20 R  
15216f00 R  
190a7c20 R  
190a7c28 R  
190a7c28 R  
190aff38 R  
3856bbe0 R

# Project 3 – Optimal algorithm

---

- Evicts the page **that will not be used the longest in the future.**

Pagefault again

0	190a7	0
1		
2	190af	3

We need to evict  
someone!!

190a7c20 R  
3856bbe0 W  
190afc20 R  
**15216f00 R**  
190a7c20 R  
190a7c28 R  
190a7c28 R  
190aff38 R  
3856bbe0 R

# Project 3 – Optimal algorithm

---

- Evicts the page **that will not be used the longest in the future.**

**Pagefault** again

0	<b>190a7</b>	0
1	<b>15216</b>	
2	<b>190af</b>	3

**We need to evict  
someone!!**

**190a7c20** R  
**3856bbe0** W  
**190afc20** R  
**15216f00** R  
190a7c20 R  
190a7c28 R  
190a7c28 R  
190aff38 R  
3856bbe0 R



# Project 3 – Optimal algorithm

---

- Evicts the page **that will not be used the longest in the future.**

**Pagefault** again

0	<b>190a7</b>	0
1	<b>15216</b>	
2	<b>190af</b>	3

**Remember that this  
will change as the  
memory trace  
progresses**

**190a7c20** R  
**3856bbe0** W  
**190afc20** R  
**15216f00** R  
190a7c20 R  
190a7c28 R  
190a7c28 R  
190aff38 R  
3856bbe0 R

# Project 3 – First In First Out(FIFO)

---

- Evicts the oldest page in memory.

# Project 3 – First In First Out(FIFO)

---

- Evicts the oldest page in memory.

0	190a7
1	3856b
2	190af

**Pagefault** again



190a7c20 R  
3856bbe0 W  
190afc20 R  
15216f00 R  
190a7c20 R  
190a7c28 R  
190a7c28 R  
190aff38 R

# Project 3 – First In First Out(FIFO)

---

- Evicts the oldest page in memory.

0	190a7
1	3856b
2	190af

We need to evict someone!!

Pagefault again

190a7c20 R  
3856bbe0 W  
190afc20 R  
15216f00 R  
190a7c20 R  
190a7c28 R  
190a7c28 R  
190aff38 R

# Project 3 – First In First Out(FIFO)

---

- Evicts the oldest page in memory.

0	3856b
1	190af
2	

We need to evict someone!!

Pagefault again

190a7c20 R  
3856bbe0 W  
190afc20 R  
15216f00 R  
190a7c20 R  
190a7c28 R  
190a7c28 R  
190aff38 R

# Project 3 – First In First Out(FIFO)

---

- Evicts the oldest page in memory.

**Pagefault** again

0	<b>3856b</b>
1	<b>190af</b>
2	<b>15216</b>

**190a7c20** R  
**3856bbe0** W  
**190afc20** R  
**15216f00** R  
190a7c20 R  
190a7c28 R  
190a7c28 R  
190aff38 R




# Project 3 – First In First Out(FIFO)

---

- Evicts the oldest page in memory.

**Pagefault** again

0	<b>3856b</b>	 <b>Next to be evicted</b>
1	<b>190af</b>	
2	<b>15216</b>	

**190a7c20** R  
**3856bbe0** W  
**190afc20** R  
**15216f00** R  
190a7c20 R  
190a7c28 R  
190a7c28 R  
190aff38 R

# Project 3 – Not Recently Used (NRU)

---

- Evicts pages that are not being used.
  - Periodically resets referenced flag.
  - Pages are ranked according to Use and Modification



# Project 3 – Not Recently Used (NRU)

---

- Evicts pages that are not being used.
  - Periodically resets referenced flag.
  - Pages are ranked according to **Use** and **Modification**

0	<b>190a7</b>
1	<b>3856b</b>
2	<b>190af</b>

**190a7c20** R  
**3856bbe0** W  
**190afc20** R  
**15216f00** R  
190a7c20 R  
190a7c28 R  
190a7c28 R  
190aff38 R

# Project 3 – Not Recently Used (NRU)

---

- Evicts pages that are not being used.
  - Periodically resets referenced flag.
  - Pages are ranked according to **Use** and **Modification**

	Referenced	Dirty	
0	1		<b>190a7</b>
1	1		<b>3856b</b>
2	1		<b>190af</b>

**190a7c20** R  
**3856bbe0** W  
**190afc20** R  
**15216f00** R  
190a7c20 R  
190a7c28 R  
190a7c28 R  
190aff38 R

# Project 3 – Not Recently Used (NRU)

---

- Evicts pages that are not being used.
  - Periodically resets referenced flag.
  - Pages are ranked according to **Use** and **Modification**

	Referenced	Dirty	
0	1	0	<b>190a7</b>
1	1	1	<b>3856b</b>
2	1	0	<b>190af</b>

**190a7c20** R  
**3856bbe0** W  
**190afc20** R  
**15216f00** R  
190a7c20 R  
190a7c28 R  
190a7c28 R  
190aff38 R

# Project 3 – Not Recently Used (NRU)

---

- Evicts pages that are not being used.
  - Periodically resets referenced flag.
  - Pages are ranked according to **Use** and **Modification**
- Page Rank (Lower Rank -> higher chance of being evicted)

Rank	Page State
3	referenced, modified
2	referenced, <b>not</b> modified
1	not referenced, modified
0	not referenced, <b>not</b> modified

# Project 3 – Not Recently Used (NRU)

---

- Evicts pages that are not being used.
  - Periodically resets referenced flag.
  - Pages are ranked according to **Use** and **Modification**

	Referenced	Dirty	
0	1	0	<b>190a7</b>
1	1	1	<b>3856b</b>
2	1	0	<b>190af</b>

**190a7c20** R  
**3856bbe0** W  
**190afc20** R  
**15216f00** R  
190a7c20 R  
190a7c28 R  
190a7c28 R  
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# Project 3 – Not Recently Used (NRU)

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- Evicts pages that are not being used.
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  - Pages are ranked according to **Use** and **Modification**

Rank	Page State
3	referenced, modified
2	referenced, <b>not</b> modified
1	not referenced, modified
0	not referenced, <b>not</b> modified

	Referenced	Dirty	
0	1	0	<b>190a7</b>
1	1	1	<b>3856b</b>
2	1	0	<b>190af</b>

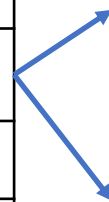
**190a7c20** R  
**3856bbe0** W  
**190afc20** R  
**15216f00** R  
190a7c20 R  
190a7c28 R  
190a7c28 R  
190aff38 R

# Project 3 – Not Recently Used (NRU)

---

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  - Periodically resets referenced flag.
  - Pages are ranked according to **Use** and **Modification**

Rank	Page State
3	referenced, modified
2	referenced, <b>not</b> modified
1	not referenced, modified
0	not referenced, <b>not</b> modified



	Referenced	Dirty	
0	1	0	<b>190a7</b>
1	1	1	<b>3856b</b>
2	1	0	<b>190af</b>

**190a7c20** R  
**3856bbe0** W  
**190afc20** R  
**15216f00** R  
190a7c20 R  
190a7c28 R  
190a7c28 R  
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- Evicts pages that are not being used.
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Rank	Page State
3	referenced, modified
2	referenced, <b>not</b> modified
1	not referenced, modified
0	not referenced, <b>not</b> modified

	Referenced	Dirty	
0	1	0	<b>190a7</b>
1	1	1	<b>3856b</b>
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**190a7c20** R  
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190a7c20 R  
190a7c28 R  
190a7c28 R  
190aff38 R



# Project 3 – Not Recently Used (NRU)

---

- Evicts pages that are not being used.
  - Periodically resets referenced flag.
  - Pages are ranked according to **Use** and **Modification**

Rank
3
2
1
0

	Referenced	Dirty	
0	1	0	<b>190a7</b>
1	1	1	<b>3856b</b>
2	1	0	<b>190af</b>

**190a7c20** R  
**3856bbe0** W  
**190afc20** R  
**15216f00** R  
190a7c20 R  
190a7c28 R  
190a7c28 R  
190aff38 R

# Project 3 – Not Recently Used (NRU)

---

- Evicts pages that are not being used.
  - Periodically resets referenced flag.
  - Pages are ranked according to **Use** and **Modification**

We need to evict someone!! **But there are 2 Rank 2 pages.**

Rank
3
2
1
0

	Referenced	Dirty	
0	1	0	<b>190a7</b>
1	1	1	<b>3856b</b>
2	1	0	<b>190af</b>



**Pagefault**

**190a7c20** R  
**3856bbe0** W  
**190afc20** R  
**15216f00** R  
190a7c20 R  
190a7c28 R  
190a7c28 R  
190aff38 R

# Project 3 – Not Recently Used (NRU)

- Evicts pages that are not being used.
  - Periodically resets referenced flag.
  - Pages are ranked according to **Use** and **Modification**

We need to evict someone!! But there are 2 Rank 2 pages. **Chose at random between lowest rank**

Rank
3
2
1
0

	Referenced	Dirty	
0	1	0	<b>190a7</b>
1	1	1	<b>3856b</b>
2	1	0	<b>190af</b>



**Pagefault**

**190a7c20** R  
**3856bbe0** W  
**190afc20** R  
**15216f00** R  
190a7c20 R  
190a7c28 R  
190a7c28 R  
190aff38 R

# Project 3 – Not Recently Used (NRU)

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- Evicts pages that are not being used.
  - Periodically resets referenced flag.
  - Pages are ranked according to **Use** and **Modification**

We need to evict someone!! But there are 2 Rank 2 pages. **Chose at random between lowest rank**

Rank
3
2
1
0

	Referenced	Dirty	
0	1	0	190a7
1	1	1	3856b
2	1	0	190af



**Pagefault**

190a7c20 R  
3856bbe0 W  
190afc20 R  
15216f00 R  
190a7c20 R  
190a7c28 R  
190a7c28 R  
190aff38 R

# Project 3 – Not Recently Used (NRU)

---

- Evicts pages that are not being used.
  - **Periodically resets referenced flag.**
  - Pages are ranked according to Use and Modification

	Referenced	Dirty	
0	1	0	<b>190a7</b>
1	1	1	<b>3856b</b>
2	1	0	<b>190af</b>

**190a7c20** R  
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**190afc20** R  
**15216f00** R  
190a7c20 R  
190a7c28 R  
190a7c28 R  
190aff38 R

# Project 3 – Not Recently Used (NRU)

---

- Evicts pages that are not being used.
  - **Periodically resets referenced flag.**
  - Pages are ranked according to Use and Modification

Has to be set to 0 **periodically** (e.g., every 10 memory accesses)

	Referenced	Dirty	
0	1	0	<b>190a7</b>
1	1	1	<b>3856b</b>
2	1	0	<b>190af</b>

**190a7c20** R  
**3856bbe0** W  
**190afc20** R  
**15216f00** R  
190a7c20 R  
190a7c28 R  
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# Project 3 – Not Recently Used (NRU)

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  - **Periodically resets referenced flag.**
  - Pages are ranked according to Use and Modification

Has to be set to 0 **periodically** (e.g., every 10 memory accesses)

	Referenced	Dirty	
0	0	0	<b>190a7</b>
1	0	1	<b>3856b</b>
2	0	0	<b>190af</b>

**190a7c20** R  
**3856bbe0** W  
**190afc20** R  
**15216f00** R  
190a7c20 R  
190a7c28 R  
190a7c28 R  
190aff38 R

# Project 3 – Clock

---

- Keeps a pointer to the last examined page in a circular list
  - Pointer resets the Referenced bit to 0
    - If R is 0 the page is evicted
  - Pointer tries to evict and moves to the next page when a page fault occur



# Project 3 – Clock

---

- Keeps a pointer to the last examined page in a circular list
  - Pointer resets the Referenced bit to 0
    - If R is 0 the page is evicted
  - Pointer tries to evict and moves to the next page when a page fault occur

	Referenced	Dirty	
0	1	0	<b>190a7</b>
1	1	1	<b>3856b</b>
2	1	0	<b>190af</b>

**190a7c20** R  
**3856bbe0** W  
**190afc20** R  
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190a7c20 R  
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	Referenced	Dirty	
0	1	0	<b>190a7</b>
1	1	1	<b>3856b</b>
2	1	0	<b>190af</b>



**190a7c20** R  
**3856bbe0** W  
**190afc20** R  
**15216f00** R  
190a7c20 R  
190a7c28 R  
190a7c28 R  
190aff38 R

# Project 3 – Clock

---

- Keeps a pointer to the last examined page in a circular list
  - Pointer resets the Referenced bit to 0
    - If R is 0 the page is evicted
  - Pointer tries to evict and moves to the next page when a page fault occur

	Referenced	Dirty	
0	1	0	<b>190a7</b>
1	1	1	<b>3856b</b>
2	1	0	<b>190af</b>



**Pagefault**

**190a7c20** R  
**3856bbe0** W  
**190afc20** R  
**15216f00** R  
190a7c20 R  
190a7c28 R  
190a7c28 R  
190aff38 R

# Project 3 – Clock

---

- Keeps a pointer to the last examined page in a circular list
  - Pointer resets the Referenced bit to 0
    - If R is 0 the page is evicted
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# Project 3 – Clock

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R is 0 evict!



**Pagefault**

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3856bbe0 W  
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	Referenced	Dirty	
0	1	0	15216
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2	0	0	190af

R is 0 evict!



**Pagefault**

190a7c20 R  
3856bbe0 W  
190afc20 R  
15216f00 R  
190a7c20 R  
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190a7c28 R  
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# Project 3 – Clock

---

- Keeps a pointer to the last examined page in a circular list
  - Pointer resets the Referenced bit to 0
    - If R is 0 the page is evicted
  - Pointer tries to evict and moves to the next page when a page fault occur

Remember to reset to 0 periodically as well

	Referenced	Dirty	
0	1	0	15216
1	0	1	3856b
2	0	0	190af



190a7c20 R  
3856bbe0 W  
190afc20 R  
15216f00 R  
190a7c20 R  
190a7c28 R  
190a7c28 R  
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# Project 3 – Program interface

---

- Program UI

```
./vmsim -n <numframes> -a <opt|clock|fifo|nru> [-r <refresh>] <tracefile>
```

# Project 3 – Program interface

---

- Program UI

```
./vmsim -n <numframes> -a <opt|clock|fifo|nru> [-r <refresh>] <tracefile>
```

Specifies the number of Memory slots.


# Project 3 – Program interface

---

- Program UI

```
./vmsim -n <numframes> -a <opt|clock|fifo|nru> [-r <refresh>] <tracefile>
```

Specifies which algorithm to run




# Project 3 – Program interface

---

- Program UI

```
./vmsim -n <numframes> -a <opt|clock|fifo|nru> [-r <refresh>] <tracefile>
```

Specifies the periodicity of the  
refresh rate for **Clock** and **NRU**





# Project 3 – Program interface

---

- Program UI

```
./vmsim -n <numframes> -a <opt|clock|fifo|nru> [-r <refresh>] <tracefile>
```

Path to memory trace file



# Project 3 – Program interface

---

- Program UI

```
./vmsim -n <numframes> -a <opt|clock|fifo|nru> [-r <refresh>] <tracefile>
```

```
python vmsim.py -n 8 -a opt -r ./swim.trace
```

```
java vmsim.class -n 8 -a opt -r ./swim.trace
```

# Project 3 – Program interface

---

- Program UI

```
./vmsim -n <numframes> -a <opt|clock|fifo|nru> [-r <refresh>] <tracefile>
```

```
python vmsim.py -n 8 -a opt -r ./swim.trace  
java vmsim.class -n 8 -a opt -r ./swim.trace
```

# Project 3 – Program interface

---

- As the simulation runs you should print in the following format for **each memory reference**.
  - hit
  - page fault – no eviction
  - page fault – evict clean
  - page fault – evict dirty

# Project 3 – Program interface

---

- As the simulation runs you should print in the following format for **each memory reference**.

```
C:>
```

```
190a7c20 R  
3856bbe0 W  
190afc20 R  
15216f00 R  
190a7c20 R  
190a7c28 R  
190a7c28 R  
190aff38 R
```

# Project 3 – Program interface

---

- As the simulation runs you should print in the following format for **each memory reference**.

```
c:> python vmsim.py -n 8 -a opt -r ./swim.trace
```

```
190a7c20 R  
3856bbe0 W  
190afc20 R  
15216f00 R  
190a7c20 R  
190a7c28 R  
190a7c28 R  
190aff38 R
```

# Project 3 – Program interface

---

- As the simulation runs you should print in the following format for **each memory reference**.

```
c:> python vmsim.py -n 8 -a opt -r ./swim.trace
```

```
hit
```

```
page fault – no eviction
```

```
hit
```

```
page fault – evict dirty
```

```
page fault – evict clean
```

```
...
```

```
190a7c20 R
```

```
3856bbe0 W
```

```
190afc20 R
```

```
15216f00 R
```

```
190a7c20 R
```

```
190a7c28 R
```

```
190a7c28 R
```

```
190aff38 R
```