操作系统原理

第十章：虚拟内存

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目录

Outline

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- 前面介绍的各种技术解决了上述问题的某一些方面，但没有提出一个整体的解决方案。
  - 虚拟内存技术基于已有的各种技术给出了一个完整的解决方案，是20世纪计算机技术最重要的发明之一。

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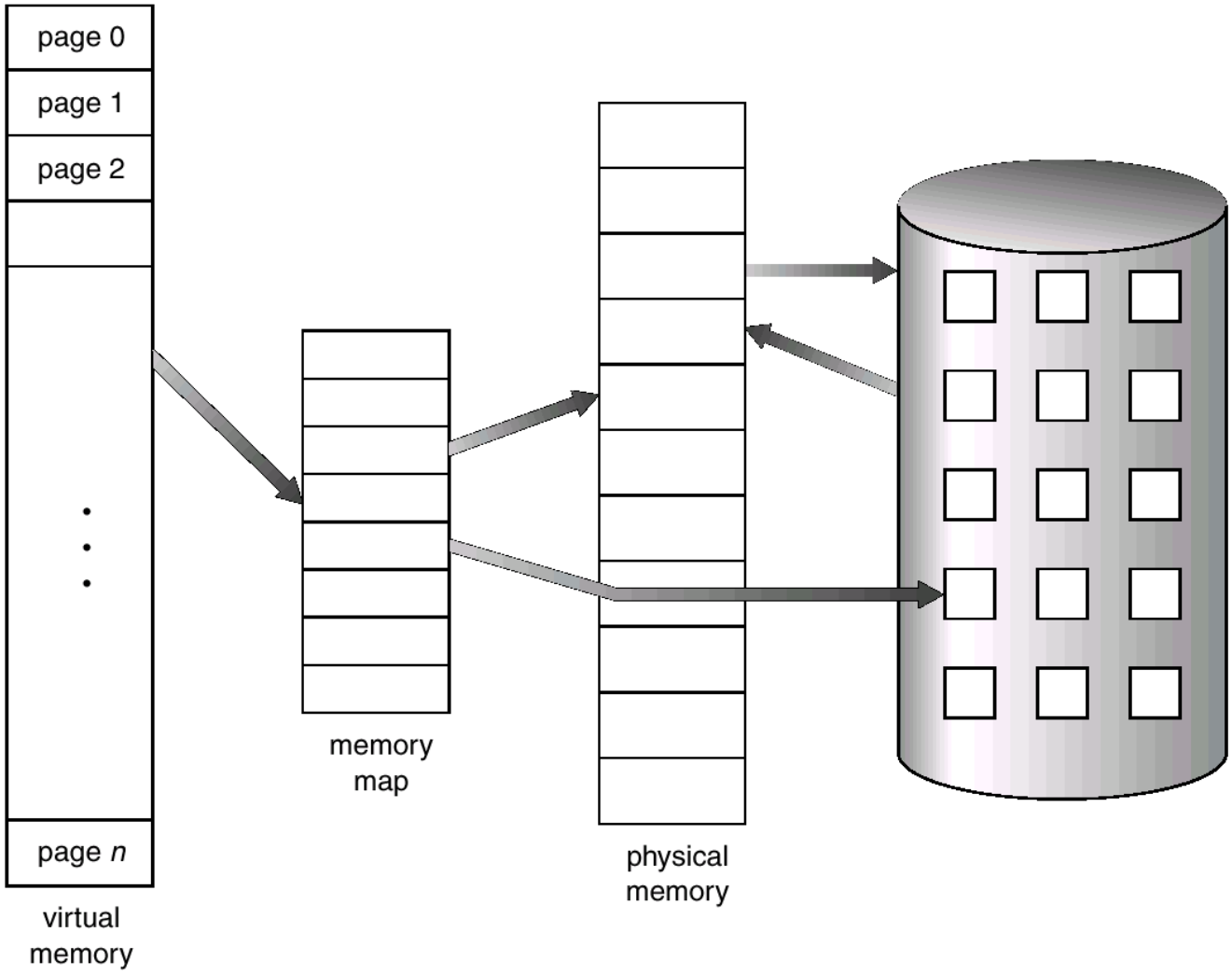

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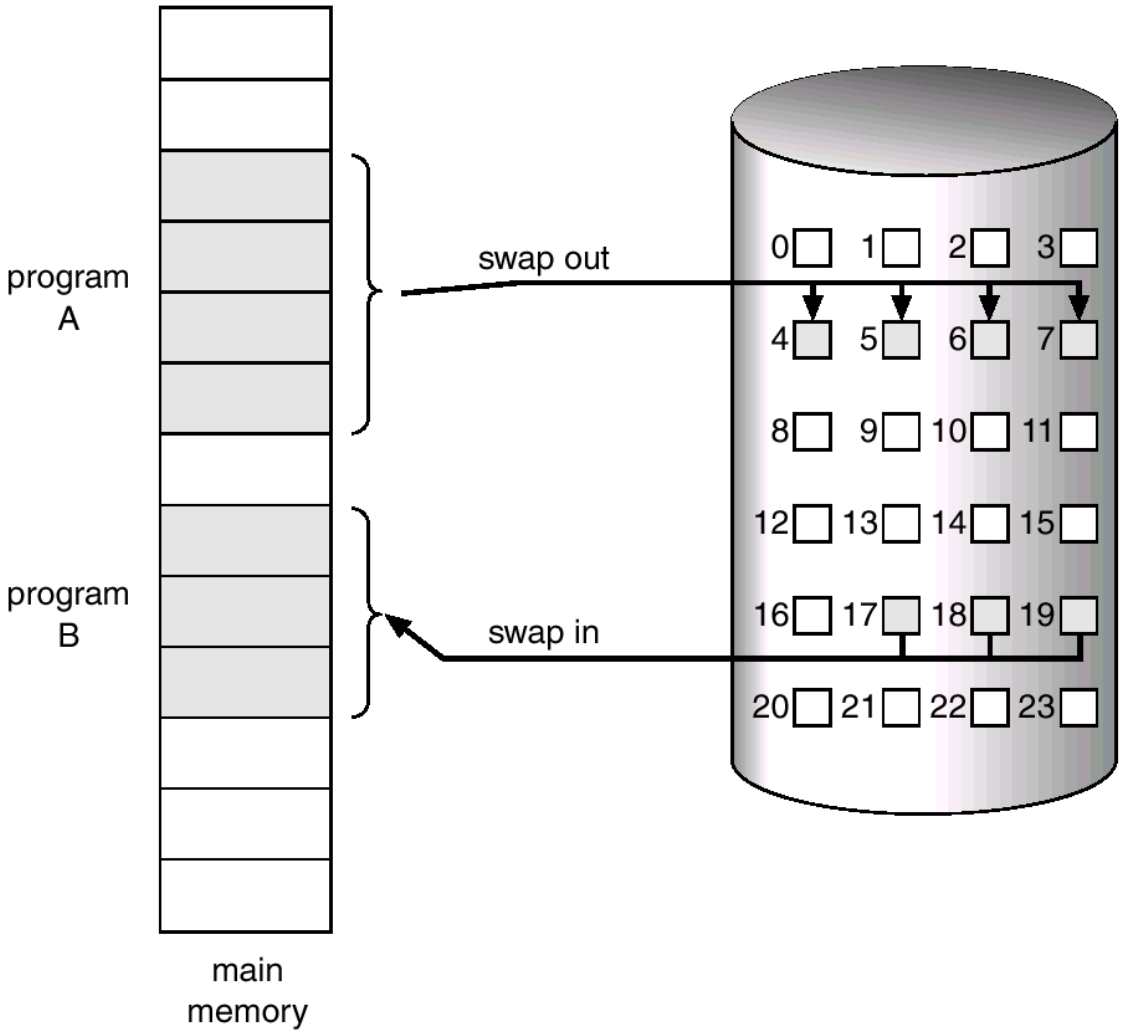
- 一般情况下，我们用swapper表示整个进程的交换；而用pager来表示对页进行交换的lazy swapper。

Pager

Pager


program
A
program
B
swap out
swap in
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
main
memory

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- Remember: With each page table entry (PTE) a valid-invalid bit is associated:
  - If the bit is set to "valid", it indicates that the associated page is both legal and in memory;
  - Otherwise, it indicates the page is not legal (i.e., not in the logical address space of the process), or is legal but currently not in memory.

Valid-Invalid bit

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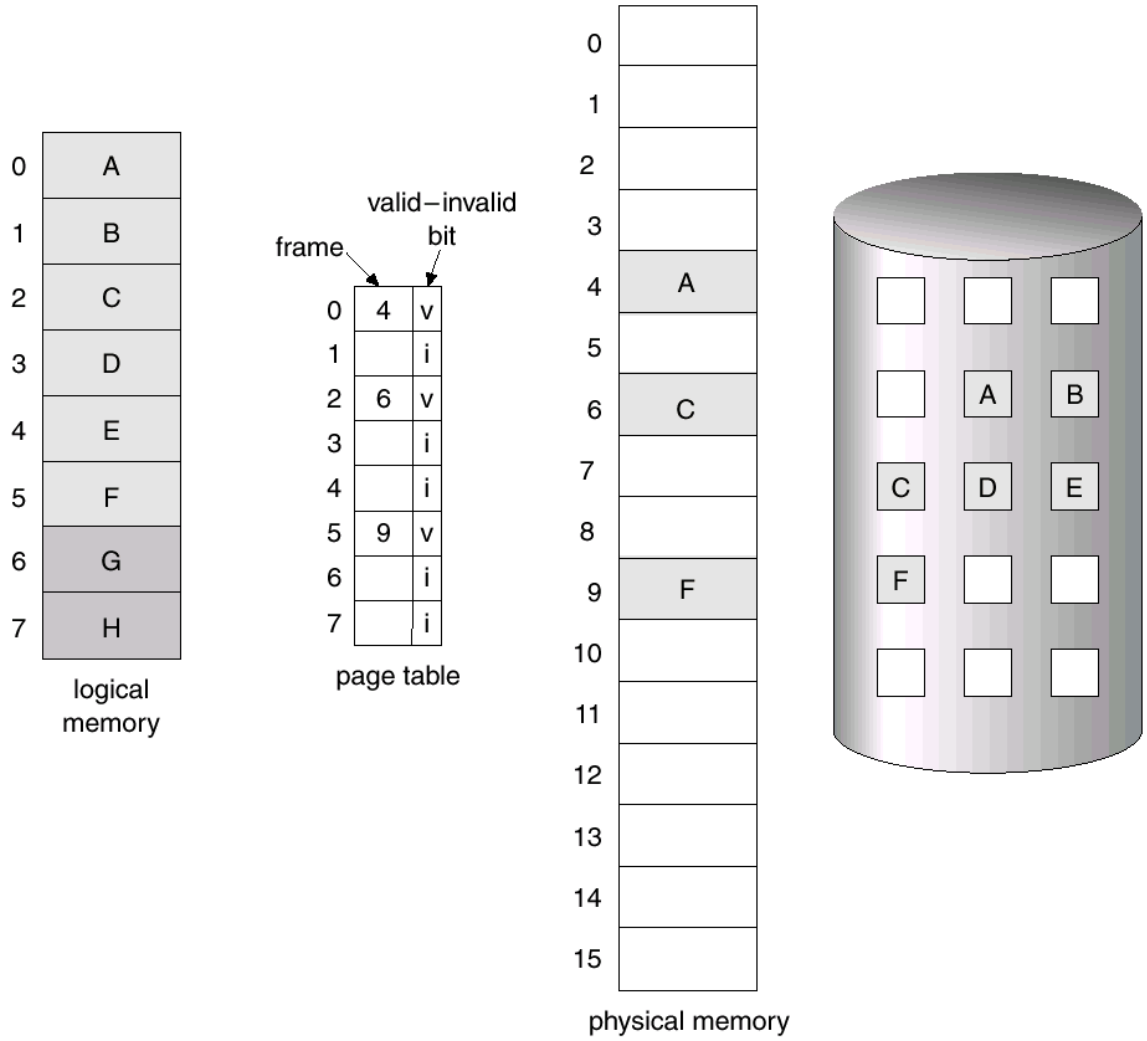

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6. We restart the instruction that was interrupted by the page-fault trap. The process can now access the page as if it had always been in memory.

Page-fault service routine(2/2)

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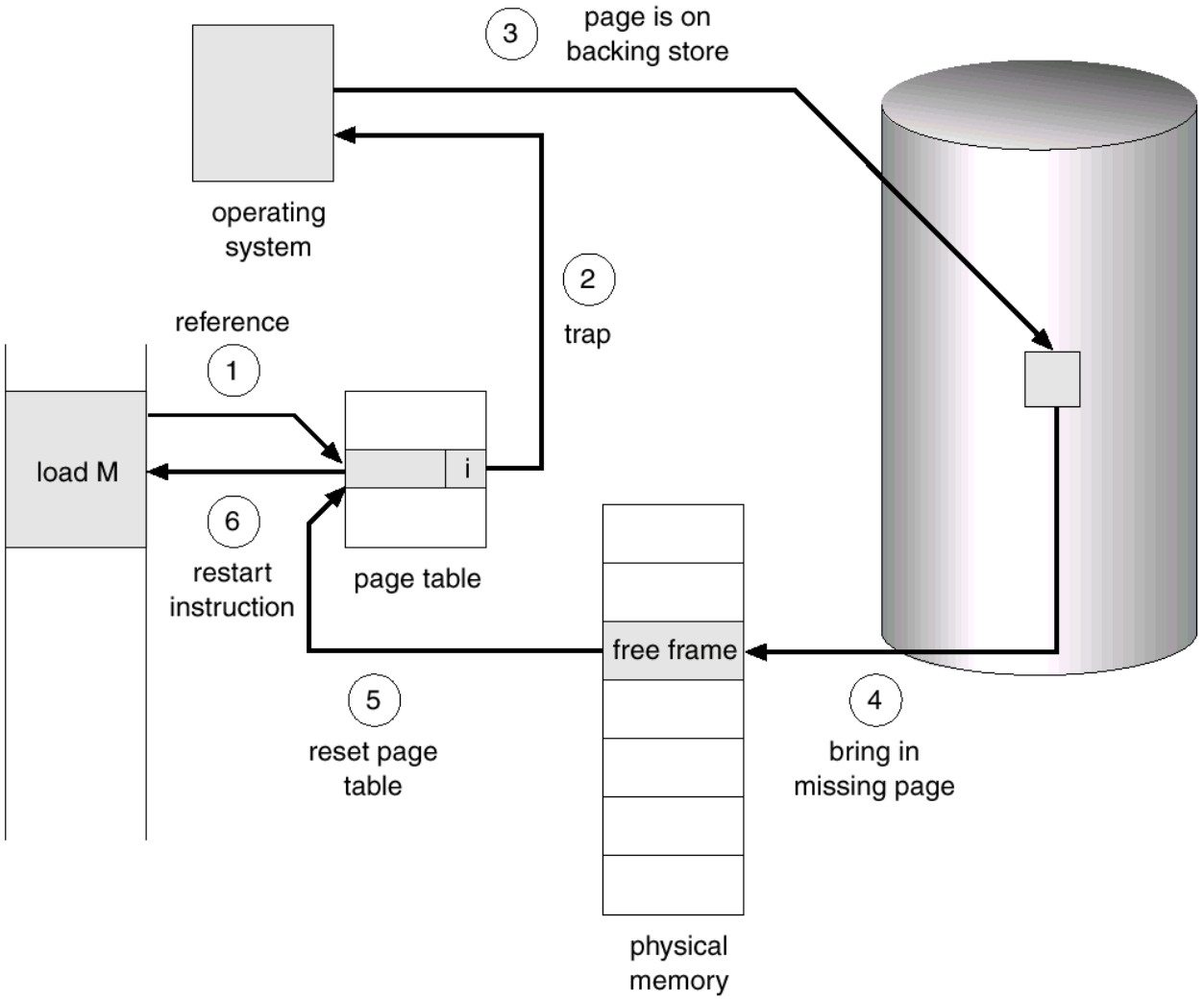

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  - **Page replacement completes that large virtual memory can be provided on a smaller physical memory.**

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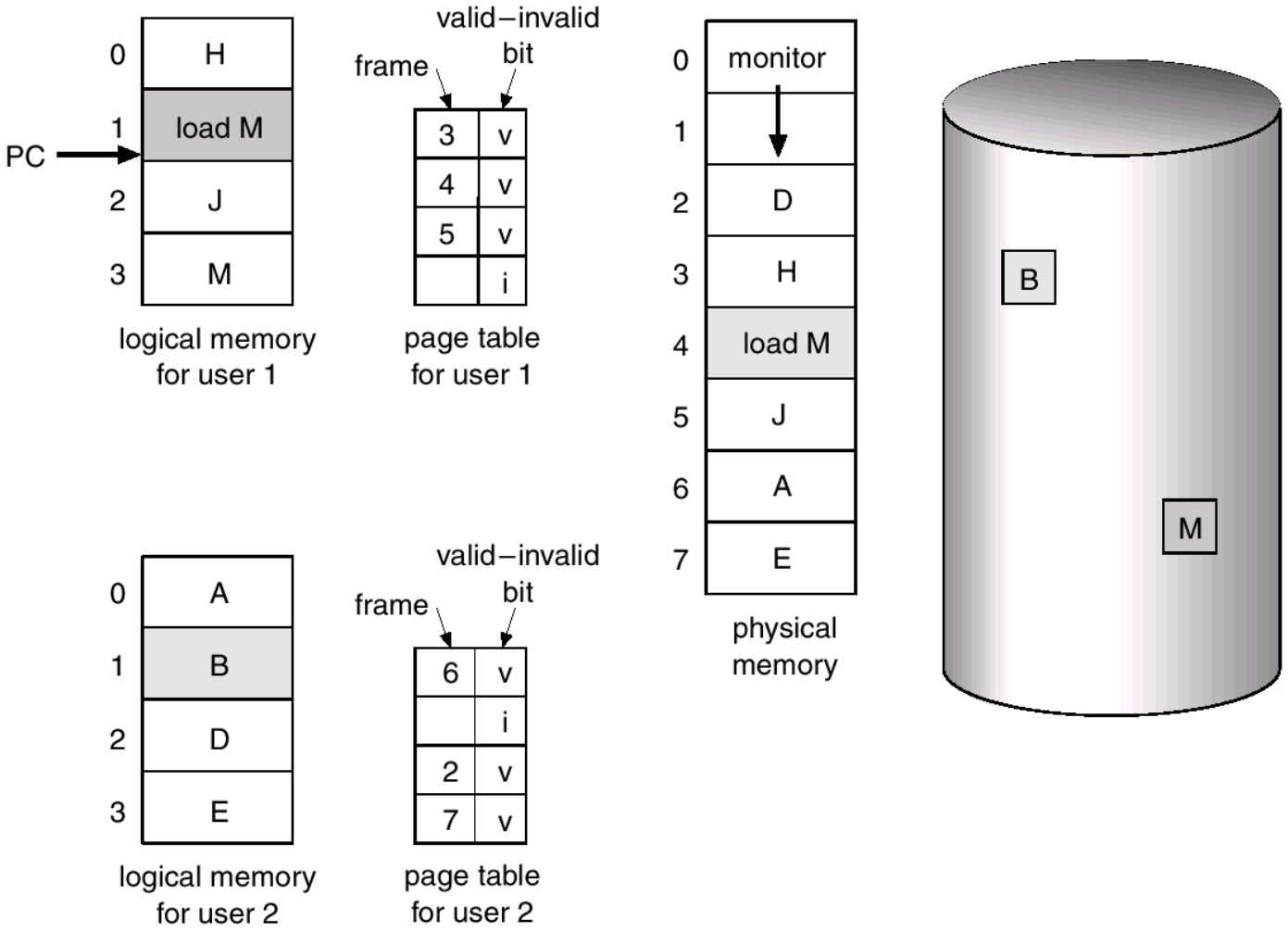

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  4. Restart the instruction.

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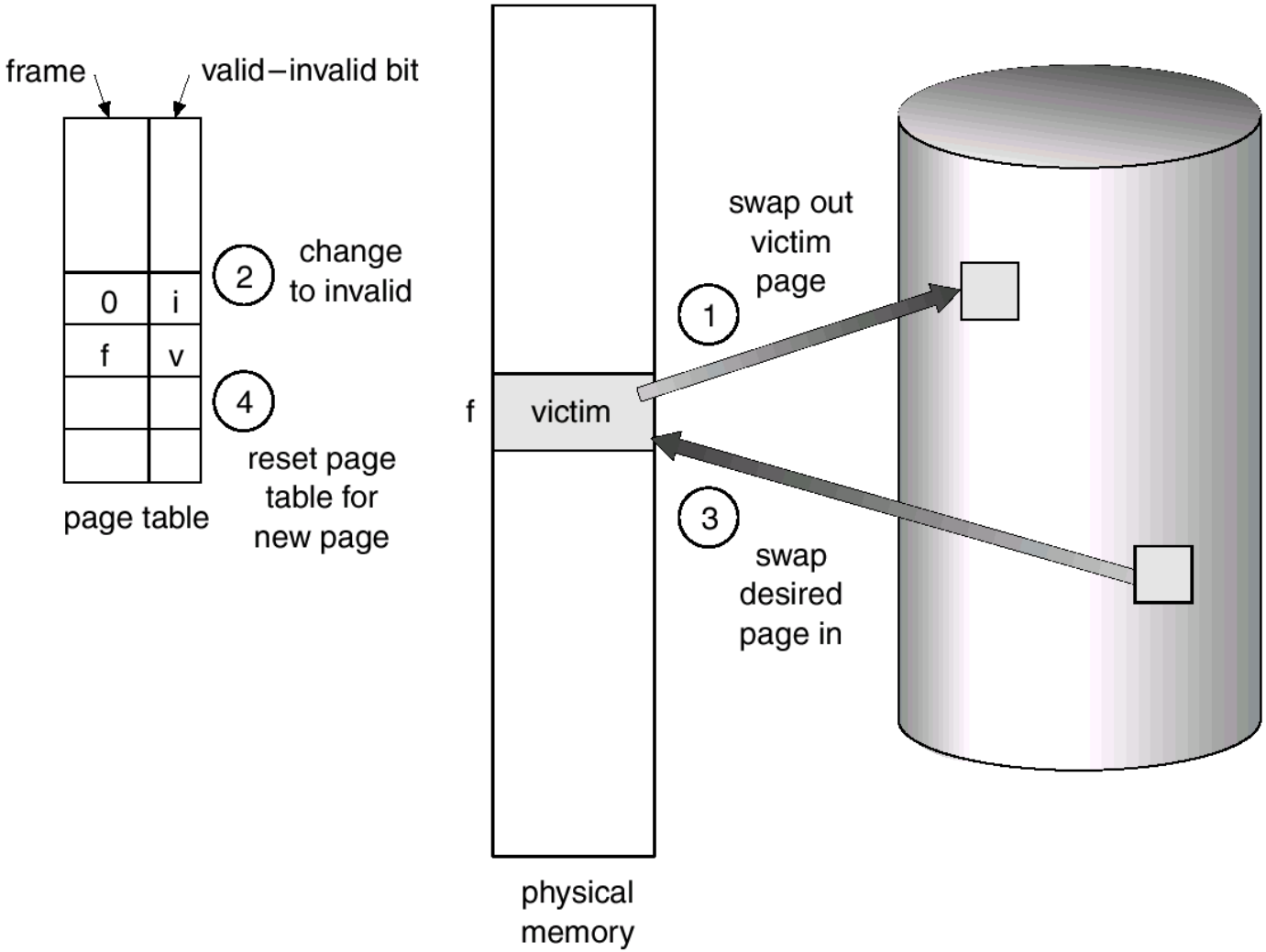

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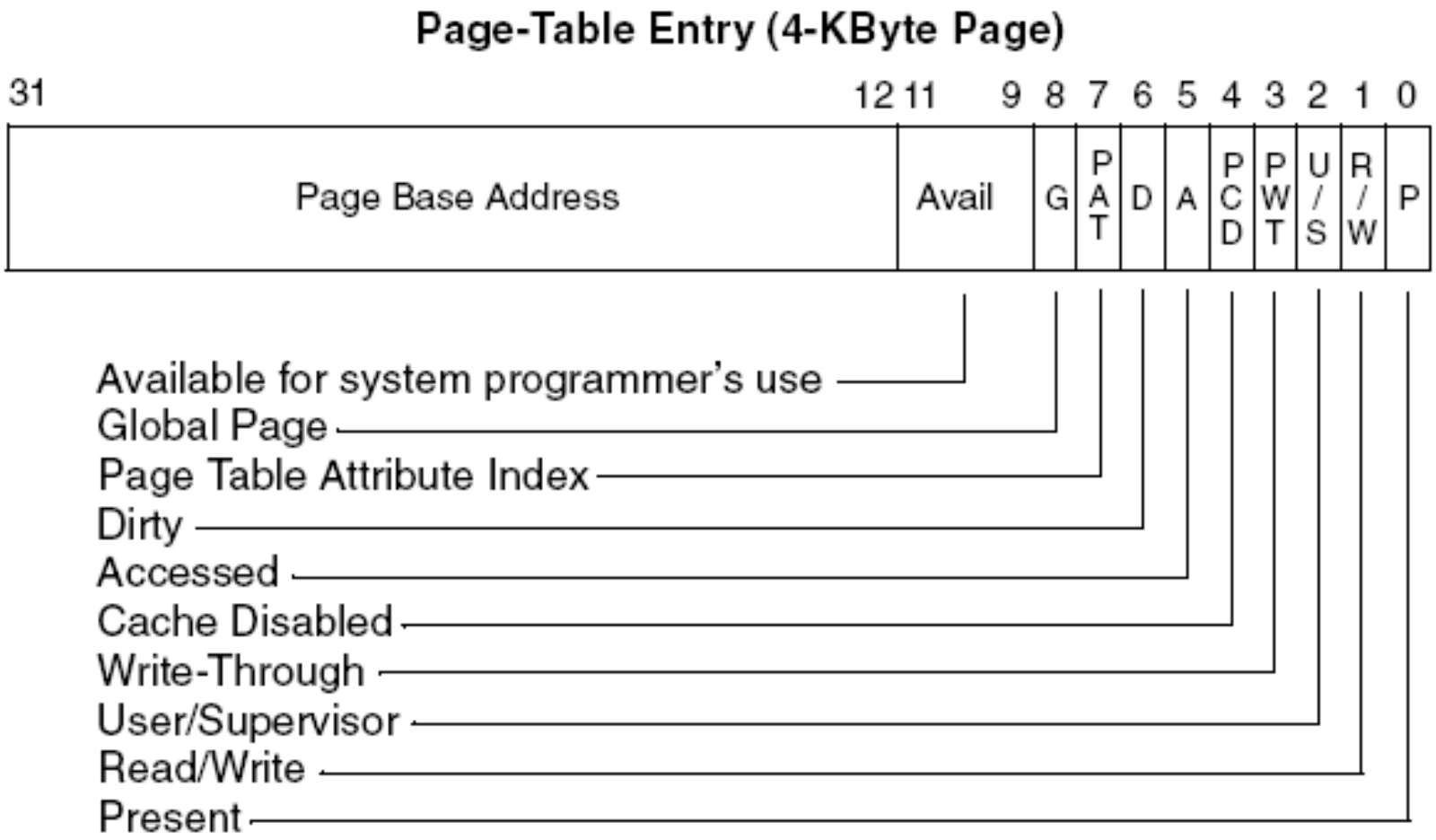

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  - In all following examples, the reference string is
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Page faults versus the number of frames

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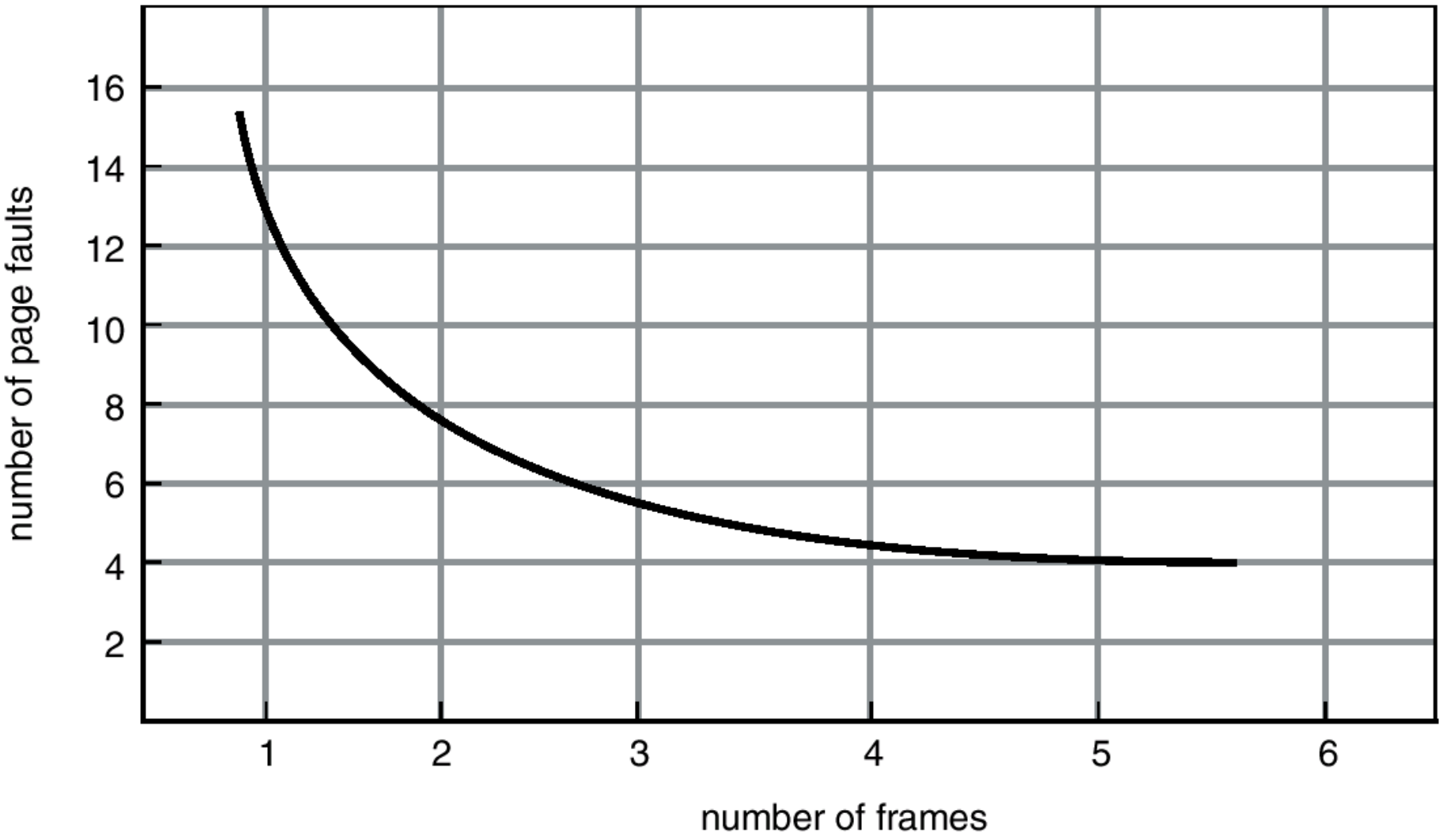

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Various page replacement algorithms

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- FIFO page replacement

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- Optimal page replacement

Various page replacement algorithms

- FIFO page replacement
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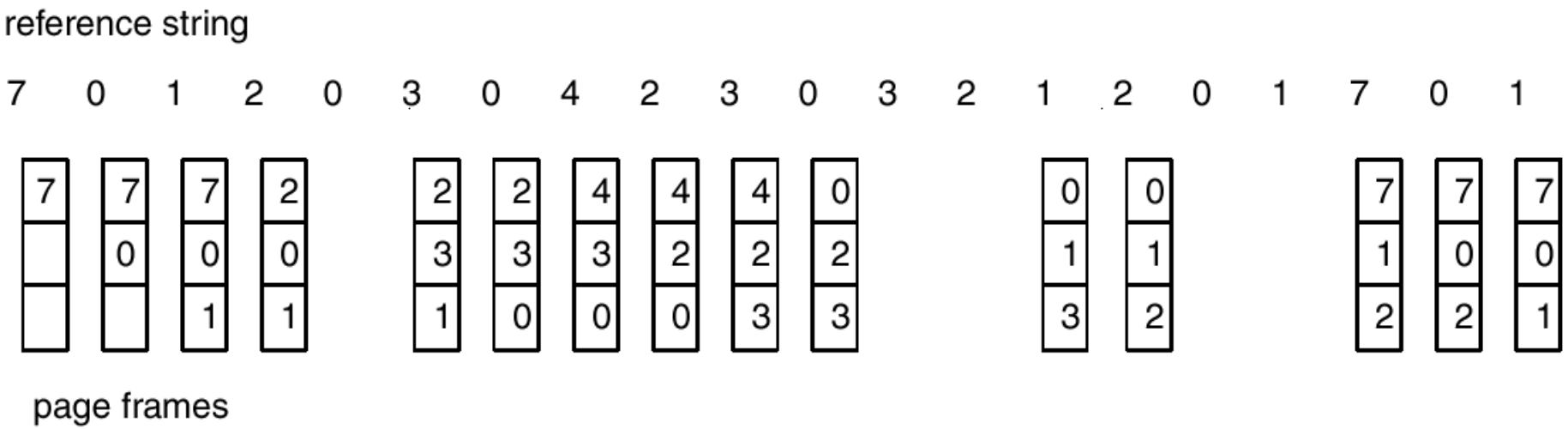

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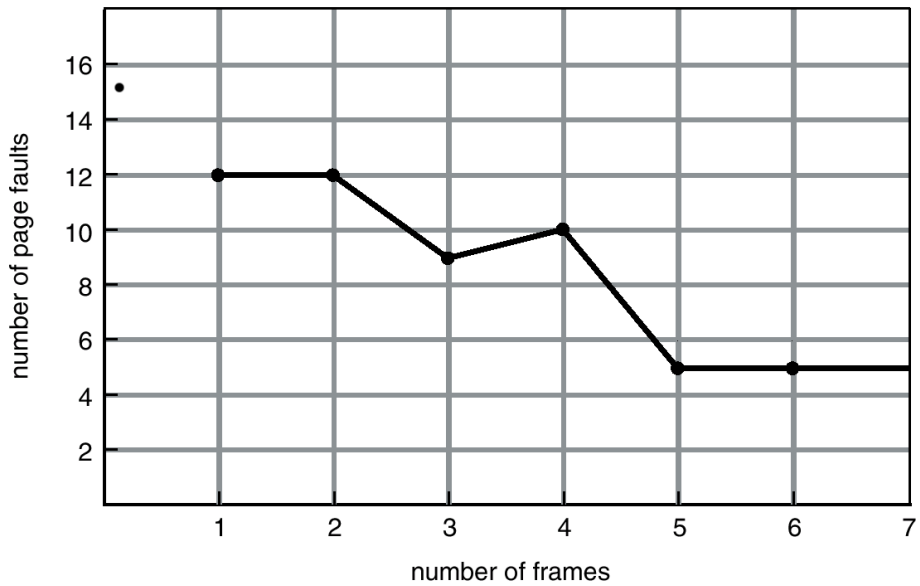

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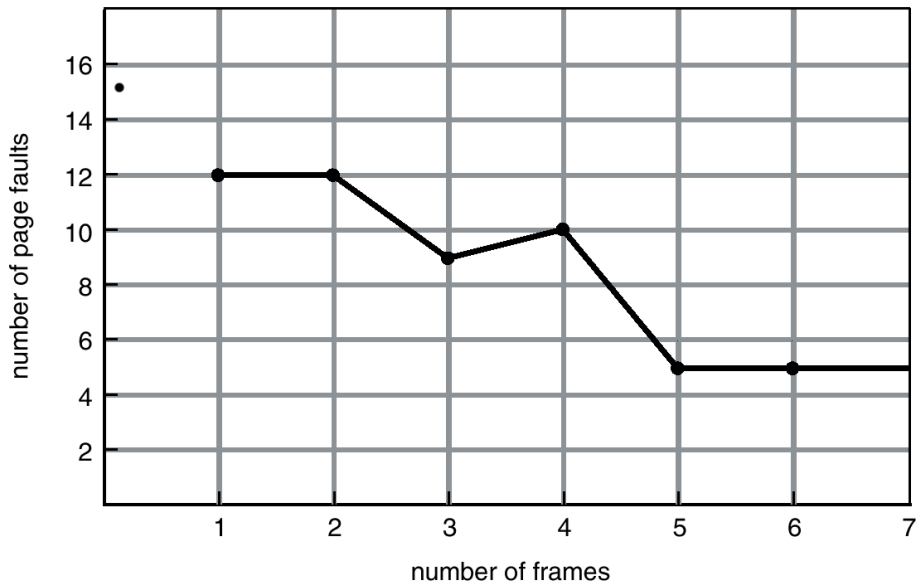

- 因此，算法的设计非常重要。

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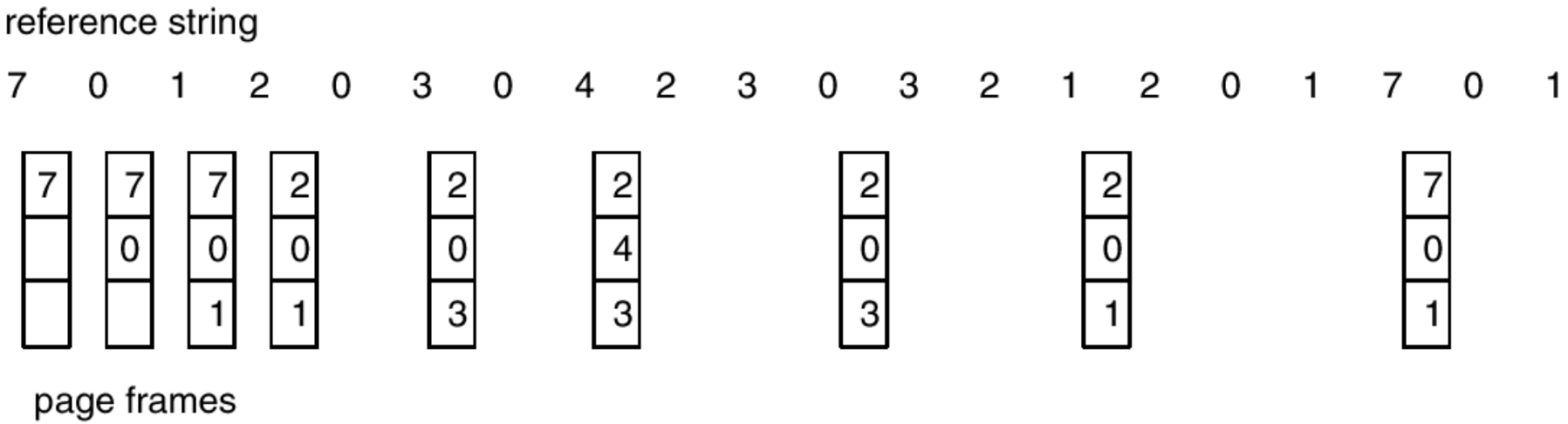

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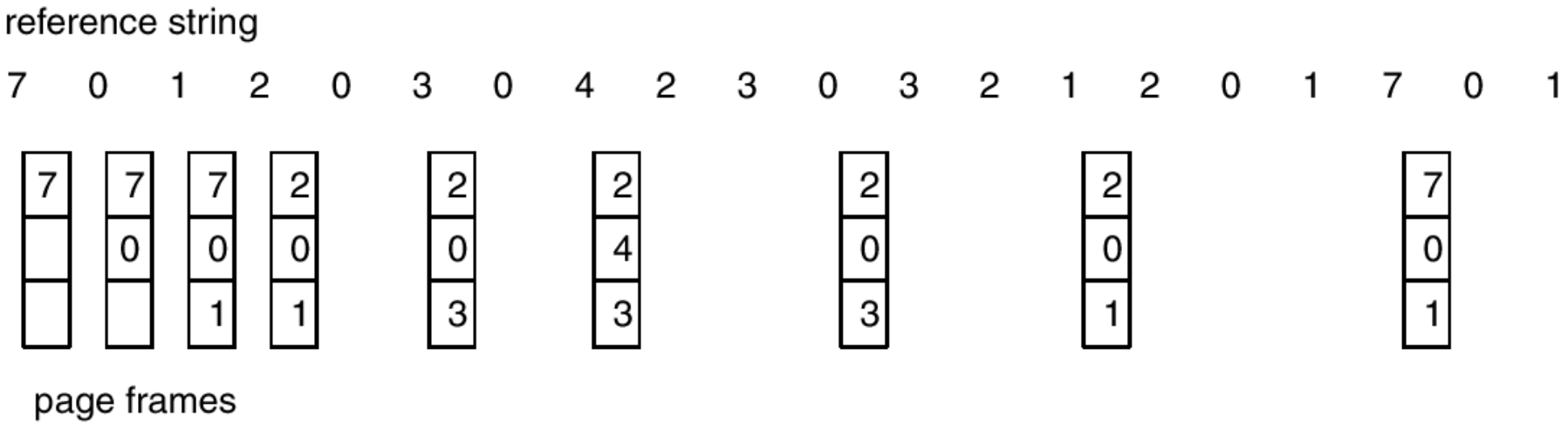

- Unfortunately, the optimal page replacement algorithm is difficult to implement because it requires future knowledge of the reference string.

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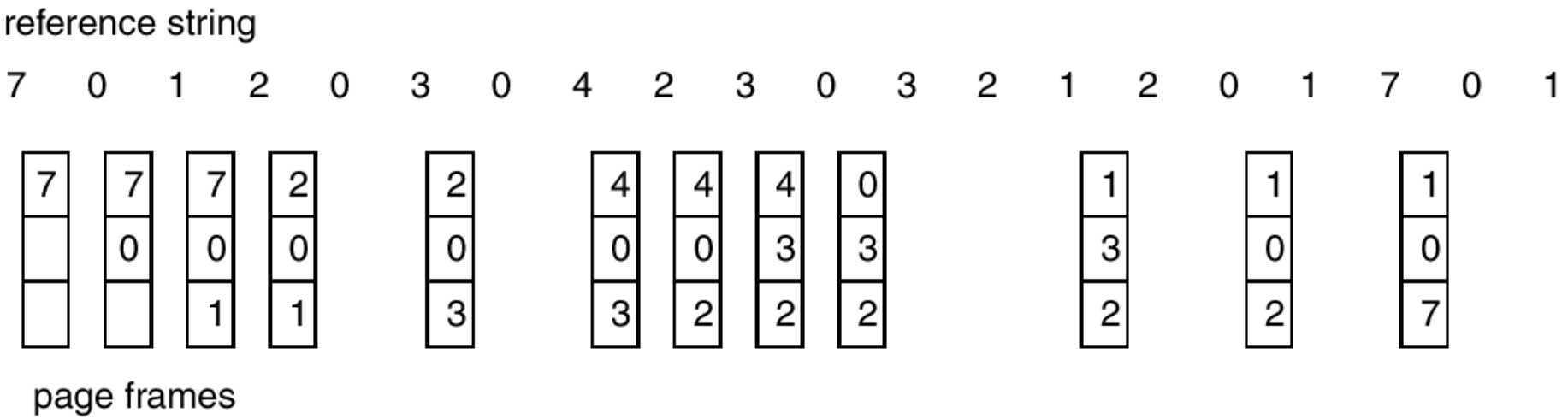

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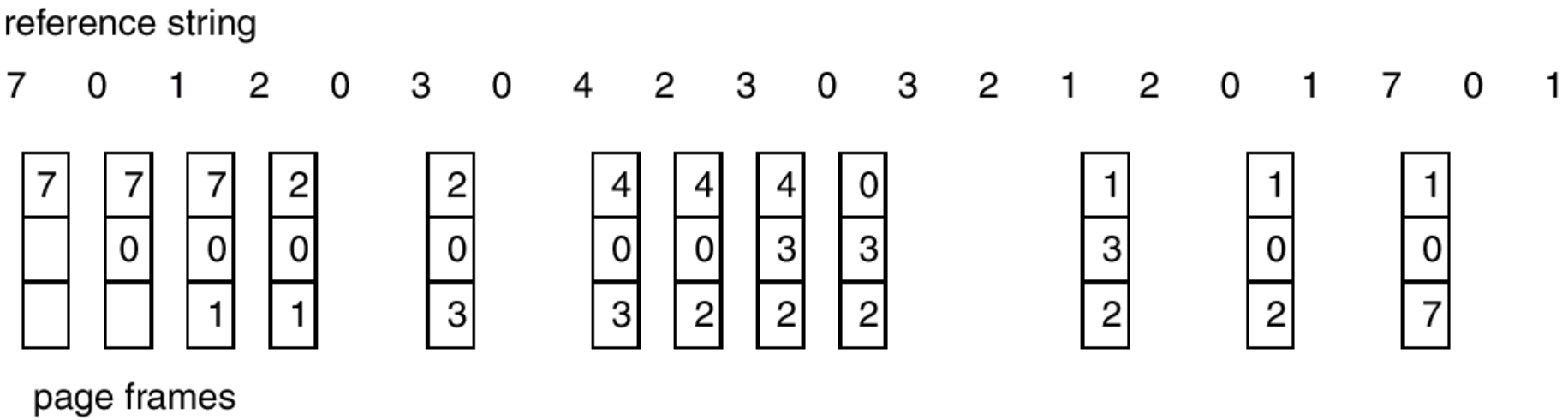

- The LRU replacement may require substantial hardware assistance to determine an order for the frames defined by the time of last use.

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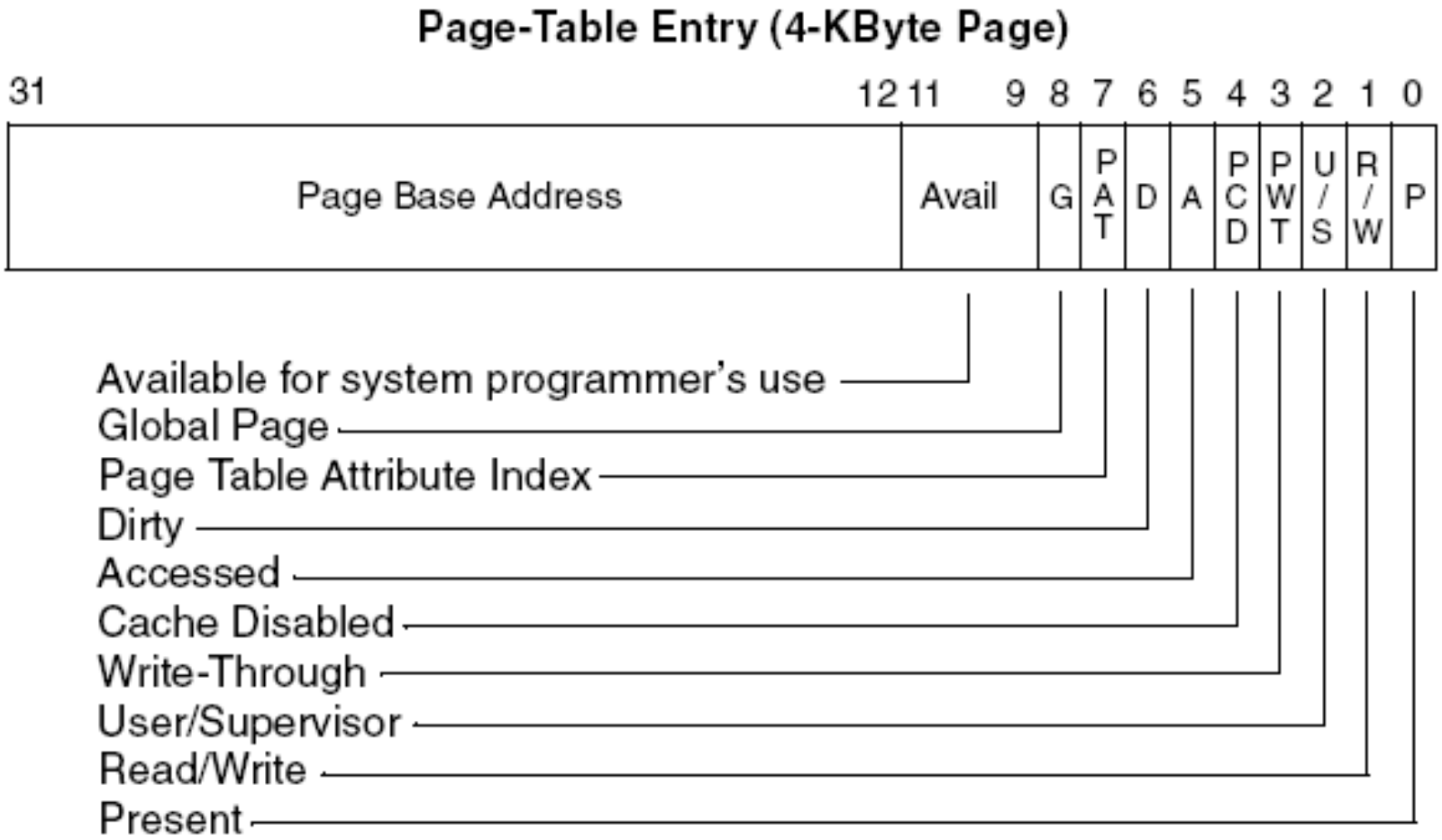

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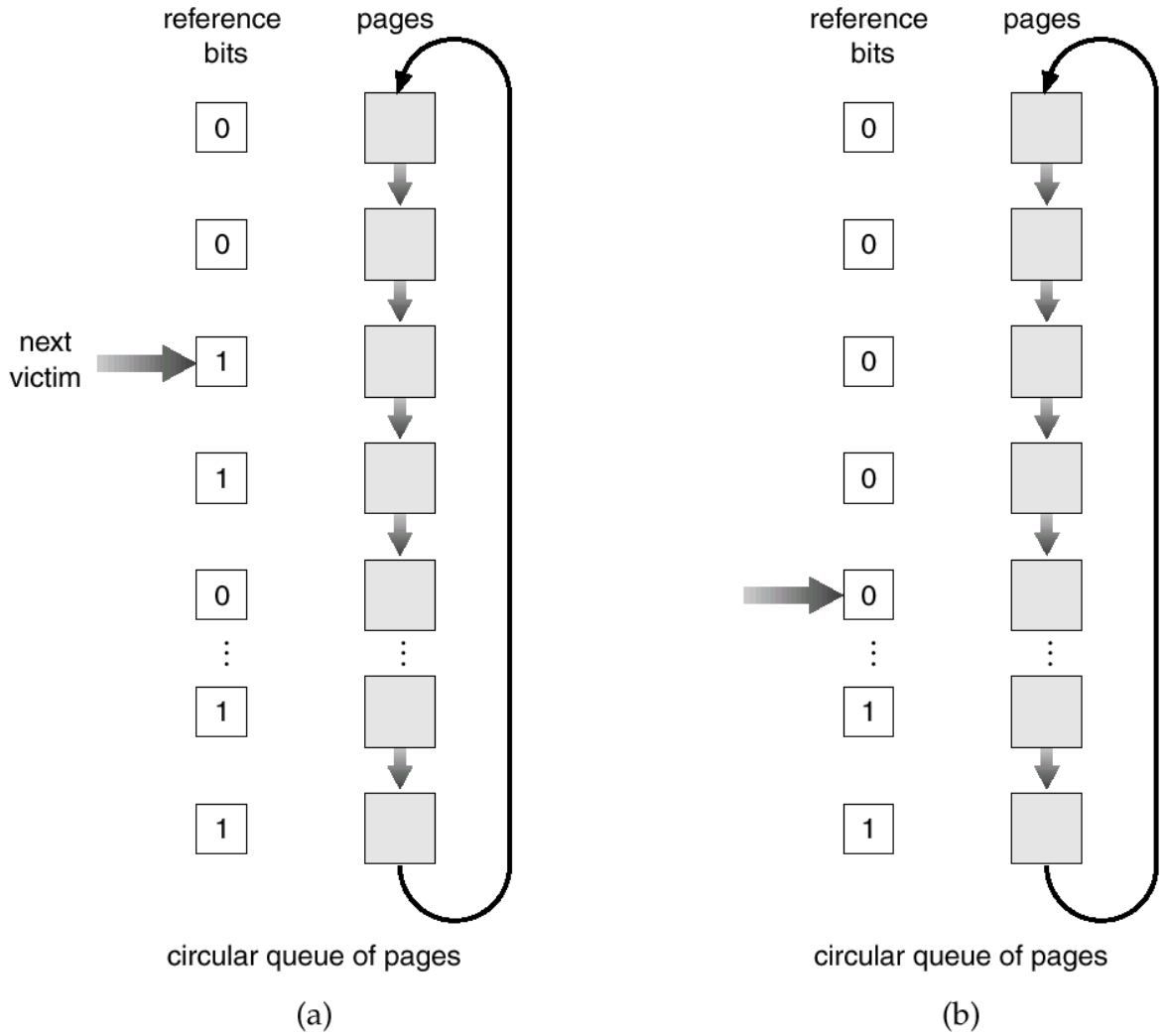

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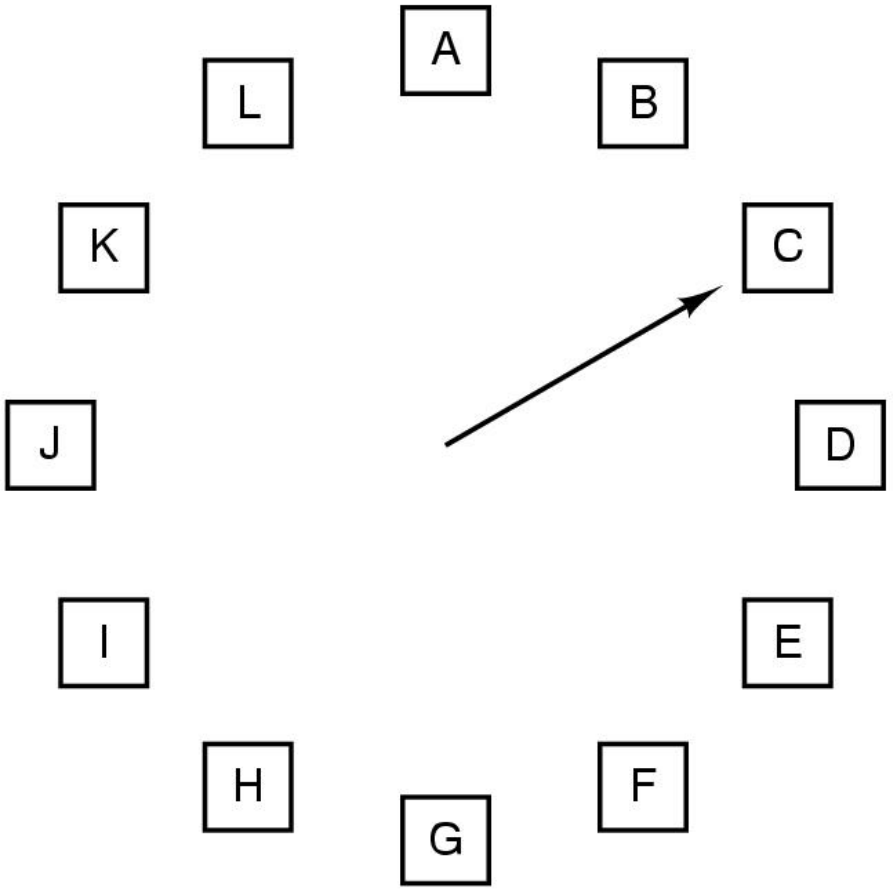

When a page fault occurs, the page the hand is pointing to is inspected. The action taken depends on the R bit:

R = 0: Evict the page

R = 1: Clear R and advance hand

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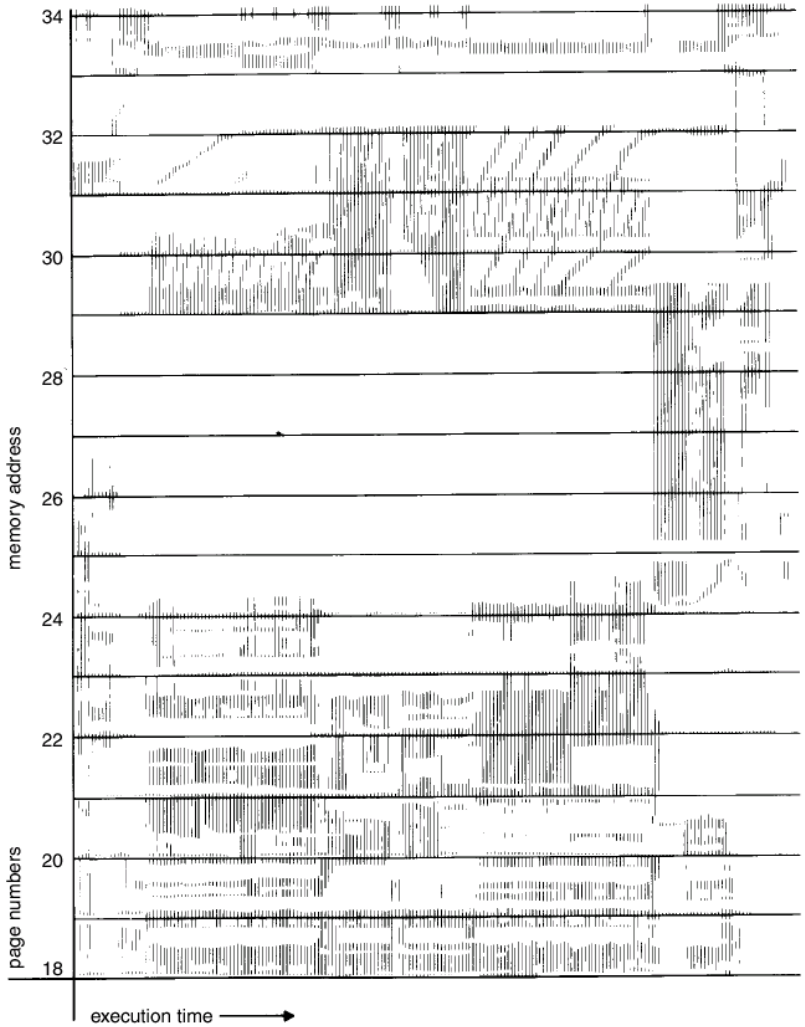

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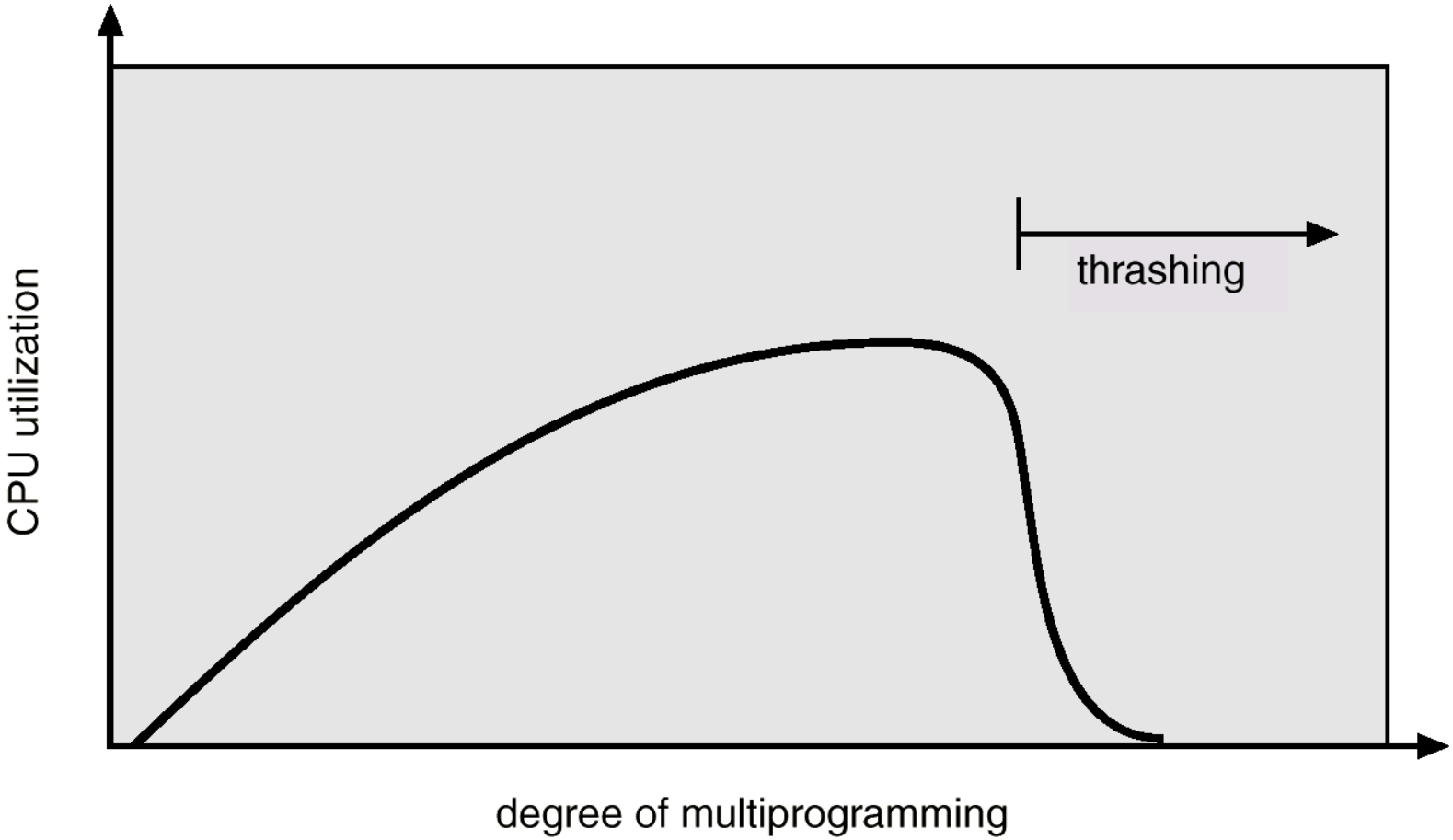

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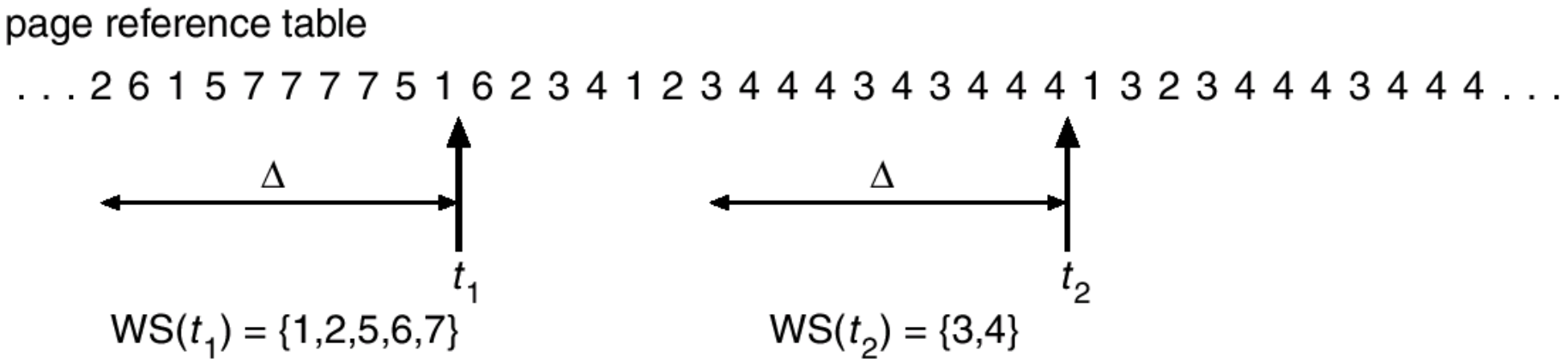

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Outline

Address space layout (1/2)

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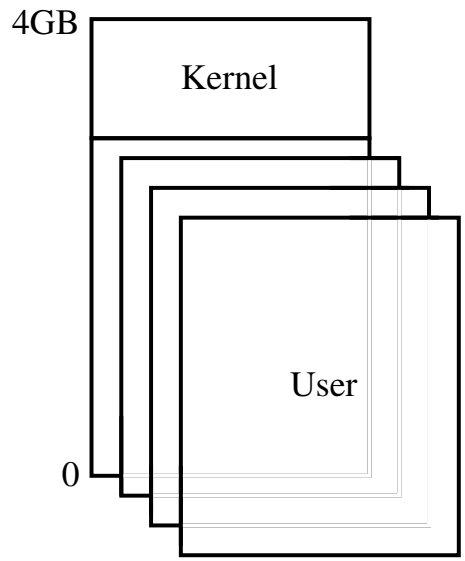

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- We will take Windows 2000 and Linux as the examples to explain their address space layout.

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Windows 2000

- References:
  - Mark E. Russinovich and David A. Solomon, Windows Internals (Part 1, Part 2), 6th Edition, Microsoft Press, 2012.
    - 中文版：深入解析Windows操作系统（第6版），潘爱民、范德成译
  - Jeffrey Richter, *Programming Applications for Microsoft Windows*, 4th Edition, Microsoft Press, 1999.
    - 中文版：Windows核心编程（第4版），王建华译

Address space layout of Windows 2000 Professional

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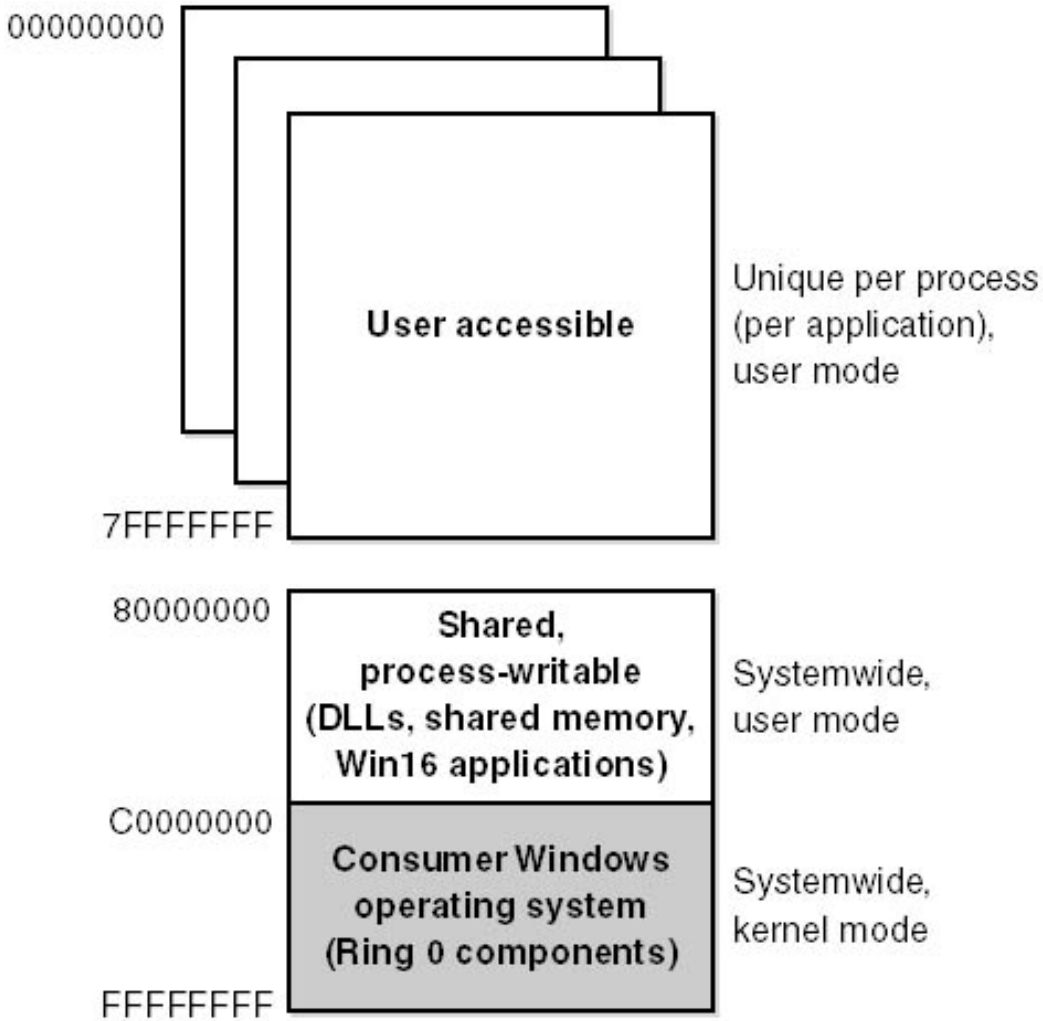

User space layout of Windows 20000 Professional

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```
00010000 Private       4096  1  -RW-
00020000 Private       4096  1  -RW-
00030000 Private    1048576  3  -RW- Thread Stack
00130000 Mapped       12288  1  -R--
00260000 Mapped       90112  1  -R-- \Device\HarddiskVolume1\WINDOWS\system32\unicode.nls
00280000 Mapped      249856  1  -R-- \Device\HarddiskVolume1\WINDOWS\system32\locale.nls
002C0000 Mapped      266240  1  -R-- \Device\HarddiskVolume1\WINDOWS\system32\sortkey.nls
00310000 Mapped       24576  1  -R-- \Device\HarddiskVolume1\WINDOWS\system32\sorttbls.nls
00320000 Mapped      266240  1  -R--
00370000 Private      65536  2  -RW-
00380000 Mapped       12288  1  -R-- \Device\HarddiskVolume1\WINDOWS\system32\ctype.nls
00390000 Private      65536  2  -RW-
00400000 Image        45056  4  ERWC C:\foo.exe
0040B000 Free     264196096
10000000 Image        49152  5  ERWC C:\foo.dll
1000C000 Free    1820278784
7C800000 Image      1163264  5  ERWC C:\WINDOWS\system32\kernel32.dll
7C920000 Image       606208  5  ERWC C:\WINDOWS\system32\ntdll.dll
```

Questions

- Any questions?

Linux

- References

- References
  - Randal E. Bryant, David O' Hallaron, *Computer System: A Programmer's Perspective*, John & Wiley, 2004.

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  - The Linux kernel source code: `http://www.kernel.org`.

User space layout of Linux (1/2)

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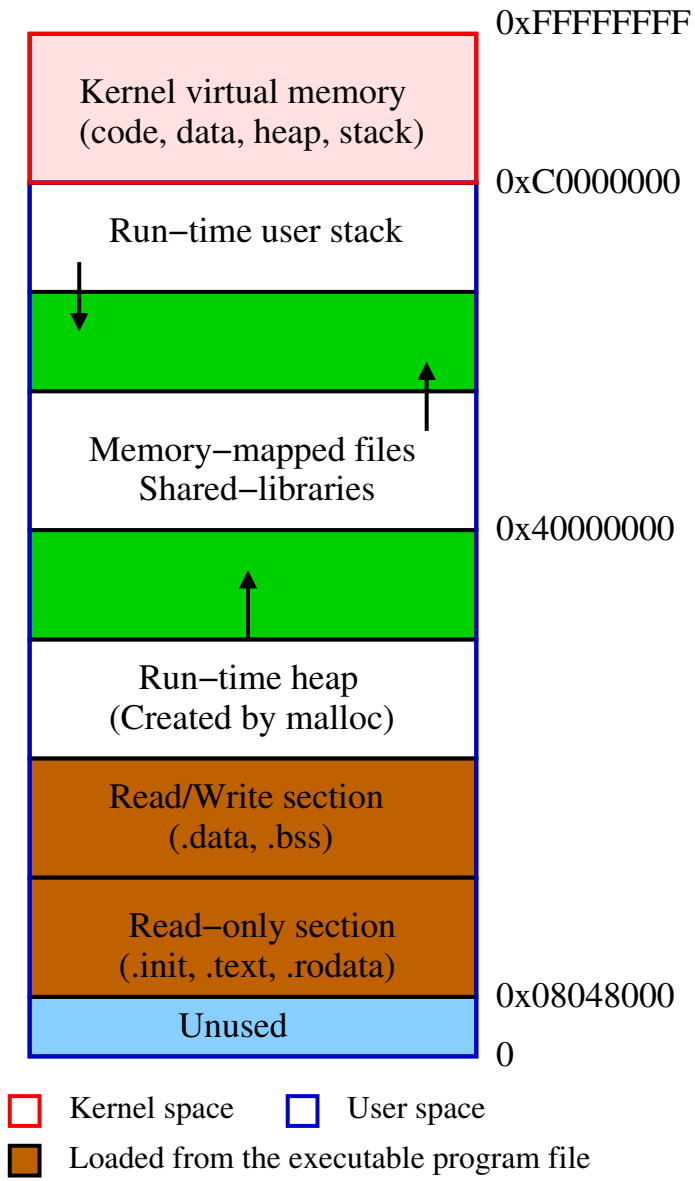

User space layout of Linux (2/2)

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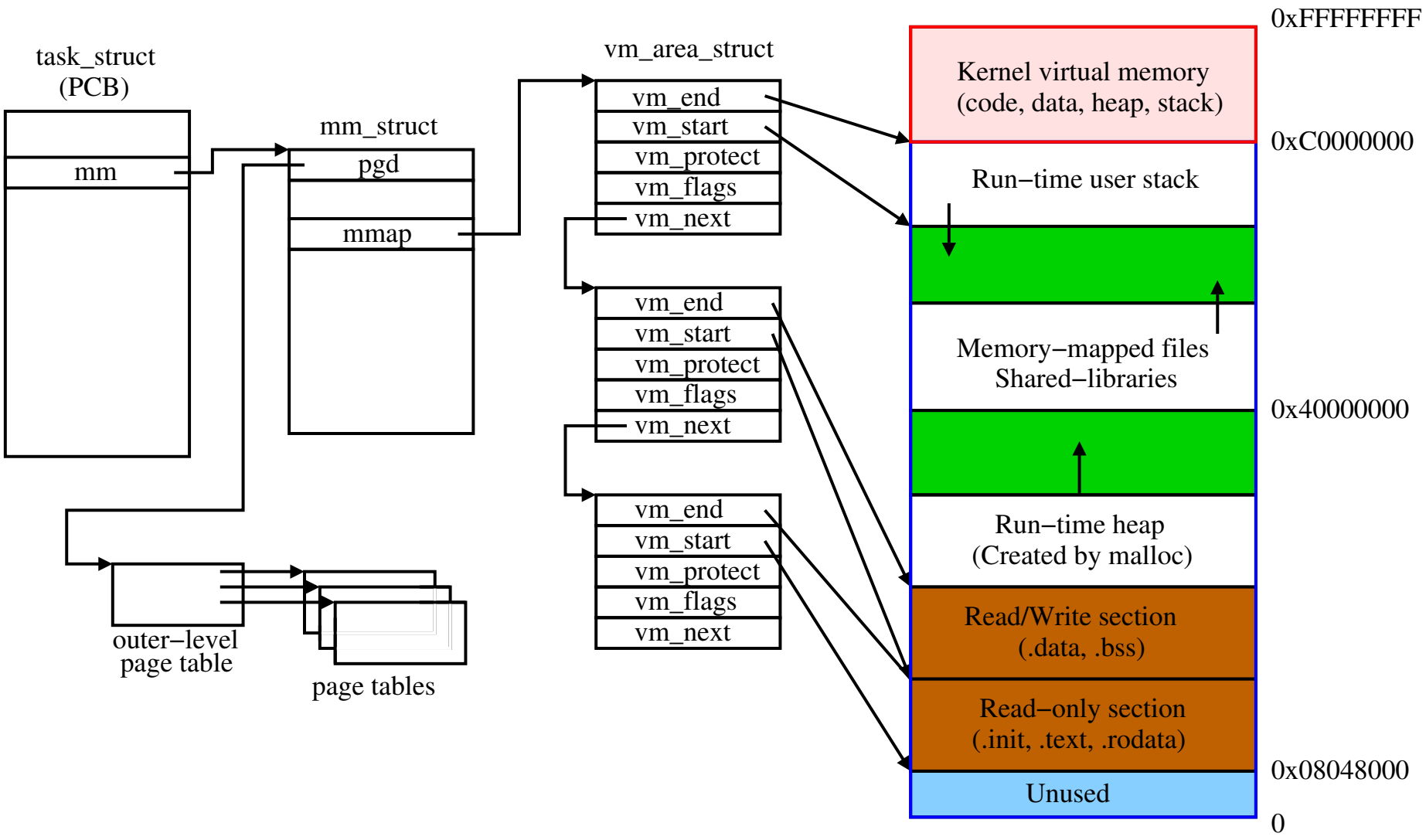

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08049000-0804a000 rwxp 00000000 00:0d 14446  /home/hmj/foo
0804a000-0806b000 rwxp 0804a000 00:00 0      [heap]
b7e06000-b7e07000 rwxp b7e06000 00:00 0
b7e07000-b7f22000 r-xp 00000000 07:00 9506   /lib/libc-2.3.6.so
b7f22000-b7f23000 r-xp 0011b000 07:00 9506   /lib/libc-2.3.6.so
b7f23000-b7f26000 rwxp 0011c000 07:00 9506   /lib/libc-2.3.6.so
b7f26000-b7f29000 rwxp b7f26000 00:00 0
b7f2e000-b7f30000 rwxp b7f2e000 00:00 0
b7f30000-b7f46000 r-xp 00000000 07:00 9507   /lib/ld-2.3.6.so
b7f46000-b7f48000 rwxp 00015000 07:00 9507   /lib/ld-2.3.6.so
bfc31000-bfc46000 rw-p bfc31000 00:00 0      [stack]
ffffe000-fffff000 ---p 00000000 00:00 0      [vdso]
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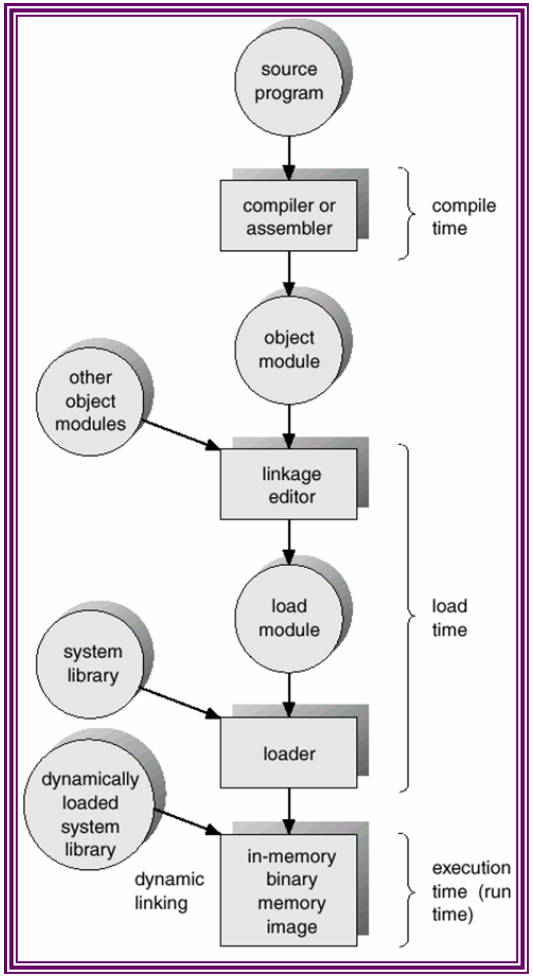

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- But the shared libraries are still NOT so lucky.

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- If a process needs to load additional shared libraries at run time dynamically
  - If the preferred address of the shared library has been occupied by another one, the operating system has to load it to another address. In this case, the relocation is absolutely needed.

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- So, if you are developing an application which contains several shared libraries, relocation may be avoided by *re-base*ing them to different preferred addresses.

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    - A per-process private *jump table* is used.

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