CSCE 313-200
Introduction to Computer Systems
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Operating Systems

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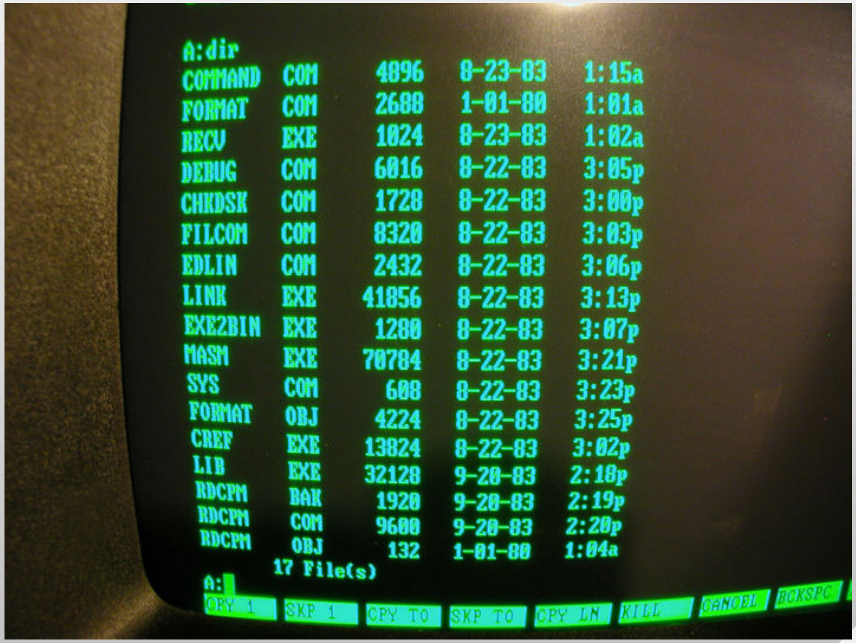
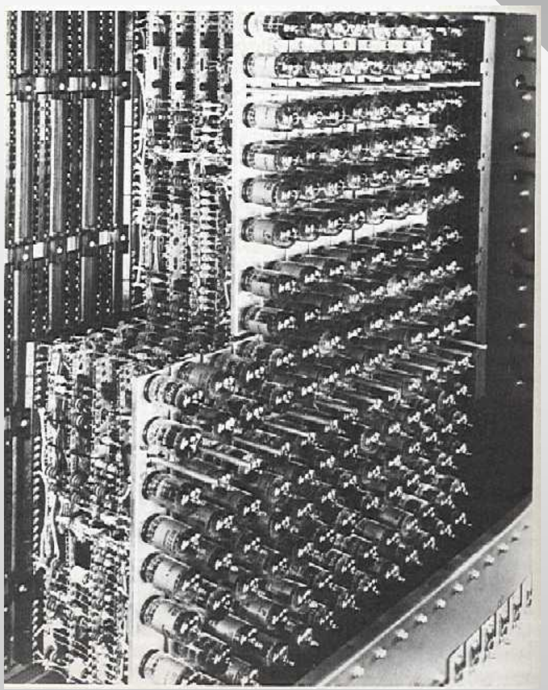
Chapter 2: Book Overview

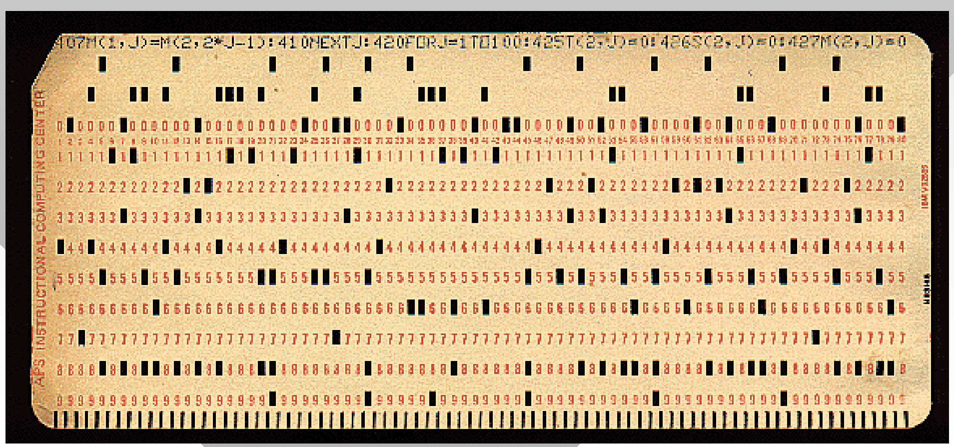
- Lectures skip chapter 1
  - Mostly 312 background with some examples
- Our goal in chapter 2
  - Understand the motivation for building an OS
  - Introduce basic terminology and history
  - Glance over the main concepts studied later



Chapter 2: Motivation



- Early computers (1940-1950s) did not have an OS
- Programs (called jobs) were loaded manually from punch cards
  - Errors were indicated by lights
  - Printer output signaled successful completion
- Three main problems:
  - Scheduling inefficiency
  - Setup delays
  - Hardware awareness



IBM punch card (invented in 1928)

Chapter 2: Motivation

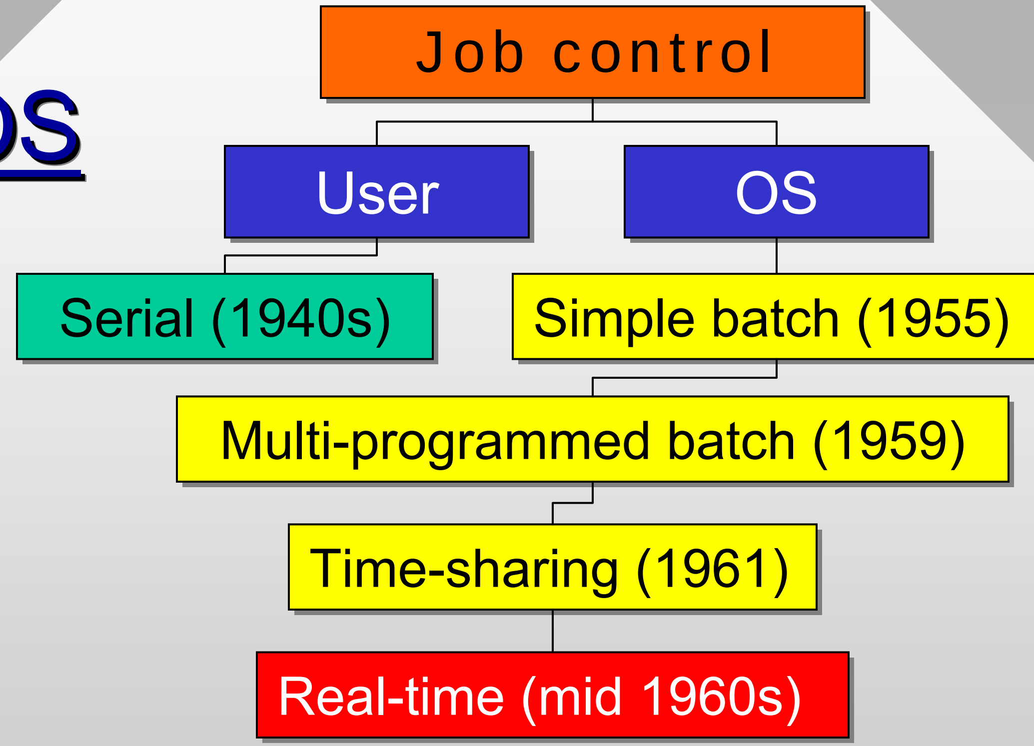
- Scheduling inefficiencies
  - Sign-up sheet to reserve computer time
  - Wasted resources if job finishes quicker than reserved time
  - Forced termination and repeated visits if taking too long
- Setup delays
  - Loading compiler, source code, libraries, input data, and linking involved mounting tapes and/or card decks
  - If an error occurred, the user had to restart the process
  - Considerable time dedicated to setting up the program to run
- Hardware awareness
  - Programmer had to write directly into device registers in every program, keep track of hardware changes
  - Time wasted on largely irrelevant code development

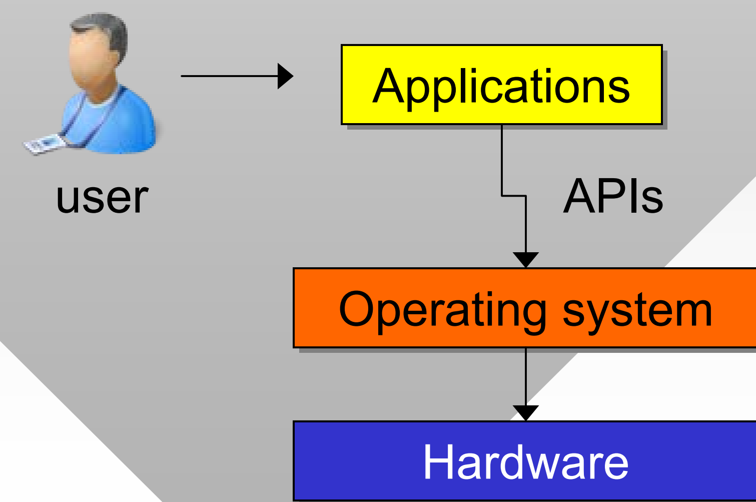
Chapter 2: Roadmap

- 2.1 OS objectives and functions
- 2.2 Evolution of the OS
- 2.3 Major achievements
- 2.4 Other developments
- 2.5 Virtual Machines
- 2.6 Multi-core considerations
- 2.7 MS Windows
- 2.6 Traditional UNIX
- 2.7 Modern UNIX
- 2.8 Linux

Evolution of the OS

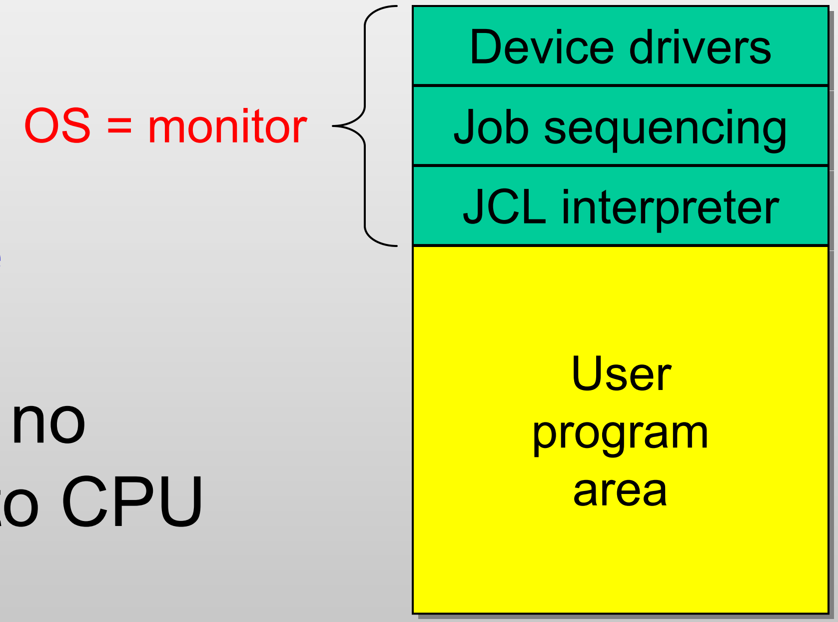
- Manual job control in the 1940s was known as serial processing
- Extreme inefficiency and inconvenience prompted automation of the process and development of an OS
- Main functions
  - Controls the execution of application programs
  - Provides an interface to hardware





Simple Batch System (1955)

- Early computers were extremely expensive
  - Was important to maximize processor utilization
- With an OS present, user no longer had direct access to CPU or devices
  - Instead, submitted jobs into a FIFO queue that was read and executed by a *monitor*
- When programs were done, they returned control to the monitor



- *Job Control Language (JCL)*
  - Directives how to run the job (e.g., compiler, input data, job owner)

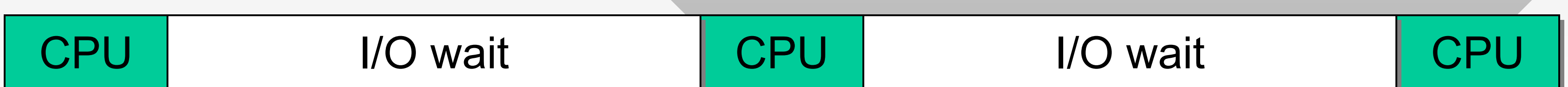
Simple Batch System

Hardware features

- Memory protection
  - Jobs with access violations (e.g., trying to wipe out the monitor) were aborted
- Timer
  - Prevented jobs from monopolizing system or infinitely looping
  - Each job had a fixed deadline by which it had to finish
- Privileged instructions
  - Execution allowed only by the monitor
  - Prevented jobs from crashing the system or reading unauthorized data (e.g., the next job)
  - Monitor controlled all I/O
- I/O interrupts
  - Were not needed as all I/O was synchronous

Multi-Programmed Batch System (1959)

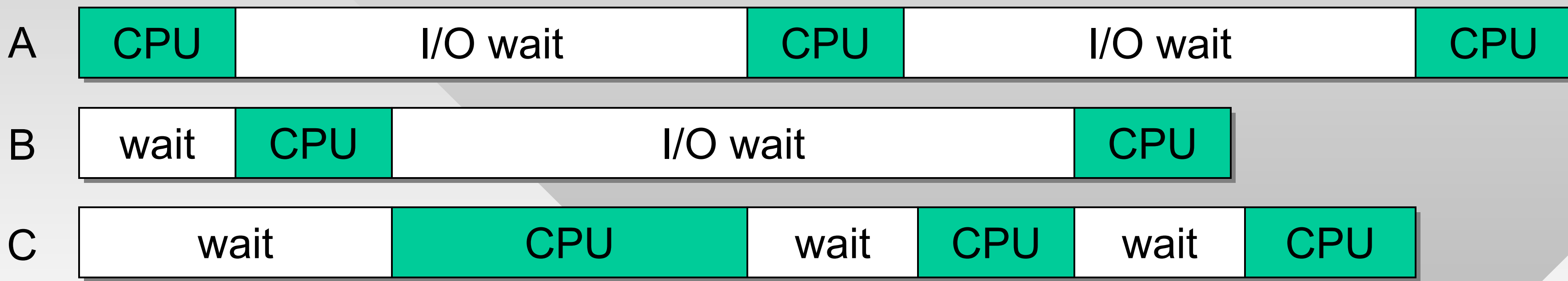
- Even in batched systems, the CPU was often idle
  - Automatic job sequencing helped reduce the delay *between* the jobs, but not *within* them
  - Reason: I/O devices are slow compared to processor
- Example: a job spends 15 ms reading a record from the file, then processes it for 1 ms, and finally writes one record to another file (also 15 ms)
  - What is the CPU utilization?



- This is often called *uni-programming*

Multi-Programmed Batch System

- Idea: when one job needs to wait for I/O, the monitor can switch the CPU to another job
  - Various scheduling algorithms are possible
  - Example below uses strict priority scheduling from A to C

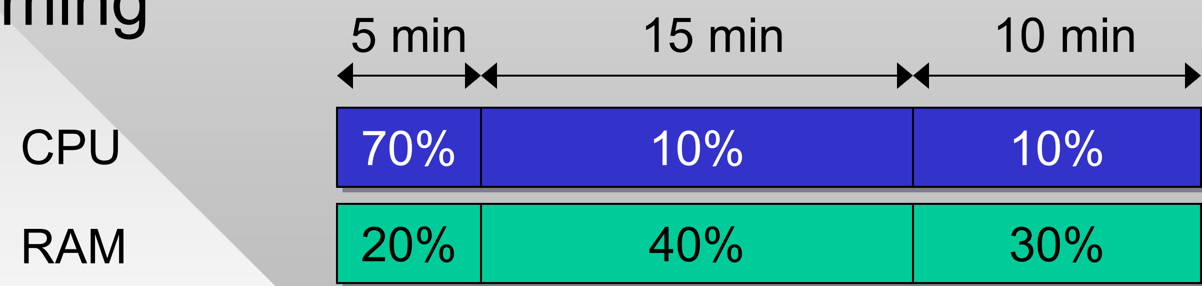


- Interrupts are now needed for monitor to regain control
- This is called multi-programming (or multi-tasking) and is now the central theme of modern OSes

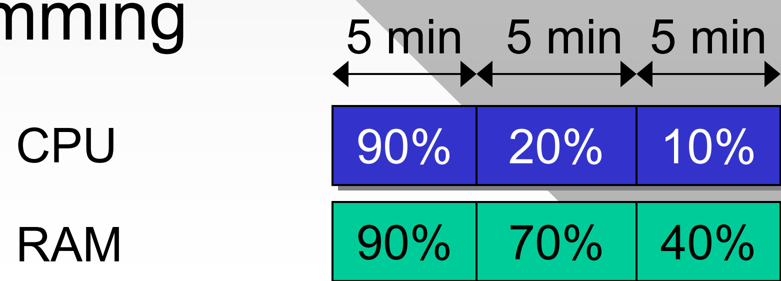
Example

	Job 1	Job 2	Job 3
CPU	70%	10%	10%
Duration	5 min	15 min	10 min
RAM	50 MB	100 MB	75 MB

- At time 0, three jobs are submitted to a monitor in a system with 250 MB of RAM
  - CPU in table means % of time task is not blocked on I/O
  - Assume jobs never conflict on the same I/O device
- Uni-programming



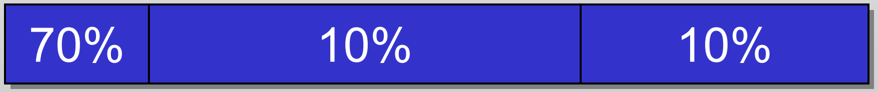
- Multi-programming



Example

	Job 1	Job 2	Job 3
CPU	70%	10%	10%
Duration	5 min	15 min	10 min
RAM	50 MB	100 MB	75 MB

- Task 1: completion time of last job in uni-programming?
- Task 2: what is the average CPU and RAM utilization?
  - Metric computed over the entire interval
- Uni-programming



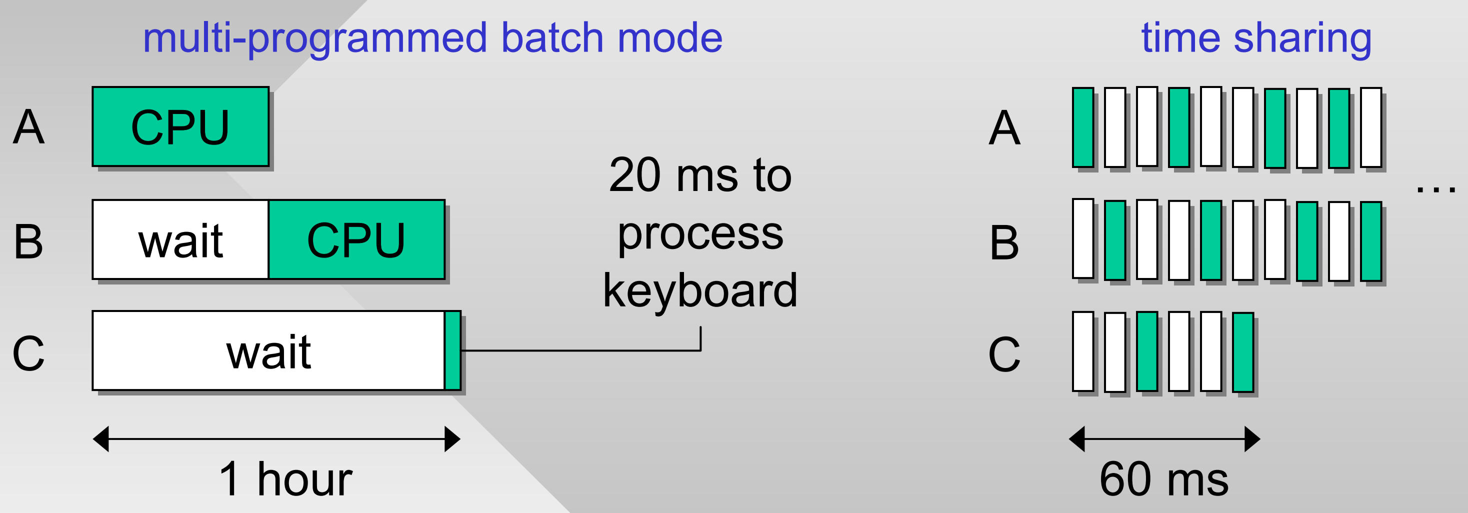
  - CPU: (70%*5 + 10%*15 + 10%*10)/30 = 20%
  - RAM: (20%*5 + 40%*15 + 30%*10)/30 = 33.3%
- Task 3: what is the throughput of the system?
  - Number of jobs finished per time unit (e.g., 1 hour)
- Task 4: what is the mean response time?
  - Average delay from job submission to its completion
  - Uniprocessing: (5 + 20 + 30)/3 = 18.333 min

Time Sharing System (1961)

- Batch mode favors long CPU-bound jobs
  - Response time for other tasks may be minutes or hours
- Maximizing CPU utilization does not suit interactive jobs
  - E.g., a text editor cannot wait 3 hours for its turn
- Under time-sharing, CPU is periodically provided to all jobs not waiting for I/O
  - Goal: minimize response delay
- Time divided into slices
  - E.g., 200 ms in early systems, 1-10 ms in modern OSes
- The kernel rotates through all jobs scheduling them to run on the CPU
- Max delay before getting on the CPU
  - Slice * (number of jobs in system – 1)

Time Sharing System

- Comparison



- Response time of C with 10-ms slices?
- First time-sharing OS
  - *Compatible Time-Sharing System* (CTSS), MIT 1961
- Modern OSes derived from these early concepts

Real-Time System

- In regular OSes, job switching delays are random and depend on the immediate backlog of CPU-bound tasks and their priority
  - Under worst-case scenarios, a job may not receive its turn for many slices
- This presents certain problems in mission-critical applications
  - E.g., car traction control, helicopter missile-guidance system
- Real-time OS (RTOS) provides guarantees on scheduling and interrupt delays
  - Examples include Windows CE, RTLinux, VxWorks

OS Growth

- OSes are complex pieces of software
  - MIT's CTSS (1961-3): 32,000 machine words
  - IBM's OS/360 (1964): 1M CPU instructions
  - Multics (1978): 20M CPU instructions
- Later, software was measured in source lines of code (SLOC)
  - Estimates from Wikipedia:

Year	OS	SLOC
93	NT 3.1	4M
94	NT 3.5	7M
96	NT 4.0	11M
00	2000	29M
01	XP	45M
03	Server 2003	50M

Year	OS	SLOC
91	Linux kernel	10K
94	Linux 1.0.0	176K
12	Linux 3.3 kernel	15M
05	MacOS 10.4	86M
07	Debian 4.0	283M
09	Debian 5.0	324M

Chapter 2: Roadmap

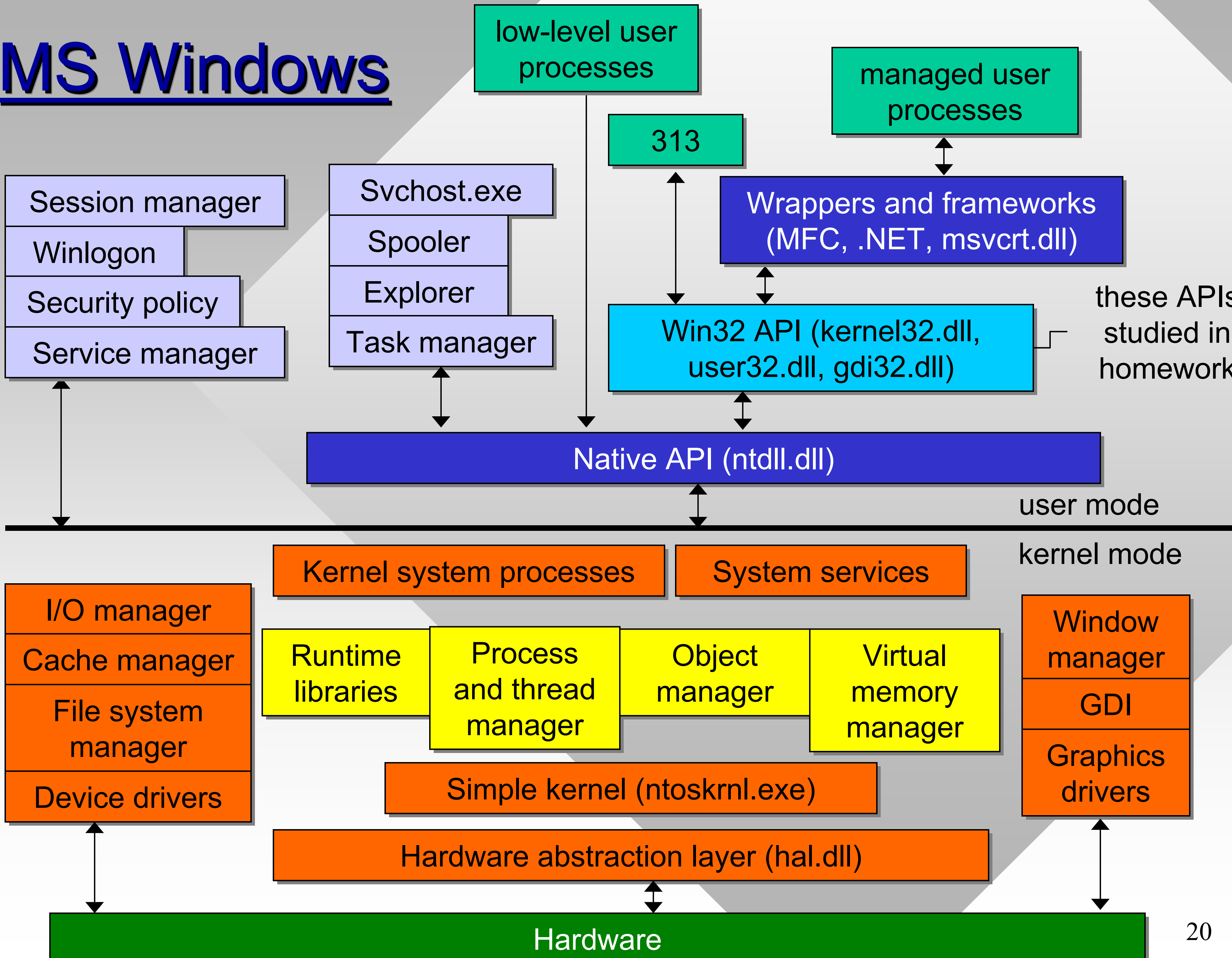
Major Achievements

- Impossible to deal with OS complexity without certain systematic ways of managing resources, jobs, and users
- Major advances in the development of operating systems (layout of the book):
  - Processes and threads (ch. 3-4)
  - IPC (inter-process communication) and synchronization mechanisms (ch. 5-6)
  - File systems (ch. 11-12)
  - Memory (RAM) management (ch. 7-8)
  - Scheduling and resource allocation (ch. 9-10)
  - Information protection and security (ch. 14-15)

covered in this class

Chapter 2: Roadmap

MS Windows

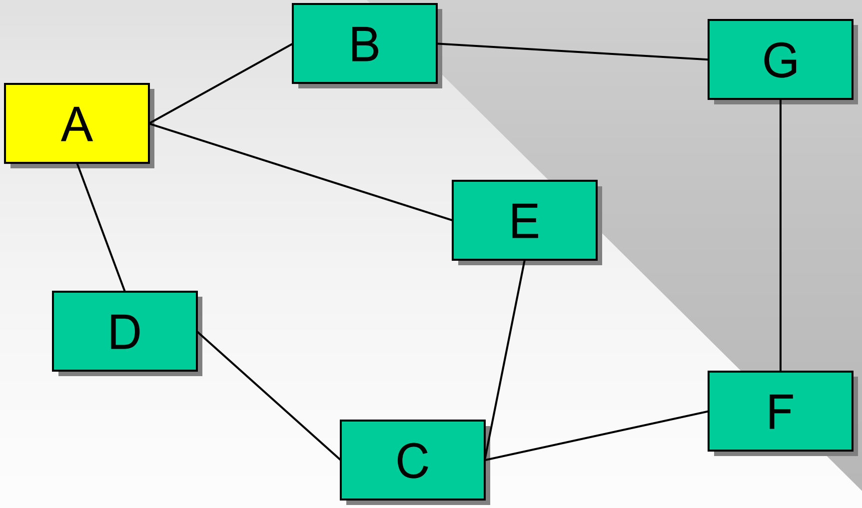


low-level user processes
managed user processes
313
Session manager
Winlogon
Security policy
Service manager
Svchost.exe
Spooler
Explorer
Task manager
Wrappers and frameworks (MFC, .NET, msvcrt.dll)
Win32 API (kernel32.dll, user32.dll, gdi32.dll)
these APIs studied in homework
Native API (ntdll.dll)
user mode
kernel mode
Kernel system processes
System services
I/O manager
Cache manager
File system manager
Device drivers
Runtime libraries
Process and thread manager
Object manager
Virtual memory manager
Window manager
GDI
Graphics drivers
Simple kernel (ntoskrnl.exe)
Hardware abstraction layer (hal.dll)
Hardware

Homework #1

q = L + (float)w / (d+1)

- When running A*
  - Incorrect # of nodes if weight is integer in q = L + w / (d+1)
- Basic BFS and DFS
  - Order of traversal on this graph?




```
Adjacency list
A: E, D, B
B: A, G
C: E, D, F
D: A, C
E: A, C
F: C, G
G: B, F
```

Homework #1

- Refresh the concept of search
  - Assume an undirected graph G = (V,E)
  - Start node s∈V
- Maintain two structures
  - Unexplored set U
  - Discovered set D
- Approach #1:

```
U.add (s)
while ( U.notEmpty () )
    x = U.removeNextNode ()          // node to explore
    if ( D.find(x) == true )         // if already explored, ignore
         continue
    N = G.getNeighbors (x)           // N is a set of nodes
    if ( N.size() == 0 ) break       // exit?
    for each y in N
         U.add (y)
```

Any problems?

Homework #1

- This code fails to actually insert anything into D
- Correct version:

```
U.add (s)
while ( U.notEmpty () )
    x = U.removeNextNode ()
    if ( D.find(x) == true )        // if already explored, ignore
         continue
    D.add (x)
    N = G.getNeighbors (x)
    if ( N.size() == 0 ) break      // exit?
    for each y in N
            U.add (y)
```

Any drawbacks?

- Requires huge storage as each node may be pushed into U as many times as there are links to it
  - Not advisable in practice

Homework #1

- Approach #2 inserts a single copy of each node in U:

```
U.add (s); D.add (s);                    // s = source node
while ( U.notEmpty () )
    x = U.removeNextNode ()
    N = G.getNeighbors (x)
    if ( N.size() == 0 ) break       // exit?
    for each y in N
        if ( D.find (y) == false ) // has been pushed in U?
            U.add (y)
            D.add (y)
```

Always use this version!

- For most types of non-trivial exploration, approach #2 is far superior to #1
- What if D has a function that combines find/add?
  - Can directly use STL set's insert() function

Homework #1

- When you find the exit, how far is it from s?
- Idea: make U keep track of tuples (nodeID, distance)

```
U.add (s, 0); D.add (s);
while ( U.notEmpty () )
    t = U.removeNextTuple ()      // t is a tuple
    N = G.getNeighbors (t.ID)
    if ( N.size() == 0 )
         printf (“Found at distance %d\n”, t.distance)
         break
    for each y in N
        if ( D.find (y) == false )          // new node?
            U.add (y, t.distance + 1)
            D.add (y)
```

- Note that U.add() also needs light intensity for bFS/A*
  - See the handout for details

Homework #1

- Reusing the search algorithm
  - Create a base class

```
class Ubase {
        virtual void Add (uint64 ID, int distance, float intensity) = 0;
        virtual UnexploredRoom RemoveNextTuple (void) = 0;
        ...
}
```

  - Inherit four classes

```
class Ubreadth : public Ubase {
        // implement a queue here
}
class Udepth : public Ubase {
        // implement a stack here
}
...
```

```
Ubase *ptr;
if (searchType == BFS)
    ptr = new Ubreadth;
else if ...

Search (ptr);
```

  - Create base pointer to a specific class, then send it to search()

```
Search (Ubase *U)
{
    while (U->size() > 0)
          ...
}
```