CSCE 313-200
Introduction to Computer Systems
Spring 2018

File System IV

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Updates

- Quiz #3 covers material since quiz #2
- Approach to homework #3
  - Basic producer-consumer between the threads
  - Start with disk thread, make it read the file correctly, pass valid buffers thru PCfull, receive slotIDs thru PCempty
  - Write the search thread without handling strings that cross boundaries between buffers, verify correctness
  - Add shadow buffers, unbuffered I/O, write report
- Parsing the keywords file in hw#3
  - Read into a buffer, use strchr() to find \n, wipe out \r and trailing spaces by placing NULL at the last alpha-numeric character of each keyword
  - Set up pointers to these strings in separate array

Semaphore Problems

- Single-track train tunnel

```
                    Train
TryEnteringTunnel (int dir) {
    // x is the tunnel ID,
    // dir is the direction (0,1)
    <your code here>
}
// this API moves the train through tunnel
PassThruTunnel (int dir);
```

OK

crash

- Three main rules:
  - Prevent head-on collisions
  - Allow multiple concurrent trains in the same direction
  - No sleep-looping or busy-looping
- Fourth rule: no more than N trains in the tunnel
- Fifth rule: deterministically prevent starvation

Chapter 12: Roadmap

12.1 Overview

12.2 File organization

12.3 Directories

12.4 Sharing

12.5 Record blocking

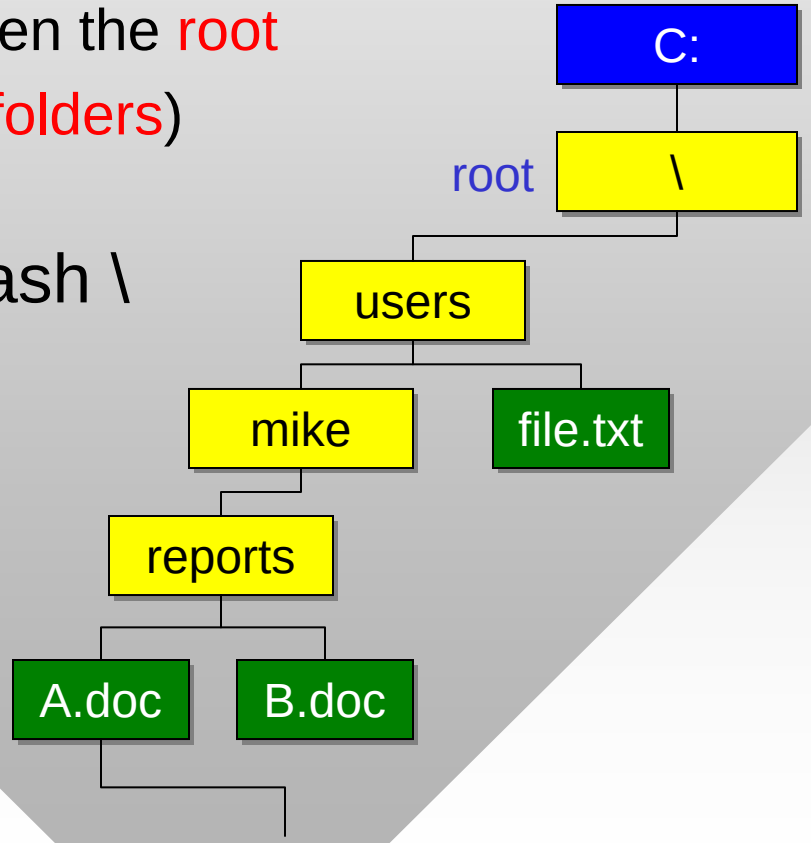
12.6 Secondary storage

12.7 File security

12.8-12.10 Unix, Linux, Windows

Directories

- Files on disk are organized into a hierarchical structure called directory tree
  - Starts from the optional drive, then the root
  - Non-leaf nodes are directories (folders) and leaves are usually files
- Windows: separator is backslash \
  - Unix: forward slash /
- Concatenation of directories from the root to the node is the path of that node
- Windows files/folders are not case-sensitive, Unix are



path = C:\users\mike\reports\A.doc

Directories

- Each process executes in some current working directory (CWD) where all files without a full path are read/written
  - fopen (“report.txt”, ...) executes in CWD
  - C-style _getcwd(), Windows API GetCurrentDirectory()
- How to find out where the exe file was started from?
  - Parse argv[0], which always contains the full path
- Manipulating directories
  - _chdir, _mkdir, _rmdir
  - SetCurrentDirectory, CreateDirectory, RemoveDirectory
- Absolute paths start from the root, relative from current directory

More APIs

```
HANDLE WINAPI FindFirstChangeNotification (
          __in  LPCTSTR lpPathName,
          __in  BOOL bWatchSubtree,
          __in  DWORD dwNotifyFilter );
```

- Directory may be watched for changes
  - Files modified, written, renamed, size changed, etc.
  - Including subdirectories
- Addition useful things:
  - CopyFile, MoveFile, DeleteFile, EncryptFile, FindFirstFile, GetFileSize, GetTempFileName
- Flushing write buffers: fflush, FlushFileBuffers
- Reading zip files: LZOpenFile / LZRead
- A list of file management APIs:
  - http://msdn.microsoft.com/en-us/library/aa364232(v=VS.85).aspx

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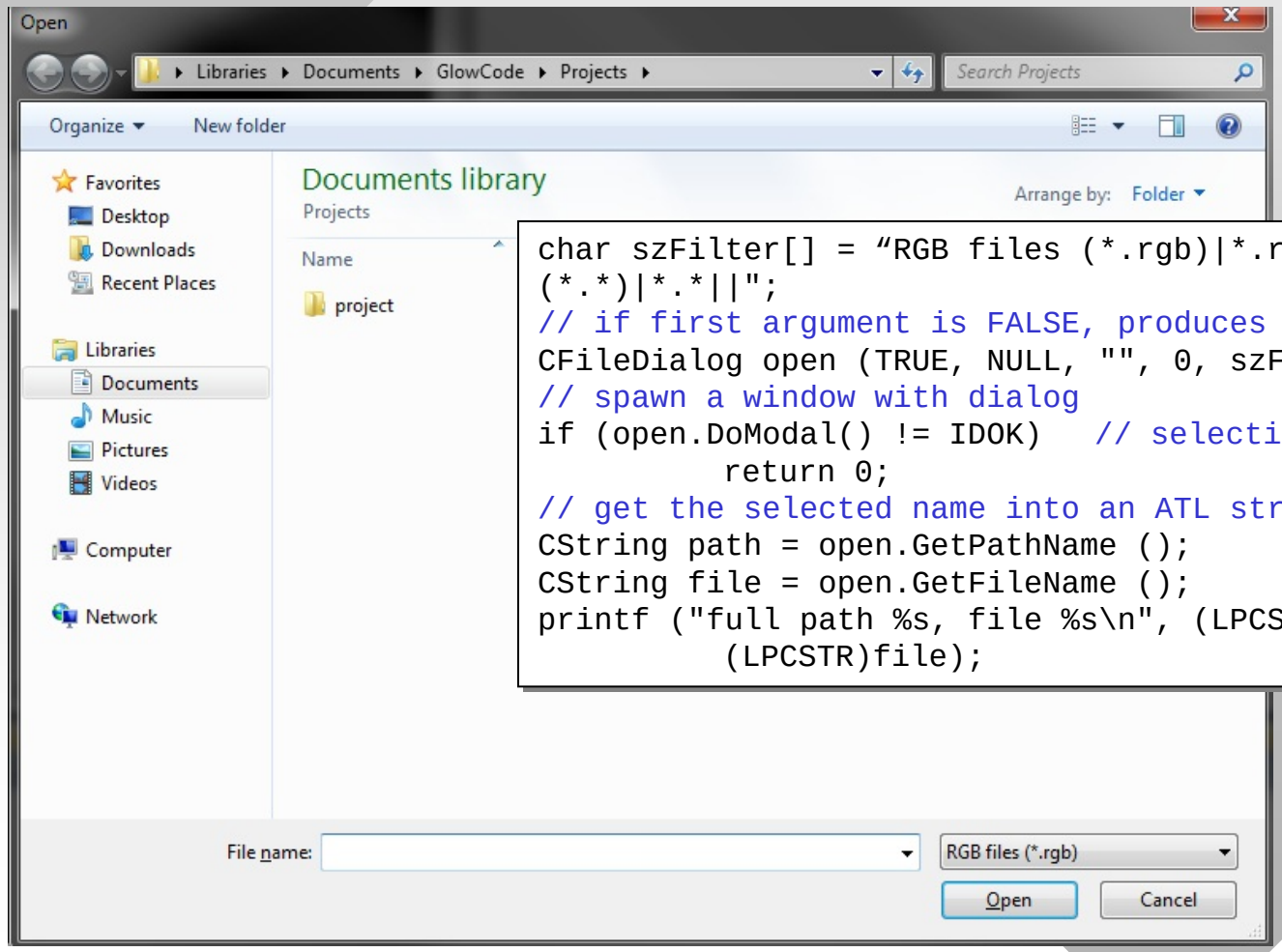
File Sharing

- Each file has one owner and a set of permissions
  - These specify what groups/users have what type of access to the file; real headache to manage from a Windows program
- Sharing mode determines concurrent access to file
  - In CreateFile, FILE_SHARE_WRITE | FILE_SHARE_READ allows to read files that are being written to by another process (assuming it also opens the file with the same parameters)
- Attributes are bit values of flags associated with file
  - E.g., archive, compressed, device, directory, encrypted, hidden, normal, read-only, system file
  - Can be manipulated using GetFileAttributes, SetFileAttributes
- If file needs to be locked temporarily, use LockFile instead of prohibiting sharing altogether

More on Files

```
#define _AFXDLL
#include <afxdlgs.h>
#include <Mmsystem.h>   // if using timeGetTime()
#include <Windows.h>    // cannot precede afxdlgs.h
// Project properties -> C/C++ -> Code Generation ->
// Runtime Library = Multi-threaded DLL (/MD)
```

- ATL/MFC dialog to prompt users to choose a file




```
char szFilter[] = “RGB files (*.rgb)|*.rgb|All Files
(*.*)|*.*||";
// if first argument is FALSE, produces Save As...
CFileDialog open (TRUE, NULL, "", 0, szFilter);
// spawn a window with dialog
if (open.DoModal() != IDOK)   // selection made?
          return 0;
// get the selected name into an ATL string; disable unicode
CString path = open.GetPathName ();
CString file = open.GetFileName ();
printf ("full path %s, file %s\n", (LPCSTR)path,
          (LPCSTR)file);
```

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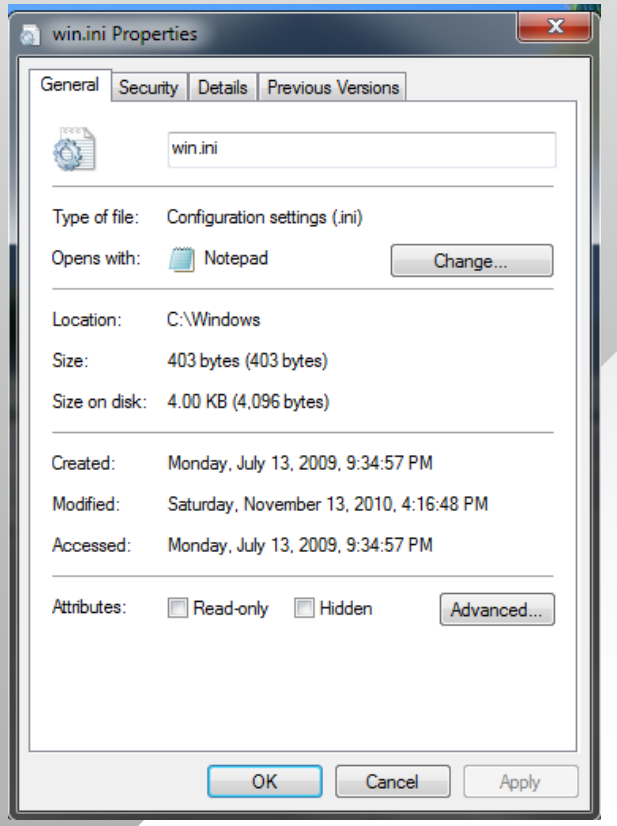
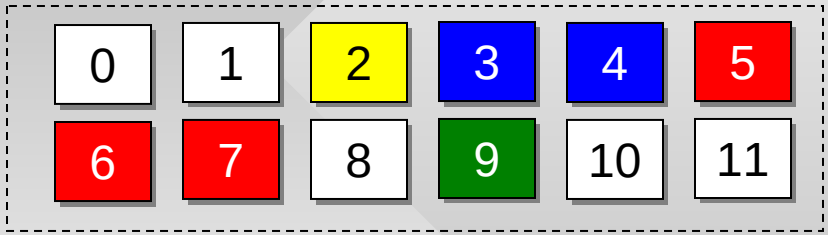
File Allocation

- Disk is split into groups of sectors called clusters
  - Cluster size is a multiple of sector size, usually up to 64 KB
- File space allocated in terms of clusters
  - Internal fragmentation refers to wasted space inside each cluster
- How to allocate clusters to files?
- 1) Pre-allocation
  - Size declared ahead of time, cannot be expanded later
- 2) Dynamic allocation
  - As more clusters are needed, they are provided by the OS

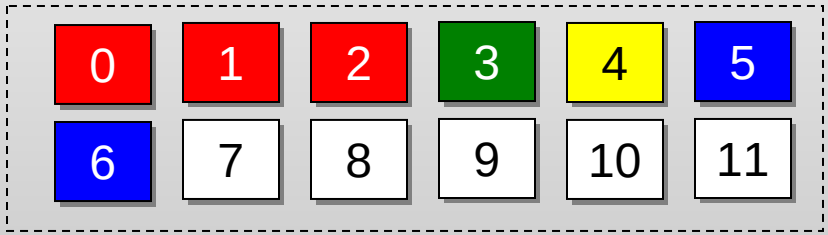


File Allocation

- 2.1) Contiguous allocation
  - Files are given only adjacent sets of blocks on disk



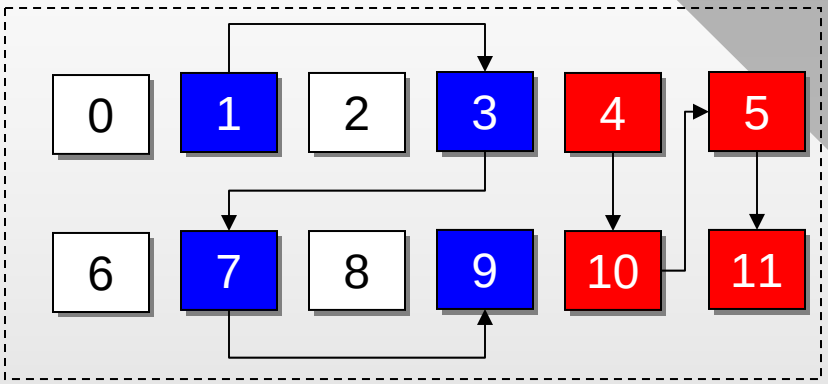
original disk, blue file cannot write



compacted disk

- First problem is external fragmentation (i.e., empty space between files not large enough for new files)
- Second problem when not enough contiguous space
  - Either request is denied, or the disk must undergo compaction
- Slow and inefficient, not used in practice

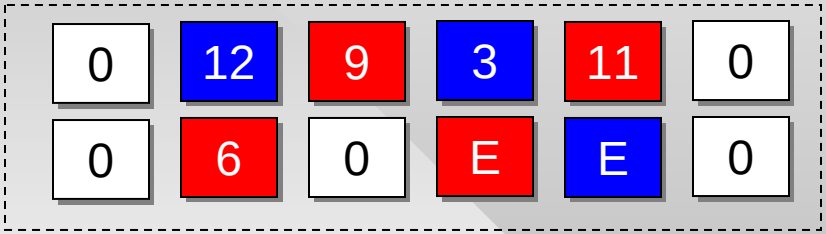
File Allocation



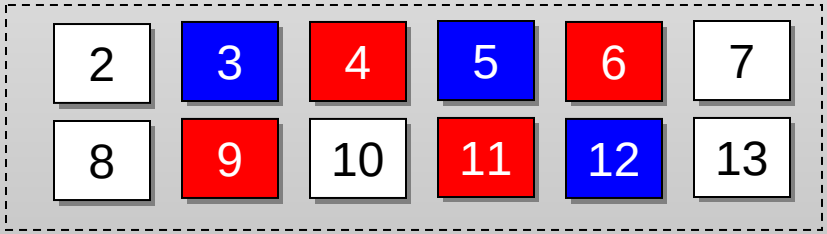
- 2.2) Chained allocation
  - Clusters in files are organized into linked lists by storing a pointer to next cluster
  - Must read the current cluster to find the next one
- File fragmentation into non-sequential disk blocks
  - Affects access speed as it may require extensive seeking
- Also, impossible to predict locality in cluster access
  - Difficult to realize that blocks 4-5 and 10-11 are sequential
  - Thus, the red file is read in 4 seeks instead of 2
- Not widely used in practice by itself

File Allocation

- 2.3) Indexed allocation
  - Special File Allocation Table (FAT) specifies next cluster
  - 0 = empty, E = EOC (end of cluster chain), 1 = reserved



FAT



disk

  - Blue file stored in clusters 5→3→12, red file in 4→9→6→11
- Primary example MS-DOS FAT12 / FAT16 / FAT32
  - Each directory holds entries with files/subdirectories
  - These include the name, attributes, creation/modification time, size, and the first cluster in FAT

File Allocation

- Many systems are hybrids of 2.2-2.3
  - UFS (Unix File System) with multi-level Inode tables
  - NTFS with B+ trees, ext3 / ext4 in Linux with H-trees
- Size limits
  - FAT16 = 2 GB and FAT32 = 8 TB (MBR limit 2 TB)
  - Most other modern systems scale to enormous numbers (e.g., NTFS 2^{80} bytes, UFS 2^{73}, ext4 2^{60}, exFAT 2^{76} for flash)
- How to manage free space?
  - Full index for the state of each cluster (e.g., FAT)
  - Bitmaps of free/occupied clusters (e.g., NTFS in Windows, HPFS in OS/2, exFAT / FAT64 in Windows CE, ext4 in Linux)
  - Free blocks chained on disk (pretty slow)
  - Separate queue/stack of free block IDs stored on disk

More Terminology

- When FAT16/32 wasn't able to use the entire disk
  - It was split into partitions, each with own drive letter C:, D:, etc.
- Now partitions fall under a more general term volume
  - Volume combines one or more partitions grouped into a logical drive (e.g., RAID-0/1 or spanned)
  - To obtain cluster size, # of free clusters, and total volume size, use GetDiskFreeSpace
- Links allow files to be referenced under different paths
  - Hard link points to the first cluster of file (see CreateHardLink)
  - Soft/symbolic link stores a text path to the file, may exist without the target file (see CreateSymbolicLink)
- Shortcuts are special files understood only by Windows Explorer, unrelated to links