

Lecture 10: File systems, databases, cloud storage

- **file**: a sequence of bytes stored on a computer
 - content is arbitrary (just bytes); any structure is imposed by the creator of the file, not by the operating system
- **file system**: software that provides hierarchical storage and organization of files, usually on a single computer (or nearby)
 - a significant part of the operating system
- **database**: an integrated collection of logically related records
 - data is organized and structured for efficient systematic access
 - may be distributed across lots of machines & geographically dispersed
- **database system**: software that provides efficient access to information in a database
 - not usually part of the operating system
- **cloud storage**: the same things, but on someone else's computer(s)
 - accessed via the Internet

Midterm rules and advice

- open book: notes, textbook, old exams, etc., all ok
- no Internet access; no collaboration (!)
- 90 minutes in a single sitting

- return exam to CS 311 as soon as possible after you finish it
 - drop in the box outside the door if I am not there
- by 5 PM Friday at the latest

- I'm trying to see if you understand; it's not meant to be tricky
- think straightforwardly; don't deconstruct; think about course topics
- if you're writing or computing a lot, you're on the wrong track
- know the powers of 2, powers of 10, hex digits, patterns thereof
- understand the Toy machine
- don't make careless arithmetic errors

File systems: managing stored information

- **logical structure: users and programs see a hierarchy of folders (== directories) and files**
 - a file is just a sequence of bytes
 - contents determined and interpreted by programs, not the operating system
 - a folder is a special file that contains names of other folders and files plus other information like size, time of change, permissions, etc.
 - contents are completely controlled by the operating system
 - "root" folder ultimately leads to all others
- **physical structure: many options with different properties**
- **the file system is the part of the operating system that converts between these two views**
 - does whatever is necessary to maintain the file/folder illusion
 - hides physical details so that programs don't depend on them
 - presents a uniform interface to disparate physical media

How the file system converts logical to physical

- **disk is physically organized into blocks of bytes**
 - each block is a fixed number of bytes, like 512 or 1024 or ...)
 - reading and writing always happens in blocks
- **each file occupies an integral number of blocks**
 - files **never** share a block
 - some space is wasted: a 1-byte file wastes all but 1 byte of the block
- **if a file is bigger than one block, it occupies several blocks**
 - the blocks are not necessarily "adjacent"
- **need a way to keep track of the blocks that make up the file**
- **usually done by a separate "file allocation table" that lists the blocks that make up each file**
 - this table is stored on disk too so it persists when computer is turned off

Converting logical to physical, continued

- every block is part of some file, or reserved by the operating system, or unused
- "file allocation table" keeps track of blocks
 - by some kind of table or array that keeps track of related blocks
- also keeps track of unused blocks
 - disk starts out with most blocks unused ("free")
 - some are reserved for file allocation table, etc.
 - as a file grows, blocks are removed from the unused list and attached to the list for the file
 - to grow a file, remove a block from the list of unused blocks and add it to the blocks for the file

Converting logical to physical: folders / directories

- a folder / directory is a file
 - stored in the same file system
 - uses the same mechanisms
- but it contains information about other files and directories
- the directory entry for a file tells where to find the blocks
IT DOES NOT CONTAIN THE DATA ITSELF
- the directory entry also contains other info about the file
 - name (e.g., midterm.doc)
 - size in bytes, date/time of changes, access permissions
 - whether it's an ordinary file or a directory
- the file system maintains the directory information
 - very important to keep directory info consistent
 - application programs can change it only indirectly / implicitly

File permissions

Upload files

Maximum file size allowed for upload: 95 MB

Please select files to upload to **/NAShomes/publichtmls/mycpanel/bwk/public_html**

No file selected.

Overwrite existing files:

| Mode | User | Group | World |
|-------------|-------------------------------------|-------------------------------------|-------------------------------------|
| Read | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |
| Write | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Execute | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Permission | <input type="text" value="6"/> | <input type="text" value="4"/> | <input type="text" value="4"/> |

Network file systems

- **the file system doesn't have to be local**
 - the data could be on some other computer
- **network file systems access remote files via network connections**
 - user programs access files and folders as if they are on the local computer
 - network file system converts these into requests to ship information to or from another computer across a network
- **there has to be a program on the other end to respond to requests**
 - "mapping a network drive" or "mounting your H: drive" sets up the connections
- **subsequent reads and writes go through the network instead of the local disk**

Cloud storage

- **the file system doesn't have to be local**
 - the data could be on some other computer
- **cloud storage systems access remote files via network connections**
 - user programs access files and folders as if they are on the local computer
 - file system converts these into requests to ship information to or from another computer across a network
- **there has to be a program on the other end to respond to requests**
 - connecting to Google Drive or Dropbox or iCloud or ... sets up the connections
- **subsequent reads and writes go through the network instead of the local disk**

What happens when you say "Open"?

- **search for file in sequence of directories as given by the components of its name**
 - report an error if any component can't be found
- **read blocks of file as needed**
 - using the location information in the file allocation table to find the blocks
 - store some of them in RAM

What happens when you say "Save"?

- **make sure there's enough space (enough unused blocks)**
 - don't want to run out while copying from RAM to disk
- **create a temporary file with no bytes in it**
- **copy the bytes from RAM and/or existing file to temporary file:**

```
while (there are still bytes to be copied) {  
    get a free block from the unused list  
    copy bytes to it until it's full or there are no more bytes to copy  
    link it in to the temporary file  
}
```
- **update the directory entry to point to the new file**
- **move the previous blocks (of old version) to the unused list**
 - or to recycle bin / trash

What happens when you remove a file?

- move the blocks of the file to the unused list
- set the directory entry so it doesn't refer to any block
 - set it to zero, maybe
- **recycle bin / trash**
 - recycle bin or trash is just another directory
 - removing a file just puts the name, location info, etc., in that directory instead
- **"emptying the trash" moves blocks into unused list**
 - removes entry from Recycle / Trash directory
- **why "removing" a file isn't enough**
 - usually only changes a directory entry
 - often recoverable by simple guesses about directory entry contents
 - file contents are often still there even if directory entry is cleared