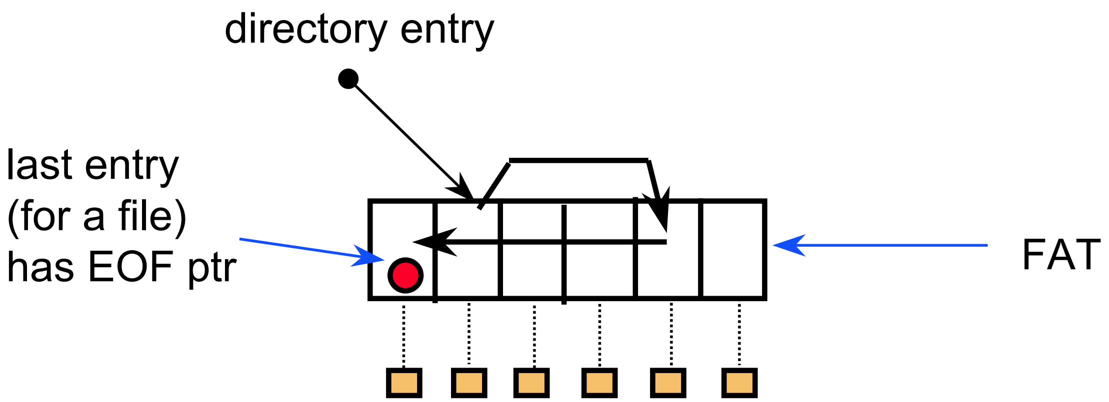
Announcements

- Reading Chapter 12

Modified Linked Allocation (FAT)

- Section of disk contains a table
  - called the file allocate table (FAT)
  - used in MS-DOS
- Directory entry contains the block number of the first block in the file
- Table entry contains the number of the next block in the file
- Last block has a end-of-file value as a table entry



i^{th} block corresponds to the i^{th} FAT entry

Performance Issues

- FAT
  - ✔ simple, easy to implement
  - ✔ faster to traverse than linked allocation
  - – random access requires following links
  - – files can’t have holes in them
- Hybrid indirect
  - ✔ fast access to any part of the file
  - ✔ files can have holes in them
  - – more complex

Free Space Management

- How do we find a disk block to allocate?
- Bit Vectors
  - array of bits (one per block) that indicates if a block is free
  - compact so can keep in memory
    - 1.3 GB disk, 4K blocks -> 78K per disk
  - easy to find long runs of free blocks
- Linked lists
  - each disk block contains the pointer to the next free block
  - pointer to first free block is keep in a special location on disk
- Run length encoding (called counting in book)
  - pointer to first free block is keep in a special location on disk
  - each free block also includes a count of the number of consecutive blocks that are free

Implementing Directories

- Linear List
  - array of names for files
  - must search entire list to find or allocate a filename
  - sorting can improve search performance, but adds complexity
- Hash table
  - use hash function to find filenames in directory
  - needs a good hash function
  - need to resolve collisions
  - must keep table small and expand on demand since many directories are mostly empty

DOS Directories

- Root directory
  - immediately follows the FAT
- Directory is a table of 32 byte entries
  - 8 byte file name, 3 byte filename extension
  - size of file, data and time stamp, starting cluster number of the file, file attribute codes
  - Fixed size and capacity
- Subdirectory
  - This is just a file
  - Record of where the subdirectory is located is stored in the FAT

Unix Directories

- Space for directories are allocated in units called *chunks*
  - Size of a chunk is chosen so that each allocation can be transferred to disk in a single operation
  - Chunks are broken into variable-length directory entries to allow filenames of arbitrary length
  - No directory entry can span more than one chunk
  - Directory entry contains
    - pointer to inode (file data-structure)
    - size of entry
    - length of filename contained in entry (up to 255)
    - remainder of entry is variable length - contains file name

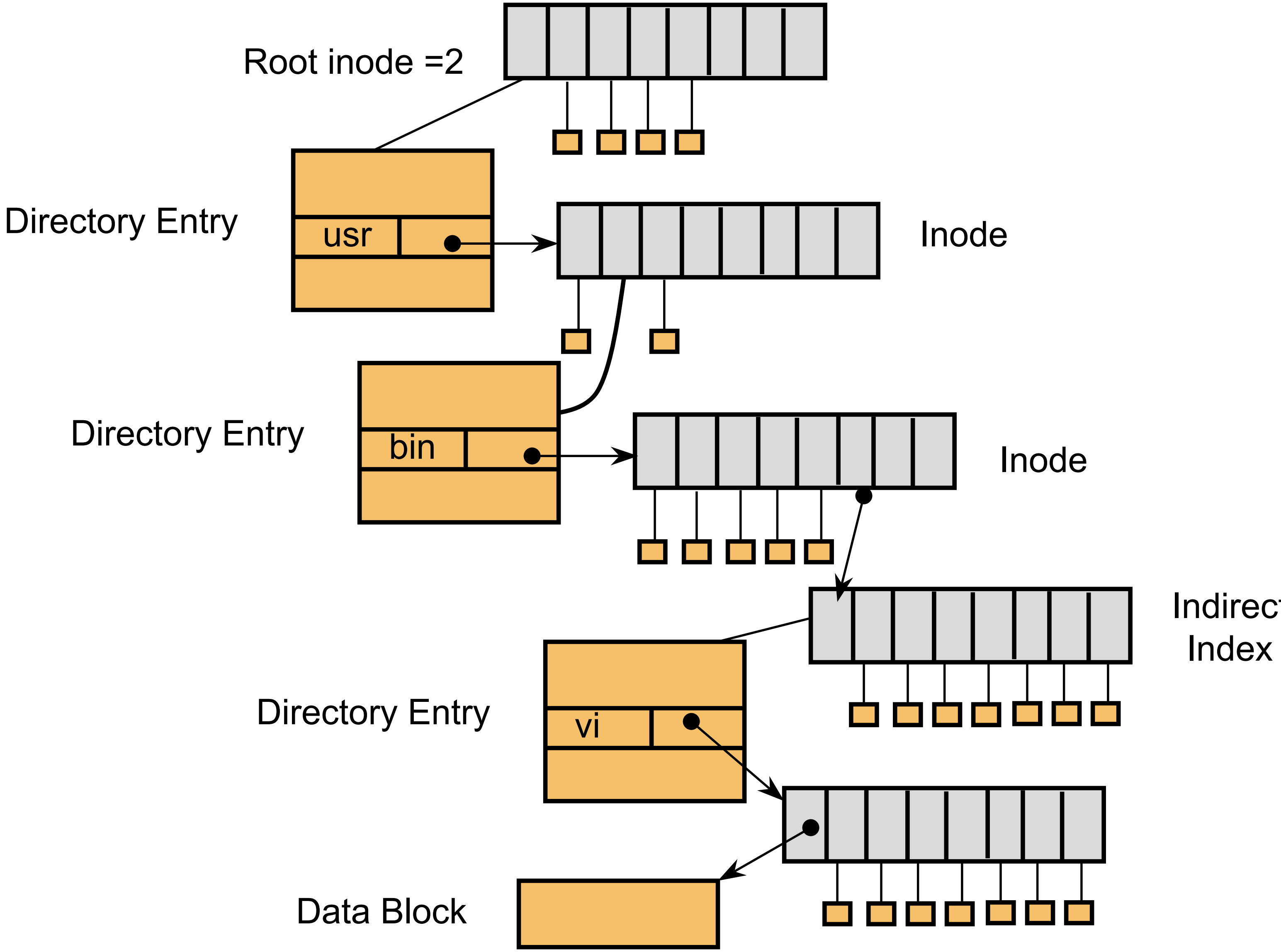
inodes

- File index node
- Contains:
  - Pointers to blocks in a file (direct, single indirect, double indirect, triple indirect)
  - Type and access mode
  - File’s owner
  - Number of references to file
  - Size of file
  - Number of physical blocks

Unix directories - links

- Each file has unique inode but it may have multiple directory entries in the same filesystem to reference inode
- Each directory entry creates a hard link of a filename to the file's inode
  - Number of links to file are kept in reference count variable in inode
  - If links are removed, file is deleted when number of links becomes zero
- Symbolic or soft link
  - Implemented as a file that contains a pathname
  - Symbolic links do not have an effect on inode reference count

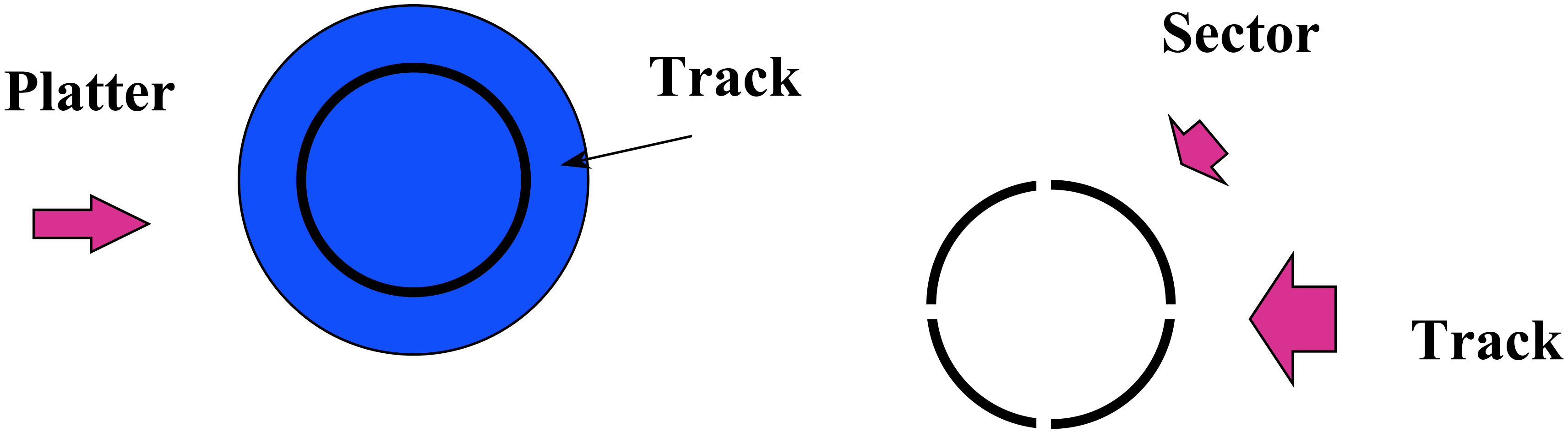
File Lookup (/usr/bin/vi)



Using UNIX filesystem data structures

- Example: find /usr/bin/vi
  - from Leffler, McKusick, Karels and Quarterman
  - Search root directory of filesystem to find /usr
    - root directory inode is, by convention, stored in inode #2
    - inode shows *where data blocks are* for root directory - *these blocks* (not the inode itself) *must* be retrieved and searched for entry user
    - we discover that the directory user's inode is inode #4
  - Search user for bin
    - access blocks pointed to by inode #4 and search contents of blocks for entry that gives us bin's inode
    - we discover that bin's inode is inode #7
  - Search bin for vi
    - access blocks pointed to by inode #7 and search contents of block for an entry that gives us vi's inode
    - we discover that vi's inode is inode #7
  - Access inode #7 - this is vi's inode

Magnetic Disks



- Collection of platters (1-20)
- Rotate at 3600-7200 RPM
- Size - usually 2.5-3.5 inch
- Usually 500-2500 tracks per platter
- Track consists of around 64 sectors
  - zones: vary number of tracks/sector based on distance from center

Access Times

- Seek: Move disk arm over appropriate track
  - Seek times vary depending on locality - seek times are order of milliseconds
- Rotational delay: Wait time until desired information is under disk arm
  - A disk that rotates at 7200 RPM will take 8.3 ms to complete a full rotation
- Transfer time: time taken to transfer a block of bits (usually a sector)
  - Depends on recording density of track, rotation speed, block size
  - Achieved transfer rate for many blocks can also be influenced by other system bottlenecks (software, hardware)
  - Rates range from 2 to 8 MB per second