Topics in Memory Management

- Uniprogrammed operating systems
  - Assembling, linking, loading
  - Static memory allocation
  - Dynamic memory allocation
    - Stacks, heaps
    - Managing the free list, memory reclamation
- Multiprogrammed operating systems
  - Includes most of the above topics
  - Static relocation
  - Dynamic relocation
    - Virtual vs. physical address
    - Partitioning (and compaction)
    - Segmentation
    - Paging
  - Swapping
  - Demand paging

Managing the Free List

- Heap-based dynamic memory allocation techniques typically maintain a *free list*, which keeps track of all the holes
- Algorithms to manage the free list:
  - Best fit
    - Keep linked list of free blocks
    - Search the whole list at each allocation
    - Choose the hole that comes the closest to matching the request size
      - Any unused space becomes a new (smaller) hole
    - When freeing memory, combine adjacent holes
    - Any way to do this efficiently?
  - First fit
    - Scan the list for the first hole that is large enough, choose that hole
    - Otherwise, same as best fit
  - Which is better? Why??

Reclaiming Dynamic Memory

- When can memory be freed?
  - Whenever programmer says to
  - Any way to do so automatically?
    - Difficult if that item is shared (i.e., if there are multiple pointers to it)
- Potential problems in reclamation
  - Dangling pointers — have to make sure that <u>everyone</u> is finished using it
  - Memory leak — must not "lose" memory by forgetting to free it when appropriate
- Implementing automatic reclamation:
  - Reference counts
    - Used by file systems
    - OS keeps track of number of outstanding pointers to each memory item
    - When count goes to zero, free the memory

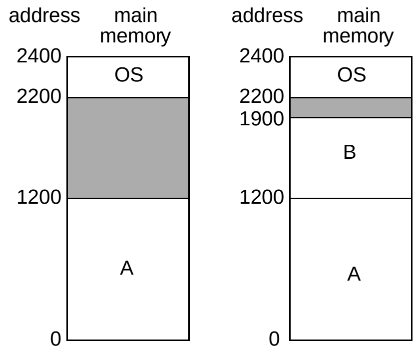
Reclaiming Dynamic Memory (cont.)

- Implementing automatic reclamation:
  - Garbage collection
    - Used in LISP
    - Storage isn't explicitly freed by a free operation; programmer just deletes the pointers and doesn't worry about what it's pointing at
    - When OS needs more storage space, it recursively searches through all the active pointers and reclaims memory that no one is using
    - Makes life easier for application programmer, but is difficult to program the garbage collector
    - Often expensive — may use 20% of CPU time in systems that use it
      - May spend as much as 50% of time allocating and automatically freeing memory

Multiprogramming — Goals in Sharing the Memory Space

- *Transparency*:
  - Multiple processes must coexist in memory
  - No process should be aware that the memory is shared
  - Each process should execute regardless of where it is located in memory
- *Safety*:
  - Processes must not be able to corrupt each other, or the OS
  - *Protection* mechanisms are used to enforce safety
- *Efficiency*:
  - The performance of the CPU and memory should not degrade very much as a result of sharing

Static Relocation



- Put the OS in the highest memory
- Compiler and linker assume each process starts at address 0
- At load time, the OS:
  - Allocates the process a segment of memory in which it fits completely
  - Adjusts the addresses in the processes to reflect its assigned location in memory

Static vs. Dynamic Relocation

- Problems with static relocation:
  - Safety — not satisfied — one process can access / corrupt another's memory, can even corrupt OS's memory
  - Processes can not change size (why…?)
  - Processes can not move after beginning to run (why would they want to?)
  - Used by MS-DOS, Windows, Mac OS
- An alternative: dynamic relocation
  - The basic idea is to change each memory address dynamically <u>as the process runs</u>
  - This translation is done by hardware — between the CPU and the memory is a *memory management unit* (MMU) (also called a *translation unit*) that converts virtual addresses to physical addresses
    - This translation happens for every memory reference the process makes

Dynamic Relocation

- There are now two different views of the address space:
  - The *physical address space* — seen only by the OS — is as large as there is physical memory on the machine
  - The *virtual (logical) address space* —seen by the process — can be as large as the instruction set architecture allows
    - For now, we'll assume it's much smaller than the physical address space
  - Multiple processes share the physical memory, but each can see only its own virtual address space
- The OS and hardware must now manage two different addresses:
  - *Virtual address* — seen by the process
  - *Physical address* — address in physical memory (seen by OS)