Memory management

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KTH

2018
virtual memory and segmentation

OS
virtual memory and segmentation

code | data | heap

↓↓↓

←-- stack

OS
virtual memory and segmentation

- code
- data
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OS

code
virtual memory and segmentation

code  data  heap  →  stack

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OS

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Virtual memory and segmentation
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virtual memory and segmentation
How do we obtain more memory for the heap data structures?
How do we obtain more memory for the heap data structures?
the process view

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brk() and sbrk() change the location of the program break, which defines the end of the process’s heap segment

```c
#include <unistd.h>

int brk(void *addr);
void *sbrk(intptr_t incr);
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Calling sbrk() with an increment of 0 can be used to find the current location of the program break.

#include <unistd.h>

int brk(void *addr);
void *sbrk(intptr_t incr);
C program - not the way to do it

#include <stdlib.h>
#include <unistd.h>

int *allocate_array_please(int size) {
    return (int*)sbrk(size * sizeof(int));
}
a growing heap
a growing heap

brk
a growing heap

brk
a growing heap

brk
a growing heap

How do we reuse allocated memory?
a growing heap

brk
How do we reuse allocated memory?

a growing heap

brk
a growing heap

brk

free
How do we reuse allocated memory?
C program

#include <stdlib.h>

int global = 42;

int main(int argc, char *argv[]) {

    if(argc < 2) return -1;

    int n = atoi(argv[1]);

    int on_stack[5] = {1,2,3,4,5};

    int *on_heap = malloc(sizeof(int)*n);

    :

}
The POSIX API

The malloc() function allocates size bytes and returns a pointer to the allocated memory. The memory is not initialized.

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The free() function frees the memory space pointed to by ptr, which must have been returned by a previous call to malloc(), ..
The operating system

Application layer

Operating system
The operating system

user process

Application layer

Operating system

Library is often just a wrapper for the system call - sometimes more complex.
The operating system

- Application layer
  - user process
  - code

- Operating system
The operating system

Operating system

- user
- process
- code

Library

- library

kernel

Application layer

- code
The operating system

user process
code

library

Application layer

Operating system

Systems calls (trap to kernel space)

kernel
The operating system

- User process
- Code
- Library
- Operating system API (POSIX)
- Operating system
- Systems calls (trap to kernel space)
- Kernel
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User space program
| User space program | Library routines | malloc() / free() |
Memory hierarchy

User space program

Library routines
  malloc() / free()

System calls
  sbrk() / brk()
Memory hierarchy

User space program

```
char a[10]
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structs person {int age; char name[20]}
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- `heap`
If we would not have to reuse freed memory areas - management would be simple.
Memory management

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A list of free blocks

Assume each free block holds a header containing: the size and a pointer to the next block.

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typedef struct __node_t {
    int size;
    struct __node_t *next;
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How do we return a block?

`free(this)`
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What’s the problem?
char *buf = malloc(128);
free(buf);
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free(buf);
Malloc - find a suitable block and split it.
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Which block shall we pick?
When we return a block we need to merge it with adjacent free blocks - if any.
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Coalescing - merging free blocks

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Free list strategies

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*You should know the pros and cons of these strategies.*
Idée - keep separate lists of blocks of different size.
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Assume we keep lists for blocks of: 8, 16, 32, 64 ... bytes.
Segregated lists

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We can build our own allocator that is optimized for a given application.
The C standard library glibc used in most GNU/Linux distributions use a memory allocator called `ptmalloc3` (pthreads malloc).
malloc in GNU/Linux

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Uses multiple \textit{bins} (free lists) to keep \textit{chunks} of different size.

Will coalesce adjacent chunks.
Buddy Allocation

If we should allow blocks to be divided then we should also provide efficient coalescing.
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Assume total memory 128Kibyte, smallest allocated frame 4Kibyte
Assume we number our 32 frames from 0b00000 to 0b11111.

Who’s the buddy of:
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Who’s the buddy of:

4K at 0b00011
Find your buddy

Assume we number our 32 frames from 0b00000 to 0b11111.

Who’s the buddy of:

4K at 0b00011

8K at 0b01000
Assume we number our 32 frames from 0b00000 to 0b11111.

Who’s the buddy of:

4K at 0b00011  16K at 0b10100
8K at 0b01000
Buddy pros and cons

Pros:

Efficient allocation and deallocations of frames.
Coalescing efficient, \( O(\log n) \)
Handles external fragmentation well.

Cons:

Internal fragmentation - if we need a frame of 9 blocks we get 16!

Linux uses Buddy allocations when managing physical memory - check \(/proc/buddyinfo\).
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Originally from 4.2BSD, default in OSX where malloc() uses mmap() to allocate memory.
sbrk() vs mmap()

brk() and sbrk()

- easy to extend the process heap
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- not easy to hand back allocated memory
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- easy to hand back allocated memory
- ability to map a file in memory
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Programmers point of view

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user process API: malloc() and free()
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system calls: sbrk() or mmap()
Summary

- user process API: malloc() and free()
- system calls: sbrk() or mmap()
- how to find suitable memory block.
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system calls: sbrk() or mmap()

how to find suitable memory block.

how to free memory blocks for efficient reuse
Summary

- User process API: `malloc()` and `free()`
- System calls: `sbrk()` or `mmap()`
- How to find suitable memory block.
- How to free memory blocks for efficient reuse
- Coalescing smaller blocks