15-213 Recitation
Malloc Part II

Your TAs

Friday, October 27th

Agenda

- Logistics
- Malloc Lab
- Checkpoint review
- Activity 1
- Appendix

Logistics

- Malloc Lab Checkpoint is due **October 31st** at **11:59 pm**
- Malloc Lab Final is due **November 7th** at **11:59 pm**
- 7% of final grade (+4% for checkpoint)
- Style matters! Don’t let all of your hard work get wasted.
  - There are many different implementations and TAs will need to know the details behind your implementation.
  - **Code Review** Signups for **Checkpoint** due **October 31st** at **11:59 pm**
  - Post-checkpoint Malloc Bootcamp on **October 29th**!

Submitting Malloc

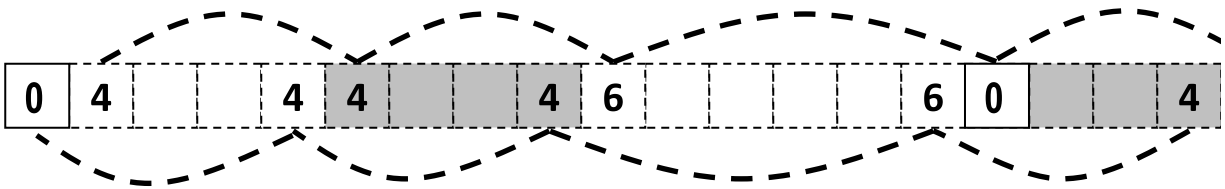
- Make sure to submit to AutoLab!
  - make submit
  - Upload mm.c to AutoLab

Understanding Your Code

- Sketch out the heap
- Add Instrumentation
- Use tools

Sketch out the Heap

Start with a heap, in this case implicit list



Now try something, in this case, extend_heap

```
block_t *block = payload_to_header(bp);
write_block(block, size, false);
// Create new epilogue header
block_t *block_next = find_next(block);
write_epilogue(block_next);
```

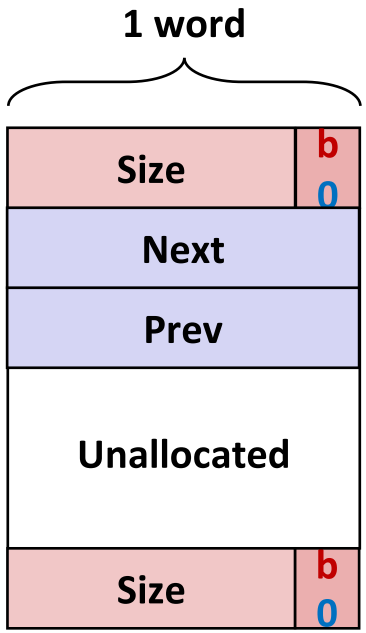
Sketch out the Heap

Here is a free block based on lectures 13 and 14

- Explicit pointers (will be well-defined see writeup and Piazza)
  - **This applies to ALL new fields you want inside your struct**
- Optional boundary tags

If you make changes to your design beyond this

- Draw it out.
- If you have bugs, pictures can help the staff help you
- Put a picture of your data structure into your file header
  (optional, but we will be impressed)



Free Block

Common Problems

Throughput is very low

- Which operation is likely the most throughput intensive?
- Hint: It uses loops!
- Solution: ??

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Utilization is very low / Out of Memory

- Which operation can cause you to allocate more memory than you may need?
- Hint: It extends the amount of memory that you have!
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Add Instrumentation

Remember that measurements inform insights.

- Add temporary code to understand aspects of malloc
- Code can violate style rules or 128 byte limits, because it is temporary

Particularly important to develop insights into performance before making changes

- What is expensive throughput-wise?
- How much might a change benefit utilization?

Add Instrumentation example

Searching in `find_fit` is often the slowest step

How efficient is your code? How might you know?

- Compute the ratio of blocks viewed to calls

```
static block_t *find_fit(size_t asize)
{
    block_t *block;  call_count++;
    for (block = heap_listp; get_size(block) > 0;
                             block = find_next(block))
    {   block_count++;
        if (!(get_alloc(block)) && (asize <= get_size(block)))
        {
            return block;
        }
    }
    return NULL; // no fit found
}
```

Add Instrumentation cont.

What size of requests?

- How many 8 bytes or less?
- How many 16 bytes or less?
- What other sizes?

What else could you measure? Why?

Remember that although the system's performance varies

- The traces are deterministic
- Measured utilization should not change between runs
- Measured throughput, however, may vary

Use tools

Use mm_checkheap()

- Write it if you haven't done so already
- Add new invariants when you add new features
- Know how to use the heap checker.
  - Why do you need a heap checker? 2 reasons.

Use gdb

- You can call print or mm_checkheap whenever you want in gdb. No need to add a whole lot of printf's.
- Offers useful information whenever you crash, like backtrace.
- Write helper functions to print out free lists that are ONLY called from GDB

Write your own traces!

- Write short traces that test simple sequences of malloc and free
- Read the README file in the traces directory and the writeup from the traces assignment to see how trace files need to be written

mdriver-emulate

Testing for 64-bit address space

Use correctly sized masks, constants, and other variables

Be careful about subtraction between size types (may result in underflow/overflow)

- Note: there are many other issues besides this.

Reinitialize your pointers in mm_init

Garbled Bytes

Malloc library returns a block

- mdriver writes bytes into payload (using memcpy)
- mdriver will check that those bytes are still present
- If malloc library has overwritten any bytes, then report garbled bytes
  - Also checks for other kinds of bugs

Now what?

The mm_checkheap call is catching it right?

If not, we want to find the garbled address and watch it

Garbled Bytes GDB and Contracts

Get out a laptop

Login to shark machine

wget http://www.cs.cmu.edu/~213/activities/rec9.tar

tar -xvf rec9.tar

cd rec9

mm.c is a fake implicit list implementation.

- Source code is based on mm.c starter code

GDB and Contracts Exercise

First, let us run without contracts and gdb
./mdriver -c ./traces/syn-struct-short.rep

(example output)

```
ERROR [trace ./traces/syn-struct-short.rep, line 16]: block 1
(at 0x8000000a0) has 8 garbled bytes, starting at byte 16
ERROR [trace ./traces/syn-struct-short.rep, line 21]: block 4
(at 0x800000180) has 8 garbled bytes, starting at byte 16


correctness check finished, by running tracefile "traces/syn-
struct-short.rep".
 => incorrect.

Terminated with 2 errors
```

Using watchpoints in GDB

gdb --args ./mdriver-dbg1 -c ./traces/syn-struct-short.rep

What is the first address that was garbled?

- Use gdb watch to find out when / what garbled it.

```
(gdb) watch *0x8000000a0
(gdb) run
```

// Keep continuing through the breaks:

// write_block()

// 4 x memcpy

```
Hardware watchpoint 1: *0x8000000a0

Old value = 129
New value = 32
write_block() at mm.c:333
```

We just broke in after overwriting

Tells us to take a closer look at write_block()

Contracts Exercise cont.

- Now let us see what happens, when we use the file with contracts
  ./mdriver-dbg2 -c ./traces/syn-struct-short.rep

```
mdriver-dbg: mm.c:331: void write_block(block_t *, size_t, _Bool): Assertion
`(unsigned long)footerp < ((long)block + size)' failed.
Aborted (core dumped)
```

- Contract failed on line 331, which gives us a better idea of the source of the issue
- Open mm.c and try to find what is causing the contract to fail
- Writing effective contracts can save a lot of debugging time!

Tips for using our tools

- Run mdriver with the –D option to detect garbled bytes as early as possible. Run it with –V to find out which trace caused the error.
- Note that sometimes, you get the error within the first few allocations. If so, you could set a breakpoint for mm_malloc / mm_free and step through every line.
- Print out local variables and convince yourself that they have the right values.
- For mdriver-emulate, you can still read memory from the simulated 64-bit address space using `mem_read(address, 8)` instead of `x /gx`.

Style

Well organized code is easier to debug and easier to grade!

- Modularity: Helper functions to respect the list interface.
- Documentation:
  - File Header: Describes all implementation details, including block structures.
- Code Structure:
  - Minimal-to-no pointer arithmetic.
  - Loops instead of conditionals, where appropriate.
- Use git!
  - Make sure you ***commit and push*** often and write descriptive commit messages

Malloc Lab

Checkpoint due Tuesday, October 31st

7% of final grade (+4% for checkpoint)

- Style matters! Don’t let all of your hard work get wasted.
- There are many different implementations and TAs will need to know the details behind your implementation.

Read the write-up. It even has a list of tips on how to improve memory utilization.

Rubber duck method

- If you explain to a rubber duck what your function does step-by-step, while occasionally stopping to explain why you need each of those steps, you may very well find the bug in the middle of your explanation.
- Remember the “debug thought process” slide from last recitation?