Recitation 10: More Malloc Lab

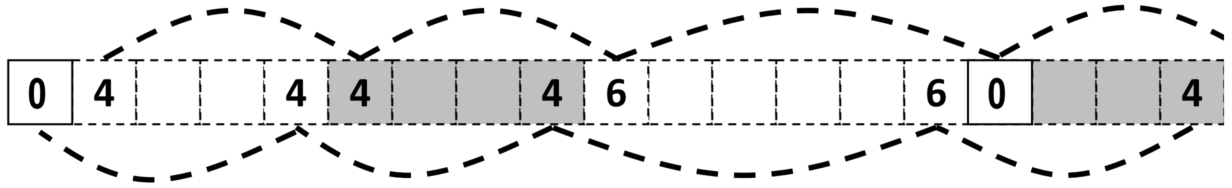
Instructor: TA(s)

Understanding Your Code

- Sketch out the heap
- Add Instrumentation
- Use tools

Sketch out the Heap

- Start with a heap, in this case implicit list

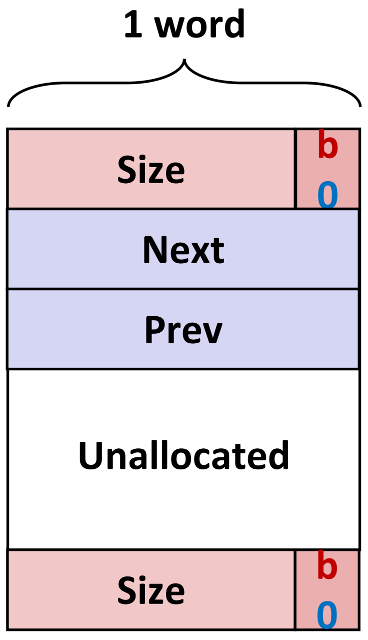


- Now try something, in this case, extend_heap

```
block_t *block = payload_to_header(bp);
write_header(block, size, false);
write_footer(block, size, false);
// Create new epilogue header
block_t *block_next = find_next(block);
write_header(block_next, 0, true);
```

Sketch out the Heap

- **Here is a free block based on lectures 19 and 20**
  - 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

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

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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 mdriver's traces are deterministic
  - Measured results should not change between runs

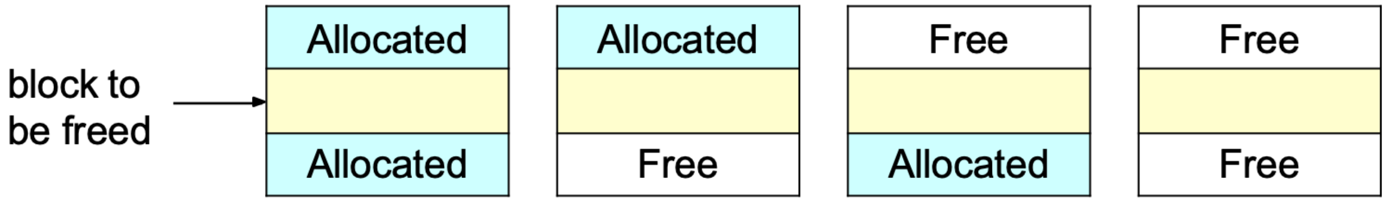
Use tools

- **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 while 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
- Write a trace that simply tests all 4 coalescing cases



- Read the README file in the traces directory 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 re result in underflow/overflow)
- 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 and gdb

- Get out a laptop

- Login to shark machine
- wget http://www.cs.cmu.edu/~213/activities/rec11b.tar
- tar xf rec11b.tar

- mm.c is a fake explicit list implementation.
  - Source code is based on mm.c starter code
  - A few lines of code are added that vaguely resembles what an explicit list implementation could have.

GDB Exercise

- gdb --args ./mdriver -c ./traces/syn-array-short.rep -D

```
(gdb) r
// Sample output follows
Throughput targets: min=6528, max=11750, benchmark=13056
Malloc size 9904 on address 0x800000010.
Malloc size 50084 on address 0x8000026d0.
ERROR [trace ././traces/syn-array-short.rep, line 7]:
block 0 has 8 garbled bytes, starting at byte 0
...
ERROR [trace ././traces/syn-array-short.rep, line 7]:
block 0 has 8 garbled bytes, starting at byte 0
...
Terminated with 14 errors
[Inferior 1 (process 8456) exited normally]
(gdb)
```

GDB Exercise cont.

- **What is the first address that was garbled?**
  - Use gdb watch to find out when / what garbled it.

```
(gdb) watch * 0x800000010
(gdb) run
```

// Keep continuing through the breaks:
// mm_init()
// 4 x memcpy

```
Hardware watchpoint 1: *0x800000010

Old value = -7350814
New value = 9928
mm_malloc (size=50084) at mm.c:214
```

We just broke in after overwriting

Second Exercise

Well fine, the bug from the first exercise was very artificial. No one just sets bytes to 0 for no reason.

Try this more plausible exercise:

```
$ gdb --args ./mdriver-2 -c traces/syn-array-short.rep
```

What error was printed to the console?

The function that prints the error is named `malloc_error`. Add a breakpoint for it if you want.

Second Exercise

The library must've written the header and footer for the out-of-bounds payload at some point. Add a watchpoint for either address, or both.

```
(gdb) watch *0x8000036c8
(gdb) run
```

…So, the writes occurred in `place`. Is the `place` function wrong, or was it just given a bad argument?

Hint: the bug is found in at basically the same place as last recitation's bug.

It's caused by a careless typo, like nearly all others bugs.

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 though 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`.

MallocLab

- **Due next Tuesday**
- **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 writeup. It even has a list of tips on how to improve memory utilization.**
- **Read the malloc roadmap posted on Piazza**
- **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’d may very well find the bug in the middle of your explanation.
  - Remember the “debug thought process” slide from Recitation 9?

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.