Recitation 10: More Malloc Lab

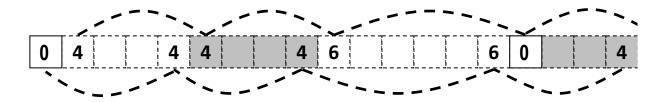
Instructor: TA(s)

Understanding Your Code

- Sketch out the heap
- Add Instrumentation
- Use tools

Sketch out the Heap

Start with a heap, in this case implicit list

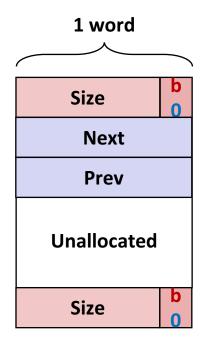


Now try something, in this case, extend_heap

```
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

■ Throughput is very low

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

Common Problems

Throughput is very low

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

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!
- Solution: ??

Common Problems

Throughput is very low

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

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!
- Solution: Instrument your code!

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

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()

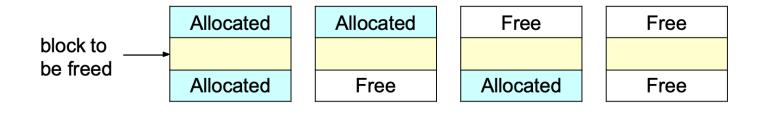
- Write it if you haven't done so already
- Add new invariants when you add new features
- Know how to use the heap checker.
 - Why do you need a heap checker? 2 reasons.

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 0x80000010.
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]
(qdb)
```

GDB Exercise cont.

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

```
(qdb) watch * 0x80000010
(qdb)
       run
// Keep continuing through the breaks:
// mm_init()
// 4 x memcpy
                                                 We just broke in
Hardware watchpoint 1: *0x80000010
                                                 after overwriting
Old value = -7350814
New value = 9928
mm malloc (size=50084) at mm.c:214
```

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-bystep, 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.