CS 33

Intro to Storage Allocation
A Queue

typedef struct list_element {
    int value;
    struct list_element *next;
} list_element_t;

list_element_t *head, *tail;
Enqueue

```c
int enqueue(int value) {
    list_element_t *newle = (list_element_t *)malloc(sizeof(list_element_t));
    if (newle == 0)
        return 0;
    newle->value = value;
    newle->next = 0;
    if (head == 0) {
        // list was empty
        assert(tail == 0);
        head = newle;
    } else {
        tail->next = newle;
    }
tail = newle;
    return 1;
}
```
Dequeue

```c
int dequeue(int *value) {
    list_element_t *first;
    if (head == 0) {
        // list is empty
        return 0;
    }
    *value = head->value;
    first = head;
    head = head->next;
    if (tail == first) {
        assert(head == 0);
        tail = 0;
    }
    return 1;
}
```

What’s wrong with this code???
Storage Leaks

```c
int main() {
    while(1) {
        if (malloc(sizeof(list_element_t)) == 0)
            break;
        return 1;
    }
}
```

For how long will this program run before terminating?
Dequeue, Fixed

```c
int dequeue(int *value) {
    list_element_t *first;
    if (head == 0) {
        // list is empty
        return 0;
    }
    *value = head->value;
    first = head;
    head = head->next;
    if (tail == first)
        assert(head == 0);
    tail = 0;
}
free(first);
return 1;
}
```
Quiz 1

```c
int enqueue(int value) {
    list_element_t *newle = (list_element_t *)malloc(sizeof(list_element_t));
    if (newle == 0)
        return 0;
    newle->value = value;
    newle->next = 0;
    if (head == 0) {
        // list was empty
        assert(tail == 0);
        head = newle;
    } else {
        tail->next = newle;
    }
    tail = newle;
    free(newle); // saves us the bother of freeing it later
    return 1;
}
```

This version of enqueue makes unnecessary the call to free in dequeue.

a) It works well.
b) It fails occasionally.
c) It hardly every works.
d) It never works.
malloc and free

```c
void *malloc(size_t size)
```
- allocate size bytes of storage and return a pointer to it
- returns 0 (NULL) if the requested storage isn’t available

```c
void free(void *ptr)
```
- free the storage pointed to by ptr
- ptr must have previously been returned by malloc (or other storage-allocation routine — calloc and realloc)
reallocate

```c
void *realloc(void *ptr, size_t size)
```

- change the size of the storage pointed to by `ptr`
- the contents, up to the minimum of the old size and new size, will not be changed
- `ptr` must have been returned by a previous call to `malloc`, `realloc`, or `calloc`
- it may be necessary to allocate a completely new area and copy from the old to the new
  - thus the return value may be different from `ptr`
  - if copying is done the old area is freed
- returns 0 if the operation cannot be done
Get (contiguous) Input (1)

```c
char *getinput() {
    int alloc_size = 4;  // start small
    int read_size = 4;   // max number of bytes to read
    int next_read = 0;   // index in buf of next read
    int bytes_read;      // number of bytes read

    char *buf = (char *)malloc(alloc_size);
    char *newbuf;

    if (buf == 0) {
        // no memory
        return 0;
    }
}
```
Get (contiguous) Input (2)

while (1) {
  if (((bytes_read
       = read(0, buf+next_read, read_size)) == -1) {
    perror("getinput");
    return 0;
  }
  if (bytes_read == 0) {
    // eof, possibly premature
    return buf;
  }
  if (((buf+next_read)[bytes_read-1] == '\n')) {
    // end of line
    break;
  }
}
Get (contiguous) Input (3)

```c
next_read += read_size;
read_size = alloc_size;
alloc_size *= 2;
newbuf = (char *)realloc(buf, alloc_size);
if (newbuf == 0) {
    // realloc failed: not enough memory.
    // Free the storage allocated previously and report
    // failure
    free(buf);
    return 0;
}
buf = newbuf;
```
Get (contiguous) Input (4)

// reduce buffer size to the minimum necessary
newbuf = (char *)realloc(buf,
    alloc_size - (read_size - bytes_read));
if (newbuf == 0) {
    // couldn't allocate smaller buf
    return buf;
}
return newbuf;
Some Common Memory-Related Errors
Dereferencing Bad Pointers

• The classic `scanf` bug

```c
int val;
...
scanf("%d", val);
```
Reading Uninitialized Memory

• Assuming that dynamically allocated data is initialized to zero

/* return y = Ax */
int *matvec(int A[][N], int x[])
{
    int *y = (int *)malloc(N*sizeof(int));
    int i, j;

    for (i=0; i<N; i++)
        for (j=0; j<N; j++)
            y[i] += A[i][j]*x[j];
    return y;
}
Overwriting Memory

- Allocating the (possibly) wrong-sized object

```c
// set up p so it is an array of int *'s, allocated dynamically
int **p;

p = (int **)malloc(N*sizeof(int));

for (i=0; i<N; i++) {
    p[i] = (int *)malloc(M*sizeof(int));
}
```
Overwriting Memory

• Not checking the max string size

```c
char s[8];
int i;
gets(s); /* reads “123456789" from stdin */
```

• Basis for classic buffer overflow attacks
Going Too Far

- Misunderstanding pointer arithmetic

```c
int *search(int p[], int val) {
    while (*p && *p != val) {
        p += sizeof(int);
    }
    return p;
}
```
Referencing Nonexistent Variables

• Forgetting that local variables disappear when a function returns

```c
int *foo () {
    int val;

    return &val;
}
```
Freeing Blocks Multiple Times

\[
x = (\text{int } *)\text{malloc}(N*\text{sizeof(int)});\\
  \langle\text{manipulate } x\rangle\\
\text{free}(x);\\
\]

\[
y = (\text{int } *)\text{malloc}(M*\text{sizeof(int)});\\
  \langle\text{manipulate } y\rangle\\
\text{free}(x);\\
\]
Referencing Freed Blocks

\[
x = (\text{int } \ast)\text{malloc} (N\ast\text{sizeof(int)});
\]
\[<\text{manipulate } x>\]
\[
\text{free}(x);
\]
\[
\ldots
\]
\[
y = (\text{int } \ast)\text{malloc} (M\ast\text{sizeof(int)});
\]
\[
\textbf{for } (i=0; i<M; i++)
\]
\[
y[i] = x[i]++;
\]
Failing to Free Blocks (Memory Leaks)

```c
foo() {
    int *x = (int *)malloc(N*sizeof(int));
    Use(x, N);
    return;
}
```
Failing to Free Blocks (Memory Leaks)

- Freeing only part of a data structure

```c
struct list {
    int val;
    struct list *next;
};

foo() {
    struct list *head = malloc(sizeof(struct list));
    head->val = 0;
    head->next = NULL;
    <allocate and manipulate the rest of the list>
    ...
    free(head);
    return;
}
```
Total Confusion

```c
foo() {
    char *str;
    str = (char *)malloc(1024);
    ...
    str = "";
    ...
    strcat(str, "c");
    ...
    return;
}
```
It Works, But ...

- Using a hammer where a feather would do ...

```c
hammer() {
    int *x = (int *)malloc(1024 * sizeof(int));
    Use(x, 1024);
    free(x);
    return;
}

feather() {
    int x[1024];
    Use(x, 1024);
    return;
}
```