CS 11 C track: lecture 7

- Last week: structs, `typedef`, linked lists
- This week:
  - hash tables
  - more on the C preprocessor
  - `extern`
  - `const`

Hash tables (1)

- Data structures we've seen so far:
  - arrays
  - `struct`s
  - linked lists

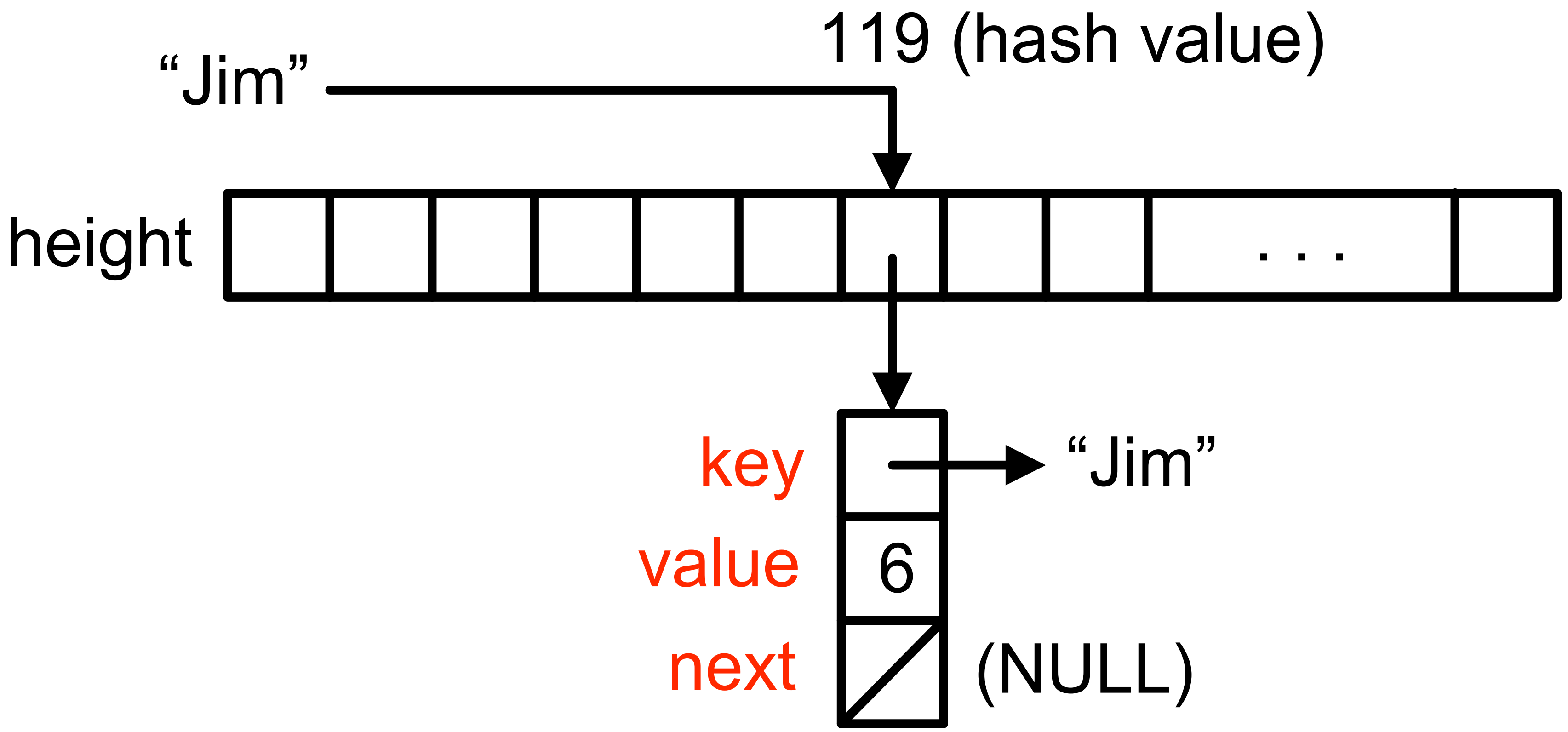
Hash tables (2)

- Hash tables are a new data structure
- Like an array indexed with strings e.g.
  - `height["Jim"] = 6;  /* not C code */`
- Very fast lookup (O(1) i.e. constant time)
- Flexible: can add/delete elements easily

Hash tables (3)

- Want to associate a string (key) with a value
- Generate an integer hash value from the string key
  - different keys should generate different hash values
- Use hash value as index into an array of linked lists
  - array length is large (128 in lab 7)
  - array values start off as NULL pointers (empty lists)
  - no linked list should ever get larger than a few elements

Hash tables (4)



Hash tables (5)

- Generating the hash value from the string
  - Many ways to do it
  - We choose a particularly simple (and lame) way
  - Treat the string as an array of `chars`
  - Treat each `char` as a small integer (0 - 127)
    - C allows this
  - Sum up the values of all the characters
  - Take the sum mod 128 (the array length)
  - Gives an integer in the range 0-127
    - that's our index into the array

Hash tables (6)

- Three things we can do with a hash table:
  - Look up the value corresponding to a particular key
  - Change the value corresponding to an existing key in the table
  - Add a new key/value pair to the table

Hash tables (7)

- How to find the value given the key
  - compute hash value to get array index
  - find array location
  - if NULL, not there (return "not found" value)
  - if not NULL, search for key in linked list
    - if found, return node value
    - if not found, not there (return "not found" value)

Hash tables (8)

- How to change the value corresponding to a given key (or add a new key/value pair):
  - compute hash value to get array index
  - find array location
  - if NULL, add node with key/value pair
  - if not NULL, search for key in linked list
    - if found, change node value
    - if not found, add new node to list
      - (anywhere in list!)

Hash tables (9)

- Adding nodes to linked list
  - nodes in linked list not in any order
  - so can add to any place in list
  - most people try to add to the end of the list
  - actually easier to add to beginning of list
  - either way, have to set some pointer values to different values

Hash tables (10)

- Hash table itself is <u>not</u> the array of linked lists
  - It's a `struct` which contains that array
  - Easy to make mistakes with this
  - Think of it as a box containing the array
- Why use a `struct` if all it contains is one array?
  - Practice in handling more complex data structures
  - Real hash tables would have more fields e.g. length of array to permit resizing of the array

Lab 7

- Pretty routine application of hash tables
- One likely problem involving a memory leak
  - May be hard to figure out where to free memory

C preprocessor: `#ifdef` (1)

- Sometimes want to conditionally compile code
- If some condition met, compile this code
- else do nothing, or do something else
- Examples:
  - debugging code
  - compiling on different platforms

C preprocessor: `#ifdef` (2)

- Debugging code:

```
#define DEBUG
    int value = 10;
#ifdef DEBUG
    printf(”value = %d\n”, value);
#endif
```

C preprocessor: `#ifdef` (3)

- Can leave out `#define` and choose at compile time:

```
% gcc -DDEBUG foo.c -o foo
```

- `-D` option means to Define DEBUG
- This makes the debugging code compile
- Otherwise it won't compile
- Usually best to do it this way

C preprocessor: `#else`

- Also use `#ifdef/#else` for portability e.g.:

```
#ifdef WINDOWS
#include <windows.h>
#else
#include <X11/X.h>
#endif
```

C preprocessor: `#ifndef` (1)

- `#ifndef` includes code if something is not defined
- `assert` is defined using `#ifndef` e.g.

```
assert(i == 0);  /* expands to: */
#ifndef NDEBUG
    if (!(i == 0)) { abort(); }
#endif
```

C preprocessor: `#ifndef` (2)

- Recall: to switch off assertions, define `NDEBUG`:

```
% gcc -DNDEBUG foo.c -o foo
```

- Then all assertions are removed from code during compilation
- Useful after code has been debugged

C preprocessor: `#if` (1)

- Can also test integer values with `#if`/`#elif`/... :

```
#if REVISION == 1
/* revision 1 code */
#elif REVISION == 2
/* revision 2 code */
#else
/* generic code */
#endif
```

C preprocessor: `#if` (2)

- Use `#if 0` to comment out large blocks of code:

```
#if 0
/* This doesn't get compiled. */
#endif
```

- Useful because can't nest `/* */` comments

C preprocessor: include guards (1)

- Multiple inclusion of header files can cause problems
  - e.g. multiple declarations of struct types
- Difficult to prevent
  - one include file includes another, etc.
- Need mechanism to prevent this

C preprocessor: include guards (2)

```
/* header file "foo.h": */
#ifndef FOO_H
#define FOO_H

/* contents of file */

#endif  /* FOO_H */
```

- contents of `foo.h` only included once

`extern` (1)

- Sometimes many files need to share some data e.g. global variable
- Can only define in one place
- Put `extern` declaration in header file
- Means: this is defined somewhere else

extern (2)

```
/* In header file "foo.h": */
extern int max_value;


/* In file "foo.c": */
/* global variable: */
int max_value = 1000000;
```

`const`

- We've seen this:

```
#define SOME_CONSTANT 100
```

- A better alternative is this:

```
const int SOME_CONSTANT = 100;
```

- Why is this better?
  - get type checking on `SOME_CONSTANT`

Next week

- Most of C language has been covered
- Virtual machines (!)
- More integer types: `short`, `long`, `unsigned`
- Wrapping up