Separate Compilation

EECS 211

Winter 2019

Initial code setup

```
$ cd eecs211
$ wget $URL211/lec/03separate.tgz
…
$ tar zxf 03separate.tgz
$ cd 03separate
```

The general problem

It would be really nice if we could:

1. Write some functions in one place.
2. Call those functions from multiple programs.

A more specific problem for today

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But: C has no facilities for testing. Your tests are just an ordinary program that calls the functions and checks the results.

So the goal is the same: one library with two (or more) clients.

Making it concrete

1. The `posn` library: provides the `struct posn` type and three functions, `read_posn()`, `make_posn()`, and `manhattan_dist()`.
2. Client 1, the `interact` program: uses the `posn` library to read positions from the standard input, calculate distances, and print the distances to the standard output.
3. Client 2, the `posn_test` test program: checks that the `posn` library's `manhattan_dist()` function gives the answers we expect.

The posn library (highlights)

```
// A 2-D point.
struct posn
{
    double x;
    double y;
};

// Computes the Manhattan distance between two posns.
double manhattan_dist(struct posn p, struct posn q)
{
    return fabs(p.x - q.x) + fabs(p.y - q.y);
}
```

The `interact` program

```
// import posn library somehow?
#include <stdio.h>

int main()
{
    struct posn target = read_posn();

    for (;;) {
        struct posn each = read_posn();
        double dist = manhattan_dist(target, each);
        printf("%f\n", dist);
    }
}
```

The `posn_test` test program

```
// import posn library somehow?
#include <assert.h>

int main()
{
    struct posn p = make_posn(0, 0);
    struct posn q = make_posn(3, 4);

    assert( manhattan_dist(p, p) == 0 );
    assert( manhattan_dist(q, p) == 7 );
}
```

(The `assert()` function crashes the program if its argument is `false`, or does nothing if its argument is `true`. We'll have nicer ways to write tests in the future, but right now we'll stick with `assert`.)

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4. Each `.c` file is its own *compilation unit*, which means it is translated by the compiler in isolation, with no direct knowledge of the other `.c` files, into a `.o` (object) file containing machine code. All dependencies are via `.h` files that the `.c` file `#include`s.

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5. Once all the `.c` files for a program have been translated into `.o` files, the *linker* combines them into a single executable, resolving the references between them.

(And the fiddly details)

- When translating individual source files, pass `cc` the `-c` switch to suppress linking.
- Every `.h` file should start with a *guard*,

  ```
  #pragma once
  ```

  to prevent processing it more than once per compilation unit.
- Never `#include` a `.c` file. Ever.

Why this works

The C compiler is pretty stupid:

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But:

- To compile a function call, it only needs to know the signature (type) of the function, not its whole definition.
- A *function declaration* specifies a function signature without the definition, like so:

  ```
  double manhattan_dist(struct posn, struct posn);
  ```

  (The parameter names are optional, so it makes sense to omit them from signatures when they aren't informative.)

Example of C scope

C compiler is happy:

```
double min2(double x, double y)
{
    return x < y ? x : y;
}

double min3(double x, double y, double z)
{
    return min2(x, min2(y, z));
}
```

Example of C scope

C compiler is unhappy, says that `min2` isn't defined:

```
double min3(double x, double y, double z)
{
    return min2(x, min2(y, z));
}

double min2(double x, double y)
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}
```

Example of C scope

C compiler is happy once again:

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double min2(double, double);

double min3(double x, double y, double z)
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    return min2(x, min2(y, z));
}

double min2(double x, double y)
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    return x < y ? x : y;
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```

The solution, applied

- `src/posn.h` contains
  - Definition of `struct posn` type
  - Signatures for shared functions (`read_posn()`, `make_posn()`, and `manhattan_dist()`)
- `src/posn.c` *`#include`*s `src/posn.h` and contains definitions of the same shared functions
- `src/interact.c` *`#include`*s `src/posn.h` and contains the `main` function for the `interact` program
- `test/posn_test.c` *`#include`*s `src/posn.h` and contains a `main` function that tests the functions defined in `src/posn.c`.

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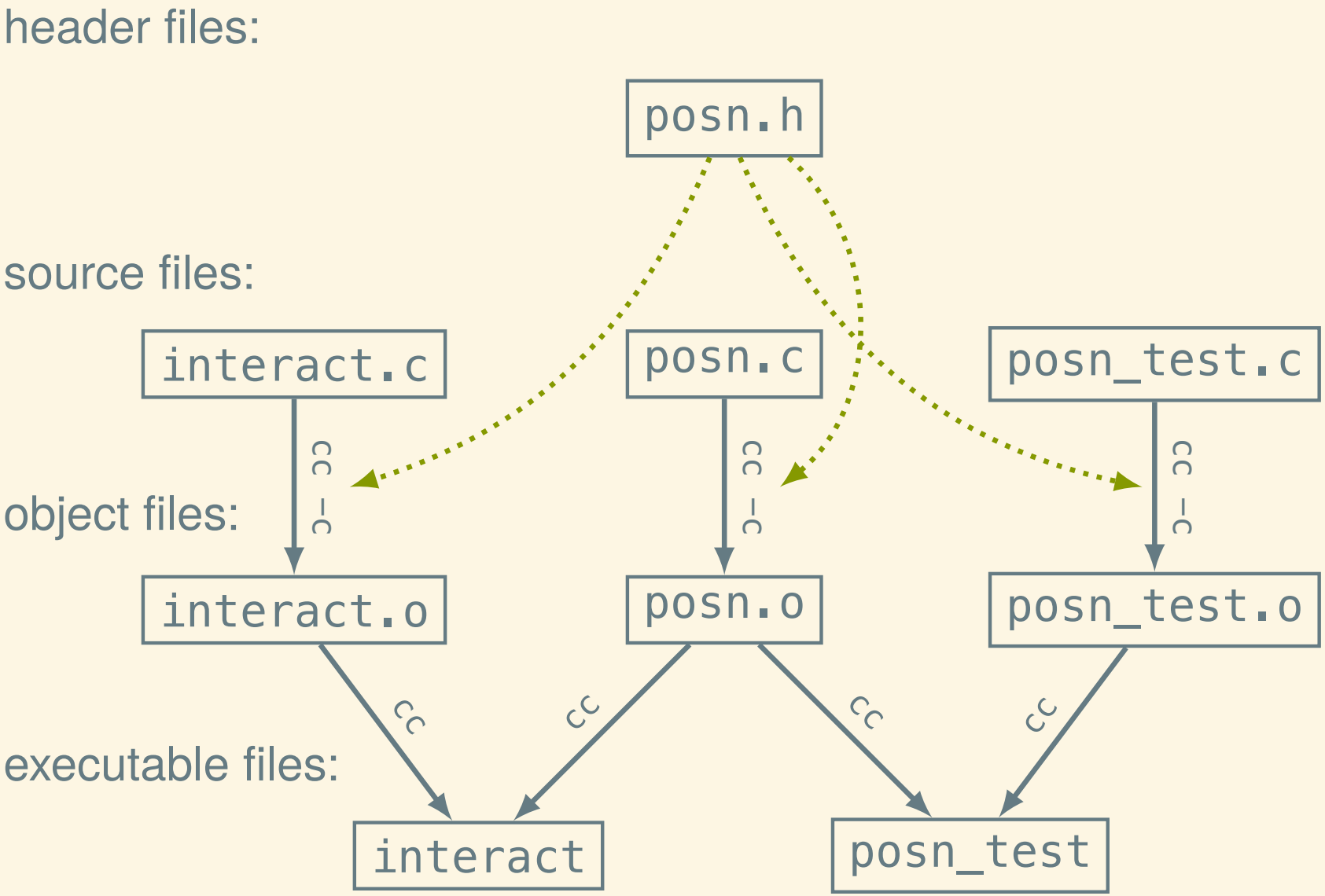
Important C rule: You cannot have more than one definition of the same symbol (variable, constant, or function) in the same program. This means that attempting to link `interact.o` and `posn_test.o` together will result in an error.

Build dependencies



A bit more Make

To implement the previous slide in Make, we define *pattern rules* for particular types of files. Here's the rule for translating any `.c` file into a `.o` file:

```
build/%.o: src/%.c | build/
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```
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```

We also need to let Make know which object files depend on which header files. These dependency specifications say that if `src/posn.h` changes then each of the three object files dependent on it needs to be rebuilt:

```
build/interact.o: src/posn.h
build/posn.o: src/posn.h
build/posn_test.o: src/posn.h
```

Make understands dependencies

Notice that when we build `build/posn_test`, Make does not recompile `src/posn.c` to `build/posn.o`, because it already did that to build `build/interact`.

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$ make clean
rm -Rf build
$ make build/interact
mkdir -p build
cc -c -o build/interact.o src/interact.c -std=c11…
cc -c -o build/posn.o src/posn.c -std=c11 -pedant…
cc -o build/interact build/interact.o build/posn.…
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cc -c -o build/posn_test.o test/posn_test.c -std=…
cc -o build/posn_test build/posn_test.o build/pos…
$ make build/posn_test
make: `build/posn_test' is up to date.
```

Make performs minimal rebuilds

The `touch` command updates a file's modification time. This lets us see how make deals with files changing:

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