# ECE326

## PROGRAMMING LANGUAGES

**Lecture 20 : C Preprocessor Macro**

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# Metaprogramming

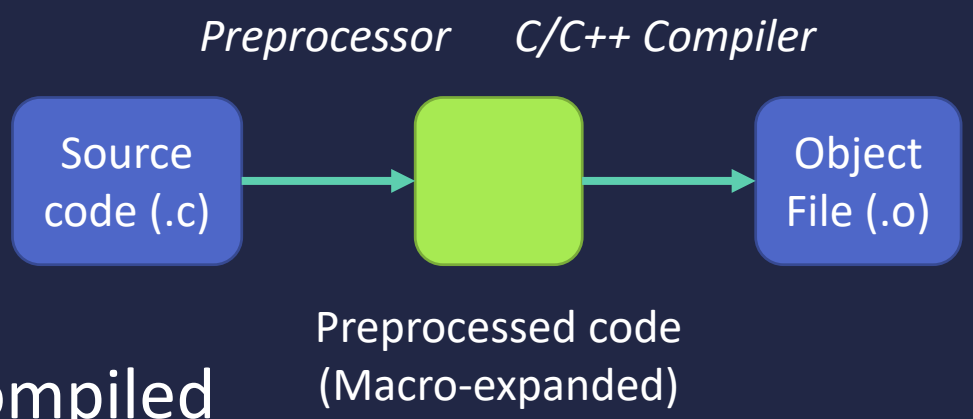
- Writing code that will generate more code
- Generic programming
  - Writing code with minimum assumption about data types
- Reflective programming
  - Access and/or modify program structure and/or behaviour
    - Has knowledge of compiler/interpreter's internals
- Different approaches
- Can have overlaps
  - E.g. C++ template programming encompasses all three

# Metaprogramming

- Macro systems
  - Maps certain input sequence into replacement output
  - E.g. text-based replacement
    - `“int a = 5;”.replace(“int”, “long long”)`
- Generative programming
  - Purpose of a program is to generate code for another program
    - May be same or different target language
    - Haskell compiler can generate C code from Haskell source code
- Template programming
  - Parameterized code which can be instantiated upon use

# C Preprocessor Macro

- Rudimentary support for metaprogramming in C/C++
- Provides text substitution of tokens
  - Token
    - A lexical unit, comprised of a type and value
    - E.g. int a;
      - *int* is a “keyword” token, of value “int”
      - *a* is an “identifier” token, of value “a”
      - ; is a “separator” token, of value “;”
- Preprocessor
  - Done before C source code is compiled



# C Preprocessor Macro

- Macro
  - A fragment of code with a name
- Macro expansion
  - Name replaced by content of macro whenever name is used
- Preprocessor
  - Scans the source code in multiple passes until no more replacement can be made
  - Has no knowledge of the C language
    - DANGER – can even use C keywords for macro names

# Macro Constant

- Also known as object-like macro
- Typically used to give name to a special literal

```
#define BUFFER_SIZE 1024

foo = (char *) malloc (BUFFER_SIZE);
// becomes this
foo = (char *) malloc (1024);
```

- Macros can be used after it is defined, but not before

```
foo = X;
#define X 4
bar = X;
```

```
foo = X;

bar = 4;
```

# Macro Function

- A macro that takes zero or more parameters
- Looks like a normal function using parentheses

```
#define hello() printf(“hello world”)
// macro with two parameters
#define min(X, Y) ((X) < (Y) ? (X) : (Y))

// function macro can be nested
min(min(a, b), c)
      →
min(((a) < (b) ? (a) : (b)), c)
      →
((((a) < (b) ? (a) : (b))) < (c) ?
    (((a) < (b) ? (a) : (b))) : (c))
```

# Macro Function

- Avoid expressions with side effects when using macro

```
#define min(X, Y) ((X) < (Y) ? (X) : (Y))

min(a++, b)
      →
((a++) < (b) ? (a++) : (b))
// a++ got called twice when macro is used
// not the same behaviour if min() is a C function

// GNU C only solution (not part of official C standard)
#define min(X, Y) \
({ typeof(X) x_ = (X); \
   typeof(Y) y_ = (Y); \
   (x_ < y_) ? x_ : y_; })
```

({ … }) acts like an expression. Its value is the value of the last statement. Similar to Rust

# Macro Function

- Multiline macro requires use of continuation \
- Emulating void functions

```
#define print_array(array) do { \
    unsigned i; \
    for (i = 0; i < sizeof(array)/sizeof(*(array)); i++) \
        printf("%ld ", (long)*((array)+i)); \
    printf("\n"); \
} while(0)

short a[] = { 2 , 3, 5, 46, 345, 1, -3 };
print_array(a);

2 3 5 46 345 1 -3
```

do { … } while(0) is necessary to allow natural use of semicolon at end of function. Just { … } will cause syntax error!

# Macro Function

- do { … } while(0)

```
#define bad_compound() { \
    printf(“hello\n”); \
    printf(“world\n”); }

if (x > 0)
    bad_compound();
else
    printf(“x too small”);
```

→

```
if (x > 0)
    { printf(“hello\n”); printf(“world\n”); };
else
    printf(“x too small”);
```

Stray semicolon

# Macro Function

- Wrap all arguments that can be an expression
  - To avoid problems with operator precedence

```
// round up an integer division: divroundup(11, 5) = 3
#define divroundup(x, y) (x + y – 1) / y

a = divroundup(b & c, sizeof (int));
      →
a = (b & c + sizeof (int) – 1) / sizeof (int);
/* C’s operator precedence works like this */
a = (b & (c + sizeof (int) – 1)) / sizeof (int);

// better version (also wraps the entire expression)
#define divroundup(x, y) (((x) + (y) – 1) / (y))
```

# Stringification

- Macro functions can turn arguments into a string
  - Use # operator in front of the expression

```
#define WARN_IF(EXP) do { \
    if (EXP) fprintf (stderr, "Warning: " #EXP "\n"); \
} while (0)

WARN_IF(x == 0);
      →
do { if (x == 0)
    /* C automatically joins string literals */
    fprintf (stderr, "Warning: " "x == 0" "\n");
} while (0);
```

# Stringification

- To stringify the value of a macro, use a helper

```
#define stringify_value(s) stringify(s)
#define stringify(s) #s
#define FOO 4

stringify_value(FOO)                stringify(FOO)
      →                                   →
stringify_value(4)                  “FOO”
      →
stringify(4)
      →
"4"
```

- Macro arguments are expanded before substitution, UNLESS they are stringified or “pasted”

# Concatenation

- Pasting macro argument with another token
  - Use ## operator between macro and another token

```
#define COMMAND(NAME) { #NAME, NAME ## _command }

struct command commands[] = {
    COMMAND (quiat),
    COMMAND (help),
    …
};
```

→

```
struct command commands[] = {
    { "quit", quit_command },
    { "help", help_command },
    …
};
```

```
struct command {
    const char *name;
    void (*function)();
};
```

# Variadic Macro

- Macro function that takes any number of arguments
  - When you put ## in front of vargs, it deletes a comma in front of it if vargs is empty

```
#define eprintf(format, vargs...) \
    fprintf(stderr, format, ##vargs)

eprintf("success!\n")
      →
fprintf(stderr, "success!\n");

eprintf(“%s:%d: ", input_file, lineno)
      →
fprintf(stderr, "%s:%d: ", input_file, lineno)
```

# X Macro

- Technique for maintaining list of tokens

```
#define ACTIONS \
      X(STAND) \
      X(HIT) \
      X(SURRENDER) \
      X(DOUBLE) \
      X(SPLIT)

#define X(e) #e,
const char * action_str[] = { ACTIONS };
#undef X

printf("%s %s\n", action_str[HIT], action_str[STAND]);

HIT STAND
```

```
#define X(e) e,
enum Action {
      ACTIONS
};
#undef X
```

#undef deletes a macro.

# Include Directive

- Adds content of file to current file
  - E.g. action.xmc

```
X(STAND)
X(HIT)
X(SURRENDER)
X(DOUBLE)
X(SPLIT)
```

```
void action_str2(Action e)
#define X(name) if (e == name) \
    return #name; else
#include “action.mcs”
#undef X
    {} // the last else uses this
    return “ERROR”;
}
```

```
void action_str2(Action e)
{
    if (e == STAND)
        return “STAND”;
    else if (e == HIT)
        return “HIT”;
    …
    else if (e == SPLIT)
        return “SPLIT”;
    else
        {}
    return “ERROR”;
}
```

# Optional Compilation

- Enable or disable parts of the code
  - Not even compiled at all, won't make it to final executable

```
int take_action(Hand hand, Action a) {
    if (a == SURRENDER) {
#ifdef ALLOW_SURRENDER
        hand.profit = hand.bet / 2.0;
        hand.state = COMPLETE;
        return ERR_OK;          // action accepted
#else
        return ERR_INVALID;     // action rejected
#endif
    }
    …
    return ERR_INVALID;
}
```

# Optional Compilation

- Used in header to avoid being included more than once

```
/* if SHOE_H is not defined */
#ifndef SHOE_H
#define SHOE_H

/* declaration of functions and definition of classes */

#endif

#include “shoe.h”  // OK – SHOE_H not defined
#include “shoe.h”  // nothing included this time
```

# Conclusion

- C macros provide some metaprogramming capability
  - Uses token based substitution
  - Invoked by compiler as first part of translation
  - Inherently unsafe, requires care
  - Reasonably powerful, when coupled with existing C constructs
- C preprocessor
  - Helps manage code into files
  - Allows for optional compilation
    - Can be abused – code will become very difficult to read
    - If executable size not a concern, should use inheritance instead