Putting C/C++ on a Macro Diet

(as in eat more macros, not abstain from macros)

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Graduate Seminar
Expressivity: What programs can you express? How hard is it to express a given program?
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General trend away from expressivity?
Types of expressivity

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- Express given program in more ways. ← you are here
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- Want easier to read code.
Types of expressivity

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- **Express given program in more ways.** ← you are here

Why care about more ways to express a program if we already have one?

- Want shorter code.
- Want easier to read code.
- Want code that is closer to your mental model.
How are languages made expressive?

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- Data representation: structs, inheritance, enums, ADTs...
- Overloading: operators, closures, `operator()`...
- Metaprogramming: templates, `macros`...
Fundamentally, macros are code (executed at compile time) that computes code.
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Long history: LISP had Fexprs since the ’60s.
So, why macros?
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Many arguments against: make code unaccessible, hide complexity, break abstraction boundaries...
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A lot of modern languages forswear metaprogramming altogether: Golang, Python...
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- **Simplify repetitive code.**
  Ever have to draw \(~16\) triangles with correct normals and texture coordinates in immediate mode OpenGL? Now try doing 16 variants of the above in a tight inner loop (e.g. marching cubes).
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- **Simplify repetitive code.**
  Ever have to draw \( \sim 16 \) triangles with correct normals and texture coordinates in immediate mode OpenGL? Now try doing 16 variants of the above in a tight inner loop (e.g. marching cubes).

- **Zero-overhead debugging.**
  Unfortunately, `-O0` still mostly means nothing is inlined, and `-O1` means the value that causes your bug has probably been optimised out.
• **Domain-specific languages.**
  Common example for C: packet (de)serialisation in network code.
  With sufficiently powerful macro system, can write shaders, packet filters etc. in-line.
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- **Configuration.**
  Maybe build system fashions have moved on, but the entire Linux ecosystem was still built on autoconf.
  Macros provide a clean, programmer-controlled interface for outside tooling to reshape code and adapt it to circumstances.
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C actually has a macro system. Unfortunately, it’s rather limited:

```
#define TEST(1) 1+TEST(1) //this won't loop forever :(  
```

There are some workarounds, but none will give you true recursion.

Also, can only create “fake variables” and “fake function calls”.
Other macro systems

LISP: Arbitrary LISP code operating on LISP code. This works because LISP code is approximately
\[ \text{thing} :: = (\text{thing ...}) | \text{name} | \text{value} \]
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Rust: DSL for matching, capturing and emitting token streams. Good start, but the Rust team fell for the “don’t surprise the reader” meme.
Let’s build something like that for C/C++!
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In fact, I did: https://github.com/blackhole89/macros
Simple example

```c
struct { int value; LinkedList *next; } LinkedList;

// define recursive macro to create a linked list
#define MakeList {
    ( {^[,]$head, ^$tail} ) => ( 
        new LinkedList( {$head, MakeList {$tail}} )
    ),
    ( ^[,]$singleton } ) => ( 
        new LinkedList( {$singleton, NULL} )
    ),
    ( {} ) => ( NULL )
}

// create a linked list with 5 elements
LinkedList *l = MakeList {1,2,3,4,5};
```
Basic summary

- `@define name {...}` creates a new macro `name`;
- `{...}` contains a series of `pattern-outcome pairs`.
- Whenever `name` is encountered, the parser tries to match the tokens following it to `patterns` in order.
- If a match succeeds, the `outcome` is processed and then emitted.
- Finally, processing proceeds with the first token that was not consumed by the match.

A successful `pattern` match may capture tokens or streams of tokens into variables, which are available for the processing of the `outcome`.
The pattern language contains facilities for matching various common grammars such as separated lists or everything until a particular token is encountered. More complex grammars should be implemented by capturing everything and rerunning the matcher on it using `match`.
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Also support S-expression-valued variables and iteration over them, basic arithmetic, basic string processing.
Can add algebraic datatypes to C++ (∼208 lines of macros):

```
datatype List<T> = Nil | Cons(T, List<T>) ;

/* flatten a list of lists */
template<class T> List<T> unions(List<List<T>> ls)
{
    match(ls) {
        case Cons(Cons(&x,&xs),&ys):
            return Cons(x, unions(Cons(xs,ys)));
        case Cons(Nil,&ys):
            return unions(ys);
        case Nil:
            return Nil<T>;
    }
}
```
Painless reflection

By redefining the keyword `class`, we can get reflection (and serialisation, and Java-style annotations...):

```cpp
class TestClass {
    int test; // (rest omitted for space)
};

int main(int argc, char* argv[]) {
    printf("Members of class TestClass:\n");
    for( auto a : Reflect<TestClass>::members ) {
        printf(" %s\n", a.c_str());
    }
    return 0;
}
```
Thoughts

- Macros are fun. Can tweak the language to be more like you want it to be without embarking on a project to write your own language.
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• For stuff like reflection, it’s easy to beat ISO (does their compromise solution make anyone happy?)
• Turns out that this approach to macros basically gives you TeX, with all its subtleties (\ texttt{expandafter}, anyone?). Many nontrivial design choices surrounding variable scope and substitution behaviour.
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Thanks for listening!