Putting C/C++ on a Macro Diet

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

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Graduate Seminar

Sliding Scale of Expressivity

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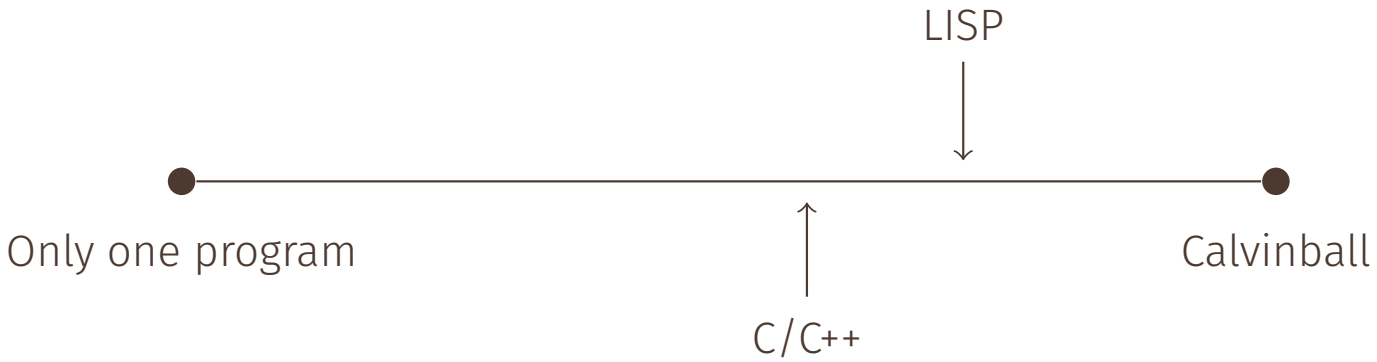

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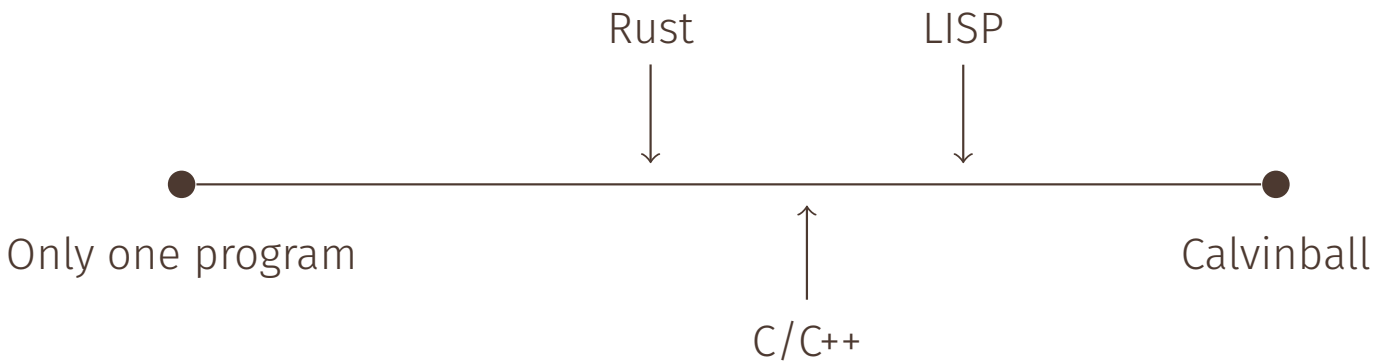

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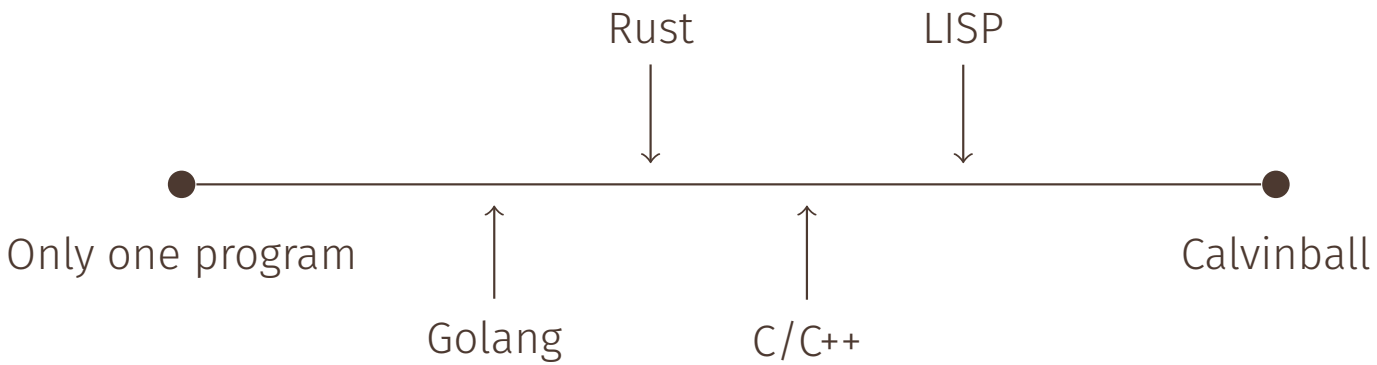

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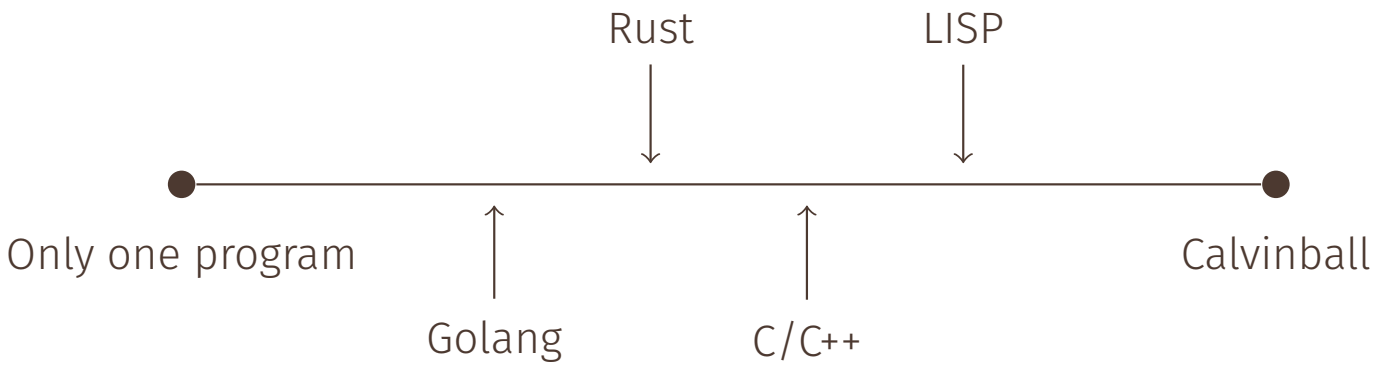

General trend away from expressivity?

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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.

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- Data representation: structs, inheritance, enums, ADTs...
- Overloading: operators, closures, `operator()`...
- Metaprogramming: templates, macros...

Macros

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Long history: LISP had Fexprs since the ’60s.

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A lot of modern languages forswear metaprogramming altogether: Golang, Python...

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- Simplify repetitive code.
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  Now try doing 16 variants of the above in a tight inner loop (e.g. marching cubes).

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  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).
- 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.

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  With sufficiently powerful macro system, can write shaders, packet filters etc. in-line.
- 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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The C preprocessor

C actually has a macro system. Unfortunately, it's rather limited:

```
1 #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.

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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.

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In fact, I did: https://github.com/blackhole89/macros

Simple example

```
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.

More features

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.

Algebraic datatypes

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 re`@define`ing the keyword `class`, we can get reflection (and serialisation, and Java-style annotations...):

```
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;
}
```

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- 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.
- 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 (`\expandafter`, anyone?). Many nontrivial design choices surrounding variable scope and substitution behaviour.

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Thanks for listening!