C2 language

Bas van den Berg

2014

Table of contents

1. Intro
2. Design
3. Changes
4. Concept: types
5. Concept: multi-pass parsing
6. Concept: modules
7. Concept: build system
8. The C2 Project

Intro C

The C programming language has been around for a long time and is still used a lot nowadays. The core of the language is very solid, but other aspects are showing their age. C2 attempts to modernize these parts, while keeping the feel of C. It should be seen as an *evolution* of C.

C2 Design goals

- Higher development speed
- Same/better speed of execution
- Better compilation times
- Integrated build system
- Stricter syntax (easier for tooling)
- Great tooling (formatting tool, graphical refactoring tool)
- C2 programs can use C libraries (and vice-versa)
- Should be easy to learn for C programmers (evolution)
- Should support avoiding common mistakes

C2 Non-goals

- higher-level features (garbage collection, classes, etc)
- completely new language

C improvement points

- Lots of typing (header/forward declarations)
- Build system separate from language
- Variable syntax complex

```
char *(*(**foo [][8])())[];
```

From C to C2

- No header files
- No forward declarations
- No includes necessary
- Integrated compiler option syntax
- Integrated Build system
- Compilation per target, not file
- Simplified type syntax
- Stricter error checking (uninitialized var usage *is* error)
- More built-in types (uint8,uint16,uint32,int8,int16,int32, ...)
- Some syntax cleanup
- ...

Keyword changes

removed keywords:

- extern
- static
- typedef
- long
- short
- signed
- unsigned

new keywords:

- module
- import
- as
- public
- local
- type
- func
- nil
- elemsof

- int8
- int16
- int32
- int64
- uint8
- uint16
- uint32
- uint64
- float32
- float64

Hello World!

hello_world.c2

```
module hello_world;

import stdio as io;

func int main(int argc, char*[] argv) {
    io.printf("Hello World!\n");
    return 0;
}
```

Spot the five differences...

Example - Base Types

types.c2

```
module types;

public type Number int;

type PNum int**;

type IntArr int[20];

public type String const uint8*;

type DoubleBufPtr DoubleBuf*;
type DoubleBuf Buffer*[2];
```

All 'typedefs' are uniform..

Example - Function Types

function_types.c2

```
module types;

type CallBack func int(int a, utils.Point* p);

type CBFunc func void (MyType* mt, ...);
CBFunc[10] callbacks;
```

Note: declaring an array/pointer to function types requires to steps.

Example - Struct Types

struct_types.c2

```
module types;

type ChessBoard struct {
    int[8][8] board;
}

type Example struct {
    int n;
    union {
        int b;
        Point c;
    } choice;
    volatile uint32 count;
}
```

Feature - multi-part array initialization

type_examples.c2

```
module types;

type Element struct {
    const char[16] name;
    int value;
}

const Element[] elements;

elements += { "test1", 10 }
...
elements += { "test2", 20 }
...
elements += { "test3", 30 }
```

This is possible because recipe file and multi-pass parsing.

multi-pass parsing

example.c2

```
module example;

Number hundred = 100;

func Number add(Number a, Number b) {
    return a + b;
}

type Number int;
```

Ordering in a file is not relevant for parsing. Variables, functions and types can be specified in any order.

Package scopes cause less prefixes in names

graphics.c2

```
module graphics;

public type Buffer {
    ...
}

public func void init() {
    ...
}

public func \
void create(Buffer* buf)
{
    ...
}
```

graphics.h (ANSI-C)

```
#ifndef GRAPHICS_H
#define GRAPHICS_H

typedef struct {
    ...
} Graphics_Buffer;

void graphics_init();

void graphics_create( \
    Graphics_Buffer* buf);

#endif
```

Symbol accessibility

application.c2

```
module gui;

import utils local;

Engine engine;  // ok

Engine_priv priv; // not ok
```

my_utils.c2

```
module utils;

public type Engine struct {
    ...
}

type Engine_priv struct {
    ...
}
```

Only public symbols can be used outside the module.
Non-public symbols can be used from any file within the same module.
Non-public roughly translates to the C keyword *static*.

Opaque pointers

application.c2

```
module application;

import foolib;

foolib.Foo* foo;

func void test() {
    foolib.init(foo);
}
```

foolib.c2

```
module foolib;

// non-public
type Foo struct {
    ...
}

public func void init(Foo* f)
{
    ...
}
```

Use of pointers to non-public Types is allowed (but no de-referencing)

Multi-file module

file1.c2

```
module utils;

Type Number int;

func void test() {
    tryMe();
}
```

file2.c2

```
module utils;

Number MAX = 20;
Number[10] numbers;

func void tryMe() {
    ...
}
```

No need to *import* your own module. Treat as if all code is in the same file.

Multi-file module usage

gui.c2

```
module gui;

import utils local;

utils.Buffer buf;

func void run()
{
   utils.log("ok");
   log("also ok");
}
```

utils_buf.c2

```
module utils;

public type Buffer int[10];
```

utils_log.c2

```
module utils;

public func void log(int8* msg)
{
    ...
}
```

Naming conflicts

gui.c2

```
module gui;

import graphics local;
import file local;

Buffer buffer; // not ok

graphics.Buffer buf1; // ok

file.Buffer buf2; // ok
```

file.c2

```
module file;

public type Buffer {
    ...
}
```

graphics.c2

```
module graphics;

public type Buffer {
    ...
}
```

Use statements are have a file scope, not module scope.

Use statement

file1.c2

```
module a_long_module_name;

Type Number int;
```

file2.c2

```
module foo;

import a_long_module_name as other;

other.Number number;
```

Syntax is 'import *long* as *short*' to avoid too much typing, while making it clear where a symbol comes from.

Use statement - example

file1.c2

```
module server;

import network as net;
import filesystem as fs;

func fs.File* getFile(net.URL url) {
    net.Socket sock = net.open(server);
    fs.File* file = net.get(sock, url);
    net.close(sock);
    return file;
}
```

$\Longrightarrow$ Both modules have been aliased.

Use statement - example 2

file1.c2

```
module server;

import network as net local;
import filesystem as fs local;

func File* getFile(URL url) {
    Socket sock = net.open(server);
    File* file = get(sock, url);
    net.close(sock);
    return file;
}
```

$\Longrightarrow$ Both modules have been aliased and imported locally.

Use statement - example 3

file1.c2

```
module server;

import network as net local;
import filesystem as fs;

func fs.File* getFile(URL url) {
    Socket sock = open(server);
    fs.File* file = get(sock, url);
    close(sock);
    return file;
}
```

$\Longrightarrow$ Only often used modules are imported locally.

the c2 module

example.c2

```
module example;

import c2;

uint64 buildtime = c2.buildtime;
const char* version = c2.version;
const char*[] options = c2.options;
```

A special module called *c2* can be used to get compile-information, build-time, (git/svn) version, build-flags etc. So no need to script some of your own.

building

To build C2 projects, simply use

```
$ c2c
```

This searches the current and parent directories for the *recipe file* (recipe.txt). This means c2c can be called from any subdir in the project, which is handy when working in a subdir:

```
drivers/networking/ethernet$ c2c
```

recipe file

Every C2 project has a recipe file in the root directory of the project. This file contains a list of all target that need to be build. For each target the recipe describes:

- name
- type - executable/library
- files - all required c2 files. This allows C2 to do better optimizations and error checking
- configuration - all 'defines' used
- exports - which modules will be exported (visible as ELF object in the resulting file

example recipe file

recipe.txt

```
executable one
  example1/gui.c2
  example1/utils.c2
end

library mylib
  config NO_DEBUG WITH_FEATURE1 FEATURE2
  export mylib
  example2/mylib1.c2
  example2/mylib2.c2
end
```

outputs

The results of building are stored in the *output* directory. So make clean is simply removing of this directory.

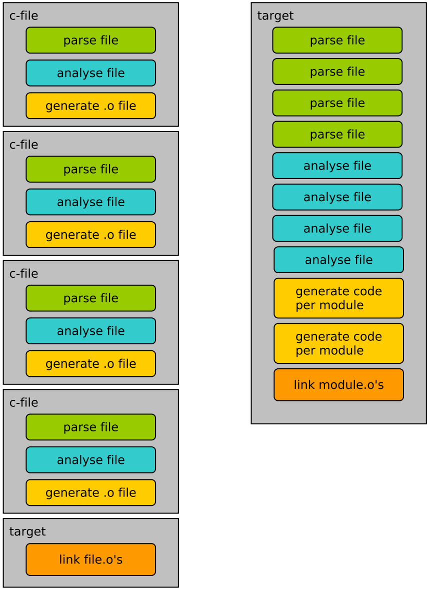
Build process

Because of the language design, compiling C2 code requires a different process then compiling C. The basic process is as follows:

- parse all c2 files into ASTs
- check all ASTs
- generate IR code per module
- generate object code per module
- link all objects

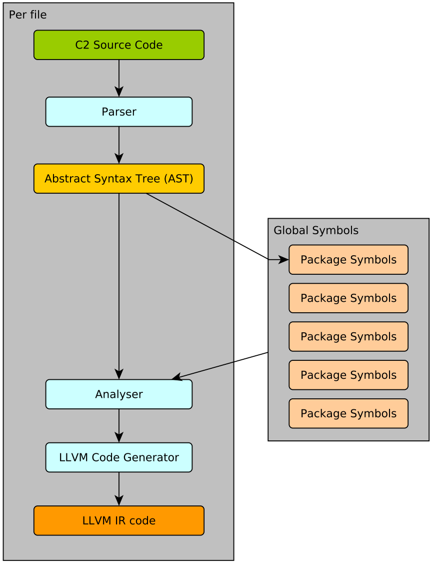
So in effect, all files are parsed simultaneously.

Build process difference



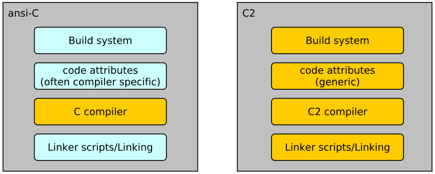
- C: a new compiler is started for each .c file
- C2 finds a compile error in file *x* much faster
- C2 generates code per module, not file
- The generation(+ optimization) step takes much longer then the parse/analyse step, so the yellow blocks are really much bigger

Build process per file



- first parse the file to the AST
- extract the symbol table and add to the global table
- generate IR code from the AST and Global Symbol table

Language Scope



The *scope* of the C2 language is wider than the C language.

For example, there is no syntax format for specifying attributes in the C language. In C2, the syntax is specified, there are common attributes and compiler-builders can add custom attributes without disturbing others.

$\Longrightarrow$ widening the language scope allows for huge improvements and ease of use.

Tooling

The language makes several interesting tooling options possible. Some of these options are grouped in *c2reto*, the C2 Refactor Tool:

- Visualizing dependencies between functions/vars/types/files/modules
- Drag 'N Drop reordering of declarations in files
- Drag 'N Drop moving of declarations between files
- renaming, style formatting, etc

Implementation

The C2 compiler is currently built on top of llvm and uses the clang Lexer/Pre-processor. The parser and semantic analyser are custom. Code is translated to an AST (Abstract Syntax Tree) that's similar to clang's (but much simpler). After generating and checking the AST's, LLVM's IR code is generated from the AST.

Links

http://www.c2lang.org

http://github.com/c2lang/c2compiler

title