C++ for Embedded development

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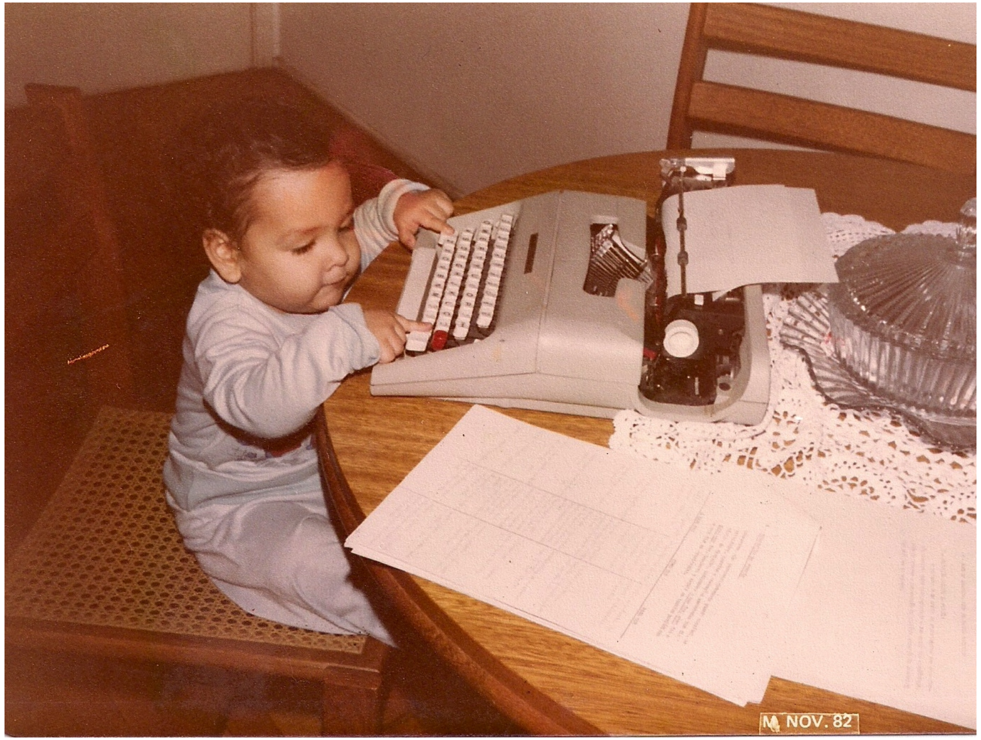
Who am I?

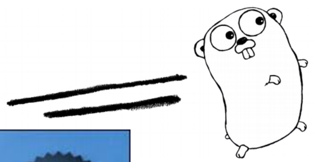


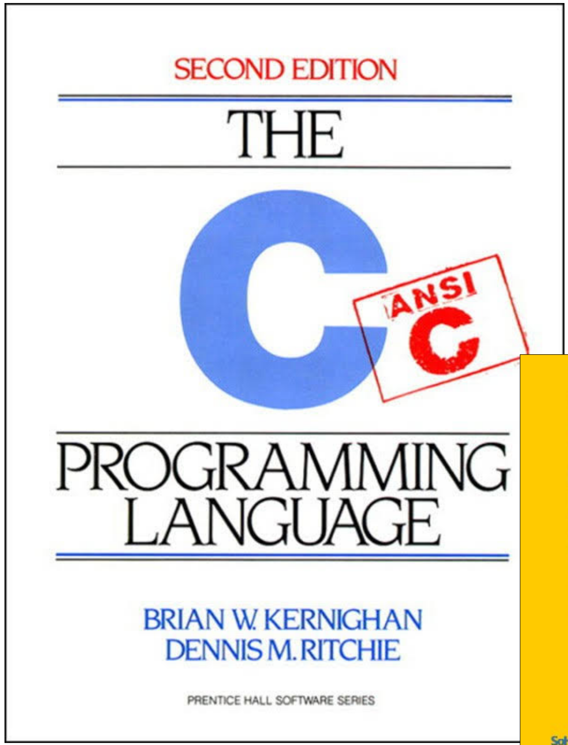
C++ is not bad

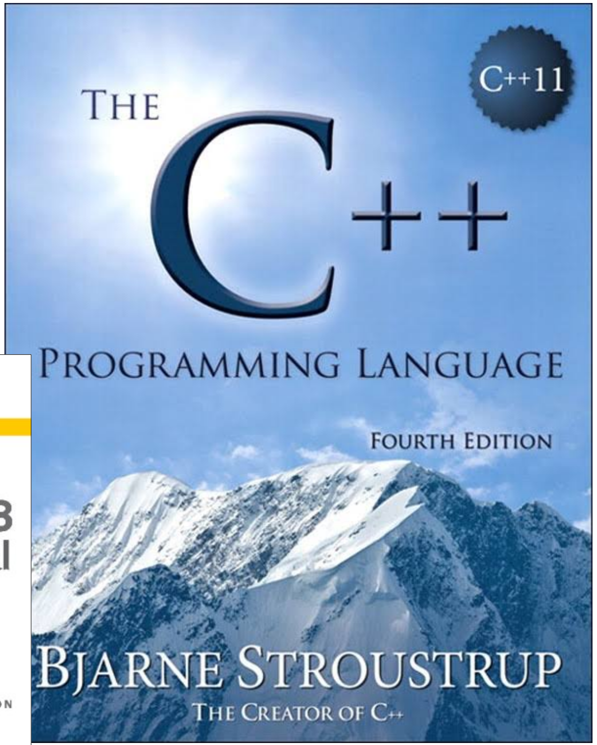
C++ is good

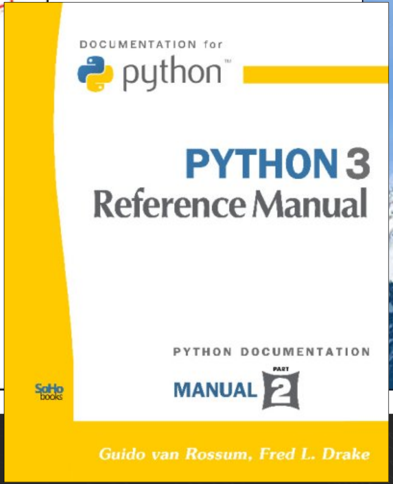
C++ is awesome

Which is the best language for embedded programming?









Myth or fact about C++

- **C++ is more complex than C**

✔ Fact but depends on what you use

  - C11 standard (N1570) is 179 pages*
  - C++14 standard (N3690) is 407 pages*
  - C++17 is draft N4606 is 452 pages*
  - * core language only, not including the library sections

Myth or fact about C++

- **C++ language generates more code / requires more RAM**

✘

Myth

Language designed around

“don’t pay for what you don’t use”

(Discussion about exceptions later)

Removing some C++ language overhead

- **If not using exceptions:**

  ```
  -fno-exceptions -fno-asynchronous-unwind-tables
  ```

- **If not using `dynamic_cast`, `typeid` or exceptions:**

  ```
  -fno-rtti
  ```

- **If not Standard Library (beyond language support):**
  - Compile only against `libsupc++` or `libc++abi`
    (Use gcc or clang to link, instead of g++ or clang++)

Myth or fact about C++

- **C++ language hides functionality from programmer**

✘

Myth

No more is hidden than macros do in C

(but you <u>can</u> do crazy things)

Myth or fact about C++

- **Using templates is more expensive**

✘✔

Increases compilation time and compiler memory consumption, but not necessarily that of generated code

(in fact, it often produces more optimal, but larger code)

Myth of fact about C++

- **C++ compilers are not as good as the C compilers**

✘

Myth

Not the case with GCC, Clang, MS Visual Studio or the Intel compiler

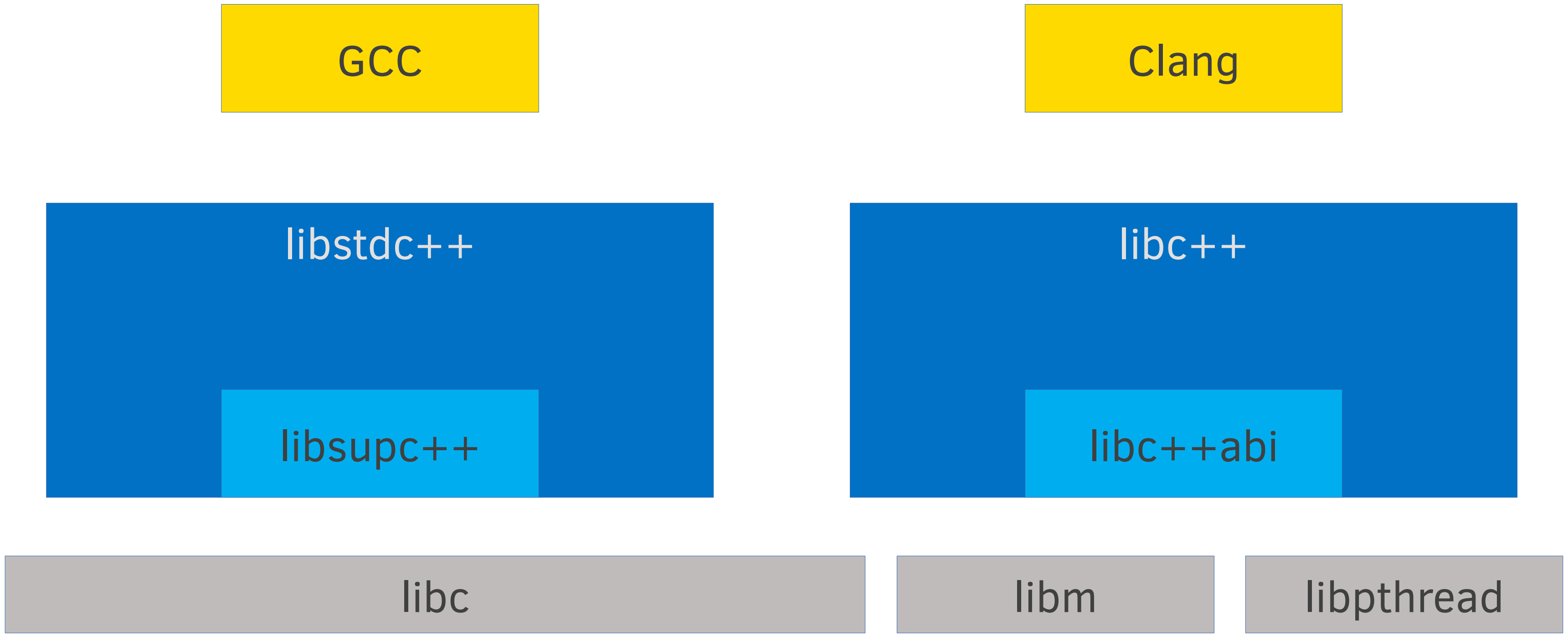
- **C++ compilers are not as widely supported as C compilers on embedded platforms**

✔

Fact

That's why we're here

Compiler and standard library on regular Linux



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Missing prototypes is an error

```
void f()
{
	g(-1);
}
```

C:

```
test.c: In function ‘f’:
test.c:3:5: warning: implicit declaration of function ‘g’ [-Wimplicit-function-declaration]
    g(-1);
    ^
```

C++:

```
test.cpp:3:9: error: ‘g’ was not declared in this scope
```

Stricter type safety – const and pointers

- **Casting across incompatible types is an error**

```
void h(int *);
void f(short *ptr) { h(ptr); }
```

```
test.c:3:5: warning: passing argument 1 of ‘h’ from incompatible pointer type [-Wincompatible-pointer-types]
test.cpp:3:8: error: cannot convert ‘short int*’ to ‘int*’ for argument ‘1’ to ‘void h(int*)’
```

```
void h(int *);
void f(const int *ptr) { h(ptr); }
```

```
test.c:2:28: warning: passing argument 1 of ‘h’ discards ‘const’ qualifier from pointer target type
[-Wdiscarded-qualifiers]
test.cpp:2:31: error: invalid conversion from ‘const int*’ to ‘int*’ [-fpermissive]
```

Stricter type safety - void*

```
void h(int *);
void g(void *ptr) { h(ptr); }
void f(short *ptr) { g(ptr); }
```

C: ***no error, no warning***

C++:

```
test.cpp:2:26: error: invalid conversion from ‘void*’ to ‘int*’ [-fpermissive]
void g(void *ptr) { h(ptr); }
                         ^
test.cpp:1:6: note:   initializing argument 1 of ‘void h(int*)’
```

Stricter type safety – cast operators

- **Easier to `grep` for!**
- **Can’t accidentally do more than intended**
  - `const_cast`
  - `static_cast`
  - `reinterpret_cast`
  - `dynamic_cast`

Organise code: classes

```
str = g_string_new (NULL);
for (n = 0; s[n] != '\0'; n++)
{
  if (G_UNLIKELY (s[n] == '\r'))
    g_string_append (str, "\\r");
  else if (G_UNLIKELY (s[n] == '\n'))
    g_string_append (str, "\\n");
  else
    g_string_append_c (str, s[n]);
}
g_print ("GDBus-debug:Auth: %s\n", str->str);
g_string_free (str, TRUE);
```

```
QByteArray str;
for (int n = 0; s[n] != '\0'; ++n) {

    if (Q_UNLIKELY(s[n] == '\r'))
        str.append("\\r");
    else if (Q_UNLIKELY(s[n] == '\n'))
        str.append("\\n");
    else
        str.append(s[n]);
}
printf("Auth: %s", str.constData());
```

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Improve code: overloads

- **C++ std section 26.9.1**

```
// 26.9.2, absolute values
int abs(int j);
long int abs(long int j);
long long int abs(long long int j);
float abs(float j);
double abs(double j);
long double abs(long double j);

float fabs(float x); // see 17.2
double fabs(double x);
long double fabs(long double x); // see 17.2
float fabsf(float x);
long double fabsl(long double x);
```

- **C std section 7.12.7.2**

```
#include <math.h>
double fabs(double x);
float fabsf(float x);
long double fabsl(long double x);
```

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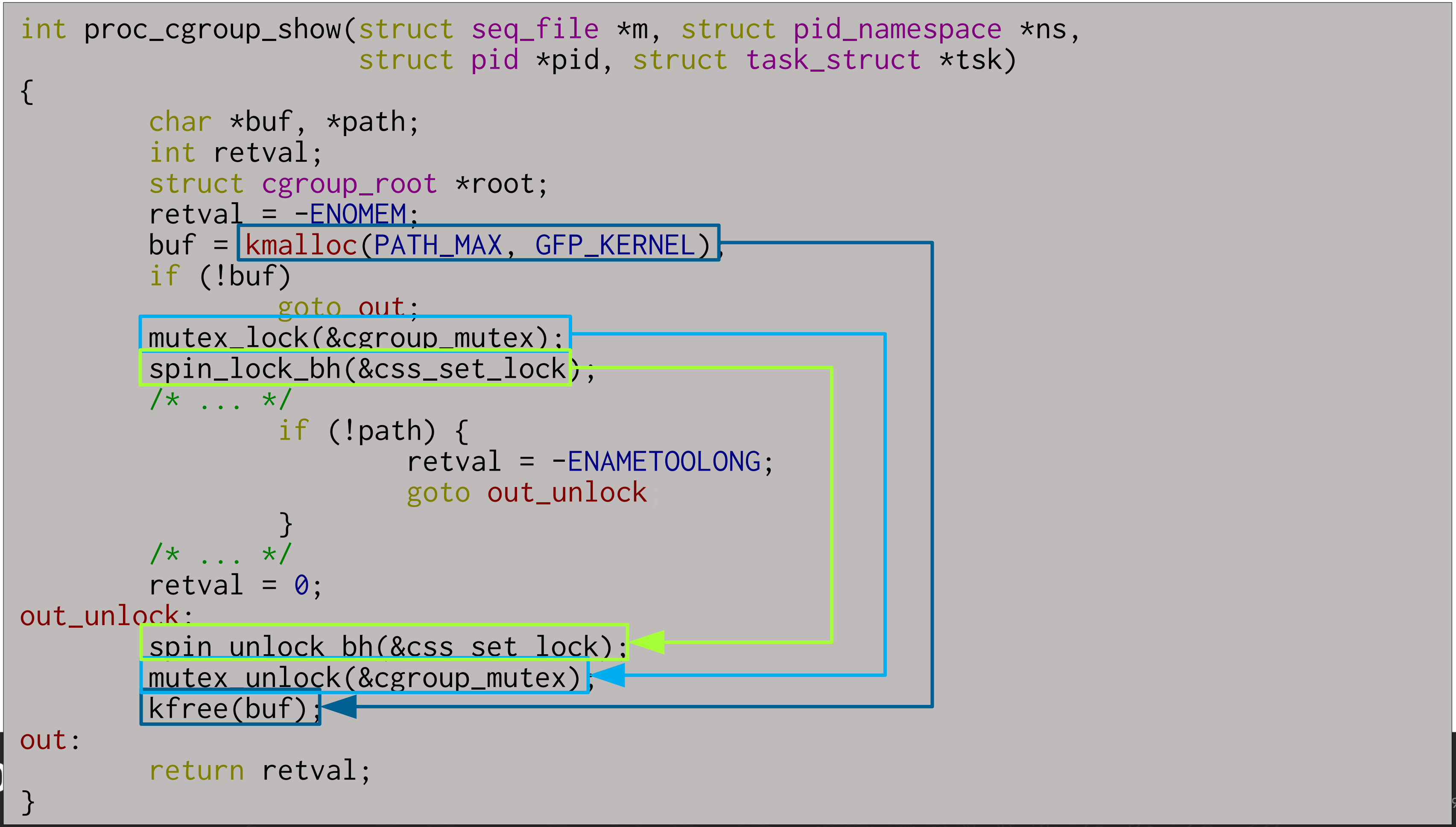
Achievement unlocked: destructors



```
int proc_cgroup_show(struct seq_file *m, struct pid_namespace *ns,
                     struct pid *pid, struct task_struct *tsk)
{
        char *buf, *path;
        int retval;
        struct cgroup_root *root;
        retval = -ENOMEM;
        buf = kmalloc(PATH_MAX, GFP_KERNEL);
        if (!buf)
                goto out;
        mutex_lock(&cgroup_mutex);
        spin_lock_bh(&css_set_lock);
        /* ... */
                if (!path) {
                        retval = -ENAMETOOLONG;
                        goto out_unlock;
                }
        /* ... */
        retval = 0;
out_unlock:
        spin_unlock_bh(&css_set_lock);
        mutex_unlock(&cgroup_mutex);
        kfree(buf);
out:
        return retval;
}
```

Resource Acquisition Is Initialisation (RAII)

```
int proc_cgroup_show(struct seq_file *m, struct pid_namespace *ns,
                     struct pid *pid, struct task_struct *tsk)
{
        char *path;
        struct cgroup_root *root;
        ptr_holder<char> buf{kmalloc(PATH_MAX, GFP_KERNEL)};
        if (!buf)
                return -ENOMEM;
        mutex_locker ml(&cgroup_mutex);
        spin_locker_bh sl(&css_set_lock);
        /* ... */
                if (!path)
                        return -ENAMETOOLONG;
        /* ... */
        return 0;
}
```

Containers (with type safety)

- C++ Standard Library containers are the most optimal possible

- Though not optimised for code size

Error checking with exceptions

```
int proc_cgroup_show(struct seq_file *m, struct pid_namespace *ns,
                     struct pid *pid, struct task_struct *tsk)
{
        ptr_holder<char> buf{kmalloc(PATH_MAX, GFP_KERNEL)};
        mutex_locker ml(&cgroup_mutex);
        spin_locker_bh sl(&css_set_lock);
        /* ... */
        return 0;
}
```

- **Differences*:**
  - `.text` grew 16 bytes (3.5%) plus 0x58 bytes of exception handling table
  - Error checking removed from main code path

* GCC 6.2.1, x86 32-bit with IAMCU ABI, not including EH walker code itself

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Lambdas

- **New in C++11**
- **Work as C callbacks too!**

```
void register_callback(void (*)(void *), void *);
void f()
{
    static struct S { int i; } data = { 42 };
    register_callback([](void *ptr) {
        auto x = static_cast<S *>(ptr);
        exit(x->i);
    }, &data);
}
```

Range for

```
static const uint16_t table[] = {
    0,     6,    40,    76,   118,   153,   191,   231,
    273,   313,   349,   384,   421,   461,   501,   540
};

void regular_for()
{
    for (int i = 0; i < sizeof(table); ++i)
        use(table[i]);
}

void range_for()
{
    for (auto i : table)
        use(i);
}
```

A lot more coming

- **C++14 added:**
  - Binary literals (0b01001001)
  - Group separators (123’456’789)
  - Return type auto-deduction
  - Variable templates

Default in GCC 6

- **C++17 is adding:**
  - Folding expressions
  - Inline variables
  - Initialisers in if and switch
    `if (char c = expr; c < ' ')`
  - `if constexpr`
  - Concepts Lite (in a Technical Spec)

Language developed almost Open-Source-like

- It’s still an ISO standard
- But almost everything discussed in mailing lists
  - https://isocpp.org
- Standard text is on GitHub
  - https://github.com/cplusplus/draft

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