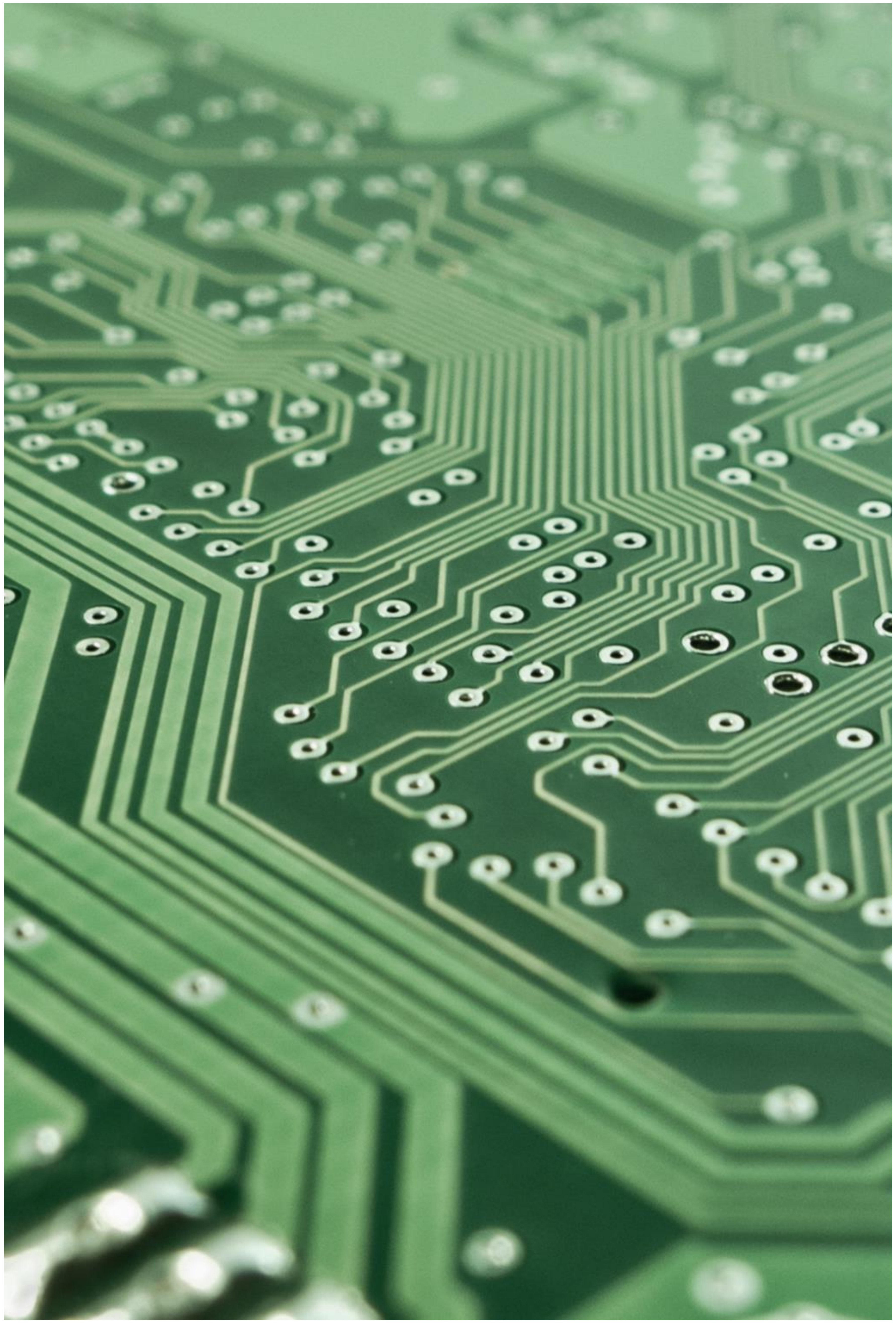
Challenges in Modern Embedded Development Using C++

Glyn Matthews, SoftKinetic

Belgian C++ User Group – 11/04/2017

Solving hard problems is why we do what we do: we must remember that we should be problem solvers first, programmers second.

The technology of tomorrow… today!



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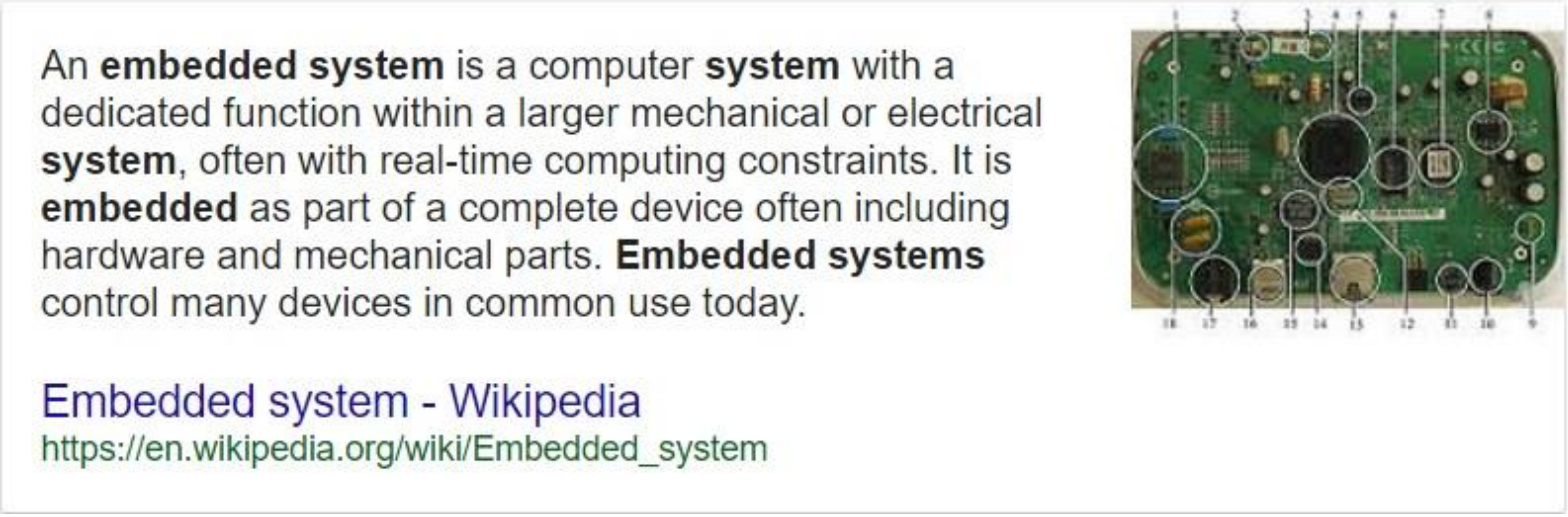
Systems



An **embedded system** is a computer **system** with a dedicated function within a larger mechanical or electrical **system**, often with real-time computing constraints. It is **embedded** as part of a complete device often including hardware and mechanical parts. **Embedded systems** control many devices in common use today.

Embedded system - Wikipedia
https://en.wikipedia.org/wiki/Embedded_system

Not about microcontrollers (deep embedded)
https://www.youtube.com/watch?v=TYqbgvHfxjM

?

Constrained systems for:

- high performance
- real-time
- low latency
- high availability
- mission/safety critical

Using:

- computer vision
- machine learning
- other cool stuff

Why do people use C++ to solve these problems?

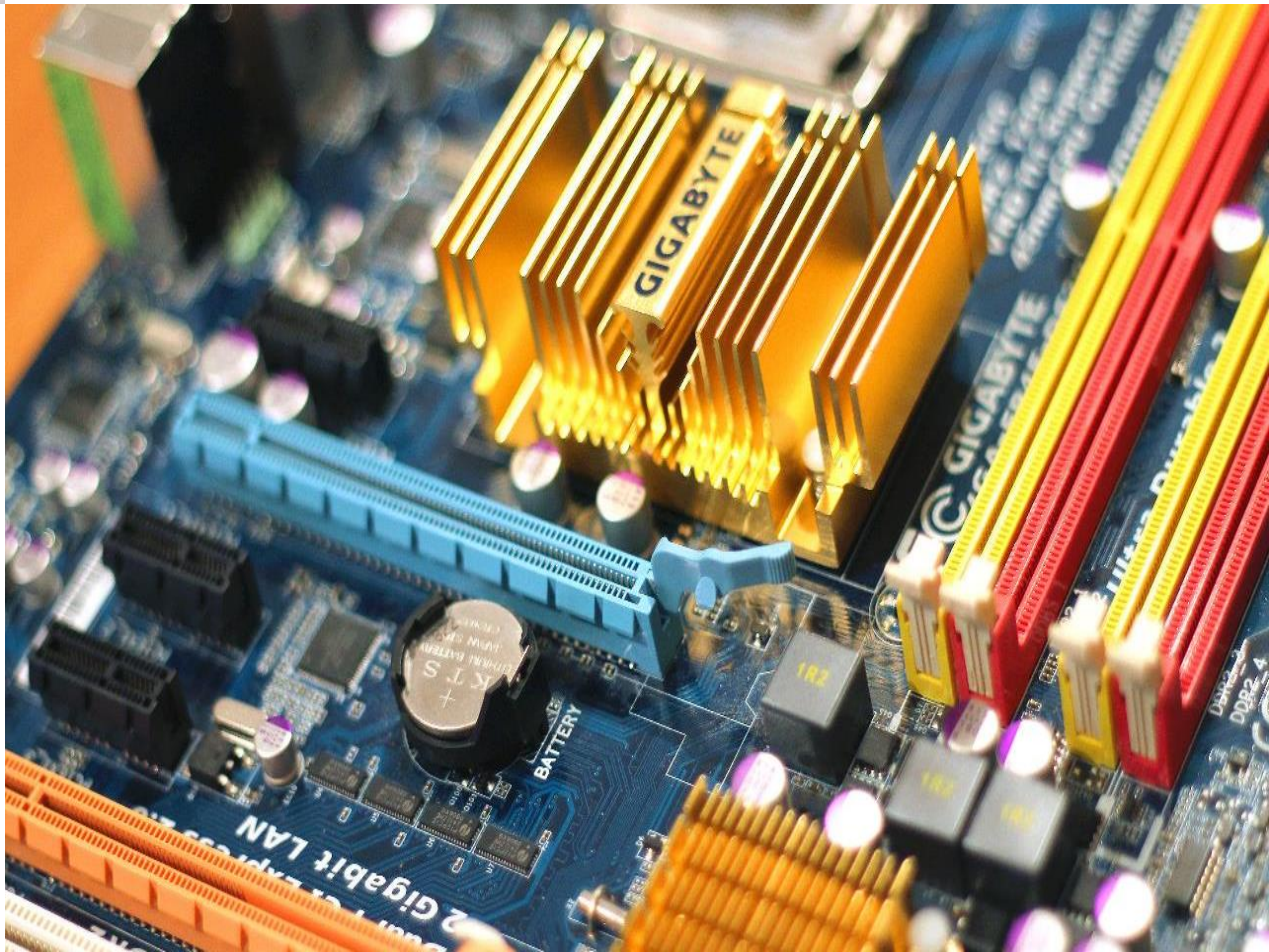
C++ doesn’t give you performance, it gives you control over performance

Chandler Carruth

https://www.youtube.com/watch?v=fHNmRkzxHWs

Large Scale

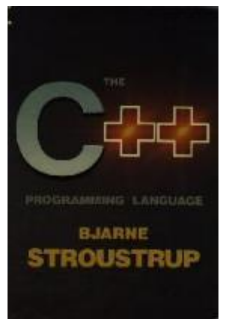
Small Scale



C++ History

C++ History

1979:
C with classes



1985: The C++ Programming Language: 1st Edition

1987: C++ support in GCC

1990: ANSI C++ Committee founded

C++ History

1991: ISO Committee founded

1995: MSVC Initial release

1998: C++98 Standard published

2003: C++03 Standard published

C++ History

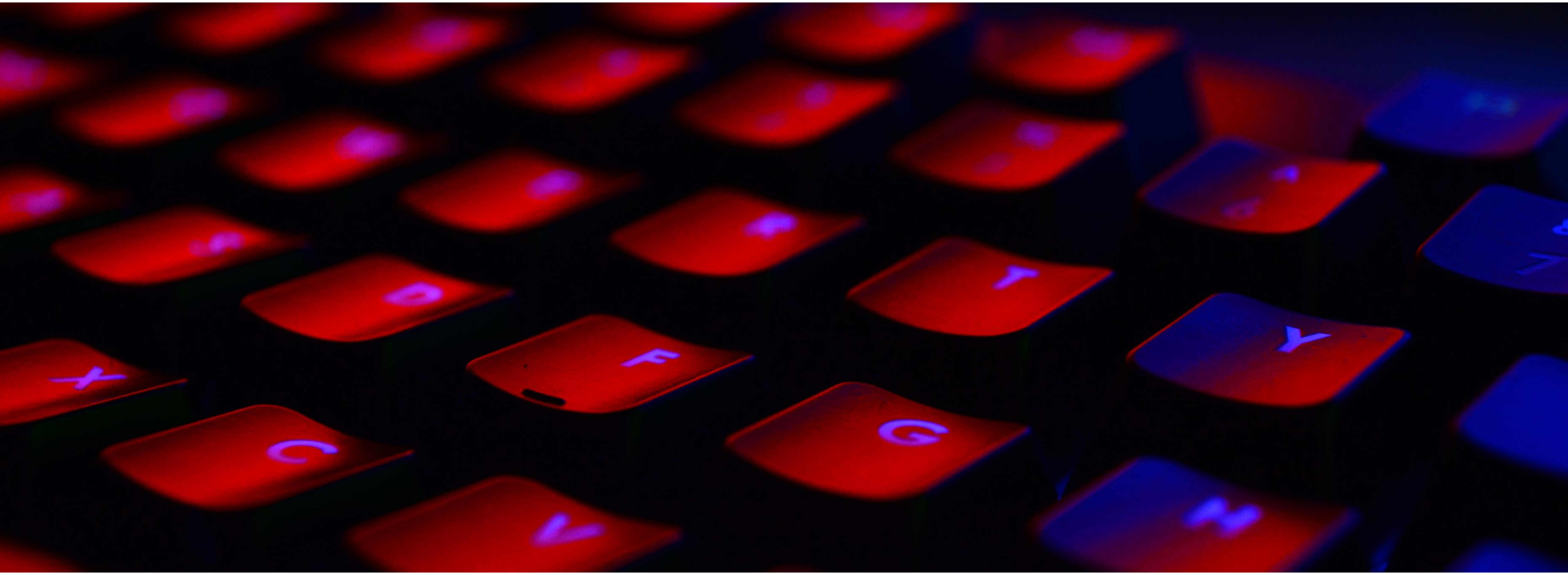
2007: Clang
Initial release

2012: C++11
Standard published

2015: C++14
Standard published

**2018: C++17
Standard will
be published**

Modern C++



Computers

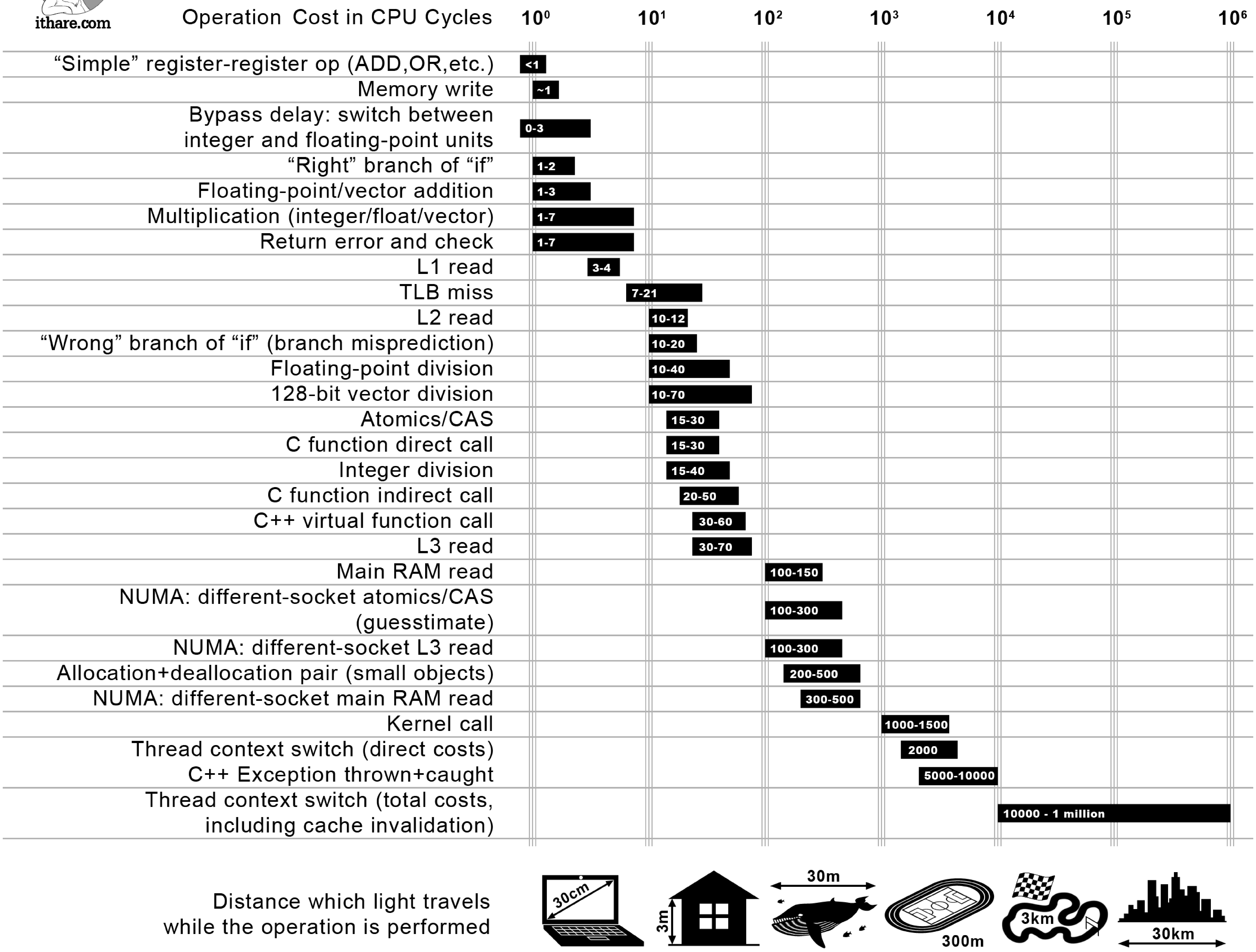
Computer Resources

We care about:

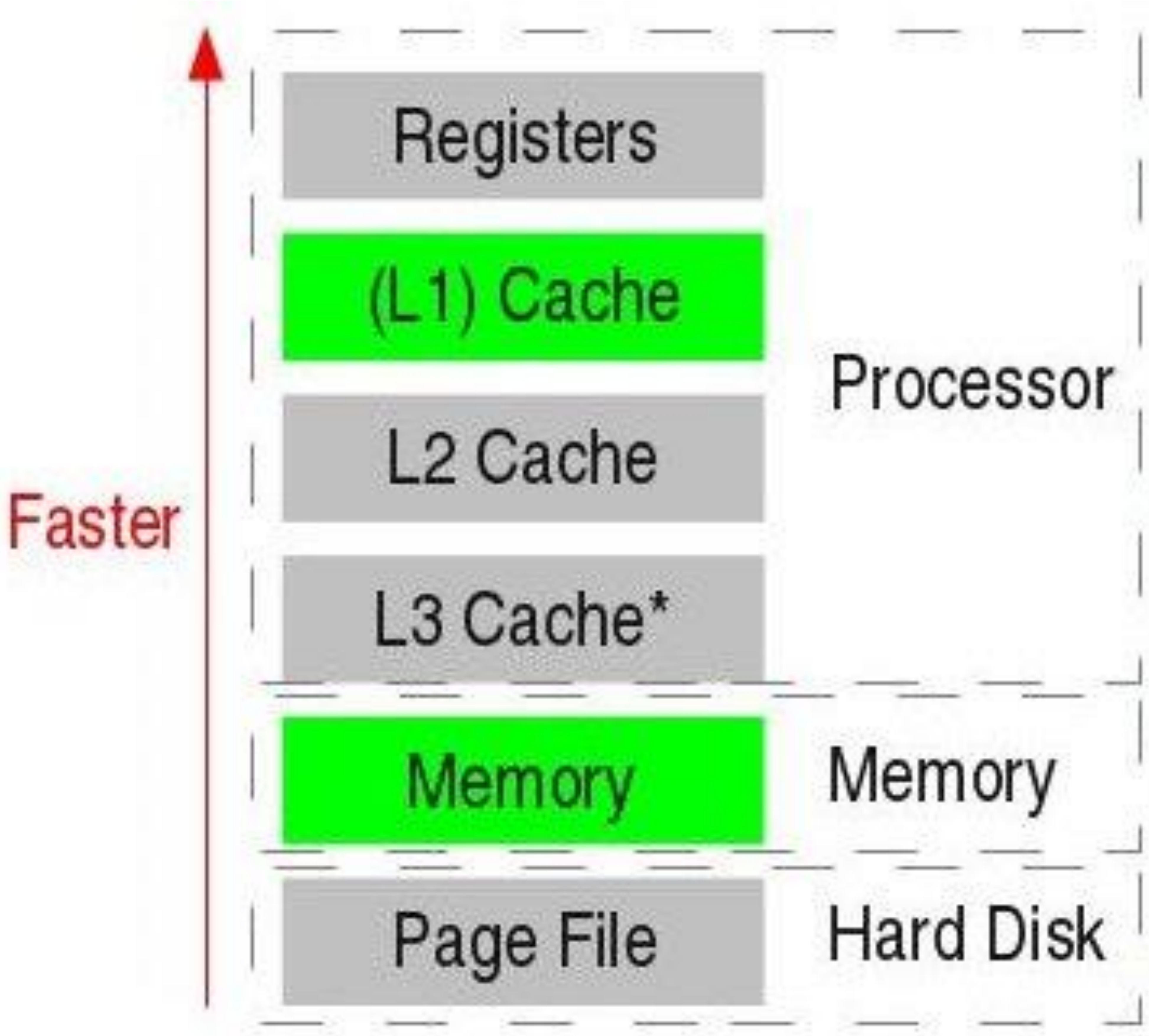
- The processor(s) and it’s core(s)
- Memory
- Filesystem
- Network
- Etc.

ithare.com

Not all CPU operations are created equal



Memory Hierarchy



C++ Features

A FILM BY ANTON CORBIJN
CONTROL
SAMANTHA MORTON SAM RILEY ALEXANDRA MARIA LARA
WINNER BEST ACTOR-SAM RILEY EDINBURGH FILM FESTIVAL
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WWW.CONTROL-MOVIE.COM

How do you take control using modern C++?

}

Some Opinions About Smart Pointers

- Use unique_ptr to indicate ownership
- Take advantage of the deleter for resources such as files
- reference_wrapper is your friend when using containers

Use unique_ptr to indicate ownership

```cpp
struct Vector3 {
  int x, y, z;
  Vector3() : x(0), y(0), z(0) {}
};

void compute_point_cloud(Vector3 *point_cloud, std::size_t length);

{
  auto point_cloud = std::make_unique<Vector3[]>(100);
  auto t1 = std::thread(compute_point_cloud, point_cloud.get(), 50);
  compute_point_cloud(point_cloud.get() + 50, 50);
  t1.join();
}
```

Take advantage of the deleter for resources such as files

```
using file_ptr = std::unique_ptr<FILE, decltype(&std::fclose)>;

{
  auto file = file_ptr(std::fopen(“cpp.txt”, “r”), &std::fclose);
  if (file) {
    // process file
  }
}
```

reference_wrapper is your friend when using containers

```cpp
struct BigData { bool is_interesting() const; };

auto data = std::vector<std::unique_ptr<BigData>>{ 100 };

{
  auto filtered_data = std::vector<std::reference_wrapper<BigData &>>{};

  std::for_each(
    std::begin(data), std::end(data),
    [&filtered_data](auto &data) {
    if (data->is_interesting()) {
      filtered_data.emplace_back(std::ref(*data.get()));
    }});
}
```

Some More Opinions

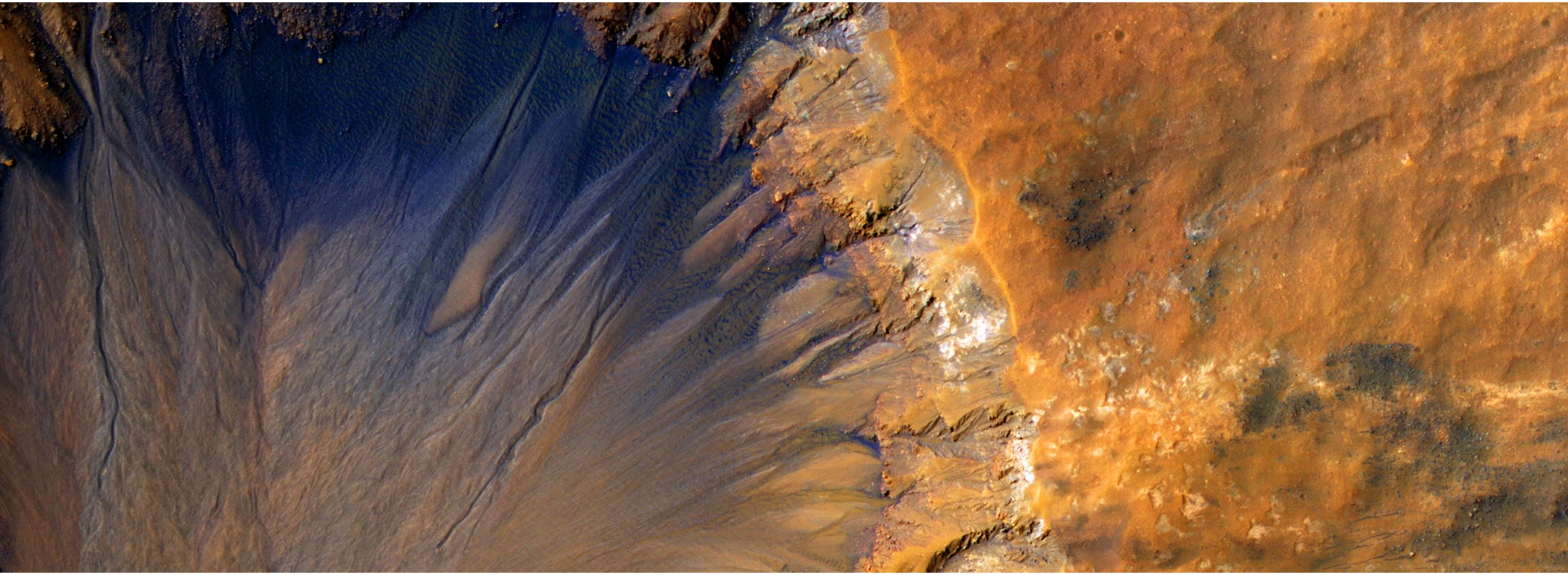
- Reference counting (using shared_ptr) is rarely needed in practice, especially in synchronous code
- Simply share data by passing by reference to functions (unless you’re transferring ownership)

C++ string_view (1)

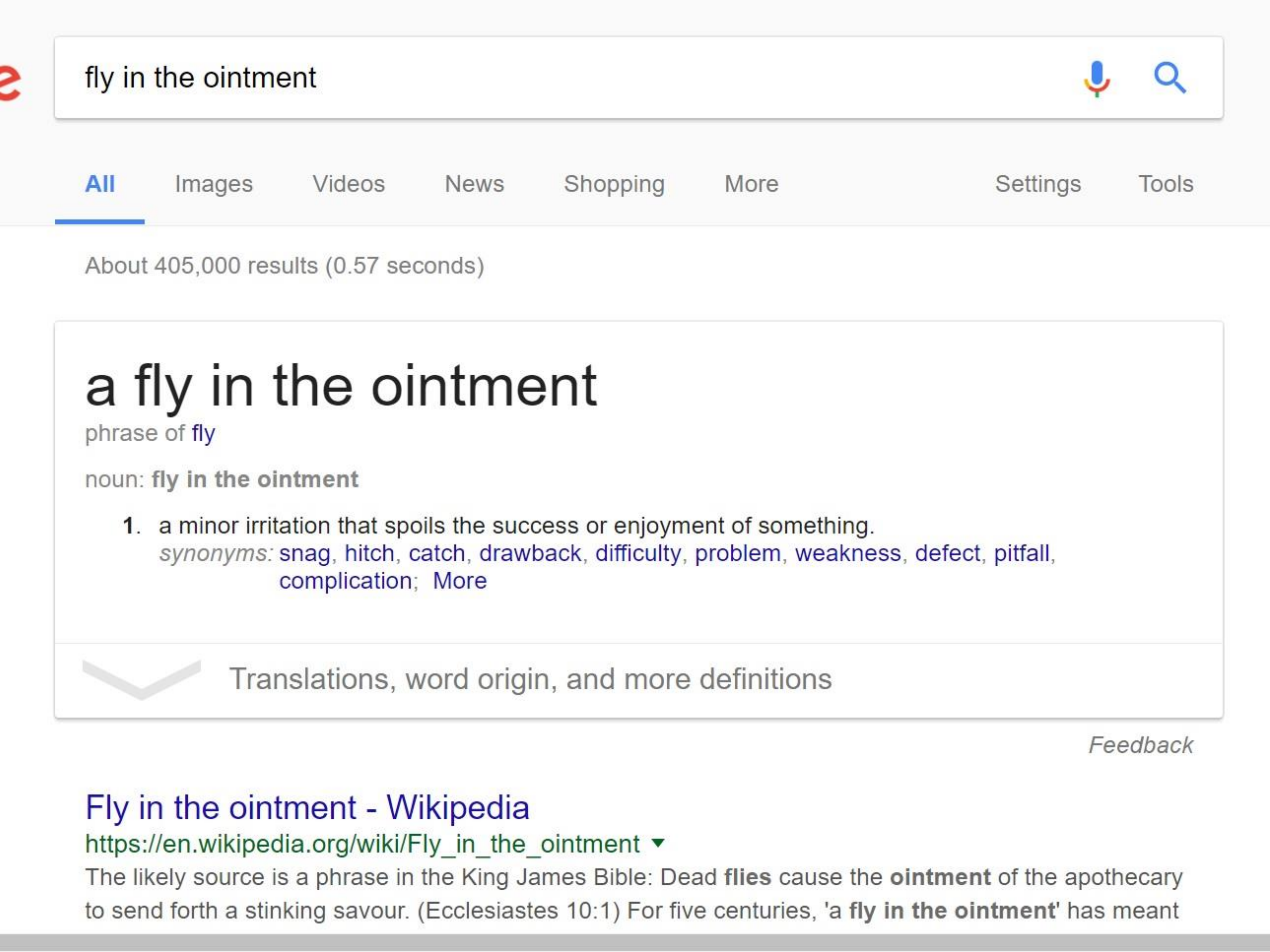
```
auto dna_sequence = std::string(“ACTGCGACGGTACGCTTCGACGTA”);

std::vector<std::size_t> find_occurrences(
  std::string_view dna_sequence,
  std::string sub_sequence);

auto sequence1 = std::string_view(dna_sequence.c_str(), 12);
auto sequence2 = std::string_view(dna_sequence.c_str() + 12, 12);

auto occurrences1 = std::async(find_occurrences, sequence1, “ACG”);
auto occurrences2 = find_occurrences(sequence2, “ACG”);
occurrences1.wait();
```

C++ string_view (2)

```cpp
int __cdecl c_find_occurrences(
  const char *dna_sequence, size_t length, const char *sub_sequence,
  size_t **occurrences, size_t *occurrence_count) {
  auto occurrences = find_occurrences(
    std::string_view(dna_sequence, length),
    std::string(sub_sequence));

  // fill in return values

  return 0;
}
```



Flies in the Ointment



About 405,000 results (0.57 seconds)

a fly in the ointment

phrase of fly

noun: **fly in the ointment**

1. a minor irritation that spoils the success or enjoyment of something.
   synonyms: snag, hitch, catch, drawback, difficulty, problem, weakness, defect, pitfall, complication; More

Fly in the ointment - Wikipedia

https://en.wikipedia.org/wiki/Fly_in_the_ointment ▾

The likely source is a phrase in the King James Bible: Dead **flies** cause the **ointment** of the apothecary to send forth a stinking savour. (Ecclesiastes 10:1) For five centuries, 'a **fly in the ointment**' has meant

Inefficient Standard Data Structures

The standard specification for following data structures requires that they are sub-optimal:

- `list`
- `map`
- `set`
- `unordered_map`
- `unordered_set`

ordered_table (1)

```
template <class K, class V,
          class Allocator = std::allocator<std::pair<K, V>>>
class ordered_table {
public:
  ordered_table(std::initializer_list<std::pair<K, V>> values)
    : table_{values} {
    sort();
  }

private:
  void sort() {
    std::sort(begin(), end(), key_less_than{});
  }

  std::vector<std::pair<K, V>, Allocator> table_;
};
```

ordered_table (2)

```
bool try_insert(const K &key, const V &value) {
  auto found = std::binary_search(
    begin(), end(),
    std::make_pair(key, value), key_less_than{});

  if (!found) {
    table_.emplace_back(key, value);
    sort();
  }

  return found;
}
```

ordered_table (3)

```
const_iterator find(const K &key) const {
  auto value = std::make_pair(key, mapped_type{});
  auto it = std::lower_bound(
    begin(), end(), value, key_equals{});
  return (it != end()) && (!key_equals(*it, value)) ?
          it : end();
}
```

Cross-Platform Development

- When you don’t own the target platform
- When the target platform doesn’t support the language feature

C++ Trends

Low Latency – WG21/SG14

- Games
- Low Latency
- Real-time Applications
- Graphics
- Financial Trading

SG14 (the GameDev & low latency ISO C++ working group) - Guy Davidson - Meeting C++ 2016

https://www.youtube.com/watch?v=IuJ79Og-CfU

A library for Study Group 14 of Working Group 21 (C++)

https://github.com/WG21-SG14/SG14

C++ Core Guidelines

This document is a set of guidelines for using C++ well. The aim of this document is to help people to use modern C++ effectively. By “modern C++” we mean C++11 and C++14 (and soon C++17). In other words, what would you like your code to look like in 5 years’ time, given that you can start now? In 10 years’ time?

From the abstract of the C++ Core Guidelines

http://isocpp.github.io/CppCoreGuidelines/CppCoreGuidelines

Write for portability and performance

- Be conservative in using language and library features
- Understand your target platform’s CPU, cache and memory
- Use cache-friendly data structures
- Consider memory locality

Measure and test

- Run benchmarks as part of acceptance testing

Follow core guidelines

- Helps understand trade-offs
- Still incomplete, but usable
- Tooling exists to support the core guidelines (e.g. c-tidy)

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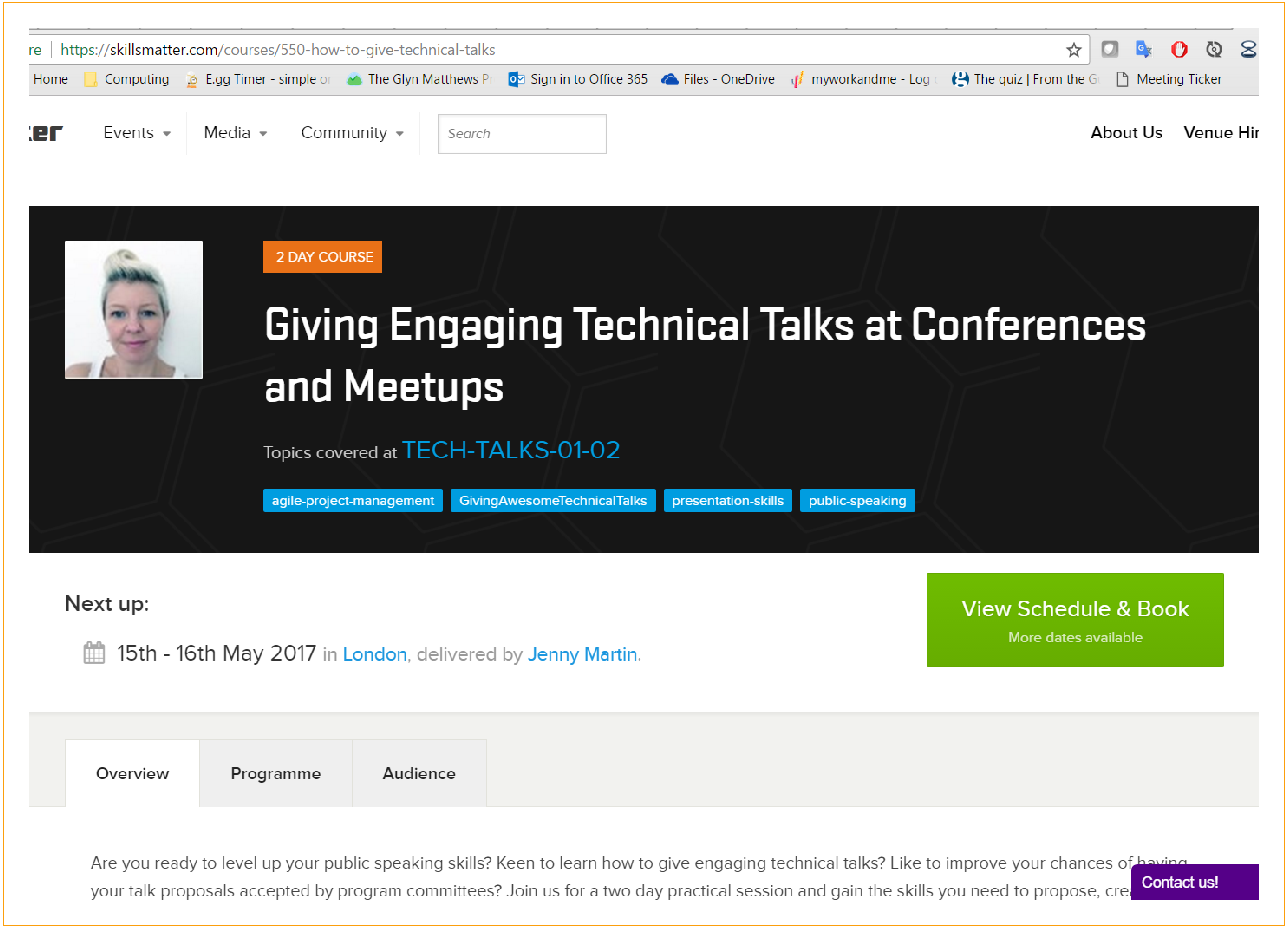

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