This is why we can('t) have nice things

Timo van der Kuil

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Meeting C++

Who am I

- Student
- Student assistant
- Research intern

- Saxion University of Applied Sciences

Disclaimer

- First talk at a conference
  - Feedback
- Opinions are my own

Outline

- Weird things
- Origins
- Design and philosophy
- Flexibility
- Weird things explained

Weird things in C++

Initialization

Initialization

```
int a;                // a is not initialized, only declared

int a{};              // a is initialized with 0

std::array<int, 100> array;
                      // array is not initialized, only declared


std::array<int, 100> array{};
                      // array is initialized with 0’s
```

Unspecified behaviour

```
int a() { return std::puts("a"); }
int b() { return std::puts("b"); }
int c() { return std::puts("c"); }
void f(int, int, int) {}

int main() {
    f(a(), b(), c());
}
```

```
a b c?
c b a?
```

More unspecified behaviour

```
int a() { return std::puts("a"); }
int b() { return std::puts("b"); }
int c() { return std::puts("c"); }
```

```
int main() {
    return a() + b() + c();
}
```

```
a b c?
c b a?
```

void

```
void f0(int i) { }                 // Void as return type -> no return

int f1(void) { return 1; }         // Void as parameter -> no parameters

int f2(void* i) {
    return *static_cast<int*>(i);      // Void* as parameter ->
}                                      // pointer to anything


(void) some_unused_var             // Void as cast -> cast to nothing
```

mutable lambdas

```
int i = 2;

auto ok = [&i](){ ++i; };                   // i captured by reference

auto err = [i](){ ++i; };                   // increment of read-only variable 'i'

auto err2 = [x{22}](){ ++x; };              // increment of read-only variable 'x'

auto ok2 = [i, x{22}]() mutable { ++i; ++x; };  // Using mutable keyword
```

future.h

```
std::async(std::launch::async,[]{
    std::this_thread::sleep_for(std::chrono::seconds(2));
    std::cout << "first thread" << '\n';
});

std::async(std::launch::async,[]{
    std::this_thread::sleep_for(std::chrono::seconds(1));
    std::cout << "second thread" << '\n';
});

std::cout << "main thread" << '\n';
```

```
first thread
second thread
main thread
```

Type punning through `unions`

```
union Pun {
    int x;
    unsigned char c[sizeof(int)];
};

void bad(Pun& u)
{
    u.x = 'x’;
    std::cout << u.c[0] << '\n';      // undefined behaviour
}
```

Origins of C++

- A brief history -

Idea for a suitable tool

- Best of both worlds
- Simula
  - Classes
  - Hierarchies
  - Concurrency
  - Static type checking
- BCPL
  - Efficiency
  - Combining compiled programs
- Portable implementation

C with classes

Issue that called for a new tool

↓

Cpre

↓

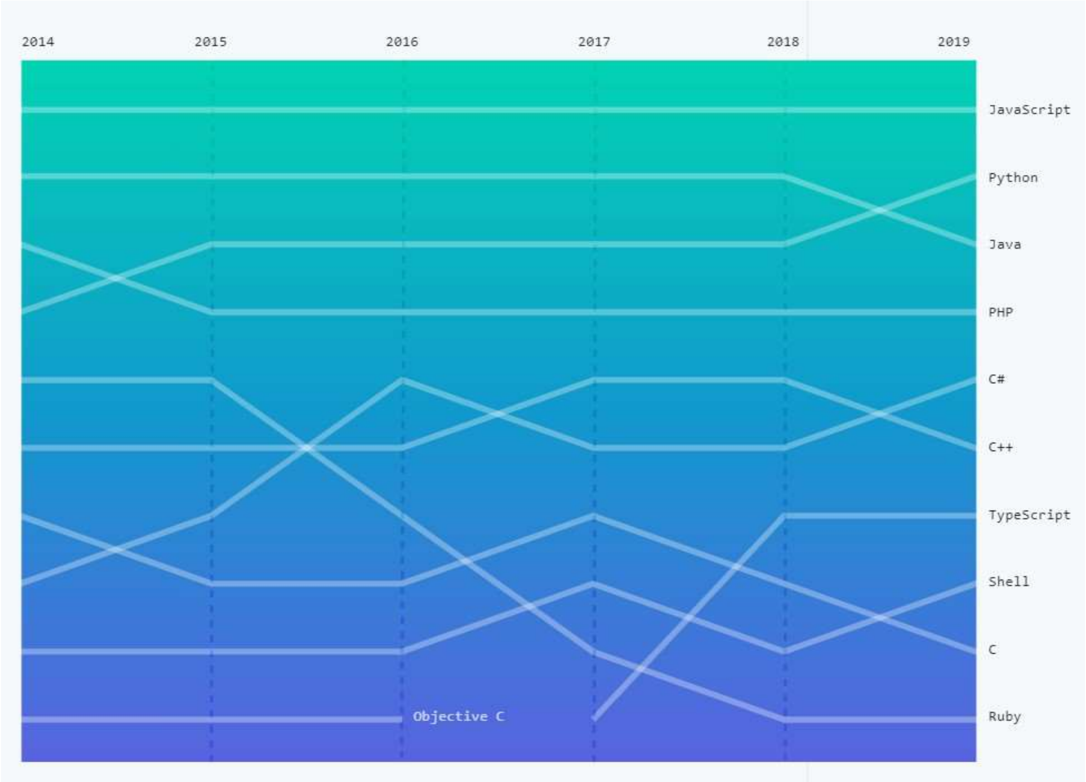
C with classes

From C with classes to C++

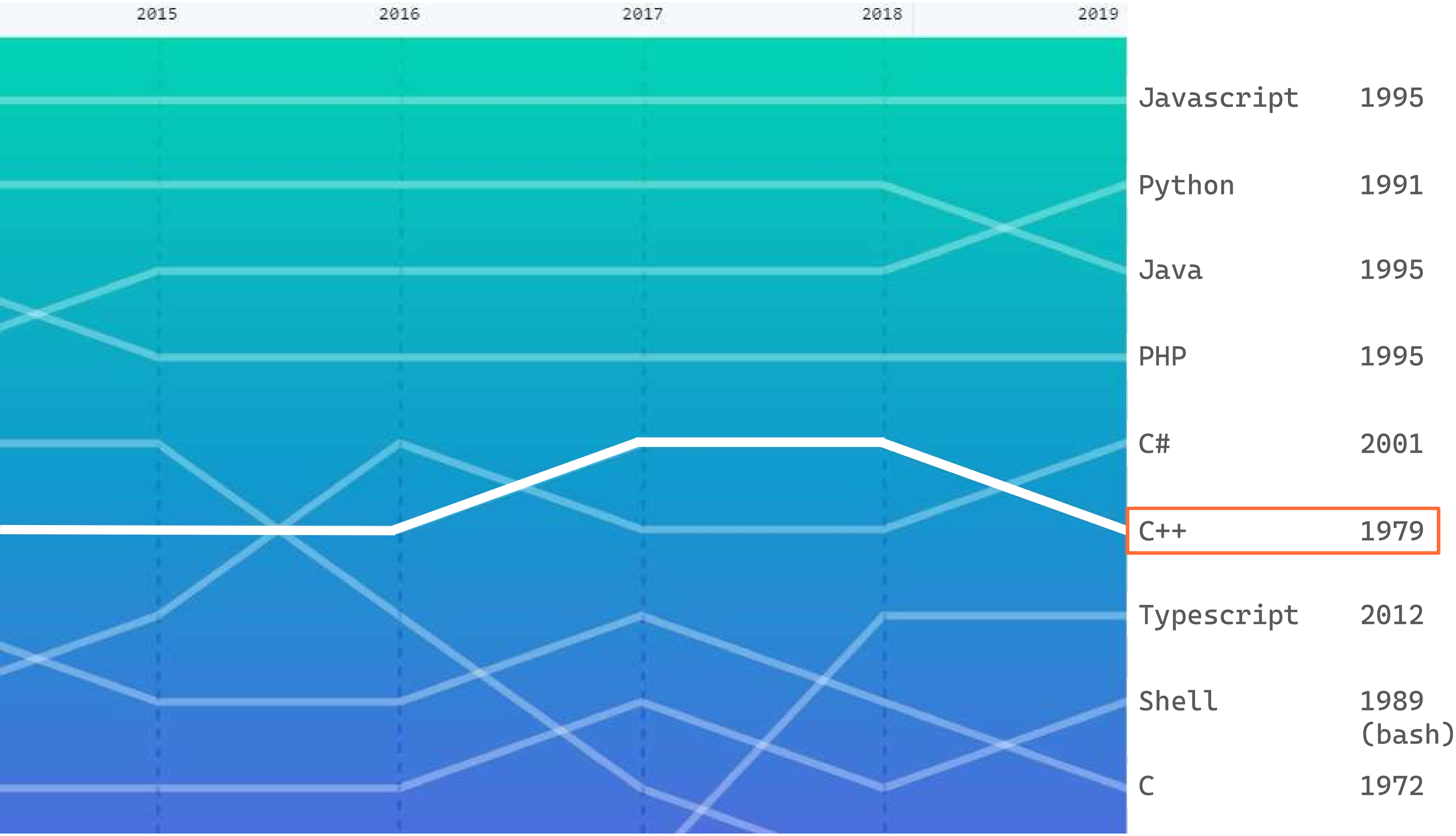
- C with classes was a medium success
- Paid for itself and developer
- Not for support and development

- Two choices:
  1. Stop supporting the language to be able to do something else
  2. Develop a new language that appeals to a larger audience to pay for its support and further development

Usage of C++



(github.com, 2019)


2015
2016
2017
2018
2019
Javascript 1995
Python 1991
Java 1995
PHP 1995
C# 2001
C++ 1979
Typescript 2012
Shell 1989 (bash)
C 1972

"C is clearly not the cleanest language ever designed nor the easiest to use, so why do so many people use it?"

\- Bjarne Stroustrup, 1987

Why C?

- C is flexible
  - Almost every application
- C is efficient
  - C is low level, relatively easy to make the most out of resources
- C is available
  - There is a compiler for pretty much every platform
- C is portable
  - Porting from OS to OS is typically feasible, but not trivial

Design and philosophy of C++

Aims of C++

- Make programming more enjoyable
- General purpose programming language that
  - Is a better C
  - Supports data abstraction
  - Supports object-oriented programming

Development rules of C++

1. Evolution must be driven by real problems
2. Don’t get involved in a sterile quest for perfection
3. Must be useful now
4. Every feature must have a reasonably obvious implementation
5. Always provide a transition path
6. It’s a language, not a system
7. Provide comprehensive support for each supported style
8. Don’t try to force people

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Flexibility

Type system

- Strongly and statically typed
- Type specifiers -> Compile time checking
- Fundamental types
  - **`char`**, **`double`**, **`int`**
- Compound types
  - 'Defined in terms of another type'
- Every type is treated equally
- The C++ Type System is your Friend by Hubert Matthews

Type system

```
class Date{                                // Ambiguous: d/m/y y/m/d m/d/y?
    Date(int, int, int) {};                // -> bug at runtime
};

class Year {};
class Month {};
class Day {};

class Date{                                // Umambiguous: y/m/d
    Date(Year, Month, Day) {};             // -> bug at compile time
};
```

Memory model

- 'The Memory Model' by Rainer Grimm

- First only sequential execution -> no need for memory model
- C++11 multi-threading
- Race conditions
  - Every thread has r/w to memory
- 6 memory orders
  - `std::atomic`

Memory model

- `memory_order_seq_cst` -> Default, strict
- `memory_order_acq_rel` -> No reordering before and after
- `memory_order_acquire` -> No reordering before
- `memory_order_release` -> No reordering after
- `memory_order_consume` -> No reordering before and after (of this atomic)
- `memory_order_relaxed` -> Weak

- Less rules -> more optimization
- Up to the programmer

Why things are weird in C++

Initialization

```
int a;               // a is not initialized, only declared

int a{};             // a is initialized with 0

std::array<int, 100> array;
                     // array is not initialized, only declared


std::array<int, 100> array{};
                     // array is initialized with 0’s
```

Initialization

- Inherited from C
- Initialization can lead to performance hits
  - Mostly on older systems
- **`std::array`** -> implicit, default, trivial constructor (POD)
  - Empty ctor but value initialized with **`{}`** or **`()`**
  - Wrapper for C-style **`array`**
- MSVC debug vs. release mode
- 'Initialization in C++' by Timur Doumler
- 'The nightmare of initialization in C++' by Nicolai Josuttis

Unspecified behaviour

```
int a() { return std::puts("a"); }
int b() { return std::puts("b"); }
int c() { return std::puts("c"); }
void f(int, int, int) {}

int main() {
    f(a(), b(), c());
}
```

```
a b c?
c b a?
```

More unspecified behaviour

```cpp
int a() { return std::puts("a"); }
int b() { return std::puts("b"); }
int c() { return std::puts("c"); }
```

```cpp
int main() {
    return a() + b() + c();
}
```

```
a b c?
c b a?
```

Unspecified behaviour

- Not specified in ISO standard
- Comma is not a sequence point
- Mistakes can easily be avoided
  - Warnings
- Don’t force compilers

```
f(a(), b(), c());
```

void

```
void f0(int i) { }               // Void as return type -> no return

int f1(void) { return 1; }       // Void as parameter -> no parameters

int f2(void* i) {
    return *static_cast<int*>(i);    // Void* as parameter ->
}                                    // pointer to anything


(void) some_unused_var           // Void as cast -> cast to nothing
```

`void`

- Inherited from C
- Used for polymorphism in C
- C++ has templates, **`std::optional`**, **`std::variant`**
- Certain platforms still need **`void*`**; limited access to header

void

```
C:
    f()     -> Any amount of arguments (marked obsolescent)
    f(void) -> No arguments

C++:
    f()     -> No arguments
    f(void) -> No arguments
```

mutable lambdas

```
int i = 2;

auto ok = [&i](){ ++i; };                    // i captured by reference

auto err = [i](){ ++i; };                    // increment of read-only variable 'i'

auto err2 = [x{22}](){ ++x; };               // increment of read-only variable 'x'

auto ok2 = [i, x{22}]() mutable { ++i; ++x; };   // Using mutable keyword
```

`mutable` lambdas

- Unnamed **`class`**
- **`::operator()`** is implicitly defined **`const`**
  - UNLESS **`mutable`** is used
- Member variables
- Prevent unwanted mutation of lambdas

mutable lambdas

```
int x{5};
int y{};

auto lambda = [x]() mutable {return x++ + 5; };

y = lambda();
std::cout << y << ’,’ << x << '\n';

x = 20;
y = lambda();
std::cout << y << ’,’ << x << '\n';
```

`mutable` lambdas

```cpp
auto lambda = [x]() mutable {return x++ + 5; };
```

```cpp
struct UnnamedType {
    // Member variable that stores captured val
    int x;
    // Ctor initializes x with captured val (5)
    UnnamedType(int x) : x{x} {}
    // operator() executes the passed statements
    int operator() () { return x++ + 5; }
};
```

mutable lambdas

```
auto lambda = [x]() mutable {return x++ + 5; };
```

```
struct UnnamedType {
    // Member variable that stores captured val
    const int x;
    // Ctor initializes x with captured val (5)
    UnnamedType(int x) : x{x} {}
    // operator() executes the passed statements
    int operator() () const { return x++ + 5; }
};
```

`mutable` lambdas

```
int x{5};
int y{};

auto lambda = [x]() mutable {return x++ + 5; };

y = lambda();
std::cout << y << ’,’ << x << '\n';      //outputs 10,5

x = 20;
y = lambda();
std::cout << y << ’,’ << x << '\n';      //outputs 11,20
```

`mutable` lambdas

- Only two ways to capture -> explicit choice by the programmer
  - Copy-by-value `[=, val]`
  - Reference `[&, &val]`

```cpp
auto lambda = [x]() {return x++ + 5; };

auto lambda = [x]() const {return x + 5; };
```

- N3424: Lambda Correctness and Usability Issues by Herb Sutter

future.h

```
std::async(std::launch::async,[]{
    std::this_thread::sleep_for(std::chrono::seconds(2));
    std::cout << "first thread" << '\n';
});

std::async(std::launch::async,[]{
    std::this_thread::sleep_for(std::chrono::seconds(1));
    std::cout << "second thread" << '\n';
});

std::cout << "main thread" << '\n';
```

```
first thread
second thread
main thread
```

future.h

```
auto first = std::async(std::launch::async,[]{
    std::this_thread::sleep_for(std::chrono::seconds(2));
    std::cout << "first thread" << '\n';
});

auto second = std::async(std::launch::async,[]{
    std::this_thread::sleep_for(std::chrono::seconds(1));
    std::cout << "second thread" << '\n';
});

std::cout << "main thread" << '\n';
```

```
main thread
second thread
first thread
```

future.h

- N2802: A plea to reconsider detach-on-destruction for thread objects by Hans Boehm
- N3630: async, ~future, and ~thread (Revision 1) by Herb Sutter
- N3636: ~thread Should Join by Herb Sutter
- N3637: async and ~future (Revision 3) by Herb Sutter, Chandler Carruth, Niklas Gustafsson
- N3679: Async() future destructors must wait by Hans Boehm
- N3773: async and ~future (Revision 4) by Herb Sutter, Chandler Carruth, Niklas Gustafsson
- N3776: Wording for ~future by Herb Sutter
- N3777: Wording for deprecating async by Herb Sutter

future.h

- One proposal to save us all
- Initially C++20, now C++23 or even C++26
  - Relies on executors

- P1054r0: A Unified Futures Proposal For C++ by Lee Howes, Bryce Adelstein Lelbach, David S. Hollman and Michal Dominiak

Type punning through `unions`

```
union Pun {
    int x;
    unsigned char c[sizeof(int)];
};

void bad(Pun& u)
{
    u.x = 'x’;
    std::cout << u.c[0] << '\n';      // undefined behaviour
}
```

Type punning through `unions`

- Popular in C; no alternative
- Used on systems with limited capacity
- (mis)Used for type punning
- C++ has **`static_cast<>()`**
- **`std::byte`** with **`static_cast<char>()`**

```
std::vector<std::byte> i_buffer;
i_buffer.push_back(std::byte(0b01000011));

std::cout << static_cast<char>(i_buffer[0]) << '\n';
```

Closing thoughts

Many ways to do the same

Hard to learn

Hard to teach

Versatile

Fun

This is why we can('t) have nice things

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