XILINX

C++20

C++ ready for Python programmers?

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ACM Turing award 2017: John L. Hennessy & David A. Patterson

A New Golden Age for Computer Architecture

John L. Hennessy, David A. Patterson, Communications of the ACM, February 2019, Vol. 62 No. 2, Pages 48-60

`https://cacm.acm.org/magazines/2019/2/234352-a-new-golden-age-for-computer-architecture/fulltext`

Award lecture: `https://www.youtube.com/watch?v=3LVeEjsn8Ts`

- *"Those who cannot remember the past are condemned to repeat it"*, George Santayana, 1905
- *"What we have before us are some breathtaking opportunities disguised as insoluble problems"*, John Gardner, 1965
- ⇝ Agile Hardware & Software Development
  - Open Architectures, inspired by the success of open source software

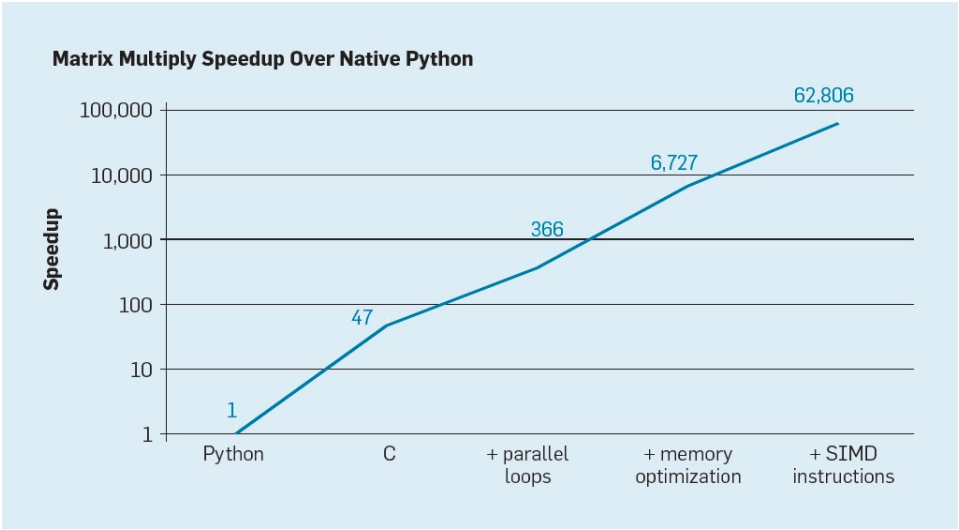
"The next decade will see a Cambrian explosion of novel computer architectures, meaning exciting times for computer architects in academia and in industry."

All Programmable [with hardware mind set]

Programming style

- Anything resolves to writing 0 and 1 in (configuration) memory
  - Great unification achieved !
  - Well done !
  - Problem solved !
- Actually done by Eckert, Mauchly and Von Neumann around 1944-1950... ☺

Huge programming dilemma: there's plenty of room at the top!



Charles E. Leiserson, Neil C. Thompson, Joel S. Emer, Bradley C. Kuszmaul, Butler W. Lampson, Daniel Sanchez, and Tao B. Schardl, "*There's plenty of room at the top: What will drive growth in computer performance after Moore's Law ends?*" unpublished manuscript submitted for publication, 2019.

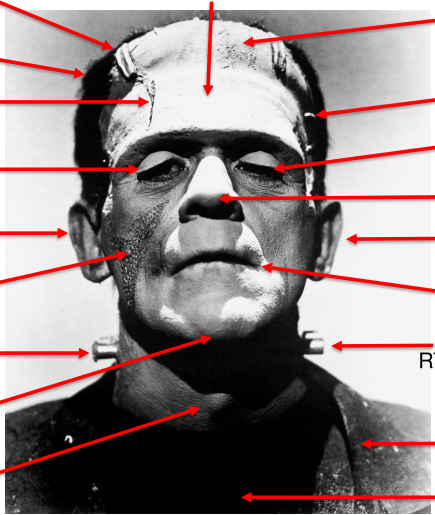
The programmer's dilemma

- Ubiquitous programming
  - Productivity & glue languages
    - Python
    - TCL
    - Perl
    - AWK
    - Shell
- Resource and performance optimization
  - Optimization/infrastructure/library/... languages
    - Assembly
    - VHDL
    - Verilog
    - C
    - C++

Real applications

- Any big enough application involves both productivity & optimization
- No one-size-fits-all language ☹
  - Involve different languages & different programming styles
- Lucky users can use scripting languages leveraging optimized libraries written with optimization languages
  - PYNQ
  - Machine Learning
  - ...
- Annoying to spend time switching languages
- Would be nice to have C++ experience less painful and with broader application domain...

Heterogeneous computing [software ~~mind set~~ nightmare]



Remember C++ ?

2-line description by Bjarne Stroustrup

- Direct mapping to hardware
- Zero-overhead abstraction

But why C++?

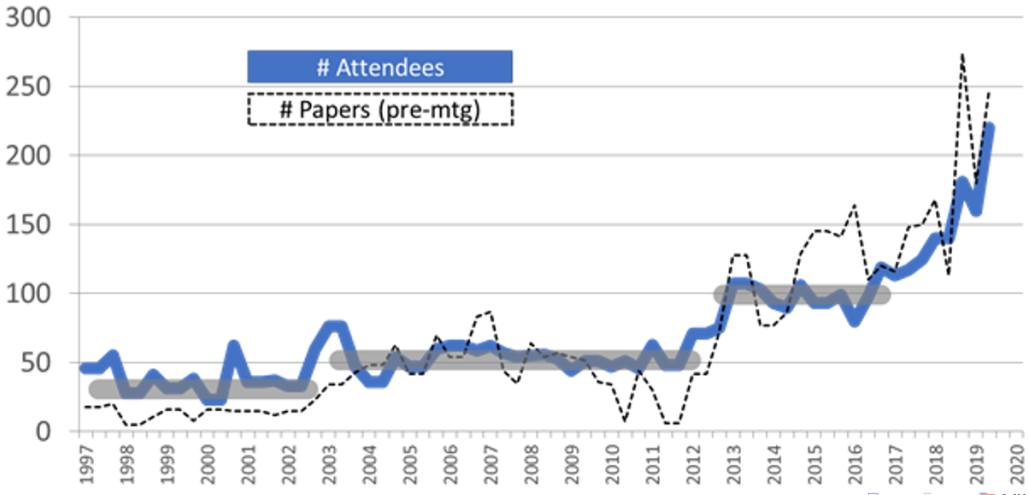
- Very successful & ubiquitous language
  - Millions of programmers
  - Billions of users: any use of cars, IoT, IT, smartphone, Internet... depend on C/C++
- Interoperability: seamless interaction with embedded world, libraries, OS, C...

⇝ Unique existing position in embedded system to control the full stack!!!

- Full-stack: combine both low-level aspects with high-level programming, multi-paradigm
  - Pay only for what you need
- Open-source production-grade compilers (GCC & Clang/LLVM) & tools
  - Implemented before specification
    - ... because it is too complex to do otherwise!!!
- Generic programming + classes can be used to define Domain Specific Embedded Language (DSEL)
  - Not directly targeting heterogeneous computing...
  - But extensible through classes (⇝ DSEL)
  - Xilinx AIE Vitis ADF framework
- Also extensible with #pragma and attributes (already in Xilinx Vitis for FPGA & AIE)

¿ And what about modern C++ ?

ISO C++ committee proposal papers & attendance



1 C++ version/3 years ⇝ Parallelizing C++ committee itself!

- Language rebooted in 2011
  - ⇝ Larger attraction & interest
- Is there any precedent of programming language developed cooperatively by of 200+ people democracy? ☺
- ⇝ Use... parallelism ! ☺ `https://isocpp.org/std/the-committee`
  - Generic working groups
    - Core Working Group. Library Working Group, Evolution Working Group, Library Evolution Working Group
  - Specialized Study Groups
    - SG1, Concurrency: Olivier Giroux (Nvidia). Concurrency, parallelism, SIMD, memory model... SYCL is a candidate here!
    - SG6, Numerics: Lisa Lippincott (Tanium). Numerics topics, fixed point, decimal floating point, fractions, arbitrary precision...
    - SG7, Compile-time programming: Hana Dusíková (Avast). Compile-time reflection & programming
    - SG14, Game Development & Low Latency: Michael Wong (Codeplay). Embedded systems, heterogeneous computing
    - SG19, Machine Learning Michael Wong (Codeplay). Better support for array, matrix, linear algebra...
    - SG20, Education: JC van Winkel (Google). Produce guidance for modern course materials for C++ education
- Production of Technical Specifications before standardization
  - Implemented in several compilers
  - Allow experiments in the fields
  - Provide feedback to the ISO C++ Committee

Make C++ more complex to make it. . . simpler!

- Modern C++ quite simpler to use
- But still compatible with old C++ & C
  - Globally more complex for. . . implementers!
- Keep **end-user only focused on simpler modern features**
- ISO C++ committee working on **C++ Core Guidelines**
  - `http://isocpp.github.io/CppCoreGuidelines/CppCoreGuidelines`
- Subliminal messages
  - Learn modern C++. . . and teach students or customers! ☺
  - Forget about what you know from old C/C++ ☺

Modern Python/C/Modern C++/Old C++

- Python 3.8

```
v = [ 1, 2, 3, 5, 7 ]
for e in v:
  print(e)
```

- C99 (also usable in C++)

```
int a[] = { 1, 2, 3, 5, 7 };
for (int i = 0;
     i < sizeof(a)/sizeof(a[0]);
     ++i)
  printf("%d ", a[i]);
```

- C++20

```
std::vector v { 1, 2, 3, 5, 7 };
for (auto e : v)
  std::cout << e << std::endl;
```

- C++03

```
std::vector<int> v;
v.push_back(1);
v.push_back(2);
v.push_back(3);
v.push_back(5);
v.push_back(7);
for (std::vector<int>::iterator i =
       v.begin(); i != v.end(); ++i)
  std::cout << *i << std::endl;
```

C++ `auto` because my laziness deserves it!

- Python

```
x = 123
s = "hello"
```

- C++ `auto` (and some user-defined literals)

```
auto x = 123;
auto s = "hello"; // C string
using namespace std::literals; // User-defined literals super-power
auto constexpr a_std_string = "hello"s; // C++20
auto& an_alias_to_x = x;
auto size = 0b1001; // C++14
auto big_num = 18'446'744'073'709'550'592llu; // C++14
auto d = 3h + 10min + 5ns;
auto const newYearsEve = 31d/December/2019; // C++20
```

- Also useful for Voldemort types (cannot be directly named...)
  - Returning some locally defined types `auto f () { struct S { int i; }; return S { 42 }; }`
  - Lambdas have anonymous types

Back to Python...

⇝ Modern C++ : like Python but with speed and type safety

- Python 3.x (interpreted):

```
def add(x, y): return x + y
print(add(2, 3))      # 5
print(add("2", "3")) # 23
print(add(2, "Boom")) # Fails at run-time :-(
```

- Same in C++20 but compiled + static compile-time type-checking:

```
auto add(auto x, auto y) { return x + y; }
std::cout << add(2, 3) << std::endl;         // 5
std::cout << add("2"s, "3"s) << std::endl; // 23
std::cout << add(2, "Boom"s) << std::endl; // ¡¡¡ Does not compile !!! :-)
```

Without using templated code! `template <typename>` ☺

https://godbolt.org/z/8E8o779cj

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Without using templated code! ~~`template <typename>`~~ ☺

`https://godbolt.org/z/8E8o779cj`

[] (){} C++ lambda emoji for functional programming

- Python feature

```python
def f():
  c = 10
  # Capture of c inside the lambda
  return lambda x : x + c

l = f()
print (l(1), f()(20)) # 11 30
```

- C++14 generic lambda (function object)

```cpp
#include <iostream>
auto f() {
  auto c = 10;
  // = to capture c by copy
  return [=] (auto x) { return x + c; };
}
int main() {
  auto l = f();
  std::cout << l(1) << ' ' << f()(20) << std::endl; // 11 30
}
```

  - `https://godbolt.org/z/MxZpPk`
    - Look at CppInsights in link above to understand the syntactic sugar
  - More features with C++17 & C++20...

Generic variadic lambdas & operator interpolation

```
#include <iostream>
#include <string>
using namespace std::string_literals;
// Define an adder on anything.
// Use new C++20 generic function syntax based on "concepts"
auto add(auto... args) {
  // Use new C++17 operator folding syntax (here from left)
  return (... + args);
}

int main() {
 std::cout << "The result is: " << add(1, 2, 3) << std::endl;
 std::cout << "The result is: " << add("begin"s, "end"s) << std::endl;
}
```

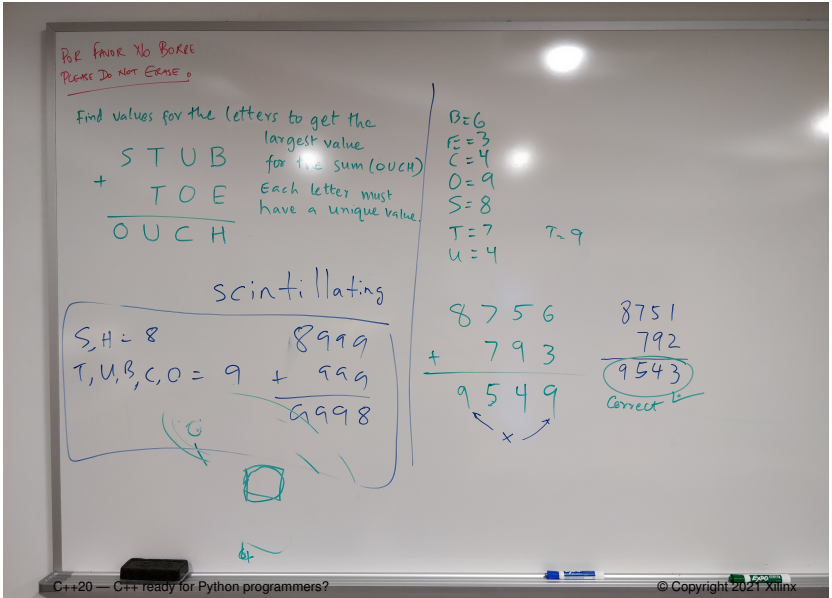
Without using templated code! ~~`template <typename>`~~ ☺
Try this example on `https://wandbox.org/permlink/LambcvLqmyaSV4JL`

Algorithms

- High-level generic algorithms (sort, map-reduce...)
- 0-cost abstraction (templated header library)
  - Efficient implementations
  - Avoid unclear raw loops and spaghetti coding
- C++20 provides vector (SIMD) & parallel execution policies
- C++20 adds bit manipulation (`std::rotl`, `std::popcount`, `std::endian`...)

`https://en.cppreference.com/w/cpp/algorithm`
`https://en.cppreference.com/w/cpp/numeric`

Real “typical” problem in XSJ B4F2 (Mont-)Blanc Area



Solution in 20 lines & 14ms later on my laptop... *(I)*

```cpp
#include <algorithm>
#include <iostream>
#include <numeric>

// Convert digits into base-10 number
auto base_10_value(auto... digits) {
  std::array a { digits... };
  return std::accumulate(a.cbegin(), a.cend(), 0,
                         [] (auto sum, auto x) { return sum*10 + x; });
}

int main() {
  std::array<int, 10> digits;
  std::iota(digits.begin(), digits.end(), 0);
  auto & [ B, C, E, H, O, S, T, U, _8, _9 ] = digits;
  decltype(digits)::value_type max = 0;
  do {
    auto a = base_10_value(S, T, U, B);
    auto b = base_10_value(T, O, E);
    auto r = base_10_value(O, U, C, H);
    if (a + b == r && r > max)
      max = r;
  } while (std::next_permutation(digits.begin(), digits.end()));
  std::cout << max << std::endl;
}
```

- https://godbolt.org/z/bGKzErvn9
- make CXX=clang++-14 CXXFLAGS="-O3 -std=c++20" quizz

Solution in 20 lines & 14ms later on my laptop... *(II)*

- Performance

```
perf stat ./quizz
9543
 Performance counter stats for './quizz':
            13.92 msec task-clock                #    0.975 CPUs utilized
                0      context-switches          #    0.000 K/sec
                0      cpu-migrations            #    0.000 K/sec
              151      page-faults               #    0.011 M/sec
       57,569,643      cycles                    #    4.136 GHz
      201,480,179      instructions              #    3.50  insn per cycle
       21,921,589      branches                  # 1575.039 M/sec
           53,233      branch-misses             #    0.24% of all branches
      0.014268630 seconds time elapsed
      0.014308000 seconds user
      0.000000000 seconds sys
```

- 10! = 3628800 iterations $\rightsquigarrow \frac{57{,}569{,}643}{10!} \approx 15.86$ cycles/iteration (including I/O)

Solution in 20 lines & 14ms later on my laptop... *(III)*

- Clean solution
  - No raw loop
    - Rely on standard algorithms from the STL
  - Generic programming without `template` keyword
  - No explicit memory allocation/deallocation
  - No pointer-based spaghetti code
  - Spoiler alert: C++20 & C++23 ranges will provide shorter solution...
    - digits .begin(), digits .end() ⇝ digits

Most vexing parse in C++

- Old C++03 syntax based on constructor calls

```
std::string s("hello world!");
```

- I personally find this unclear when browsing code (for my heavy C background...)
  - It looks like a normal function call...
  - but this is a variable declaration!
- https://en.wikipedia.org/wiki/Most_vexing_parse

```
struct Timer { };
struct TimeKeeper {
  TimeKeeper(const Timer& t) {}
  int get_time() { return 0; }
};
int main() {
  TimeKeeper tk(Timer()); // what is tk?
  return tk.get_time();
}
```

https://godbolt.org/z/SZnkE7

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}
```

https://godbolt.org/z/SZnkE7

- Function declaration for a function `tk` that returns an object of type `TimeKeeper` and has a single (unnamed) parameter that is a pointer to function returning an object of type `Timer` (and taking no input)

Uniform initialization and list initialization since C++11

- https://en.cppreference.com/w/cpp/language/list_initialization

```
struct Timer { };
struct TimeKeeper {
  TimeKeeper(const Timer& t) {}
  int get_time() { return 0; }
};
int main() {
  // tk is a TimeKeeper initialized from a default Timer
  TimeKeeper tk { Timer {} };
  return tk.get_time();
}
```

https://godbolt.org/z/szyBPT

- Prefer { and } when possible and keep (and) for explicit constructor calls

```
std::vector<int> v1 { 2, 3, 4 }; // Vector with elements 2, 3, 4
std::vector<int> v2 { 2 }; // Vector with element 2
std::vector<int> v3(2); // Vector with elements 0, 0
std::vector<int> v3(3, 42); // Vector with elements 42, 42, 42
```

Extended with designated initializer with C++20

https://en.cppreference.com/w/cpp/language/aggregate_initialization

```
// Before C++20, like in C
struct A { int x; int y; int z; };
A b { .x = 1, .z = 2 }; // b.y initialized to 0
// Since C++20, combining with default values
struct B {
  string a;
  int b = 42;
  int c = -1;
};
A { .c = 21 }; // Initializes a with {} (default constructor), then
               // initializes b with = 42, then initializes c with = 21
```

Named parameters (using designated initializer in C++)

- Cool Python feature

```python
def print_point(x = 3, y = 42):
  print(x, y)
print_point()             # 3 42
print_point(1, 2)         # 1 2
print_point(x = 7)        # 7 42
print_point(y = 8)        # 3 8
print_point(x = 7, y = 8) # 7 8
```

- https://brevzin.github.io/c++/2019/12/02/named-arguments (Barry Revzin)

```cpp
#include <iostream>
struct point {
  int x = 3;
  int y = 42;
};
void print_point(point p = {}) { std::cout << p.x << ' ' << p.y << std::endl; }
int main() {
  print_point();                    // 3 42
  print_point({ 1, 2 });            // 1 2
  print_point({ .x = 7 });          // 7 42
  print_point({ .y = 8 });          // 3 8
  print_point({ .x = 7, .y = 8 }); // 7 8
}
```

https://godbolt.org/z/FfE8pn

  - In C++20, it works also for template parameters... ☺

Tuple (product type)

- “Product type” in algebraic types (computer science jargon)
- Python tuple: immutable heterogeneous sequence

```python
def t():
  return (1, 5.6, "hello")

tup = t()
print (tup[0], tup[1], tup[2]) # 1 5.6 hello
```

- Useful to lazily gather data (passing arguments, returning several values at once)
- C++11 provides `std:tuple` https://en.cppreference.com/w/cpp/utility/tuple and `std:pair` https://en.cppreference.com/w/cpp/utility/pair

```cpp
#include <iostream>
#include <tuple>
auto t() {
  return std::tuple { 1, 5.6, "hello" };
}
int main() {
  auto tup = t();
  std::cout << std::get<0>(tup) << ' ' << std::get<1>(tup) << ' '
            << std::get<2>(tup) << std::endl;
}
```

https://godbolt.org/z/A4jB5G

- Both Python & C++ syntax would be cumbersome if there was no...

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            << std::get<2>(tup) << std::endl;
}
```

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- Both Python & C++ syntax would be cumbersome if there was no...

Structured binding

- Python tuple unpacking

```python
def t():
  return (1, 5.6, "hello")

i, f, s = t()
print (i, f, s) # 1 5.6 hello
```

- C++

```cpp
#include <iostream>
#include <tuple>
auto t() {
  return std::tuple { 1, 5.6, "hello" };
}
int main() {
  auto [i, f, s] = t(); // C++17, works also with structures and arrays
  std::cout << i << ' ' << f << ' ' << s << std::endl; // 1 5.6 hello
  // Old C++11 way
  int ii; float ff; const char *ss; // Need to declare first
  std::tie(ii, ff, ss) = t();
  std::cout << ii << ' ' << ff << ' ' << ss << std::endl; // 1 5.6 hello
}
```

https://godbolt.org/z/wGYuU_

Sum type (algebraic type) `std::variant`

- Python is very dynamic and agile (and slow): native sum type!

```
v = 1
v = 5.6
v = "hello"
```

Use dynamic typing, dynamic allocation and garbage collection...

- C++: *only pay for what you need*

`https://en.cppreference.com/w/cpp/utility/variant`

```
#include <iostream>
#include <variant>
int main() {
  std::variant<int, double, char> v; // C++17: declare allowed types ahead of time
  v = 1;
  std::cout << std::get<int>(v) << std::endl; // 1
  v = 5.6;
  std::cout << std::get<double>(v) << std::endl; // 5.6
  std::cout << std::get<char>(v) << std::endl; // Throw 'std::bad_variant_access'
}
```

`https://godbolt.org/z/WXiGjE`

- Replace typically C structure + tag in a nicer/safer way
- Does not use dynamic allocation

Wilder C++ sum type with `std::any`

- Closer to Python variable
- C++: *only pay for what you need*
  - Can hold any type, not only among predefined ones
  - More expensive: add dynamic allocation & RTTI for not declaring allowed type ahead
    - `https://en.wikipedia.org/wiki/Run-time_type_information`

`https://en.cppreference.com/w/cpp/utility/any`

```
#include <any>
#include <iostream>
int main() {
  std::any v; // C++17
  v = 1;
  std::cout << std::any_cast<int>(v) << std::endl; // 1
  v = 5.6;
  std::cout << std::any_cast<double>(v) << std::endl; // 5.6
  std::cout << std::any_cast<char>(v) << std::endl; // Throw 'std::bad_variant_access'
}
```

`https://godbolt.org/z/e6Z53v`

- Still no need for garbage collector ☺

Dealing with optionality

- Python provides `None`

```
def compute():
  if no_error:
    return 42
  else:
    return None
v = compute()
if v is not None:
  print(v) # Process v...
```

- C++17 introduced `std::optional` https://en.cppreference.com/w/cpp/utility/optional

```
#include <iostream>
#include <optional>

std::optional<int> compute() {
  if (no_error)
    return 42;
  return {};
}
int main() {
  auto v = compute();
  // v is a std::optional<int>, not an int...
  if (v)
    std::cout << *v << std::endl;
}
```

- Recurring examples in Xilinx code base

```
T * p == nullptr;
p = new T; // or malloc()
if (p)
  // OK, we have a thing, work on it...
if (p)
  delete p; // or free()
```

  - Spaghetti code, unsafe, memory leaks, no exception safety... ☹

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Text formatting

- Python `https://docs.python.org/3/library/string.html?highlight=format`

```
print ("Hello {} {}!\n".format("world", 42)) # Hello world 42!
```

- C++20

```
#include <iostream>
#include <format>
int main() {
    std::cout << std::format("Hello {} {}!\n", "world", 42);
} // Hello world 42!
```

  - `https://en.cppreference.com/w/cpp/utility/format/format`
  - Reuse the format specification in Python!!! ☺

Move semantics

- Python use references and garbage collector

```python
SIZE = 1 << 26
def vector_inc(x):
  result = [0] * len(x)
  for i in range(len(x)):
    result[i] = x[i] + 1
  return result
x = [0] * SIZE
v = vector_inc(x)
print (v[0])
```

- C++03 (& C style)

```cpp
#include <iostream>
#include <vector>
std::size_t constexpr size = 1 << 29;
void vector_inc(std::vector<int> &result,
                const std::vector<int> &x) {
  result.resize(x.size());
  for (std::size_t i = 0; i < x.size(); ++i)
    result[i] = x[i] + 1;
}
int main() {
  std::vector<int> x(size);
  std::vector<int> v;
  vector_inc(v, x);
  std::cout << v[0] << std::endl;
}
```

- C++17 with move semantics & copy elision

```cpp
#include <iostream>
#include <vector>
std::size_t constexpr size = 1 << 29;
std::vector<int> vector_inc(const std::vector<int> &x) {
  std::vector<int> result(x.size());
  for (std::size_t i = 0; i < x.size(); ++i)
    result[i] = x[i] + 1;
  // Use Named Return Value Optimization or "move" constructor
  return result;
}
int main() {
  std::vector<int> x(size);
  // v (re)use dynamic storage of result: no copy
  std::vector<int> v = vector_inc(x);
  std::cout << v[0] << std::endl;
}
```

Ranges in C++

- Python `https://docs.python.org/3/howto/functional.html`
- One of the most exciting features of C++20
  - Yet another completely new programming style!
  - Functional programming and composability

Xilinx HR tooling problem

- Xilinx hiring managers have to use Taleo to handle candidates
- Does not work correctly when more than 50 candidates
  - Not possible to extract résumés
- But HR people can use Talemetry to extract candidate list with 1 URL for each résumé
  - ⇝ A lot of mouse clicks per candidate... ☹
- Need a tool to fetch all the résumés on my computer
- Obvious use case for Python...

CSV HP dump

```
First Name,Last Name,Email,Home Phone,City,State,Country,Profile Url
Xzwla,Nhrnmfknb,fahgpkywe.yiblv@pxreq.lcq,+9 (738) 390 0177,Vbx Xbmcmpd,KZ,EY,hcfds://bkvje.lakfqphiu.bbb/fgimbfbz/628c8169-433y-00vk-17c8-3s0ce15624rt
Osufn,Pkagalvm,mmngxqkf48@tyulr.dvv,+3 (564) 991 6254,Yhgoems,MC,VU,mlept://gndqd.fxrqmzzzd.lsu/wwznukkf/16277617-922r-02cw-289s-4g6092be1b2n
Uwrozxb,Fapveghhu,eazlrczu4944@anqwy.equ,+2 (177) 489 7972,Kgu Zkzf,IV,HG,pztff://mwzin.qhnuzrwpj.iil/fojrckdw/llxat3pp-1158-561y-jb75-413vz4400188
Gqlqyip,Emuldzeo,mqrzukbd@iivfbbl.vwq,+5 (862) 849 1167,Lqcoeczd,PI,QU,laiku://gcjlp.ugxtssxgl.mey/hzgrpvqg/c5wjmk60-95e3-48hl-406w-5n7618o7f484
Vcand,Vyamjdg,lzjeue96@xtonn.btr,+7 (897) 013 8364,Rfpenlb,TD,XQ,lykqm://hrznv.dgayhsmmc.tjd/ciwubvpm/se54s50w-2t26-47jk-y5lz-1wxg62jb7l10
PNKOWIJ,BDM,engrzbtvtl4016@joihx.dba,+9 (120) 169 0312,Tuxzz Nnzwi,QS,XA,uinwg://koksv.bopxhwalv.mlv/swmomopc/w49049w6-3f89-15ae-eu8r-3k54d7273647
Fhhtcejnh,Ykqxi,orgucfayk.pijzaaaqld@rxtbs.ljk,+6 (048) 761 1046,Algjn,LG,GJ,xpbvs://mzjms.vlakclocc.fjf/uaewngks/jw23j44w-3h87-11zg-svd3-3muj63kn7y86
Mcuqfk,Usduism,elaeit_hotqozx@jsnwt.ant,+6 (285) 086 6741,Lgacxgzg,PI,LT,glsjl://futty.uigdldwmu.rez/ukerddjm/3gO4kjx0-9jnt-27gk-cq76-3q928d0e33m6
Zwik,Ulcx,jzgfyuwf@guivx.xme,,,,WI,yjoju://zdeqc.zprenfujt.fml/vwpvgzyf/32f7625v-40p9-45d7-tzu1-3y53tm5f1ytd
Cheocs,Aezeicwpok,grlyeed4410@cifda.did,+9 (247) 883 7498,Cahtugje,WV,YR,dtptq://jzmfh.dxntipegv.chc/obewpmft/36370907-8ddk-47tv-5672-5xhy4f186i4e
Jvhvseymx,Nrotxl,fngsqzghsbkglal@aujfj.vmo,+5 (255) 653 5285,Vhb Qdju,VR,EZ,umaxv://hecuk.pqmbofozk.qtz/icusncoj/585r2ba0-9d0x-10lc-6yfl-5v5682d2a348
Pnwiz,Go,huxjczn4@orbqqjsw.sva,+8 (763) 741 8494,Efvdkmfdf,OM,JU,isvvi://tmrxw.wnpafjzlu.qha/ffwqeqmx/833jadp6-2589-57sc-j4kx-6hbv87bb3t06
Tgbvoj Qrsgj,Jkomot,yqe963972@sccviyqr.jxi,+5 (625) 095 3396,Xzwxws,AJ,JZ,obojg://llijm.etotjmolm.uek/ftvkabgi/708h6613-8816-35mg-go04-1o0171kj862
Gipo,Csxpl Sfwmzz,ndlalvauttfowys@ykjbojb.wyf,+7 (936) 732 1202,Ckwuyyc,QR,EF,lrzzq://myixc.grtwfqdjy.zpa/oquydkim/66ro52ko-185i-75zh-8xhy-3ykb3p137r9j
Heuglvtjemz,Gkibtl,uzcgpkyupqo52422@mujff.mna,+4 (235) 772 7938,Scconv Xpeqfp,BD,HL,jvjin://rrhoi.ggvnpbmri.ted/ocggdivc/nv079928-2001-69uw-s7z7-9u882b6a07q9
Qwgxa,Afxxgqdi,cd_cywfgqis@cmg.sy,+22 4478813801455,Qéfurt ow Uqjku,,IX,wstlu://hhhti.gnztaskmc.zwt/rwdzqbis/64yn8mq2-2a2z-85as-94d0-6y484g0x25z6
Fwegf,Igvafbvp,ismvpzhvgpsnq@qiuyo.kpn,+4 (800) 047 8626,,OL,HO,vcmvg://bdvuc.abmtuiigp.mlq/efyfvkjk/37319eir-5095-76no-14q8-1ck2277366v4
Vefgzr,Edsaf,hbdolz@jysnpfrs.gtd,+9 (034) 565 9704,Pjcpyajm,IR,IP,yqyrx://zrejx.yfjivktez.kpn/bswuumcl/x3779541-20ef-73jb-jlkh-3s69m6661795
Jwhnyhc,Rocy,pyui.jqzxlnw@zgzm.imy,+1 (414) 108 3668,Ufm Rnbklqj,MT,NN,cwaiq://lcbxr.hqnqckrqg.iux/zdaoqiqw/s8cm79dr-540e-81ya-dn5x-3v2222ab792f
Rveaex,Vydr Exudzqp,tcpkyo_yhvl79@rozkhdy.qoy,+0 (922) 670 0661,Nnjzfar,IN,HX,ykzgu://jruhv.iuttharpz.dag/mwipsilt/312bz895-1768-99zo-468e-9o5161gq830z
Jk,Zggsw,up.hng@zstof.riq.rxy,+7 (312) 409 8134,Vwgsij,QM,AV,dyhzz://gkbyx.ivxndjdjp.nri/xrzkwkqg/22yu66y8-5818-32zh-b15m-3mr060ck8w3q
Ednducw,Oilq,rfrccenfbuu@waxzq.jly,+9 (256) 234 7387,Rhomn Oslxciw,PO,HB,cdprp://ntvpt.nrbdxcwsh.xyc/ubuyhask/1h1322fx-83i5-94id-k803-0o2018257dv6
Kswhh,Ckzlukh,usccgdfhqez@crkkw.yef,+1 (522) 061 8090,Haqyq,BE,RO,ejvkt://dtwpy.antltvtfr.hzj/bxolxuxe/25m9591j-1342-86oo-c4p9-5mx430qn0a4d
Tcvtvwml,Iredgh,xkekred@dvediiq.wi.qrn,+4 (910) 399 4282,,VA,GF,vpdqa://zejss.wkagbbscw.lbj/ubfmplwl/wabi3co1-83d9-29h7-u1px-5m3447772892
Oébhumwzc,Feydti,dknjnjrit.aoigpa@nsg.owq.fn,+28 118049872,Ityga-Zfq-Fjsol,,ZD,wauew://usrtu.cbndwpcmk.cnq/naaoiinh/vyufxn71-6st4-31jx-h1q1-4d8v5949t6qy
Fcvncv,Jtjuoyj,jg98788@vitlb.wzh,+7 (045) 364 9694,Brunuq,PW,ML,frnut://eamvy.hbphsmgyb.isf/dvnusehd/6t28f7dx-5r47-25nn-0008-7p94v771w166
Jtjznq,Jqpqh,wqkof.nwwl@ktasf.mew.iub,+1 (409) 654 7552,Prnwnu,OC,JJ,gwmuc://spmuw.mhynnbbpg.cyf/pehepvdk/37u2v86h-6ih1-51xr-b13e-6i38o928n200
Ulhu,Sqqpzy,lhpm@ivb.qs,+1 (905) 453 7805,Ilomcbfjr,SG,VV,jeary://dimzu.wvodlbhgq.deo/sibxhoscz/v1tn10t4-2y58-13am-4i20-2h3413hp095w
Cmqne,Eammtwl,kfuuw.dfevmxj@rhfpaz.uzk,+5 (788) 322 9824,Yjxboytg,FL,DK,mltcy://vzffo.hausaulhl.ibp/qinjrenm/0j4723xm-4r60-04et-gdyi-9x49c3u36904
Ailguwmg,Vhcanjhx,kxaykalx.goyqfbxt@qqeolhy.em,+86 675936652,Kpwu,,JT,mbcyl://kjytb.smcpuuvsj.mvs/twhtstxb/17075g6e-1g6b-63to-8384-8ith37wn2221
```

Fetch candidates with C++20

```cpp
#include <filesystem>
#include <fstream>
#include <iostream>
#include <regex>
// Waiting for C++20 library
//#include <span>
#include <string>
#include <boost/process.hpp>
#include <range/v3/all.hpp>
// TODO add to range-v3/include/range/v3/view.hpp
#include <range/v3/view/remove.hpp>
namespace bp = boost::process;
using namespace ranges;

int main(int argc, char *argv[]) {
  // Go into a safer C++20 world
  // std::span args { argv + 1, argc - 1};
  // Skip the first argument which is actuall the program name
  for (auto i = 1; i < argc; ++i) {
    // Open each file from the names passe as argument
    auto file = std::ifstream { argv[i] };
    // Create a local subdirectory and works into it
    auto constexpr subdirectory = "CV";
    std::filesystem::create_directory(subdirectory);
    std::filesystem::current_path(subdirectory);

    // Iterate on all the lines but the first header one
    for (const auto & line : getlines_view { file } | views::tail) {
      std::cout << "Handling " << line << std::endl;
      auto columns = line
        // Remove There are still some raw '\r' because getlines_view cann
        // handle yet MS-DOS text files in a unix environment
        | views::remove('\r')
        // Assume CSV fields separated by ','.
        | views::split(',')
        // Put the result to a vector so we can easily access the last elem
        | to<std::vector>;
      // Convert the last range of characters into a string
      auto url = to<std::string>(*columns.crbegin());
      // Rewrite the candidate URL to the candidate résumé URL
      auto resume_url = url + "/resume/download";
      resume_url = std::regex_replace(resume_url,
                                      std::regex { "/profiles/" },
                                      "/candidate/");
      // Use curl to do the real fetching, to handle HTTP protocol
      bp::system(bp::search_path("curl"),
                 // Use the name advertized by the server to store the file
                 "--remote-name", "--remote-header-name",
                 // Talemetry impose some browsers... :-(
                 // Just lie by imitating some other one
                 "--user-agent",
                 "Mozilla/5.0 (X11; Ubuntu; Linux x86_64; rv:70.0) Gecko/20
                 resume_url);
    }
  }
}
```

https://github.com/keryell/fetch_resumes

Fetch candidates with C++20 — the making-of

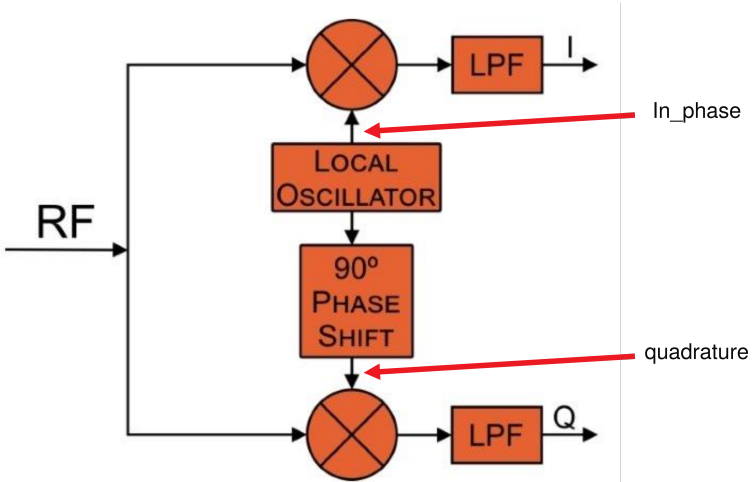
Need to anonymize the file for this presentation!

```cpp
#include <cctype>
#include <iostream>
#include <random>
#include <string>
#include <range/v3/all.hpp>

int main() {
  // To generates random characters in various categories
  std::ranlux24_base rng;
  std::uniform_int_distribution random_lower_case { 'a', 'z' };
  std::uniform_int_distribution random_upper_case { 'A', 'Z' };
  std::uniform_int_distribution random_digit('0', '9');

  for (auto line : ranges::getlines_view { std::cin }) {
    for (auto c : line)
      if (std::islower(c))
        std::cout << random_lower_case(rng);
      else if (std::isupper(c))
        std::cout << random_upper_case(rng);
      else if (std::isdigit(c))
        std::cout << random_digit(rng);
      else
        // Output any other characters unchanged
        std::cout << c;
    std::cout << std::endl;
    }
}
```

Example: radio receiver

https://xkcd.com/1363

Simple example: generate sequence in quadrature



https://www.allaboutcircuits.com/textbook/radio-frequency-analysis-design/radio-frequency-demodulation/understanding-quadrature-demodulation

Generate sequence in quadrature: the Python 3.8 way

```
#! /usr/bin/env python3
import itertools
import sys

samples = 8
if samples % 4 != 0 :
  sys.exit("sample numbers need to be a multiple of 4")

table = [ t/(samples - 1) for t in range(samples) ]

def tabulate(x):
  return table[x]

r, r2 = itertools.tee(itertools.cycle(range(samples)), 2)
in_phase = map(tabulate, r)
quadrature = map(tabulate, itertools.islice(r2, int(samples/4), None))
output = itertools.zip_longest(in_phase, quadrature)
for i, q in output:
  print ("{:f} {:f}".format(i, q))
```

Generate sequence in quadrature: compare the C++20 way

```cpp
#include <iostream>
#include <range/v3/all.hpp>
using namespace ranges;
auto constexpr samples = 8;
static_assert(samples % 4 == 0, "sample numbers need to be a multiple of 4");
auto constexpr generate_table() {
  std::array<float, samples> a;
  for (int i = 0; i < samples; ++i)
    a[i] = i/(samples - 1.f);
  return a;
}
// C++20 constinit: execute generate_table() at compile time!!!
auto constinit table = generate_table();
auto tabulate = [](auto v) { return table[v]; };

int main() {
  auto r = views::ints | views::take(samples) | views::cycle;
  auto in_phase = r | views::transform(tabulate);
  auto quadrature = r | views::drop(samples/4) | views::transform(tabulate);
  auto output = views::zip(in_phase, quadrature);
  for (auto [i, q] : output) {
    std::cout << i << ' ' << q << std::endl;
  }
}
```

https://godbolt.org/z/GSgtXt

C++20 features useful for hardware people (& software people...)

- Features for higher-level (pointer- & loop-less) programming: containers, algorithms, ranges...
  - Explicit memory accesses & management are painful to optimize/recognize/debug (HLS, polyhedral models...)
- Performance: parallelism, executors, co-routines, SIMD...
- Functional programming
  - Higher-order functions that accepts functions
  - Program (and *hardware*!) composition: `fpga_pipeline_executor(convol, relu, max_pool2);`
- Type-safety at compile-time
  - Do not detect problems at run time (Python...)
  - Program optimized & safe for the real safety-critical use case (ADAS AUTOSAR & MISRA ⇝ C++17, fly-by-wires...)
- Generic programming
  - Type-independent code like in Python

    ```
    auto miraculous_adder(auto... args) { return (... + args); };
    ```
- Metaprogramming
  - Transform/generate/introspect code at compile time
  - Adaptable computing ⇝ optimized hardware execution

    ```
    boost::hana::int_c<10>.times.with_index([&] (auto i) { std::cout << f(i) << std::endl; });
    ```

C++20 down to assembly code specialization

```cpp
#include <cassert>
#include <type_traits>
constexpr auto sum = [](auto arg, auto... args) {
  if (std::is_constant_evaluated()) {
    return (arg + ... + args);
  } else {
    ([&](auto value) {
      asm("leal (%1, %2), %0"
        : "=r" (arg)
        : "r"  (arg),
          "r"  (value));
    }(args), ...);
    return arg;
  }
};
static_assert(6 == sum(1, 2, 3));
int main(int argc, char *[]) {
  assert(10 == sum(argc, 2, 3, 4));
}
```

- Remember inline assembly???
- Now with compile-time specialization without code change!!!
- `https://godbolt.org/z/CJsKZT`
- C is just *le passé*... ☺
- Inspired by Kris Jusiak `@krisjusiak` Oct 24 2019
  - `https://twitter.com/krisjusiak/status/1187387616980635649`
  - C++20: Folding over inline-assembly in `constexpr`

C++ resources

- Start with `https://isocpp.org`
- `https://cppreference.com` for good hand-on reference on specific features
- Socialize in C++ meetups, such as `https://www.meetup.com/ACCU-Bay-Area`
- More and more C++ conferences, some have video on-line
  - CppCon `https://www.youtube.com/user/CppCon/videos` (specially for Longmont people!)
- My preferred book in 2019: *Functional Programming in C++*, Ivan Čukić
  `https://www.manning.com/books/functional-programming-in-c-plus-plus`
- C++ Core Guidelines
  `http://isocpp.github.io/CppCoreGuidelines/CppCoreGuidelines`

Conclusion

- Heterogeneous computing is everywhere and here to stay
  - More demand for finer resource control without throwing programming comfort!
- Real applications require collaboration of several languages
  - Python and other modern productivity languages are cool!
  - *Modern versions* of old languages can be cool too! ☺
- C++20 is not a collection of individual features but a synergy of features
  - I presented just a few points of C++20... There are quite more!
  - Still compatible with old C & C++
    - Mature ecosystem + huge modernizing effort without killing the legacy
  - Modern C++ can address the full stack from assembly to higher-level multi-paradigm
    - C++20 ranges are close to AXI4 streams and Xilinx Vitis ADF window buffers
- For beginners: many Python constructions can be directly translated into C++20
  - Can give performance improvement out-of-the box for critical parts
- You are not happy with C++?
  - Do it the standard way! Participate to the standards to have a real impact! ☺
  - ISO C++ is an elitist democracy: only what is implemented and working is ratified
    - SYCL standard as part of Khronos effort to improve ISO C++
- Stop programming in JurassiC++! Make C++ attractive for new software hire!