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Evolving a language in and for the real world

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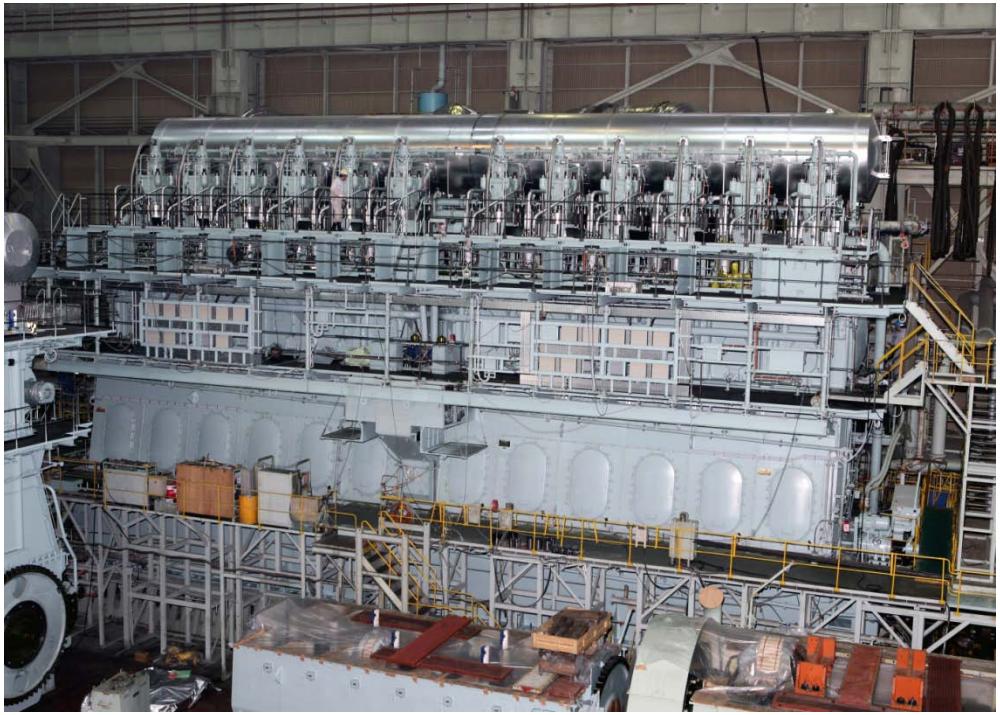
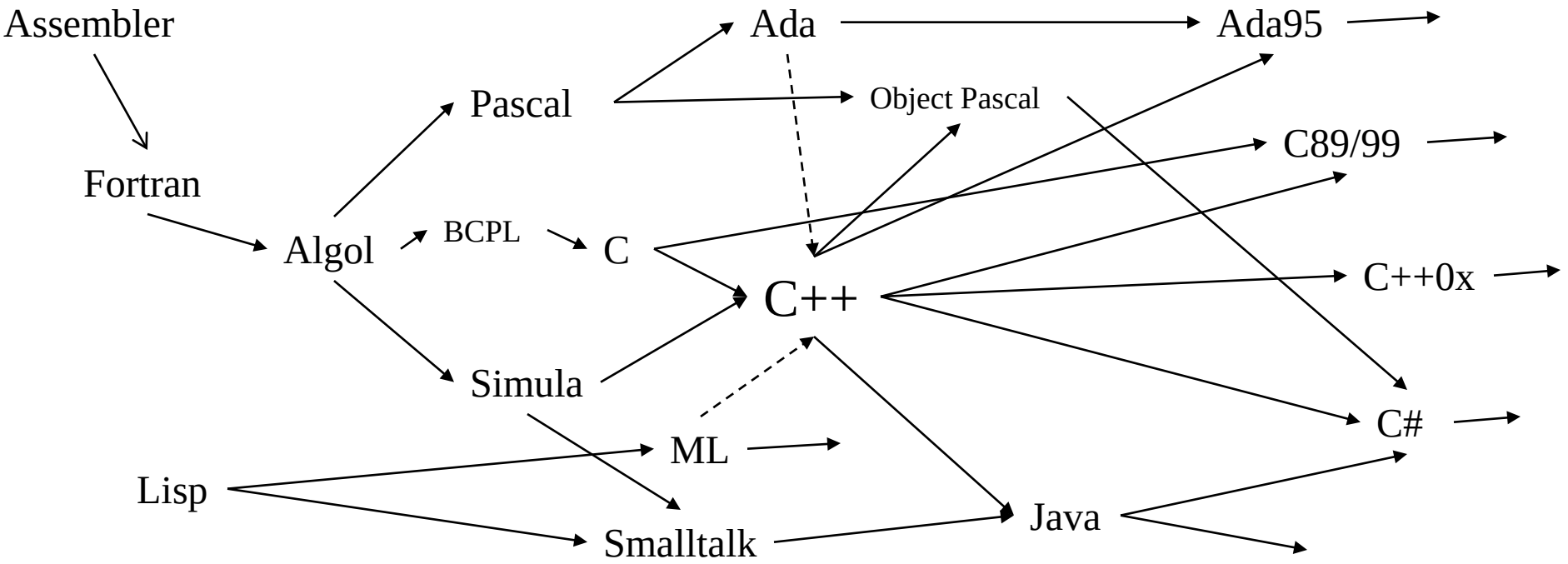
Overview

- 1951-1978: Prehistory – Aims and Ideals
- 1979-1990: The early years – C with Classes and C++
- 1991-1997: Explosive growth – STL and C++98
- 1998-2008: Living in the real world – C++0x



8000+ Programming Languages

- C++'s family tree (part of)



- And this is a gross oversimplification!

Programming languages

- A programming language exists to help people express ideas
  - Programming language features exist to serve design and programming techniques
  - The real measure of value is the number, novelty, and quality of applications

Assembler –1951

- Machine code to assembler and libraries
  - Abstraction
  - Efficiency
  - Testing
  - documentation

THE USE OF SUB-ROUTINES IN PROGRAMMES

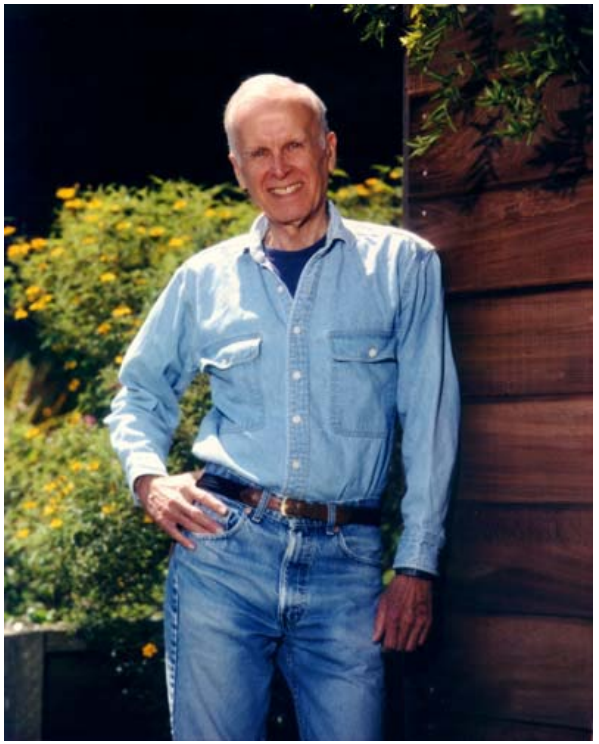
D. J. Wheeler

Cambridge & Illinois Universities

[illegible] the prime objectives to be born in mind when constructing them are simplicity of use, correctness of codes and accuracy of description. All complexities should-if possible -be buried out of sight.

Fortran –1956

- A notation fit for humans
  - For a specific application domain
    - **A(I) = B(I)+C*D(I)**
  - Efficiency a premium
  - Portability



Simula –1967

- Organize code to model “the real world”
  - Object-oriented design
- Let the users define their own types (classes)
  - In general: concepts map to classes
  - “Data abstraction”
- Organize classes into hierarchies
  - Object-oriented programming

C –1974

- An simple and general notation for systems programming
  - Somewhat portable
  - Direct mapping of objects and basic operations to machine
    - Performance becomes somewhat portable

C with Classes –1980

- General abstraction mechanisms to cope with complexity
  - From Simula
- General close-to-hardware machine model for efficiency
  - From C
  - Became C++ in 1984
  - Commercial release 1985

ISO Standard C++

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- C++ is a general-purpose programming language with a bias towards systems programming that
  - is a better C
  - supports data abstraction
  - supports object-oriented programming
  - supports generic programming

From day 1 (1980)

From mid-1983

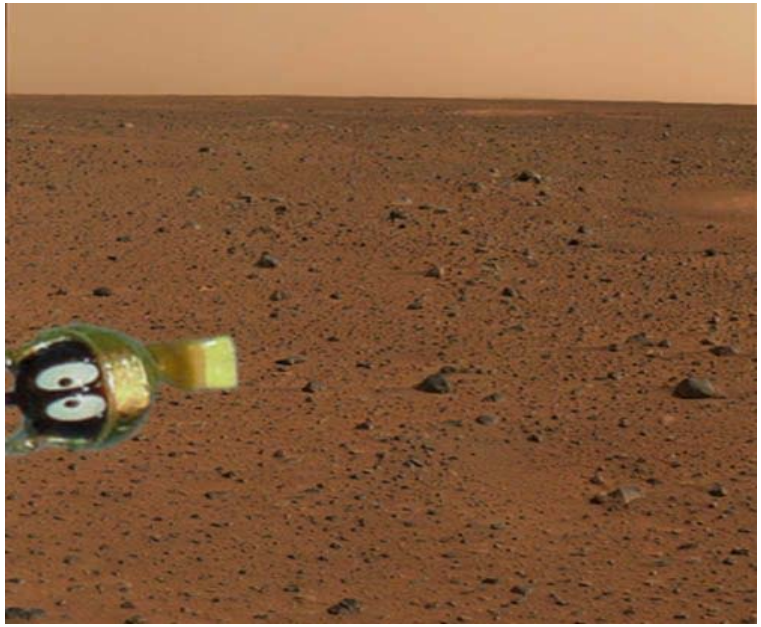
From about 1994

- A multi-paradigm programming language
  - The most effective styles use a combination of techniques

C++ applications

(www.research.att.com/~bs/applications.html)

- Telecommunications
- Google, Amazon, …
- Microsoft applications and GUIs
- Linux tools and GUIs
- Financial
- Games
- PhotoShop
- Most browsers
- …



- Mars Rovers
- Marine diesel engines
- Cell phones
- Human genome project
- High-energy physics
- Micro electronics design and manufacturing
- …

What's distinctive about C++?

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- Stability
  - Essential for real-world software
  - 1985-2008
  - 1978-2008 (C and C with Classes)
- Non-proprietary
  - Yet almost universally supported
  - ISO standard from 1998
- Direct interface to other languages
  - Notably C, assembler, Fortran
- Abstraction + machine model
  - Zero overhead principle
    - For basic operations (e.g. memory access) and abstraction mechanisms
  - User-defined types receive the same support as built-in types
  - Standard library written in the language itself
    - And most non-standard libraries

Aims for C++

- Support real-world software developers
  - "better software now"
  - by "better" I mean correct, maintainable, efficient, portable, …
- Change the way people think about software
  - Object-oriented programming
  - Generic programming
  - Resource management
  - Error handling
- Functional, not academic, beauty
  - "even I could have designed a much prettier language" – B.S. 1984 or so

Ideals

- The fundamental ideals for good design
  - Represent ideas directly in code
  - Represent independent ideas independently in code
  - Represent relationships among ideas directly in code
    - Hierarchical
    - Parametric
  - Combine ideas expressed in code freely
    - where and only where combinations make sense

- C++
  - Make these ideals viable for the largest possible range of application areas
    - "viable" includes "affordable" and "on available hardware"
    - "viable" includes "performs as well as the gold standard in a given area"
      - e.g. Fortran for scientific computation and C for systems programming
    - "viable" includes "in the hands of ordinary programmers"

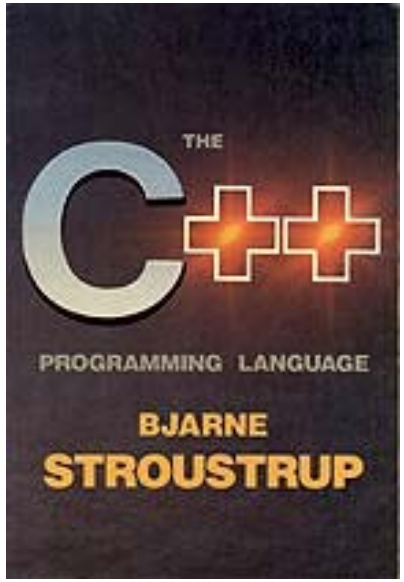
Language features – 1979-1990

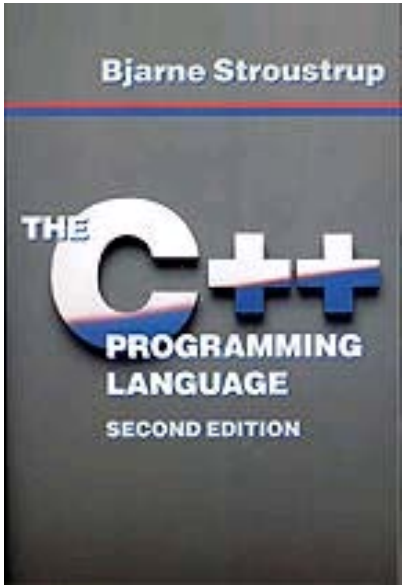
- C with Classes (1979-84)
  - Function argument declarations and checking
  - **const** (also in constant expressions)
  - Classes
  - Derived classes
  - Constructors, destructors
  - **new** and **delete**
  - Inline functions
- C++ (in 1983-86)
  - Overloading (incl. =, [], and ())
  - **virtual** functions
  - Type-safe linkage
- C++ (1988-90)
  - Templates
  - Exceptions

Not in C until much later

Huge impact

Rather late





Basic resource management

- A resource can be memory, file handle, lock, socket, etc.

```
class vector {
    vector(int s);  // constructor: validate arguments, acquire resources
    ~vector();      // destructor: release resources
    // …
};

void f(int s)
{
    vector v(s);
    // …
}
```

Object-oriented programming

- Class hierarchies, dynamic lookup, and static interfaces

```
class Shape {
    Point c;      // common implementation detail: often a dumb idea
    Color col;
public:           // common user interface
    virtual void draw();
    virtual void move(Point p) { c=p; }
    virtual void rotate(int deg);
    // …
};

class Circle : public Shape {
    Circle(Point cc, Color co);
    void rotate(int) {}     // nice optimal algorithm
    // …
};
```

C++ ISO Standardization – Membership

- About 22 nations
  (8 to 12 at a meeting)
  - ANSI (US national committee) hosts the technical meetings
  - Other nations have further technical meetings
- Membership have varied
  - 100 to 200+
    - 200+ members currently
  - 40 to 100 at a meeting
    - ~60 currently
- Most members work in industry
- Most are volunteers
  - Even many of the company representatives
- Most major platform, compiler, and library vendors are represented
  - E.g., IBM, Intel, Microsoft, Sun
- End users are underrepresented

C++ ISO Standardization – Process

Formal, slow, bureaucratic, and democratic

- "the worst way, except for all the rest" (apologies to W. Churchill)

Most technical work happens

- in "working groups"
- electronically between meetings

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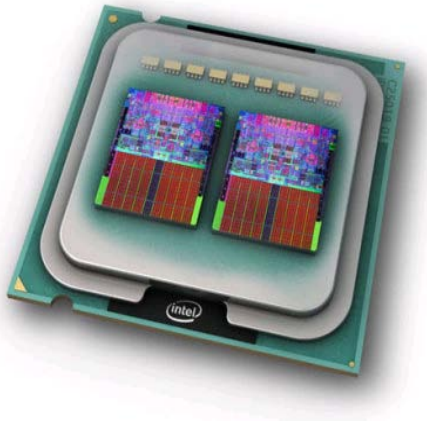
For C++, the ISO standards process is central



- Standard support needed for mainstream use
  - Huge potential for improvement of application code
  - For (far too) many “if it isn’t in the standard it doesn’t exist’
- Significant defense against vendor lock-in
- C++ has no rich owner
  - who can dictate changes, pay for design, implementation, marketing, etc.
- The C++ standards committee is the central forum of the C++ community
  - Endless discussions among people who would never meet otherwise
- The committee receives feedback from a broad section of the community
  - Much of it industrial
- The committee is somewhat proactive
  - Adds features not previously available in the C++ world

C++ ISO Standardization – Results

1998 ISO standard
- 22-0 vote

2003 Technical Corrigenda
- "bug fix release"; no new features

2008 Registration draft for C++0x
- 2011?

- Technical reports
  - Library (2004)
  - Performance (2004)
  - Decimal floating point (2008)
  - Library2
  - Modularity

Language features: 1991-1998

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1992	Covariant return types
1993	Run-time type identification (RTTI: **dynamic_cast**, **typeid**, and **type_info**)
	Declarations in conditions
	Overloading based on enumerations
	namespaces
	mutable
	New casts (**static_cast**, **reinterpret_cast**, and **const_cast**)
	A Boolean type (**bool**)
	Explicit template instantiation
	Explicit template argument specification in function template calls
1994	Member templates (“nested templates”)
	Class templates as template arguments
1996	In-class member initializers
	Separate compilation of templates (**export**)
	Template partial specialization
	Partial ordering of overloaded function templates

The sum is far more significant than the parts

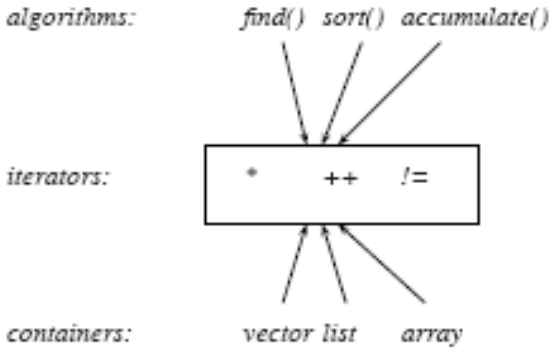
C++98 example: Resource management

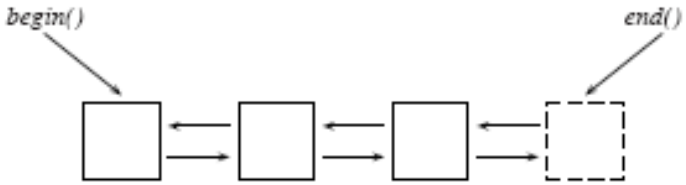
- Standard library containers
  - with exception-safety guarantees (e.g., **vector**)
  - the techniques can be used by every user
- No resources are leaked
  - E.g. **vector** elements and file handles (handled by **ifstream**)
  - Destructors do cleanup
    - guaranteed, implicitly
  - Based on a simple and systematic view of resource management
    - Resources: e.g. locks, sockets, memory, thread handles, file handles
    - Exception safety guarantees
    - RAII

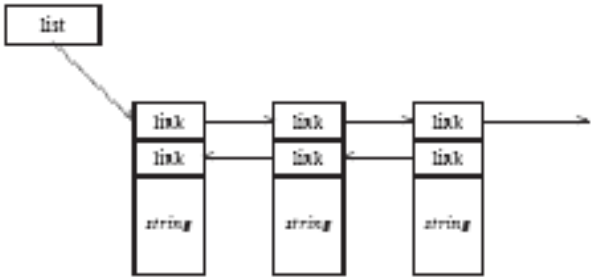
```
void f(string s)
{
    vector<int> v;
    ifstream is(s);
    // …
    int x;
    while (is>>x) {
        if (x<=0) throw Bad_value(x);
        v.push_back(x);
    }
    // …
}
```

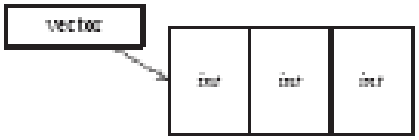
The STL

- Ideal: The most general and most efficient expression of an algorithm
  - Focus on algorithms
  - Separate algorithms from data
    - Using iterators
  - Go from the concrete to the abstract
    - Not the other way
  - Use compile-time resolution to eliminate overheads
    - Inlining and overloading
  - Where needed, parameterize with policies
    - E.g. sorting criteria

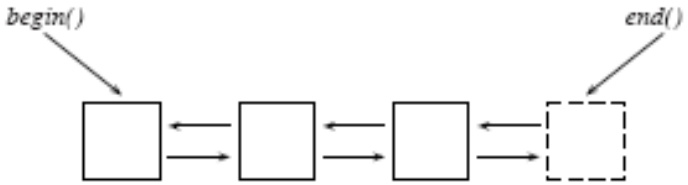








STL example: find_if



- Definition

```
template<class Iter, class Pred>
Iter find_if(Iter first, Iter last, Pred p)
{
    while (first!=last && !p(*first)) // while not at end and predicate not met
      ++first;                        // advance to next element
    return first;  // return the element reached
}

pi = find_if(v.begin(), v.end(), Less_than<int>(42));
if (pi!=v.end()) {
    // found it!
}
```

C++0x: 2002-2008

- Overall goals
  - Make C++ a better language
    - for systems programming
    - for library building
  - Make C++ easier to teach and learn
    - generalization
    - better libraries
- Massive pressure for
  - More language features
  - Stability / compatibility
    - Incl. C compatibility
- Insufficient pressure for
  - More standard libraries
    - The committee doesn't have the resources required for massive library development

C++0x: Areas of change

- Machine model and concurrency
  - Memory model
  - Threads library, asynchronous return
  - Atomic API
  - Thread-local storage
- Support for generic programming
  - **auto**, **decltype**, template aliases, Rvalue references, …
  - General and uniform initialization
  - Lambdas
- Etc.
  - improved **enum**s
  - **long long**, C99 character types, etc.
  - …
- Libraries
  - Regular expressions
  - Hashed containers
  - …

C++0x: language features

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- **decltype** and **auto** — type deduction from expressions
- Template aliases
- Move semantics (rvalue references)
- Static assertions (**static_assert**)
- **long long** and many other C99 features
- >> (without a space) to terminate two template specializations
- Unicode data types
- Variadic templates
- Generalized constant expressions (**constexpr**)
- Generalized initializer lists
- Scoped and strongly typed enumerations (**class enum**)
- Control of alignment
- **nullptr** — Null pointer constant
- A for-statement for ranges
- Delegating and forwarding constructors
- Thread-local storage (**thread_local**)
- Defaulting and inhibiting common operations
- Lambda expressions
- …

The whole is much more than its parts

Performance and convenience

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```
template<class C, class V> vector<typename C::iterator> find_v(C& s, V v)
    // find all occurrences of v in s
{
    vector<C::iterator> res;
    for (auto p = s.begin(); p!=s.end(); ++p)
        if (*p==v) res.push_back(p);
    return res;
}
```

```
vector<string> m = { "Dennis", "Joe", "Brian", "Al", "Joe", "Bill" };
for (auto x : find_v(m,"Bill"))
        if (x!= "Bill") cerr << "bug!\n";
```

Why did C++ succeed?

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- Reasons
  - Low-level access plus abstraction mechanisms
    - Performance
    - Direct access to real hardware
    - Very general zero-overhead abstraction
  - C compatibility
  - A useful tool (from day #1)
  - Timing
  - Non-proprietary – ISO standard
  - Stable
  - Evolving

"Being *best* at one or two things is not enough, you must be *good enough* at everything someone consider important"

Why did C++ succeed?

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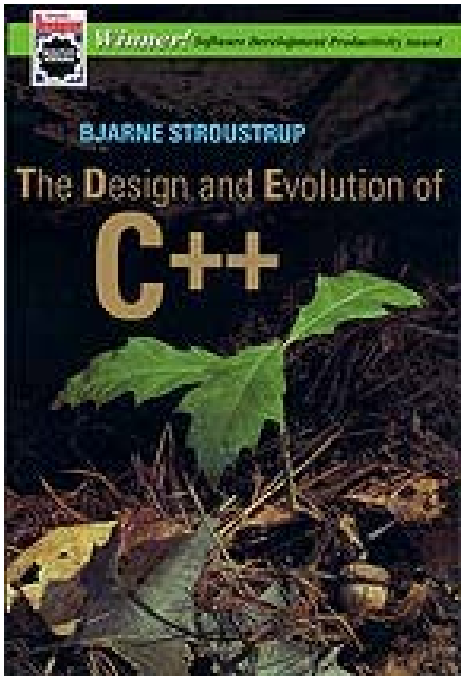
- Popular non-reasons
  - Just luck
    - For 25 years!
  - AT&T's marketing might
    - Must be a joke ☺
  - It was first
    - Except for Ada, CommonLoops, Smalltalk, Eiffel, Objective C, Modula-2, C, Fortran, ML, …
  - Just C compatibility
    - Never 100%
  - It was cheapest
    - Not for most of its lifetime (incl. all the early years)



What is C++?

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Template meta-programming!

A hybrid language

A multi-paradigm programming language

Buffer overflows

It's C!

Embedded systems programming language

Too big!

Supports generic programming

An object-oriented programming language

Low level!

A random collection of features

C++

A language for building software infrastructures and resource-constrained applications

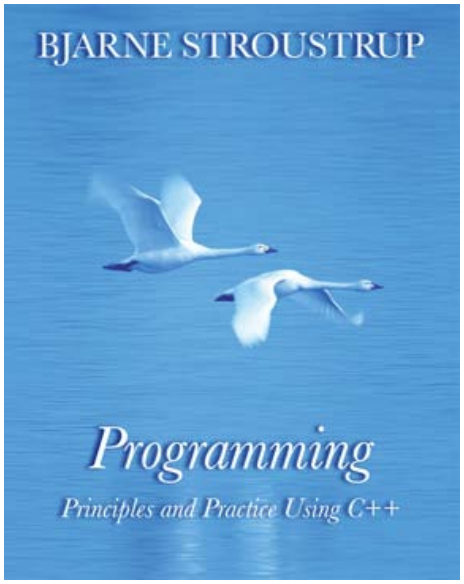
A light-weight-abstraction programming language

Thanks!

- C and Simula
  - Brian Kernighan
  - Doug McIlroy
  - Kristen Nygaard
  - Dennis Ritchie
  - …
- ISO C++ standards committee
  - Steve Clamage
  - Francis Glassborow
  - Andrew Koenig
  - Tom Plum
  - Herb Sutter
  - …
- C++ compiler, tools, and library builders
  - Beman Dawes
  - David Vandevoorde
  - …
- Application builders

More information

- My HOPL-II and HOPL-III papers
- The Design and Evolution of C++ (Addison Wesley 1994)
- My home pages
  - Papers, FAQs, libraries, applications, compilers, …
    - Search for "Bjarne" or "Stroustrup"
- The ISO C++ standard committee's site:
  - All documents from 1994 onwards
    - Search for "WG21"
- The Computer History Museum
  - Software preservation project's C++ pages
    - Early compilers and documentation, etc.
      - http://www.softwarepreservation.org/projects/c_plus_plus/
      - Search for "C++ Historical Sources Archive"



C/C++ compatibility

- A constant sore point
  - Separate standards committees
    - A tragedy
  - Constant borrowing
    - Both ways
    - Often incompatibly
  - Widely demanded by users
    - Rightfully so
  - Widely despised by users
    - “Against OO”
    - “Against the spirit of C”