C/C++ LANGUAGE SERVERS
THE NEXT GENERATION IS NOW

AGENDA

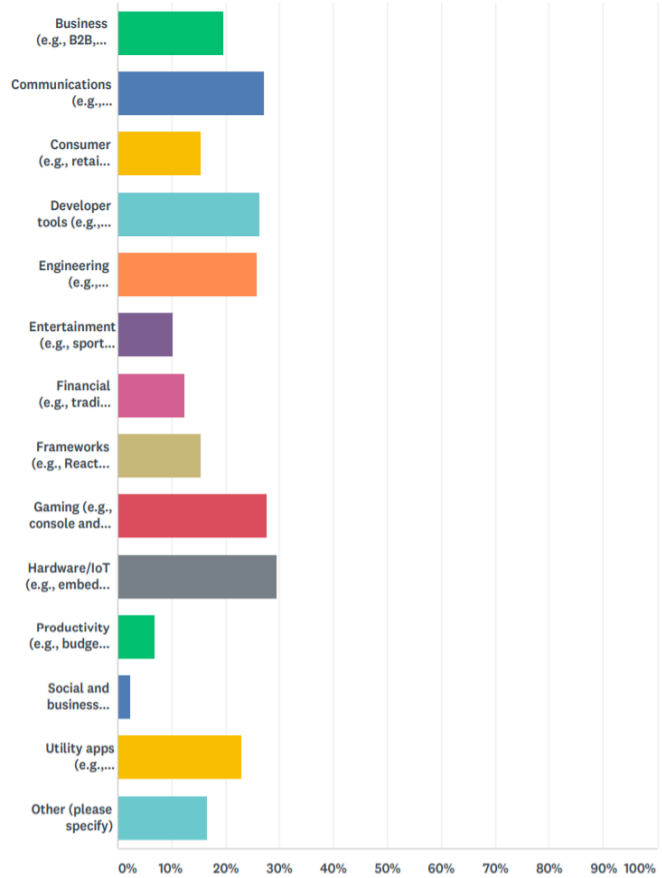
- Why C++
- Modern C++
- CDT's language services
- Clangd and the clang based language servers
- LSP for CDT
- Going forward

WHERE IS C++ TODAY

- From ISO C++: C++ Developer Survey “Lite”: 2018-02

Q4 What types of projects do you work on? (select all that apply)

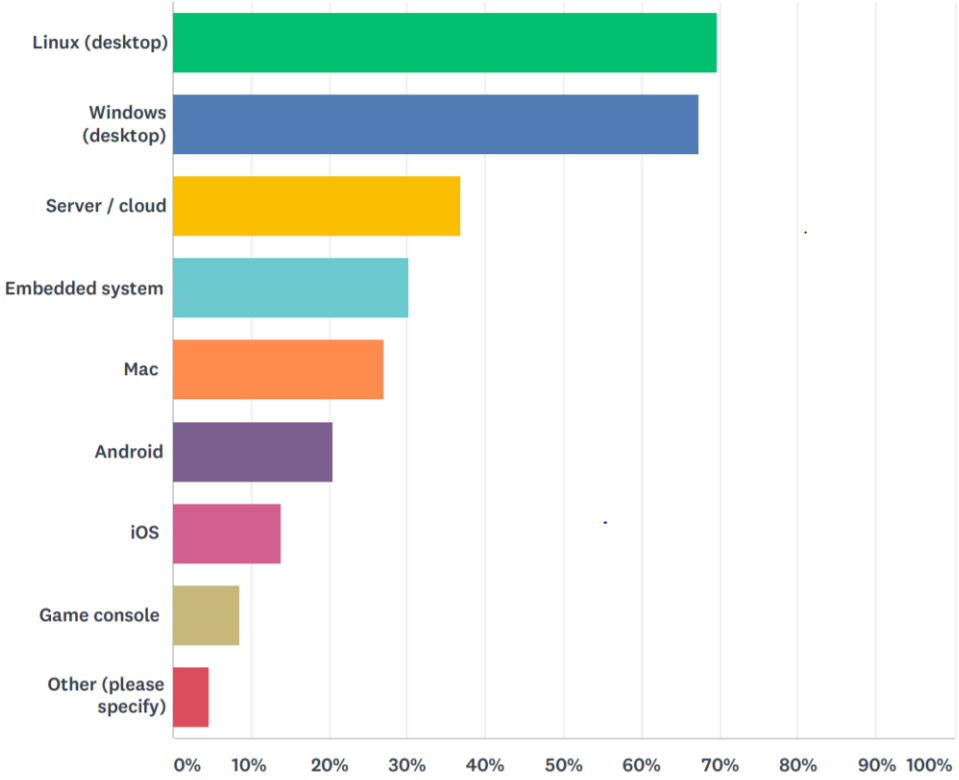
Answered: 3,269 Skipped: 17



QNX™
A Subsidiary of BlackBerry

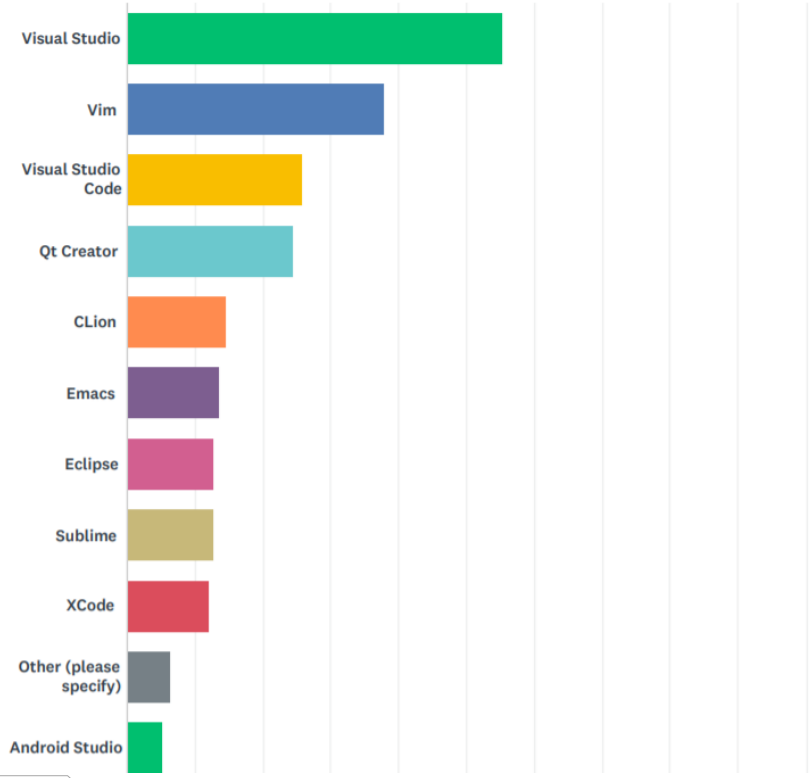
Q5 What platforms do you develop for? (select all that apply)

Answered: 3,271 Skipped: 15



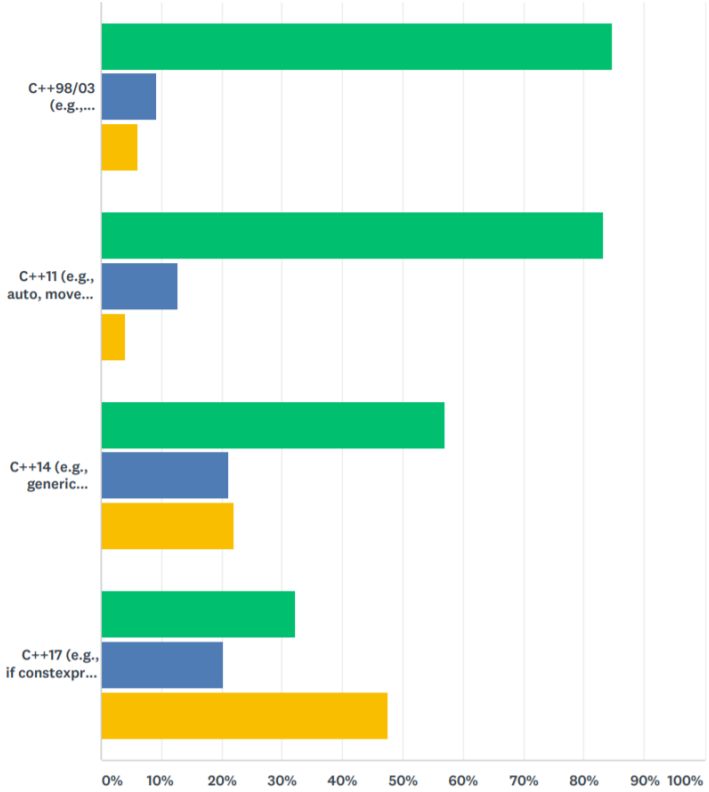
Q13 Which development environments (IDEs) or editors do you use for C++ development?

Answered: 3,240 Skipped: 46



Q8 What version(s) of C++ are you allowed to use on your current project (work or school)?

Answered: 3,257 Skipped: 29



MODERN C++ - C++11, C++14, C++17, C++20, …

- Safety through stack based scoping instead of direct heap
- Ownership and move semantics
- Smart pointers instead of raw pointers
- std::string instead of raw character arrays
- STL containers – vector, list and map
- STL algorithms for generic collection search and manipulation
- Lambdas instead of small functions
  - myfunc([capture_x](param_y) { … })
- Range-based for loops
  - for(auto &x : myvector) { … }

C++ CORE GUIDELINES

- http://isocpp.github.io/CppCoreGuidelines/CppCoreGuidelines
- Edited by Bjarne Stroustrup and Herb Sutter
- “The aim is to help C++ programmers to write simpler, more efficient, more maintainable code.”
- A large collection of rules on how to use C++ properly
- Also provide instruction to tool makers on enforcement of the rules

R.1: RESOURCE MANAGEMENT

- Bad

```
void send(X* x, cstring_span destination)
{
    auto port = open_port(destination);
    my_mutex.lock();
    // ...
    send(port, x);
    // ...
    my_mutex.unlock();
    close_port(port);
    delete x;
}
```

R.1: RESOURCE MANAGEMENT

- Good

```
void send(unique_ptr<X> x, cstring_span destination) // x owns the X
{
    Port port{destination}; // port owns the PortHandle
    lock_guard<mutex> guard{my_mutex}; // guard owns the lock
    // ...
    send(port, x);
    // ...
} // automatically unlocks my_mutex and deletes the pointer in x
```

R.1: RESOURCE MANAGEMENT

- What is Port?

```
class Port {
    PortHandle port;
public:
    Port(cstring_span destination) : port{open_port(destination)} { }
    ~Port() { close_port(port); }
    operator PortHandle() { return port; }

    // port handles can't usually be cloned
    // so disable copying and assignment if necessary
    Port(const Port&) = delete;
    Port& operator=(const Port&) = delete;
};
```

INTERESTING USES OF C++

MICROCONTROLLER PROGRAMMING

- Popularized with Arduino
- Very resource constrained boards
  - E.g. Uno 32K flash, 2K SRAM, 1K EEPROM
  - Though newer ARM Cortex M0/M4, ESP32 getting more powerful
- I/O through traditional GPIO, I2C, SPI, UART (including over USB)
  - Built to interact with sensors and indicators
- Arduino Sketch (ino) language a slight subset of C++
  - Forward declaration, #include <Arduino.h>, only things missing
- Some boards have more advanced SDKs
  - Like ESP32's ESP-IDF which includes things like MQTT (AWS IoT)

WEBASSEMBLY (WASM)

- Stack based virtual instruction set
  - Compiled to native at load time
- Operates in a sandbox
  - Memory is an ArrayBuffer also accessible from host
  - Wasm code has no access to host objects
  - Host imports functions to wasm, wasm exports functions to host
  - Only 4 data types: int64, int32, float64, float32, i.e. number
- WebAssembly becoming first class citizen in upcoming clang 8.0
- Emscripten provides a rich emulation environment for C++ code
  - Commonly used for games, e.g. Unity

LANGUAGE SERVERS

- CDT
- Clangd (and a bit on cquery and ccls)

CDT LANGUAGE SERVICES – IN THE BEGINNING

- Standard Eclipse editor services like syntax highlighting, bracket matching
- Search provided using a ctags based index
  - Really only properly supported C
- Then we built our own parsers for C and C++
  - Recursive descent parser with backtracking to deal with ambiguities
  - Great error handling to deal with partial files (like at content assist time)
- Cloned the JDT index to persist symbols
  - While accurate, full indexing didn't scale well

CDT FAST INDEXER – LIVING UP TO IT'S NAME

- Be faster by doing less, cutting out duplication
  - Parse each header file once
  - Store symbol information in a fast database
  - plug objects from that database into the AST (resolveBindings)
  - Rest of the code that uses the AST just works (mostly)
- Indexing of large projects from over an hour to a few minutes
- Incremental indexing almost unnoticeable
- Accuracy fades with bad code patterns
  - But luckily there aren't many of those

CDT SCANNER DISCOVERY

- In order to parse properly need to consider the compiler environment
  - Built-in macros, include path of particular compiler
  - Arguments used when compiling each source file
- CDT traditionally scanned built output to find which compiler and it's args
- GCC, for example, has magic options to give macros and the include path
  - gcc -v -E -P -dD
- CDT's new Core build can also ask builders for this information
  - CMake provides compile_commands.json
  - Qt's qmake supports query options

CDT REFACTORING

- Leverage the LTK started by JDT for managing refactoring
- Ask the AST to produce TextEdit's needed to affect a change
- Uses Preview UI to see changes before committing
- Standard rename refactoring, including in place
- Other built in structural refactorings
  - E.g. extract constant, extract local variable, extract function
- Fully extendible for custom refactorings

CDT CODE ANALYSIS (CODAN)

- Static analysis of code using the AST
  - Find problems before build and launch
- Configurable to run at different times of the project lifecycle
  - From as you type to only on full builds
  - Some checkers take to long to run all the time
- Numerous built in checkers
  - Coding style, e.g. naming conventions
  - Potential code problems, e.g. assignment in condition, missing return
  - Real semantic errors, e.g. instantiating abstract class
- Fully extensible for other team standards, etc.

OTHER CDT LANGUAGE SERVICE FEATURES

- Code formatter
- Call hierarchy
- Type hierarchy
- Include hierarchy
- Organize/Add Includes
- Explore Macro Expansion

CDT'S BIGGEST CHALLENGE

- C++ standards being released every three years
  - With pretty major language changes each time
  - Compilers will often adopt the features before the standard
- How do we keep up?
  - All time spent on updating parsers and index
  - No time for new refactorings, code analysis checks
  - And the community is now very small

LANGUAGE SERVER PROTOCOL

- Provides language smarts for editors
- Code completion
- Go to declaration, find references
- Workspace symbols (search), document symbols (outline)
- Hover
- Diagnostics and Code actions (quick fix)
- Code formatting
- Rename refactoring (but that’s all)
- No semantic highlighting, call hierarchy, etc.
- But protocol is extensible, but each client needs to know about them

CLANGD

- Official part of LLVM project in tree under clang/extras
  - Lots of useful utilities in the core LLVM
- Determines build commands from compile_commands.json files
- Parsed using the clang parser driven by clang compiler driver
  - Works in place of other compilers since clang itself does
- Speeds up parsing by keeping preamble around
  - Precompiles header in memory
- Great diagnostics from clang itself and supports clang fix-its

CLANGD THE BAD

- It has no persistent index! No search
  - The design for one is underway
  - At lest they recently added remembering opened files
  - But given that surprisingly useful anyway
- Doesn’t implement LSP “CodeLens” feature
- Releases tied to LLVM/Clang releases
- Hard to extend
  - Adding support for non clang environments
  - new compiler built-ins, include paths, architectures

CQUERY AND CCLS

- cquery is out of tree built against libclang
- Has an index
- Implements all LSP features
- Extends in interesting ways
  - Semantic highlighting, call hierarchy
- But very small community (one person project with a few PRs)
- ccls is a fork of cquery to build in tree
  - Smaller, stronger faster
- Also a one person project
- Neither have considered how to support non-clang environments

CDT LSP4E

- GSOC project this summer by Manish Khurana mentored by Nate Ridge
- Full LSP4E support for both clangd and cquery
- But no support for cquery extensions

- Demo

WHERE DO WE GO FROM HERE?

- Add support for cquery's extensions
- Work to have those extensions added to the protocol
- Work with clangd to implement those extensions
  - And generally help mature the project
- How do we support non-clang environments
  - Not necessarily upstreamable. Fork?
- Do we work with cquery and/or ccls too?

ADOPT THE NEW IDE ARCHITECTURE

- Language Server takes us down a new path
- Build a Debug Adapter as well for gdb
  - Encourage other debugger integrations to use DAP
- Ensure the LSP4E components for language and debug server are fully featured
  - Parity with existing CDT services
- Continue our effort to support external build systems
  - CMake, Meson, Qt qmake
  - Can we make CDT Managed Build work in the same way

PROVIDE OUR USERS CHOICE

- Help ensure Eclipse is a full partner in the new world
- Take our expertise with C/C++ IDEs and help other IDE platforms
  - Visual Studio Code
  - Theia/Che
  - Others?
- Being a tools developer is about serving the needs of developers
  - CDT has provided the features C/C++ developers need
  - But we need to fit into our user's workflows
  - Allow them to choose the IDE front end that allows them to be their best

THANK YOU!