Tools from the C++ eco-system to save a leg

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Time for a quote

“C makes it easy to shoot yourself in the foot;
C++ makes it harder, but when you do it blows your whole leg off”
- Bjarne Stroustrup

http://www.stroustrup.com/bs_faq.html#really-say-that

Time for a story

Each time someone was leaving the team, the C++ code written by that person was aggressively rewritten by those who stayed.

Time for a sample: goto fail

About the security content of iOS 7.0.6

This document describes the security content of iOS 7.0.6.

iOS 7.0.6

- **Data Security**

  Available for: iPhone 4 and later, iPod touch (5th generation), iPad 2 and later

  Impact: An attacker with a privileged network position may capture or modify data in sessions protected by SSL/TLS

  Description: Secure Transport failed to validate the authenticity of the connection. This issue was addressed by restoring missing validation steps.

  CVE-ID

  CVE-2014-1266

Time for a sample: goto fail

```
static OSStatus
SSLVerifySignedServerKeyExchange(SSLContext *ctx, bool isRsa, SSLBuffer signedParams,
                                 uint8_t *signature, UInt16 signatureLen)
{
    OSStatus        err;
    ...

    if ((err = SSLHashSHA1.update(&hashCtx, &serverRandom)) != 0)
        goto fail;
    if ((err = SSLHashSHA1.update(&hashCtx, &signedParams)) != 0)
        goto fail;
        goto fail;
    if ((err = SSLHashSHA1.final(&hashCtx, &hashOut)) != 0)
        goto fail;
    ...
```

Time for a sample: know the type

```
template<typename T, typename U>
auto doOperation(T t, U u) -> decltype(t + u) {
    return t + u;
}

void fun_type() {
    auto op = doOperation(3.0, 0);
    //...
}
```

Time for a sample: where is type

```
#ifdef MAGIC
template<int>
struct x {
    x(int i) { }
};
#else
int x = 100;
#endif

void test(int y) {
    const int a = 100;
    auto k = x<a>(0);
}
```

Define code quality

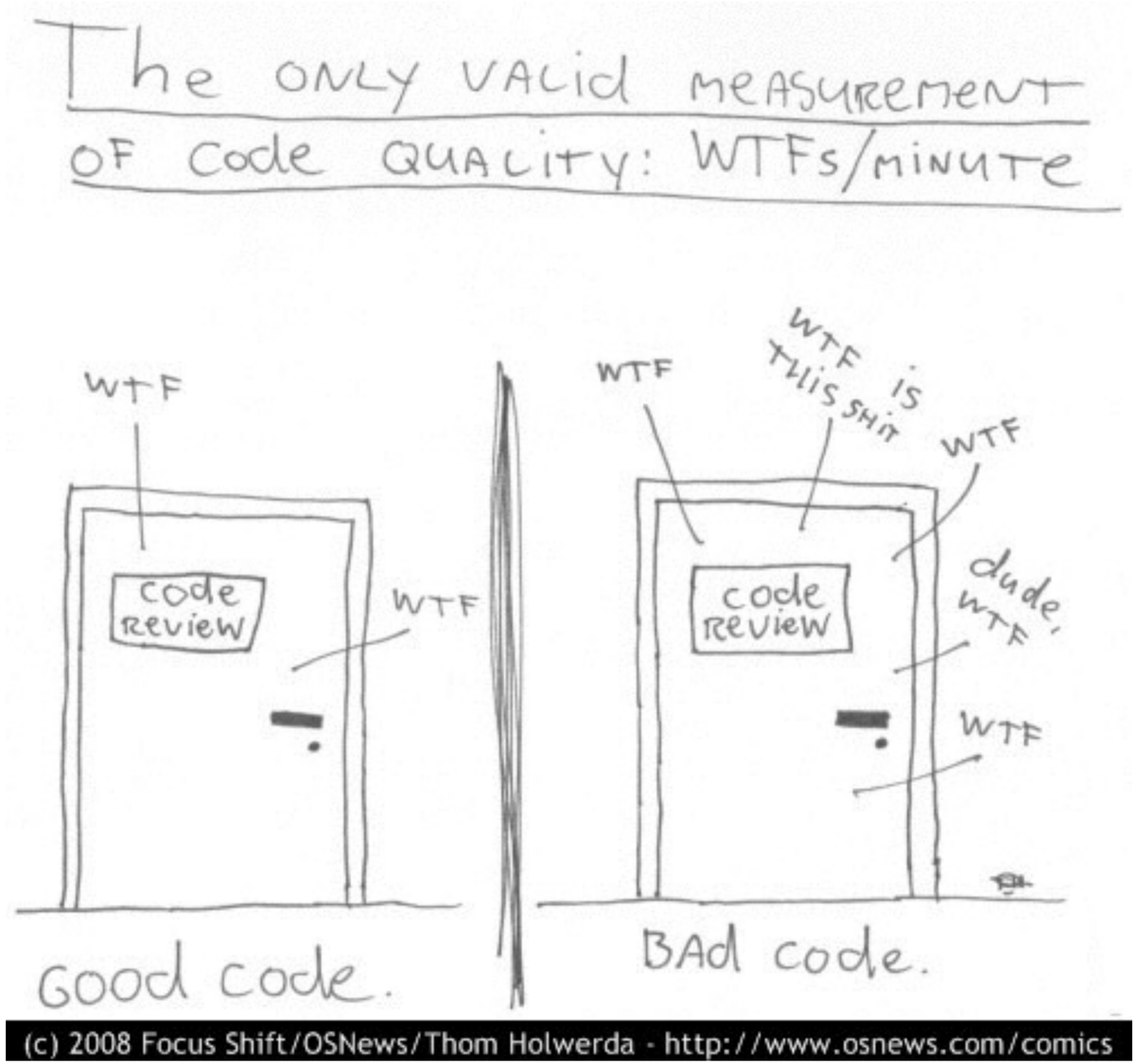
Code quality =

- easy to read
- easy to maintain
- easy to use
- works correct

Code quality (CISQ) =

- reliability
- efficiency
- security
- maintainability
- size

Define code quality



We need tools

“Tool support is essential… We need tools”

- *Bjarne Stroustrup*

Tools for code quality

1. Follow the code style, formatter
2. Generate code
3. Run code analysis
4. Refactor
5. Check with unit tests

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Tools: Formatter
C++ specific

—

C++ specific

- Formatting with/without parsing/resolve

```
void test() {
    struct x {
        x(int) { };
    };

    int y = 100;

    auto a = (x)-5;
    auto b = (y)-5;
}
```

Tools: Formatter
C++ specific

—

C++ specific

- Formatting with/without parsing/resolve

```
void test() {
    struct x {
        x(int) { };
    };

    int y = 100;

    auto a = (x)-5;
    auto b = (y)-5;
}
```

```
x a = (x) -5;
int b = (y) - 5;
```

Tools: Formatter
C++ specific

—

C++ specific

- Formatting with/without parsing/resolve
- Variety
  - Variety of standards
    - Google, LLVM/LLDB, Qt, GNU, Chromium, Mozilla, WebKit, etc.
  - Heritage: Custom style guides in companies, big projects, etc.
  - Style guides are different in essence

Tools: Formatter Workflow

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When to reformat?

- On file save
- On-the-fly formatting
- Pre-commit hook
- Explicit actions: format line, selection, file

Tools: Formatter

- Clang-Format http://clang.llvm.org/docs/ClangFormat.html
  - Command-line tool
  - `// clang-format off/on`
  - Library profiles
  - Integration
    - Vim, Emacs, VS, VS Code, Qt Creator, NetBeans, ReSharper C++

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Tools: Formatter

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  - Library profiles
  - Integration
    - Vim, Emacs, VS, VS Code, Qt Creator, NetBeans, ReSharper C++
  - Fuzzy parser
- IDEs
  - Built-in formatter tool
  - Import/export/convert issues

Tools: Formatter
Extract style

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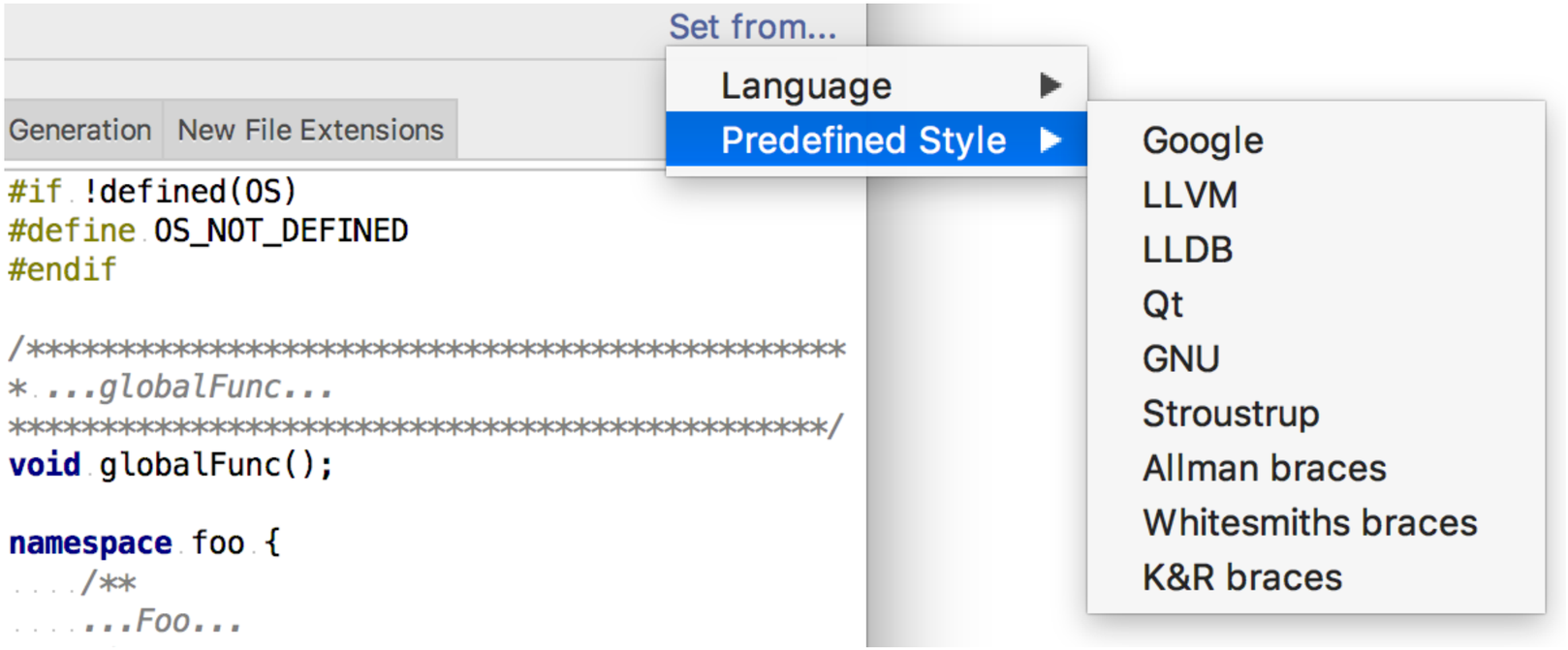
- Idea: get style from the actual code
- Problem: lots of settings, dependant parameters
- Genetic algorithm



Tools for code quality

1. Follow the code style, formatter
2. Generate code
3. Run code analysis
4. Refactor
5. Check with unit tests

Generate C++ code

Why?

- Keep to style guidelines
- Use common design patterns
- Avoid errors

What?

- File templates
- Comments/Docs
- Code snippets

Tools: Code generation

- IDEs
  - class/file templates
  - getters/setters
  - other

```
class Human {
    float height;
    float weight;
    int age;
    std::string name;

public:
    Human::Human(float height, float weight, int age) :
            height(height), weight(weight), age(age) {}


    friend std::ostream &operator<<(std::ostream &os, const Human &human) {
        os << "height: " << human.height << " weight: " << human.weight <<
              " age: " << human.age << " name: " << human.name;
        return os;
    }

    bool operator==(const Human &rhs) const {
        return height == rhs.height && weight == rhs.weight &&
               age == rhs.age && name == rhs.name;
    }

    bool operator!=(const Human &rhs) const {
        return !(rhs == *this);
    }

    bool operator<(const Human &rhs) const {
        return std::tie(height, weight, age, name) <
               std::tie(rhs.height, rhs.weight, rhs.age, rhs.name);
    }

    bool operator>(const Human &rhs) const {
        return rhs < *this;
    }
```

Tools: Code generation

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- IDEs
- Specialized tools
  - protobuf,
  - cog and other transformation tools,
  - clang based tools

Tools: Code generation

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- IDEs
- Specialized tools
- C++ Metaclasses

Code generation
Metaclasses

```
$class interface {
    constexpr {
        compiler.require($interface.variables().empty(),
                         "interfaces may not contain data");
        for... (auto f : $interface.functions()) {
            compiler.require(!f.is_copy() && !f.is_move(),
                "interfaces may not copy or move; consider a"
                " virtual clone() instead");
            if (!f.has_access()) f.make_public();
            compiler.require(f.is_public(),
                "interface functions must be public");
            f.make_pure_virtual();
        }
    }
    virtual ~interface() noexcept { }
};
```

```
interface Shape {
    int area() const;
    void scale_by(double factor);
};
```

```
struct Shape {
    virtual int area() const = 0;
    virtual void scale_by(double factor) = 0;
    virtual ~Shape() noexcept {
    }
}
```

Tools for code quality

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Tools: Code analysis

- Static code analysis tools
  - compiler warning
  - extra checks
- Dynamic code analysis tools

Tools: Clang Analyzer

Clang Analyzer: https://clang-analyzer.llvm.org/available_checks.html

- `clang -analyze -analyzer-checker=…`
- Clang-Tidy: `clang-analyzer-*`
- Xcode
- C, C++, Objective-C
- 40 checks for C/C++
  - core checks
  - new/delete leaks
  - dead code
  - nullability
  - security checks

Tools: (Modernize with) Clang-Tidy

Clang-Tidy: http://clang.llvm.org/extra/clang-tidy/

- `-checks=-*,modernize-*`
  - replace std::bind with lambdas
  - use auto in iterators, new expressions, cast expressions
  - replace C standard library headers with their C++ alternatives
  - replace a default constructor's member initializers with the new default member initializers in C++11
  - more (24 checks)
- In total >200 checks!

Tools: (Modernize with) Clang-Tidy

modernize.cpp

```cpp
#include <functional>
#include <vector>
#include <iostream>

int add(int x, int y) { return x + y; }

void bind_to_lambda(int num) {
    int x = 2;
    auto clj = std::bind(add, x, num);
}

void loop_convert(const std::vector<int>& vec) {
    for(auto iter = vec.begin(); iter != vec.end(); ++iter) {
        std::cout << *iter;
    }
}

class MyClass {
public:
    MyClass(const std::string &Copied,
            const std::string &ReadOnly)
            : Copied(Copied), ReadOnly(ReadOnly) {}

private:
    std::string Copied;
    const std::string &ReadOnly;
};
```

Tools: C++ Core Guidelines

C++ Core Guideines: https://github.com/isocpp/CppCoreGuidelines

- Support in Clang-Tidy (16 checks)
- Via Clang-Tidy
  - Eclipse, CLion, NetBeans
- Native support
  - CppCoreCheck in Visual Studio
  - Cevelop

Tools: More static code analysis

- CppCheck: https://sourceforge.net/p/cppcheck/wiki/ListOfChecks/
  - approx 170 checks
  - variable scope, out-of-bounds, memory leaks, sizeof args, etc.

Tools: More static code analysis

- CppCheck: https://sourceforge.net/p/cppcheck/wiki/ListOfChecks/
- Coverity: http://www.coverity.com
  - C, C++, C#, Objective-C and more
  - incremental & full analysis, parallel analysis, CI plugins
  - approx 80 checks
    - out-of-bounds reads double free, use after free
    - incorrect buffer size
    - integer overflow
    - uninitialised variable
    - null dereference

Tools: More static code analysis

—

- CppCheck: https://sourceforge.net/p/cppcheck/wiki/ListOfChecks/
- Coverity: http://www.coverity.com
- PVS-Studio (https://www.viva64.com/en/w/)
- Infer (Facebook) (http://fbinfer.com/docs/infer-bug-types.html)
- IDEs checks

Tools: Data Flow Analysis in CLion

```
typedef enum class Color { Red, Blue, Green, Yellow };

void do_shadow_color(int shadow) {
    Color cl1, cl2;

    if (shadow)
        cl1 = Color::Red, cl2 = Color::Blue;
    else
        cl1 = Color::Green, cl2 = Color::Yellow;

    if (cl1 == Color::Red || cl2 == Color::Yellow) {

    }
}
```

Condition is always true when reached more... (⌘F1)

```
void Sample2(int flag) {
    Color c;

    switch (flag) {
        case 0:
            c = Color::Red;
            break;
        case 1:
            c = Color::Blue;
            break;
        default:
            c = Color::Green;
    }

    switch (c) {
        case Color::Red:
            break;
        case Color::Blue:
            break;
        case Color::Green:
            break;
        case Color::Yellow:
            break;
    }

}
```

Unreachable code more... (⌘F1)

Tools: Dynamic code analysis

- Valgrind

- Google LLVM sanitizers
- GNU gprof, gperftools

- Oracle Developer Tools (SunStudio)
- and more

Tools: Valgrind

- compiler/language doesn’t matter
- slow down 20-50x
- much more than memory check!

Tools: Valgrind

- Memcheck http://valgrind.org/docs/manual/mc-manual.html
  - illegal read/write/frees
  - using uninitialized or derived from uninitialized value
  - overlapping src and dst in memcpy, strcpy, strncpy, strcat, strncat
  - fishy size arguments in allocators
  - memory leaks

```
==27492== Source and destination overlap in memcpy(0xbffff294, 0xbffff280, 21)
==27492==    at 0x40026CDC: memcpy (mc_replace_strmem.c:71)
==27492==    by 0x804865A: main (overlap.c:40)
```

Tools: Valgrind

- Memcheck http://valgrind.org/docs/manual/mc-manual.html
- Cachegrind http://valgrind.org/docs/manual/cg-manual.html
  - cache profiler

```
==31751== I   refs:      27,742,716
==31751== I1  misses:           276
==31751== LLi misses:           275
==31751== I1  miss rate:        0.0%
==31751== LLi miss rate:        0.0%
==31751==
==31751== D   refs:      15,430,290  (10,955,517 rd + 4,474,773 wr)
==31751== D1  misses:        41,185  (    21,905 rd +    19,280 wr)
==31751== LLd misses:        23,085  (     3,987 rd +    19,098 wr)
==31751== D1  miss rate:        0.2% (       0.1%   +       0.4%)
==31751== LLd miss rate:        0.1% (       0.0%   +       0.4%)
==31751==
==31751== LL misses:         23,360  (     4,262 rd +    19,098 wr)
==31751== LL miss rate:         0.0% (       0.0%   +       0.4%)
```

Tools: Valgrind

- Memcheck http://valgrind.org/docs/manual/mc-manual.html
- Cachegrind http://valgrind.org/docs/manual/cg-manual.html
- Callgrind http://valgrind.org/docs/manual/cl-manual.html
  - records the call history in the program
  - KCachegrind is a viewing tool

Tools: Valgrind

- Memcheck http://valgrind.org/docs/manual/mc-manual.html
- Cachegrind http://valgrind.org/docs/manual/cg-manual.html
- Callgrind http://valgrind.org/docs/manual/cl-manual.html
- Hellgrind, massif, etc.
  - Hellgrind = thread error detector
  - Massif = heap profiler

Tools: Sanitizers

- requires recompilation
- 2x slow down
- Clang (3.1-3.2), GCC (4.8)
- https://github.com/google/sanitizers

Tools: Sanitizers

- Address Sanitizer (ASan) `-fsanitize=address`
  - out-of-bound access
  - use-after-free
  - use-after-return
  - use-after-scope
  - double-free, invalid-free
  - memory leaks (LeakSanitizer)

Tools: Sanitizers

```
=================================================================
==58237==ERROR: AddressSanitizer: stack-use-after-scope on address 0x7ffc4d830880 at
pc 0x0000005097ed bp 0x7ffc4d830850 sp 0x7ffc4d830848
WRITE of size 4 at 0x7ffc4d830880 thread T0
    #0 0x5097ec  (/tmp/use-after-scope+0x5097ec)
    #1 0x7ff85fa6bf44  (/lib/x86_64-linux-gnu/libc.so.6+0x21f44)
    #2 0x41a005  (/tmp/use-after-scope+0x41a005)

Address 0x7ffc4d830880 is located in stack of thread T0 at offset 32 in frame
    #0 0x5096ef  (/tmp/use-after-scope+0x5096ef)

  This frame has 1 object(s):
    [32, 36) 'x' <== Memory access at offset 32 is inside this variable
HINT: this may be a false positive if your program uses some custom stack unwind mechanism or swapcontext
      (longjmp and C++ exceptions *are* supported)
SUMMARY: AddressSanitizer: stack-use-after-scope (/tmp/use-after-scope+0x5097ec)
Shadow bytes around the buggy address:
  0x100009afe0c0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x100009afe0d0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x100009afe0e0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x100009afe0f0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x100009afe100: 00 00 00 00 00 00 00 00 00 00 00 00 f1 f1 f1 f1
=>0x100009afe110:[f8]f3 f3 f3 00 00 00 00 00 00 00 00 00 00 00 00
  0x100009afe120: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x100009afe130: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x100009afe140: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x100009afe150: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x100009afe160: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
```

Tools: Sanitizers

- Address Sanitizer (ASan)
- Thread sanitizers (TSan) `-fsanitize=thread`
  - data race detector

Tools: Sanitizers

- Address Sanitizer (ASan)
- Thread sanitizers (TSan)
- Memory sanitizer (MSan) `-fsanitize=memory`
  - detects uninitialized memory reads

Tools: Sanitizers

- Address Sanitizer (ASan)
- Thread sanitizers (TSan)
- Memory sanitizer (MSan)
- Undefined Behavior sanitizer (UBSan) `-fsanitize=undefined`
  - using null pointers
  - signed integer overflow
  - floats conversion with overflow
  - out-of-bounds array index
  - division by zero
  - more

Tools: Sanitizers

- Address Sanitizer (ASan)
- Thread sanitizers (TSan)
- Memory sanitizer (MSan)
- Undefined Behavior sanitizer (UBSan)
- Data Flow sanitizer API

Tools for code quality

1. Follow the code style, formatter
2. Generate code
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4. Refactor
5. Check with unit tests

Tools: Refactoring

- Basic set
  - rename
  - extract Function
  - inline
- Profound set
  - change signature
  - extract variables / parameters / constants / typedefs / defines
  - pull/push members up/down the hierarchy
  - modernize
  - etc.

Tools: Refactoring

Test suite for C++ refactoring tools:

- https://github.com/LegalizeAdulthood/refactor-test-suite
- Test cases on:
  - change signature
  - create setters, getters
  - extract constant, function, parameter, variable
  - inline macro, variable, etc.
  - rename
  - simplify boolean expression
  - etc.

Tools: Refactoring
Clang-rename

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- clang family
- integrated into Vim, Emacs
- renaming inside TU

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Tools: unit testing

- Google Test - 45%
- Boost.Test - 26%
- CppUnit - 11%, CppUTest - 5%, Catch - 5%, others

Tools for code quality

1. Follow the code style, formatter
2. Generate code
3. Run code analysis
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5. Check with unit tests
6. Bonus! Package managers

Tools: package manager

Problem:

- Pre-compiled libraries may violate One-Definition Rule
- Usual way
  - download sources
  - build
  - include into project’s build
- A variety of build systems for C++ projects

Tools: package manager

Package managers solution

- Language level vs external
- Build-system agnostic vs build-system built-in
- Source-based vs pre-built binaries vs combined
- System vs language-specific

Tools: package manager

A Packaging System for C++ proposal (P0235R0)

- Language level
- By Blizzard
- *using*, *MANIFEST*, *options* syntax
- https://github.com/Blizzard/clang
- https://github.com/berkus/clang-packaging-P0235R0
- cppget first, default public repo later

```
#using package "foo" \
  ("foo/foo.h", "bar/bar.h") \
  [foo, bar.baz] \
  version "1.2.3"
```

```
#if PLATFORM == WINDOWS
  #using option PLATFORM = "Win32"
#elif PLATFORM == LINUX
  #using option PLATFORM = "Linux"
#else
  #error Unknown platform
#endif

#if BUILD == DEBUG
  #using option TARGET = "Debug"
#else
  #using option TARGET = "Release"
#endif

#using package "mypackage"
```

Tools: package manager

Conan

- External, build-system agnostic
- Predefined helpers for CMake
- Win, Linux, Mac, FreeBSD, SunOS
- C, C++, Python, Go, Fortran
- Download binaries or build from sources
- Web server or local storage
- VS, Xcode, Android Studio, CLion
- OS: https://github.com/conan-io/conan
- Detailed doc: http://docs.conan.io/en/latest/

conanfile

```
[requires]
Poco/1.7.8p3@pocoproject/stable

[generators]
cmake

[options]
Poco:shared=True # PACKAGE:OPTION=VALUE
OpenSSL:shared=True
```

conanprofile

```
[settings]
compiler=clang
compiler.version=3.5
compiler.libcxx=libstdc++11

[options]
MyLib:shared=True

[env]
CC=/usr/bin/clang
CXX=/usr/bin/clang++
```

Tools: package manager

Hunter: https://github.com/ruslo/hunter

- CMake-based
- Linux, Mac, Windows, iOS, Android, Raspberry Pi
- HunterGate
- Shareable directories with packages
- >20 supported packages
- GTest/GMock, Boost, Catch, Android*, LLVM, OpenCL, Qt, etc

```
hunter_add_package(Boost COMPONENTS system filesystem iostreams)
find_package(Boost CONFIG REQUIRED system filesystem iostreams)
```

References

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Thank you
for your attention
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Questions?