Dr Ivan Čukić
KDAB, KDE

(DON'T) USE COROUTINES FOR THIS

INTRO TO
RECURSION
OF HAPPINESS
IN THE ZEN GARDEN
OF CHAINS

ABOUT ME

- KDAB PM, TL, SSE
  Trusted Software Excellence
- Author of “Functional Programming in C++”
  available in English, Chinese, Korean, Russian, Polish
- Trainer / Consultant
- ISO WG21
- KDE developer
- Former university professor

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PROG C++

Too old to Rock 'n' Roll,
to young to die

– Ian Anderson

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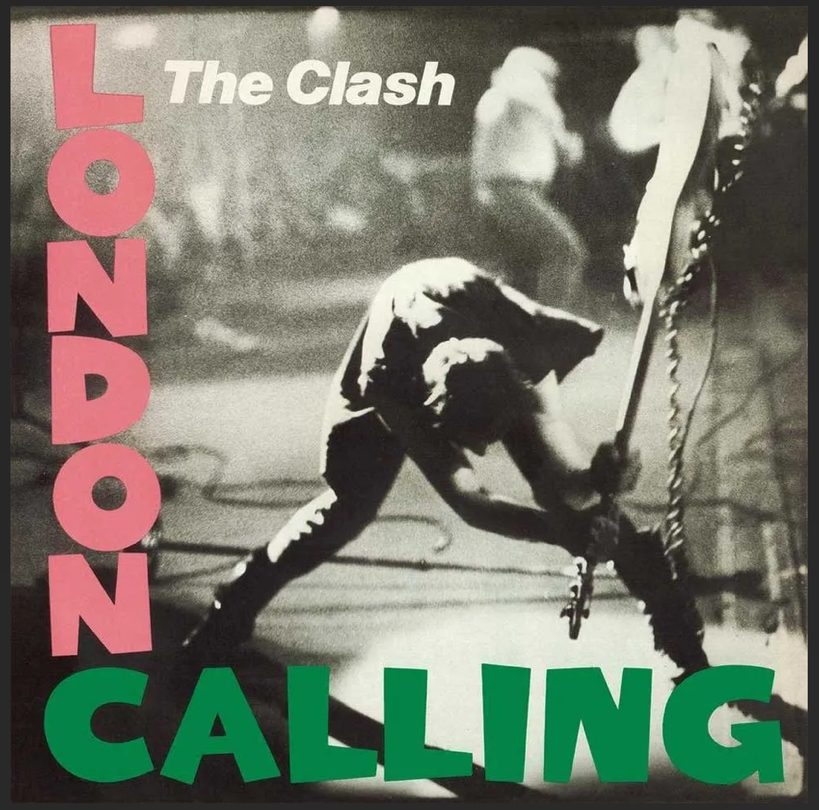
PUNK C++



Berlin Calling

– Meeting C++

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DISCLAIMER

The code in this presentation is slideware,
with chunks written by AI.
Do not use in production.

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Functions shall not call themselves,
either directly or indirectly.

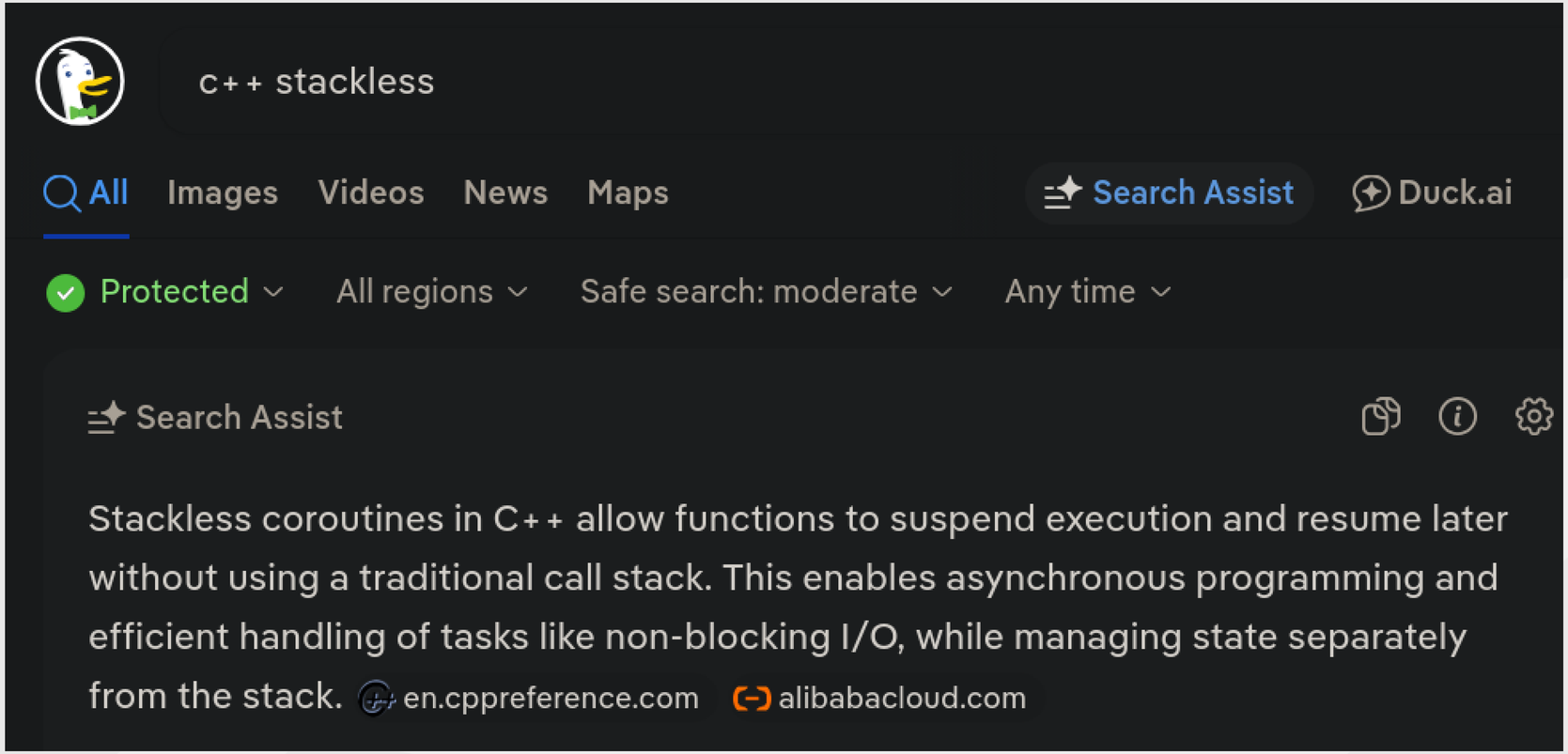
Variables local to a function are stored in the call stack.

If a function calls itself directly or indirectly several times,

the available stack space can be exceeded,

causing serious failure.

STACKLESS



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RECURSION

```
co_recursion<int> fib(int n) {
    if (...) //
    auto last = co_await fib(n);
    auto penultimate = co_await fib(n - 1);
    co_return last + penultimate;
}
```

Done in collab with S. Malkov and P. Djordjević.

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NO SAINTS HERE

HALO – Heap Allocation eLision Optimization (P0981)

```
.
std::generator<int> range(int from, int to) {
    for (int i = from; i < to; ++i)
        co_yield i;
}

auto s = range(1, 10);
return std::accumulate(s.begin(), s.end(), 0);
```

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RECURSION

```
template<typename TResult>
struct co_recursion {
    struct promise_type {
        static void* operator new(std::size_t count) { ... }
        static void* operator new[](std::size_t count) { ... }
        static void operator delete(void* ptr, std::size_t sz) { ...
        static void operator delete[](void* ptr, std::size_t sz)  {
        ...
    };
};
```

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RECURSION

```
template<typename TResult>
struct co_recursion {
    struct promise_type {
        std::suspend_always initial_suspend()
            noexcept { return {}; }
        std::suspend_always final_suspend()
            noexcept { return {}; }
        ...
    };
};
```

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RECURSION

```
template<typename TResult>
struct co_recursion {
    bool await_ready() const {
        return false;
    }

    TResult await_resume() const;
    void await_suspend(coro_handle cont);
};
```

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RECURSION

```
template<typename TResult, typename THandle>
struct recursion_context {
    TResult result;
    std::stack<THandle> handles_to_resume;
};
```

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RECURSION

```
TResult await_resume() const {
    // result is set in promise_type::return_value
    return recursion_context->result;
}

void await_suspend(coro_handle cont) {
    recursion_context = cont.promise()
        .promise_recursion_context;
    recursion_context->handles_to_resume.push(cont);
}
```

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RECURSION

```
template<typename T>
T get(const co_recursion<T> &rec_def) {
    typename co_recursion<T>::context context;
    rec_def.context = std::addressof(context);
    context.handles_to_resume.push(rec_def.handle);

    while (!context.handles_to_resume.empty()) {
        ...
    }

    return context.result;
}
```

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RECURSION

```
while (!context.handles_to_resume.empty()) {
    auto &current_handle = context.handles_to_resume.top();
    if (current_handle.done()) {
        current_handle.destroy();
        context.handles_to_resume.pop();

    } else {
        current_handle.promise().promise_recursion_context =
            std::addressof(context);
        current_handle.resume();
    }
}
```

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DEFINITION

Definition (not) – Coroutines are a mechanism to redefine how (parts of) the C++-abstract machine works.

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HOOKS

```
.
struct logger {
    void increase_indent() { indent++; }
    void decrease_indent() { indent--; }
    void print(auto&& ... args) {
        log << std::string(indent * 4, ' ');
        // log the args
    }
};
```

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HOOKS

Custom contextual data for function execution.

Shared context for all, but also per-call context.

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DEFINITION

Definition (not) – Coroutines are a mechanism to hook into function call events and provide shadow contextual data.

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HAPPY PATH

C++ error handling, let’s abuse the co_await operator

Antoine Morrier

https://cpp-rendering.io/

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HAPPY PATH

```
co::expected<std::string, err_t> get_input();
co::expected<email_t, err_t> parse_email(const std::string&);

co::expected<std::string, err_t> generate_email_link() {
    std::string input = co_await get_input();
    auto email = co_await parse_email(input);
    auto html = format_link(email->user, email);
    co_return html;
}
```

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HAPPY PATH

```
template<typename T, typename E>
struct promise_expected {
    co::expected<T, E>* result_ptr = nullptr;
    co::expected<T, E> get_return_object();

    std::suspend_never initial_suspend() ...
    std::suspend_never final_suspend() ...

    void return_value(T value);
    void unhandled_exception() { ... }
};
```

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HAPPY PATH

```
template<typename T, typename E>
co::expected<T, E>
promise_expected<T, E>::get_return_object() {
    co::expected<T, E> result;
    result_ptr = &result; // !!!
    return result;
}
```

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HAPPY PATH

```
template<typename T, typename E>
void promise_expected<T, E>::return_value(T value) {
    if (result_ptr) {
        result_ptr->value_ = std::move(value);
    }
}
```

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HAPPY PATH

```
struct expected {
    struct awaiter {
        co::expected<T, E>& exp;

        bool await_ready() const noexcept {
            return exp.has_value();
        }

        T await_resume() {
            return *std::move(exp);
        }
```

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HAPPY PATH

```
struct expected {
    struct awaiter {
        void await_suspend(auto h) {
            if (h.promise().result_ptr) {
                h.promise().result_ptr->value_ =
                    std::unexpected(exp.error());
            }
            h.destroy();
        }
    };
```

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HAPPY PATH

```
co::expected<int, err_t> f() {
    auto* _obj =
        co_await co_dynamic_cast<SubClass*>(obj);
    ...
    return _obj->size();
}
```

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MANY PATHS

```
struct inhale_t { int depth; quality_t quality; };
struct peak_t { seconds stillness; };
struct exhale_t { seconds release; };
struct rest_t { seconds stillness; string thought; };

using state = co::variant<
    inhale_t, peak_t, exhale_t, rest_t>;
```

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MANY PATHS

```
state_t inhale_update(state_t state)
{
    auto inhaling = co_await co_get<inhale_t>(state);

    inhaling.depth++;

    co_return inhaling;
}
```

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MANY PATHS

```
state_t inhale_to_peak(state_t state)
{
    auto _ = co_await co_get<inhale_t>(state);

    co_return peak_t{12};
}
```

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MANY PATHS

```
state_t peak_update(state_t state)
{
    auto inhaling = co_await co_get<peak_t>(state);

    inhaling.stillness++;

    co_return inhaling;
}
```

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MANY PATHS

```
auto breathing_cycle =
        fn::compose(
            peak_update,
            inhale_to_peak,
            inhale_update,
            ...)
```

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DEFINITION

Definition (not) – Coroutines are the most complex control flow structure in C++ that somehow turned out to be useful for asynchrony and lazy evaluation.

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PARSER COMBINATORS

https://github.com/no-more-secrets/parsco

.

```
parsco::parser<char> parse_two_same() {
    char c1 = co_await parsco::any_chr();
    char c2 = co_await parsco::any_chr();
    if (c1 != c2) {
        co_await parsco::fail( "expected two equal chars" );
    }
    co_return c1;
}
```

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QT TASKS

https://qcoro.dev by Daniel Vratil

.

```
QCoro::Task<> MyClass::fetchData() {
    QNetworkReply nam;
    auto *reply = co_await nam.get(...);
    const auto data = co_await reply->readAll();
    reply->deleteLater();
    doSomethingWithData(data);
}
```

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DEFINITION

Definition (not) – Coroutines are a way to chain weird kinds of functions in C++.

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COMPLEXITY

- Functions that can be suspended
- Functions on a custom abstract machine
- Way to register hooks for function invocation
- Complex control flow structure
- State machines
- Parser combinators
- Monads?

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(Fran's, Anthony's, mine, ...)