Dr Ivan Čukić KDAB, KDE

PROG C++

INTRODUCTION

WRAPS
SWAPS
STATES
ERRORS
VALUES
SAFETY

ABOUT ME

- KDAB PM, TL, SSE

  Software expertise in Qt, C++ and 3D / OpenGL
- Author of “Functional Programming in C++”

  available in English, Chinese, Korean, Russian, Polish
- Trainer / Consultant
- ISO WG21
- KDE developer
- University professor

10 YEARS

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

– Ian Anderson

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PROG ROCK

Prog rock is a broad genre of rock music. The style was an emergence of psychedelic bands who abandoned standard pop traditions in favour of instrumentation and compositional techniques more frequently associated with jazz, folk, or classical music.

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PROG C++

Prog C++ is a broad genre of C++ code. The style was an emergence of psychedelic developers who abandoned standard C with classes traditions in favour of instrumentation and compositional techniques more frequently associated with generic, functional, or value-based object oriented coding practices.

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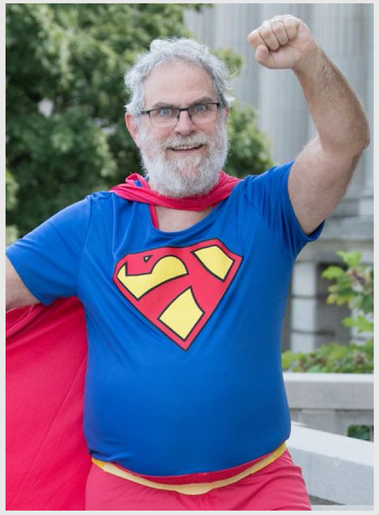
DISCLAIMER



Make your code readable. Pretend the next person who looks at your code is a psychopath and they know where you live.

– Philip Wadler

DISCLAIMER

The code snippets are optimized for presentation,
it is often not production-ready code.

- `_t` suffix is used for user types,
- assumes `using std::string_literals`,

  ...

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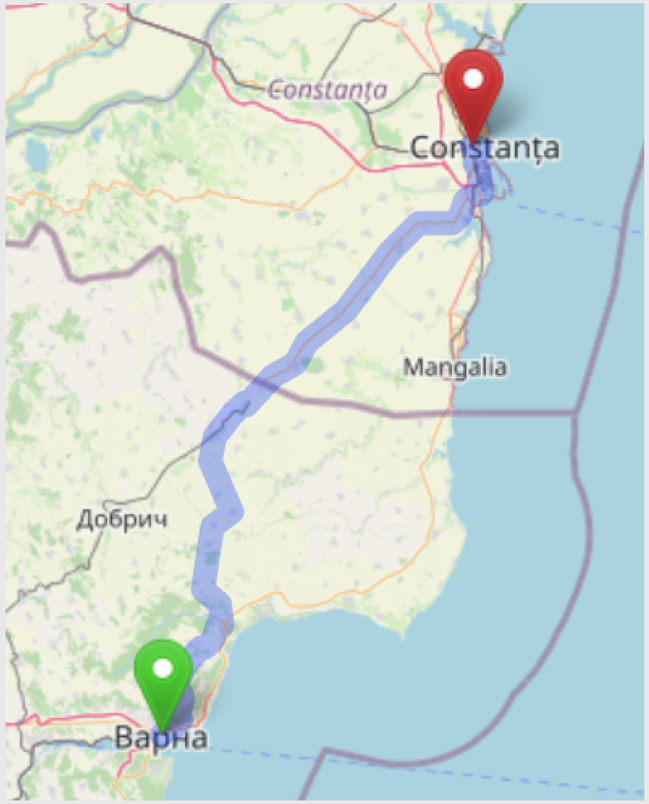
ALMOST ALWAYS CONST



Constanța, Romania

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CONST...RUCTION

```
const person_t person("Martha Jones"s, 42);
```

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CONST...RUCTION

```
person_t person("Martha Jones"s, 42);
person.bad_hash =
        person.name.size() ^ person.age;
```

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IMMEDIATE LAMBDA

```
const auto person = [] {
    person_t result;
    result.age = 42;
    result.name = "Martha Jones"s;
    result.bad_hash =
        result.name.size() ^ result.age;
    return result;
}();

print_person(person);
```

LAZY LAMBDA

```
const lazy person = [] {
    person_t result;
    result.age = 42;
    result.name = "Martha Jones"s;
    result.bad_hash =
        result.name.size() ^ result.age;
    return result;
};

print_person(person);
```

LAZY LAMBDA

```
template<typename Fn>
class lazy {
public:
    using value_type = std::invoke_result_t<Fn>;

private:
    Fn m_function;
    mutable std::once_flag m_once;
    mutable std::optional<value_type> m_data;

    // ...
```


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LAZY LAMBDA

```
    // ...

    operator const value_type &() const
    {
        std::call_once(m_once, [&] {
            m_data = std::invoke(m_function);
        });
        return *m_data;
    }
};
```

PHASES OF CONST

- Building the value
- Using the value

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ALMOST ALWAYS CONST

Declare everything const by default, except:

- Member variables
- Local variables that will be returned from the function
- Variables you want to give away

ALWAYS CONST

Can we have a move-enabled const?

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IMMUTABLE<T>

```
template<typename T>
class immutable {
    T m_value;

    // ...
};
```

Applied rule: Make everything const, except member variables.

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IMMUTABLE<T>

```
template<typename T>
class immutable {
    // ...
    immutable(const immutable<T>& other) = default;
    immutable(immutable<T>&& other) = default;
    immutable& operator=(const immutable<T>& other) = default;
    immutable& operator=(immutable<T>&& other) = default;
    // ...
};
```

IMMUTABLE<T>

```
template<typename T>
class immutable {
    // ...
    operator T& () const& { return m_value; }
    const T& operator*() const& { return m_value; }
    const T* operator->() const& {
        return std::addressof(m_value);
    }
};
```

IMMUTABLE<T>

```
template<typename T>
class immutable {
    // ...
    operator T&& () && { return std::move(m_value); }
};
```

Applied rule: Make everything const, except variables you want to give away.

IMMUTABLE<T>

```
struct person_t { immutable<std::string> name; /* ... */ };

auto get_person() {
    immutable<person_t> result("Martha Jones"s, 42);
    // ...
    return result;
}

auto create_person() {
    immutable person = get_person();
    database.add(std::move(person));
}
```

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IMMUTABLE AND LAZY

```
lazy l_person = [] { /* ... */ };
immutable i_person = [] { /* ... */ }();
```

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AGAINST THE GRAIN

It is fine to implement things that go against the language...

... when the language is insufficient or wrong
for your use-case or domain.

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AGAINST THE GRAIN

Belle Views on C++ Ranges,
their Details and the Devil

Nicolai Josuttis, Meeting C++ 2022

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ASSIGNMENT

```
class person_t {
    // ...
    person_t& operator=(const person_t& other) = default;
    person_t& operator=(person_t&& other) = default;
    // ...
};
```


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ASSIGNMENT

```
class person_t {
    // ...
    person_t& operator=(const person_t& other) = default;
    person_t& operator=(person_t&& other) = default;
    // ...

private:
    std::string name;
    std::string surname;
};
```

ASSIGNMENT

```
person_t person("Martha"s, "Jones"s);

person.name = "John"s; // exception
person.surname = "Smith"s;
```

ASSIGNMENT

```
person_t person("Martha"s, "Jones"s);

person_t new_person;
new_person.name = "John"s;
new_person.surname = "Smith"s;

swap(person, new_person);
```

ASSIGNMENT

```
friend void swap(person_t& left, person_t& right) noexcept {
    std::swap(
        std::tie(left.name, left.surname),
        std::tie(right.name, right.surname));
}
```


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ASSIGNMENT

```
class person_t {
    person_t& operator=(const person_t& other) {
        auto temp = other;
        swap(*this, temp);
        return *this;
    }
};
```

ASSIGNMENT

```
class person_t {
    person_t& operator=(person_t&& other) {
        auto temp = std::move(other);
        swap(*this, temp);
        return *this;
    }
};
```


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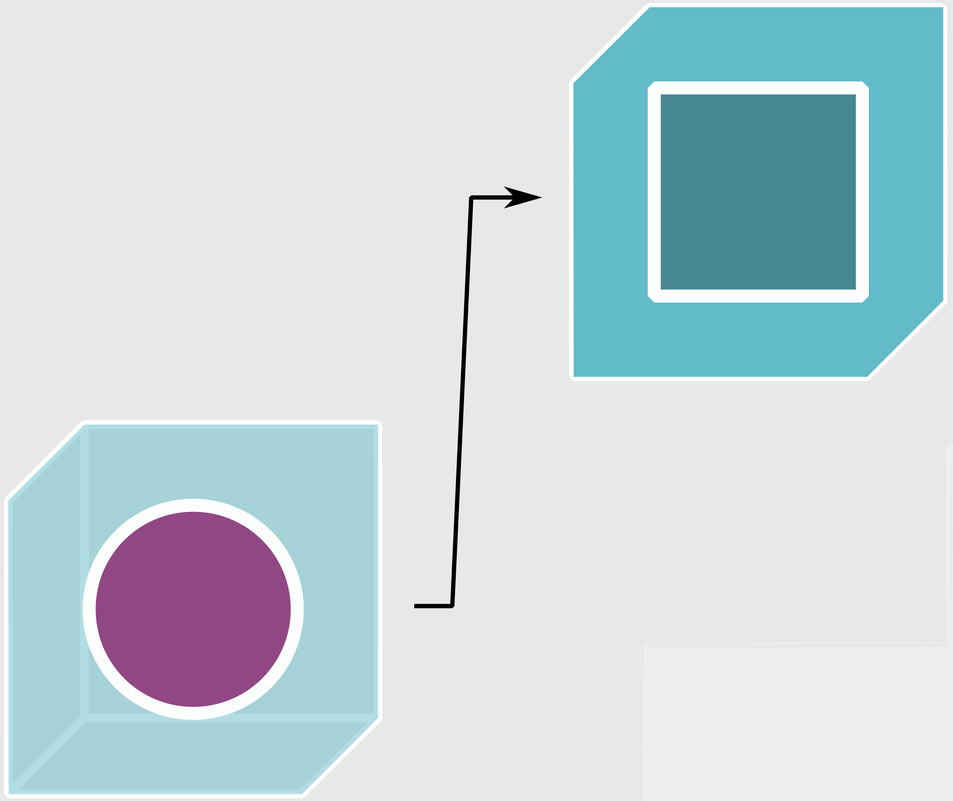
ASSIGNMENT



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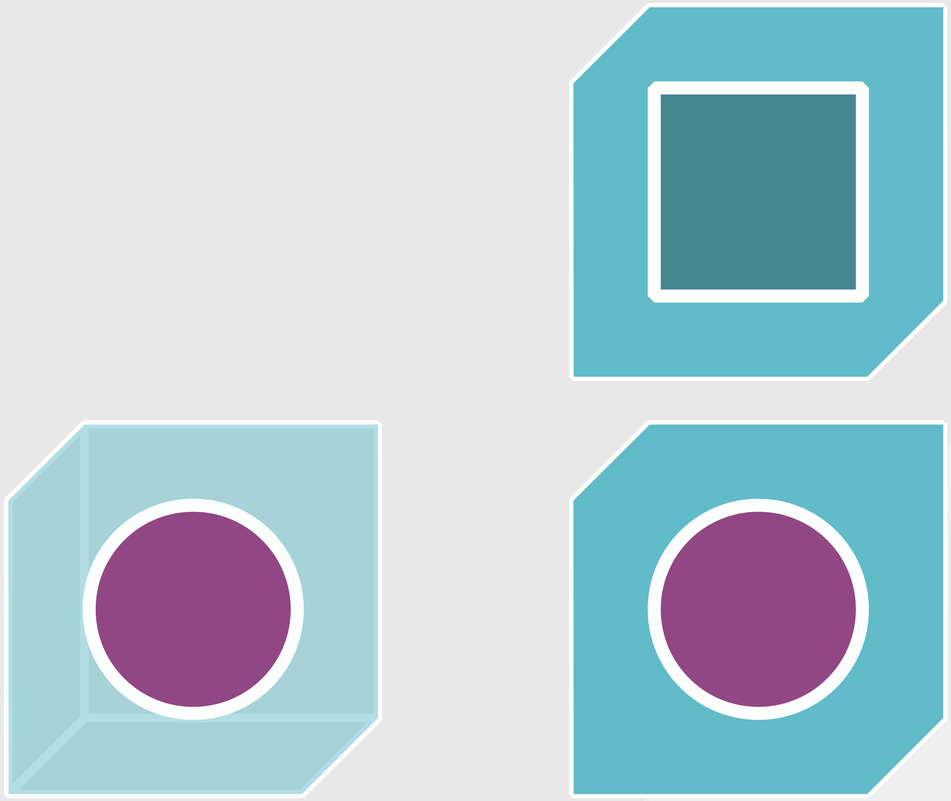

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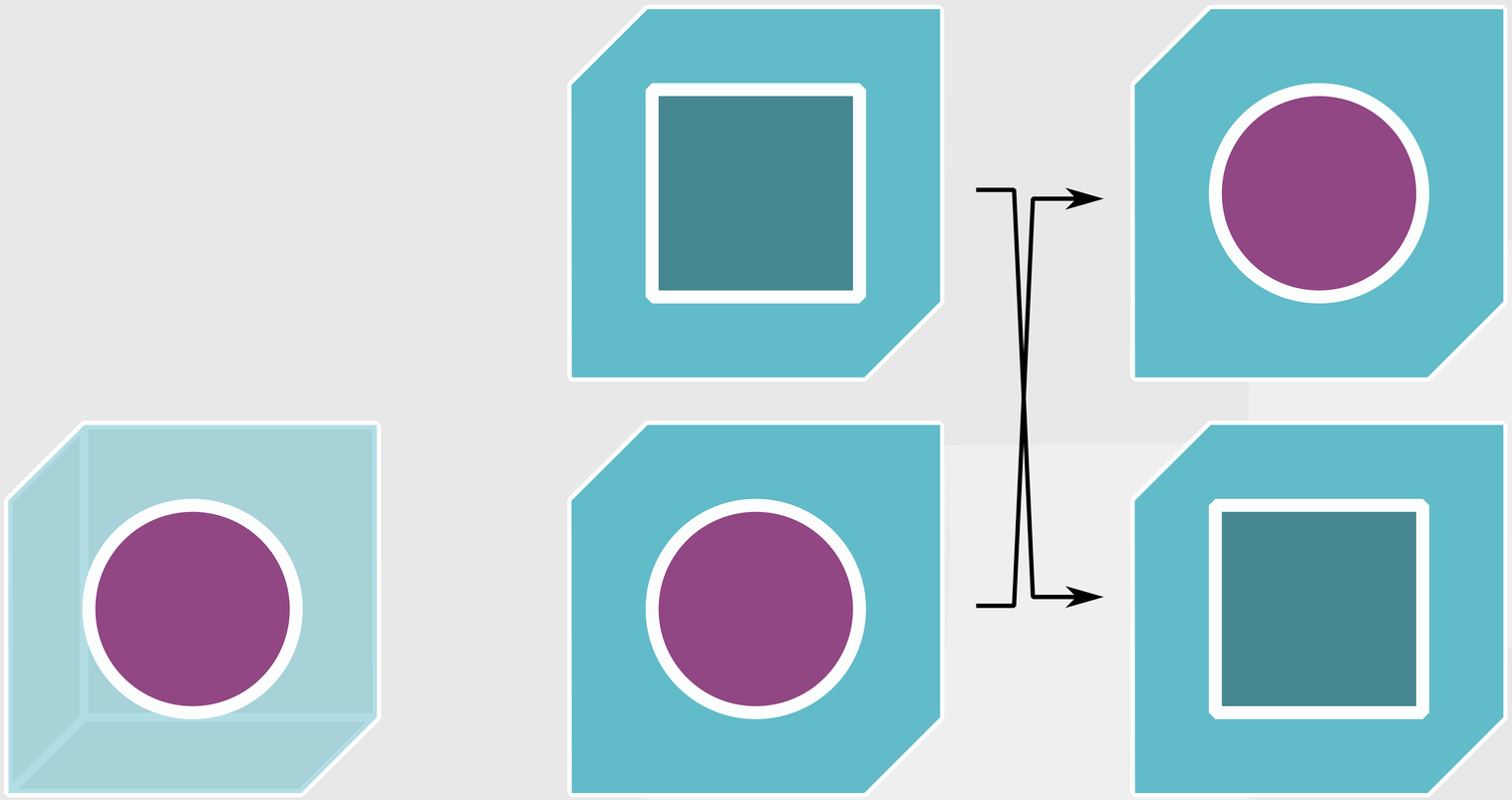

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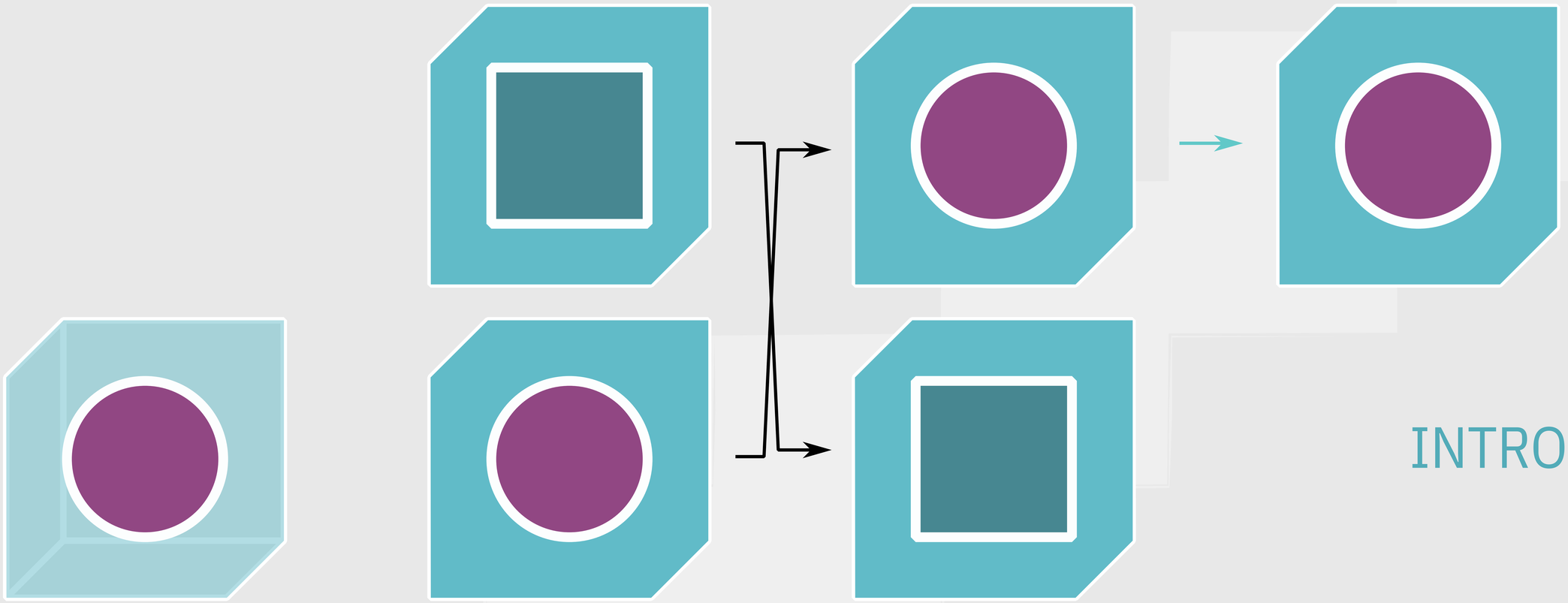

PREREQUISITES

Member variables can not be references:

```
struct person_t {
    std::string name;
    std::string surname;
    std::string& quick_access_name;

    // ...
};
```

RULE

Member variables should be value types.

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SWAPPING

- Double buffering
- Processing collections in separate threads

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MARK AND SWEEP

```
mark(root_object);
for (auto* object: objects) {
    if (object->is_marked()) {
        object.marked = false;
    } else {
        delete object;
    }
}
```


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MARK AND SWEEP

```
mark(root_object);
for (auto* object: objects) {
    if (object->is_marked()) {
        object.marked = false;
    } else {
        garbage.push_back(object);
    }
}
```


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MARK AND SWEEP

```
garbage_t current_garbage;
swap(garbage, current_garbage);
gc.collect(current_garbage);
```

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STATES

A large fraction of the flaws in software development are due to programmers not fully understanding all the possible states their code may execute in.

– John Carmack

STATES

```
struct page_t {
    std::string url;
    socket_t connection;
    bool loading;
    std::unique_ptr<html::dom> dom;
};
```


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STATES

"A nice bag to put things in"

– Miloš Anđelković, Class Layout

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STATES

```
struct page_t {
    // ...
    void render() {
        [[assert: dom != nullptr]];
        // ...
    }
};
```


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STATES

```
struct page_t {
    // ...
    void execute_event_loop() {
        [[assert: dom != nullptr]];
        [[assert: not loading]];
        // ...
    }
};
```

STATES

```
void load_page() {
    [[assert: dom == nullptr]];
    [[assert: not loading]];
    [[assert: not connection]];

    connection = open(url);
    loading = true;

    // ...
```

STATES

```
struct page_t {
    std::string url;
    socket_t connection;                    // connected
    bool loading;                           // false
    std::unique_ptr<html::dom> dom;         // not nullptr
};
```

STATES

```
struct initial_t { std::string url; };

struct loading_t {
    immutable<socket_t> connection;
    immutable<std::unique_ptr<html::dom>> dom;
};

struct loaded_t {
    immutable<std::unique_ptr<html::dom>> dom;
};
```

STATES

```
using page_t = std::variant<
    initial_t,
    loading_t,
    loaded_t>;
```


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STATES

```
std::visit(
    overloaded {
        [&] (const initial_t& initial) {
            page = start_loading(initial.url);
        },
        // ...
    }, page);
```


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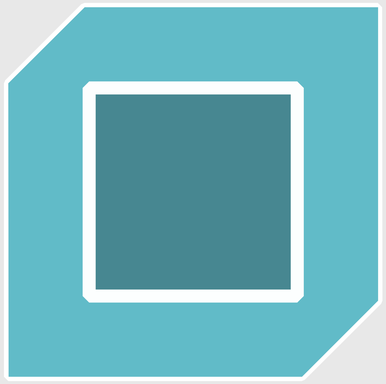
STATES

```
if (auto* loading = std::get_if<loading_t>(&page)) {
    page = loaded_t{ std::move(loading.dom) };
}
```

STATES



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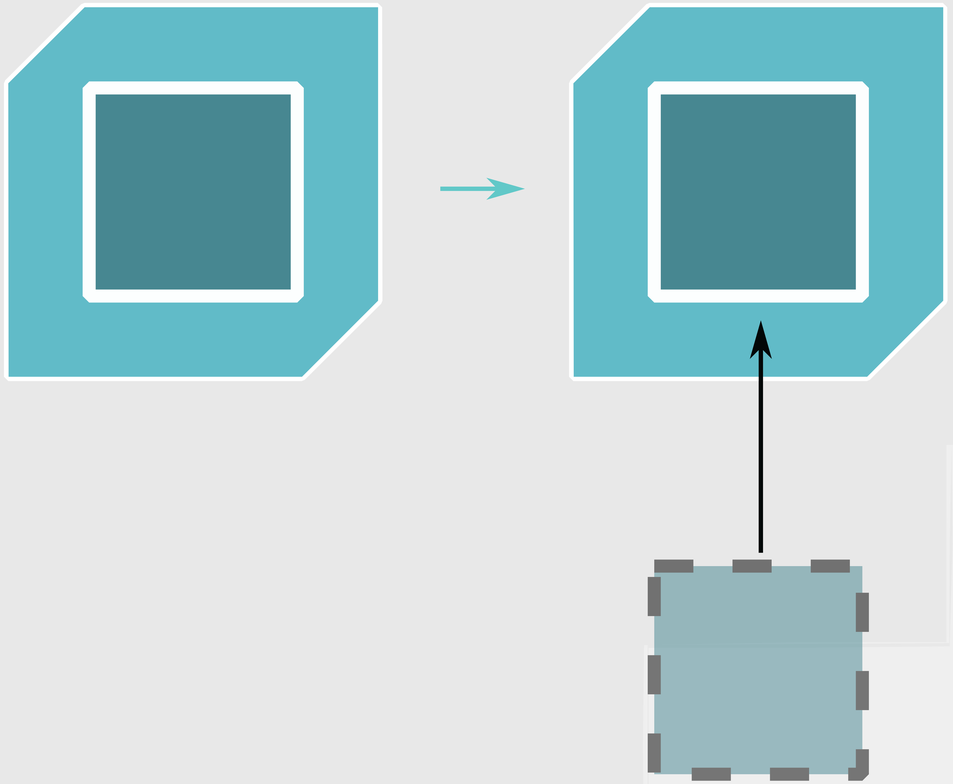
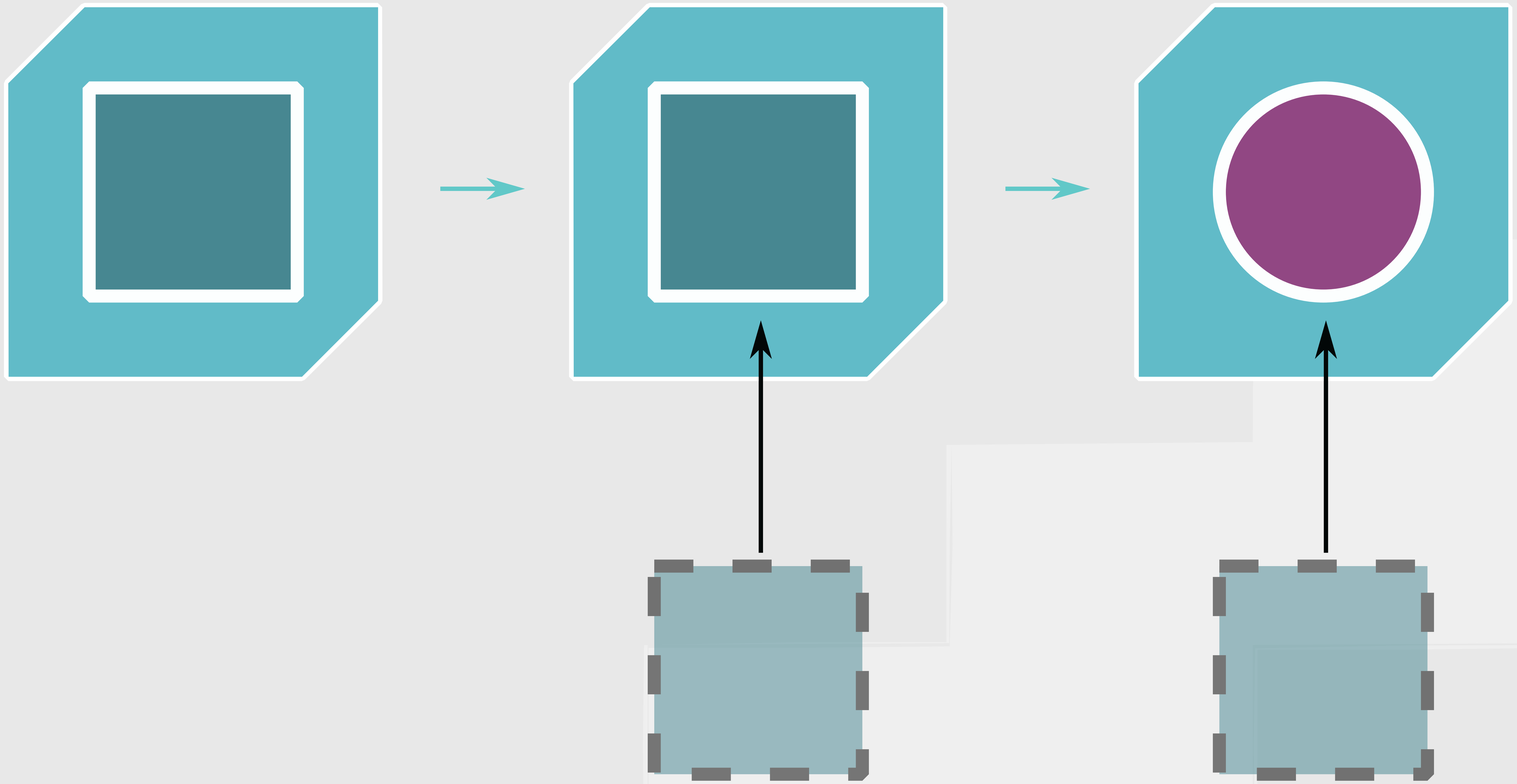
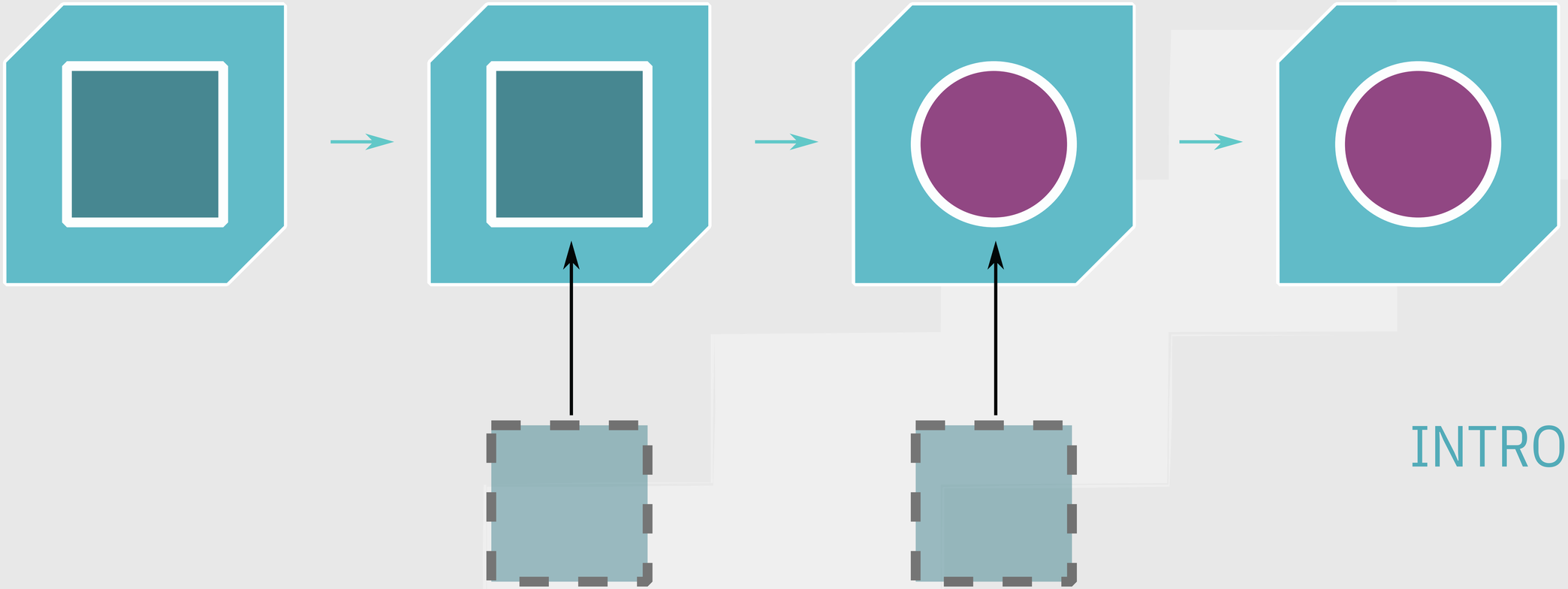


STATES



STATES



STATES

```
page_t new_page;

// generate the new state ...

std::swap(page, new_page);
```

STATES

```
page_t new_page;

if (auto* loading = std::get_if<loading_t>(&page)) {
    new_page = loaded_t{ std::move(loading.dom) };
}

std::swap(page, new_page);
```

STATES

```
std::optional<page_t> new_page;

if (auto* loading = std::get_if<loading_t>(&page)) {
    new_page = loaded_t{ std::move(loading.dom) };
}

if (new_page) std::swap(page, *new_page);
```

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ERRORS

- NaN, -1, ...
- exceptions
- success flags

ERRORS

```
std::expected<Result, Error>
    .transform
    .and_then
    .or_else
```


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ERRORS

```
my::expected<std::string, err_t> get_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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C++ error handling, let’s abuse the co_await operator

Antoine Morrier

https://cpp-rendering.io/

MESS IN THE KITCHEN

- Making lunch
- Cleaning up
- Burnt lunch

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MESS IN THE KITCHEN

Forget about making lunch,
and destroy the kitchen.

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- Try to find the fix
- Continue with the process

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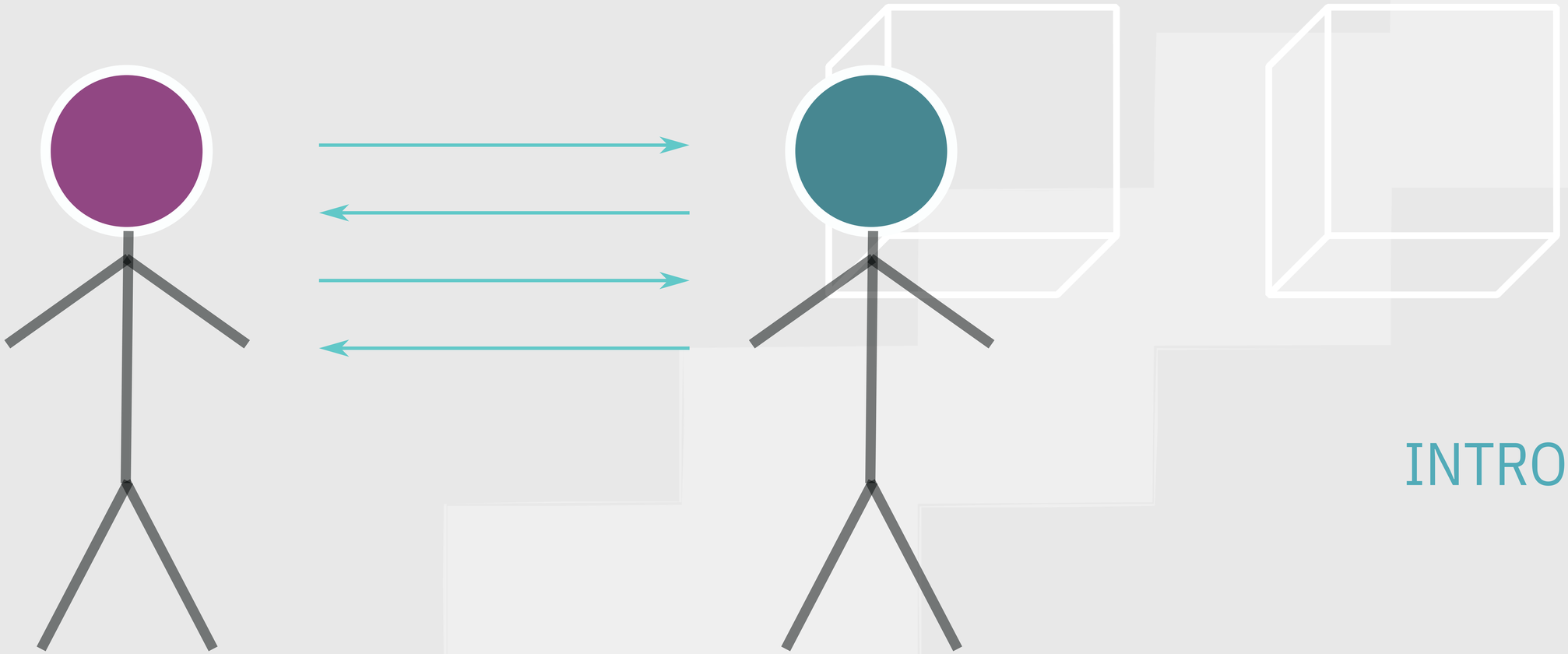
ERRORS

- Fixing, or choosing a fix, is the job of the caller
- Continuation is the job of the calee

ERRORS



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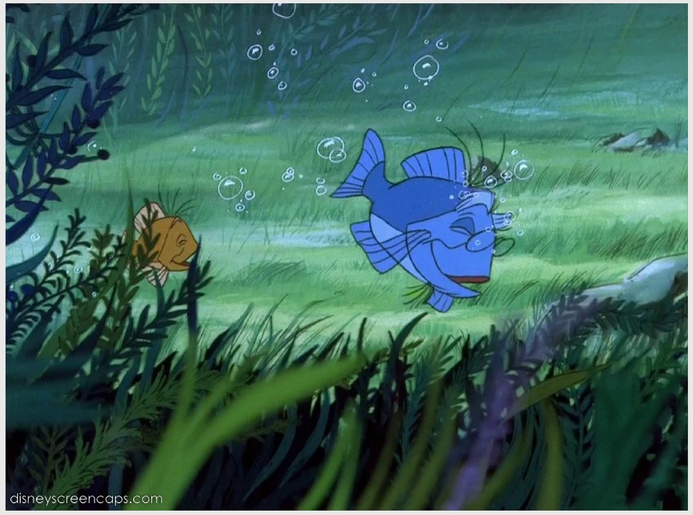
ERRORS



To and fro

Stop and go

That’s what makes the world go round

The Sword in the Stone, (C) Disney

ERRORS

```
enum class error_t {
    number_parsing_error,
    invalid_type_error
};

enum class fix_t {
    use_zero,
    skip_line
};
```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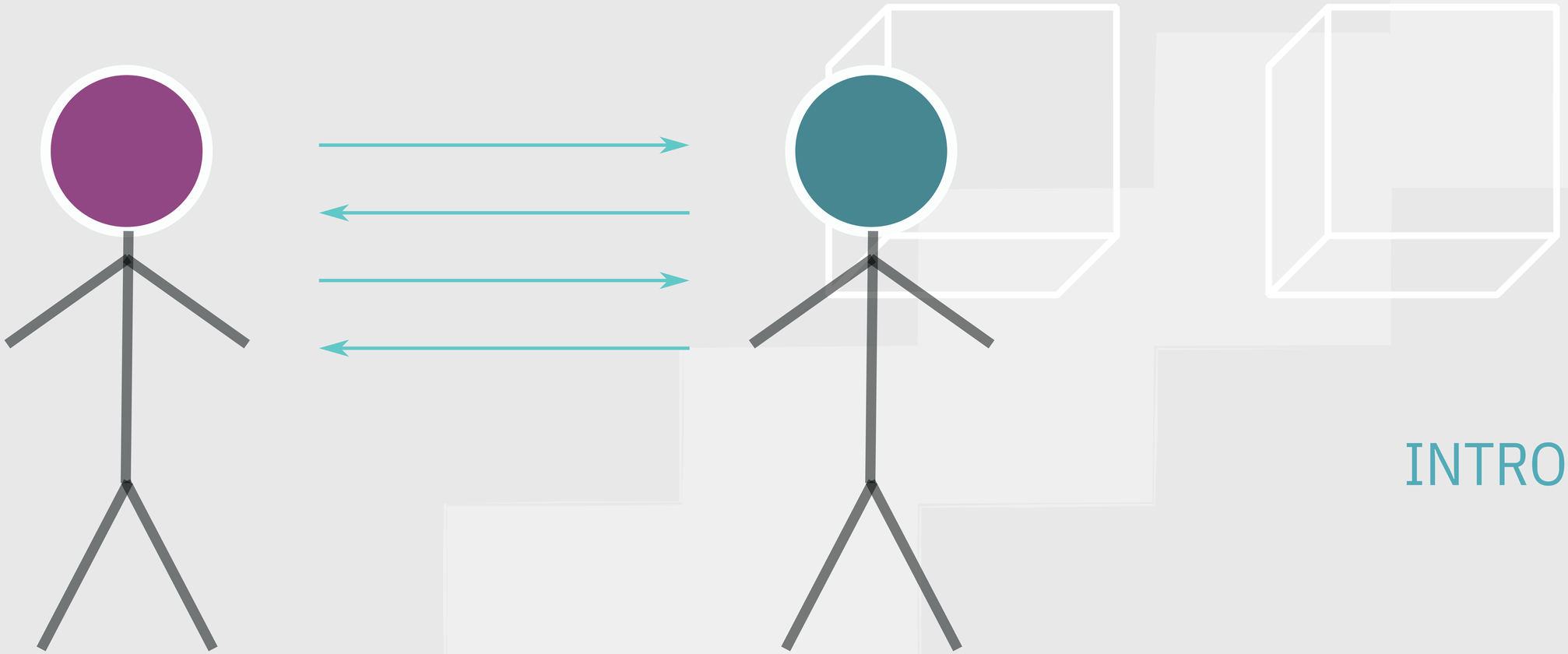
ERRORS



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ERRORS

```
using message_t = std::variant<
    error_t, fix_t>;

template<typename Result>
using result_t = std::expected<
    Result, message_t*>;
```


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ERRORS

```
std::generator<result_t<int>> parse()
{
    message_t message;

    // an error occurred
    message = error_t::invalid_type_error;
    co_yield std::unexpected{
        std::addressof(message)};

    // ...
```


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ERRORS

```
while (true) {
    auto result = co_await parse();

    if (result) // ...

    auto* message = result.error();
    // propose a fix
    (*message) = skip_line;
}
```


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ERRORS

```
std::generator<result_t<int>> parse()
{
    // ...

    // if no error
    co_yield 42;
```


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ERRORS

Allows to continue the process in presence of errors.

Still, if we can not handle a specific error, we can still bail out.

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Regular Revisited

Victor Ciura

VALUES

- Values and variables
- Value assignment semantics

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VALUES

- `std::unique_ptr<const something>`
- `std::shared_ptr<const something>`

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Optimizing Multithreaded Performance

Shivam Kunwar

VALUES

- Construction, destruction
- Copying, moving
- Assignment
- Comparison
- Always valid

```
class page_t {
private:
    class page_private_t;
    std::unique_ptr<page_private_t> m_pimpl;

public:
    // ...
};
```


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VALUES

- Invalid state(s)
- Shallow const
- Copying disabled
- Pointer redirection

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VALUES

```
page_t()
    : m_pimpl(std::make_unique
          <page_private_t>(some, arguments))
{}
```


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```
const& page_private_t pimpl() const;
page_private_t& pimpl();
```

Note: Or use `std::experimental::propagate_const`

```
page_t(const page_t& original)
    : m_pimpl(std::make_unique
          <page_private_t>(original.pimpl()))
{
}

// and copy-and-swap for operator=
```

```
std::shared_ptr<const page_private_t> m_pimpl;
```

COW?

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VALUES

```
void some_function(const page_t& original_page) {
    page_t page = original_page;
}
```


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VALUES

```
class page_t {
    page_t transformed(auto fn) const {
        // ...
    }
}
```


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VALUES

```
template<typename T>
class heap_value {
private:
    std::unique_ptr<T> _data;

public:
    template<typename... Args> requires (...)
    heap_value(Args&& args...)
        : _data(std::make_unique<T>
            (std::forward<Args>(args)...))
    {}

    // ...
```


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VALUES

```
template<typename T>
class heap_value {
    // ...

    const T& operator*() const;
    const T* operator->() const;
    T& operator*();
    T* operator->();

    // swap, copy and move operations...
```


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TYPE ERASURE

Breaking Dependencies:

Type Erasure - The Implementation Details

Klaus Iglberger

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TYPE ERASURE

Dyno: Runtime polymorphism done right

https://github.com/ldionne/dyno

Louis Dionne

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ERRORS
VALUES
SAFETY

Meeting C++ 2023

Ivan Čukić kdab.com, cukic.co

INTRODUCTION
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IDIOMS

```
for (const auto& person: persons) {
    person ... // idiomatic
    persons ... // not idiomatic
}
```


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IDIOMS

```
for (auto index = 0UZ;
     index != persons.size();
     ++index) {

    persons[index] ... // idiomatic
    persons ... // not idiomatic
    index ... // const access is idiomatic
}
```


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IDIOMS

```
std::vector<int> result;
result.resize(words.size());
std::transform(words.cbegin(), words.cend(),
               result.begin(),
               parse_int);
```

IDIOMS

- Previous knowledge
- Comprehension
- Safety

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JF Bastien

Safety and Security: The Future of C++

CppNow 23

```
catch (...) {
    log("Error");
}
```


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IDIOMS

```
for (auto index = 0UZ;
     index != persons.size();
     ++index) {

    persons[index]
}
```

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```
std::vector<int> result;
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               result.begin(), parse_int);
```


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LAZY LAMBDA

```
operator const value_type &() const
{
    std::call_once(m_once, [&] {
        m_data = std::invoke(m_function);
    });

    return *m_data;
}
```

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VALUES

```
template<typename T>
class heap_value {
    // ...
};
```

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IDIOMS

```
std::mutex mutex;

void do_something() {
    mutex.lock();

    // ...

    mutex.unlock();
}
```

IDIOMS

```
std::mutex mutex;

void do_something() {
    std::lock_guard<std::mutex> lock(mutex);
    // or unique_lock

    // ...
}
```


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IDIOMS

Use a recursive mutex by default?

Don’t lock at all?

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IDIOMS

```
private:
    std::mutex mutex;
    struct unique_key { std::lock_guard<std::mutex> lock; }

public:
    unique_key take_key() { ... }

    void do_something(const unique_key&) {
        // ...
    }
```


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LANGUAGE BARRIER

Tsukiji Hongan-Ji

(C) TokyoViews

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LANGUAGE BARRIER

```
volatile int counter = 0;
```

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BENEFITS

- Easier to prove *safety
- Easier to triage bugs
- Easier to prove correctness (easier, not easy)

DOWNSIDES

- Development under heavy chains
- More bureaucracy
- Rewriting everything

GUIDELINES

- TDD + IDD
- Idioms that can become generic functions, should be generic functions
- Idioms that can be coded in a way that is enforced by the compiler, should be
- Other idioms, write static analysis tools