

C++Now 2016

LET'S MAKE A WEB MATCH-3 GAME IN C++14

<https://github.com/modern-cpp-examples/match3>

BEING CROSS-PLATFORM?

WRITE ONCE, DEPLOY EVERYWHERE!

Platform

Desktop Windows / OS X / Linux

Mobile Android / iOS / Windows

Web Chrome / IE / Safari / Firefox

Applications

Mobile	QT/NDK+djinni
--------	---------------

Desktop	QT/wxWidgets
---------	--------------

Web	Emscripten/Cheerp/WebAssembly
-----	-------------------------------

Games

Mobile	NDK+OpenGL+SDL/Cocos2d-x/Marmalade
--------	------------------------------------

Desktop	Unreal Engine/Cocos2d-x
---------	-------------------------

Web	Emscripten/Cheerp/WebAssembly
-----	-------------------------------

COMBINE C++ WITH JS

- Cordova
- Titanium
- ReactNative
- QML

C++ AND THE WEB



**EMSCRIPTEN IS AN LLVM-BASED PROJECT
THAT COMPILES C AND C++ INTO HIGHLY-
OPTIMIZABLE JAVASCRIPT IN ASM.JS FORMAT**


```
#include <iostream>
int main() {
    std::cout << "hello world!" << std::endl;
}
```

```
em++ hello_world.cpp -o index.html
```

```
$browser index.html
```



CHEERP IS THE C++ COMPILER FOR THE WEB

write a web application, or port your existing one, all in C++.
cheerp will generate JavaScript code that can run on any
browser

WEBASSEMBLY

WEBASSEMBLY OR WASM IS A NEW PORTABLE, SIZE- AND
LOAD-TIME-EFFICIENT FORMAT SUITABLE FOR
COMPILATION TO THE WEB

In Progress!

LET'S MATCH SOME CANDIES / JEWELS



CORE MECHANICS

1. Swipe items (2 given items)
2. For given items
 - 2.1 Find matches
 - 2.2 Remove matches
 - 2.3 Scroll down items (which were above removed)
 - 2.4 Generate new items
 - 2.6 Find affected items (new or scrolled items)
 - 2.7 For affected (new given items) items go to 2

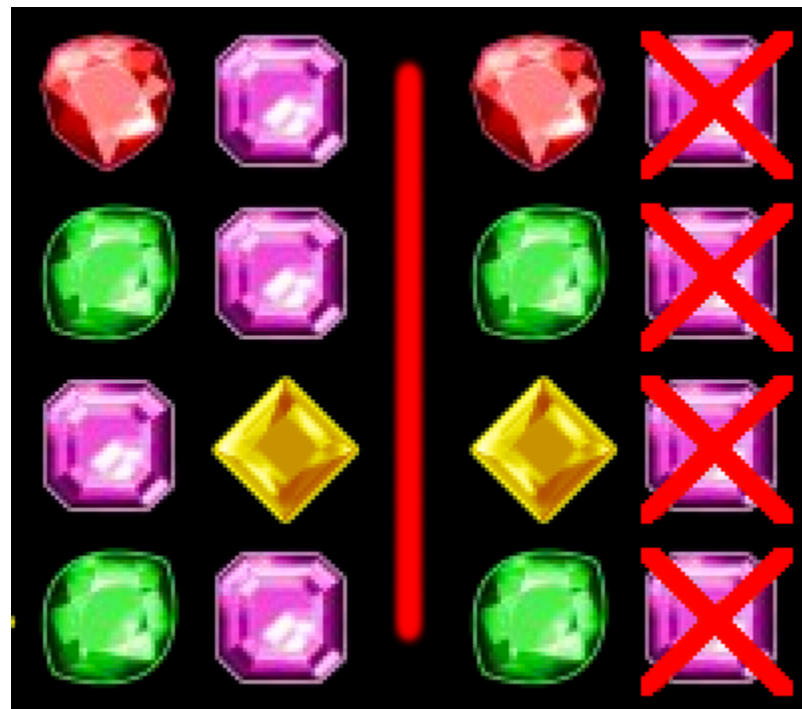
MATCH 3



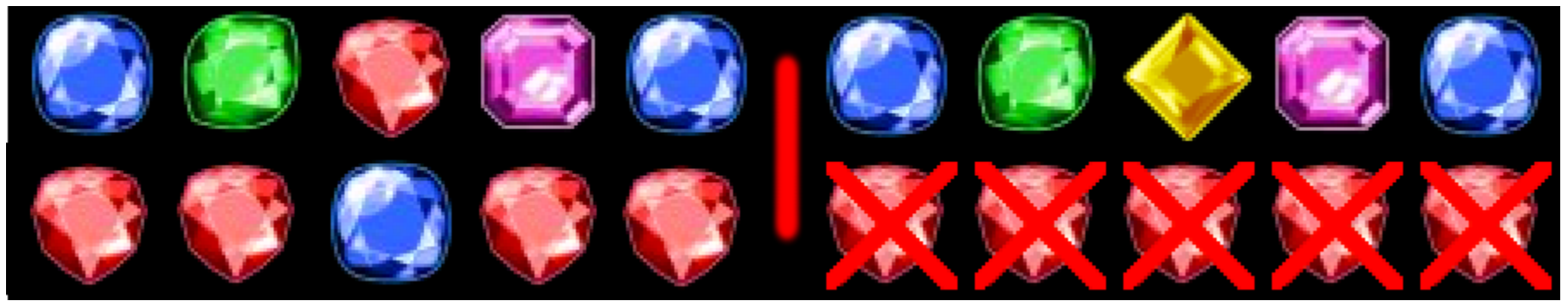
MATCH 3 - TWICE



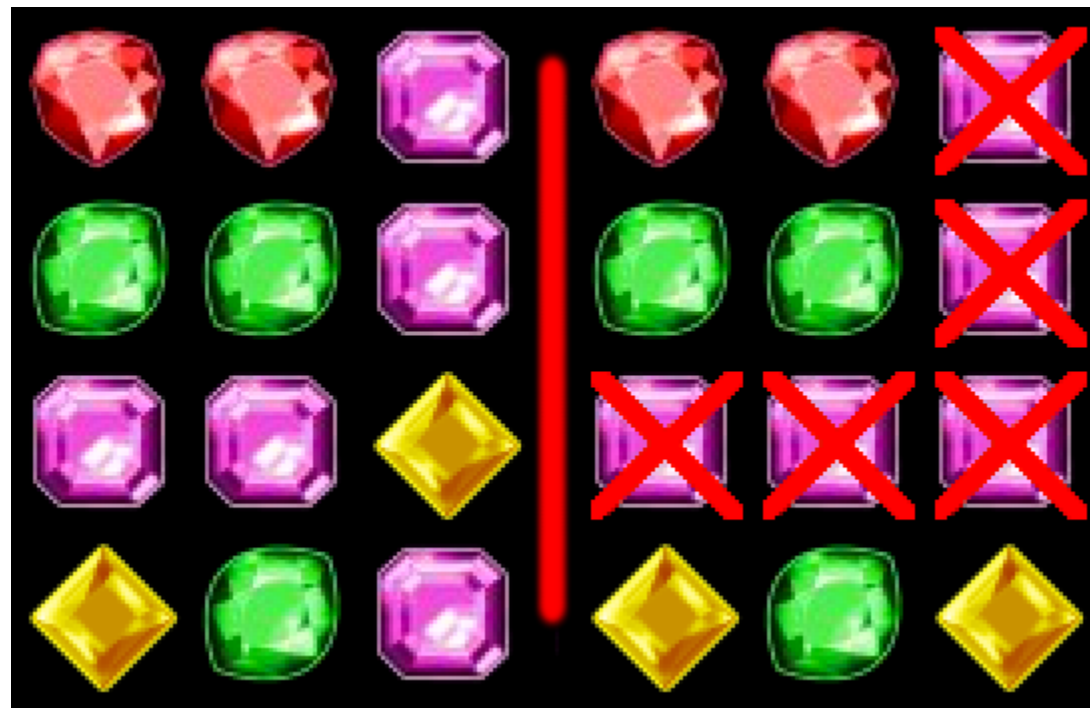
MATCH 4



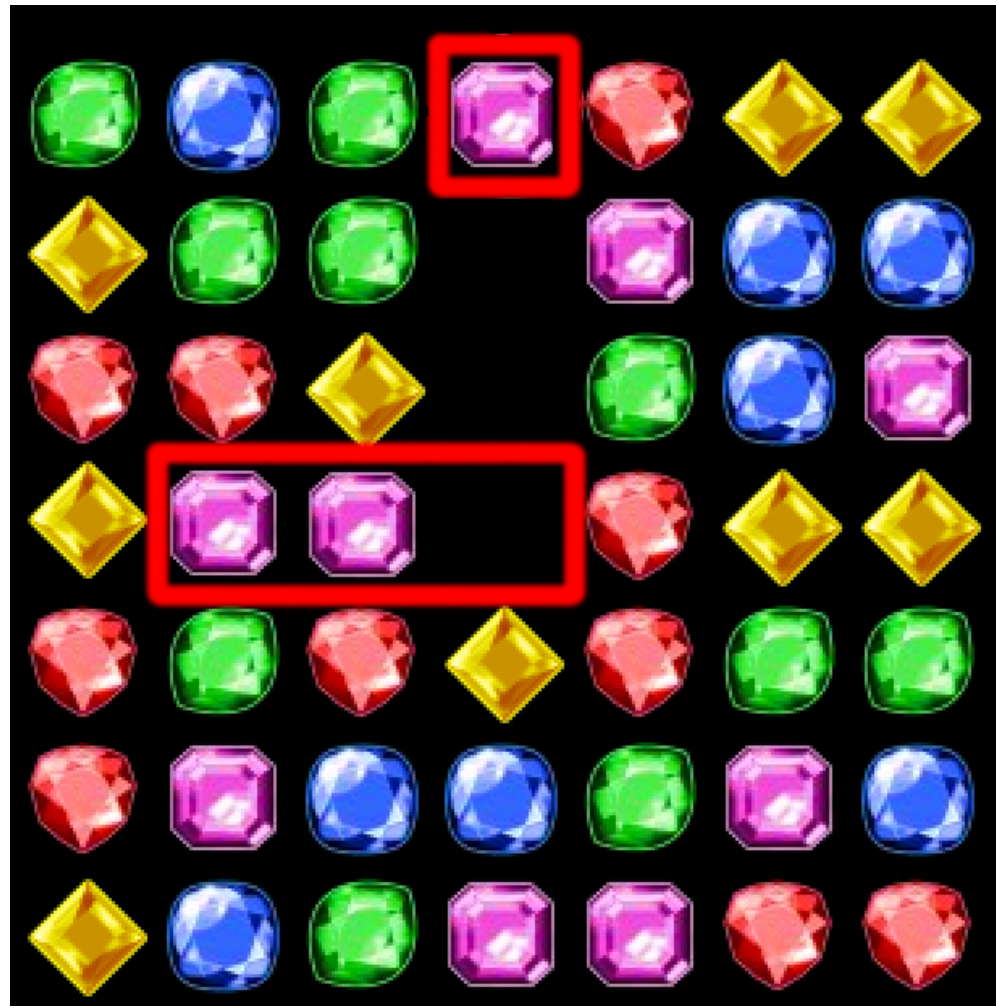
MATCH 5



MATCH L



MATCH CAN GENERATE MORE MATCHES



REQUIREMENTS

C++14 / STL

- Clang-3.7+
- GCC-6+
- Emscripten-1.35

DEPENDENCIES

SDL2

<https://www.libsdl.org>

- SDL2_image
- SDL2_ttf

EXPERIMENTAL BOOST.DI

<https://github.com/boost-experimental/di>

```
#include <boost/di.hpp>

namespace di = boost::di;

struct renderer { int device; };
struct view { view(std::string title, const renderer&) {} };
class model {};
struct controller { controller(model&, view&) {} };
class user {};
struct app { app(controller&, const user&) {} };

int main() {
    auto injector = di::make_injector();
    injector.create<app>();
}
```

EXPERIMENTAL BOOST.MSM-LITE

<https://github.com/boost-experimental/msm-lite>

```
#include <boost/msm-lite.hpp>

namespace msm = boost::msm::lite;

auto guard = [] { return true; };
auto action = [] { std::cout << "action" << std::endl; };

struct hello_world {
    auto configure() const noexcept {
        using namespace msm;
        return make_transition_table(
            * "idle"_s + event1 = "s1"_s
            , "s1"_s + event2 [ guard ] / action = "s2"_s
        );
    }
};
```

```
int main() {
    msm::sm<hello_world> sm;
    using namespace msm;
    sm.process_event(event1{});
    sm.process_event(event2{});
}
```

RANGE-V3

<https://github.com/ericniebler/range-v3>

```
#include <range/v3/all.hpp>

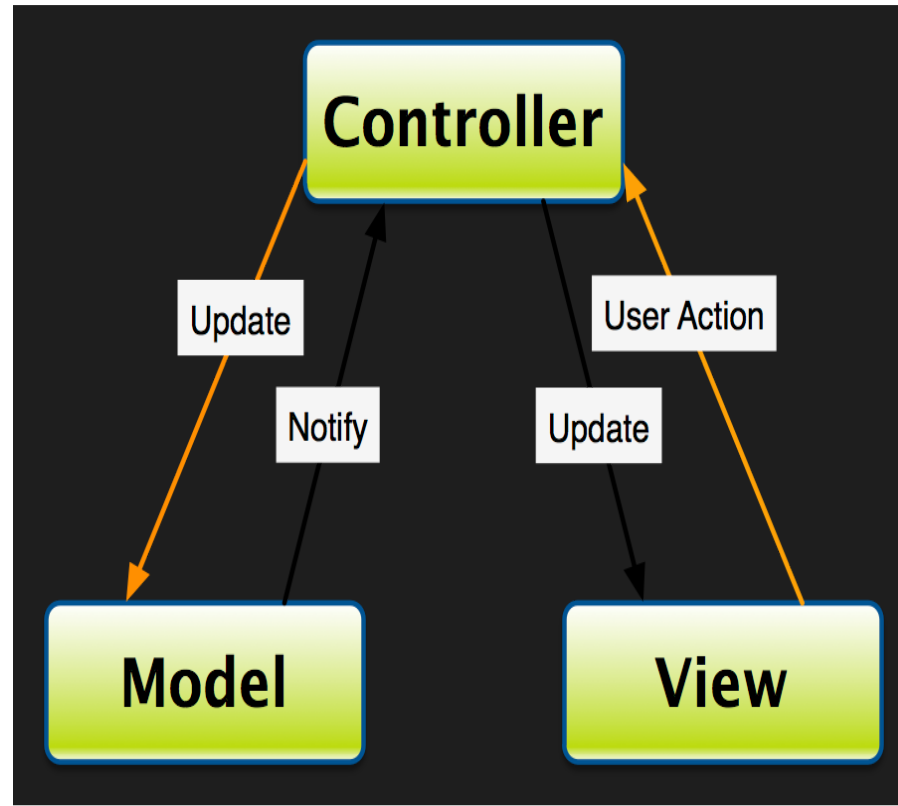
int main() {
    using namespace ranges::view;

    ranges::recursive_range_fn<int> const fibs { [&]{
        return concat(
            closed_ints(0,1)
            , zip_with(std::plus<int>{}, fibs(), tail(fibs()))
        );
    }};

    auto x = take(fibs(), 20);
    ranges::for_each(x, [](int i) { std::cout << i << std::endl; });
}
```

DESIGN

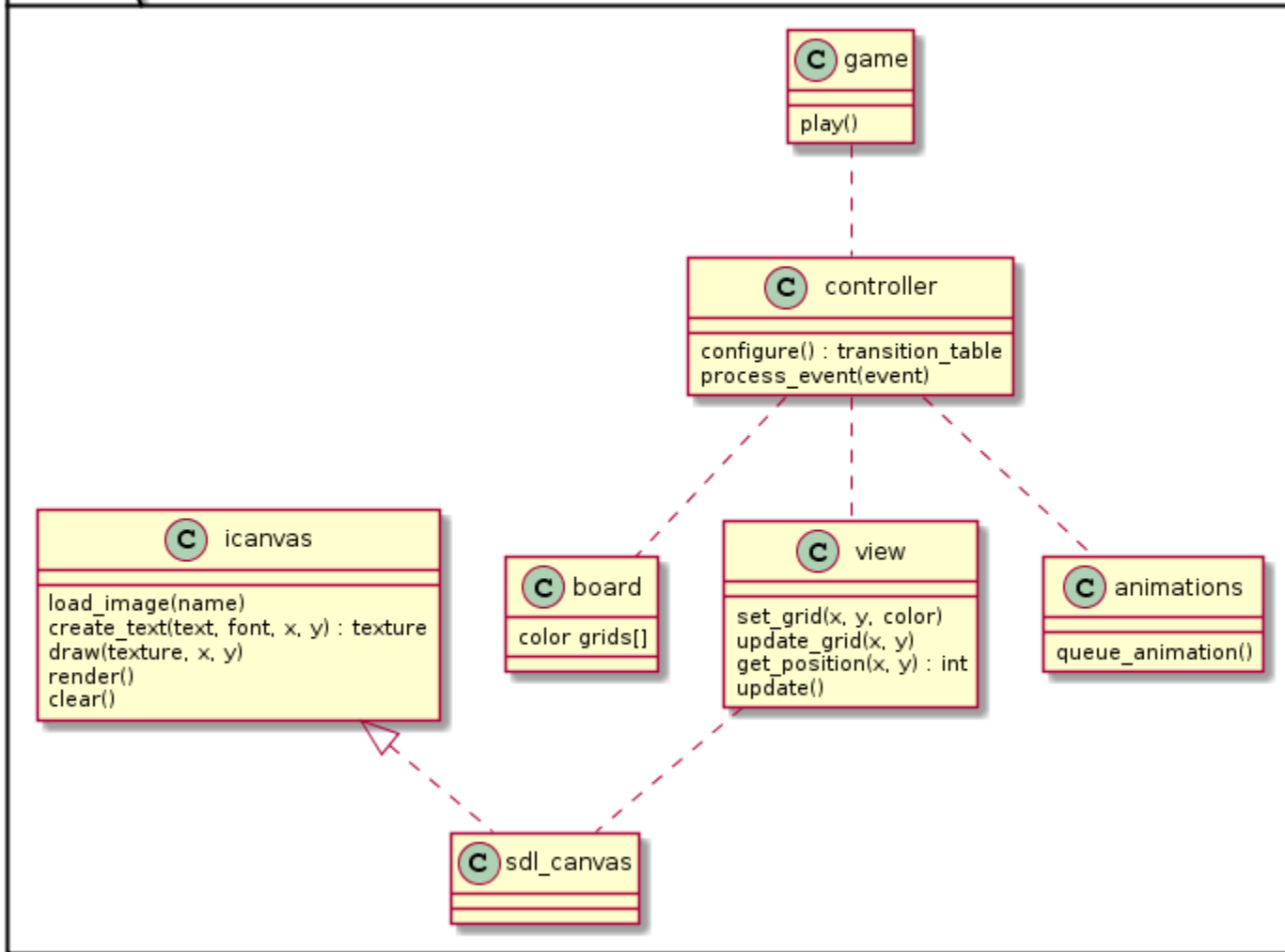
MODEL-VIEW-CONTROLLER



- Separates business logic from UI
- Good for applications and/or games
- Compatible with Entity-Component-System

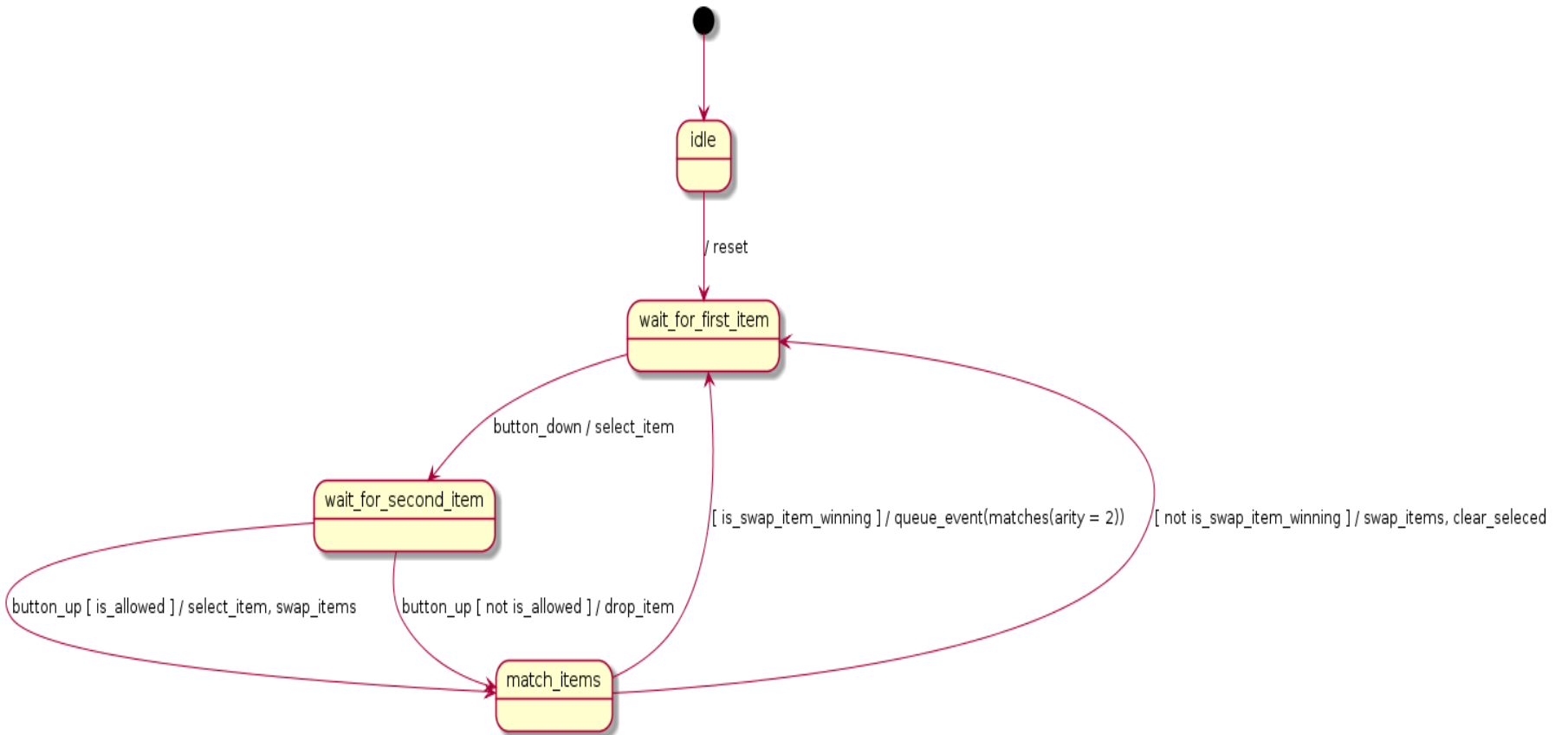
CLASS DIAGRAM

match3

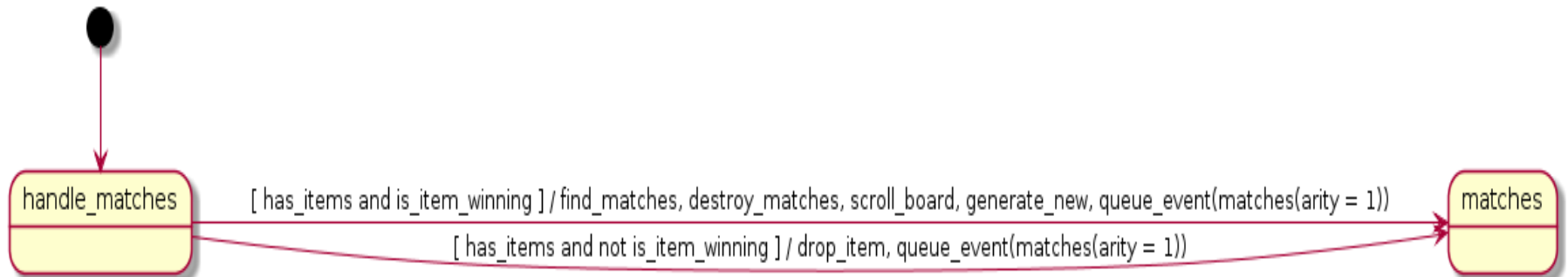


STATE DIAGRAM

Swap



Match



COMPILE & RUN

DESKTOP

COMPILE

```
clang++ -std=c++14 -lSDL2 -lSDL2_image -lSDL2_ttf  
-o match3 src/main.cpp
```

RUN

```
./match3
```

CMAKE

```
mkdir build  
cmake ..  
make app
```

WEB

EMSCRIPTEN

Linux / Mac OSX

<https://s3.amazonaws.com/mozilla-games/emscripten/releases/emsdk-portable.tar.gz>

Windows (*Installer available)

<https://s3.amazonaws.com/mozilla-games/emscripten/releases/emsdk-1.35.0-portable-64bit.zip>

```
# Fetch the latest registry of available tools.  
./emsdk update
```

```
# Download and install the latest SDK tools.  
./emsdk install latest
```

```
# Make the "latest" SDK "active"  
./emsdk activate latest
```

```
# Set the current Emscripten path on Linux/Mac OSX  
source ./emsdk_env.sh
```

```
./emsdk list
```


The following precompiled tool packages are available for download:

```
clang-e1.30.0-64bit
clang-e1.34.1-64bit
(*) clang-e1.35.0-64bit          INSTALLED
(*) node-4.1.1-64bit            INSTALLED
spidermonkey-37.0.1-64bit
spidermonkey-nightly-2015-04-12-64bit
emscripten-1.30.0
emscripten-1.34.1
(*) emscripten-1.35.0          INSTALLED
crunch-1.04
```

The following tools can be compiled from source:

```
clang-tag-e1.36.2-32bit
clang-tag-e1.36.3-32bit
clang-tag-e1.36.2-64bit
clang-tag-e1.36.3-64bit
clang-incoming-32bit
clang-incoming-64bit
clang-master-32bit
clang-master-64bit
emscripten-tag-1.36.2-32bit
emscripten-tag-1.36.3-32bit
emscripten-tag-1.36.2-64bit
emscripten-tag-1.36.3-64bit
emscripten-incoming-32bit
emscripten-master-32bit
emscripten-incoming-64bit
emscripten-master-64bit
```

The following precompiled SDKs are available for download:

```
sdk-1.30.0-64bit
sdk-1.34.1-64bit
*  sdk-1.35.0-64bit          INSTALLED
```

The following SDKs can be compiled from source:

```
sdk-incoming-64bit
sdk-master-64bit
```

COMPILE

```
em++ -std=c++14 -s USE_SDL=2 -s USE_SDL_IMAGE=2 -s USE_SDL_TTF=2
--emrun # log to the console
--preload-file data # images and fonts
--use-preload-plugins # load data
--shell-file data/template.html # custom html template
-o index.html src/main.cpp
```

RUN

```
$browser index.html
```

OR

```
emrun --port 8080 index.html # start http server
$browser localhost:8080
```

CMAKE

```
mkdir build  
CXX=em++ cmake ..  
make web emrun
```

COMPILATION TIME BENCHMARK

Compiler (-O2)	Note	Time
Clang-3.8	Without Range-V3	2.122s
Clang-3.8	With Range-V3	9.521s
Emscripten-1.35	Without Range-v3	2.822s
Emscripten-1.35	With Range-V3	9.912s

IMPLEMENTATION

MATCH-3 GAME

<https://github.com/modern-cpp-examples/match3>

FILES...

```
▼ src/  
  ▼ controller/  
    controller.hpp  
    logic.hpp  
  ▼ model/  
    board.hpp  
    config.hpp  
  ▼ view/  
    animations.hpp  
    icanvas.hpp  
    sdl_canvas.hpp  
    view.hpp  
  pph.hpp  
  game.hpp  
  main.cpp
```

MAIN

CREATE AND PLAY THE GAME

```
int main() {  
    auto injector = di::make_injector(configuration());  
    injector.create<match3::game>().play();  
}
```

DI CONFIGURATION

EXPERIMENTAL BOOST.DI

<https://github.com/boost-experimental/di>

BIND ICANVAS TO SDL_CANVAS

```
di::bind<icanvas>.to<SDL_canvas>()
```

SET-UP CONFIGURATION DETAILS

```
di::bind<>.to(  
  config{.win_title = "match3",  
        .win_width = 320,  
        .win_height = 480,  
        .board_width = 7,  
        .board_height = 10,  
        .board_colors = 5,  
        .max_moves = 10}  
)
```

SET-UP BOARD

```
di::bind<board::color[]>.to({  
  3, 5, 1, 4, 3, 2, 2,  
  1, 1, 4, 2, 5, 1, 3,  
  5, 3, 5, 4, 5, 3, 2,  
  4, 4, 2, 1, 3, 4, 5,  
  5, 1, 1, 2, 4, 5, 1,  
  5, 2, 3, 5, 4, 2, 1,  
  1, 5, 5, 1, 5, 5, 4,  
  2, 3, 3, 1, 3, 3, 4,  
  3, 2, 2, 5, 4, 4, 1,  
  1, 2, 3, 4, 1, 3, 4  
})
```

BIND RANDOMIZER

```
di::bind<randomize>.to([](int begin, int end) {  
    static std::random_device rd;  
    std::mt19937 gen(rd());  
    std::uniform_int_distribution<int> dis(begin, end);  
    return dis(gen);  
})
```

GAME LOOP

PLAY

```
class game {
public:
    explicit game(msm::sm<controller>& c) : controller_(c) {}

    void play() {
        EM(emsripten_set_main_loop_arg(
            play_impl, reinterpret_cast<void*>(&controller_), 0, 0))
        (play_impl(reinterpret_cast<void*>(&controller_)));
    }
}
```

HANDLE EVENTS

```
static void play_impl(void* c) {
    auto& controller_ =
        *reinterpret_cast<msm::sm<controller*>>(c);

    do {
        auto dispatch_event = msm::make_dispatch_table<
            SDL_Event, SDL_QUIT, SDL_FINGERMOTION>(controller_);
        controller_.process_event(time_tick{});
        SDL_Event event;
        while (SDL_PollEvent(&event)) {
            dispatch_event(event, event.type);
        }
    } while (EM(false &&) () !controller_.is(msm::X));
}
```

MODEL

BOARD

```
struct board {  
    using color = int;  
    std::vector<color> grids;  
};
```

VIEW

SDL2

<https://www.libsdl.org>

CANVAS

```
class icanvas {
public:
    virtual ~icanvas() noexcept = default;
    virtual std::shared_ptr<void>
load_image(const std::string&) const = 0;
    virtual std::shared_ptr<void>
create_text(
    const std::string&, const std::string&, int) const = 0;
    virtual void draw(
        std::shared_ptr<void>, int x = 0, int y = 0, bool = true) = 0;
    virtual void render() = 0;
    virtual void clear() = 0;
};
```

VIEW

```
class view {
    view(icanvas&, config);
    void set_grid(int x, int y, int c);
    void update_grid(int x, int y);
    auto get_position(int x, int y) const;
    void set_text(const std::string& text, int x, int y);
    void update() { canvas_.render(); }
    void clear() { canvas_.clear(); }
};
```


ANIMATIONS

```
class animations {  
    explicit animations(view& v);  
    void queue_animation(const std::function<void()>& f  
                        , std::chrono::milliseconds length = {});  
    void update();  
};
```

CONTROLLER

EXPERIMENTAL BOOST.MSM-LITE

<https://github.com/boost-experimental/msm-lite>

```

return make_transition_table(
// +-----+
    "wait_for_first_item"_s <= *("idle"_s)                    / (reset, show_board, show_points, show_moves)

, "wait_for_click"_s      <= "wait_for_first_item"_s        [ not [](moves& m) { return m > 0; } ] / show_game_over
, "wait_for_first_item"_s <= "wait_for_click"_s            + event<button_up> [ not is_mobile ] / (reset, show_board, show_points, show_moves)

, "wait_for_second_item"_s <= "wait_for_first_item"_s + event<button_down> / select_item
, "match_items"_s          <= "wait_for_second_item"_s + event<button_up> [ is_allowed ] / (select_item, swap_items, show_swap)
, "wait_for_first_item"_s <= "wait_for_second_item"_s + event<button_up> [ not is_allowed ] / drop_item

, "wait_for_first_item"_s <= "match_items"_s                [ is_swap_items_winning ] / (
                                                                [](moves& m) {--m;}, show_moves,
                                                                msm::queue_event(matches{.arity = 2})
                                                                )

, "wait_for_first_item"_s <= "match_items"_s                / (swap_items, show_swap, clear_selected)
// +-----+
,
                                                                *("handle_matches"_s) + event<matches> [ has_items and is_item_winning ] / (
                                                                find_matches, show_matches
                                                                , destroy_matches, show_board
                                                                , add_points, show_points
                                                                , scroll_board, show_board
                                                                , generate_new, show_board
                                                                , msm::queue_event(matches{.arity = 1})
                                                                )

,
                                                                "handle_matches"_s + event<matches> [ has_items and not is_item_winning ] / (
                                                                drop_item, msm::queue_event(matches{.arity = 1})
                                                                )

// +-----+
, X          <= *("wait_for_client"_s) + event<key_pressed> [ is_key(SDLK_ESCAPE) ]
, X          <= "wait_for_client"_s + event<quit>
// +-----+
,
                                                                *("handle_animations"_s) + event<time_tick> / [](animations& a) { a.update(); }
// +-----+
);

```

GUARDS/ACTIONS

IS MOVE ALLOWED

```
auto is_allowed =
  [](auto event, const view& v, const selected& s, config c) {
    assert(!s.empty());
    const auto _1 = s.back();
    const auto _2 = v.get_position(event.x, event.y);
    const auto diff = std::abs(_1 - _2);
    const auto board_size = c.board_width * c.board_height;
    return (_1 >= 0 && _1 < board_size) &&
           (_2 >= 0 && _2 < board_size) &&
           (diff == 1 || diff == c.board_width);
  };
```

GENERATE NEW ITEMS

```
auto generate_new = [](board& b, const auto& m, selected& s,  
                      config c, randomize r) {  
    ranges::action::transform(b.grids,  
        [c, r](auto i) { return i ? i : r(1, c.board_colors); }  
    );  
  
    s |= ranges::action::push_front(affected(m.matches, c.board_width)  
        | ranges::action::sort | ranges::action::unique;  
};
```

SWAP ITEMS

```
auto swap_items = [](const selected& s, board& b) {  
    assert(s.size() >= 2);  
    std::swap(b.grids[s[0]], b.grids[s[1]]);  
};
```


MORE GUARDS/ACTIONS

<https://github.com/modern-cpp-examples/match3/blob/master/src/controller/controller.hpp>

LOGIC

RANGE-V3

<https://github.com/ericniebler/range-v3>

ROW VIEW

IDEA

```
| 1 2 3 |  
| 3 4 5 | => n:1 -> | 1 2 3 |  
| 6 7 8 |           | [3] [4] [5] |  
|           |           | 6 7 8 |
```

ROW

```
auto row = [](View&& v, Number n, Number width) {  
    return v | ranges::view::drop(width * n) |  
             ranges::view::take(width); // or slice  
};
```

COLUMN VIEW

IDEA

```
| 1 2 3 |  
| 3 4 5 | => n:1 -> | 1 [2] 3 |  
| 6 7 8 |           | 3 [4] 5 |  
                   | 6 [7] 8 |
```

COLUMN

```
auto col = [](View&& v, Number n, Number width) {  
    return v | ranges::view::drop(n) |  
             ranges::view::stride(int(width));  
};
```

MATCH N

IDEA

```
| 1 3 3 3 2 1 | => color:3, n:3 -> {begin: 1, length: 3}  
| 1 2 3 3 3 3 | => color:3, n:3 -> {begin: 2, length: 4}
```

MATCH 3

```
auto match_n = [](View&& v, Color color, Number n = 3) {
    const auto&& matches =
        ranges::view::ints |
        ranges::view::take(ranges::size(v) - n + 1) |
        ranges::view::transform( [=](auto i) {
            return ranges::count(v | ranges::view::drop(i) |
                                ranges::view::take(n), color) == n;
        });
};
```

MATCH 3

```
constexpr auto is_match = true;
const auto it = ranges::find(matches, is_match);
const auto found = it != ranges::end(matches);
const auto mlength =
    found ? ranges::count(matches, is_match) + (n - 1) : 0;
const auto mbegin =
    found ? ranges::distance(ranges::begin(matches), it) : 0;

struct { decltype(mbegin) begin; decltype(mlength) length; }
    result{mbegin, mlength};

return result;
};
```

IS MATCH

IDEA - MATCH FOUND

```
| 2 3 4 5 | | 2 3 4 5 | | 2 3 4 5 |  
| 7 7 9 3 | | 7 7 9 3 | | 7 7 9 3 |  
| 3 4 5 3 | => value:10 -> | 3 4 [5] 3 | => | 3 4 [5] 3 | => true  
| 1 3 5 1 | | 1 3 5 1 | | 1 3 [5] 1 |  
| 2 1 5 8 | | 2 1 5 8 | | 2 1 [5] 8 |
```

IDEA - NO MATCH

```
| 2 3 4 5 | | 2 3 4 5 | | 2 3 4 5 |  
| 7 7 9 3 | | 7 7 9 3 | | 7 7 9 3 |  
| 3 4 5 3 | => value:11 -> | 3 4 5 [3] | => | 3 4 5 3 | => false  
| 1 3 5 1 | | 1 3 5 1 | | 1 3 5 1 |  
| 2 1 5 8 | | 2 1 5 8 | | 2 1 5 8 |
```

IS MATCH

```
auto is_match = [](View&& v, Number value, Number width) {  
    const auto color = v[value];  
    const auto x = value % width;  
    const auto y = value / width;  
    return match_n(row(v, y, width), color).length ||  
           match_n(col(v, x, width), color).length;  
};
```

MATCH

IDEA

```
| 1 2 3 4 5 |
| 6 7 7 9 3 |
| 2 5 5 5 3 | => value:13 -> | 1 2 3 4 5 |
| 2 1 3 5 1 |                | 6 7 7 9 3 |
| 4 2 1 5 8 |                | 2 5 5 [5] 3 | =>
| 4 2 1 5 8 |                | 2 1 3 5 3 |
| 4 2 1 5 8 |                | 4 2 1 5 8 |

=> | 1 2 3 4 5 |
   | 6 7 7 9 3 |
   | 2 [5] [5] [5] 3 | => [11, 12, 13, 18, 23]
   | 2 1 3 [5] 3 |
   | 4 2 1 [5] 8 |
```


MATCH 1/2

```
auto match = [](View&& v, Number value, Number width) {
    const auto color = v[value];
    const auto x = value % width;
    const auto y = value / width;
    const auto match_r = match_n(row(v, y, width), color);
    const auto match_c = match_n(col(v, x, width), color);
    const auto transform = [](auto length, auto expr) {
        return ranges::view::ints | ranges::view::take(length) |
            ranges::view::transform(expr);
    };
};
```

MATCH 2/2

```
std::vector<decltype(value)> result = ranges::view::concat(
    transform(match_r.length,
        [=](auto i) { return y * width + match_r.begin + i; }),
    transform(match_c.length, [=](auto i) {
        return (match_c.begin + i) * width + x;
    }));
result |= ranges::action::sort | ranges::action::unique;
return result;
};
```

SCROLL

IDEA

```
| 3 |           | 3 |           | 0 |  
| 0 |           | [0] |          | 0 |  
| 0 | => value:1 -> | 0 | => | 0 |  
| 0 |           | 0 |           | 3 |  
| 4 |           | 4 |           | 4 |
```

SCROLL

```
auto scroll = [](View&& v, const Container& value, Number width) {
    const auto&& c = col(v, value % width, width) |
        ranges::view::take(value / width + 1);
    auto begin = ranges::begin(c);
    ranges::advance(begin, value / width);
    ranges::rotate(c, begin);
};
```

AFFECTED ITEMS

IDEA

```
[11, 12, 13, 18, 23] => | 1  2  3  4  5 |
                        | 6  7  7  9  3 |
                        | 2 [5] [5] [5] 3 | =>
                        | 2  1  3  [5] 3 |
                        | 4  2  1  [5] 8 |

=> | 1  [2] [3] [4] 5 |
   | 6  [7] [7] [9] 3 |
   | 2  [5] [5] [5] 3 | => [1, 2, 3, 6, 7, 8, 11, 12, 13, 18, 23]
   | 2  1  3  [5] 3 |
   | 4  2  1  [5] 8 |
```

AFFECTED

```
auto affected = [](const Container& matches, Number width) {
    const auto&& columns =
        matches | ranges::view::transform( [=](auto m) {
            return ranges::view::ints |
                ranges::view::take(m / width + 1) |
                ranges::view::transform( [=](auto i) {
                    return m % width + (i * width); }); });
    });

    std::decay_t<decltype(matches)> result =
        columns | ranges::view::join;

    result |= ranges::action::sort | ranges::action::unique;
    return result;
};
```


WARNING

IT'S NOT 100% C++14!

- `"idle"_s` - GNU extension / string-literal-operator-template
 - Standard replacement: `state<class idle>`
- `matches{.arity = 2}` - C99 / designated-initializer
 - Standard replacement: `matches{2}`

TESTS

UNIT TESTS

LOGIC

```
"scroll"_test = [] {  
  int v[] = {1, 1, 3, 4, 0, 2, 7, 2, 3};  
  scroll(v, 4, 3);  
  expect(ranges::equal({1, 0, 3, 4, 1, 2, 7, 2, 3}, v));  
};
```

GUARDS

```
"is key"_test = [] {  
    constexpr auto key = 42;  
    struct {  
        int key;  
    } event{key};  
    expect(is_key(key) (event));  
};
```

ACTIONS


```
"swap_items"_test = [] {  
  board b;  
  b.grid = {1, 2};  
  selected s = {0, 1};  
  swap_items(s, b);  
  expect(ranges::equal({2, 1}, b.grid));  
};
```

FUNCTIONAL TESTS

FAKEIT - MOCKING FRAMEWORK

<https://github.com/eranpeer/Fakelt.git>

HELPERS

FAKE SWIPE

```
template <class SM>
void
swipe(SM& sm, std::pair<int, int> from, std::pair<int, int> to) {
    sm.process_event(
        make_click_event<match3::button_down>(from.first, from.second));
    sm.process_event(
        make_click_event<match3::button_up>(to.first, to.second));
};
```

MOCKS PROVIDER

AUTOMATICALLY CREATES MOCKS USING FAKEIT FOR ABSTRACT TYPES

DI - MOCKS PROVIDER

```
auto injector = di::make_injector<mocks_provider>(...);
```

GIVEN

CONFIGURATION

```
di::bind<>.to(match3::config{"", 0, 0, 7, 10, 5, 10})
```

BOARD

```
di::bind<match3::board::color[]>.to({
  /*0 1 2 3 4 5 6*/
/*0*/ 3,5,1,4,3,2,2,
/*1*/ 1,1,4,2,5,1,3,
/*2*/ 5,3,5,4,5,3,2,
/*3*/ 4,4,2,1,3,4,5,
/*4*/ 5,1,1,2,4,5,1,
/*5*/ 5,2,3,5,4,2,1,
/*6*/ 1,5,5,1,5,5,4,
/*7*/ 2,3,3,1,3,3,4,
/*8*/ 3,2,2,5,4,4,1,
/*9*/ 1,2,3,4,1,3,4
})
```

FAKE RANDOMIZER

```
di::bind<match3::randomize>.to([](int, int) {  
    static auto i = 42; return i++;  
})
```

CANVAS MOCK

```
using namespace fakeit;
auto&& canvas = mocks_provider::get_mock<match3::icanvas>();
When(Method(canvas, load_image)).AlwaysReturn(shared_ptr<void>{});
When(Method(canvas, create_text)).AlwaysReturn(shared_ptr<void>{});
When(Method(canvas, draw)).AlwaysDo([](...){});
When(Method(canvas, render)).AlwaysDo([]{});
When(Method(canvas, clear)).AlwaysDo([]{});
```

CONTROLLER

```
auto sm = injector.create<msm::sm<match3::controller>>();
```

WHEN

TRIGGER SWIPE

```
swipe(sm, {3, 5}, {3, 6});
```

THEN

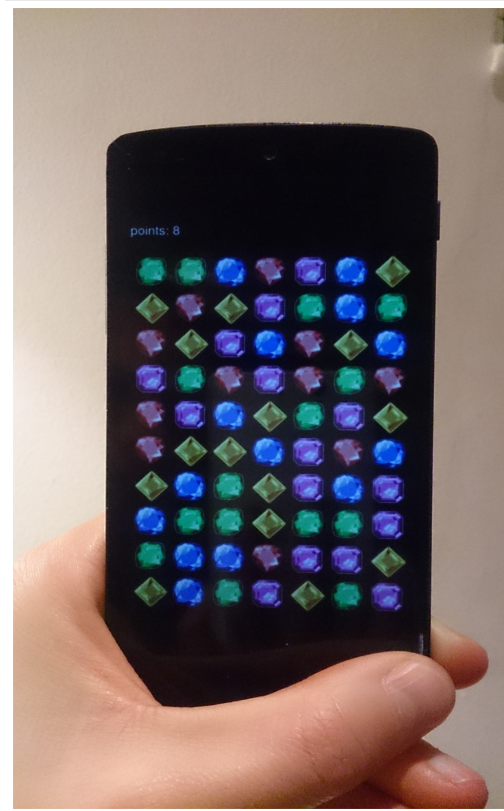
BOARD SHOULD CHANGE

```
expect (ranges::equal ({/*0 1 2 3 4 5 6*/  
                        /*0*/ 3, 42, 43, 44, 45, 46, 2,  
                        /*1*/ 1, 5, 1, 4, 3, 2, 3,  
                        /*2*/ 5, 1, 4, 2, 5, 1, 2,  
                        /*3*/ 4, 3, 5, 4, 5, 3, 5,  
                        /*4*/ 5, 4, 2, 1, 3, 4, 1,  
                        /*5*/ 5, 1, 1, 2, 4, 5, 1,  
                        /*6*/ 1, 2, 3, 1, 4, 2, 4,  
                        /*7*/ 2, 3, 3, 1, 3, 3, 4,  
                        /*8*/ 3, 2, 2, 5, 4, 4, 1,  
                        /*9*/ 1, 2, 3, 4, 1, 3, 4},  
                        injector.create<match3::board>().grids));  
};
```

LET'S TRY SOMETHING CRAZY?



C++ -> JS -> MOBILE -> BROWSER



EMBEDDING JS IN C++

IS MOBILE DEVICE

```
auto is_mobile = [] {  
    return bool(EM_ASM_INT_V({  
        return /iPhone|iPad|iPod|Android/i.test(navigator.userAgent);  
    }));  
};
```

FINGER TOUCH INSTEAD OF BUTTON CLICK

TRANSITION TABLE

```
"second_item"_s <= "first_item"_s + touch_down [is_mobile] ...  
"match_items"_s <= "second_item"_s + touch_up [is_mobile] ...  
  
"second_item"_s <= "first_item"_s + button_down [!is_mobile] ...  
"match_items"_s <= "second_item"_s + button_up [!is_mobile] ...
```

PROBLEMS / LIMITATIONS

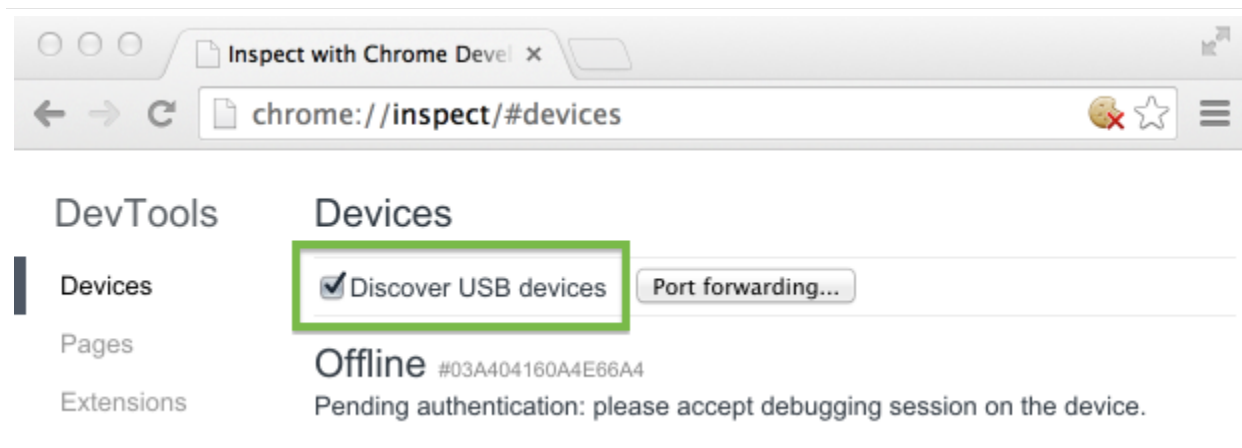
IOS

SECURITY REASONS

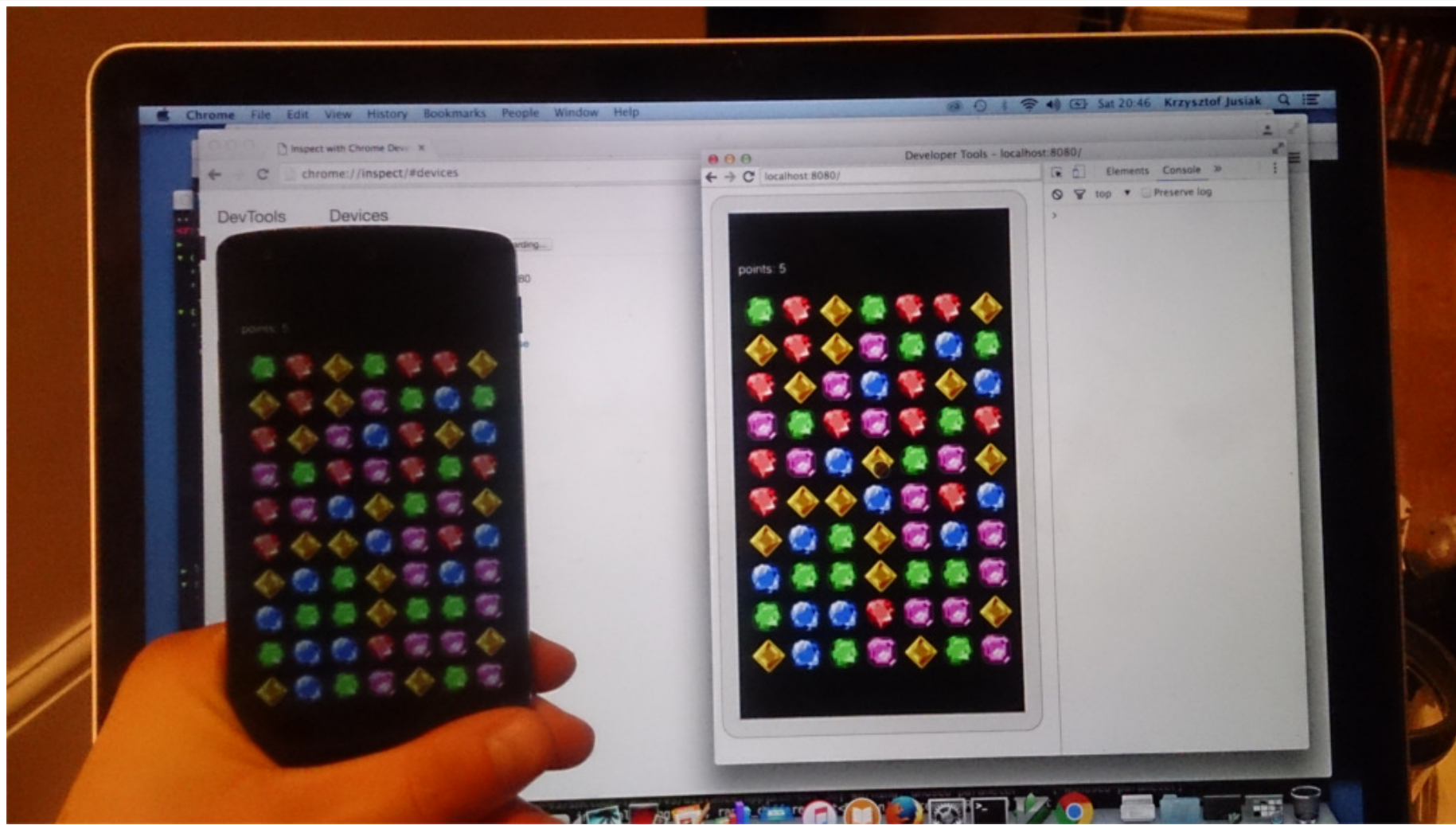
- JS is not compiled causing a slow execution
- Full screen is not allowed

DEBUGGING C++ -> JS -> MOBILE -> CHROME

ANDROID / CHROME



```
chrome://inspect/#devices
```



IOS / SAFARI

SAFARI WEB INSPECTOR

BEAT THE RECORD / PLAY



QUESTIONS?

Match-3 Game

<https://github.com/modern-cpp-examples/match3>

Experimental
Boost.DI

<https://github.com/boost-experimental/di>

Experimental
Boost.MSM-lite

<https://github.com/boost-experimental/msm-lite>

Range-V3

<https://github.com/ericniebler/range-v3>

Fakelt

<https://github.com/eranpeer/Fakelt.git>

King

Thank you