Wasm Blocks

Procedural Modeling with Micro Webassemblies

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Software = Code + Data

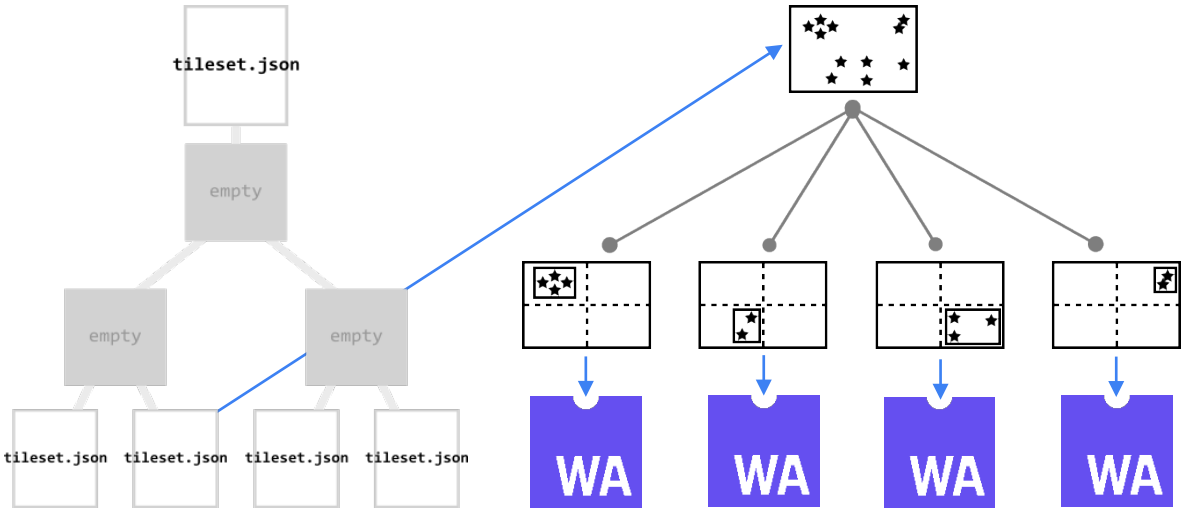
- Someone, Some Year

What if we could procedurally replace portions of our data with code for greater efficiency and fidelity?

What is Procedural Modeling?

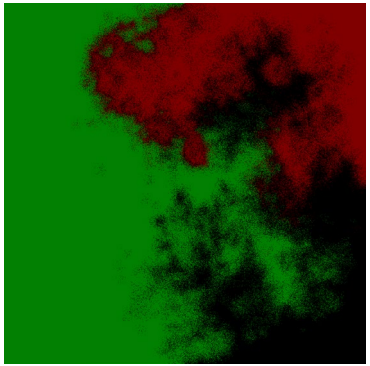
- Create data programatrically instead of manually
- Examples: Formal grammars, L-systems, fractals, generative
- Add artistic variation at massive scale
- Incorporate randomness with heuristics
- Integrate with high-quality manual data
- Efficient use of space

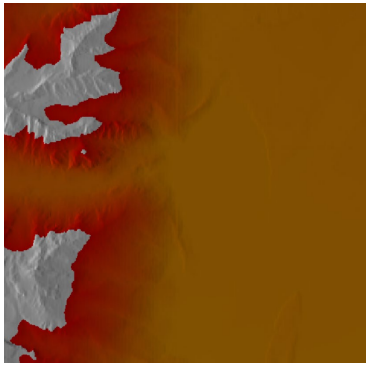
What does this have to do with Wasm?

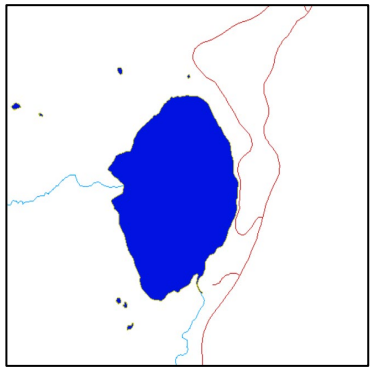


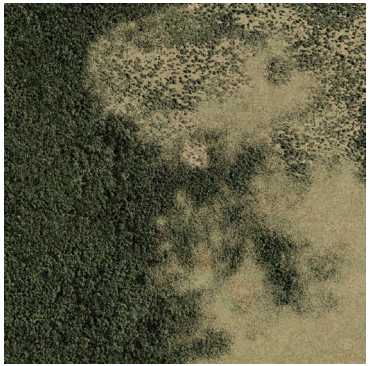
- Thesis: Code more efficient than data (binary size)
- High performance
- Portable
- Dynamic compilation
- Fast startup
- Secure by default for arbitrary code
- Support User-Generated Content

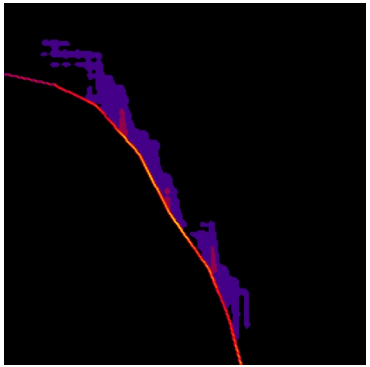
EXAMPLE 1: Vector Maps

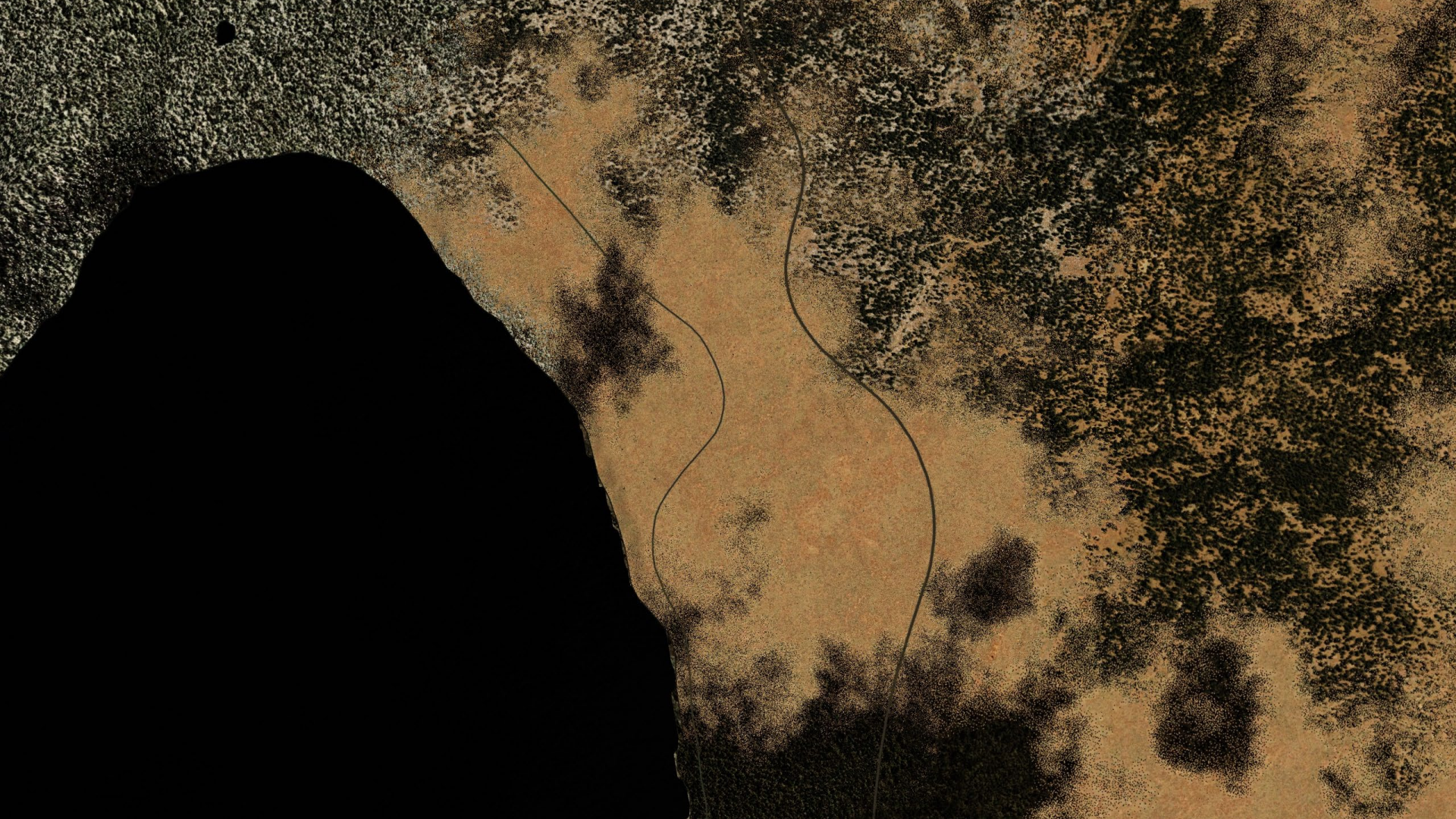










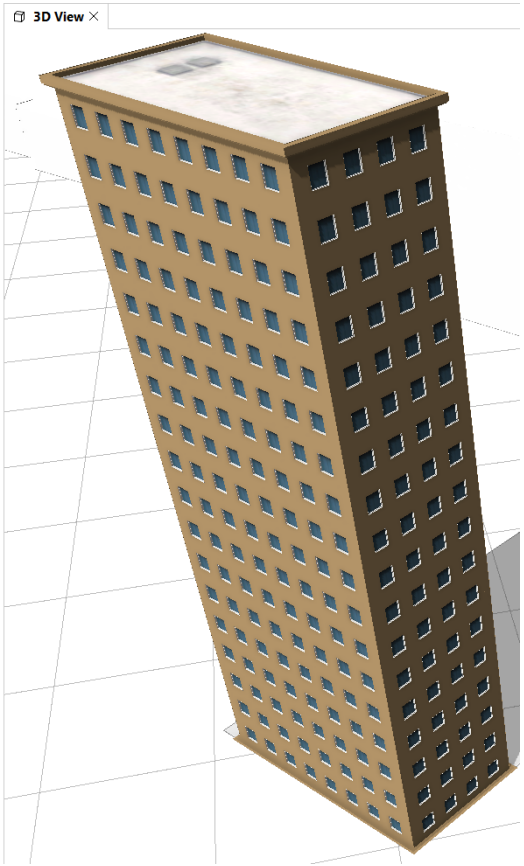


EXAMPLE 2: 3D Building Models

oro.cga | *Scene

```
// Grammar 0

attr depth = 7.95272636
attr height = 38.7053642
attr roof_height = 0.406891108
attr roof_overhang = 0.346042305
attr width = 15.07317114


@StartRule
Start-->
//translate(rel, world, 0, 0, 0)
s(width, 0, depth)
extrude(height)
comp(f) { bottom : Base | side : Facade | top : Roof }

Roof-->
offset(roof_overhang*0.8)
comp(f){ inside: TopFaceOffset }

TopFaceOffset-->
extrude(roof_height*0.2)
comp(f) { bottom : RoofLedge | side : RoofLedge | top :  TopFaceOf

TopFaceOffsetTop-->
offset(roof_overhang*0.2)
comp(f) { inside: TopFaceOffsetTopOffset }

TopFaceOffsetTopOffset-->
extrude(roof_height*0.8)
comp(f) { bottom : RoofLedge | side : RoofLedge | top : TopFaceOff

TopFaceOffsetTopOffsetTop-->
offset(-roof_overhang) comp(f){ inside: TopFaceOffsetTopOffsetTopIn

TopFaceOffsetTopOffsetTopInside-->
extrude(-roof_height*0.5)
comp(f) { side : RoofLedge | top : reverseNormals() RoofTop }

// Grammar 1

attr p00_GH = 0.317185193
attr p01_FH = 2.13179612
attr p02_AH = 0.0158432871
attr p03_SW = 0.417930305
attr p04_TW = 1.77921629
attr p05_GW = 7.11686516
attr p06_WT = 0.629350841
```

3D View



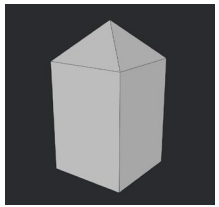
Implementation

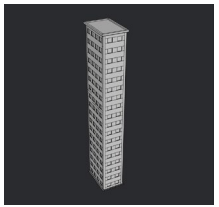
```
void AddGrammarColor(std::vector<cga::Grammar>& grammars)
{
    using namespace boost;

    cga::Grammar grammar;

    grammar.addAttr("", "facade_color", Attribute("facade_color", "#a3875e"));
    grammar.addAttr("", "facade_color0", Attribute("facade_color0", "#a3875e"));
    grammar.addAttr("", "facade_color1", Attribute("facade_color1", "#373226"));
    grammar.addAttr("", "facade_color2", Attribute("facade_color2", "#8c7a74"));
    grammar.addAttr("", "facade_color3", Attribute("facade_color3", "#60635e"));
    grammar.addAttr("", "facade_color4", Attribute("facade_color4", "#bbeaff"));
    grammar.addAttr("", "facade_color5", Attribute("facade_color5", "#f3c89d"));
    grammar.addAttr("", "facade_color6", Attribute("facade_color6", "#282425"));
    grammar.addAttr("", "facade_color7", Attribute("facade_color7", "#f0cda8"));
    grammar.addAttr("", "facade_color8", Attribute("facade_color8", "#808080"));
    grammar.addAttr("", "facade_color9", Attribute("facade_color9", "#808080"));

    grammar.addRule("", "DoorGlass");
    grammar.addOperator("", "DoorGlass", make_shared<ColorOperator>("#202020"));

    grammar.addRule("", "LedgeFace");
    grammar.addOperator("", "LedgeFace", make_shared<ColorOperator>("facade_color"));

    grammar.addRule("", "RoofLedge");
    grammar.addOperator("", "RoofLedge", make_shared<ColorOperator>("facade_color"));

    grammar.addRule("", "RoofTop");
    grammar.addOperator("", "RoofTop", make_shared<SetupProjectionOperator>(axesSelector:AXES_SCOPE_XY,
                                                                            texHeight:Value(Value::TYPE_RELATIVE,
    grammar.addOperator("", "RoofTop", make_shared<TextureOperator>("roof2.png"));

    grammar.addRule("", "Wall");
    grammar.addOperator("", "Wall", make_shared<ColorOperator>("facade_color"));

    grammar.addRule("", "Wall0");
    grammar.addOperator("", "Wall0", make_shared<ColorOperator>("facade_color0"));
```

- Grammar compiled using C++ / clang
- Opportunity to go direct to wasm
- Parameterized input (WASI)
- Pipe stdout with obj/mtl files
- Stream *.wasm tiles in quadtree
- Grammar(s) per building
- SIMD – Performance within 68% x64
- Code size challenges – 589kb
  - Split off host functionality
  - Group buildings / LOD?

Performance

- 200 Buildings – Low complexity vs High complexity (and cached compilation)





What's Next?

- Component Model
- Separate Host Functionality
- Graphics APIs
- Binary Size Optimization
- Compilation Performance
- Recompilation

Input `*.wit`

```
interface grammar {
  record matrix4 {

  }

  record shape {
    name: string
  }

  record rectangle {
    shp: shape,
    x: u32,
    y: u32,
    pivot: matrix4,
    scope: matrix4
  }

  get-stack: func() -> list<shape>
  push-stack: func(shp: shape)
  pop-stack: func() -> shape

  record operator {
    rule: string
  }

  record operator-comp {
    op: operator,
    name: string,
    values: list<tuple<string, string>>
  }

  add-rule: func(rule: string)
  add-operator-comp: func(rule: string, comp: operator-co
  get-operators: func() -> list<operator>
}

default world terragen {
  import derive: func(start-rule: string)
  import generate-geometry: func()
  import api: self.grammar

  export run: func(params: string)
}
```

Generated bindings

Language: C · File: terragen.c

```c
#include "terragen.h"


__attribute__((import_module("api"), import_name("get-sta
void __wasm_import_api_get_stack(int32_t);

__attribute__((import_module("api"), import_name("push-st
void __wasm_import_api_push_stack(int32_t, int32_t);

__attribute__((import_module("api"), import_name("pop-sta
void __wasm_import_api_pop_stack(int32_t);

__attribute__((import_module("api"), import_name("add-rul
void __wasm_import_api_add_rule(int32_t, int32_t);

__attribute__((import_module("api"), import_name("add-ope
void __wasm_import_api_add_operator_comp(int32_t, int32_t

__attribute__((import_module("api"), import_name("get-ope
void __wasm_import_api_get_operators(int32_t);

__attribute__((import_module("terragen"), import_name("de
void __wasm_import_terragen_derive(int32_t, int32_t);

__attribute__((import_module("terragen"), import_name("ge
void __wasm_import_terragen_generate_geometry(void);

__attribute__((weak, export_name("cabi_realloc")))
void *cabi_realloc(void *ptr, size_t orig_size, size_t or
  void *ret = realloc(ptr, new_size);
  if (!ret) abort();
  return ret;
}

// Helper Functions

void api_shape_free(api_shape_t *ptr) {
  terragen_string_free(&ptr->name);
}

void api_operator_free(api_operator_t *ptr) {
  terragen_string_free(&ptr->rule);
}

void api_tuple2_string_string_free(api_tuple2_string_stri
  terragen_string_free(&ptr->f0);
  terragen_string_free(&ptr->f1);
```

THANKS

Sean Isom

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https://github.com/seanisom/WasmBlocks