Cross-Language Component Testing: Performance and Interoperability Insights

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Outline

Introduction

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  - Same or new language
  - Implements existing features

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  - Second system effect
  - New developments in libraries/languages
  - Initial choices restrictive as application scales

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  - Better understanding and new technologies

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- Rewrites in software development:
  - Key component
  - Thesis explores effective approaches

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- **Objective:**
  - Determine if the component works better in another language

Research Questions

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Performance and Real world applications

How does the overhead and restrictions on optimization techniques effect their application in performance performance dependent production code?

system design

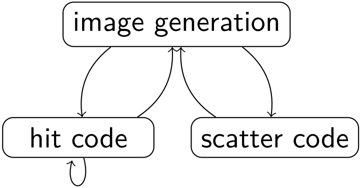

Figure: Ray tracer overview

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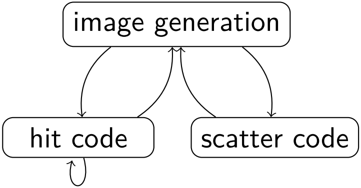

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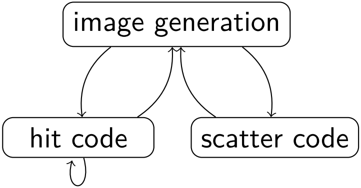

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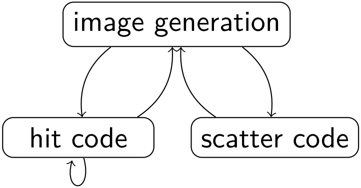

Figure: Ray tracer overview

- Complex enough system to demonstrate the idea in an applied setting.
- Distinct components that can be isolated for testing.
- Requires high performance to function effectively, making it ideal for assessing performance needs.

Testing Approach: Q & A Format

- How do we isolate the most performance impacting component?
  - Profile our application for runtime and memory.
  - Use the profiling data to make a judgement on the most performance impacting component.

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- What languages do we choose for rewriting?
  - Choose languages with embedding APIs for Julia.
  - Opt for Python and C++ due to their differing fundamental properties and available interface libraries.
- How do we test the rewritten components?
  - Use the language specific benchmarking tools to test components in isolation.
  - Use Julia's benchmarking tools to test compontents & overhead

rewriting

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- Efficiency concern: If target languages perform poorly with hit functions, rewriting the entire ray tracer may not be feasible.
- Rewriting components: Trivial task due to similar syntax across languages.

C++

```cpp
bool hit(const aabb& box, const ray& r, const interval& ray_t);
```

Python

```python
def hit(bbox: aabb, r: ray, ray_t: interval[float]) -> bool:
```

Julia

```julia
function hit!(bbox::aabb, r::ray, ray_t::interval)::Bool
```

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2. Prefer an API that simplifies component attachment.

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Languages supporting reflection reduce additional code, simplifying rewriting and testing.

Testing setup

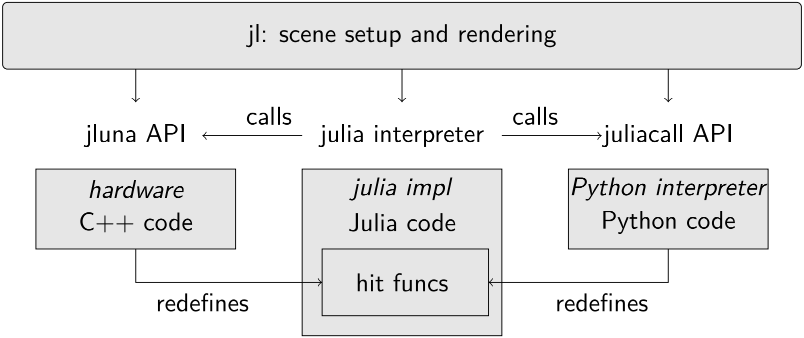

Figure: Testing setup for component isolation

dynamic mapping

Mapping Objects to Statically Typed Languages

Static Mapping

- User describes interface for types (e.g., class/struct).
- API maps Julia type to corresponding C++ type.
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- Define functions get(x) and put(x).
- Property x represented as a string.
- get : $S \rightarrow V =$ object property x
- set : $S, V \rightarrow S =$ modified property x

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Note: Similar to functional programming lens.

Challenges with Getter/Setter Pairs

Limitation

Issues arise when source S has an abstract type.

Notation

- $[S : T], [V : T]$ represent source and value types.
- $\text{set} : [S : T_B], [V : T_{bi}] \rightarrow S_m$

Problem: Julia uses strings for type representation:

- $\text{set} : [S : T_B], [V : \text{str}(T_{bi})] \rightarrow S_m$
- Need to map strings to C++ types.

Solution: Create a mapping mechanism

- string to type mapping *st* and type comparison *f*:

$$st : \text{str}(T_i) \rightarrow \text{typeinf}(T_i) \quad f : st, \text{typeinf}(T_p) \rightarrow \text{bool}$$

- Use compile-time code generation with variadic templates.

Achieve correspondence using fold expressions on variadic templates.

Optimizing Setter Functions

An issue with the current approach:

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Preferable solution:

- Define the set of derived types once.
- Allow all setters for attributes of a class to access this information.

Improved Design with Varadic Templates

We can improve upon this design by utilizing varadic templates for types, getters, and setters to create a compile-time mapping:

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We can improve upon this design by utilizing varadic templates for types, getters, and setters to create a compile-time mapping:

```
def initalize_type[T, attr..., derived...]() -> void:
    fold => (attr,
        mapping.insert(attr::name,
            (
                // getter
                [instance: T]() { instance[T](attr::get(instance)) }
                // setter
                [instance: T, jl_val: jlval, jl_type_string: str] {
                    fold(derived,
                        if (f(st(jl_type_string), typeinfo(derived))):
                            attr::set(instance, instance[derived](jl_val))
                            matched = true
                        )
                    if (!matched):
                        attr::set(instance, instance[T](jl_val))
                }
            )
        )
    )
```

Template Metafunctions for Object Properties

Template metafunctions are used to define object properties:

```
template <typename Ot, typename Ft, const char* name>
struct Property {
    static constexpr const char* get_name() { return name; }
    static std::function<Ft(Ot&)> getter;
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Example property declaration:

```
Usertype<bvh_node>::initialize_type(
    tl<
        Property<bvh_node, Hittable*, #left>,
        Property<bvh_node, Hittable*, #right>,
        Property<bvh_node, aabb, #bbox>
    >(),
    tl<Triangle, Sphere, bvh_node>()
);
```

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key challenge

Find some means of having the base type interface discern the correct derived type to instantiate.

Benefits

This system offers

- Simplified object deduction process
- Ability to map abstract objects
- Utilization of modern C++ principles for futureproofing
- Increased maintainability and extensibility
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Key Takeaway

It provides a more concise approach compared to traditional methods, enhancing ease of implementation and potential for future extensions.

Insights

Observations

- Possible to implement a generic method for polymorphic object mapping.
- Offers JuliaCall API capabilities with C++ speed.
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Main takeaways

- Metaprogramming approaches effective for object reflection
- We can map to static languages with minimal additional boilerplate
- Straightforward testing and integration across languages

Baseline performance

Isolated performance

Results