Cross-Language Component Testing: Performance and Interoperability Insights

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   - System Design
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Introduction

Reasons for rewrites

- Second system effect
- New developments in libraries/languages
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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

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How can we effectively test the performance of a system component rewritten in another programming language?

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Performance

How do performance attributes effect the application of interop APIs in performance dependent code?

System design

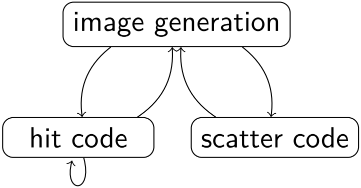

Figure: Ray tracer overview

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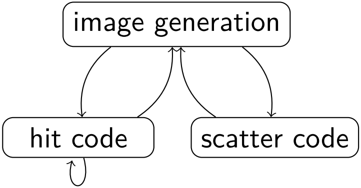

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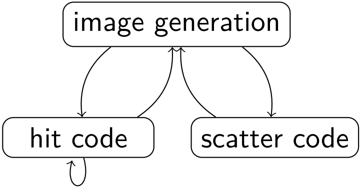

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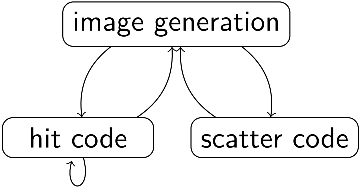

Figure: Ray tracer overview

- 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.

Study Approach: Q&A Format

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- Opt for Python and C++ due to their differing fundamental properties and available interface libraries.

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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

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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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1. Choose an API that minimizes additional code.
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Languages supporting reflection reduce additional code, simplifying rewriting and testing.

Testing setup

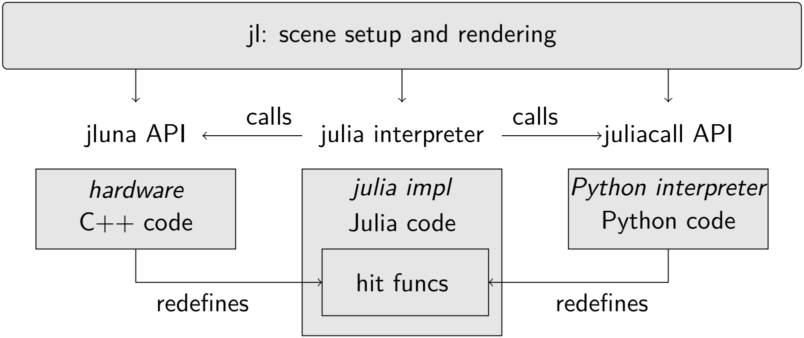

Figure: Testing setup for component isolation

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.
- User-defined reflection system parses low-level types.

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Note: Similar to functional programming lens.

Challenges with Getter/Setter Pairs

Limitation

Problems occur when the setter has an abstract type.

Problem:

- Julia uses strings to represent types.
- Need to convert these strings back to C++ types.

Solution:

- Create a mechanism to map strings to types and compare them to find the right derived type

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Key issue with trivial approach

- Requires providing all derived types to each getter/setter pair.
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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.

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 - RQ2

Observations

- Possible to implement a generic method for polymorphic object mapping.
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Main takeaways

- We can map to static languages with minimal additional boilerplate
- Mostly straightforward testing and integration across languages

Baseline Performance analysis

Timing method

- Call to `bvh_hit` from Julia
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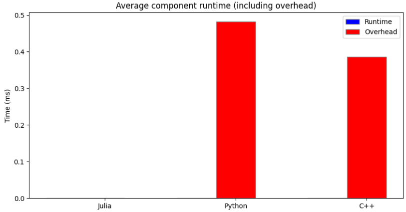
Results

- Julia
  - Fastest average component execution time since no overhead
- Python and C++:
  - Similar average component execution times
  - Execution time primarily attributed to overhead



Isolated Performance - RQ3

Results

- C++ outperforms Julia and Python in component runtime.
- Substantial overhead from Julia API (dynamic dispatch, type inference).
- Julia performs well with type stability, hindered by cross-language calls.

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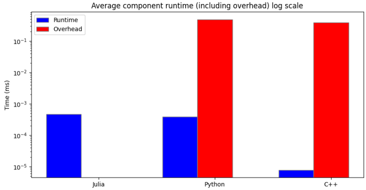
Conclusion

- High-performance interop between different languages is challenging.
- Effective on a smaller scale, but less viable for very different languages.



Results and Takeaways

- Different language APIs have varied integration approaches.
- Adapting APIs to specific use cases is generally manageable depending on the language
- Metaprogramming is effective for implementing generic, extensible interop libraries.
- Performance overhead can depends alot on language compatability and paradigms
- APIs work well for benchmarking and testing components in isolation
- Careful consideration needed for using these APIs in performance-dependent production code.