Building Confidently in Julia with Interface-Driven Design

Sam Buercklin

G2I COMPUTING

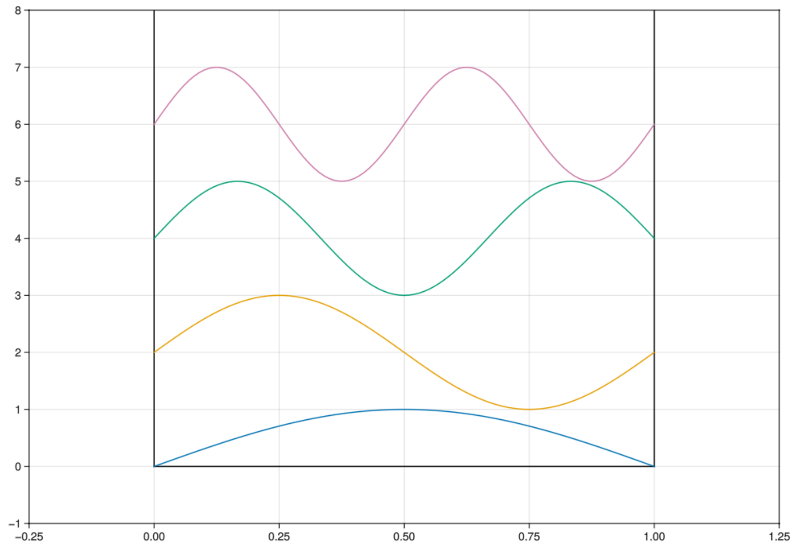
https://github.com/SBuercklin/InterfaceDesignJuliacon2024

Using a Julia Project

```julia
using SamsFunkySolver: InfiniteSquareWell, AnalyticSolver

isw = InfiniteSquareWell(; well_width = 5)
solver = AnalyticSolver()

solution = solve_problem(solver, isw)
```



✓

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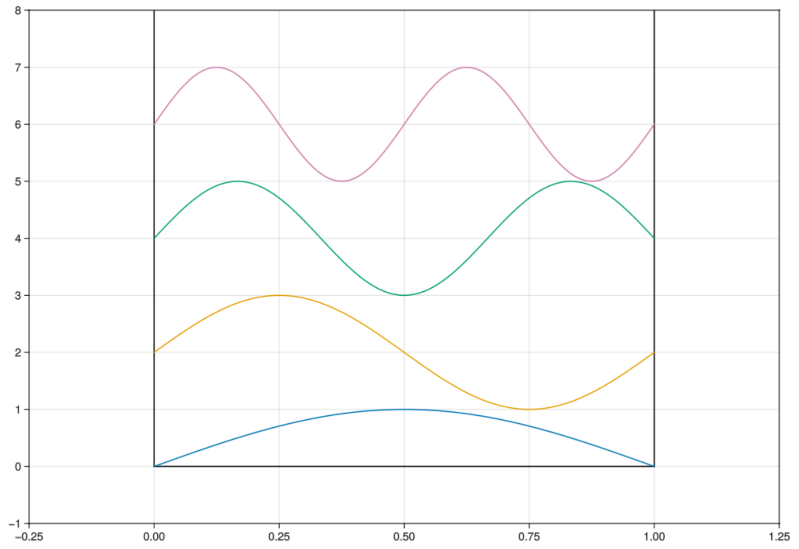


✓

```julia
fsw = FiniteSquareWell(; well_width = 5, V1 = 2, V3 = 8)
s_solver = ShootingMethod(; ψ0 = 1, dψ0 = 0.5)

solution = solve_problem(s_solver, fsw)
```

```
julia> solution = solve_problem(s_solver, fsw)
ERROR: type FiniteSquareWell has no field boundary_conditions
```

```
julia> solution = solve_problem(s_solver, fsw)
ERROR: MethodError: no method matching solve(::ShootingMethod{Float64},
::Vector{Float64}, ::Vector{Float64})
```

✗

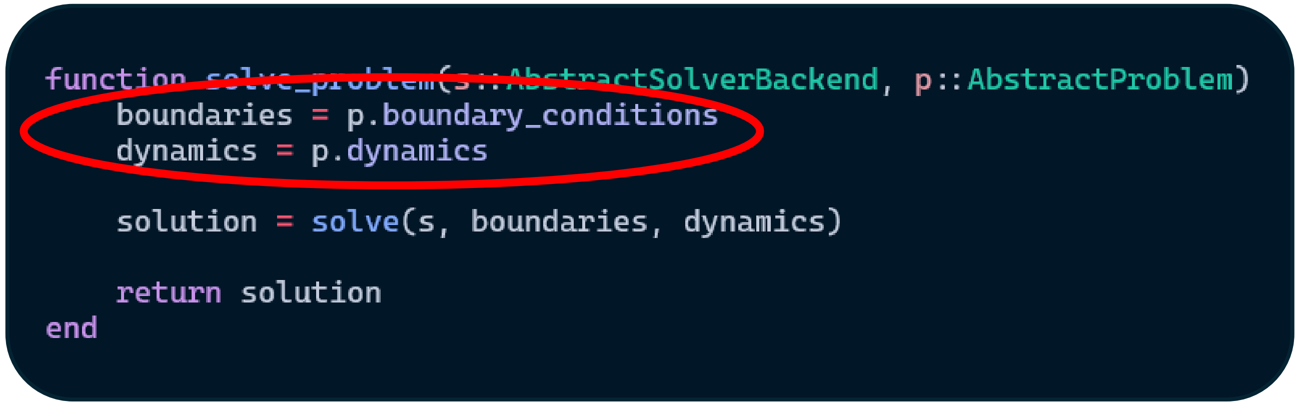
What’s the problem?

```julia
function solve_problem(s::AbstractSolverBackend, p::AbstractProblem)
    boundaries = p.boundary_conditions
    dynamics = p.dynamics

    solution = solve(s, boundaries, dynamics)

    return solution
end
```

What’s the problem?



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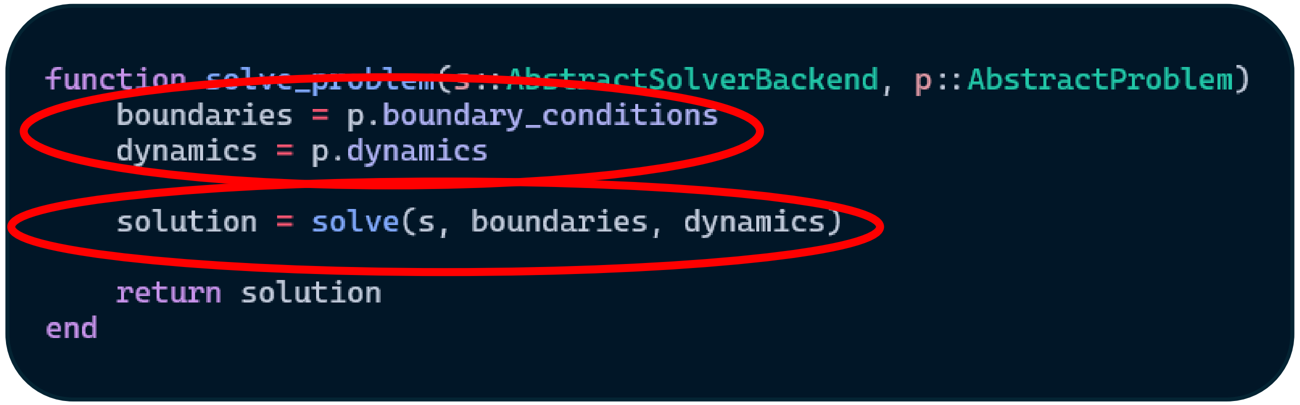

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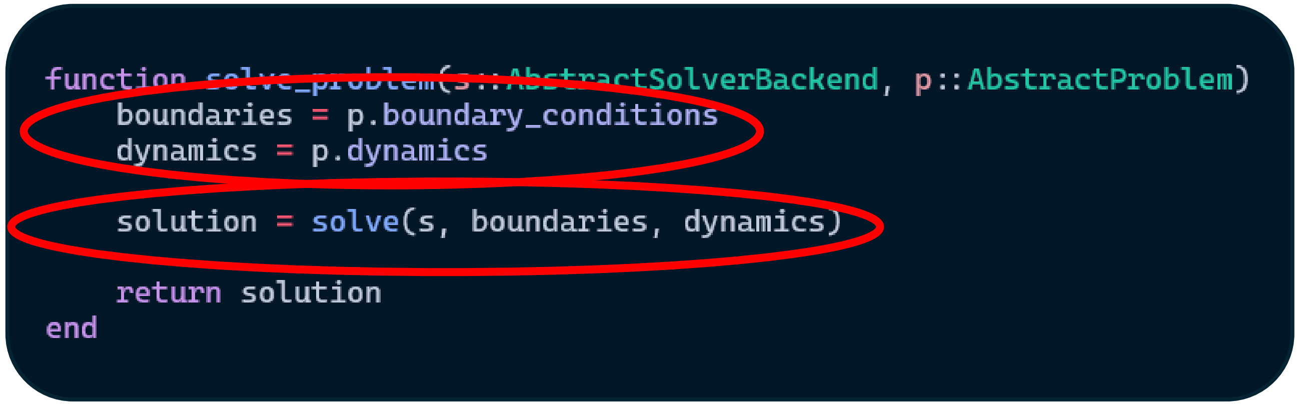

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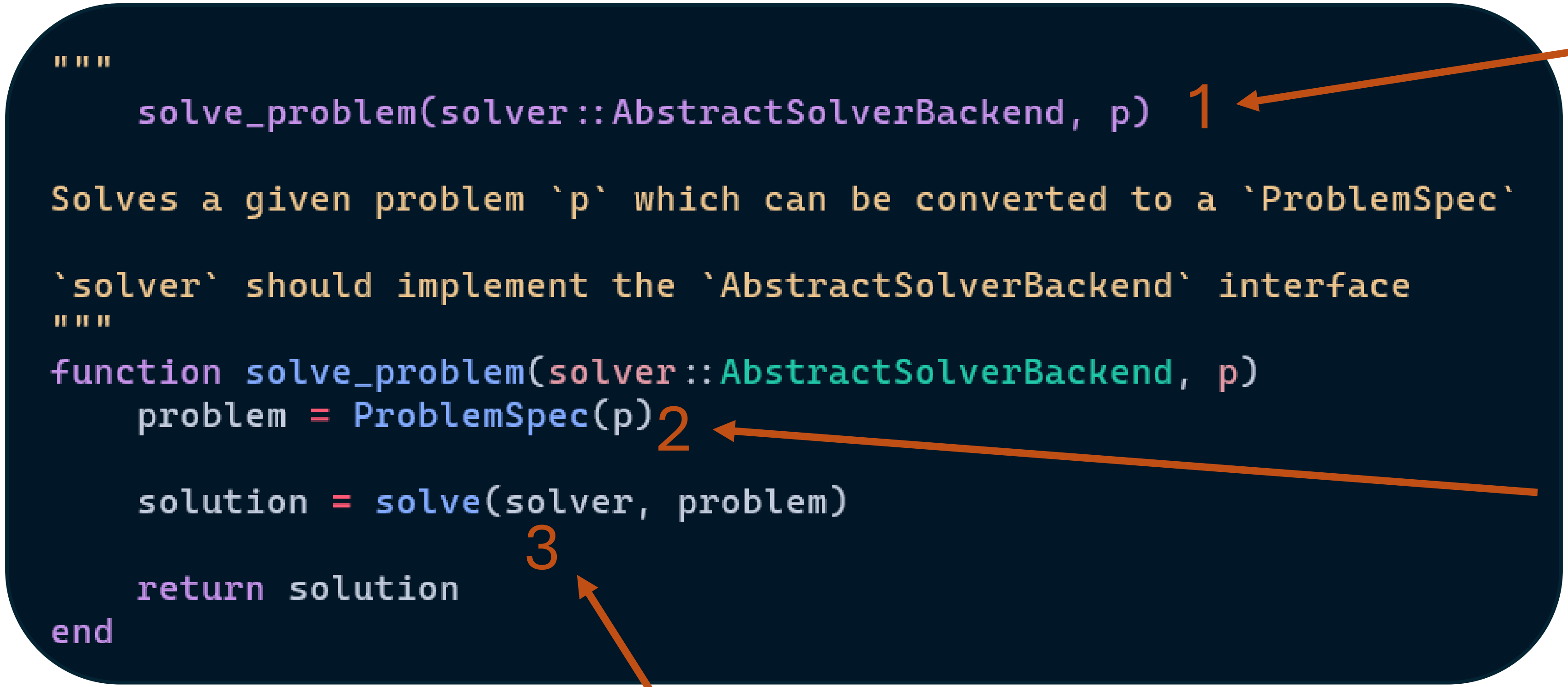
- Hard coding required fields
- Solver needs a custom solve method
- How were you supposed to know?

What could be better?



```julia
"""
    solve_problem(solver::AbstractSolverBackend, p)

Solves a given problem `p` which can be converted to a `ProblemSpec`

`solver` should implement the `AbstractSolverBackend` interface
"""
function solve_problem(solver::AbstractSolverBackend, p)
    problem = ProblemSpec(p)

    solution = solve(solver, problem)

    return solution
end
```

Added a docstring

Standardized the problem representation

Formalized + generalized solve function

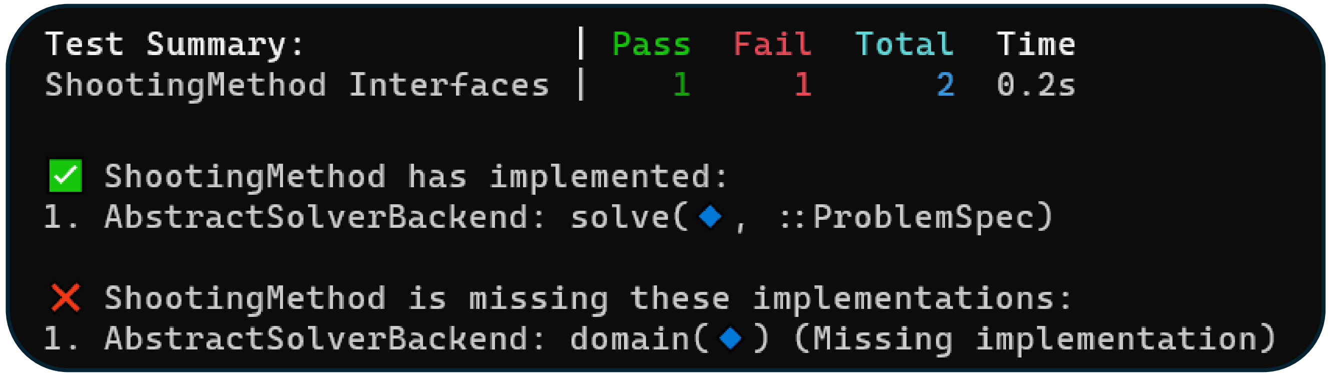
Is this good enough?

Is there anything my implemented missed?

What if the package assumptions change?

Will this require downstream changes?

Doing Better



```
Test Summary:           | Pass  Fail  Total  Time
ShootingMethod Interfaces |    1     1      2  0.2s

✅ ShootingMethod has implemented:
1. AbstractSolverBackend: solve(🔷, ::ProblemSpec)

❌ ShootingMethod is missing these implementations:
1. AbstractSolverBackend: domain(🔷) (Missing implementation)
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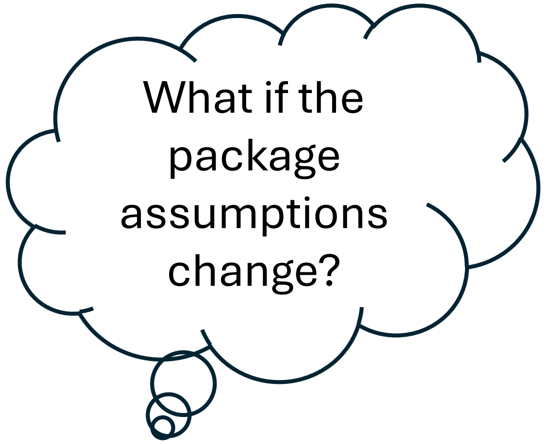

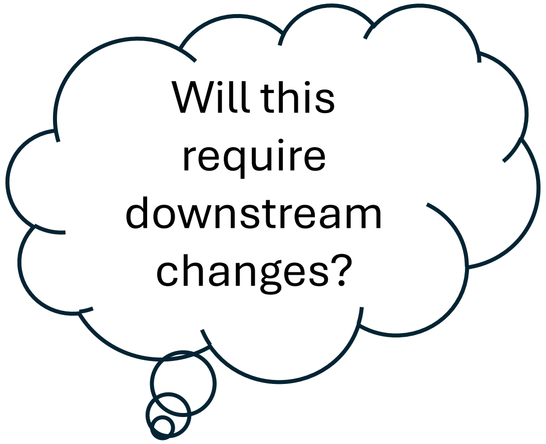

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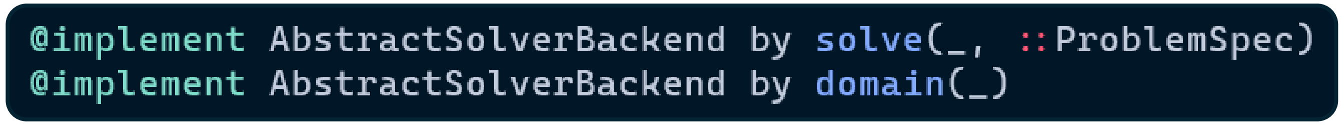

```
@implement AbstractSolverBackend by solve(_, ::ProblemSpec)
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```

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function solve(s::ShootingMethod, p::ProblemSpec)
    ....
```

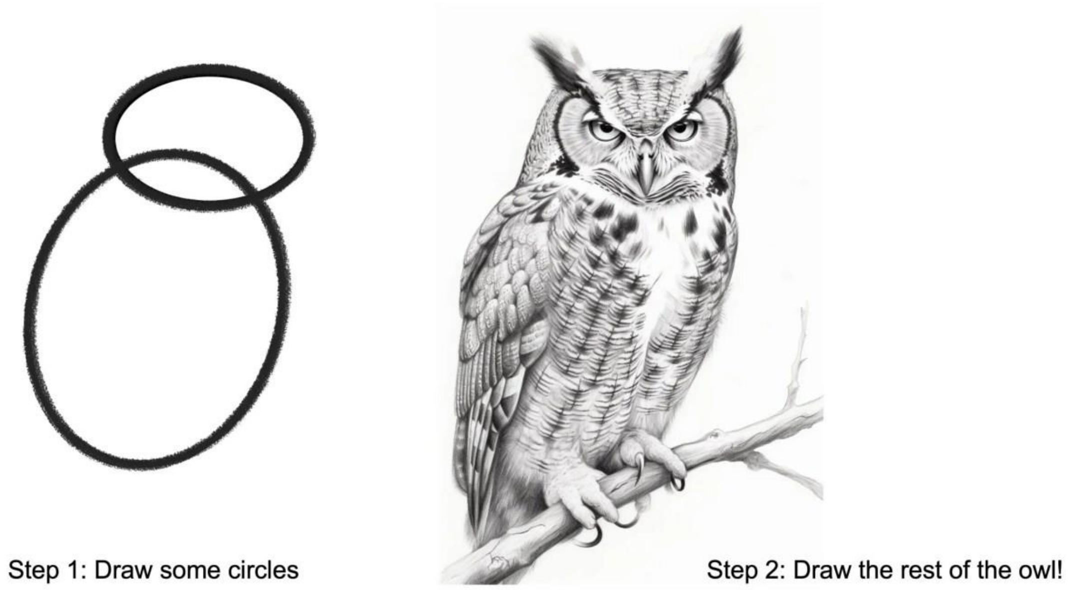
to enable higher order behaviors for a type

```julia
function solve_problem(solver::AbstractSolverBackend, p)
    problem = ProblemSpec(p)

    solution = solve(solver, problem)

    return solution
end
```

Isn’t this just abstraction?



YES!

- ...with a focus on the actions, not just the subjects
- ...plus formalizing contracts of methods

Interface Definition via Packages

```julia
@implement AbstractSolverBackend by solve(_, ::ProblemSpec)
@implement AbstractSolverBackend by domain(_)
```

```julia
struct ShootingMethod end
@assign ShootingMethod with AbstractSolverBackend

function solve(s::ShootingMethod, p::ProblemSpec)
    ...
end
```

```
Test Summary:                | Pass  Fail  Total  Time
ShootingMethod Interfaces |    1     1      2  0.2s

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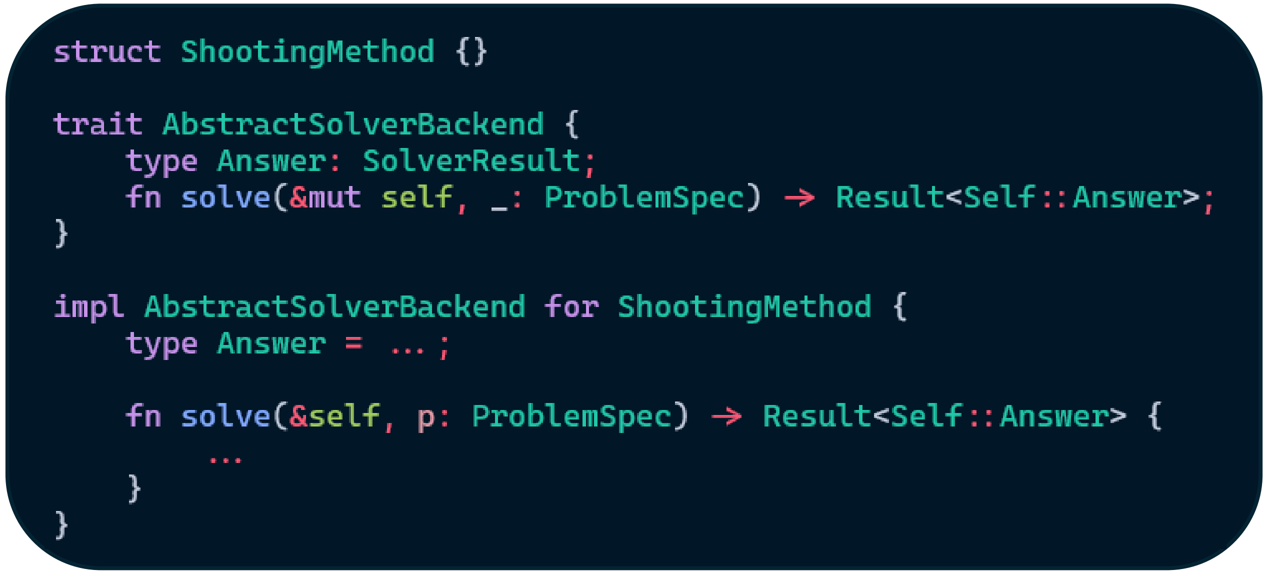
How do others solve this problem?

Traits + impl blocks, statically guaranteed, write methods explicitly in terms of interfaces



```rust
struct ShootingMethod {}

trait AbstractSolverBackend {
    type Answer: SolverResult;
    fn solve(&mut self, _: ProblemSpec) -> Result<Self::Answer>;
}

impl AbstractSolverBackend for ShootingMethod {
    type Answer = ... ;

    fn solve(&self, p: ProblemSpec) -> Result<Self::Answer> {
        ...
    }
}
```

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    fn solve(&self, p: ProblemSpec) -> Result<Self::Answer> {
        ...
    }
}
```

Abstract base classes, dynamic but class definitions fail without base class requirements

```python
class AbstractSolverBackend(ABC):
    @abstractmethod
    def solve(self, p):
        pass

class ShootingMethod(AbstractSolverBackend):
    # If we don't define this, we can't instantiate
    #   ShootingMethod
    def solve(self, p):
        ...
```

Tools for Interfaces

- RequiredInterfaces.jl + Supposition.jl
  - Interfaces + property based testing from Sukera
- Interfaces.jl
  - By Rafael Schouten, has a talk on this package later this week
- SimpleTraits.jl, WhereTraits.jl, BinaryTraits.jl, …
  - Many trait implementations solve similar interface problems

Interfaces vs Traits in Julia

Traits

- Often a dispatch tool, attempt at multiple inheritance
- Used with the Holy Traits pattern
- May assume an interface internally

Interfaces

- Just a collection of methods
- Not currently a dispatchable construct
- Interface inheritance could be:
  - Ad hoc
  - Abstract-type
  - Trait-based

Where do interfaces crop up?

Subject	Interface

DataToolkit.jl

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For loops	Base.iterate interface

DataToolkit.jl

Advantages of Interfaces

Technical

- Write testers for interfaces
    - Implementation (methods exist)
    - Property based (correctness)
- Catch errors/fail faster than integration tests
- Mock your interfaces
    - Catch higher order errors

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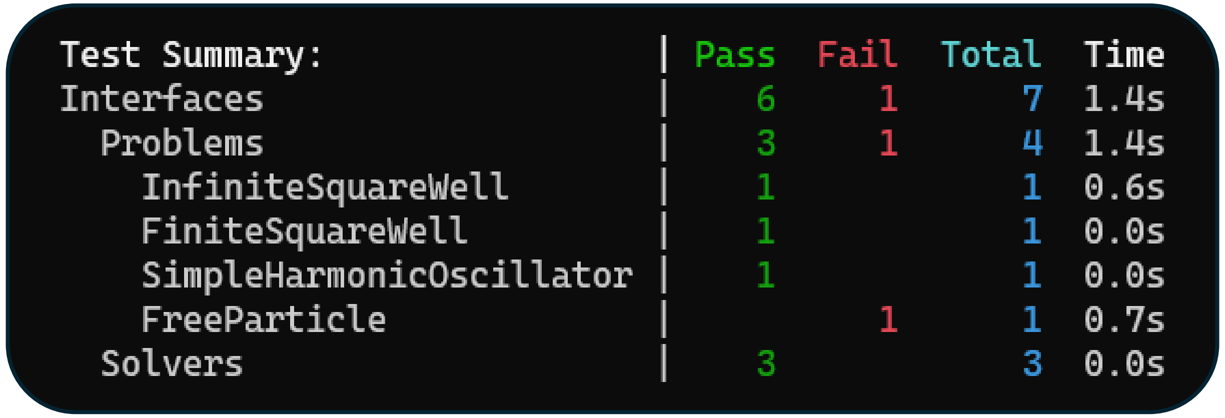
Development

- Defines boundaries for new code
- Limits **where** logical errors can occur
- Standardizes “language” and assumptions around your code

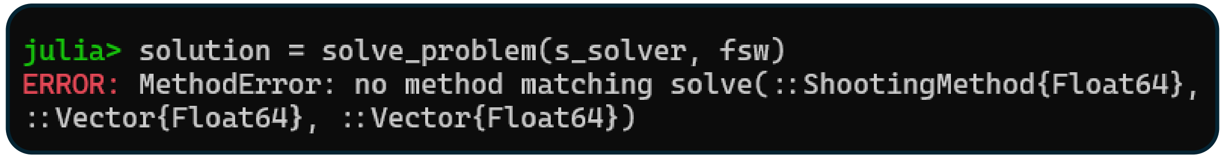
Building Confidently

- Stop `MethodErrors` missed by an incomplete test suite
  - Combinatorial explosion of multiple dispatch
- Helps isolate logical units to test, separate from integration tests
- SemVer is much easier to handle with interface testers



```
Test Summary:                | Pass  Fail  Total  Time
Interfaces                   |    6     1      7  1.4s
  Problems                   |    3     1      4  1.4s
    InfiniteSquareWell       |    1            1  0.6s
    FiniteSquareWell         |    1            1  0.0s
    SimpleHarmonicOscillator |    1            1  0.0s
    FreeParticle             |          1      1  0.7s
  Solvers                    |    3            3  0.0s
```

vs



```
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ERROR: MethodError: no method matching solve(::ShootingMethod{Float64},
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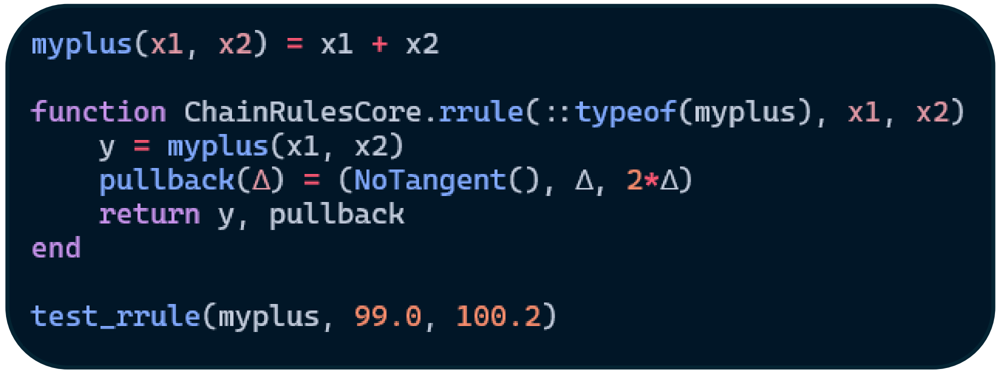
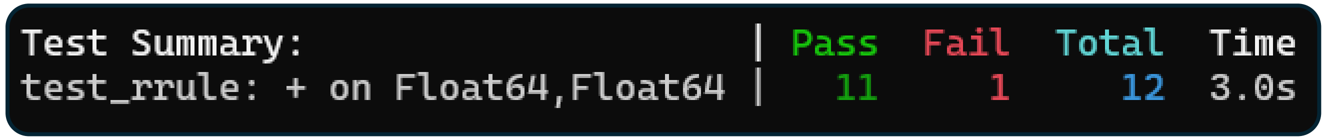
Testing Interfaces: ChainRules.jl

- Source-to-source autodiff uses libraries of differentiation rules
- This is an interface defined over functions!
- ChainRulesTestUtils.jl verifies interface **and** correctness



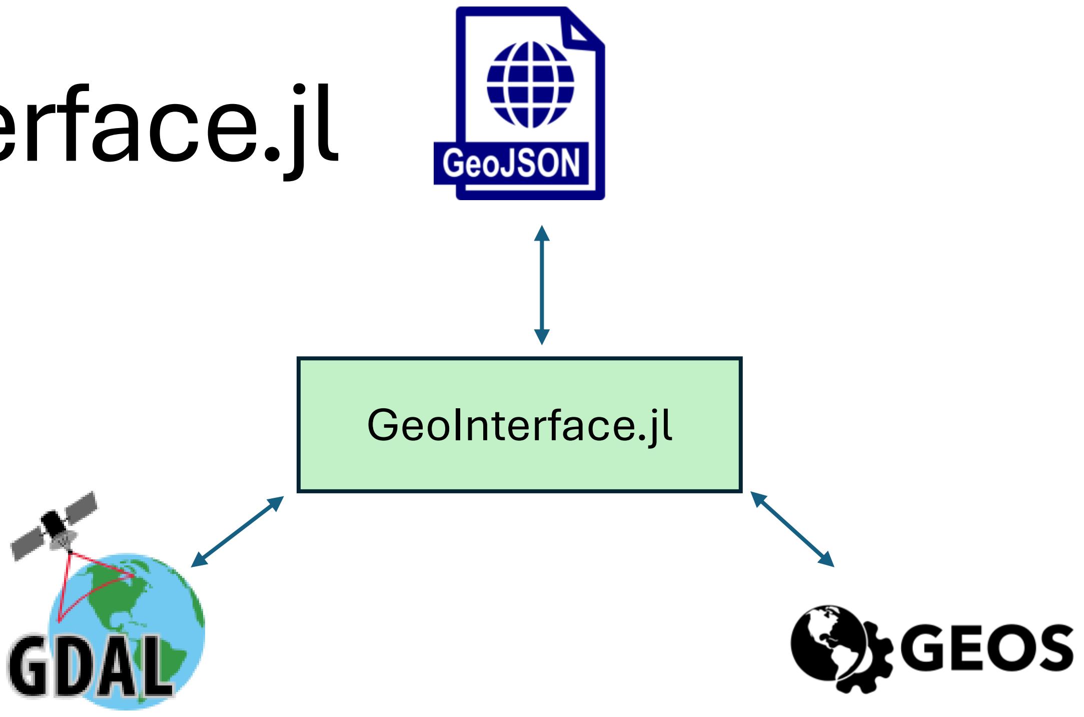
```julia
myplus(x1, x2) = x1 + x2

function ChainRulesCore.rrule(::typeof(myplus), x1, x2)
    y = myplus(x1, x2)
    pullback(Δ) = (NoTangent(), Δ, 2*Δ)
    return y, pullback
end

test_rrule(myplus, 99.0, 100.2)
```

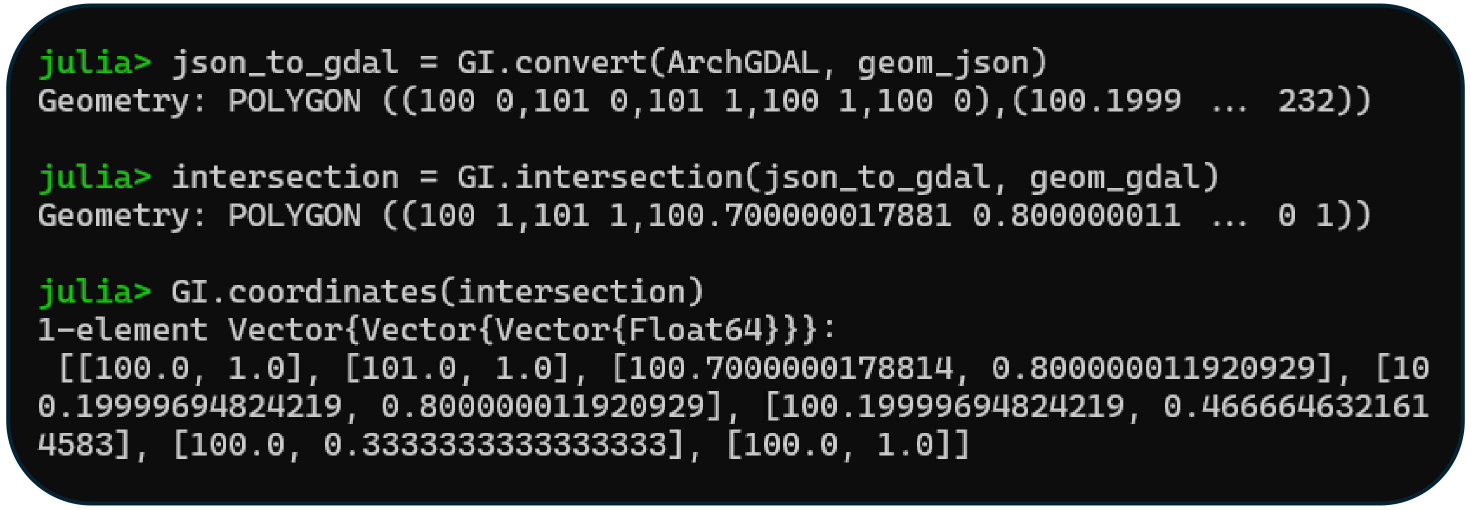


```
Test Summary:                    | Pass  Fail  Total  Time
test_rrule: + on Float64,Float64 |   11     1     12  3.0s
```

Uniting Packages: GeoInterface.jl

- Standard interface for geospatial data
- Trait system to represent geo features
- Facilitates inter-package conversions
- Package-agnostic algorithm implementations





```
julia> json_to_gdal = GI.convert(ArchGDAL, geom_json)
Geometry: POLYGON ((100 0,101 0,101 1,100 1,100 0),(100.1999  ...  232))

julia> intersection = GI.intersection(json_to_gdal, geom_gdal)
Geometry: POLYGON ((100 1,101 1,100.700000017881 0.800000011  ...  0 1))

julia> GI.coordinates(intersection)
1-element Vector{Vector{Vector{Float64}}}:
 [[100.0, 1.0], [101.0, 1.0], [100.7000000178814, 0.800000011920929], [10
0.19999694824219, 0.800000011920929], [100.19999694824219, 0.466664632161
4583], [100.0, 0.3333333333333333], [100.0, 1.0]]
```

Closing Thoughts

- Interface management is still awkward in Julia
  - No canonical “right” way to apply interfaces
- DuckDispatch.jl from Micah Rufsvold
  - Interfaces are ad-hoc but dispatchable
  - Can this be tightened up to improve usability?
- InterfaceSpecs.jl from Keno
  - Interface verification
  - Opens questions of “how do we handle incomplete interfaces”

Further Reading

[1] JuliaLang Issues 5 and 6975

- https://github.com/JuliaLang/julia/issues/6975

[2] Sukera’s writeup on RequiredInterfaces.jl

- https://github.com/Seelengrab/RequiredInterfaces.jl

[3] Jakob Nissen’s “What’s bad about Julia”

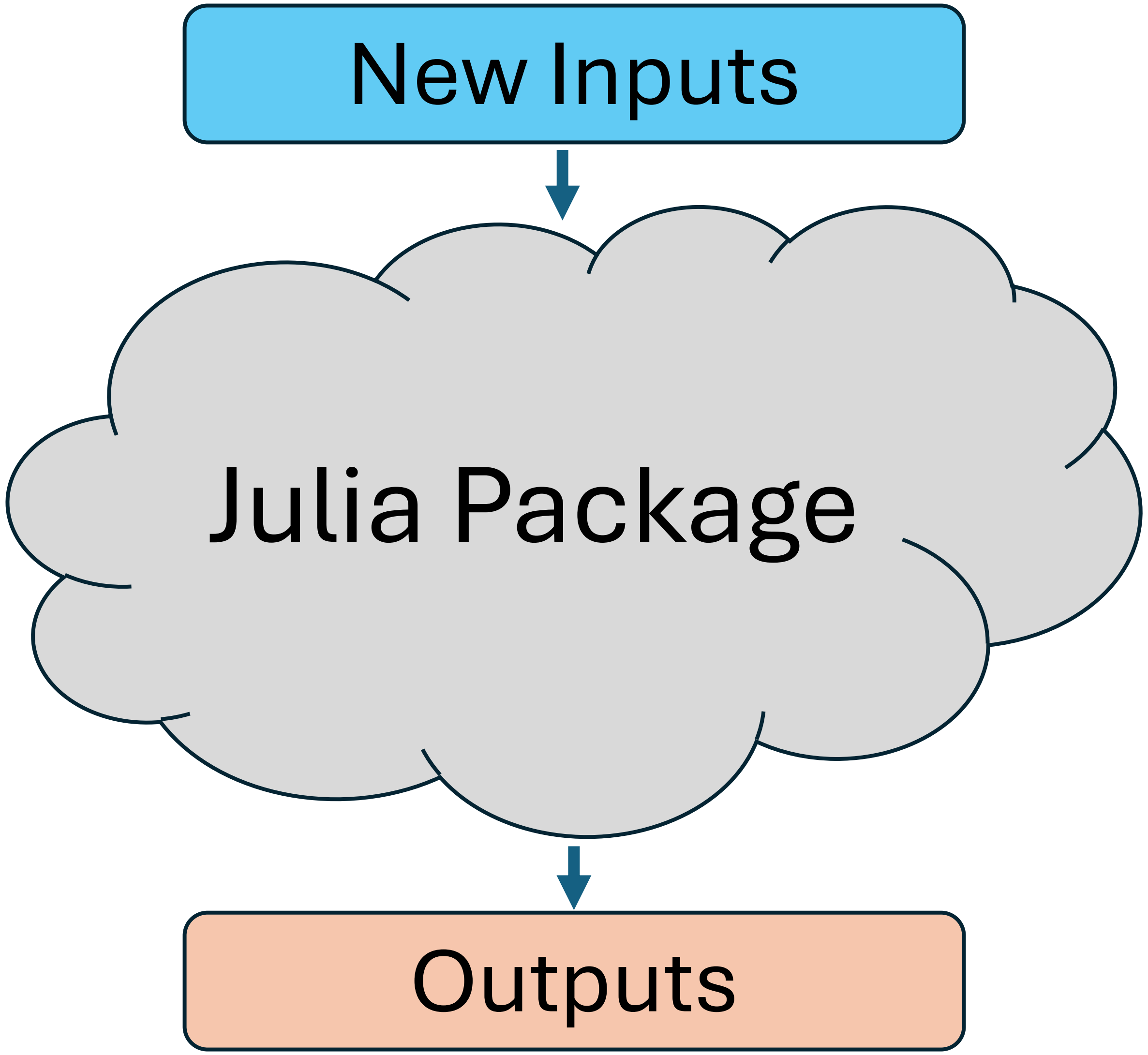
- https://viralinstruction.com/posts/badjulia/

[4] Keno Fischer’s InterfaceSpecs.jl

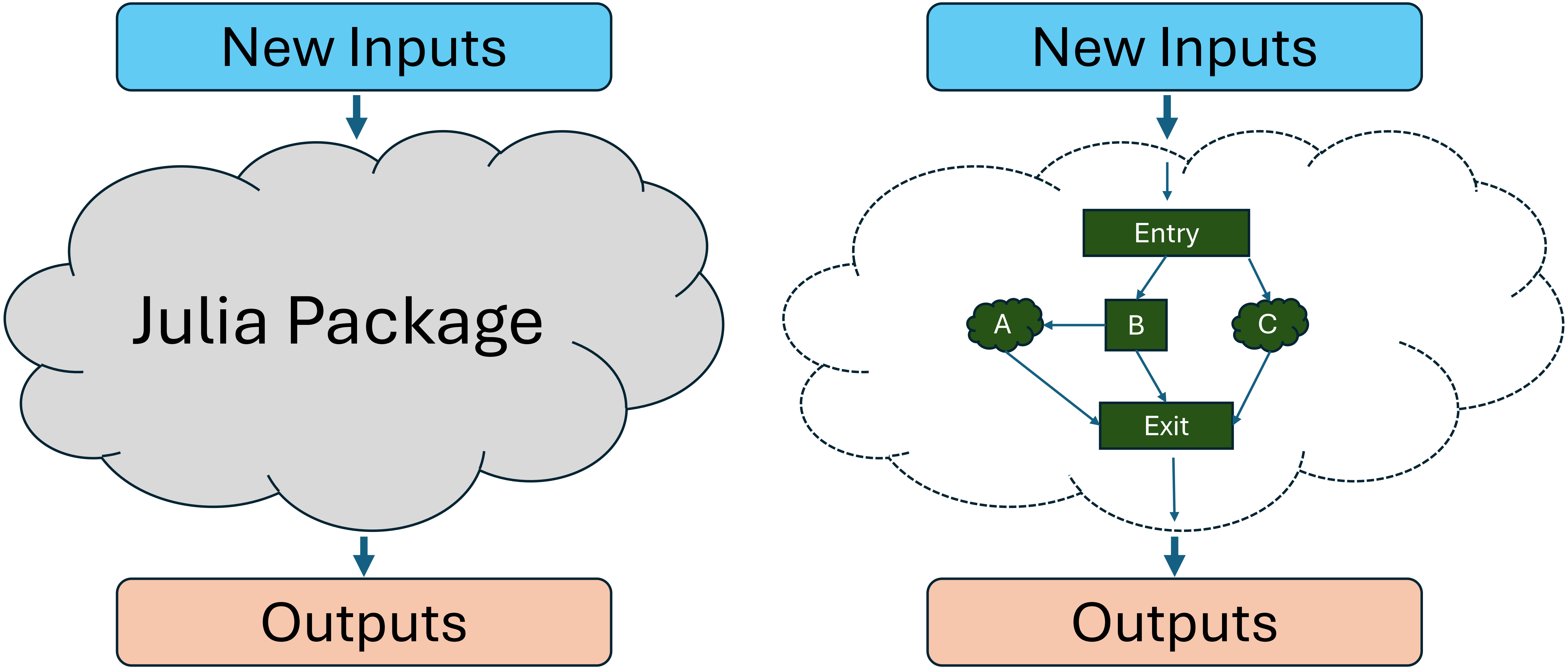
- https://github.com/Keno/InterfaceSpecs.jl

Thank You!

“Localizing” the Unknown



“Localizing” the Unknown


New Inputs
Julia Package
Outputs
New Inputs
Entry
A
B
C
Exit
Outputs