Forge:

Usable Model-Finding

IETF 120

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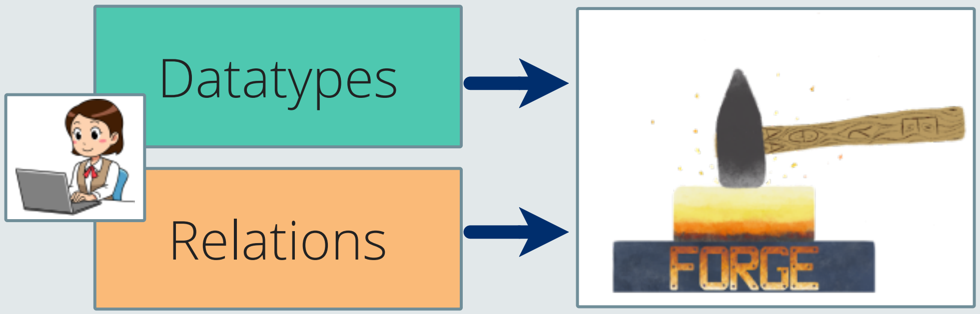
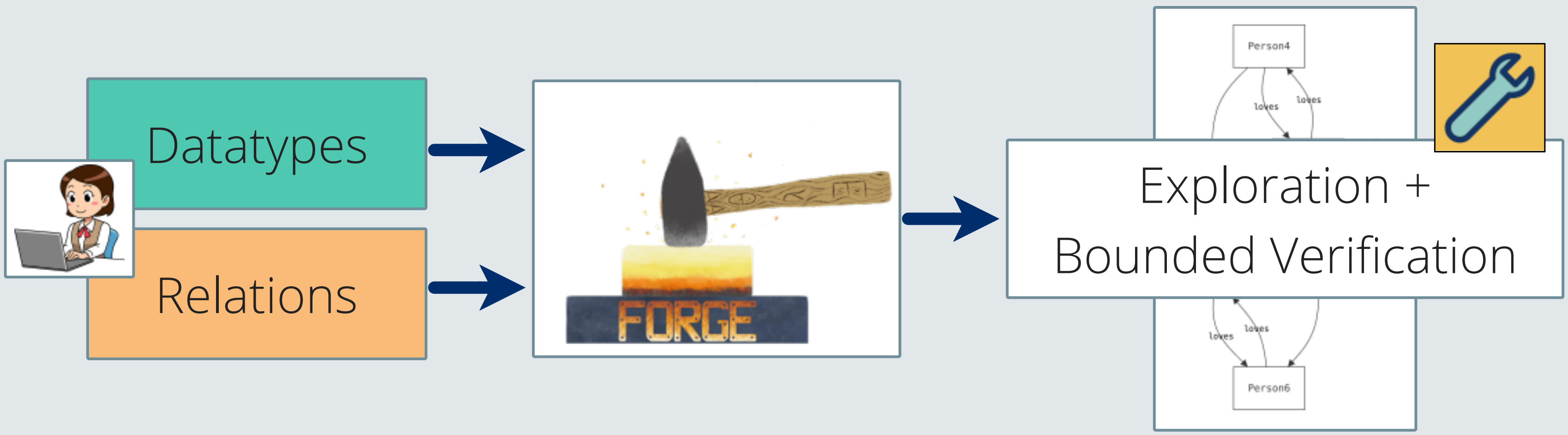
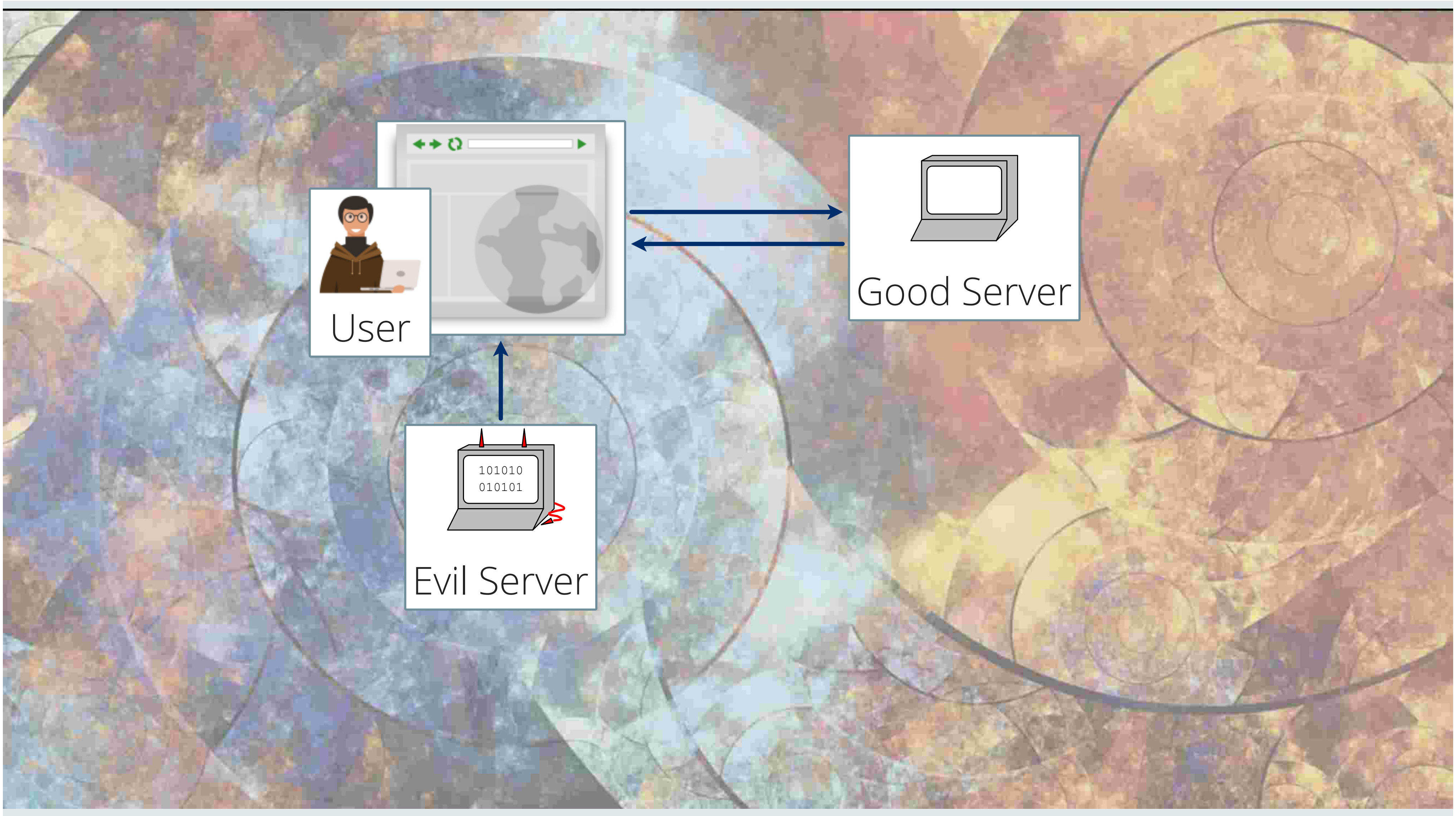
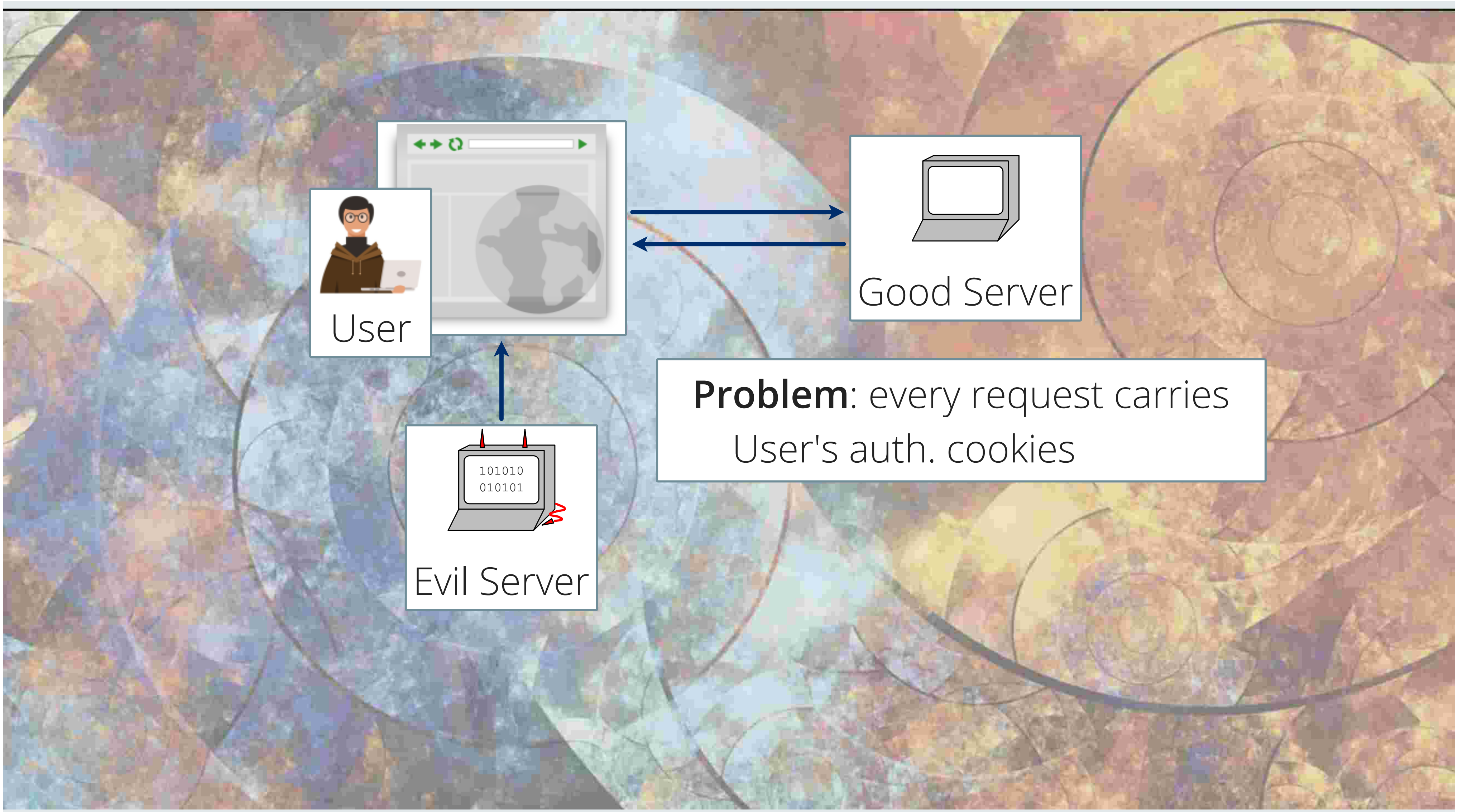
BROWN
THE UNIVERSITY OF UTAH


Datatypes
Relations
FORGE


Datatypes
Relations
FORGE
Person4
loves
loves
Exploration +
Bounded Verification
loves
loves
Person6

Example:
Cross-Site Request Forgery


User
Good Server
101010
010101
Evil Server



User
Good Server
Evil Server
101010
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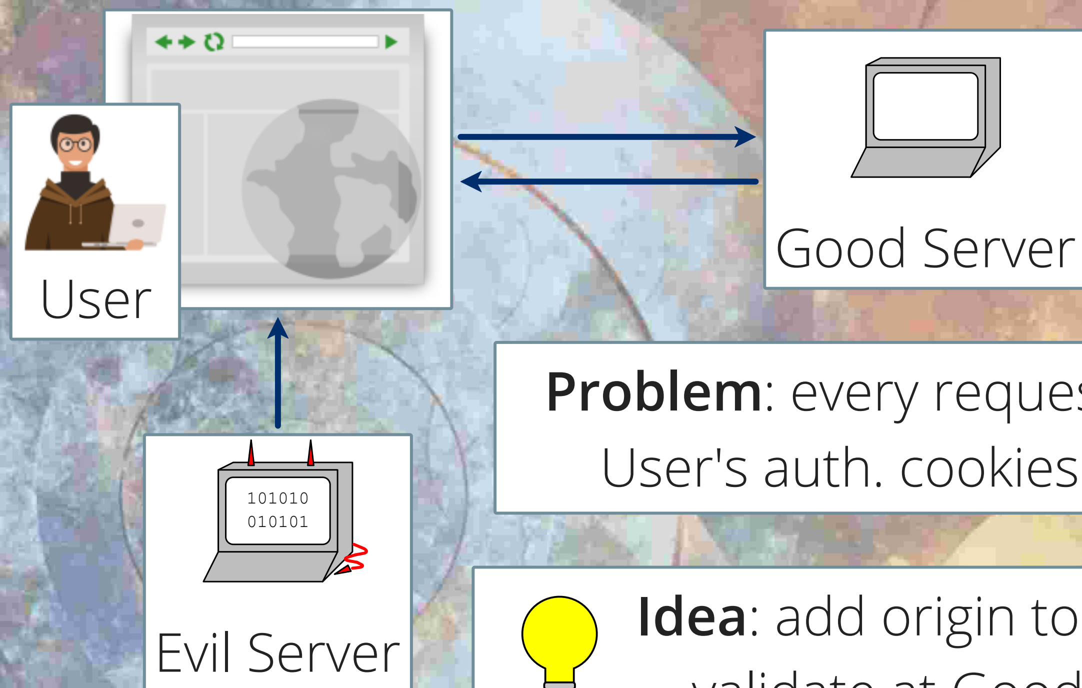
Problem: every request carries User's auth. cookies



Problem: every request carries User's auth. cookies

Idea: add origin to requests, validate at Good Server

Datatypes

```
abstract sig EndPoint {}

sig Client
 extends EndPoint {}
```

Datatypes

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sig Server
 extends EndPoint {
  causes: set HTTPEvent
}
```

multiplicity

Datatypes

```
abstract sig EndPoint {}

sig Client
 extends EndPoint {}

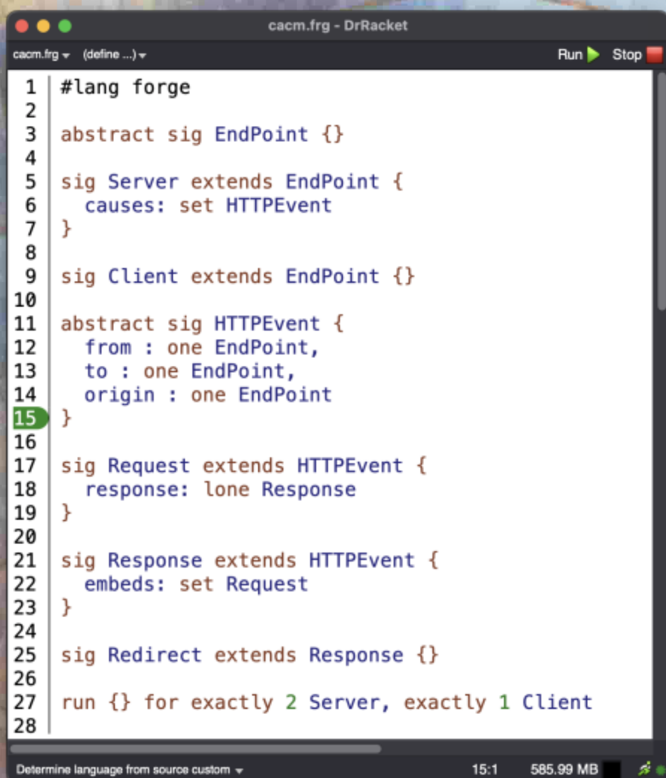
sig Server
 extends EndPoint {
  causes: set HTTPEvent
}
```

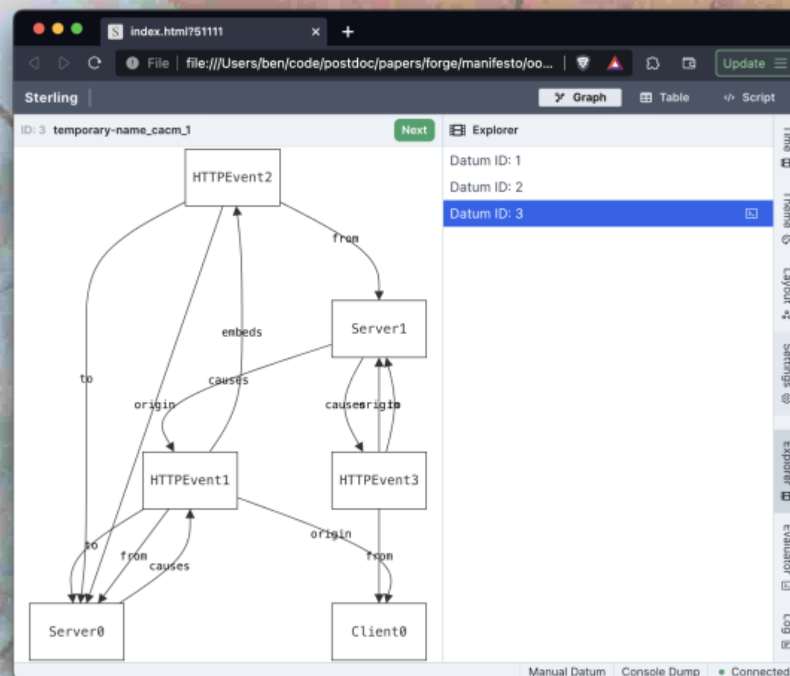
```
abstract sig HTTPEvent {
  from : one EndPoint,
  to : one EndPoint,
  origin : one EndPoint
}

// Request, Response, Redirect
//  extends HTTPEvent
```

Datatypes

==> Exploration





Relations

Type 1: facts about the world

```
pred RequestResponse {
  all r: Response | one response.r
  // every Response is paired with
  //  a unique request
}

// ...
```

Relations

Type 2: facts about our design

```
pred EnforceOrigins[good: Server] {
  all r:Request | r.to = good =>
    r.origin = good    // from good server
    or
    r.origin = r.from  // from client
}
```

Checks

```
run {
  // can we find (hope not)
  some good, bad: Server {
    EnforceOrigins[good]
    // ...
  }
} for exactly 2 Server,
      exactly 1 Client,
      5 HTTPEvent
```

bounds

Checks

```
run {
  // can we find (hope not)
  some good, bad: Server {
    EnforceOrigins[good]
    // ...
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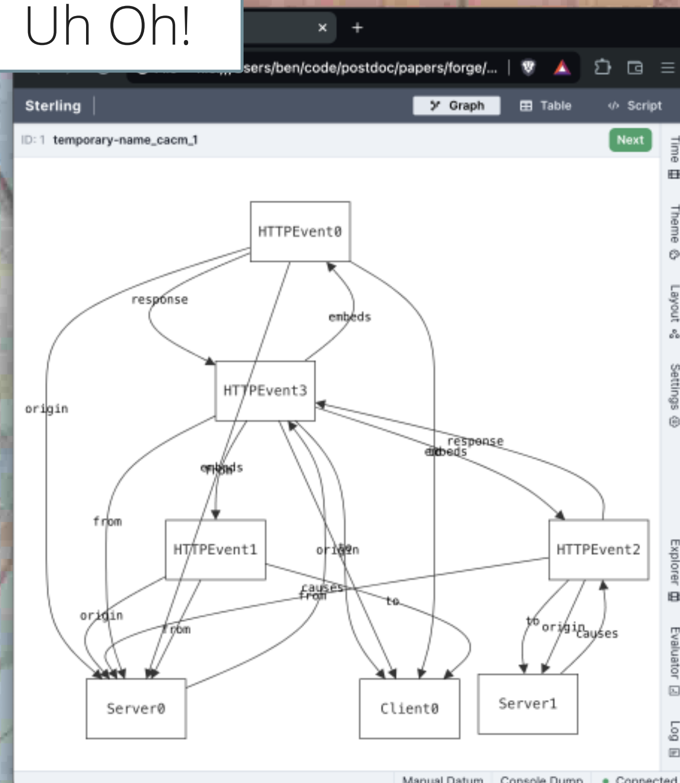
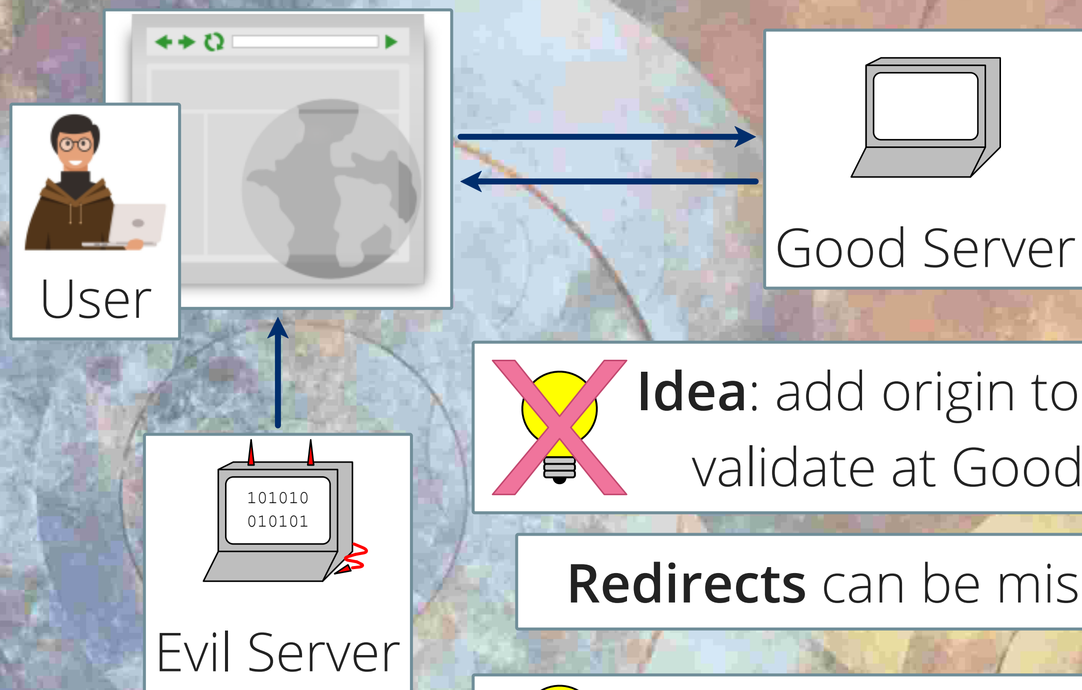
} for exactly 2 Server,
      exactly 1 Client,
      5 HTTPEvent
```

Uh Oh!



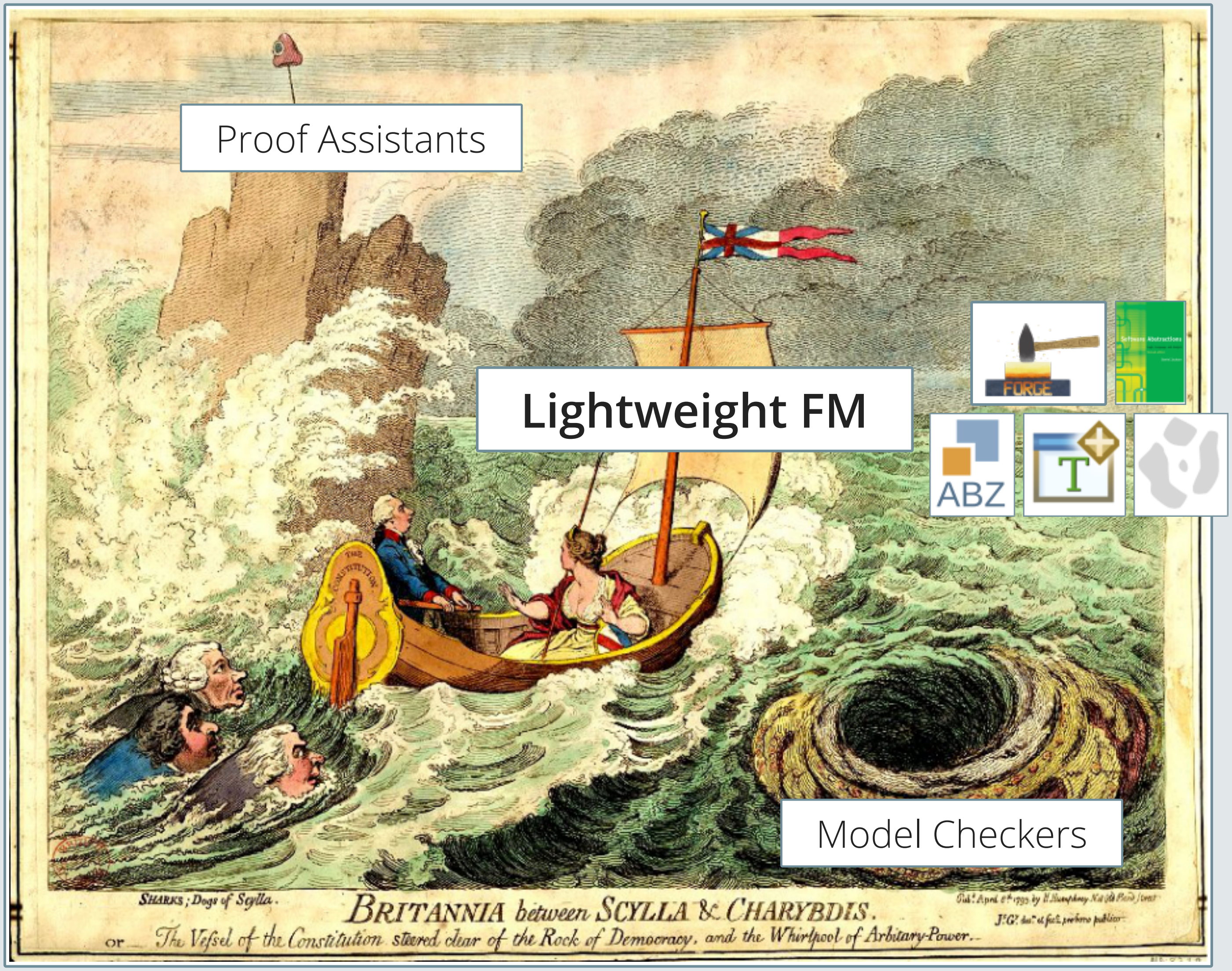


Idea: add origin to requests, validate at Good Server

Redirects can be mis-labeled

How about a set of origins??

Quickly found a bug!


Proof Assistants
Lightweight FM
Model Checkers
FORGE
ABZ
T
SHARKS; Dogs of Scylla.
BRITANNIA between SCYLLA & CHARYBDIS.
or — The Vessel of the Constitution steered clear of the Rock of Democracy, and the Whirlpool of Arbitary-Power.

Lightweight FM

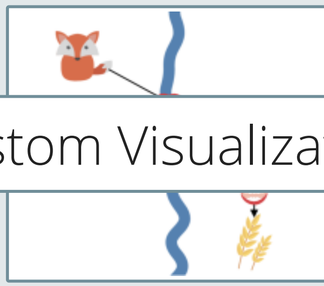
Usability >> Completeness

Insight: Most bugs have **small** instances

small scope hypothesis - D. Jackson

What sets Forge apart?

What sets Forge apart?

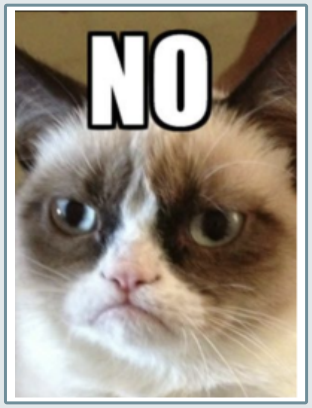


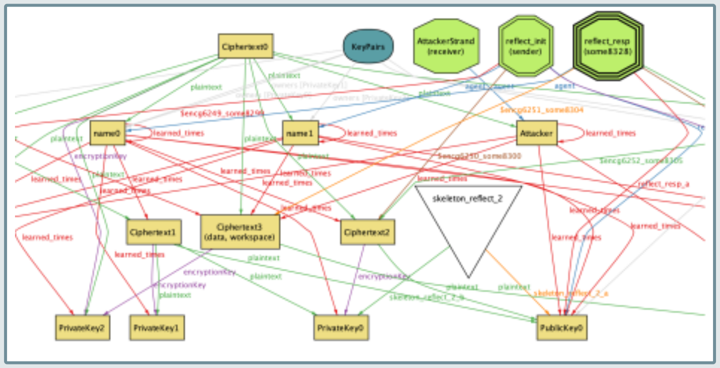
Custom Visualization

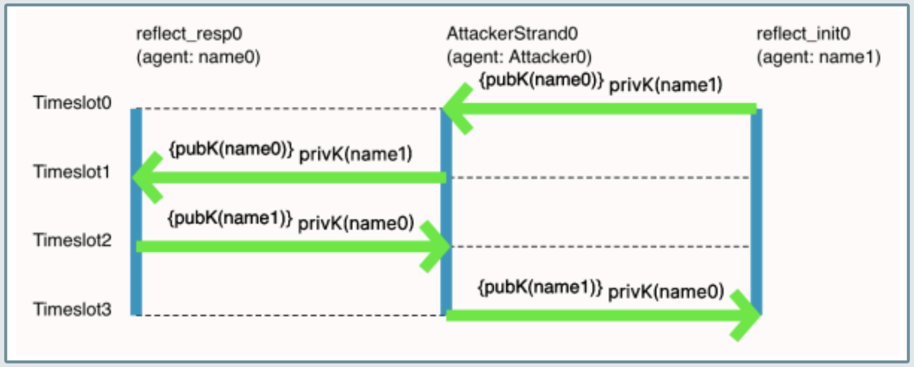
Unit Testing

Language Levels

Custom Visualization







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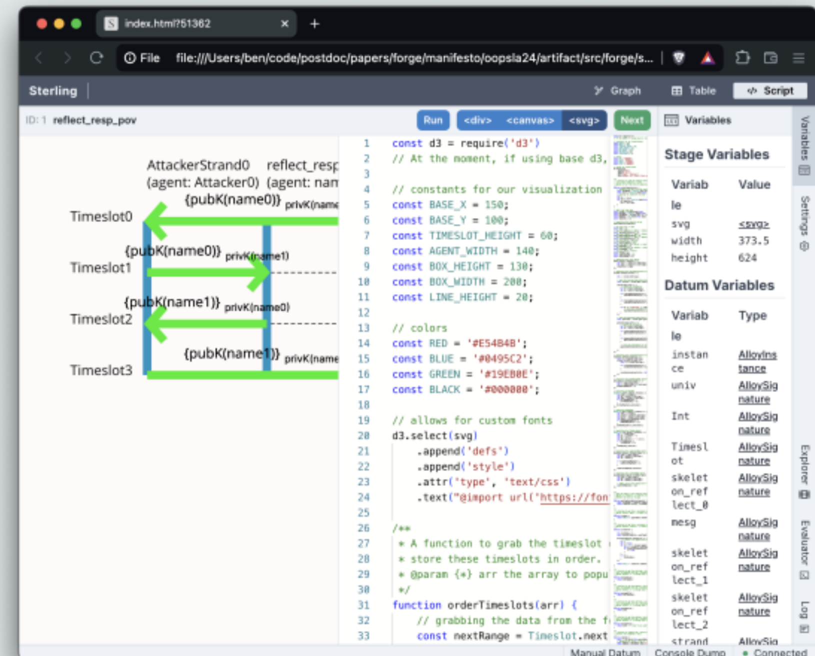

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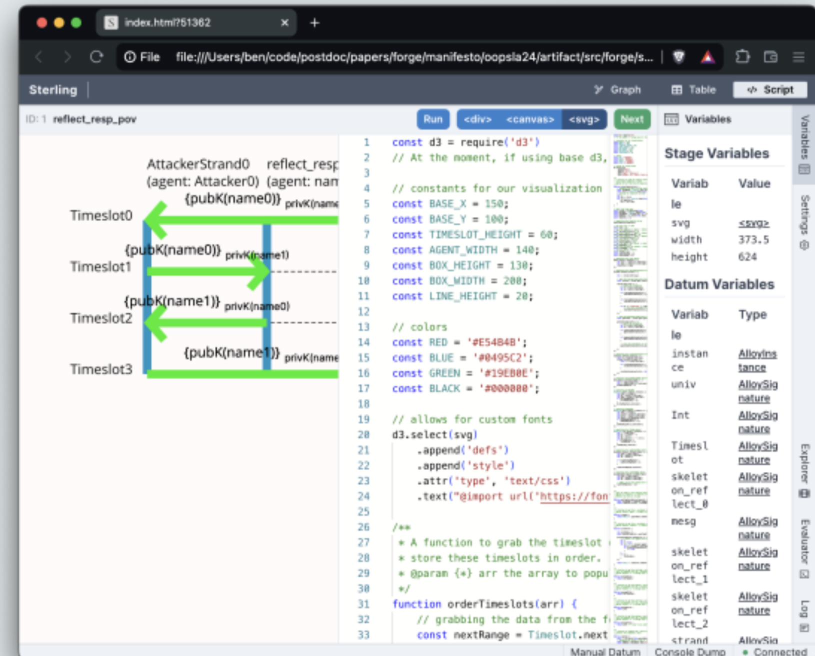
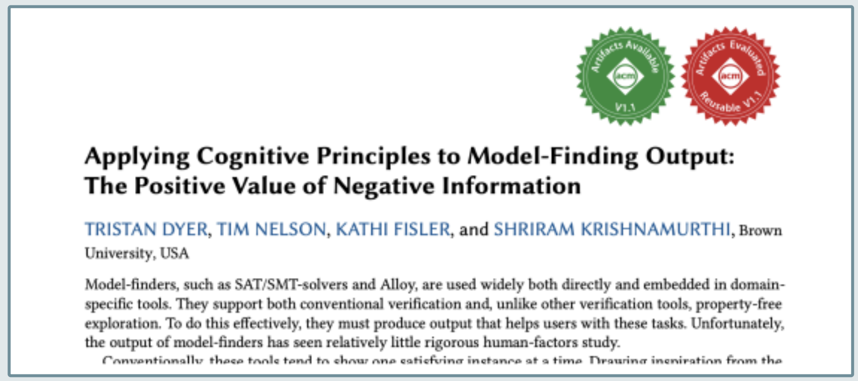


Much more than pretty pictures!

Building on decades of CogSci research



Applying Cognitive Principles to Model-Finding Output: The Positive Value of Negative Information

TRISTAN DYER, TIM NELSON, KATHI FISLER, and SHRIRAM KRISHNAMURTHI, Brown University, USA

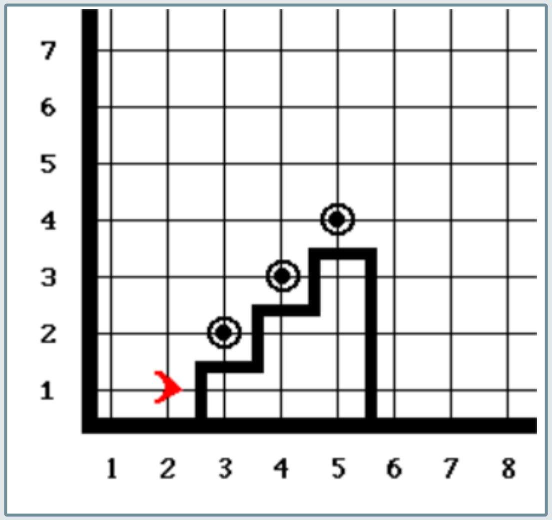
Model-finders, such as SAT/SMT-solvers and Alloy, are used widely both directly and embedded in domain-specific tools. They support both conventional verification and, unlike other verification tools, property-free exploration. To do this effectively, they must produce output that helps users with these tasks. Unfortunately, the output of model-finders has seen relatively little rigorous human-factors study.
Conventionally, these tools tend to show one satisfying instance at a time. Drawing inspiration from the

Unit Testing

`example` `assert` `test suite` `test expect`

How do we know the **model** is correct?

Unit Testing



Challenge: Programming != Modeling

Language Levels

```
r not in r.^(response.embeds)
```

Language Levels

```
r not in r.^(response.embeds)
```


```
CS1 in prereqs.CS2
```

"What a travesty that would be!"

Language Levels

`#lang forge/temporal`
++ Linear Temporal Logic

`#lang forge/relational`
++ N-ary Relations

`#lang forge/bsl`
Functional Relations

Language Levels

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#lang forge/temporal
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++ Linear Temporal Logic

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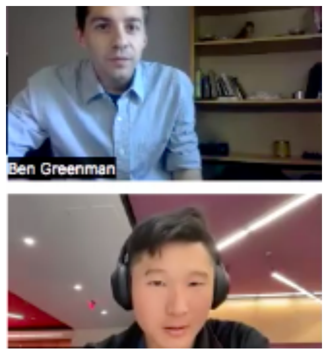
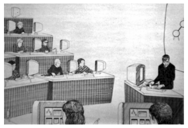
++ N-ary Relations

```
#lang forge/bsl
```
Functional Relations

In what ways is LTL difficult to use?

+3 years of studies with researchers and students





Categories of LTL Errors

Bad Prop	Implicit G
Bad State Index	Implicit Prefix
Bad State Quantification	Other Implicit
Cycle G	Trace Split U
Exclusive U	Spreading X
Implicit F	Weak U

Q. Translate to LTL:

The green light turns on exactly once

F = eventually **G** = always **X** = next state

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```
F(green) & G(green => X(!green))
```

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✗ **F**(green) & **G**(green => **X**(!green))

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✓ `F(green) & G(green => X(G(!green)))`

Q. Translate to LTL:

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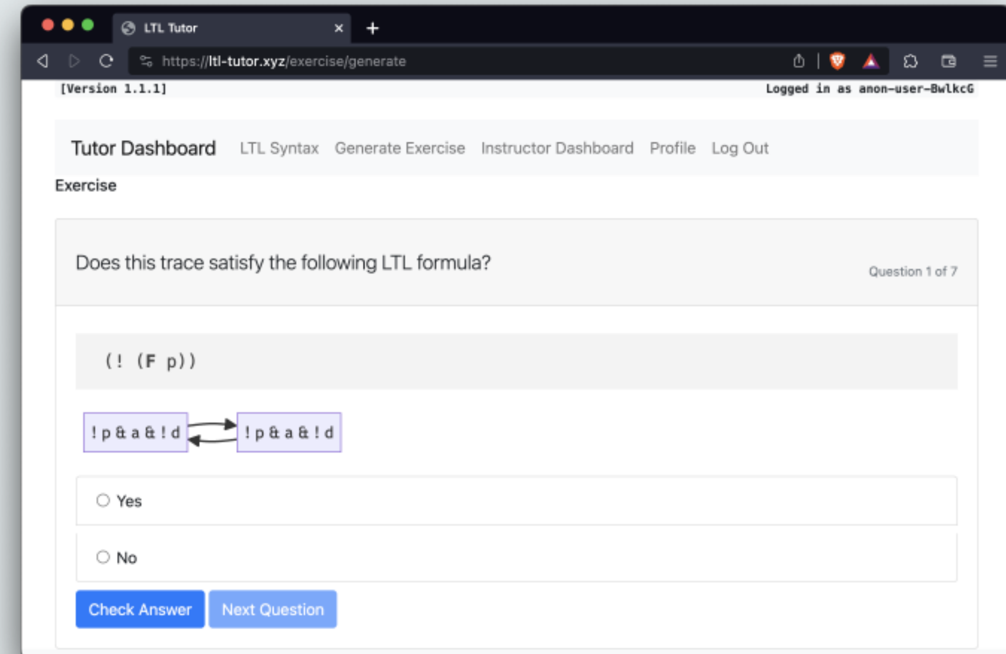
Implicit G

✓ `F(green) & G(green => X(G(!green)))`

https://ltl-tutor.xyz



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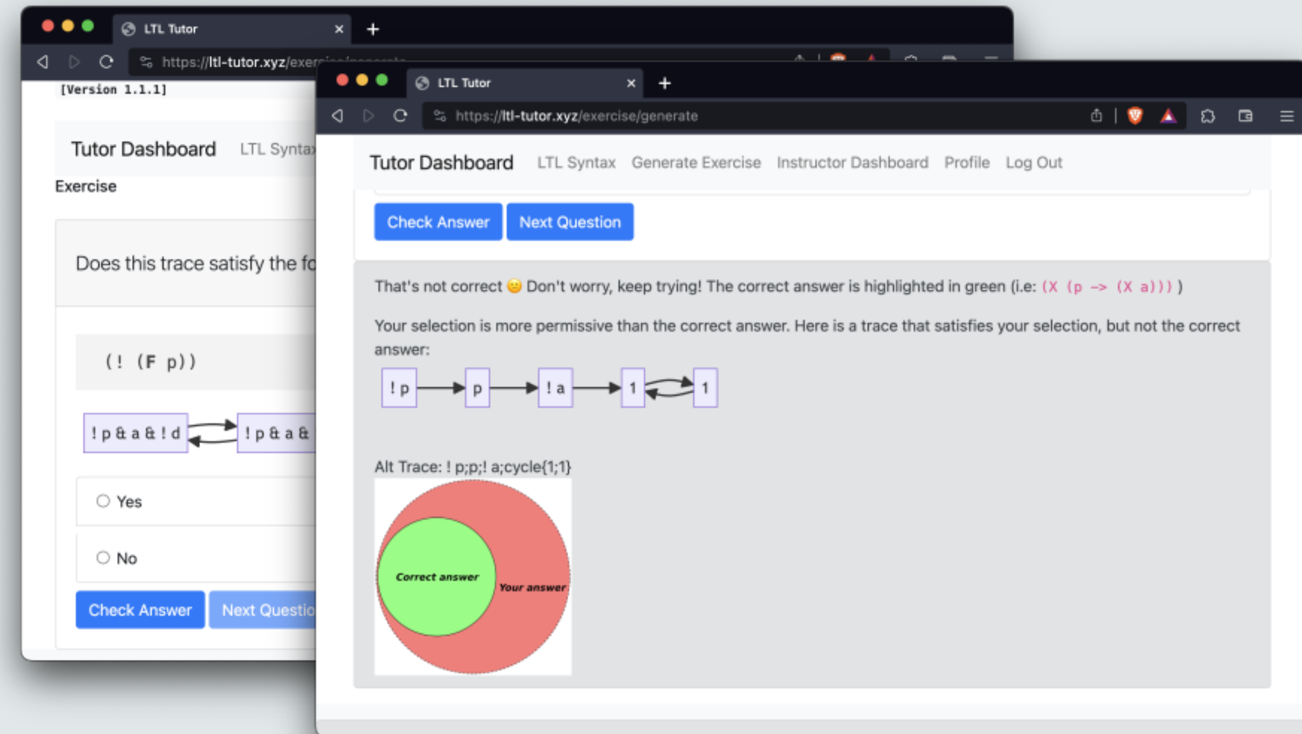

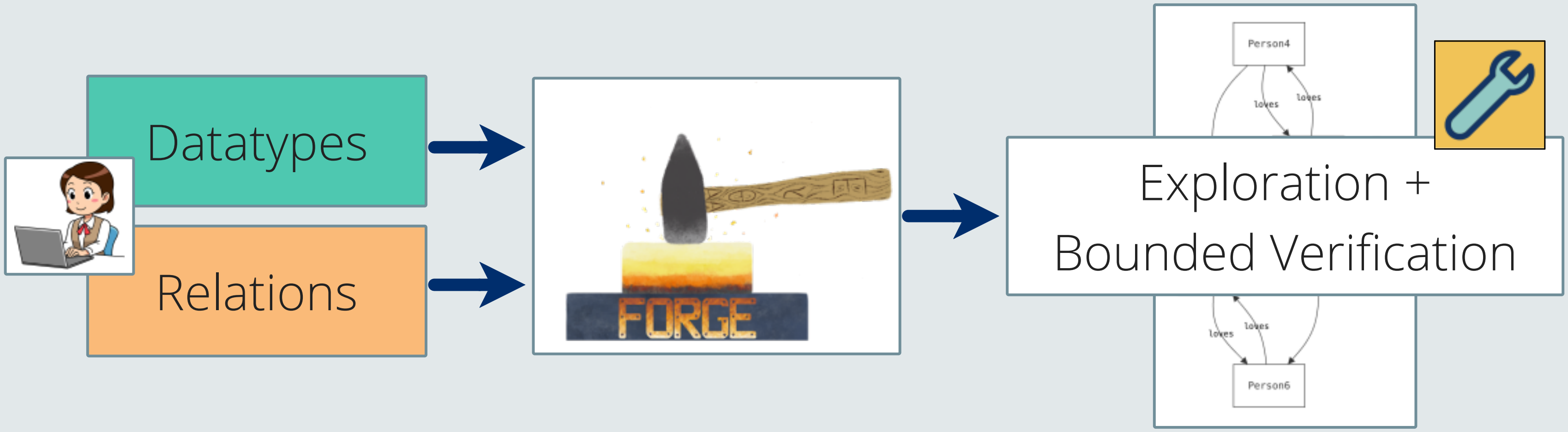
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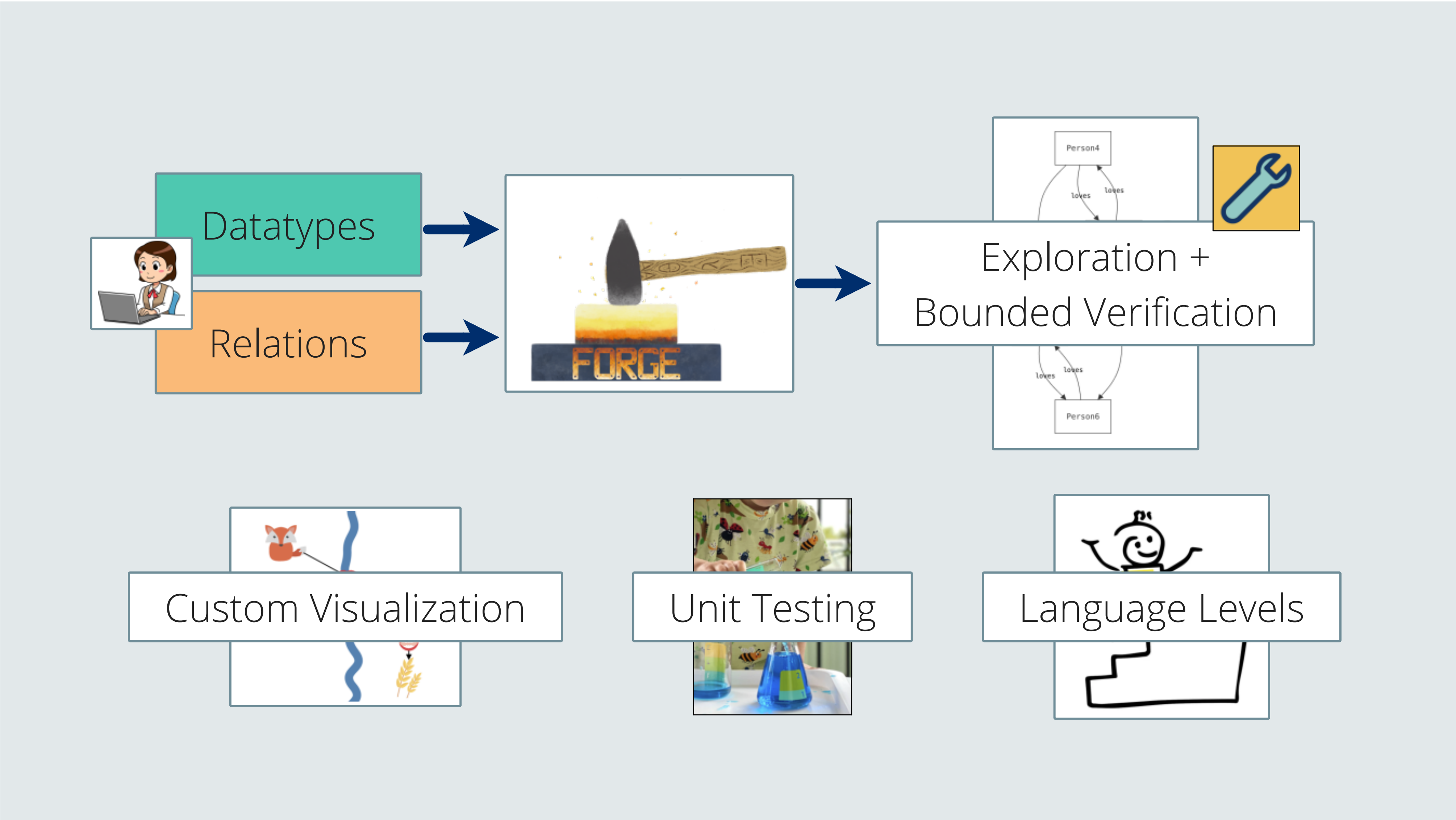
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https://forge-fm.org

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