RESTler: Stateful REST API Fuzzing

Vaggelis Atlidakis (Columbia University), Patrice Godefroid (Microsoft Research), and Marina Polishchuk (Microsoft Research)

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- Explosion of cloud services (in Azure and AWS)
- Rapidly evolving ecosystem
- REST APIs is the standard way to use cloud services

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➢ **What about testing?**

Testing REST APIs

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  - Not Stateful

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  - New grammar for every new service
- HTTP fuzzers (e.g., Sulley, Burp, ...)
  - Requires live traffic
  - Not Stateful
- Custom tools for specific APIs
  - Labour intensive
  - High maintenance

Our solution

- RESTler: A stateful REST API fuzzer

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Key techniques for stateful REST API fuzzing

1. Dependency analysis between request types

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Key techniques for stateful REST API fuzzing

1. Dependency analysis between request types
2. Dynamic feedback loop that learns from past tests

Our solution

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Kinds of bugs RESTler can find

- “500 Internal Server Error” (unhandled exceptions) after executing a sequence of API requests

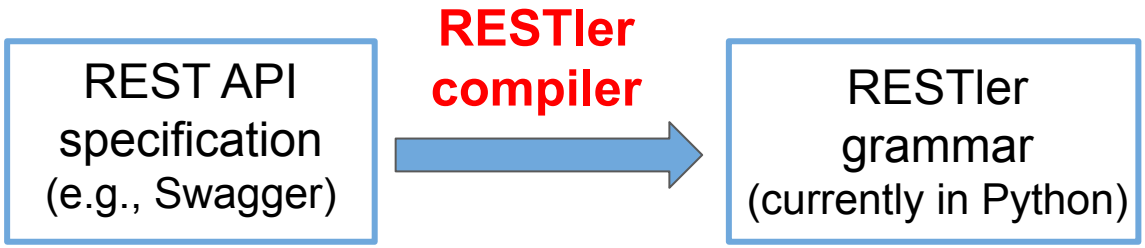
Outline

- Limitations of existing solutions
- **System overview**
- **Evaluation & bugs found**
- **Experiences with public cloud services**
- **Conclusions**

System overview

REST API specification (e.g., Swagger)

System overview



- Describe how to fuzz each request type
- Identify producer/consumer dependencies
- Generate code to parse responses

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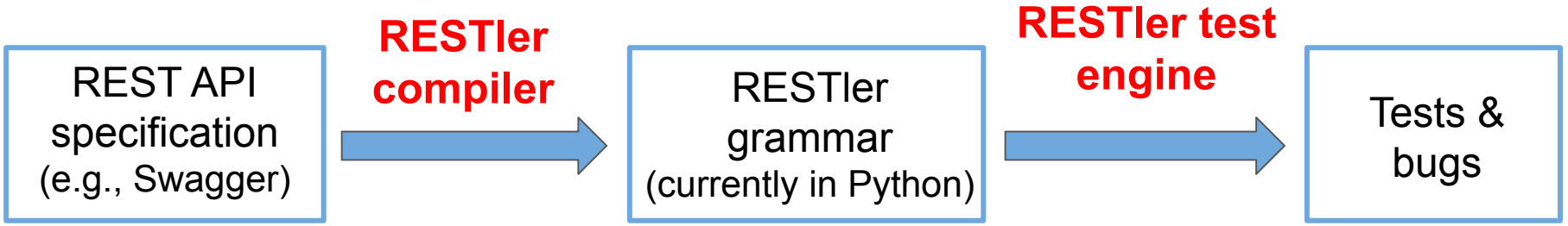
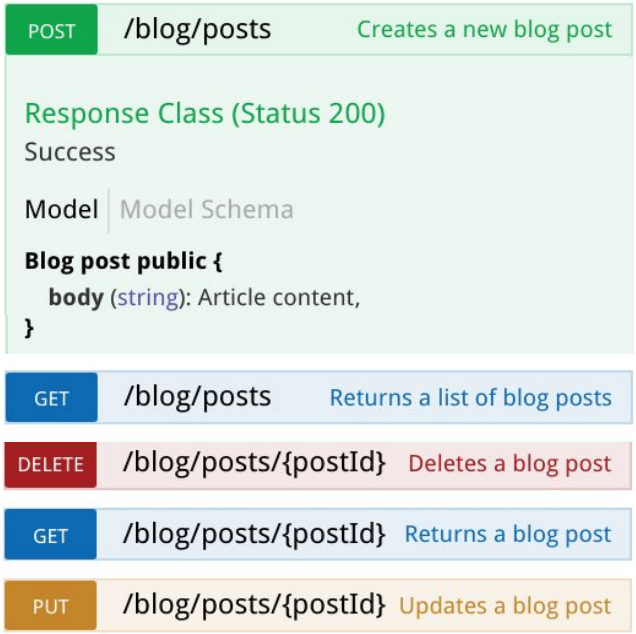


- Describe how to fuzz each request type
- Identify producer/consumer dependencies
- Generate code to parse responses

- Generate and execute tests: sequences of requests
- Systematic state-space exploration (breadth first search and others)
- Analyze test results: Dynamic feedback loop learns from service responses in past tests

RESTler: Stateful REST API Fuzzing

Example



Sample Swagger specification

```
from restler import requests
from restler import dependencies

def parse_posts(data):
  post_id = data["id"]
  dependencies.set_var(post_id)

request = requests.Request(
  restler_static("POST"),
  restler_static("/api/blog/posts/"),
  restler_static("HTTP/1.1"),
  restler_static("{"),
  restler_static("body:"),
  restler_fuzzable("string"),
  restler_static("}"),
  'post_send': {
      'parser': parse_posts,
      'dependencies': [
          post_id.writer(),
      ]
  }
          ...
```

RESTler grammar fragment

```
Sending: POST /api/blog/posts/ HTTP/1.1
Accept: application/json
Content-Type: application/json
Host: localhost:8888
{"body":"sampleString"}

Received: HTTP/1.1 201 CREATED
Content-Type: application/json
Content-Length: 37
Server: Werkzeug/0.14.1 Python/2.7.12
Date: Sun, 01 Apr 2018 05:10:32 GMT
{"body": "sampleString", "id": 5889}
```

Sample test
(request and response)

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- Q2: Can RESTler find bugs in large-scale production services?

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- Q2: Can RESTler find bugs in large-scale production services?

Case study: Gitlab

- Open-source self-hosted GIT service (millions of users)
- ~376 kLOC (Ruby + native libraries)
- Complex REST API

Deeper service exploration (Q1)

API Family	Total requests	Seq. len.	Cumulative code coverage (lines of code)	Tests
Commits	11	1	598	1
		2	1108	7
		3	1196	250
		4	1760	2220
		5	1760	3667
Branches	7	1	598	1
		2	1089	8
		3	1172	58
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Issues	22	1	816	37
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Testing GitLab APIs with RESTler (5h per API family)

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- **Brute-force**: 11 request types / 4 renderings on avg / (11*4)^3 = 85k feasible sequences of length 3
- **RESTler:** Seq. Len. 3 / Test generated 250

(feedback + dependencies!)

New bugs found in GitLab (Q2)

API Family	BFS	BFS-Fast	Random-Walk	∩	U
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Branches	7	7	7	5	8
Issues	0	1	1	0	1
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- All bugs were easily reproducible, confirmed, and fixed!

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- Example Bug [#50268]
  1. Create a gitlab project
  2. Create a repository file with a proper commit message
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➢ "500 Internal Server Error"

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Experiences with Azure and Office 365

- Four production cloud services with open-source specs
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- Needed new features
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  - Authentication Hooks (short-lived access tokens)
  - Resource-specific mutations (exotic naming schemes)
- **RESTler found bugs in all services tested so far!**

Conclusions

- Build the first stateful REST API fuzzer!
- Found bugs in Azure and Office 365 cloud services!
- Found 28 new bugs in Gitlab!

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➢ **Developers are fixing the bugs found with RESTler!**

Thank you!

Paper link

https://tinyurl.com/yyg5a8je

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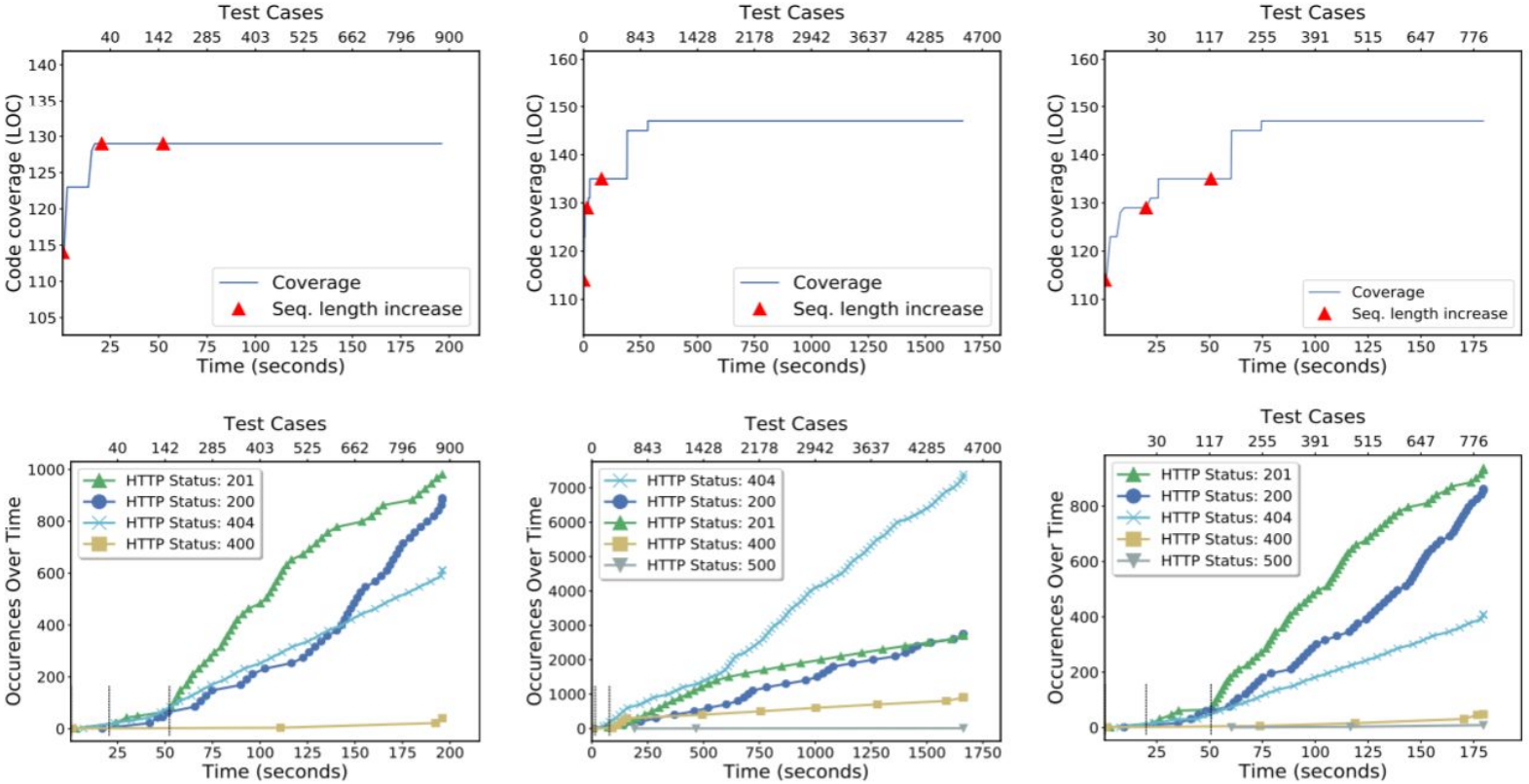
Scalability of state-space exploration strategies

API	Total Requests	Time (hrs)	BFS			BFS-Fast			RandomWalk		
			Len.	Coverage	seqSet	Len.	Coverage	seqSet	Len. (restarts)	Coverage	seqSet
Commits	11 (*11)	1	4	1202		7	1697		13 (16)	1285	
		3	5	1760		9	1731		13 (35)	1295	
		5	5	1760	20679	12	1731	33	13 (56)	1303	1
Branches	7 (*2)	1	5	1182		21	1154		15 (24)	1182	
		3	5	1185		37	1178		19 (92)	1187	
		5	5	1185	5528	47	1178	11	22 (158)	1208	1
Issues	22 (*82)	1	2	1150		2	1086		10 (1)	770	
		3	3	1163		4	1551		10 (1)	770	
		5	3	1163	15658	5	1570	26	16 (2)	847	1
Repos	10 (*24)	1	3	1127		5	1141		10 (29)	1195	
		3	3	1127		7	1141		13 (88)	1231	
		5	3	1181	2194	8	1161	64	13 (142)	1231	1
Groups	50 (*2)	1	2	961		6	1275		19 (41)	1167	
		3	3	1177		11	1275		19 (120)	1250	
		5	3	1177	79518	14	1275	130	22 (186)	1283	1
Projects	48 (*4)	1	2	1006		5	1318		4 (3)	889	
		3	2	1053		11	1319		22 (31)	1024	
		5	3	1203	18173	15	1319	171	22 (45)	1273	1

Impact of the two key techniques



Extending sequences in Randoop

```
public class A {
  public A() {...}
  public B m1(A a1) {...}
}
```

```
public class B {
  public B(int i) {...}
  public void m2(B b, A a) {...}
}
```

sequence s_1	sequence s_2	sequence s_3
`B b1 = new B(0);`	`B b2 = new B(0);`	`A a1 = new A();` `B b3 = a1.m1(a1);`

seqs	*vals*	*extend*(m2, *seqs*, *vals*)

$\langle s_1, s_3 \rangle$	$\langle s_1.1, s_1.1, s_3.1 \rangle$
	(i.e.: b1, b1, a1)
		`B b1 = new B(0);`
		`A a1 = new A();`
		`B b3 = a1.m1(a1);`
		`b1.m2(b1,a1);`

$\langle s_3, s_1 \rangle$	$\langle s_1.1, s_1.1, s_3.1 \rangle$
	(i.e.: b1, b1, a1)
		`A a1 = new A();`
		`B b3 = a1.m1(a1);`
		`B b1 = new B(0);`
		`b1.m2(b1,a1);`

$\langle s_1, s_2 \rangle$	$\langle s_1.1, s_2.1, \text{null} \rangle$
	(i.e.: b1, b2, null)
		`B b1 = new B(0);`
		`B b2 = new B(0);`
		`b1.m2(b2,null);`

Sample bugfix in Gitlab

Showing 3 changed files +18

changelogs/unreleased/api-empty-commit-message.yml 0 → 100644 — View file @ ceaee58c

```
+ ---
+ title: 'API: Catch empty commit messages'
+ merge_request: 21322
+ author: Robert Schilling
+ type: fixed
```

lib/api/files.rb — View file @ ceaee58c

```
@@ -59,7 +59,7 @@ module API
       params :simple_file_params do
         requires :file_path, type: String, desc: 'The url encoded path to the file. Ex. lib%2Fclass%2Erb'
         requires :branch, type: String, desc: 'Name of the branch to commit into. To create a new branch, also provide `start_branch`.'
-        requires :commit_message, type: String, desc: 'Commit message'
+        requires :commit_message, type: String, regexp: /^\S+$/, desc: 'Commit message'
         optional :start_branch, type: String, desc: 'Name of the branch to start the new commit from'
         optional :author_email, type: String, desc: 'The email of the author'
         optional :author_name, type: String, desc: 'The name of the author'
```

spec/requests/api/files_spec.rb — View file @ ceaee58c

```
@@ -337,6 +337,18 @@ describe API::Files do
       expect(response).to have_gitlab_http_status(400)
     end

+    it 'returns a 400 bad request if the commit message is empty' do
+      invalid_params = {
+        branch: 'master',
+        content: 'puts 8',
+        commit_message: ''
+      }
+
+      post api(route(file_path), user), invalid_params
+
+      expect(response).to have_gitlab_http_status(400)
+    end
+
     it "returns a 400 if editor fails to create file" do
       allow_any_instance_of(Repository).to receive(:create_file)
         .and_raise(Gitlab::Git::CommitError, 'Cannot create file')
```

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Developers' Responses