Till REcollapse

Fuzzing the Web for Mysterious Bugs

@0xacb

$ whoami

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Agenda

- 1. Input & Regex quirks
- 2. The REcollapse technique
- 3. Mysterious bugs
- 4. Real-world examples

Intro

https://example.com/redirect?url=https://legit.example.com ✅

https://example.com/redirect?url=https://evil.com ❌

1. User Input

Dealing with User Input

- Modern webapps / APIs rely on:
  - Validation

```
>>> import re
>>> re.match(r"^\S+@\S+\.\S+$", "aa.com") ❌
>>> re.match(r"^\S+@\S+\.\S+$", "a@a.com")
<re.Match object; span=(0, 7), match='a@a.com'>
```

Dealing with User Input

- Modern webapps / APIs rely on:
  - Validation
  - Sanitization

```
> htmlspecialchars("input'\"><script>alert(1);</script>");
= "input&#039;&quot;&gt;&lt;script&gt;alert(1);&lt;/script&gt;"
```

Dealing with User Input

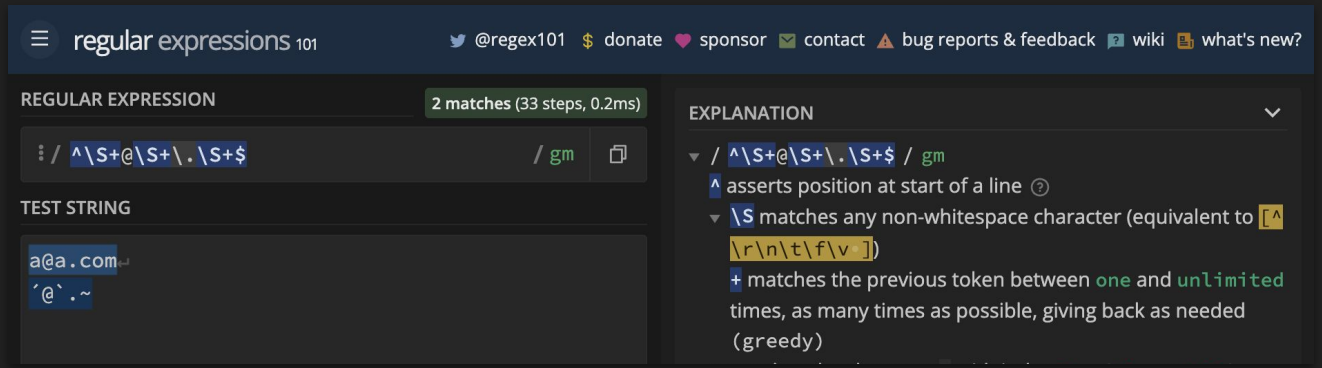
- Modern webapps / APIs rely on:
  - Validation
  - Sanitization
  - Normalization

```
> iconv("UTF-8", "ASCII//TRANSLIT", "Ãéï°úç");
= "~A'e"i^0'uc"
```

```
>>> import unidecode
>>> unidecode.unidecode("Ãéï°úç")
'Aeideguc'
```

Problems with Validation

- Regex is widely used to validate parameters from the user
  - Copied from StackOverflow, etc
  - Mostly not tested by devs (copy paste)
  - Sometimes testing code exists but it's specific to a subset of the cases



GitHub Copilot

```
def url_is_subdomain(url, domain):
    """Check if the url is a subdomain of the domain."""
    return re.match(r'^(?:https?://)?(?:[^/]+\.)?%s(?:/.*)?$' % domain, url)
```

"example.com"

```
"https://example^com"
"https://examplexcom"
"https://x.com#.example.com"
"https://x.com?.example.com"
```

✅

$ asserts position at the end of the string, or before the line terminator right at the end of the string (if any)

We are Not the Same

JavaScript

```
> "aaa".match(/^[a-z]+$/)
[ 'aaa', index: 0, input: 'aaa', groups: undefined ]
> "aaa123".match(/^[a-z]+$/) ❌
null
> "aaa\n".match(/^[a-z]+$/) ❌
null
> "aaa\n123".match(/^[a-z]+$/) ❌
null
```

We are Not the Same

Python

```
>>> re.match(r"^[a-z]+$", "aaa")
<re.Match object; span=(0, 3), match='aaa'>

>>> re.match(r"^[a-z]+$", "aaa123") ❌
>>> re.match(r"^[a-z]+$", "aaa\n")
<re.Match object; span=(0, 3), match='aaa'>

>>> re.match(r"^[a-z]+$", "aaa\n123") ❌
```

We are Not the Same

Ruby

```
"aaa".match(/^[a-z]+$/) #=> #<MatchData "aaa">
"aaa123".match(/^[a-z]+$/) #=> nil
"aaa\n".match(/^[a-z]+$/) #=> #<MatchData "aaa">
"aaa\n123".match(/^[a-z]+$/) #=> #<MatchData "aaa">
```

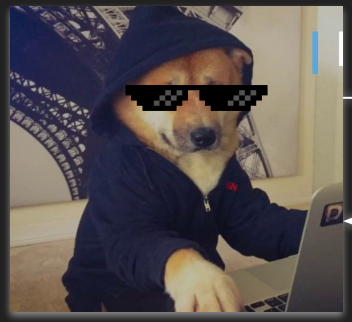
We are Not the Same

/^[a-z]+$/

	JavaScript	Python	Ruby
"aaa"	✅	✅	✅
"aaa123"	❌	❌	❌
"aaa\n"	❌	✅	✅
"aaa\n123"	❌	❌	✅

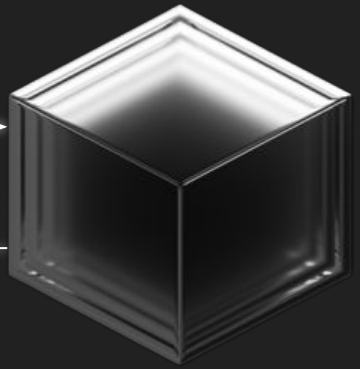
2. REcollapse

Probing the Unknown



Unexpected Input

Weird behavior



The REcollapse Technique

1. Identify the regex pivot positions
   a. Starting & termination positions
   b. Separator positions
   c. Normalization positions
2. Fuzz positions with all possible bytes
3. Analyze the responses

The REcollapse Technique

https://example.com/redirect?url=$https://legit.example.com$

Starting position

Termination position

The REcollapse Technique

https://example.com/redirect?url=https$:$/$/$legit$.$example$.$com

Separator positions

The REcollapse Technique

https://example.com/redirect?url=https://l$git.ex$mple.c$m

Normalization positions

Typically vowels

A á ᵃ ã ⓐ → a

The REcollapse Technique

https://example.com/redirect?url=$https$:$/$/$l$git$.$ex$mple$.cm$

Fuzz all positions from **%00** to **%ff** ⚡

More Examples

https://legit.example.com → $https$:$/$/$l$git$.$ex$mple$.cm$

legit@example.com → $l$git$@$ex$mple$.cm$

user_name → usr$_$nme

y → $<$$$ hrf$=$$$>$$$<$/$$$>$

REcollapse Tool

- Helper tool capable of generating inputs according to these rules
- Supports multiple fuzzing sizes and encodings
- Easy to paste on Burp or other tools
- Available at https://github.com/0xacb/recollapse

```
%07legit@example.com
%08legit@example.com
%09legit@example.com
%0alegit@example.com
%0blegit@example.com
%0clegit@example.com
%0dlegit@example.com
%0elegit@example.com
%0flegit@example.com
%10legit@example.com
%11legit@example.com
%12legit@example.com
%13legit@example.com
```

Demo

3. Mysterious Bugs

What to Look for?

Literally anything that gets validated, sanitized, normalized, used in queries, etc.

This will open the door to mysterious bugs.

Uncovering Mysterious Bugs

1. Set your goal (e.g. ATO)
2. Pick your target field (e.g. email)
3. Identify all flows that consume it
4. For every endpoint: `REcollapse`
5. Analyze all response codes. Any successful response?
    a. Is the regex always the same in all endpoints? Usually not
    b. Pick a weird byte that went through

Uncovering Mysterious Bugs

6. Go through all the flows from step 3

   Recovery, login, signup, OAuth, SSO, email change & confirmation (depends on target field)

7. Hopefully, you just found a mysterious bug
   a. Look for errors and weird behaviors
   b. Try to realize the impact or an attack scenario
   c. If not, go back to step 5b or 1 / 2

4. Real-world Examples

1. REcache Deception

- https://redacted.com/wp-json/v1/user 200

```
{
  "username": "xxxxxxxx",
  "api_token": "xxxxxxxx"
}
```

- https://redacted.com/wp-json/v1/user.css 404
  [...] .pdf 404
  [...] .js 404

1. REcache Deception

- Caching rules are usually regex-based
- A static extension is not enough these days to perform web cache deception
- We need to enforce the correct `Content-Type` in the response
- Let’s fuzz it!

1. REcache Deception

- Fuzzing https://redacted.com/wp-json/v1/user$.[extension] from %00 to %ff and well-known extensions returned 200 with %23 [#] and %3f [?]

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- Fuzzing https://redacted.com/wp-json/v1/user$.[extension] from %00 to %ff and well-known extensions returned 200 with %23 [#] and %3f [?]

  Age: 35, X-Cache: Hit

https://redacted.com/wp-json/v1/user%23.pdf

We can send a link to a logged-in victim that will request this URL, and then we just need to access the cached content from our end and steal the api_token.

2. Zero-interaction ATO (OAuth)

- Shopify offers a "Signup/Login with Shopify" OAuth mechanism
- OAuth scope includes email address to login in multiple applications
- In taler.app, the email address doesn't need to be verified to create an account
- If the email already exists, you can't login or sign up on Shopify

2. Zero-interaction ATO [OAuth]

- Let's fuzz the email change request on accounts.shopify.com
  - Proper regex in place, no weird characters allowed ❌

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- Let's fuzz the email change request on accounts.shopify.com
  - Proper regex in place, no weird characters allowed ❌
- Fuzzing the signup request on accounts.shopify.com:
  - victⓘm@domain.com goes through ✅
- Login with Shopify in this state on taler.app
- Successful ATO

Free Online Graphic, Banner, C | Shopify account profile

accounts.shopify.com/accounts/148290879

shopify

Victim Account

- General
- Security

General

Details

Upload photo | Remove photo

First name: Victim

Last name: Account

Email: 0xacb+talervictim@wearehackerone.co

Change email

Phone (optional)

Login service

Connect an external login service to quickly and securely access your Shopify ID.

Connected login service

You do not have an external login service connected to your Shopify ID.

Connect to Google

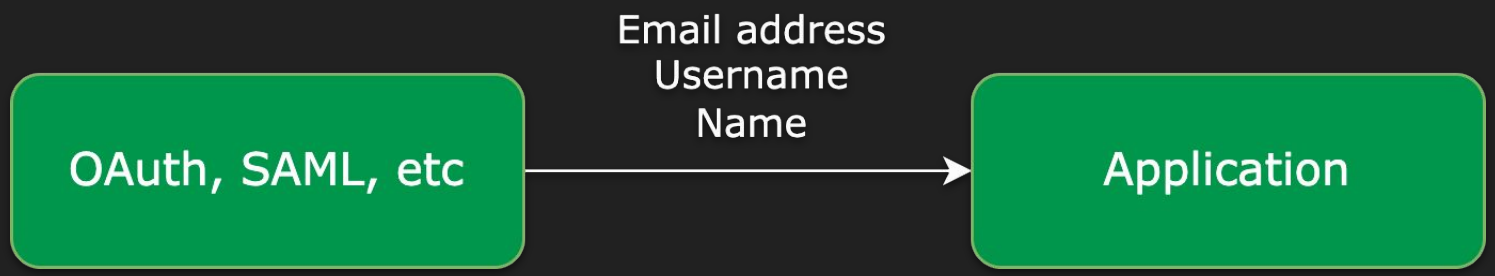
Stores, programs, and resources

Visit or manage the following stores, programs, and resources connected to

Create store

You don't have any stores yet. Create a store on Shopify, and get the first 14

2. Zero-interaction ATO (OAuth)



Normalization is often used in these flows.

Takeaways

- Developers: always test/fuzz your regex, or rely on well-known libraries
- Simple input modifications can result in great damage
  - Fuzz by flipping or adding bytes ⚡

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- Black-box regex testing is still not very touched
  - Creative and manual work. Go for it 💰
- Regex behavior can reveal information about libraries, languages, etc

Takeaways

- Developers: always test/fuzz your regex, or rely on well-known libraries
- Simple input modifications can result in great damage
  - Fuzz by flipping or adding bytes ⚡
- Black-box regex testing is still not very touched
  - Creative and manual work. Go for it 💰
- Regex behavior can reveal information about libraries, languages, etc
- If something is being validated and you can bypass it…
  - Think about the impact and you'll see the big picture! 🖼️

Special thanks

@regala_ / fisher
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@0xdisturbance team
@hacker0x01 team

Thank you

@0xacb