Exploring Regular Expression Usage and Context in Python

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Why regular expressions?

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- Everyone writes regexes! (we think...)
- Regexes are hard to read/write! (again, we think...)

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We don't know how/when/why developers use regexes!

Research goals

1. RQ1: In what contexts do professional developers use regular expressions?
2. RQ2: How is the re module used in Python projects?
3. RQ3: Which regular expression language features are most commonly used in Python?
4. RQ4: How behaviorally similar are regexes across projects?

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Regular expressions: The basics

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Survey context

- 18 professional developers
- 9 years average development experience
- Small mobile payment management company
- 30 questions in a Google form

How frequently do developers use regexes?

- 50% – at least once per week
- Regexes are most frequently composed within command line and text editor tools
- 2 developers write more than 50 regexes in general programming languages (e.g., Java) annually
- Database queries using regexes were rare

Common regex activities

How often do you use regexes for...

Activity	Frequency
Locating content within a file or files	4.4
Capturing parts of strings	4.3
Parsing user input	4.0

Key: 6 = very frequently, 5 = frequently, 4 = occasionally, 3 = rarely, 2 = very rarely, 1 = never

Testing regular expressions

Developers test regular expressions less often than other code.

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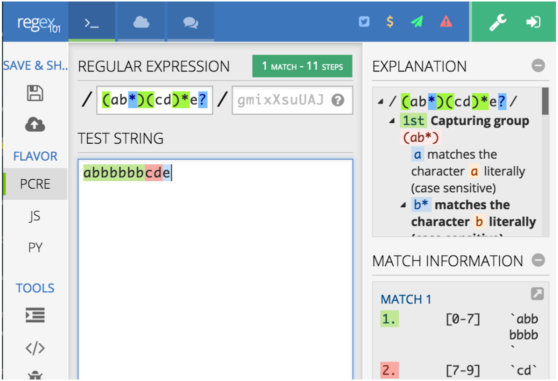

REGULAR EXPRESSION 1 MATCH - 11 STEPS

/ (ab*)(cd)*e? / gmixXsuUAJ

TEST STRING

abbbbbbcde

EXPLANATION

/ (ab*)(cd)*e? /
1st Capturing group (ab*)
a matches the character a literally (case sensitive)
b* matches the character b literally (case sensitive)

MATCH INFORMATION

MATCH 1

1.	[0-7]	`abbbbbb`
2.	[7-9]	`cd`

50% say they use testing tools like www.regex101.com

Pain points

hard to compose (11 = 61%)

...very difficult to write them since I‘ve never read up on them.

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Readability. Edge cases.

It is terrible to read (especially later after initial development)

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inconsistency across implementations (3 = 17%)

Differences in implementation across languages

Some regexes work differently (or don‘t work) in some languages.

Notable Observations

- Regexes are composed fairly frequently by developers
- Testing regexes is less common than testing other code
- Developers find regexes hard to read and write

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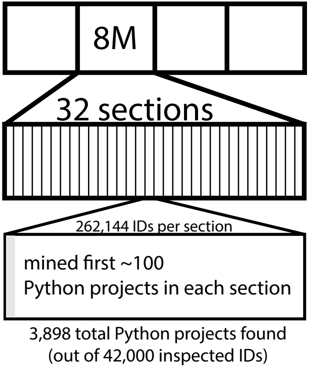
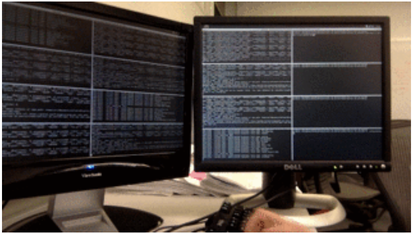
How do developers really use regexes?

Project selection with the GitHub API


8M
32 sections
262,144 IDs per section
mined first ~100
Python projects in each section
3,898 total Python projects found
(out of 42,000 inspected IDs)



Out of 3,898 pseudo-randomly selected Python projects, 1,645 (42%) contained one or more regex utilization.

In Python: Utilizations of the re module

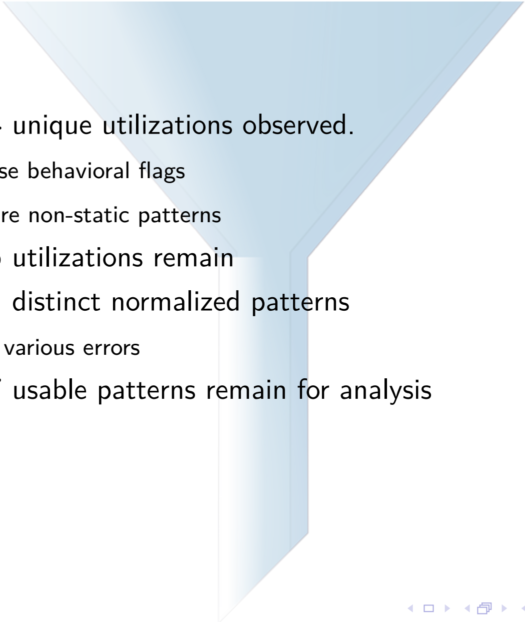
```
            function           pattern               flags
r1 = re.compile("(0|-?[1-9][0-9]*)$", re.MULTILINE)
```

function which function of the re module is called?

pattern string used to specify regex behavior

flags modifies the regex engine

Filtering utilizations and patterns



53,894 unique utilizations observed.

12.7% use behavioral flags

6.5% were non-static patterns

43,525 utilizations remain

13,711 distinct normalized patterns

114 had various errors

13,597 usable patterns remain for analysis

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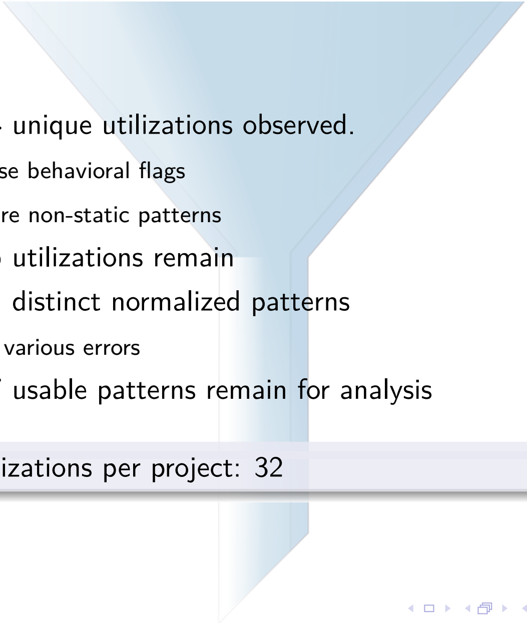

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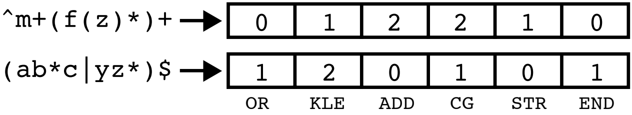
Average utilizations per project: 32

PCRE Parsing Patterns



	OR	KLE	ADD	CG	STR	END
`^m+(f(z)*)+`	0	1	2	2	1	0
`(ab*c|yz*)$`	1	2	0	1	0	1

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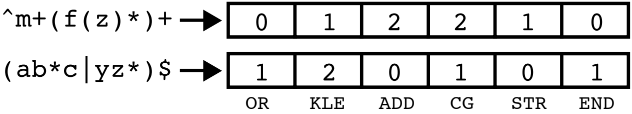

	OR	KLE	ADD	CG	STR	END
`^m+(f(z)*)+` →	0	1	2	2	1	0
`(ab*c|yz*)$` →	1	2	0	1	0	1

All Python features are recognizable by PCRE

Feature statistics - Top 8

Rank	Code	Example	% Projects	NProjects	NFiles	NPatterns	MaxTokens
1	ADD	`z+`	73.2	1,204	9,165	6,003	30
2	CG	`(caught)`	72.6	1,194	9,559	7,130	17
3	KLE	`.*`	66.8	1,099	8,163	6,017	50
4	CCC	`[aeiou]`	62.4	1,026	7,648	4,468	42
5	ANY	`.`	61.1	1,005	6,277	4,657	60
6	RNG	`[a-z]`	51.6	848	5,092	2,631	50
7	STR	`^`	51.4	846	5,458	3,563	12
8	END	`$`	50.3	827	5,393	3,169	12

Regex research tools

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How well do regex research tools meet the needs of developers? (Hampi, Rex, RE2, brics)

Which features are supported by analysis tools?

Rank	Code	Example	Brics	Hampi	Rex	RE2
1	ADD	z+	●	●	●	●
2	CG	(caught)	●	●	●	●
3	KLE	.*	●	●	●	●
4	CCC	[aeiou]	●	●	●	●
5	ANY	.	●	●	●	●
6	RNG	[a-z]	●	●	●	●
7	STR	^	🔴	●	●	●
8	END	$	🔴	●	●	●
9	NCCC	[^qwxf]	●	●	●	●
10	WSP	\s	🔴	●	●	●
11	OR	a|b	●	●	●	●
12	DEC	\d	🔴	●	●	●
13	WRD	\w	🔴	●	●	●
14	QST	z?	●	●	●	●
15	LZY	z+?	🔴	●	🔴	●
16	NCG	a(?:b)c	🔴	●	🔴	●
17	PNG	(?P<name>x)	🔴	●	🔴	🔴

Rank	Code	Example	Brics	Hampi	Rex	RE2
18	SNG	z{8}	●	●	●	●
19	NWSP	\S	🔴	●	●	●
20	DBB	z{3,8}	●	●	●	●
21	NLKA	a(?!yz)	🔴	🔴	🔴	🔴
22	WNW	\b	🔴	🔴	🔴	●
23	NWRD	\W	🔴	●	●	●
24	LWB	z{15,}	●	●	●	●
25	LKA	a(?=bc)	🔴	🔴	🔴	🔴
26	OPT	(?i)CasE	🔴	●	🔴	●
27	NLKB	(?<!x)yz	🔴	🔴	🔴	🔴
28	LKB	(?<=a)bc	🔴	🔴	🔴	🔴
29	ENDZ	\Z	🔴	🔴	🔴	●
30	BKR	\1	🔴	🔴	🔴	🔴
31	NDEC	\D	🔴	●	●	●
32	BKRN	\g<name>	🔴	●	🔴	🔴
33	VWSP	\v	🔴	🔴	●	●
34	NWNW	\B	🔴	🔴	🔴	●

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- Current regex research tools cover the most common features

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What are the regexes doing?

How to find common behaviors?

1. ~~thorough inspection of 53K utilizations~~
2. ~~cluster by syntactic similarity like Jaccard or longest substring~~
3. ~~formal analytical subsumption, no sufficient tools at the moment~~
4. Chosen technique: cluster by behavioral similarity using Rex

Example

A `(ab*c|yz*)$`

- abbbbbbbc
- y
- abcy
- pac
- abcyzzz

B `(ab*c|yz*)`

- y
- abc
- abcy
- abcccc
- yxw

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A matches $3/5 =$ 60% of B's strings

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B `(ab*c|yz*)`

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B matches $5/5 =$ 100% of A's strings

Example

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A matches $3/5 =$ 60% of B's strings

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B matches $5/5 =$ 100% of A's strings

A and B are 80% similar

Similarity Matrix → MCL

```
Pattern A matches 100/100 of A's strings
Pattern B matches  90/100 of A's strings
Pattern A matches  50/100 of B's strings
Pattern B matches 100/100 of B's strings
```

	A	B
A	1.0	0.9
B	0.5	1.0

	A	B	C	D
A	1.0	0.0	0.9	0.0
B	0.2	1.0	0.8	0.7
C	0.6	0.8	1.0	0.2
D	0.0	0.6	0.1	1.0

→

	A	B	C	D
A	1.0			
B	0.1	1.0		
C	0.75	0.8	1.0	
D	0.0	0.65	0.15	1.0

Rex generates
400 strings for each regex.
Convert scores to half-matrix for
MCL

Clustering Results

Example Cluster

Index	Pattern	NProjects	Index	Pattern	NProjects
1	`\s*([^: ]*)\s*:(.*)`	9	7	`[:]`	6
2	`:+`	8	8	`([^:]+):(.*)`	6
3	`(:)`	8	9	`\s*:\s*`	4
4	`(:+)`	8	10	`\:`	2
5	`(:)(:*)`	8	11	`^([^:]*):[^:]*$`	2
6	`^([^:]*): *(.*)`	8	12	`^[^:]*:([^:]*)$`	2

From 2,871 distinct regexes

186 clusters where size ≥ 2

2,042 unclustered regexes

Six Categories Of Clusters

Category	Clusters	Patterns	Projects	% Projects
Multi Matches	21	237	295	40%
Specific Char	17	103	184	25%
Anchored Patterns	20	85	141	19%
Two or More Chars	16	40	120	16%
Content of Parens	10	46	111	15%
Code Search	15	27	92	13%

Multi Matches `(\s)` , `,|;`

Specific Char `:+` , `}` , `%`

Anchored Patterns `^[-_A-Za-z0-9]+$`

Two Or More Chars `@[a-z]+`

Content of Parens `<(.+)>` , `<[^>]*?>`

Code Search `.*rlen=([0-9]+)`

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- Regexes are often used to parse source code!

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What's the bigger picture?

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Our similarity metrics are empirical, can we do it analytically?

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Identifying Best Practices?

Could impact regex education and improve comprehension.

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Recap

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- Everyone writes regexes! (50% of surveyed developers write them weekly)
- Regexes are hard to read/write! (this was reported as a pain point)

also...

- Current tools support most of the most common features
- Regexes are often used for code search
- Many opportunities for future work!

Questions?

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(psst! Graduate students! I'm actively recruiting for my research lab!)