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

Explore regex

1. Context (developer survey)
2. Features (repository analysis)
3. Use cases (similarity analysis)

Regular expressions: The basics

- `(ab*c|yz*)$`
  - ✓ abbbbbbbc
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Part 1

RQ1

In what contexts do professional developers use regular expressions?

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

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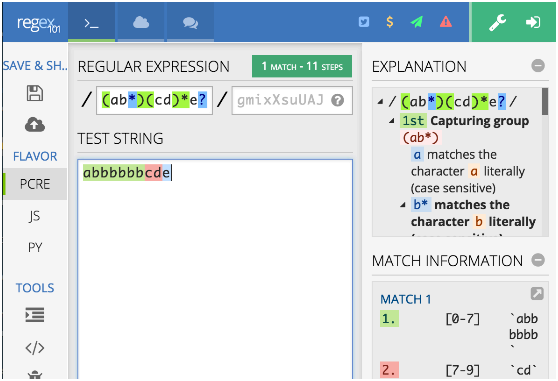

REGULAR EXPRESSION 1 MATCH - 11 STEPS

/ (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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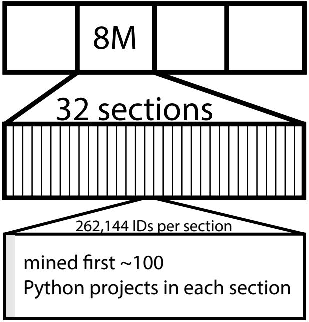
How do developers really use regexes?

Part 2

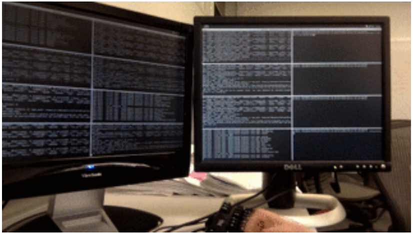
RQ3

Which regular expression language features are most commonly used in Python?

Project selection with the GitHub API



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

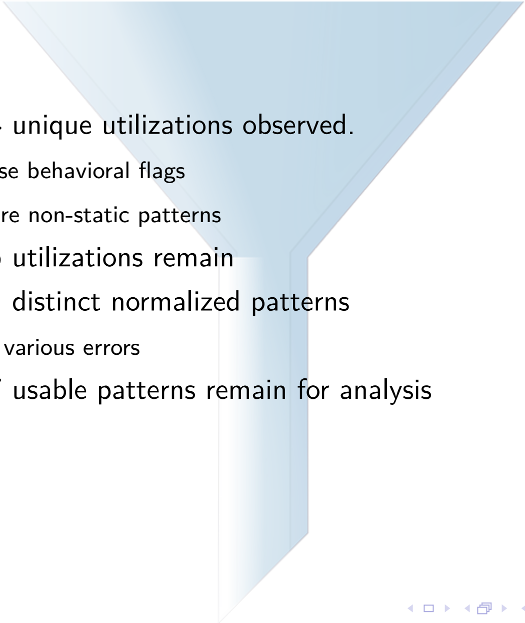
```
r1 = re.compile("(0|-?[1-9][0-9]*)$", re.MULTILINE)
```

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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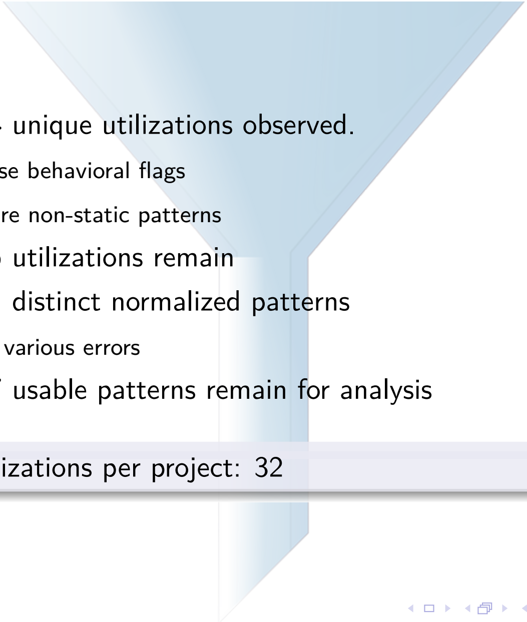

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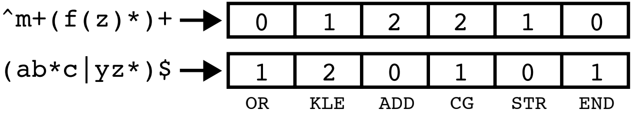
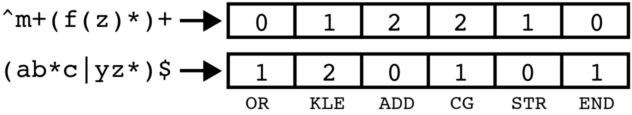
Average utilizations per project: 32

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

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

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 past and present 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)`	🔴	●	🔴	🔴
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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What are the regexes doing?

Part 3

RQ4

How behaviorally similar are regexes across projects?

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

Example

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

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

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

B `(ab*c|yz*)`

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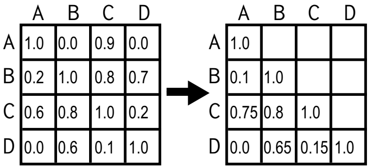
B matches 5/5 = 100% of A's strings

A and B are 80% similar

Similarity Matrix → MCL



	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.
Average scores to
half-matrix for MCL

Scope

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- 2,871 patterns analyzed from 722 (44%) of the projects

Clustering Results

From 2,871 distinct regexes:

$\rightarrow$ 186 clusters with size ≥ 2

$\rightarrow$ 2,042 unclustered regexes

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

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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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- Similarity metric is approximate
- Metric is perhaps too sensitive to differences in literals

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Better Similarity Metrics

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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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 hiring!)