Exploring Regular Expression Usage and Context in Python

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Why regular expressions?

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- Regexes are hard to read/write!

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

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Regex feature usage references are missing!

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
  - ✓ y
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Part 1: Context

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 often and where do developers use regexes?

- 50% – at least once per week

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- **Most often**: command line and text editor tools
- **Often**: general purpose and scripting languages
- **Rare**: Database queries

Testing regular expressions

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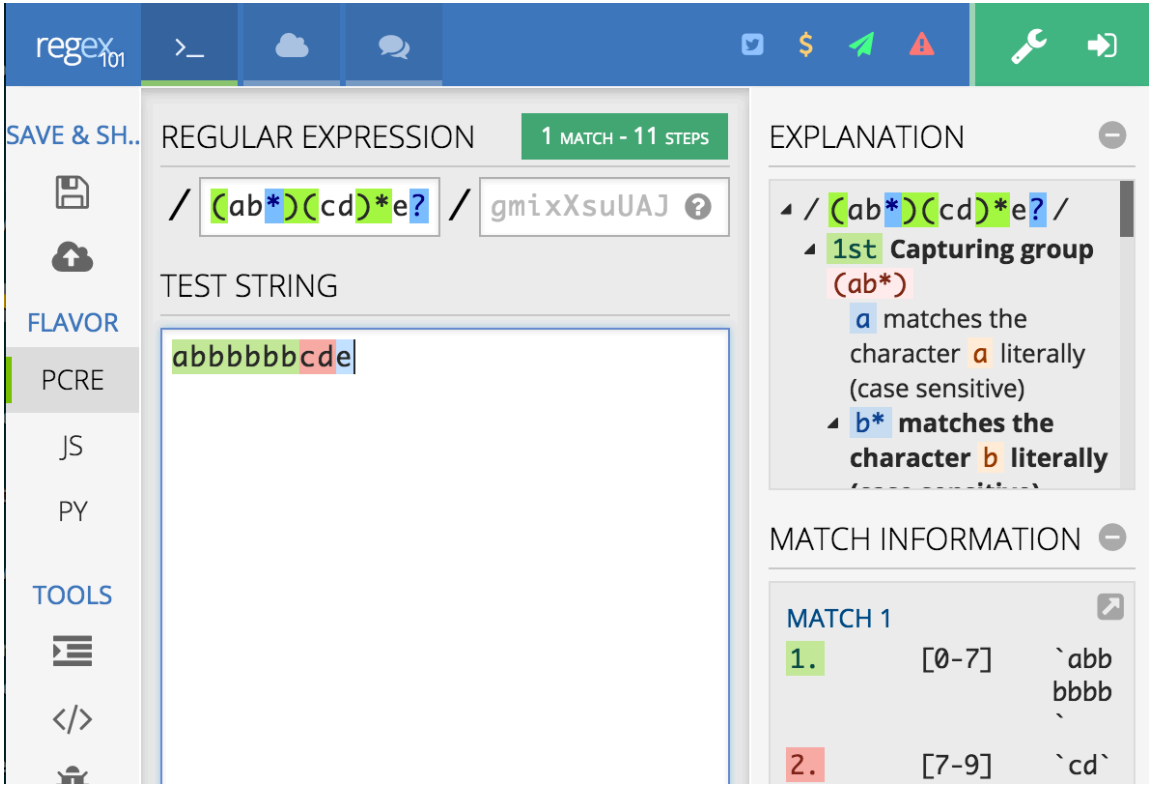

50% say they use testing tools like www.regex101.com

Pain points

hard to compose (11 = 61%)

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

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inconsistency across implementations (3 = 17%)

Some regexes work differently (or don't work) in some languages.

Notable observations: Context

- Everyone (sort of) writes regexes regularly
- Developers find regexes hard to read and write
- Most often written in text editors and IDEs
- Testing regexes is less common than testing other code

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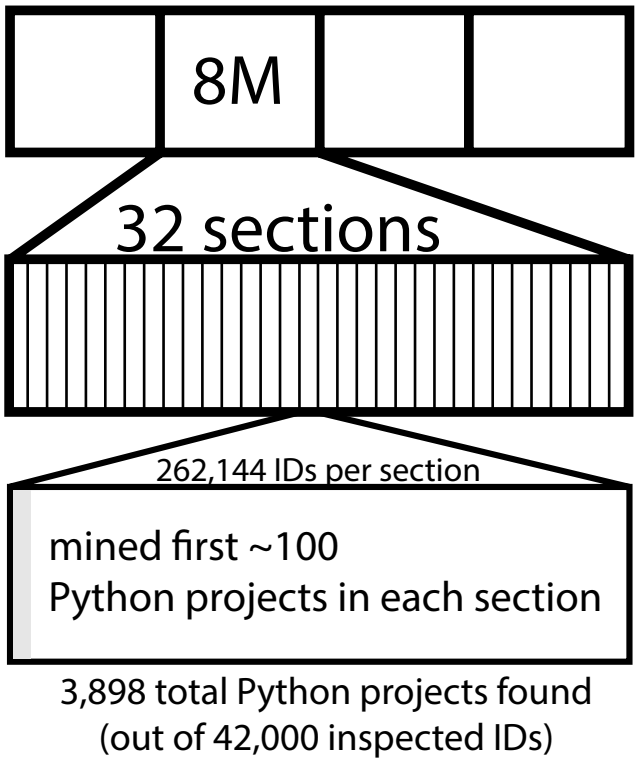
Are regexes everywhere?

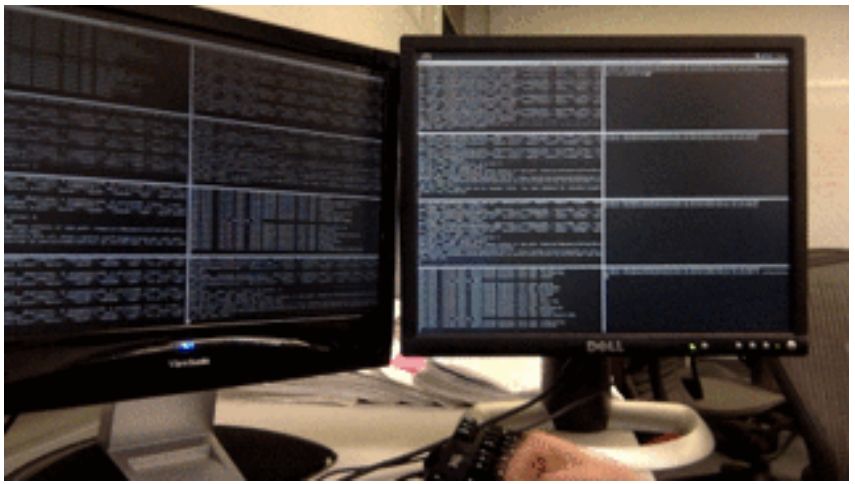
Part 2: Features

RQ3

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

Project selection with the GitHub API





Of 3,898 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

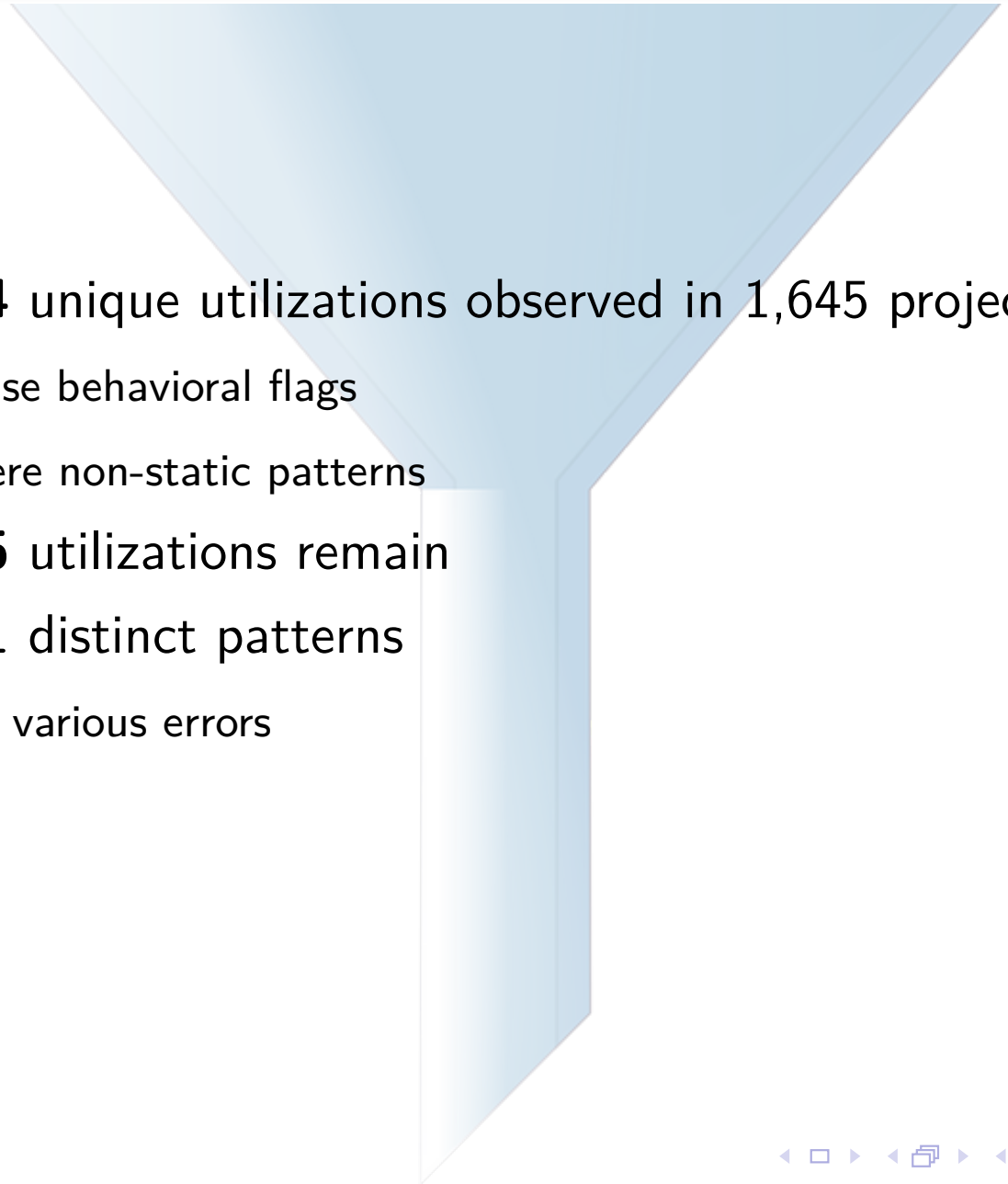
53,894 unique utilizations observed in 1,645 projects.

12.7% use behavioral flags

6.5% were non-static patterns

43,525 utilizations remain

Filtering utilizations and patterns



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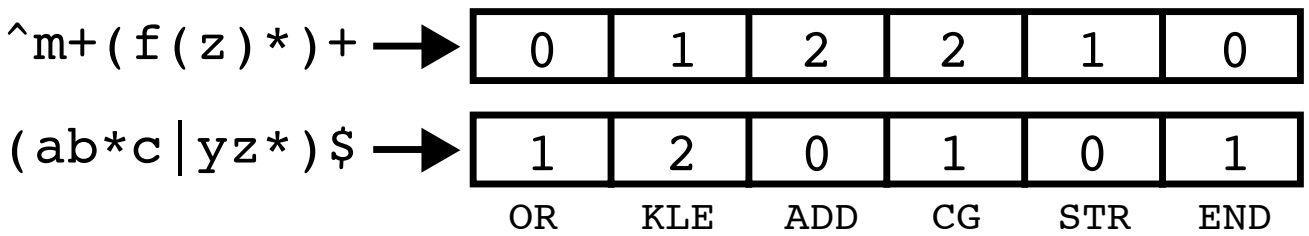
13,597 patterns from 1,544 projects remain for analysis

PCRE parsing patterns



Feature statistics - Top 8

Rank	Code	Example	% Projects	% Patterns
1	ADD	`z+`	73.2	44.1
2	CG	`(caught)`	72.6	52.4
3	KLE	`.*`	66.8	44.3
4	CCC	`[aeiou]`	62.4	32.9
5	ANY	`.`	61.1	34.3
6	RNG	`[a-z]`	51.6	19.3
7	STR	`^`	51.4	26.2
8	END	`$`	50.3	23.3

Regex research tools

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- So,

We analyzed your tools instead! (Hampi, Rex, RE2, brics, Automata.Z3)

Which features are supported by analysis tools?

Rank	Code	Example	Brics	Hampi	Rex	RE2	A.Z3
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	A.Z3
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`	○	○	○	●	○

Notable observations: Features

- Regexes are (sort of) everywhere (42% of projects, 32 utilizations per project)
- Current regex research tools cover the most common features

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What are the regexes doing?

Part 3: Use Cases

RQ4

How behaviorally similar are regexes across projects?

How to find common behaviors?

1. ~~thorough inspection of 53K utilizations~~

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How to find common behaviors?

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3. ~~formal analytical subsumption, no sufficient tools at the moment~~
4. Chosen technique: cluster by behavioral similarity using Rex

Similarity metric 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 matches 5/5 = 100% of A's strings

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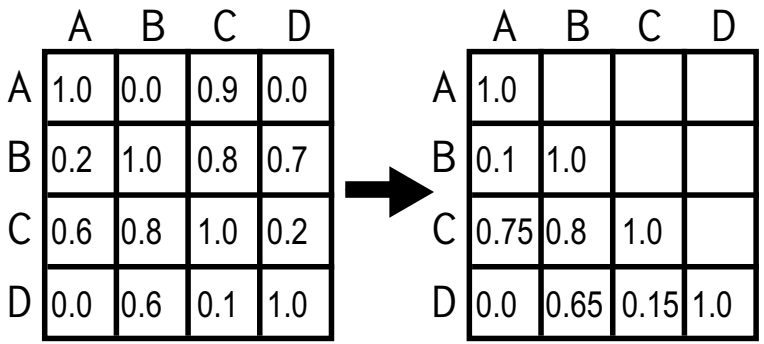
B matches $5/5 =$ 100% of A's strings

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

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- 2,871 patterns analyzed from 722 (44%) of the projects
  - 186 clusters with size ≥ 2
  - 2,042 clusters with size $= 1$

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

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%

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

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

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

Notable observations: Use cases

- Finding a specific character is quite common, 25% of projects (in contrast with survey)
- Regexes are often used to capture the contents of ( ), <>, and [ ] (aligning with survey)
- Regexes are often used to parse source code

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

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Migration Support for Developers

Supported regex features are different among languages.

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Identifying Best Practices?

Could impact regex education and improve comprehension.

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Identifying Best Practices?

Could impact regex education and improve comprehension.

Domain-Specific Support?

Does regex feature usage vary based on environment (IDE, code, text editor, etc.)?

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also...

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

Questions?

Katie Stolee – ktstolee@ncsu.edu

(psst! Graduate students! I'm hiring!)

Survey vs. Repository

How often do you use....

Group	**Code**	**Survey**	**Repo Rank**
endpoint anchors	(STR, END)	4.4	7, 8
capture groups	(CG)	4.2	2
word boundaries	(WNW)	3.5	22
lazy repetition	(LZY)	2.9	15
(neg) look-ahead/behind	(LKA, NLKA, LKB, NLKB)	2.5	25, 21 28, 27

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