Generating Evil Test Strings for Regular Expressions

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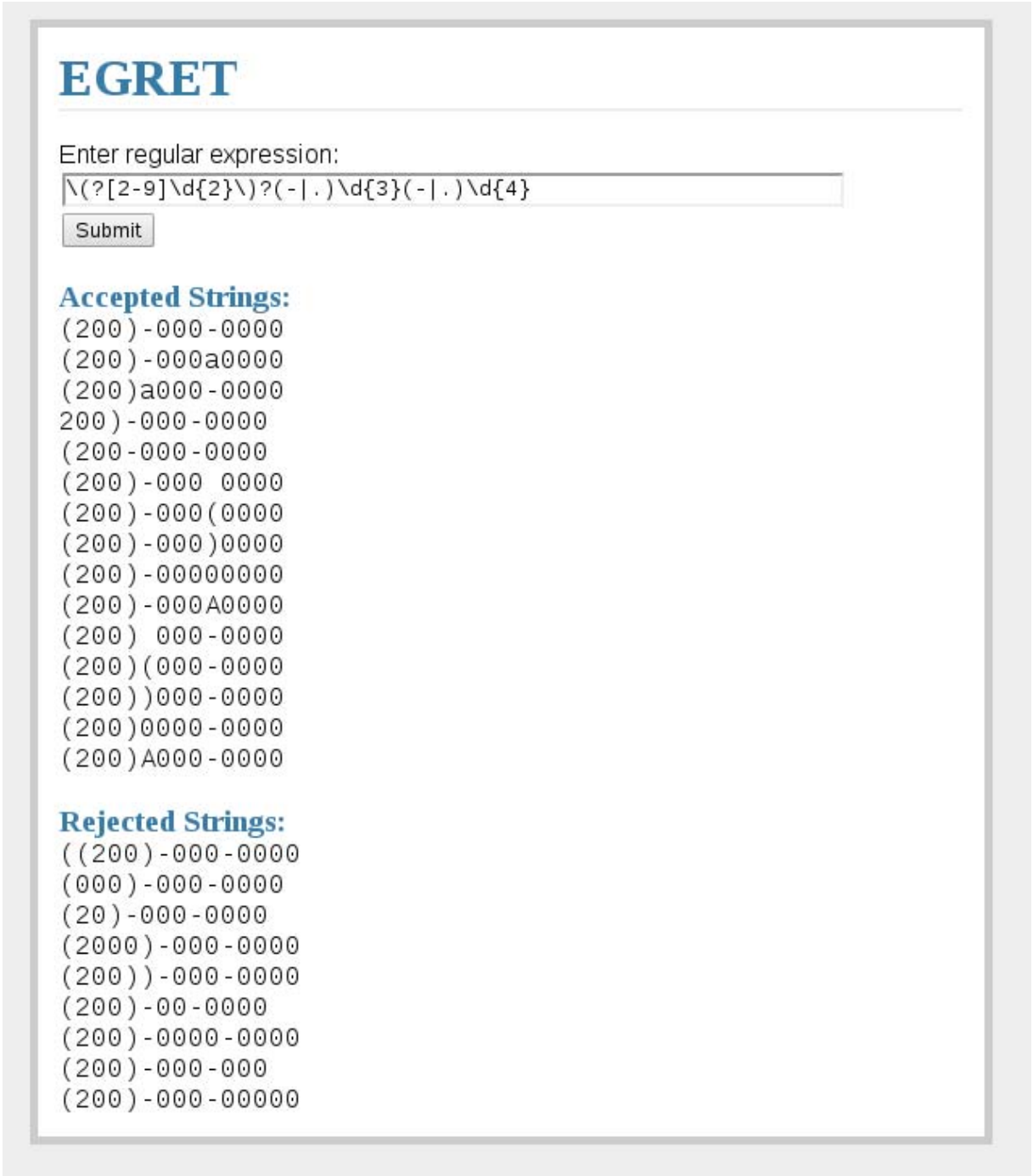
Writing Regular Expressions

Writing a completely correct regular expression (regex) is challenging.

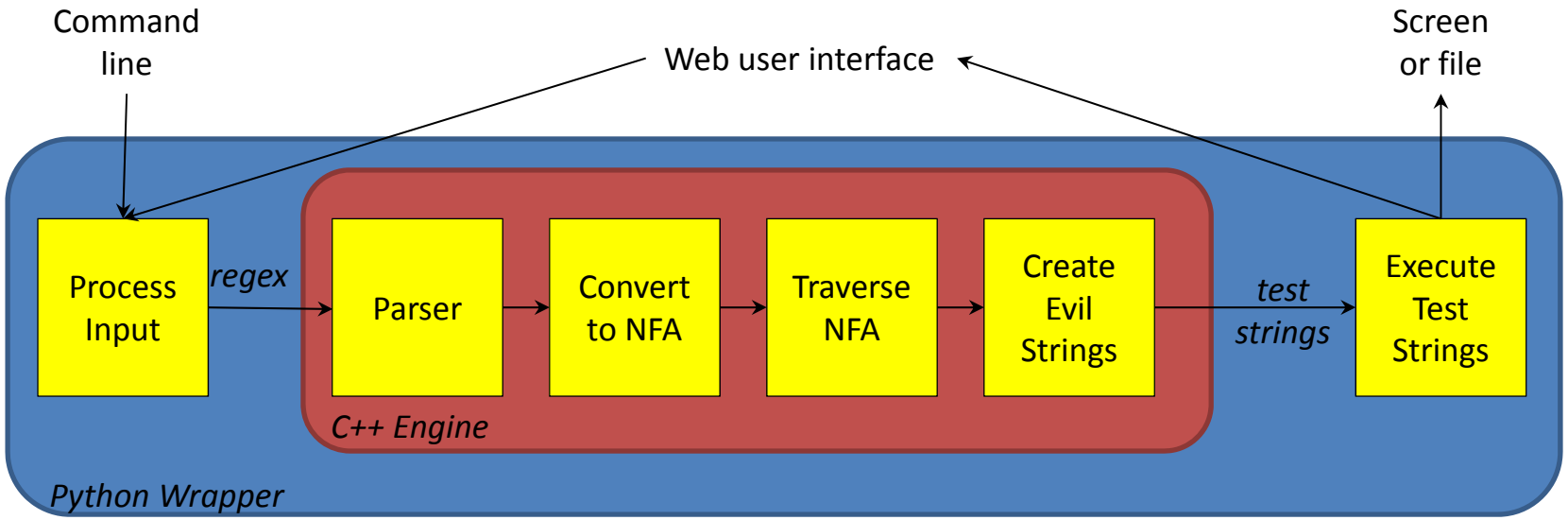
1. A regex often permits more strings than what should be accepted.
   - Example: `^(\d|,)*\.?\d*$`
2. The regex compiler catches very few errors.
   - Most regexes are syntactically correct.
   - Cannot emit warnings at run-time.
   - Example: `[A|M|P|M]{2}|[a|m|p|m]2}`



EGRET

Evil Generation of Regular Expression Tests

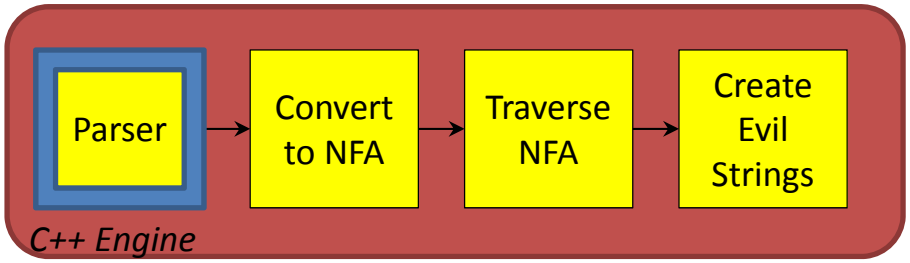
EGRET Overview



- Works on Python regular expressions.
- Supports most of the primary regular expression constructs.
- Limited support for extensions (?...)

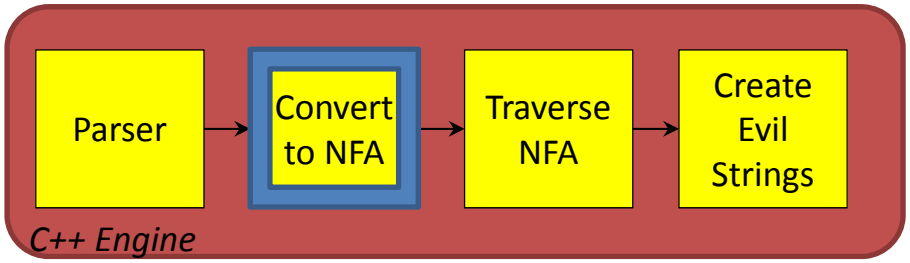
Parser

- Converts regular expression into a parse tree.
- Uses a “character set” node broadly to represent any construct that represents multiple characters:
  - Character sets such as `[A-Z\s_]` and `[^;]`
  - Character classes such as `\w` and `\D`
  - Wildcards using `.`
- Emits warnings on poorly formed character sets.



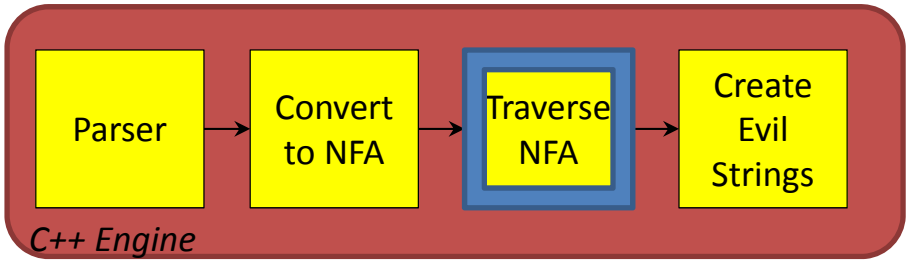
Convert to NFA

- The parse tree is converted to a NFA (non-deterministic finite state automata).
- Edges can be:
  - Individual characters
  - Character sets
  - Anchors such as ^ and $
  - Epsilon transitions
- Repeat quantifiers (such as * and +) are represented using special states.
  - The NFA is free of cycles.



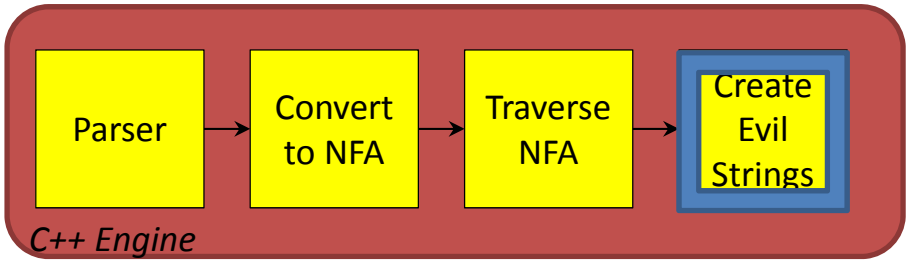
Traverse NFA

- NFA is traversed to obtain basis path coverage.
  - State or transition coverage is not sufficient.
  - Path coverage generates too many paths.
- An initial set of strings is generated.
  - Repeat quantifiers are iterated once (or *n* times for `{n,m}` or `{n}` if *n* > 1).
  - A valid character is chosen for each character set.
- Emits warning on poor anchor (^ and $) usage.



Create Evil Strings

- Using the initial set of strings, create new strings by:
  - altering the number of iterations for each repeat quantifier
  - changing the character used for a character set
- Changes are only applied to one string that contains that element.



Repeat Quantifier Iterations

Repeat Quantifier	Number of Iterations
* or {0,}	0, ***1***, 2
+ or {1,}	0, ***1***, 2
? or {0,1}	0, ***1***, 2
{0,n} or {,n}	0, ***1***, n, n + 1
{m,n} (m > 0 and n > m)	m – 1, ***m***, n, n + 1
{m} or {m,m}(m > 0)	m – 1, ***m***, m + 1
{m,} (m > 1)	m – 1, ***m***

The number of iterations in the initial string are ***bold and italicized***

Character Set Processing

- Each character specified individually in a character set will appear in a test string.
- For digits:
  - If all digits 0-9 are allowed, a test string using one digit will be generated.
  - If some digits are allowed and some are not, two test strings are generated: one with a good digit and one with a bad digit
  - Uppercase and lowercase letters separately are handled similarly.
- For character sets that accept all punctuation marks:
  - A test string is generated for all punctuation marks that appear somewhere in the regex.

Evaluation

		Regexes	***Not Supported***	***Tested Regexes***	***Buggy Regexes***
RegExLib.com Category	address / phone	104	6	98	40
	dates / time	135	18	117	59
	email	38	5	33	12
	markup / code	63	13	50	23
	misc	173	23	150	51
	numbers	107	5	102	23
	string	91	18	73	31
	uri	74	5	69	26
Python Program	advas (0.2.5)	16	0	16	0
	beautifulsoup4 (4.3.2)	7	0	7	3
	pychecker (0.8.19)	4	0	4	1
	pymetrics (0.8.1)	6	1	5	0
	tables (3.1.1)	8	0	8	0
	Trac (1.0.1)	63	4	59	15
	Library total	785	93	692	265
	Programs total	104	5	99	19
	Total	***889***	***98***	***791***	***284***

Classifying Bugs

Bug Type	Example Buggy Regex	Generated Bad String (or WARNING)	Number of Bugs
Bad Range	`^[D-d][K-k]-[1-9]{1}[0-9]{3}$`	WARNING	22
Anchor Usage	`^[-+]?\d+(\.\d+)?|[-+]?\.\d+?$`	WARNING	22
Character Set	`[AM|PM|am|pm]{2,2}`	`|m`	41
Delimiter Mismatch	`href[ ]*=[ ]*('|\")([^\"'])*('|\")`	`href = 'a"`	72
Insufficient Negation	`href=[\"\']?((?:[^>]|[^\s]|[^"]|[^'])+)[\"\']?`	`href='''`	31
Wildcard Too Wild	`(\w+?@\w+?\x2E.+)`	`a@a..`	41
Wrong Repeat	`^\d+(?:\.\d{0,2})?$`	`0.0`	28
Other	`(.*\.([wW][mM][aA])|([mM][pP][3])$)`	`MP3`	90

Other Key Results

- Number of generated strings is manageable.
  - 96% regexes generated less than 100 strings.
  - Most strings generated: 307
  - EXREX, another tool, generated over 1,000 strings for 472 regexes.
- Only 3 bugs were detected by generating a rejected string that should be accepted.
  - But there's value in confirming similar strings are actually rejected.

Future Work

- Add support for elements currently unsupported.
- Improve the algorithm.
  - Add more warnings to detect likely errors.
- Make the generated strings more readable.
  - Many character strings are only 1 or 2 characters long.
- Perform a usability study with likely users.

Questions?

- For more information:

http://fac-staff.seattleu.edu/elarson/web/egret.htm

- Tool (code and web interface) will be available on April 12 (start of ICST)