AUTOMATIC ATTACK GENERATION FOR FIREFOX EXTENSIONS

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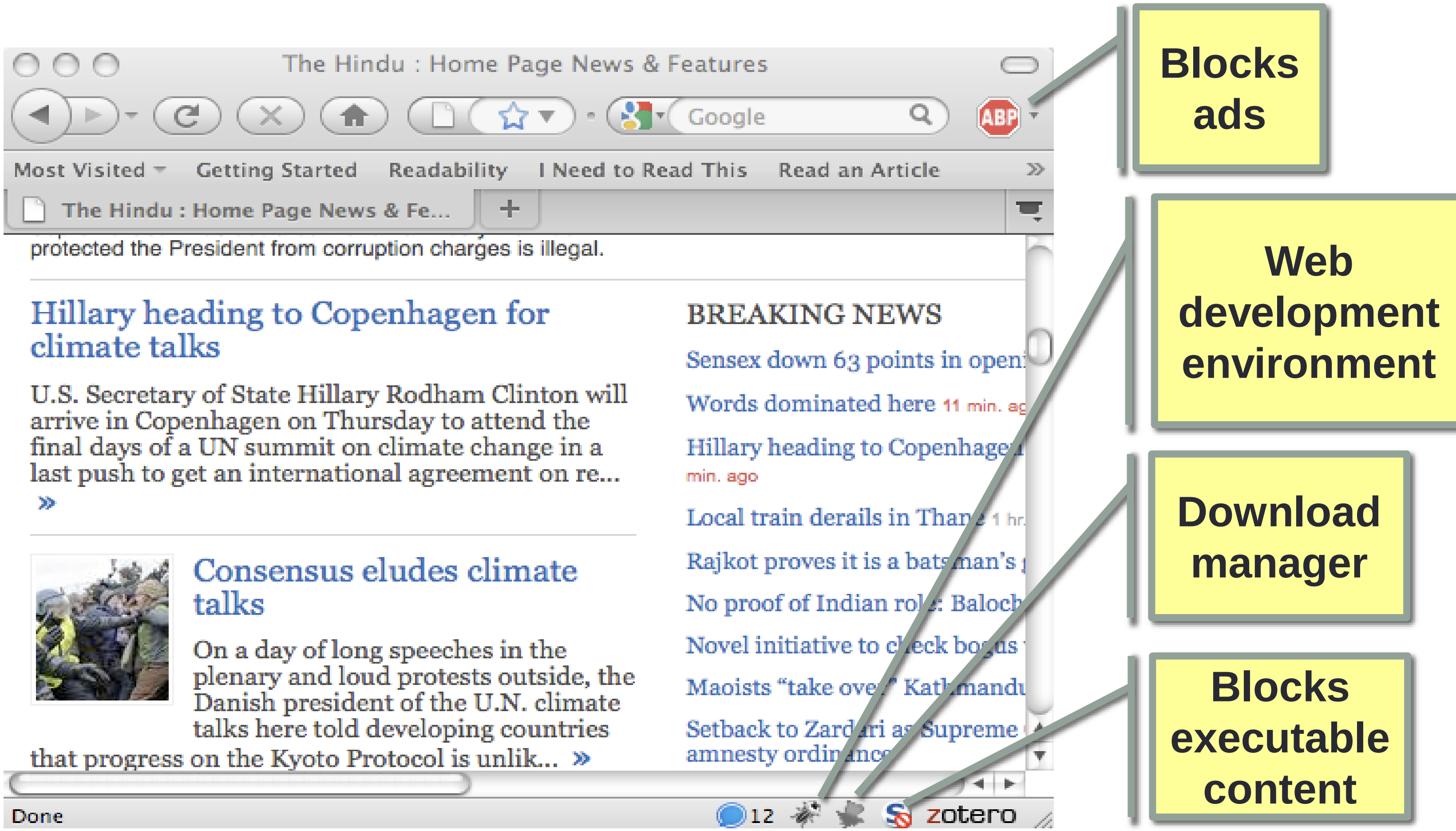
Around 150 Million extensions are in use



Google chrome extensions

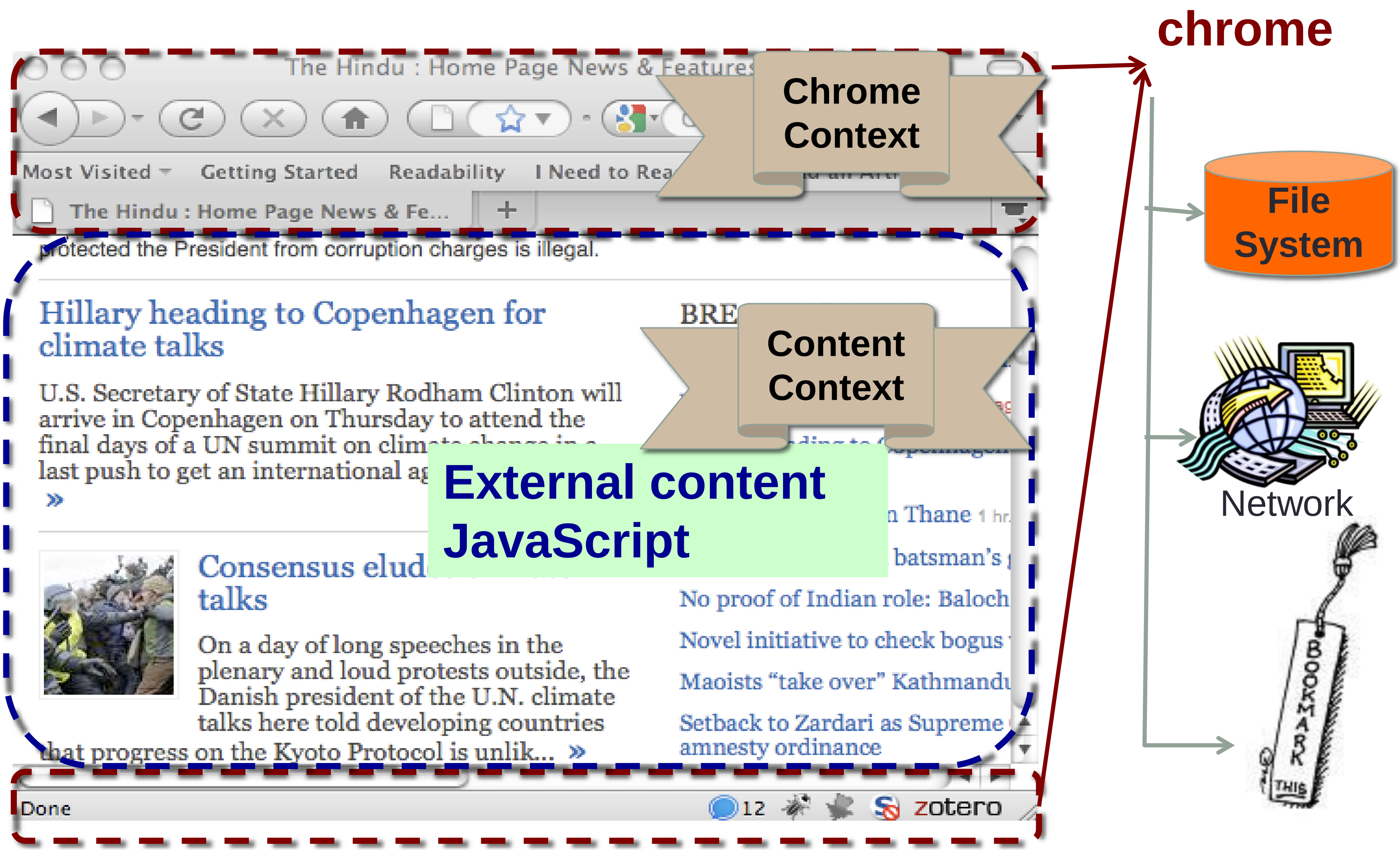
Safari Extensions

The source for Safari 5 extensions

Outline

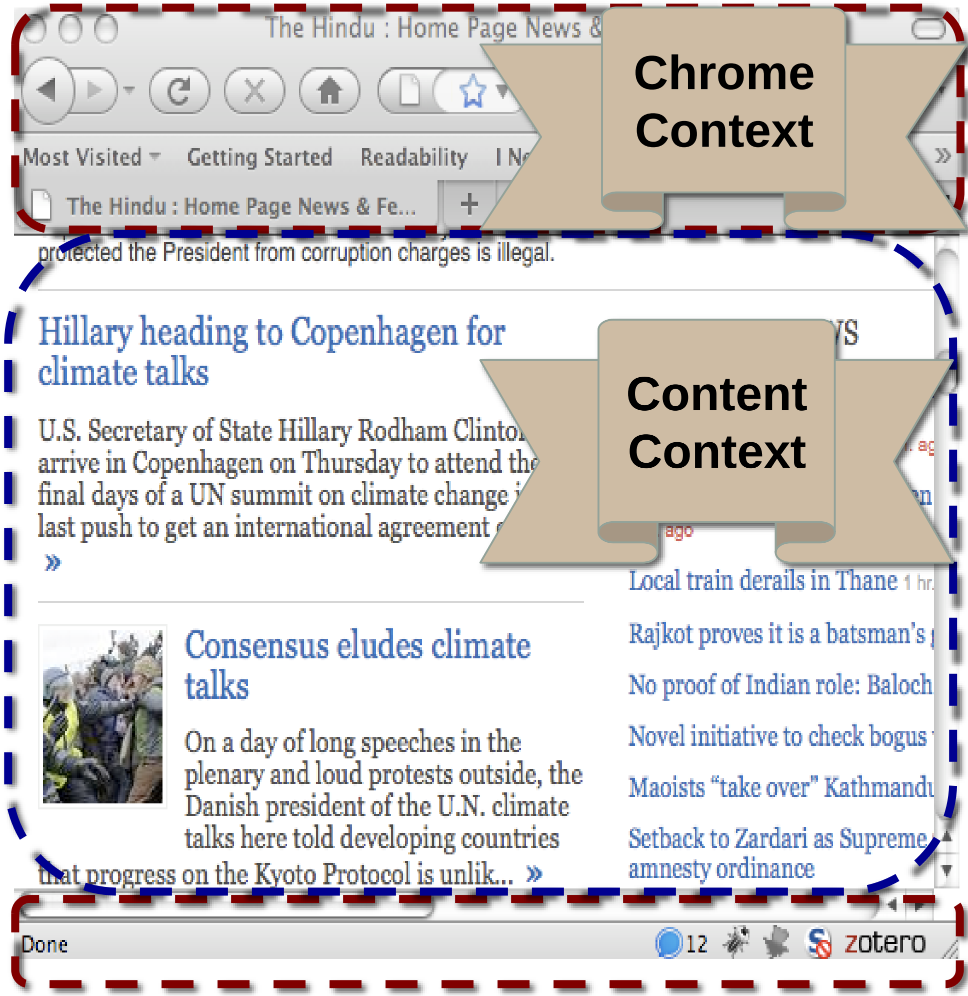
- Firefox Extensions : Background
- Attacks on extensions
- Sanitization Procedures
- String Constraint Solvers
- Feed Sidebar 3.2
- Conclusions

Working of Extensions



Attacks on Extensions

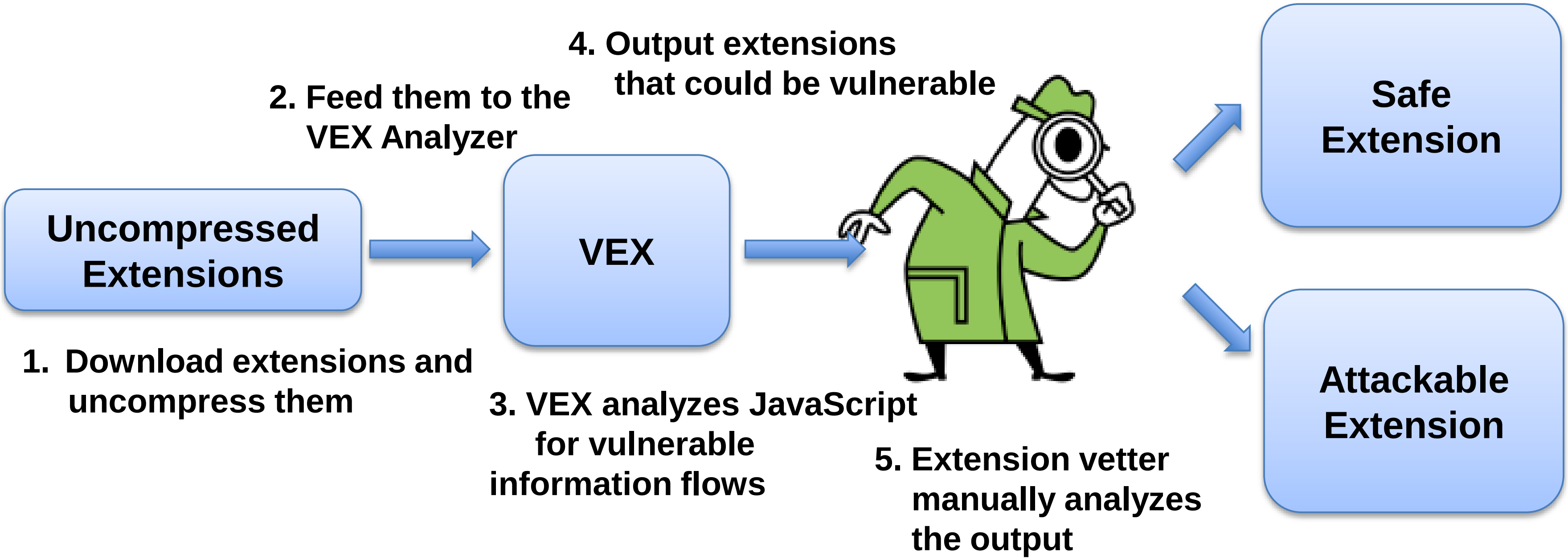
- Document Object Model
- *InnerHTML* Object
- Extension creates new *InnerHTML* object in chrome context
- Input is subjected to sanitization
- Analyze paths from the *document* to *InnerHTML*
- Attack could occur if JavaScript is executed in Chrome context
- **VEX** – a tool for vetting extensions uncovered bugs in Wikipedia toolbar, fizzle, etc…



Challenges in analyzing Extensions

- Developed by third party developers
- JavaScript – powerful language for web development
- Different purposes of extensions
- VEX – analyzes the information flow from document to InnterHTML paths

VEX – Vetting Browser Extensions For Security Vulnerabilities (USENIX Security 2010)



Detecting Vulnerable Extensions Automatically

Desired Properties

- Eliminate the manual analysis of output by Vetter
- Automatically detect whether the extension is vulnerable
- Generation of counterexamples

Tasks required

- Analyze the information flow
- Analyze the operations performed on input

Sanitization Procedures

- Procedure that sanitizes the input
- Typically consists of string manipulation techniques

Input : I; Output : O;
I' = Operations(I);
O = Sanitized(I');

- Checking sanitization procedures
  1) Fix an attack pattern P (i.e. O satisfies the pattern P)
  2) Generate string constraints
  3) Solve the string constraints using any string constraint solver

Sanitization Procedures

- Feed Sidebar 3.2

```
…
itemObject.description = itemObject.
description.replace(/<script[ˆ>]*>[\s\S]+<\/script>/gim, "");
...
```

Sanitization Procedures

- YouTube Cinema 4.8

```
…
theDescription = theDescription.replace ("\r", " ", "g");
theDescription = theDescription.replace ("\n", " ", "g");
while(theDescription.indexOf("  ") != -1)
  theDescription = theDescription.replace("  ", " ");
…
var hasHttp = (theString.indexOf ("http://") != -1);
for (var i = 0; i < theString.length; i++)
{
if (hasHttp){
if (theString.substr (i, 7) == "http://"){
j = theString.indexOf (" ", i);
if (j == -1)  j = theString.length;
j -= i;
theAddress = theString.substr (i, j);
res += ("<a class = \"fiveone\" target = \"_blank\" href = \"" + theAddress + "\">" + theAddress + "</a>");
i += (j - 1);
continue;
}
res += ("&#" + theString.charCodeAt (i) + ";");
```

Sanitization Procedures

- Sanitizes the input for a pattern
- Can be distributed throughout the extension
- Third party developers have their own procedures
- A set of procedures provided by Firefox API
- Collect all the operations on the input

Generating String Constraints

- Operations performed by Sanitization Procedures
- Commonly used string manipulation functions
  1) *indexOf*
  2) *concat*
  3) *replace*
  4) *subString*
- Next Step : To model the operations as string constraints

String Constraints

- A set of equations over strings

String : s_2, s_3;
String : $s_1 = \text{concat}(s_2, s_3)$;
ASSERT(s_1 != TEST);

- Counterexamples

s_1 = TEST, s_2 = T, s_3 = EST
s_1 = TEST, s_2 = TE, s_3 = ST
s_1 = TEST, s_2 = TES, s_3 = T

String Constraints

- String constraints involve equations over
  - Concatenation
  - Containment in Regular/context free grammar
  - Length
  - Boolean operations

Constraint := ¬ Formula
| Formula V Formula
| Formula
Formula := Var ∊ RegExp
| Var ∊ CfgExp
| Var = Var
| Var = StringConst
| Var = Var · Var
| *len*(var) Rel *len*(var)
| *len*(var) Rel *Number*
Rel := ≤ | ≥ | < | >

String Constraint Solvers

- Two classes
  - Use symbolic techniques and automata theory
  - Use BitVector constraint solvers

- Solvers that use symbolic techniques

  ~ Uses automata theoretic techniques

  + Analyze strings of unbounded length
  + Constraints in CFG and regular expressions
  + Flexible length constraints
  - No efficient tools yet

Solvers Using Bit Vector Constraints

- Hampi and Kudzu
- Hampi – for attack generation for PHP codes
- Kudzu – symbolic analysis of AJAX applications
- Can analyze strings of only bounded length

Key idea:

1. Bound length of strings for high expressiveness, efficiency
2. Typical applications require short solutions

Solvers Using Bit Vector Constraints

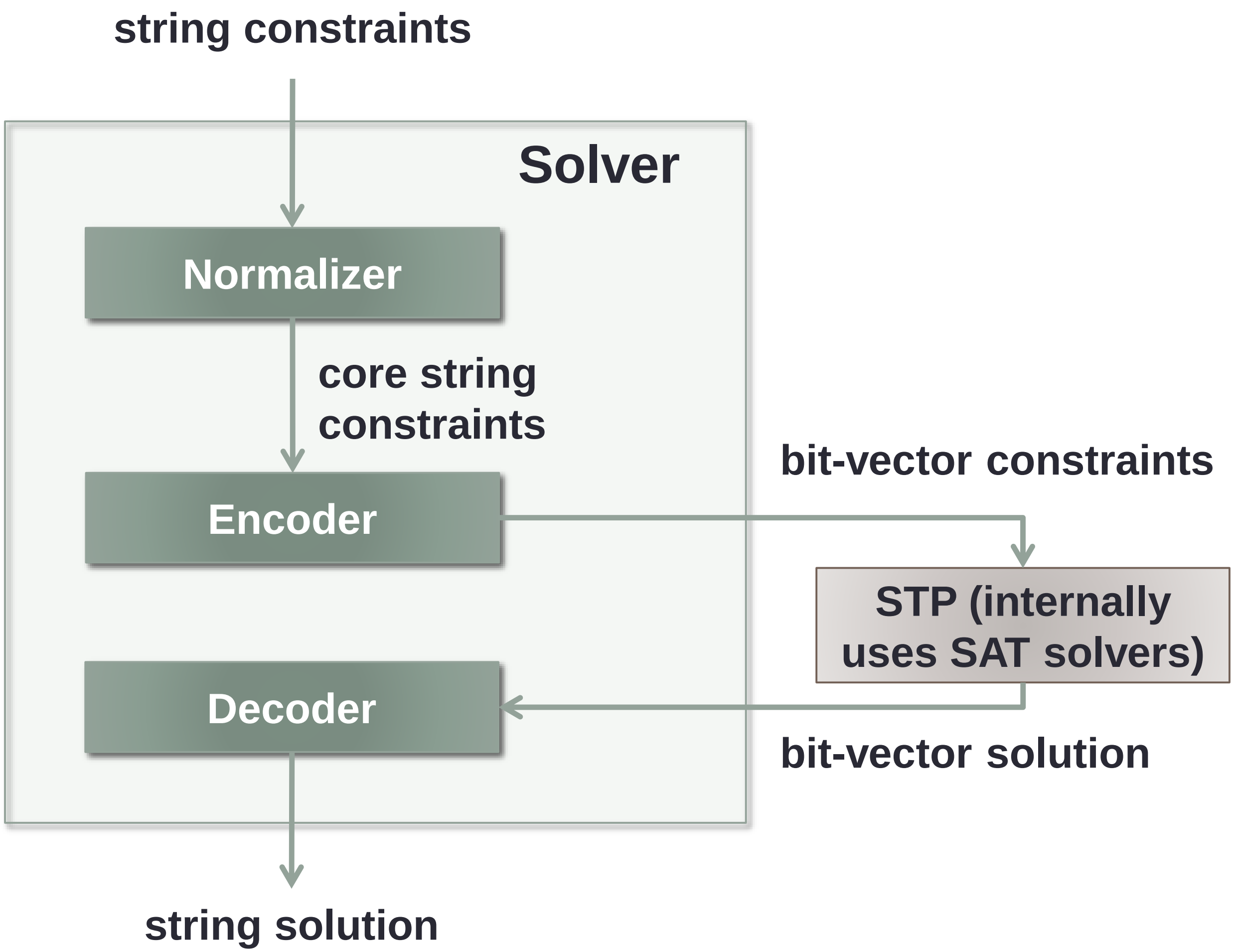
more expressive

context-free	$L_1 \cap \ldots \cap L_N$	Undecidable
regular	$R_1 \cap \ldots \cap R_N$	PSPACE-complete
bounded regular	$r_1 \cap \ldots \cap r_N$	NP-complete

more tractable

bound(any language) ➔ bounded regular

Internals of String Constraint Solver



Internals of String Constraint Solvers

var v:4;
cfg *E* := "()" | *E E* | "(" *E* ")";
var *q* := concat("(", v ,")");
q in E;
assert *q* contains "()()";

String Constraint

cfg *E* := "(" *E* ")" | *E E* | "()";

bound(*E*, 6) ➔ ([()() + (())]) + ()[()() + (())] + [()() + (())]()

Parsing and Normalizing

bit-vector constraints

Bit-vector Solver STP

B = 404041404141

Decoder

Maps bits back to alphabet Σ

B = (()())
v = ()()

Decoding

Drawbacks

- Fixed size input attack string
- Cannot handle length constraints
- Predetermined number of replaces/substrings

Back to Firefox extensions

- Looked at string constraint solvers
- Translating sanitization procedures is not trivial

```
while(theDescription.indexOf("  ") != -1)
  theDescription = theDescription.replace("  ", " ");
```

- Recursion and loops cannot be handled effectively
- Fixed size attack input?
- Scalability issues

However, there is hope

- Feed Sidebar 3.2

```
var_0xINPUT \in CapturedBrack(/.+/,0);
var_0xINPUT := P1 . P2;
P2 \in CapturedBrack(/<script[^>]*>[\s\S]+<\/script>/,0);
P1 \notin CapturedBrack(/<script[^>]*>[\s\S]+<\/script>/,0);
P3 == "";
output := P1 . P3;
test := output == "&lt;script&gt;a&lt;\/script&gt;" ;
ASSERT(test);
```

- Attack pattern : <script>a<\/script>
- Input String : <script>a<script><script>@<script>

Complete Plan

- Build a database of attacks
- Model the sanitization routines using string constraints
- Run the constraint solver for possible attacks

Drawbacks

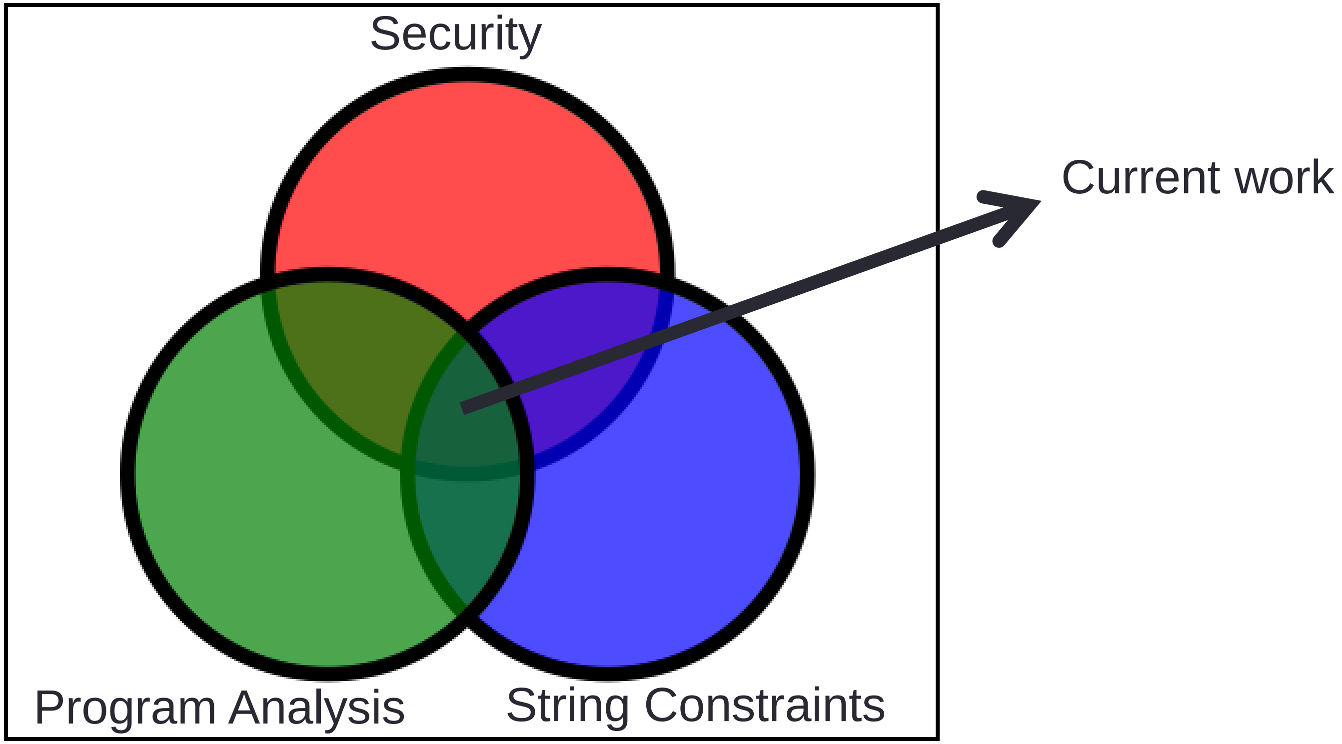
- Fixed size input
- Loops and recursive procedures

Future Work

- Explore symbolic string constraint solvers
- Improve **VEX** for collecting sanitization routines

Conclusions

- Verification of third party web applications
- Provide a counterexample for the security loophole(if any)



THANK YOU