Synode: Understanding and Automatically Preventing Injection Attacks on Node.js

Cristian-Alexandru Staicu[1] Michael Pradel[1]
Ben Livshits[2]

[1]TU Darmstadt

[2]Imperial College London, Brave Software

February 20, 2018

SOLA SoftwareLab

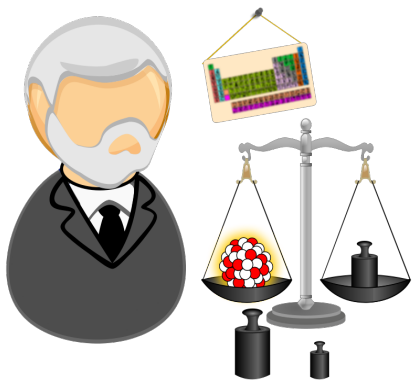
TECHNISCHE UNIVERSITÄT DARMSTADT

This Talk

Node.JS and Injections

Empirical Study

Synode



Evaluation

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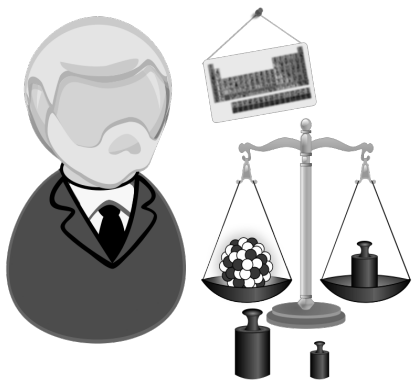

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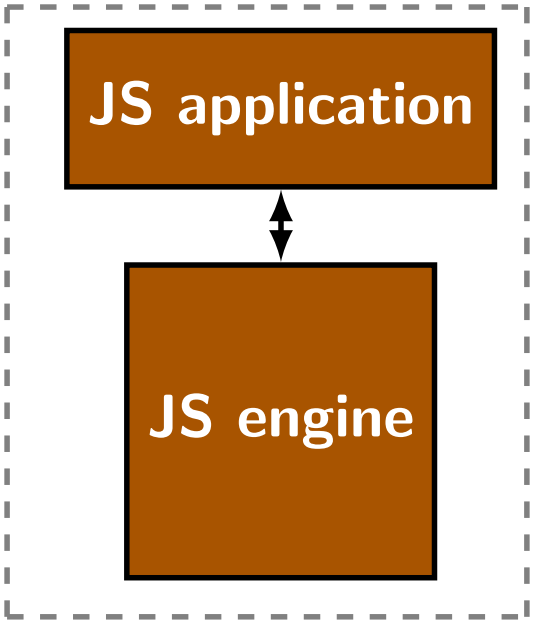

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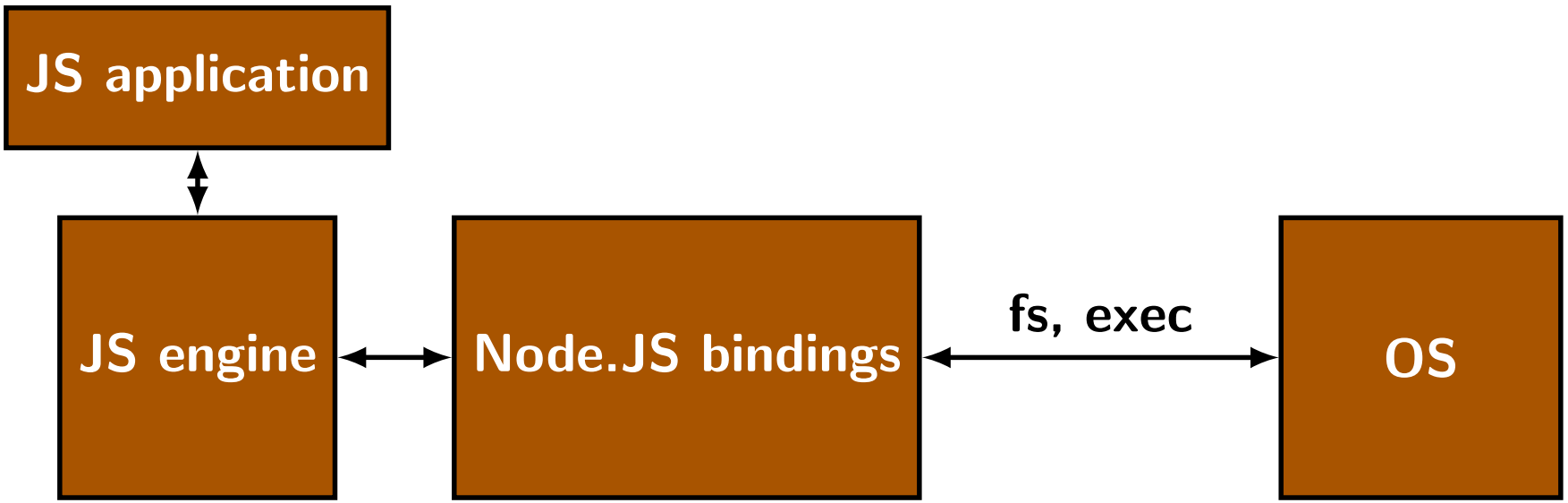

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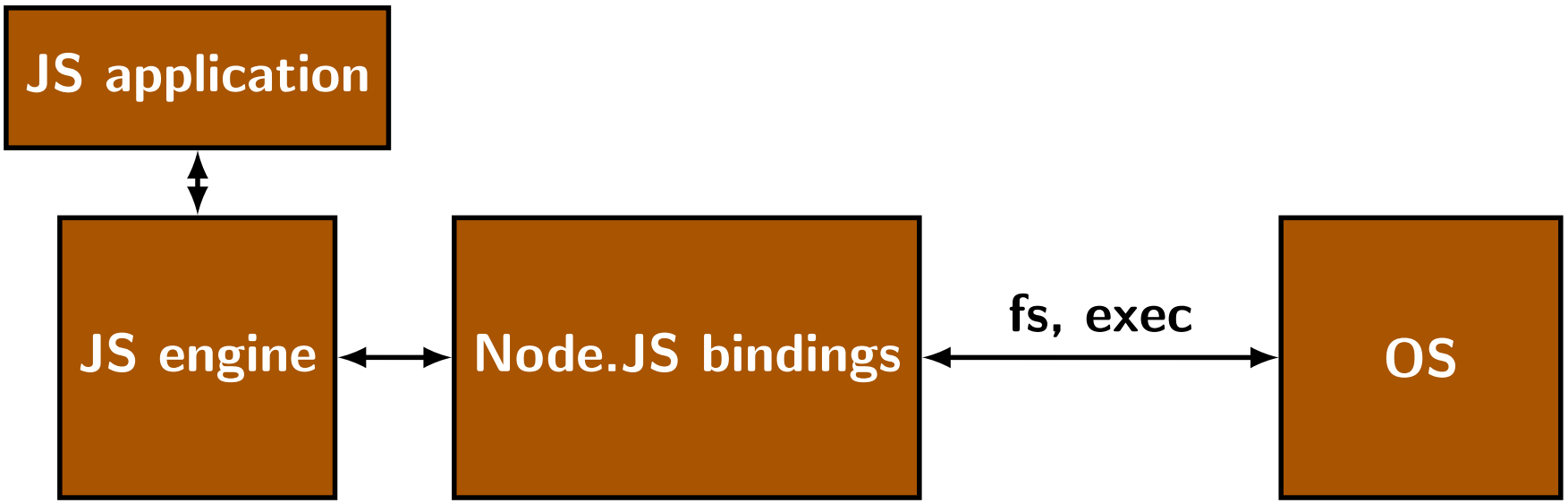

Node Package Manager

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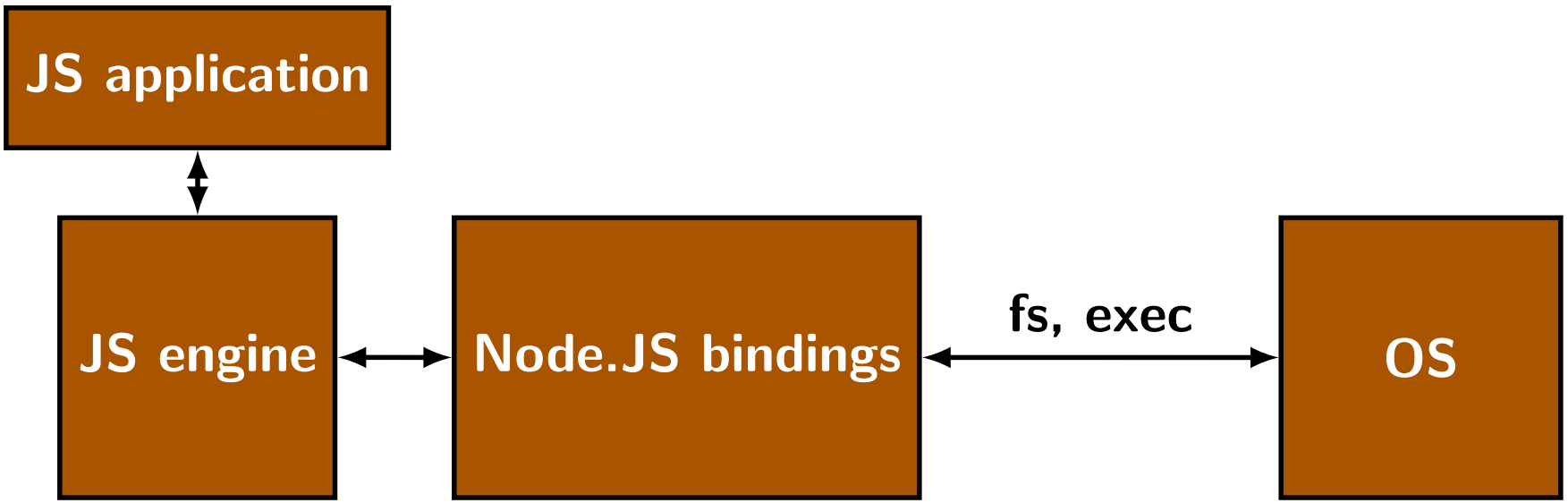
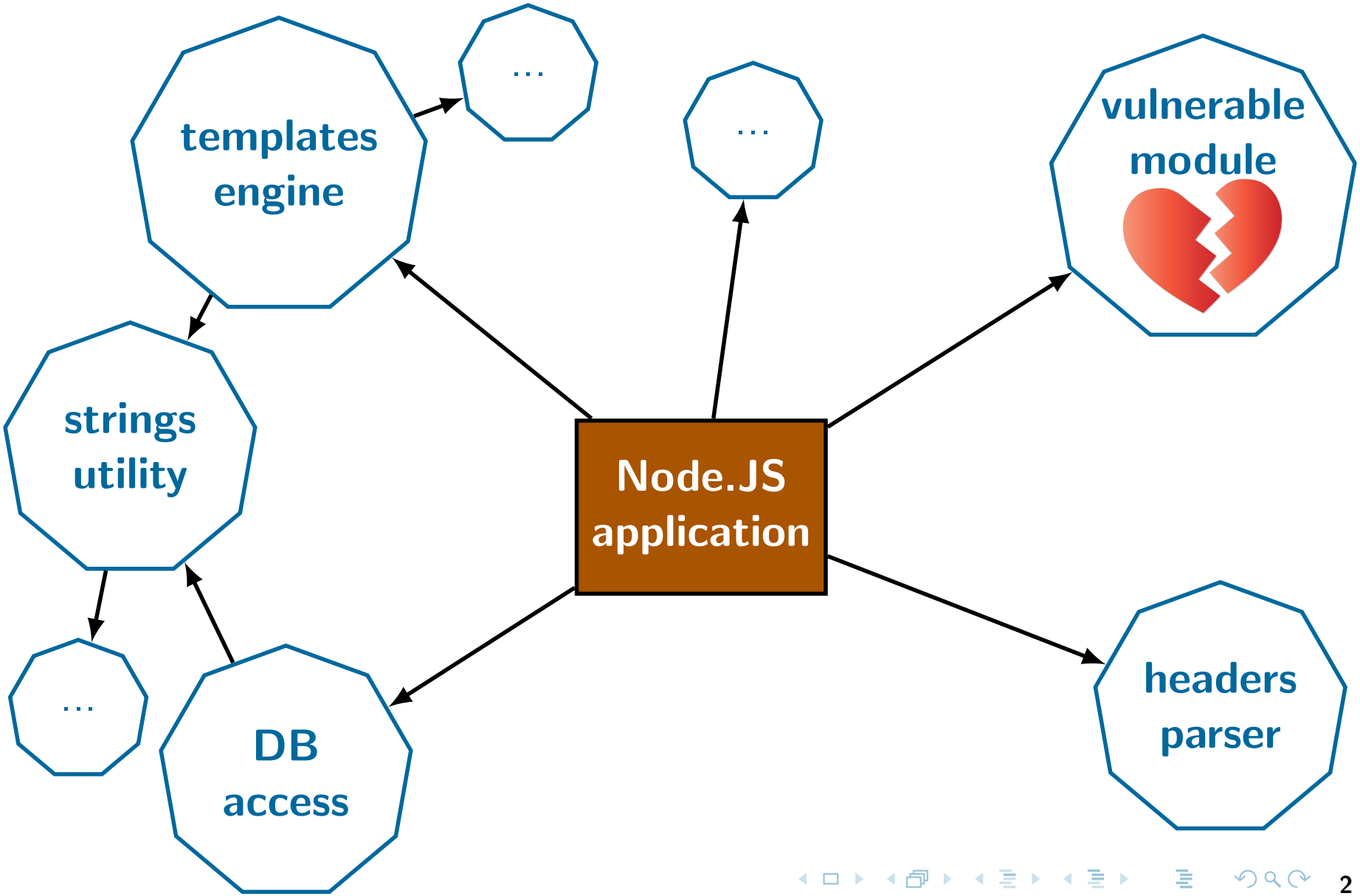


Node Package Manager

Node Security Project

Typical Node.JS Application



Running Example

```
function backupFile(name, ext) {
  var cmd = [];
  cmd.push("cp");
  cmd.push(name + "." + ext);
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  exec(cmd.join(" "));
}
```

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  exec(cmd.join(" "));
}
```

Malicious Payload

```
backupFile("-h && rm -rf * && echo ", "")
```

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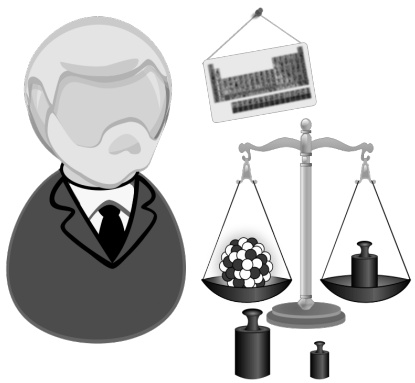


Evaluation

npm Codebase

236,337
packages

2.471
average number of package dependences

816,840,082
lines of JavaScript code

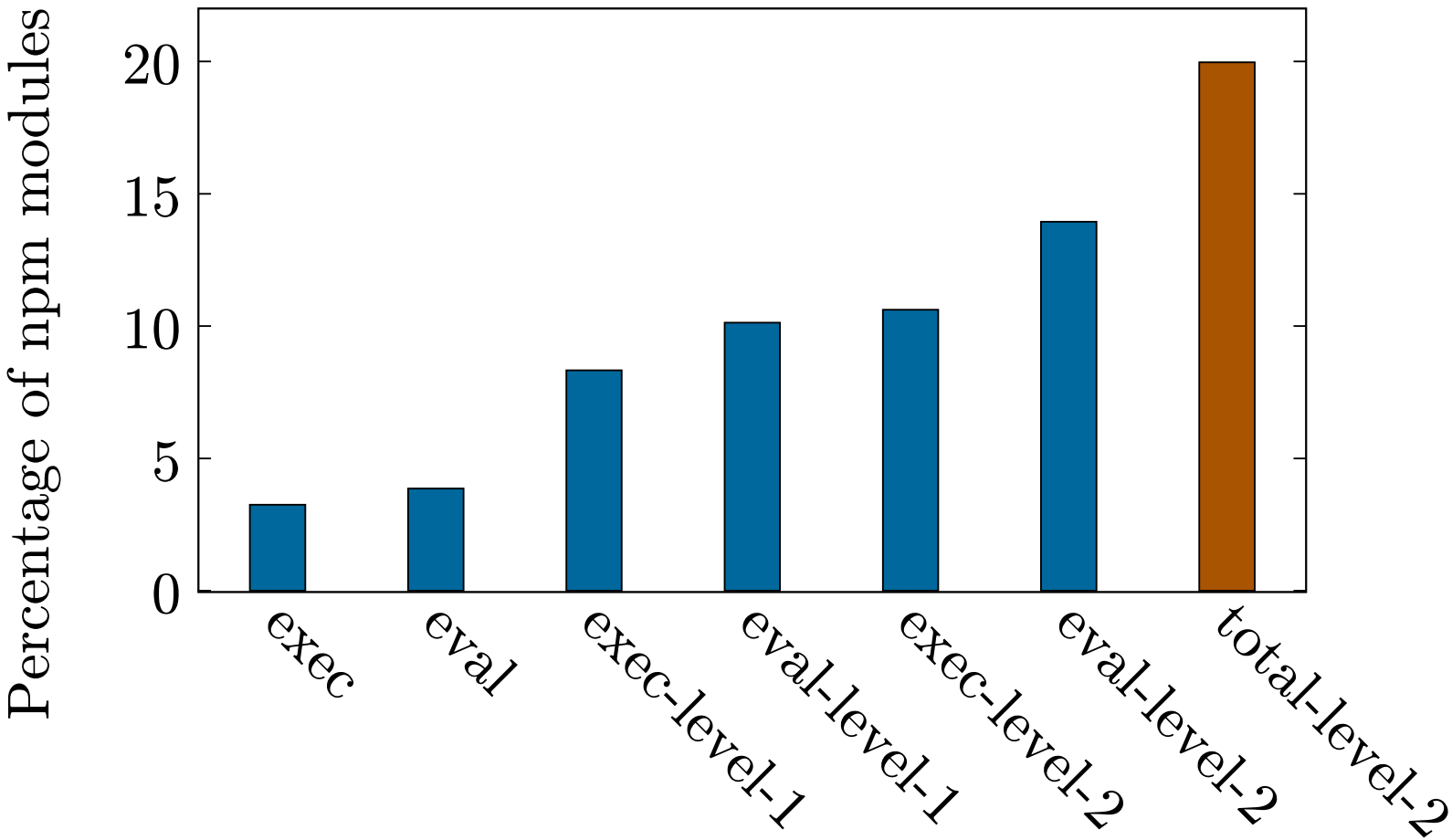
>40,000
C files

7,685
number of packages containing exec

9,110
number of packages containing eval

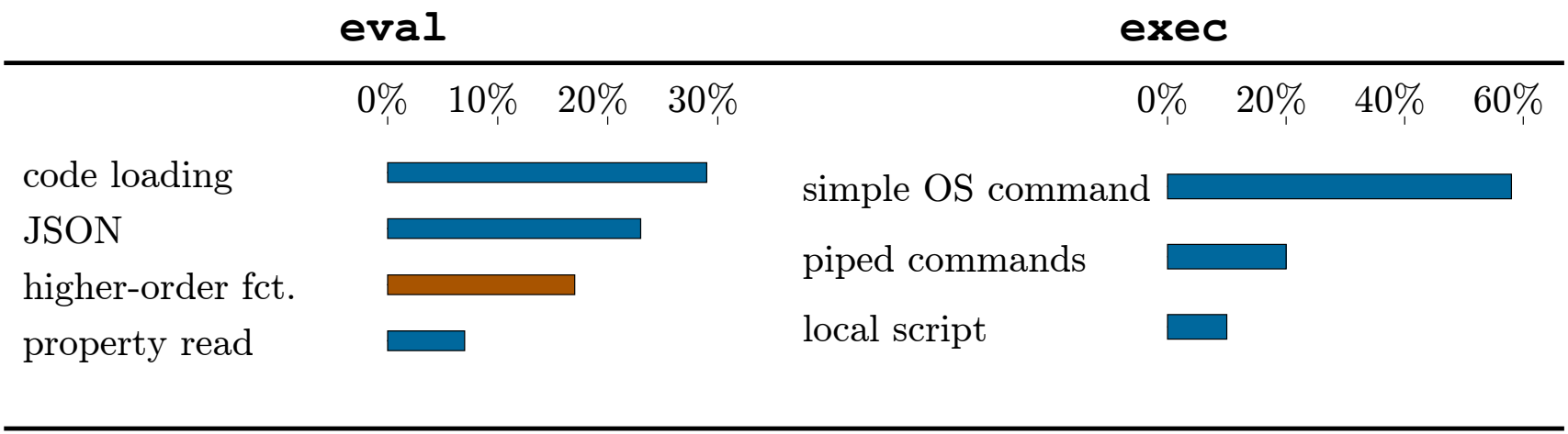
February 2016

Dependences on Injection APIs



Data Passed to Injection APIs

Manual inspection of **150** call sites



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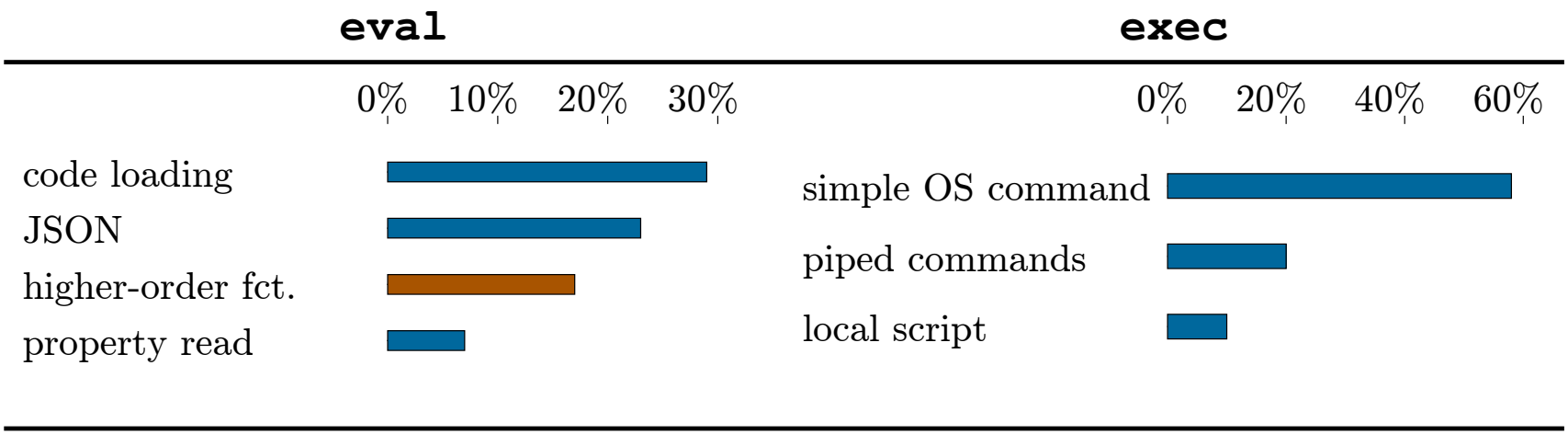

58% contain user-controlled data, out of which:

- **90%** perform no check on this data
- **9%** use regular expressions

Submitted Bug Reports

Affected module	Confirmed	Time until fixed
mixin-pro	yes	1 day
modulify	no	–
proto	yes	155 days*
mongoosify	yes	73 days
summit	yes	–
microservicebus.node	yes	–
mobile-icon-resizer	yes	2 days
m-log	–	–
mongo-edit	–	–
mongo-parse	yes	–
mock2easy	–	–
mongui	–	–
m2m-supervisor	–	–
nd-validator	–	–
nameless-cli	–	–
node-mypeople	–	–
mongoosemask	–	–
kmc	–	–
mod	–	–
growl	yes	–

– indicates a lack response and * an incomplete fix

180 days after reporting

Lessons Learned

multiple dependences

on average each module has 2.5 direct dependences

no sanitization

only 9% use sanitization, often broken

unresponsive developers

within six months only 25% of the issues were fixed

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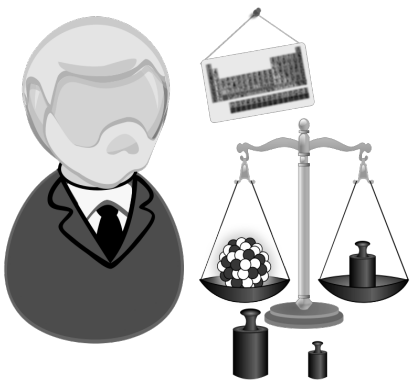
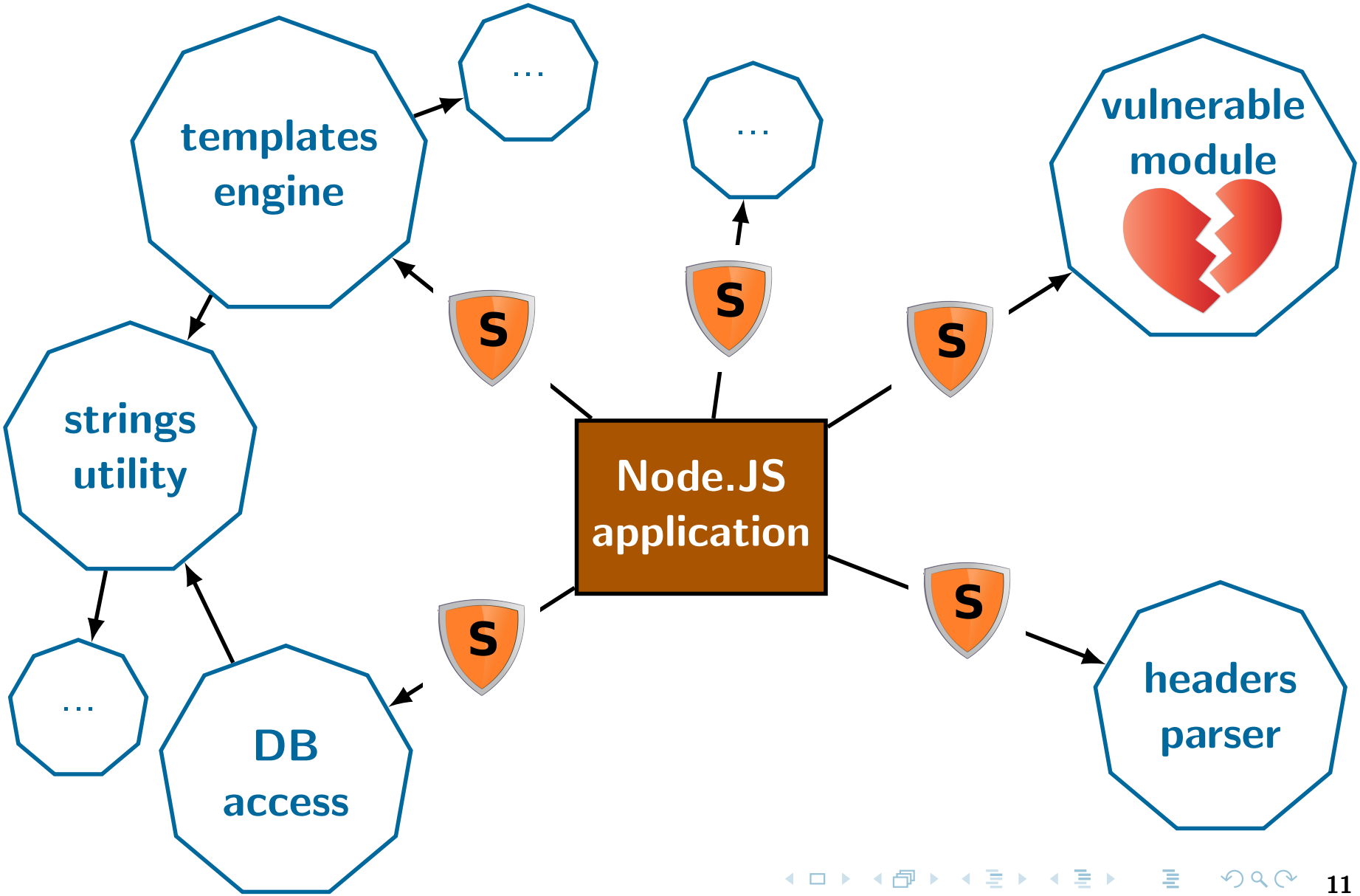
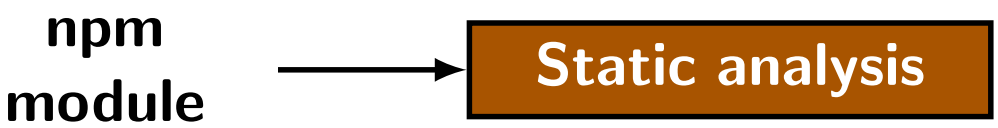


Evaluation

Safe Use of Modules with Synode



Overview of Synode



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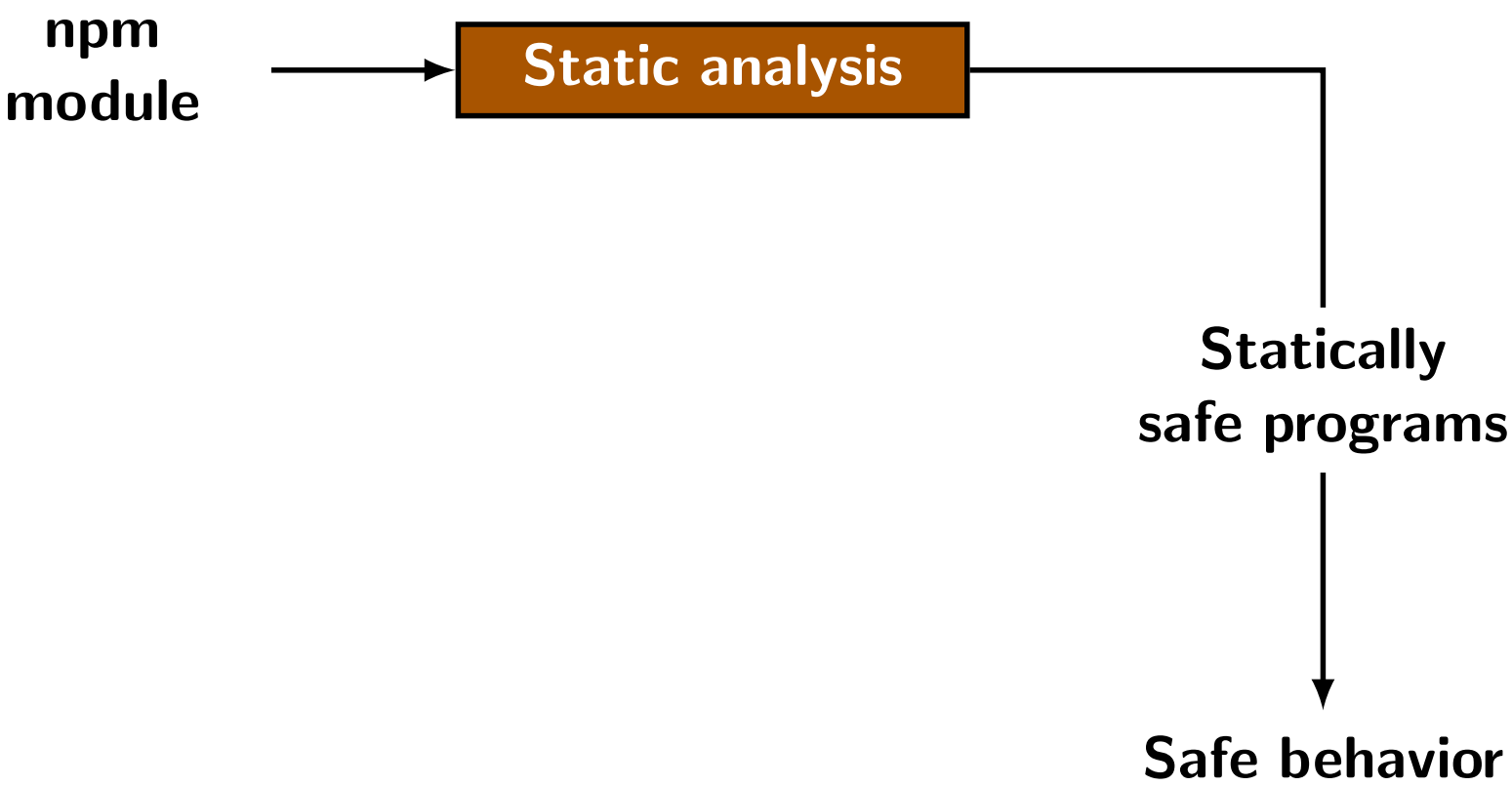

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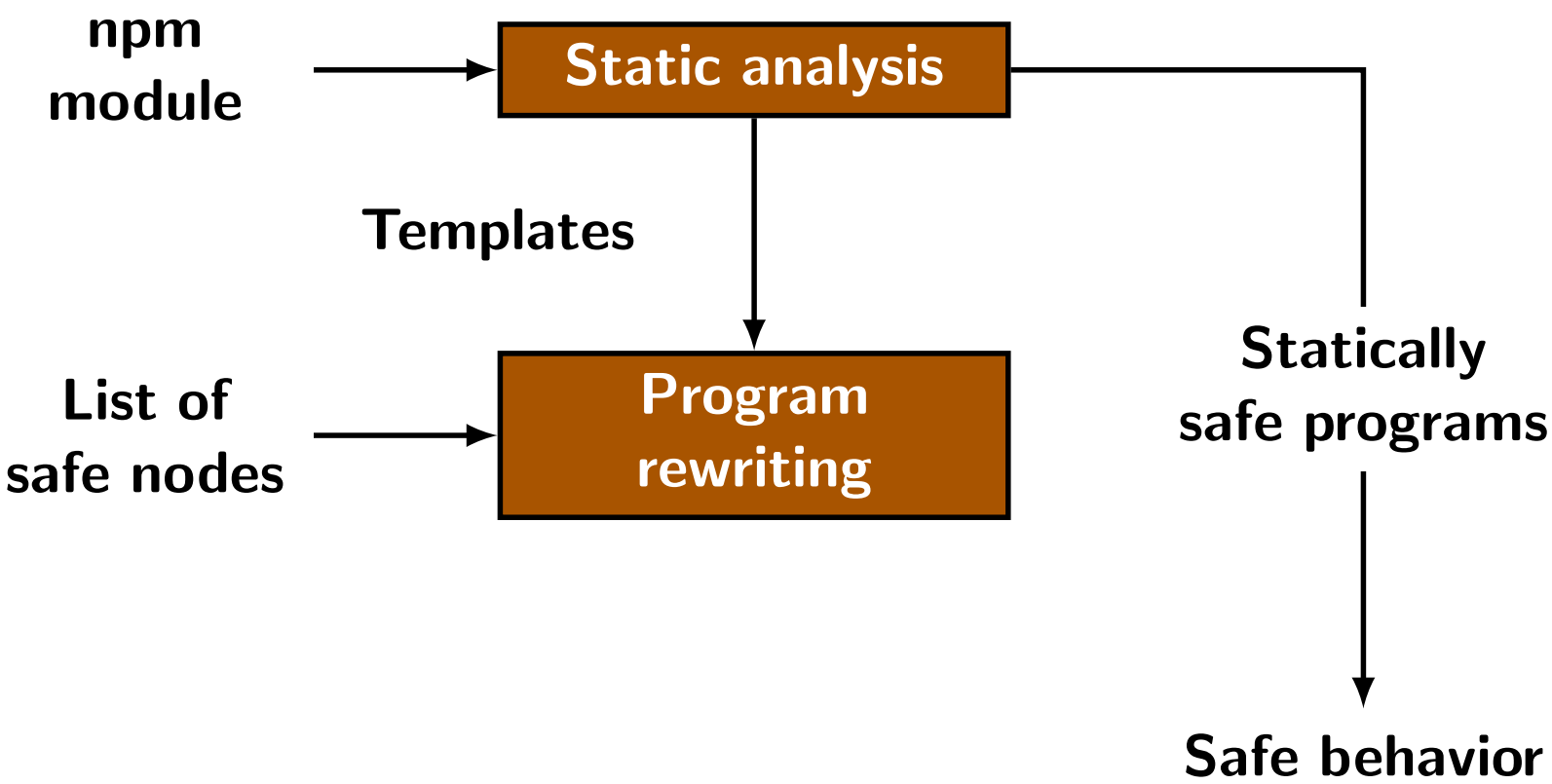

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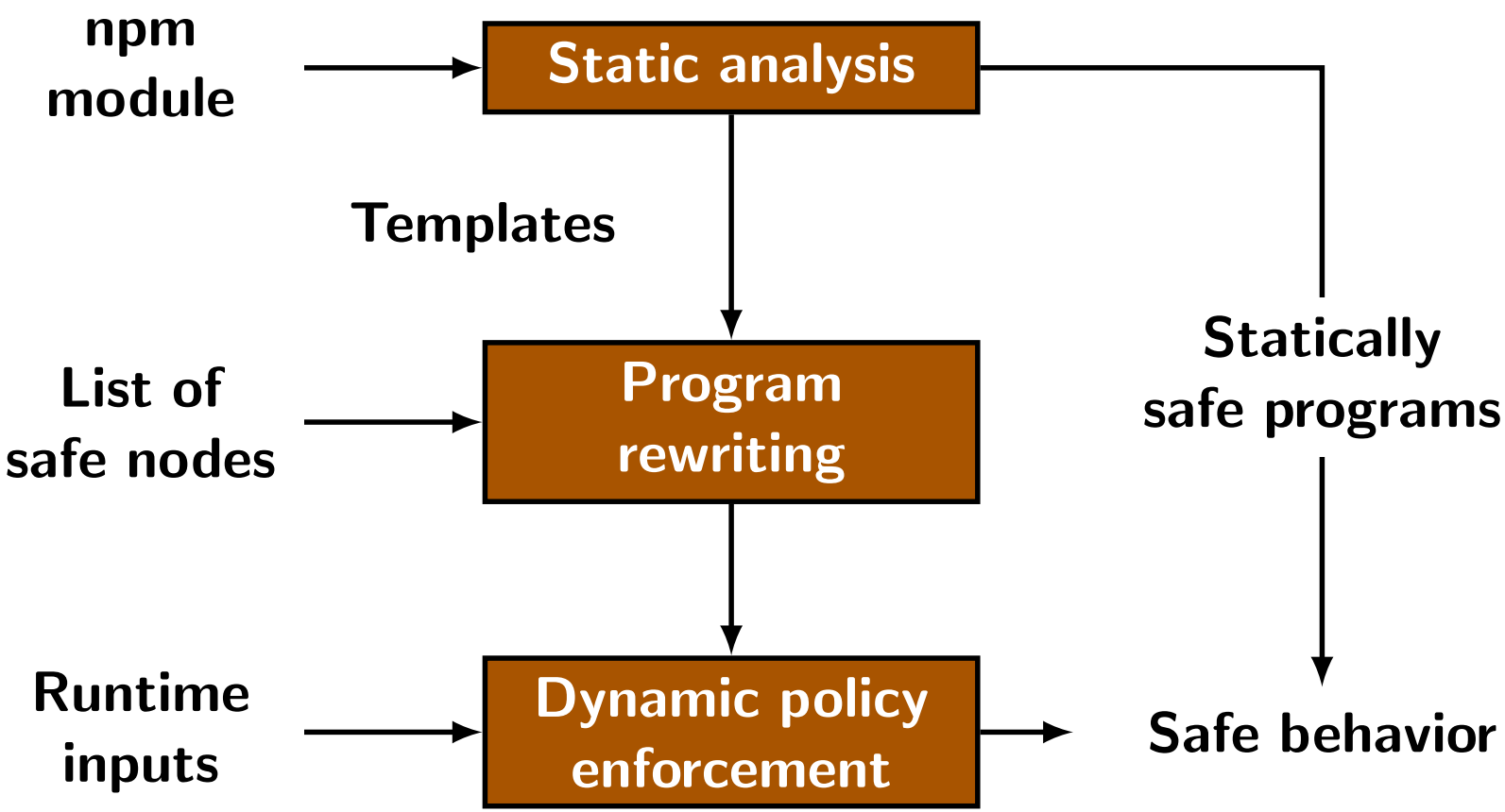

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1. Intra-procedural backward data flow analysis:
   - Over-approximates strings passed to injection APIs
   - Unknown parts to be filled at runtime

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"$hole"

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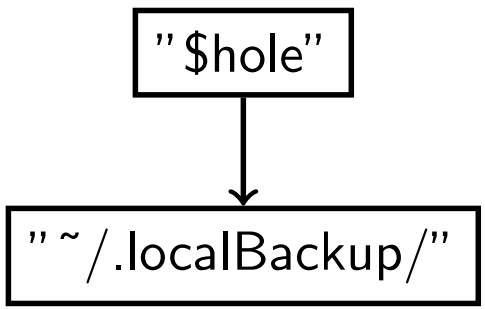

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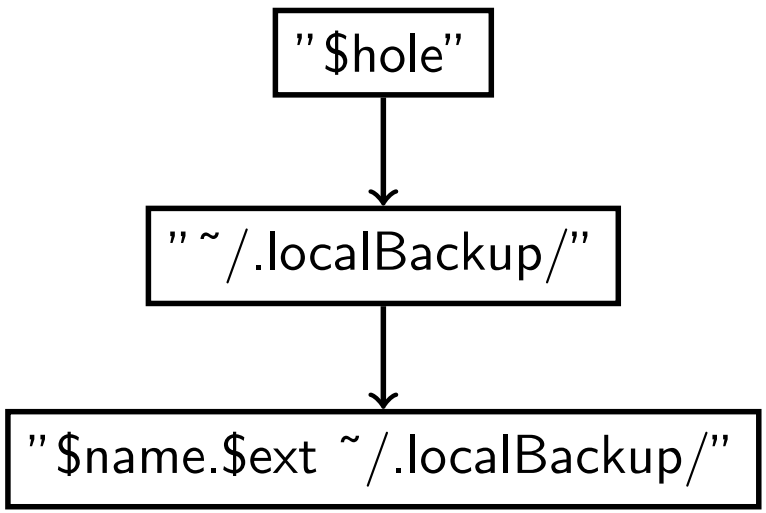

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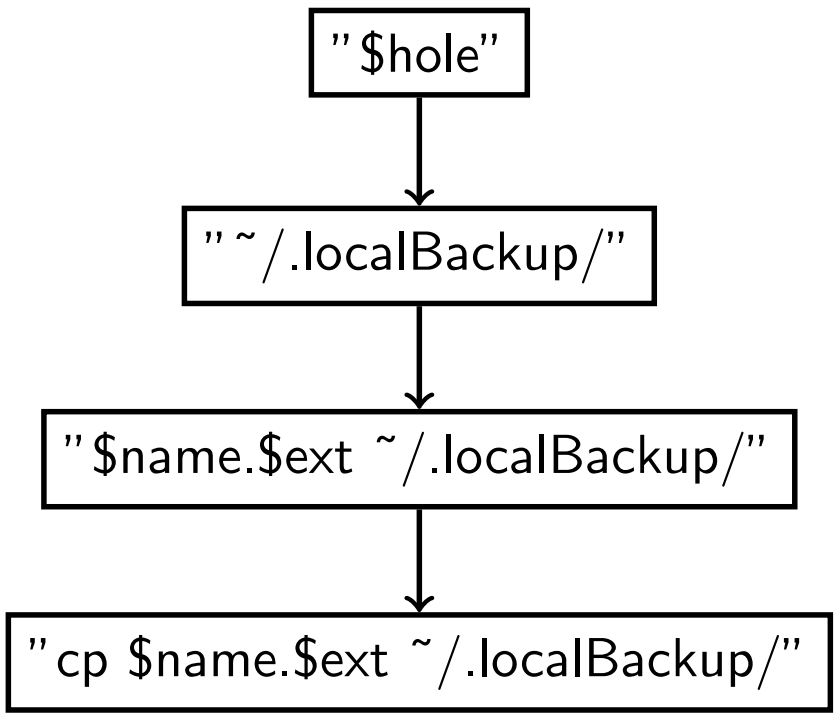

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2. Synthesize runtime policy using templates:
   - Enforce structure via partial AST
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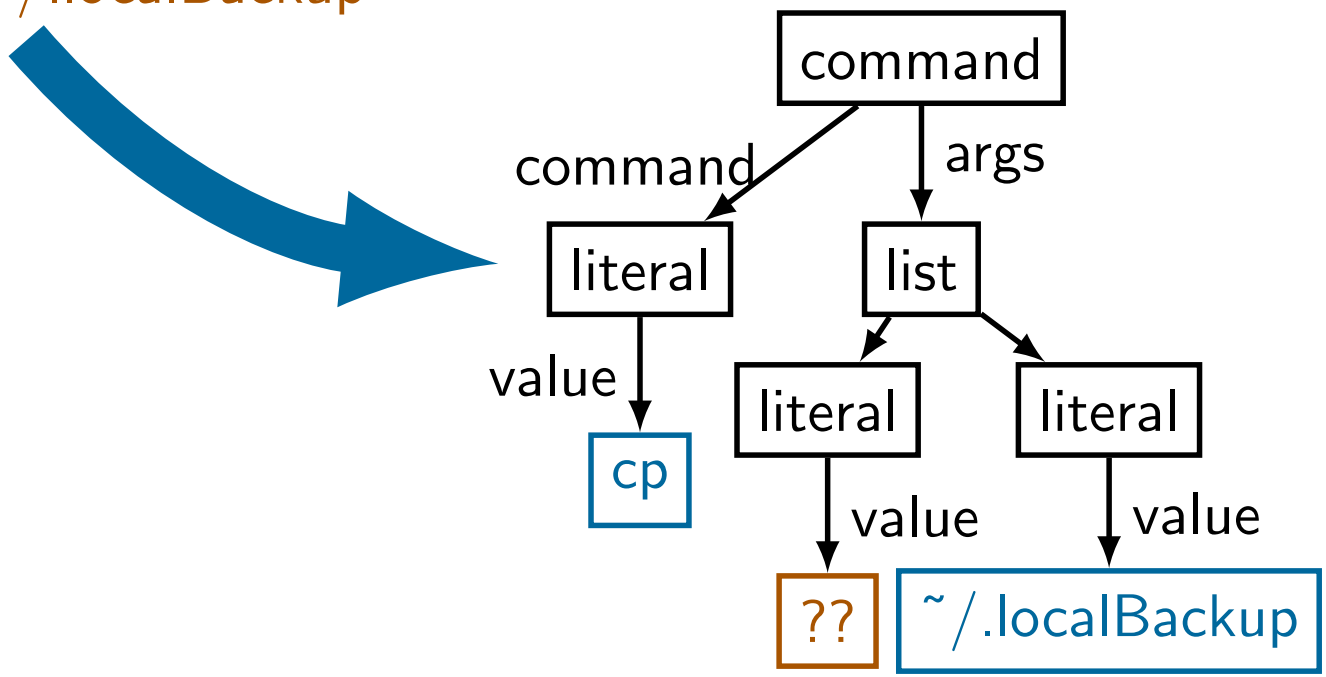
"cp $name.$ext ~/.localBackup"



Runtime Phase

Enforce policy on strings passed to injection APIs

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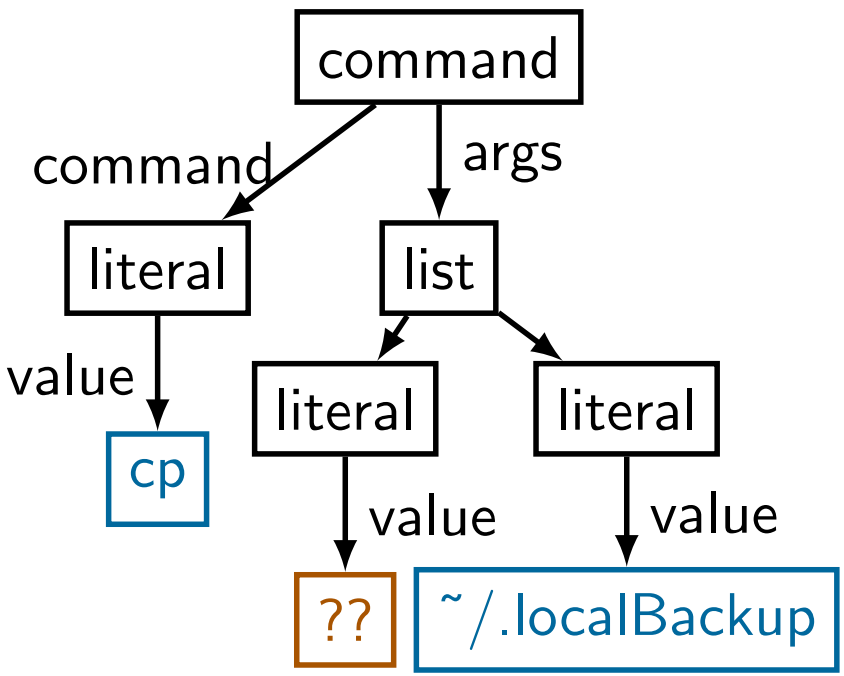

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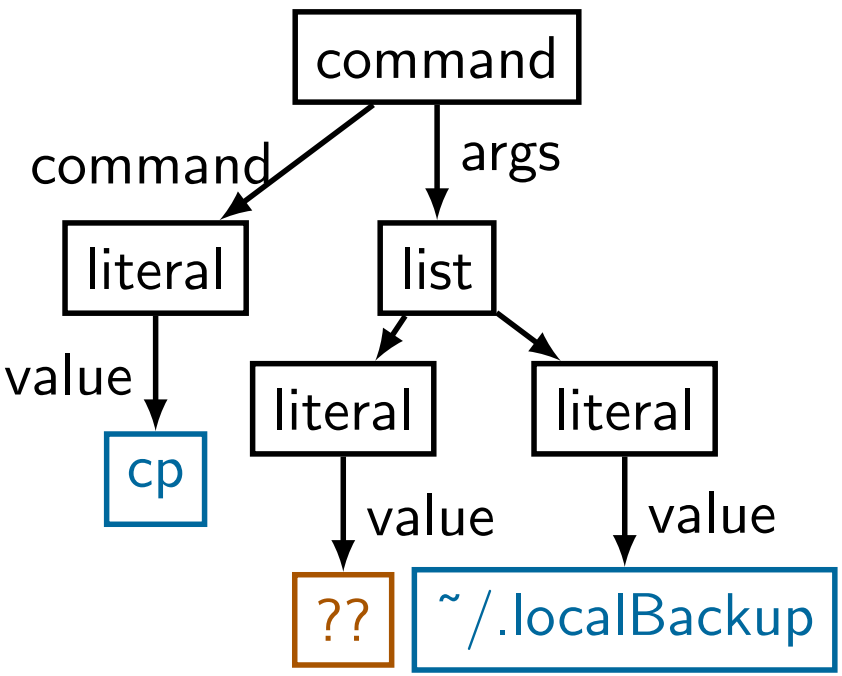
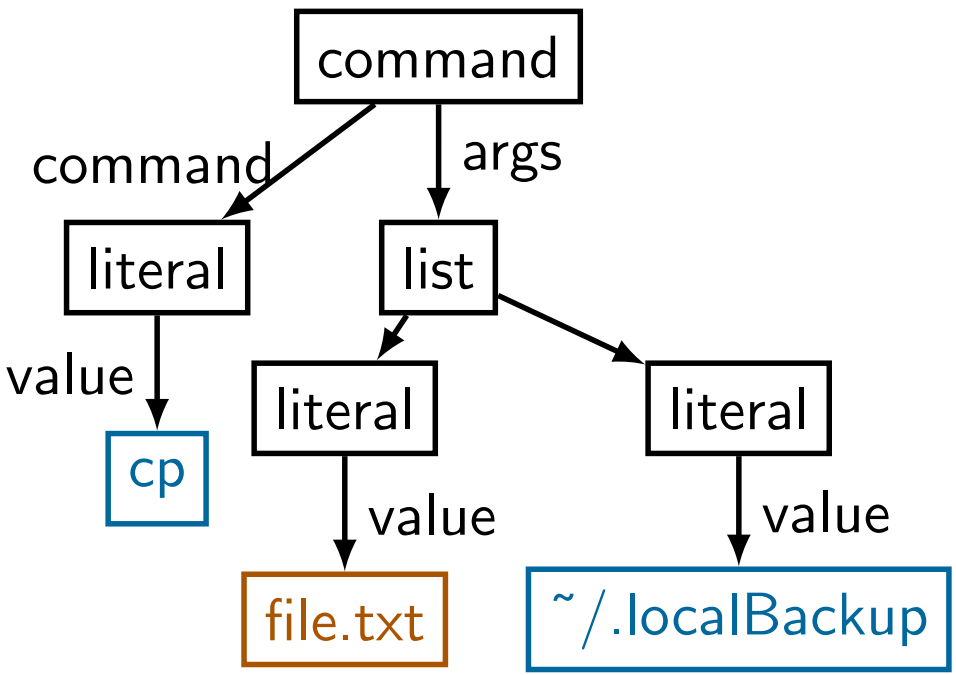


Runtime string:

"cp file.txt ~/.localBackup"



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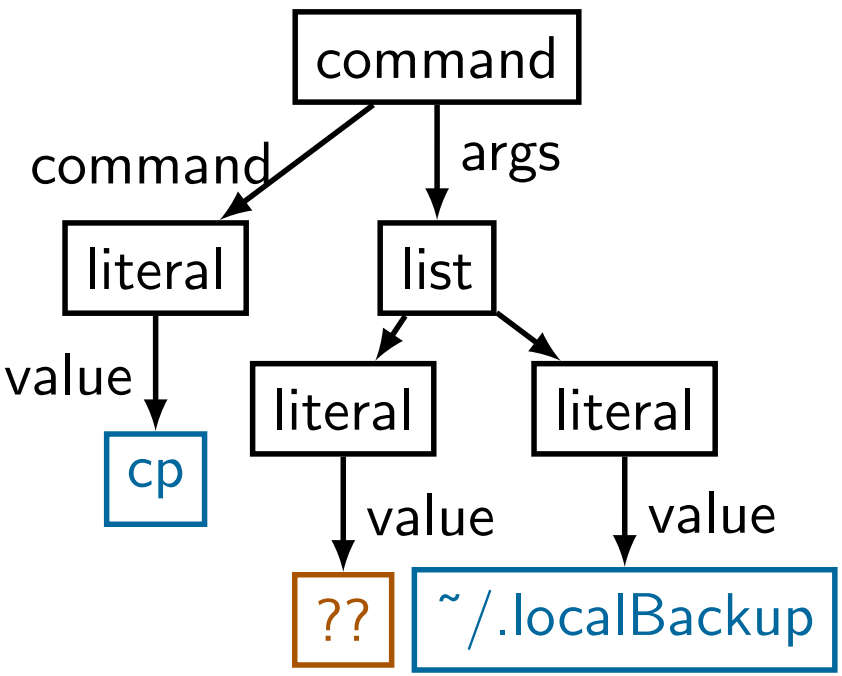

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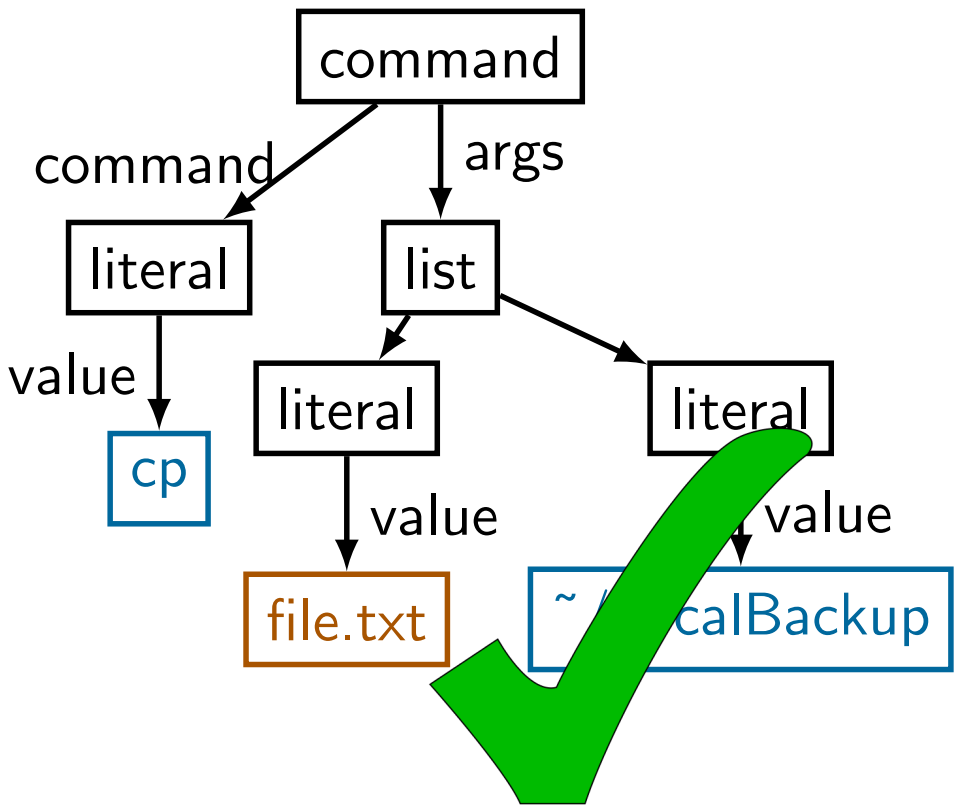
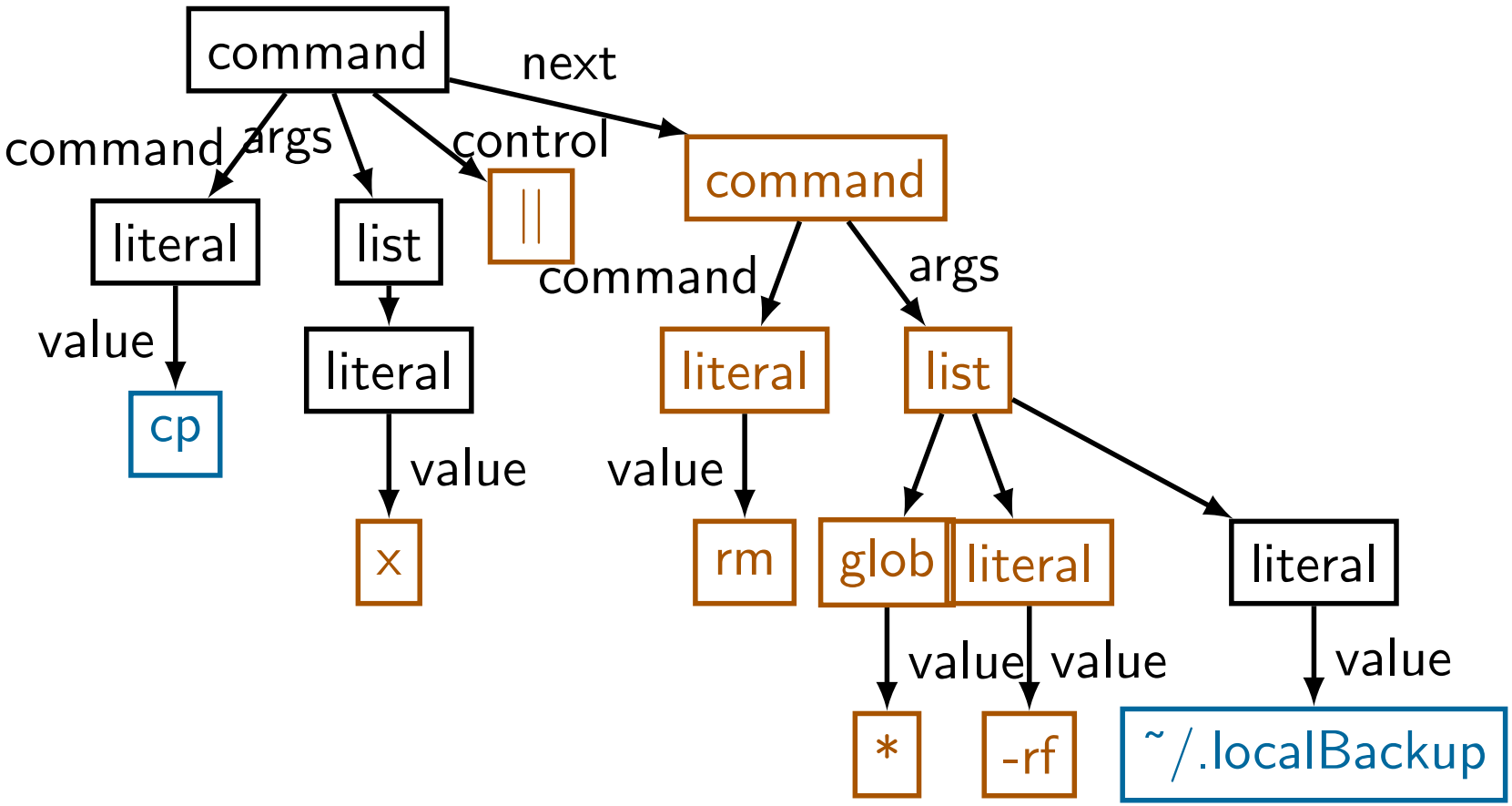


Runtime Phase

Runtime string:

"cp x || rm * -rf ~/.localBackup"



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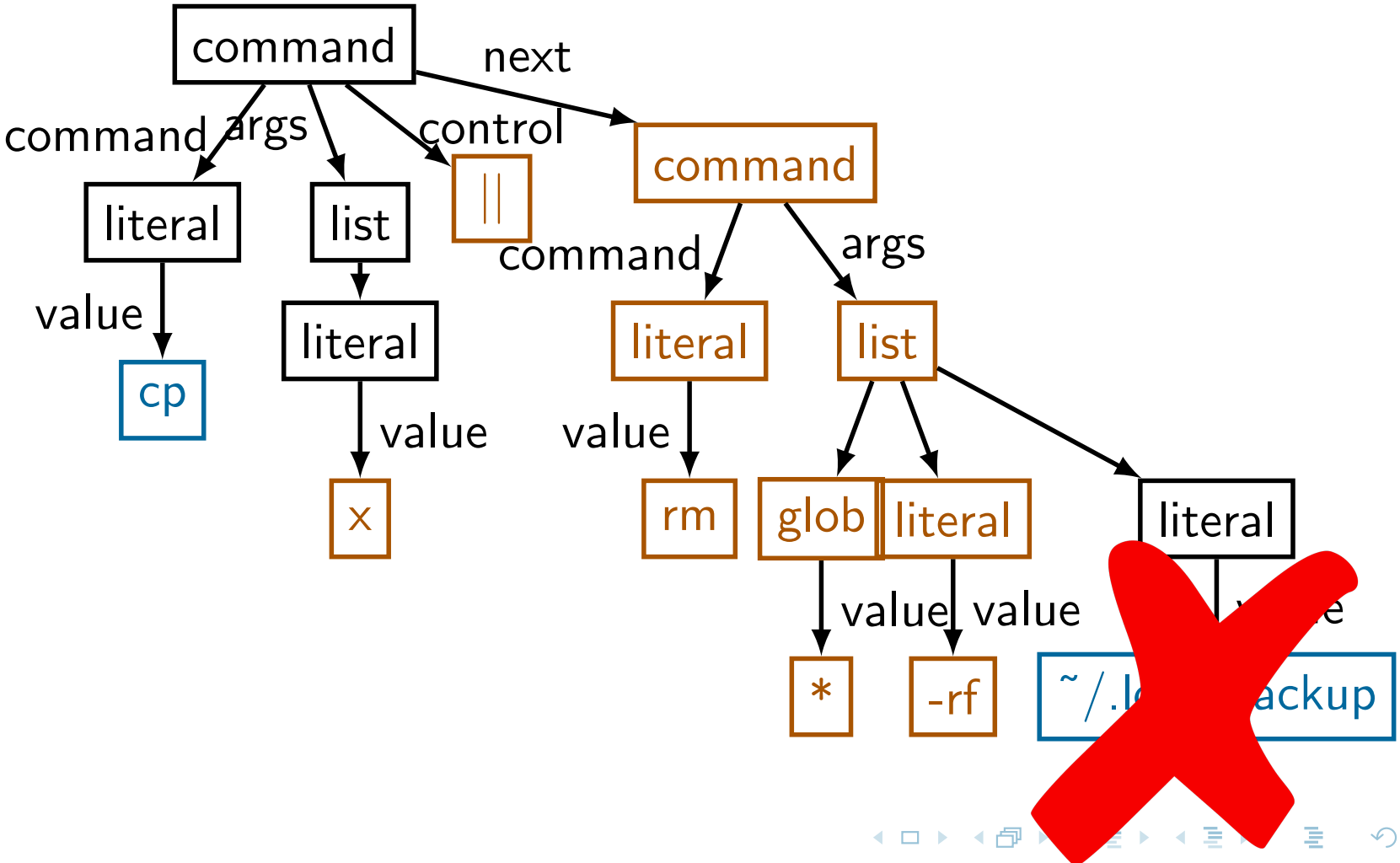

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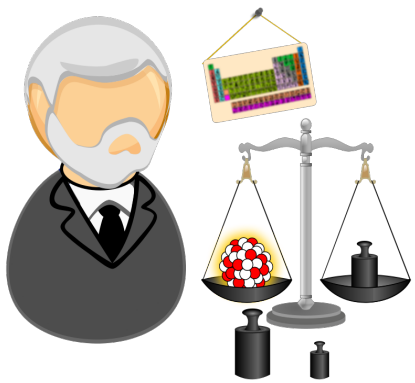

Evaluation

Evaluation: Static Phase

Setup

- 51K call sites of injection APIs

Precision

- **36.7%** of the call sites statically safe
- **63.3%** to be checked at runtime

Context

- most call sites have at least:
  - 10 constant characters per template
  - 1 unknown per template

Performance

- 4.4 seconds per module

Evaluation: Runtime Phase

Setup

- 24 modules
- 56 benign and 65 malicious inputs

Results

- **zero** malicious inputs that we do not stop
- five benign inputs that we incorrectly stop
- overhead: 0.74 milliseconds per call

Conclusions

Study of injection vulnerabilities

- First large-scale study of Node.js security
- `exec` and `eval` are prevalent in npm ecosystem
- Developers are slow to react

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Prevention of injections

- Automatic and easy to deploy
  `https://github.com/sola-da/Synode`
- Small overhead and high accuracy

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Open challenges

- More precise static analysis
- Automatic generation of attacks

Example Limitation: Array.map()

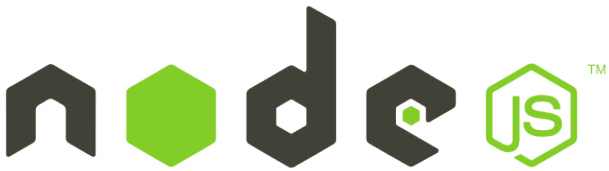
```
var keys = Object.keys(dmenuOpts);
var dArgs = keys.map(function(flag) {
  return '-' + flag + ' "' + dmenuOpts[flag] + '"';
}).join(' ');

var cmd = 'echo | dmenu -p "Password:" ' + dArgs;
exec(cmd);
```

Inferred template

```
'echo | dmenu -p "Password:" $dArgs'
```

Implementation



- Intraprocedural static analysis
- Based on **Google Closure Compiler**
- Policy for unknown parts:
  - **`exec`**: literal
  - **`eval`**: literal, identifier, property, array expression, object expression, member expression, expression statement

Beyond eval and exec

- `vm.runIn*Context()`

```
var vm = require('vm');
vm.runInThisContext(
        "console.log('" + input + "');");
```

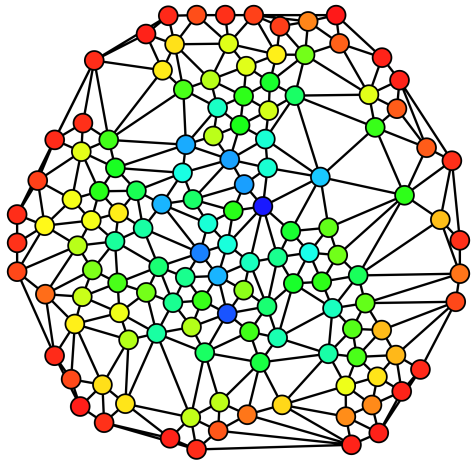
- `execa` module (1,000 dependents)

```
module.exports.shell = function(cmd) {
    args = ['-c', cmd]
    childProcess.spawnSync("/bin/sh", args);
}
```

Why is the Application Domain Unique?

20 out of 66 advisories are injections (Node Security Project)

Bad habits



Unnecessary code reuse (see left-pad)

No sandbox