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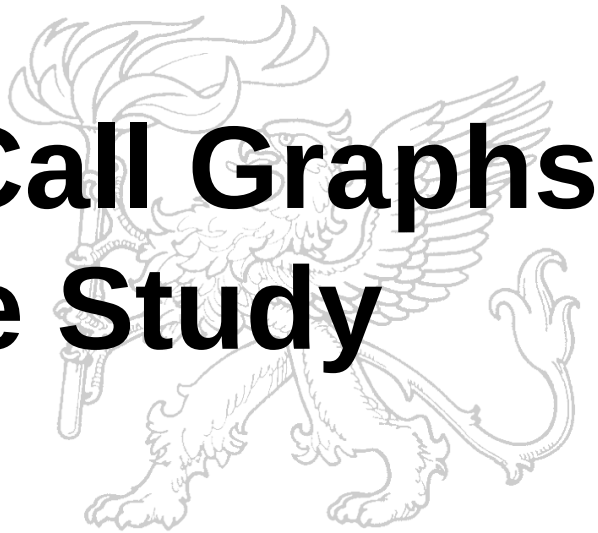

Static JavaScript Call Graphs: a Comparative Study

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Introduction

- JavaScript
  - increasing popularity for years
  - supports both server and client side
  - code analysis became very important
- Call graph is a basis for e.g.
  - **S**ource **C**ode **A**nalysis and **M**anipulation
    - e.g. interprocedural control flow
  - Software Visualization

```
function f() {} // node f
function g() { f(); } // edge g->f
```

Call graphs for JavaScript

- Static approaches
  - might miss dynamic calls – e.g. eval()
  - are relatively fast
  - require no testbed
- Dynamic approaches
  - find only realized calls
  - are slower
  - require large testbed with high coverage

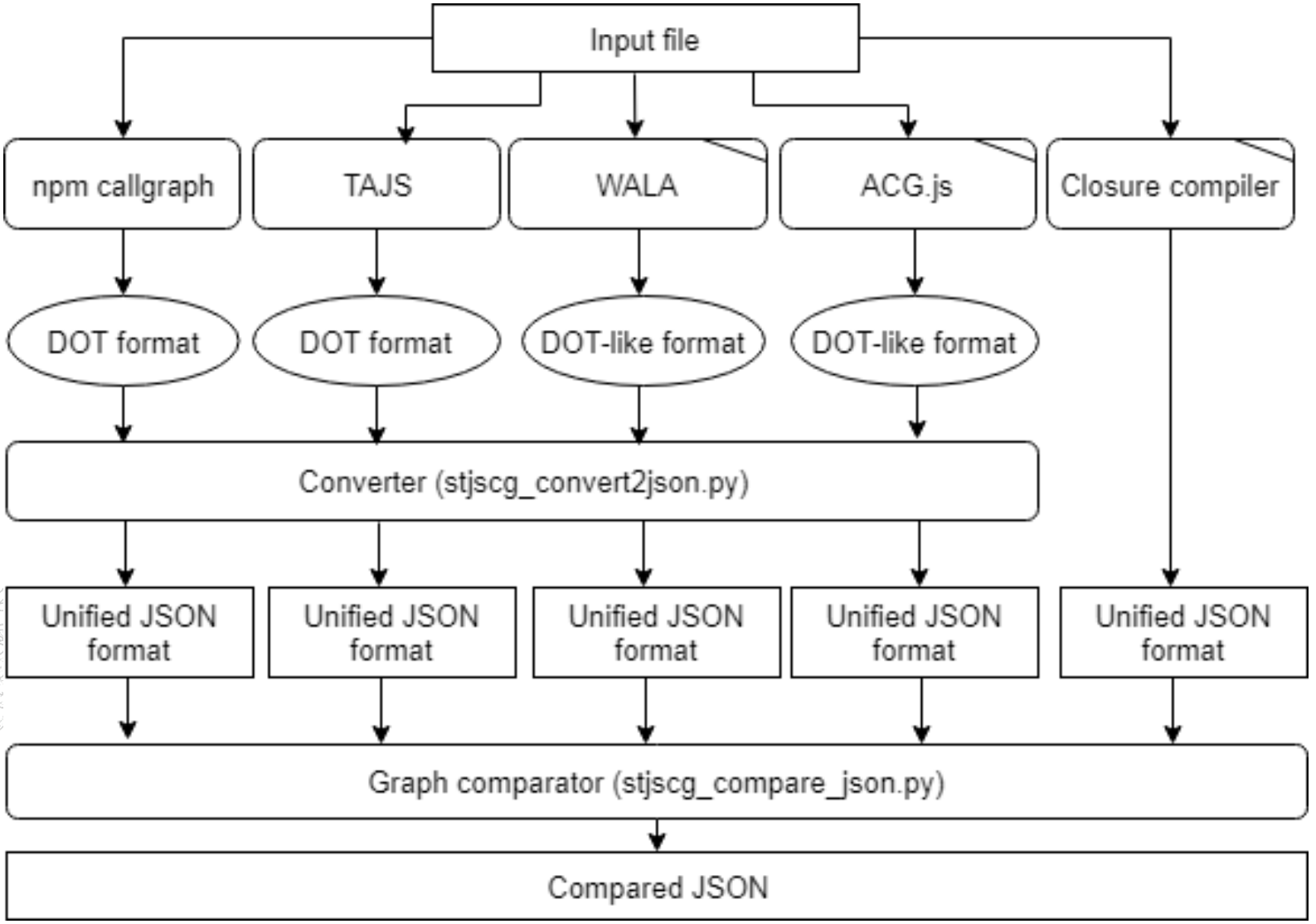
Motivation

- JavaScript is quite hard to analyze statically because of its dynamic behavior
  - However, several static code analysis tools exist
- We wanted to know
  - is building usable static call graphs feasible?
  - how accurate are the static call graphs?
  - which tools are the most popular?
  - what are the characteristics of these tools?
  - can they handle new EcmaScript standards?

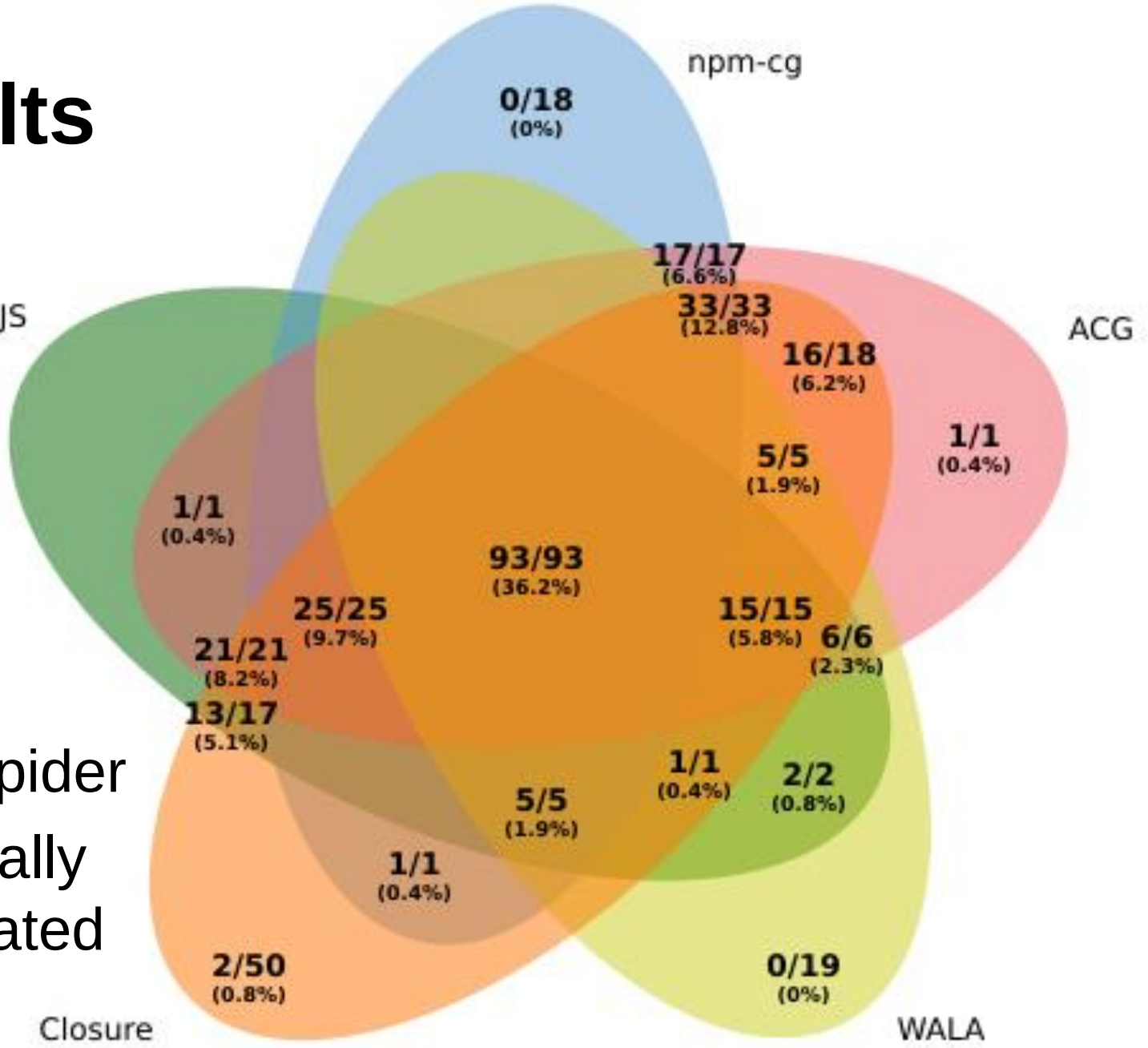
Study design

- Five static JavaScript call graph extraction tools
  - npm callgraph
  - IBM WALA
  - Google Closure Compiler
  - ACG (Approximate Call Graph)
  - TAJS (Type Analyzer for JavaScript)
- Quantitative and qualitative analysis on
  - 26 SunSpider benchmark programs
  - 6 real-world Node.js modules
  - generated inputs

Methodology

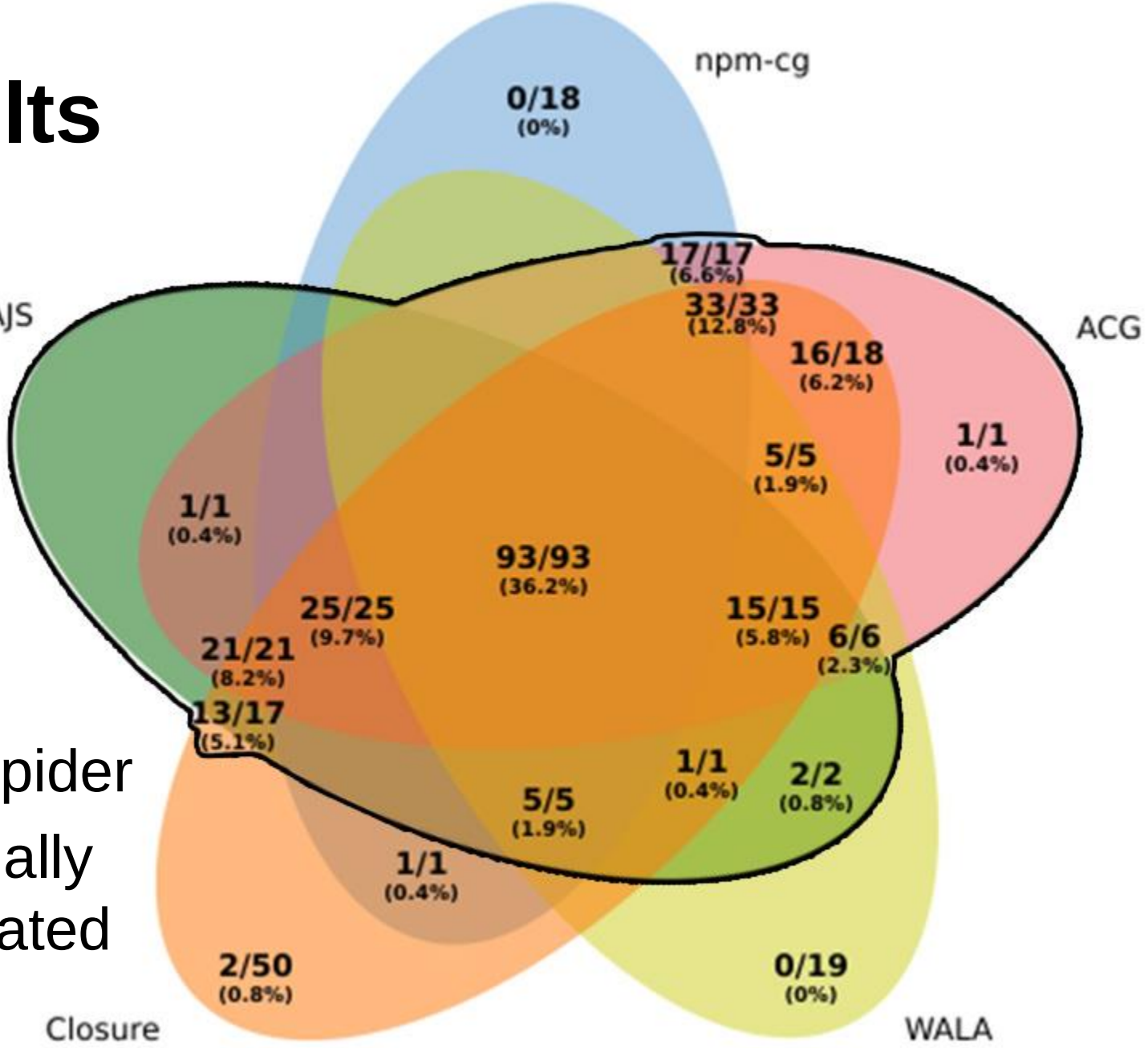


Results



- SunSpider
- Manually evaluated

Results



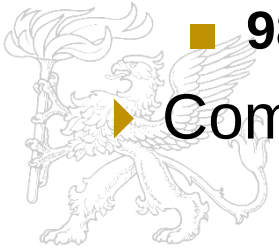
- SunSpider
- Manually evaluated

Discussion of results

- npm callgraph (prec.: **91%**, recall: **68%**)
  - treats calls from anonymous functions as calls from global scope
- Closure Compiler (prec.: **81%**, recall: **89%**)
  - can find recursive edges
  - relies often only on name matching
- WALA (prec.: **87%**, recall: **49%**)
  - can detect calls of function arguments
  - can analyze eval() in some cases

Discussion of results

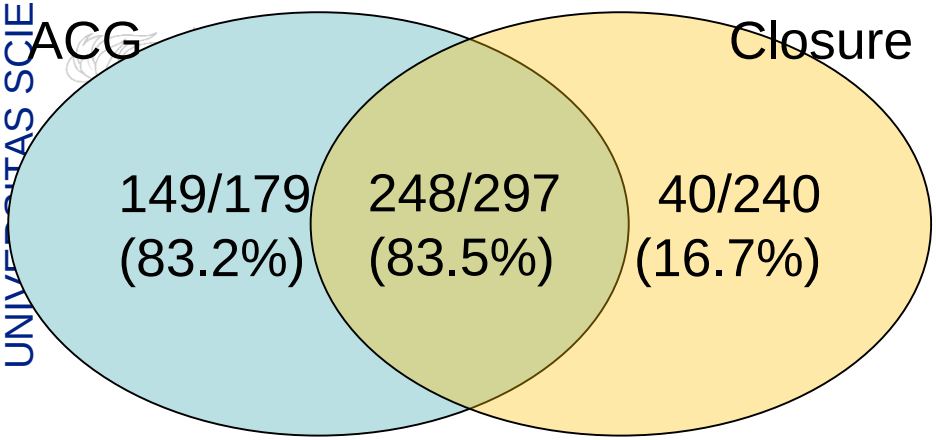
- TAJS (prec.: **98%**, recall: **71%**)
  - can detect calls of function arguments
  - is able to track complex control flows and detect non-trivial call edges
- ACG (prec.: **99%**, recall: **91%**)
  - is able to track complex control flows and detect non-trivial call edges
- **ACG+TAJS** together perform almost perfectly
  - **98%** precision, **99%** recall
- Combining all tools have 74% precision, 100% recall



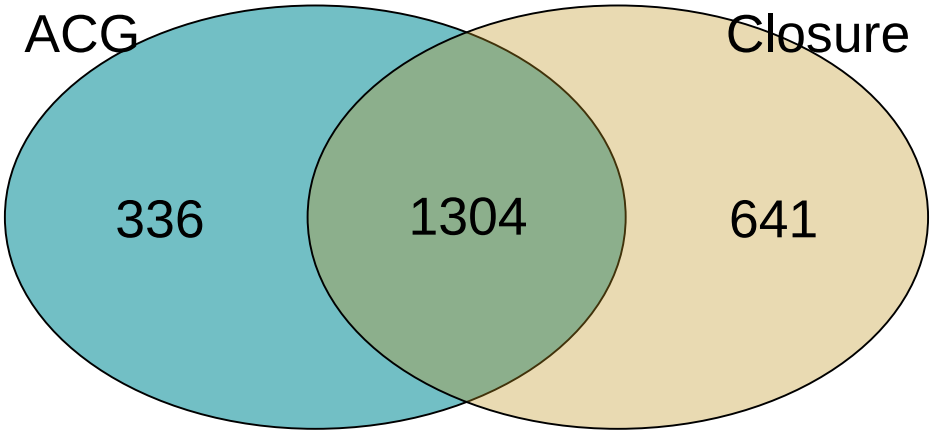
Results – Node.js modules

- Only ACG and Closure compiler were able to analyze multifile Node.js modules
- We manually evaluated a statistically significant random sample
  - 716 out of 2281 edges

Manually evaluated sample



All edges



Results – Performance

- Normal PC
- Created both simple and complex inputs
- Ran each analysis 10 times

		npm callgraph		ACG		WALA	
Category	File	Memory	Runtime	Memory	Runtime	Memory	Runtime
Simple	s_small.js	404	13.33	**237**	**3.11**	1151	16.55
	s_medium.js	2234	175.76	**1168**	49.35	2537	181.62
	s_large.js	5702	1401.88	3338	636.49	8784.22	1085
Complex	c_medium.js	281	4.76	**239**	**2.56**	826	8.27
	c_large.js	3283	76.49	1452	39.63	4010	210.45

		Closure Compiler		TAJS	
Category	File	Memory	Runtime	Memory	Runtime
Simple	s_small.js	519	6.41	718	5.18
	s_medium.js	1338	**17.28**	1671	23.83
	s_large.js	3277	**50.16**	**3132**	102.91
Complex	c_medium.js	411	4.92	370	2.74
	c_large.js	**1388**	27.29	2067	**23.79**

Conclusion

- Small and medium sized input: ACG
- Large input
  - Speed: Closure compiler/TAJS
  - Memory usage: Closure compiler/TAJS
  - Most accurate: ACG
  - npm callgraph and WALA: unusuable
- Node.js input: ACG
- Lots of eval(): WALA
- Lots of recursion: Closure compiler
- Most accurate (but slow): ACG + TAJS

Conclusion

- No absolute winner
  - each tool has its strengths and weaknesses
- Combining them carefully might be a good approach
- There are several missed calls
  - In the future, we would like to extend the comparison with dynamic call graphs
- No real ES6 support
- All artefacts are available as online appendix
  - Inputs, call graphs, Venns, our tools, tool patches

New development

- Berkeley and Szeged teams reincarnated ACG
  - Added ES6 support
  - npm package is to be released soon
  - https://github.com/Persper/js-callgraph
- Incorporated into OpenStaticAnalyzer™
  - In next release (soon)
  - http://OpenStaticAnalyzer.github.io

Thank you for your attention!

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