World of Code: Enabling a Research Workflow for Mining and Analyzing the Universe of Open Source VCS Data

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Outline

About the speaker

Where/Who/What

- Moscow Physical Technical Institute, Carnegie Mellon University
- 23 years at Bell Labs/Avaya Labs
- Since Fall'14 at the University of Tennessee
  - Professor of Digital Archeology and Evidence Engineering
  - or Data Science/Big data/Software Engineering
- Looking for interested students, postdocs, visitors

Open Source Software

- 1980-90s: a mere curiosity
  - Free Software GNU (35 years);
  - Linux (28 years);
  - Slackware (26 years);
  - Apache (24 years);
  - Mozilla (25 years)
- Attacked by critics then as
  - Expensive to maintain
  - Unsafe
  - Unsustainable

Open Source Software Miracle

- 2021:
  - Over 170M projects
  - 60M contributors
  - RedHat 3.4B revenue / 15 percent annual growth
- Why:
  - Reuse that works
  - Distributed decision making
  - Code can be trusted to be there
  - Sophisticated collaboration tools

Future is clouded

- What worked over past 20+ years may break
  - Supply chain attacks
    - Easy to exploit OSS-wide dependencies
  - Maintainer exhaustion
    - Aging out in critical projects
    - Increasing complexity
    - Increasing user base
    - Commercial participants not contributing back
  - Move to the cloud
    - No need for software when using a service
    - Amazon appropriating open source to provide competing services

Two outcomes

- To believers:
  - I am scared, tell me how my research can save OSS (and the world)?
- To skeptics:
  - I hear emotional BS, are these problems real?

To skeptics

- E.g., NPM has over 1.7M packages
  - Median number of direct dependents is 2, recursive 200 (emberjs)
  - supply chain (introducing malicious dependencies) attacks are common
- Skeptic: well...
  - NPM is a house of cards built on sandcastles
  - gone with a gust of wind
  - and good riddance...
- Response:
  - Much of web infrastructure is built on NPM
  - Many developers rely/work on it
  - Would be very difficult to replace

Press Releases: arstechnica.com

A rash of supply chain attacks hitting open source software over the past year shows few signs of abating, following the discovery this week of two separate backdoors slipped into a dozen libraries downloaded by hundreds of thousands of server administrators.

. . . someone compromised the server used to develop new versions of the program. The attacker then used the access to distribute a backdoor that was downloaded more than 900,000 times . . .

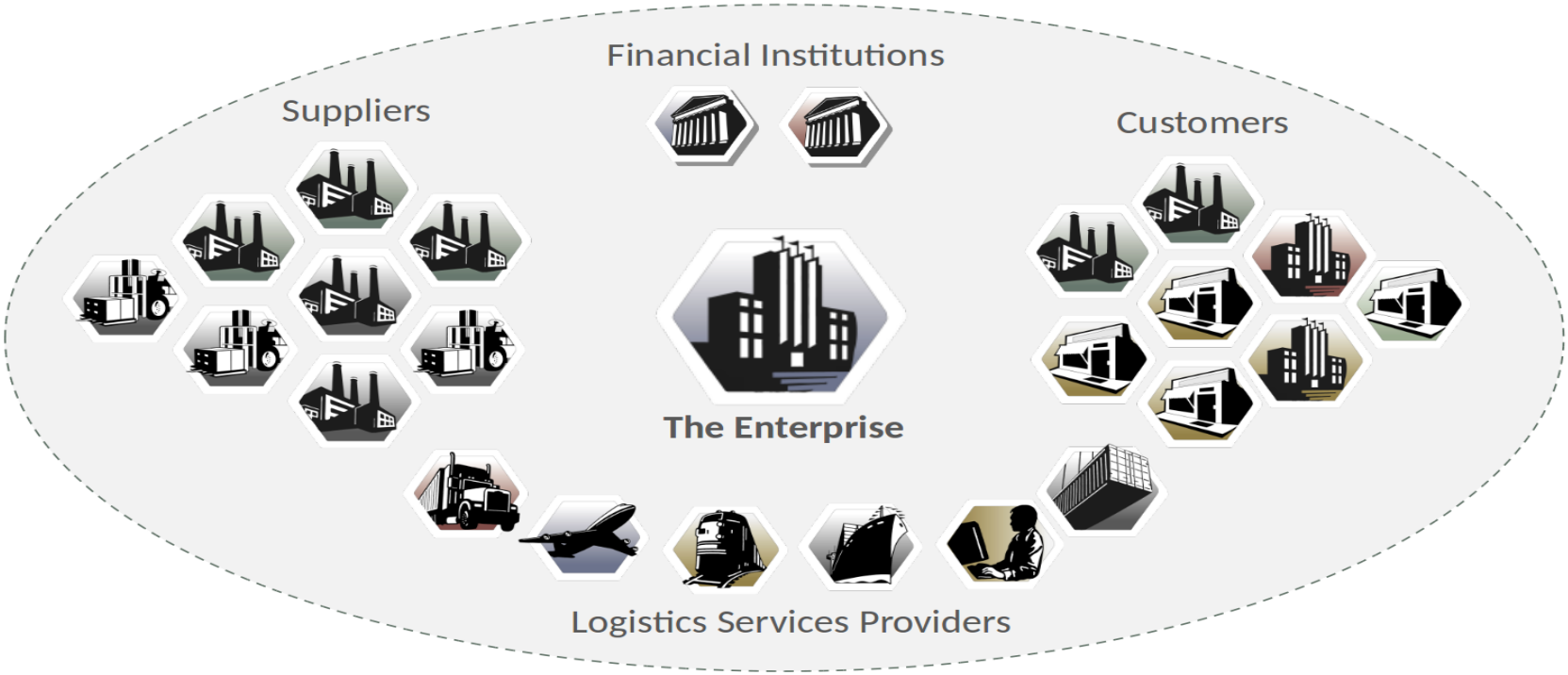
The problem may be real, but what to do?

- What is Open Source Software Supply Chain?
- What are its Risks and How to Manage Them?
- How to do Research on it?
  - World of Code or WoC
    - Current, Complete, Curated, Cross-referenced Collection of Open Source Version Control Data (CCCCCosvCd)
    - "Research Ready" for Supply Chain Research

Definition (What is Supply Chain)

is a set of three or more companies directly linked by one or more of the upstream or downstream flows of products, services, finance, and information from a source to a customer
Key features:

- Complex interdependencies
- Distributed decisions



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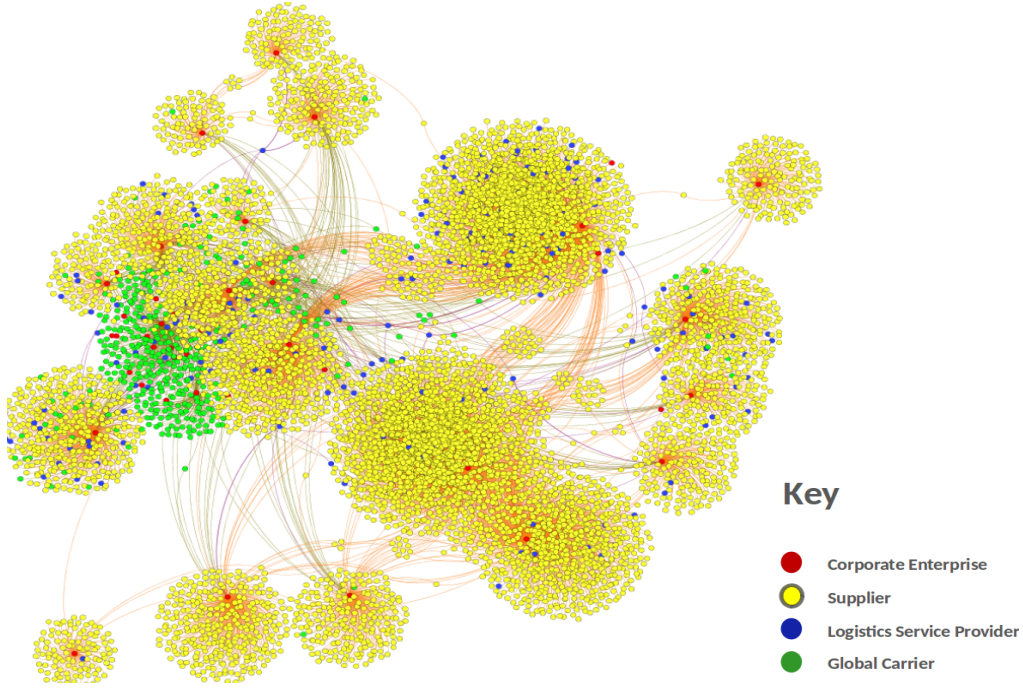


Definition (Elements of Software Supply Chains (SSCs))

- Developers and groups ("companies")
- Relationships among software projects or packages
- Changes to the source code (e.g., to files, modules, frameworks, or entire distributions)

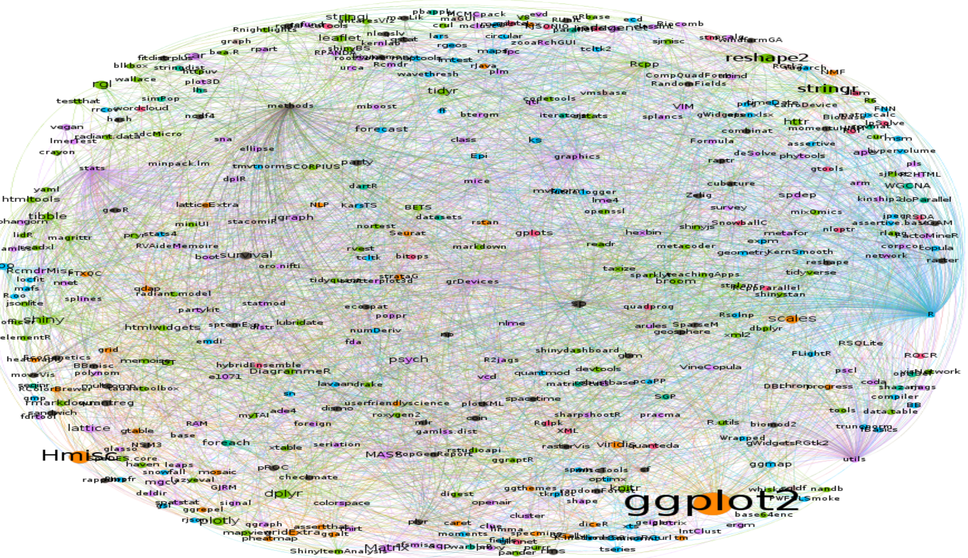
SSC of the 1st kind

- Technical dependencies among projects with change effort as product flow
- Primary risks: unknown vulnerabilities, breaking changes, lack of maintenance, lack of popularity

Examples of SSC of the first kind

- Python: import re
- Java: import java.util.Collection;
- JavaScript: package.json

e.g., CRAN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SSC of the 2nd kind

- Copying of the source code from project to project as product flow
- Primary risks: license compliance, unfixed vulnerabilities/bugs, missing updated functionality

Examples of SSC of the second kind

- Implementation of a complex algorithm
- Useful template
- Build configuration

SSC of the 3rd kind

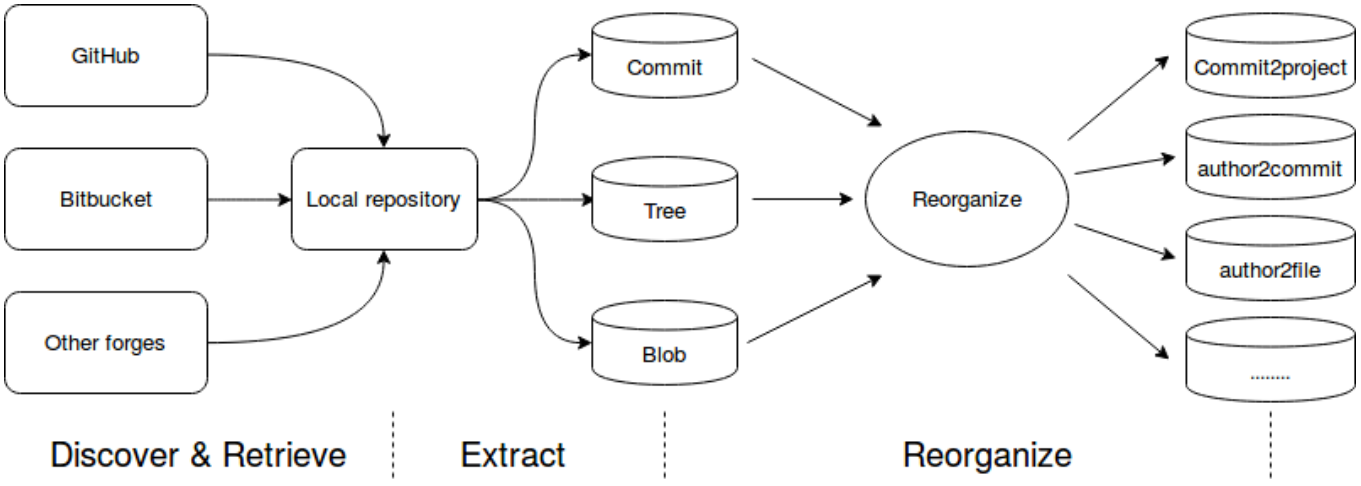
- Knowledge (product) flow through code changes as developers learn from and impart their knowledge to the source code
- Primary risks: developers may leave, companies may discontinue support

Examples of SSC of the third kind

- Developers gaining skills with tools/packages/practices
- Developers spreading practices, e.g., testing frameworks

Skeptic: OK, but how to measure?

- WoC: Discover, Retrieve, Store, Analyze, Update [10, 8]



- 170+M projects; 60+M Authors; 3.1B Commits; 12B Blobs and Trees
- Simply cloning: $\geq$\$3PB
- Specialized database without redundancies: 200TB

WoC: What is it?

- Complete: capture data from all public git repos (approx 50 forges)
- Current: quarterly releases
- Curated/Research Ready: e.g., author aliasing, deforking, bot identification, ...
- Cross-referenced: First-class entities mapped to other first-class entities
- WoC version U numbers are at bitbucket.org/swsc/overview/
- How to use: github.com/woc-hack/tutorial
- Web interface: worldofcode.org

Skeptic: but OSS data are rather bad

"productive" authors

Number of commits	Author
10960000	one-million-repo < *mikigal.acc@gmail.com* >
4400778	datakit < *datakit@docker.com* >
2463758	greenkeeper[bot] < *greenkeeper[bot]@users.noreply.github.com* >
2063212	Auto Pilot < *noreply@localhost* >
1864730	Your Name < *you@example.com* >

Silly competitions

- Fake commits with everyone's name to have most contributors

Authors	Repo
389993	cirosantilli/imagine-all-the-people

- The longest chain of commits

Length of commit chain	Repo
9959999	github.com/one-million-repo/biggest-repo-ever

More examples at bitbucket.org/swsc/overview/fun/

Data That Needs to be Curated

- Author IDs
- Repository forks
- Code dependencies (dozens of languages)
- Project types
- Link to external data sources
- Many other challenges

Example: Identifying Authors

- We have 34M strings
- Are these two the same person?
  - Aaron Lee < aaron.lee@rackspace.com>
  - Aaron Lee < wwkeyboard@gmail.com>
- Text similarity (adjusted for common names)
- Behavioral fingerprints:
  - Similarity of written text (Doc2Vec embedding)
  - Change the same source code files
  - Work in the similar time-zones
- Trained machine learning: 99.99 accuracy

Skeptic: but why would I use it?

- To improve research quality
  - Most software development is not for isolated projects
  - But current research practices ignore SSC relationships and lead to inadequate models/tools/practices
- To do entirely new types of research
  - What made OSS so successful so far?
  - Create fundamental theories in software engineering enabled by WoC and similar observatories

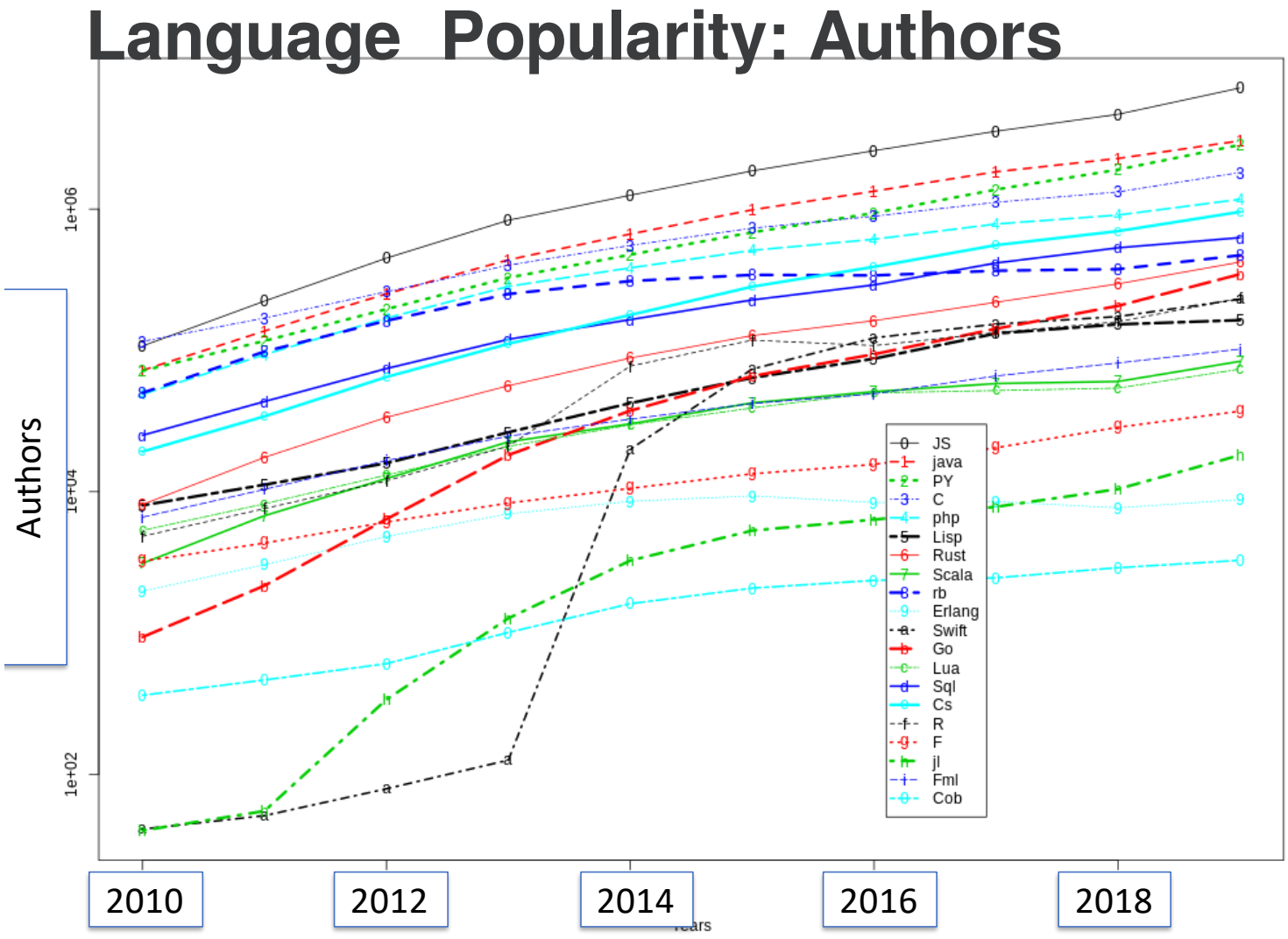
Skeptic: what exactly is presently inadequate?

- Key advantages WoC-like infrastructure
- Completeness: proper instead of convenience sampling
- Cross-referencing:
  - first time ever measure/study Type II and III SSCs and downstream of Type I SSCs
- Curation: don't need to spend a lifetime cleaning data Not accounting for activities downstream

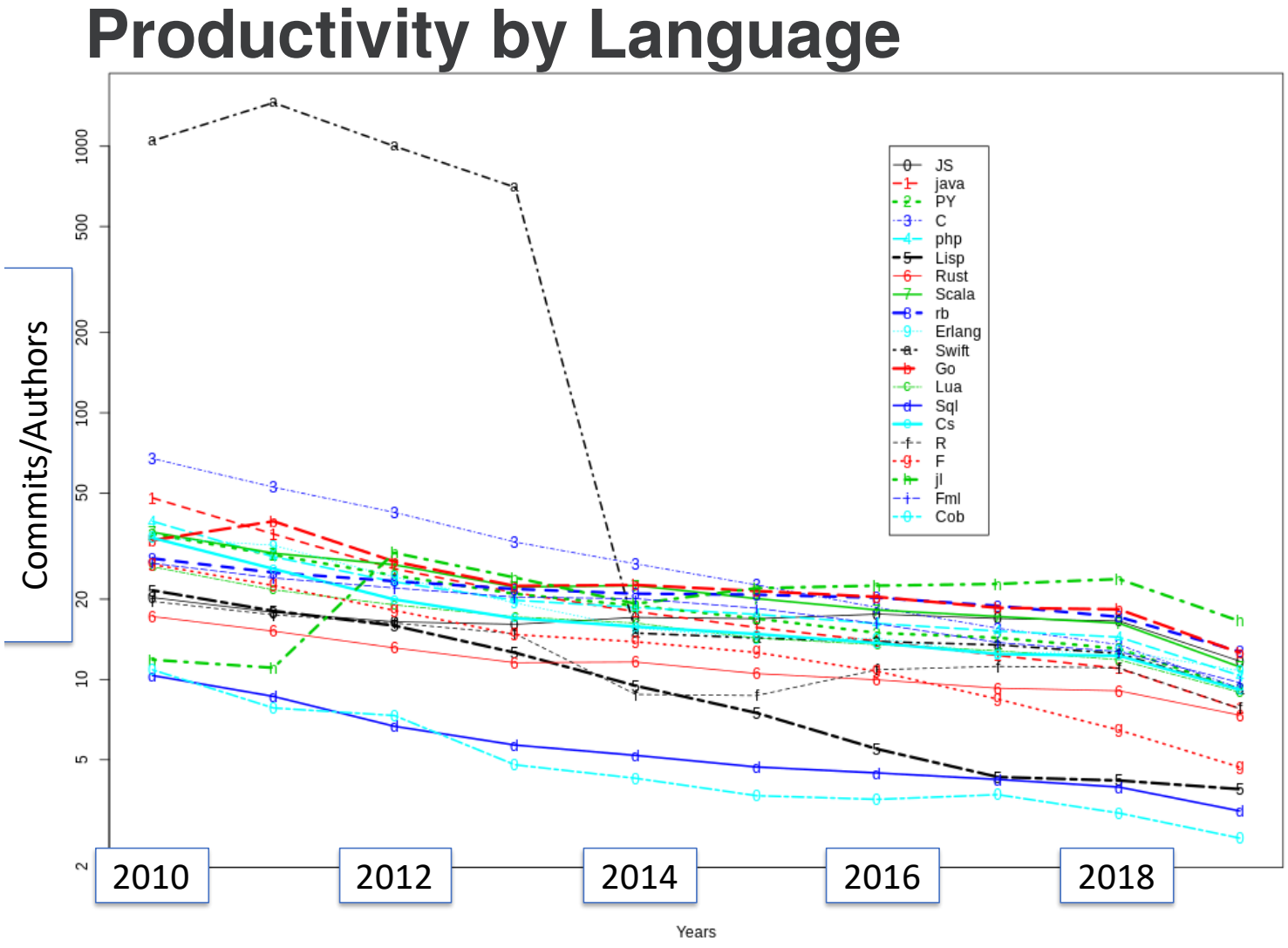
Skeptic: any track record?

- Contextualize/Correct/Impute [11]
  - Author aliasing/Bot detection: via behavioral fingerprinting [1, 5, 6]
  - De-forking/de-cloning via shared commits [12]
- Type I: dependencies
  - Models of spread [9]
  - Models of popularity [4]
  - Patterns of effort contribution [3]
- Type II: copying
  - Orphan vulnerabilities [13]
- Type III: knowledge
  - Knowledge at loss [14]
  - Developer impact [7]
  - Skill spaces [2]
  - Eight implemented use cases
    - Relationships: code flow, technical and tool dependencies, knowledge flow [3, 4, 13]

What Languages are Popular?



How Difficult Each Language is?



Can we predict which technology will prosper/fail?

- Two data-science technologies: abstraction of data.frame in R
  - tidy vs data.table
- Sample: all R-language files in public repositories
  - 1.5M files, 5M versions
- When was the first time tidy or data.table included?
  - 17,536 projects use data.table
  - 7,032 projects use tidy

Results (Choice and Decision Maker)

- Choice
  - Exposure: Recent and Cumulative deployments, Mentions on StackOverflow
  - Qualities: Activity, developers,responsiveness, open issues
- Decision maker
  - Activity, developers
  - Performance needs
  - Social network
  - Technical network

Note: Red- negative, Green- positive

Skeptic (turned into believer): ok ok, how do I sign up for this?

- bitbucket.org/swsc/overview:
  - related publications / data / analysis
- Hackathon Nov 1-3
  - woc-hack.slack.com : sign up at `http://bit.ly/WoC-Hack`
  - github.com/woc-hack/tutorial
  - Signup form `http://bit.ly/WoC-Signup`

Takeaways

- OSS: why it is worthy of study
- SSC: why relevant for present software, types and risks
- OSS Observatory (WoC): help speed discovery in this novel area
- You can benefit too!

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