Software Development in the Next Decade: Beyond the Dichotomy of Open-Source and Corporate Worlds

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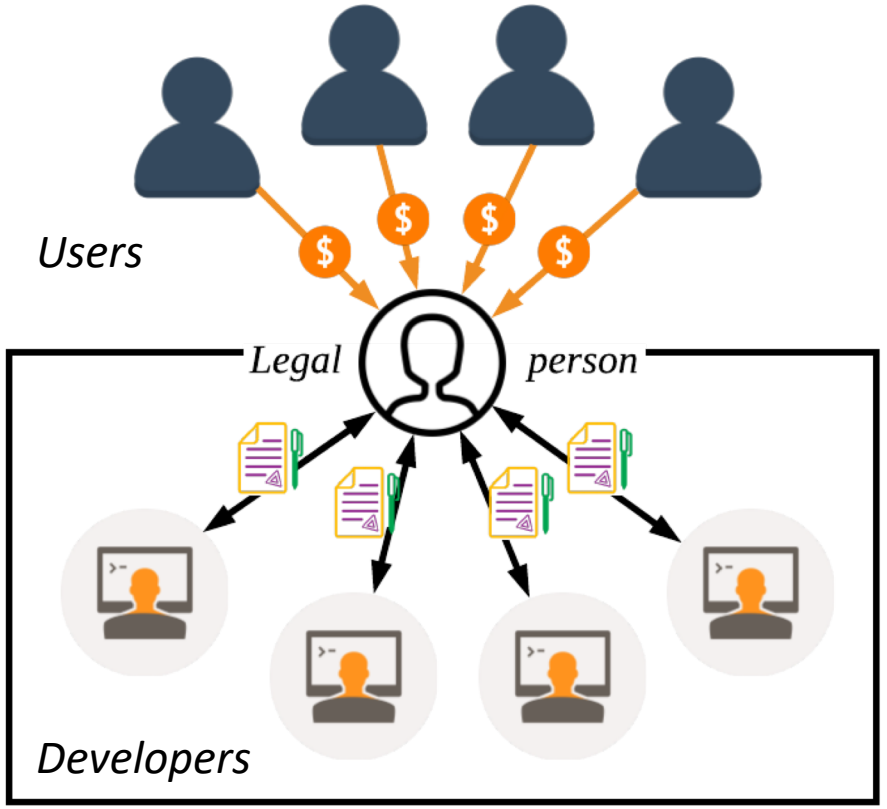
(Advised by Armando Fox from UC Berkeley)

Corporate World vs. Open-Source World



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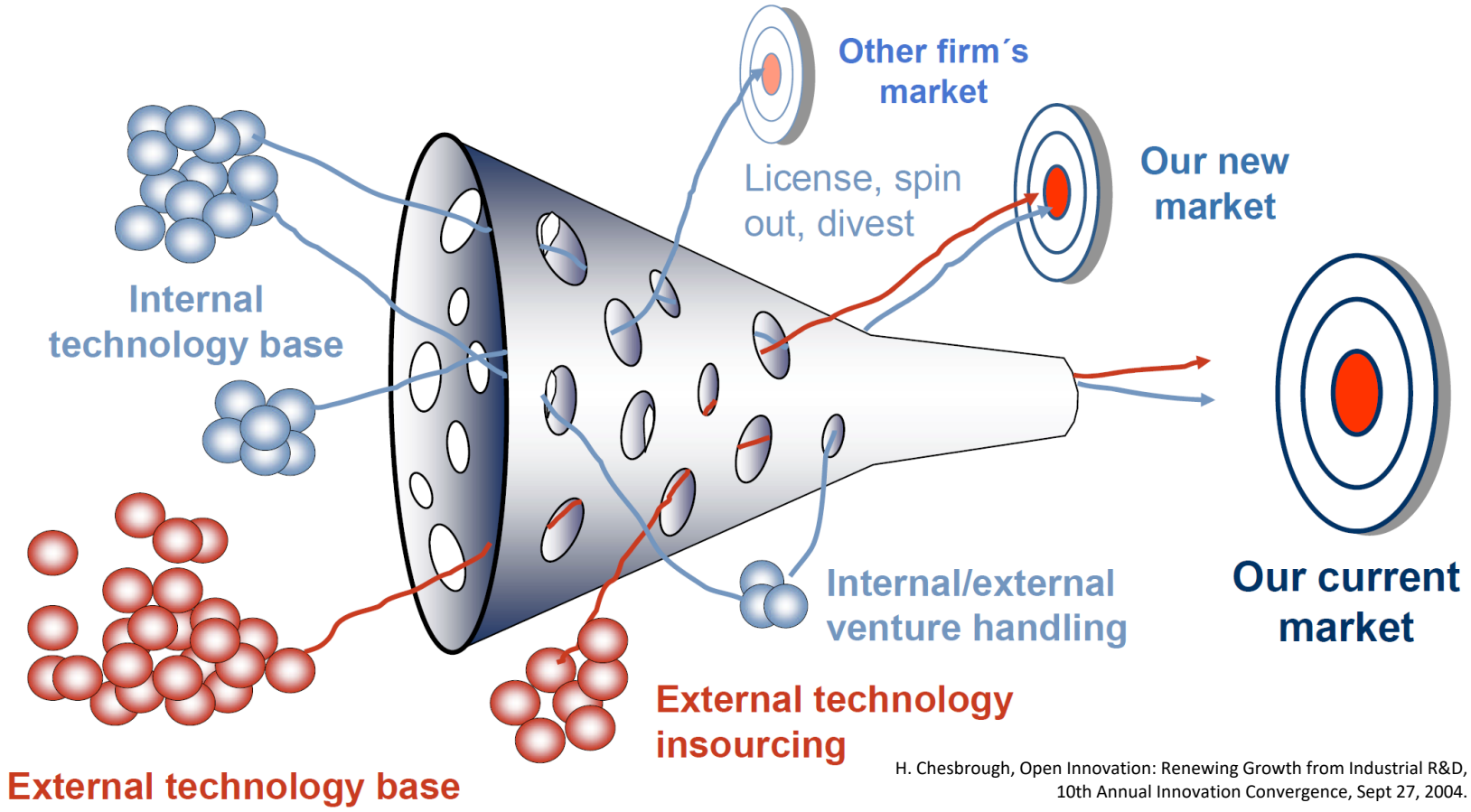
Classic Open Innovation



H. Chesbrough, Open Innovation: Renewing Growth from Industrial R&D, 10th Annual Innovation Convergence, Sept 27, 2004.

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Why the dichotomy of the two worlds?

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Overview

- Reasons leading to the two worlds
  - Information asymmetry
  - Transaction cost
- Imperfect solutions
- Technologies with potentials
  - Assessing the value of code contributions ⇢ Information asymmetry
  - Decentralized value sharing ⇢ Transaction cost
- Virtual shareholding: Beyond the dichotomy
  - Value-shared open source
  - Virtual open corporation
  - Virtual closed corporation

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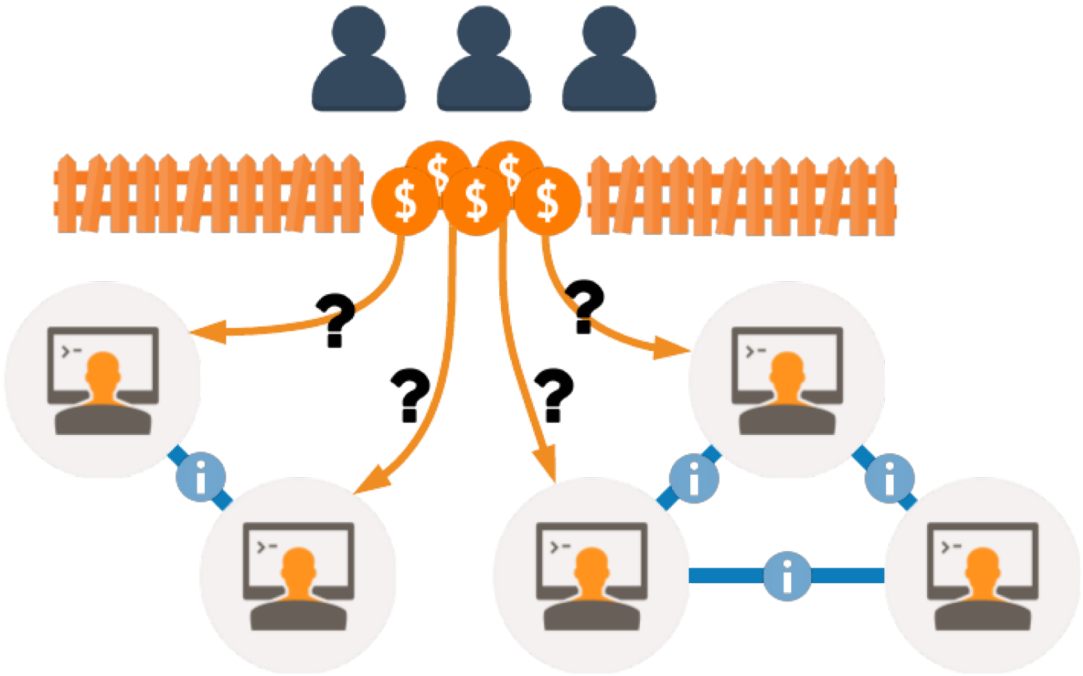
Information Asymmetry

- How to allocate value?
  - Users don't understand developers' work.
  - Individual developers lack a consistent global view.
- Practice in corporation: Corporate structures
- Practice in open source: Relinquish the value



Transaction Cost

- Suppose n developers and m users
- # of contracts $\cong n^2 + nm$
- Dynamics of the network
  - Turnover of developers
  - Churn of users
- Practice in corporation: Legal person
- Practice in open source: Open source license

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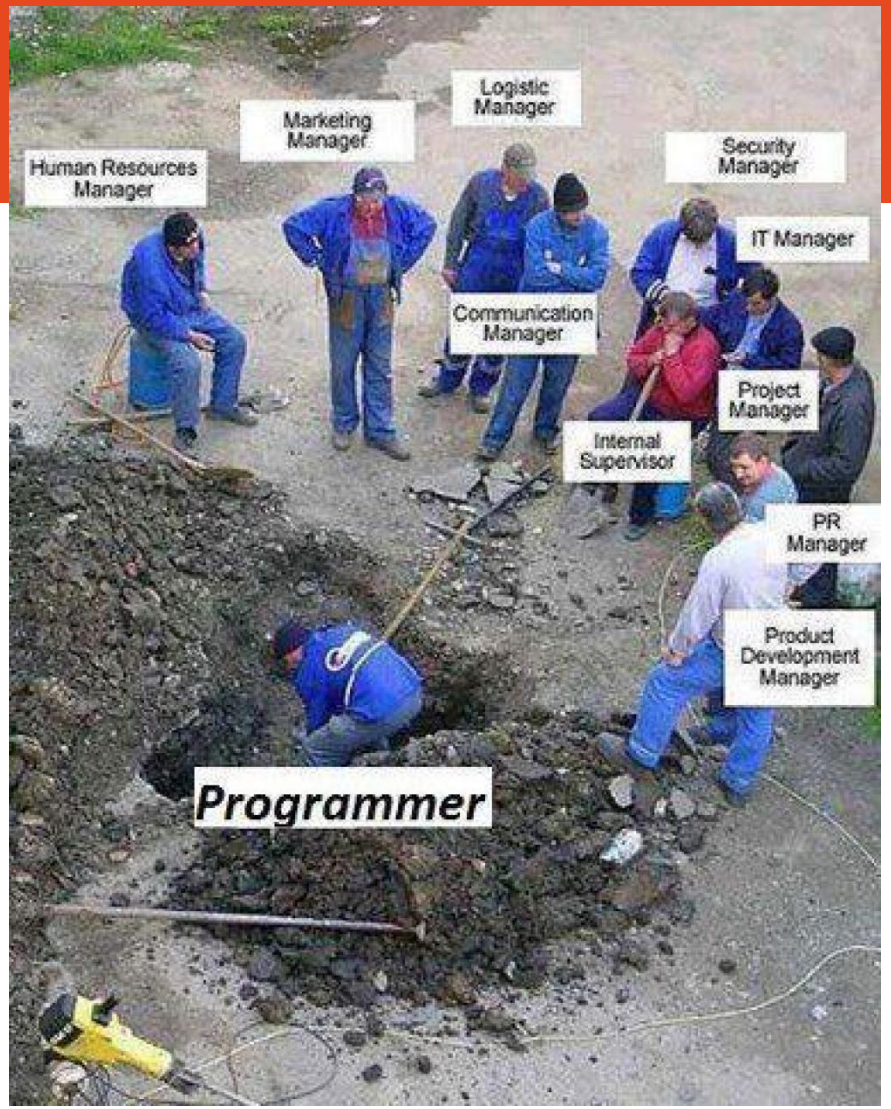
Corporate Issues

- Unfair value allocation
  - Bias on personality and social relationships
  - Why employees leave:
    “low salary” (69.44%);
    “overworked” (63.12%);
    “*lack of recognition or reward*” (45.24%);
    “*boss didn’t honor commitments*” (43.49%).
- Unnecessary operating overhead
- Your code is *not* yours!



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Open-Source Issues

- Financial crisis

"The worst vulnerability found... since commercial traffic began to flow on the Internet."
-- *Joseph Steinberg*, Forbes.

"Free Can Make You Bleed."
-- *John Walsh*, SSH Communications Security.

Open-Source Issues

- No general method for value allocation

"… if he took some of the money, then it seemed fair for other contributors … [to take some]."

-- *Evan You*, creator of vue.js.

Linus' Law: "given enough eyeballs, all bugs are shallow"

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Corporation and open source are compromises.

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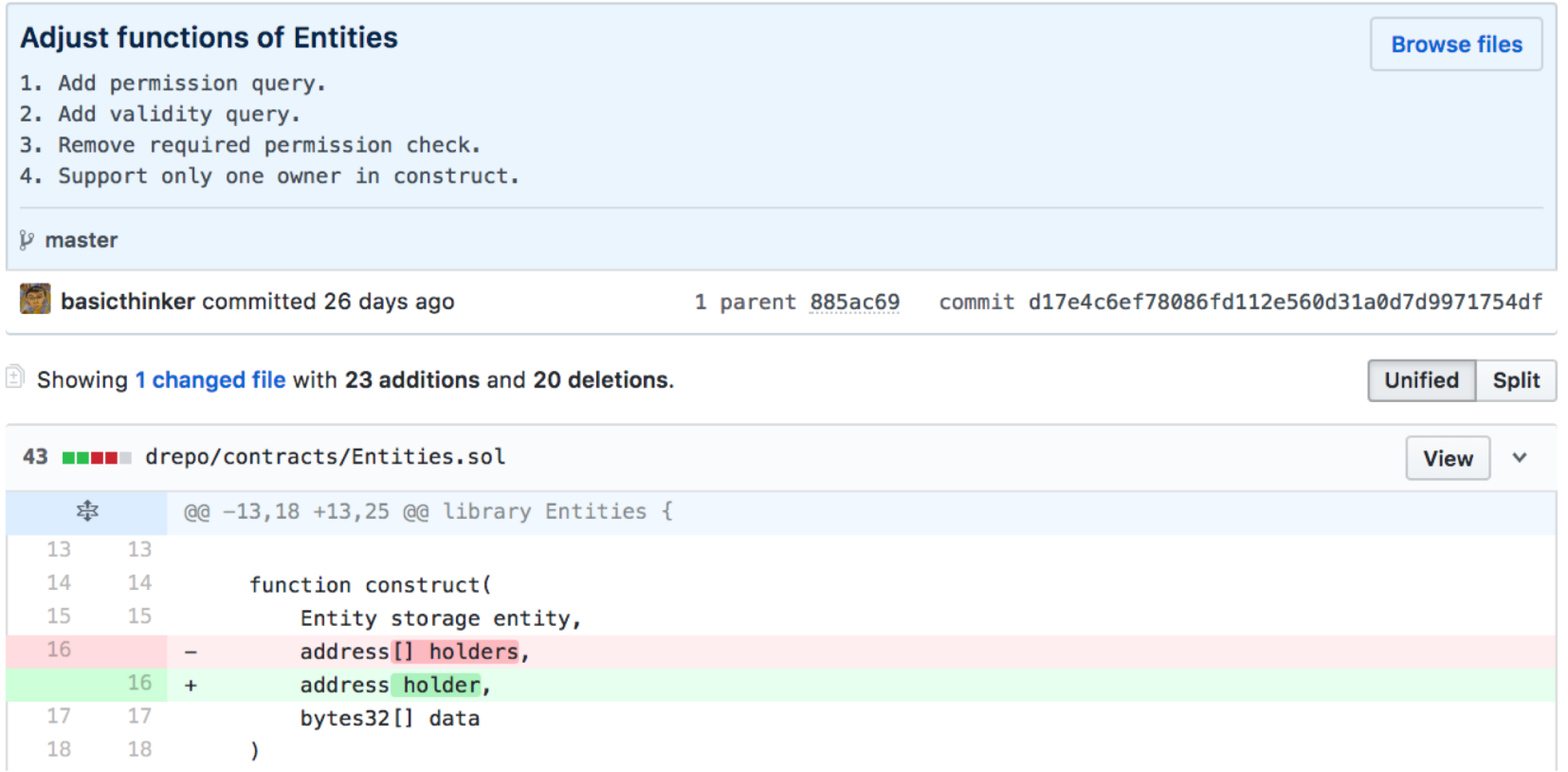
Assessing the Value of Code Contributions

- Various definitions of value (e.g., market price)
- Development value
  - Development labor embodied in a code contribution
  - Development labor that the code contribution saves
- Abstract development labor in general
  - Assume a hypothetical average developer
  - Similar to the abstract human labor in classic economics
- A coherent concept for building the model

Assessing the Value of Code Contributions

- Basic metric of development labor
  - Commits, additions, and deletions
  - Our metric:
    # of changed LOCs



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Assessing the Value of Code Contributions

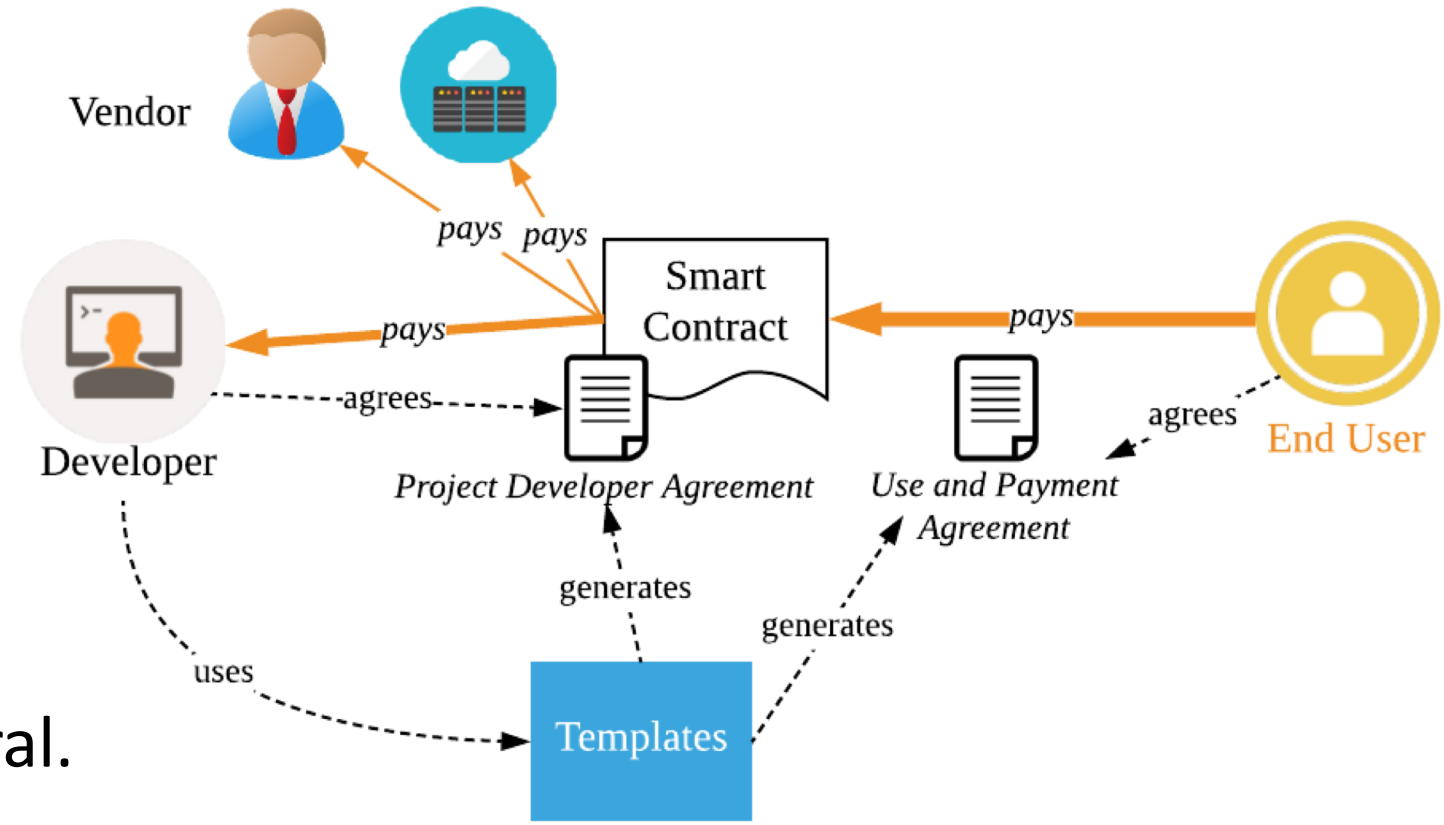
- Commit-specific calibration
  - E.g.: a fix to a very hard-to-track bug
  - A few lines solve a huge issue!
  - Such a commit requires an large effort of an average developer
- Program analysis and natural language processing/machine learning
  - Code structure ⇢ Reuse of code
  - Commit messages + large developer surveys ⇢ Commit-specific calibration

Decentralized Value Sharing

- A blockchain is an *immutable* ledger of user-defined records
- Smart contracts
  - E.g., “store received tokens in the current account; upon the 1st day of every month, divide the balance by total shares and transfer dividends to shareholders.”
  - Transparent
  - Unstoppable
  - Tamper-proof
- Reduce the cost of trust-building, contracting and enforcement
- Much more expressive than open source licenses

Decentralized Value Sharing

- Framework/workflow



- Value assessment and value sharing are integral.

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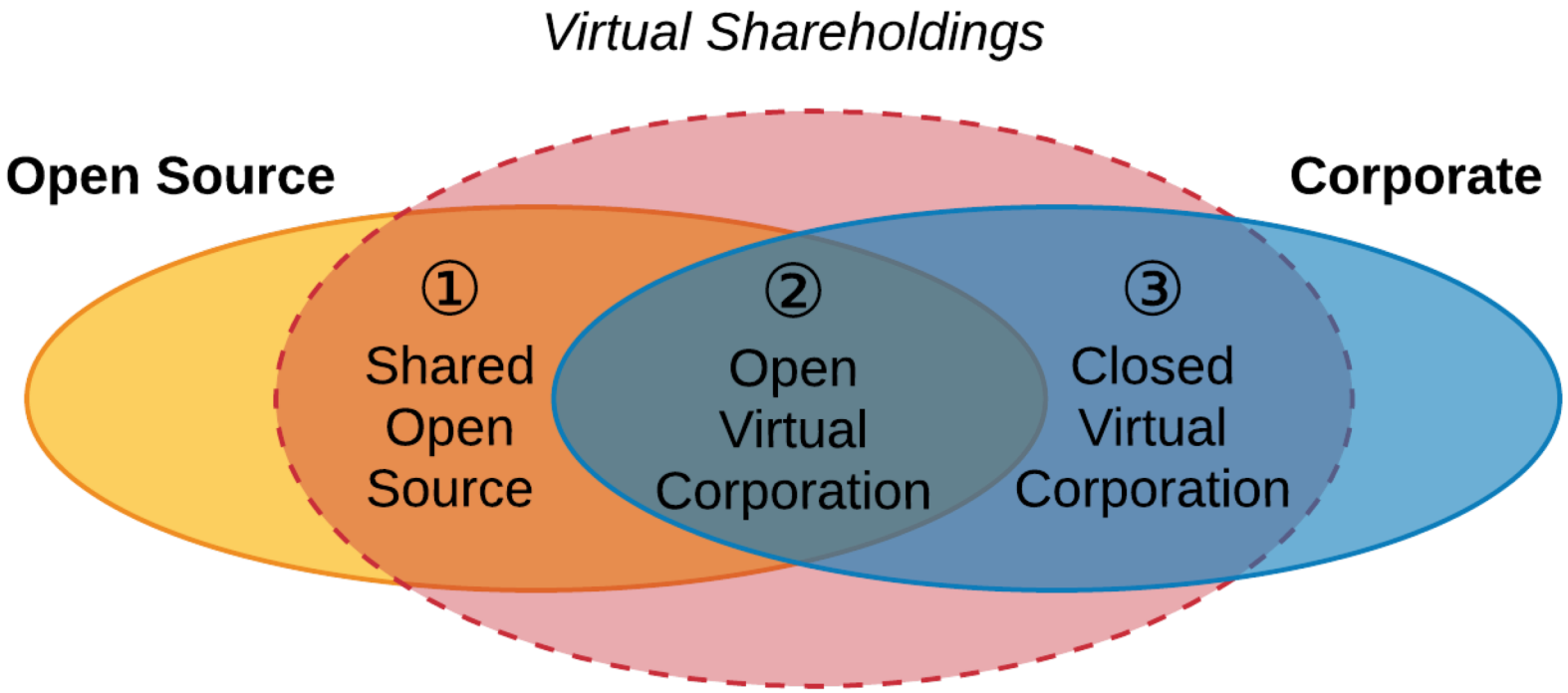
Virtual Shareholding: Beyond the Dichotomy



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Virtual Shareholding: Beyond the Dichotomy

	Traditional open source	Traditional corporation	Value-shared open source	Open virtual corporation	Closed virtual corporation
Financial risk	☹	😀	☹	😀	😀
Fair allocation	☹	☹	😀	😀	😀
Global talent	😀	☹	😀	😀	☹
Long-term return	☹	☹	😀	😀	😀

Outlook: Open Research Questions

- Gaming behavior and counteraction
- Influence on the project governance
- *Real application!*
  - Persper Foundation
  - Sponsor selected open source projects with $10,000 per month for 6 months.
  - *How would developers react?*

Assessing the Value of Code Contributions

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Goal

" … and it becomes a problem how to properly quantify and measure the work that each contributor does."

-- Evan You, creator of Vue.js

- Goal: Assess the value of code contributions in a way that's
  - Consistent (produce same results for same codebase each time)
  - Efficient (automatable so minimal human effort required)
  - Accurate (true value -> expert developer's assessment)

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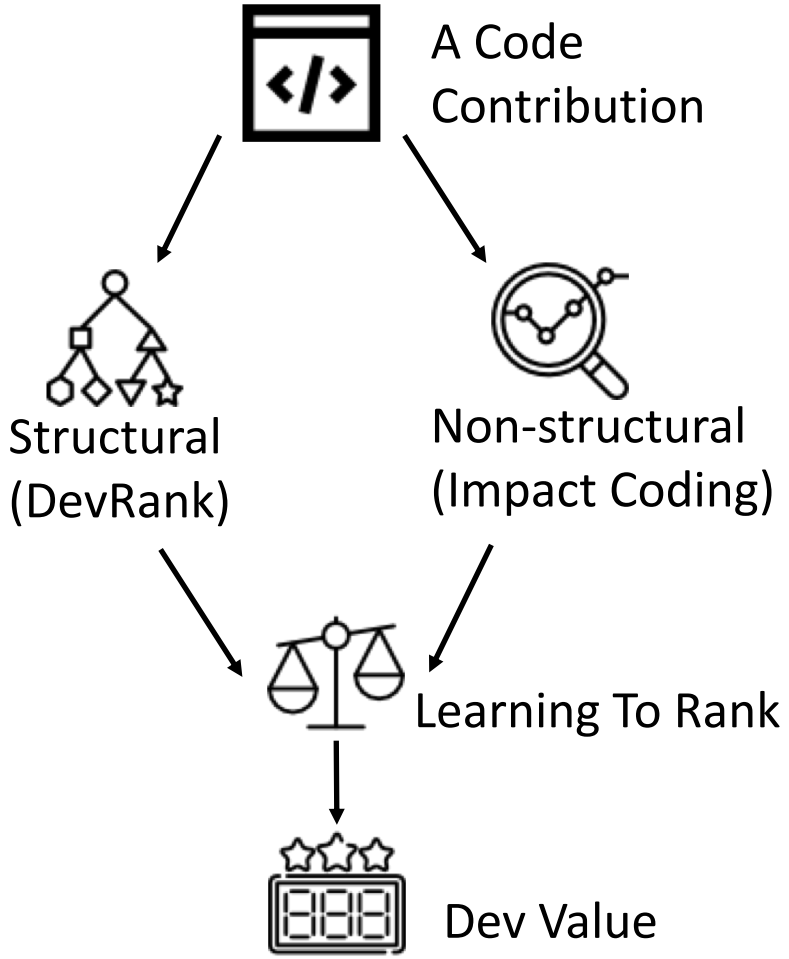
Development Value (Dev Value)

- Observation: Two types of code tend to have high value
  - Addresses a time-consuming dev task
  - Saves a huge amount of development effort for other developers
- Definition: Dev value of a code contribution is the sum of
  - Development labor embodied in itself
  - Development labor that it saves other developers

Dev Value = Structural + Non-structural Value

- Structural value: role of code in codebase structure
- Non-structural value: other impact of code on the team
- Learning To Rank (L2R): combining structural and non-structural value



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Measure Structural Value: PageRank

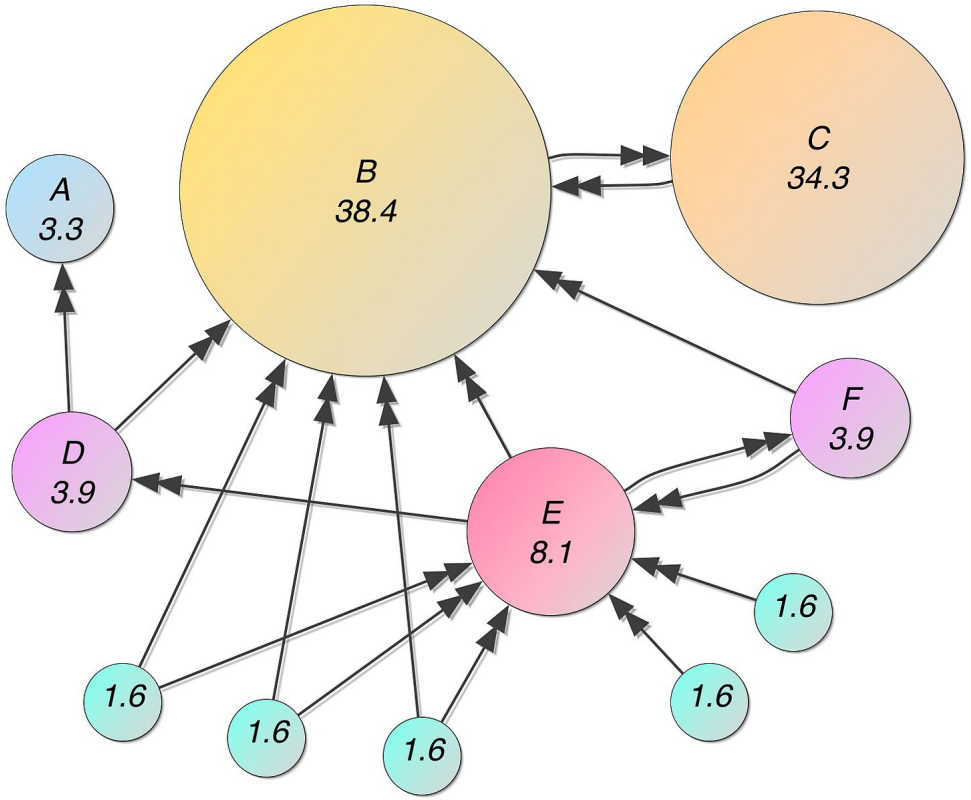
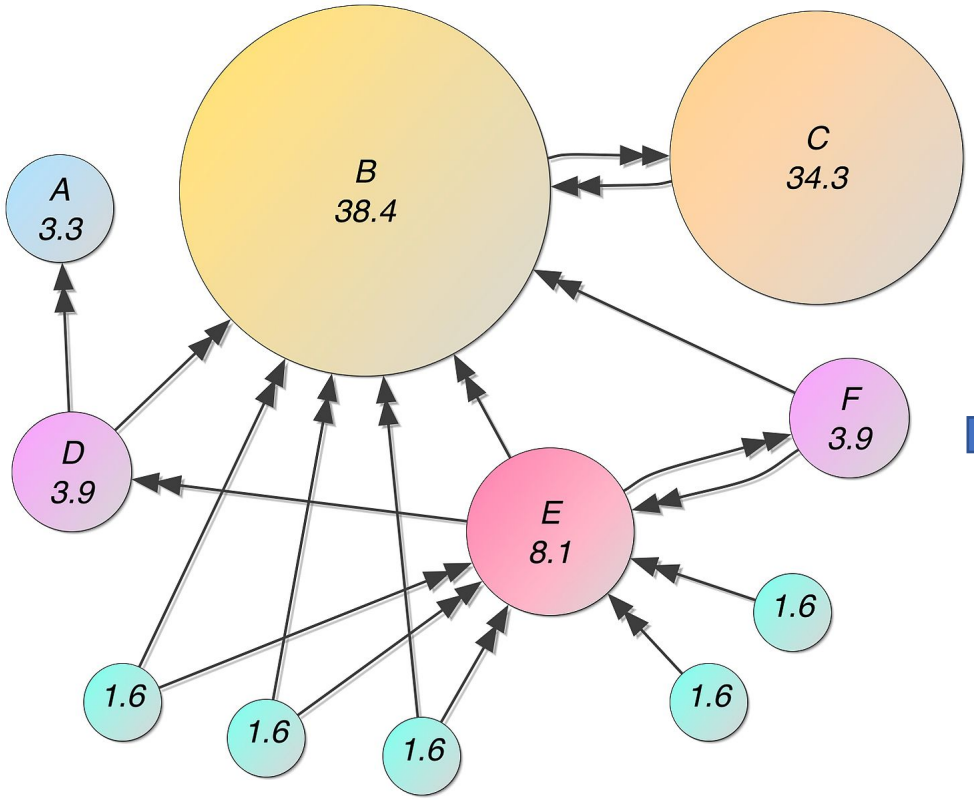


Figure: PageRank for a simple web graph (in %)

- What is PageRank?
  - Used by Google to rank websites
  - Assigns a numerical score to any given webpage
  - Higher score -> more important
- How it works?
  - Runs on a directed graph representing the web structure
  - All nodes start with equal score
  - In each iteration…
  - Repeat until reaches a fixed point

Measure Structural Value: Call Graph



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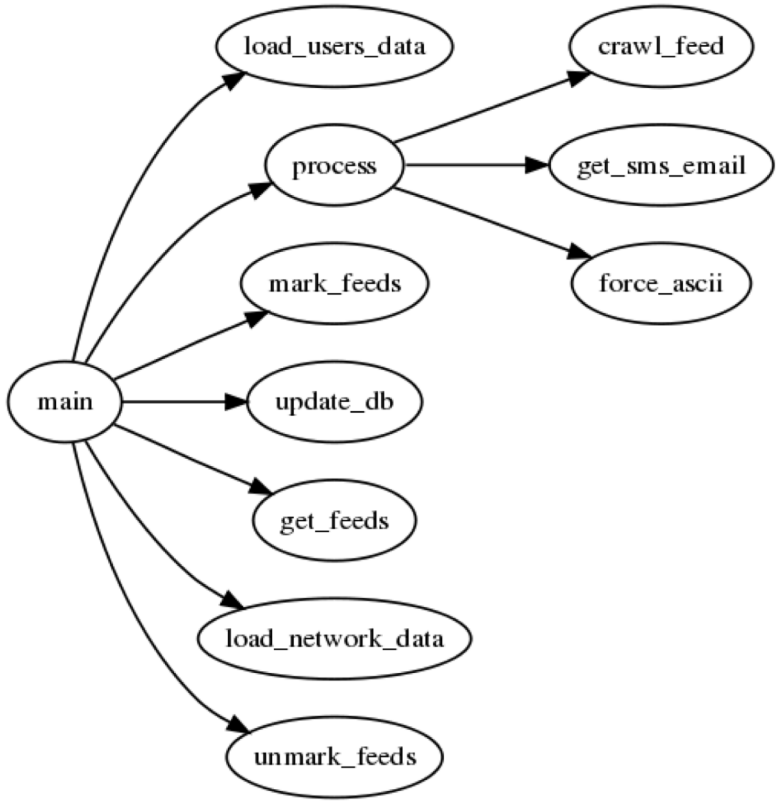

Figure: A simple Python Call Graph

http://blog.prashanthellina.com/generating-call-graphs-for-understanding-and-refactoring-python-code.html

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Measure Structural Value: DevRank

- As a result, two qualities would contribute to high DevRank value
  - High in-degree
  - High dev labor
- Align well with our definition of development value

	PageRank	DevRank
Node	Website	Function
Edge	Hyperlink	Function call
Weight on edge	Equal weight	Proportional to dev labor

DevRank Results on Linux Kernel Project

	#	Function	File
DevRank	1	slob_free	mm/slob.c
	2	mempool_alloc	mm/mempool.c
	3	dma_pool_free	mm/dmapool.c
	4	kasan_slab_free	mm/kasan/kasan.c
	5	mempool_free	mm/mempool.c
LOC	1	shrink_page_list	mm/vmscan.c
	2	shmem_getpage_gfp	mm/shmem.c
	3	__vma_adjust	mm/mmap.c
	4	balance_dirty_pages	mm/page-writeback.c
	5	__alloc_pages_slowpath	mm/page_alloc.c

Table: Most valuable functions under mm directory

	slob_free (DevRank)	shrink_page_list (LOC counting)
# lines	81	412
# times called	≈ 7,000	2

Note: Calls to slob_free are mostly through kfree.

Measure Non-structural Value: Impact Coding

- Not all dev value is captured by the code structure
- Interviewed 3 veteran open source developers
  - Author of a popular Twitter client
  - Two FreeBSD developers
- Q: “How would you compare the value of two commits?”
- A: ”…classify commits by its impact...”

Ranking	Commit Type
1	Fix for build errors
2	Fix for severe non-build errors
3	Important new features
4	Fix for severe speculative errors
5	Fix for minor errors
6	Regular new features
7	Cosmetic errors
8	Source code hygiene

Table: Hierarchy of commit value, by a FreeBSD developer

Can We Automate Commit Classification?

- Solution: text classification on commit messages
- Classify N = 267,446 JIRA issues into one of four categories
  - Maintenance
  - Feature
  - Improvement
  - Bug
- Trained 3 classifiers on 2 types of inputs (msg title/entire msg)

	Maint.	Feature	Improv.	Bug
# commits	329	1517	14136	28818
BoW-title	0.28	0.34	0.63	0.85
BoW-message	0.2	0.33	0.62	0.85
CNN-title	0.37	0.39	0.65	0.86
CNN-message	0.46	0.39	0.64	0.87
RNN-title	0.4	0.35	0.67	0.86
RNN-message	0.33	0.36	0.68	0.87

Table: Performance (F1 score) of three NLP + ML models for JIRA experiment

Combine Structural and Non-structural Value

- Notations
  - d: devrank value
  - t: impact type of a commit
  - v: overall development value

$$\varphi(d, \mathbf{t}) = \mathbf{w}^{\mathsf{T}} \begin{bmatrix} d \\ \mathbf{t} \end{bmatrix}$$

- Our approach: Learn weight vector w from data provided by expert developers
- Ask many developers to compare random pairs of commits, identifying which in each pair is more valuable
- Use Learning to Rank to learn from this “pairwise ground truth”

Results: Commit Value Comparison Task

- Our dataset
  - 772 commit pair comparisons
  - Contributed by 35 developers from FreeBSD & Linux Kernel

Feature	Model	Accuracy
LOC	-	53.2%
DevRank	-	59.0%
Coding	Ranking SVM	69.1%
Coding + LOC	Ranking SVM	70.2%
DevRank + Coding	Ranking SVM	73.1%

Conclusion

- Assessing the value of code contributions is difficult for developers
  - Inherent subjectivity
  - Few developers have a wide enough view of the entire project
- We postulated that a given code contribution has both
  - Structural value
  - Non-structural value
- We proposed a combination of
  - A PageRank-inspired algorithm
  - An impact coding scheme

Thank You!

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Backup

- Non-code contributions

> "The most important feature of Linux, however, was not *technical* but *sociological*."
>
> —*Eric S. Raymond*, The Cathedral & the Bazaar, 2001.

Backup

- Other incentives than money