The Plastic Surgery Hypothesis

E. Barr, Y. Brun, P. Devanbu, M. Harman, F. Sarro

TR available at http://www.cs.ucl.ac.uk/research/research_notes/

Federica Sarro

Research Associate, CREST centre
Department of Computer Science
University College London

f.sarro@ucl.ac.uk

London, 19/05/2014

2009

GenProg Clearview

FixWizard SemDiff

LibSync PAR

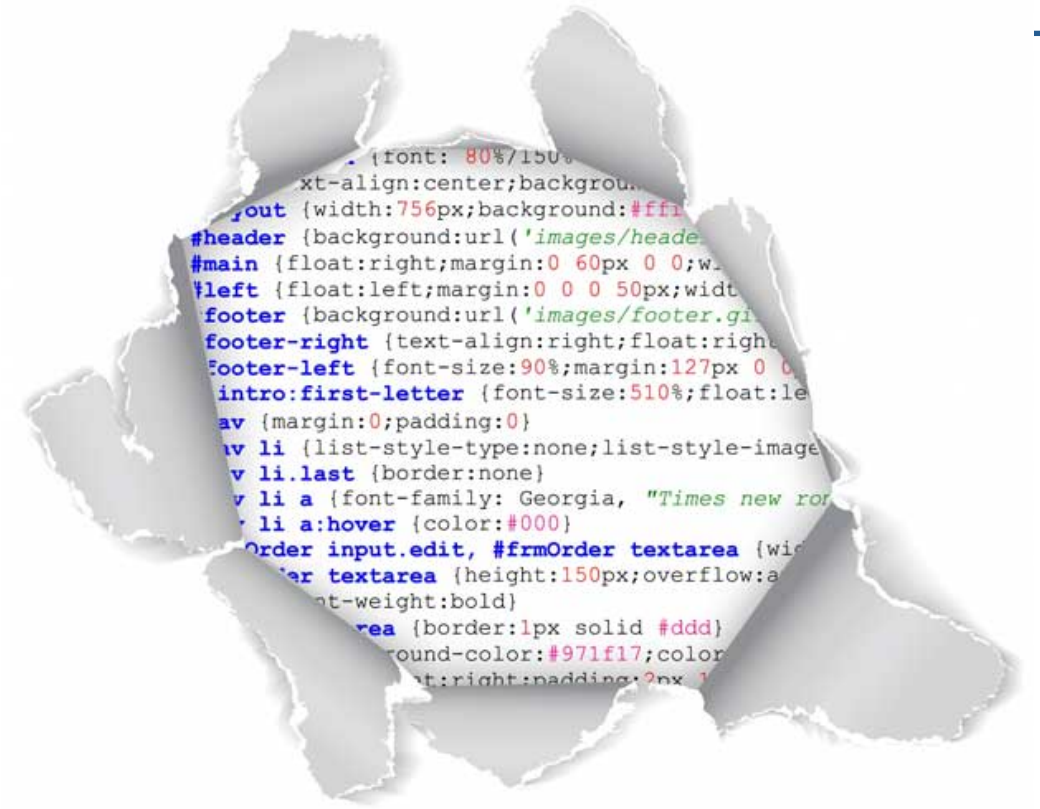
...

Automatic Software Repair

Automated Refactoring

Genetic Improvement

Why Do They Work?



The content of new code can often be assembled out of code fragments that already exists elsewhere in the system under evolution (*plastic surgery**)

*M. Harman. Automated patching techniques: The fix is in: technical perspective. Communications of the ACM, 53(5):108, 2010

Contributions of Our Work

- Formal statement and validation of the Plastic Surgery Hypothesis (PSH)
- Large-scale, empirical study of the extend to which changes can be reconstructed from code already available during the development
- Analysis of the distribution of grafts in codebase to which a change applies

The Plastic Surgery Hypothesis

Changes to a code base contain snippets that *already exist* in the code base *at the time of the change*,

(1) Changes are repetitive related to the program to which they are applied (parent)

The Plastic Surgery Hypothesis

Changes to a code base contain snippets that
already exist in the code base *at the time of the change*,
and these snippets can be *efficiently found* and exploited

(1) Changes are repetitive related to the program to which they are applied (parent)
(2) This repetitiveness is exploitable

The Plastic Surgery Hypothesis

Changes to a code base contain snippets that *already exist* in the code base *at the time of the change*, and these snippets can be *efficiently found* and exploited

(1) Changes are repetitive related to the program to which they are applied (parent)
(2) This repetitiveness is exploitable

- Previous works have found repetitiveness of changes across the project history
  - neglecting the primordial code that remained unchanged from the first version to the last

Project	Core
Camel	26%
CXF	85%
HIVE	97%
….	
Wicked	<0.5%

C. Le Goues, S. Forrest, and W. Weimer. Current challenges in automatic software repair. SQJ, 21(3):421–443, 2013
H. D. T. Nguyen, D. Qi, A. Roychoudhury, and S. Chandra. SemFix: Program repair via semantic analysis. In ICSE 2013.
M. Martínez, W. Weimer, and M. Monperrus. Do the fix ingredients already exist? An empirical inquiry into the redundancy assumptions of program repair approaches. In ICSE NIER track, 2014.

Federica Sarro - f.sarro@ucl.ac.uk

The Plastic Surgery Hypothesis

Changes to a code base contain snippets that *already exist* in the code base *at the time of the change*, and these snippets can be *efficiently found* and exploited

(1) Changes are repetitive related to the program to which they are applied (parent)

(2) This repetitiveness is exploitable

"How much of each change to a codebase can be constructed from the existing code?"

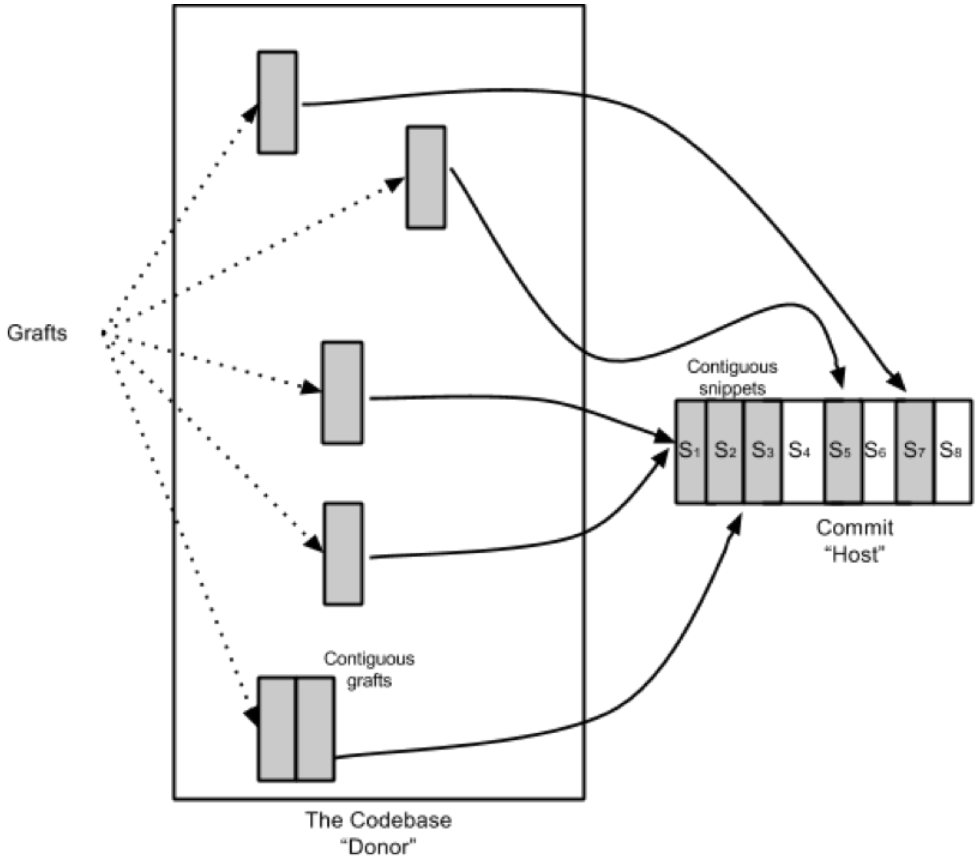
"What is the cost of finding these snippets?"

- Previous works have found repetitiveness of changes across the project history
  - neglecting the primordial code that remained unchanged from the first version to the last
  - ignoring the cost of finding redundancies

C. Le Goues, S. Forrest, and W. Weimer. Current challenges in automatic software repair. SQJ, 21(3):421–443, 2013
H. D. T. Nguyen, D. Qi, A. Roychoudhury, and S. Chandra. SemFix: Program repair via semantic analysis. In ICSE 2013.
M. Martínez, W. Weimer, and M. Monperrus. Do the fix ingredients already exist? An empirical inquiry into the redundancy assumptions of program repair approaches. In ICSE NIER track, 2014.

The Plastic Surgery Hypothesis

How much of each change to a codebase can be constructed from the existing code?



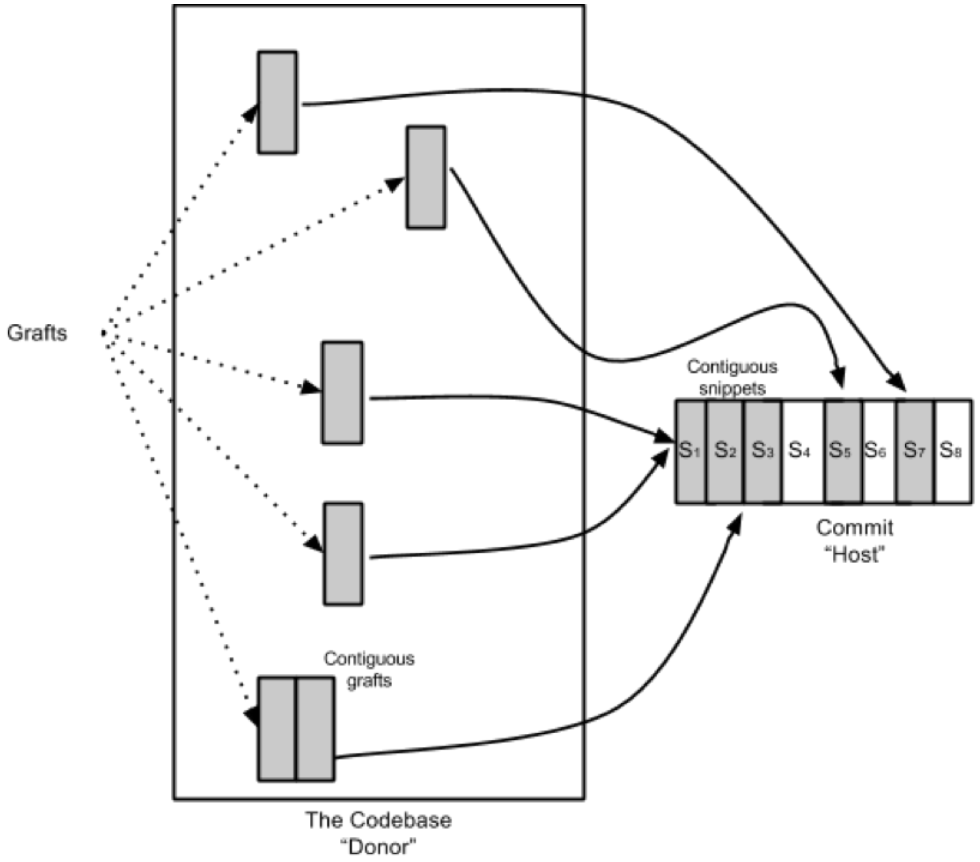
Graftability of a change

percentage of snippets in a commit that match a snippet in the codebase

- line-granularity
- exact matching, ignoring whitespace

The Plastic Surgery Hypothesis

How much of each change to a codebase can be constructed from the existing code?



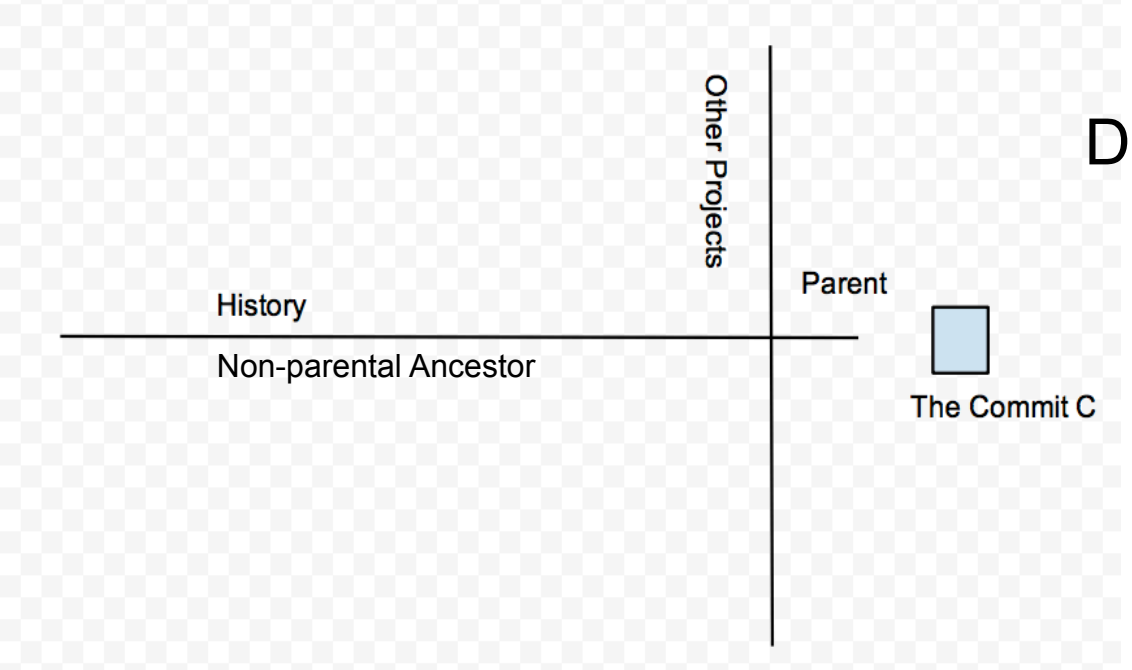
Graftability of a change

percentage of snippets in a commit that match a snippet in the codebase

- line-granularity
- exact matching, ignoring whitespace

The Plastic Surgery Hypothesis

What is the cost of finding these snippets?



Density of a search-space

number of grafts found in a given search-space over its size

Corpus

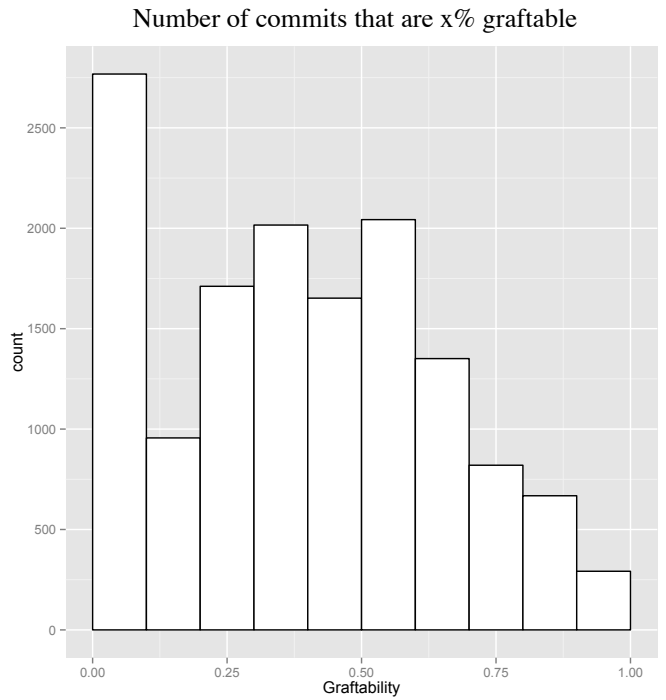
- 12 open-source software projects
  - 15,723 commits from 2004 to 2012
  - 1,038,761 LOC

- 5 types of changes
  - Bug, Improvement, New Feature, Task, Custom Issue

RQ1: PSH Validation

Changes to a code base contain *snippets that already exist* in the code base *at the time of the change*, and these snippets can be *efficiently found and exploited*

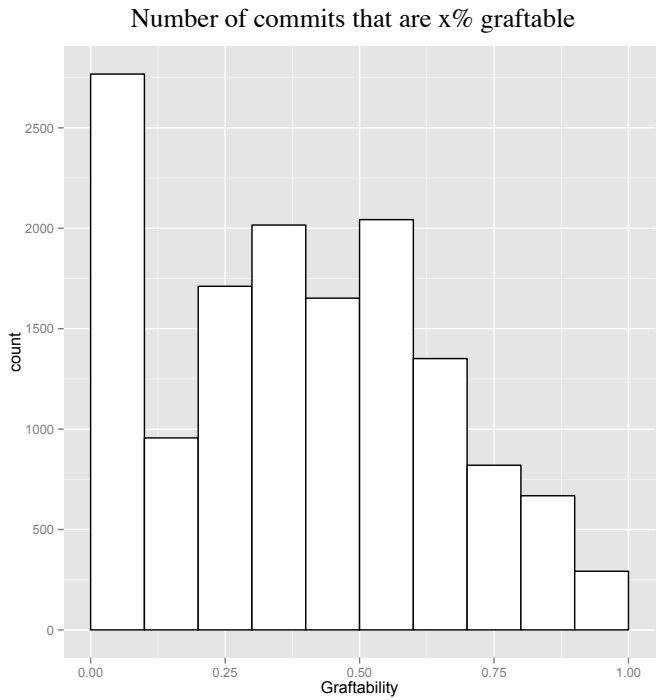
- Changes are 43% graftable on average
- What percentage of the changes are x% graftable?
  - 16% of the changes are novel
  - 42% of the changes are more than 50% graftable
  - 10% of the changes are fully graftable



RQ1: PSH Validation

Changes to a code base contain snippets that *already exist* in the code base *at the time of the change*, and these snippets can be *efficiently found and exploited*

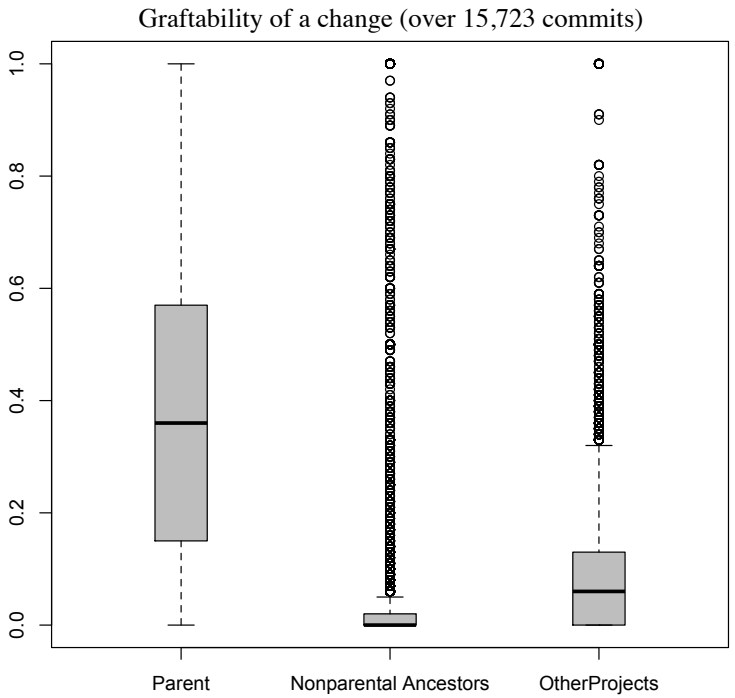
- Changes are 43% graftable on average
- What percentage of the changes are x% graftable?
  - 16% of the changes are novel
  - 42% of the changes are more than 50% graftable
  - 10% of the changes are fully graftable



RQ1: PSH Validation

Changes to a code base contain snippets that *already exist* in the code base *at the time of the change*, and these snippets can be *efficiently found and exploited*

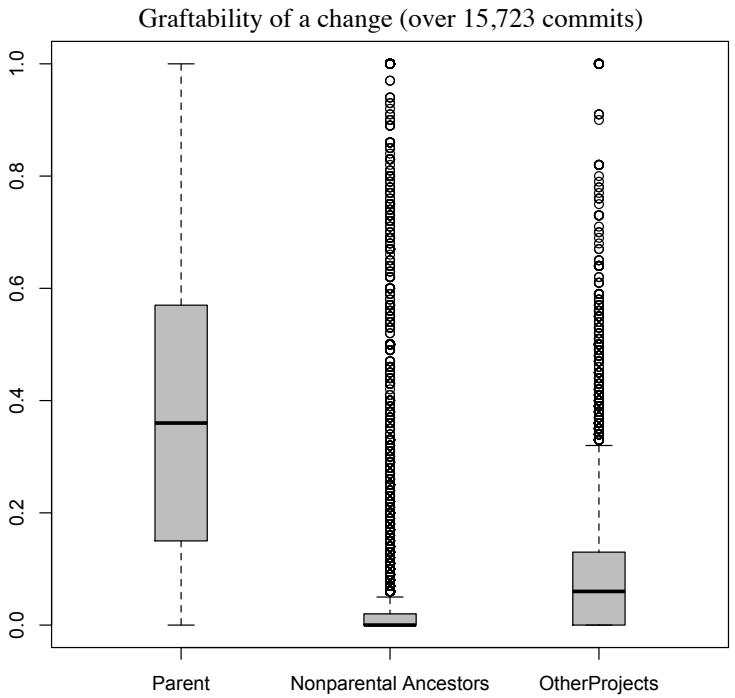
- How do parents fare as *possible* source of grafts, when compared to nonparental ancestors and other projects?
  - non-parental ancestors contribute only 5% more grafts than the parents, while other projects only provide 9% on average
  - there is statistical significant difference in favour of the parent codebase with high effect size



RQ1: PSH Validation

Changes to a code base contain snippets that *already exist* in the code base *at the time of the change*, and these snippets can be *efficiently found and exploited*

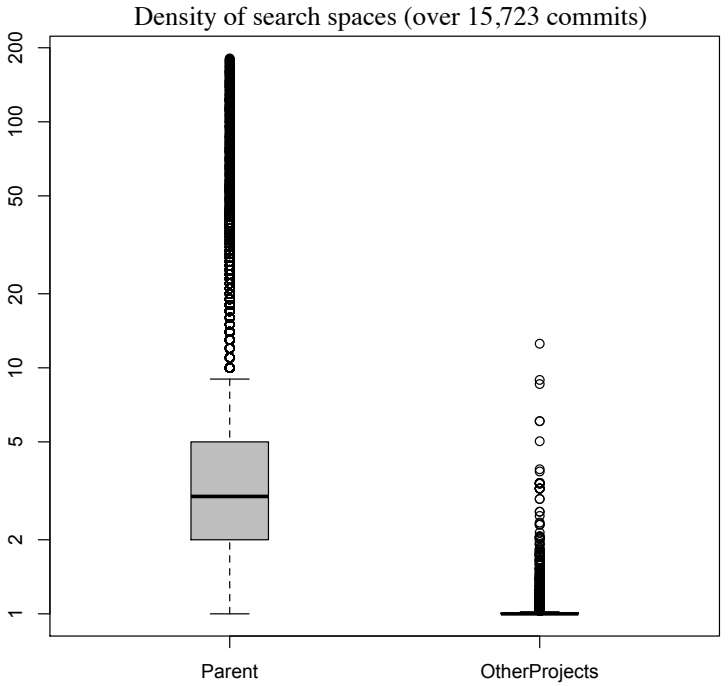
- How do parents fare as *possible* source of grafts, when compared to nonparental ancestors and other projects?
  - non-parental ancestors contribute only 5% more grafts than the parents, while other projects only provide 9% on average
  - there is statistical significant difference in favour of the parent codebase with high effect size



RQ1: PSH Validation

Changes to a code base contain snippets that *already exist* in the code base *at the time of the change*, and these snippets can be *efficiently found and exploited*

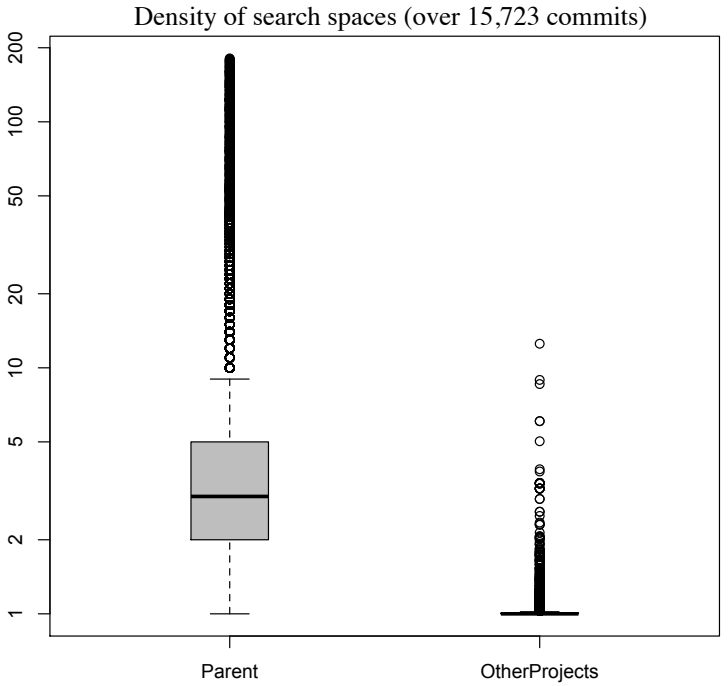
- How do parents fare as *efficient* source of grafts, when compared to other projects?
  - The density of parent is significantly higher than those of the other search-spaces with a high effect size



RQ1: PSH Validation

Changes to a code base contain snippets that *already exist* in the code base *at the time of the change*, and these snippets can be *efficiently found and exploited*

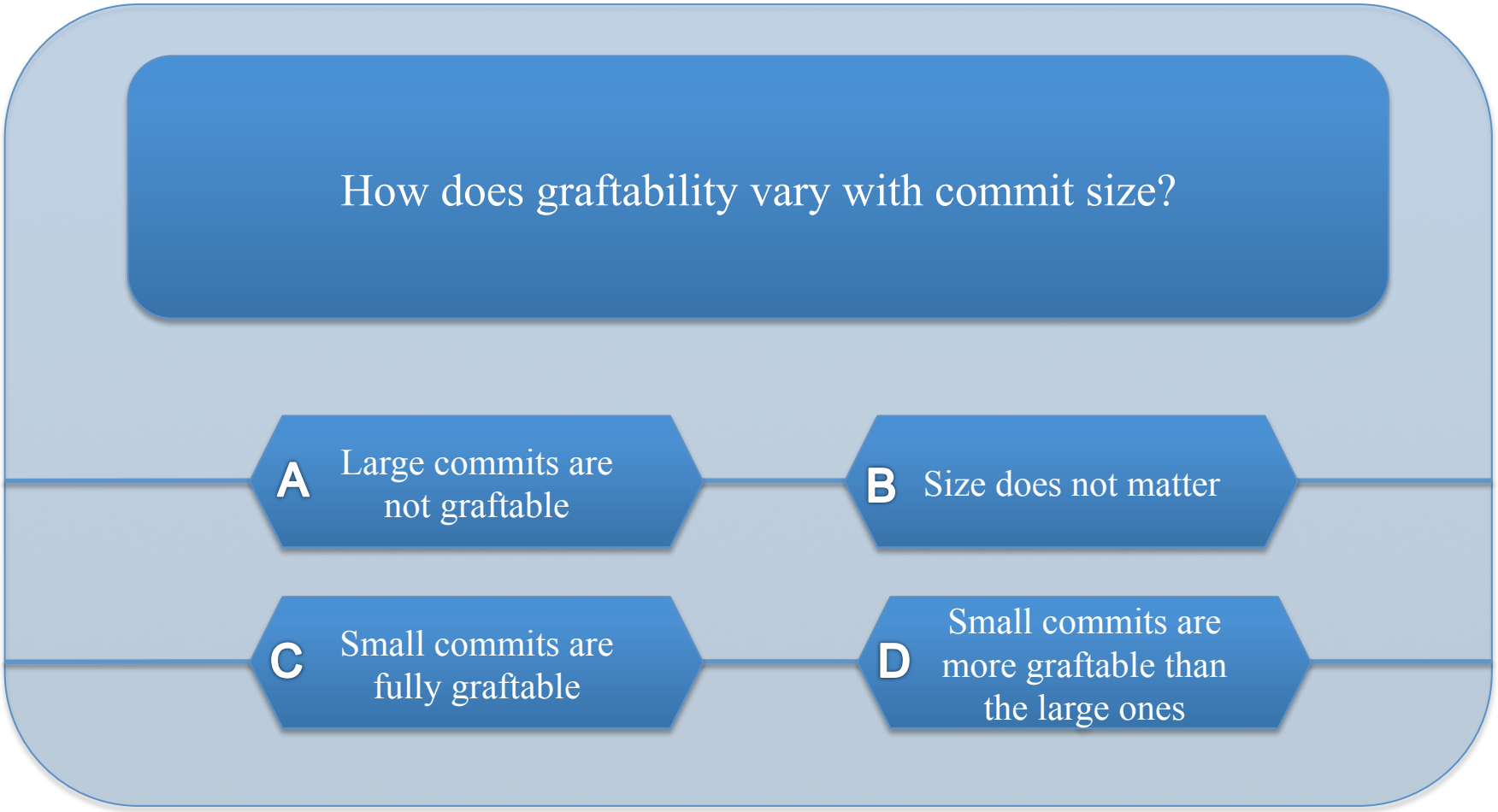
- How do parents fare as *efficient* source of grafts, when compared to other projects?
  - The density of parent is significantly higher than those of the other search-spaces with a high effect size



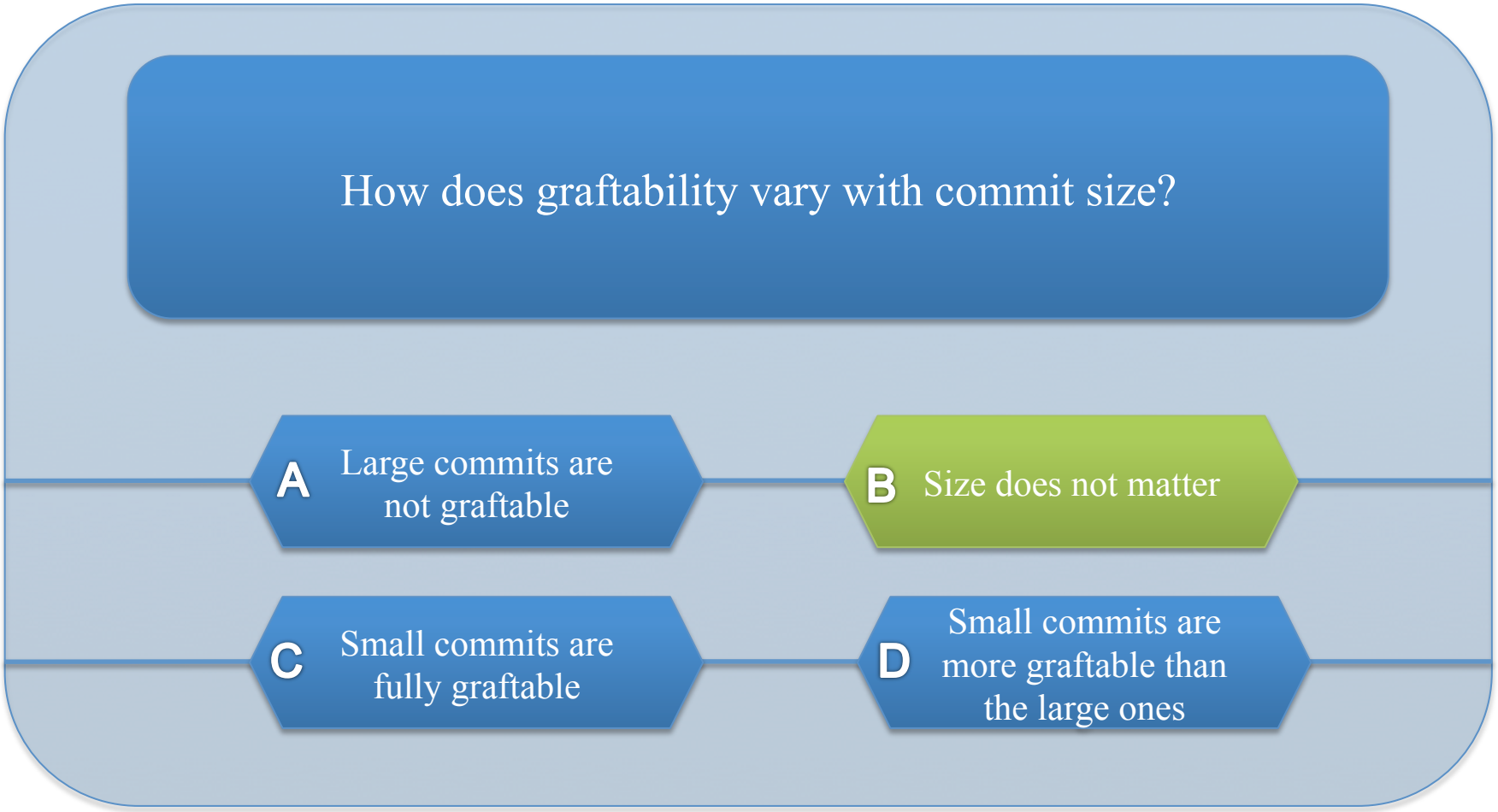
Further Insights

- Graftability by Commit Size
- Graftability by Commit Type
- Graft Contiguity
- Graft Clustering

Graftability by Commit Size

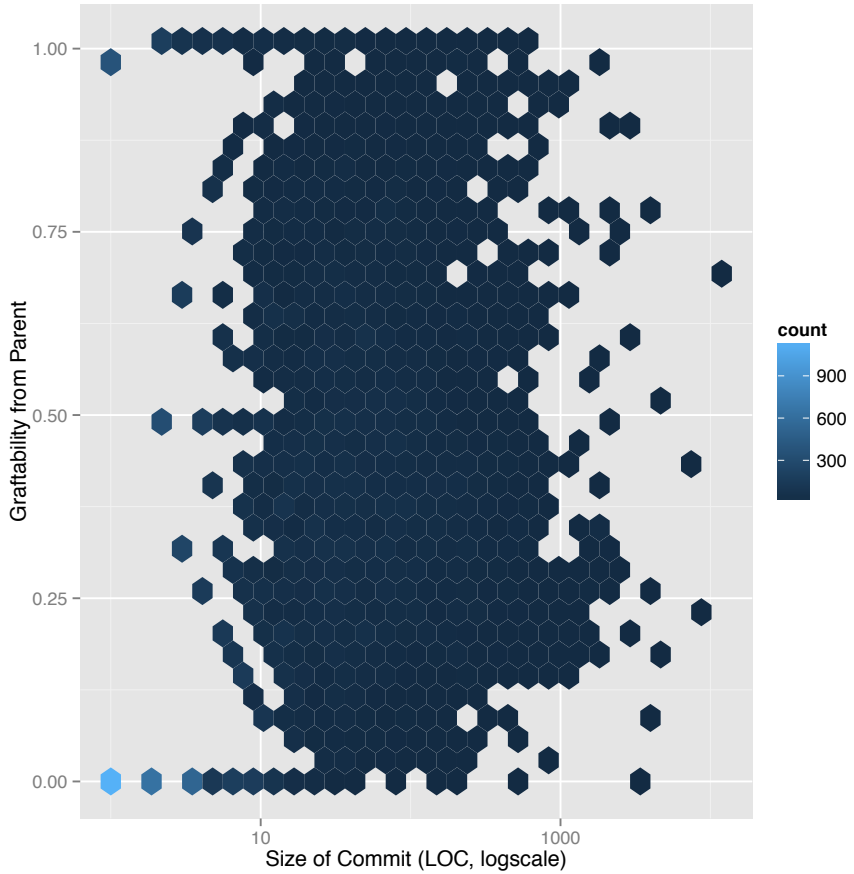


Graftability by Commit Size



Graftability by Commit Size

RQ2: How does graftability vary with commit size?



Regression model, graftability as response.

	Model 1	Model 2
Intercept	0.29***	0.30***
	(0.00)	(0.00)
Commit Size (*Log* scaled)	0.07***	0.08***
	(0.00)	(0.00)
Improvement vs. *Bug*		−0.04***
		(0.01)
New Feature vs. *Bug*		0.02
		(0.01)
Task vs. *Bug*		−0.03***
		(0.01)
Custom Issue vs. *Bug*		0.00
		(0.01)
R^2	0.04	0.04
Adj. R^2	0.04	0.04
Num. obs.	15723	15723

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$

Graftability by Commit Type

RQ3: Do different kinds of commits exhibit same graftability?

Bug

A problem which impairs/prevents the functions of the product

New Feature

A new feature of the product

Task

A project task that needs to be done

Improvement

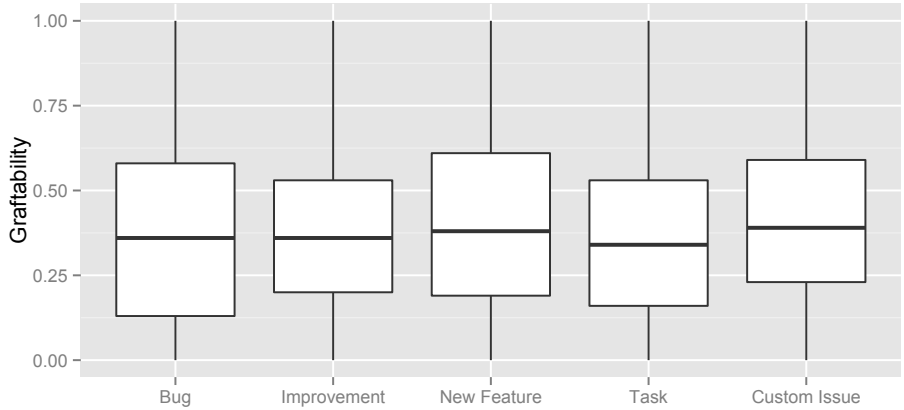
An enhancement to an existing feature

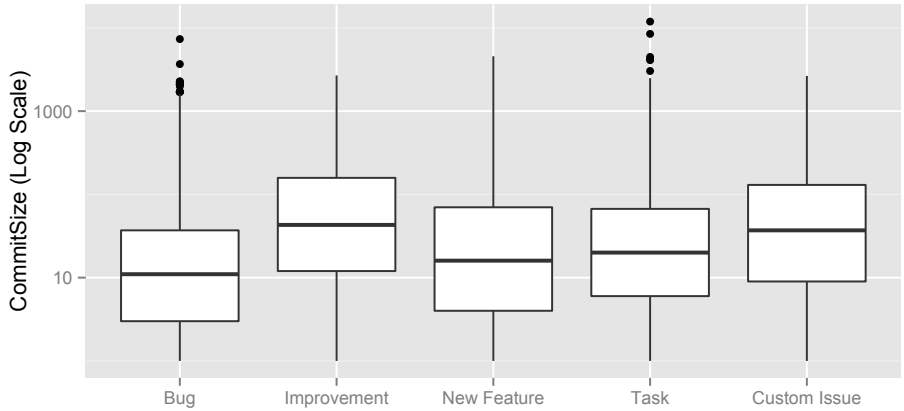
Custom Issue

A custom issue type, as defined by the organization

Graftability by Commit Type

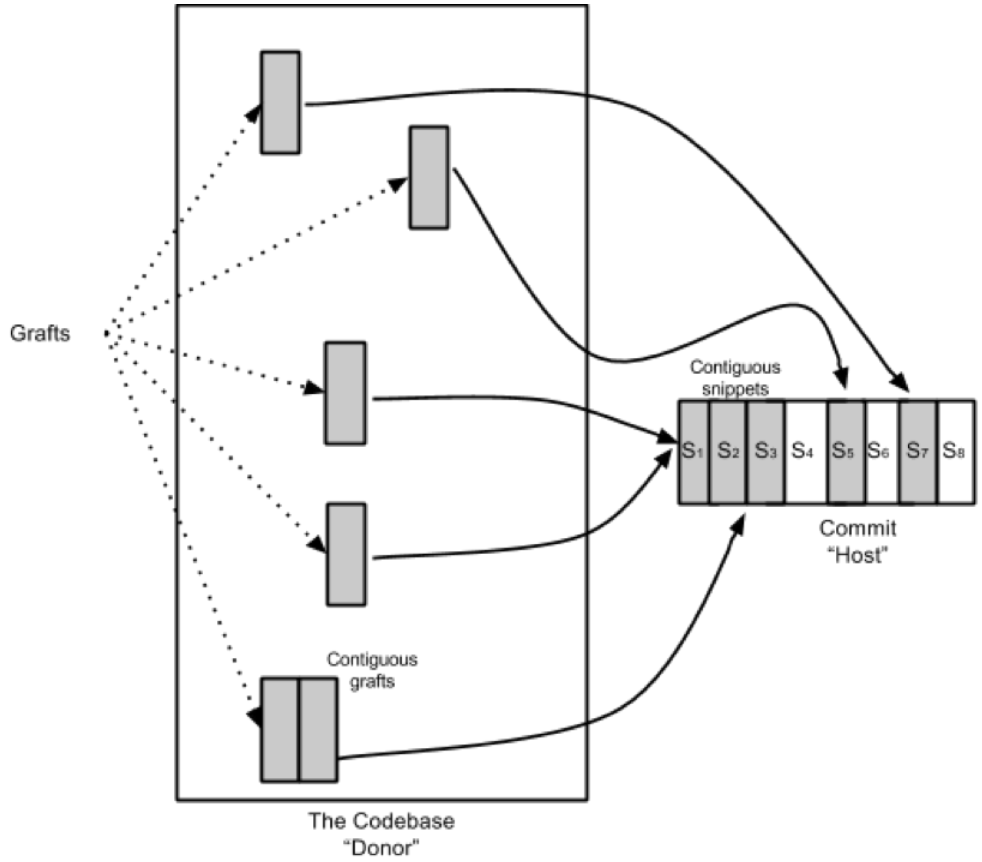
RQ3: Do different kinds of commits exhibit same graftability?





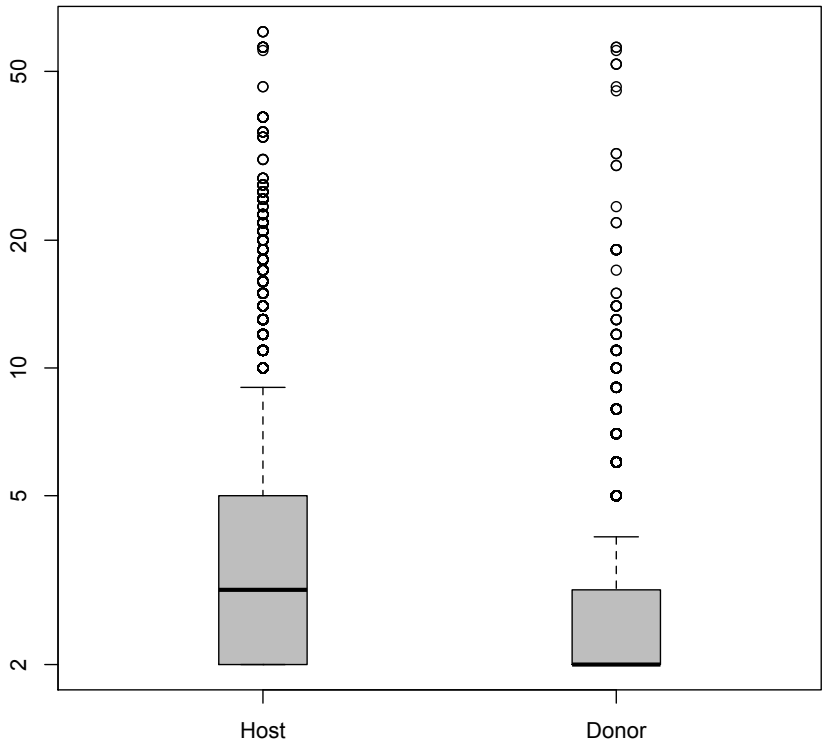
Graft Contiguity

RQ4: To what extend are grafts contiguous?

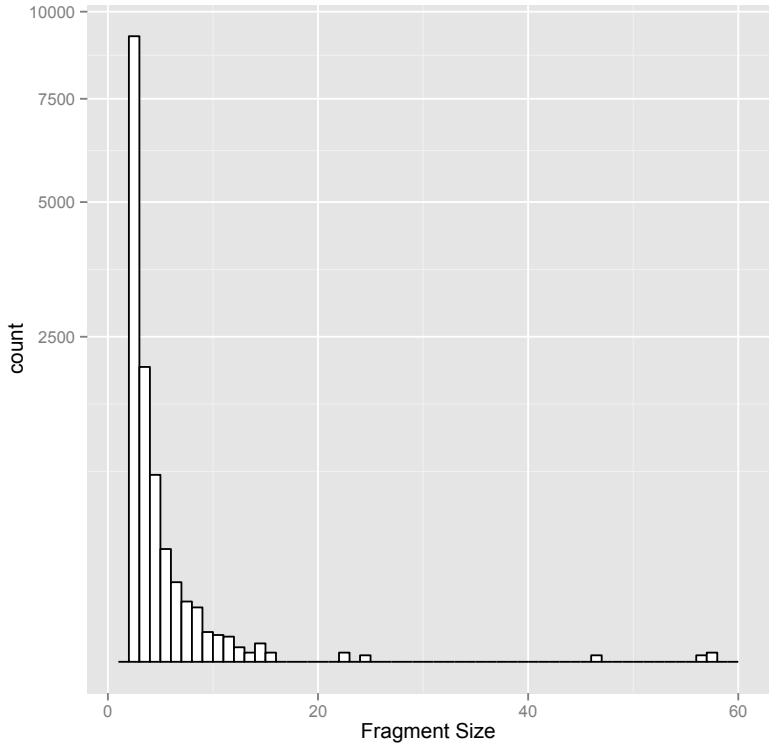


Graft Contiguity

RQ4: To what extend are grafts contiguous?



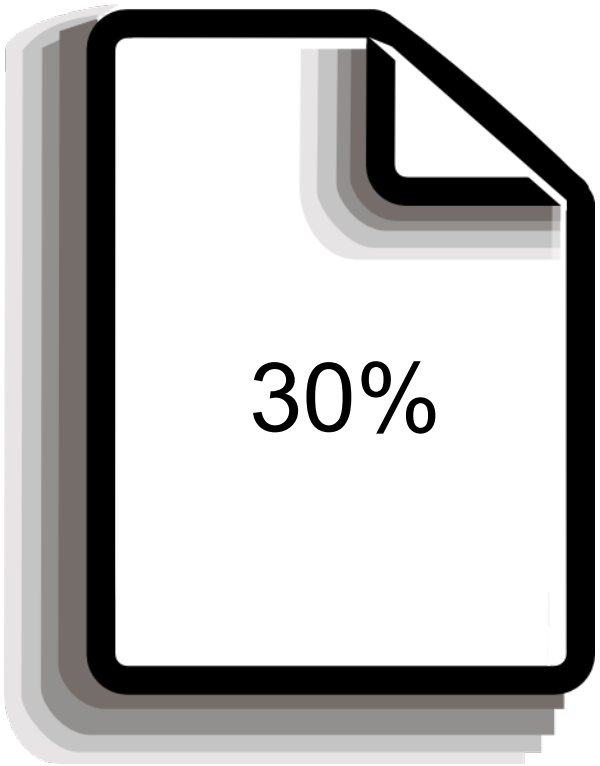
How big are contiguos grafts? The figure reports the size (log scale) of both host and donor snippets.

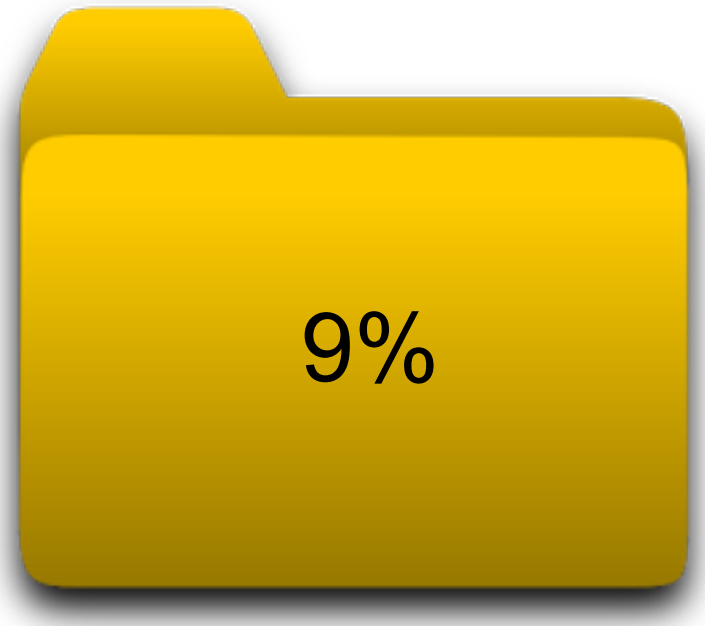


How many host and donor snippets have the same size? The figure shows the number (sqrt scale) of those host and donor snippets having the same size.

Graft Clustering

RQ5: Are the donor snippets needed to graft a host snippet in the same file?





Conclusion

Changes to a code base contain snippets that *already exist* in the code base *at the time of the change*, and these snippets can be *efficiently found and exploited*

(1) Changes are 43% graftable on average
16% are novel, 42% are more than 50% graftable, 10% are fully graftable

(2) The parent is a rich and effective search space

(3) The size and type of a commit have no significant practical impact on its graftability

(4) 53% of the snippets can be fully grafted from a single donor; in the remaining cases two donors are needed on average

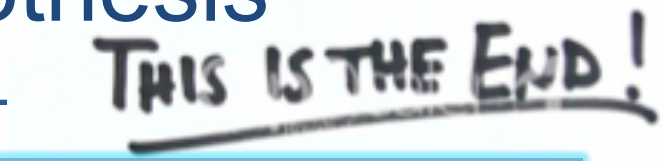
(5) Donor snippets are often found in the same file, not requiring more extensive search

Future Work

The complement of graftability measures the novelty of changes

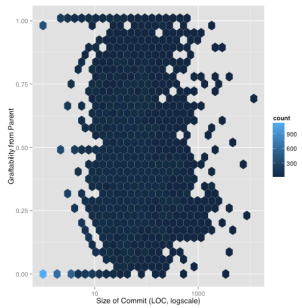
- explore whether the feature set of novel changes is more predictable than we have found grafts to be

The Plastic Surgery Hypothesis



Changes to a code base contain snippets that *already exist* in the code base *at the time of the change*, and these snippets can be *efficiently found and exploited*

RQ2: How does graftability vary with commit size?



Regression model, graftability as response.

	Model 1	Model 2
Intercept	0.29***	0.30***
	(0.00)	(0.00)
Commit Size (*Log* scaled)	0.07***	0.08***
	(0.00)	(0.00)
Improvement vs. *Bug*		−0.04***
		(0.01)
New Feature vs. *Bug*		0.02
		(0.01)
Task vs. *Bug*		−0.03***
		(0.01)
Custom Issue vs. *Bug*		0.00
		(0.01)
R^2	0.04	0.04
Adj. R^2	0.04	0.04
Num. obs.	15723	15723

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$

RQ3: Do different kinds of commits exhibit same graftability?

Bug
A problem which impairs/prevents the functions of the product

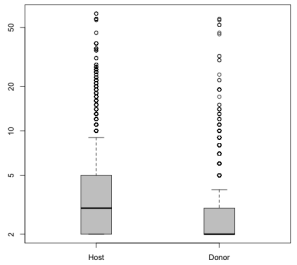
New Feature
A new feature of the product

Task
A project task that needs to be done

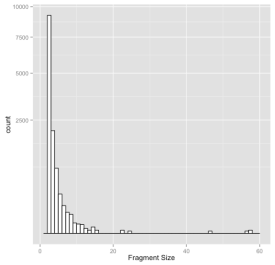
Improvement
An enhancement to an existing feature

Custom Issue
A custom issue type, as defined by the organization

RQ4: To what extend are grafts contiguous?



How big are contiguos grafts? The figure reports the size (log scale) of both host and donor snippets.



How many host and donor snippets have the same size? The figure shows the number (sqrt scale) of those host and donor snippets having the same size.

RQ5: Are the donor snippets needed to graft a host snippet in the same file?