

Analysing Structural Dependencies in Software Product Lines

Using Distribution and Network Statistics

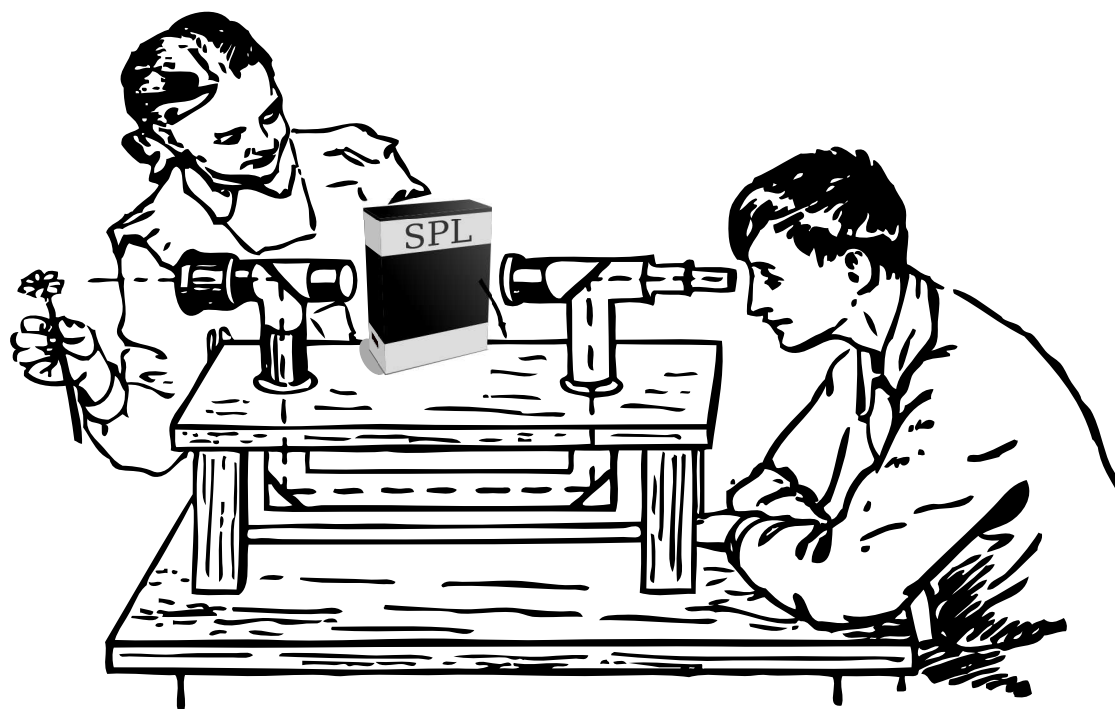
by Sven Apel, Sergiy Kolnesikov, Stefan Sobernig;

in cooperation with Jörg Liebig and Norbert Siegmund

March 21, 2012

Structure of the talk

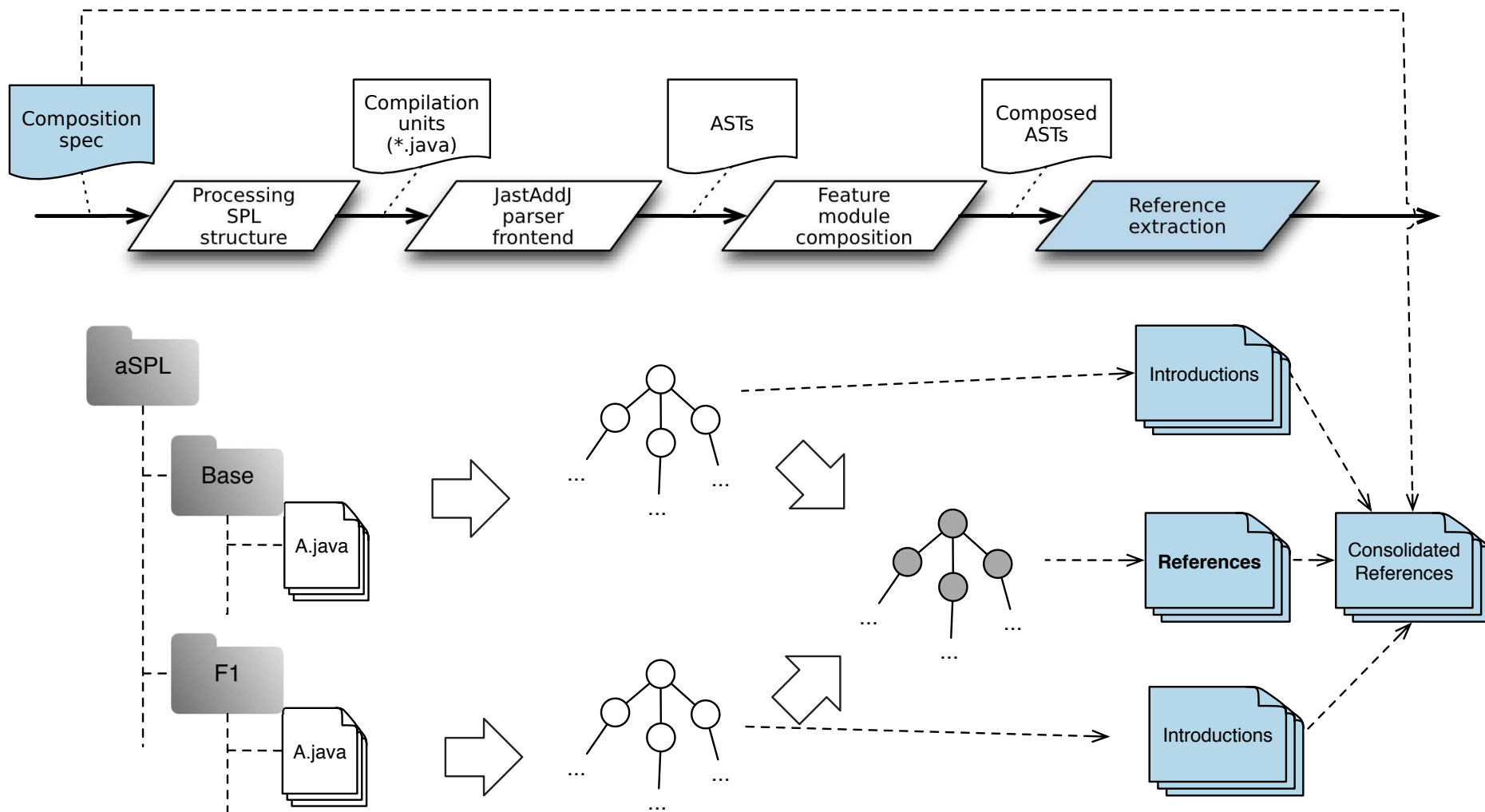
1. Motivation
2. Gathering syntactic reference data from Java-based SPLs (Fuji)
3. Notions of reference
4. Degree statistics over reference data



“Ufff! A false x-ray apparatus for SPLs?”

(Illustration adapted from Perelman (1913/2008): *Physics for Entertainment*, Fig. 95, p. 132)

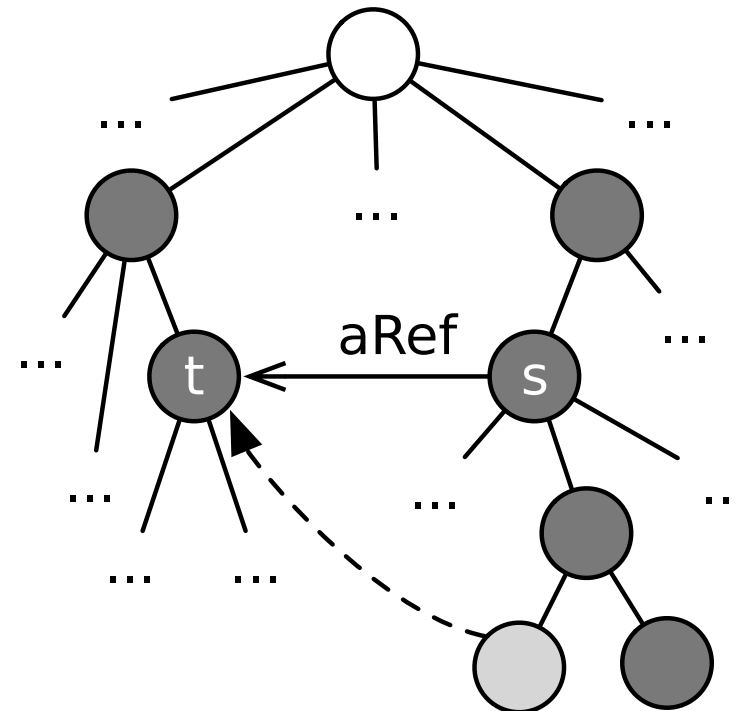
Data collection for Fuji-driven SPLs



See [Kol11] for details on Fuji

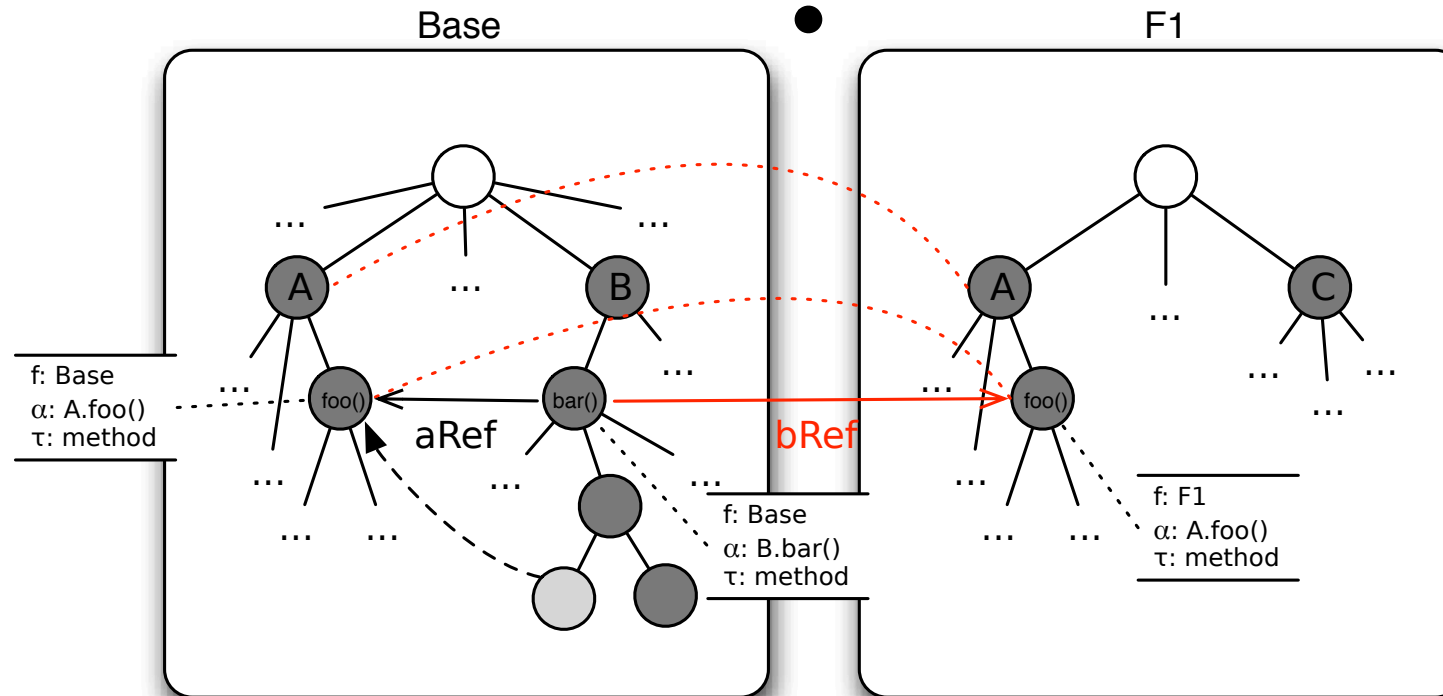
A generic notion of reference

- In the Fuji/Java context, relevant DeclExpressions are ...
 - Class declarations
 - Constructor and initializer declarations
 - Method declarations
 - Field declarations
- Relevant UseExpressions are ...
 - Class-instance creation expressions
 - Field access expressions
 - Method invocation expressions



- DeclExpression
- UseExpression

An extended notion of “Fuji reference”



$$R : F \times A \times \Gamma \mapsto F \times A \times \Gamma$$

$$= ((\{f_i, \alpha_m, \tau\}, \{f_j, \alpha_n, \tau\}), \dots)$$

$$1 \leq i, j \leq |F|, i \neq j$$

$$1 \leq m, n \leq |A|, m \neq n$$

$$\tau \in \Gamma : \{\text{type, field, method, constructor}\}$$

- Intra-module references, e.g.: aRef

({Base, B.bar(), method}, {Base, A.foo(), method})

- Inter-module references, e.g.: bRef

({Base, B.bar(), method}, {F1, A.foo(), method})

Available reference data sets (SPLs)

- References and introductions data of **28** SPLs
- **Feature modules:** $\Delta = 99$ (BerkeleyDB) vs. $\delta = 5$ (Raroscope)
- **Introductions:** $\Delta = 9379$ (BerkeleyDB) vs. $\delta = 43$ (EPL)
- **(Unique) references:** $\Delta = 52890$ (BerkeleyDB) vs. $\delta = 80$ (EPL)
- **(Unique) inter-module references:** $\Delta = 30061$ (BerkeleyDB) vs. $\delta = 51$ (Raroscope)

Fuji reference space

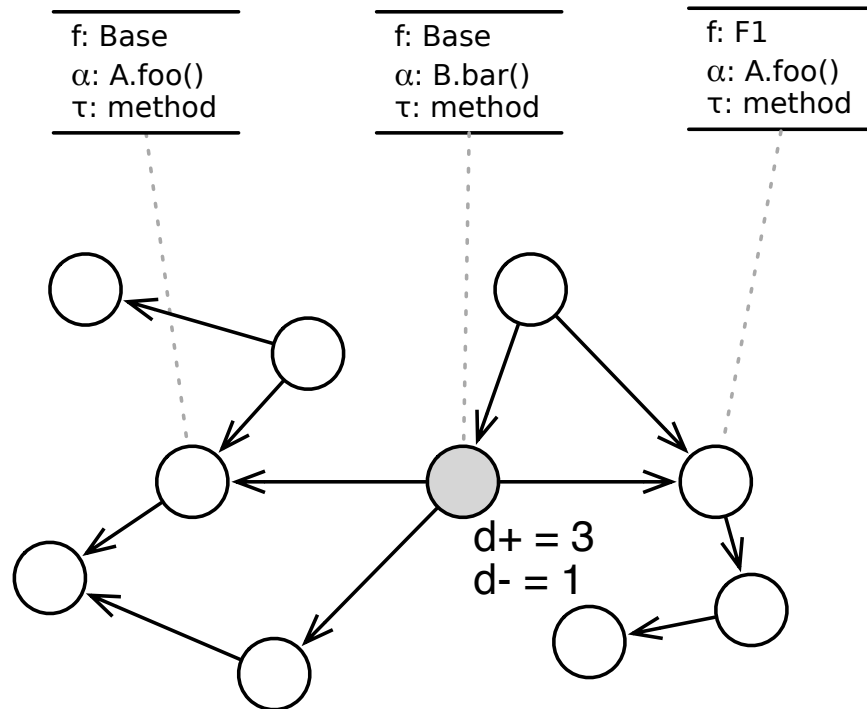
The reference data can be sliced by ...

- ... pairs of syntactic categories:

source → target	field	method	constructor	type
field				
method				
constructor				
type				

- $4 \times 4 = 16$ subsets of reference data per SPL
- Column-wise aggregation: field accesses, method accesses
- ... the level of abstraction: per-element vs. per-feature-module
- ... the kind of reference: intra-module vs. inter-module
- ... the reference direction: in- vs. outgoing
- ... or any combination of the above!

Degrees in reference networks



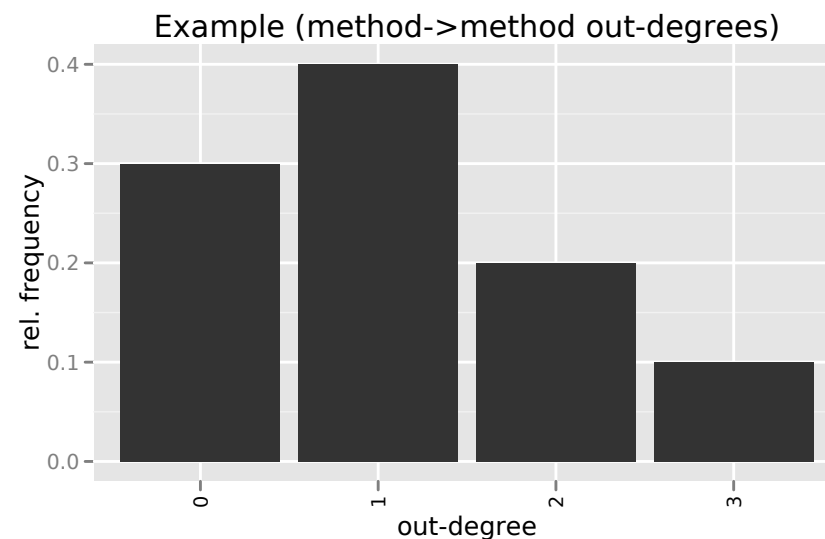
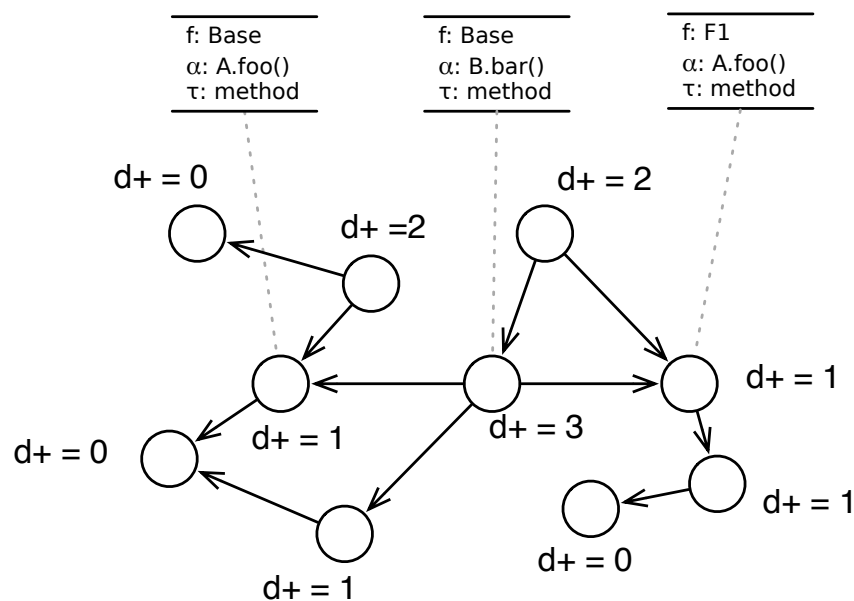
- For each possible reference-data slice, e.g.:
 - method \rightarrow method
 - per-element,
 - intra- and inter-module references ...
- ... we can form a graph G_R
- We can identify *local* properties of each node n (e.g., element, feature module), such as:
 - out-degree $d^+(n)$
 - in-degree $d^-(n)$
 - ... as well as their relative forms
- and *global*, degree-based characteristics
 - Average, minimum, and maximum degrees: $\phi d^+(G_R)$, $\phi d^-(G_R)$, $\Delta d^+(G_R)$, $\Delta d^-(G_R)$, $\delta d^+(G_R)$, $\delta d^-(G_R)$
 - **(In-/Out-) Degree distribution**

An exemplary out-degree distribution

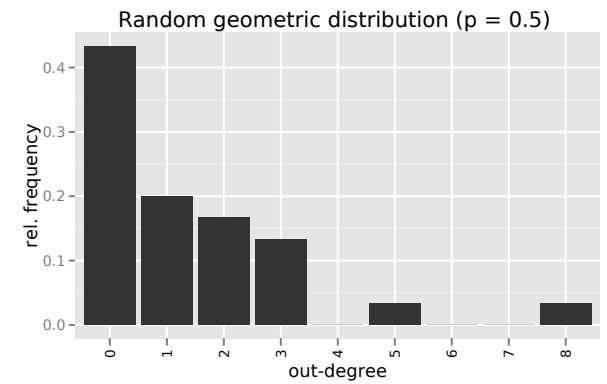
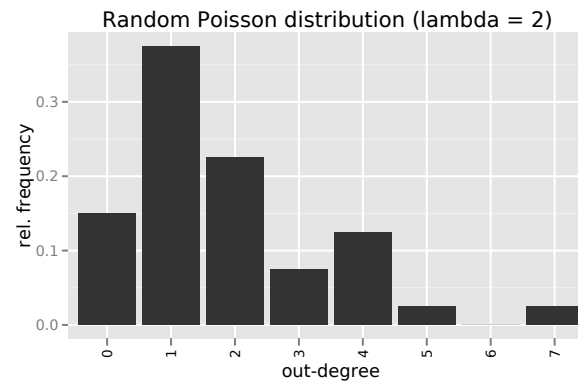
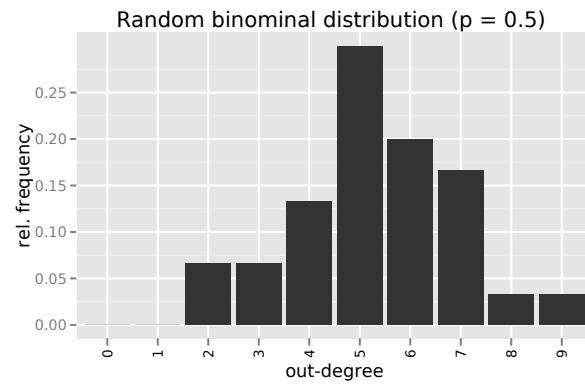
For the given example, the *global*, out-degree characteristics are:

- $\Delta d^+(G_R) = 3$
- $\delta d^+(G_R) = 0$
- $\phi d^+(G_R) = ?$
- The distribution of out-degree frequencies in G_R :

out-degree	0	1	2	3
frequency	3	4	2	1
rel. frequency	0.3	0.4	0.2	0.1



Do degrees follow a particular distribution?

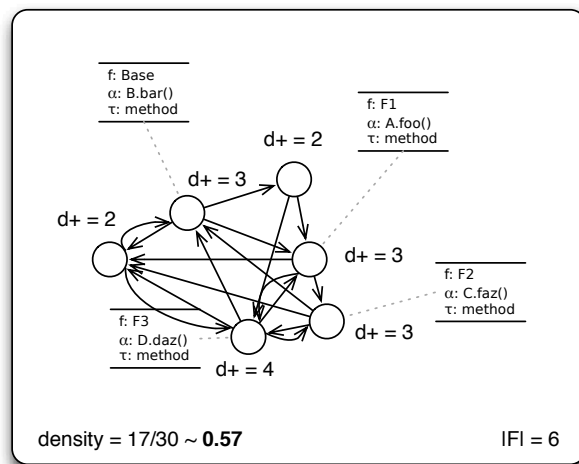


Towards Smell Detection, Ex. 1 (1)

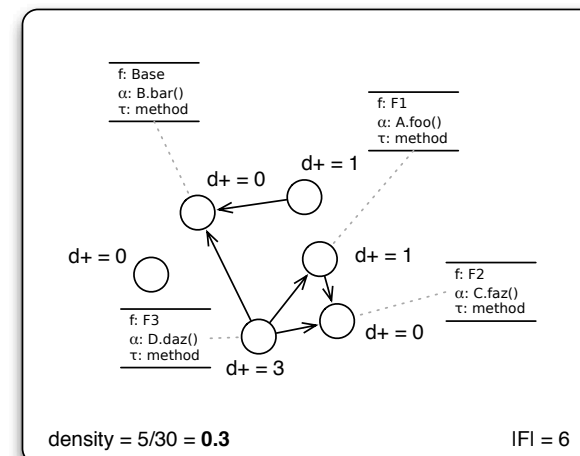
A variant of a Feature Envy [Fow03]: Excessive Inter-Module Method Invocations

1. For a given SPL, choose the appropriate data slice: per-element, * \rightarrow method references, out-degrees, inter-module
2. Indicator measures: network density, **strength** distribution (skewness)

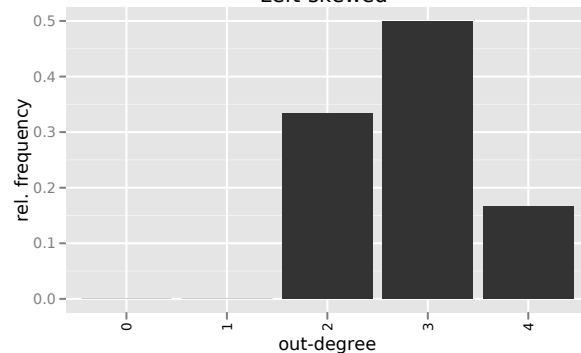
Possible envies?



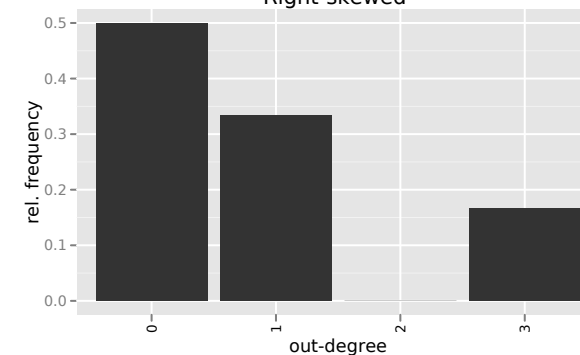
Mostly ego-centric?



Left-skewed

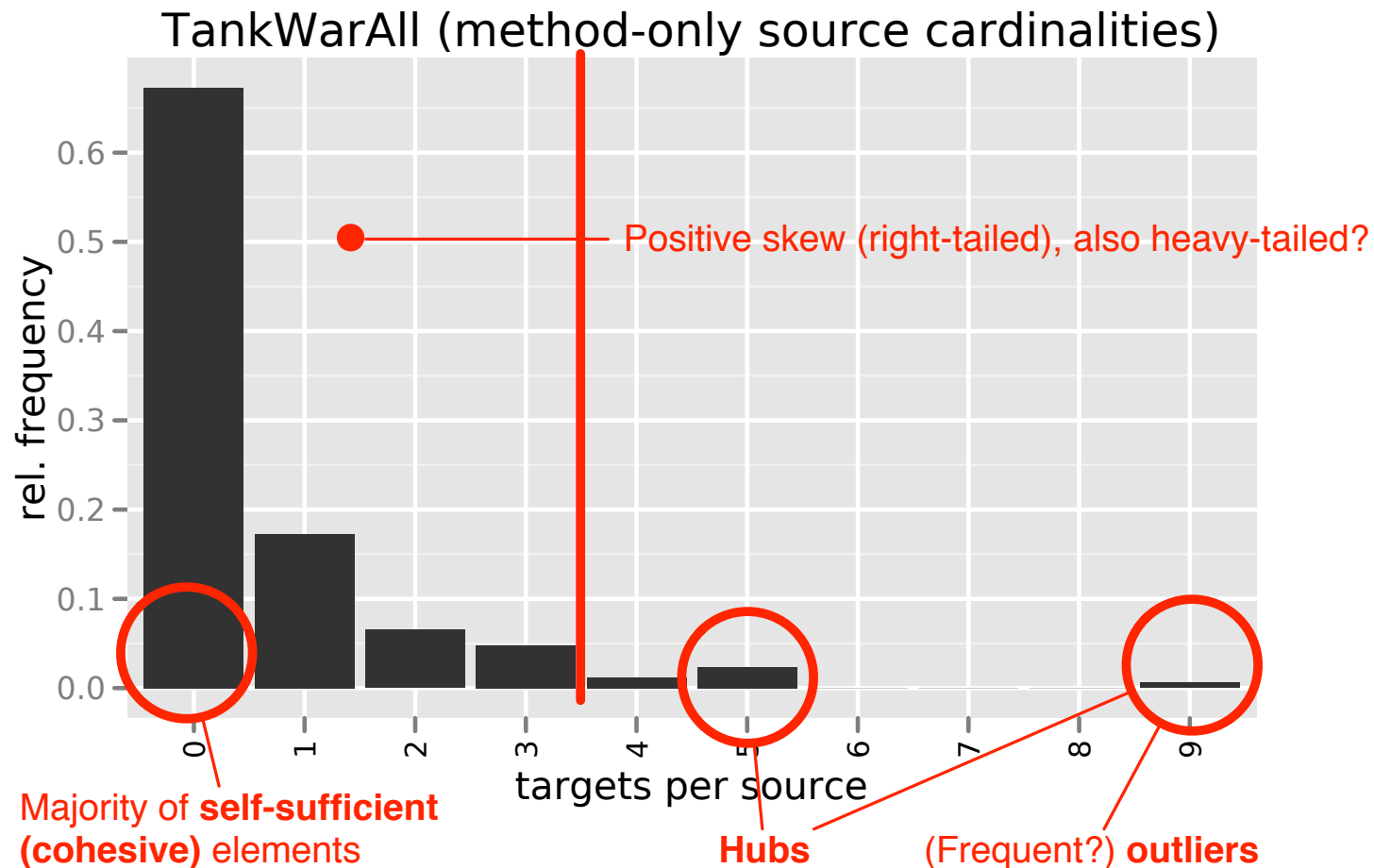


Right-skewed



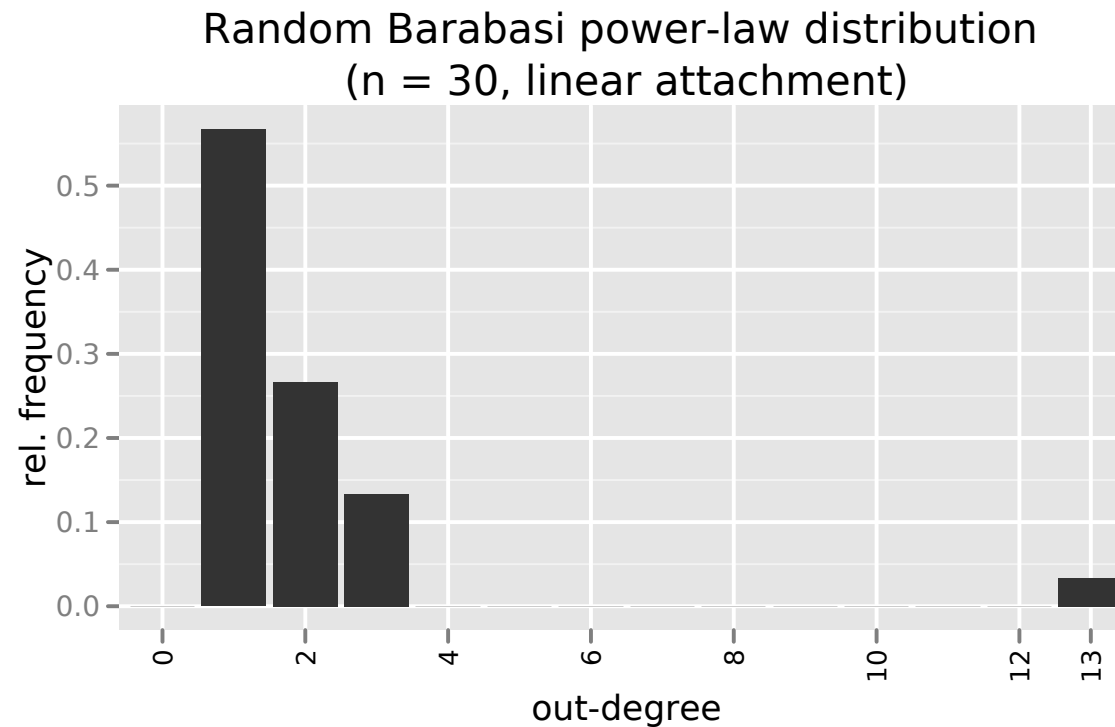
Towards Smell Detection, Ex. 1 (2)

Can one observe method-level feature Envy in the TankWar Fuji-SPL?



Research question(s): Are we looking at ...

... variants of a *power-law* distribution for our SPLs and for all/certain slices?

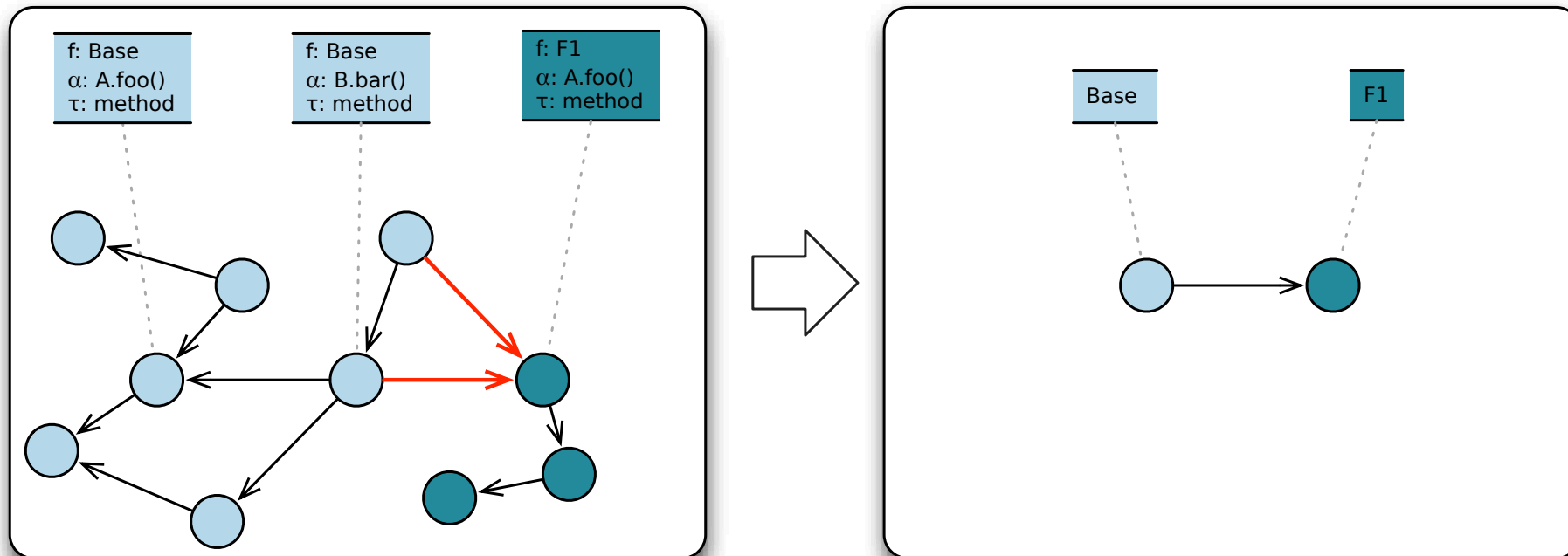


Why would one expect to find such a degree distribution in a Fuji SPL?

On Power Laws (or the like)

- Numerous reports for important OO program structures:
 - Many hierarchical (ownership) and non-hierarchical (statements) relations within and between class boundaries; Qualitas Corpus [TSWW11]; also states the correspondence between overall connectivity and between-class connectivity.
 - Classes and class relations such as inheritance and aggregation; JDK class libraries [WC03]
 - Variable type annotations, object creation, and parameter passing; Squeak and VisualWorks Smalltalk [MPST04].
 - Global layout of 60 object graphs, extracted from object-object references from sources as diverse as C++ frontend to GCC, the Self runtime, and Java ArgoUML [PNFB05]
- Underlying forces (development processes and practises)
 - Preferential attachment in the development process
 - OO design patterns (e.g., template & hook methods, abstract class designs)
 - Key classes

Per-feature-module statistics



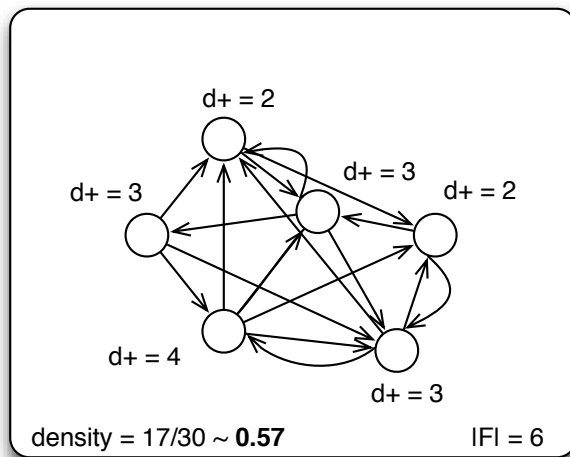
- Only inter-module reference are considered
- Per-element references become aggregated/subsumed by per-module references (edge weights)

Towards Smell Detection, Ex. 2

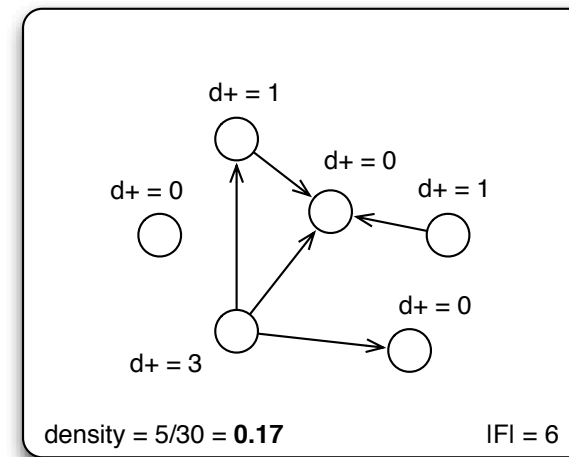
Direct Field Accesses vs. Feature-Module Boundaries [AKL⁺12]

1. For a given SPL, choose the appropriate data slice: per-feature, * \rightarrow field references, out-degrees, inter-module
2. Indicator measures: network density, degree distribution (skewness)

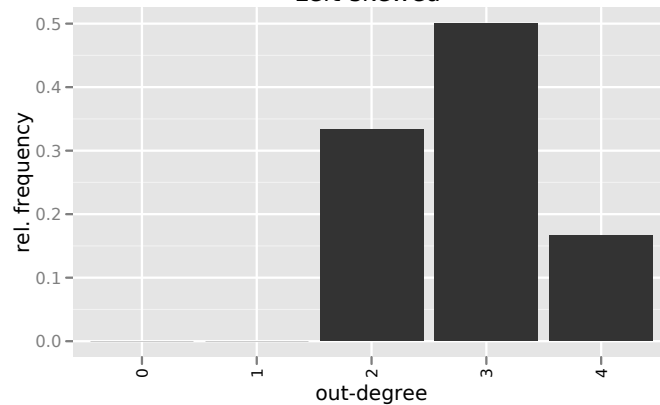
Relatively *high* coupling



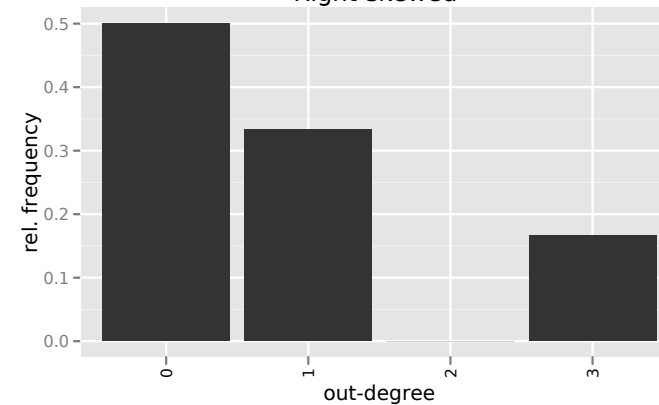
Relatively *low* coupling



Left-skewed



Right-skewed



Closing: Further directions of analysis

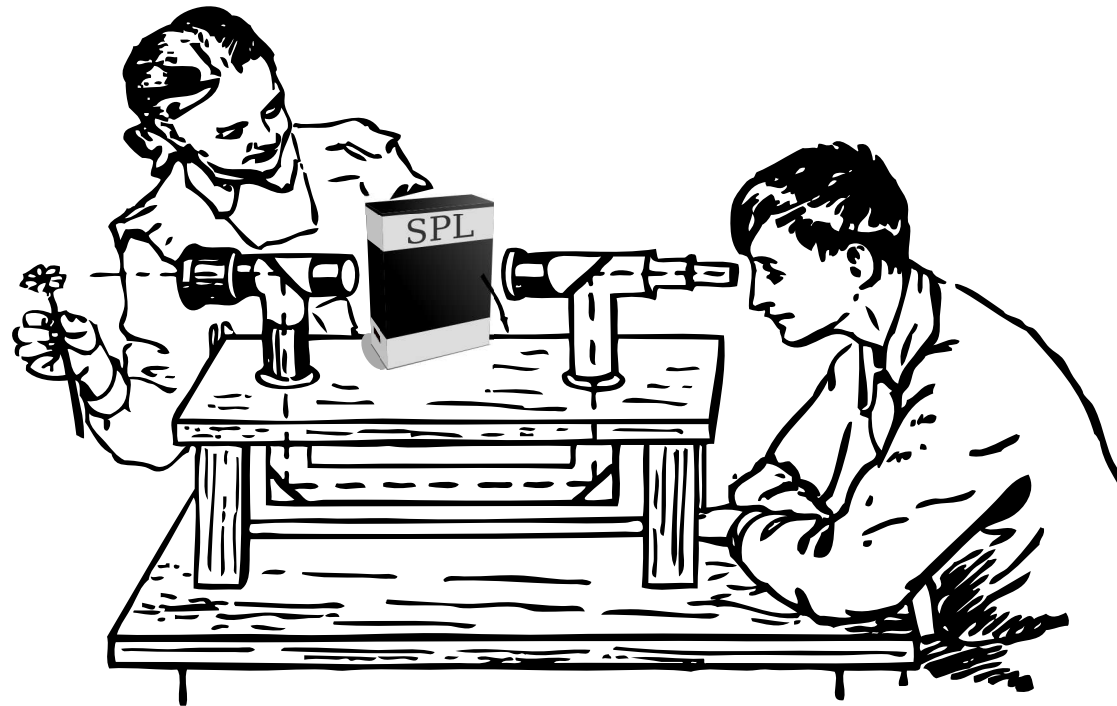
1. Short-term objectives (**Stefan, Sven, Sergiy**)

- Additional slicing dimensions: Incorporate co-occurrence dependencies between feature modules (never, always, optional)
- Usage frequencies of introductions
- Distribution statistics for field and method accesses per feature module
- Local/global characteristics of *derivative* features (**Jörg**)
- Detection/calibration of *intrinsic* (statistical) thresholds for degree and distribution statistics
- Input for Performance Prediction (see **Norbert's** and **Sergiy's** talks): Higher-Order (e.g., triangles) and Hot-Spot Features (hubs, betweenness)

2. Mid-term objectives

- Detection/calibration of *extrinsic* thresholds, by incorporating the non-functional data profiles of the SPLs (**Sergiy, Norbert, Jörg**)
- Weighted network statistics (**Stefan, Sven, Jörg**)
 - Edge weights based on reference counts (per-element, per-feature)
 - Attribute measures as edge weights (e.g., degrees of coupling and scattering, ...)
 - ...

Shooting time!



“What do you see through the walls of SPL code data?”

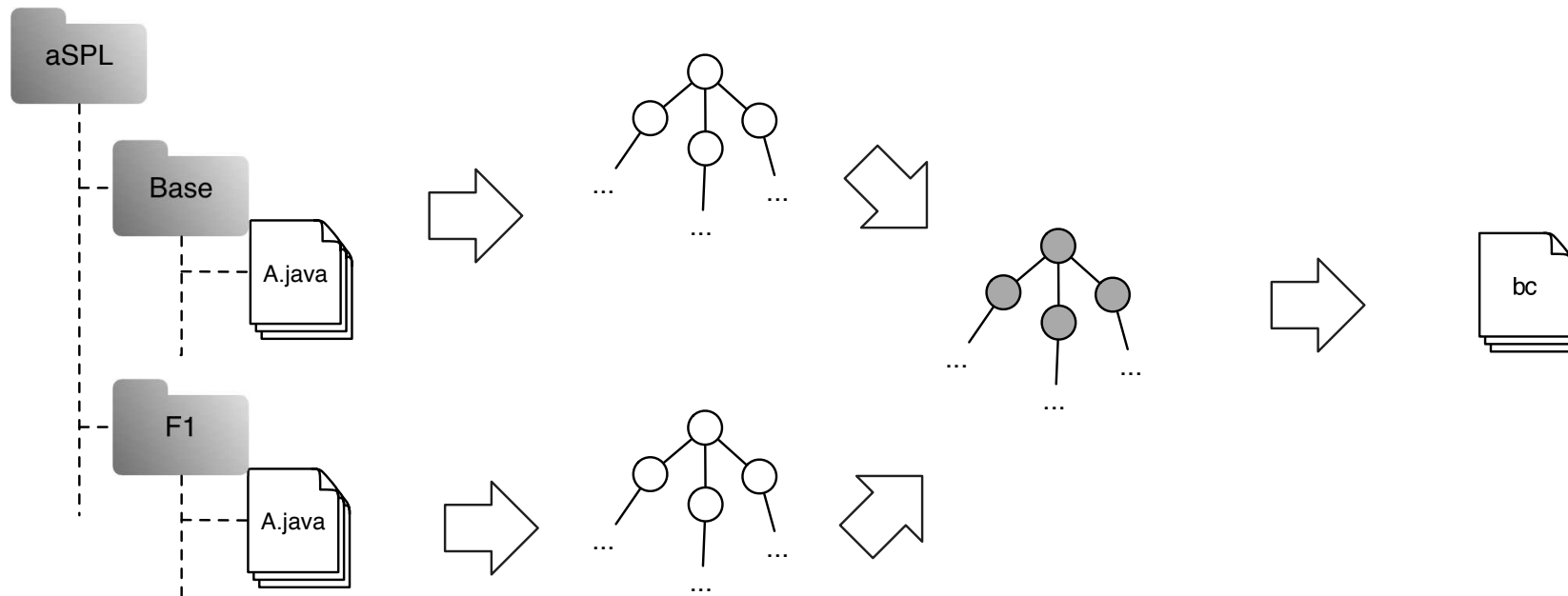
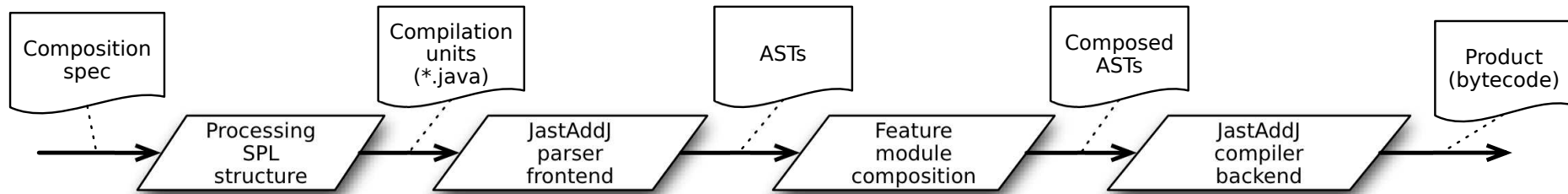
(Illustration adapted from Perelman (1913/2008): Physics for Entertainment, Fig. 95, p. 132)

References

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Appendix

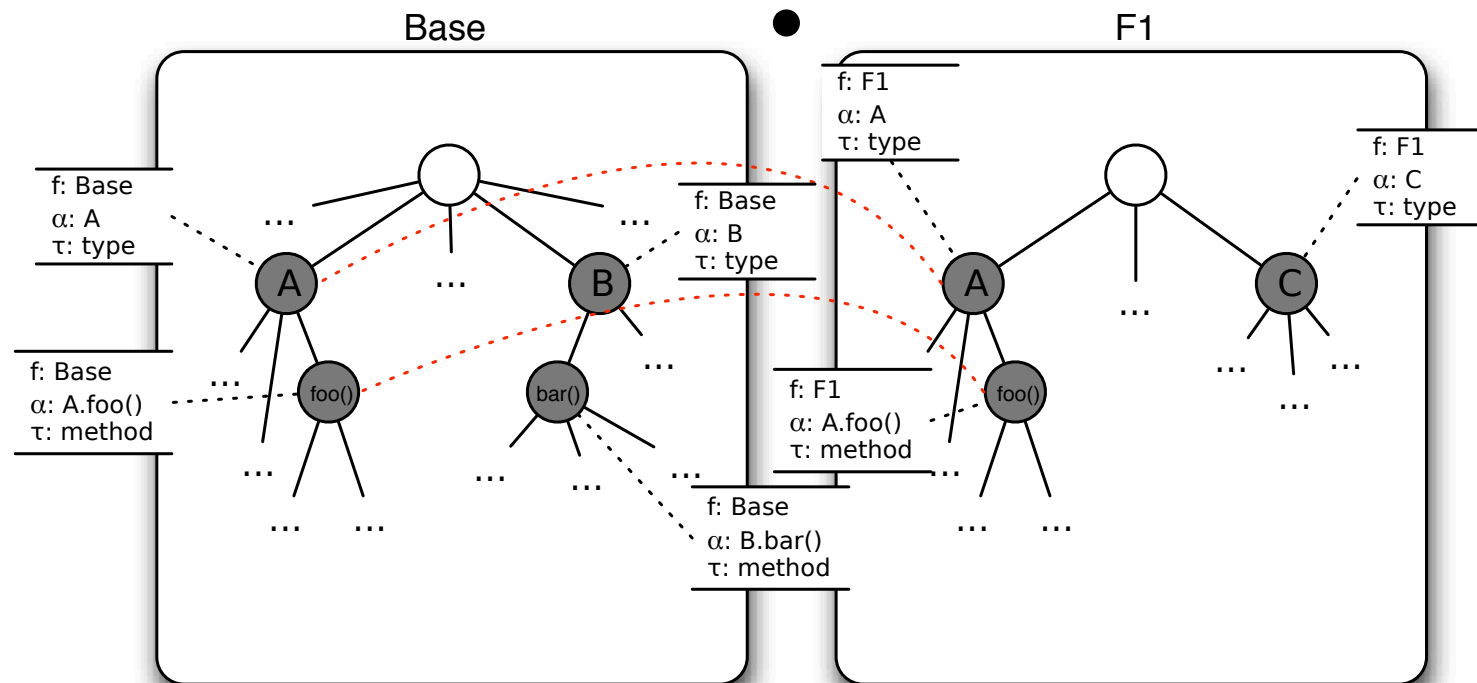
Fuji-driven SPLs



See [Kol11] for details on Fuji

Feature-module composition

Fuji composes feature modules using AST superimposition: $Base \bullet F1$



Each declaration element are identified by ...

- ... its introducing feature module $f: Base, F1$
- ... its label $\alpha: A, B, \dots, foo()$
- ... its syntactic category $\tau: type, method$

Exploratory issue: Per-feature-module statistics (1)

