UNIVERSITÄT
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Mining Software Repositories

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Roadmap

> **Introduction**
> Recovering entity evolution
  — Origin analysis
  — Refactoring detection
> Mining the history for relationships
  — Logical coupling
  — Change propagation
> Mining a history for rules
  — Common error patterns
  — Associating artefacts with tasks
> And more...

Software is Data...

> Data that you analyze
> Data that you measure
> Data that **evolves** and can be ***mined***
> ...
> Data that is big data
> Data that you visualize

A History of History Analysis in Software

NATO Software Engineering Conference '68

SCCS Bell Labs '72

RCS Purdue University '82

CVS Client Server '90

Seesoft Paper, by Eick et al. '92

Logical Coupling, by Gall et al. '98

MSR Workshop '04

Mylyn becomes an official Eclipse project '10

1970 1980 1990 2000 2010

> 20 years of **software engineering** before people start doing research in **analyzing software repositories**

References

> **Main Materials**
- An Integrated Approach for Studying Architectural Evolution, **Tu & Godfrey, ’02**
- Automated Detection of Refactorings in Evolving Components, **Dig et al., ’06**
- Detection of Logical Coupling Based on Product Release History, **Gall et al., ’98**
- Predicting Change Propagation in Software Systems, **Hassan & Holt, ’04**
- DynaMine: finding common error patterns by mining software revision histories, **Livshits & Zimmerman, ’05**

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A Quick Softwarenaut Demo...

- ... showing that new classes appear all the time during the evolution of the system
- But are they really “new”?

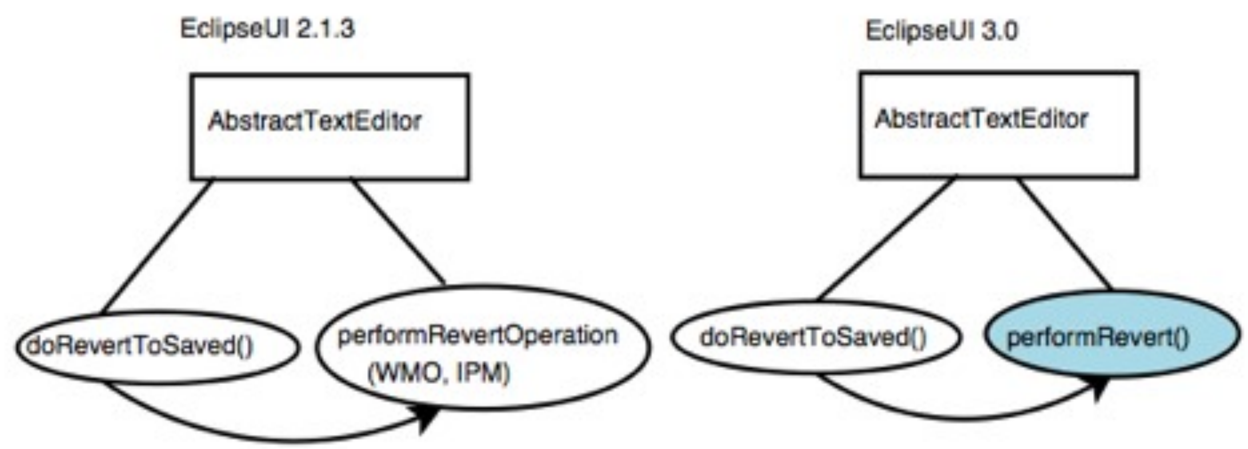
Origin Analysis

> Tu & Godfrey '02
> Works at the function level
> Combines
  - Bertillonage Analysis
    - *Assumes that Complexity Metrics do not change much*
  - Dependency Analysis
    - *Assumes that relationships do not change much*
> ...

How to know if an entity is the same in two versions?

Refactoring Detection

- > Dig et al. ’06 detect refactorings of Packages, Classes, Methods
- > Combination of **syntactic** and **semantic** analysis
- > Shingles Algorithm



How to detect refactorings in object-oriented systems?

The Approach of Dig et al.: The Shingles Algorithm

- Input
  - sequence of tokens representing method body without signature
- Output
  - Multi-sets of integeres
  - Similar inputs generate similar outputs

- Algorithm
  - W: window size
  - S: maximum set size
  - Compute hashes while sliding the window
  - Sort shingles and keep the first S

The original Shingles paper:
Broder, On the resemblance and containment of documents

The Approach of Dig et al.: Shingles Algorithm (Example with W=2 and S=10)

```
void doRevertToSaved() {
IDocumentProvider p= getDocumentProvider();
if (p == null)
   return;
performRevertOperation(createRevertOperation(),
            getProgressMonitor());
}
```

Shingles: { -1942396283, -1672190785, -12148775115, -56733233372, 208215292, 1307570125, 1431157461, 190471951, 969607679 }

```
void doRevertToSaved() {
IDocumentProvider p= getDocumentProvider();
if (p == null)
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performRevert();
}
```

Shingles: {-1942396283, 1672190785, -1214877515, -5673233372, 208215292, 1307570125, 1431157461, 577482186 }

The Approach of Dig et al.: Semantic Analysis

> Seven Detection Strategies
  - applied in order
  - based on dependencies between artifacts
    - *method calls*
    - *subclassing*
    - *fields*
    - *arguments*
    - *parameters*

1. RenamePackage (RP)
2. RenameClass (RC)
3. RenameMethod (RM)
4. PullUpMethod (PUM)
5. PushDownMethod (PDM)
6. MoveMethod (MM)
7. ChangeMethodSignature (CMS)

The Approach of Dig et al.: Results

- More than 85% Precision and Recall on
  - Eclipse
  - Struts
  - HotDraw
- What’s next? CatchUp!

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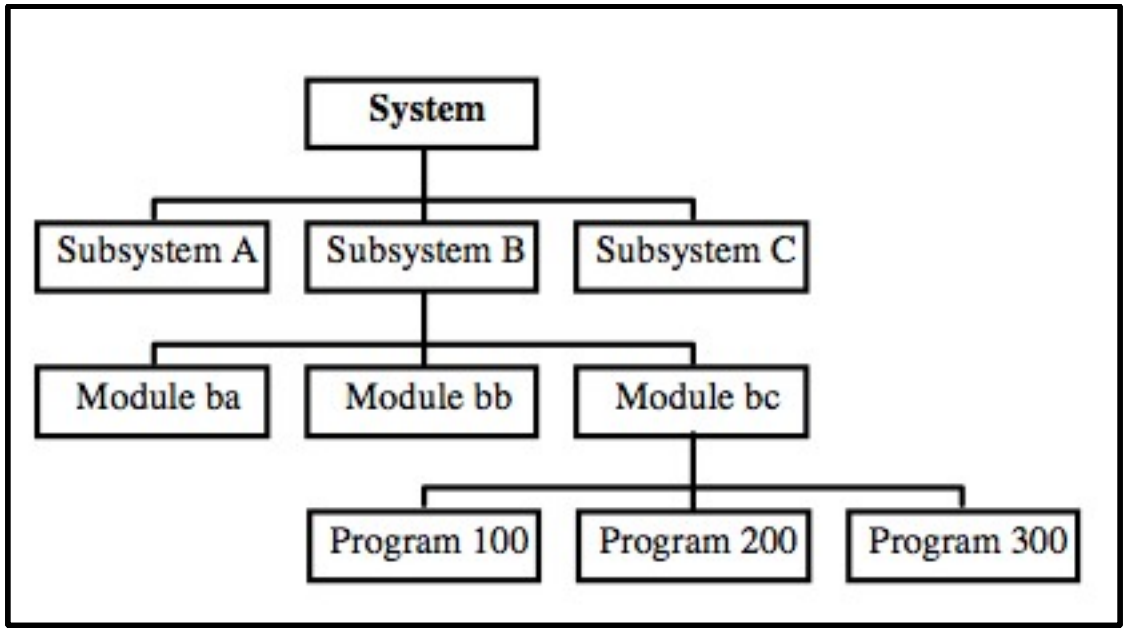
Logical Coupling

> Gall et al. ‘98
> Based on an an industrial case study
  — Subsystems
  — Modules
  — Programs
> Two steps
  1. Change Sequence Analysis
  2. Change Report Analysis



How to detect dependencies based on history?

Why history based?

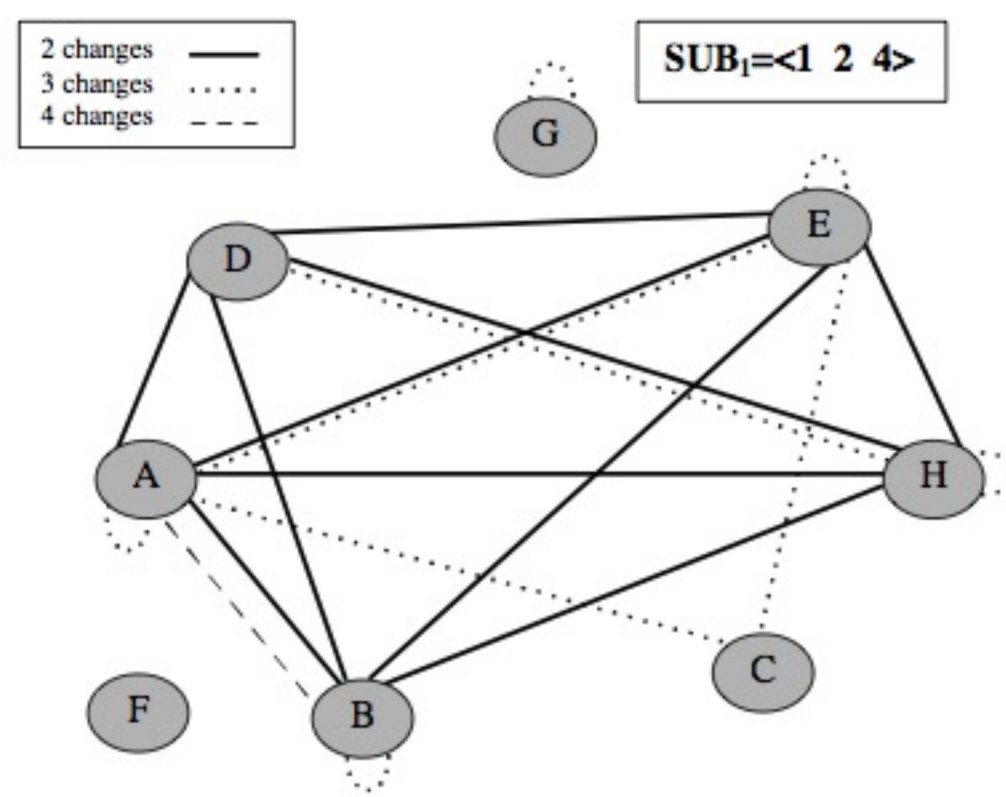
- Structural / Data Flow Analysis
  - Disadvantages:
    - *can not capture all the situations (i.e. writing to a file, reading from a file)*
    - *does not work with documents that are not source code*

Change Sequence Analysis

SUB_2=<1 2 3 4 6 7 9 10 14>											
A.aa.111	**1**	**2**	**3**	**4**	**6**	**7**	**9**	**10**	**14**	17	19
B.ba.222	**1**	**2**	**3**	**4**	**6**	**7**	**9**	**10**	**14**	16	18

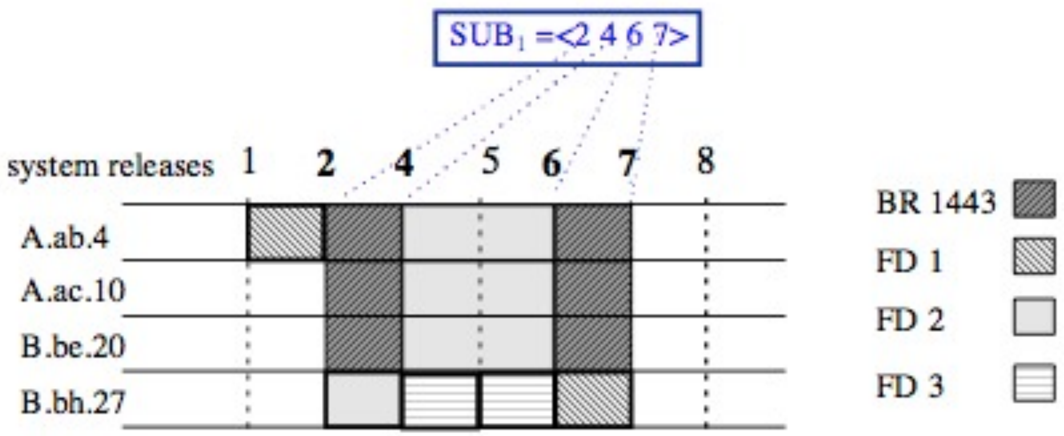
> Detects when two sub-systems change together

> Logical coupling is stronger if the subsequence is larger



Change Report Analysis

> There are two types of changes that are documented
  — Feature additions
  — Bug Requests



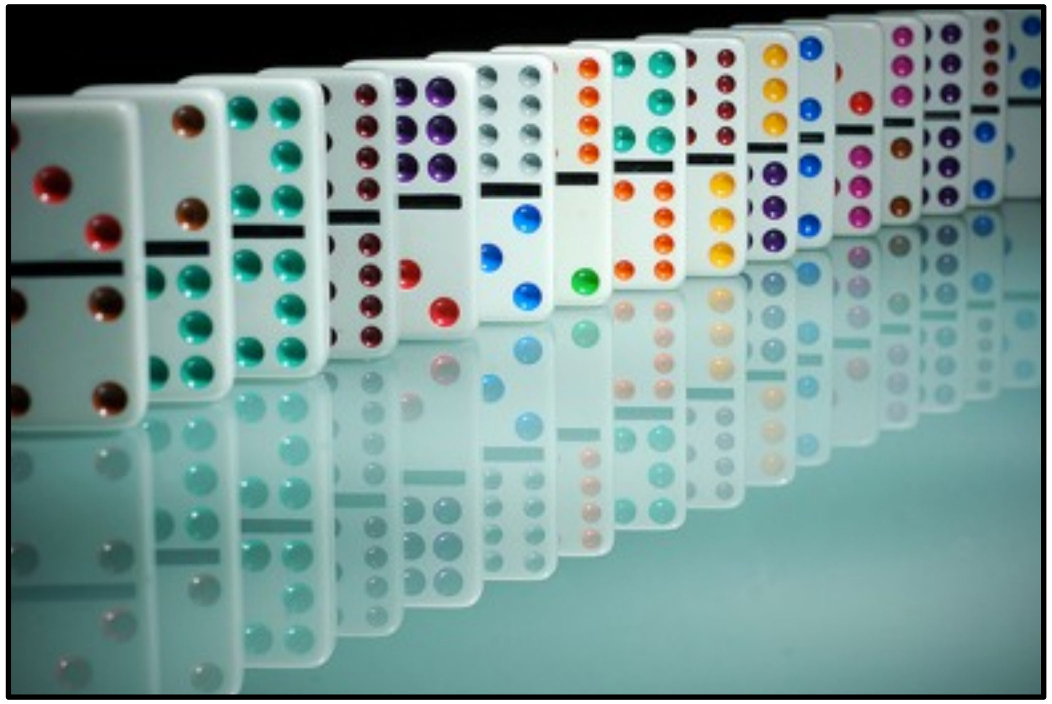
> The coupling between subsystems must be verified

Logical Coupling Summary

- Advantages
  - Does not require the code to compile
  - Can work with any types of documents
- Simplification
  - Versioning systems in the real world are a mess (CVS)

Change Propagation

- Hassan & Holt '04
- Compare heuristics
  - Developer (DEV)
  - Historical co-change (HIS)
  - Structural: Call/Use/Define (CUD)
  - Code layout (FIL)



What other entities have to change when a given one changes?

Evaluating the heuristics based on history with precision and recall

> Precision
> Recall
> Compute for every relevant change set and average

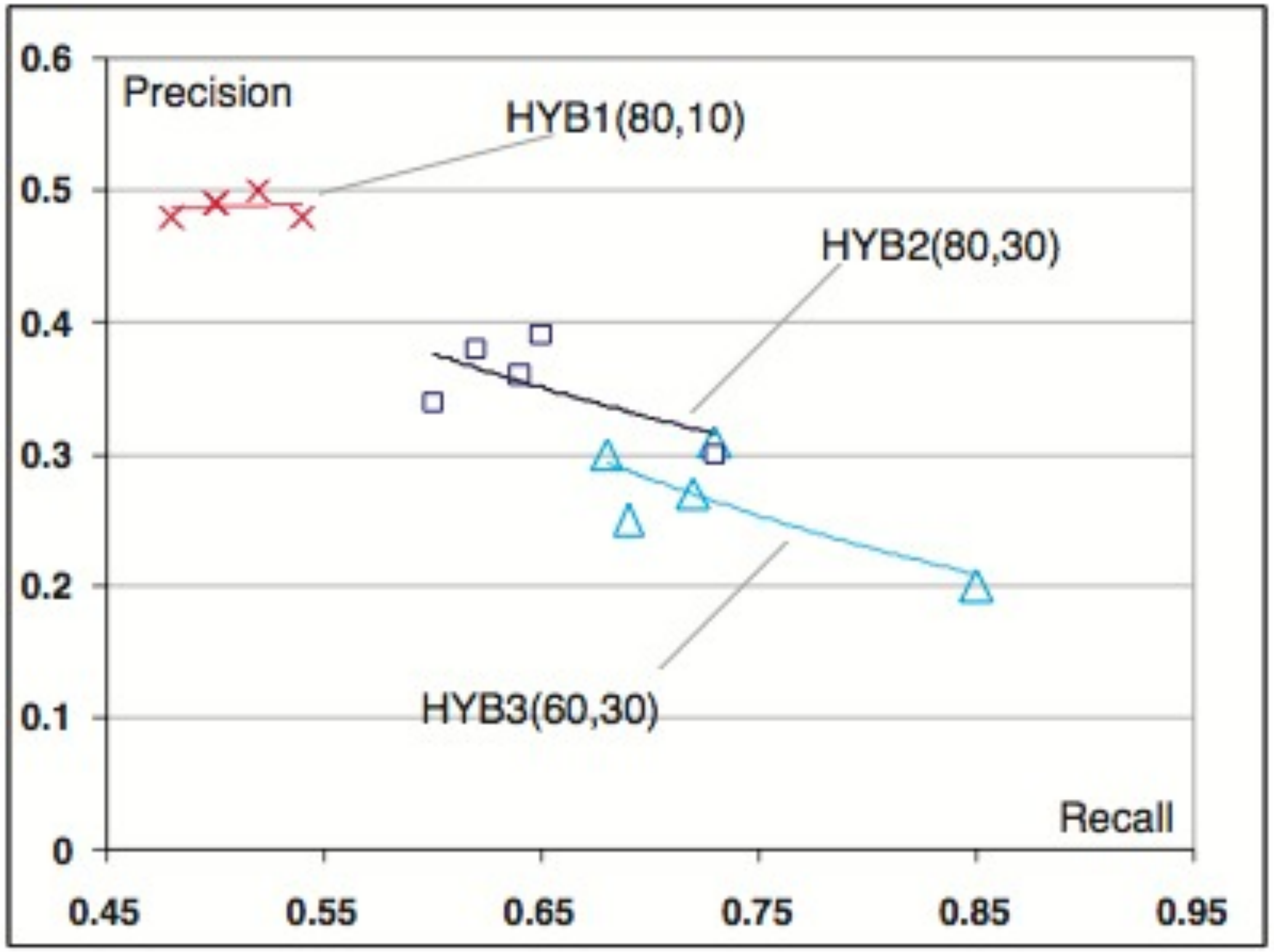
Application	DEV		HIS		CUD		FIL	
	Recall	*Precision*	*Recall*	*Precision*	*Recall*	*Precision*	*Recall*	*Precision*
NetBSD	0.74	0.01	0.87	0.06	0.37	0.02	0.79	0.16
FreeBSD	0.68	0.02	0.87	0.06	0.40	0.02	0.82	0.11
OpenBSD	0.71	0.02	0.82	0.08	0.38	0.01	0.80	0.14
Postgres	0.78	0.01	0.86	0.05	0.47	0.02	0.77	0.12
GCC	0.79	0.01	0.94	0.03	0.46	0.02	0.96	0.06
Average	0.74	0.01	0.87	0.06	0.42	0.02	0.83	0.12

Hybrid Technique

Entities that changed together at least A% of the time (prune HIS)

OR

Entities in the same file that changed together at least A%-B% of the time (FIL)



Change Propagation Discussion

> Heuristics
  - Only work with one element in the prediction set
  - Are symmetric
> File-level is a limitation

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Common Error Patterns

> Livshits & Zimmermann '05
> Data mining reveals frequent patterns
  - Matching Method Pairs
  - State Machines

How to detect bugs in apps that use APIs about which you do not have knowledge?

Principles

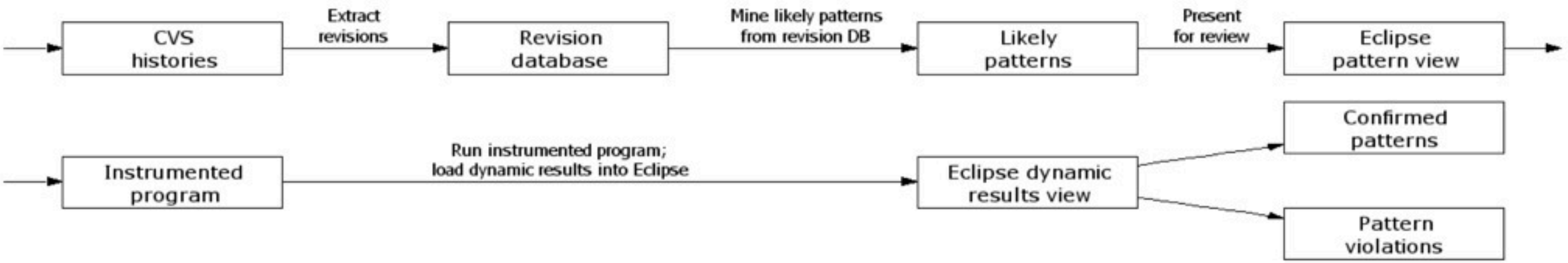
1. API specific errors
2. Co-addition is a pattern
3. Small commits are fixes

File	Revision	Added method calls
Foo.java	1.12	o1.addListener o1.removeListener
Bar.java	1.47	o2.addListener o2.removeListener System.out.println
Baz.java	1.23	o3.addListener o3.removeListener list.iterator iter.hasNext iter.next
Qux.java	1.41	o4.addListener
	1.42	o4.removeListener

When to look for pattern violations?

> Runtime
  + Scalability
  + Simplicity (no interprocedural analysis)
  + Counting occurrences
  + Zero False Positives
  — Coverage

Dynamine: The Approach



- Human Input is required
- Mines from the history
- Validates at runtime

Mining for Likely Patterns: The Apriori Algorithm

- Concepts
  - Usage Pattern
  - Transaction
  - Support Count

- Input
  - Minimum Support
- Output
  - Frequent Patterns
- Implementation
  - Iterative
  - Exponential

Pattern Filtering

- Consider a subset of the methods
  - ignore initial revisions
  - ignore common calls
- Consider small patterns only
  - group calls by access path

Pattern Ranking & Classification

- Lexicographically on support count
- Corrective ranking
  - assumes on one-line changes are bug-fixes
  - used as first lexicographic category improves bug finding
- Classification
  - Usage
  - Error
  - Unlikely

Results

	Method pair ⟨a, b⟩		Confidence			Support	Dynamic		Static		Type
	Method a	**Method b**	$conf$	$conf_{ab}$	$conf_{ba}$	$count$	v	e	v	e	
	Corrective Ranking										
Eclipse (16 pairs)	NewRgn	DisposeRgn	0.76	0.92	0.82	49					
	kEventControlActivate	kEventControlDeactivate	0.69	0.83	0.83	5					
	addDebugEventListener	removeDebugEventListener	0.61	0.85	0.72	23	4	1	4	1	Unlikely
	beginTask	done	0.60	0.74	0.81	493	332	759	41	28	Unlikely
	beginRule	endRule	0.60	0.80	0.74	32	7	0	4	0	Usage
	suspend	resume	0.60	0.83	0.71	5					
	NewPtr	DisposePtr	0.57	0.82	0.70	23					
	addListener	removeListener	0.57	0.68	0.83	90	143	140	35	29	Error
	register	deregister	0.54	0.69	0.78	40	2,854	461	17	90	Error
	malloc	free	0.47	0.68	0.68	28					
	addElementChangedListener	removeElementChangedListener	0.42	0.73	0.57	8	6	1	1	1	Error
	addResourceChangeListener	removeResourceChangeListener	0.41	0.90	0.46	26	27	1	21	1	Usage
	addPropertyChangeListener	removePropertyChangeListener	0.40	0.54	0.73	140	1,864	309	54	31	Error
	start	stop	0.39	0.59	0.65	32	69	18	20	9	Error
	addDocumentListener	removeDocumentListener	0.36	0.64	0.56	29	38	2	14	2	Usage
	addSyncSetChangedListener	removeSyncSetChangedListener	0.34	0.62	0.56	24					
jEdit (8 pairs)	addNotify	removeNotify	0.60	0.77	0.77	17	3	0	3	0	Unlikely
	setBackground	setForeground	0.57	0.67	0.86	12	75	175	5	5	Unlikely
	contentRemoved	contentInserted	0.51	0.71	0.71	5	17	11	7	5	Error
	setInitialDelay	start	0.40	0.80	0.50	4	0	32	0	2	Unlikely
	registerErrorSource	unregisterErrorSource	0.28	0.45	0.62	5					
	start	stop	0.20	0.39	0.52	33	83	98	10	13	Error
	addToolBar	removeToolBar	0.18	0.60	0.30	6	24	43	5	5	Error
	init	save	0.09	0.40	0.24	31					
(24 pairs)						**Subtotals for the corrective ranking scheme:**	**5,546**	**2,051**	**241**	**222**	3 U, 8 E

Associating Artefacts with Tasks

- Kersten & Murphy ‘05
- Mylar/Mylin
- Task-Focused Interface
- Degree of Interest ranking

How to filter the large amount of information available in the IDE?

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Further Directions (Kagdi et al. ’07)

> Basic evolution principles
  - Refactorings breaking clients (Dig & Johnson ’05)
  - Understanding the rethoric of small changes (Puru & Perry ’05)

> Change-Based repositories
  - Replay (Hattori et. al ’11)

> Bug prediction
  - Extensive comparison of approaches (D’Ambros et al. ’10)

> Risk Prediction
  - The Code Orb, (Lopez ’11)

Benefits of Historical Analysis

> Predict various aspects of the system based on the past
  - Temporal locality
  - Co-change patterns

> Increase the amount of available information

> Allows empirical validation of hypotheses

Enablers of Historical Analysis

- Versioning systems
- Increased amounts of historical data
- Availability of different types of data
  - developer interaction
  - bug/issue tracking
- Modern IDE's
  - plugin philosophy
    - *collecting data*
    - *playground for features*

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What you should know!

- What is origin analysis
- What is logical coupling
- How does the Apriori algorithm function
- What are shingles and how do they work

Can you answer these questions?

> How does origin analysis work in the approach of Tu & Godfrey?

> Can you compare the Bertillonage and the Shingles approaches?

> Why does the Dynamine tool require dynamic analysis?

> What heuristics would you use to predict classes that change together and why?

> Can you discuss some of the advantages and some of the disadvantages of the shingles technique?

Further Reading

- Mylar, a Degree of Interest model for IDE’s, Kersten & Murphy ’05
- The Role of Refactorings in API Evolution, Dig & Johnson, ’05
- The code orb: supporting contextualized coding via at-a-glance views, Lopez ’11
- Modeling History to Understand Software Evolution, Girba, ’05
- An extensive comparison of bug prediction approaches, D’Ambros et al., ’10
- Software Evolution Comprehension: Replay to Rescue, Hattori et al., ’11
- A survey and taxonomy of approaches for mining software repositories in the context of software evolution, Kagdi et al. ’07