Mining Software Repositories

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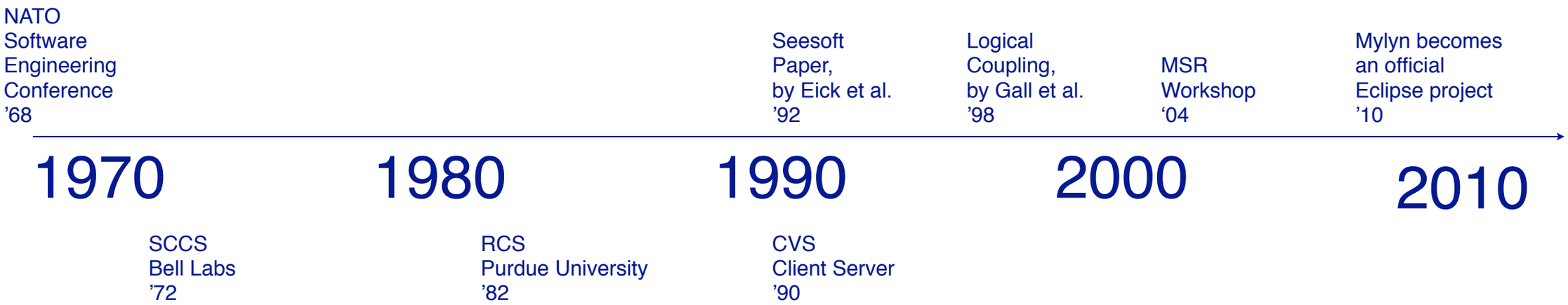
Roadmap

- **Introduction**
- Mining the history for relationships
  - Logical coupling
- Recovering entity evolution
  - Origin analysis
  - Refactoring detection
- Mining a history for rules
  - Common error patterns
- And more...

A History of Repository-Based Analysis in Software



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

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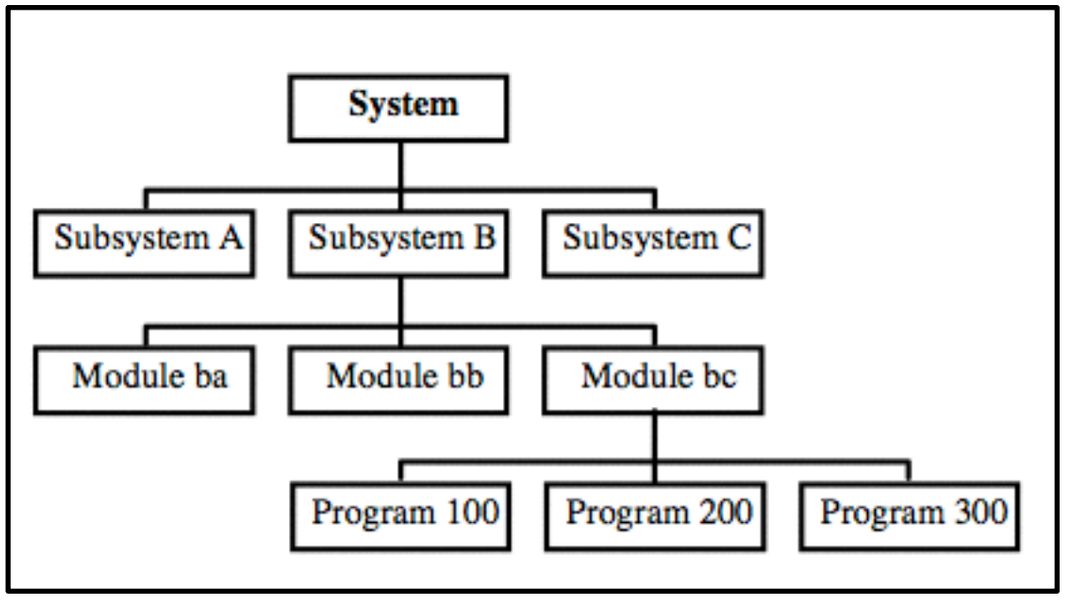
Logical Coupling

- 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?

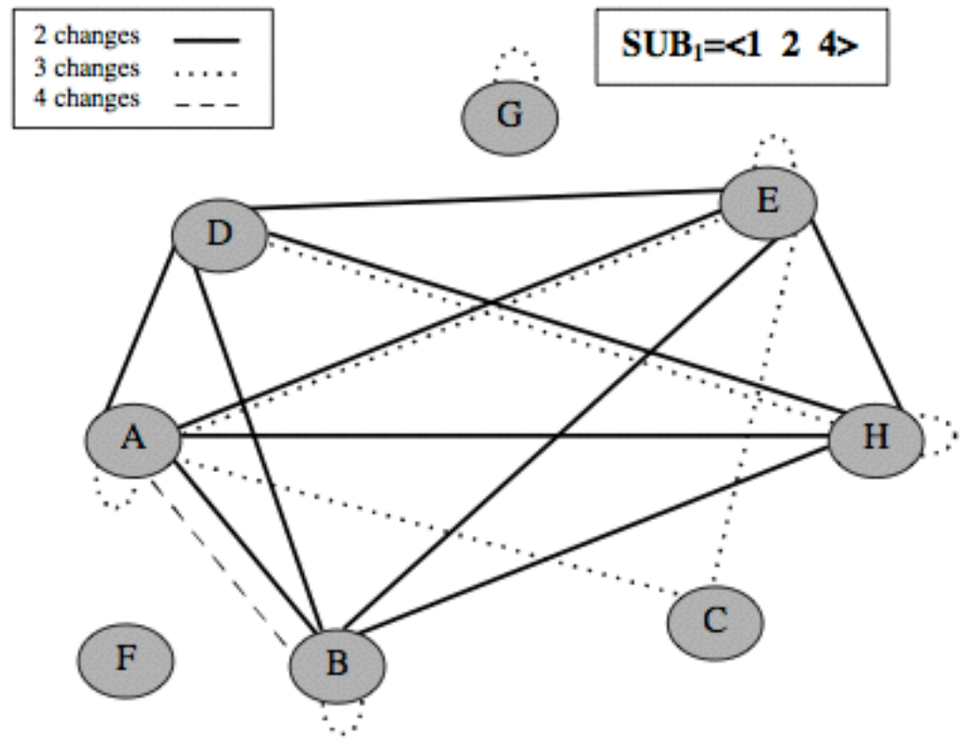
Why history based?

- 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

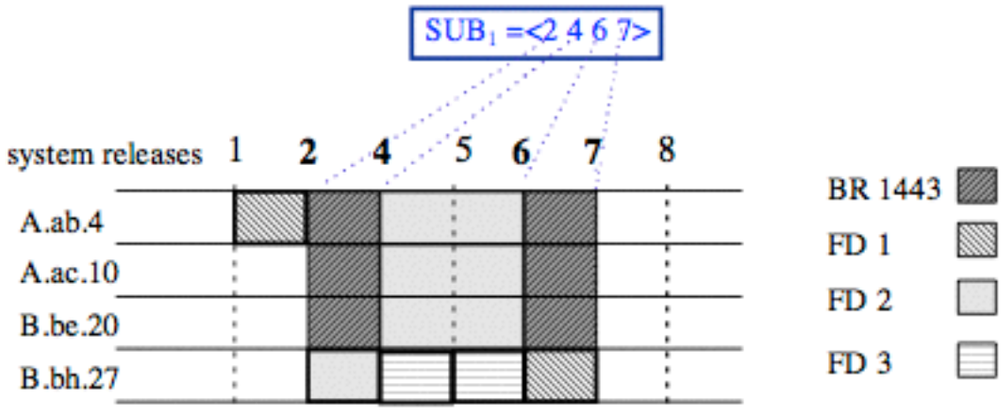
- Detects when two sub-systems change together
- Logical coupling is stronger if the subsequence is larger



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)
    - *does not group*

Alternative read:

Mining Version Histories to Guide Software Changes

Zimmerman et al.

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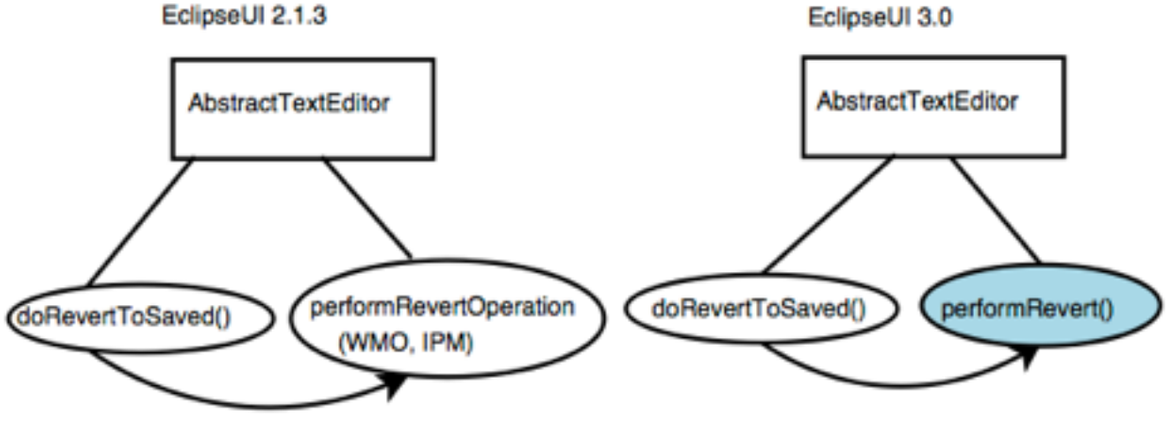
Origin Analysis

- 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 integers
  - 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 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();
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}
```

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! (Automatically refactoring clients)

Automated Detection of Refactorings in Evolving Components
Dig et al., ECOOP 2006

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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`

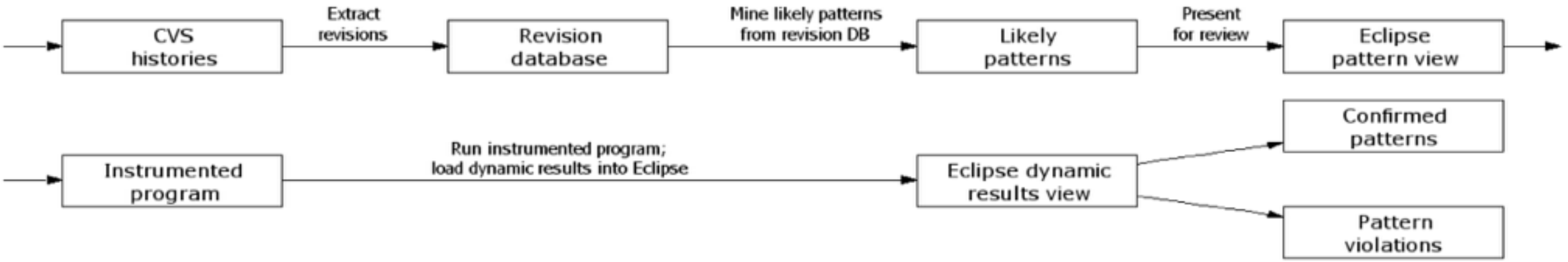
`Baz.java`	1.23	`o3.addListener`
		`o3.removeListener`
		`list.iterator`
		`iter.hasNext`
		`iter.next`

`Qux.java`	1.41	`o4.addListener`
	1.42	`o4.removeListener`

When to look for pattern violations?

- Compile Time
  - — complicated (inter procedural analysis)
- 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 $\langle a, b \rangle$		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

DynaMine: Finding Common Error Patterns by Mining Software Revision Histories

Livshits and Zimmerman, FSE 2005

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Associating Artifacts 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?

Further Directions (Kagdi et al. ’07)

- 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)

Enablers of Historical Analysis

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

Benefits of Historical Analysis

- Increase the amount of available information
- Allows temporal mining
- Predict various aspects of the system based on the past
- Allows empirical validation of hypotheses based on mining many systems

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What you should know!

- What are some of the problems that can be solved by mining software repositories
- What is the problem of origin analysis and how to solve it
- How can logical coupling be detected, and why it matters
- What kind of error patterns can be detected by mining software repositories
- How to architect a system that can recommend entities that are likely to need to be changed

Can you answer these questions?

- How would you solve the problem of origin analysis?
- What are some of the challenges when in comes to automatically detecting refactorings?
- What are the advantages of taking into account dynamic analysis when mining API protocols?
- 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?

References

- **Mandatory Reading (minimum one paper)**
  - **Detection of Logical Coupling Based on Product Release History,** Gall et al., ’98
  - **Automated Detection of Refactorings in Evolving Components,** Dig et al., ’06
  - **Mining Version Histories to Guide Software Changes,** Zimmermann et al. ‘04
  - **DynaMine: finding common error patterns by mining software revision histories,** Livshits & Zimmerman, ’05

- **Further Reading**
  - An Integrated Approach for Studying Architectural Evolution, Tu & Godfrey, ’02
  - 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

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